

ATTACHMENT 2

**SOUTH REGION REACTIVE POWER
REQUIREMNET STUDY**



South Region Reactive Power Requirement Study



September 13, 2012

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APEGA Permit to Practice P8200

EXECUTIVE SUMMARY

The Alberta Electric System Operator (AESO) identified the need for reactive power devices in the southern region of the Alberta Interconnected Electric System (AIES) in the Southern Alberta Transmission Reinforcement (SATR) Needs Identification Document (NID)¹, which was approved by the Alberta Utilities Commission on September 8, 2009.² As the SATR components are now being built by the TFOs and the AESO continues to develop its long-term transmission plans and forecasts, the AESO has completed an updated assessment of the required reactive power control devices in Southern Alberta.

This assessment takes into consideration certain factors that differ from the original reactive power evaluation undertaken in preparation of the SATR NID. These include, among others, changes in the timing and planned configuration of the transmission system in southern Alberta. For example, in the SATR NID, the Foothills-Peigan 240 kV lines were originally proposed to be terminated at the Peigan 59S substation in 2014. Instead, the AESO is now proposing to terminate the same 240 kV lines at the new Windy Flats substation (east of Peigan 59S) in 2015.³ There have also been other changes associated with the Fidler/Pincher Creek area and the connection between Goose Lake and the planned 500/240 kV Chapel Rock 491S substation⁴ as well as the approved Hanna Region Transmission Development (HRTD).⁵ This assessment also uses load and generation forecasts consistent with the AESO 2012 Long-term Outlook (2012 LTO).⁶

The main purpose of this need reassessment is to investigate the adequacy of the originally recommended reactive power control devices in the SATR NID based on the current planned system configuration in Southern Alberta and propose updates to these if required.

Steady State, Dynamic and Voltage stability analyses were conducted to identify the reactive power requirements in Southern Alberta. Following are the

¹ Sections 5.2 and 7, SATR NID, Application No. 1600862, Proceeding ID No. 171.

² *Decision 2009-126* and Approval No. U2009-340; subsequent amendments have culminated in the current SATR NID Approval No. U2011-115.

³ The AESO is preparing an amendment application that will seek Alberta Utilities Commission approval to replace the approved upgrades at Peigan 59S with development of a new Windy Flats 138S substation.

⁴ The AESO is preparing an amendment application that will seek Alberta Utilities Commission approval to replace the approved Goose Lake to Crowsnest 240 kV line and Crowsnest substation with the proposed 500/240 kV Chapel Rock 491S substation connected to Goose Lake via a 240 kV line from either the proposed Fidler 312S substation or the existing Castle Rock Ridge 205S substation.

⁵ *Decision 2010-188* and Approval No. U2010-135; subsequent amendments have culminated in the current HATD NID Approval No. U2011-114(Errata)..

⁶ The 2012 LTO is available at: http://www.aeso.ca/downloads/AESO_2012_Long-term_Outlook_bookmarked.pdf

conclusions and recommendations of this study. Table I provides a summary of the currently proposed reactive power devices compared to those proposed under the original SATR plan.

- The reactors originally proposed in the SATR NID are adequate to keep the operating voltage under light load, no wind conditions to within the continuous operating limit design target of 1.05 p.u.
- At the Chapel Rock substation, install a +200/-100 MVar SVC in addition to two (2) 100 MVar 240 kV capacitor banks in a Static VAR System (SVS) configuration and a 45 MVar reactor.
- Replace the originally proposed SVC at the existing Cypress substation with three (3) 45 MVar 240 kV capacitor banks.
- The similarly sized SVCs at Chapel Rock and other substations (Hansman Lake, Lanfine and, Pemukan) have the potential of providing additional benefits in terms of reductions in costs associated with sparing, maintenance and operational flexibility. The inductive range of the SVC specified for Chapel Rock represents the minimum requirement. The actual VAr inductive capability of the SVC, if based on economic optimization, is more than the identified 100 MVar need, would be identified during the detailed design stage of this project. The specified 45 MVar reactor at the Chapel Rock site can accordingly be eliminated if the Chapel Rock SVC design can provide the full required 145 MVar inductive range. Even though the proposed configuration of VAR support at Chapel Rock consists of several discrete components i.e. a reactor, capacitor banks and SVC in a Static VAR System setup, the optimal configuration of the SVC/SVS would be determined at the detailed design Stage
- The study also confirmed the ability of the SATR configuration with the proposed reactive power compensation to enable the utilization of the Alberta – British Columbia (AB-BC) 500 kV tie line up to its import path rating of 1200 MW. Although this flow level is higher than the current operating limit of the tie line, the proposed size of the Chapel Rock reactive power support would enable restoring of the tie capacity along with appropriate measures to ensure the transient stability of the AIES under the loss of the tie line. These additional measures required to ensure internal AIES frequency stability is outside the scope of this study and shall be covered under a separate more detailed assessment. This design of the Chapel Rock Substation shall ensure adequate equipment ratings to accommodate the full 1200 MW rating of the AB-BC 500 kV tie line.

Table I: Summary of the SATR Reactive Power Devices

Substation	Present Recommendation SATR Plan			Original SATR Recommendation			Current Project Status
	Shunt Reactor (MVar)	Shunt capacitor (MVar)	SVC (MVar)	Shunt Reactor (MVar)	Shunt capacitor (MVar)	SVC (MVar)	
Peigan (Now in Windy Flats)138S* 240 kV	2 x -75 (Total = -150)	N/A	N/A	N/A	N/A	-200 to 0	NID Amendment under preparation
Whitla (Sub D) 251S 240 KV	2 x -75 (Total = -150)	N/A	N/A	N/A	N/A	-100 to 0	Substation Under Construction (Assumed to be in-service in this study)
Chapel Rock (Crows Nest) 491S 240 kV	1 x -45	2 x 100 (Total = 200)	-100 to +200	N/A	N/A	0 to +400	NID Amendment under preparation
Journault (Sub C) 260S 240 kV	2 x -45 (Total = -90)	N/A	N/A	N/A	N/A	-100 to 0	NID Amendment and Facility Application under preparation
Cypress 562S 240 kV	N/A	3 x 45 (Total = 135)	N/A	N/A	N/A	-50 to +25	NID Amendment and Facility Application under preparation

*The reactive devices at this location was previously planned for the Peigan 240 kV substation
N/A: Not Applicable

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- Appendix B: Steady State Assessment Tables and Plots
- Appendix C: Dynamic Stability Fault Descriptions and Diagrams
- Appendix D: Dynamic Stability Results and Plots
- Appendix E: Voltage Rise on Open Ended Transmission Lines

1. INTRODUCTION

The Alberta Electric System Operator (AESO) identified the need for reactive power devices in the southern region of the Alberta Interconnected Electric System (AIES) in the Southern Alberta Transmission Reinforcement (SATR) Needs Identification Document (NID)¹, which was approved by the Alberta Utilities Commission on September 8, 2009.² As the SATR components are now proceeding and the AESO continues to develop its long-term transmission plans and forecasts, the AESO has completed an updated assessment of the required reactive power control devices in Southern Alberta.

This assessment takes into consideration certain factors that differ from the original reactive power evaluation undertaken in preparation of the SATR NID including changes in the timing and planned configuration of the transmission system in southern Alberta. The southern termination of the planned Foothills-Peigan 240 kV lines was originally proposed to be at the Peigan 59S substation in 2014. The AESO is now proposing to terminate the 240 kV lines at the new Windy Flats 138S substation (east of Peigan 59S) in 2015.³ There have also been changes associated with the Fidler/Pincher Creek area and the connection between Goose Lake and the planned 500/240 kV Chapel Rock 491S substation⁴ as well as the approval of Hanna Region Transmission Development (HRTD)⁵. This assessment also assumes load and generation forecasts consistent with the AESO 2012 Long-term Outlook (2012 LTO).⁶

Table I provides a summary of the reactive power devices currently proposed under this study and those which were originally recommended in the SATR NID. The table also provides the current status of these projects. Figure 1-1,

Figure 1-2 and Figure 1-3 show the Southern Alberta transmission network including the SATR development modeled in the study scenarios.

It is to be noted that the proposed 911L rebuild was originally proposed to be terminated at Peigan 59S. The AESO is now proposing to construct a new termination substation, Windy Flats 138S, located a few kilometers east of Peigan 59S. From a system performance perspective, the change is not significant. This study assumes the termination of the Foothills 1037L/1038L 240 kV lines at the proposed Windy Flats 138S.

The main driver of need for the proposed reactors at Windy Flats 138S, Whitla 251S, Chapel Rock 491S, Cypress 562S and Journault 260S is to provide the means to control voltage under light load, low wind generation conditions with low transfer on the Montana Alberta Transmission Line (MATL). The SVC proposed at the Chapel Rock 491S substation is to provide fast and smooth regulation of the network voltage under variable wind and Alberta – BC tie line flow conditions as well as provide the required VAR support to the network under contingency conditions. The SVC at Cypress Substation was proposed to provide the needed reactive power support under contingencies with the wind connections in the area assumed in the original SATR application.

This South Region Reactive Power Requirement Study (South Reactive Power Study) was initiated to re-assess the need for and the size of the originally recommended reactive power control devices at the proposed Journault 260S (Sub C), Windy Flats 138S, Chapel Rock 491S and Cypress 562S substations in light of changes to the system configuration, desired normal voltage operating range and changes in load and generation assumptions since the original studies were completed in 2008. The shunt reactors at the Whitla substation, which is currently under construction, were assumed to be in-service in this South Reactive Study. The study confirmed the need for those reactors at the Whitla substation for voltage control under light load and low wind generation conditions.

This report is presented in the following sections:

- Executive Summary
- Introduction
- Criteria, Methodology and Assumptions
- Line Voltage Rise Assessment
- Need Assessment
- Reactive Power Requirements
- Voltage Stability Assessment
- System Losses
- Summary and Conclusions

Figure 1-1: Pincher Creek/Ft. MacLeod Area System Configuration

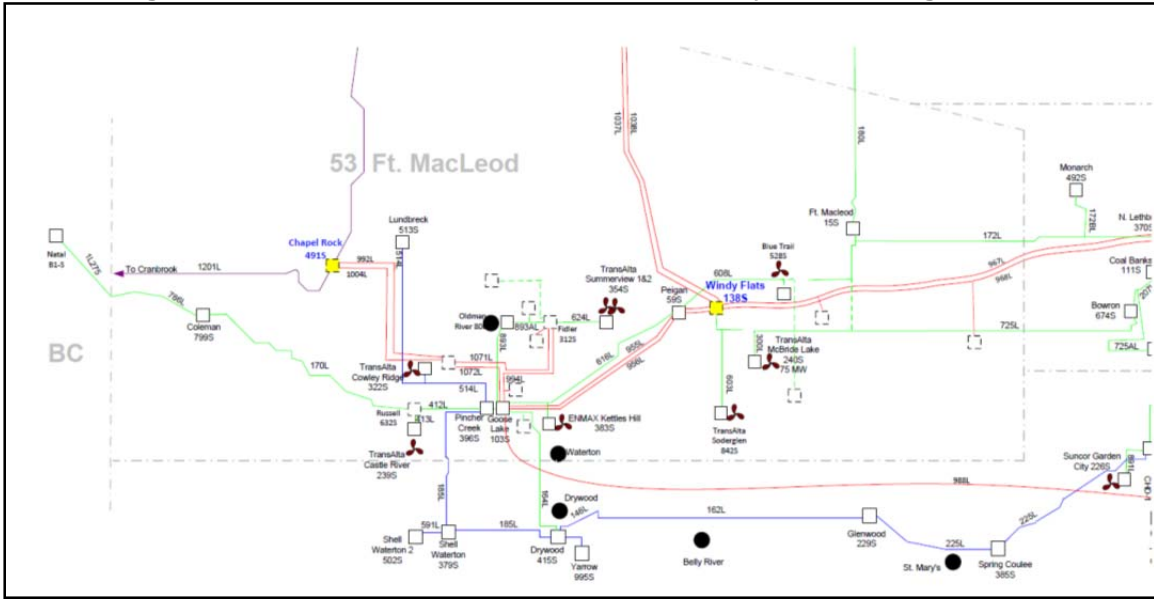


Figure 1-2: Lethbridge Area System Configuration

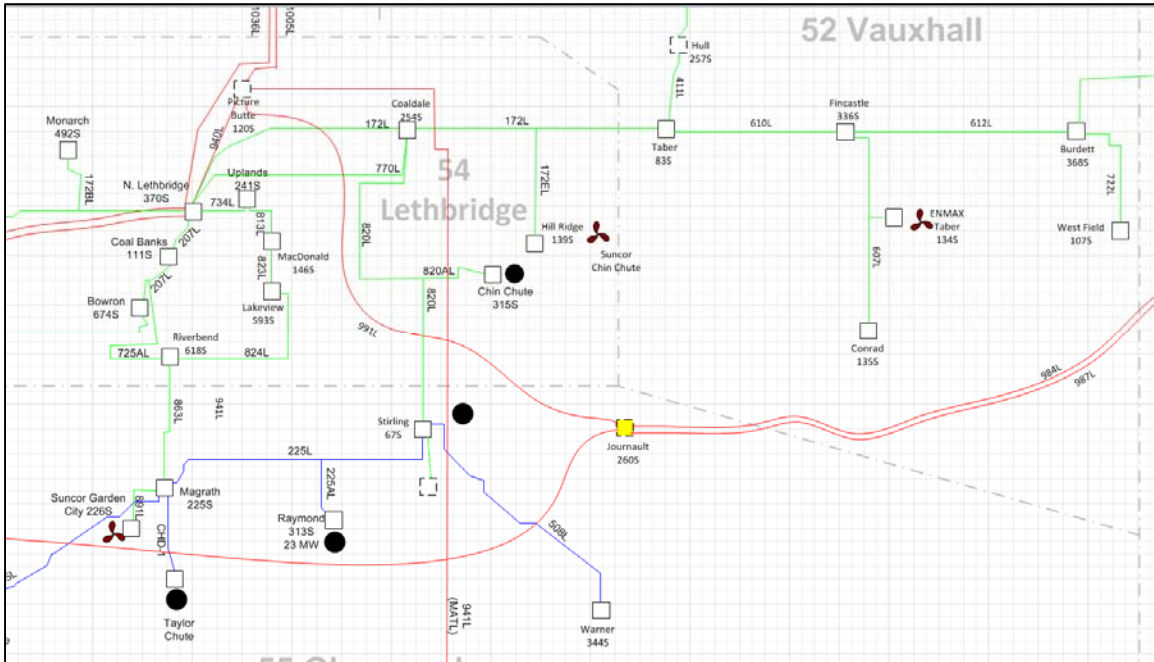
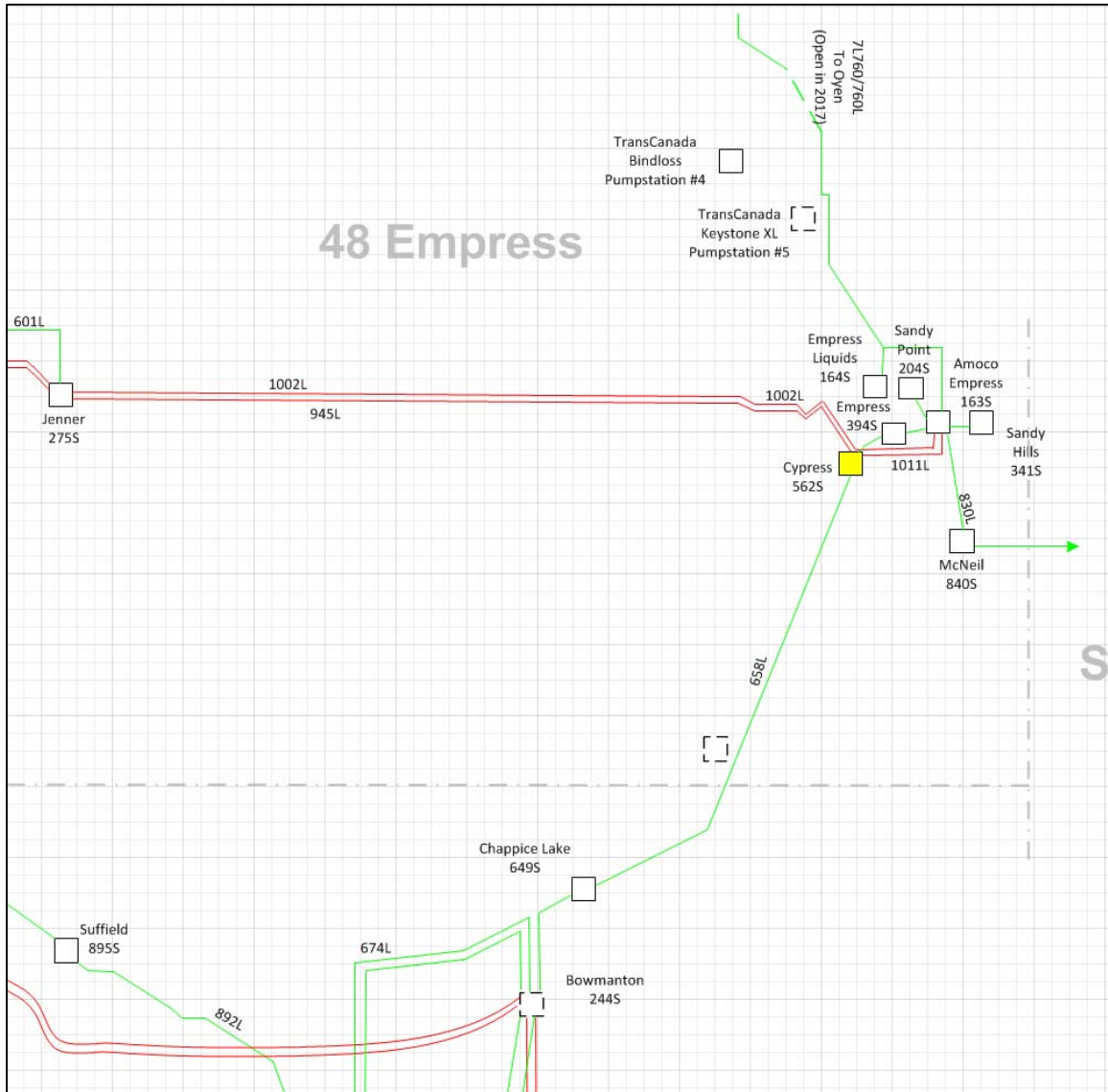


Figure 1-3: Medicine Hat/Empress Area System Configuration



Note: Figure 1-1, 1-2 and 1-3 are not to scale and do not represent the actual routing of the proposed or existing transmission lines.

2. CRITERIA, METHODOLOGY AND ASSUMPTIONS

The following sections describe the major components of criteria, methodology and assumptions used in the South Reactive Study.

2.1 AESO Transmission Reliability Criteria

The planning criteria established for the sizing of the reactive power devices in this study assumed a voltage target of 1.05 p.u. and 1.08 p.u. for the normal maximum operating voltage throughout the 240 kV and 500 kV network in Southern Alberta. The maximum and minimum contingency voltages were assumed to be 1.10 p.u. and 0.92 p.u. respectively on the 240 kV network. The extreme minimum and maximum voltages for the 500 kV network were assumed to be 1.00 p.u. and 1.10 p.u. respectively. These values are summarized in Table 2-1.

The applicable Alberta Reliability Standards (ARS) (TPL-001-AB-0, TPL-002-AB-0 and TPL-003-AB-0) were applied to assess system reliability under various system conditions. Category A (TPL-001-AB-0, all transmission elements in-service), Category B (TPL-002-AB-0, a single transmission element out-of-service), and selected Category C (TPL-003-AB-0, multiple transmission elements out-of-service) conditions were examined. The following is a general explanation of the Transmission Reliability Criteria applied throughout this study:

- Under Category A and Category B conditions, the system must be able to supply all firm transfers on the interties, i.e., no shedding of load or generation is allowed for these conditions in order to maintain acceptable system performance.
- Equipment loadings are monitored to record any violations based on 100% of their applicable static seasonal rating. The ARS require all transmission elements to operate within their ratings with no thermal overloads.
- All equipment must operate within its applicable rating, voltages must be within their allowable limits as provided in Table 2-1 and the system must be stable.

Table 2-1: Allowable Voltage Limits

Nominal Voltage (kV)	Extreme Minimum Voltage (Cat B & C) (p.u.)	Normal Minimum Voltage (Cat A) (p.u.)	Normal Maximum Voltage (Cat A) (p.u.)	Extreme Maximum Voltage (Cat B & C) (p.u.)
500	1.00	1.02	1.08	1.10
240	0.92	1.00	1.05*	1.10
144	0.90	0.95	1.05	1.08
144 kV on 138 kV Base	0.94	0.99	1.09	1.12
138	0.90	0.98	1.05	1.09

*Note that the 240 kV Normal Maximum of 1.05 p.u. is the desired target voltage for this study.

2.2 Study Area and Contingencies

The study areas monitored in the South Reactive Power Requirements Study are summarized in Table 2-2 below. Category B and specific Category C5 contingencies at 138 kV or higher were simulated in the study areas along with ties to the study areas as indicated in Table 2-2. The list of Category C5 outages simulated is provided in Appendix C. System elements at 240 kV or higher were monitored in all the areas and 138 kV and above in the Hanna and Empress areas. Only voltage violations on neighboring system buses were reported in this Study as other system issues in the study area are being addressed by the AESO's south regional plan. The list of neighboring buses is provided in Appendix A.

Table 2-2: Study Areas

Area	Area #	Monitored Elements	Contingencies
4	Medicine Hat	240 kV and above	240 kV and above
42	Hanna	138 kV and above	138 kV and above
43	Sheerness	240 kV and above	240 kV and above
45	Strathmore	240 kV and above	240 kV and above
46	High River	240 kV and above	240 kV and above
47	Brooks	240 kV and above	240 kV and above
48	Empress	138 kV and above	138 kV and above
52	Vauxhall	240 kV and above	240 kV and above
53	Fort Macleod	240 kV and above	240 kV and above
54	Lethbridge	240 kV and above	240 kV and above
55	Glenwood	240 kV and above	240 kV and above

2.3 Load and Generation Assumptions

Load Assumptions

The South Region Reactive Power Requirement studies were conducted using the 2012 Long-term Outlook (2012 LTO), the most recent AESO Corporate Load Forecast. Two boundary conditions (summer peak and light load conditions) for years 2015, 2017 and 2022 were examined. Summer peak load condition was selected because southern Alberta is a summer peaking area and summer line ratings are typically lower than winter ratings, so this represents the most stressful system condition. The Summer Light loading conditions were selected for studying light loading conditions when combined with no wind generation scenarios. The 2015, 2017 and 2022 load forecasts for the South planning region are presented in Table 2-3 below. Further details can be found in the South Region Load and Generation Forecasts filed under Attachment A.

Table 2-3: South Planning Region Load Assumptions (MW)

South Planning Region	2015	2017	2022
Summer Peak	3,275	3,423	3,826
Summer Light	1,810	1,889	2,109

Generation Assumptions

Wind generation is the source of expected generation additions in the study area. The AESO has received numerous wind generation system access applications with total applied-for capacity of 3,196 MW in the South planning region as of August 2012. A number of these projects have advanced through the greater part of the development process. To assess the reactive power requirements for the South planning region, the AESO considered both the wind capacity forecast as well as project specific information to dispatch wind generation in the study area. Details on the generation forecast can be found in the attached South Region Load and Generation Forecasts document, Attachment A. Forecast wind capacity additions were allocated first to projects under construction, then to projects in the Fort MacLeod planning area, as this was the most stressed case for most scenarios. Any remaining forecast capacity additions were allocated to projects throughout the province. Attachment A presents the total generation dispatched by planning area for the study scenarios.

2.4 Study Scenarios

The South Reactive Power Study was completed using base cases developed for steady state and dynamic stability assessments. Table 2-4 through Table 2-6 describe the study scenarios evaluated in the need assessment and reactive device sizing analysis.

All study scenarios in Table 2-4 were evaluated for the assessment of the Southern Region under steady state conditions, except for scenario C15 which is used solely for the dynamic stability study. The study area generation and load totals modeled in each of the twenty one base cases are summarized in Attachment A.

The stressed study scenarios provided in Table 2-5 were evaluated for the dynamic assessment of the dynamic reactive power requirements in the Southern Region of the AIES as well as around the Empress area of the AIES.

The study scenarios shown in Table 2-6 were used for dynamic analysis simulating faults on the Alberta-BC tie close to the BC Hydro network under the shown system conditions. These study models contain the full representation of the Western Electricity Coordinating Council (WECC) system as represented in the published WECC 2015 cases. These study scenarios represent a number of AB-BC tie flow levels ranging from the existing 780 MW operating limit to the path rating of the tie at 1,200 MW.

Table 2-4: Steady State Study Scenarios

Scn #	Year	Load Scenario	Generation Dispatch		WECC Path Flows			Configuration		
			Wind	Hydro	BC Import (MW)	Sask Import (MW)	MATL Import (MW)	FATD West*	7L760/760L Keystone Tap to Oyen*****	1009L Cypress to Bowmanton**
C1M ¹	2015	Summer Light	100%	Seasonal Average	~500 MW export	~0 MW	300 MW export	Offline	Closed	Removed
C1x	2015	Summer Light	100%	Seasonal Average	~800 MW export	~0 MW	~0 MW	Offline	Closed	Removed
C2	2015	Summer Light	0%	Seasonal Average	~0 MW	~0 MW	~0 MW	Offline	Closed	Removed
C3	2015	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW	Offline	Closed	Removed
C10	2015	Summer Peak	100%	Seasonal Average	~780MW import	~0 MW	~0 MW	Offline	Closed	Removed
C4M ¹	2017	Summer Light	100%	Seasonal Average	~500 MW export	~0 MW	300 MW export	Online	Closed	Removed
C4MS ¹	2017	Summer Light	100%	Seasonal Average	~500 MW export	~0 MW	300 MW export	Offline	Closed	Removed
C5	2017	Summer Light	0%	Seasonal Average	~0 MW	~0 MW	~0 MW	Online	Closed	Removed
C5S	2017	Summer Light	0%	Seasonal Average	~0 MW	~0 MW	~0 MW	Offline	Closed	Removed
C6	2017	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW	Online	Closed	Removed

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C6S	2017	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW	Offline	Closed	Removed
C11	2017	Summer Peak	100%	Seasonal Average	~780MW import	~150 MW import	~0 MW	Online	Closed	Removed
C11S	2017	Summer Peak	100%	Seasonal Average	~780MW import	~150 MW import	~0 MW	Offline	Closed	Removed
C7M ¹	2022	Summer Light	100%	Seasonal Average	~500 MW export	~0 MW	300 MW export	Online	Closed	Removed
C7x	2022	Summer Light	100%	Seasonal Average	~800 MW export	~0 MW	~0 MW	Online	Closed	Removed
C8	2022	Summer Light	0%	Seasonal Average	~0 MW	~0 MW	~0 MW	Online	Closed	Removed
C9	2022	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW	Online	Closed	Removed
C12	2022	Summer Peak	100%****	Seasonal Average	~1200 MW import	~0 MW	~0 MW	Online	Closed	Removed
C13	2022	Summer Peak	0%	Seasonal Average	~0 MW	~150 MW export	~0 MW	Online	Open	Removed
C14S	2017	Summer Light	0%	Seasonal Average	~500 MW export	~0 MW	300 MW export	Offline	Open	Removed
C15	2022	Summer Peak	0%	Seasonal Average	~0 MW	~0 MW	~0 MW	Online	Open	Removed

- * FATD West – Double circuit 240 kV line from Foothills to Sarcee substation
- ** 1009L – 240 kV line from Cypress to Bowmanton
- *** Full SATR configuration in all the study scenarios.
- **** Wind generation in the Pincher Creek area is 263 MW, with the remaining wind generation dispersed in the South Region.
- ***** 7L760/760L 138kV line from Oyen to Keystone Tap is planned to be normally open as part of the Hanna Region Transmission Development (HRTD)
- 1 - MATL 2 x 50 MVAR capacitor banks switched online and locked.

Table 2-5: Dynamic Stability Study Scenarios for AIES Faults

Scenario #	Year	Load Scenario	Generation Dispatch		WECC Path Flows		
			Wind	Hydro	BC Import (MW)	Sask Import (MW)	MATL Import (MW)
C3	2015	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW
C3X	2015	Summer Peak	100%	Seasonal Average	~0 MW	~0 MW	~0 MW
C12*	2022	Summer Peak	100%	Seasonal Average	~1200 MW import	~0 MW	~0 MW
C13	2022	Summer Peak	0%	Seasonal Average	~0 MW	~150 MW export	0
C14	2017	Summer Light	0%	Seasonal Average	~500 MW export	~0 MW	300 MW export
C15	2022	Summer Peak	0%	Seasonal Average	~0 MW	~0 MW	~0 MW

*Wind generation in the Pincher Creek area is 263 MW, with the remaining wind generation dispersed in the South Region.

Table 2-6: Dynamic Stability Study Scenarios for WECC Faults

Scenario #	Year*	Load Scenario	Generation Dispatch		WECC Path Flows		
			Wind	Hydro	BC Import (MW)	Sask Import (MW)	MATL Import (MW)
W4	2017	Winter Peak	819 MW	Seasonal Average	780	0	0
W5	2017	Winter Peak	806 MW	Seasonal Average	830	0	0
W6	2017	Winter Peak	806 MW	Seasonal Average	1000	0	0
W7	2017	Winter Peak	806 MW	Seasonal Average	1200	0	0

2.5 Study Scenario Reactive Devices

The list of discrete and continuous control shunt reactive devices modeled in the study area is provided in Appendix A.

3. LINE VOLTAGE RISE ASSESSMENT

The line open-end voltage rise assessment was performed to determine the anticipated voltage rise at the open-ended lines to ensure the voltages during switching operations do not exceed the permissible limits. The assessment was conducted for the lines terminating at the Journault, Windy Flats, Chapel Rock and Cypress substations.

3.1 Assessment Methodology

The assessment was based on calculating the required inductive reactive power requirement to reflect the maximum target design operating voltages of 1.05 p.u. Using the normal maximum operating voltage of 1.05 p.u. and the maximum extreme voltage of 1.1 p.u., the open end voltage rise of the open ended lines were calculated individually using the transmission line parameters for each of the 240 kV lines terminating at the Journault, Windy Flats, Chapel Rock and Cypress substations.

The open-circuit voltage rise coefficient A, as described in Appendix E, were calculated to estimate the voltage rise on the open end of each line.

3.2 Summary of Results

The no-load receiving-end voltages of each line terminating at the Journault, Windy Flats, Chapel Rock and Cypress substations were calculated. Table 3-1 shows the voltage rise coefficient (A) calculated for each of the lines terminating at the four substations.

Table 3-1: Voltage Rise Calculations

Sending-End Bus	Receiving-End Bus	Circuit ID	Circuit Length (km)	Resistance (p.u.) [R]	Reactance (p.u.) [X]	Susceptance (p.u.) [B]	A = $[1+(Y*Z)/2]$
165 PEIGAN 4	746 WINDY FLATS	48	7	0.00074	0.00454	0.01795	0.99996
165 PEIGAN 4	746 WINDY FLATS	49	7	0.00074	0.00454	0.01752	0.99996
641 TURNIP_T	746 WINDY FLATS	48	20.6	0.00217	0.01335	0.05281	0.99965
617 FOOTHLL1*	746 WINDY FLATS	37	126.4	0.00630	0.08280	0.32400	0.98659
617 FOOTHLL1*	746 WINDY FLATS	38	126.4	0.00630	0.08280	0.32400	0.98659
721 KAIYA_1	746 WINDY FLATS	84	16.9	0.00178	0.01096	0.04229	0.99977
451 MATLB1	611 JOURNAULT/SUBC	91	51.49	0.00421	0.03145	0.14024	0.99779
632 OLDELMH	611 JOURNAULT/SUBC	10	85.31	0.00696	0.05209	0.23236	0.99395
662 SUBD1	611 JOURNAULT/SUBC	84	96.86	0.00796	0.05846	0.26763	0.99218

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Sending-End Bus	Receiving-End Bus	Circuit ID	Circuit Length (km)	Resistance (p.u.) [R]	Reactance (p.u.) [X]	Susceptance (p.u.) [B]	A = $[1+(Y*Z)/2]$
662 SUBD1	611 JOURNAULT/SUBC	87	96.86	0.00796	0.05846	0.26763	0.99218
158 LANGDON2	458 CHAPELROCK	01	205.56	0.00188	0.02597	2.59647	0.96629
90000 1201L	458 CHAPELROCK	01	6	0.00006	0.00076	0.07616	0.99997
221 CRR-W1	4458 CHAPELROCK	04	40	0.00200	0.02010	0.09076	0.99909
221 CRR-W1	4458 CHAPELROCK	92	40	0.00200	0.02010	0.09076	0.99909
260 JENNER 4	677 CYPRES2	45	77.06	0.00867	0.04962	0.19392	0.99519
262 DOME EM4	677 CYPRES2	11	4.18	0.00050	0.00275	0.01062	0.99999

*The Foothills to Windy Flats series capacitors were assumed to be by-passed

The no-load receiving end voltages were calculated for the normal maximum and extreme maximum voltage levels allowed at the 240 kV and 500 kV buses (refer to Table 2-1 above). Table 3-2 shows the range of the no-load receiving end voltages for each of the lines connected to the Windy Flats, Journault, Chapel Rock and Cypress substations.

Table 3-2: No-Load Receiving-End Voltages

Sending-End Bus	Receiving-End Bus	Circuit ID	A = $[1+(Y*Z)/2]$	Assumed Sending-End Voltage V_s (p.u.)	Calculated No-Load Receiving-Open End Voltage V_{NL} (p.u.)	Open-End Voltage (kV)
165 PEIGAN 4	746 WINDY FLATS	48	1.000	[1.05 - 1.1]	[1.05 - 1.1]	[252 - 264]
165 PEIGAN 4	746 WINDY FLATS	49	1.000	[1.05 - 1.1]	[1.05 - 1.1]	[252 - 264]
641 TURNIP_T	746 WINDY FLATS	48	1.000	[1.05 - 1.1]	[1.05 - 1.1]	[252 - 264]
617 FOOTHLL1 240.00	746 WINDY FLATS	37	0.987	[1.05 - 1.1]	[1.064 - 1.115]	[255 - 268]
617 FOOTHLL1 240.00	746 WINDY FLATS	38	0.987	[1.05 - 1.1]	[1.064 - 1.115]	[255 - 268]
721 KAIYA_1	746 WINDY FLATS	84	1.000	[1.05 - 1.1]	[1.05 - 1.1]	[252 - 264]
451 MATLB1	611 JOURNAULT/SUBC	91	0.998	[1.05 - 1.1]	[1.052 - 1.102]	[253 - 265]
632 OLDELMH	611 JOURNAULT/SUBC	10	0.994	[1.05 - 1.1]	[1.056 - 1.107]	[254 - 266]
662 SUBD1	611 JOURNAULT/SUBC	84	0.992	[1.05 - 1.1]	[1.058 - 1.109]	[254 - 266]
662 SUBD1	611 JOURNAULT/SUBC	87	0.992	[1.05 - 1.1]	[1.058 - 1.109]	[254 - 266]
158 LANGDON2	458 CHAPELROCK	01	0.966	[1.08 - 1.1]	[1.118 - 1.138]	[559 - 569]
90000 1201L	458 CHAPELROCK	01	1.000	[1.08 - 1.1]	[1.08 - 1.1]	[540 - 550]
221 CRR-W1	4458 CHAPELROCK	04	0.999	[1.05 - 1.1]	[1.051 - 1.101]	[252 - 264]
221 CRR-W1	4458 CHAPELROCK	92	0.999	[1.05 - 1.1]	[1.051 - 1.101]	[252 - 264]
260 JENNER 4	677 CYPRES2	45	0.995	[1.05 - 1.1]	[1.055 - 1.105]	[253 - 265]

Sending-End Bus	Receiving-End Bus	Circuit ID	A = $[1+(Y*Z)/2]$	Assumed Sending-End Voltage V_s (p.u.)	Calculated No-Load Receiving-Open End Voltage V_{rNL} (p.u.)	Open-End Voltage (kV)
262 DOME EM4	677 CYPRES2	11	1.000	[1.05 - 1.1]	[1.05 - 1.1]	[252 - 264]

The results of the voltage rise calculations indicate that the voltage rise is not significant and a sending end voltage of 1.05 p.u. would be able to keep the open-end voltage under 1.064 p.u., below the extreme maximum voltage of 1.10 p.u.

A number of 240 kV lines with lengths of 75 km or longer may experience a voltage rise at the open end slightly higher than the extreme maximum operating voltage of 1.10 p.u. (264 kV) level. However, the calculated voltage rise for these lines remains below the equipment capability for continuous operation provided that the receiving end voltage is brought down from 1.10 p.u to 1.05 p.u.

For the 500 kV Alberta-BC tie line from Langdon to Chapel Rock, the analysis shows that the open end voltage can rise to a range of 1.118 p.u.- 1.138 p.u. for an assumed extreme maximum sending end voltage range of 1.08 p.u.-1.10 p.u. It is to be noted that for energization of this line segment from the Langdon or the Chapel Rock substations, the SVCs at either Langdon or Chapel Rock shall be able to control the sending end voltage to below 1.05 p.u. At this sending end voltage, the voltage rise at the open-end shall not exceed 1.09 p.u. (545 kV) which is below the extreme maximum voltage of 1.1 p.u. (550kV).

The AESO has concluded that with the target design normal maximum voltage limit of 1.05 p.u. for the 240 kV and 500 kV systems in Southern Alberta, the open ended voltage rise for the transmission lines in the area should be acceptable and within the equipment and reliability criteria limits. The following sections will illustrate the reactive power device sizing studies conducted to establish the target design voltage and performance levels.

4. REACTIVE POWER NEED ASSESSMENT

This section discusses the results of the system reactive power need assessment studies conducted under steady state and transient conditions with all reactive power devices listed in Table I removed except for the devices at Whitla substation which are under construction. The following sections describe the summary of the Need Assessment Studies and the performance of the system under Category A and B contingencies and some selected Category C contingencies caused by the outage of a common element.

4.1 Steady State Need Assessment

The steady state Need Assessment was performed to determine the voltage violations in the system under Categories A and B contingency conditions without any reactive power control devices at the Journault, Windy Flats, Chapel Rock and Cypress substations. The contingency analysis was performed using the base cases listed in Table 2-4 above.

Table 4-1 shows the worst voltage violations observed at critical buses throughout the study area under Category A conditions. Only overvoltage violations were observed under Category A conditions except for the Cypress area in scenario C13. Table 4-1 also shows the scenarios where each overvoltage violation was observed under Category A conditions with V_{init} representing the initial bus voltage. Table 4-2 lists the under voltage violation in the Cypress area in scenario C13. The corresponding steady state plots for each of the twenty scenarios can be found in Appendix B.

Table 4-1: Need Assessment – Category A Overvoltage Violations

Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario
458 CHAPR1 500.00	1.104	1.080	1.020	C5S_2017SL_0_0_0
458 CHAPR1 500.00	1.103	1.080	1.020	C2_2015SL_0_0_0
458 CHAPR1 500.00	1.103	1.080	1.020	C5_2017SL_0_0_0
458 CHAPR1 500.00	1.102	1.080	1.020	C8_2022SL_0_0_0
2451 MATLB2 240.00	1.089	1.050	1.000	C5S_2017SL_0_0_0
2451 MATLB2 240.00	1.088	1.050	1.000	C2_2015SL_0_0_0
346 GOOSEL4 240.00	1.088	1.050	1.000	C5S_2017SL_0_0_0
98856 HW785 240.00	1.087	1.050	1.000	C5S_2017SL_0_0_0
536 HERITAG1 240.00	1.087	1.050	1.000	C5S_2017SL_0_0_0
751 FIDLER01 240.00	1.087	1.050	1.000	C5S_2017SL_0_0_0
2451 MATLB2 240.00	1.087	1.050	1.000	C5_2017SL_0_0_0
611 SUBC_240 240.00	1.087	1.050	1.000	C5S_2017SL_0_0_0
221 CRR-W1 240.00	1.087	1.050	1.000	C5S_2017SL_0_0_0
165 PEIGAN 4 240.00	1.086	1.050	1.000	C5S_2017SL_0_0_0
346 GOOSEL4 240.00	1.086	1.050	1.000	C2_2015SL_0_0_0
721 KAIYA_1 240.00	1.086	1.050	1.000	C5S_2017SL_0_0_0
165 PEIGAN 4 240.00	1.086	1.050	1.000	C2_2015SL_0_0_0
98856 HW785 240.00	1.086	1.050	1.000	C2_2015SL_0_0_0

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Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario
746 WINDYFLATS 240.00	1.086	1.050	1.000	C5S_2017SL_0_0_0
451 MATLB1 240.00	1.086	1.050	1.000	C5S_2017SL_0_0_0
721 KAIYA_1 240.00	1.086	1.050	1.000	C2_2015SL_0_0_0
346 GOOSEL4 240.00	1.086	1.050	1.000	C5_2017SL_0_0_0
611 SUBC_240 240.00	1.086	1.050	1.000	C5_2017SL_0_0_0
641 TURNIP_T 240.00	1.086	1.050	1.000	C5S_2017SL_0_0_0
641 TURNIP_T 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
536 HERITAG1 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
751 FIDLER01 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
746 WINDYFLATS 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
98856 HW785 240.00	1.085	1.050	1.000	C5_2017SL_0_0_0
536 HERITAG1 240.00	1.085	1.050	1.000	C5_2017SL_0_0_0
751 FIDLER01 240.00	1.085	1.050	1.000	C5_2017SL_0_0_0
221 CRR-W1 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
451 MATLB1 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
611 SUBC_240 240.00	1.085	1.050	1.000	C2_2015SL_0_0_0
221 CRR-W1 240.00	1.085	1.050	1.000	C5_2017SL_0_0_0
451 MATLB1 240.00	1.084	1.050	1.000	C5_2017SL_0_0_0
167 N LETHB4 240.00	1.084	1.050	1.000	C2_2015SL_0_0_0
536 HERITAG1 240.00	1.084	1.050	1.000	C8_2022SL_0_0_0
751 FIDLER01 240.00	1.084	1.050	1.000	C8_2022SL_0_0_0
346 GOOSEL4 240.00	1.083	1.050	1.000	C8_2022SL_0_0_0
2451 MATLB2 240.00	1.083	1.050	1.000	C8_2022SL_0_0_0
167 N LETHB4 240.00	1.083	1.050	1.000	C5S_2017SL_0_0_0
98856 HW785 240.00	1.083	1.050	1.000	C8_2022SL_0_0_0
165 PEIGAN 4 240.00	1.083	1.050	1.000	C5_2017SL_0_0_0
221 CRR-W1 240.00	1.083	1.050	1.000	C8_2022SL_0_0_0
721 KAIYA_1 240.00	1.083	1.050	1.000	C5_2017SL_0_0_0
641 TURNIP_T 240.00	1.083	1.050	1.000	C5_2017SL_0_0_0
746 WINDYFLATS 240.00	1.082	1.050	1.000	C5_2017SL_0_0_0
4458 CHAPR2 240.00	1.081	1.050	1.000	C5S_2017SL_0_0_0
167 N LETHB4 240.00	1.081	1.050	1.000	C5_2017SL_0_0_0
4458 CHAPR2 240.00	1.080	1.050	1.000	C2_2015SL_0_0_0
4458 CHAPR2 240.00	1.080	1.050	1.000	C5_2017SL_0_0_0
262 DOME EM4 240.00	1.080	1.050	1.000	C4M_2017SL_500_0_300
677 CYPRES2 240.00	1.079	1.050	1.000	C4M_2017SL_500_0_300
165 PEIGAN 4 240.00	1.079	1.050	1.000	C8_2022SL_0_0_0
262 DOME EM4 240.00	1.079	1.050	1.000	C4MS_2017SL_500_0_300
677 CYPRES2 240.00	1.079	1.050	1.000	C4MS_2017SL_500_0_300
611 SUBC_240 240.00	1.079	1.050	1.000	C8_2022SL_0_0_0
451 MATLB1 240.00	1.079	1.050	1.000	C8_2022SL_0_0_0
721 KAIYA_1 240.00	1.078	1.050	1.000	C8_2022SL_0_0_0
4458 CHAPR2 240.00	1.078	1.050	1.000	C8_2022SL_0_0_0
746 WINDYFLATS 240.00	1.078	1.050	1.000	C8_2022SL_0_0_0
641 TURNIP_T 240.00	1.078	1.050	1.000	C8_2022SL_0_0_0
167 N LETHB4 240.00	1.076	1.050	1.000	C8_2022SL_0_0_0
260 JENNER 4 240.00	1.074	1.050	1.000	C2_2015SL_0_0_0
677 CYPRES2 240.00	1.074	1.050	1.000	C2_2015SL_0_0_0
677 CYPRES2 240.00	1.074	1.050	1.000	C1X_2015SL_800_0_0
262 DOME EM4 240.00	1.073	1.050	1.000	C1X_2015SL_800_0_0
262 DOME EM4 240.00	1.073	1.050	1.000	C2_2015SL_0_0_0
2451 MATLB2 240.00	1.072	1.050	1.000	C1X_2015SL_800_0_0
260 JENNER 4 240.00	1.071	1.050	1.000	C4M_2017SL_500_0_300

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Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario
260 JENNER 4 240.00	1.071	1.050	1.000	C4MS_2017SL_500_0_300
669 MEDHAT2 240.00	1.070	1.050	1.000	C5S_2017SL_0_0_0
260 JENNER 4 240.00	1.070	1.050	1.000	C1X_2015SL_800_0_0
669 MEDHAT2 240.00	1.069	1.050	1.000	C5_2017SL_0_0_0
611 SUBC_240 240.00	1.067	1.050	1.000	C1M_2015SL_500_0_300
260 JENNER 4 240.00	1.067	1.050	1.000	C1M_2015SL_500_0_300
260 JENNER 4 240.00	1.067	1.050	1.000	C5S_2017SL_0_0_0
677 CYPRES2 240.00	1.066	1.050	1.000	C1M_2015SL_500_0_300
260 JENNER 4 240.00	1.066	1.050	1.000	C5_2017SL_0_0_0
262 DOME EM4 240.00	1.066	1.050	1.000	C1M_2015SL_500_0_300
451 MATLB1 240.00	1.065	1.050	1.000	C1M_2015SL_500_0_300
2451 MATLB2 240.00	1.065	1.050	1.000	C3_2015SP_0_0_0
611 SUBC_240 240.00	1.065	1.050	1.000	C1X_2015SL_800_0_0
451 MATLB1 240.00	1.063	1.050	1.000	C1X_2015SL_800_0_0
669 MEDHAT2 240.00	1.063	1.050	1.000	C2_2015SL_0_0_0
669 MEDHAT2 240.00	1.062	1.050	1.000	C1M_2015SL_500_0_300
2451 MATLB2 240.00	1.062	1.050	1.000	C10_2015SP_-780_0_0
451 MATLB1 240.00	1.062	1.050	1.000	C4M_2017SL_500_0_300
611 SUBC_240 240.00	1.062	1.050	1.000	C4M_2017SL_500_0_300
262 DOME EM4 240.00	1.061	1.050	1.000	C5S_2017SL_0_0_0
677 CYPRES2 240.00	1.061	1.050	1.000	C5S_2017SL_0_0_0
451 MATLB1 240.00	1.061	1.050	1.000	C4MS_2017SL_500_0_300
669 MEDHAT2 240.00	1.061	1.050	1.000	C1X_2015SL_800_0_0
611 SUBC_240 240.00	1.061	1.050	1.000	C4MS_2017SL_500_0_300
262 DOME EM4 240.00	1.061	1.050	1.000	C5_2017SL_0_0_0
677 CYPRES2 240.00	1.061	1.050	1.000	C5_2017SL_0_0_0
2451 MATLB2 240.00	1.060	1.050	1.000	C6_2017SP_0_0_0
2451 MATLB2 240.00	1.060	1.050	1.000	C6S_2017SP_0_0_0
260 JENNER 4 240.00	1.059	1.050	1.000	C8_2022SL_0_0_0
2451 MATLB2 240.00	1.059	1.050	1.000	C1M_2015SL_500_0_300
2451 MATLB2 240.00	1.058	1.050	1.000	C7X_2022SL_800_0_0
669 MEDHAT2 240.00	1.058	1.050	1.000	C8_2022SL_0_0_0
2451 MATLB2 240.00	1.056	1.050	1.000	C4M_2017SL_500_0_300
2451 MATLB2 240.00	1.056	1.050	1.000	C4MS_2017SL_500_0_300
451 MATLB1 240.00	1.055	1.050	1.000	C3_2015SP_0_0_0
611 SUBC_240 240.00	1.055	1.050	1.000	C3_2015SP_0_0_0
669 MEDHAT2 240.00	1.055	1.050	1.000	C4M_2017SL_500_0_300
2451 MATLB2 240.00	1.054	1.050	1.000	C9_2022SP_0_0_0
167 N LETHB4 240.00	1.054	1.050	1.000	C1X_2015SL_800_0_0
669 MEDHAT2 240.00	1.054	1.050	1.000	C4MS_2017SL_500_0_300
260 JENNER 4 240.00	1.054	1.050	1.000	C11_2017SP_-780_0_-150
260 JENNER 4 240.00	1.053	1.050	1.000	C7M_2022SL_500_0_300
2451 MATLB2 240.00	1.053	1.050	1.000	C11_2017SP_-780_0_-150
167 N LETHB4 240.00	1.053	1.050	1.000	C1M_2015SL_500_0_300
260 JENNER 4 240.00	1.053	1.050	1.000	C10_2015SP_-780_0_0
262 DOME EM4 240.00	1.053	1.050	1.000	C8_2022SL_0_0_0
677 CYPRES2 240.00	1.053	1.050	1.000	C8_2022SL_0_0_0
260 JENNER 4 240.00	1.052	1.050	1.000	C11S_2017SP_-780_0_-150
167 N LETHB4 240.00	1.052	1.050	1.000	C4M_2017SL_500_0_300
2451 MATLB2 240.00	1.051	1.050	1.000	C11S_2017SP_-780_0_-150
260 JENNER 4 240.00	1.051	1.050	1.000	C7X_2022SL_800_0_0
260 JENNER 4 240.00	1.051	1.050	1.000	C3_2015SP_0_0_0
451 MATLB1 240.00	1.051	1.050	1.000	C10_2015SP_-780_0_0

Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario
167 N LETHB4 240.00	1.051	1.050	1.000	C4MS_2017SL_500_0_300
4458 CHAPR2 240.00	1.050	1.050	1.000	C3_2015SP_0_0_0
2451 MATLB2 240.00	1.054	1.05	1.000	C13_2022SP_0_0_150
260 JENNER 4 240.00	1.062	1.05	1.000	C14_2017SL_500_0_300
262 DOME EM4 240.00	1.066	1.05	1.000	C14_2017SL_500_0_300
451 MATLB1 240.00	1.06	1.05	1.000	C14_2017SL_500_0_300
611 SUBC_240 240.00	1.059	1.05	1.000	C14_2017SL_500_0_300
669 MEDHAT2 240.00	1.052	1.05	1.000	C14_2017SL_500_0_300
677 CYPRES2 240.00	1.066	1.05	1.000	C14_2017SL_500_0_300
2451 MATLB2 240.00	1.055	1.05	1.000	C14_2017SL_500_0_300

Table 4-2: Need Assessment – Category A Under voltage Violations

Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario
677 CYPRES2 240.00	0.9881	1.05	1.000	C13_2022SP_0_0_150
262 DOME EM4 240.00	0.9884	1.05	1.000	C13_2022SP_0_0_150
1454 BINDLOS7 138	0.9241	0.98	1.05	C13_2022SP_0_0_150
1456 CAVDISH1 138	0.9296	0.98	1.05	C13_2022SP_0_0_150
1473 MCNEILL 138	0.9601	0.98	1.05	C13_2022SP_0_0_150
263 EMP LIQ7 138	0.9688	0.98	1.05	C13_2022SP_0_0_150
266 EMPRESA7 138	0.9757	0.98	1.05	C13_2022SP_0_0_150
111 SANDHIL7 138	0.9759	0.98	1.05	C13_2022SP_0_0_150
53 SANDYPT7 138	0.9759	0.98	1.05	C13_2022SP_0_0_150
674 CYPRES1 138	0.976	0.98	1.05	C13_2022SP_0_0_150
267 DOME EM7 138	0.9761	0.98	1.05	C13_2022SP_0_0_150

Table 4-3 and Table 4-4 show the overvoltage and under voltage violations respectively observed under Category B conditions. The corresponding steady state plots for each of the twenty scenarios can be found in Appendix B. The results showed that the loss of Langdon 500/240 kV transformer under low AB-BC transfer could cause higher voltages compared to the Category A voltage levels.

The results presented in Table 4-2 reflect the system conditions without any of the original reactive power control devices recommended in SATR plan in place. All initial voltages leading to voltage violations above the post-contingency extreme maximum voltage of 1.1 p.u., the voltages are well above the target system normal (pre-contingency) voltage design level of 1.05 p.u. This indicates that a second 500/240kV transformer at Langdon 102S can mitigate the overvoltage violations due to the outage of the existing Langdon 500/240 kV transformer, however, it won't be able to resolve the initial (i.e. pre-contingency) high voltage profile throughout southern Alberta transmission network.

There were several outages that caused under voltage violations at the Chapel Rock 500 kV bus. These outages were either due to the loss of generation (e.g., one Sheerness unit) under peak conditions or the outage of 1201L (Chapel Rock to Langdon) 500 kV line.

In addition, there were under voltage violations in the Cypress area under certain contingencies. These outages are only present in the scenario C13 in which the 7L760/760L Oyen – Keystone Tap 138kV line is normally open. The transmission network configuration and additional reinforcements in the Cypress area is currently being studied under the southern Alberta regional plan in order to reliably serve load and maintain interchanges with Saskatchewan when the 760L line is open.

Table 4-5 shows that there were two non-converged contingencies observed in the 2022 summer peak high-import scenario C12 – loss of 1201L and an outage of the Langdon 500/240 kV transformer. These non-converged contingencies occur under the C12 study scenario which represents a 2022 summer peak case with maximum 1,200 MW import level on the AB-BC tie line coupled with full wind generation. This 1,200 MW import level currently exceeds the operational limits of 780 MW import and 800 MW export on the BC tie line. However, the results indicate that in order to enable a higher utilization of the tie capacity up to the path rating of 1,200 MW, additional reactive power reinforcement is required along with other measures to ensure frequency stability within the Alberta system under the loss of the tie line. Further analysis and discussion of this scenario is presented in the following sections.

Table 4-3: Need Assessment – Category B Overvoltage Violations

Bus/Substation	Contingency	VCont	Vlnit	Vmax	Vmin	Scenario
458 CHAPR1 500.00	Langdon 500/240 kV Transformer	1.14245	1.1034	1.1	1	C2_2015SL_0_0_0
165 PEIGAN 4 240.00	Langdon 500/240 kV Transformer	1.10216	1.08578	1.1	0.917	C2_2015SL_0_0_0
221 CRR-W1 240.00	Langdon 500/240 kV Transformer	1.11045	1.08505	1.1	0.917	C2_2015SL_0_0_0
346 GOOSEL4 240.00	Langdon 500/240 kV Transformer	1.10836	1.08633	1.1	0.917	C2_2015SL_0_0_0
536 HERITAG1 240.00	Langdon 500/240 kV Transformer	1.10892	1.08526	1.1	0.917	C2_2015SL_0_0_0
746 WINDYFLATS 240.00	Langdon 500/240 kV Transformer	1.10016	1.0852	1.1	0.917	C2_2015SL_0_0_0
751 FIDLER01 240.00	Langdon 500/240 kV Transformer	1.10892	1.08526	1.1	0.917	C2_2015SL_0_0_0
4458 CHAPR2 240.00	Langdon 500/240 kV Transformer	1.11333	1.08006	1.1	0.917	C2_2015SL_0_0_0
98856 HW785 240.00	Langdon 500/240 kV Transformer	1.10947	1.08576	1.1	0.917	C2_2015SL_0_0_0
458 CHAPR1 500.00	Langdon 500/240 kV Transformer	1.10405	1.07963	1.1	1	C3_2015SP_0_0_0
458 CHAPR1 500.00	Langdon 500/240 kV Transformer	1.13995	1.10311	1.1	1	C5_2017SL_0_0_0
221 CRR-W1 240.00	Langdon 500/240 kV Transformer	1.1072	1.08457	1.1	0.917	C5_2017SL_0_0_0
346 GOOSEL4 240.00	Langdon 500/240 kV Transformer	1.10479	1.08559	1.1	0.917	C5_2017SL_0_0_0
536 HERITAG1 240.00	Langdon 500/240 kV Transformer	1.10576	1.08506	1.1	0.917	C5_2017SL_0_0_0
751 FIDLER01 240.00	Langdon 500/240 kV Transformer	1.10576	1.08506	1.1	0.917	C5_2017SL_0_0_0
4458 CHAPR2 240.00	Langdon 500/240 kV Transformer	1.11052	1.07974	1.1	0.917	C5_2017SL_0_0_0
98856 HW785 240.00	Langdon 500/240 kV Transformer	1.10606	1.08515	1.1	0.917	C5_2017SL_0_0_0
458 CHAPR1 500.00	Langdon 500/240 kV Transformer	1.14403	1.10432	1.1	1	C5S_2017SL_0_0_0
165 PEIGAN 4 240.00	Langdon 500/240 kV Transformer	1.10371	1.08639	1.1	0.917	C5S_2017SL_0_0_0
221 CRR-W1 240.00	Langdon 500/240 kV Transformer	1.11257	1.08672	1.1	0.917	C5S_2017SL_0_0_0
346 GOOSEL4 240.00	Langdon 500/240 kV Transformer	1.11047	1.08802	1.1	0.917	C5S_2017SL_0_0_0
536 HERITAG1 240.00	Langdon 500/240 kV Transformer	1.11139	1.08728	1.1	0.917	C5S_2017SL_0_0_0
721 KAIYA_1 240.00	Langdon 500/240 kV Transformer	1.10062	1.08586	1.1	0.917	C5S_2017SL_0_0_0
746 WINDYFLATS 240.00	Langdon 500/240 kV Transformer	1.10165	1.08572	1.1	0.917	C5S_2017SL_0_0_0
751 FIDLER01 240.00	Langdon 500/240 kV Transformer	1.11139	1.08728	1.1	0.917	C5S_2017SL_0_0_0
4458 CHAPR2 240.00	Langdon 500/240 kV Transformer	1.11502	1.08127	1.1	0.917	C5S_2017SL_0_0_0
98856 HW785 240.00	Langdon 500/240 kV Transformer	1.11159	1.08744	1.1	0.917	C5S_2017SL_0_0_0

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Bus/Substation	Contingency	VCont	Vinit	Vmax	Vmin	Scenario
458 CHAPR1 500.00	Langdon 500/240 kV Transformer	1.1391	1.10185	1.1	1	C8_2022SL_0_0_0
221 CRR-W1 240.00	Langdon 500/240 kV Transformer	1.10652	1.0828	1.1	0.917	C8_2022SL_0_0_0
346 GOOSEL4 240.00	Langdon 500/240 kV Transformer	1.10374	1.08339	1.1	0.917	C8_2022SL_0_0_0
536 HERITAG1 240.00	Langdon 500/240 kV Transformer	1.10559	1.08357	1.1	0.917	C8_2022SL_0_0_0
751 FIDLER01 240.00	Langdon 500/240 kV Transformer	1.10559	1.08357	1.1	0.917	C8_2022SL_0_0_0
4458 CHAPR2 240.00	Langdon 500/240 kV Transformer	1.11004	1.07842	1.1	0.917	C8_2022SL_0_0_0
98856 HW785 240.00	Langdon 500/240 kV Transformer	1.1052	1.08316	1.1	0.917	C8_2022SL_0_0_0

Table 4-4: Need Assessment – Category B Under Voltage Violations

Bus	Contingency	VCont	Vinit	Vmax	Vmin	Scenario
458 CHAPR1 500.00	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	0.990	1.056	1.1	1	C11_2017SP_-780_0_-150
458 CHAPR1 500.00	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	0.975	1.052	1.1	1	C11S_2017SP_-780_0_-150
458 CHAPR1 500.00	736[BSR_1 240.00] to 737[SW_SUB_1 240.00] CKT 42	0.964	1.021	1.1	1	C12_2022SP_-1200_0_0
458 CHAPR1 500.00	1481[SHEER 14 240.00] to 1484[ANDERSO4 240.00] CKT 99	0.950	1.021	1.1	1	C12_2022SP_-1200_0_0
458 CHAPR1 500.00	1484[ANDERSO4 240.00] to 1486[SHEER 24 240.00] CKT 00	0.951	1.021	1.1	1	C12_2022SP_-1200_0_0
262 DOME EM4 240.00	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	0.899	0.971	1.100	0.917	C13_2022SP_0_0_150
677 CYPRES2 240.00	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	0.898	0.972	1.100	0.917	C13_2022SP_0_0_150
262 DOME EM4 240.00	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	0.902	0.971	1.100	0.917	C13_2022SP_0_0_150
677 CYPRES2 240.00	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	0.902	0.972	1.100	0.917	C13_2022SP_0_0_150
262 DOME EM4 240.00	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	0.898	0.971	1.100	0.917	C13_2022SP_0_0_150
677 CYPRES2 240.00	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	0.900	0.972	1.100	0.917	C13_2022SP_0_0_150
262 DOME EM4 240.00	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	0.894	0.971	1.100	0.917	C13_2022SP_0_0_150
677 CYPRES2 240.00	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	0.892	0.972	1.100	0.917	C13_2022SP_0_0_150

Table 4-5: Need Assessment – Non-Converged Category B Contingencies

Case	Contingency
C12_2022SP_-1200_0_0	1201L – Chapel Rock to Langdon 500 kV line
	Langdon 500/240 kV Transformer 102ST1

Table 4-6 below shows that there were two non-converged contingency case results observed in the peak loading case. With the 7L760/760L Oyen to Empress 138 kV line opened as per HRTD, the Empress area is served solely by the 138 kV line 658L from Medicine Hat under certain contingencies. There is insufficient transmission capacity to serve the forecasted load in the Empress area and this issue cannot be resolved by the addition of reactive power devices. The transmission network configuration and additional 138 kV network reinforcements in the area are currently being studied under the southern Alberta regional plan.

Table 4-6: Need Assessment – Non-Converged Category C5 Contingencies

Scenario	Contingency Description
C3_2015SP_0_0_0	1002-1011_B Category C5 outage of Cypress to Dome Empress 240 kV line, Cypress to Jenner 240 kV line and Jenner 240/138 kV transformer.
C6_2017SP_0_0_0	
C6S_2017SP_0_0_0	
C9_2022SP_0_0_0	
C10_2015SP_-780_0_0	
C11_2017SP_-780_0_-150	944-951_A Category C5 outage of 944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L
C11S_2017SP_-780_0_-150	
C12_2022SP_-1200_0_0	
C13_2022SP_0_0_150	
C14_2017SL_500_0_300	

4.2 Dynamic Stability Need Assessment

This section discusses the methodology and results of the dynamic stability assessment of the system without additional reactive power devices at the Journault, Windy Flats, Chapel Rock and Cypress substations.

Assessment Methodology

A select set of critical Categories B and C5 fault conditions was defined to assess the dynamic stability of the AIES using the base cases defined in Table 2-5 and Table 2-6. The system performance during and post fault conditions within the AIES were assessed with the AIES base cases in Table 2-5. The fault conditions around the BC-Alberta tie line were assessed using the WECC base cases defined in Table 2-6. The Cypress area was assessed with the 2015 summer peak scenarios, C3 and C3X. The southwest part of the system was assessed with the scenario C12 with maximum 1,200 MW import (to be consistent) and Ft. Macleod (Area 53) generation.

The fault scenarios simulated and the corresponding fault location diagrams for the AIES and WECC base cases are presented in Appendix C.

Dynamic Analysis Results

The dynamic stability need assessment studies were performed to study the system dynamic performance under Categories B and C5 fault scenarios without the reactive power devices at the Windy Flats, Journault, Chapel Rock and Cypress locations. The fault scenarios described in Appendix C were simulated using the respective AIES and WECC base case models.

The complete set of results for the studied fault scenarios and the corresponding dynamic response plots are provided in Appendix D. Table 4-7 shows the Category B fault conditions that caused system instability. Details of potential load shedding requirements to maintain system stability are provided in Appendix D.

The results show that the Category B fault on 1201L - Chapel Rock to Langdon 500 kV line caused high frequency oscillations within the immediate system around Chapel Rock. This is consistent with the results of the steady state assessment reflecting a lack of adequate voltage support in the area.

The Category C5 fault on 944L and 951L – Jenner to Ware Junction 240 kV lines caused voltage instability in the immediate system around Cypress. This is consistent with the results of the steady state assessment showing voltage collapse. An operational study will be carried out to develop a detailed Remedial Action Scheme that addresses this issue. The initial indications are to transfer trip export to Saskatchewan to limit load curtailment in the Empress area. In

addition to these Category C5 contingencies, the Category B contingencies shown in Table 4-4 indicate severe under voltage violations in the Cypress Area with the 7L760/760L line open. These under-voltage violations indicate potential risk of fast voltage collapse in the 138 kV network associated with the large motor component of the area load.

Table 4-7: Need Assessment Category B-Dynamic Analysis Results

Fault ID	Fault Name	Observation		
		C3	C3X	C12
B06	CHPR_LAND	System Stable	System Stable	Extreme Low voltages at Chapel Rock, Peigan, Windy Flats.
B07	CHPR_LAND	System Stable	System Stable	Extreme Low voltages at Chapel Rock, Peigan, Windy Flats.
B08	LAND_XFMR500	System Stable	System Stable	Extreme Low voltages at Chapel Rock, Peigan, Windy Flats.
B09	LAND_XFMR240	System Stable	System Stable	Extreme Low voltages at Chapel Rock, Peigan, Windy Flats.

Table 4-8: Need Assessment Category C5 Stability Results

Fault ID	Fault Name	Observation		
		C3	C3X	C12
C509	944-951_A	Voltage Collapse at Cypress, Dome Empress	Low Voltage at Cypress, Dome Empress	Voltage Collapse at Cypress, Dome Empress
C510	944-951_B	Voltage Collapse at Cypress, Dome Empress	Voltage Collapse at Cypress, Dome Empress	Voltage Collapse at Cypress, Dome Empress
C512	1002-1011_B	Voltage Collapse at Cypress, Dome Empress	Low Voltage at Cypress, Dome Empress	Low Voltage at Cypress, Dome Empress

4.3 Reactive Power Need Assessment Study: Summary & Conclusions

Both steady state and dynamic analyses studies revealed the following:

- The voltages on the 240 kV and 500 kV network in the study area under Category A and B conditions exceeded their respective limits and thus violate reliability criteria under steady state conditions.
- Under voltages were found under steady state Category A conditions in the Cypress area under peak load and transfer out via McNeill HVDC.
- Under voltages were observed for Category B and the select Category C conditions simulated. The majority of these violations occur under the loss of the 500/240 kV Langdon transformer or 1201L. Few under voltage violations occur under the loss of generators in the study area.
- Dynamic stability analysis indicated that the system would experience voltage instability/collapse conditions in the Empress area under certain contingency conditions.
- Under high import conditions, the system would become unstable near Chapel Rock for specific contingencies along the AB-BC tie-line due to excessive reactive power demand to support the combined import and wind generation from the Pincher Creek area into the AIES.

All the above results indicate there is a need for reactive power support in Southern Alberta to alleviate voltage instability and maintain voltages within prescribed limits as per the Alberta Reliability Standards. The need assessment results also indicate the need for a Remedial Action Scheme to alleviate voltage instability due to Category C5 events in the Empress area.

5. REACTIVE POWER REQUIREMENTS

This section discusses the determination of the reactive power devices required at the Windy Flats, Journault, Chapel Rock and Cypress substations to resolve the system violations identified in the Need Assessment. The following sections describe the methodology and results of the steady state and dynamic stability analyses performed to determine the sizing of the reactive devices.

5.1 Reactive Power Requirements - System Normal Conditions

The results of the steady state need assessment revealed multiple over voltages and under voltage violations under Category A and Category B conditions. This section discusses the methodology employed in the determination of the steady state reactive power requirements and the corresponding results. As the reported violations under system normal conditions, Category A, are over voltages in their entirety, the reactive power sizing is focused on identifying the required reactor sizes to bring the normal system operating voltage within the design target normal operating limit of 1.00 p.u. to 1.05 p.u.

The reactive power requirements under steady state conditions were determined in the following steps:

1. Determination of Inductive Reactive Power Requirements

In order to resolve the overvoltage violations identified in the need assessment, the Inductive reactive power requirements at the four key SATR substations of Chapel Rock, Windy Flats, Journault and Cypress 240 kV buses with their voltages at the target maximum voltage limit of 1.05 p.u. under Category A conditions in each of the twenty need assessment base cases were determined. These inductive reactive power requirements are shown in Table 5-1 below.

Table 5-1: Category A Inductive Reactive Power Requirement for 1.05 pu Voltage

Scenario	Condition	746 Windy Flats (MVAR)	611 Journault (MVAR)	677 Cypress (MVAR)	4458 Chapel Rock (MVAR)
C1M_2015SL_500_0_300	Category A	N/A	-67.4	-27.2	N/A
C1X_2015SL_800_0_0	Category A	N/A	-66.1	-46.9	N/A
C2_2015SL_0_0_0	Category A	-150	-69.7	-33.9	-116.8
C3_2015SP_0_0_0	Category A	N/A	-24.7	N/A	-21.6
C4M_2017SL_500_0_300	Category A	N/A	-49.5	-56	N/A
C4MS_2017SL_500_0_300	Category A	N/A	-49	-56	N/A
C5_2017SL_0_0_0	Category A	-150	-78	-7.8	-121.1

Scenario	Condition	746 Windy Flats (MVAR)	611 Journault (MVAR)	677 Cypress (MVAR)	4458 Chapel Rock (MVAR)
C5S_2017SL_0_0_0	Category A	-150	-79	-7.9	-124
C6_2017SP_0_0_0	Category A	N/A	-6.5	N/A	-19.3
C6S_2017SP_0_0_0	Category A	N/A	-4.1	N/A	-11.9
C7M_2022SL_500_0_300	Category A	N/A	-1.6	N/A	N/A
C7X_2022SL_800_0_0	Category A	N/A	N/A	N/A	N/A
C8_2022SL_0_0_0	Category A	-147.5	-57.7	N/A	-125.4
C9_2022SP_0_0_0	Category A	N/A	N/A	N/A	N/A
C10_2015SP_-780_0_0	Category A	N/A	-0.5	N/A	N/A
C11_2017SP_-780_0_-150	Category A	N/A	N/A	N/A	N/A
C11S_2017SP_-780_0_-150	Category A	N/A	N/A	N/A	N/A
C12_2022SP_-1200_0_0	Category A	N/A	N/A	N/A	N/A
C13_2022SP_0_0_150	Category A	N/A	N/A	N/A	N/A
C14_2017SL_500_0_300	Category A	N/A	-49.0	-27.5	N/A
Max Reactive Power (MVAR)		-150	-79	-56	-125

The inductive reactive power requirements under Category A at these four key substations were used to identify the initial shunt reactor size for further simulation testing.

2. Initial Reactor Sizing

Fixed shunt reactors sized to match the reactor size determined in Step 1 above and shown in Table 5-1 were placed in the twenty one need assessment base cases. The initial sizes of the fixed shunt reactors are shown in Table 5-2 below.

While scenario C4MS shows a higher inductive requirement, this C4MS scenario is a sensitivity case with line 7L760/760L closed. Thus, the inductive requirement as per the approved plan of having line 7L760/760L normally open is -27.5 MVAR as per scenario C14.

Table 5-2: Initial Shunt Reactor Sizes for Category A Conditions

746 Windy Flats (MVAR)	611 Journault (MVAR)	677 Cypress (MVAR)	4458 Chapel Rock (MVAR)
-150	-79	-27.5	-125

3. Resolution of Outstanding Category A Overvoltage Violations

The need assessment base cases with the initial reactor sizes shown above in Table 5-2 were evaluated under Category A conditions for substation buses in the study area. The results of the Category A evaluation including the initial shunt reactor sizes showed that there were several buses in the study area with voltages marginally higher than the target design operating voltage limit of 1.05 p.u. as shown in Table 5-3. Rather than placing shunt reactor devices at additional substations, adjustments were made to the size of the reactors at the Journault and Chapel Rock substations to resolve each outstanding Category A voltage violation as shown in Table 5-3.

The Journault reactor size was increased from the preliminarily identified 79 MVAR to 119 MVAR to address the North Lethbridge violation while the Chapel Rock reactor size was increased to 145 MVAR from the preliminary identified 125 MVAR to address the Fidler and Heritage 240 kV bus overvoltage violations. The adjusted shunt reactor sizes shown in Table 5-4 were tested with all twenty one scenarios and there were no outstanding Category A overvoltage above the design target 1.05 p.u. voltage on the critical buses in the study area.

Table 5-3: Adjusted Shunt Reactor Sizes

Bus	Max Voltage (pu)	Case with Max Voltage	Reactor	Adjusted Reactor Size (MVAR)
167 N LETHB4 240.00	1.0539	C2_2015SL_0_0_0	Journault	-119
221 CRR-W1 240.00	1.0509	C5S_2017SL_0_0_0	Chapel Rock	-135
346 GOOSEL4 240.00	1.0516	C5S_2017SL_0_0_0	Chapel Rock	-140
536 HERITAG1 240.00	1.0519	C5S_2017SL_0_0_0	Chapel Rock	-145
641 TURNIP_T 240.00	1.0503	C2_2015SL_0_0_0	Chapel Rock	-130
751 FIDLER01 240.00	1.0519	C5S_2017SL_0_0_0	Chapel Rock	-145
98856 HW785 240.00	1.0513	C5S_2017SL_0_0_0	Chapel Rock	-140

Table 5-4: Shunt Reactor Sizes for Category A Overvoltage Violations

746 Windy Flats (MVAR)	611 Journault (MVAR)	677 Cypress (MVAR)	4458 Chapel Rock (MVAR)
-150	-119	-27.5	-145

4. Confirmation of Reactor Sizes under Categories B and C5 Conditions

The final reactor sizes shown in Table 5-4 were evaluated with the twenty study scenarios under both Category B and Category C5 steady state contingency conditions. There was no overvoltage violations observed.

This analysis confirmed the adequacy of the reactor size reported in Table 5-4 under the Categories B and C5 conditions as well.

5. Determination of Outstanding Under voltage Violations

The results of the contingency analysis with the four shunt reactors, assumed fixed (non-switchable), showed that there were under voltage violations under Categories A, B and C5 conditions. Table 5-5 through Table 5-8 show the results of the Categories A, B and C5 assessments with the four shunt reactors in place.

Due to the low initial voltages at these identified busses under Category A (system normal) conditions, the identified reactors at the four locations will therefore need to be switchable instead of fixed.

Table 5-5: Fixed Reactors – Category A Under Voltage Violations

Bus	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Scenario Name
165 PEIGAN 4 240	0.989	1.05	1.00	C11S_2017SP_-780_0_-150
721 KAIYA_1 240	0.989	1.05	1.00	C12_2022SP_-1200_0_0
746 WINDYFLATS 240	0.988	1.05	1.00	C11S_2017SP_-780_0_-150
746 WINDYFLATS 240	0.988	1.05	1.00	C12_2022SP_-1200_0_0
641 TURNIP_T 240	0.988	1.05	1.00	C12_2022SP_-1200_0_0
165 PEIGAN 4 240	0.988	1.05	1.00	C12_2022SP_-1200_0_0
346 GOOSEL4 240	0.987	1.05	1.00	C12_2022SP_-1200_0_0
536 HERITAG1 240	0.987	1.05	1.00	C12_2022SP_-1200_0_0
751 FIDLER01 240	0.987	1.05	1.00	C12_2022SP_-1200_0_0
167 N LETHB4 240	0.987	1.05	1.00	C12_2022SP_-1200_0_0
669 MEDHAT2 240	0.987	1.05	1.00	C12_2022SP_-1200_0_0
611 SUBC_240 240.00	0.987	1.05	1.00	C13_2022SP_0_0_150
4458 CHAPR2 240	0.987	1.05	1.00	C7X_2022SL_800_0_0
611 SUBC_240 240	0.986	1.05	1.00	C11_2017SP_-780_0_-150
98856 HW785 240	0.985	1.05	1.00	C12_2022SP_-1200_0_0
611 SUBC_240 240	0.984	1.05	1.00	C12_2022SP_-1200_0_0
221 CRR-W1 240	0.983	1.05	1.00	C12_2022SP_-1200_0_0
260 JENNER 4 240.00	0.983	1.05	1.00	C13_2022SP_0_0_150
611 SUBC_240 240	0.982	1.05	1.00	C11S_2017SP_-780_0_-150
4458 CHAPR2 240	0.969	1.05	1.00	C12_2022SP_-1200_0_0
262 DOME EM4 240.00	0.940	1.05	1.00	C13_2022SP_0_0_150
677 CYPRES2 240.00	0.940	1.05	1.00	C13_2022SP_0_0_150

Table 5-6: Fixed Reactors – Category B Under Voltage Violations

Bus	Vcont (p.u.)	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Contingency	Scenario Name
458 CHAPR1 500	0.999	1.028	1.100	1.000	1481[SHEER 14 240] to 1484[ANDERSO4 240] CKT 99	C11_2017SP_-780_0_-150
458 CHAPR1 500	0.999	1.028	1.100	1.000	1484[ANDERSO4 240] to 1486[SHEER 24 240] CKT 00	C11_2017SP_-780_0_-150
458 CHAPR1 500	0.996	1.029	1.100	1.000	1469[BAT RV79 240] to 1499[CORDEL 4 240] CKT 79	C10_2015SP_-780_0_0
458 CHAPR1 500	0.986	1.020	1.100	1.000	1481[SHEER 14 240] to 1484[ANDERSO4 240] CKT 99	C11S_2017SP_-780_0_-150

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Bus	Vcont (p.u.)	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Contingency	Scenario Name
458 CHAPR1 500	0.986	1.020	1.100	1.000	1484[ANDERSO4 240] to 1486[SHEER 24 240] CKT 00	C11S_2017SP_-780_0_-150
458 CHAPR1 500	0.980	0.992	1.100	1.000	Wildrose 240/34.5 kV Transformer 547ST1	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.980	0.992	1.100	1.000	7L16 Ghost Pine to Three Hills to Nevis 138 kV Line	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.980	0.992	1.100	1.000	10064[274ST1_M 240] to 462[WR2WF1 240] CKT T1	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.980	0.992	1.100	1.000	Langdon 500/240 kV Transformer 102ST4	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.979	1.020	1.100	1.000	1469[BAT RV79 240] to 1499[CORDEL 4 240] CKT 79	C11S_2017SP_-780_0_-150
458 CHAPR1 500	0.978	0.992	1.100	1.000	Wildrose 240/34.5 kV Transformer 547ST2	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.978	0.992	1.100	1.000	10065[274ST2_M 240] to 462[WR2WF1 240] CKT T2	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.977	1.028	1.100	1.000	1469[BAT RV79 240] to 1499[CORDEL 4 240] CKT 79	C11_2017SP_-780_0_-150
458 CHAPR1 500	0.976	0.992	1.100	1.000	658L Chappice Lake to Cypress to Glenridge	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.975	1.028	1.100	1.000	Langdon 500/240 kV Transformer 102ST1	C11_2017SP_-780_0_-150
458 CHAPR1 500	0.974	0.992	1.100	1.000	1390[MOTHER1 240] to 1447[963S_HV 240] CKT 1	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.970	1.029	1.100	1.000	Langdon 500/240 kV Transformer 102ST1	C10_2015SP_-780_0_0
458 CHAPR1 500	0.964	0.992	1.100	1.000	1431[SWITCH_H 240] to 1435[HALKIRK1 240] CKT 93	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.959	0.992	1.100	1.000	477[ELKWATR1 240] to 531[WILDRO1 240] CKT 78	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.959	0.992	1.100	1.000	462[WR2WF1 240] to 477[ELKWATR1 240] CKT 76	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.949	1.020	1.100	1.000	Langdon 500/240 kV Transformer 102ST1	C11S_2017SP_-780_0_-150
458 CHAPR1 500	0.925	1.029	1.100	1.000	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
167 N LETHB4 240	0.917	0.996	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
746 WINDYFLATS 240	0.915	0.988	1.100	0.917	Langdon 500/240 kV Transformer 102ST1	C11S_2017SP_-780_0_-150
165 PEIGAN 4 240	0.914	0.989	1.100	0.917	Langdon 500/240 kV Transformer 102ST1	C11S_2017SP_-780_0_-150
167 N LETHB4 240	0.911	0.991	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
346 GOOSEL4 240	0.910	1.008	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
98856 HW785 240	0.910	1.007	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
221 CRR-W1 240	0.909	1.007	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
641 TURNIP_T 240	0.907	1.000	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
458 CHAPR1 500	0.906	0.992	1.100	1.000	736[BSR_1 240] to 737[SW_SUB_1 240] CKT 42	C12_2022SP_-1200_0_0
721 KAIYA_1 240	0.904	0.999	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
4458 CHAPR2 240	0.901	1.000	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
165 PEIGAN 4 240	0.899	0.999	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
746 WINDYFLATS 240	0.899	0.998	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C10_2015SP_-780_0_0
4458 CHAPR2 240	0.896	0.969	1.100	0.917	736[BSR_1 240] to 737[SW_SUB_1 240] CKT 42	C12_2022SP_-1200_0_0
641 TURNIP_T 240	0.892	0.997	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150

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Bus	Vcont (p.u.)	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Contingency	Scenario Name
458 CHAPR1 500	0.892	1.028	1.100	1.000	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
458 CHAPR1 500	0.890	0.992	1.100	1.000	1484[ANDERSO4 240] to 1486[SHEER 24 240] CKT 00	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.888	0.992	1.100	1.000	1481[SHEER 14 240] to 1484[ANDERSO4 240] CKT 99	C12_2022SP_-1200_0_0
721 KAIYA_1 240	0.887	0.996	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
641 TURNIP_T 240	0.884	0.990	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
4458 CHAPR2 240	0.883	0.969	1.100	0.917	1484[ANDERSO4 240] to 1486[SHEER 24 240] CKT 00	C12_2022SP_-1200_0_0
458 CHAPR1 500	0.882	1.020	1.100	1.000	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
4458 CHAPR2 240	0.882	0.969	1.100	0.917	1481[SHEER 14 240] to 1484[ANDERSO4 240] CKT 99	C12_2022SP_-1200_0_0
721 KAIYA_1 240	0.879	0.990	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
746 WINDYFLATS 240	0.877	0.996	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
536 HERITAG1 240	0.874	0.994	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
751 FIDLER01 240	0.874	0.994	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
165 PEIGAN 4 240	0.873	0.997	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
536 HERITAG1 240	0.873	1.003	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
751 FIDLER01 240	0.873	1.003	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
346 GOOSEL4 240	0.871	1.002	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
98856 HW785 240	0.870	1.002	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
346 GOOSEL4 240	0.869	0.994	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
221 CRR-W1 240	0.869	1.001	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
746 WINDYFLATS 240	0.869	0.988	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
98856 HW785 240	0.867	0.994	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
165 PEIGAN 4 240	0.866	0.989	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
221 CRR-W1 240	0.866	0.993	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
4458 CHAPR2 240	0.865	0.997	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11_2017SP_-780_0_-150
4458 CHAPR2 240	0.858	0.990	1.100	0.917	120L - Chapel Rock to Langdon 500 kV line	C11S_2017SP_-780_0_-150
260 JENNER 4 240.00	0.912	0.983	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	C13_2022SP_0_0_150
262 DOME EM4 240.00	0.870	0.940	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	C13_2022SP_0_0_150
677 CYPRES2 240.00	0.870	0.940	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	C13_2022SP_0_0_150
260 JENNER 4 240.00	0.916	0.983	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	C13_2022SP_0_0_150
262 DOME EM4 240.00	0.874	0.940	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	C13_2022SP_0_0_150
677 CYPRES2 240.00	0.874	0.940	1.100	0.917	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	C13_2022SP_0_0_150
262 DOME EM4 240.00	0.869	0.940	1.100	0.917	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	C13_2022SP_0_0_150
677 CYPRES2 240.00	0.871	0.940	1.100	0.917	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	C13_2022SP_0_0_150

Bus	Vcont (p.u.)	Vinit (p.u.)	Vmax (p.u.)	Vmin (p.u.)	Contingency	Scenario Name
262 DOME EM4 240.00	0.866	0.940	1.100	0.917	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	C13_2022SP_0_0_150
677 CYPRES2 240.00	0.864	0.940	1.100	0.917	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	C13_2022SP_0_0_150

Table 5-7: Fixed Reactors – Non-Converged Category B Contingencies

Case	Contingency
C12_2022SP_-1200_0_0	1201L – Chapel Rock to Langdon 500 kV line
	Langdon 500/240 kV Transformer 102ST1

The complete list of Category C5 under voltage violations can be found in Appendix B. The most severe Category C5 under voltage violation was observed under the combined outage of 944L and 951L, the double circuit 240 kV lines from Jenner to Ware Junction. Table 5-8 also shows that the Category C5 outage of 944L and 951L did not converge under the summer peak scenarios.

As seen in Table 5-5 through Table 5-8, no contingencies in the Journault area cause an under voltage condition when the reactors were fixed at Journault. Thus the fixed reactors are found to be adequate to meet the criteria and no dynamic VArS are required.

Table 5-8: Fixed Reactors – Non-Converged Category C5 Contingencies

Scenario	Contingency Description
C3_2015SP_0_0_0_B3_R5 C6_2017SP_0_0_0_B3_R5 C6S_2017SP_0_0_0_B3_R5 C9_2022SP_0_0_0_B3_R5 C10_2015SP_- 780_0_0_B3_R5 C11_2017SP_-780_0_- 150_B3_R5 C11S_2017SP_-780_0_- 150_B3_R5 C12_2022SP_- 1200_0_0_B3_R5 C13_2022SP_0_0_150 C14_2017SL_500_0_300	1002-1011_B Category C5 outage of Cypress to Dome Empress 240 kV line, Cypress to Jenner 240 kV line and Jenner 240/138 kV transformer. 944-951_A Category C5 outage of 944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L

6. Determination of Reactive Power Deficiency

The results of the assessment with the shunt reactors online show that since there were under voltage violations under Category A and B conditions, the reactors at the four identified locations will need to be switchable as required based on operating load and generation profile conditions.

From a capacitive reactive power deficiency perspective, the most severe Category B under voltage violation was the outage of 1201L (Chapel Rock to Langdon 500 kV line) and the most severe under voltage Category C5 contingency was the combined outage of 944L and 951L (Jenner to Ware Junction 240 kV lines)⁷.

Since these two contingencies are related to the Chapel Rock and Cypress substations, the reactive power deficiencies at the Chapel Rock and Cypress for the target minimum 1.00 p.u. bus voltages under the Category B and C5 contingencies were determined for the worst case scenarios. Since the shunt reactors are to be switchable, the Chapel Rock reactive power deficiency level was determined without the reactors at Windy Flats and Journault (Sub C) online during the high import scenarios C10, C11, C11S and C12. Under high tie flow conditions, the voltages at Windy Flats and Journault (Sub C) are well below the target maximum operating voltage of 1.05 p.u. and accordingly will be automatically switched off to maintain acceptable voltage at these busses.

Table 5-9 shows that the maximum reactive power deficiency at Chapel Rock under the Category B loss of 1201L was 477 MVAR for the 1,200 MW tie flow condition (C12 scenario). Under the current tie flow limit of 780 MW, the minimum reactive power deficiency is 161 MVAR. However, under the 780 MW flow condition, the loss of 1201L line between Chapel Rock and Langdon imposes an extreme VAR demand on the Langdon and Chapel Rock busses to compensate for the transmission network losses. The reactive power support required at the Chapel Rock bus will have to be sized to not only ensure adequate bus voltages, rather, it shall ensure reasonable reactive power demand from the BC system and the Langdon SVC under the loss of 1201L. This ensures the system is operated within its safe equipment capabilities to avoid a potential cascading to the tie or an intolerable trip of the Langdon SVC under the loss of 1201L.

It is to be noted that the 477 MVAR requirement under the tie line flow of 1,200 MW provides an indication to the higher reactive power requirements at Chapel Rock to enable the system of utilizing a the tie line capacity up to its path rating. Further discussion in this regard is presented in the dynamic analysis section of this report.

Table 5-10 shows that the maximum reactive power deficiency at Cypress under the Category B loss of 945L was 137 MVAR.

A further investigation with an improved coordination of existing capacitor banks at Dome and with the 240/138kV autotransformer equipped with automatic tap changing control, reveals that the voltage profile in the Cypress area can be controlled to within the target voltage of 1.00 p.u. without the use of reactors.

⁷ The Category C5 outage of 944L and 951L also caused the outage of the Jenner 240/138 kV transformer and the Ware Junction to Anderson 240 kV line.

It is not cost effective to remotely control voltage at North Lethbridge 370S from Journault 260S by a larger reactor since these two subs are connected via a 240 kV 92 km long line. The proposed 90 MVar reactor at Journal is adequate to maintain the local area voltage within limits while bringing down North Lethbridge close to 1.052 p.u

Table 5-9: Chapel Rock Reactive Power Deficiency

Scenario	4458 Chapel Rock (MVar)
C10_2015SP_-780_0_0	18
C11_2017SP_-780_0_-150	115
C11S_2017SP_-780_0_-150	161
C12_2022SP_-1200_0_0	477
Reactive Power Deficiency (MVar)	477

Table 5-10: Cypress Reactive Power Deficiency

Scenario	Contingency	677 Cypress (MVar)
C13_2022SP_0_0_150	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	137
C13_2022SP_0_0_150	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	132
C13_2022SP_0_0_150	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	133
Reactive Power Deficiency (MVar)		137

7. Resolution of Under voltage Violations

In order to address both the voltage collapse conditions around Chapel Rock and the overvoltage violations observed under light loading and low wind conditions, a Static Var Compensator (SVC) at Chapel Rock with a reactive power range of -145 MVar to 477 MVar was evaluated.

With the Chapel Rock SVC, no voltage excursions beyond the target voltage band were observed at the critical buses under Categories A, B and C5 conditions.

The Category C5 Jenner-Cypress contingency leading to a voltage collapse in the Empress area will be mitigated through a Remedial Action Scheme to be designed and implemented at a later stage of the project. With the identified reactive power deficiency of 137 MVar at Cypress to accommodate the most limiting Category B contingency, a set of three (3) 45 MVar capacitor banks was assessed using Scenario C13. With 135 MVar capacitors banks, all under voltage violations are resolved for Category B contingencies without violating any Category A over voltages.

8. Sizing of Reactive Power Devices for Steady State Conditions

The switchable shunt reactors and the Chapel Rock SVC needed to resolve all nearby bus overvoltage and under voltage violations are shown in Table 5-11 below. The reactors at Windy Flats and Journault were sized in combinations of 45 MVar and 75 MVar steps.

Table 5-11: Recommended Reactive Power Devices for Steady State Conditions

Switchable Reactor Requirements		
Location	Total Size	Steps (MVar)
746 Windy Flats	150 MVar	2 x -75
611 Journault	90 MVar	2 x -45
SVC Requirements		
Location	Inductive Range (MVar)	Capacitive Range (MVar)
677 Cypress	0	135
4458 Chapel Rock	-145	477

Table 5-12 below shows the maximum and minimum voltages observed at the Windy Flats, Journault, Chapel Rock and Journault buses as well as their neighboring buses with the above devices in place. Table 5-12 also identifies the study scenario in which the maximum and minimum voltages were observed. The Category A power flow plots of the system voltages with the switchable reactors and SVCs at the Journault, Windy Flats and Chapel Rock substations respectively can be found in Appendix B.

Table 5-12: Category A Voltages with Reactive Devices Online

Bus	Max Voltage (p.u.)	Min Voltage (p.u.)	Study Scenario with Max Voltage	Study Scenario with Min Voltage
165 PEIGAN 4 240.00	1.04	1.00	C5S_2017SL_0_0_0	C7X_2022SL_800_0_0
167 N LETHB4 240.00	1.05	1.00	C2_2015SL_0_0_0	C12_2022SP_-1200_0_0
221 CRR-W1 240.00	1.05	1.00	C8_2022SL_0_0_0	C7X_2022SL_800_0_0
2451 MATLB2 240.00	1.06	1.01	C2_2015SL_0_0_0	C7M_2022SL_500_0_300
260 JENNER 4 240.00	1.05	1.02	C1X_2015SL_800_0_0	C7X_2022SL_800_0_0
262 DOME EM4 240.00	1.04	1.00	C4M_2017SL_500_0_300	C6_2017SP_0_0_0
346 GOOSEL4 240.00	1.05	1.00	C5S_2017SL_0_0_0	C7X_2022SL_800_0_0
4458 CHAPR2 240.00	1.04	1.00	C5S_2017SL_0_0_0	C1X_2015SL_800_0_0
451 MATLB1 240.00	1.05	1.02	C2_2015SL_0_0_0	C12_2022SP_-1200_0_0
458 CHAPR1 500.00	1.07	1.02	C5S_2017SL_0_0_0	C12_2022SP_-1200_0_0
536 HERITAG1 240.00	1.05	1.00	C8_2022SL_0_0_0	C7X_2022SL_800_0_0
611 SUBC_240 240.00	1.05	1.00	C3_2015SP_0_0_0	C7M_2022SL_500_0_300
641 TURNIP_T 240.00	1.05	1.01	C2_2015SL_0_0_0	C7M_2022SL_500_0_300
669 MEDHAT2 240.00	1.04	1.00	C5S_2017SL_0_0_0	C12_2022SP_-1200_0_0
677 CYPRES2 240.00	1.04	1.00	C4M_2017SL_500_0_300	C6_2017SP_0_0_0
721 KAIYA_1 240.00	1.04	1.01	C2_2015SL_0_0_0	C7M_2022SL_500_0_300
746 WINDYFLATS 240.00	1.04	1.00	C2_2015SL_0_0_0	C7X_2022SL_800_0_0

Bus	Max Voltage (p.u.)	Min Voltage (p.u.)	Study Scenario with Max Voltage	Study Scenario with Min Voltage
751 FIDLER01 240.00	1.05	1.00	C8_2022SL_0_0_0	C7X_2022SL_800_0_0
98856 HW785 240.00	1.05	1.00	C5S_2017SL_0_0_0	C7X_2022SL_800_0_0
53 SANDYPT7 138.00	1.03	1.02	C10_2015SP_-780_0_0	C8_2022SL_0_0_0
111 SANDHIL7 138.00	1.03	1.02	C10_2015SP_-780_0_0	C8_2022SL_0_0_0
263 EMP LIQ7 138.00	1.02	1.01	C10_2015SP_-780_0_0	C8_2022SL_0_0_0
266 EMPRESA7 138.00	1.03	1.02	C10_2015SP_-780_0_0	C8_2022SL_0_0_0
267 DOME EM7 138.00	1.03	1.02	C10_2015SP_-780_0_0	C8_2022SL_0_0_0
292 JENNER7 138.00	1.03	1.01	C3_2015SP_0_0_0	C7M_2022SL_500_0_300
344 WARLOW7 138.00	1.03	1.01	C3_2015SP_0_0_0	C11_2017SP_-780_0_-150
674 CYPRES1 138.00	1.03	1.02	C3_2015SP_0_0_0	C1X_2015SL_800_0_0
724 GLNRDG1 138.00	1.02	1.01	C12_2022SP_-1200_0_0	C11S_2017SP_-780_0_-150
1473 MCNEILL 138.00	1.03	1.02	C3_2015SP_0_0_0	C1X_2015SL_800_0_0

Changes in system conditions from light load, low generation conditions to high import, peak load conditions require corresponding adjustments to the energized capacitor banks and reactors at the Chapel Rock, Windy Flats, Cypress, and Journault substations. These reactors are required to be equipped with circuit breakers adequate for frequent switching duty.

The voltage deviation resulting from switching on each of the steps of the capacitor banks and reactors at Windy Flats, Journault, and Cypress was investigated and the results are provided Table 5-13. The results show that the voltage deviations from each switching action is less than 3%, the target maximum allowed voltage deviation resulting from the switching of shunt devices in this study.

Table 5-13: Voltage Deviation from Reactor Switching

Bus	Vinit (p.u.)	Initial Step	Additional Steps Switched on	Vfinal (p.u.)	Vdiff (%)
Windy Flats	1.085	None	1 x -75	1.072	1.3%
Windy Flats	1.072	1 x -75	1 x -75	1.058	1.4%
Journault/Sub C	1.085	None	1 x -45	1.068	1.7%
Journault/Sub C	1.085	None	1x -75	1.057	2.8%
Journault/Sub C	1.068	1 x -45	1x -75	1.041	2.7%
Journault/Sub C	1.057	1 x -75	1x -45	1.041	1.6%
Cypress	1.049	1 x 45	2 x 45	1.071	2.2%

Vinit - voltage at bus with Initial Step Switched Online

Vfinal - Voltage at bus after switching on the additional step

The impact of switching the reactors on the Transient Recovery Voltage (TRV) and Temporary Overvoltage (TOV) should be further investigated during the substation Facility Application stage to ensure the appropriate sizing of the substation breakers and surge arrestors.

5.2 Summary of Steady State Reactive Power Device Requirements

Table 5-14 below shows the system conditions, including system load, generation levels and contingency conditions, for which the reactive devices were sized. These combinations of study scenarios and contingency conditions constitute the drivers for the reactive devices size and type.

The preliminarily sized reactive power devices at Chapel Rock and Cypress were initially based on steady-state analysis for locations that required additional injection and/or absorption of reactive power, i.e., Cypress and Chapel Rock, in order to address the voltage violations under various Categories A, B and C5 conditions. These reactive device sizes were further investigated under dynamic stability conditions as discussed in the following section. Switchable reactors were recommended for the Windy Flats and Journault locations to prevent under voltage violations under peak and high transfer conditions. The use of an SVC at Cypress showed no material added benefit to the system response in the area around Cypress due to the limitations of the local 138 kV network and accordingly was later replaced with 3 x 45 MVar capacitor banks as shown below. These revised static compensation levels provide the same reliability level of the Cypress SVC given the reduction in wind forecast and the characteristics of motor loads in the area. This will be further illustrated in the following sections.

The driving system conditions for reactors were all summer light load, zero wind generation conditions (except at Cypress) under Category A conditions. The driving system conditions for additional reactive power (SVC and Capacitor banks) were all 2022 peak load conditions under Category B (for the Chapel Rock location) or Category C5 (for the Cypress location) contingency conditions.

Table 5-14: Drivers for Steady State Reactive Power Device Requirements

Reactive Device Location	Type	Size (MVar)	DRIVING SCENARIOS AND CONTINGENCY CONDITIONS			
			Condition	Worst Bus Voltage	Bus Voltage	Worst Case
Windy Flats	Reactors	2 x -75	Category A	746 WINDYFLATS 240.0	1.086	C2_2015SL_0_0_0
Journault	Reactors	2 x -45	Category A	167 N LETHB4 240.0	1.084	C2_2015SL_0_0_0
Cypress	Reactors	0	Category A	677 CYPRES2 240.0	1.050	C4MS_2017SL_500_0_300
	Capacitors	3 x 45	Cat B – 945L Cypress – Jenner 240kV line	677 CYPRES2 240.0	0.864	C13_2022SP_0_0_150
Chapel Rock	SVC	-145	Category A	751 FIDLER01 240.0	1.087	C5S_2017SL_0_0_0
		477	Cat B - 1201L (Chapel Rock - Langdon 500 kV line)	4458 CHAPR2 240.0	Non Converged Voltage Collapse	C12_2022SP_-1200_0_0*

*C12 study scenario had the highest import and Ft. Macleod generation total

5.3 Dynamic Reactive Power Requirements

The results of the steady state assessment revealed the need for capacitive reactive power devices to resolve the Categories B and C5 voltage violations. However, the sizing of the reactive devices is also a function of the amount of dynamic power requirements of the system and thus needs to be evaluated under transient conditions.

The dynamic reactive requirements at Chapel Rock and Cypress were evaluated separately due to the geographic separation between the two locations. The Chapel Rock SVC was evaluated under the Category B loss of 1201L (Chapel Rock to Langdon 500 kV line).

Since the Category C5 loss of 944L and 951L (Jenner to Ware Junction 240 kV common tower outage) caused voltage collapse in the Cypress area under peak load conditions, an SVC was initially thought to be necessary at Cypress in order to dynamically adjust the Cypress 240 kV voltage under various Categories A, B and C5 conditions. The dynamic analysis revealed that the Cypress SVC provides no material benefit to the system response in the area around Cypress due to the limitations of the local 138 kV network and accordingly was later replaced with 3 x 45 MVar capacitor banks. The dynamic analysis presented in the following sections indicate that regardless of the Cypress SVC placement or even with increasing its size to reasonable range, there will be some loss of motor load in the area due to the high reactive power demand from induction motors and the relatively low short circuit level provided by the local 138 kV network.

Given the anticipated rare frequency of occurrence of the Category C5 voltage instability condition under the loss of 944L/951L, the AESO will be developing appropriate Remedial Action Scheme(s) to either trip load up to the capability of the 138 kV network or isolate the local 138 kV area by transfer tripping other 138 kV lines supplying the weakened network which will ensure reliable system operation.

5.4 Cypress Reactive Power Sizing

The initial size of the Cypress capacitive reactive compensation, 0 MVar to 137 MVar, was based on the steady state reactive power requirements under Category A conditions and the Category B loss of 944L, 951L, 945L, or 1002L which cases low voltages in the area.

Specific Categories B and C5 fault scenarios were simulated with the critical scenarios, 2017 summer peak and 2022 summer peak scenarios; specifically, scenarios C13, C14 and C15 (defined in Table 2-5) were used to assess the dynamic stability under the most severe Categories B conditions for the Cypress Area. These most severe contingencies are selected from the list of contingencies simulated in the Need Assessment Stage. The fault scenarios

simulated and the corresponding fault location diagrams for the AIES and WECC base cases are presented in Appendix C.

In particular, the Category C5 outage of 944L and 951L, results in only one 138 kV line between Cypress and Chappice Lake remaining in-service, which is insufficient to simultaneously supply the load at Cypress and the rated export transfer of 150 MW via the McNeill back-to-back HVDC tie. This voltage collapse condition cannot be resolved using reactive devices only and requires system upgrades.

The scenario C13 is the summer peak load case with 150 MW transfer-out via the McNeill back-to-back HVDC tie. This case defines the upper limit of reactive compensation need.

The scenario C14 is the summer light load case with 0 MW interchange via McNeill. This scenario is used to assess if dynamic reactive capability is required at the Cypress location.

The scenario C15 is the summer peak load case with 0 MW interchange via McNeill. This scenario is used to assess the operation of additional capacitor banks in coordination with the McNeill HVDC tie.

Under all studied scenarios with line 760L/7L760 open, motor stalling conditions were observed at the Cavendish and Bindloss pump stations for the contingencies in Table 5-15. These pump stations are comprised of large induction motors with low inertia and this load characteristic makes these motors highly prone to stalling under depressed voltage conditions. These two pump stations are located at the end of a radial network and reactive power injected at Cypress does not have significant impact on the local voltage at the far end of the line.

The complete set of results of the fault simulation results and plots are provided in Appendix D. Table 5-15 show the system response to the most severe Category B faults. Detail load shedding observations and the simulation plots can be found in Appendix D.

Table 5-15: Cypress Reactive Power Compensation Sizing: Cat-B Stability Results

Fault ID	Fault Name	C13	C14	C15
B34	Cypress - Jenner 240 kV	Stable	Stable	Stable
B42	Cypress - Mc Neil 138 kV	Stable	Stable	Stable
B44	Cypress - Dome Empress 138 kV	Stable	Stable	Stable
B46	Cypress - Empress 138 kV	Stable	Stable	Stable
B48	Cypress – Glenridge – Chapprice Lake 138 kV	Stable	Stable	Stable
B51	Dome Empress - Empress 138 kV	Stable	Stable	Stable

5.5 Chapel Rock SVC Sizing

The initial size of the Chapel Rock SVC, -145 MVAR to 477 MVAR, was based on the steady state reactive power requirements under Category A conditions and the Category B loss of 1201L for a high tie flow scenario of 1,200 MW on the AB-BC tie line (see Scenario C12, Section 5.1). However, steady state analysis revealed that for the current operational tie flow capability of 780 MW (import), a capacitive range of 161 MVAR is adequate to maintain acceptable voltages profile.

The loss of 1201L connecting Chapel Rock to Langdon significantly increases the flow on the 240 kV network between Chapel Rock and Calgary through the Chapel Rock-Windy Flats-Foothills-Langdon path. With a 161 MVAR SVC capacitive range, the outage of 1201L increases the reactive demand on the Langdon SVC from below 100 MVAR to nearly 300 MVAR. In addition, extra burden is placed on the BC Hydro system to supply the reactive power demands along the Chapel Rock-Cranbrook segment as well as supporting the Alberta system 240 kV network. The reactive losses along the 240 kV network increase significantly as the power flow from the tie is diverted to the 240 kV network which as well carries the dispatched wind generation in the Fidler/Pincher Creek area.

Since the tie flow is a dispatchable quantity, the steady state requirements to cover the reactive power requirements of the 240 kV network and the tie-line can be provided through switchable capacitors at the Chapel Rock substation. The study accordingly investigated providing the required steady state VAR requirements (161 MVAR) through two 100 MVAR 240 kV switchable capacitor banks. The remainder of the reactive power requirements at Chapel Rock due to

the outage of 1201L can be accordingly covered through the size of the Chapel Rock SVC. This configuration basically establishes the requirement of a Static VAR System (SVS) at the Chapel Rock substation comprising the two 100 MVAR capacitor banks and the required SVC size to cover the dynamic reactive power demand. The SVC in this SVS setup will be required to control the switching of the capacitor bank to meet the steady state requirements at Chapel Rock.

To validate the finding in the steady state analysis, dynamic simulation of Category B & Category C5 contingencies were conducted. The fault scenarios simulated and the corresponding fault location diagrams for the AIES base cases are presented in Appendix C. The complete results of the fault simulation results and plots are provided Appendix D.

The reactive requirement at Chapel Rock is strongly dependent on the import level on the Alberta-BC tie line while also influenced by the network outside the AIES. The most severe contingency, a 3-phase fault on 1201L between Chapel Rock and Langdon at the Chapel Rock end is simulated using the WECC case. The outage of 1201L is the most severe contingency as it forces BC import to route through the SATR 240 kV network.

Using the full WECC model, the reactive requirement is generally in line with the results presented in Section 5.1. The full WECC model includes the connection between the terminus of 1201L at Cranbrook, BC and the southern end of MATL at Great Falls, MT. The analysis using the full WECC model indicated the reactive requirement immediate post-contingency is lower than the AIES result. This is due in part to a portion of the BC import (approximately 50 to 100 MW) being wheeled through MATL. This wheeling is due to the phase shifting transformer not immediately reacting to the change of impedance caused by the outage of the 500 kV line, and this wheeling places less reactive consumption on the highly loaded 500 kV and 240 kV network from Chapel Rock to Windy Flats.

Dynamic analysis was conducted for import levels of 780 MW (Scenario W4C), 1,000 MW (Scenario W6C) and 1,200 MW (Scenario W7C). The results show that the system remains stable with transfers up to 1,200 MW on 1201L and that the two 100 MVAR capacitor banks and one +200/-100 MVAR SVC can support the post-contingency voltage in the Chapel Rock area without voltage collapse.

A sensitivity case (Scenario W4C1) was simulated with an import level of 780 MW with only the +/- 200 MVAR SVC at Chapel Rock and without the two switchable capacitor banks, as predicted in the steady state study, the voltage is stable following the outage of the 1201L between Langdon and Chapel Rock. The complete results of the fault simulation results and plots are provided Appendix D.

6. VOLTAGE STABILITY ASSESSMENT

P-V (Power-Voltage) analysis was performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology, as described in more detail in the AESO's Reliability Standards/Criteria to determine the maximum operating load levels with and without the recommended SVCs at Chapel Rock and Cypress.

6.1 Methodology

The WECC voltage stability criteria states,

“for load areas, post-transient voltage stability is required for the area modeled at a minimum of 105% of the reference load level for system normal conditions (Category A event) and for single contingencies (Category B events). For multiple contingencies (Category C), post-transient voltage stability is required with the area modeled at a minimum of 102.5% of the reference load level. For this standard, the reference load level is the maximum established planned load”.

For this standard, the reference load level used for the Chapel Rock P-V analysis was the AB-BC import level. This AB-BC import level was increased by reducing the Wabamun Area 40 generation level with a corresponding generation increase in the WECC Area 15.

The reference load level used for the Cypress P-V analysis was the Empress Area 2022 summer peak forecasted load level of 319 MW, of which 136 MW is motor⁸ loads. Only the non-motor loads in the Empress area were scaled up with a corresponding generation increase in the Wabamun Area 40.

P-V curves were generated for Category A conditions and the Category B outage of 1201L (Chapel Rock to Langdon 500 kV line) and the Category C5 outage of 944L & 951L. The maximum operating load limits were determined to be the lowest of the following:

1. 5% below the load at the collapse point on the P-V curve for Category A.
2. 5% below the pre-contingency load corresponding to the collapse point on the P-V curve for Category B contingencies.
3. 2.5% below the pre-contingency load corresponding to the collapse point on the P-V curve for Category C contingencies.

⁸ The motor loads referred to in this section are loads modeled machines with negative power

6.2 Chapel Rock P-V Results

The P-V analysis was performed to determine the increase in the maximum AB-BC transfer capability due to the addition of the Chapel Rock SVC.

The 2022 summer peak high import case (study scenario C12) was used for the Chapel Rock P-V analysis. The Chapel Rock 500 kV and 240 kV voltages were monitored during the transfer increase. Discrete and continuous reactive power devices were allowed to adjust during the transfer.

The results of the P-V analysis showed that the maximum import transfer under Category A conditions with and without the Chapel Rock SVC were 1,597 MW and 1,540 MW respectively. However, without the SVC, the system does not voltage requirements of Table 2-1. The results of the P-V analysis showed that the maximum operating transfer limit under the Category B 1201L outage with the Chapel Rock SVC was 1,331 MW. Since the Category B 1201L outage did not converge without the Chapel Rock SVC, the maximum operating transfer limit without the SVC is expected to be significantly lower than the reference transfer level.

Table 6-1 below summarizes the results for the Chapel Rock P-V analysis. Figure 6-1 and Figure 6-2 illustrate system performance for the base case and 1201L Category B outage. With the Category B 1201L 500kV line outage, losses in AIES substantially increased, and thus increasing the AB-BC interchange by 110 MW in order to sustain the energy balance of 1200 MW pre-contingency interchange.

Table 6-1: Chapel Rock P-V Analysis Summary

C13 2022SP P-V Summary				
Contingency	SVC	Reference Import Level (MW)	Import at Point of Collapse (MW)	Operating Limit* (MW)
Base Case	Without SVC	1,202	1,621	1,540
	With SVC	1,203	1,681	1,597
Category B: 1201L Chapel Rock - Langdon 500 kV	Without SVC	1,202	Voltage Collapse @ 1,200 MW	< 1,200 MW
	With SVC	1,203	1,401	1,331

*Operating Limit is 5% away from the collapse point for Category A and B, 2.5% for Category C5

Figure 6-1: Chapel Rock Category A P-V Plot

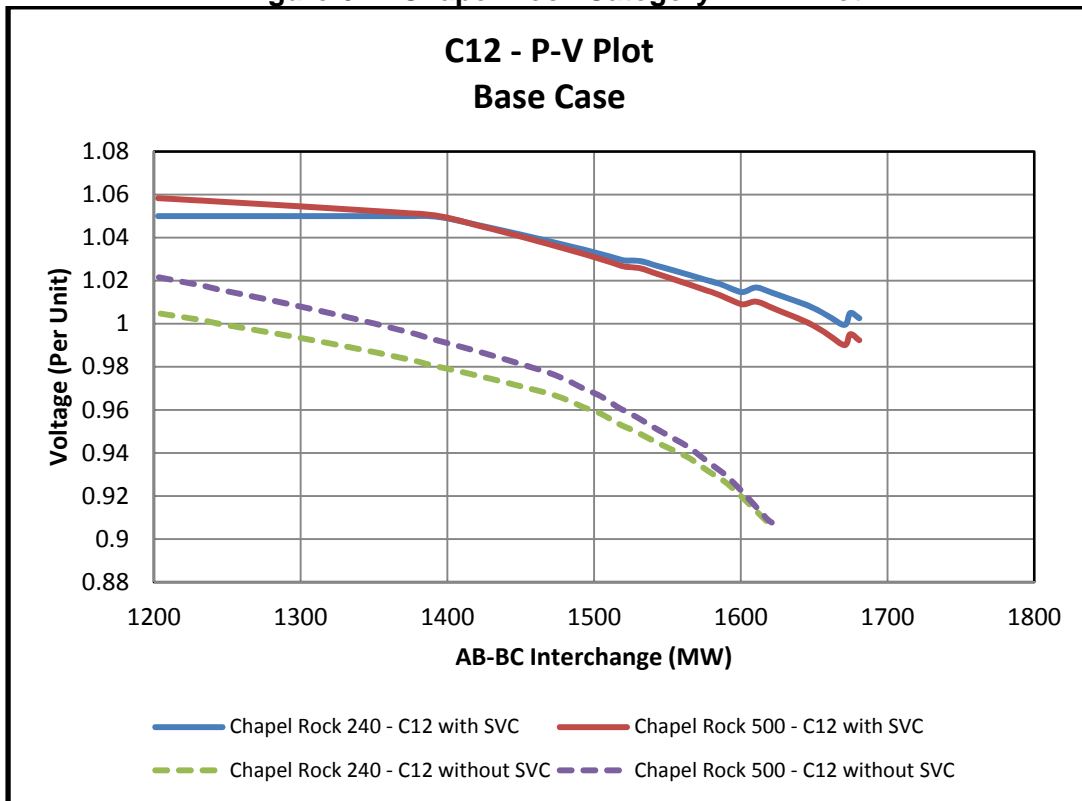
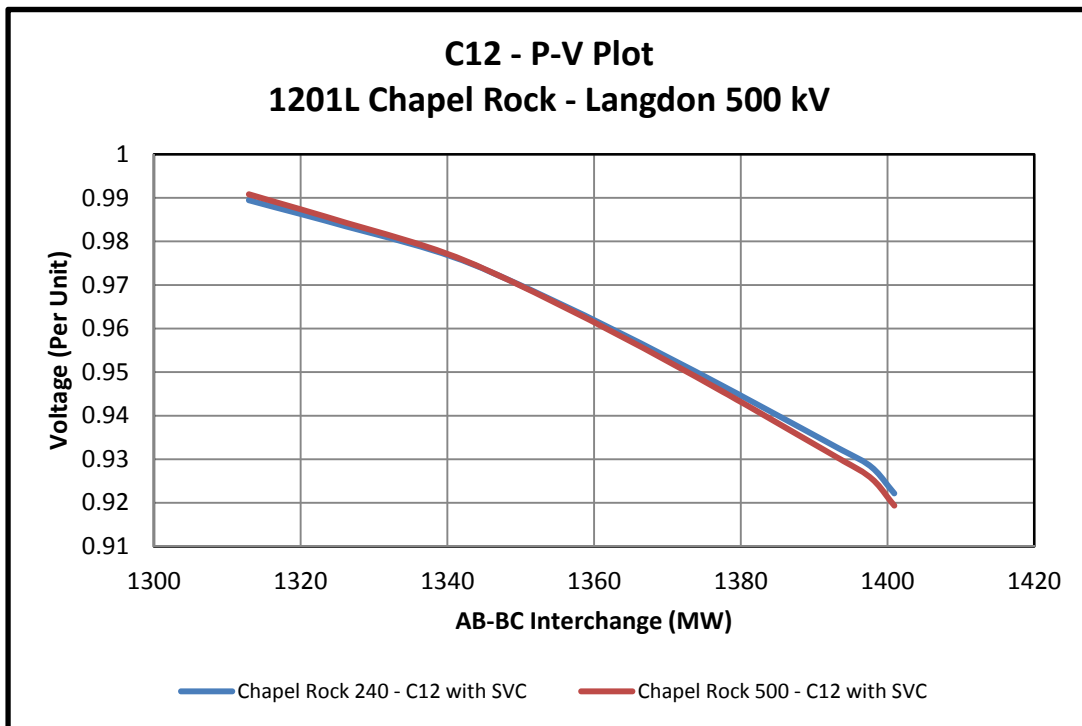


Figure 6-2: Chapel Rock Category B P-V Plot



6.3 Cypress P-V Results

The P-V analysis was performed to determine the increase in the maximum Empress Area operating load limit due to the addition of the Cypress capacitor banks.

The 2022 summer peak case (study scenario C13) was used for the Cypress capacitor banks with 150 MW of transfer via McNeill HVDC. This transfer is not included in the load.

The Cypress 240 kV voltage was monitored during the transfer increase. Discrete and continuous reactive power devices were allowed to adjust during the transfer.

The results of the P-V analysis revealed that the maximum operating load limit under Category A conditions with and without the Cypress capacitor banks were 504 MW and 456 MW respectively. Without the capacitor banks, the system will not meet the voltage criteria given in Table 2-1. With the capacitor banks, the system can satisfy the voltage requirement given in Table 2-1 up to a load of 360 MW. Since the 2022 summer peak forecasted load of 318 MW, the system with capacitor banks satisfied the P-V criteria, while the system without the capacitor banks does not.

The results of the P-V analysis showed that the most restrictive operating limit is under the 945L 240 kV between Jenner and Cypress Category B outage with the Cypress capacitor banks at 420 MW. Without the capacitor banks, this transfer limit is at 370 MW, however, the voltage dips below 0.80 p.u.

Category C5 outages are not evaluated as the system has a thermal constraint of 81 MVA on 760L 138 kV under Category C5 outage conditions of 240 kV lines from Ware Junction to Jenner to Cypress/Dome Empress.

It is to be noted that the static P-V analysis results do not reflect the dynamic reactive power needs in the area as dictated by the dominating induction motor loads in the area. As illustrated in earlier sections, the system does not have sufficient dynamic VAR margin to satisfy the reactive power requirements allowing for successful recovery of some motor loads from Category B faults in the area.

Furthermore, the induction motor has the characteristics of consuming more reactive power as the voltage drops. The dynamic analysis in Sections 4.2 & 5.3 illustrated this effect. Thus, it is important to maintain a reasonable margin from the voltage collapse point

Table 6-2 summarizes the results for the Cypress P-V analysis. Figure 6-3 and Figure 6-4 illustrate system performance for the base case and 945L critical Category B outage. With the proposed capacitor banks, pre- and post-contingency voltages meet voltage criteria given in Table 2-1.

Table 6-2: Cypress P-V Analysis Summary

C13 2022SP P-V Summary

Contingency	Cap Banks	Reference Load Level (MW)	Maximum Load (MW)	Operating Limit* (MW)
Base Case	No Cap Banks	318	480	456
	Cap Banks	318	531	504
Category B: 945L Cypress - Jenner 240 kV	No Cap Banks	318	389	370
	Cap Banks	318	442	420

*Operating Limit is 5% away from the collapse point for Category A and B

Figure 6-3: Cypress Category A P-V Plot

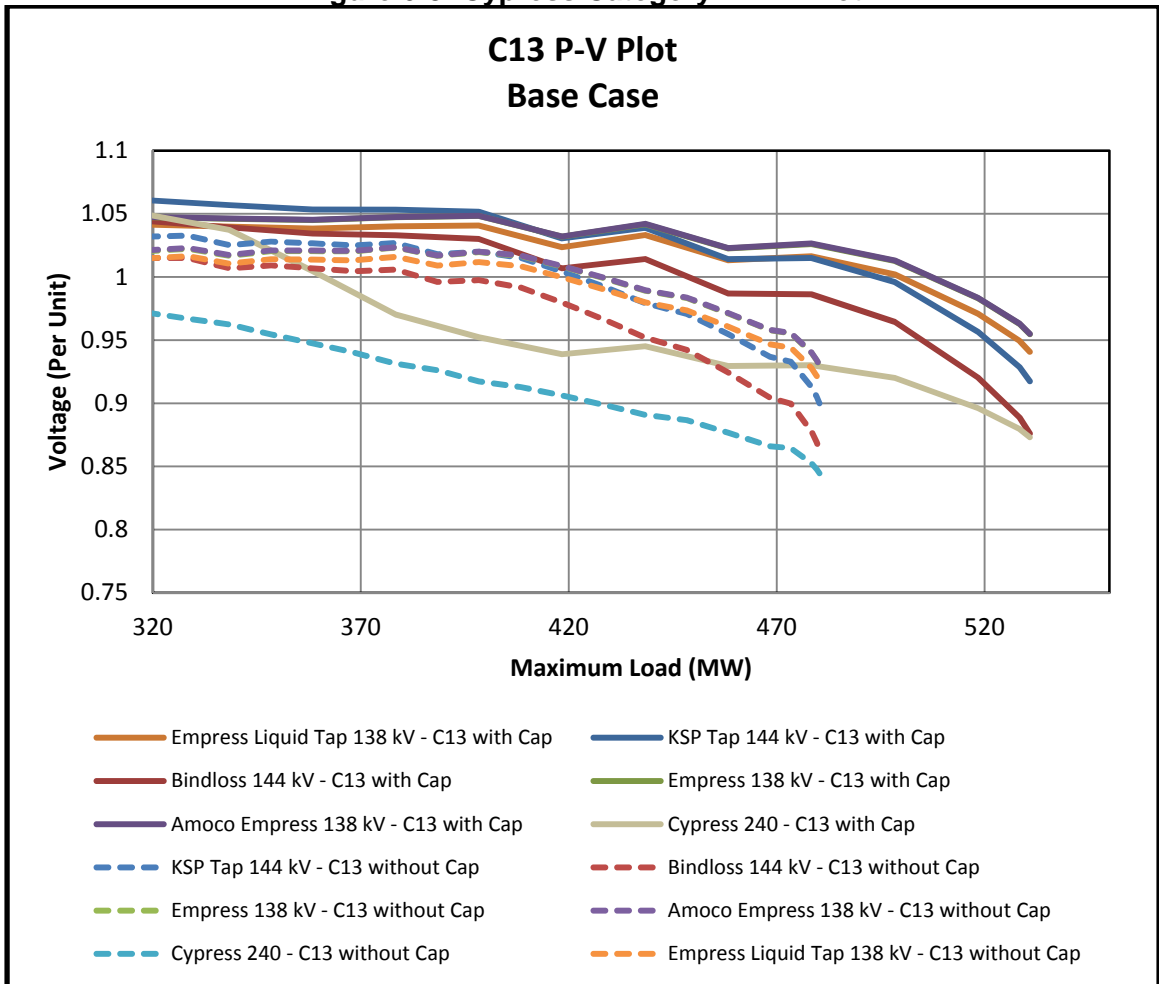
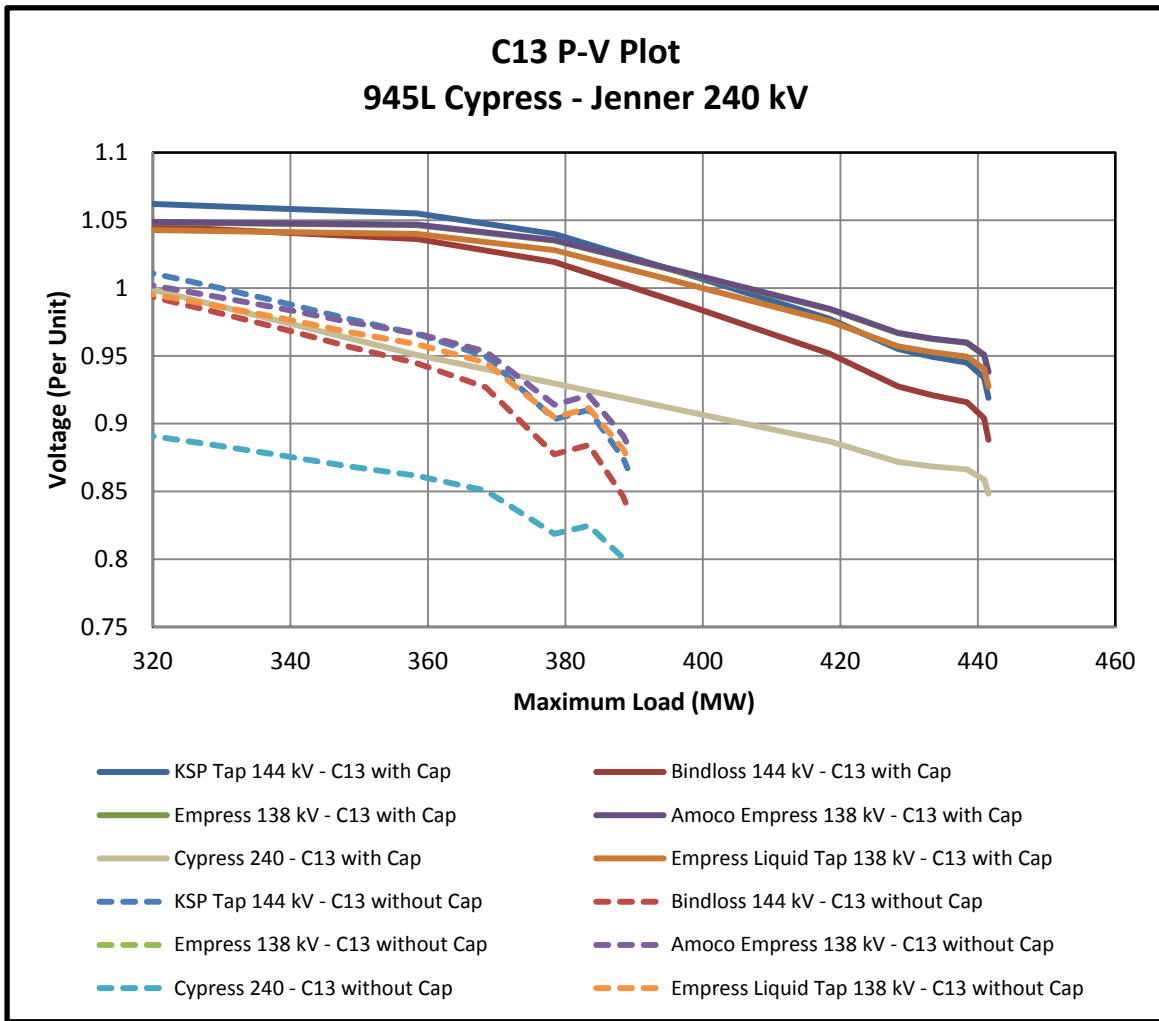


Figure 6-4: Cypress Category C5 P-V Plot



7. SUMMARY AND CONCLUSIONS

The Alberta Electric System Operator (AESO) identified the need for reactive power devices in the southern region of the Alberta Interconnected Electric System (AIES) in the Southern Alberta Transmission Reinforcement (SATR) Needs Identification Document (NID)¹, which was approved by the Alberta Utilities Commission on September 8, 2009.² As the SATR components are now proceeding and the AESO continues to develop its long-term transmission plans and forecasts, the AESO has completed an updated assessment of the required reactive power control devices in Southern Alberta.

This assessment takes into consideration certain factors that differ from the original reactive power evaluation undertaken in preparation of the SATR NID including changes in the timing and planned configuration of the transmission system in southern Alberta. The southern termination of the planned Foothills-Peigan 240 kV lines was originally proposed to be at the Peigan 59S substation in 2014. The AESO is now proposing to terminate the 240 kV lines at the new Windy Flats substation (east of Peigan 59S) in 2015.³ There have also been changes associated with the Fidler/Pincher Creek area and the connection between Goose Lake and the planned 500/240 kV Chapel Rock 491S substation⁴ as well as the approved Hanna Region Transmission Development (HRTD).⁵ This assessment also assumes load and generation forecasts consistent with the AESO 2012 Long-term Outlook (2012 LTO).⁶

The main objective of this assessment is to investigate the adequacy of the originally proposed reactive power control devices identified in the original SATR NID based on the current planned system configuration in Southern Alberta and recommend any changes to these if required.

Steady State, Dynamic and Voltage stability analyses were conducted under this study to identify the reactive power requirements in Southern Alberta. Study results revealed that the proposed reactors under the SATR NID are adequate to keep the light load, no wind operating voltage conditions to within the target design 1.05 p.u. continuous operating limit.

The study proposes revisions to the reactive power requirements at both the Cypress and Chapel Rock substations. The study recommends the installation of a +200/-100 MVar SVC in addition to two 100 MVar 240 kV capacitor banks in a Static VAR System (SVS) configuration at Chapel Rock 491S. This is different from the originally approved SATR plan for the Crowsnest substation of 0 to +400 MVar SVC. The Chapel Rock SVC is required to provide the needed dynamic reactive power needs at the Chapel Rock substation under contingency conditions. The switchable capacitor banks are to provide the required steady state reactive power demand of the network and the tie line under heavy flow and wind generation conditions.

The study also recommends replacing the originally approved Cypress -50/+25 SVC with 3x45 MVar capacitor banks to provide the needed VAr support under all Category B contingency conditions. Currently due to the reduced wind

forecast in the area, the reactive power demands in the Cypress area can be reliably met through the proposed shunt compensation devices only as shown in Table 7-2.

The study recommends replacing the Windy Flats and Journault SVCs originally proposed under SATR NID with 240 kV reactors sized at 2x75 and 2x45 MVAR respectively. With these proposed reactors, the southern AIES can operate within the target normal operating voltage limits and within the extreme maximum and minimum limits under contingency conditions.

The study recommends the development of a RAS to ensure system reliability under the Category C5 contingency involving the simultaneous loss of 944L & 951L.

Table 7-1 : Steady State Reactive Power Requirements

Reactive Device Location	Type	Size (MVar)	DRIVING SCENARIOS AND CONTINGENCY CONDITIONS			
			Condition	Worst Bus Voltage	Bus Voltage	Worst Case
Windy Flats	Reactors	2 x -75	Category A	746 WINDYFLATS 240.0	1.086	C2_2015SL_0_0_0
Journault	Reactors	2 x -45	Category A	167 N LETHB4 240.0	1.084	C2_2015SL_0_0_0
Cypress	Capacitor Banks	3 x 45	Cat B – 945L Cypress – Jenner 240kV Line	677 CYPRES2 240.0	0.864	C13_2022SP_0_0_150
Chapel Rock	SVC	-100	Category A	751 FIDLER01 240.0	1.087	C5S_2017SL_0_0_0
		200	Cat B - 1201L (Chapel Rock - Langdon 500 kV line)	4458 CHAPR2 240.0	Voltage Collapse	C12_2022SP_-1200_0_0*
	Capacitor Banks	2 x 100	Steady-State High tie flow and high Wind generation Conditions	N/A	N/A	C12_2022SP_-1200_0_0*
	Reactor	1 x -45	Steady-State Light Load, Zero Wind Scenarios	N/A	N/A	C12_2022SP_-1200_0_0*

The similarly sized +200/-100 SVCs at Chapel Rock and other substations (Hansman Lake, Lanfine and, Pemukan) have the potential of providing additional benefits in terms of reductions in costs associated with sparing, maintenance and operational flexibility. The inductive range of the SVC specified for Chapel Rock represents the minimum requirement. The actual VAR inductive capability of the SVC, if based on economic optimization, is higher than the identified 100 MVar need, would be identified during the detailed design stage of this project. The specified 45 MVar reactor at the Chapel Rock site can accordingly be eliminated if the Chapel Rock SVC design can provide the full required 145 MVar inductive range. Even though the proposed VAR support configuration at Chapel Rock consists of several discrete components i.e. a reactor, capacitor banks and SVC in a Static VAR System setup, the optimal configuration of the SVC/SVS would be determined at the detailed design Stage

The study also confirmed the ability of the SATR configuration with the proposed reactive power compensation to enable the utilization of the AB-BC tie up to its rated path capacity of 1,200 MW. Although this flow level is higher than the current operating limit of the tie line, the proposed size of the Chapel Rock reactive power support shall enable future upgrading of the tie capacity along with appropriate measures to ensure the transient stability of the AIES under the loss of the tie line. This is outside the scope of this study and shall be covered under a separate more detailed assessment.

Table 7-2 : Steady State Reactive Power Requirements

Reactive Device Location	Type	Size (MVA _r)	DRIVING SCENARIOS AND CONTINGENCY CONDITIONS			
			Condition	Worst Bus Voltage	Bus Voltage	Worst Case
Windy Flats	Reactors	2 x -75	Category A	746 WINDYFLATS 240.0	1.086	C2_2015SL_0_0_0
Journault	Reactors	2 x -45	Category A	167 N LETHB4 240.0	1.084	C2_2015SL_0_0_0
Cypress	Capacitor Banks	3 x 45	Cat B – 945L Cypress – Jenner 240kV Line	677 CYPRES2 240.0	0.864	C13_2022SP_0_0_150
Chapel Rock	SVC	-100	Category A	751 FIDLER01 240.0	1.087	C5S_2017SL_0_0_0
		200	Cat B - 1201L (Chapel Rock - Langdon 500 kV line)	4458 CHAPR2 240.0	Voltage Collapse	C12_2022SP_-1200_0_0*
	Capacitor Banks	2 x 100	Steady-State High tie flow and high Wind generation Conditions	N/A	N/A	C12_2022SP_-1200_0_0*
	Reactor	1 x -45	Steady-State Light Load, Zero Wind Scenarios	N/A	N/A	C12_2022SP_-1200_0_0*

Appendix A
Study Assumptions

List of Tables

Table A-1: List of Critical System Buses

Table A-2: Area Generation Total

Table A-3: Area Load Total

Table A-4: List of Switch Shunts

Table A-5: Steady State Category C5 Contingency Definitions

Table A-1: List of Critical System Buses

Bus Number	Bus Name	Bus Voltage (kV)	Area
53	53 SANDYPT7 138	138	48
111	111 SANDHIL7 138	138	48
165	PEIGAN 4	240	53
167	N LETHB4	240	54
221	CRR-W1	240	53
260	JENNER 4	240	48
262	DOME EM4	240	48
263	263 EMP LIQ7 138	138	48
266	266 EMPRESA7 138	138	48
267	267 DOME EM7 138	138	48
292	292 JENNER7 138	138	48
344	344 WARLOW7 138	138	48
346	GOOSEL4	240	53
451	MATLB1	240	54
458	CHAPR1	500	53
536	HERITAG1	240	53
611	SUBC_240	240	4
641	TURNIP_T	240	53
669	MEDHAT2	240	4
674	674 CYPRES1 138	138	48
677	CYPRES2	240	48
720	HIGHWAY1	240	53
721	KAIYA_1	240	53
724	724 GLNRDG1 138	138	48
746	WINDYFLATS	240	53
751	FIDLER01	240	53
845	845 OYENHV1 138	138	42
1454	1454 BINDLOS7 138	138	48
1456	1456 CAVDISH1 138	138	48
1459	1459 EXCEL7 138	138	42
1473	1473 MCNEILL 138	138	48
2451	MATLB2	240	54
4458	CHAPR2	240	53
19438	19438 959S_LV 138	138	42
98856	HW785	240	53

Table A-2: Area Generation Total

Case	Area Generation (MW)											TOTAL (MW)	AB-BC TIE (MW)
	4 MEDICINE	42 HANNA	43 SHEERNESS	45 STRATHMORE	47 BROOKS	48 EMPRESS	49 STAVELY	52 VAUXHALL	53 FORT MAC	54 LETHBRIDGE	55 GLENWOOD		
C1M_2015SL_500_0_300_B1_R5	96	232	499	101	0	-92	0	81	996	-258	60	1716	519
C1X_2015SL_800_0_0_B1_R5	96	232	499	101	0	-92	0	81	996	42	60	2016	844
C2_2015SL_0_0_0_B1_R5	84	0	427	101	0	-92	0	0	25	12	30	587	21
C3_2015SP_0_0_0_B1_R5	84	232	616	99	0	-127	0	81	993	42	62	2082	56
C4M_2017SL_500_0_300_B1_R5	87	132	650	101	0	-99	0	81	1273	-258	63	2031	543
C4MS_2017SL_500_0_300_B1_R5	87	132	650	101	0	-99	0	81	1273	-258	63	2031	542
C5_2017SL_0_0_0_B1_R5	84	0	435	101	0	-99	0	0	24	12	33	591	46
C5S_2017SL_0_0_0_B1_R5	84	0	435	101	0	-99	0	0	24	12	33	591	46
C6_2017SP_0_0_0_B1_R5	84	231	718	99	0	-129	0	81	1272	67	62	2485	32
C6S_2017SP_0_0_0_B1_R5	84	231	718	99	0	-129	0	81	1272	67	62	2485	28
C7M_2022SL_500_0_300_B1_R5	212	133	538	101	0	-74	75	81	1577	-238	134	2539	546
C7X_2022SL_800_0_0_B1_R5	212	133	538	101	0	-74	75	81	1577	62	134	2839	872
C8_2022SL_0_0_0_B1_R5	84	0	502	101	0	-100	0	0	25	12	29	653	-64
C9_2022SP_0_0_0_B1_R5	215	195	911	99	0	-111	74	81	1311	62	136	2973	-10
C10_2015SP_-780_0_0_B1_R5	243	232	616	0	0	-127	0	81	837	42	62	1986	-775
C11_2017SP_-780_0_-150_B1_R5	355	231	718	0	0	-129	156	81	837	67	62	2378	-779
C11S_2017SP_-780_0_-150_B1_R5	355	231	718	0	0	-129	156	81	837	67	62	2378	-785
C12_2022SP_-1200_0_0_B1_R5	583	195	942	0	0	-38	330	81	424	122	136	2775	-1204

Table A-3: Area Load Total

Case	Area Load (MW)*										
	4 MEDICINE	42 HANNA	43 SHEERNES	45 STRATHMO	47 BROOKS	48 EMPRESS	49 STAVELY	52 VAUXHALL	53 FORT MAC	54 LETHBRID	55 GLENWOOD
C1X_2015SL_800_0_0_B1_R5	123	96	33	58	74	188	13	108	10	109	19
C2_2015SL_0_0_0_B1_R5	121	96	33	58	74	188	13	83	10	109	19
C3_2015SP_0_0_0_B1_R5	199	120	47	106	102	292	21	171	35	219	37
C4M_2017SL_500_0_300_B1_R5	142	99	34	72	84	209	15	125	13	430	22
C4MS_2017SL_500_0_300_B1_R5	142	99	34	72	84	209	15	125	13	430	22
C5_2017SL_0_0_0_B1_R5	142	99	38	72	84	209	15	125	13	130	22
C5S_2017SL_0_0_0_B1_R5	142	99	38	72	84	209	15	125	13	130	22
C6_2017SP_0_0_0_B1_R5	211	126	51	109	108	298	22	148	36	232	39
C6S_2017SP_0_0_0_B1_R5	211	126	51	109	108	298	22	148	36	232	39
C7M_2022SL_500_0_300_B1_R5	156	112	36	79	97	227	17	143	14	450	25
C7X_2022SL_800_0_0_B1_R5	156	112	36	79	97	227	17	143	14	150	25
C8_2022SL_0_0_0_B1_R5	143	116	47	66	90	209	15	129	12	133	22
C9_2022SP_0_0_0_B1_R5	235	143	55	118	125	319	24	206	40	269	44
C10_2015SP_-780_0_0_B1_R5	199	120	47	106	102	292	21	171	35	219	37
C11_2017SP_-780_0_-150_B1_R5	211	126	51	109	108	298	22	148	36	232	39
C11S_2017SP_-780_0_-150_B1_R5	211	126	51	109	108	298	22	148	36	232	39
C12_2022SP_-1200_0_0_B1_R5	235	143	55	118	125	319	24	206	40	269	44

* Load Total includes Motor Loads.

Table A-5: Steady State Category C5 Contingency Definitions

Label	Contingency
1002-1011_A	260 [JENNER 4 240.00] to 262 [DOME EM4 240.00] CKT 02 262 [DOME EM4 240.00] to 677 [CYPRES2 240.00] CKT 11
1002-1011_B	260 [JENNER 4 240.00] to 262 [DOME EM4 240.00] CKT 02 260 [JENNER 4 240.00] to 677 [CYPRES2 240.00] CKT 45 260 [JENNER 4 240.00] to 5260 [JENNERE9 240.00] CKT T1
1005-1036_A	737 [SW_SUB_1 240.00] to 943 [MILO 1 240.00] CKT 36 451 [MATLB1 240.00] to 943 [MILO 1 240.00] CKT 05
1005-1036_B	737 [SW_SUB_1 240.00] to 167 [N LETHB4 240.00] CKT 41 451 [MATLB1 240.00] to 167 [N LETHB4 240.00] CKT 40
1029-1030_A	617 [FOOTHLL1 240.00] to 643 [SC1D 240.00] CKT 37 617 [FOOTHLL1 240.00] to 653 [SC1B 240.00] CKT 38
951L-952L	430 [W BROOK4 240.00] to 918 [CASS01 240.00] CKT 52 430 [W BROOK4 240.00] to 918 [CASS01 240.00] CKT 51 430 [W BROOK4 240.00] to 276 [W BROOK7 138.00] CKT 1T
PEIG-WINDY	165 [PEIGAN 4 240.00] to 746 [WINDYFLATS 240.00] CKT 49 165 [PEIGAN 4 240.00] to 746 [WINDYFLATS 240.00] CKT 48
1037-1038_A	746 [WINDYFLATS 240.00] to 642 [SC1C 240.00] CKT 37 746 [WINDYFLATS 240.00] to 652 [SC1A 240.00] CKT 38
74S-SS25_A	160 [JANET 4 240.00] to 772 [ENMX25S7 240.00] CKT 03 160 [JANET 4 240.00] to 772 [ENMX25S7 240.00] CKT 85
923-934_A	918 [CASS01 240.00] to 1012 [NEWELL2 240.00] CKT 87 918 [CASS01 240.00] to 1012 [NEWELL2 240.00] CKT 88
924-927_A	159 [LANGDON4 240.00] to 943 [MILO 1 240.00] CKT 24 159 [LANGDON4 240.00] to 943 [MILO 1 240.00] CKT 27
944-951_A	225 [WARE JCT 240.00] to 260 [JENNER 4 240.00] CKT 44 225 [WARE JCT 240.00] to 260 [JENNER 4 240.00] CKT 51 225 [WARE JCT 240.00] to 1484 [ANDERSO4 240.00] CKT 50 260 [JENNER 4 240.00] to 5260 [JENNERE9 240.00] CKT T1
964-983_A	662 [SUBD1 240.00] to 477 [ELKWATR1 240.00] CKT 64 662 [SUBD1 240.00] to 477 [ELKWATR1 240.00] CKT 83
1073-1074	477 [ELKWATR1 240.00] to 669 [MEDHAT2 240.00] CKT 74 477 [ELKWATR1 240.00] to 669 [MEDHAT2 240.00] CKT 73
955-956_A	165 [PEIGAN 4 240.00] to 346 [GOOSEL4 240.00] CKT 55 165 [PEIGAN 4 240.00] to 346 [GOOSEL4 240.00] CKT 56
WINDY-LETH	746 [WINDYFLATS 240.00] to 721 [KAIYA_1 240.00] CKT 84 746 [WINDYFLATS 240.00] to 641 [TURNIP_T 240.00] CKT 48
984L_987L	611 [SUBC_240 240.00] to 662 [SUBD1 240.00] CKT 84 611 [SUBC_240 240.00] to 662 [SUBD1 240.00] CKT 87
ANDERS_WAJCT	1484 [ANDERSO4 240.00] to 225 [WARE JCT 240.00] CKT 34 1484 [ANDERSO4 240.00] to 225 [WARE JCT 240.00] CKT 50
CRR_CHAPRK	221 [CRR-W1 240.00] to 4458 [CHAPR2 240.00] CKT 04 221 [CRR-W1 240.00] to 4458 [CHAPR2 240.00] CKT 92
9L70-9L97	1484 [ANDERSO4 240.00] to 1440 [946S_HV 240.00] CKT 70 1484 [ANDERSO4 240.00] to 1440 [946S_HV 240.00] CKT 97
925-929B	152 [RED DEE4 240.00] to 160 [JANET 4 240.00] CKT 25 152 [RED DEE4 240.00] to 661 [HAZLWOD1 240.00] CKT 82
925-929A	152 [RED DEE4 240.00] to 160 [JANET 4 240.00] CKT 25 661 [HAZLWOD1 240.00] to 160 [JANET 4 240.00] CKT 29
906-928A-B	155 [BENALTO4 240.00] to 161 [SARCEE 4 240.00] CKT 06 155 [BENALTO4 240.00] to 161 [SARCEE 4 240.00] CKT 28
936-937B-A	159 [LANGDON4 240.00] to 160 [JANET 4 240.00] CKT 64 159 [LANGDON4 240.00] to 160 [JANET 4 240.00] CKT 65
936-937C-D	159 [LANGDON4 240.00] to 162 [E CALGAR 240.00] CKT 36 159 [LANGDON4 240.00] to 162 [E CALGAR 240.00] CKT 37
1005L-1036-A	167 [N LETHB4 240.00] to 451 [MATLB1 240.00] CKT 40 737 [SW_SUB_1 240.00] to 943 [MILO 1 240.00] CKT 36
1005L-1041-A	167 [N LETHB4 240.00] to 451 [MATLB1 240.00] CKT 40 167 [N LETHB4 240.00] to 737 [SW_SUB_1 240.00] CKT 41 167 [N LETHB4 240.00] to 692 [N LETHB7 138.00] CKT T5

Label	Contingency
933L-934L	225 [WARE JCT 240.00] to 1484 [ANDERSO4 240.00] CKT 33 225 [WARE JCT 240.00] to 1484 [ANDERSO4 240.00] CKT 34
931-933	430 [W BROOK4 240.00] to 225 [WARE JCT 240.00] CKT 31 430 [W BROOK4 240.00] to 225 [WARE JCT 240.00] CKT 33
1005L-1041LB	451 [MATLB1 240.00] to 943 [MILO 1 240.00] CKT 05 167 [N LETHB4 240.00] to 737 [SW_SUB_1 240.00] CKT 41
SS25-SS65-A	772 [ENMX25S7 240.00] to 544 [ENMX65S4 240.00] CKT 80 772 [ENMX25S7 240.00] to 544 [ENMX65S4 240.00] CKT 09
929-932A	661 [HAZLWOD1 240.00] to 160 [JANET 4 240.00] CKT 29 187 [BEDDING1 240.00] to 160 [JANET 4 240.00] CKT 32
923L-935LA-B	918 [CASS01 240.00] to 943 [MILO 1 240.00] CKT 35 1012 [NEWELL2 240.00] to 943 [MILO 1 240.00] CKT 23
9L_9L29	1440 [946S_HV 240.00] to 1447 [963S_HV 240.00] CKT 31 1440 [946S_HV 240.00] to 1447 [963S_HV 240.00] CKT 29
9L24_9L65	1440 [946S_HV 240.00] to 1438 [959S_HV 240.00] CKT 24 1440 [946S_HV 240.00] to 1438 [959S_HV 240.00] CKT 65
9L49_9L16	1499 [CORDEL 4 240.00] to 1431 [SWITCH_H 240.00] CKT 16 1499 [CORDEL 4 240.00] to 1431 [SWITCH_H 240.00] CKT 49

Appendix B
Steady State Assessment Tables and Plots

List of Tables

Table B-1: Need Assessment – Category A Plot List

Table B-2: Need Assessment – Category B Plot List

Table B-3: Reactive Case – Category A Plot List

Table B-4: Reactive Case – Category B Plot List

Table B-5: Reactive Case – Category C5 Plot List

Table B-1: Need Assessment –Category A Plot List

Fig #	Plot Type	Figure Description
Fig A-W- 1	South West	C1M_2015SL_500_0_300 Category A
Fig A-E- 1	South East	C1M_2015SL_500_0_300 Category A
Fig A-W- 2	South West	C1X_2015SL_800_0_0 Category A
Fig A-E- 2	South East	C1X_2015SL_800_0_0 Category A
Fig A-W- 3	South West	C2_2015SL_0_0_0 Category A
Fig A-E- 3	South East	C2_2015SL_0_0_0 Category A
Fig A-W- 4	South West	C3_2015SP_0_0_0 Category A
Fig A-E- 4	South East	C3_2015SP_0_0_0 Category A
Fig A-W- 5	South West	C4M_2017SL_500_0_300 Category A
Fig A-E- 5	South East	C4M_2017SL_500_0_300 Category A
Fig A-W- 6	South West	C4MS_2017SL_500_0_300 Category A
Fig A-E- 6	South East	C4MS_2017SL_500_0_300 Category A
Fig A-W- 7	South West	C5_2017SL_0_0_0 Category A
Fig A-E- 7	South East	C5_2017SL_0_0_0 Category A
Fig A-W- 8	South West	C5S_2017SL_0_0_0 Category A
Fig A-E- 8	South East	C5S_2017SL_0_0_0 Category A
Fig A-W- 9	South West	C6_2017SP_0_0_0 Category A
Fig A-E- 9	South East	C6_2017SP_0_0_0 Category A
Fig A-W- 10	South West	C6S_2017SP_0_0_0 Category A
Fig A-E- 10	South East	C6S_2017SP_0_0_0 Category A
Fig A-W- 11	South West	C7M_2022SL_500_0_300 Category A
Fig A-E- 11	South East	C7M_2022SL_500_0_300 Category A
Fig A-W- 12	South West	C7X_2022SL_800_0_0 Category A
Fig A-E- 12	South East	C7X_2022SL_800_0_0 Category A
Fig A-W- 13	South West	C8_2022SL_0_0_0 Category A
Fig A-E- 13	South East	C8_2022SL_0_0_0 Category A
Fig A-W- 14	South West	C9_2022SP_0_0_0 Category A
Fig A-E- 14	South East	C9_2022SP_0_0_0 Category A
Fig A-W- 15	South West	C10_2015SP_-780_0_0 Category A
Fig A-E- 15	South East	C10_2015SP_-780_0_0 Category A
Fig A-W- 16	South West	C11_2017SP_-780_0_-150 Category A
Fig A-E- 16	South East	C11_2017SP_-780_0_-150 Category A
Fig A-W- 17	South West	C11S_2017SP_-780_0_-150 Category A
Fig A-E- 17	South East	C11S_2017SP_-780_0_-150 Category A
Fig A-W- 18	South West	C12_2022SP_-1200_0_0 Category A
Fig A-E- 18	South East	C12_2022SP_-1200_0_0 Category A
FIG A-W-19	South West	C13_2022SP_0_0_150_B1_R6 Category A
FIG A-E-19	South East	C13_2022SP_0_0_150_B1_R6 Category A
FIG A-W-20	South West	C14_2017SL_500_0_300_B1_R6 Category A

FIG A-E-20	South East	C14_2017SL_500_0_300_B1_R6 Category A
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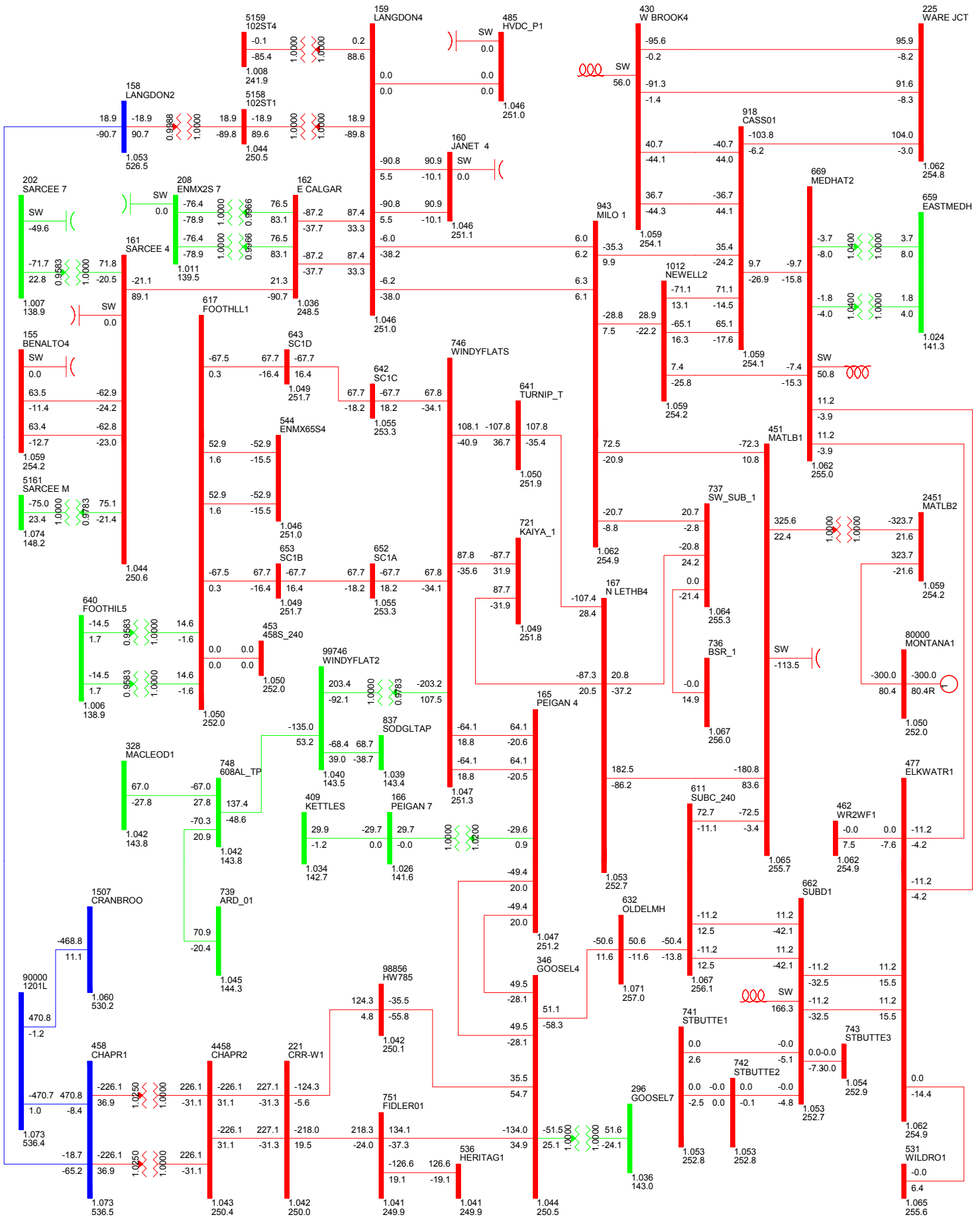


FIG A-W-1: BASECASE
 C1M_2015SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

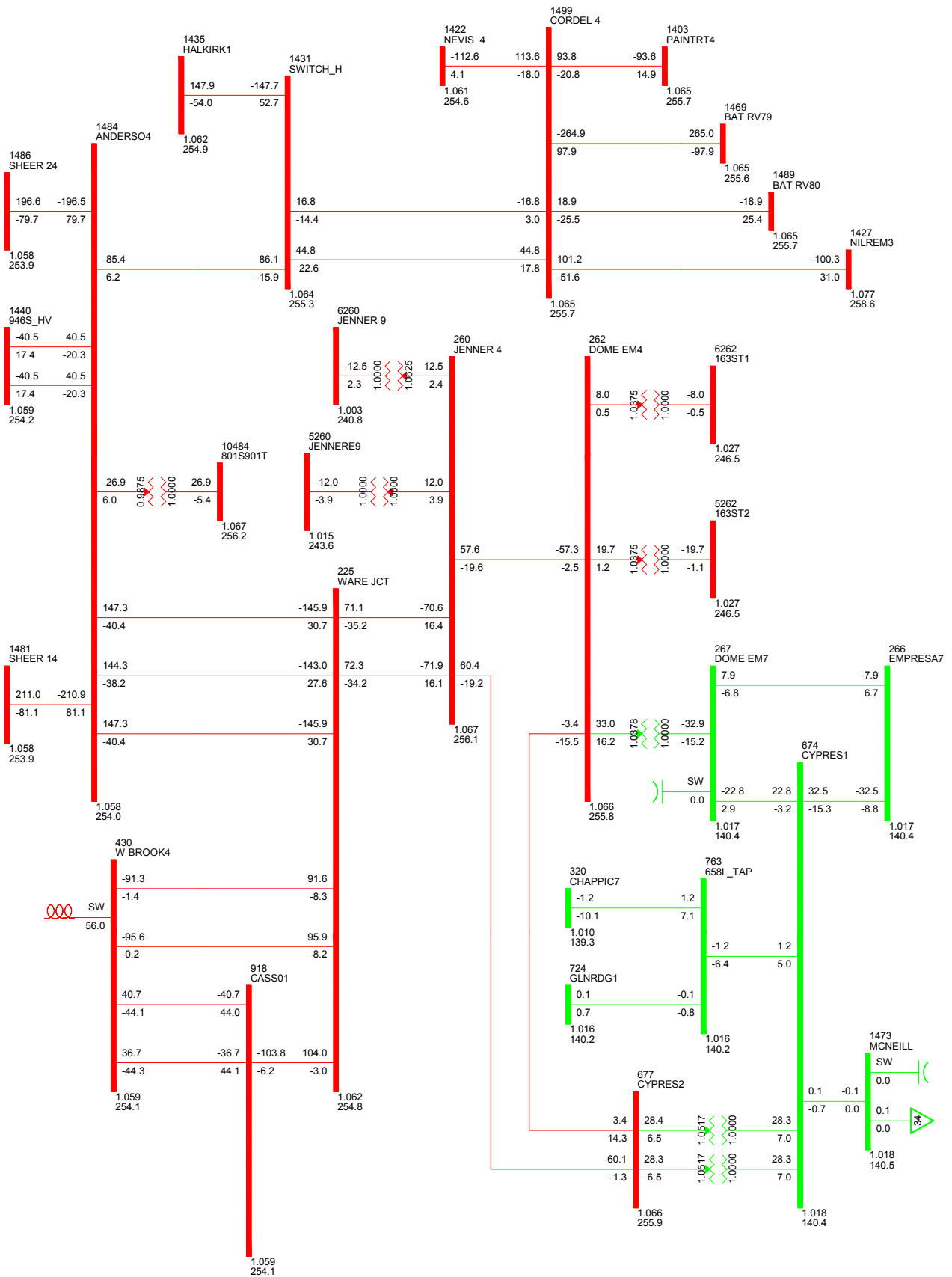


FIG A-E-1: BASECASE
 CIM_2015SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

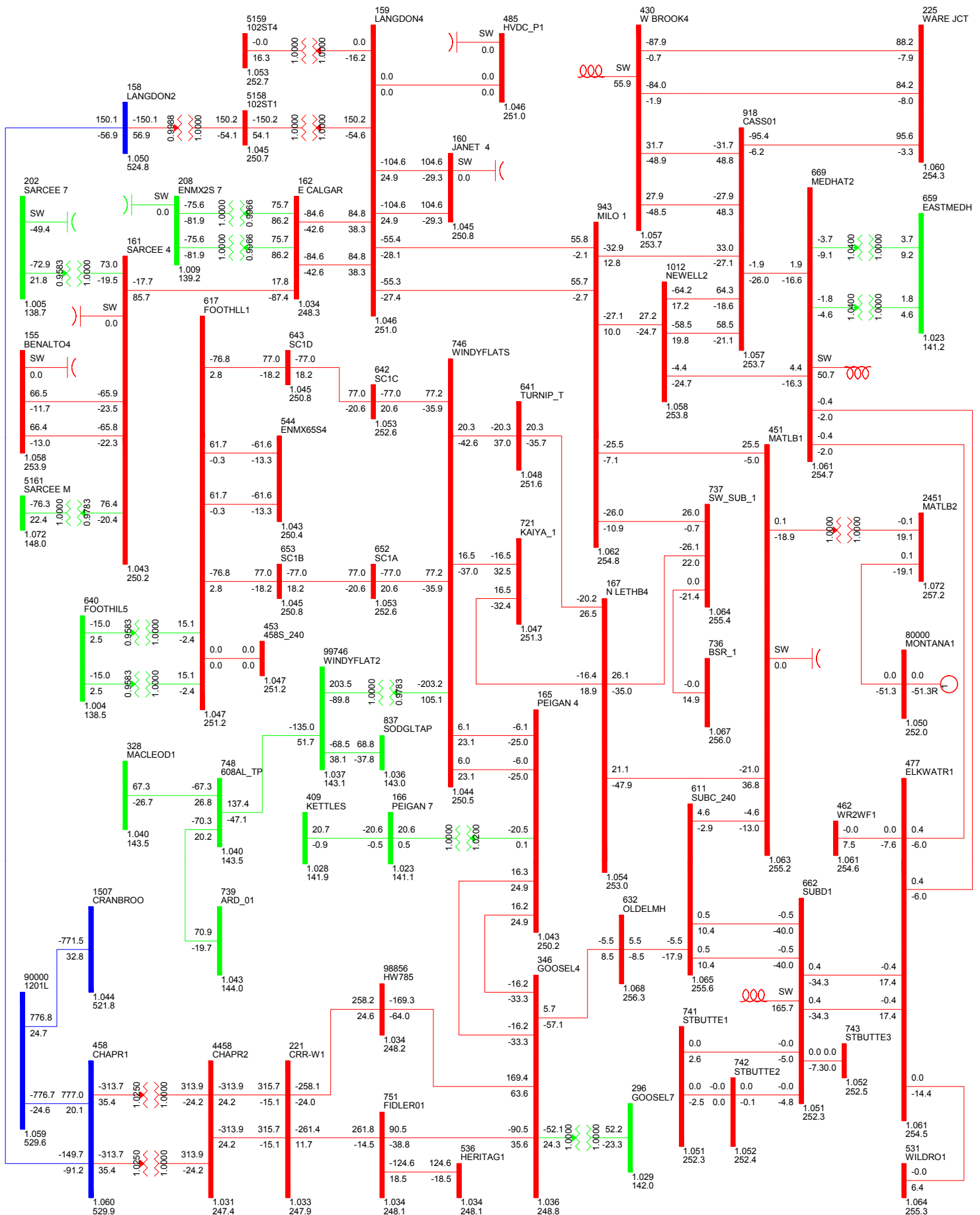


FIG A-W-2: BASECASE
 C1X_2015SL_800_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

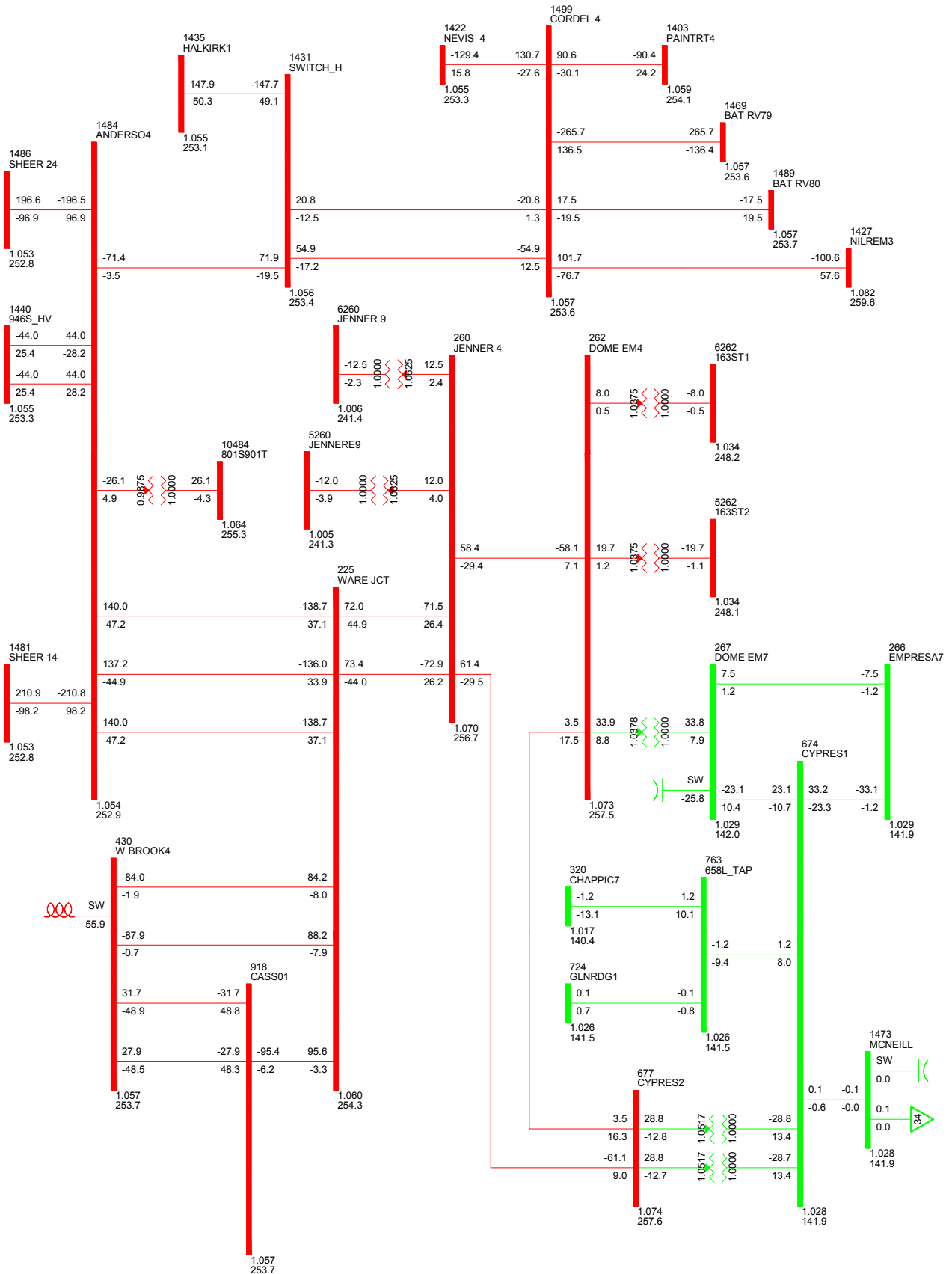


FIG A-E-2: BASECASE
 C1X_2015SL_800_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

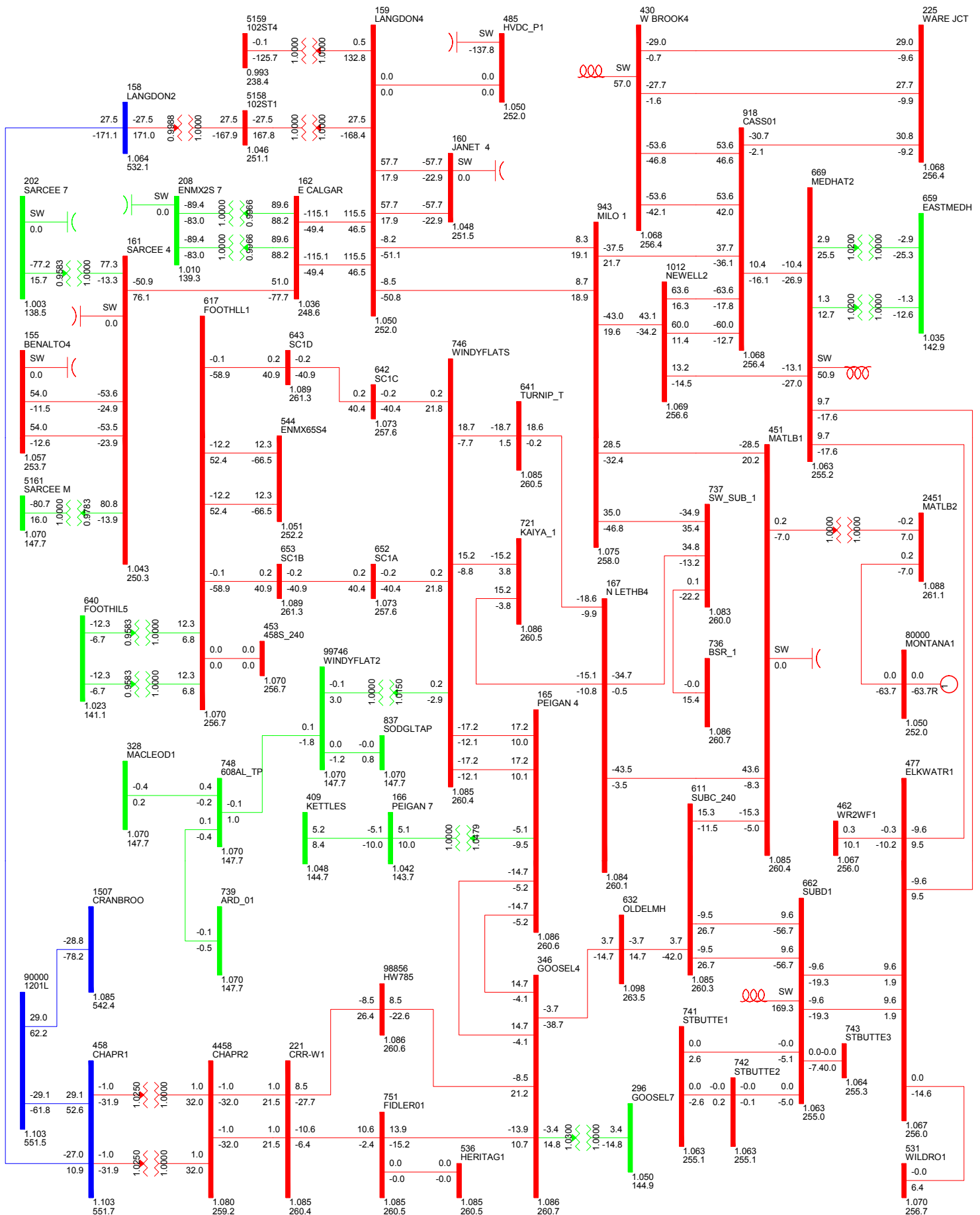


FIG A-W-3: BASECASE
 C2_2015SL_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

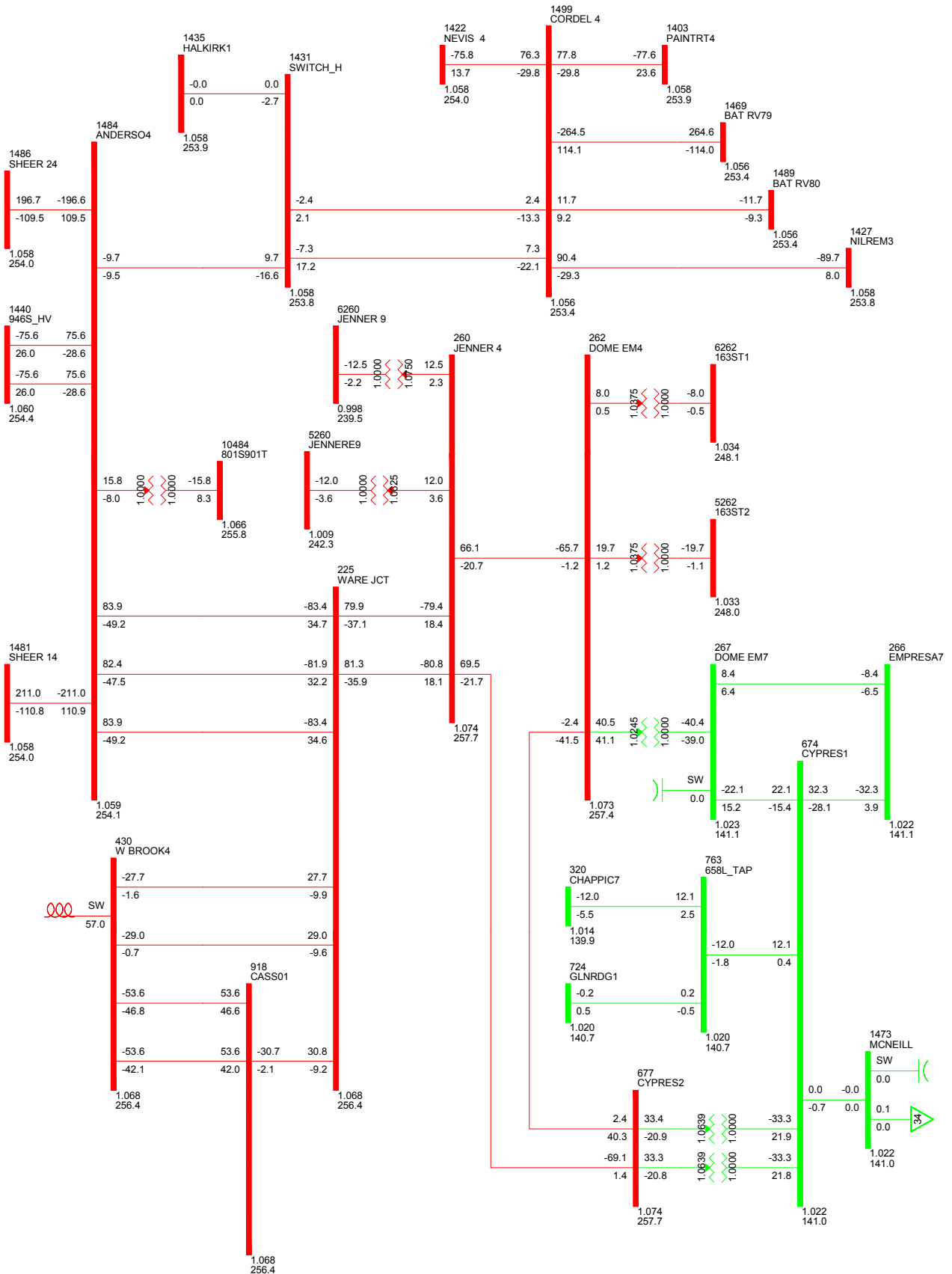


FIG A-E-3: BASECASE
 C2_2015SL_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

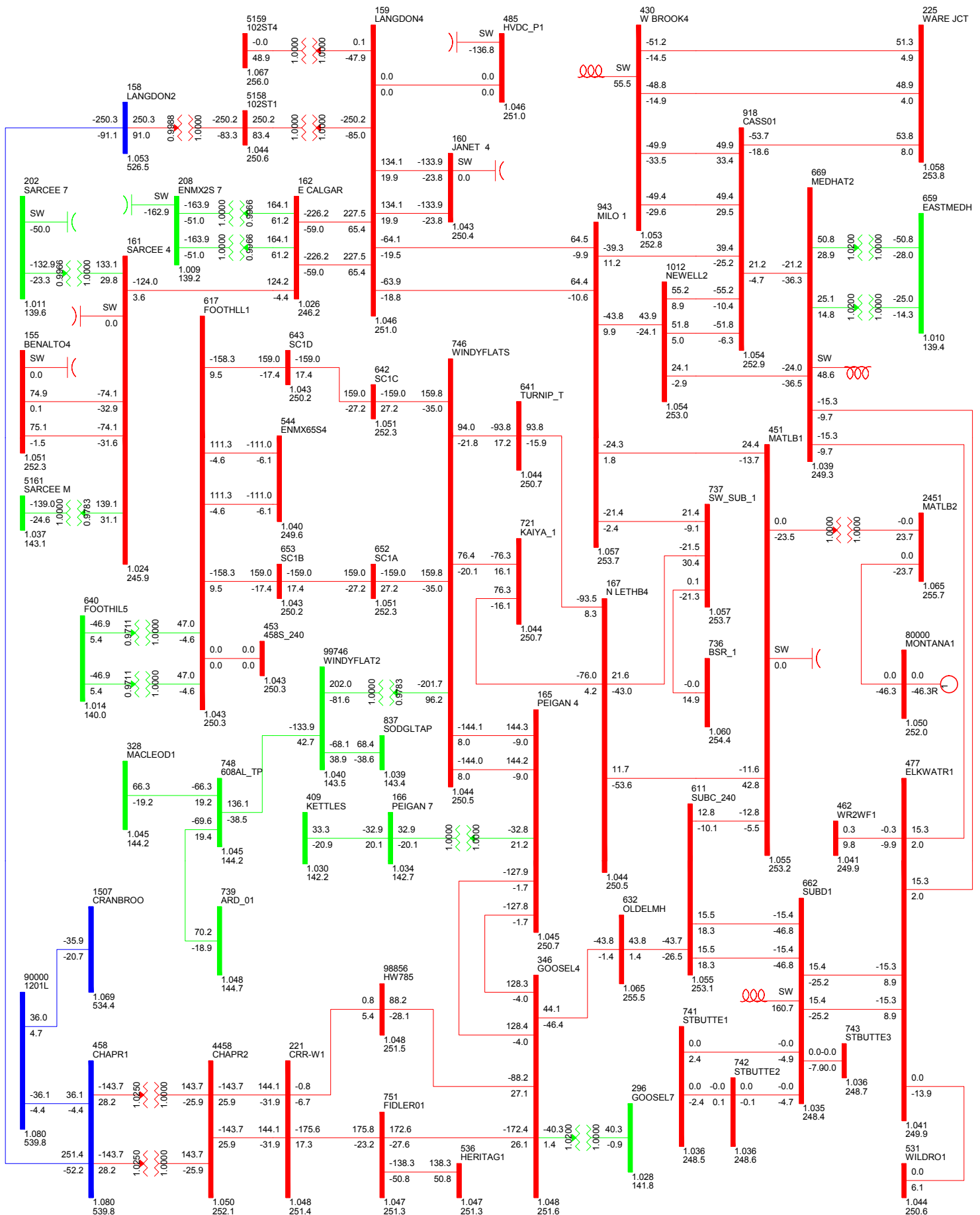
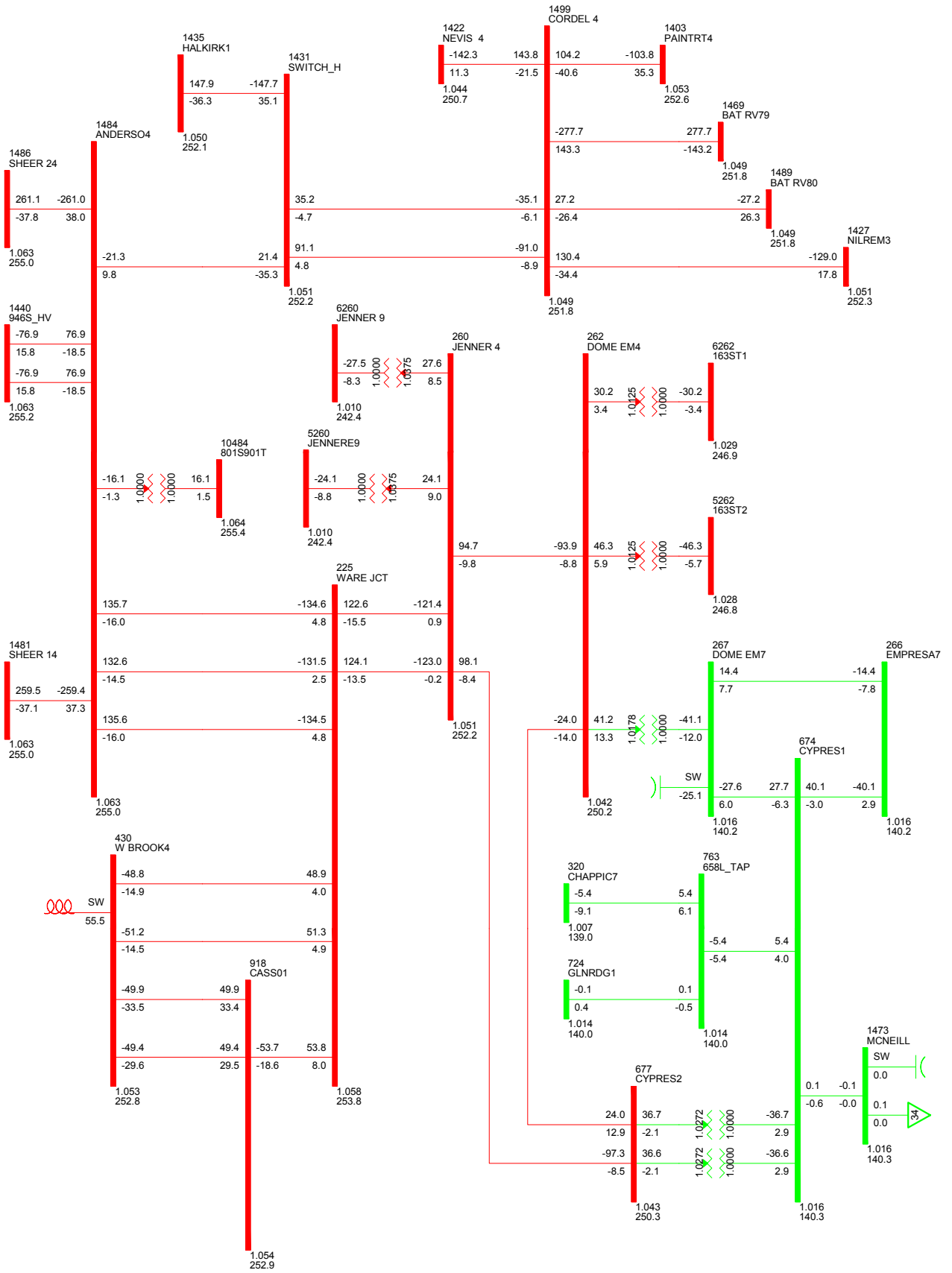


FIG A-W-4: BASECASE
 C3_2015SP_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



South Reactive Study East (Need Assessment)

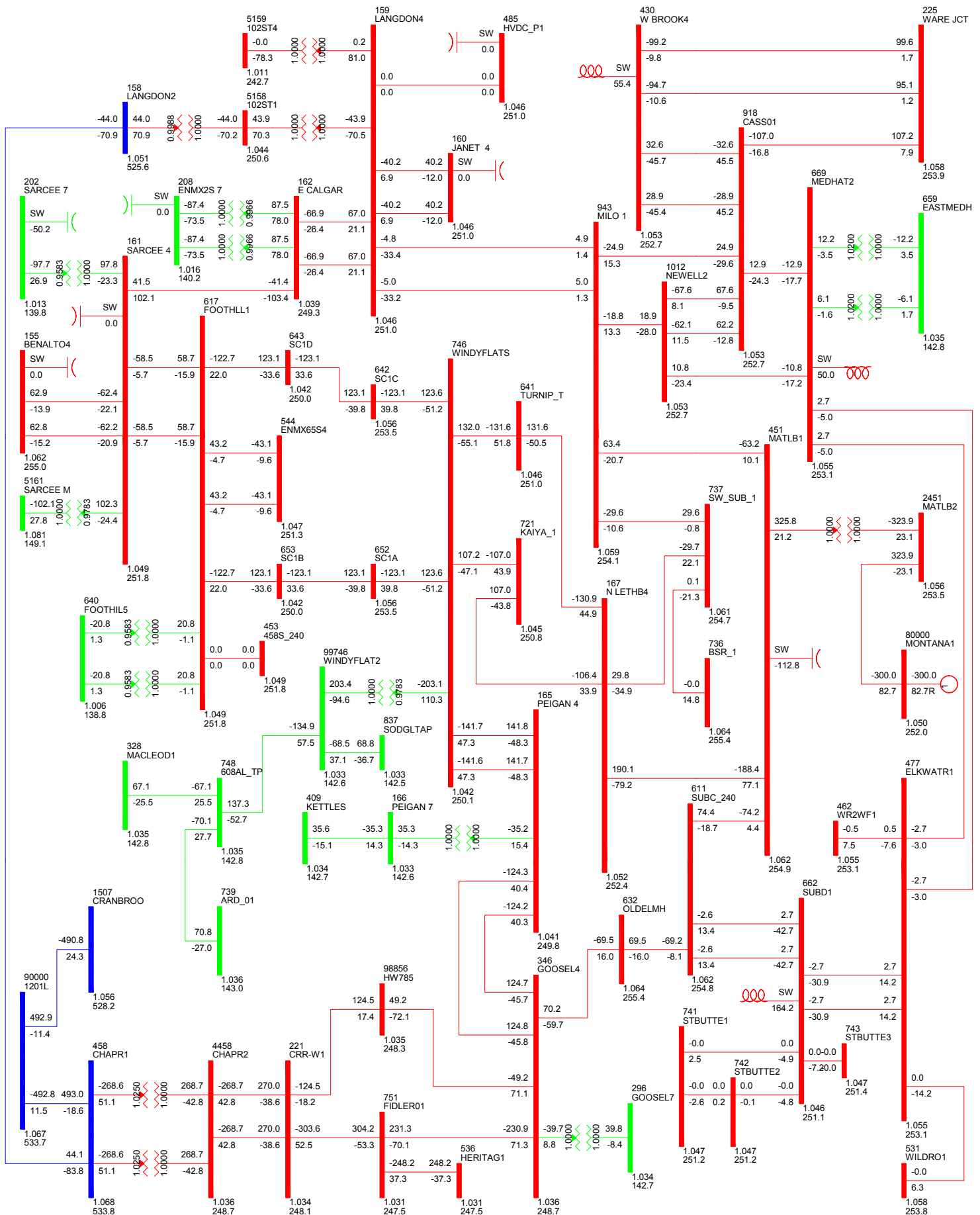
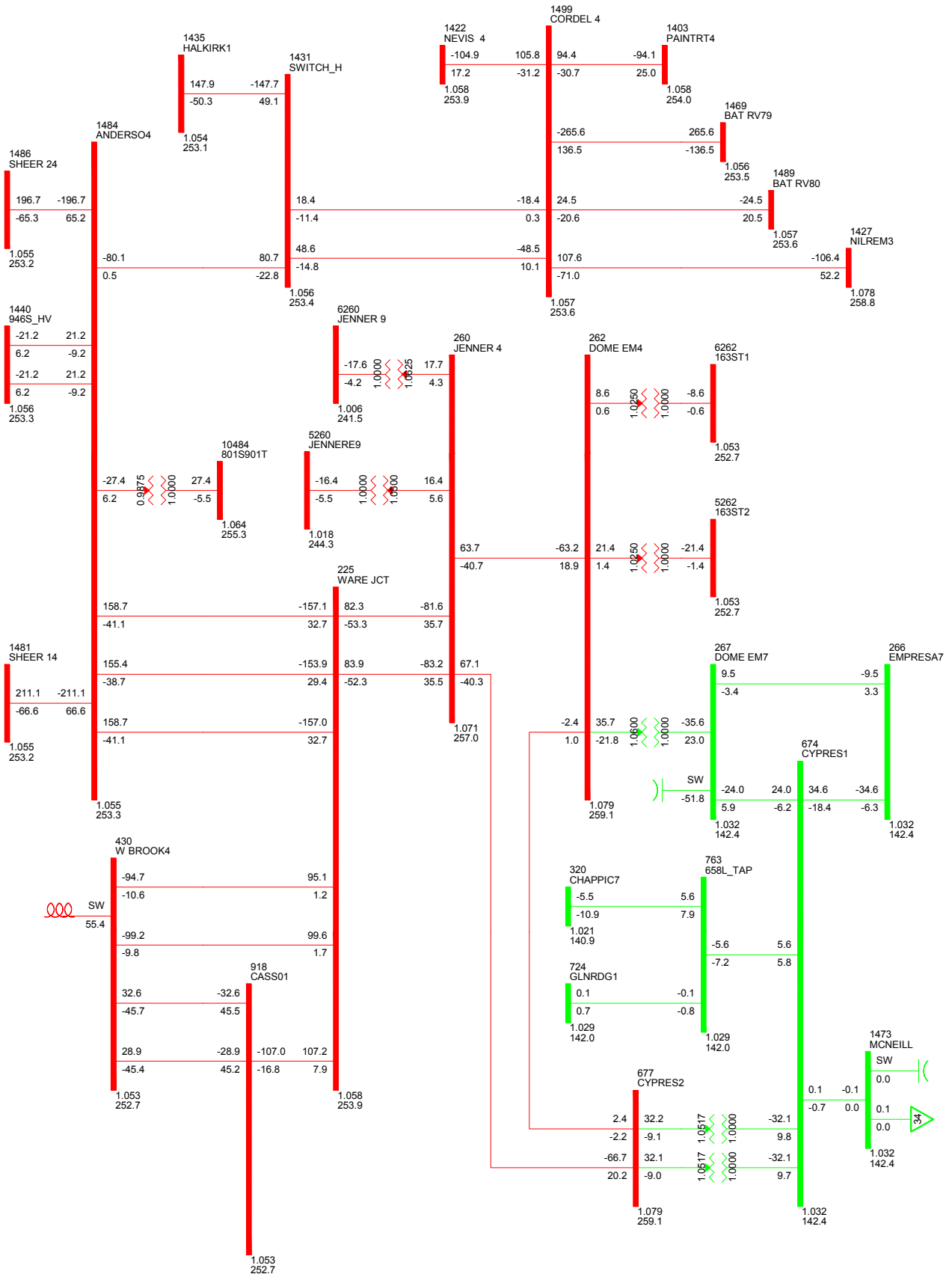


FIG A-W-5: BASECASE
 C4M_2017SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



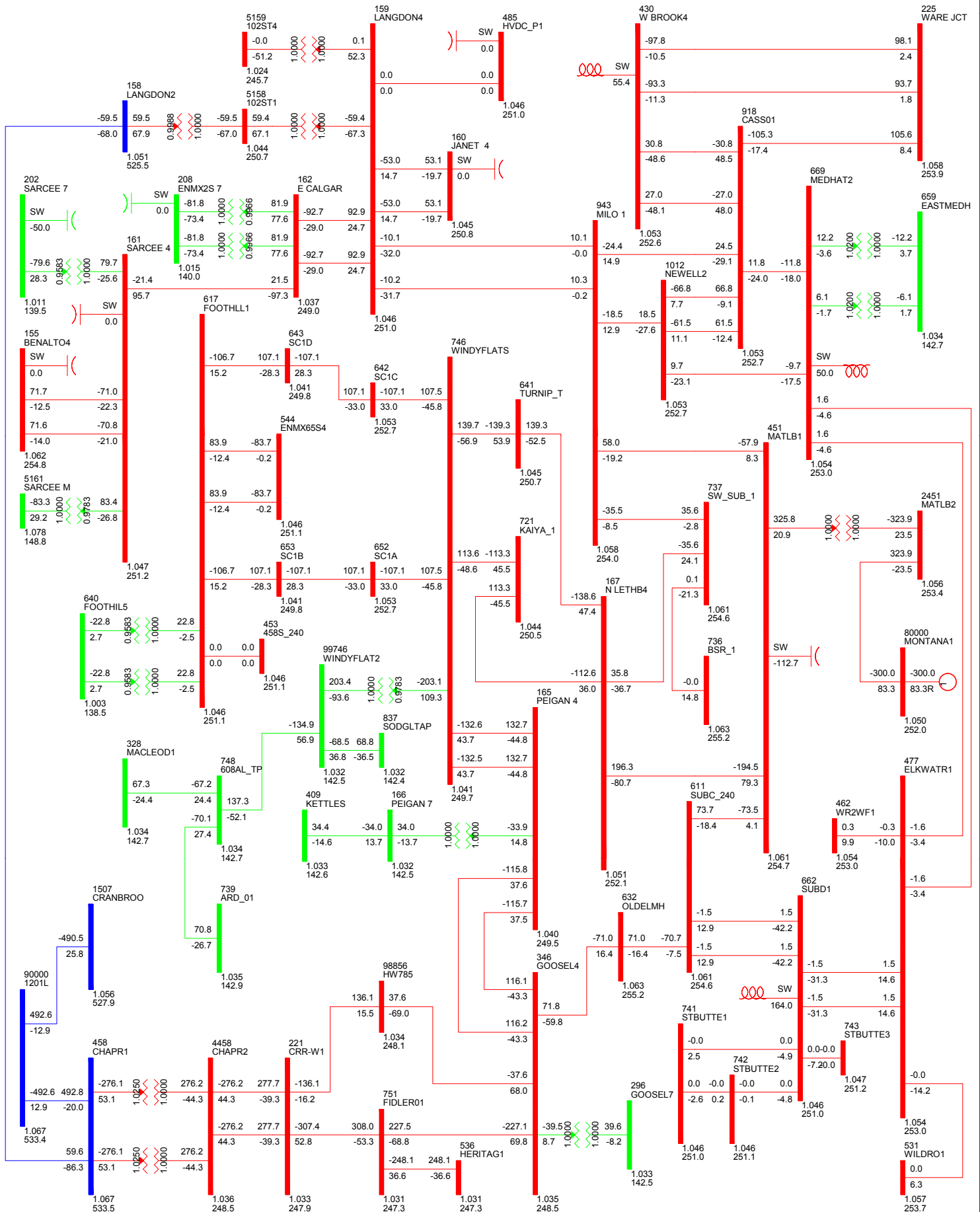
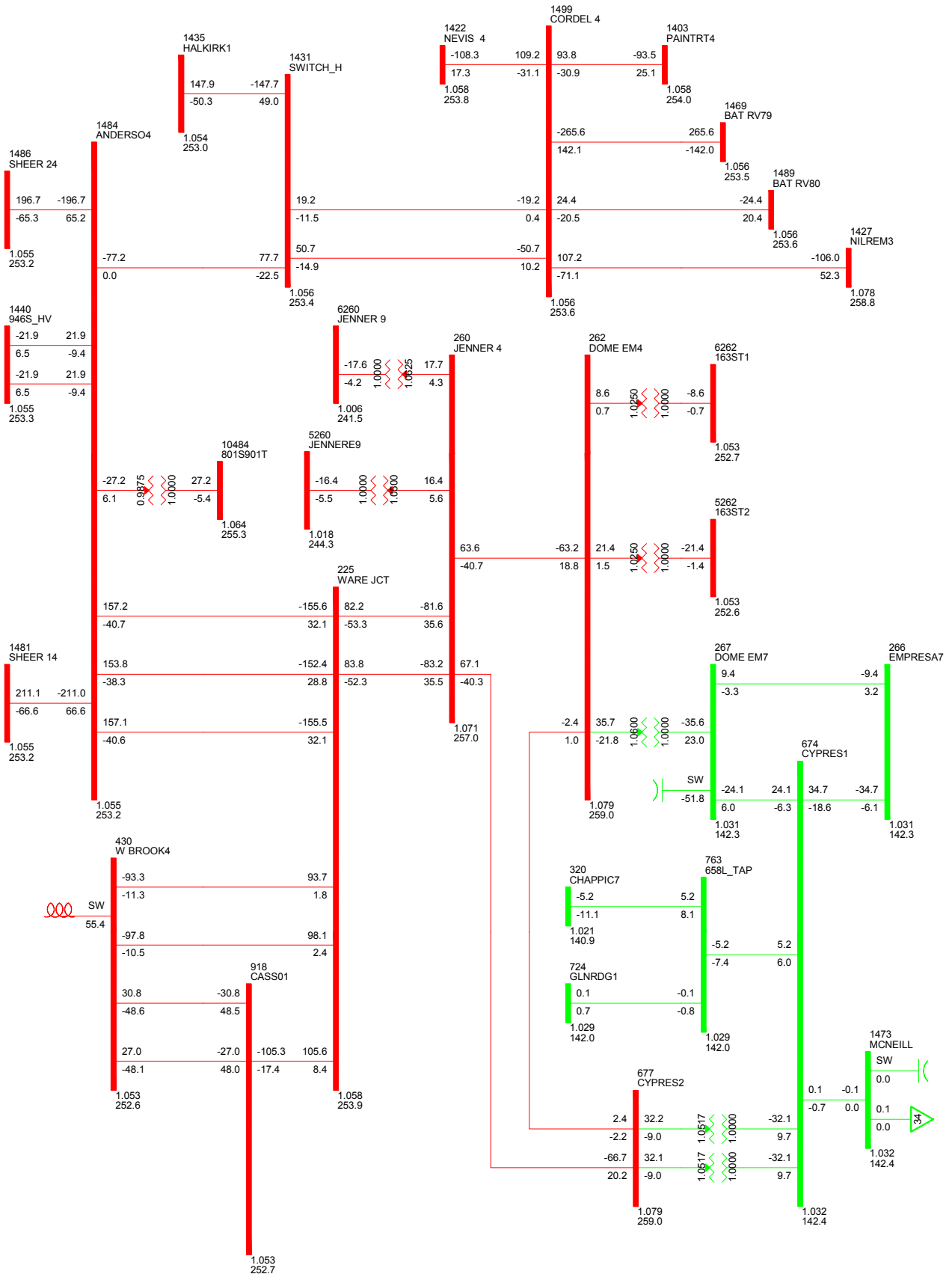


FIG A-W-6: BASECASE
 CAMS_2017SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



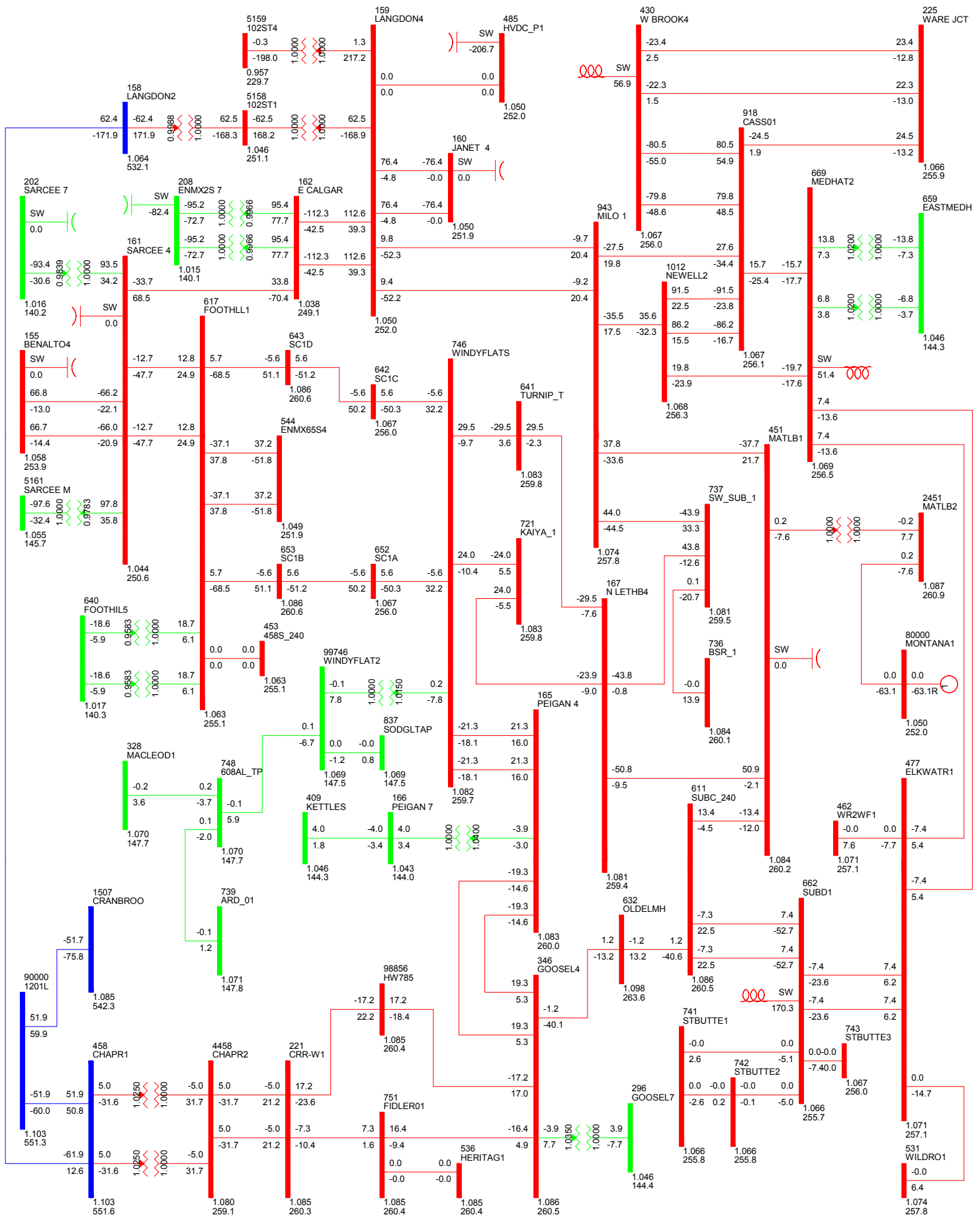


FIG A-W-7: BASECASE
 C5_2017SL_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

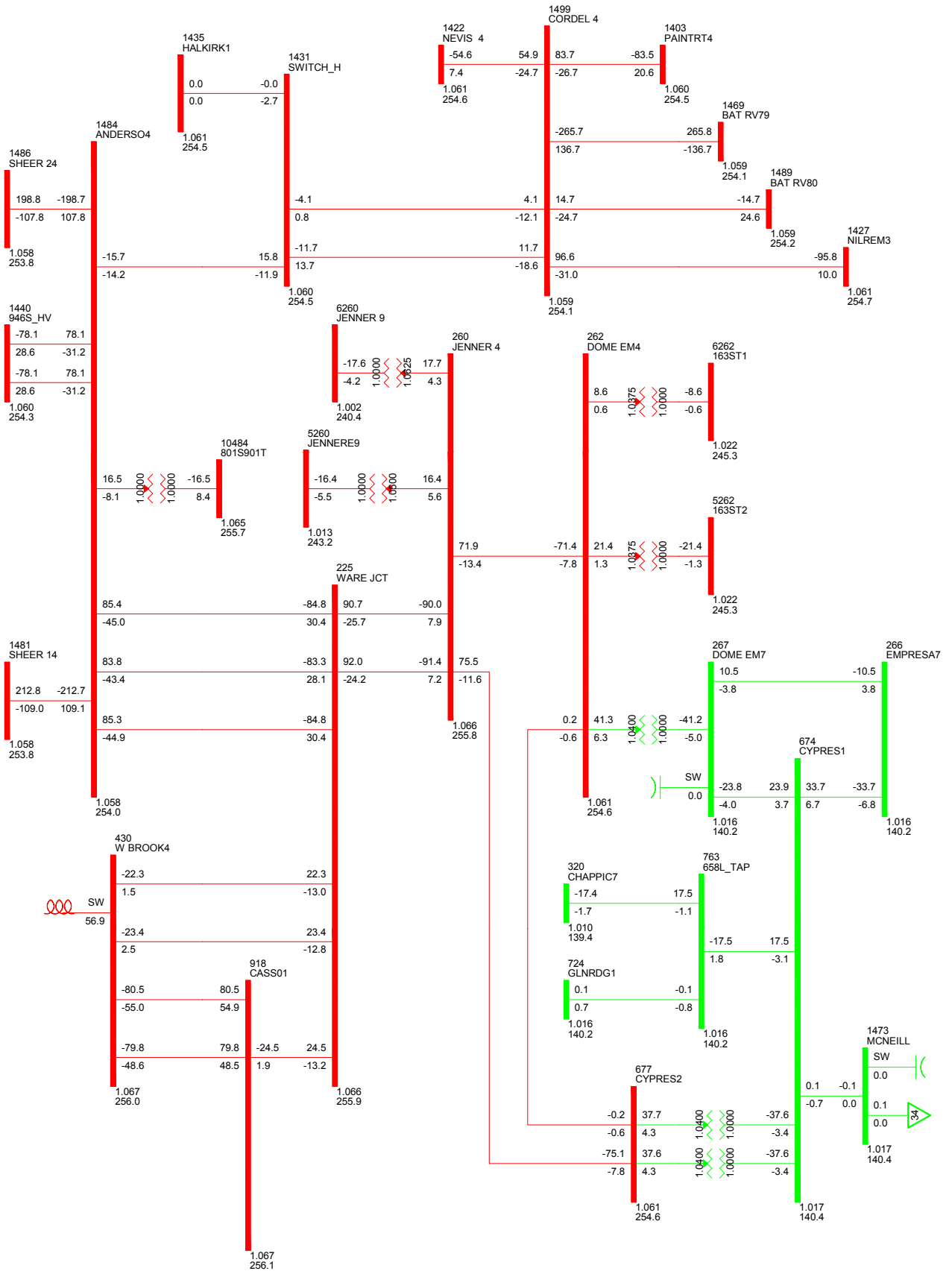


FIG A-E-7: BASECASE
 C5_2017SL_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

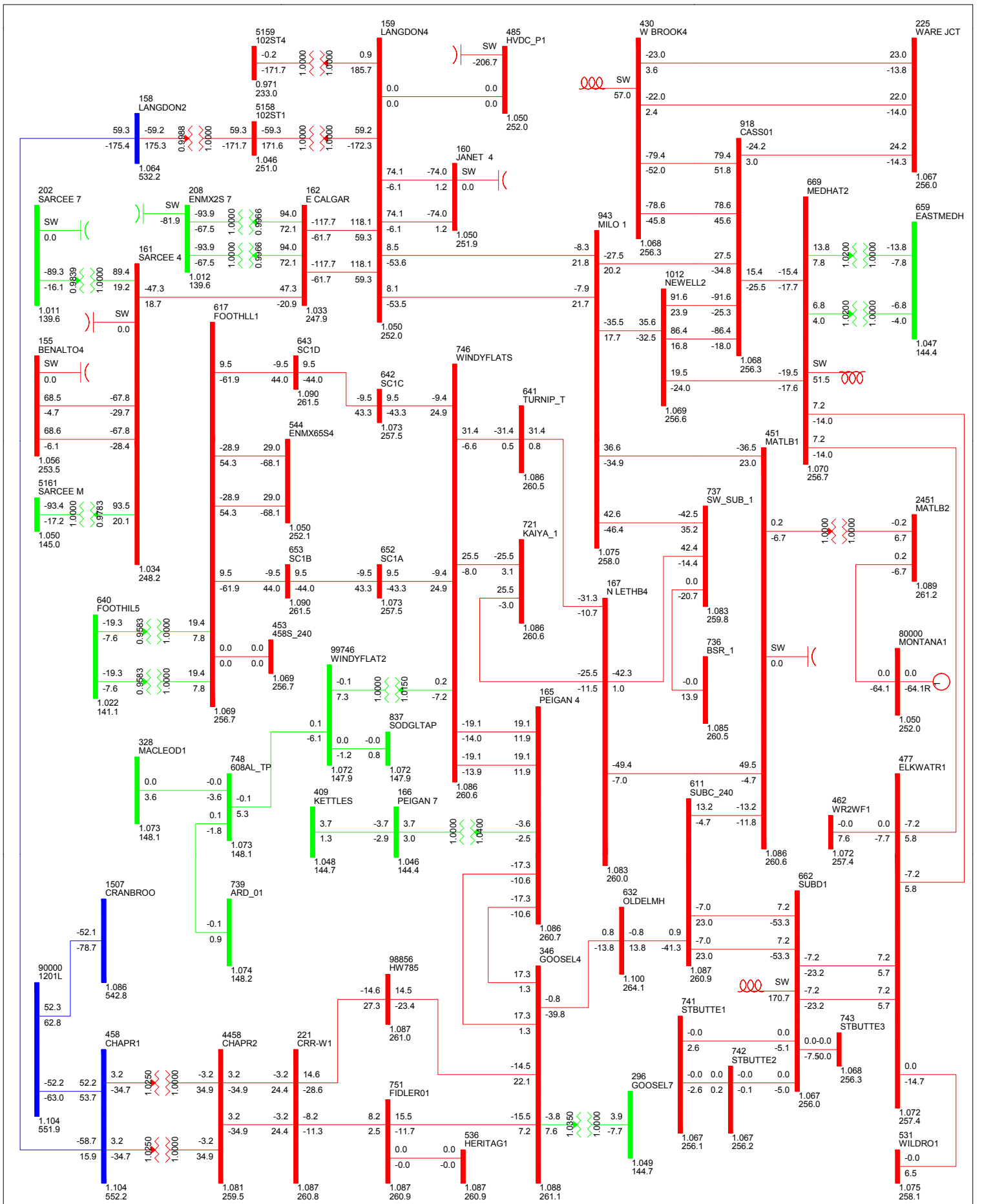
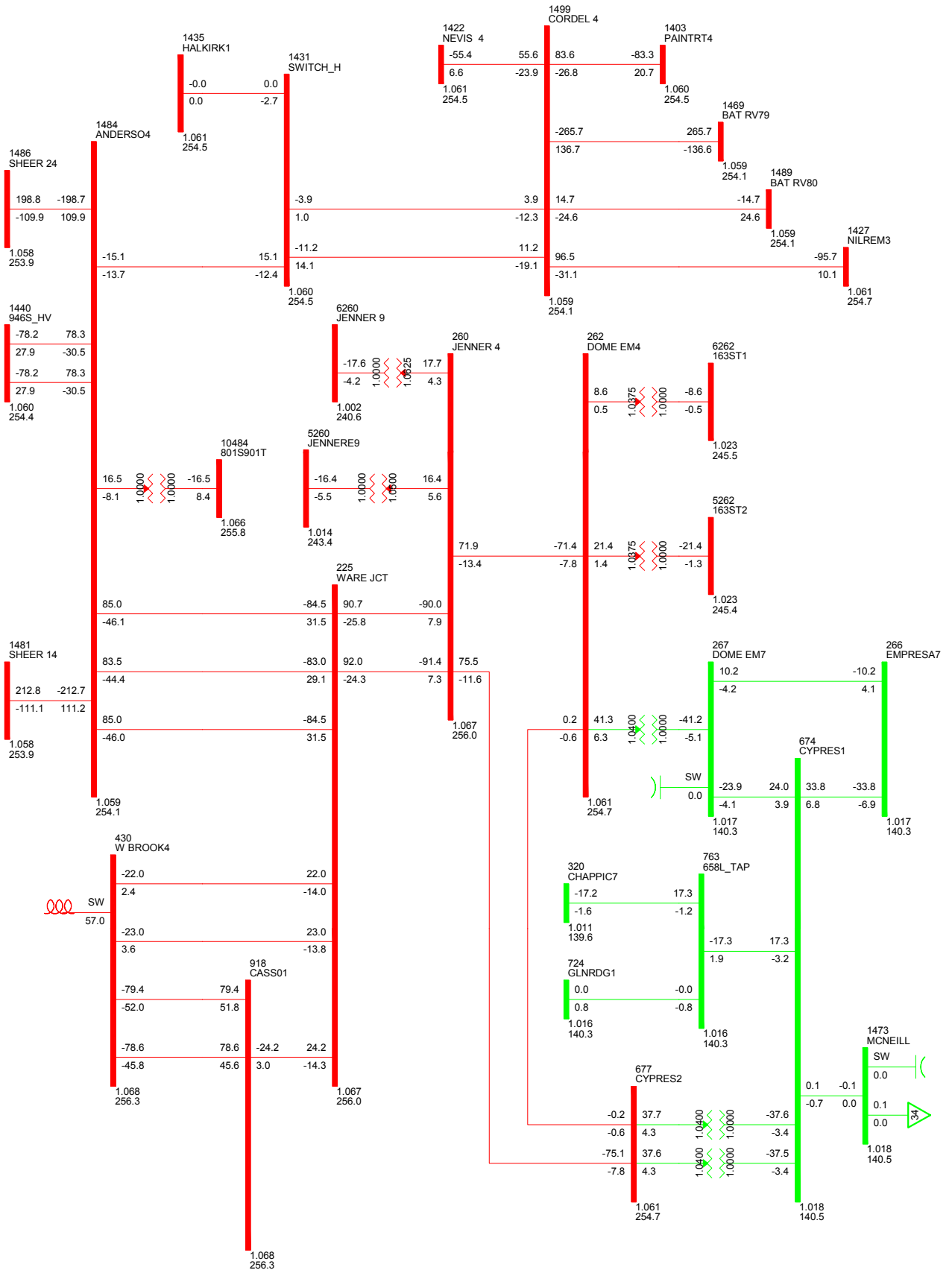


FIG A-W-8: BASECASE
 C5S_2017SL_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000



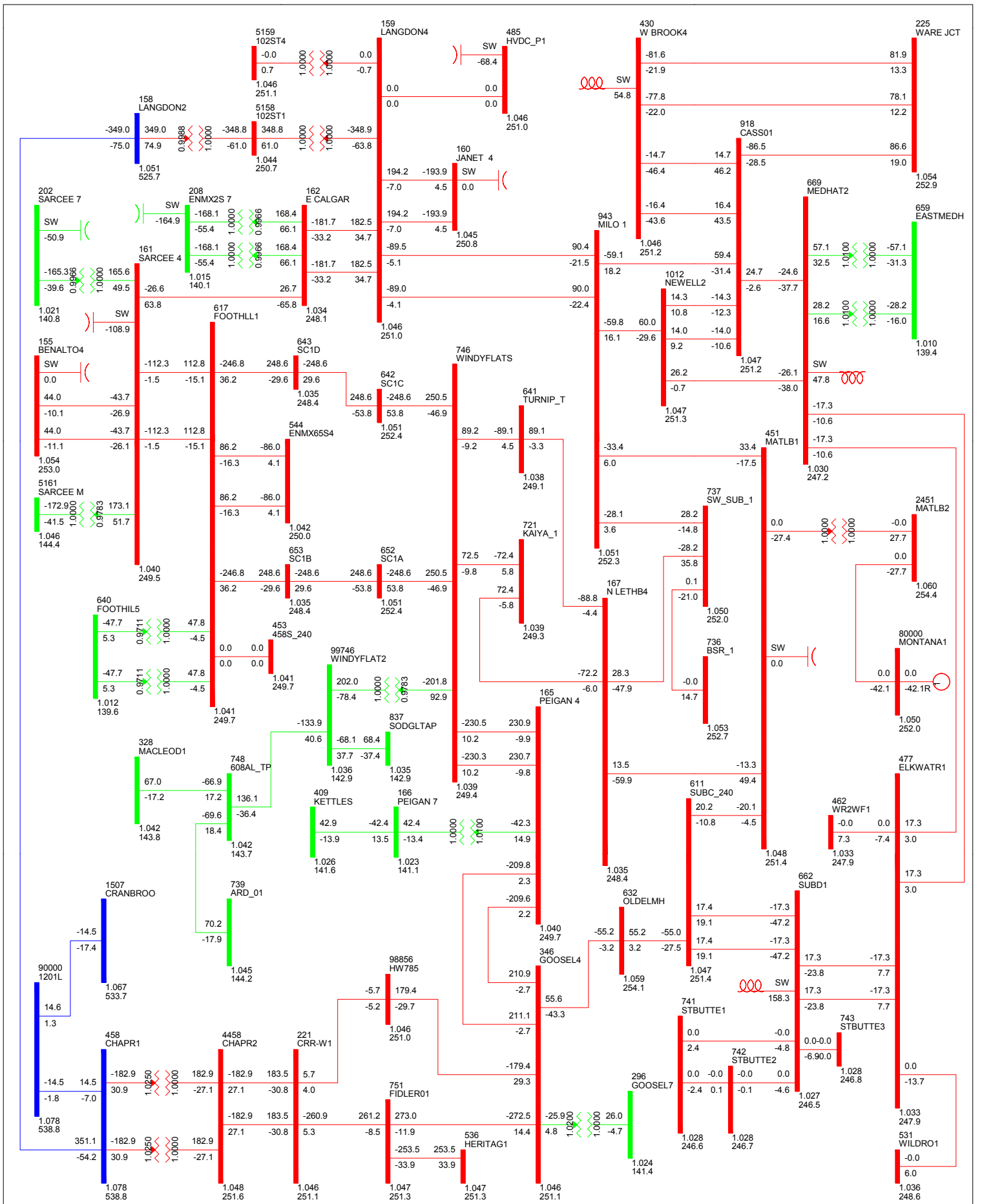


FIG A-W-9: BASECASE
 C6_2017SP_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

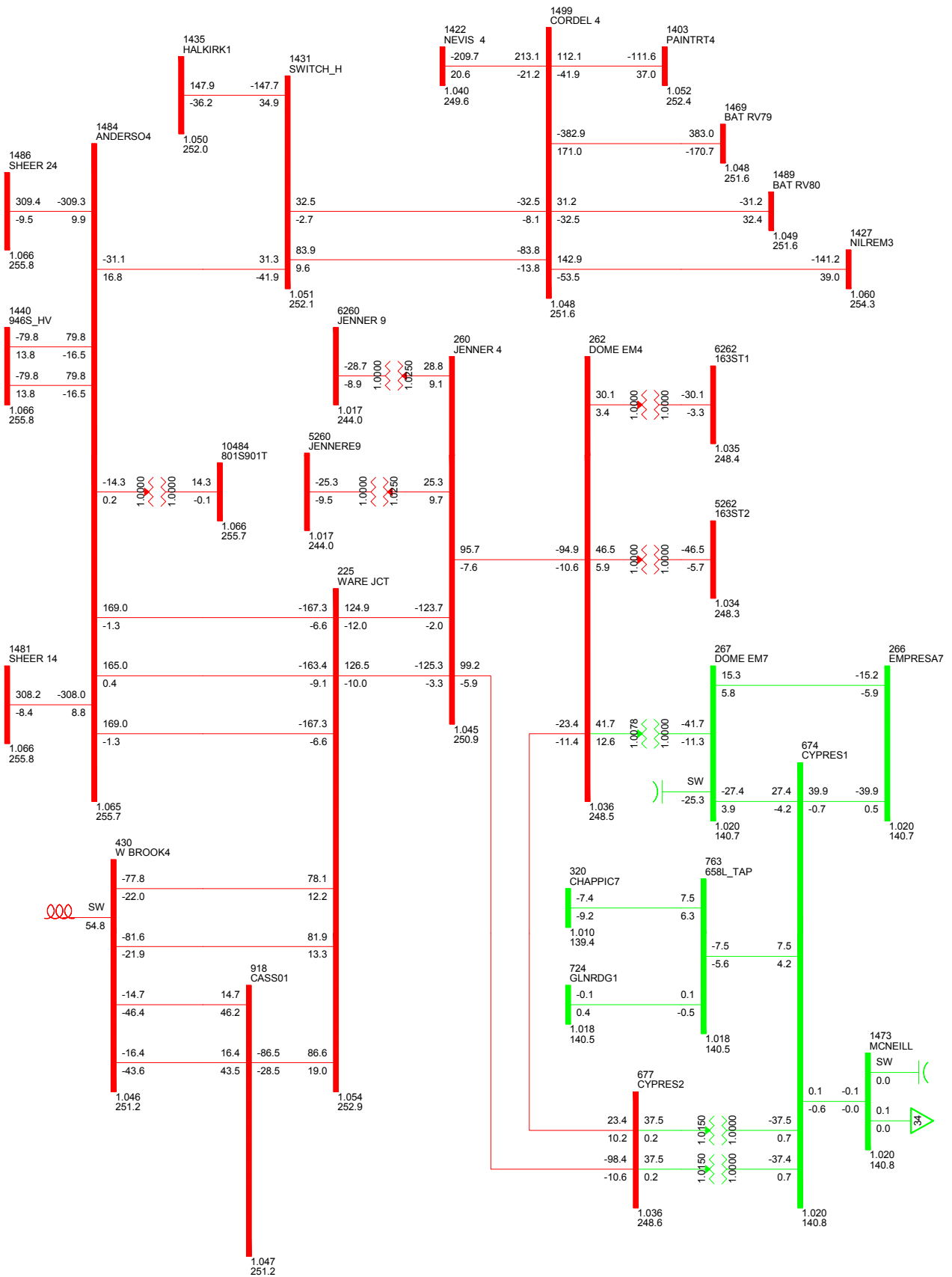


FIG A-E-9: BASECASE
 C6_2017SP_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

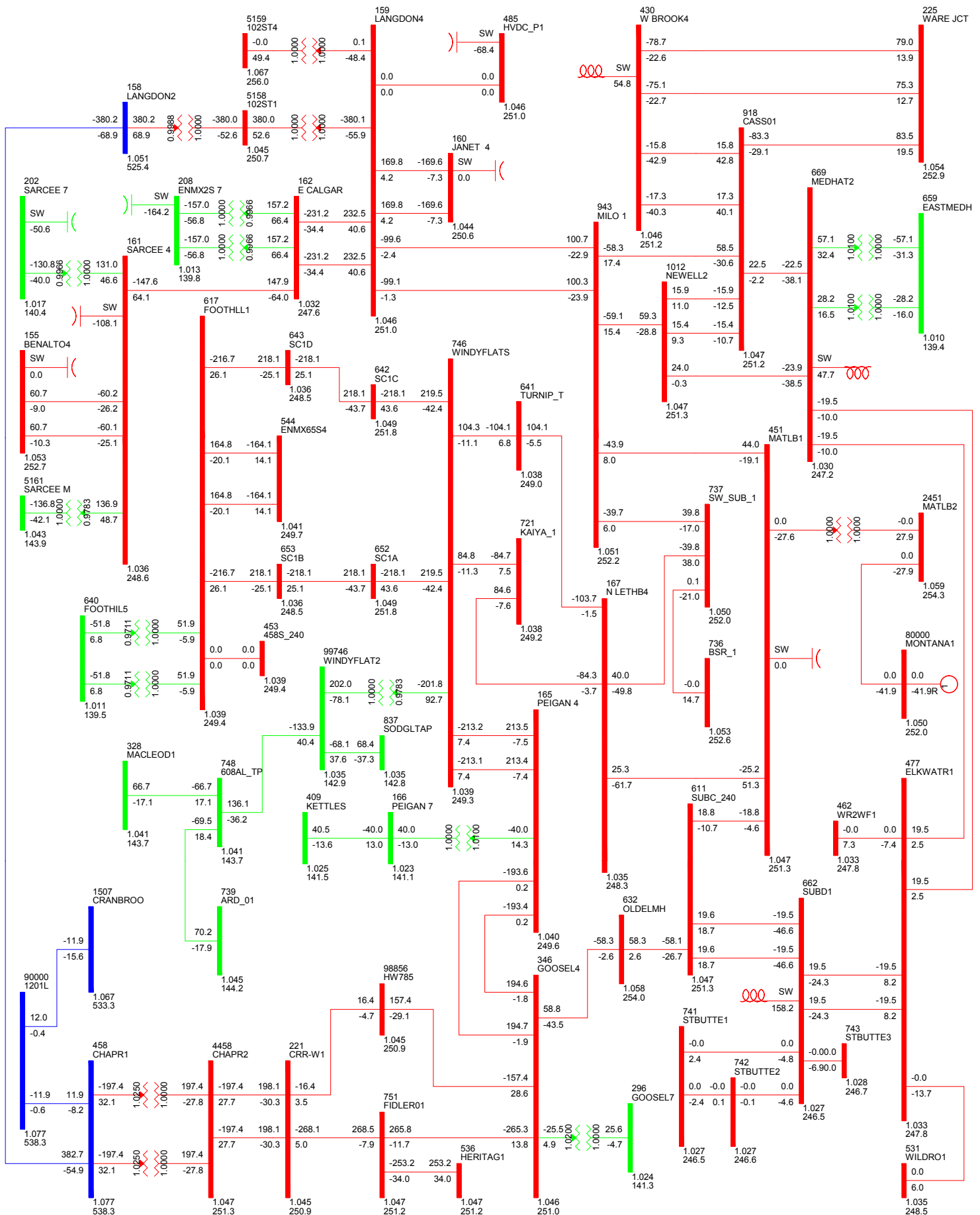
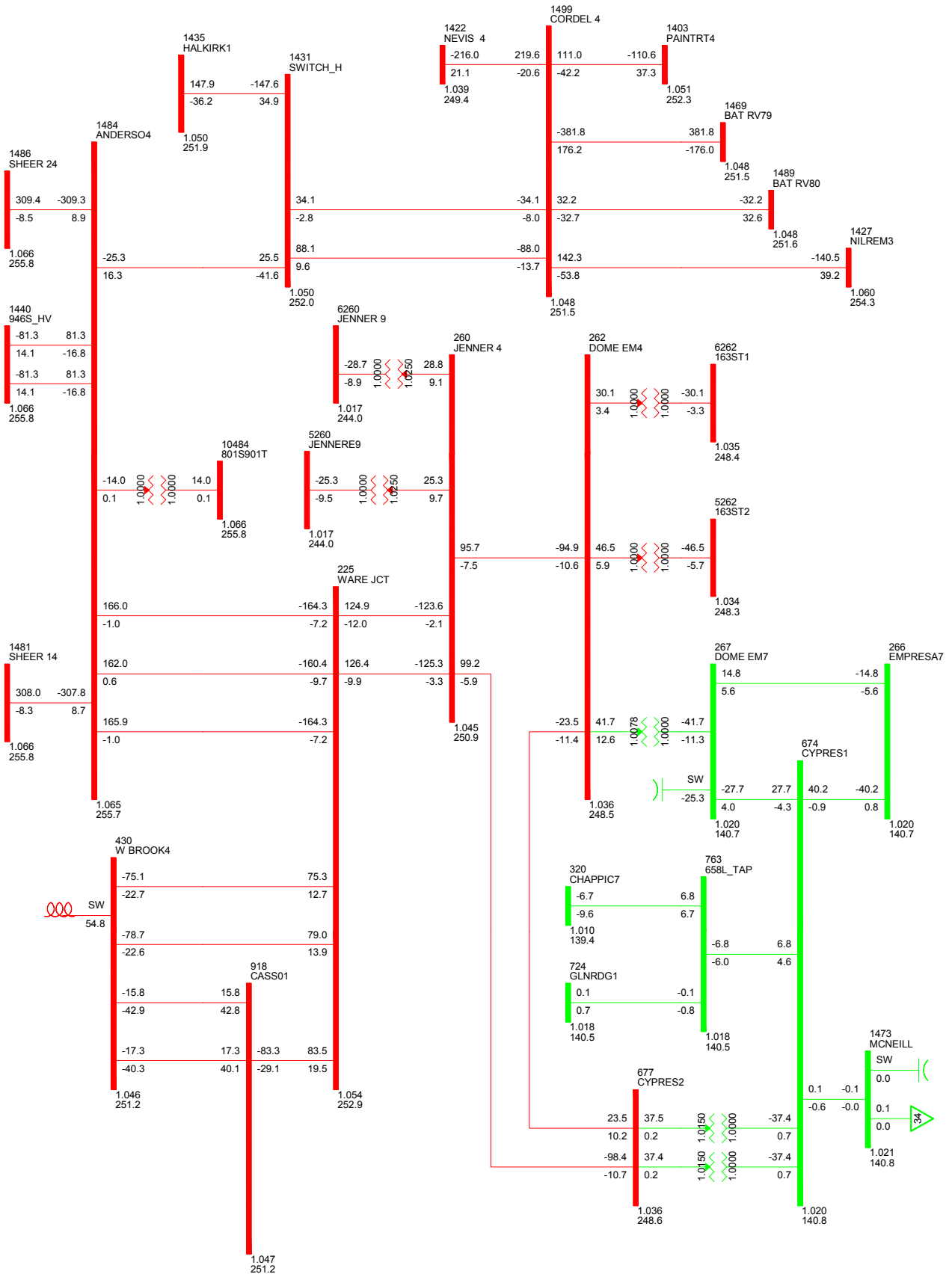


FIG A-W-10: BASECASE
 C&S_2017SP_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



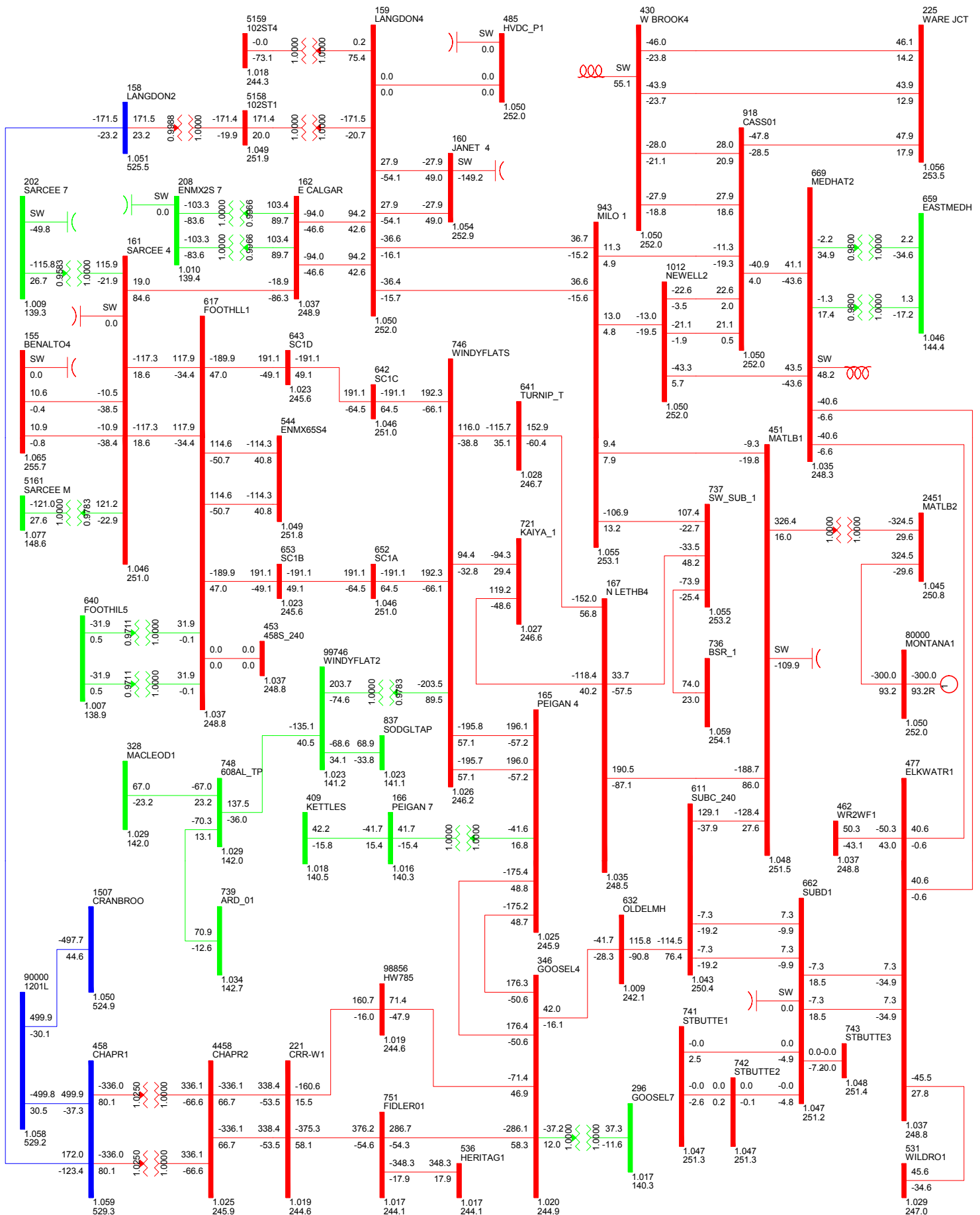


FIG A-W-11: BASECASE
 C7M_2022SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

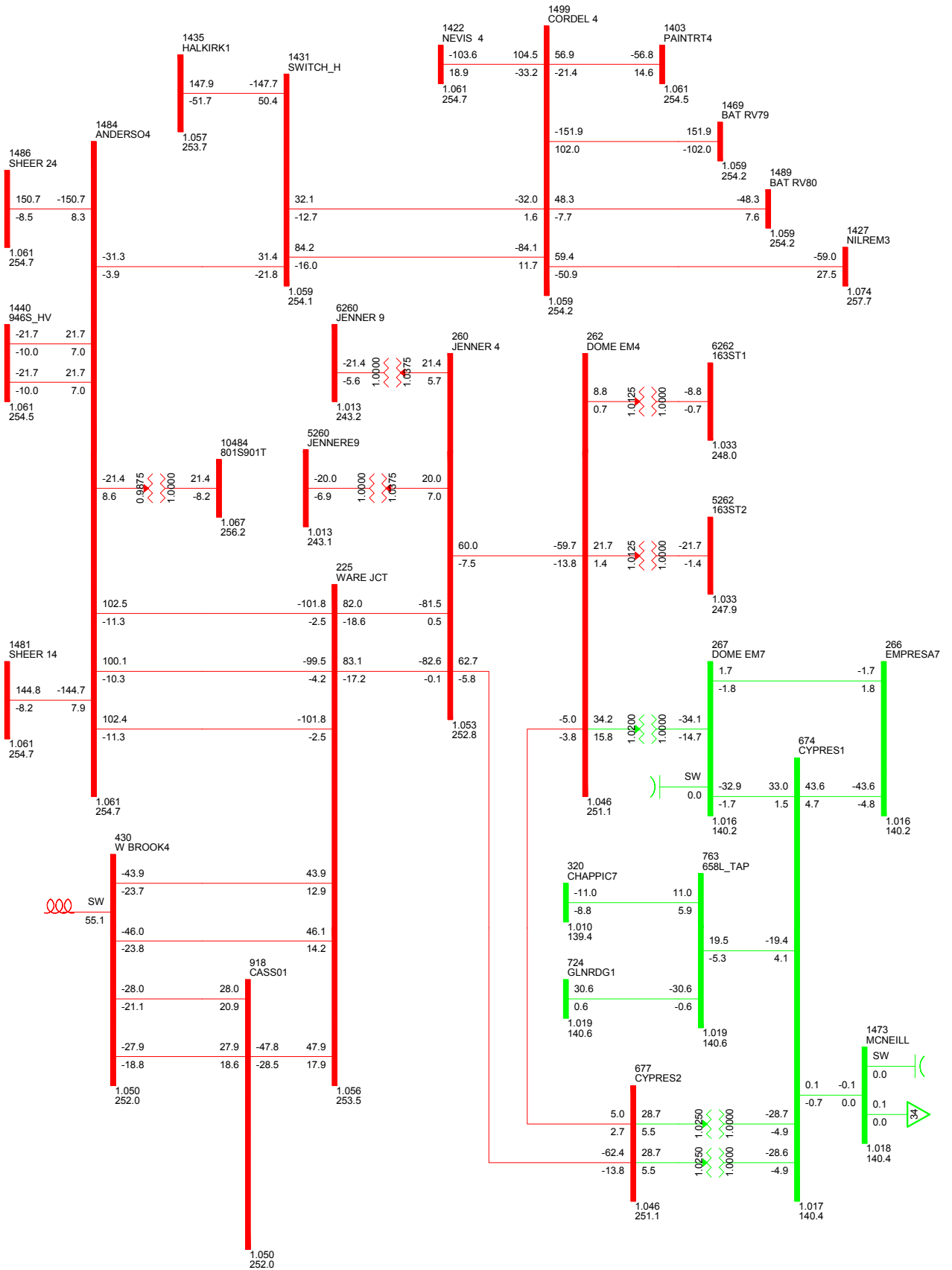


FIG A-E-11: BASECASE
 CTM_2022SL_500_0_300_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

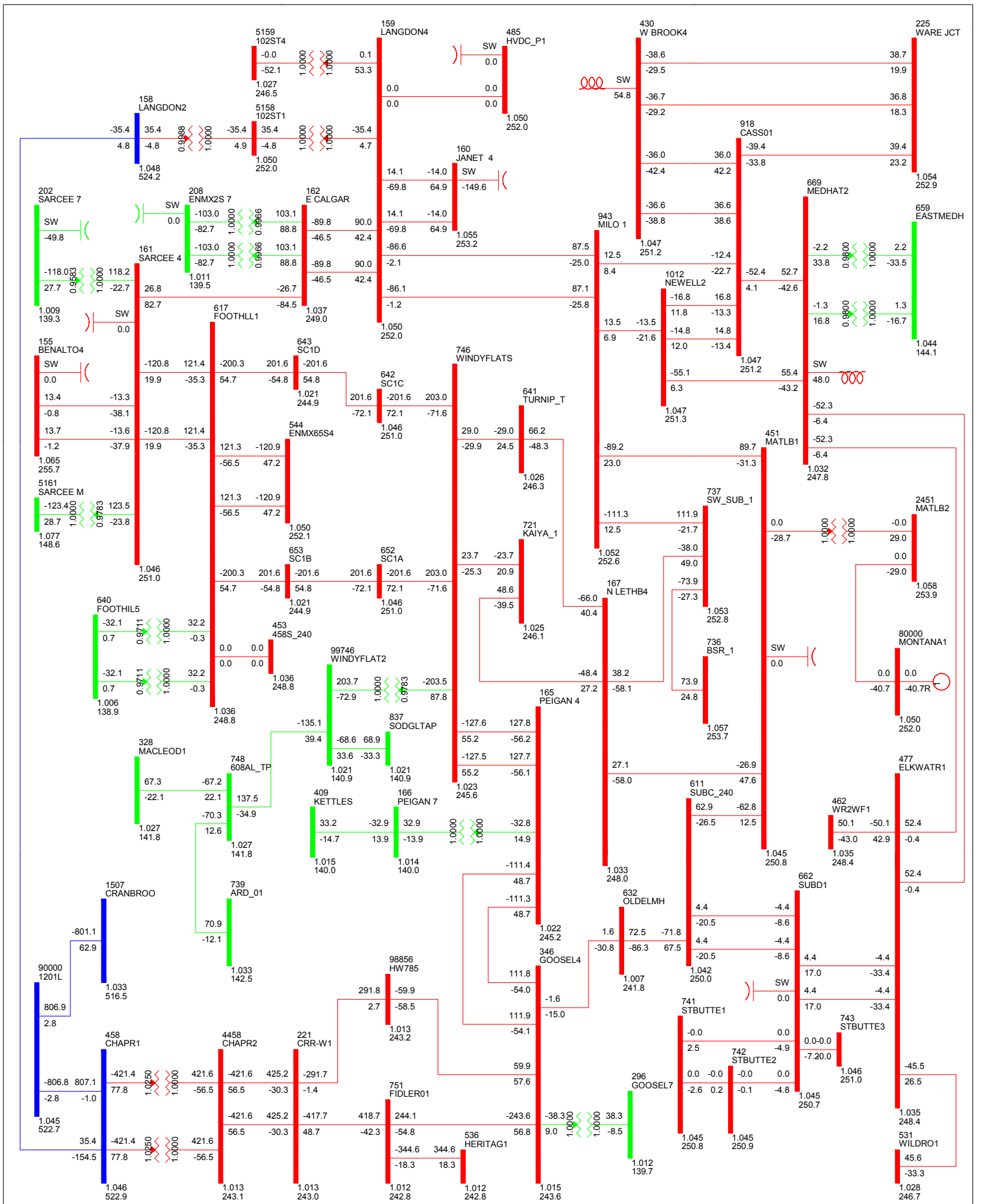


FIG A-W-12: BASECASE
 C7X_2022SL_800_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

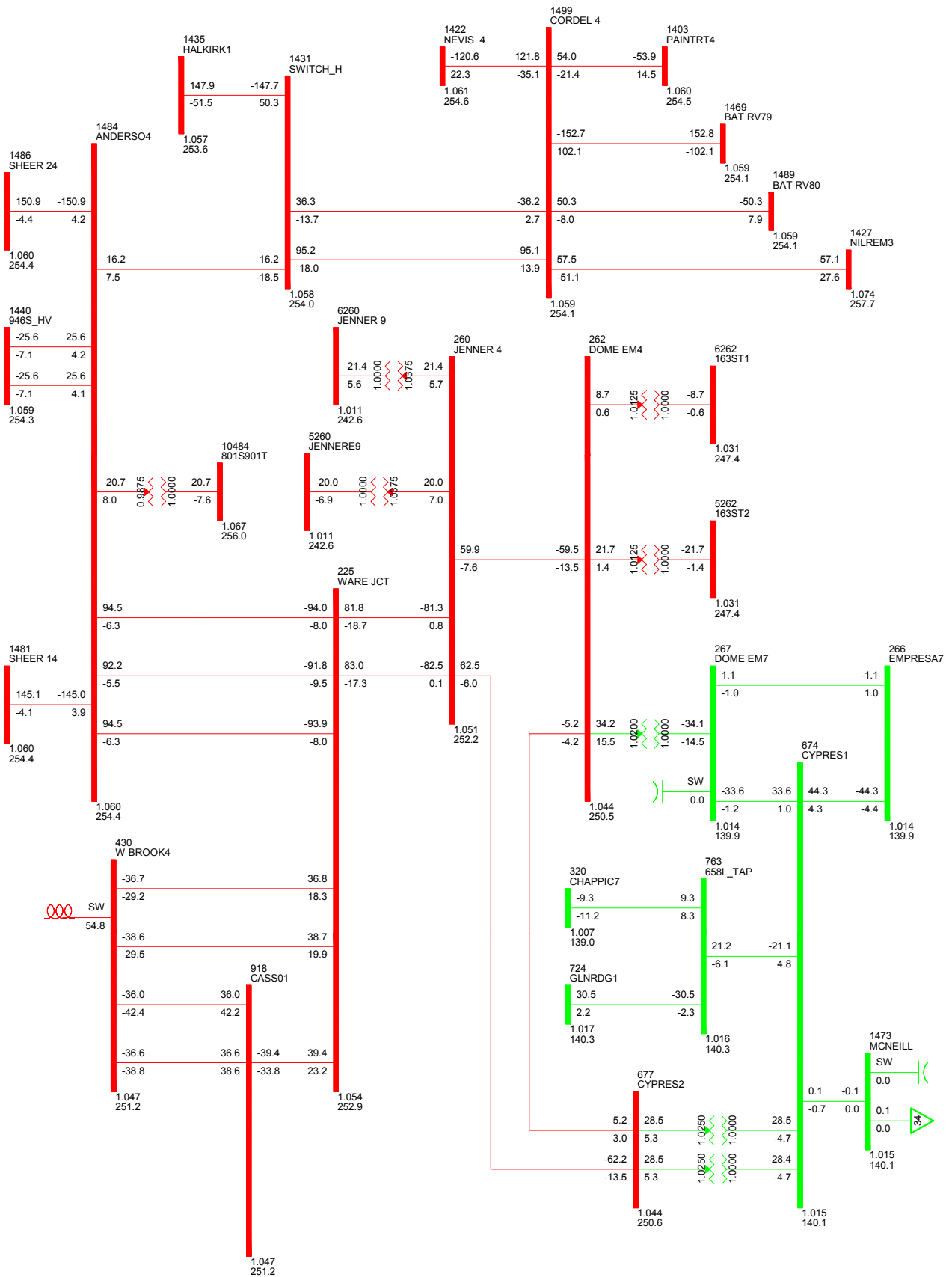


FIG A-E-12: BASECASE
 C7X_2022SL_800_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

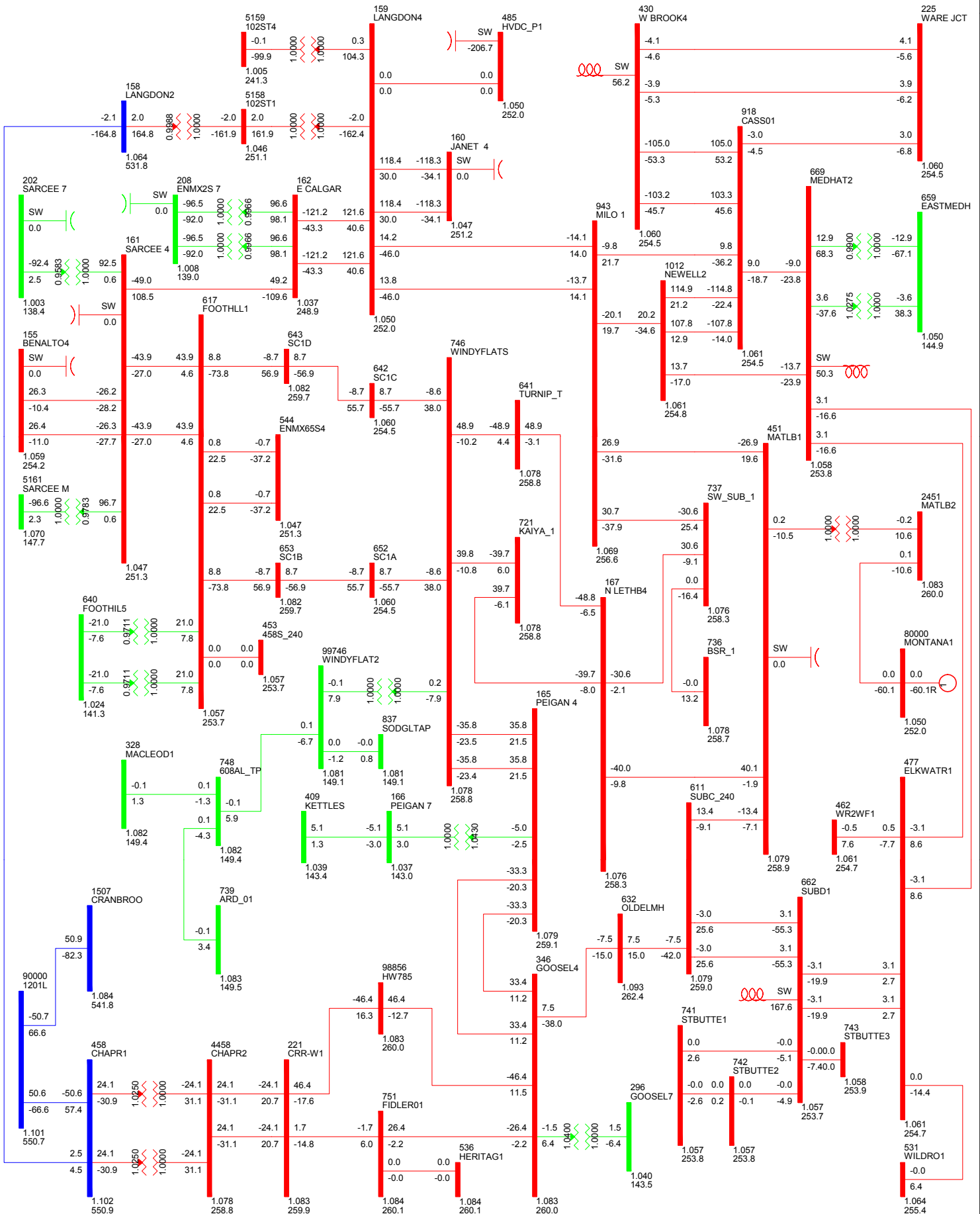


FIG A-W-13: BASECASE
 C8_2022SL_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

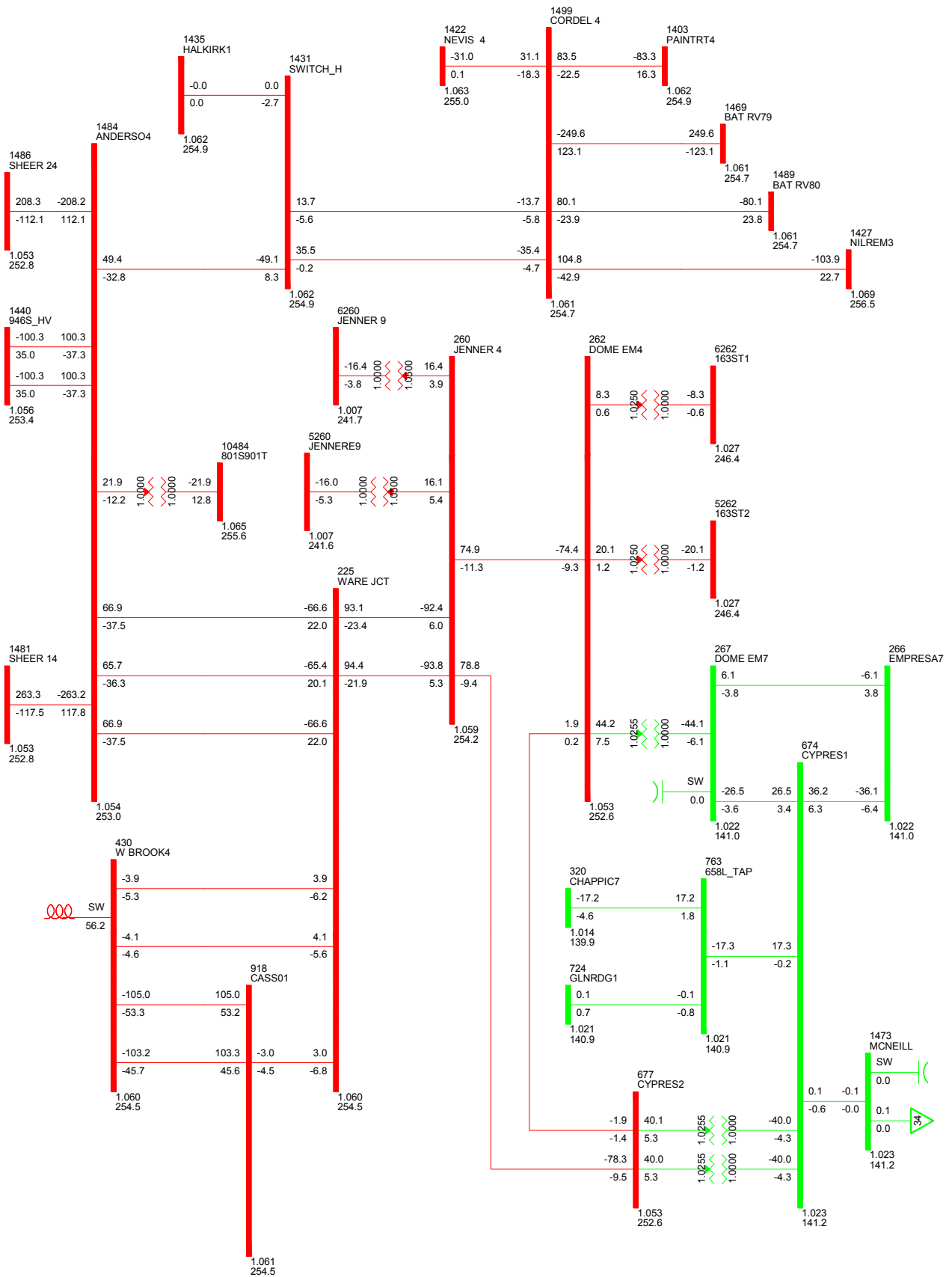


FIG A-E-13: BASECASE
 C8_2022SL_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

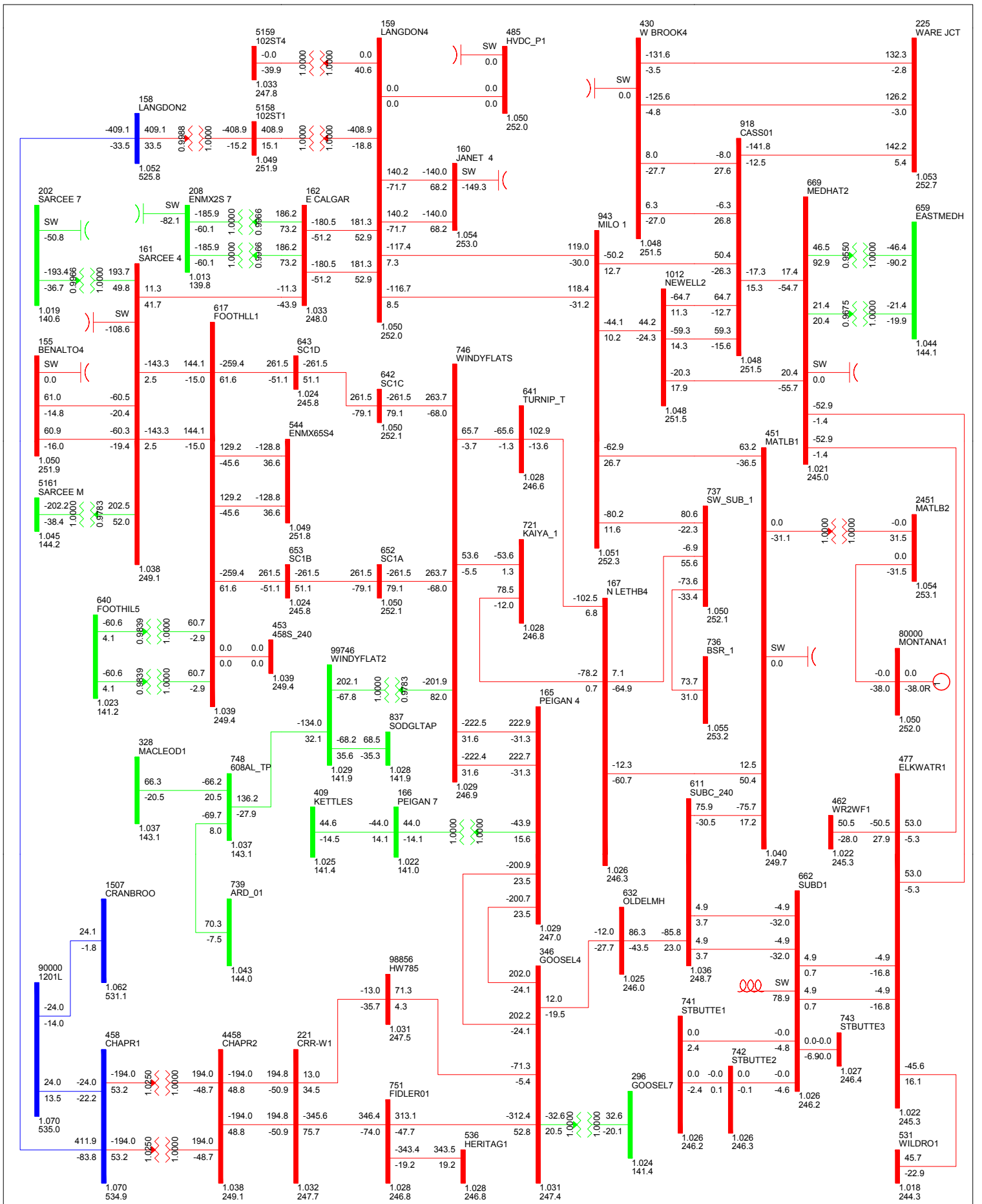


FIG A-W-14: BASECASE
 C9_2022SP_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

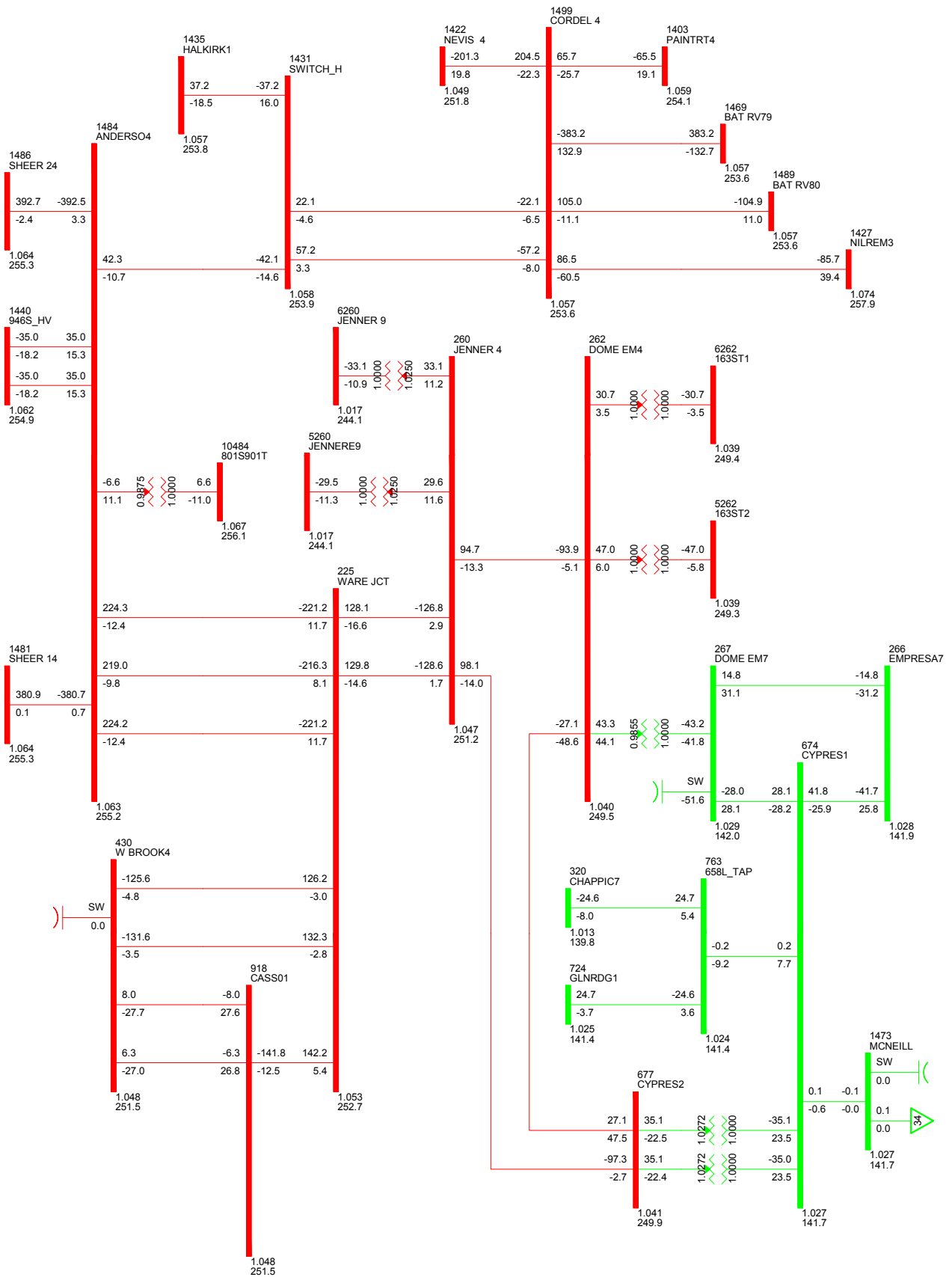


FIG A-E-14: BASECASE
 C9_2022SP_0_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

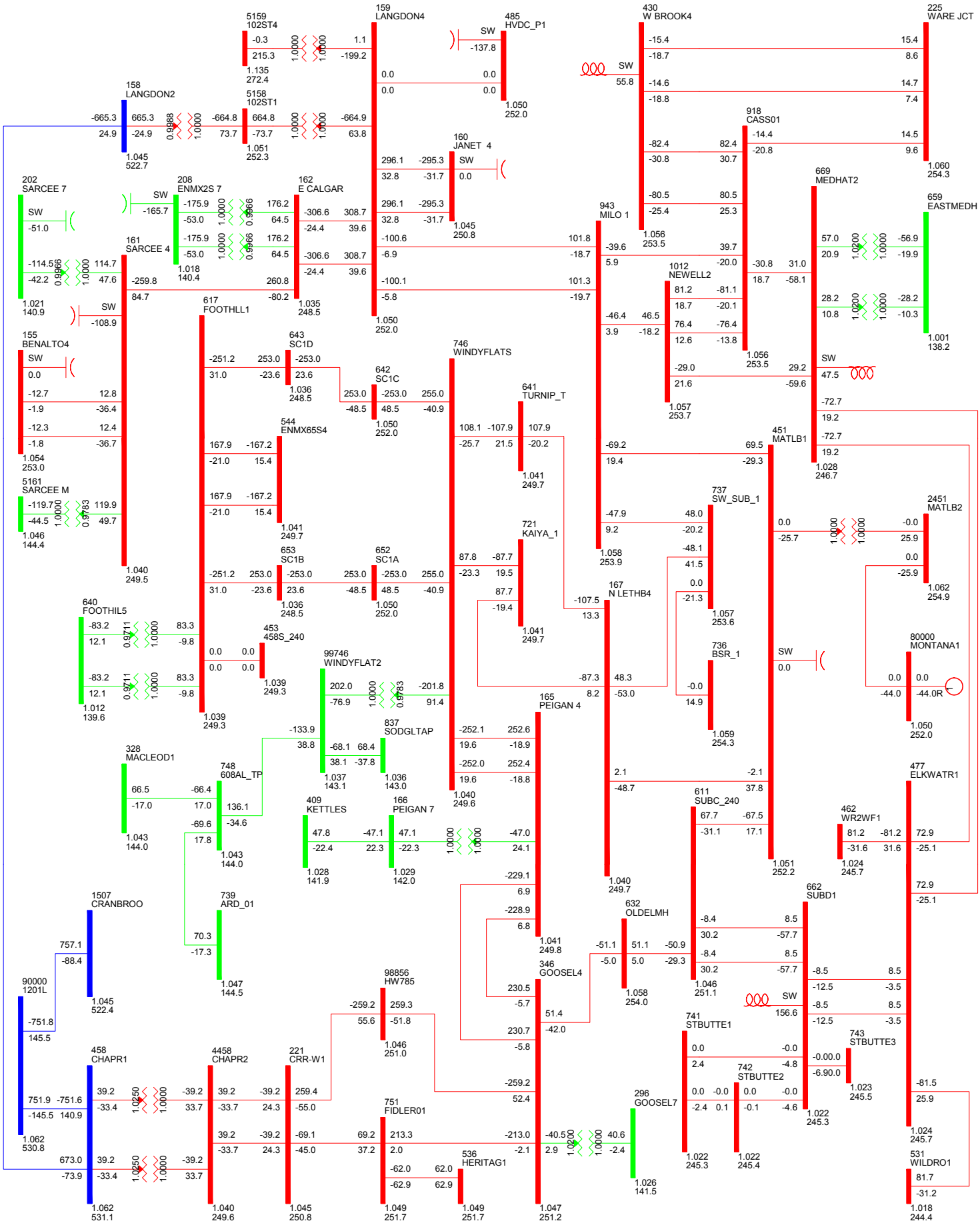


FIG A-W-15: BASECASE
 C10_2015SP_-780_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

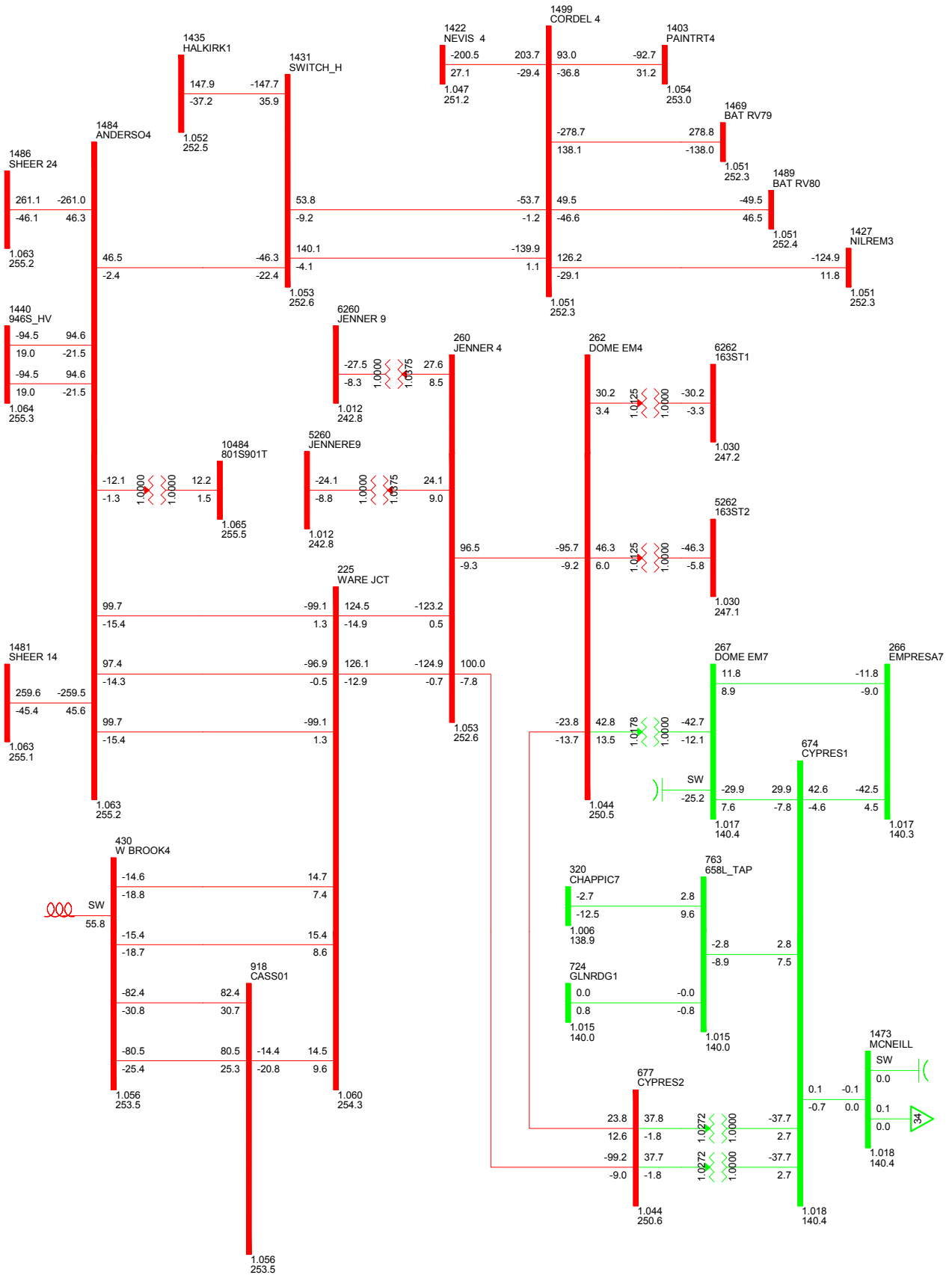


FIG A-E-15: BASECASE
 C10_2015SP_-780_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

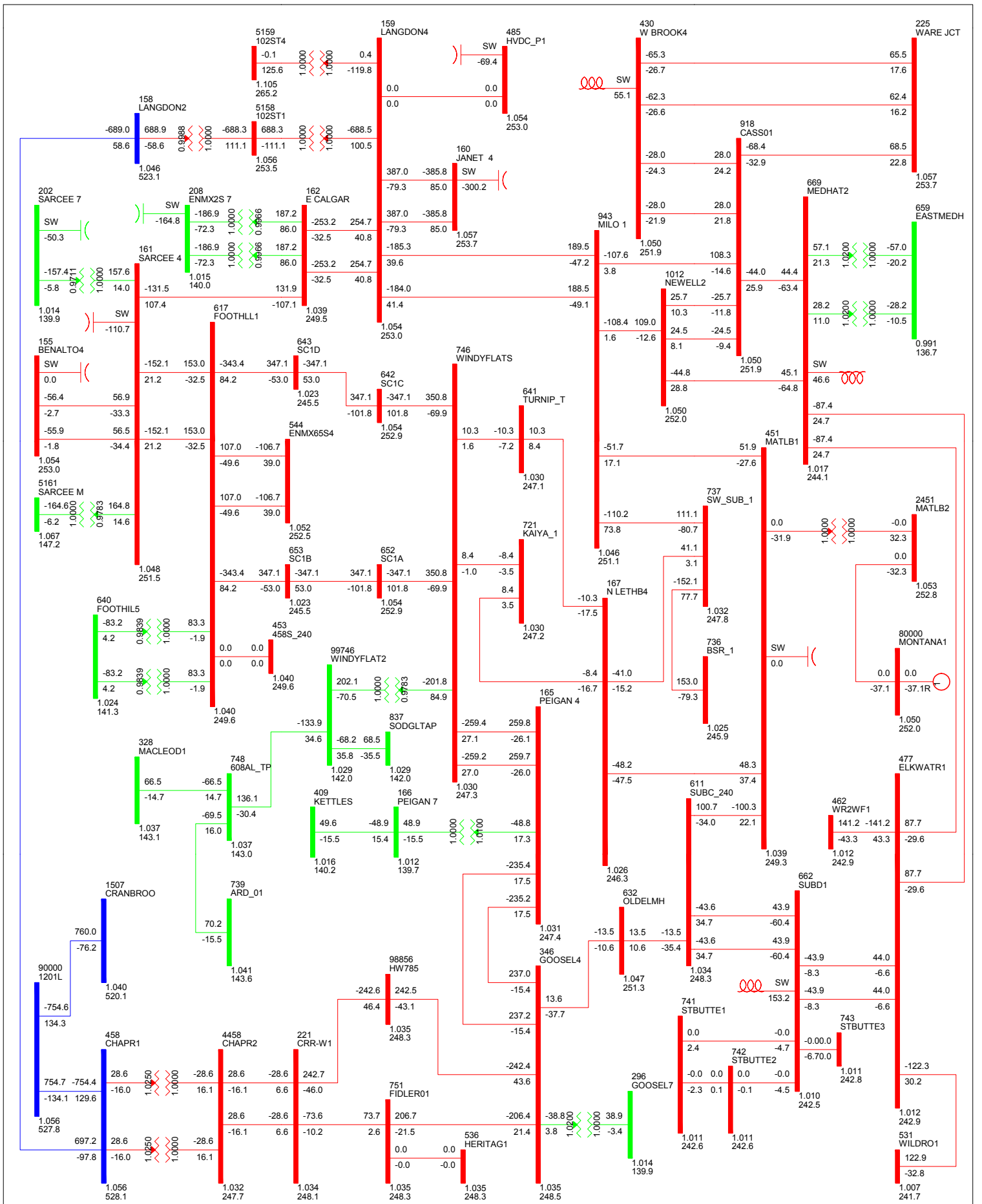


FIG A-W-16: BASECASE
 C11_2017SP_-780_0_-150_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

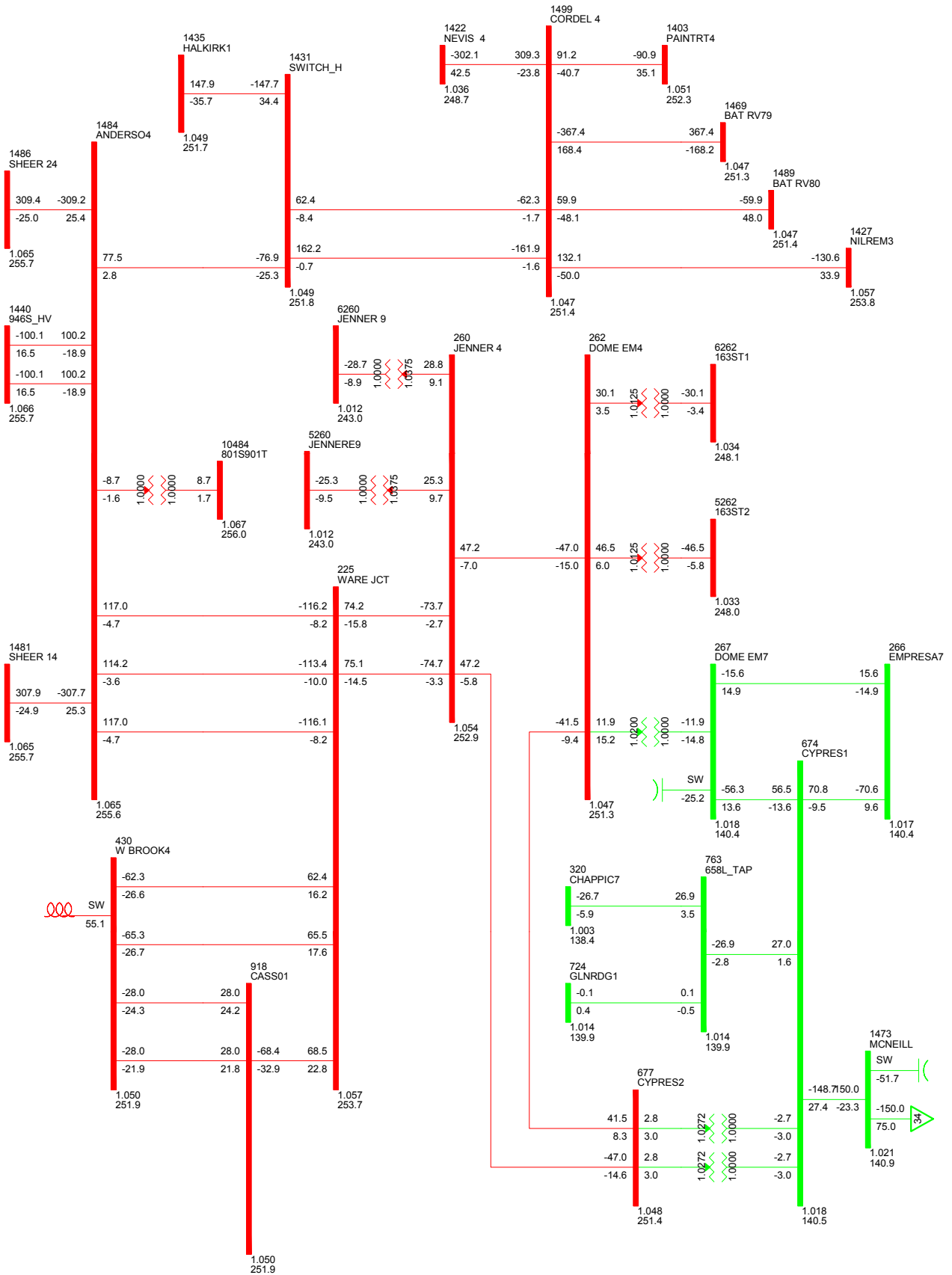


FIG A-E-16: BASECASE
 C11_2017SP_780_0_-150_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

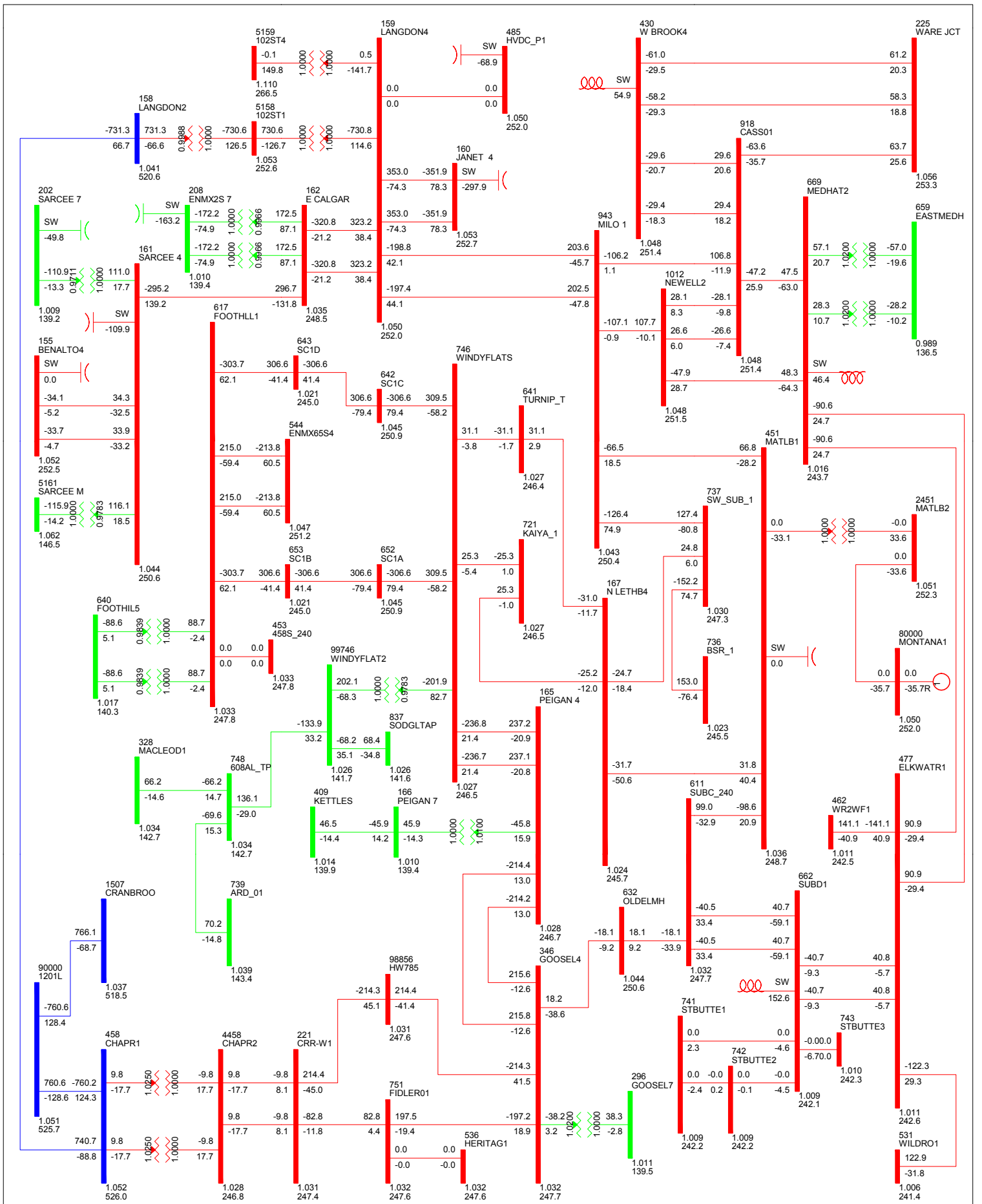


FIG A-W-17: BASECASE
 C11S_2017SP_-780_0_-150_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

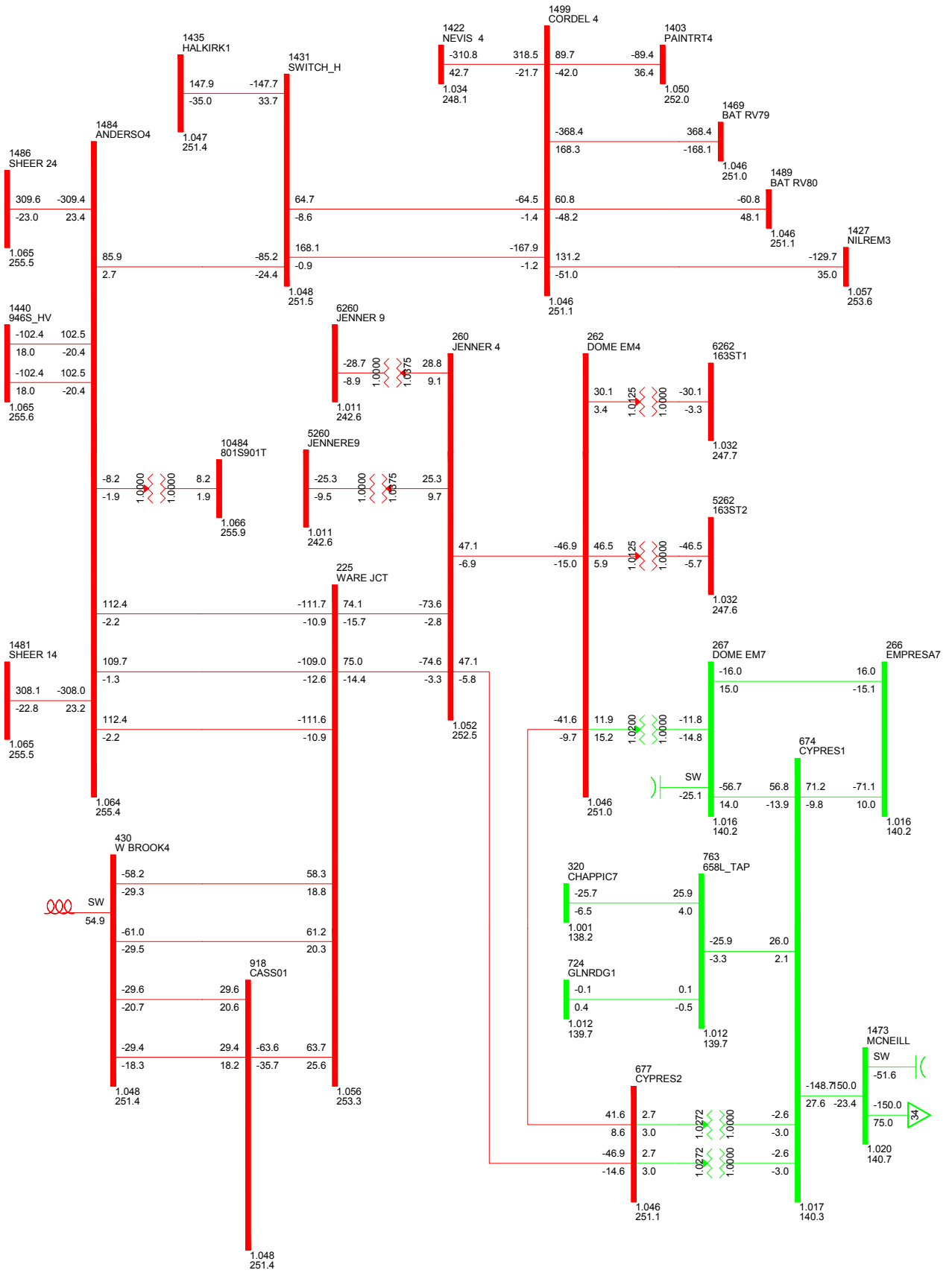


FIG A-E-17: BASECASE
 C11S_2017SP_-780_0_-150_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

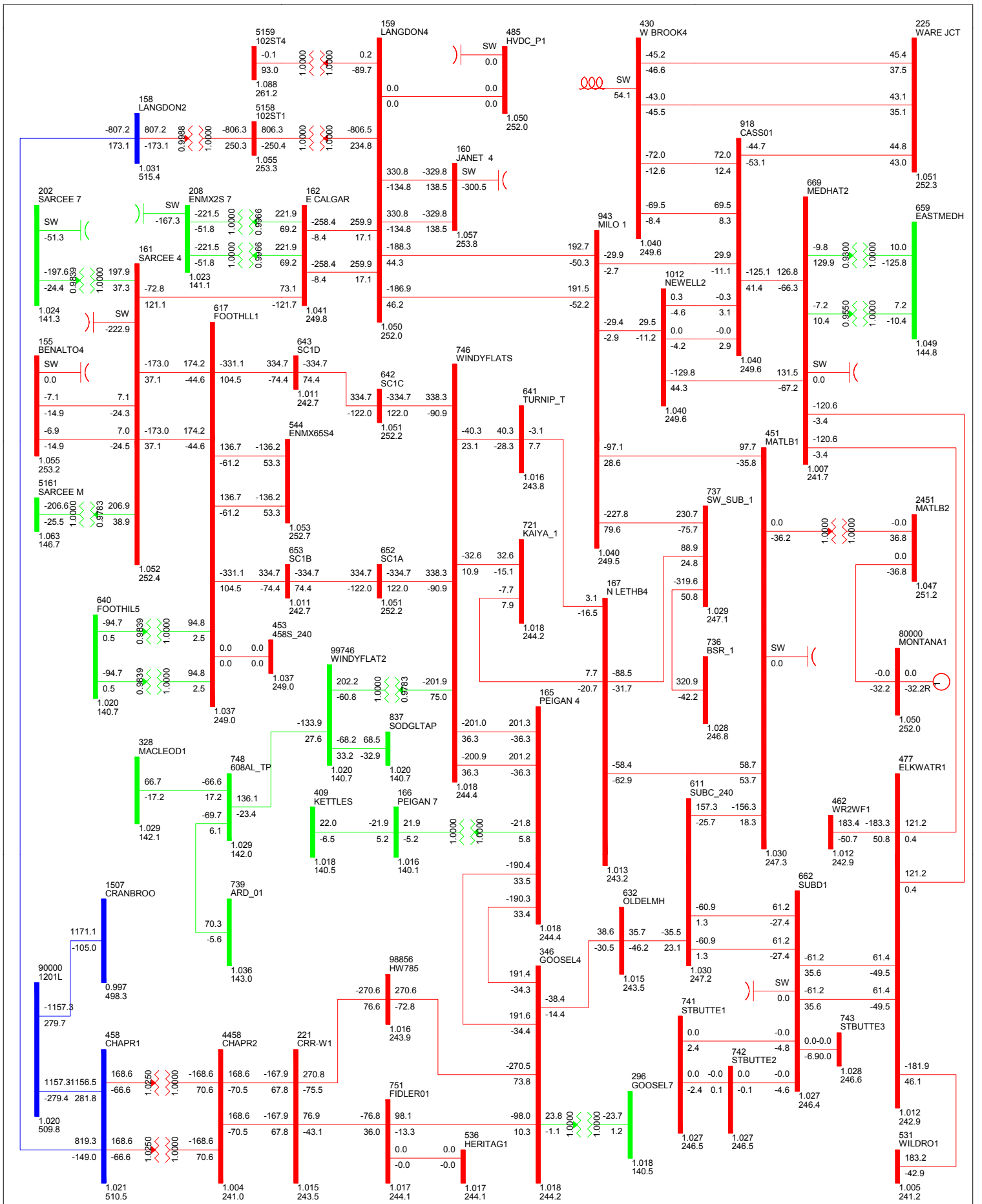


FIG A-W-18: BASECASE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

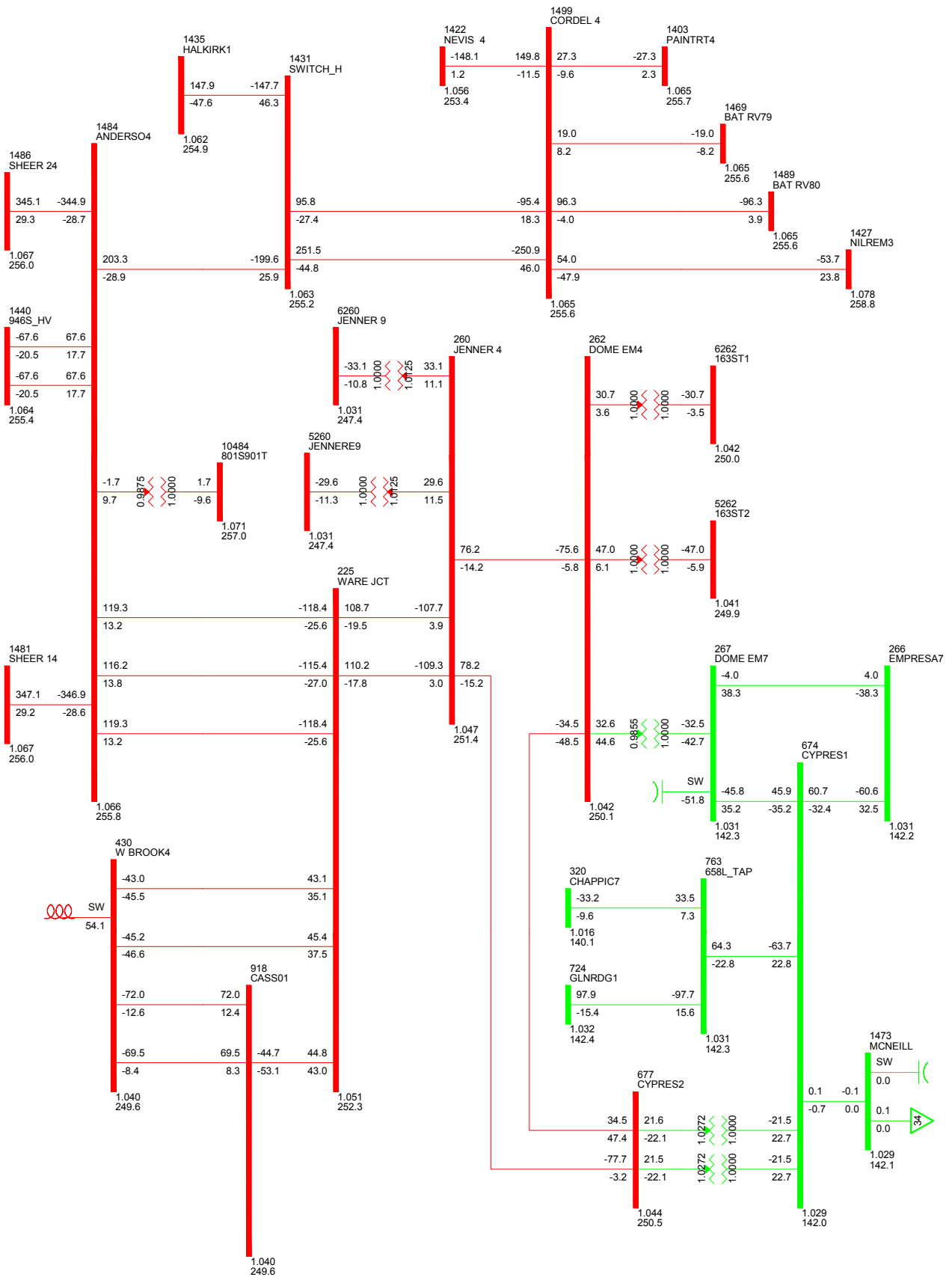


FIG A-E-18: BASECASE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

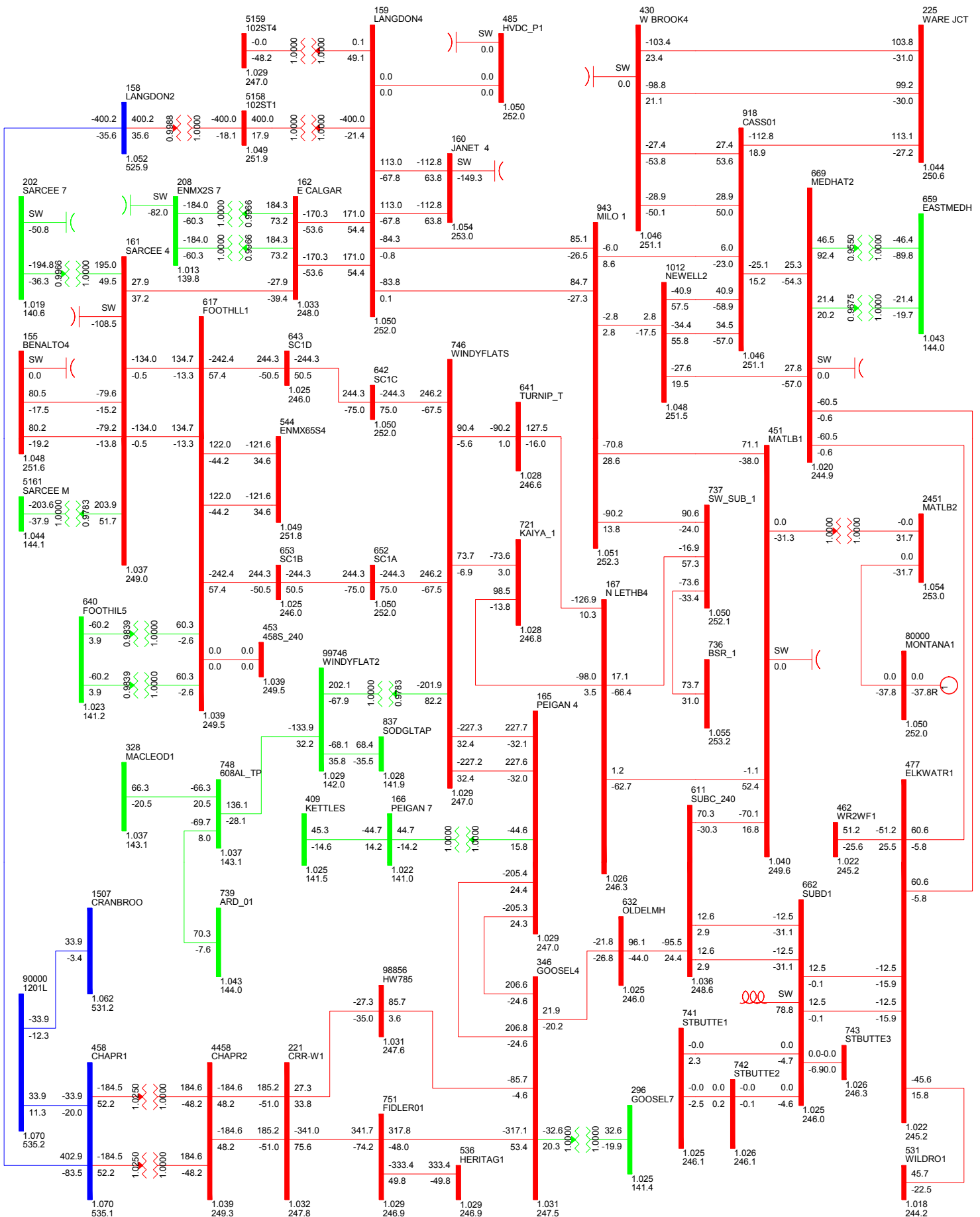


FIG A-W-19: BASECASE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

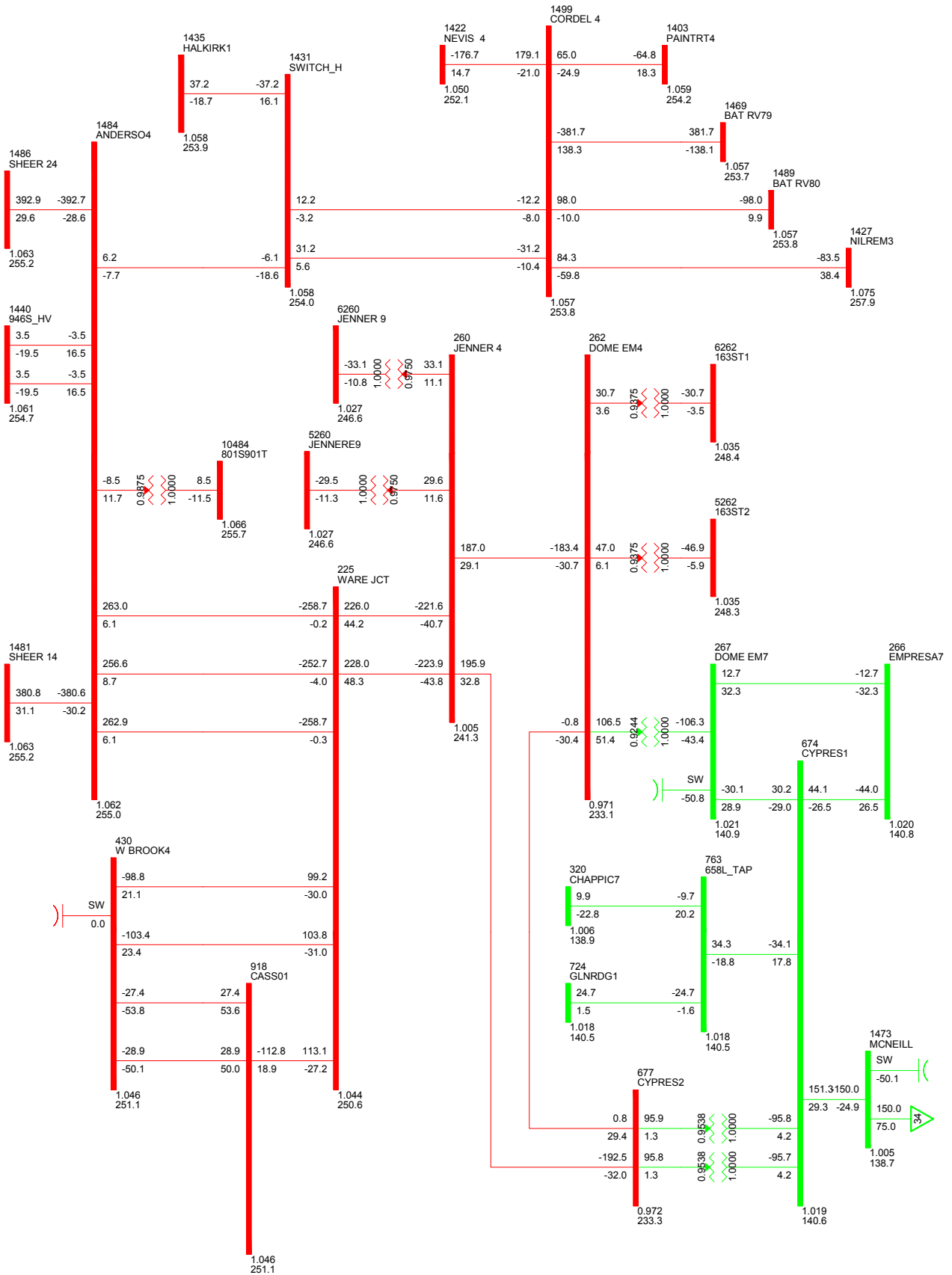


FIG A-E-19: BASECASE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

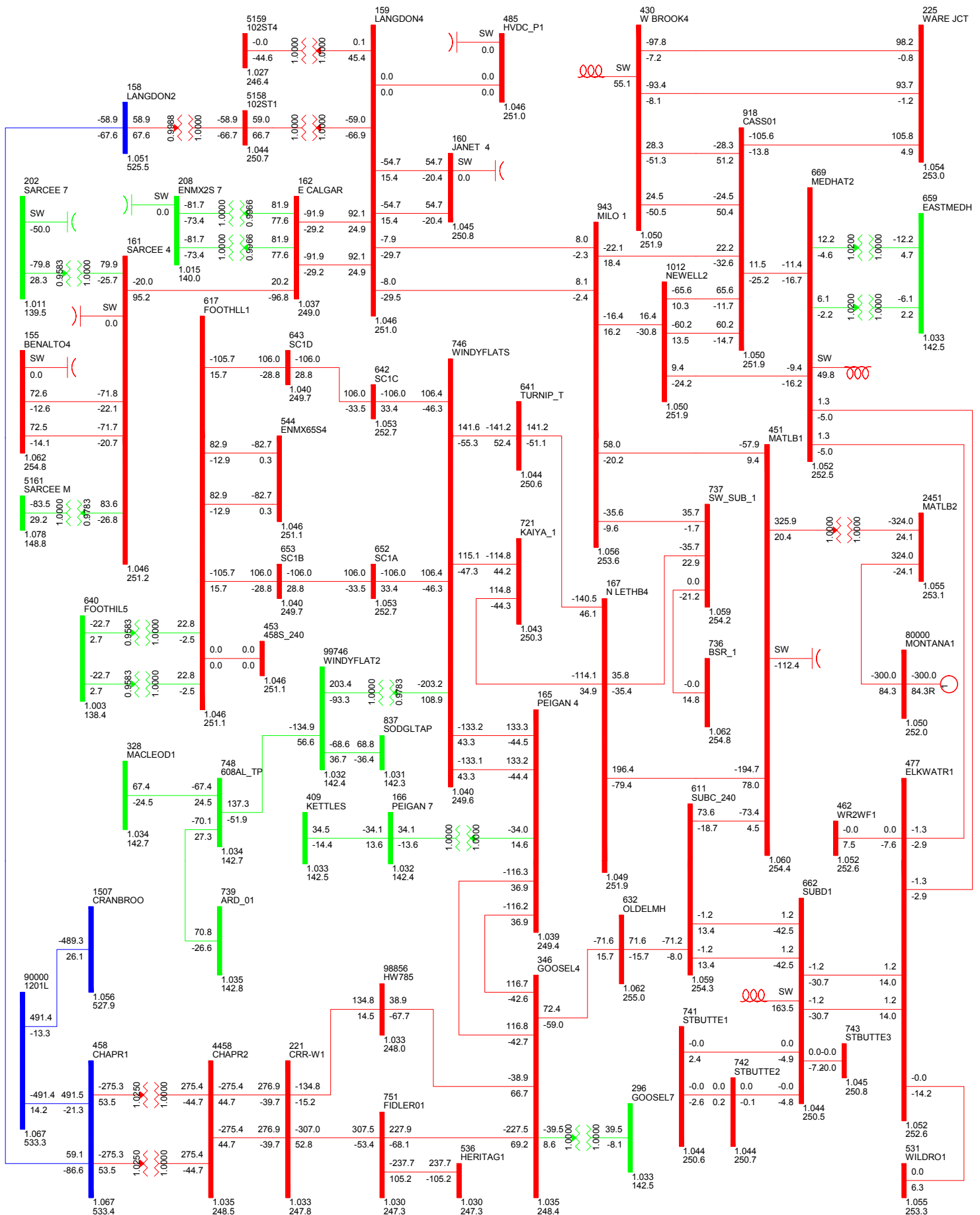


FIG A-W-20: BASECASE
 C14_2017SL_500_0_300_B1_R6
 THU, AUG 30 2012 15:28

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

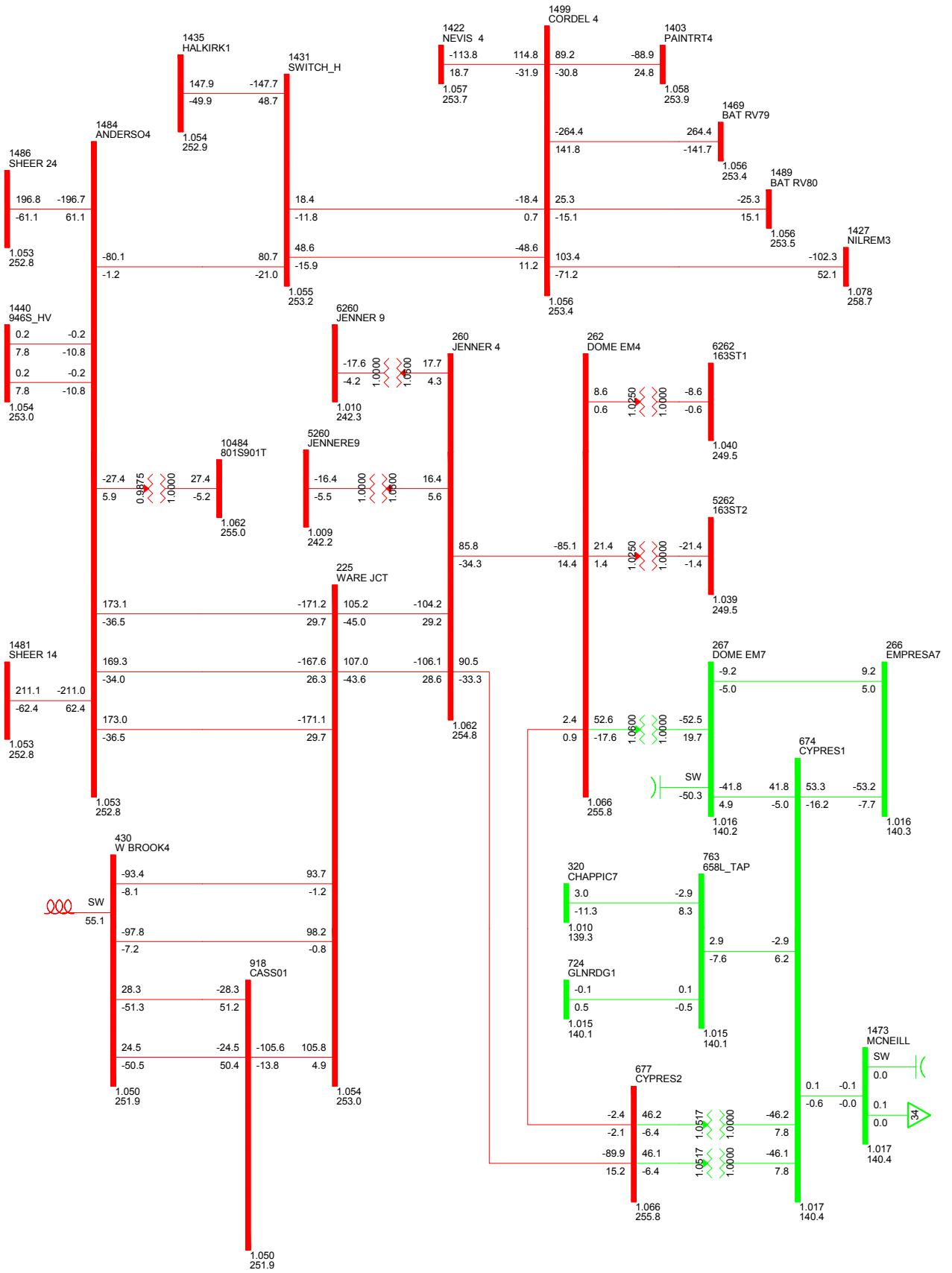


FIG A-E-20: BASECASE
 C14_2017SL_500_0_300_B1_R6
 THU, AUG 30 2012 15:28

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

Table B-2: Need Assessment –Category B Plot List

Figure #	Contingency	Bus	VCont	VInit	Vmax	Vmin	Scenario
Fig B-W-1 Fig B-E-1	Langdon 500/240 kV Transformer	458 CHAPR1 500.00	1.14245	1.1034	1.1	1	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	165 PEIGAN 4 240.00	1.10216	1.08578	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	221 CRR-W1 240.00	1.11045	1.08505	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	346 GOOSEL4 240.00	1.10836	1.08633	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	536 HERITAG1 240.00	1.10892	1.08526	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	746 WINDYFLATS 240.00	1.10016	1.0852	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	751 FIDLER01 240.00	1.10892	1.08526	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	4458 CHAPR2 240.00	1.11333	1.08006	1.1	0.917	C2_2015SL_0_0_0
	Langdon 500/240 kV Transformer	98856 HW785 240.00	1.10947	1.08576	1.1	0.917	C2_2015SL_0_0_0
Fig B-W-2 Fig B-E-2	Langdon 500/240 kV Transformer	458 CHAPR1 500.00	1.10405	1.07963	1.1	1	C3_2015SP_0_0_0
Fig B-W-3 Fig B-E-3	Langdon 500/240 kV Transformer	458 CHAPR1 500.00	1.13995	1.10311	1.1	1	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	221 CRR-W1 240.00	1.1072	1.08457	1.1	0.917	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	346 GOOSEL4 240.00	1.10479	1.08559	1.1	0.917	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	536 HERITAG1 240.00	1.10576	1.08506	1.1	0.917	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	751 FIDLER01 240.00	1.10576	1.08506	1.1	0.917	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	4458 CHAPR2 240.00	1.11052	1.07974	1.1	0.917	C5_2017SL_0_0_0
	Langdon 500/240 kV Transformer	98856 HW785 240.00	1.10606	1.08515	1.1	0.917	C5_2017SL_0_0_0
Fig B-W-4 Fig B-E-4	Langdon 500/240 kV Transformer	458 CHAPR1 500.00	1.14403	1.10432	1.1	1	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	165 PEIGAN 4 240.00	1.10371	1.08639	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	221 CRR-W1 240.00	1.11257	1.08672	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	346 GOOSEL4 240.00	1.11047	1.08802	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	536 HERITAG1 240.00	1.11139	1.08728	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	721 KAIYA_1 240.00	1.10062	1.08586	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	746 WINDYFLATS 240.00	1.10165	1.08572	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	751 FIDLER01 240.00	1.11139	1.08728	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	4458 CHAPR2 240.00	1.11502	1.08127	1.1	0.917	C5S_2017SL_0_0_0
	Langdon 500/240 kV Transformer	98856 HW785 240.00	1.11159	1.08744	1.1	0.917	C5S_2017SL_0_0_0
Fig B-W-5 Fig B-E-5	Langdon 500/240 kV Transformer	458 CHAPR1 500.00	1.1391	1.10185	1.1	1	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	221 CRR-W1 240.00	1.10652	1.0828	1.1	0.917	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	346 GOOSEL4 240.00	1.10374	1.08339	1.1	0.917	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	536 HERITAG1 240.00	1.10559	1.08357	1.1	0.917	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	751 FIDLER01 240.00	1.10559	1.08357	1.1	0.917	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	4458 CHAPR2 240.00	1.11004	1.07842	1.1	0.917	C8_2022SL_0_0_0
	Langdon 500/240 kV Transformer	98856 HW785 240.00	1.1052	1.08316	1.1	0.917	C8_2022SL_0_0_0
Fig B-W-6 Fig B-E-6	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	458 CHAPR1 500.00	0.98959	1.05611	1.1	1	C11_2017SP_-780_0_-150

Fig B-W-7 Fig B-E-7	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	458 CHAPR1 500.00	0.97503	1.05193	1.1	1	C11S_2017SP_-780_0_-150
Fig B-W-8 Fig B-E-8	462[WR2WF1 240.00] to 477[ELKWATR1 240.00] CKT 76	458 CHAPR1 500.00	0.99558	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-9 Fig B-E-9	477[ELKWATR1 240.00] to 531[WILDRO1 240.00] CKT 78	458 CHAPR1 500.00	0.99571	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-10 Fig B-E-10	736[BSR_1 240.00] to 737[SW_SUB_1 240.00] CKT 42	458 CHAPR1 500.00	0.96449	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-11 Fig B-E-11	1431[SWITCH_H 240.00] to 1435[HALKIRK1 240.00] CKT 93	458 CHAPR1 500.00	0.99914	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-12 Fig B-E-12	1481[SHEER 14 240.00] to 1484[ANDERSO4 240.00] CKT 99	458 CHAPR1 500.00	0.94975	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-13 Fig B-E-13	1484[ANDERSO4 240.00] to 1486[SHEER 24 240.00] CKT 00	458 CHAPR1 500.00	0.95057	1.02101	1.1	1	C12_2022SP_-1200_0_0
Fig B-W-14 Fig B-E-14	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	262 DOME EM4 240.00	0.899	0.971	1.100	0.917	C13_2022SP_0_0_150
	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	677 CYPRES2 240.00	0.898	0.972	1.100	0.917	C13_2022SP_0_0_150
Fig B-W-15 Fig B-E-15	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	262 DOME EM4 240.00	0.902	0.971	1.100	0.917	C13_2022SP_0_0_150
	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	677 CYPRES2 240.00	0.902	0.972	1.100	0.917	C13_2022SP_0_0_150
Fig B-W-16 Fig B-E-16	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	262 DOME EM4 240.00	0.898	0.971	1.100	0.917	C13_2022SP_0_0_150
	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	677 CYPRES2 240.00	0.900	0.972	1.100	0.917	C13_2022SP_0_0_150
Fig B-W-17 Fig B-E-17	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	262 DOME EM4 240.00	0.894	0.971	1.100	0.917	C13_2022SP_0_0_150
	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	677 CYPRES2 240.00	0.892	0.972	1.100	0.917	C13_2022SP_0_0_150

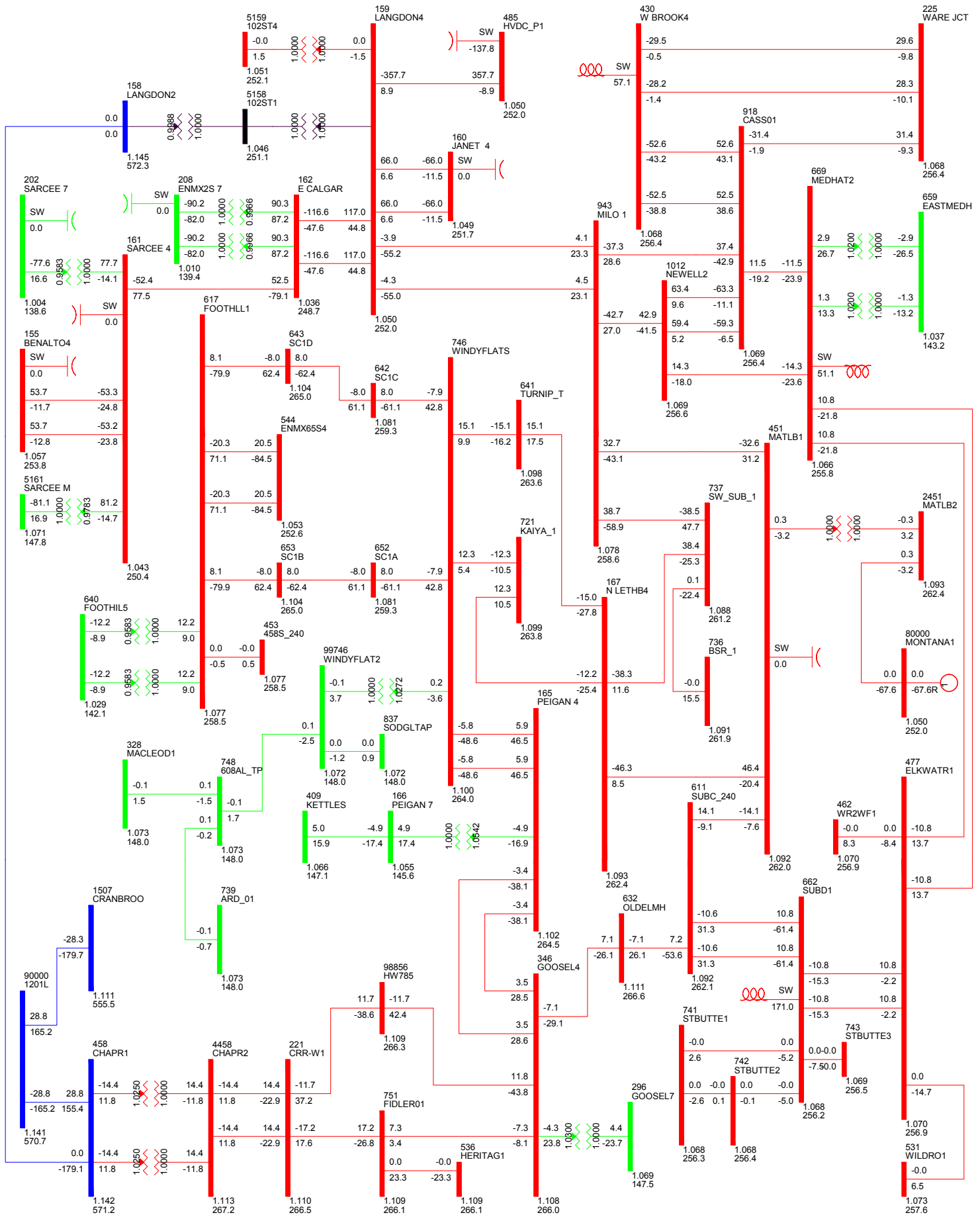


FIG B-W-1: LANGDON 500/240 KV TRANSFORMER 102ST1
 C2_2015SL_0_0_B1_R5
 THU, AUG 30 2012 15:57

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

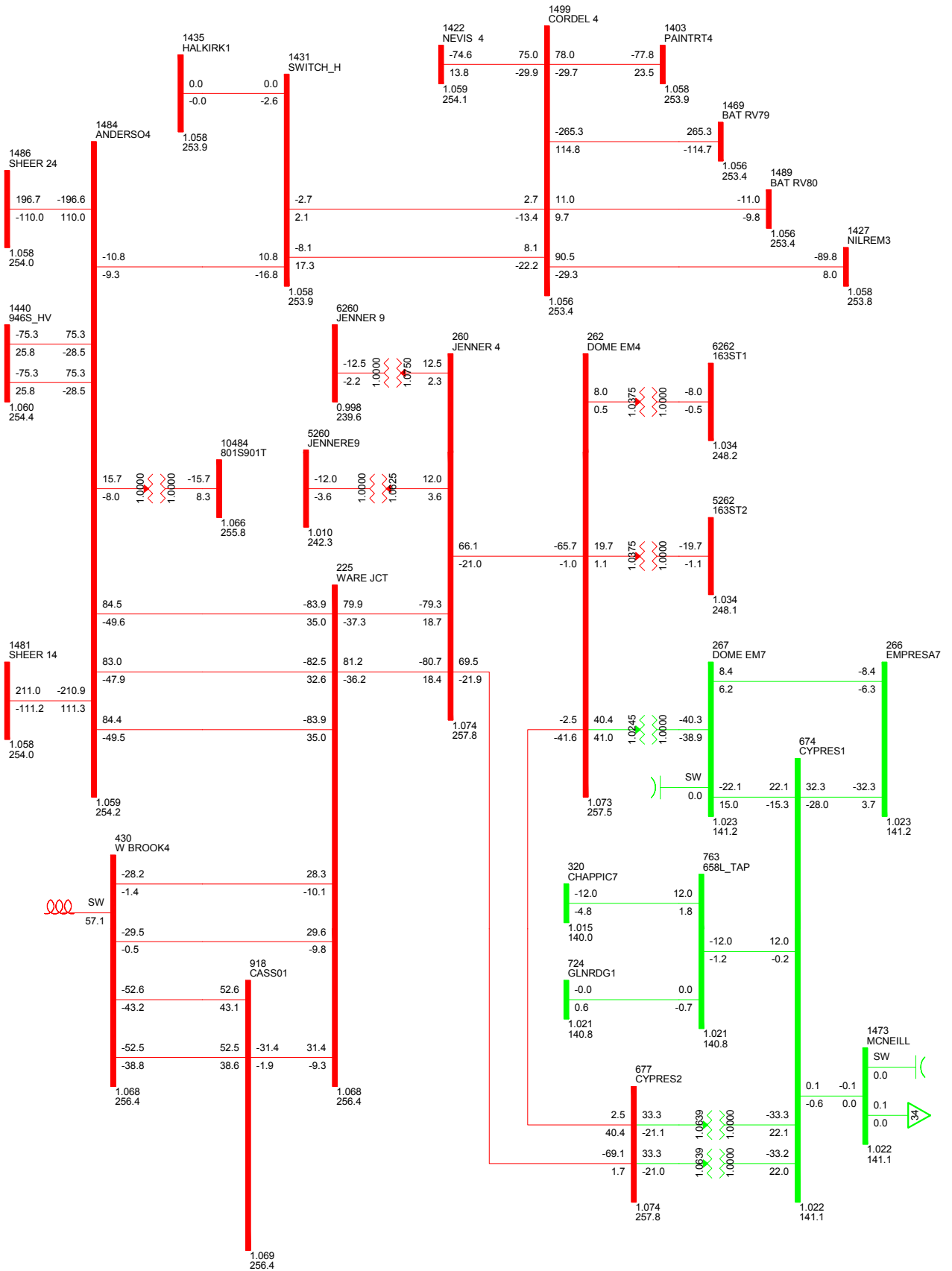


FIG B-E-1: LANGDON 500/240 KV TRANSFORMER 102ST1
 C2_2015SL_0_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

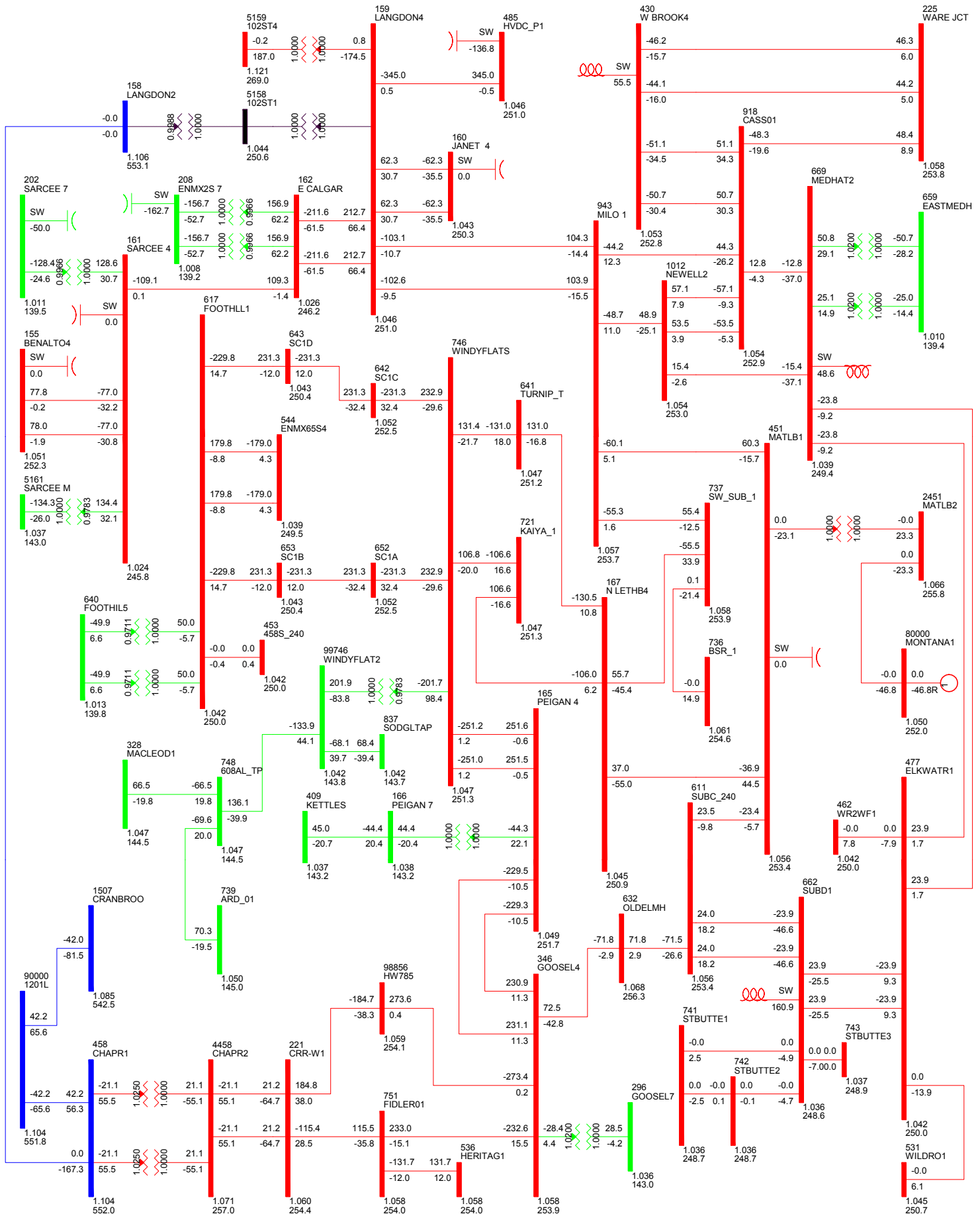


FIG B-W-2: LANGDON 500/240 KV TRANSFORMER 102ST1
 C3_2015SP_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

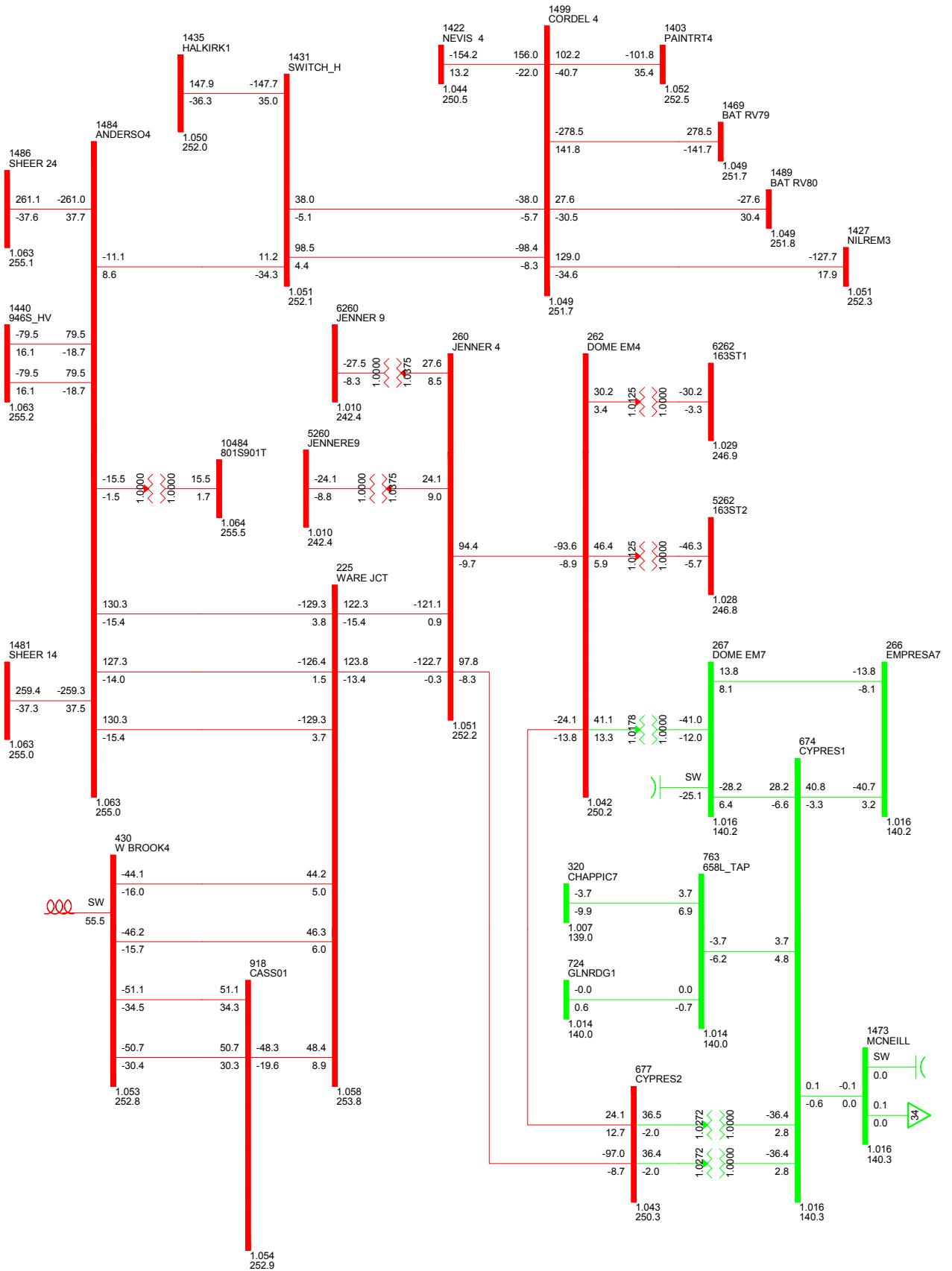


FIG B-E-2: LANGDON 500/240 KV TRANSFORMER 102ST1
 C3_2015SP_0_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

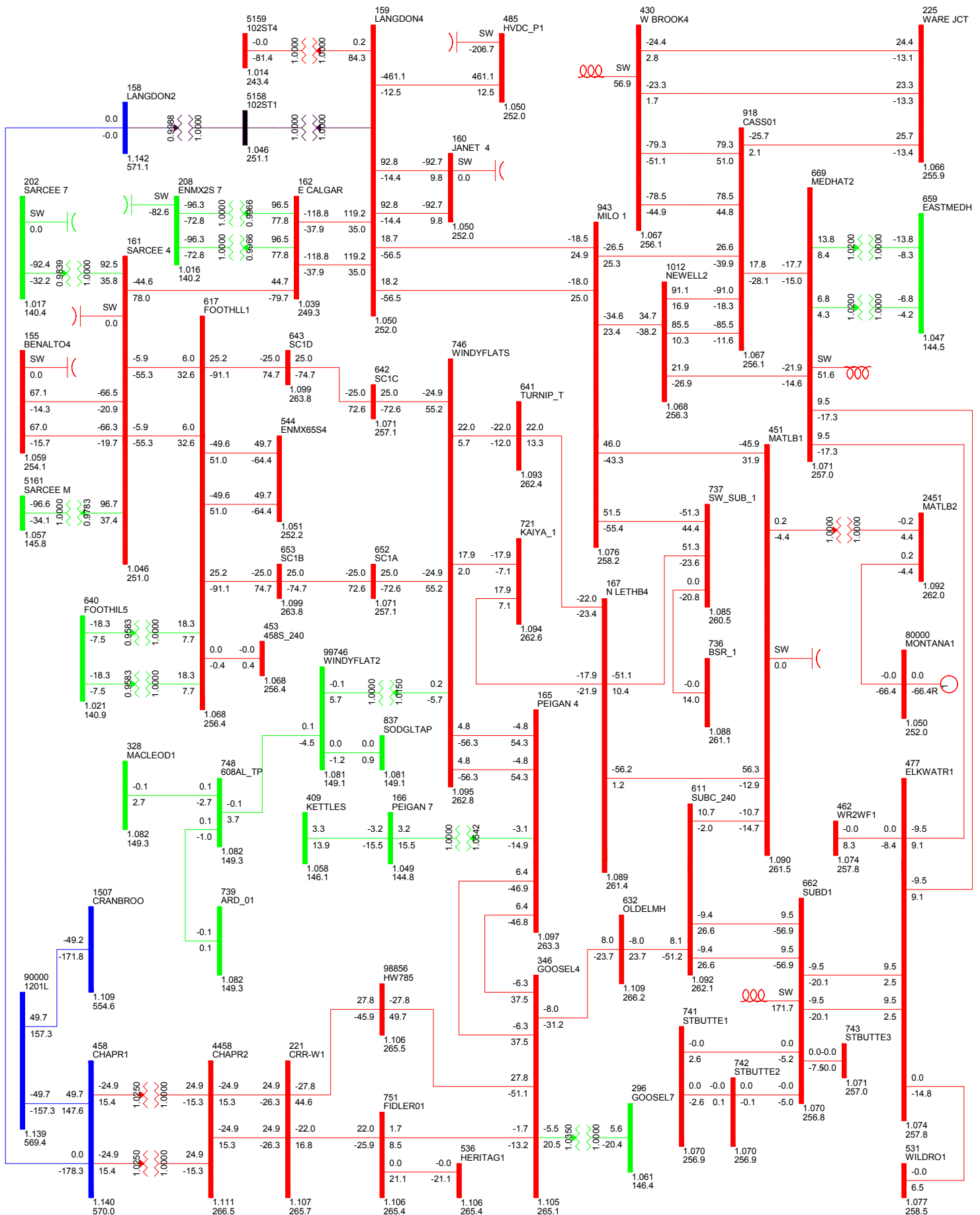


FIG B-W-3: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5_2017SL_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

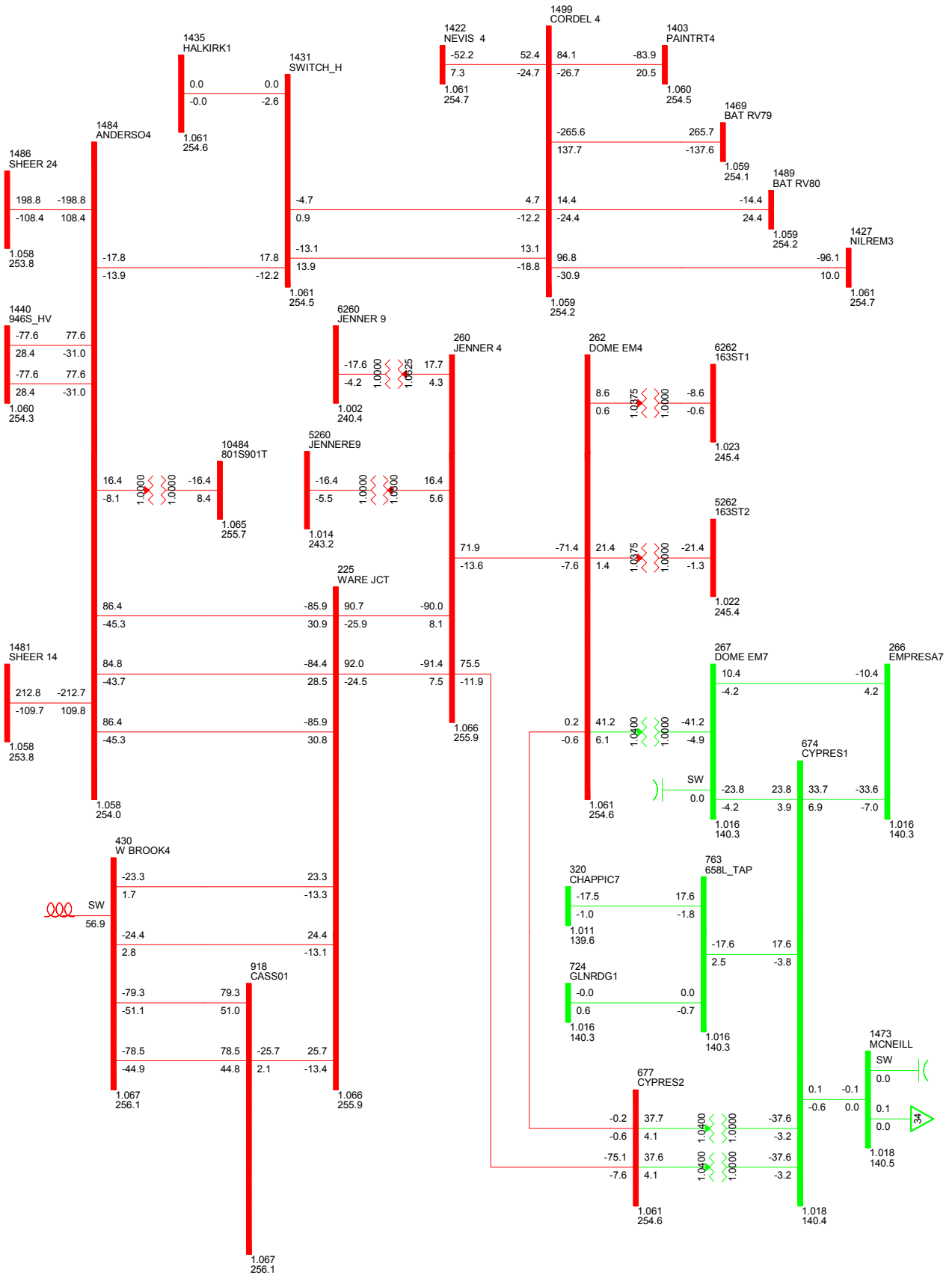


FIG B-E-3: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5_2017SL_0_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

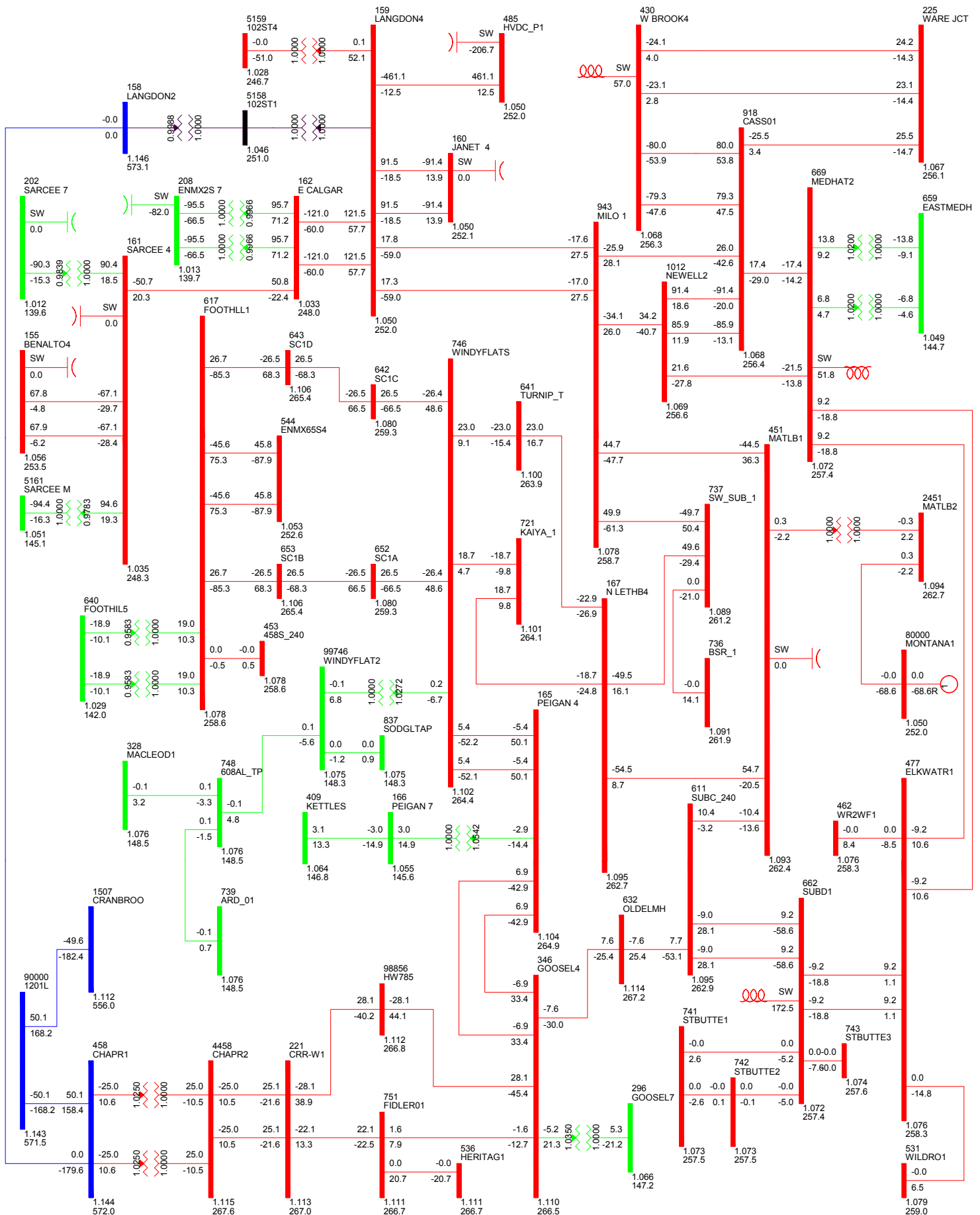


FIG B-W-4: LANGDON 500/240 KV TRANSFORMER 102ST1

CSS_2017SL_0_0_0_B1_R5

THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

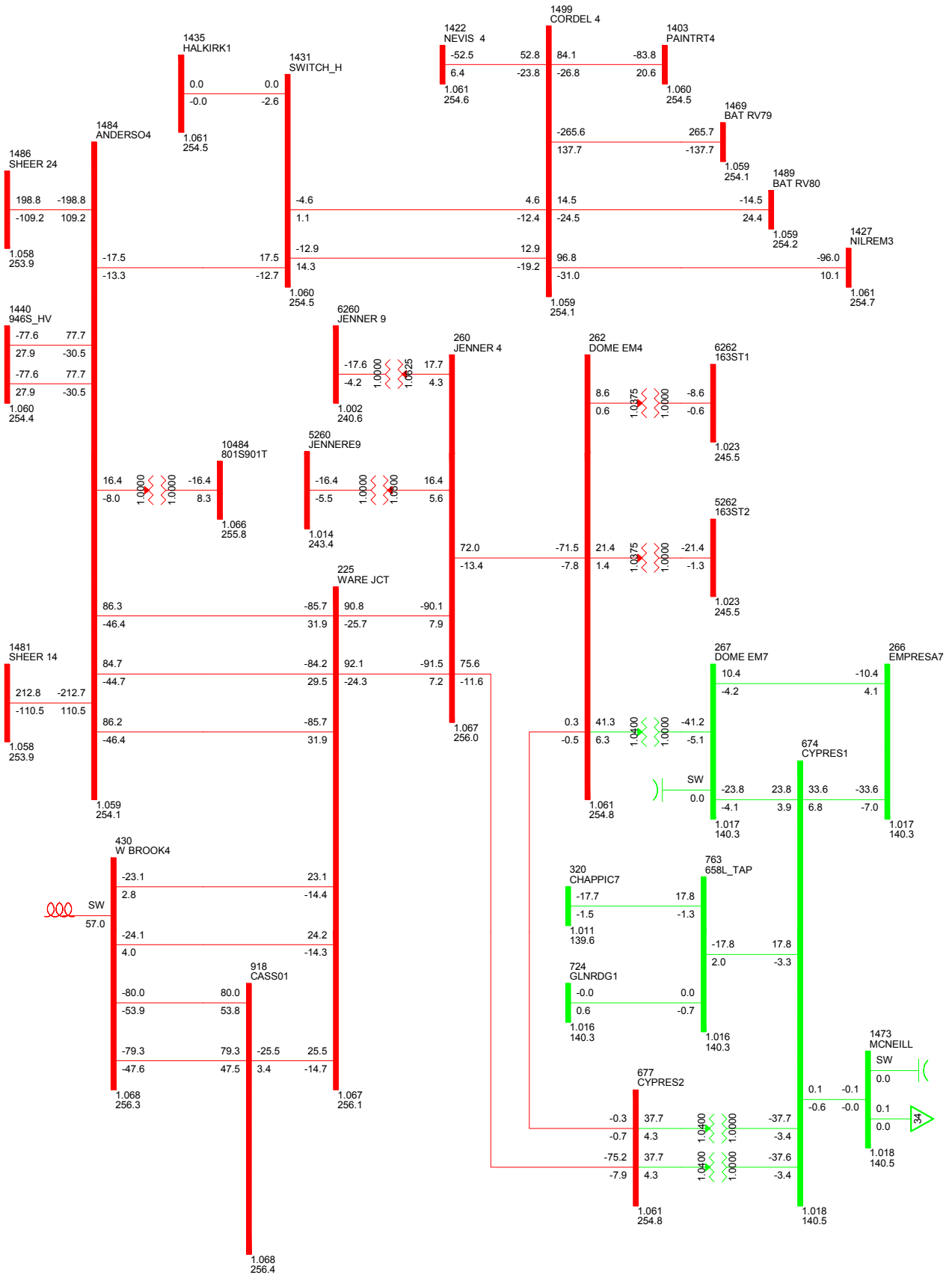


FIG B-E-4: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5S_2017SL_0_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

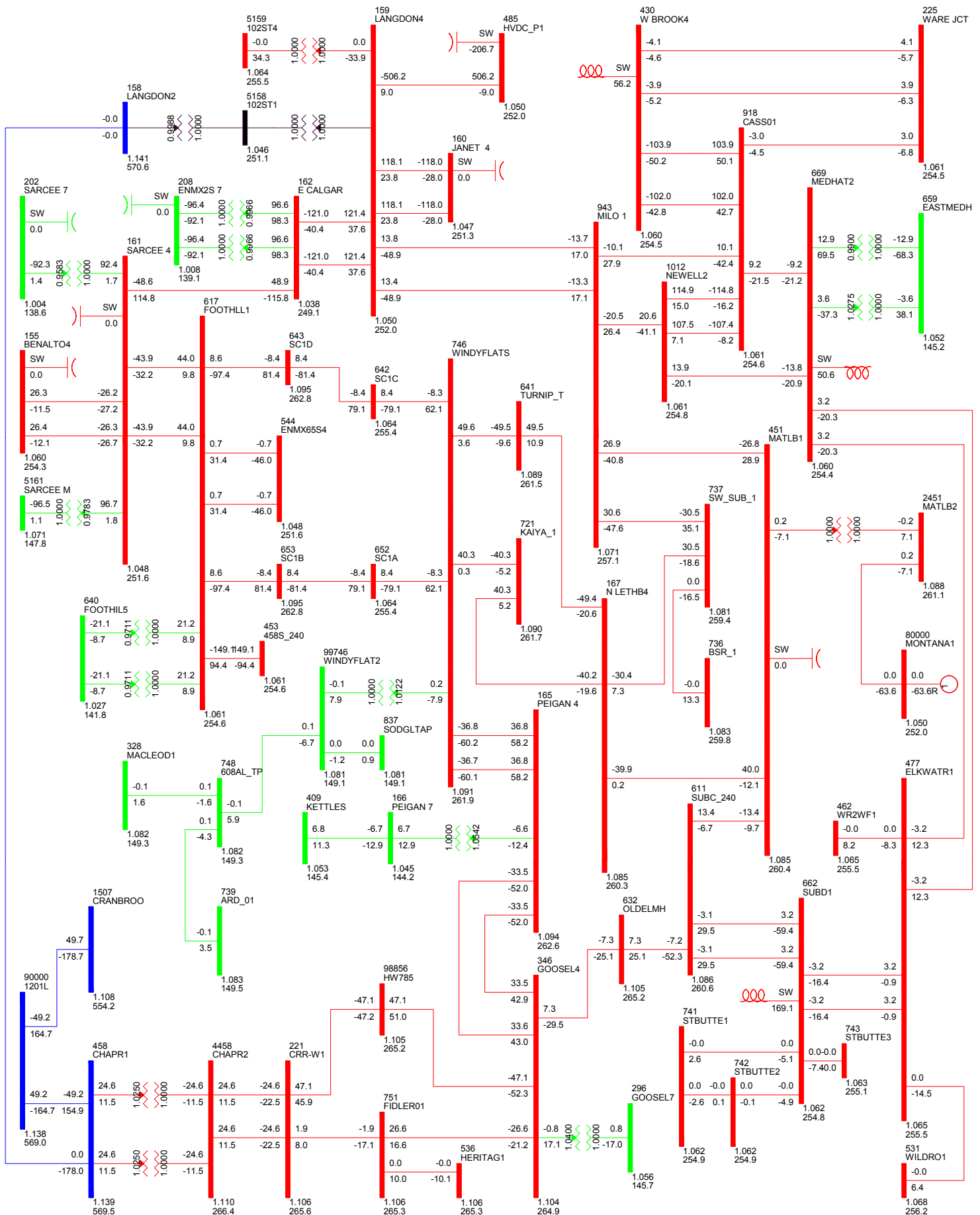


FIG B-W-5: LANGDON 500/240 KV TRANSFORMER 102ST1
 C8_2022SL_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

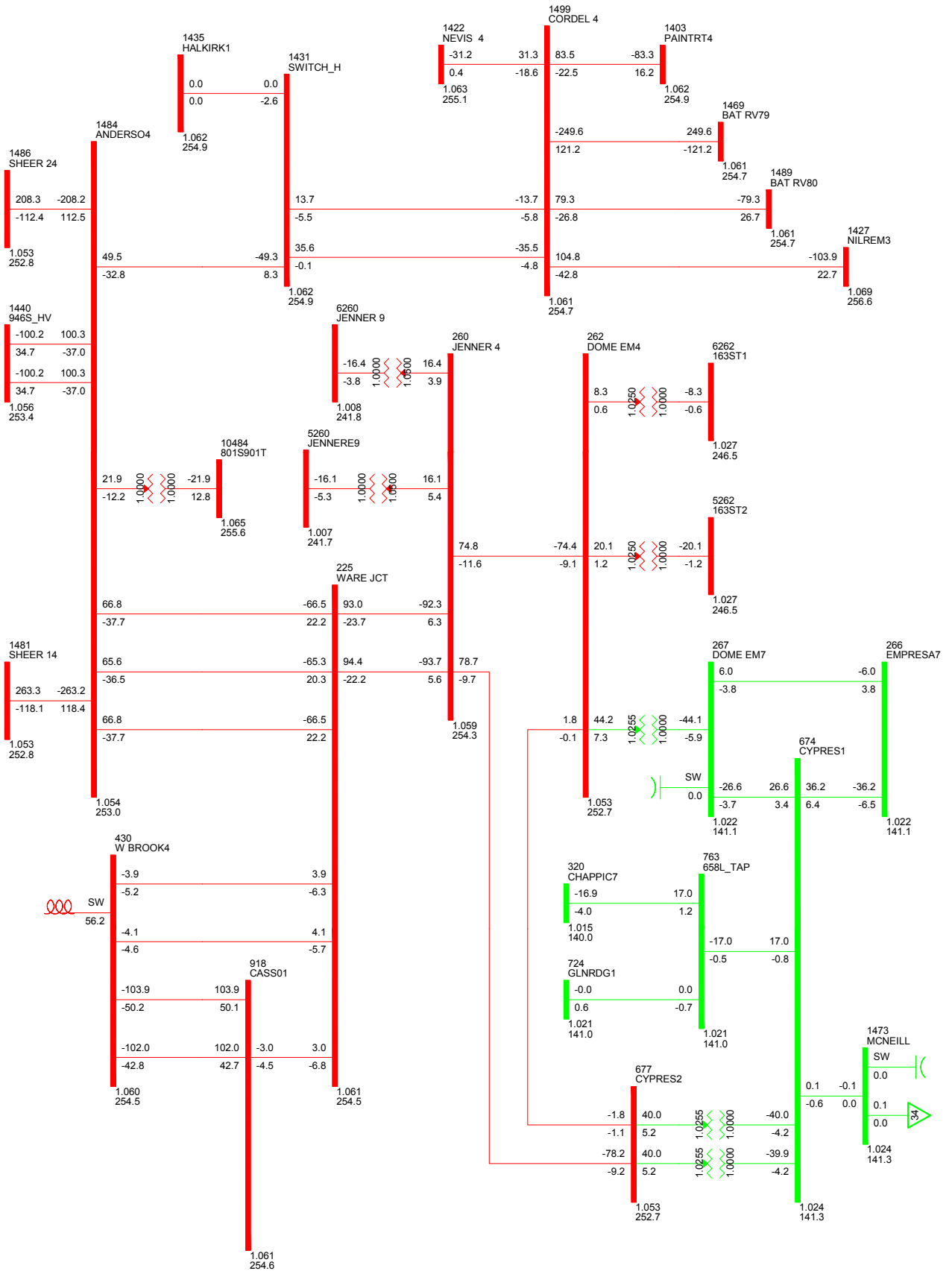


FIG B-E-5: LANGDON 500/240 KV TRANSFORMER 102ST1
 C8_2022SL_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

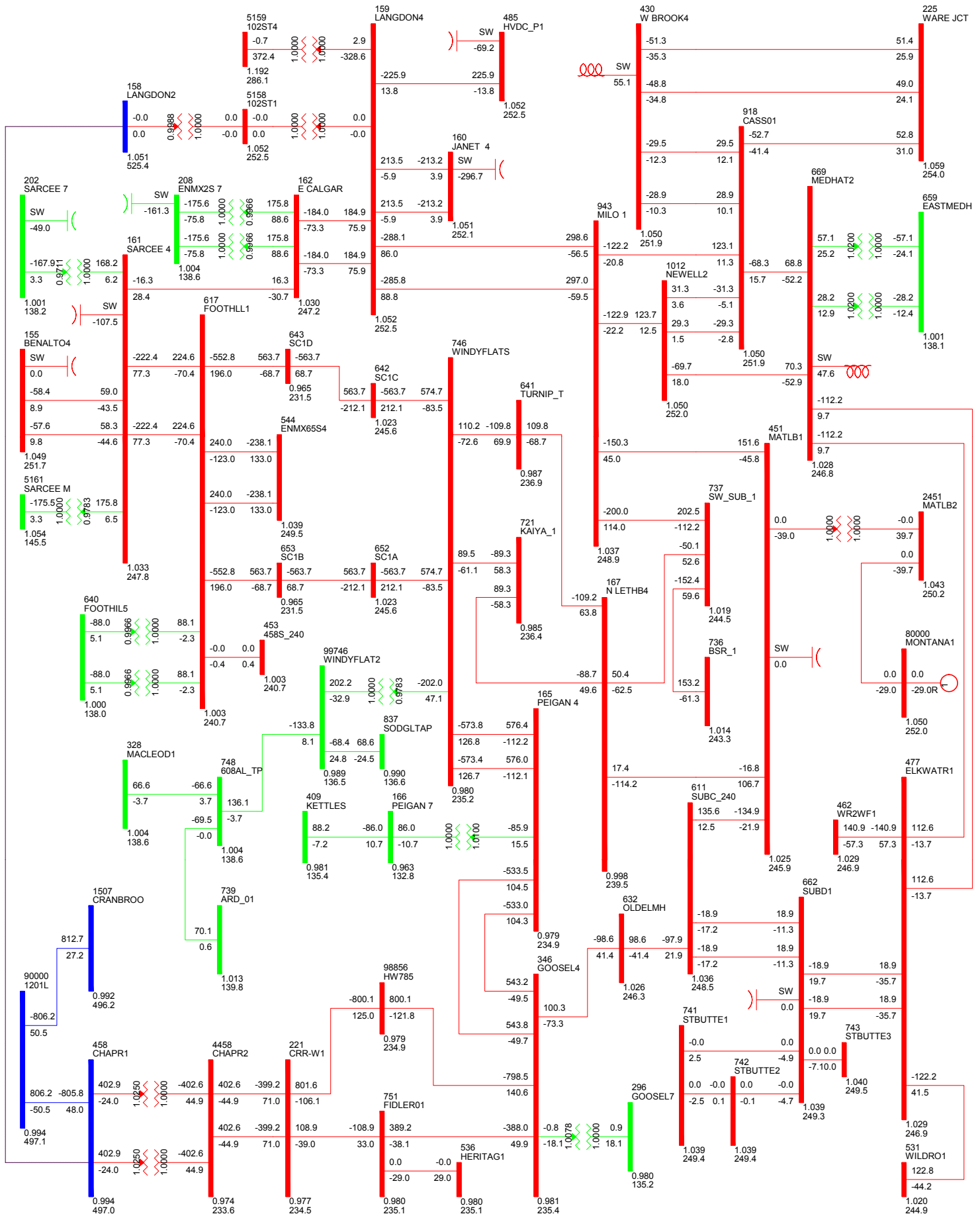


FIG B-W-6: LANGDON2 TO CHAPR1 500 KV LINE
 C11_2017SP_780_0_-150_B1_R5

THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

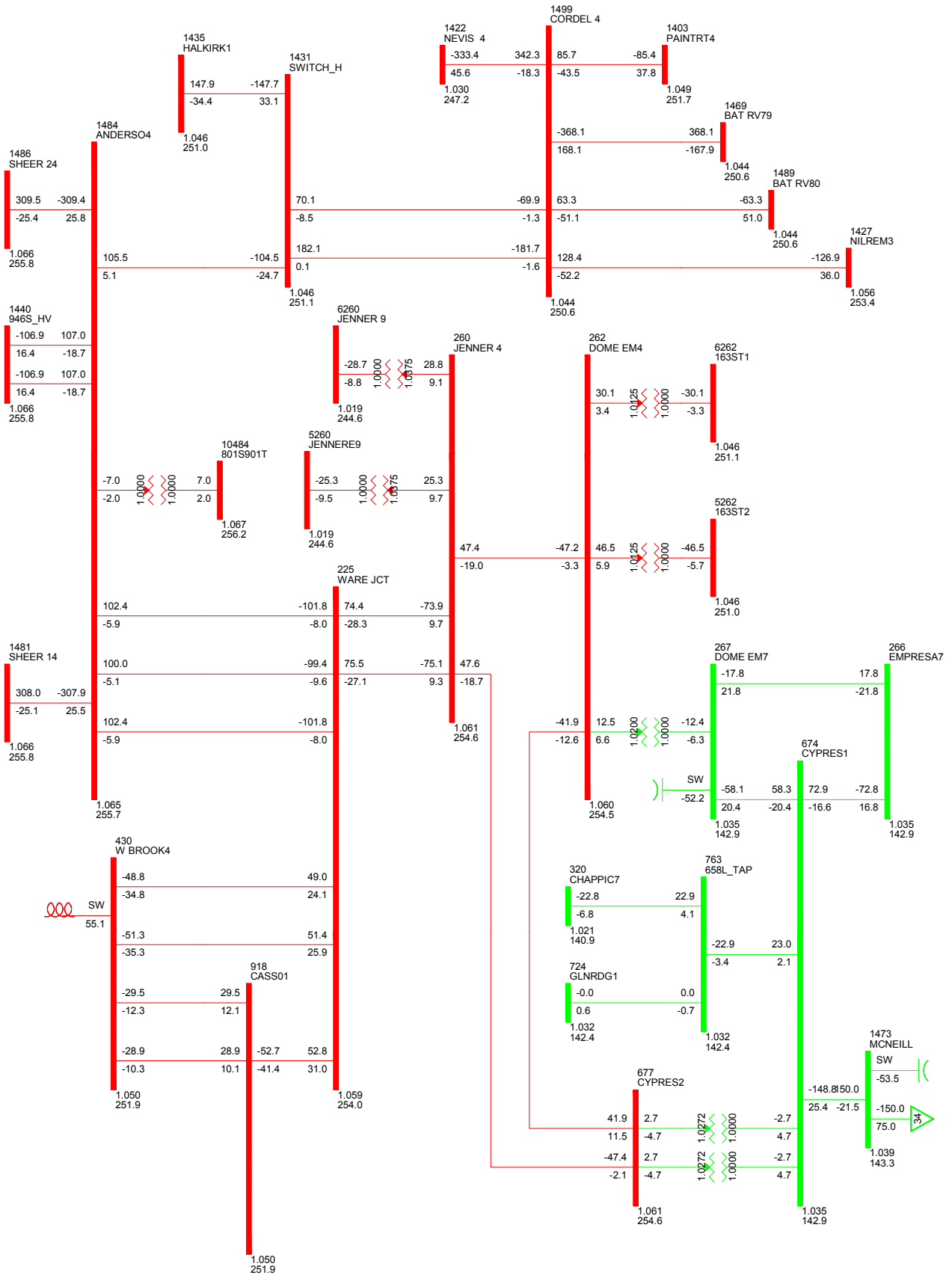


FIG B-E-6: LANGDON2 TO CHAPR1 500 KV LINE
 C11_2017SP_780_0_-150_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

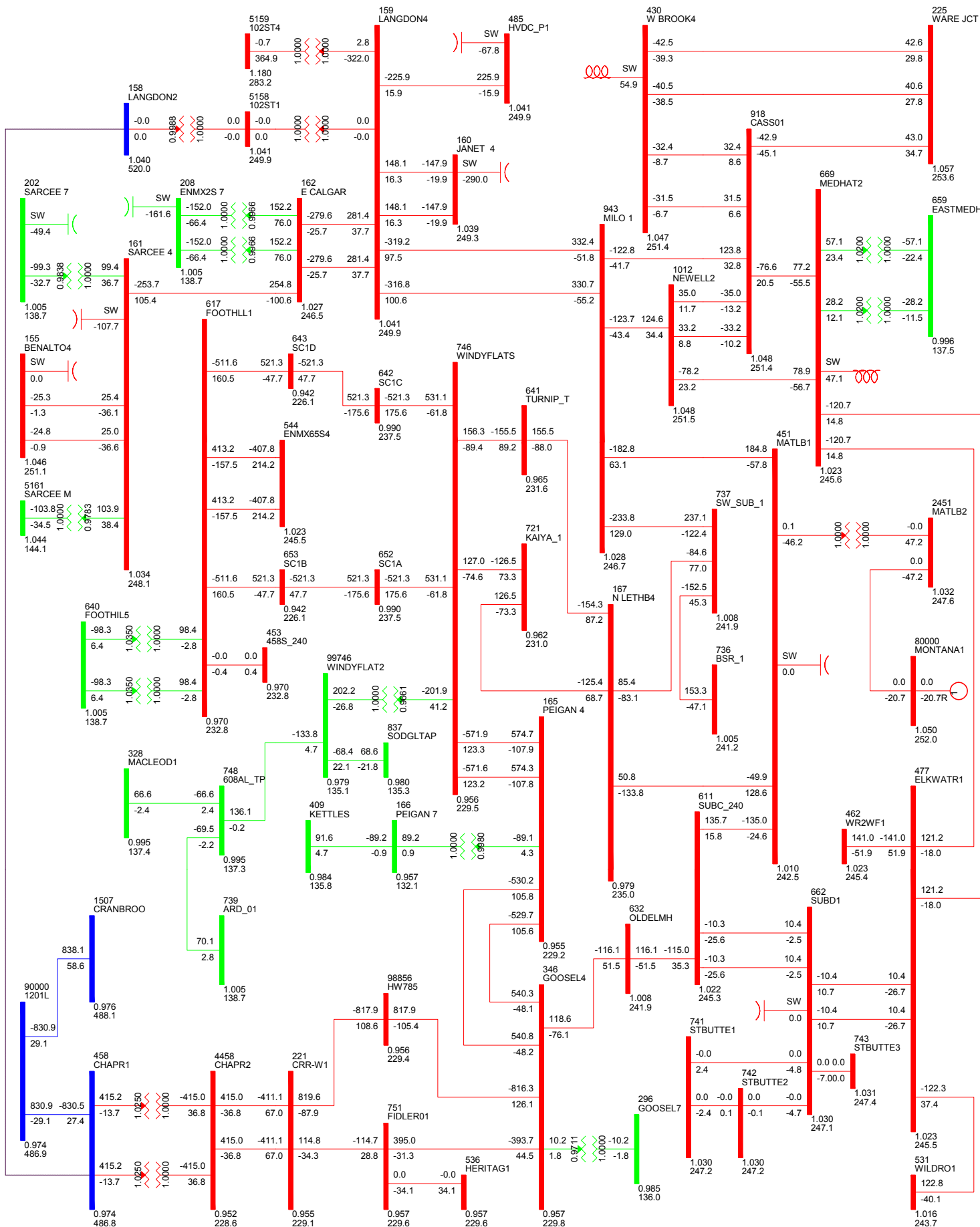


FIG B-W-7: LANGDON2 TO CHAPR1 500 KV LINE
 C11S_2017SP_-780_0_-150_B1_R5

THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

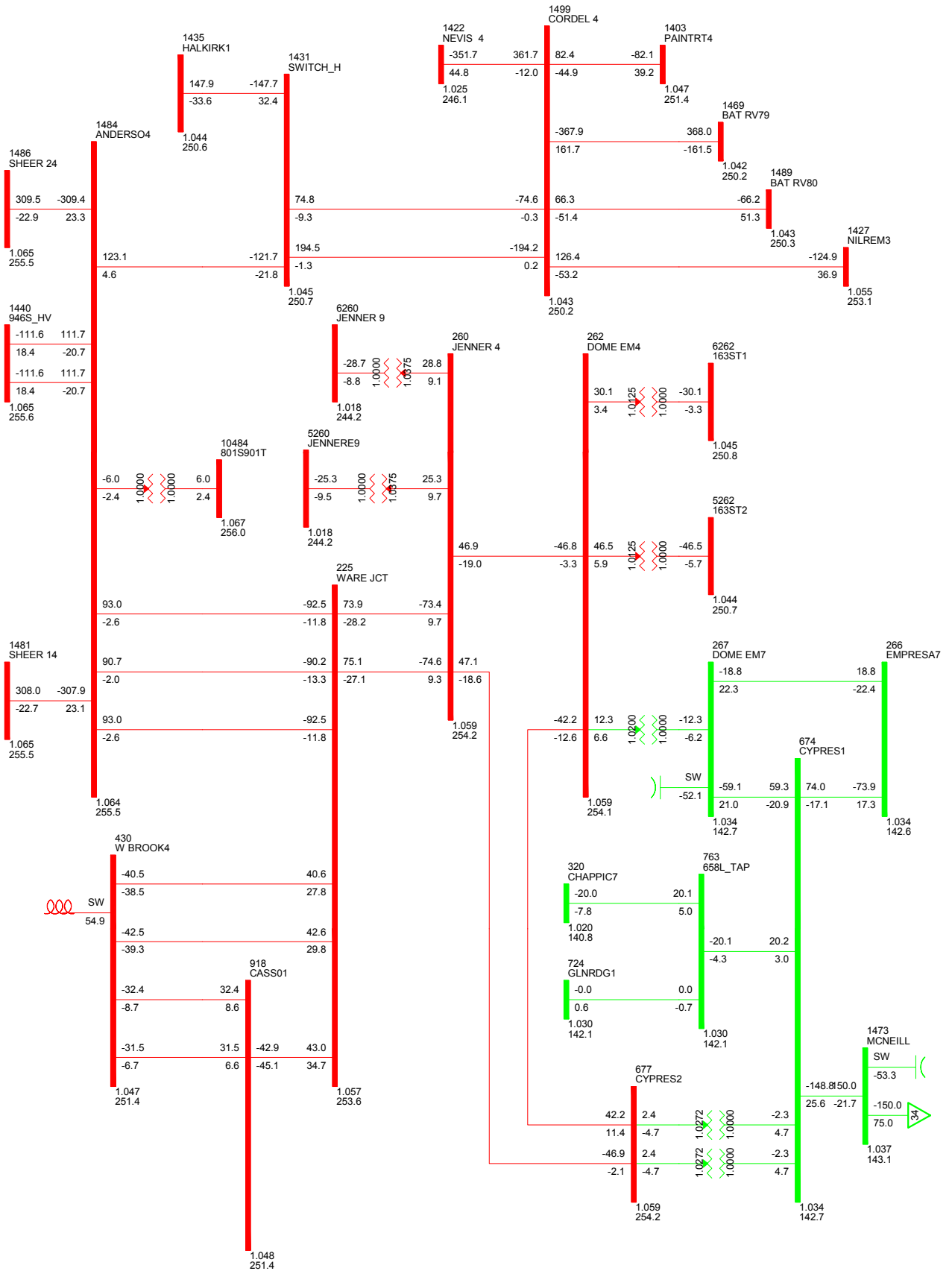


FIG B-E-7: LANGDON2 TO CHAPR1 500 KV LINE
 C11S_2017SP_-780_0_-150_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

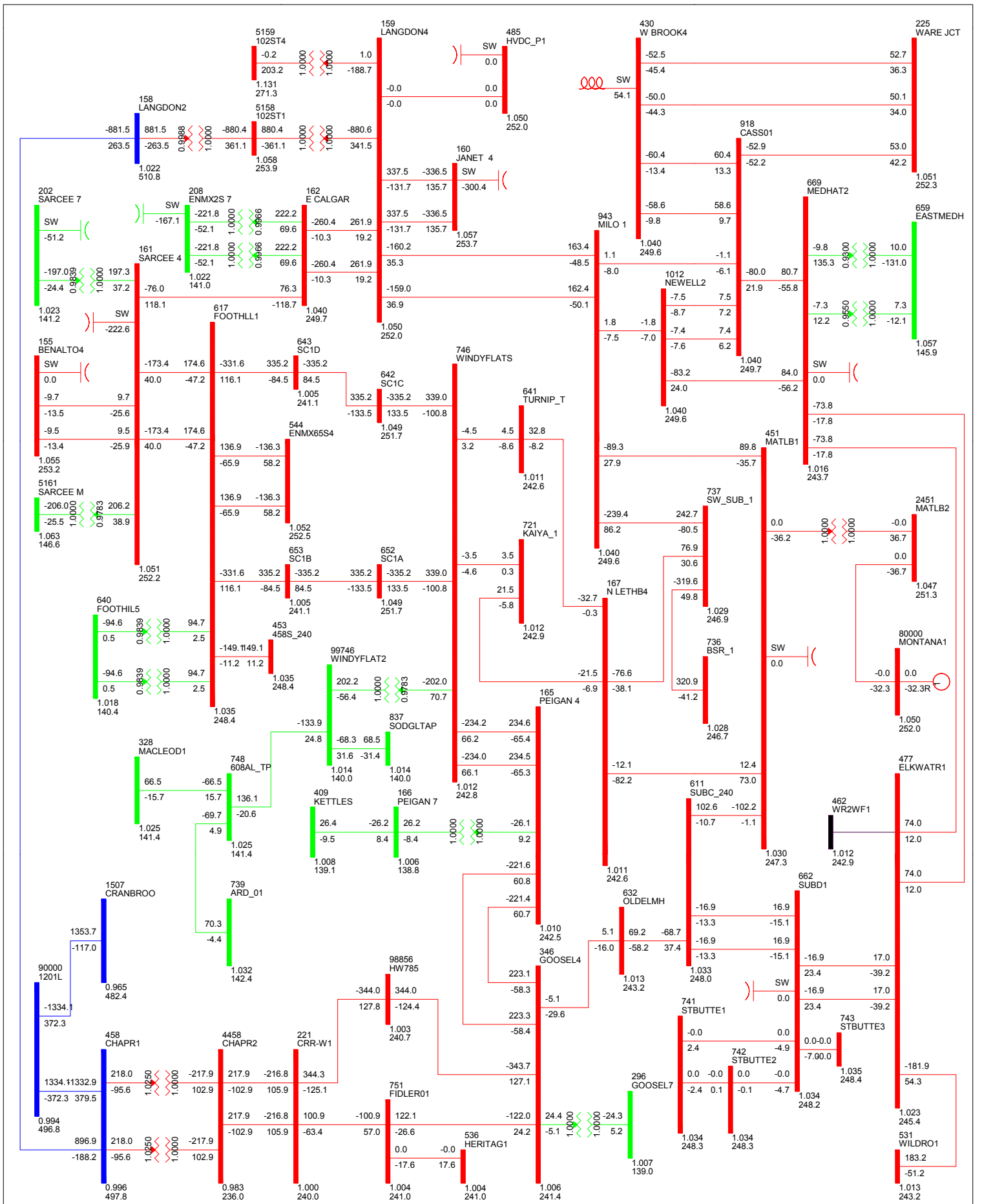


FIG B-W-8: WR2WF1 TO ELKWATR1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

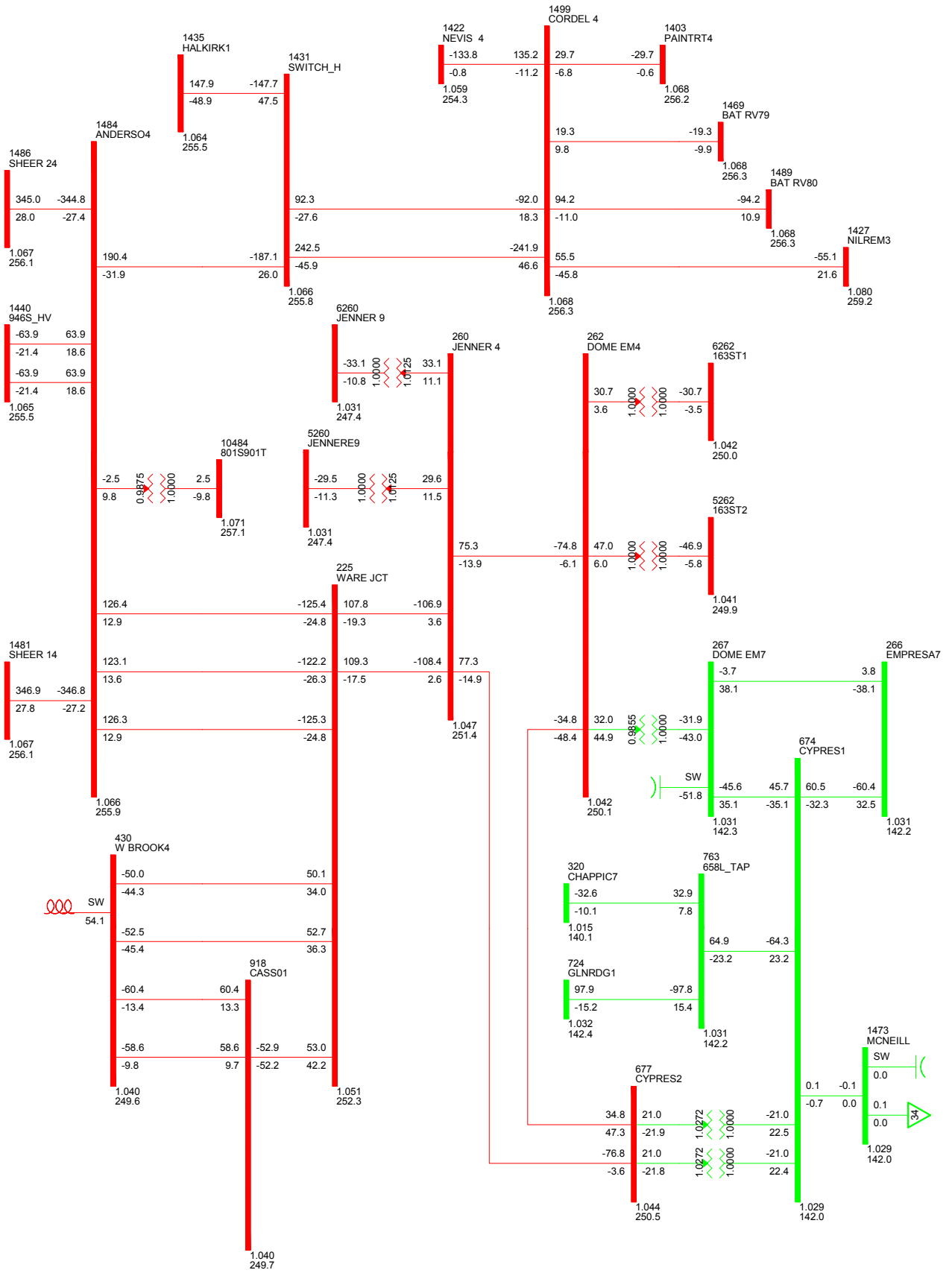


FIG B-E-8: WR2WF1 TO ELKWATR1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

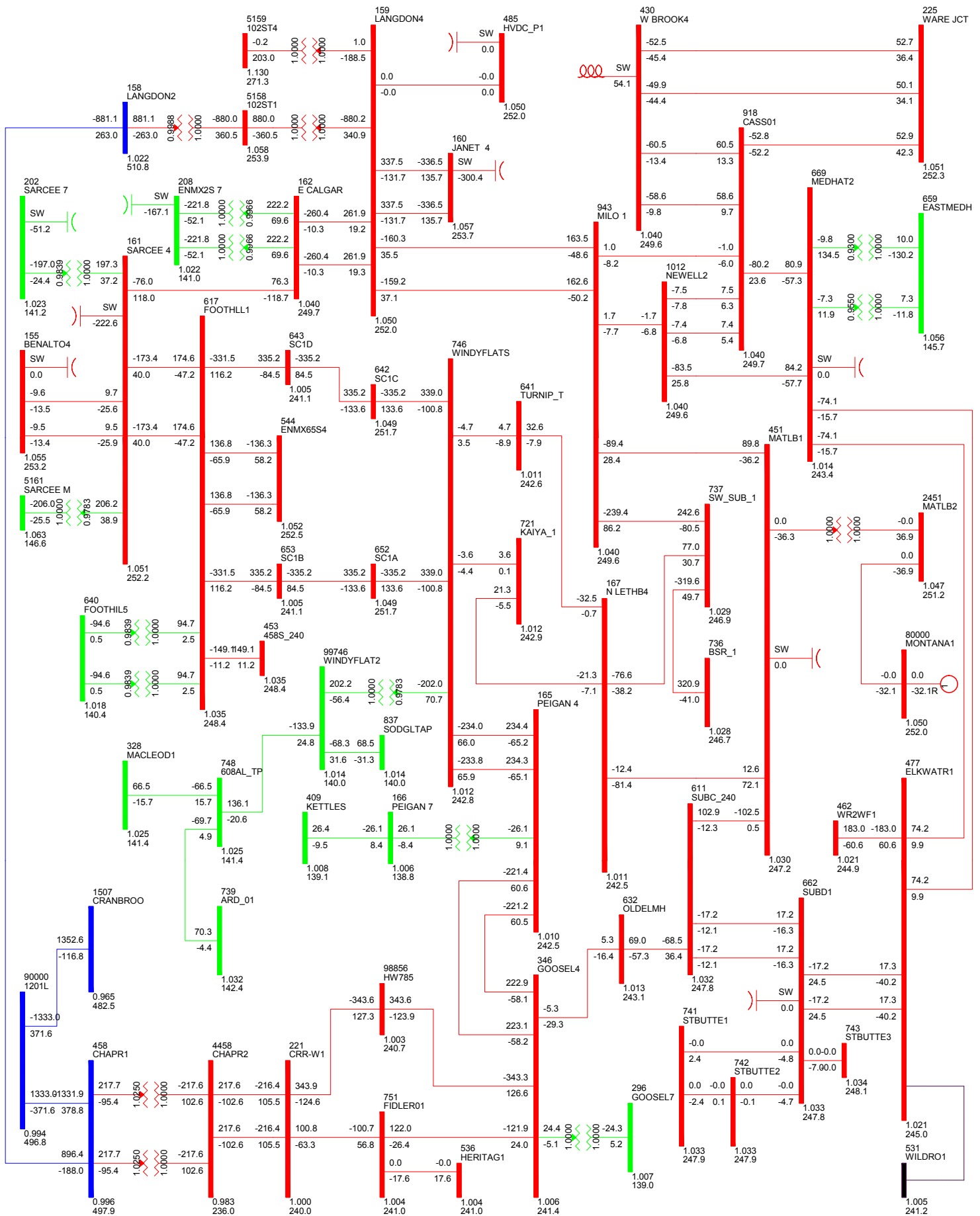


FIG B-W-9: ELKWATR1 TO WILDRO1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

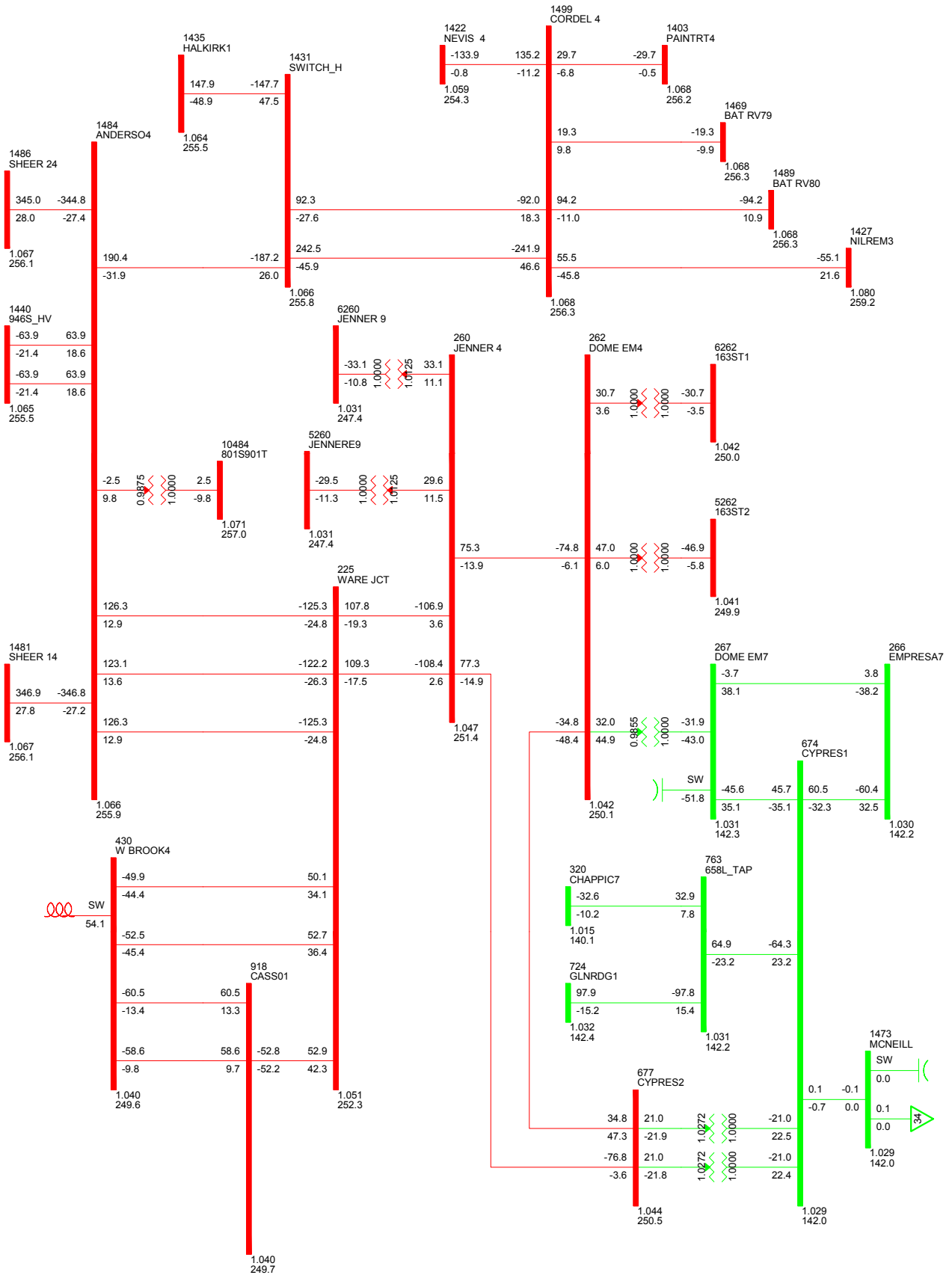


FIG B-E-9: ELKWATR1 TO WILDRO1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

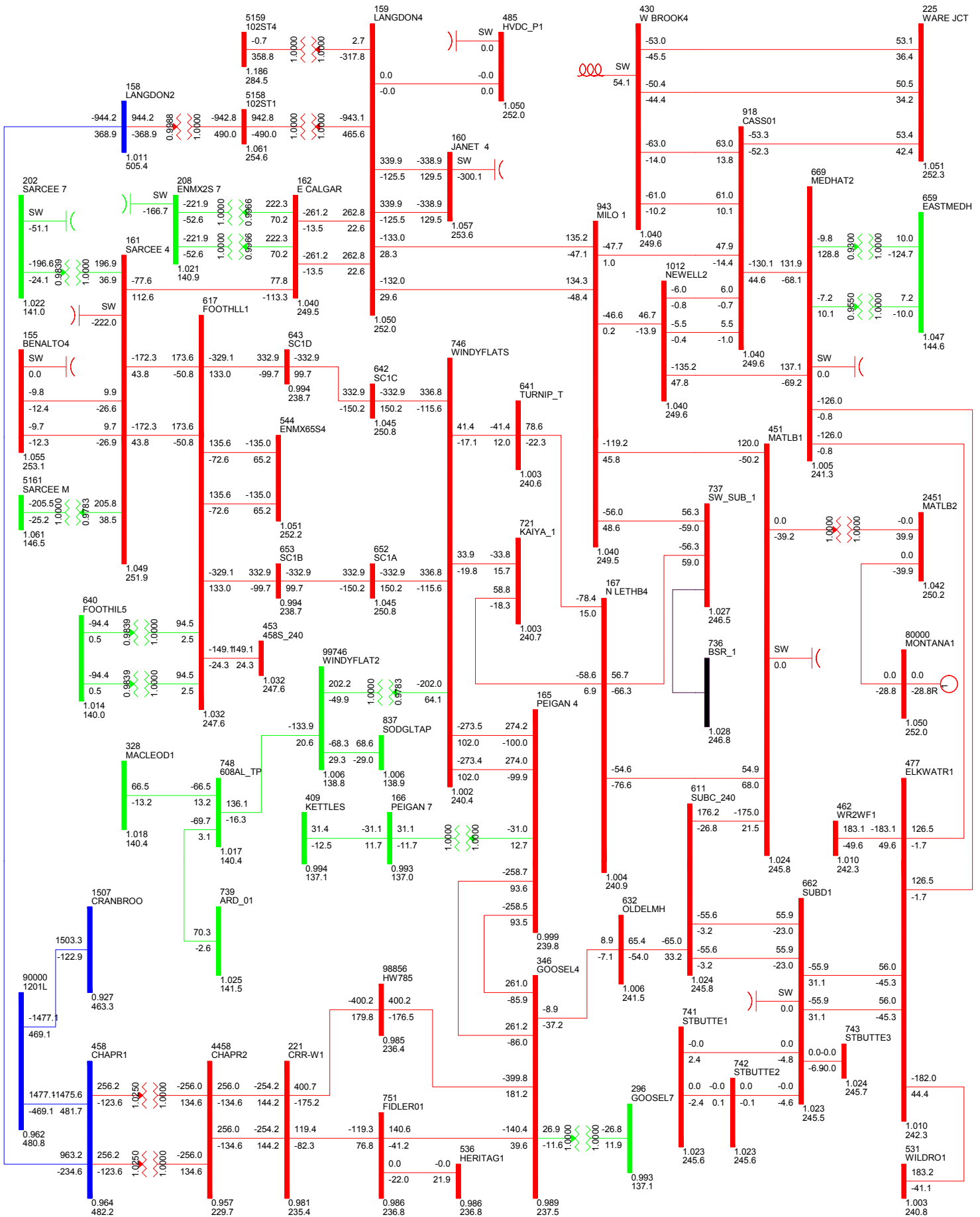


FIG B-W-10: BSR_1 TO SW_SUB_1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

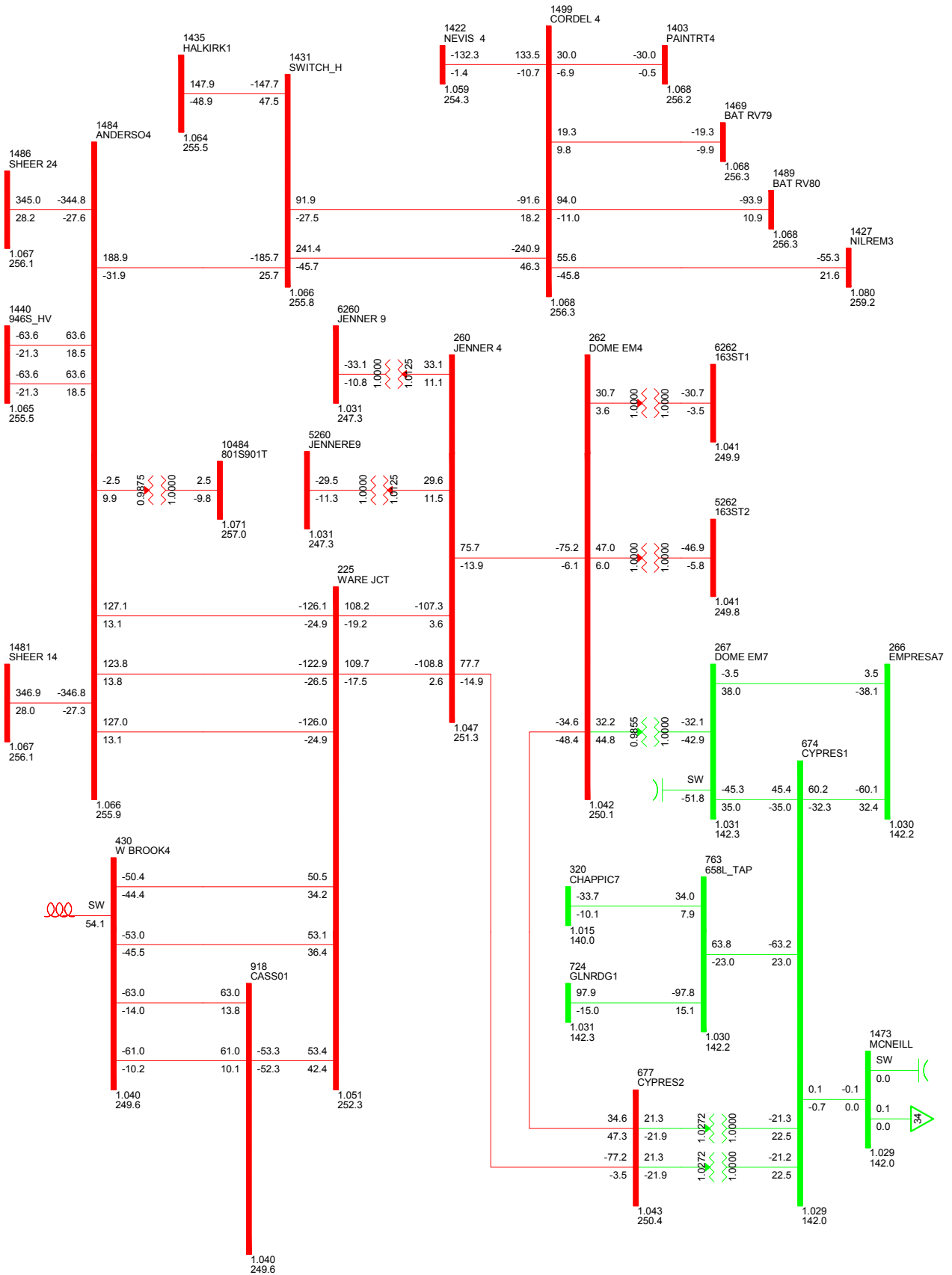


FIG B-E-10: BSR_1 TO SW_SUB_1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

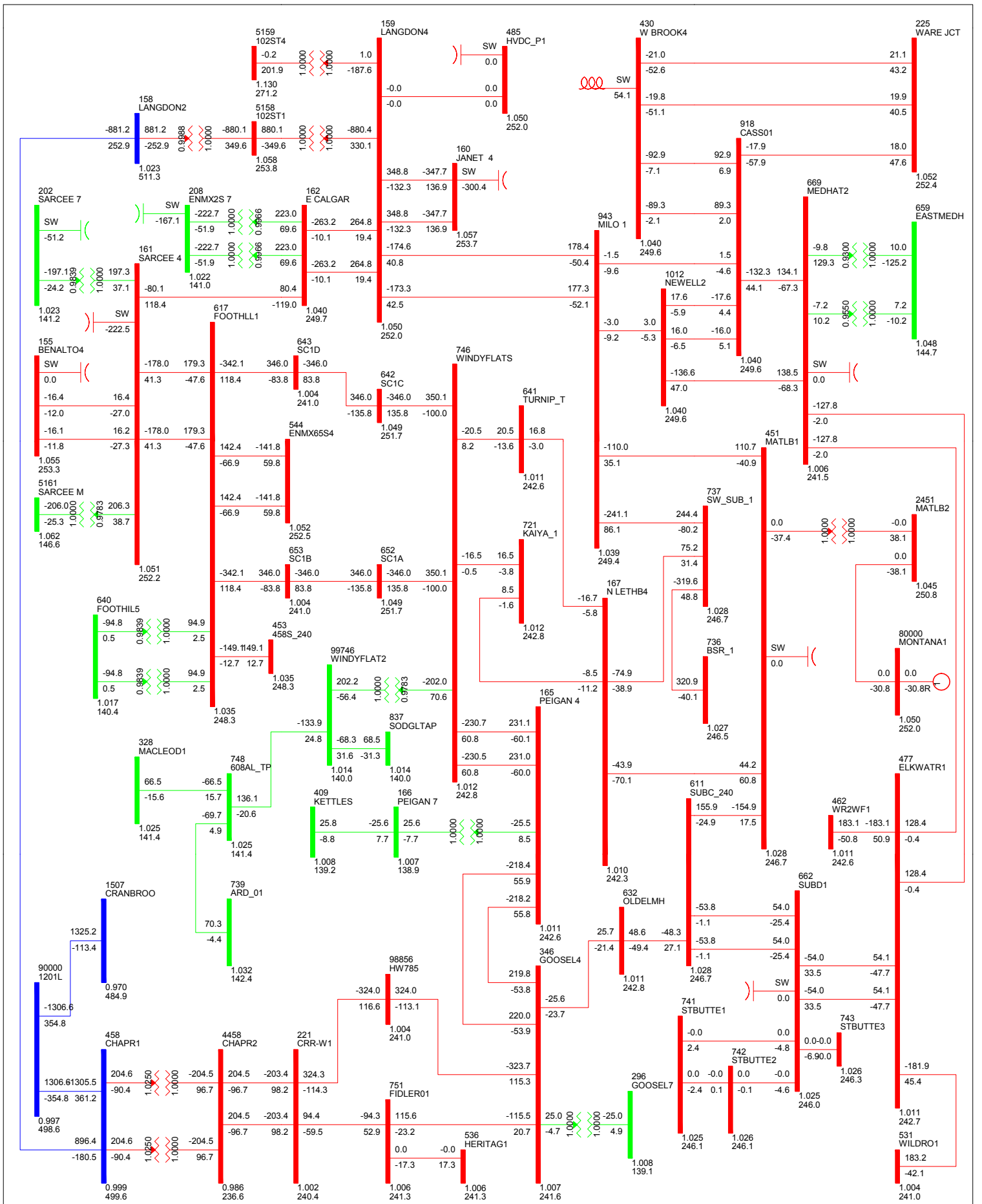


FIG B-W-11: SWITCH_H TO HALKIRK1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

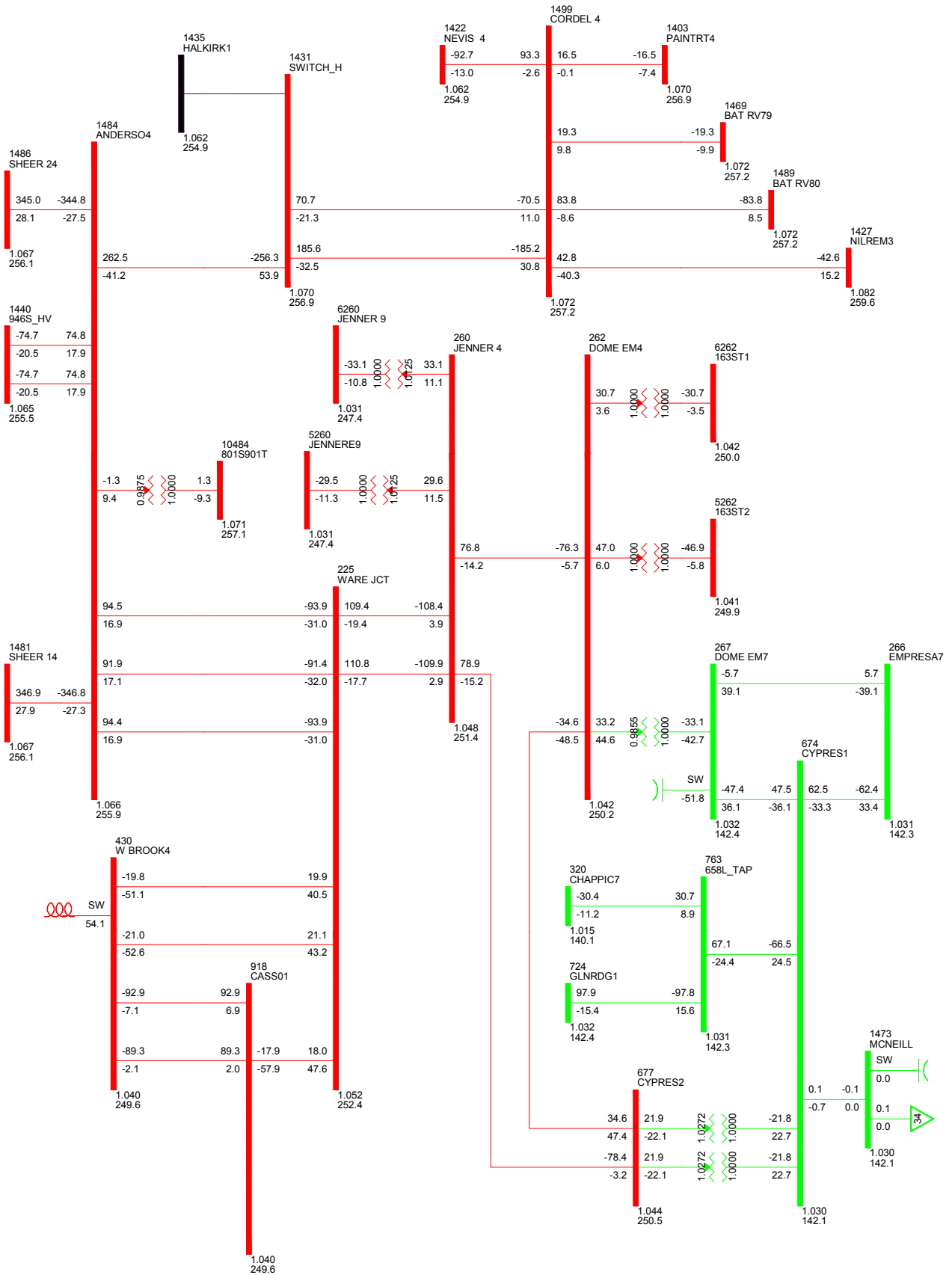


FIG B-E-11: SWITCH_H TO HALKIRK1 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

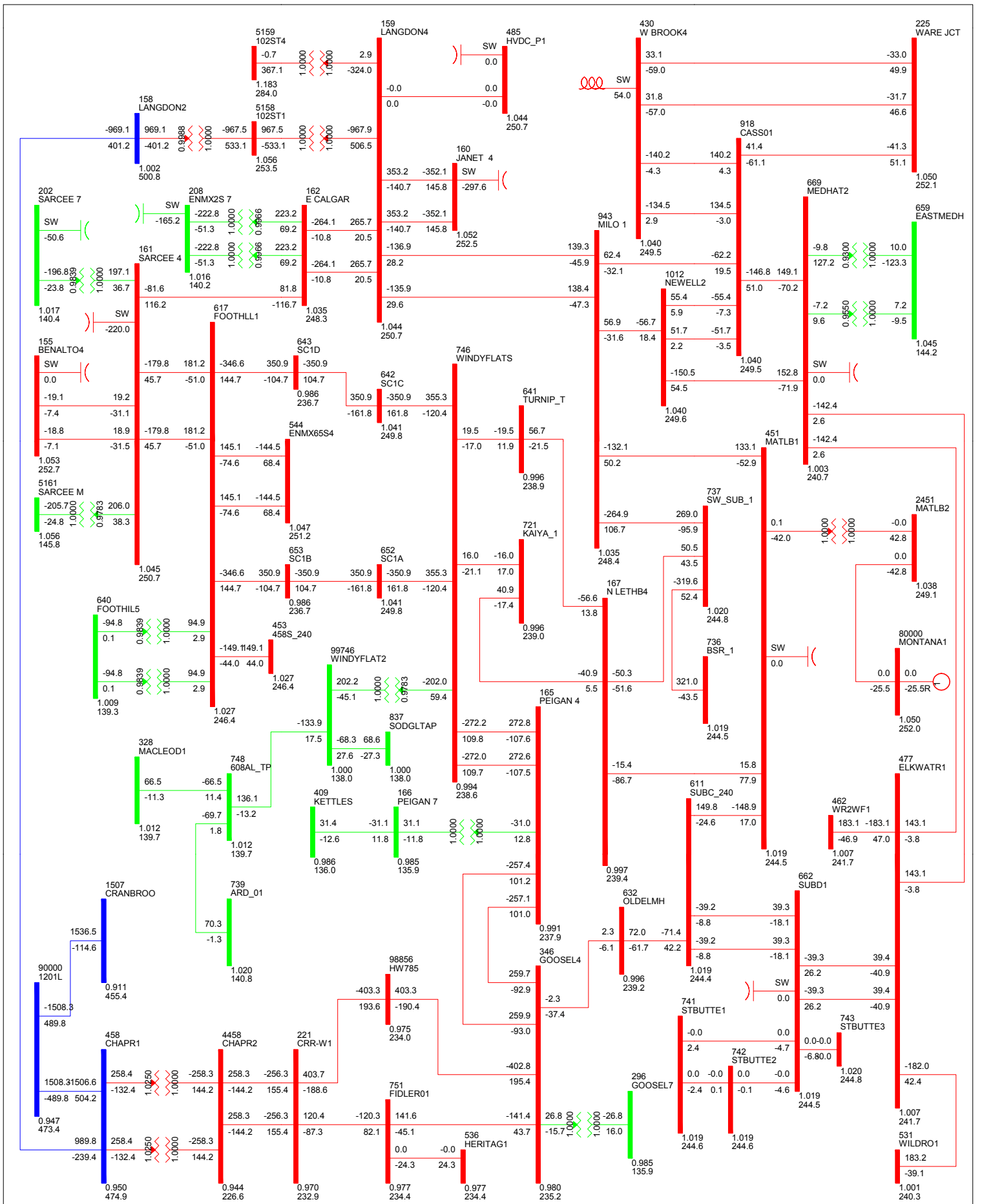


FIG B-W-12: SHEER 14 TO ANDERSON 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

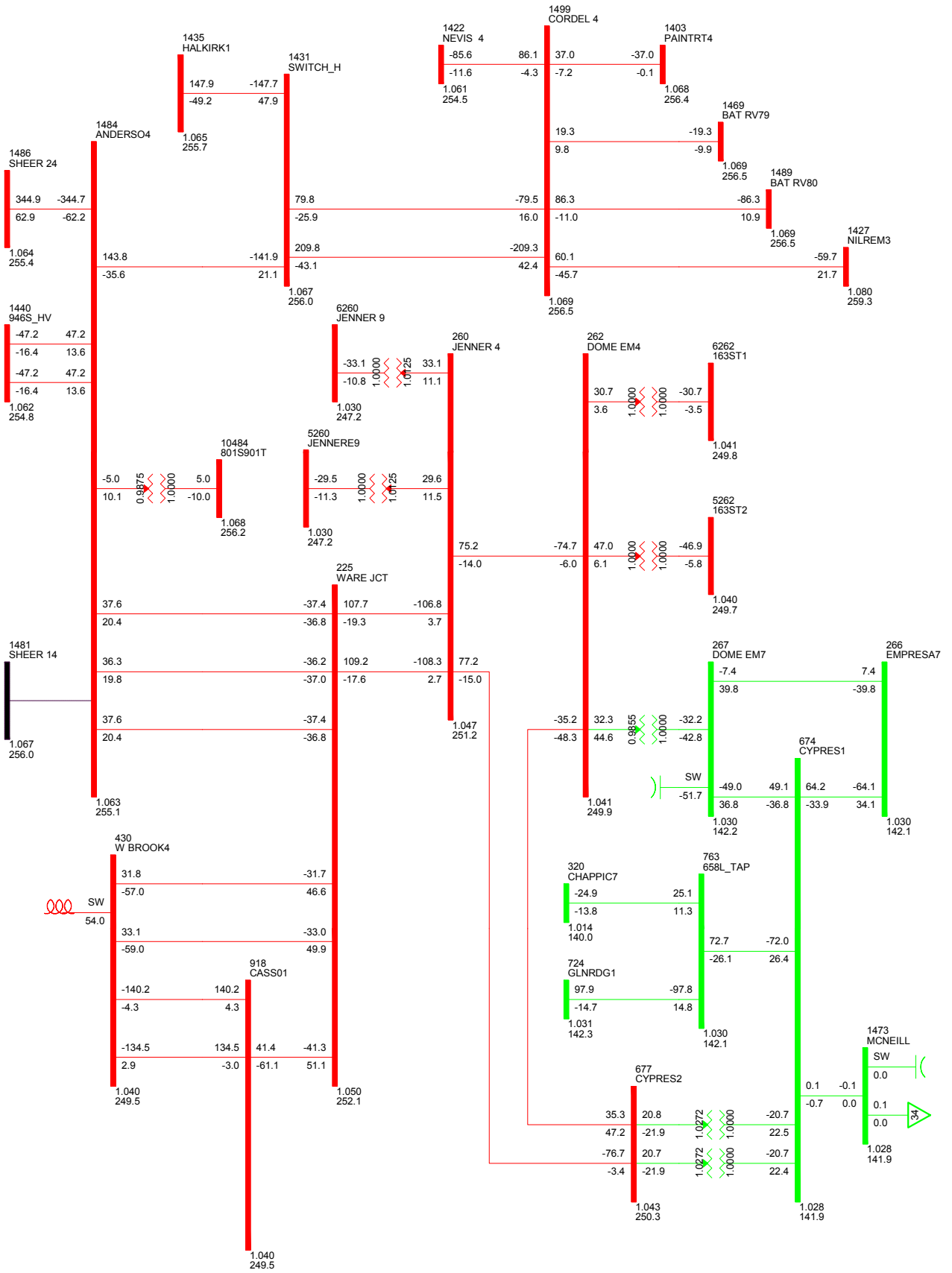


FIG B-E-12: SHEER 14 TO ANDERSO4 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

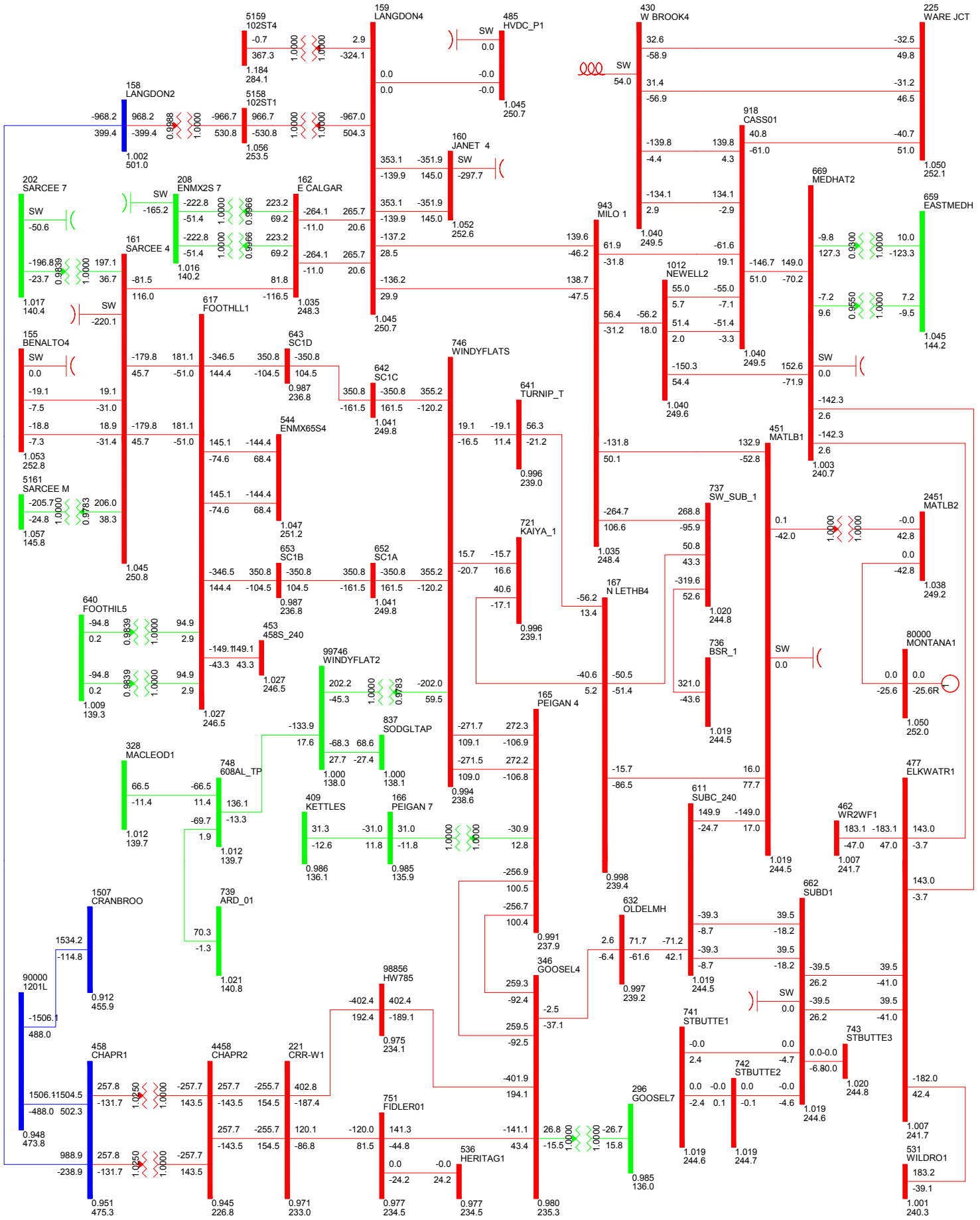


FIG B-W-13: ANDERSON4 TO SHEER 24 240 KV LINE
 C12_2022SP_1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

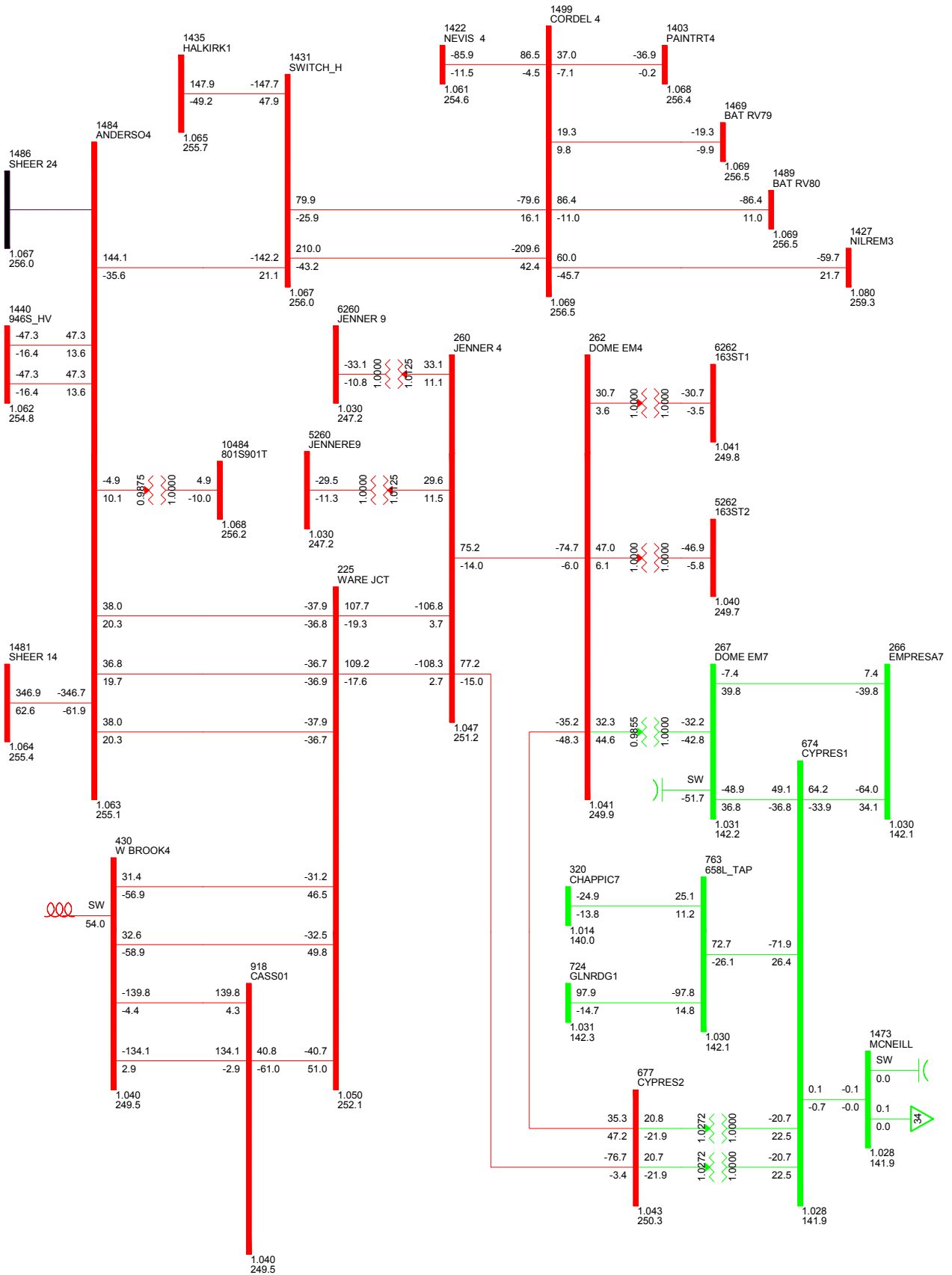


FIG B-E-13: ANDERSON4 TO SHEER 24 240 KV LINE
 C12_2022SP_-1200_0_0_B1_R5
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

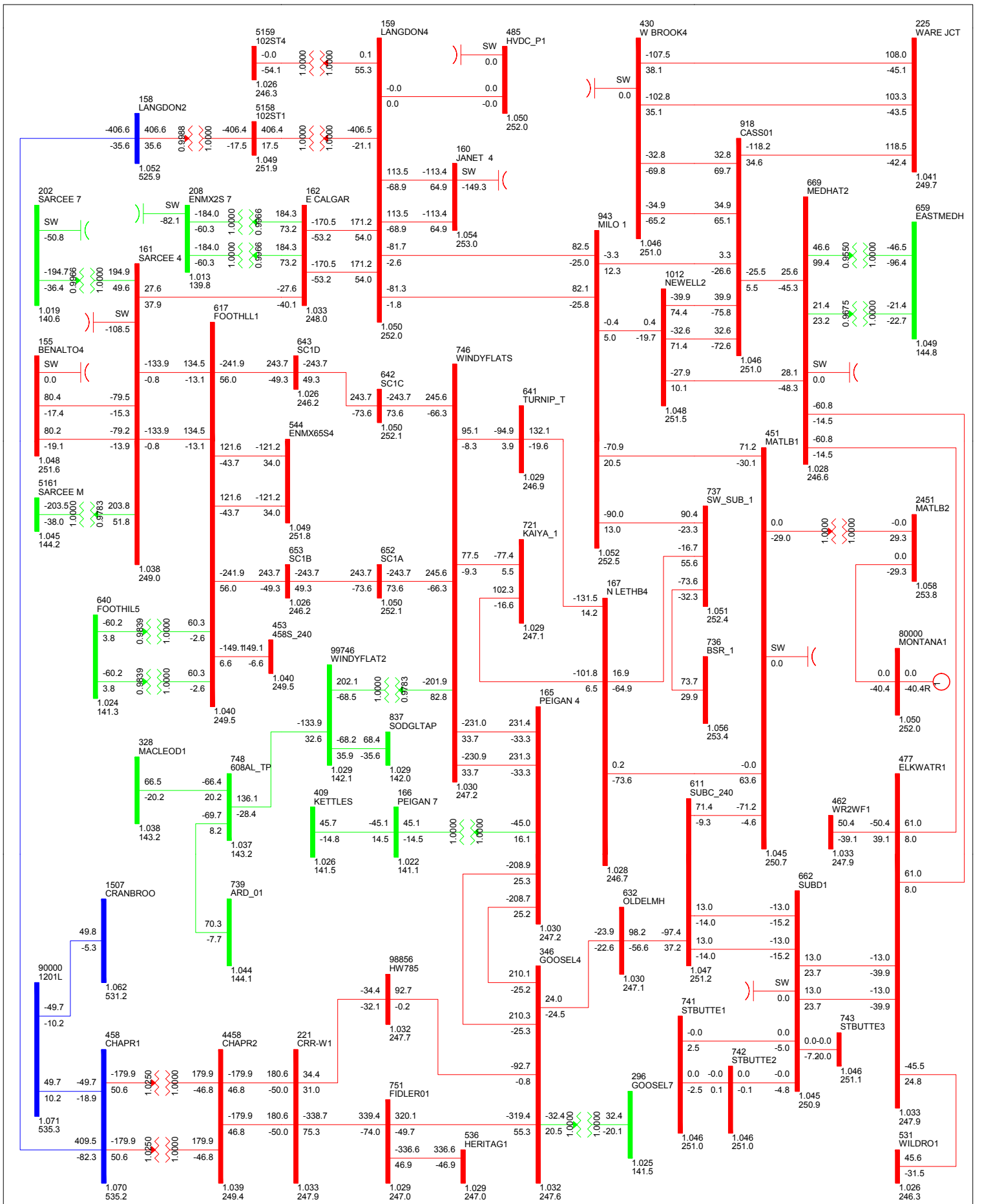


FIG B-W-14: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

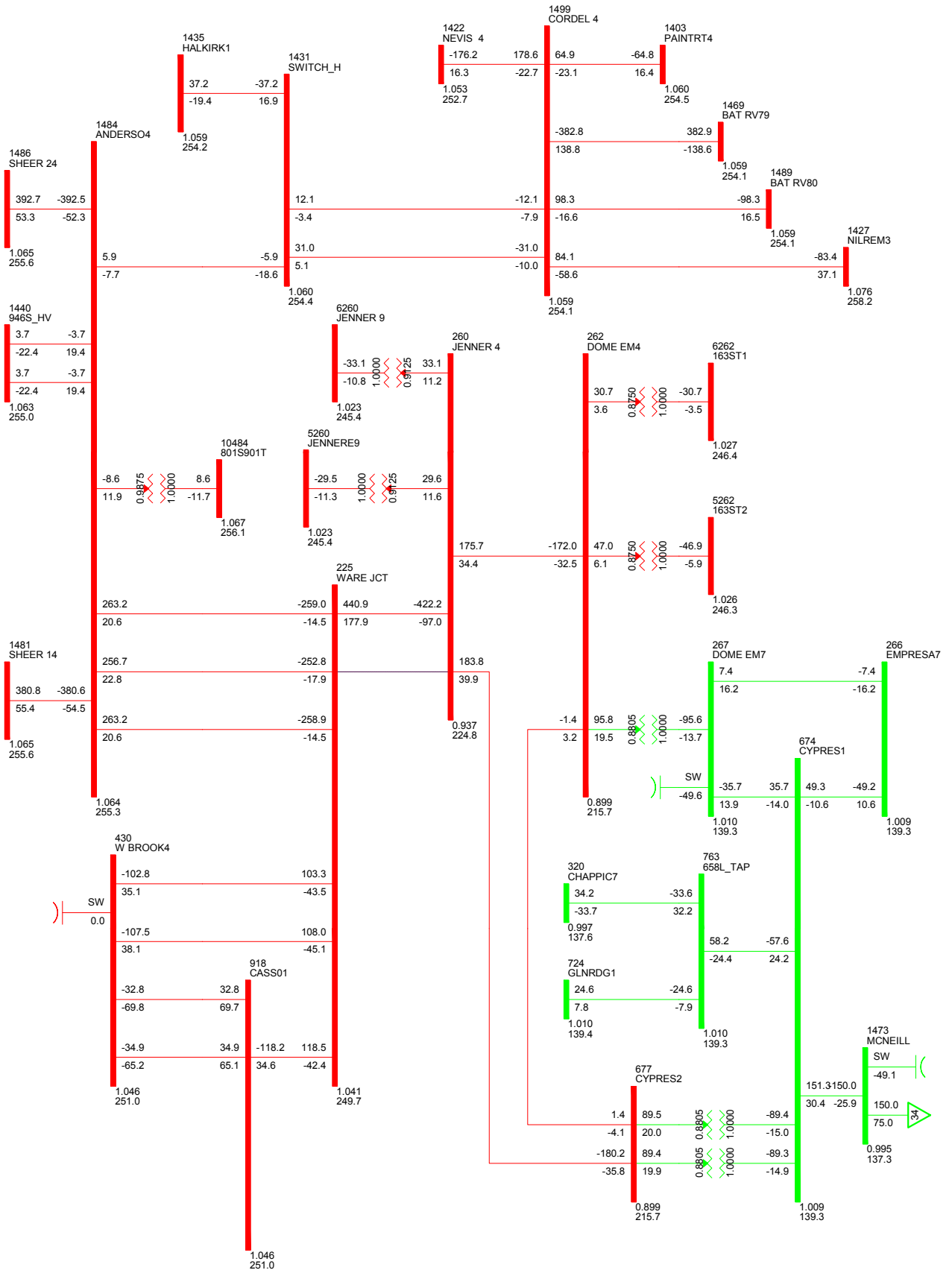


FIG B-E-14: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

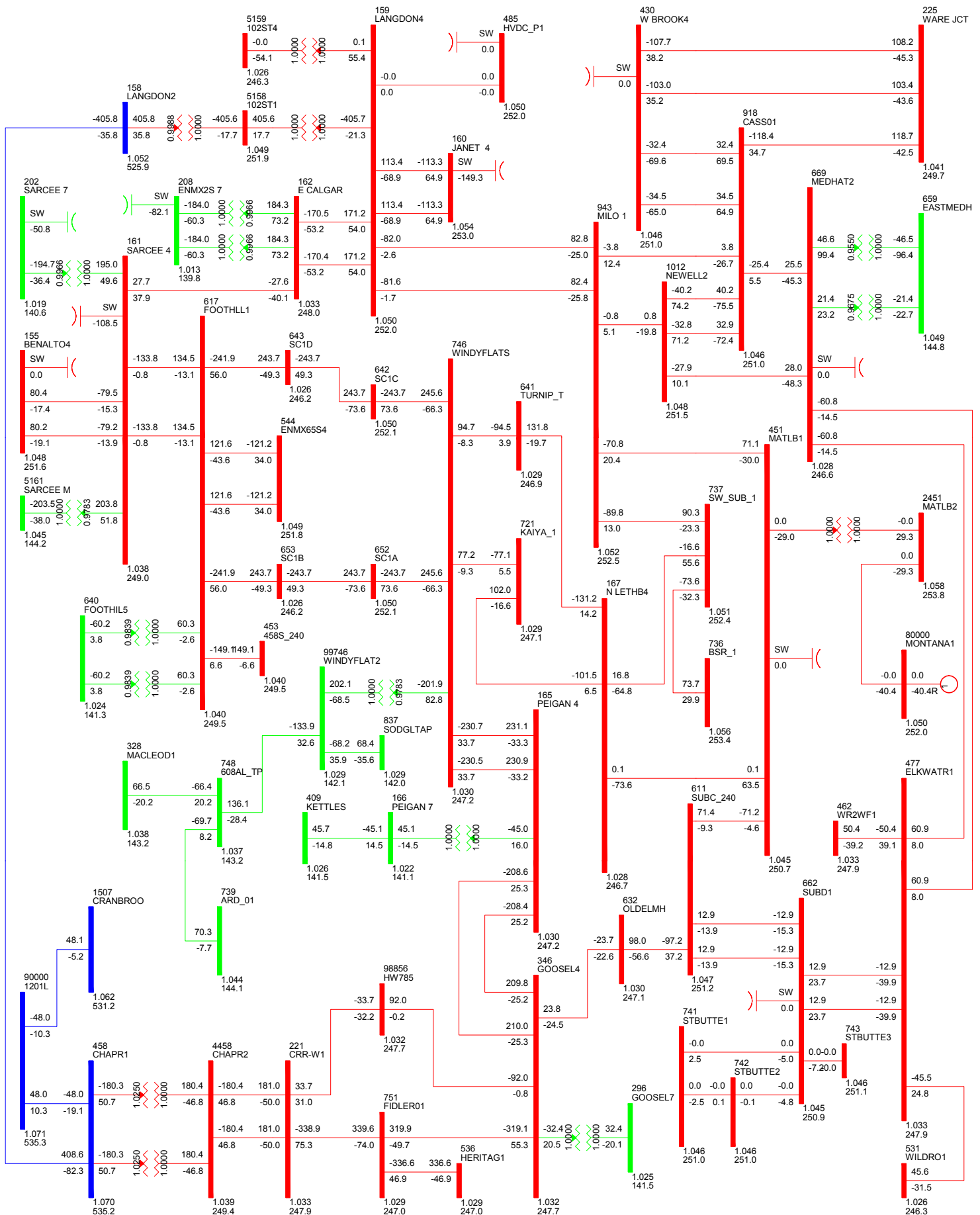


FIG B-W-15: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

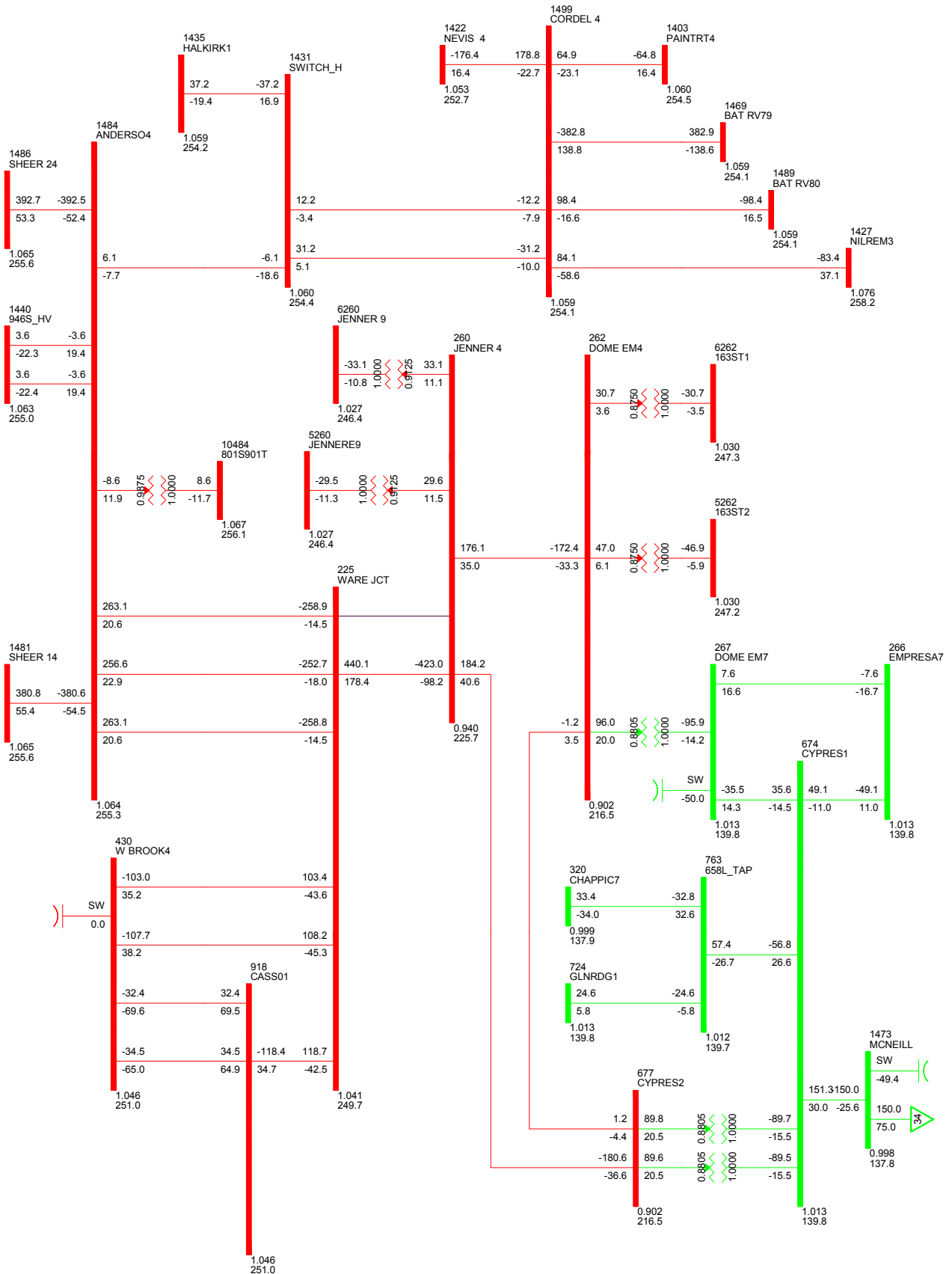


FIG B-E-15: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

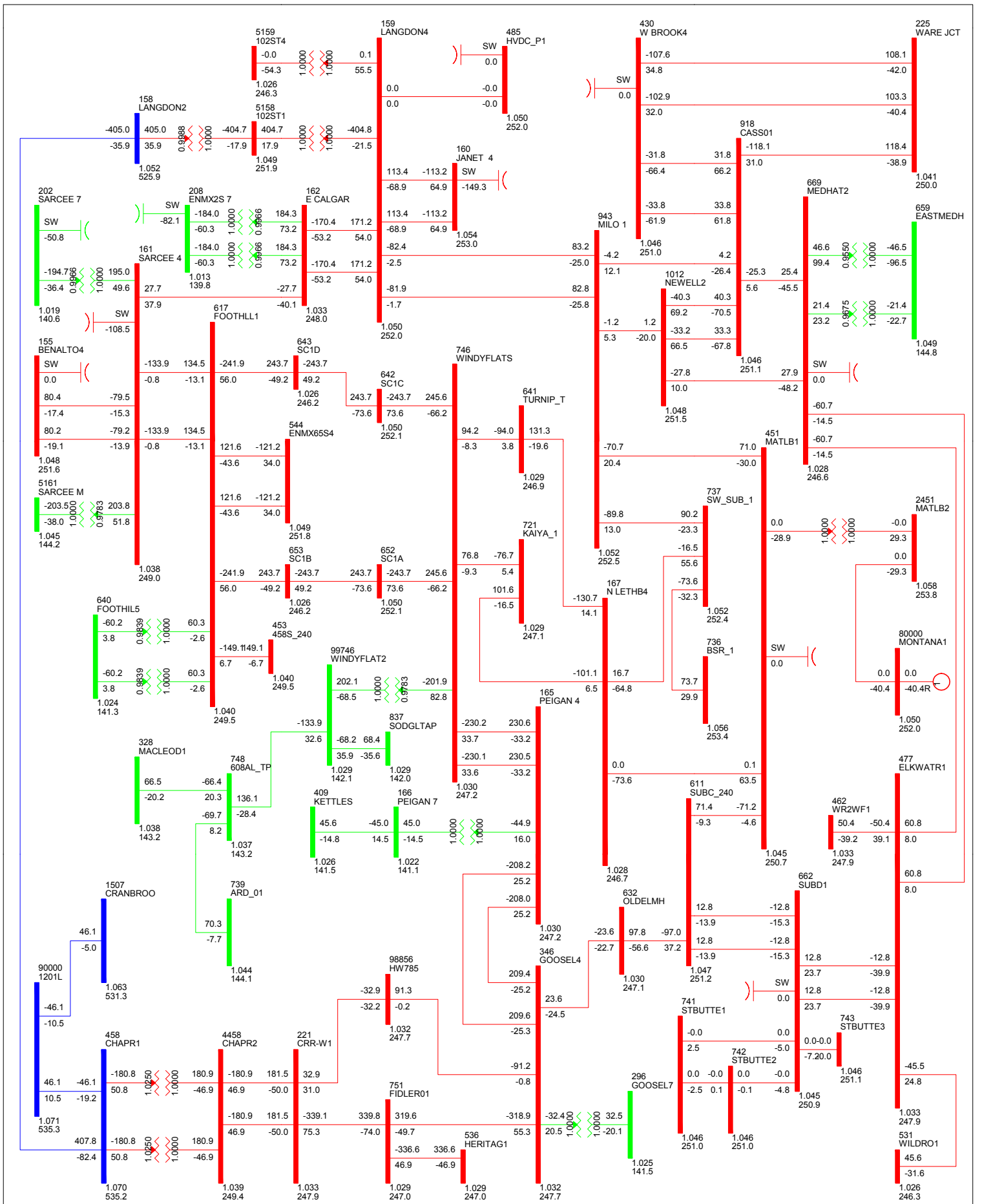


FIG B-W-16: JENNER 4 TO DOME EM4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

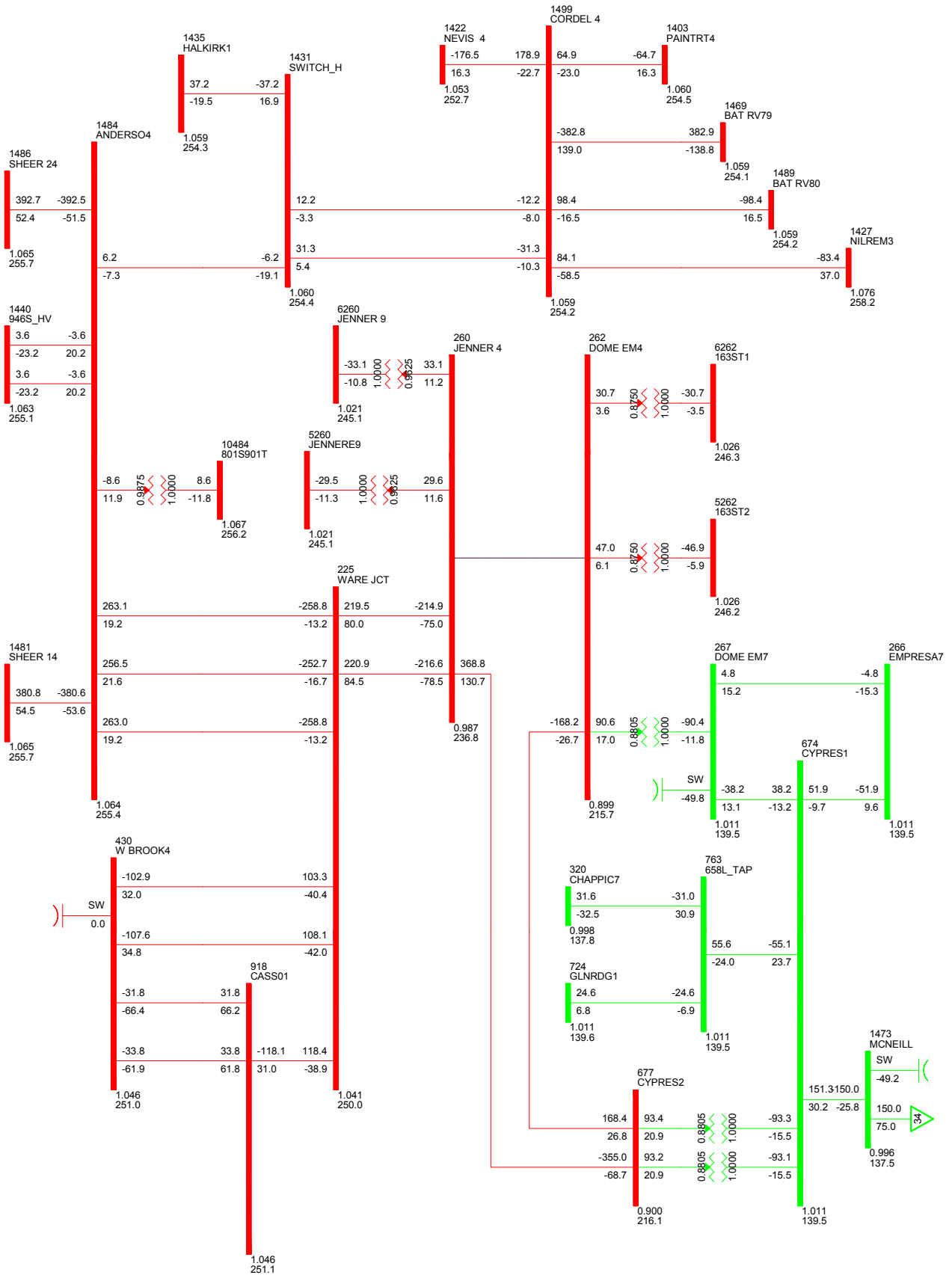


FIG B-E-16: JENNER 4 TO DOME EM4 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

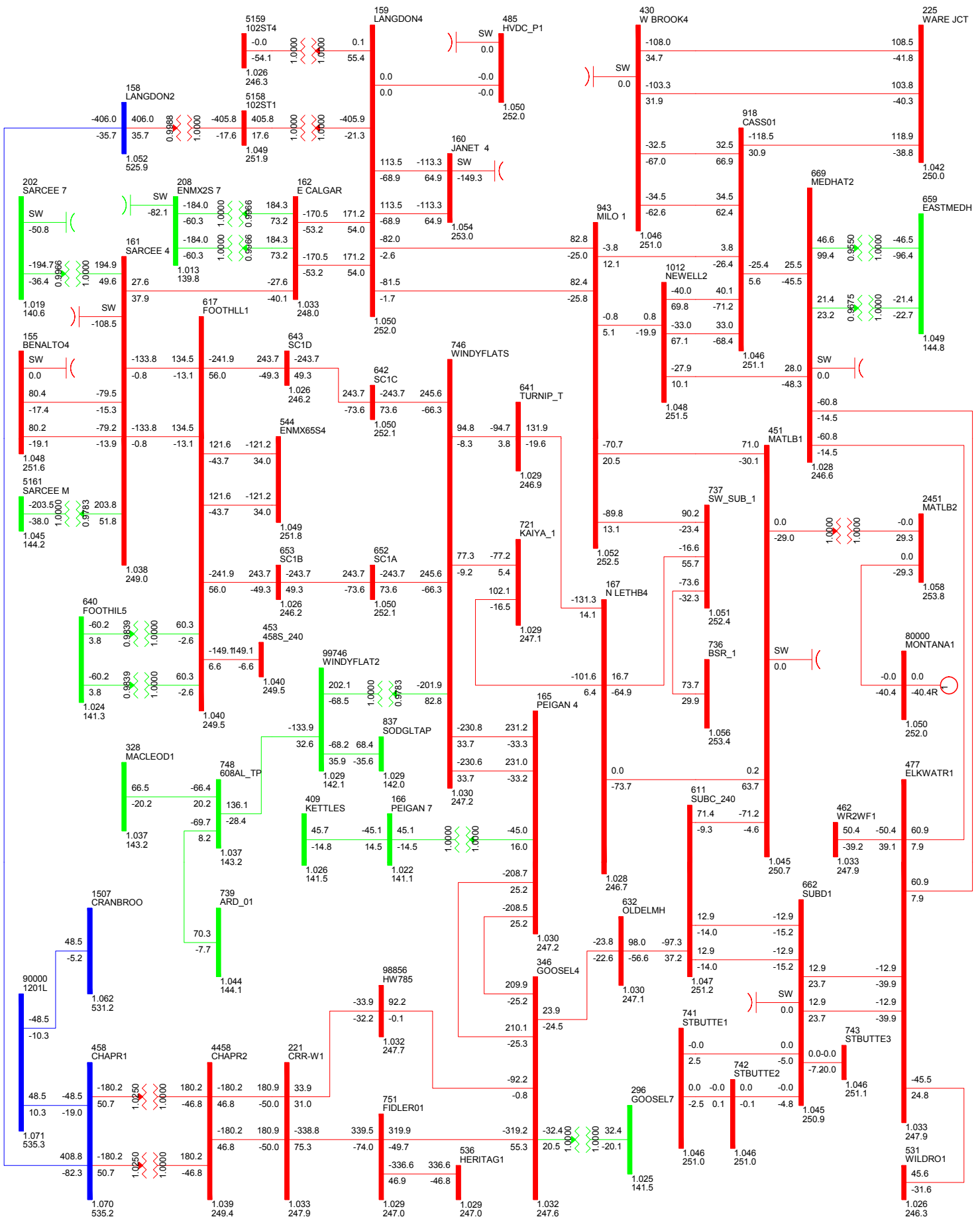


FIG B-W-17: JENNER 4 TO CYPRES2 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

South Reactive Study West (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

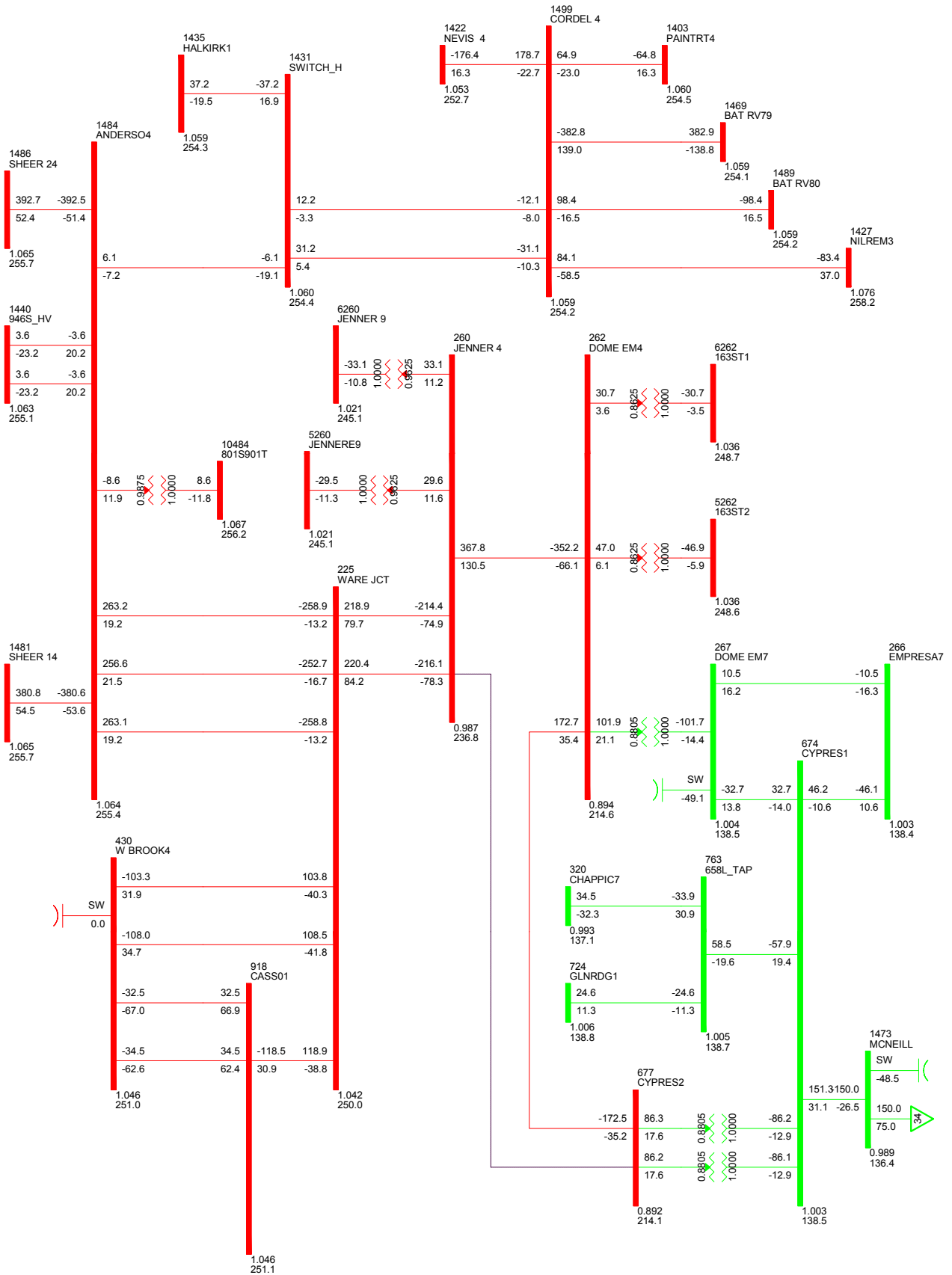


FIG B-E-17: JENNER 4 TO CYPRES2 240 KV LINE
 C13_2022SP_0_0_150_B1_R6
 THU, AUG 30 2012 15:58

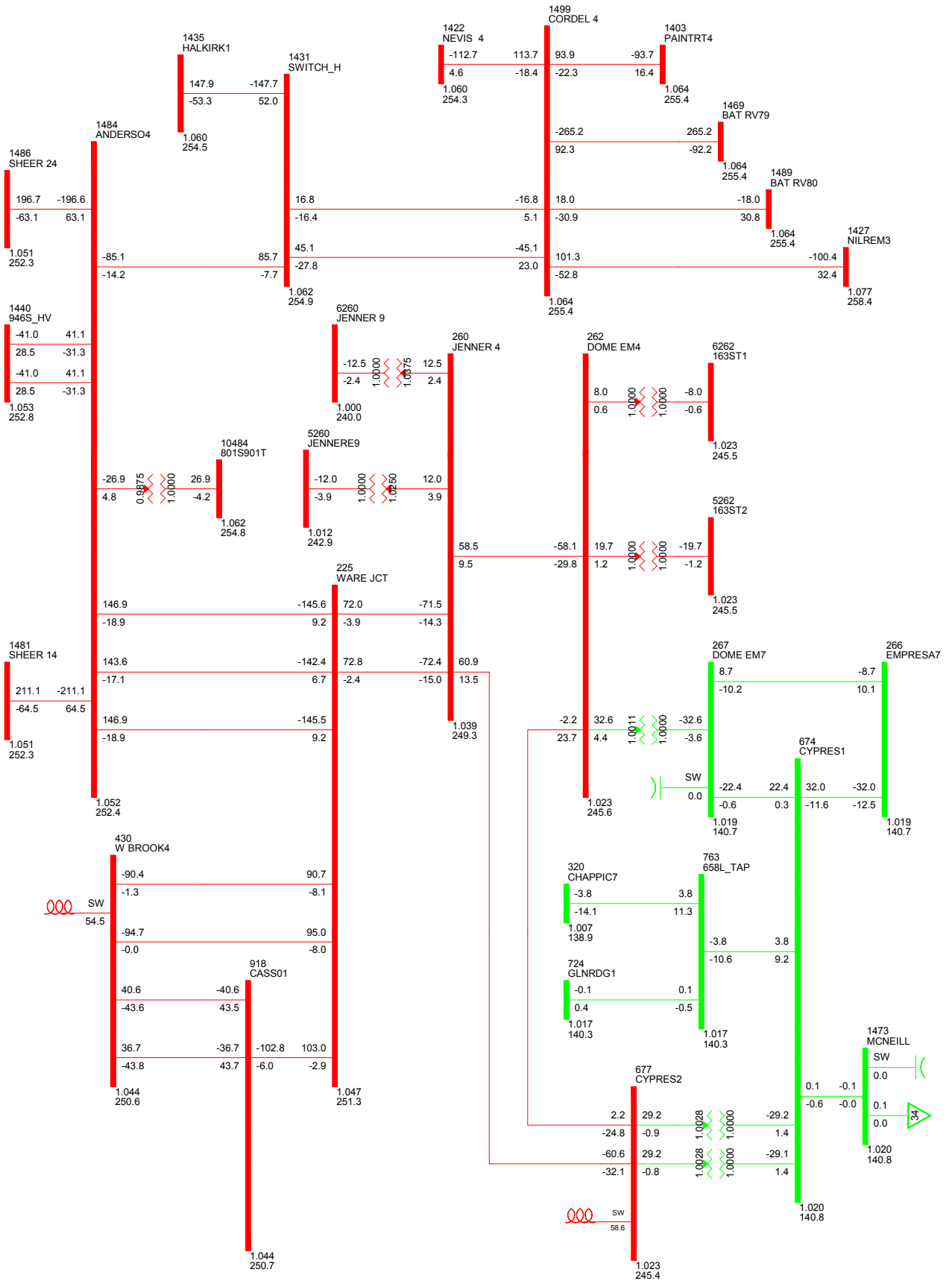
South Reactive Study East (Need Assessment)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000>500.000

Table B-3: Reactive Cases –Category A Plot List

Fig #	Plot Type	Figure Description
Fig C-W- 1	South West	C1M_2015SL_500_0_300 Category A
Fig C-E- 1	South East	C1M_2015SL_500_0_300 Category A
Fig C-W- 2	South West	C1X_2015SL_800_0_0 Category A
Fig C-E- 2	South East	C1X_2015SL_800_0_0 Category A
Fig C-W- 3	South West	C2_2015SL_0_0_0 Category A
Fig C-E- 3	South East	C2_2015SL_0_0_0 Category A
Fig C-W- 4	South West	C3_2015SP_0_0_0 Category A
Fig C-E- 4	South East	C3_2015SP_0_0_0 Category A
Fig C-W- 5	South West	C4M_2017SL_500_0_300 Category A
Fig C-E- 5	South East	C4M_2017SL_500_0_300 Category A
Fig C-W- 6	South West	C4MS_2017SL_500_0_300 Category A
Fig C-E- 6	South East	C4MS_2017SL_500_0_300 Category A
Fig C-W- 7	South West	C5_2017SL_0_0_0 Category A
Fig C-E- 7	South East	C5_2017SL_0_0_0 Category A
Fig C-W- 8	South West	C5S_2017SL_0_0_0 Category A
Fig C-E- 8	South East	C5S_2017SL_0_0_0 Category A
Fig C-W- 9	South West	C6_2017SP_0_0_0 Category A
Fig C-E- 9	South East	C6_2017SP_0_0_0 Category A
Fig C-W- 10	South West	C6S_2017SP_0_0_0 Category A
Fig C-E- 10	South East	C6S_2017SP_0_0_0 Category A
Fig C-W- 11	South West	C7M_2022SL_500_0_300 Category A
Fig C-E- 11	South East	C7M_2022SL_500_0_300 Category A
Fig C-W- 12	South West	C7X_2022SL_800_0_0 Category A
Fig C-E- 12	South East	C7X_2022SL_800_0_0 Category A
Fig C-W- 13	South West	C8_2022SL_0_0_0 Category A
Fig C-E- 13	South East	C8_2022SL_0_0_0 Category A
Fig C-W- 14	South West	C9_2022SP_0_0_0 Category A
Fig C-E- 14	South East	C9_2022SP_0_0_0 Category A
Fig C-W- 15	South West	C10_2015SP_-780_0_0 Category A
Fig C-E- 15	South East	C10_2015SP_-780_0_0 Category A
Fig C-W- 16	South West	C11_2017SP_-780_0_-150 Category A
Fig C-E- 16	South East	C11_2017SP_-780_0_-150 Category A
Fig C-W- 17	South West	C11S_2017SP_-780_0_-150 Category A
Fig C-E- 17	South East	C11S_2017SP_-780_0_-150 Category A
Fig C-W- 18	South West	C12_2022SP_-1200_0_0 Category A
Fig C-E- 18	South East	C12_2022SP_-1200_0_0 Category A
FIG C-W-19	South West	C13_2022SP_0_0_150 Category A
FIG C-E-19	South East	C13_2022SP_0_0_150 Category A
FIG C-W-20	South West	C14_2017SL_500_0_300 Category A

FIG C-E-20	South East	C14_2017SL_500_0_300 Category A
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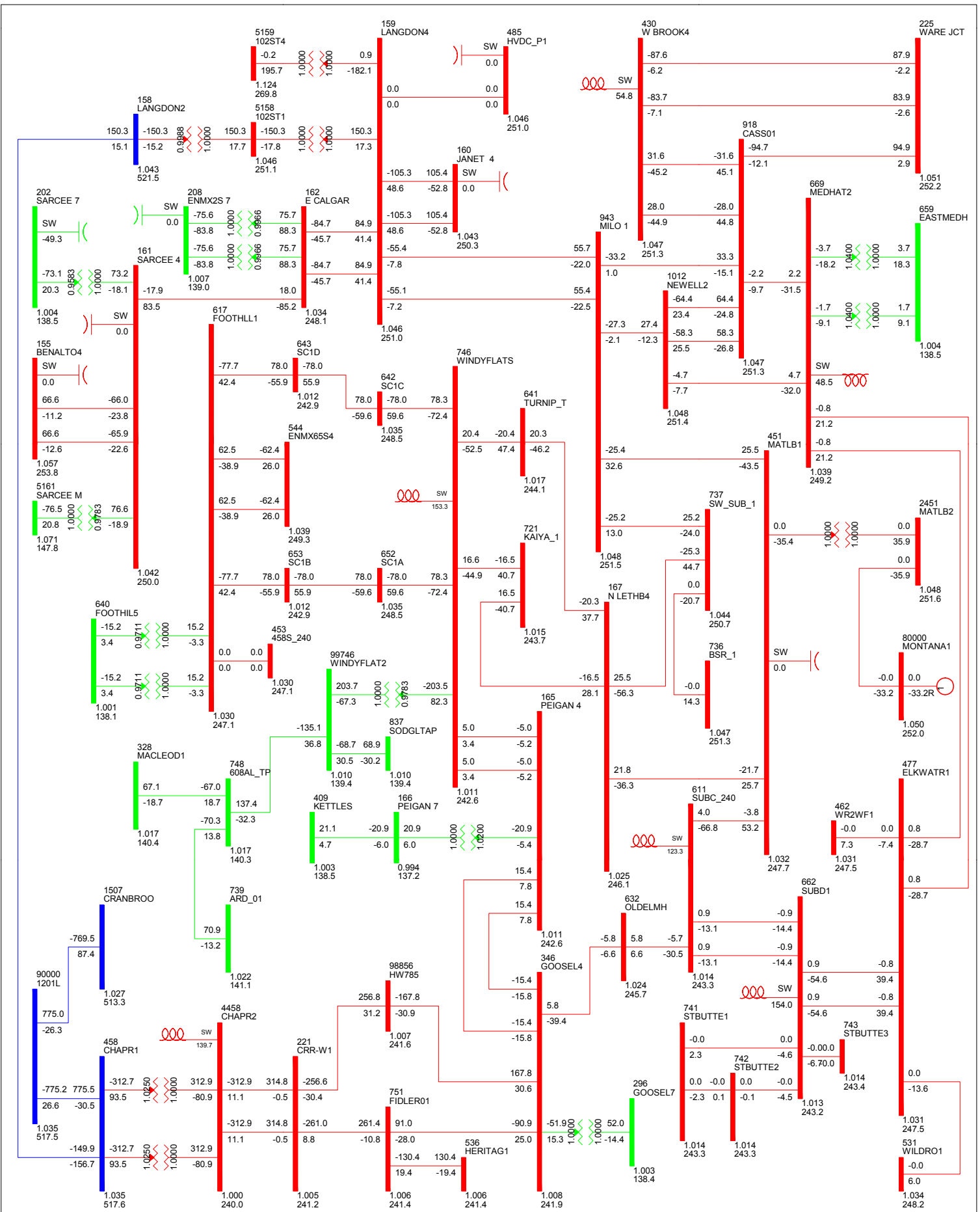


FIG C-W-2: BASECASE
 C1X_2015SL_800_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

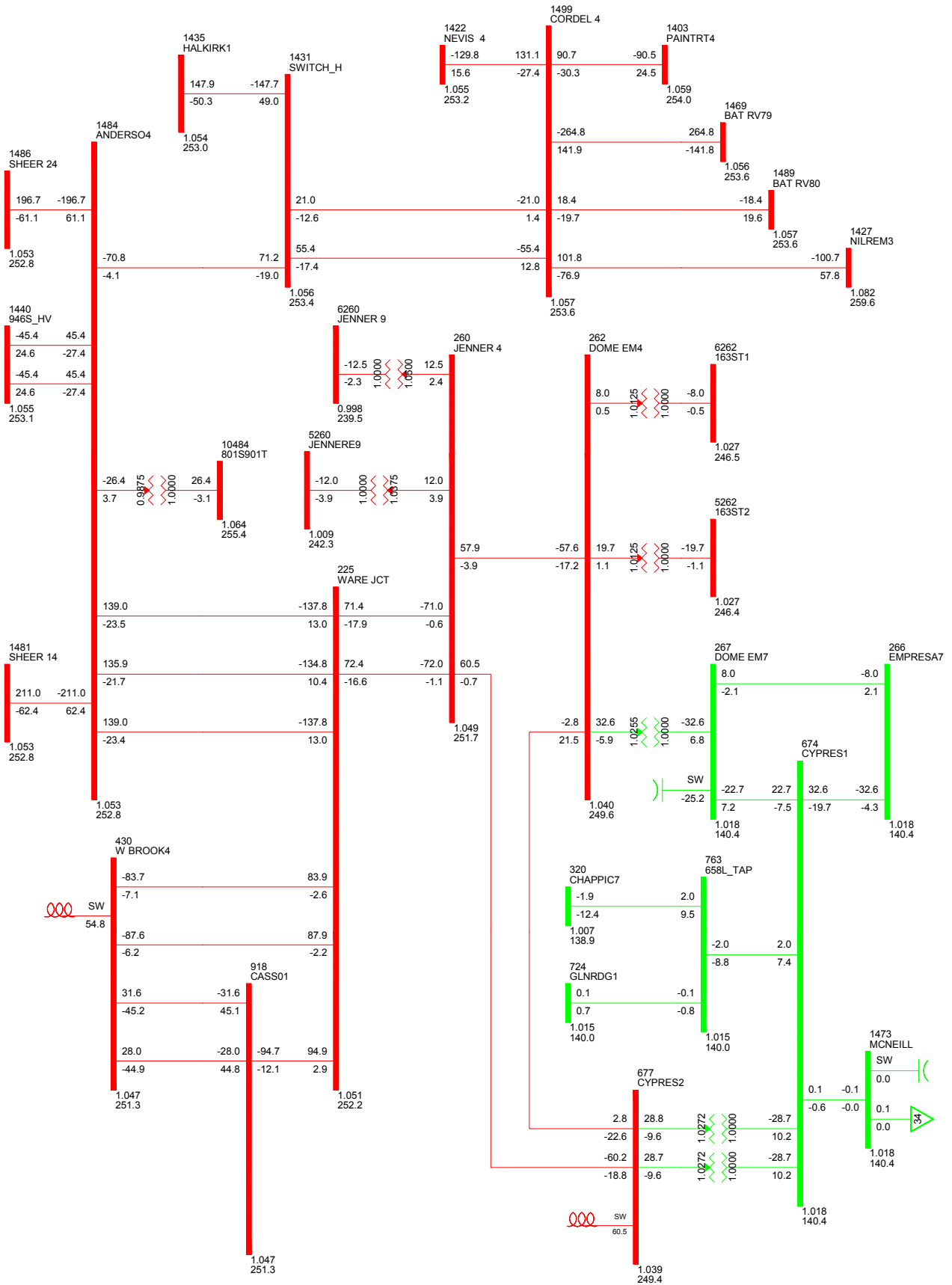


FIG C-E-2: BASECASE
 C1X_2015SL_800_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

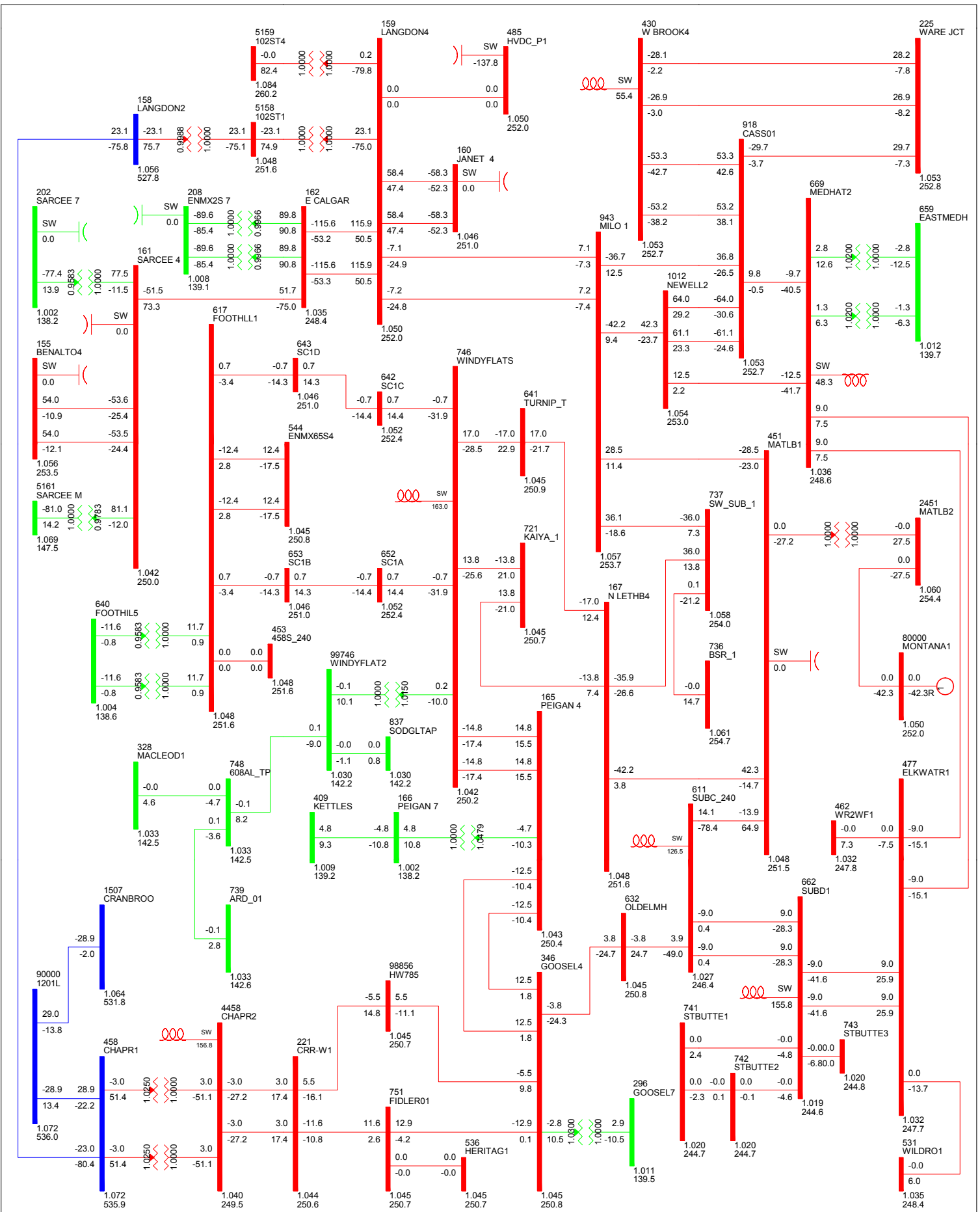


FIG C-W-3: BASECASE
 C2_2015SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <math>Q < -34.500</math> <math>Q < -69.000</math> <math>Q < -138.000</math> <math>Q < -240.000</math> $Q > -500.000$ $Q > 500.000$

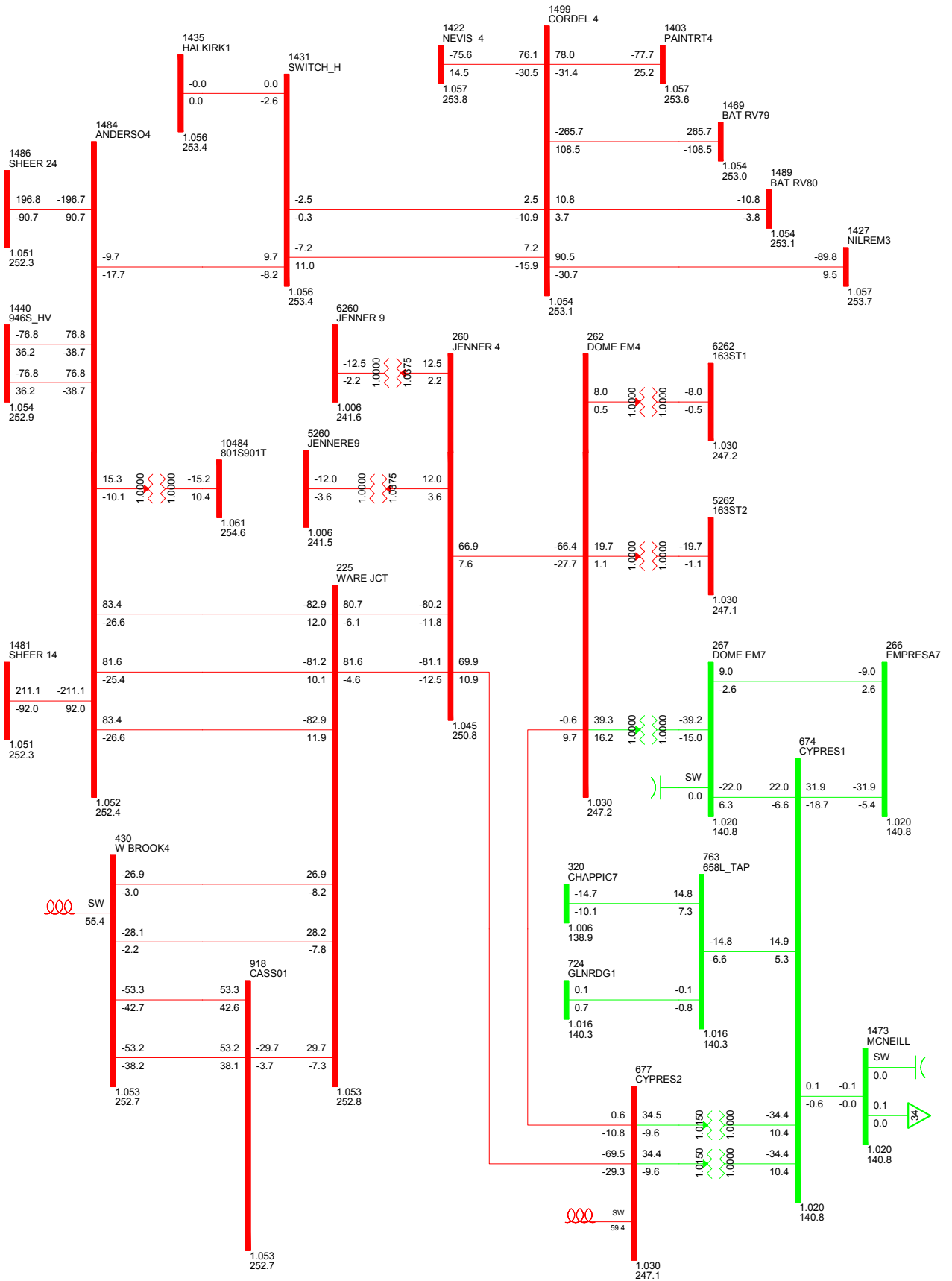


FIG C-E-3: BASECASE
 C2_2015SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

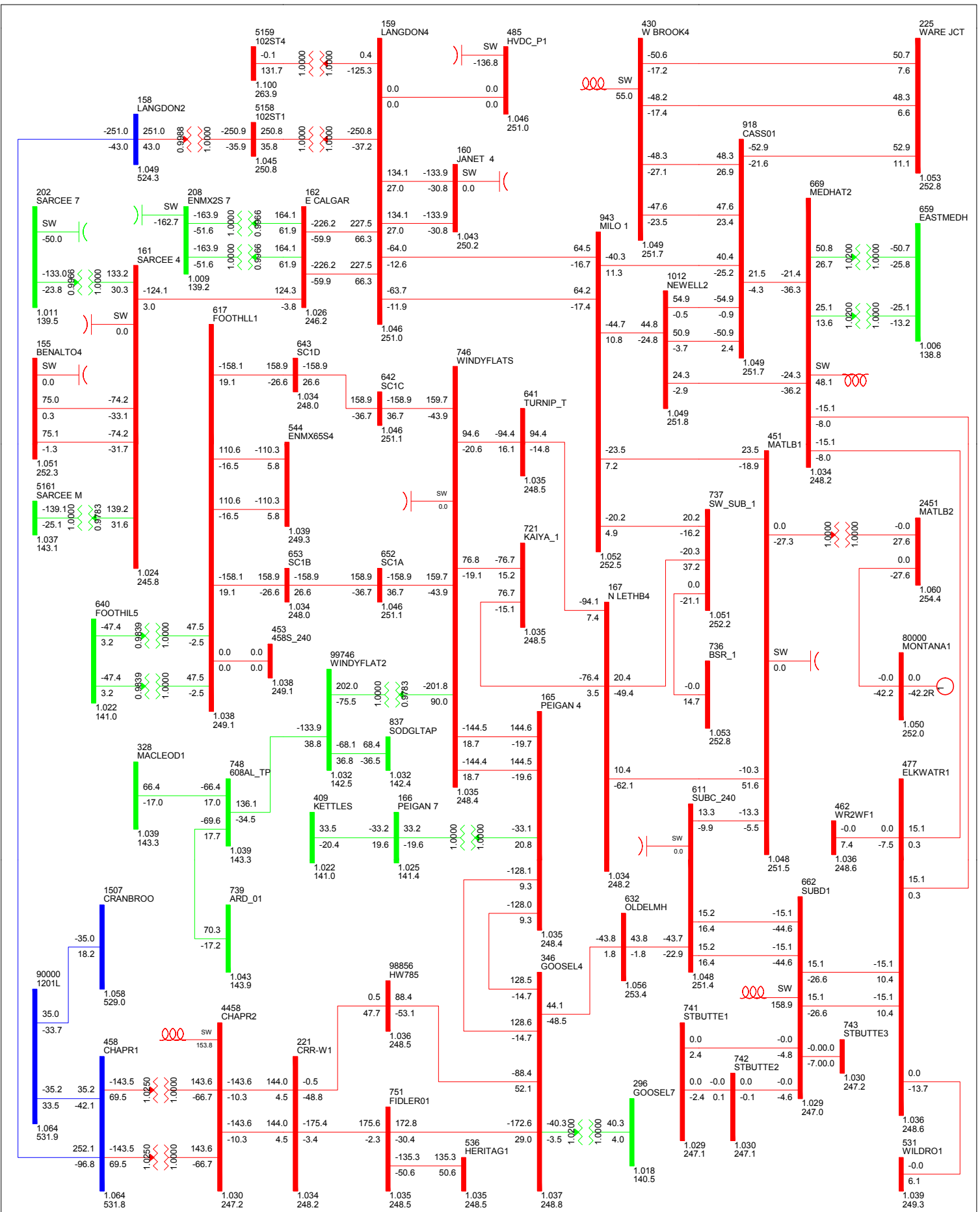


FIG C-W-4: BASECASE
 C3_2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

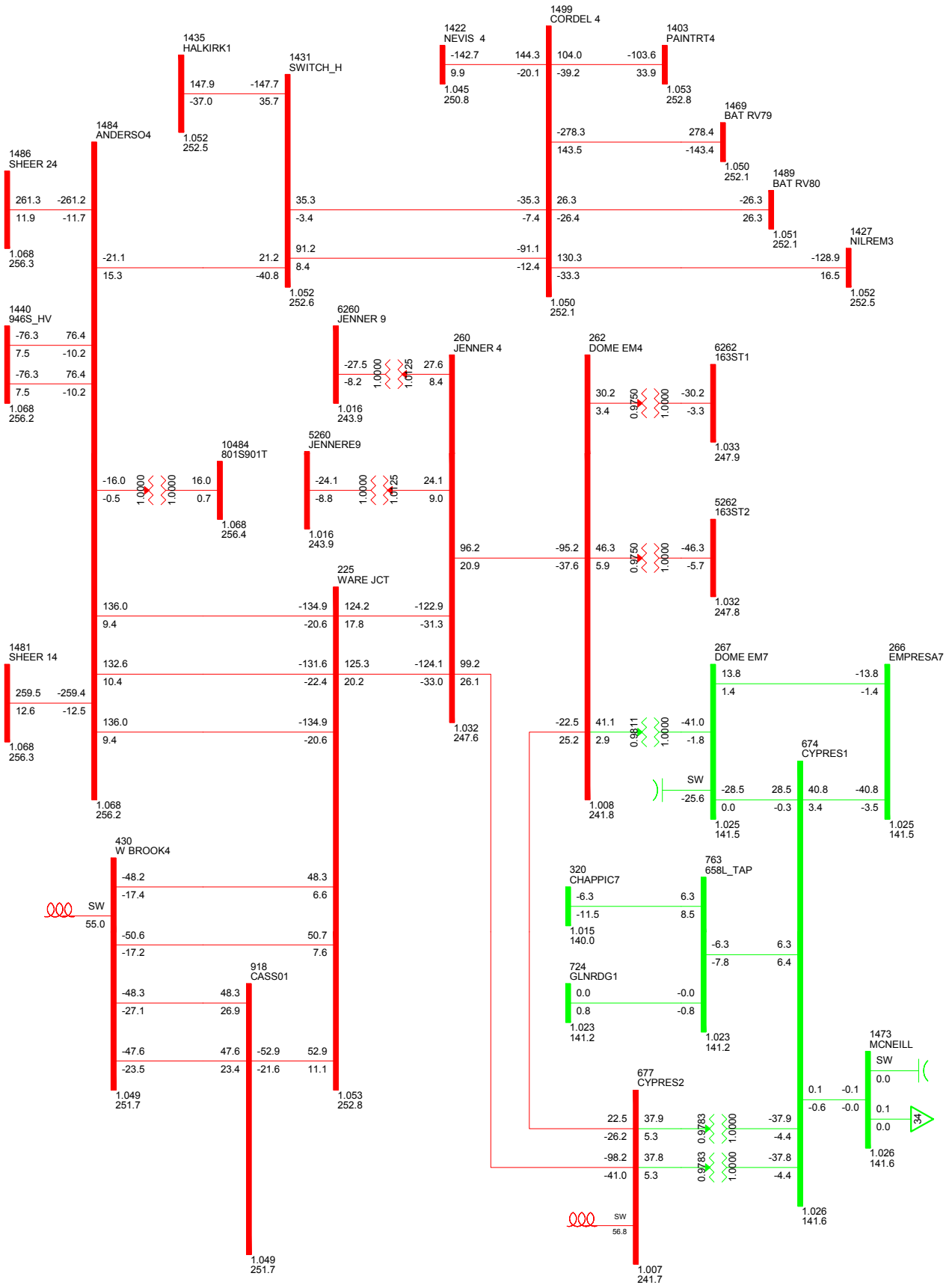


FIG C-E-4: BASECASE
 C3_2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

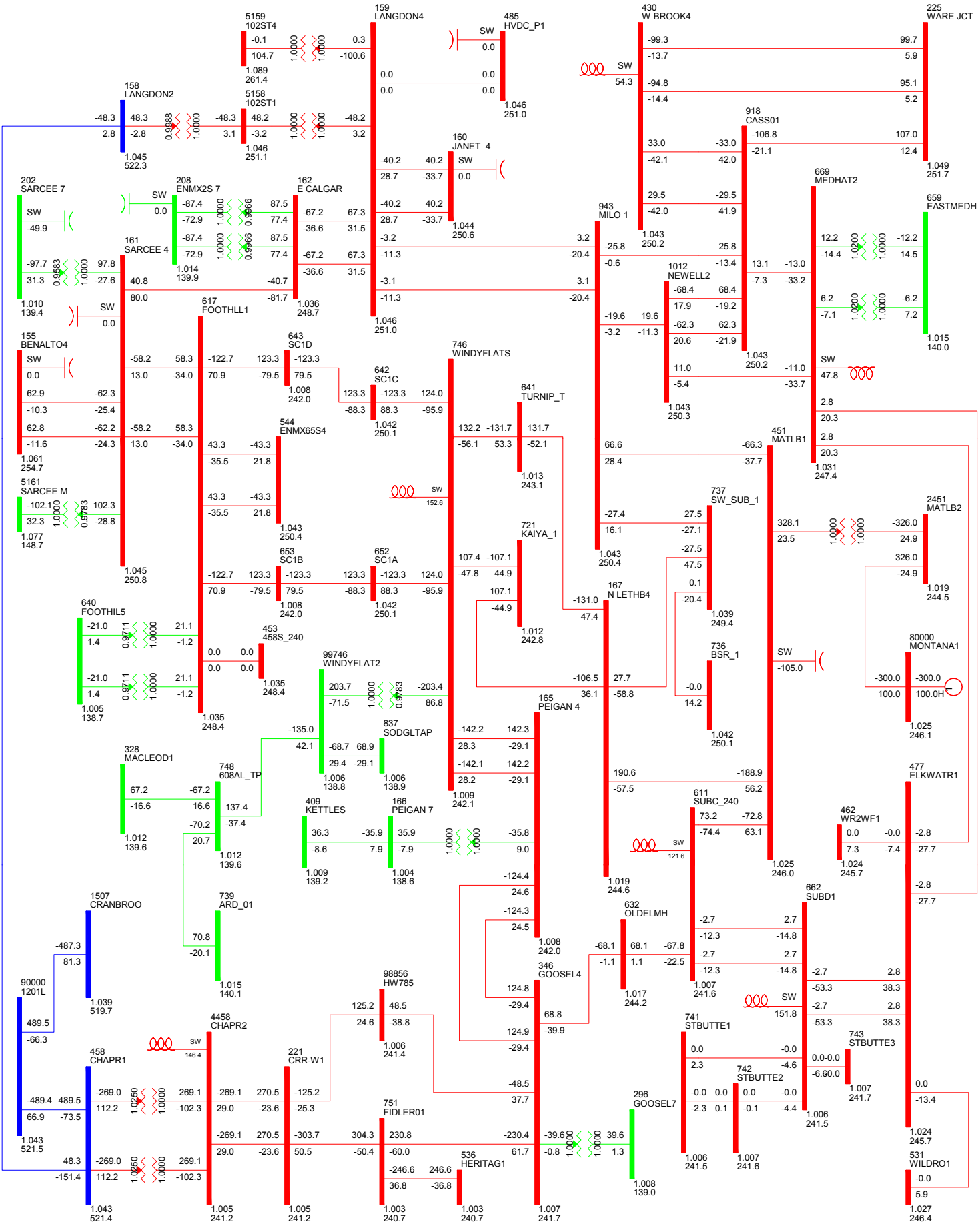
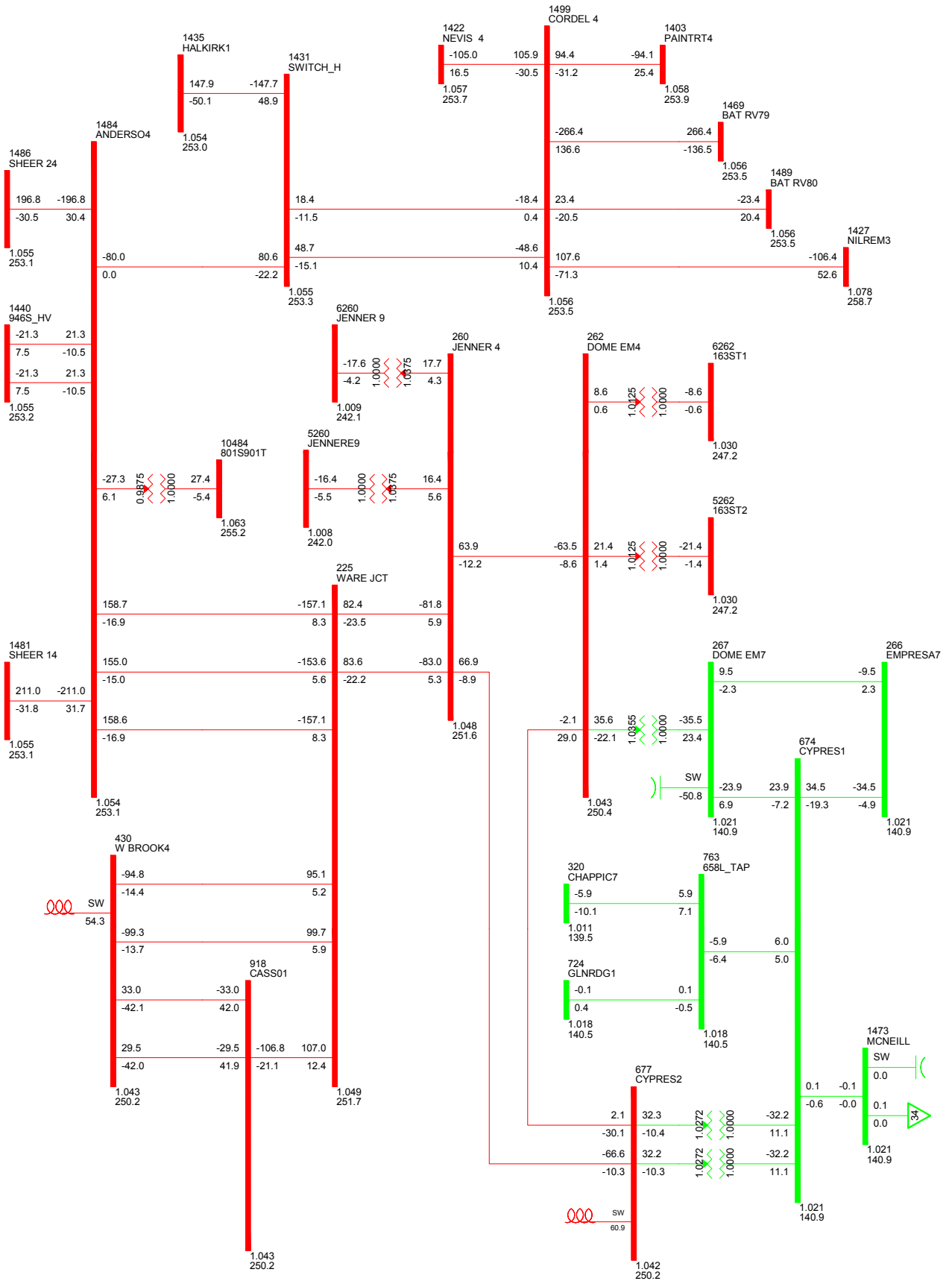


FIG C-W-5: BASECASE
 C4M_2017SL_500_0_300_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=-69.000 <=138.000 <=240.000 <=500.000 >500.000



South Reactive Study East (Reactive Cases)

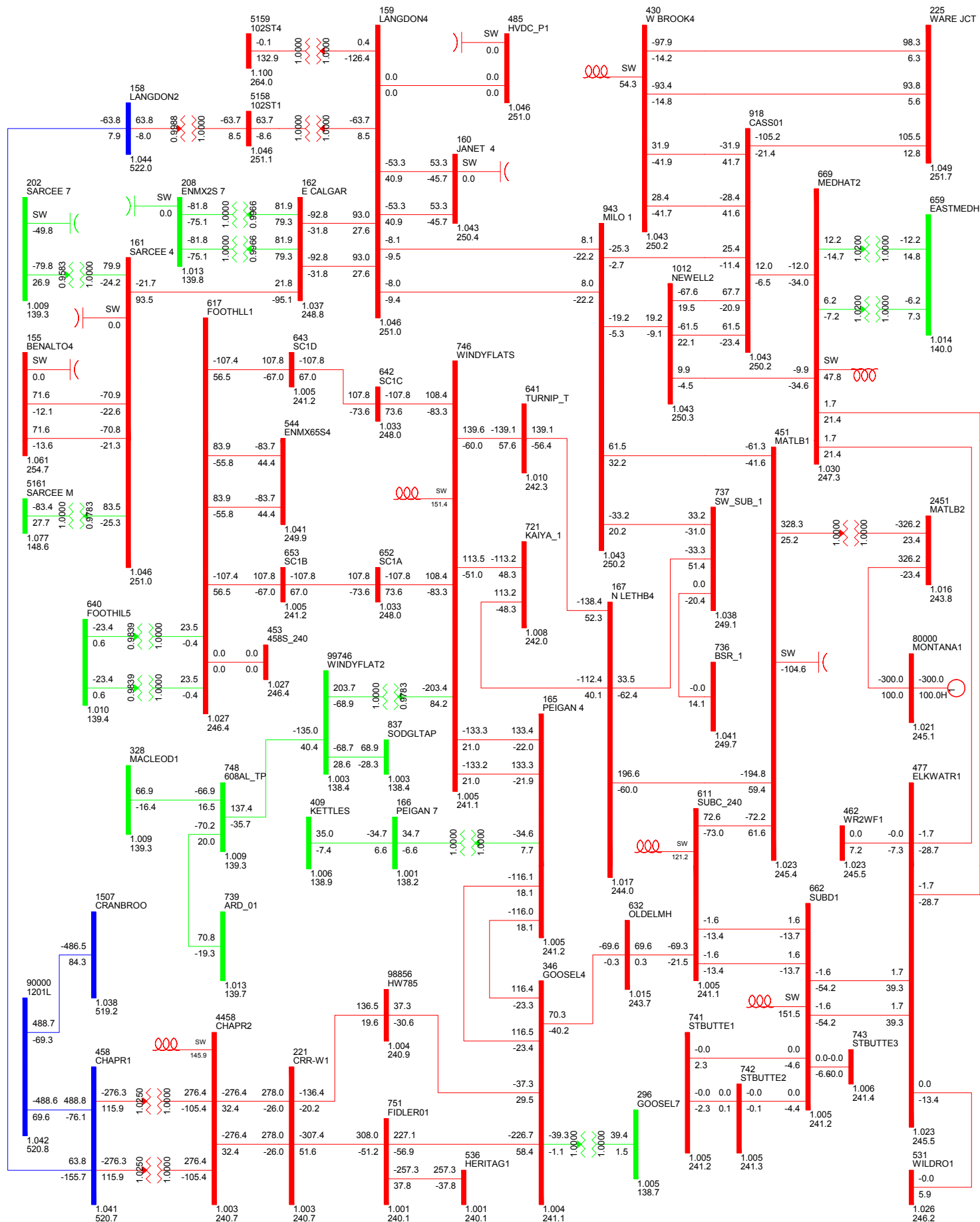


FIG C-W-6: BASECASE
 C4MS_2017SL_500_0_300_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

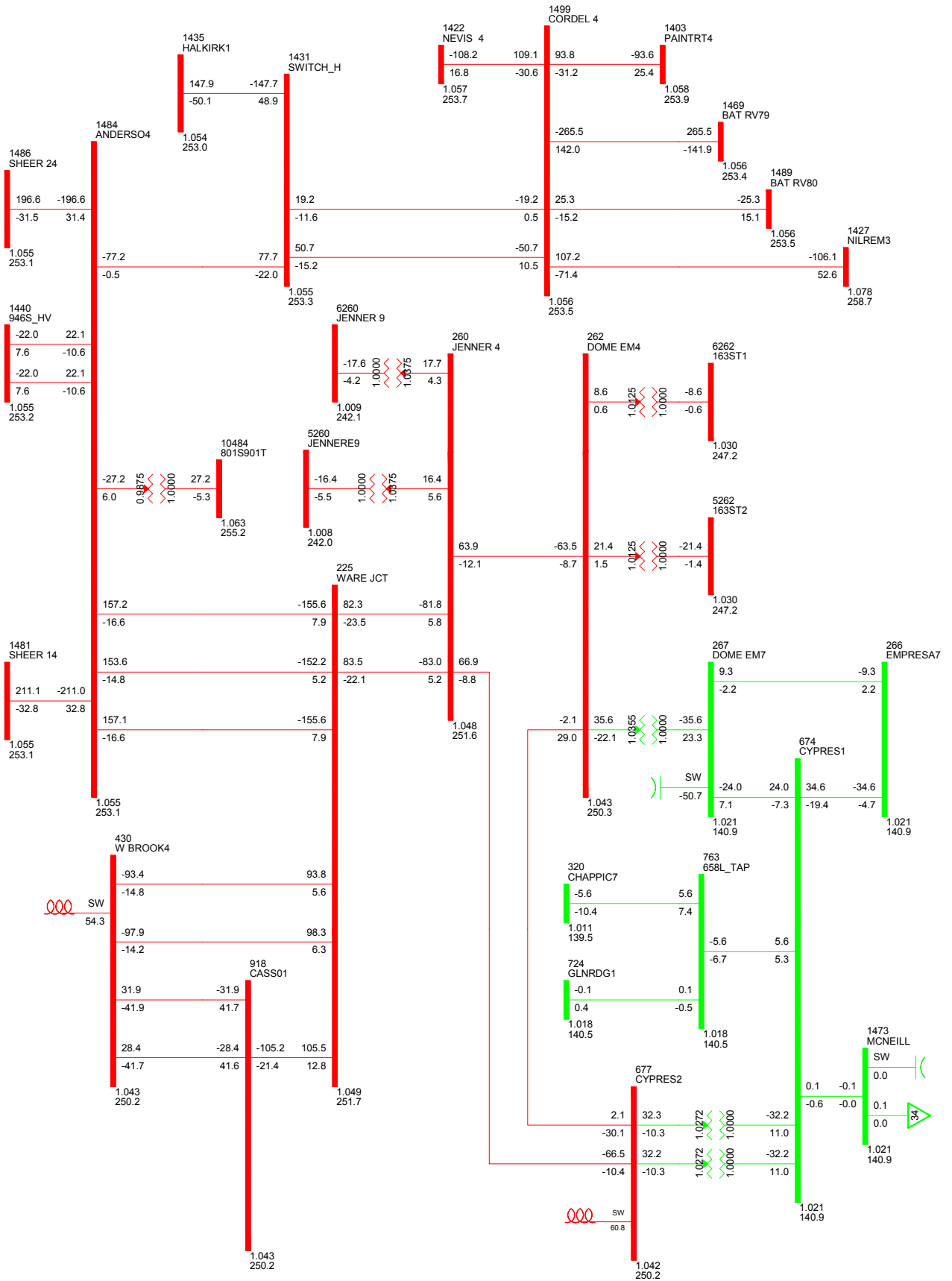


FIG C-E-6: BASECASE
 C4MS_2017SL_500_0_300_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

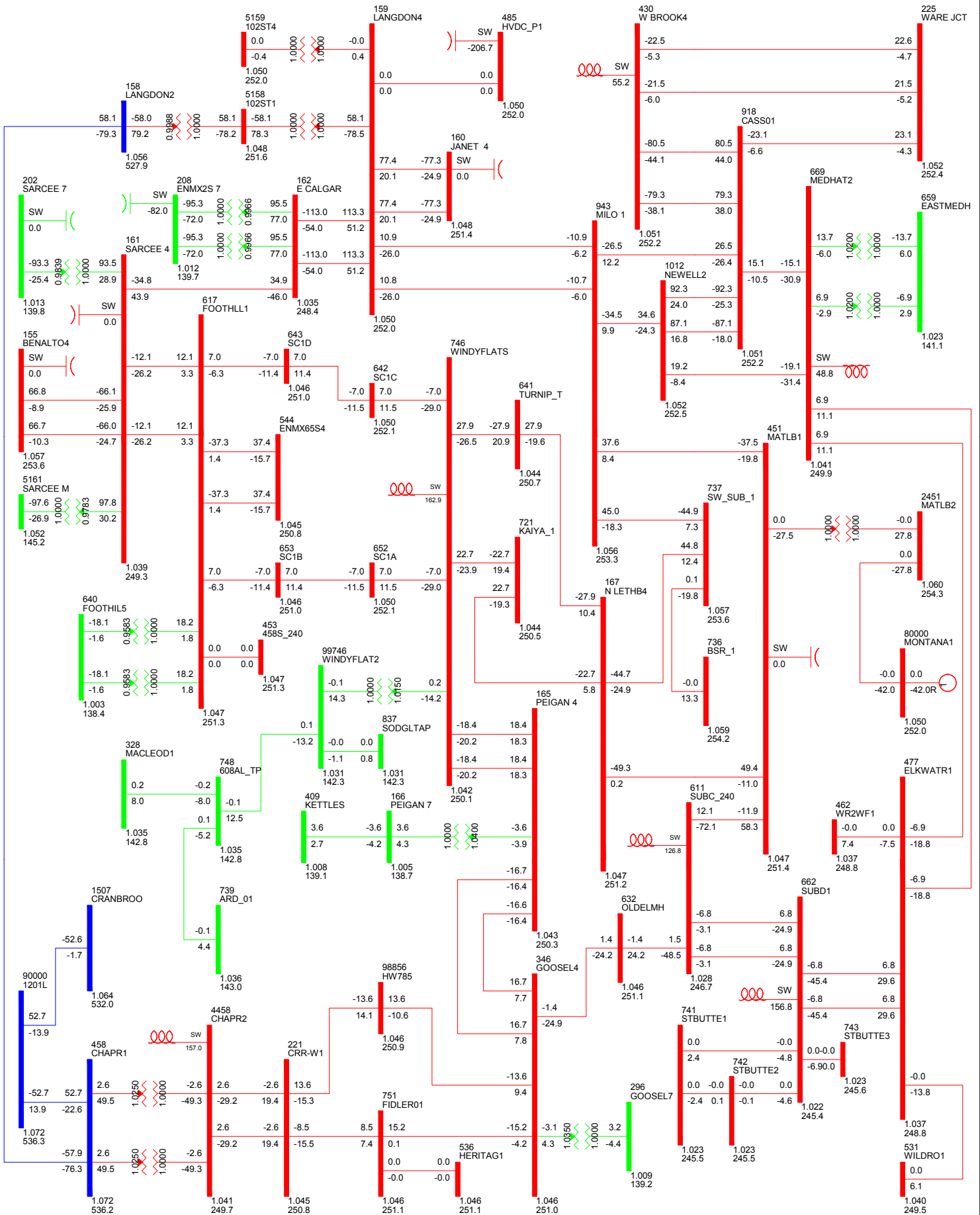


FIG C-W-7: BASECASE
 C5_2017SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

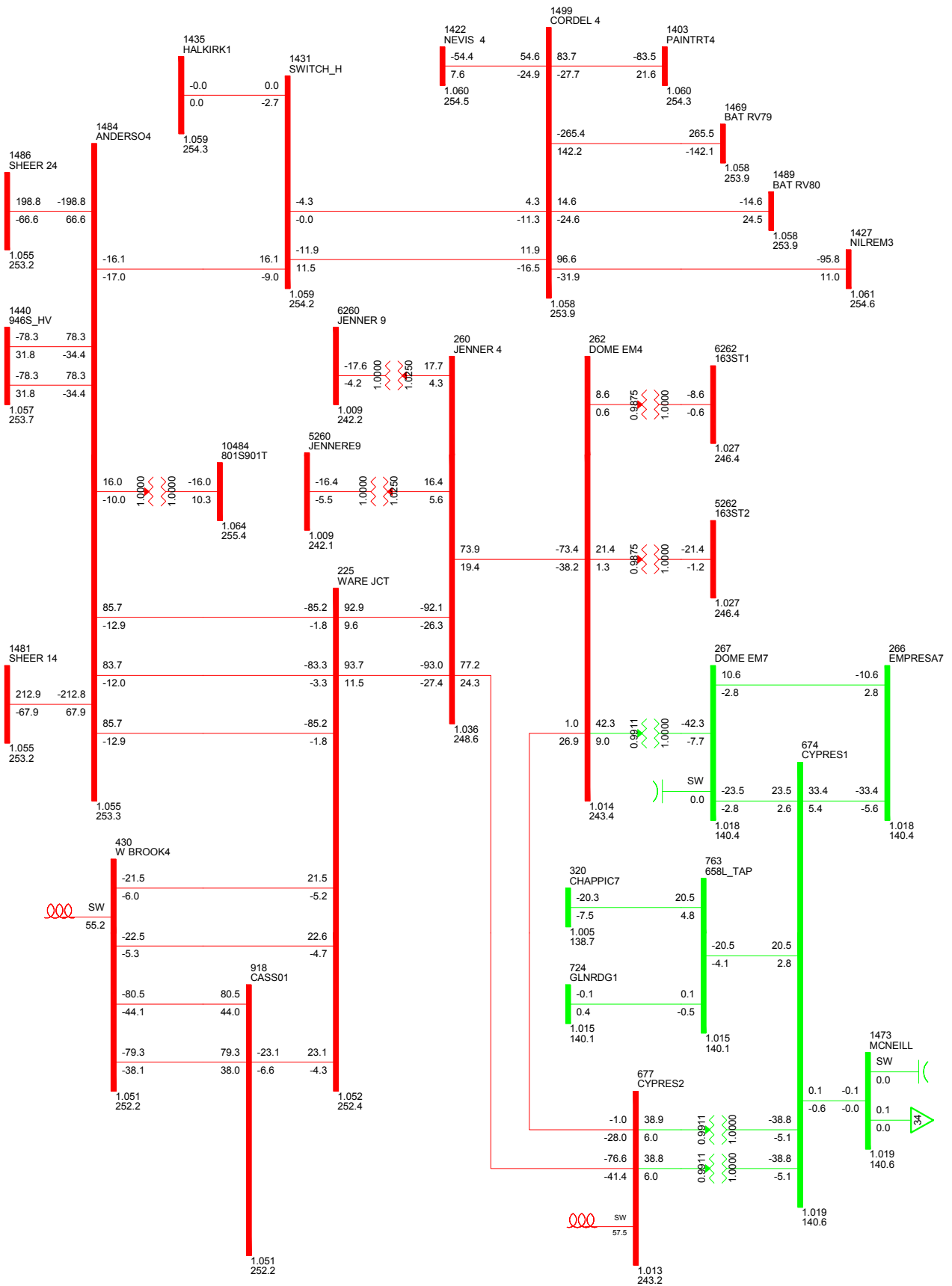


FIG C-E-7: BASECASE
 C5_2017SL_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

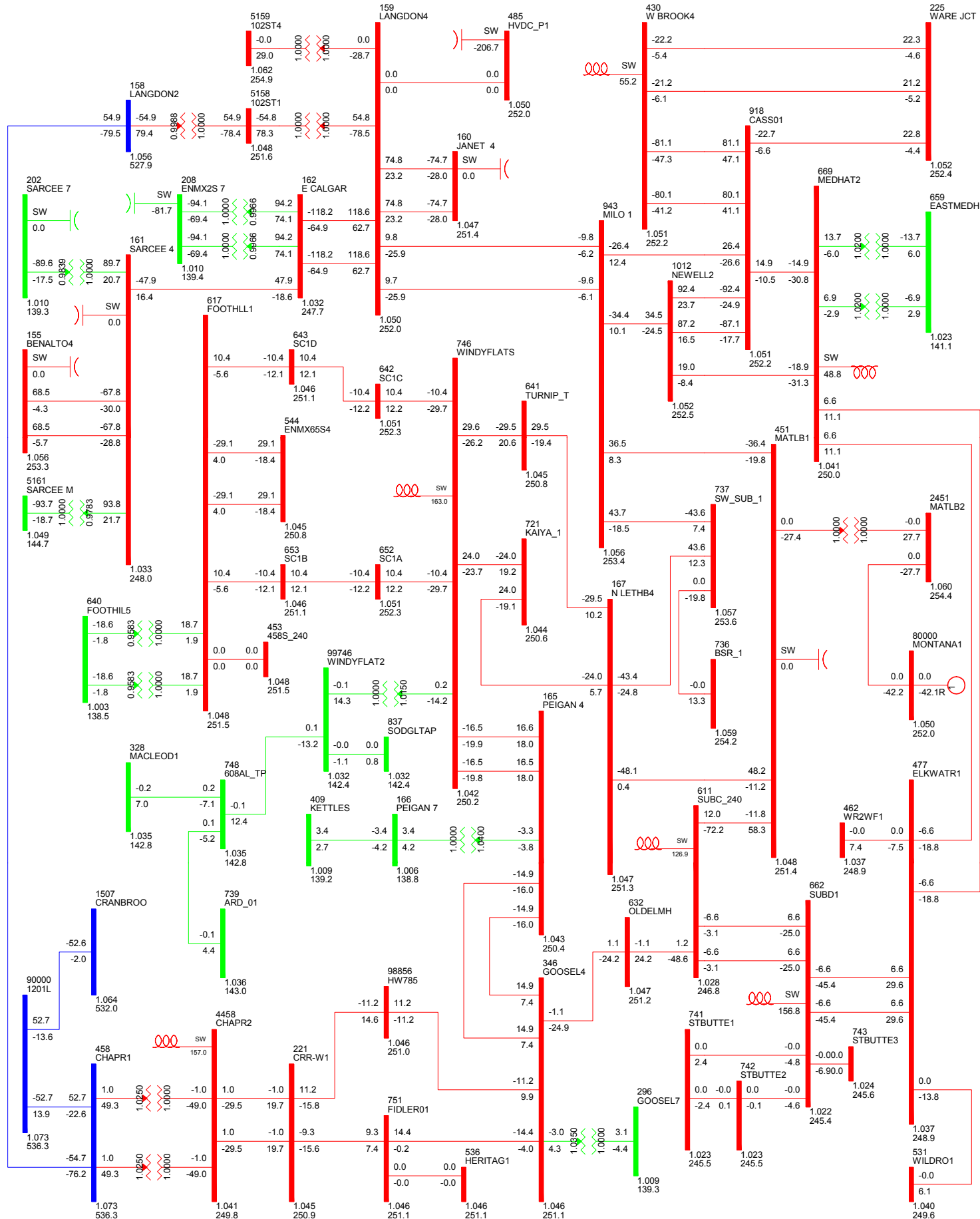


FIG C-W-8: BASECASE
 CSS_2017SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

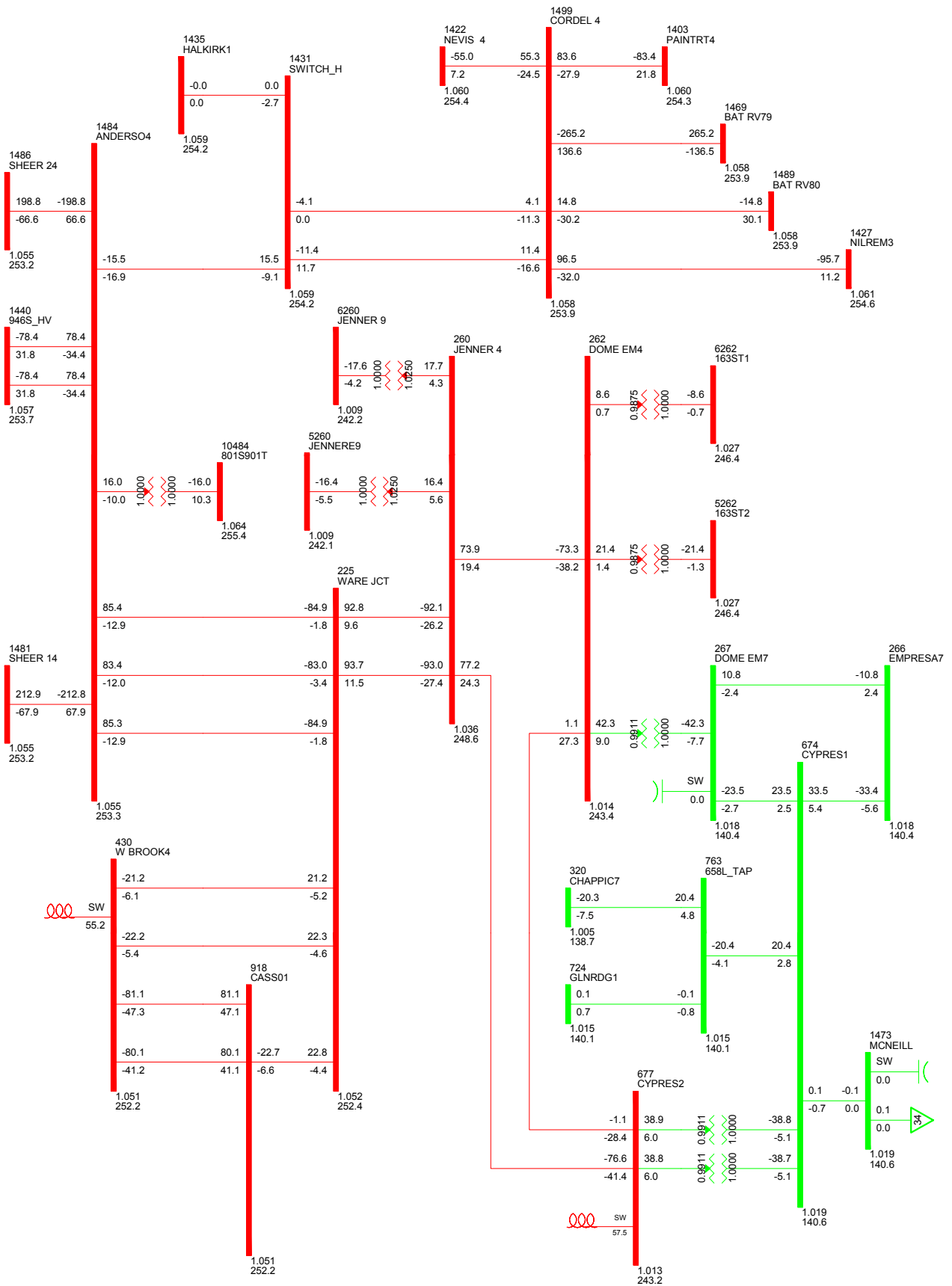


FIG C-E-8: BASECASE
 C6S_2017SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <math> <= 34.500 < 69.000 < 138.000 < 240.000 < 500.000 > 500.000 </math>

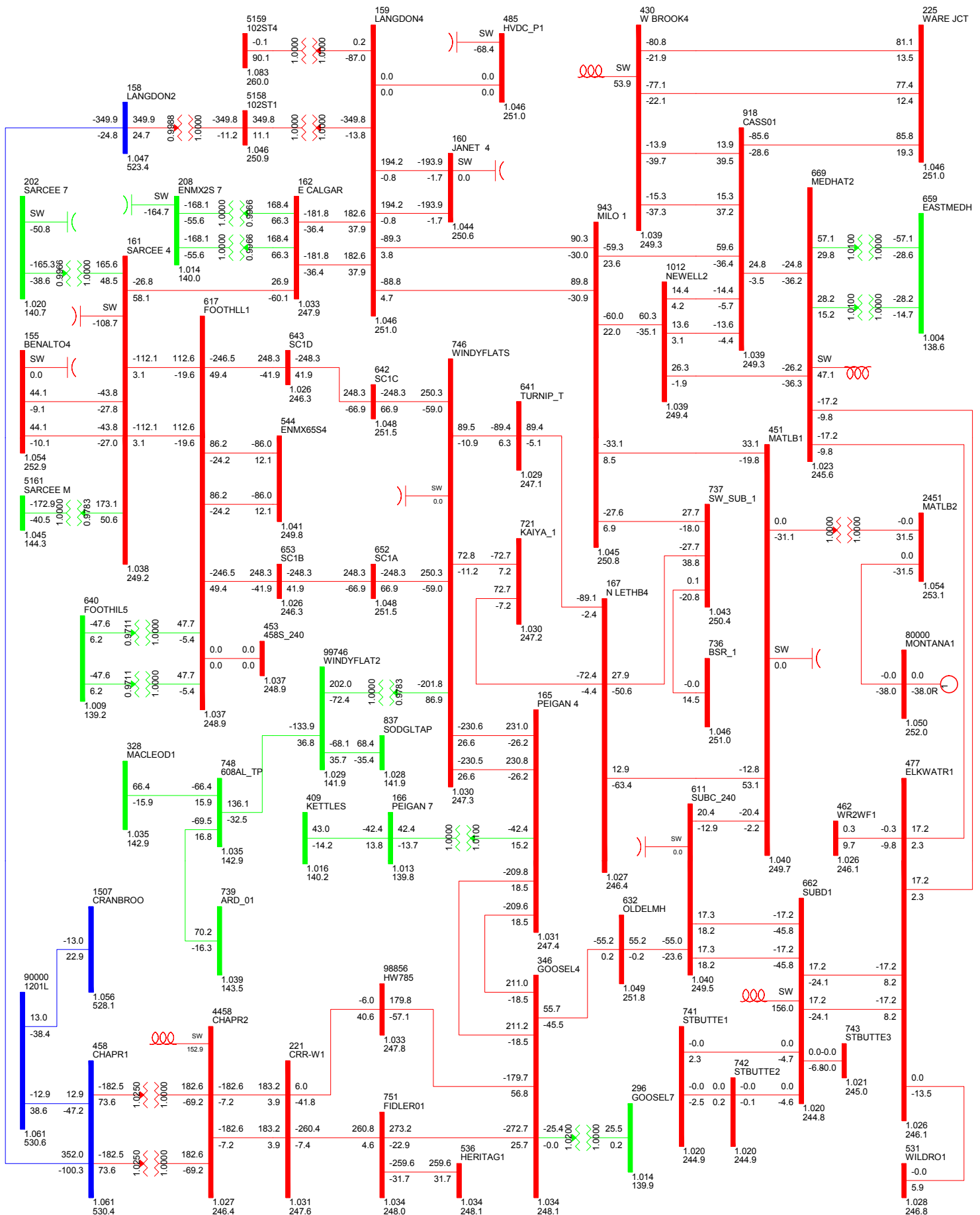


FIG C-W-9: BASECASE
 C6_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

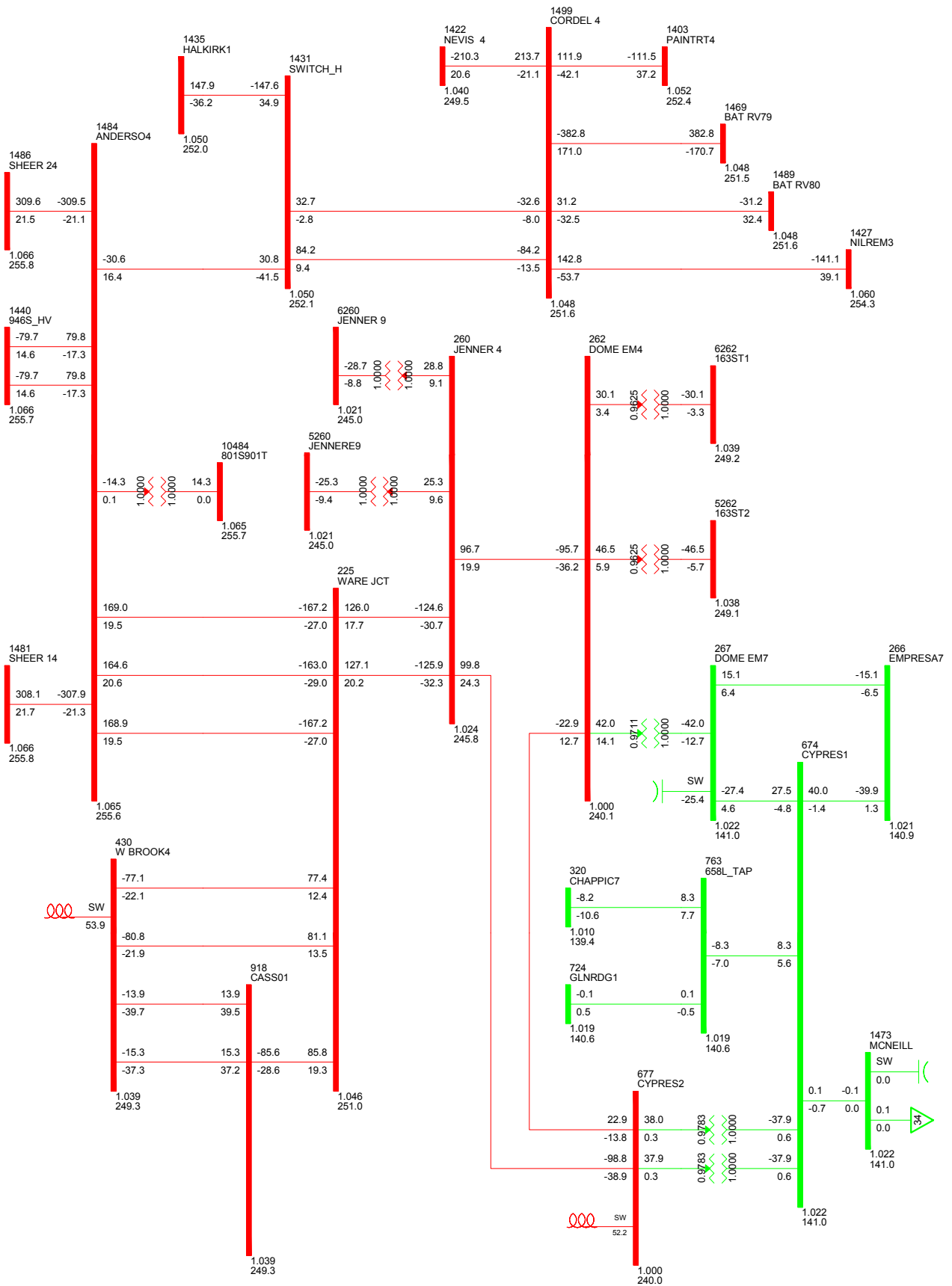


FIG C-E-9: BASECASE
 C6_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

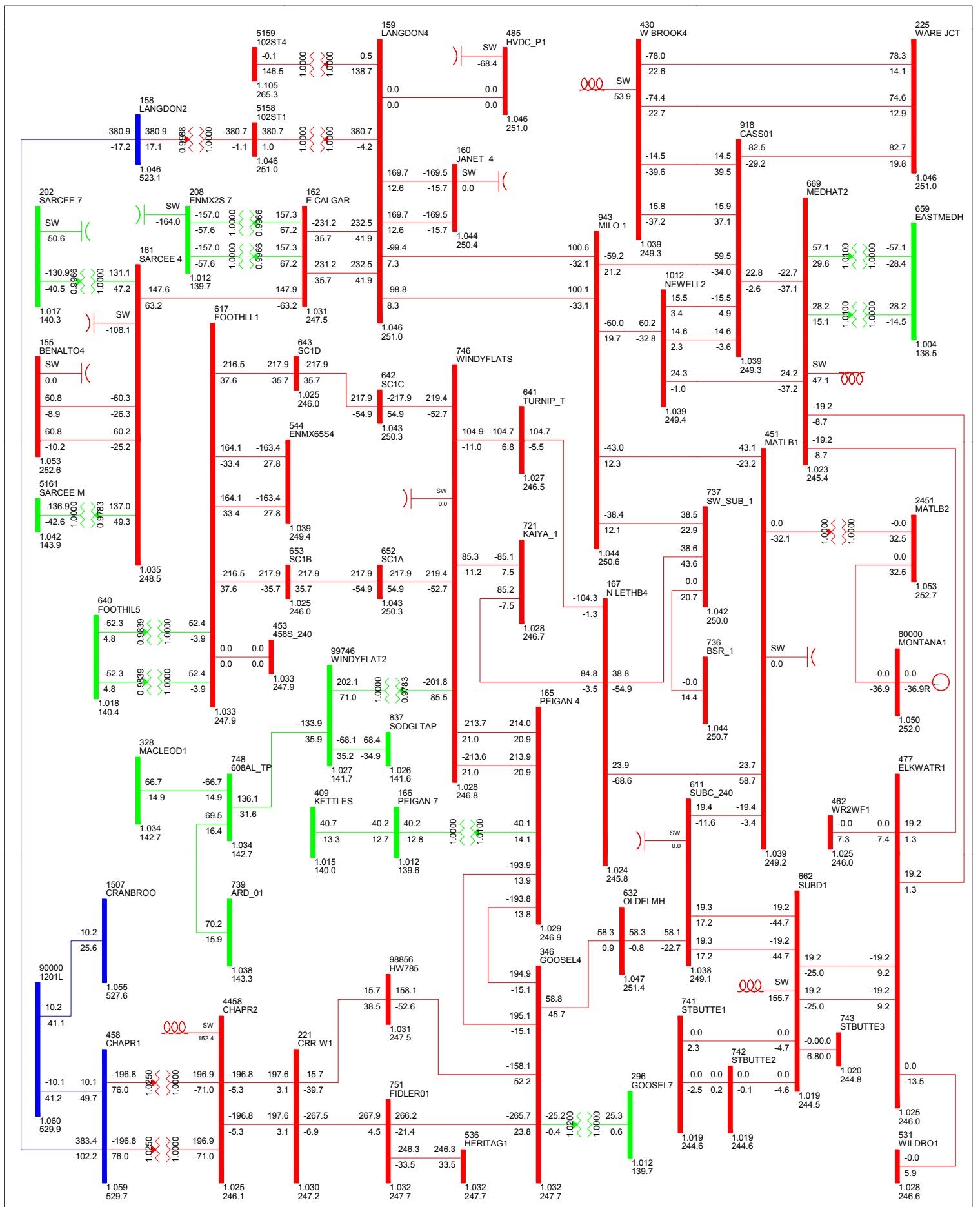


FIG C-W-10: BASECASE
 CGS_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

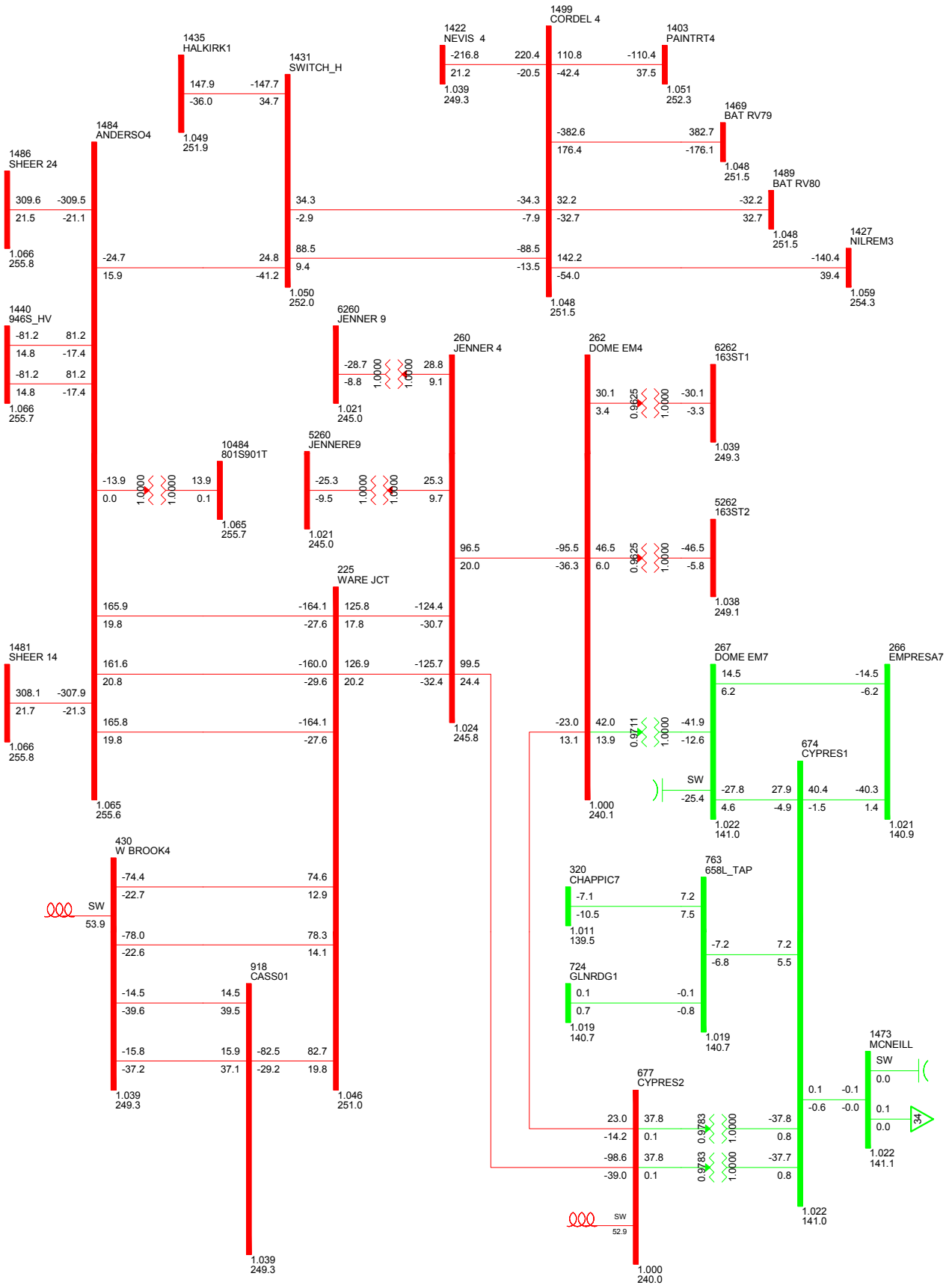


FIG C-E-10: BASECASE
 C6S_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

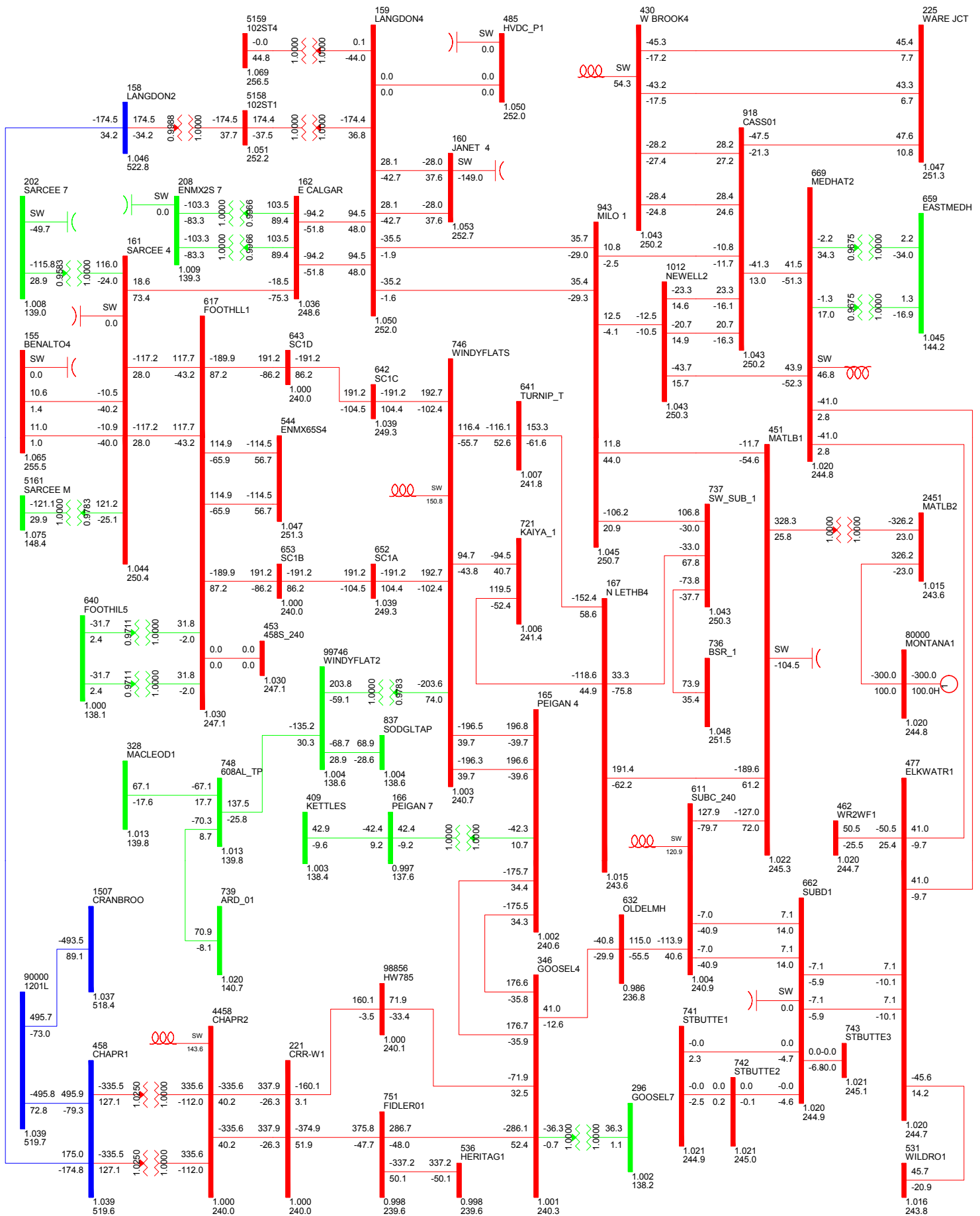
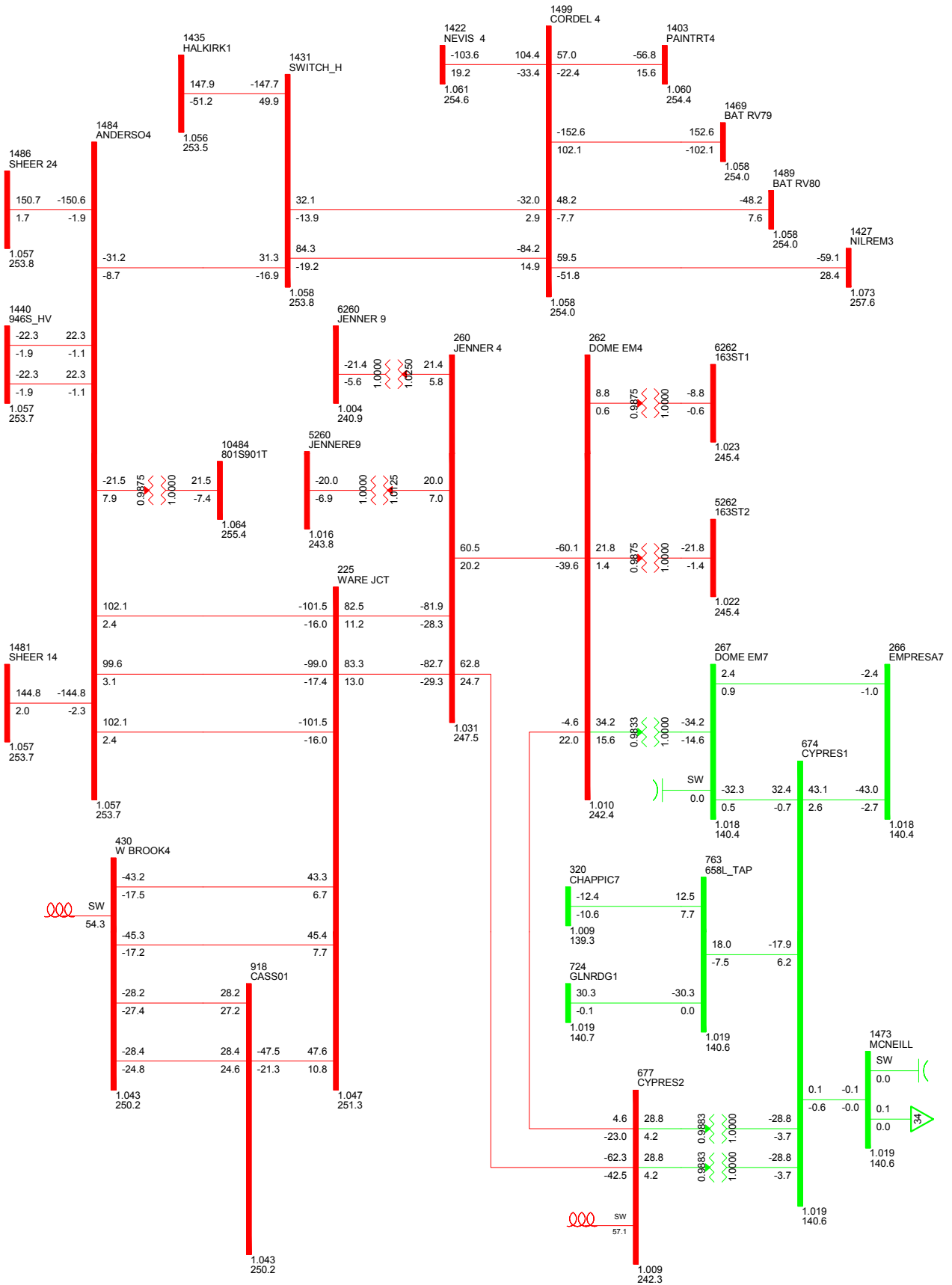


FIG C-W-11: BASECASE
 C7M_2022SL_500_0_300_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



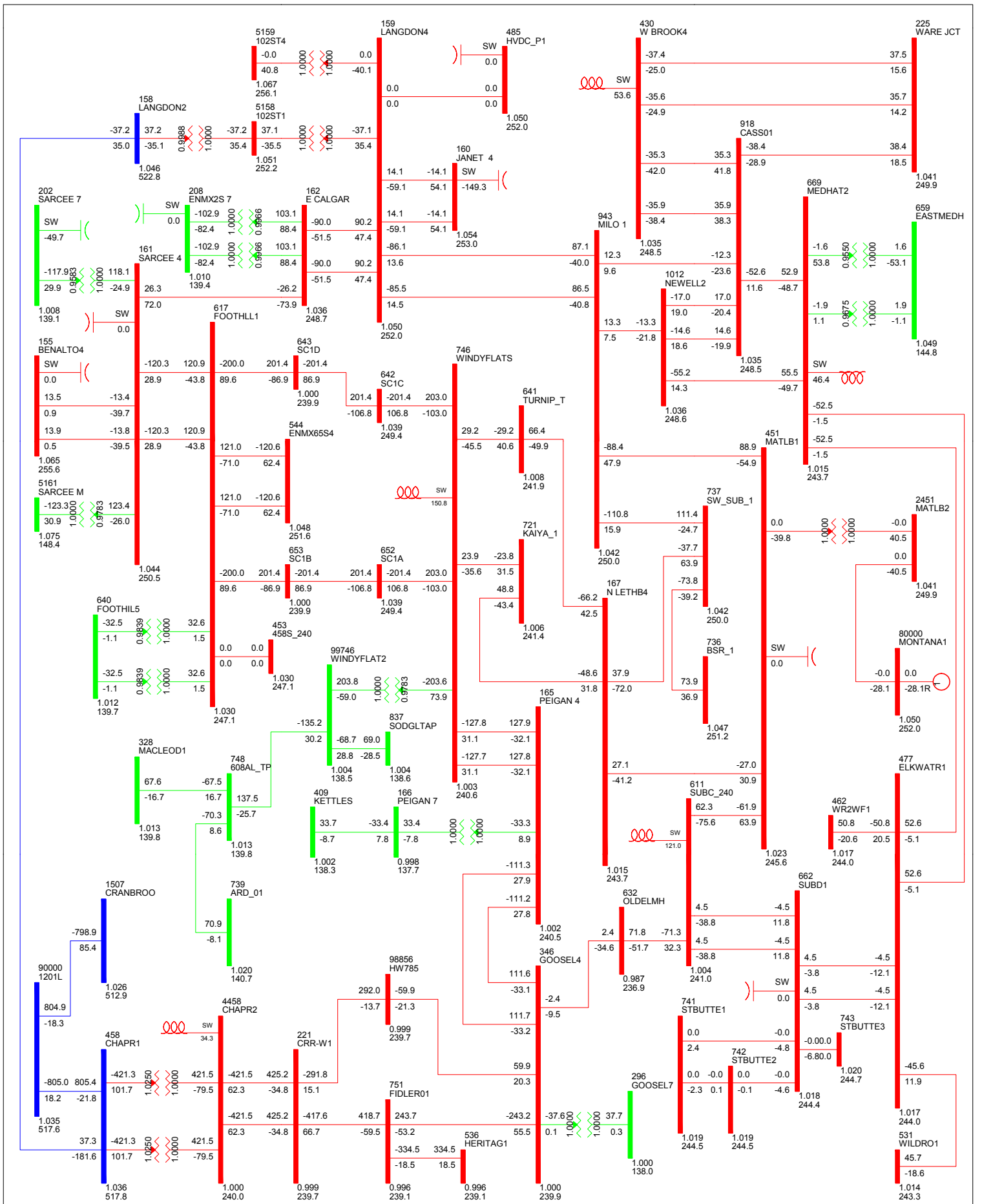


FIG C-W-12: BASECASE
 C7X_2022SL_800_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

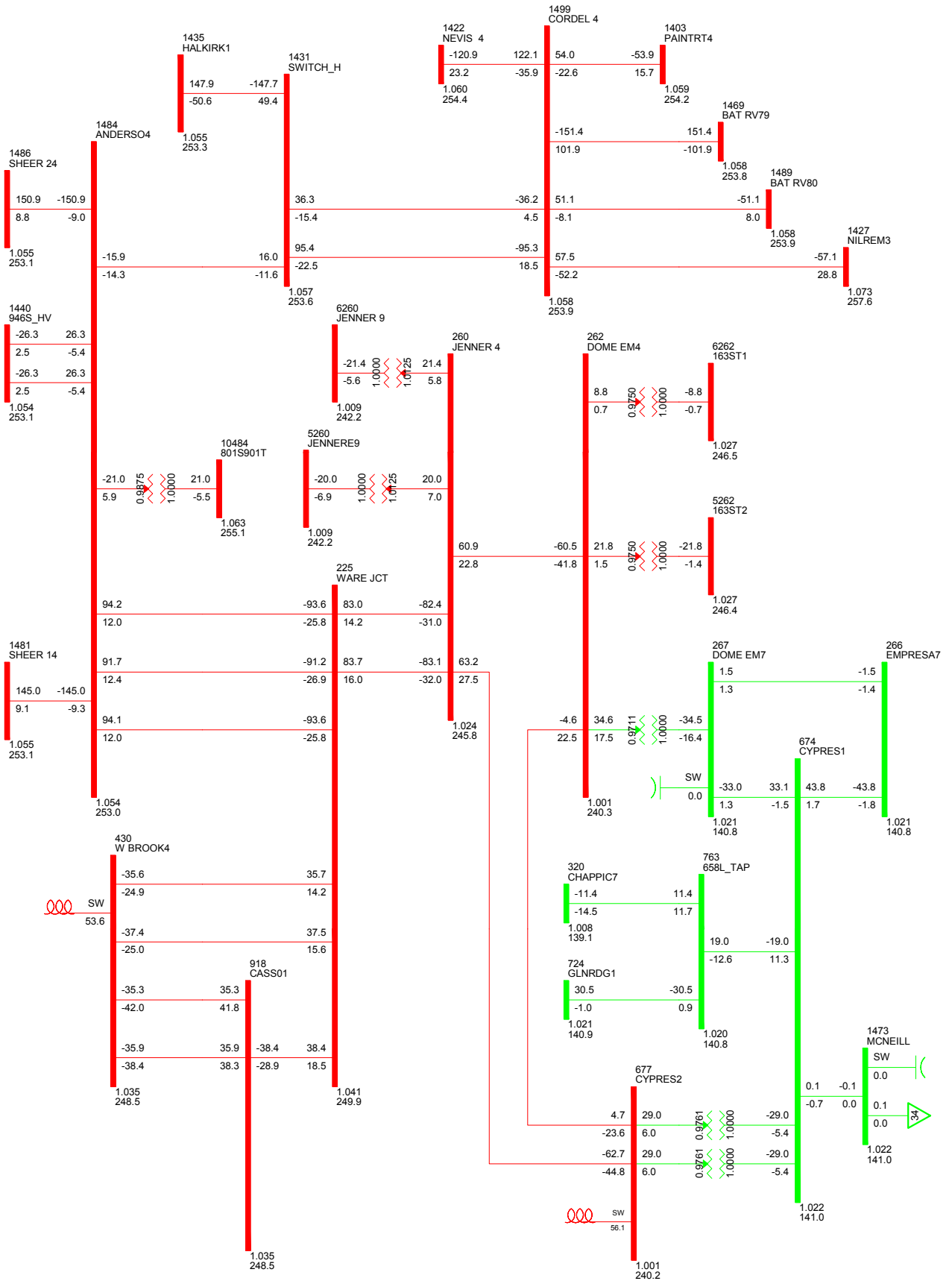


FIG C-E-12: BASECASE
 C7X_2022SL_800_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

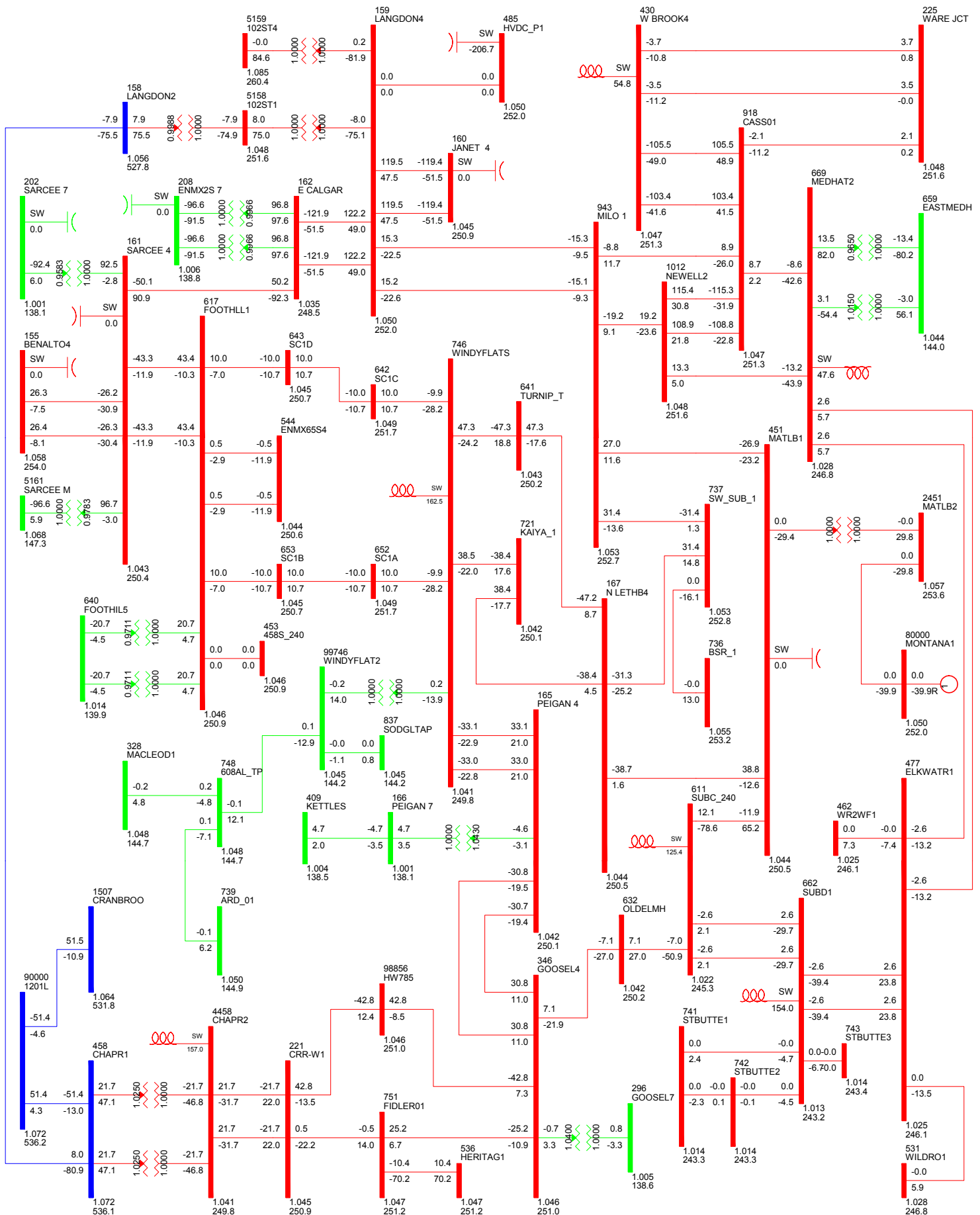


FIG C-W-13: BASECASE
 C8_2022SL_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

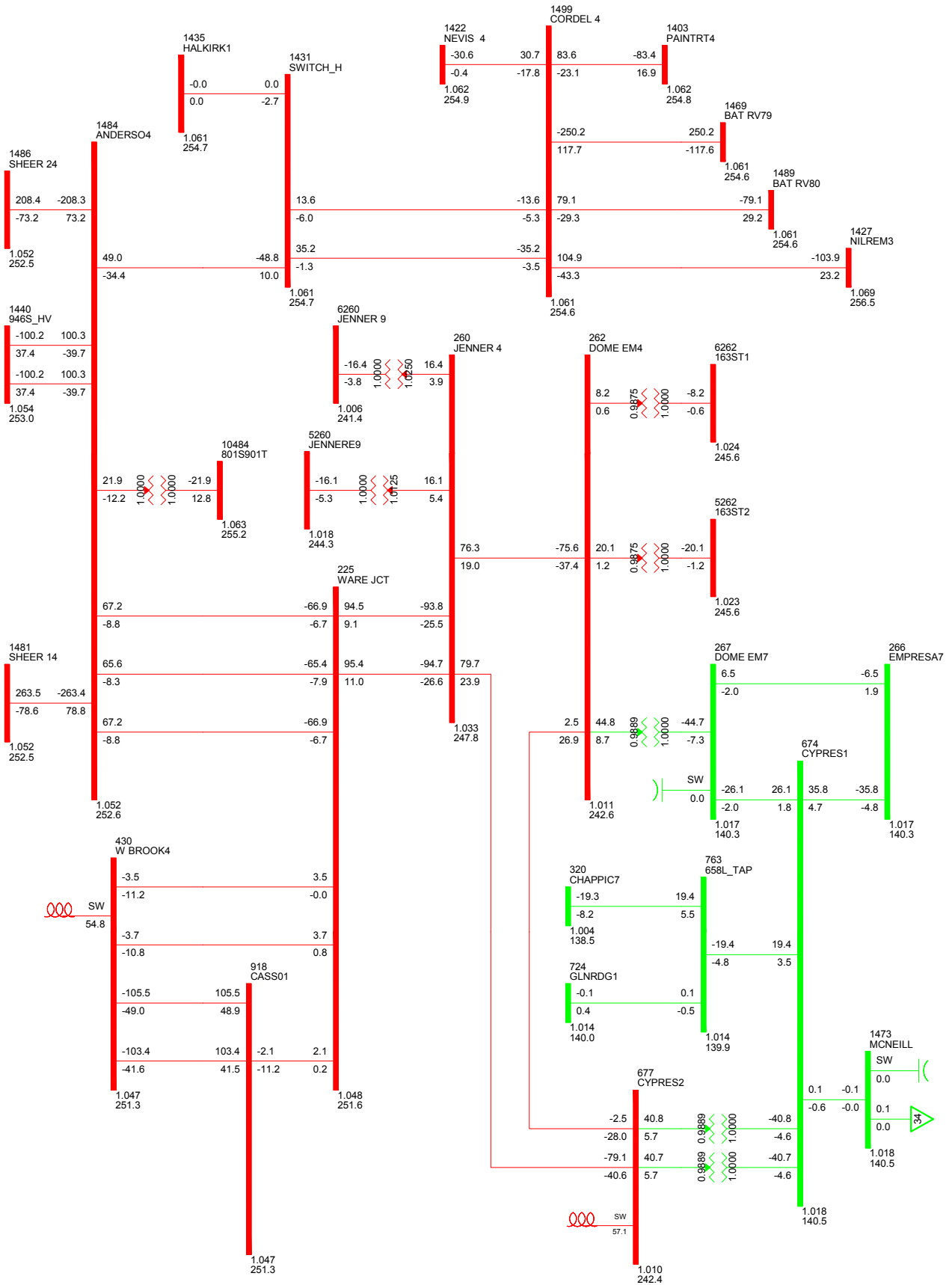


FIG C-E-13: BASECASE
 C8_2022SL_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

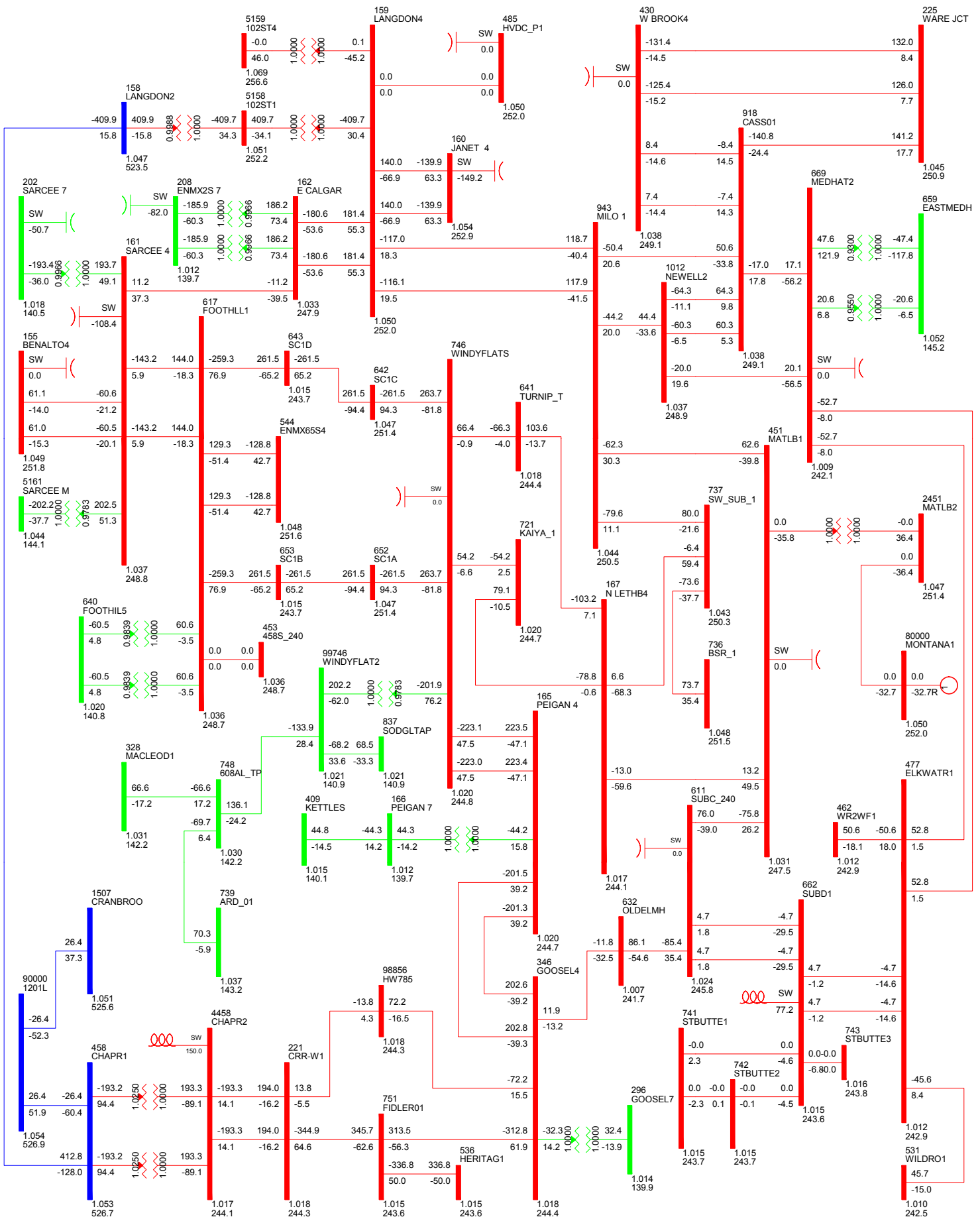


FIG C-W-14: BASECASE
 C9_2022SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

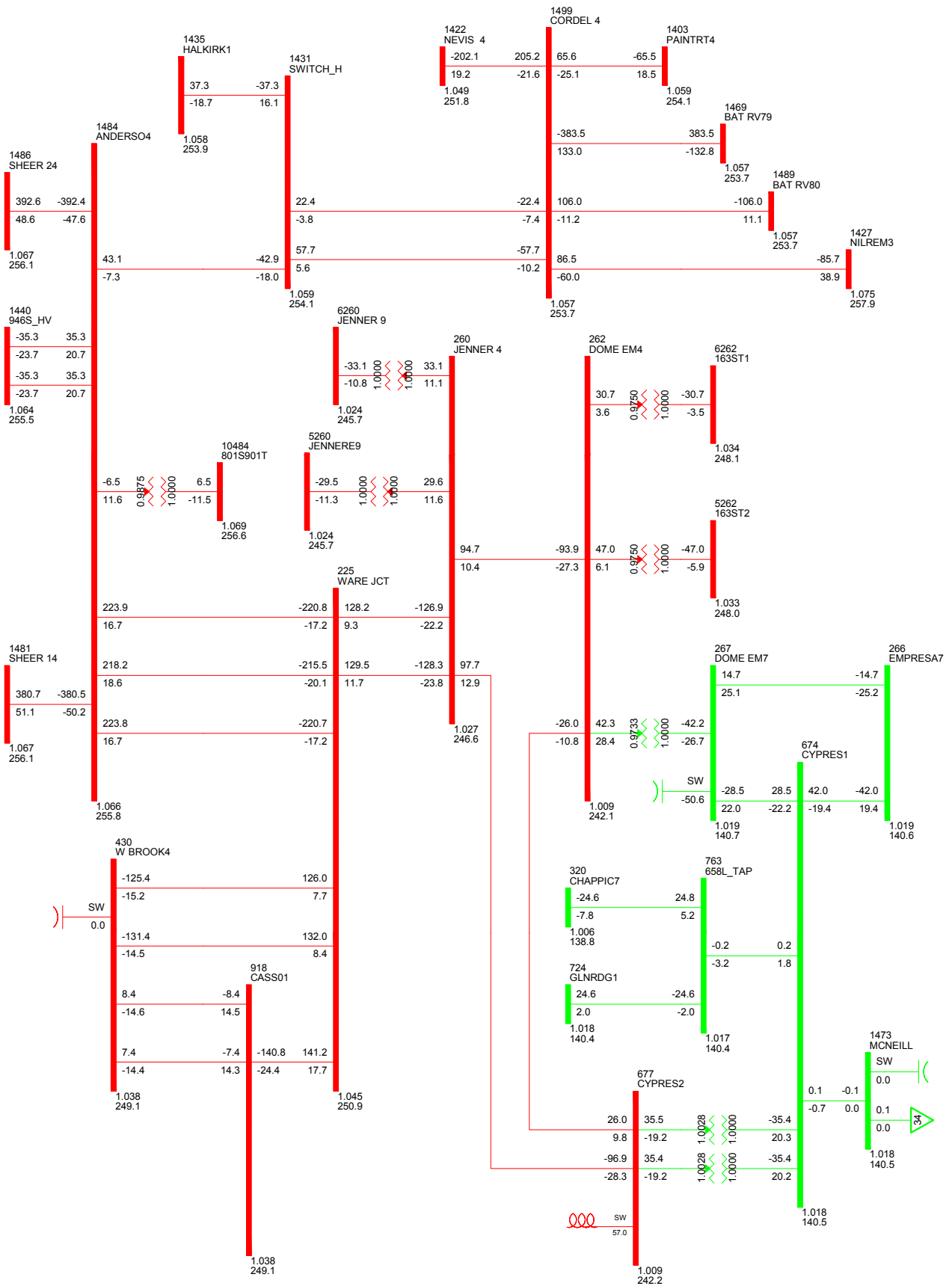


FIG C-E-14: BASECASE
 C9_2022SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

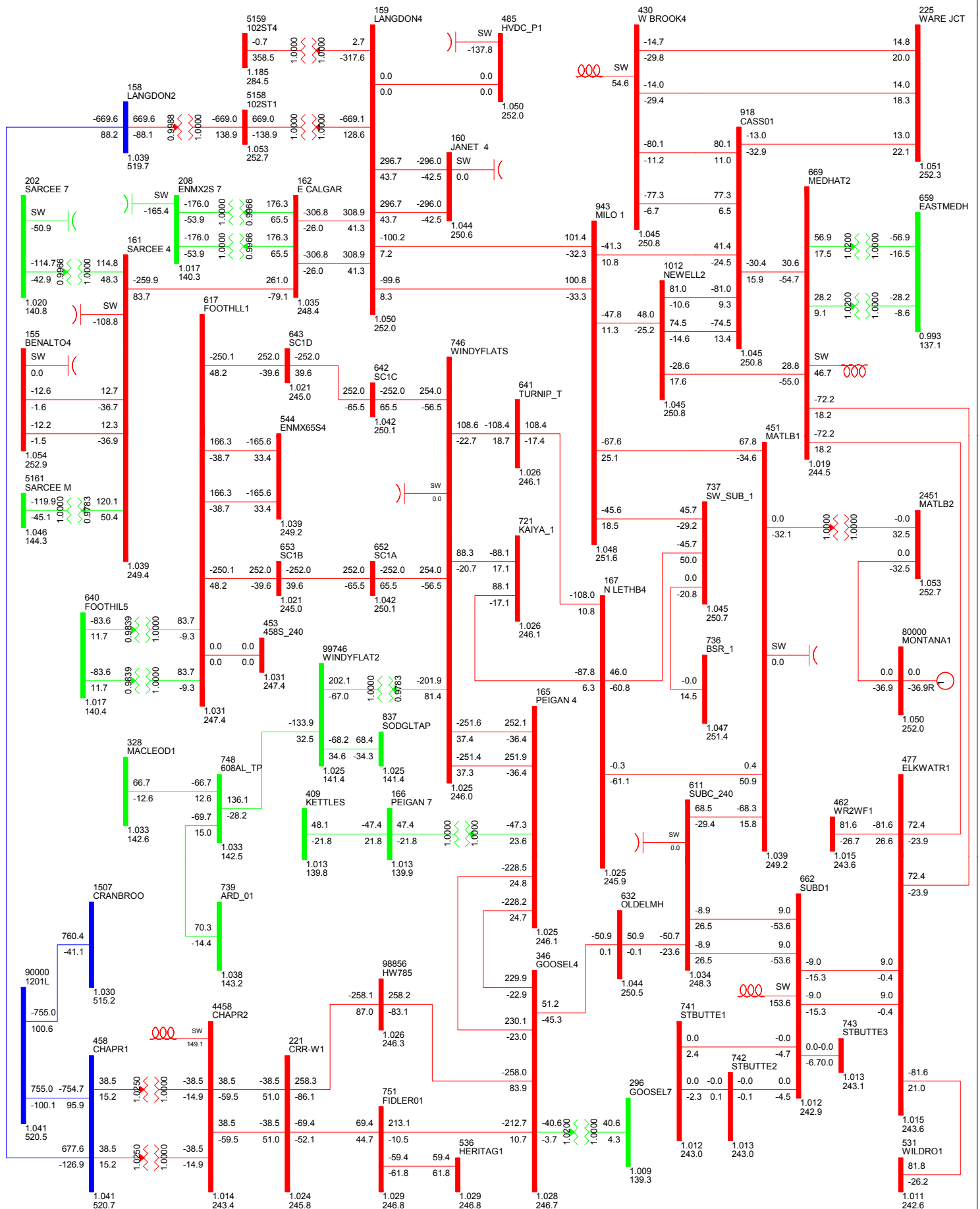


FIG C-W-15: BASECASE
 C10_2015SP_780_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

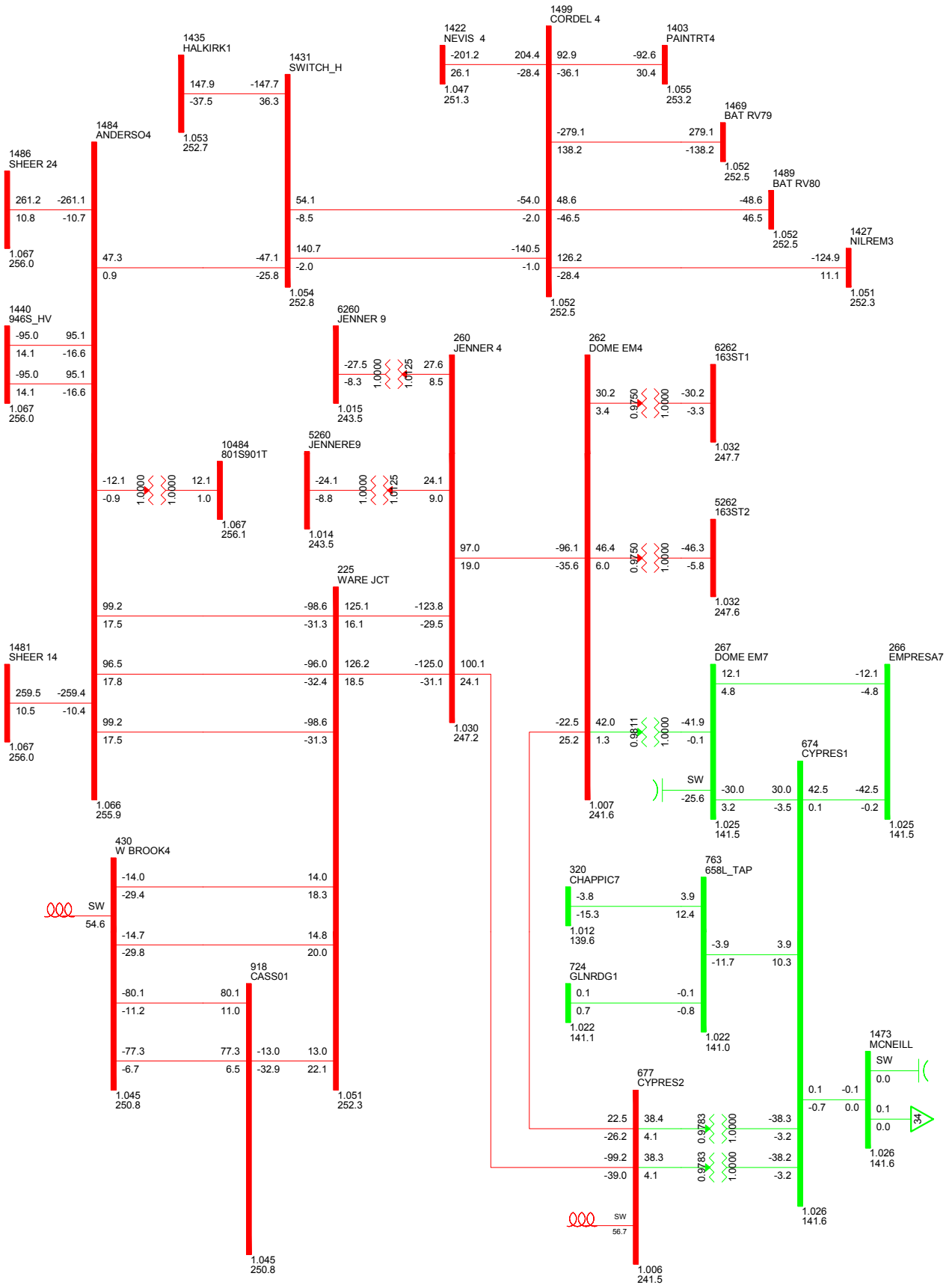


FIG C-E-15: BASECASE
 C10_2015SP_-780_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: ≤ 34.500=69.000 ≤ 138.000 ≤ 240.000=500.000>500.000

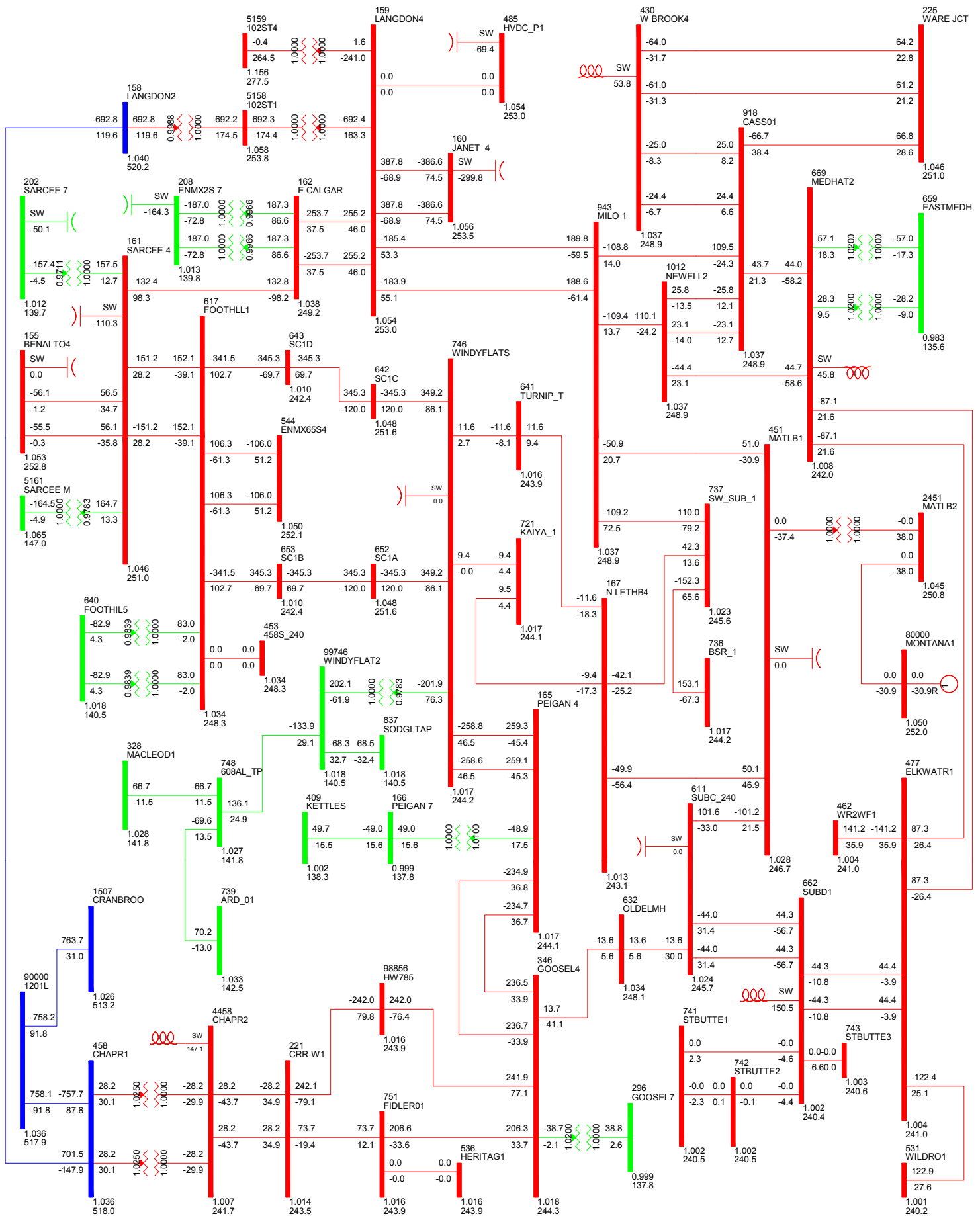


FIG C-W-16: BASECASE
 C11_2017SP_-780_0_-150_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

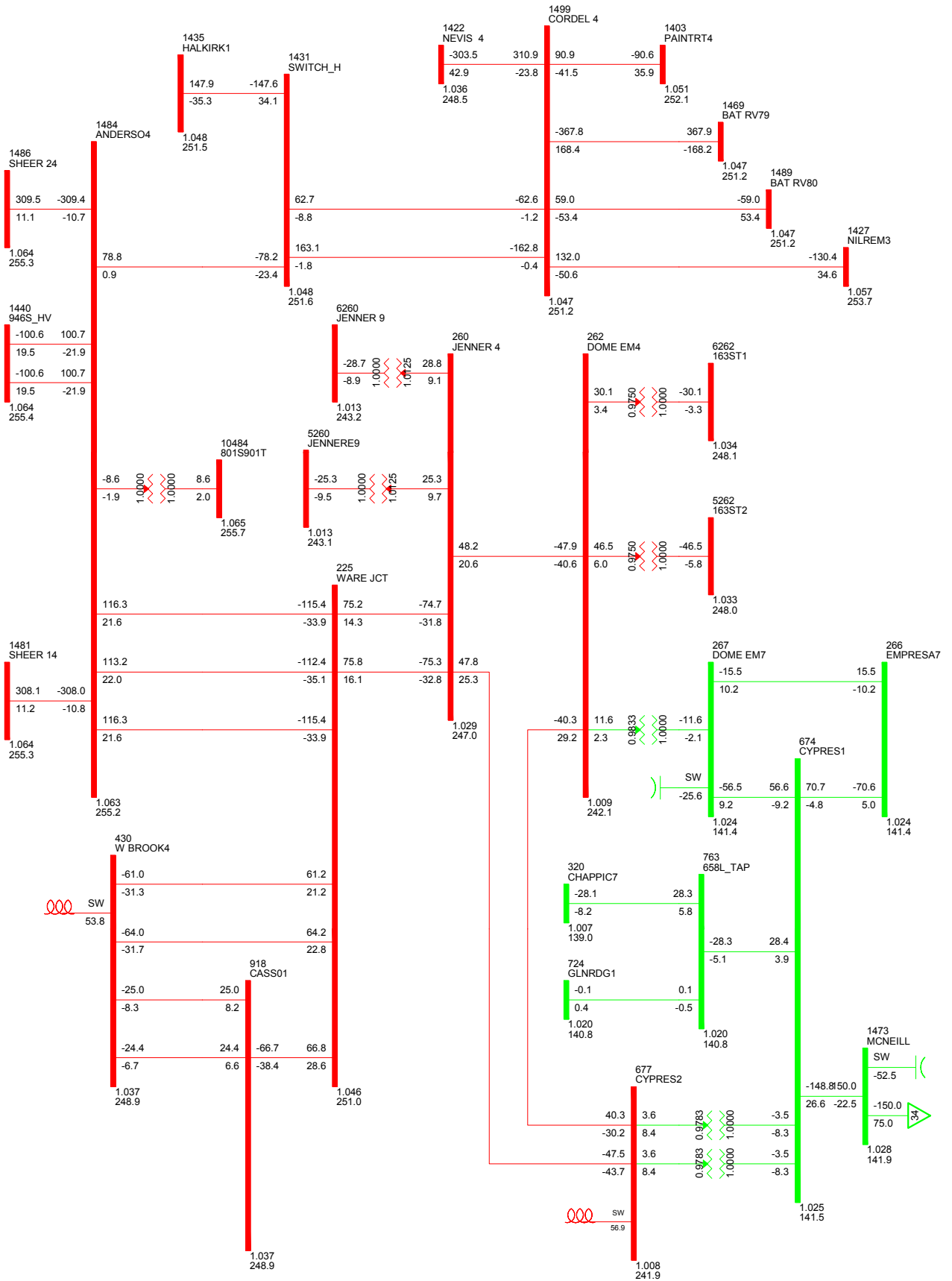


FIG C-E-16: BASECASE
 C11_2017SP_780_0_-150_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

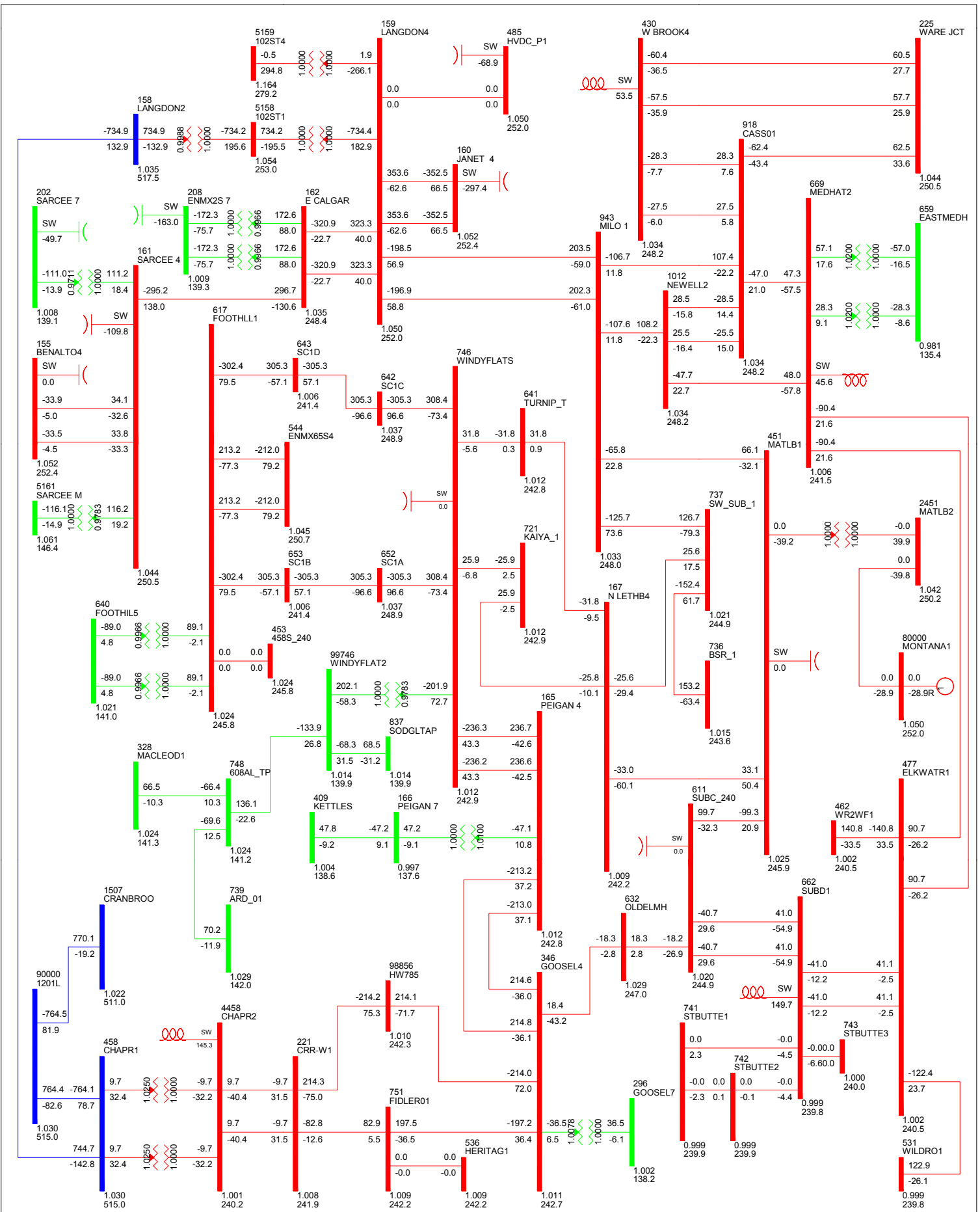


FIG C-W-17: BASECASE
 C11S_2017SP_-780_0_-150_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

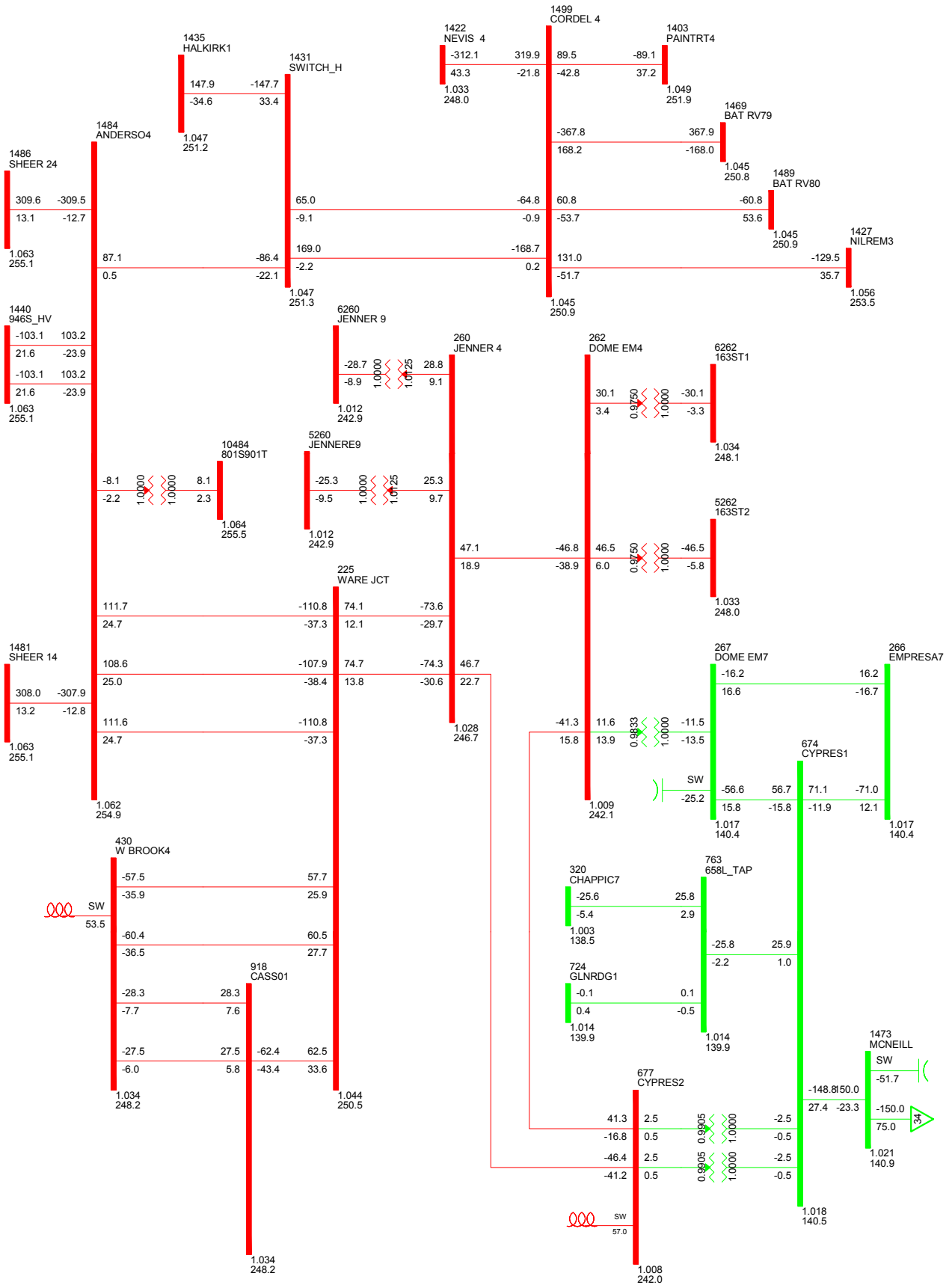


FIG C-E-17: BASECASE
 C11S_2017SP_-780_0_-150_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

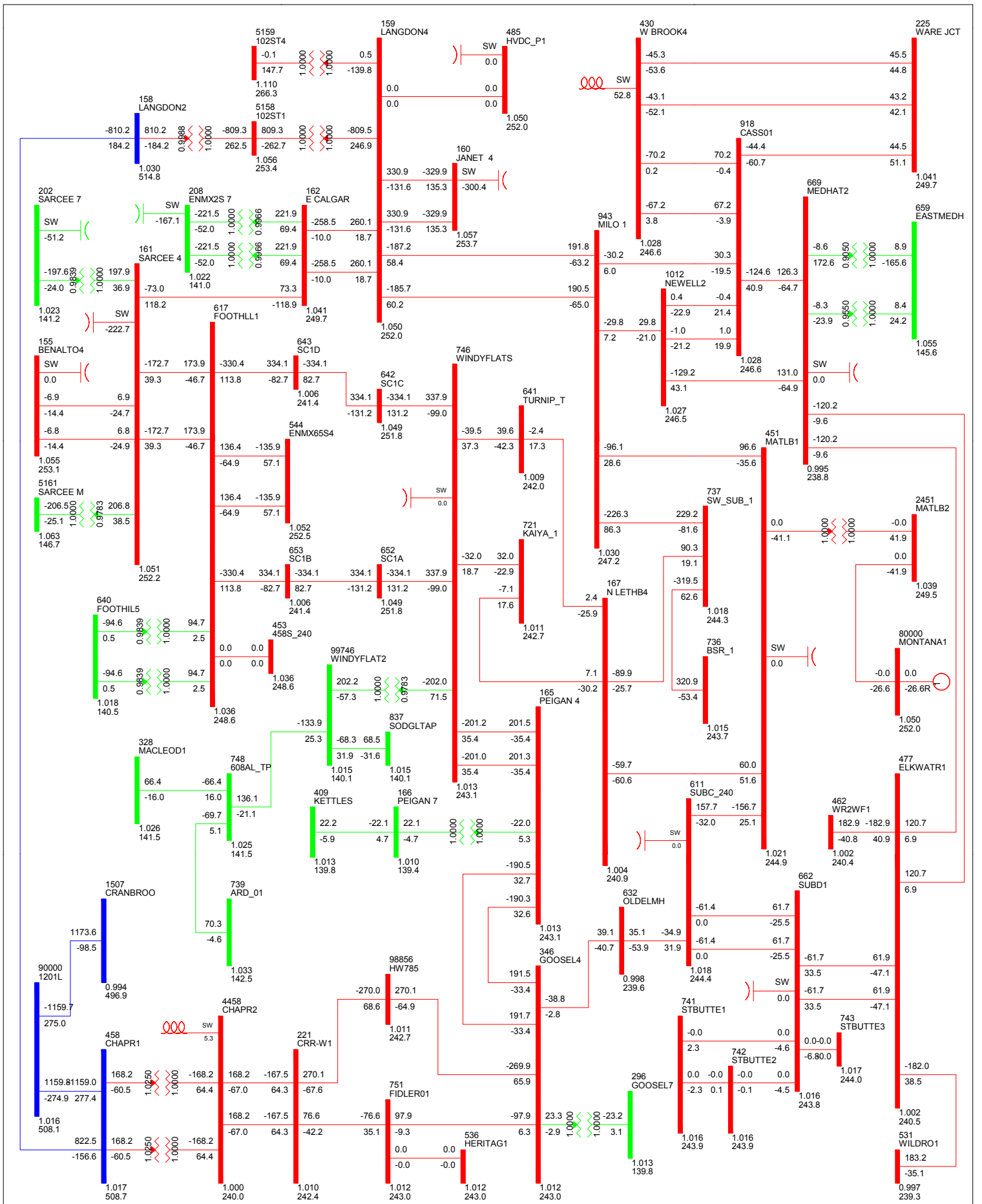


FIG C-W-18: BASECASE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: ≤ 34.500 ≤ 69.000 ≤ 138.000 ≤ 240.000 ≤ 500.000 >500.000

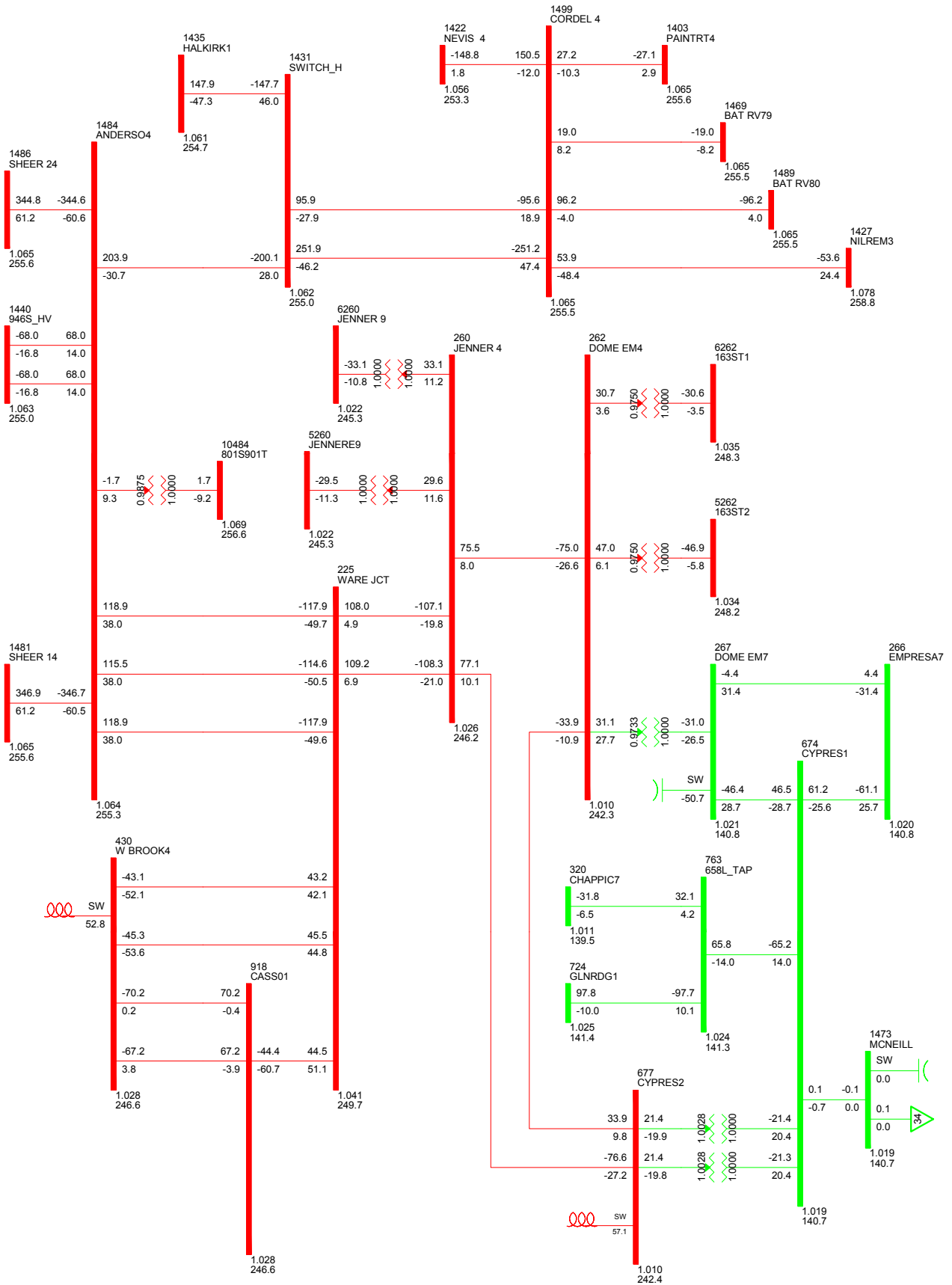


FIG C-E-18: BASECASE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

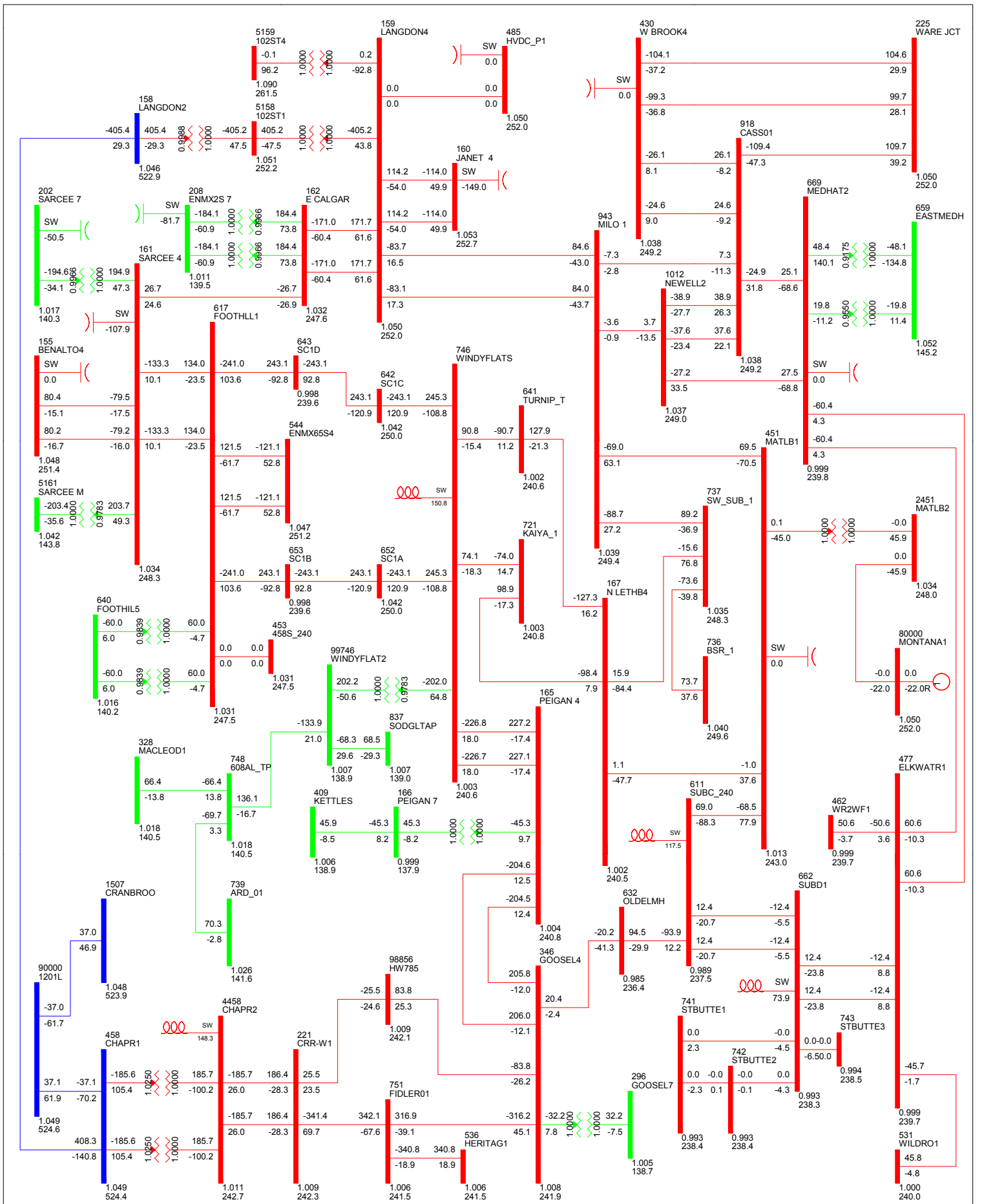


FIG C-W-19: BASECASE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

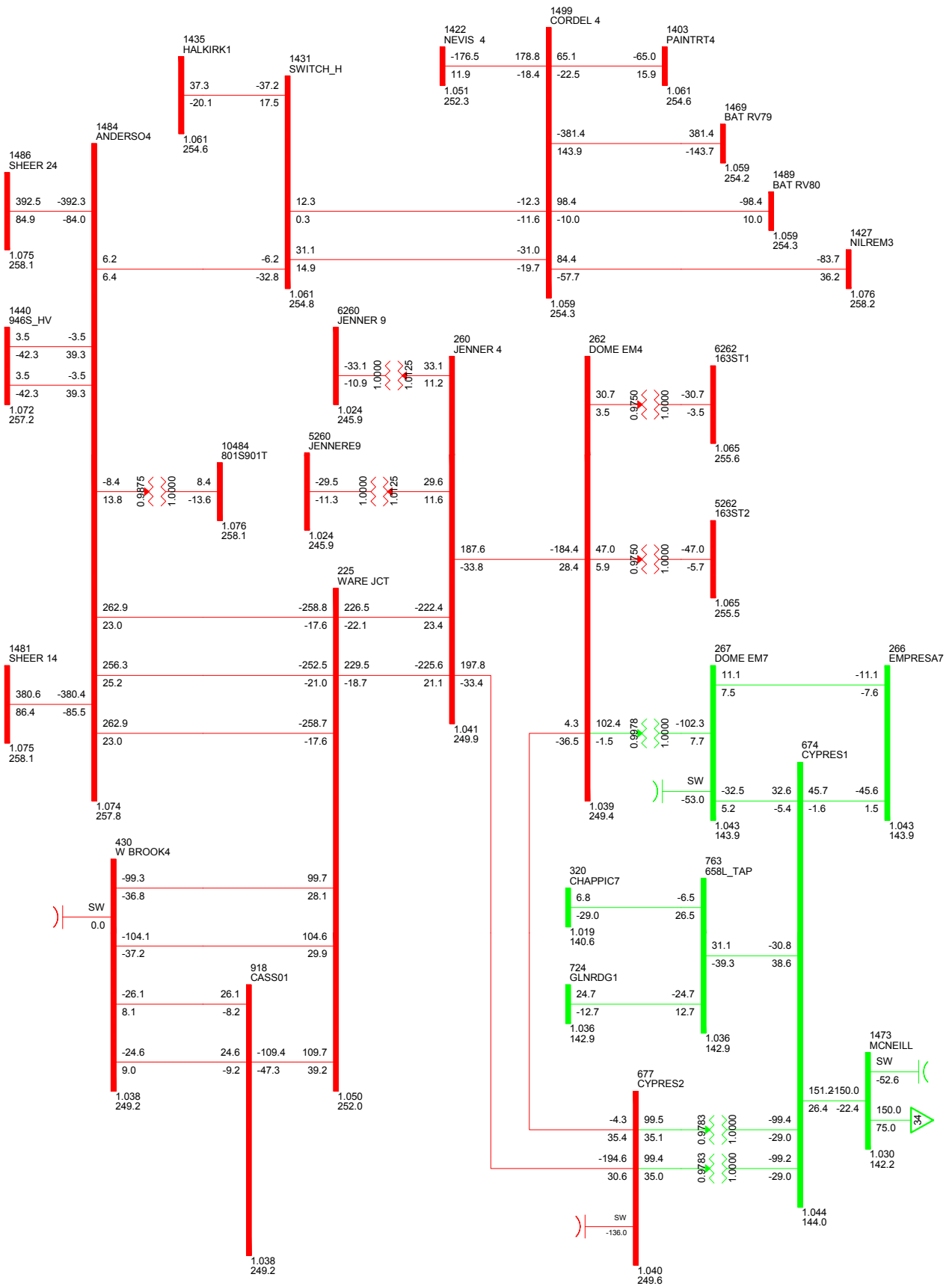


FIG C-E-19: BASECASE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

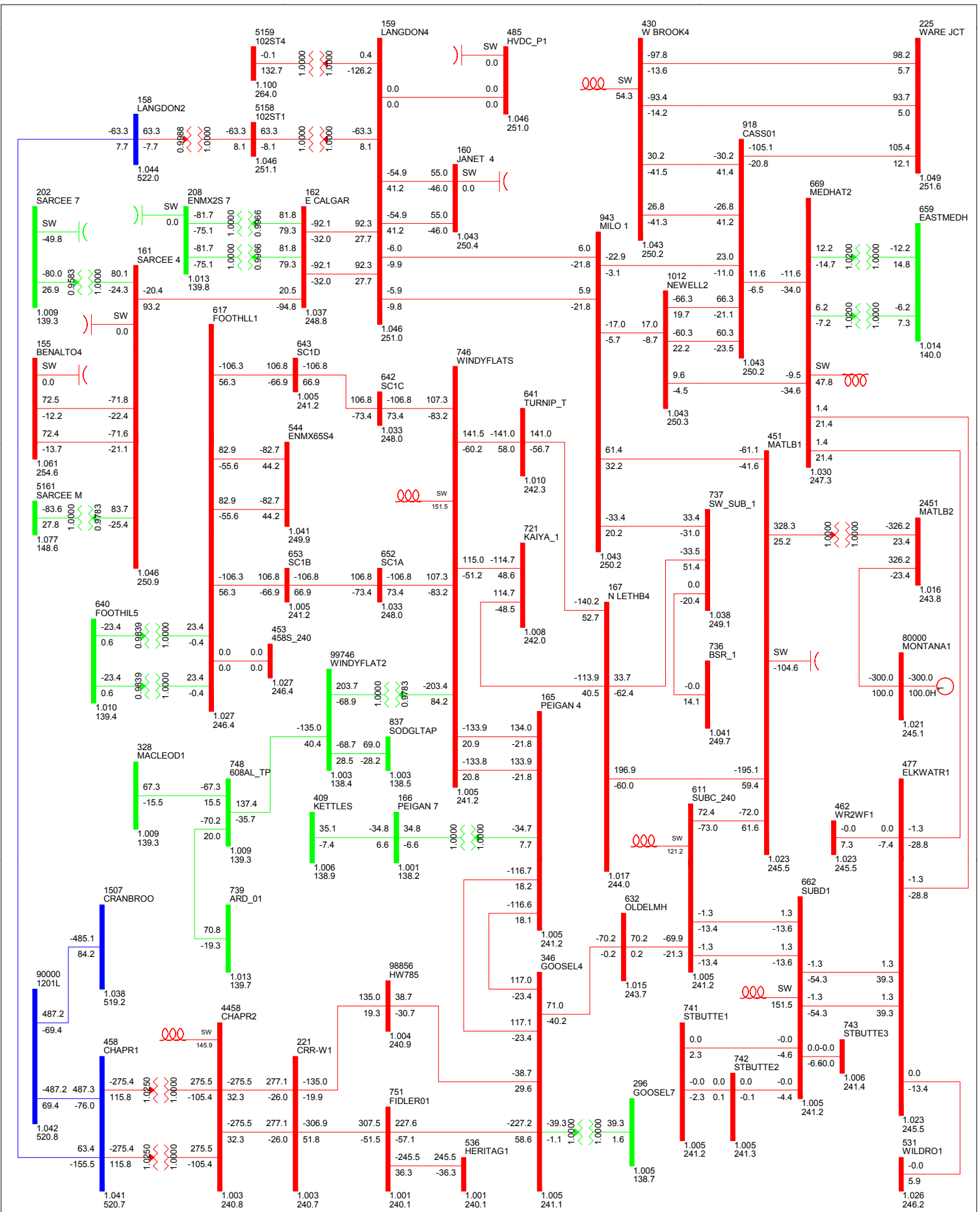


FIG C-17-20: BASECASE
 C14_2017SL_500_0_300_B6_R6
 THU, AUG 30 2012 15:29

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <math>=< 34.500</math> <math>=< 69.000</math> <math>=< 138.000</math> <math>=< 240.000</math> <math>=< 500.000</math> $=> 500.000$

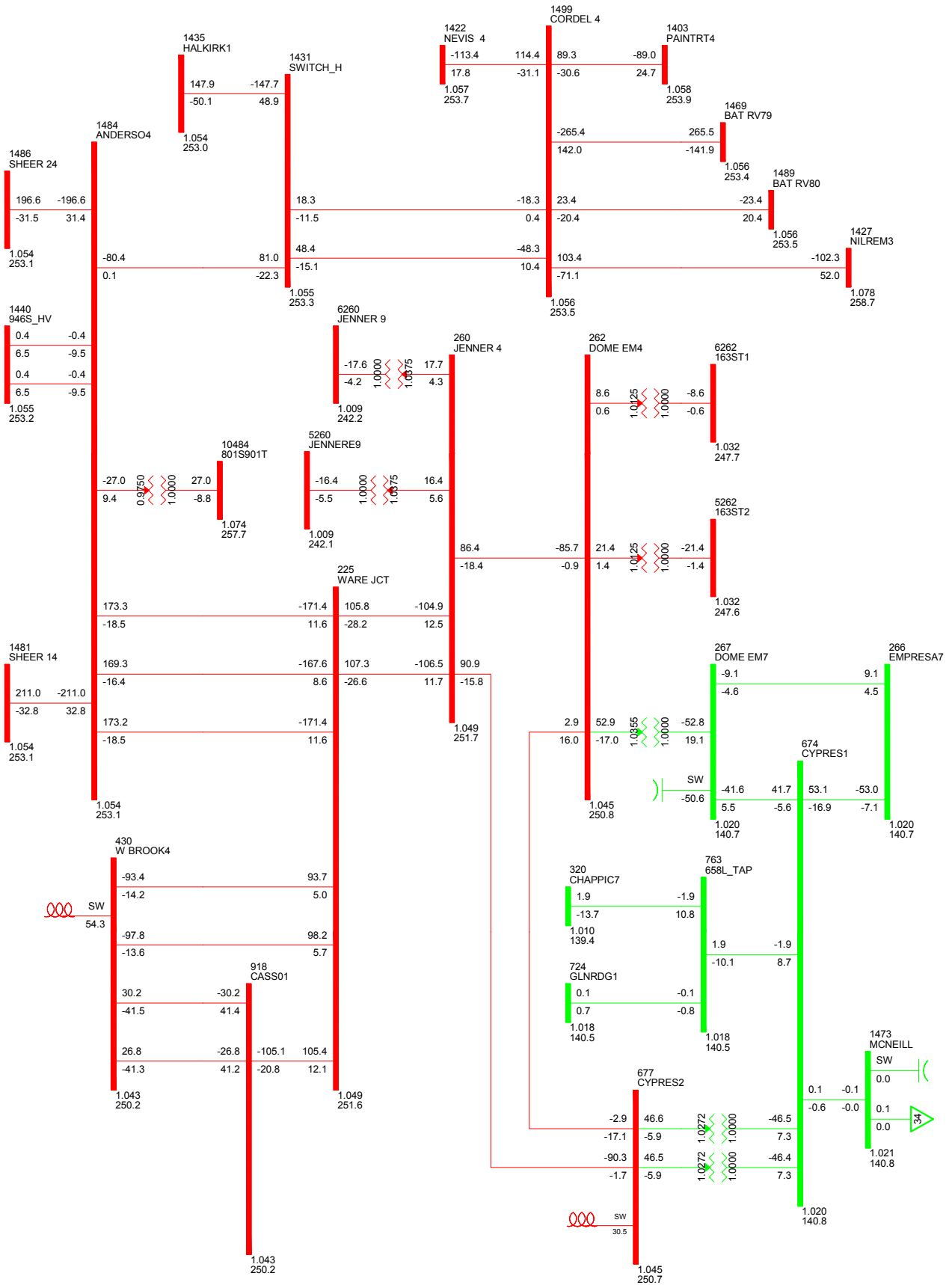


FIG C-E-20: BASECASE
 C14_2017SL_500_0_300_B6_R6
 THU, AUG 30 2012 15:29

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

Table B-4: Reactive Case – Category B Plot List

Figure #	Contingency	Scenario
Fig D-W-1 Fig D-E-1	Langdon 500/240 kV Transformer	C2_2015SL_0_0_0
Fig D-W-2 Fig D-E-2	Langdon 500/240 kV Transformer	C3_2015SP_0_0_0
Fig D-W-3 Fig D-E-3	Langdon 500/240 kV Transformer	C5_2017SL_0_0_0
Fig D-W-4 Fig D-E-4	Langdon 500/240 kV Transformer	C5S_2017SL_0_0_0
Fig D-W-5 Fig D-E-5	Langdon 500/240 kV Transformer	C8_2022SL_0_0_0
Fig D-W-6 Fig D-E-6	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	C11_2017SP_-780_0_-150
Fig D-W-7 Fig D-E-7	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	C11S_2017SP_-780_0_-150
Fig D-W-8 Fig D-E-8	462[WR2WF1 240.00] to 477[ELKWATR1 240.00] CKT 76	C12_2022SP_-1200_0_0
Fig D-W-9 Fig D-E-9	477[ELKWATR1 240.00] to 531[WILDRO1 240.00] CKT 78	C12_2022SP_-1200_0_0
Fig D-W-10 Fig D-E-10	736[BSR_1 240.00] to 737[SW_SUB_1 240.00] CKT 42	C12_2022SP_-1200_0_0
Fig D-W-11 Fig D-E-11	1431[SWITCH_H 240.00] to 1435[HALKIRK1 240.00] CKT 93	C12_2022SP_-1200_0_0
Fig D-W-12 Fig D-E-12	1481[SHEER 14 240.00] to 1484[ANDERSO4 240.00] CKT 99	C12_2022SP_-1200_0_0
Fig D-W-13 Fig D-E-13	1484[ANDERSO4 240.00] to 1486[SHEER 24 240.00] CKT 00	C12_2022SP_-1200_0_0
Fig D-W-14 Fig D-E-14	158[LANGDON2 500.00] to 458[CHAPR1 500.00] CKT 01	C12_2022SP_-1200_0_0
Fig D-W-15 Fig D-E-15	Langdon 500/240 kV Transformer	C12_2022SP_-1200_0_0
Fig D-W-16 Fig D-E-16	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	C13_2022SP_0_0_150
	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 44	C13_2022SP_0_0_150
Fig D-W-17 Fig D-E-17	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	C13_2022SP_0_0_150
	225[WARE JCT 240.00] to 260[JENNER 4 240.00] CKT 51	C13_2022SP_0_0_150
Fig D-W-18 Fig D-E-18	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	C13_2022SP_0_0_150
	260[JENNER 4 240.00] to 262[DOME EM4 240.00] CKT 02	C13_2022SP_0_0_150
Fig D-W-19 Fig D-E-19	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	C13_2022SP_0_0_150
	260[JENNER 4 240.00] to 677[CYPRES2 240.00] CKT 45	C13_2022SP_0_0_150

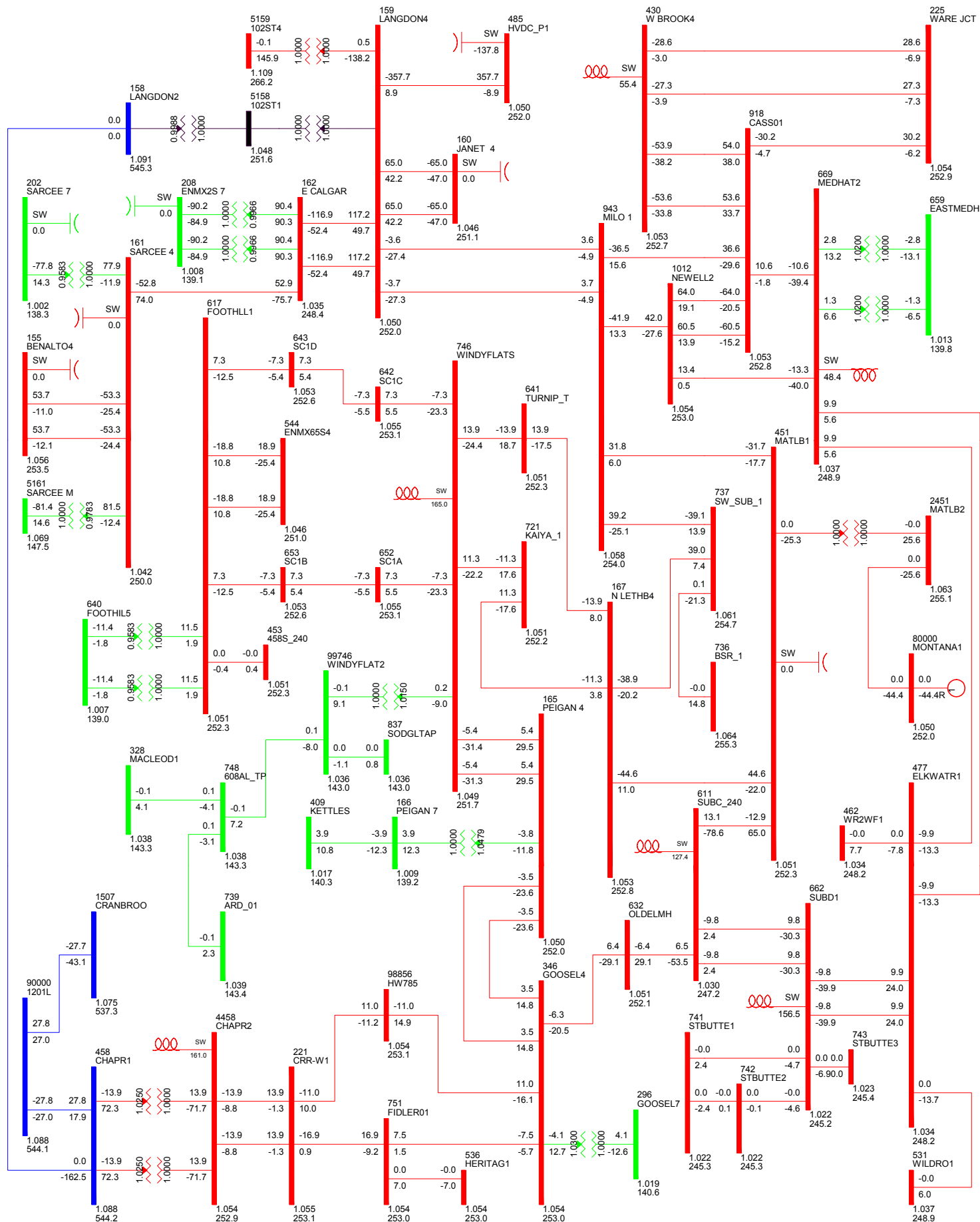


FIG D-W-1: LANGDON 500/240 KV TRANSFORMER 102ST1
 C2_2015SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

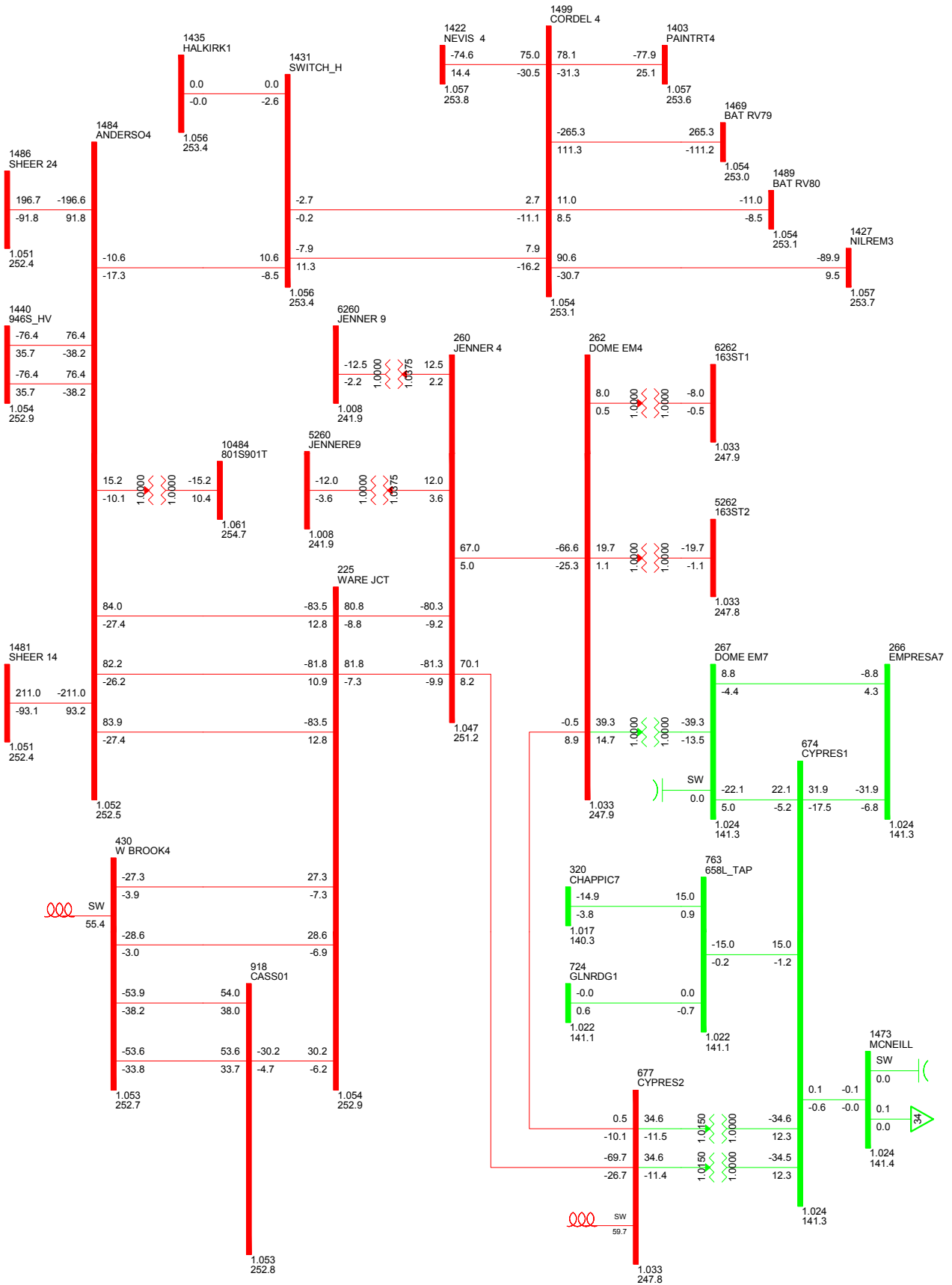


FIG D-E-1: LANGDON 500/240 KV TRANSFORMER 102ST1
 C2_2015SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

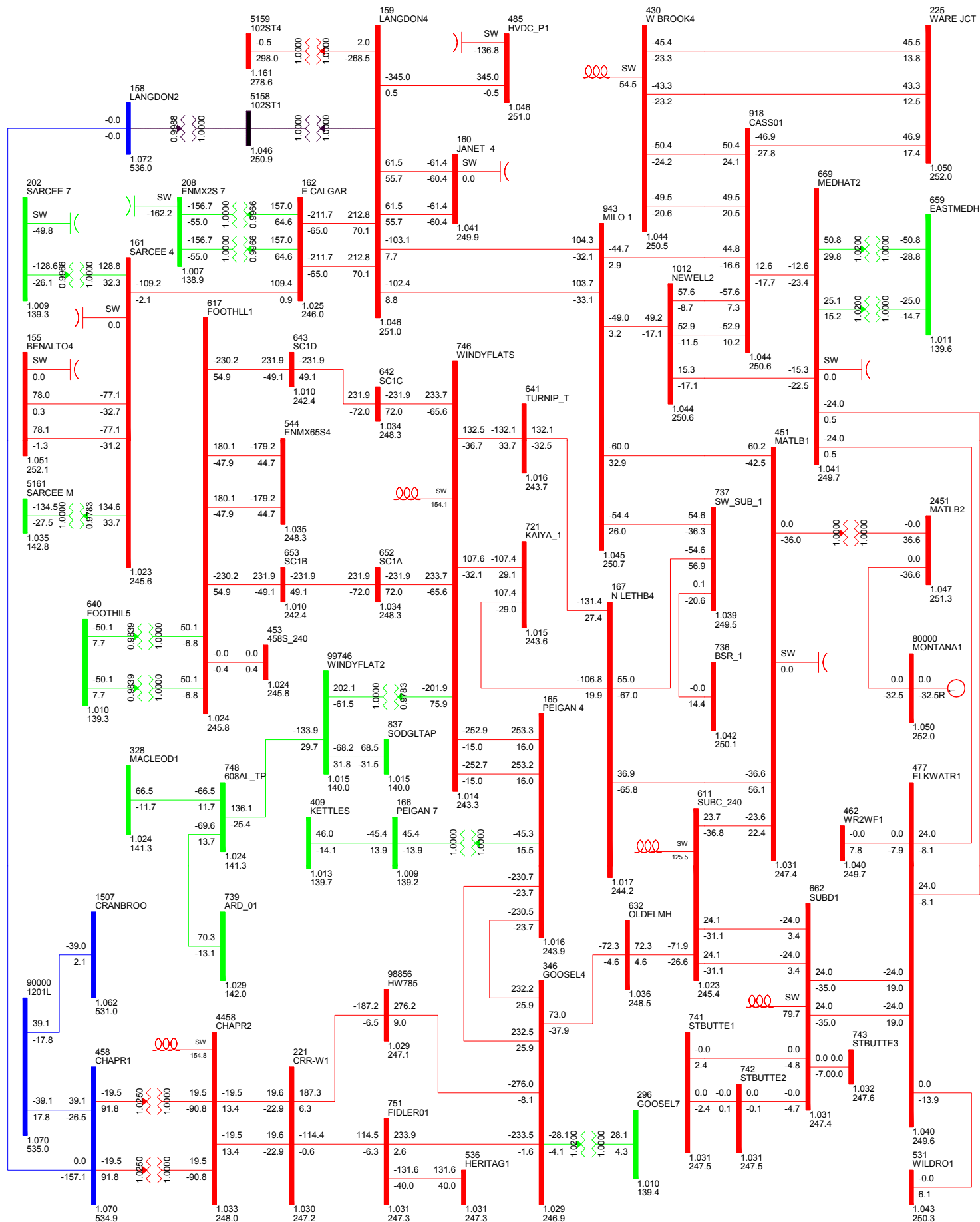


FIG D-W-2: LANGDON 500/240 KV TRANSFORMER 102ST1
 C3_2015SP_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

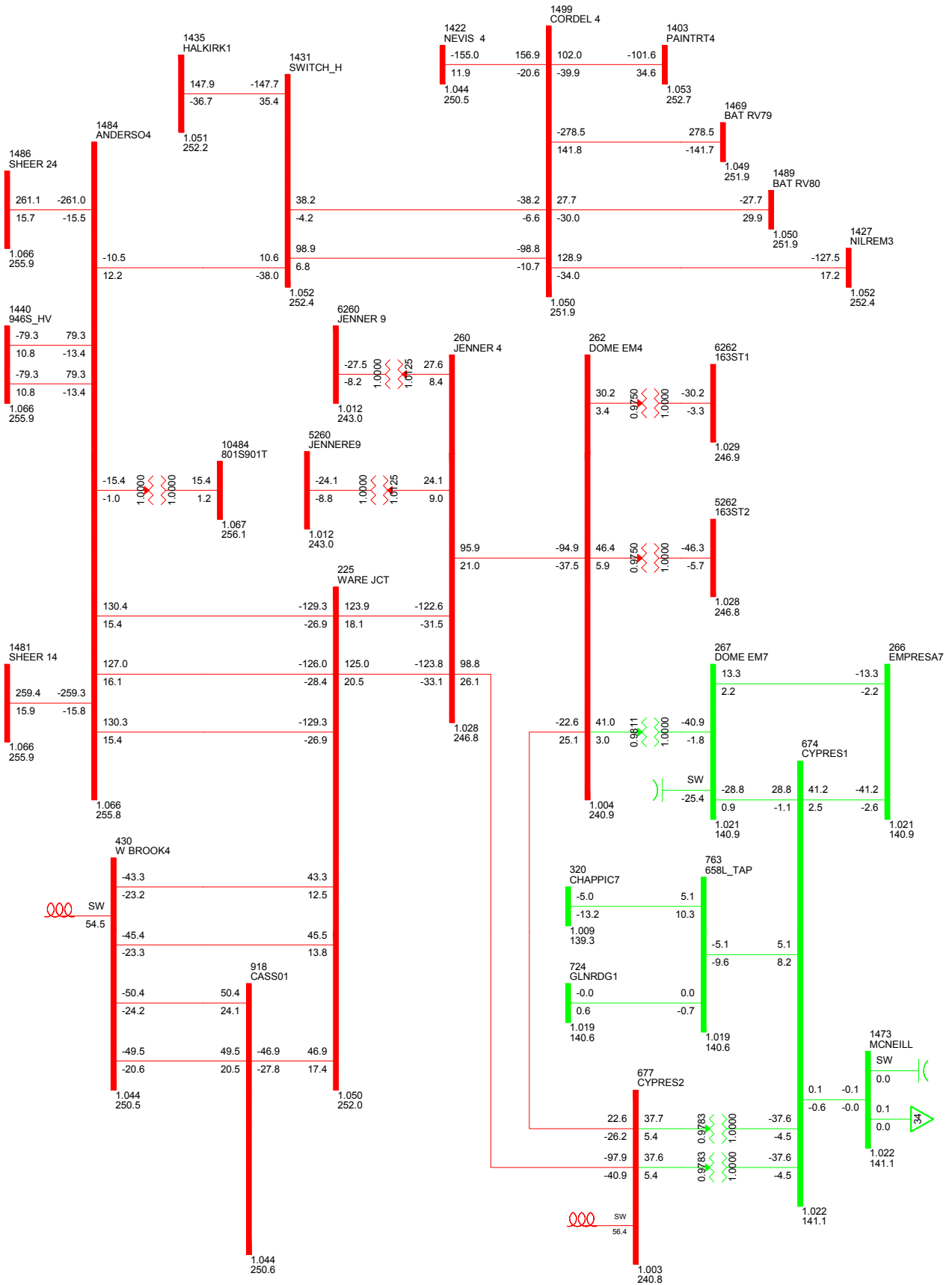


FIG D-E-2: LANGDON 500/240 KV TRANSFORMER 102ST1
 C3_2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

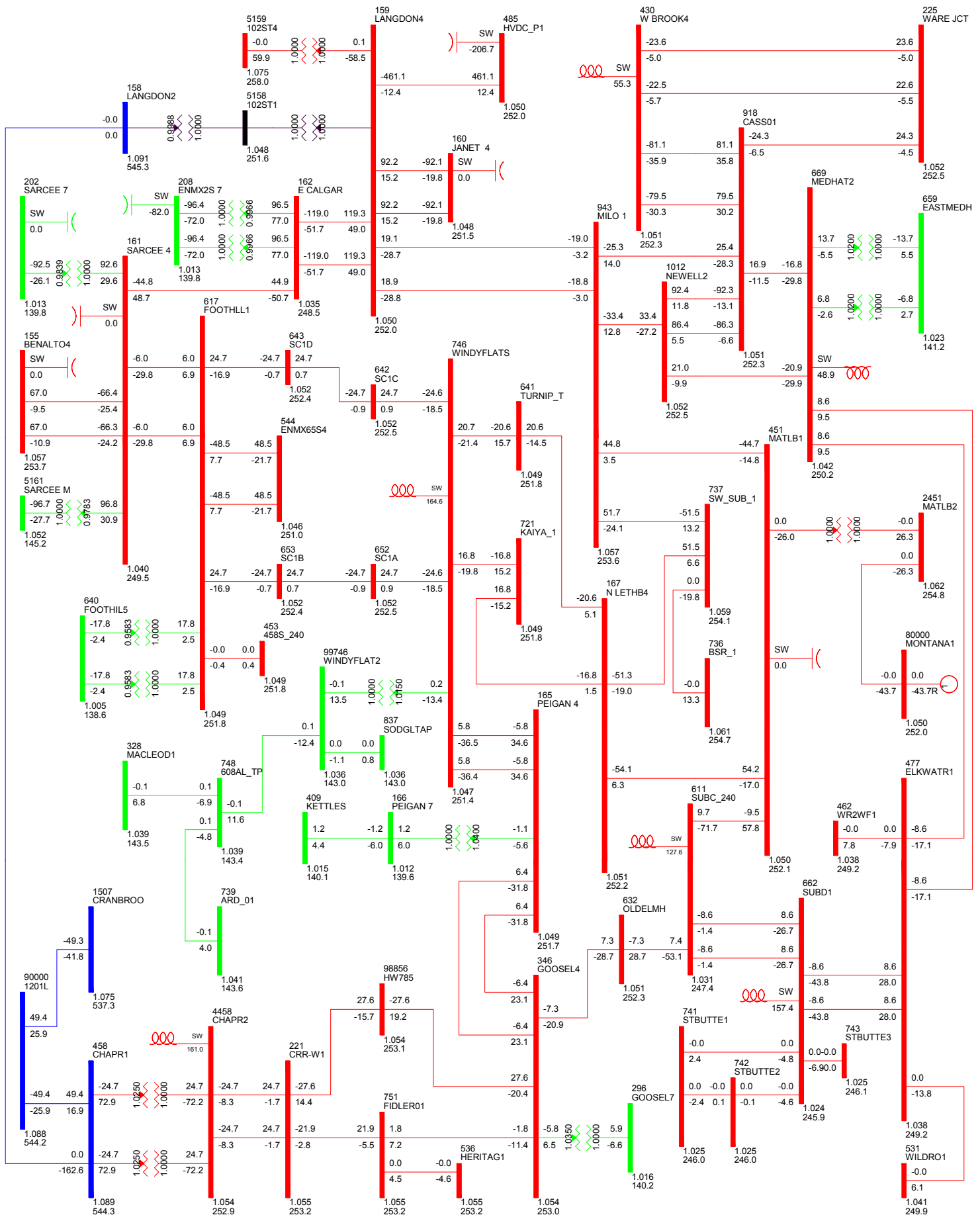


FIG D-W-3: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5_2017SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

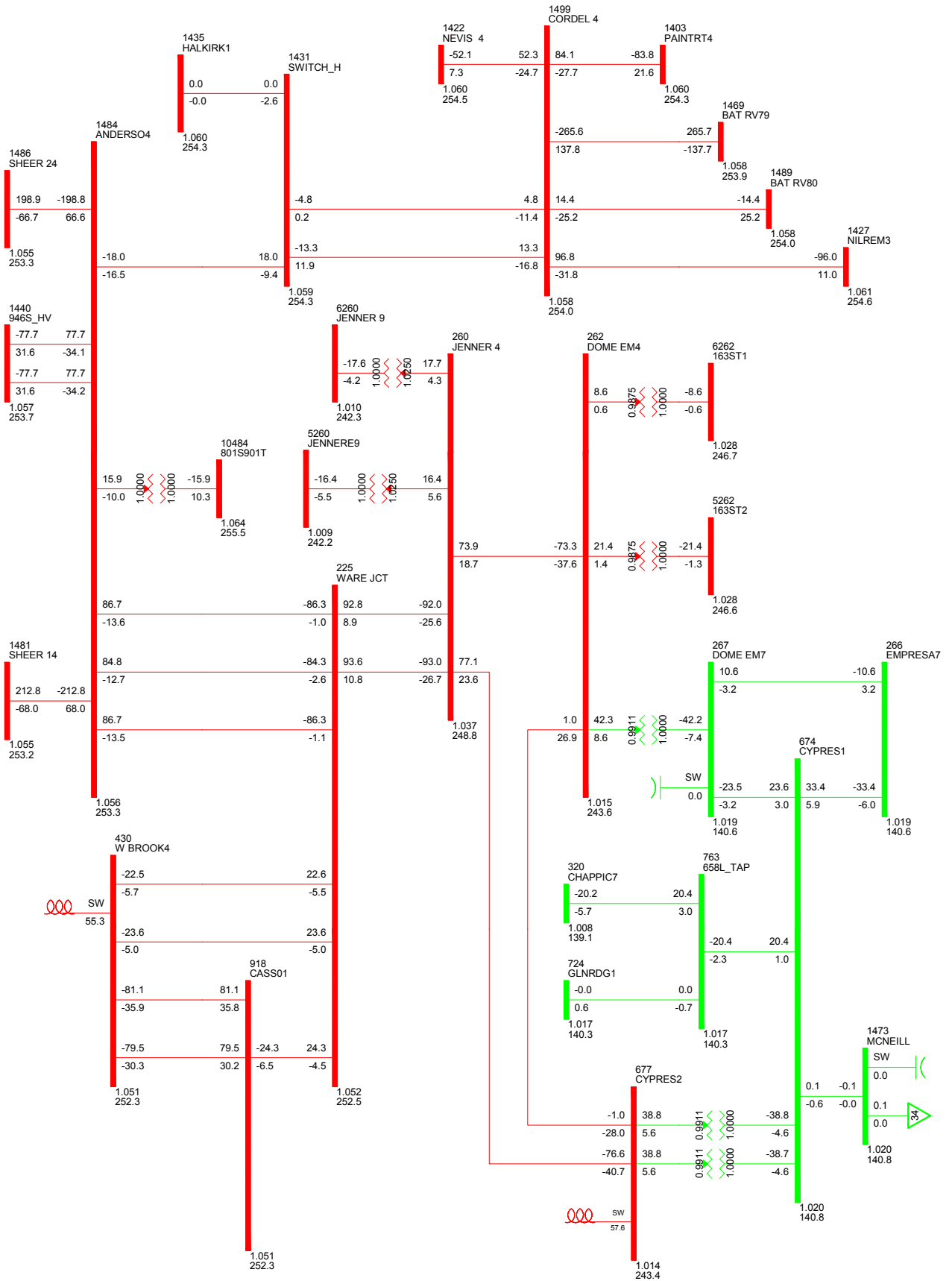


FIG D-E-3: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5_2017SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

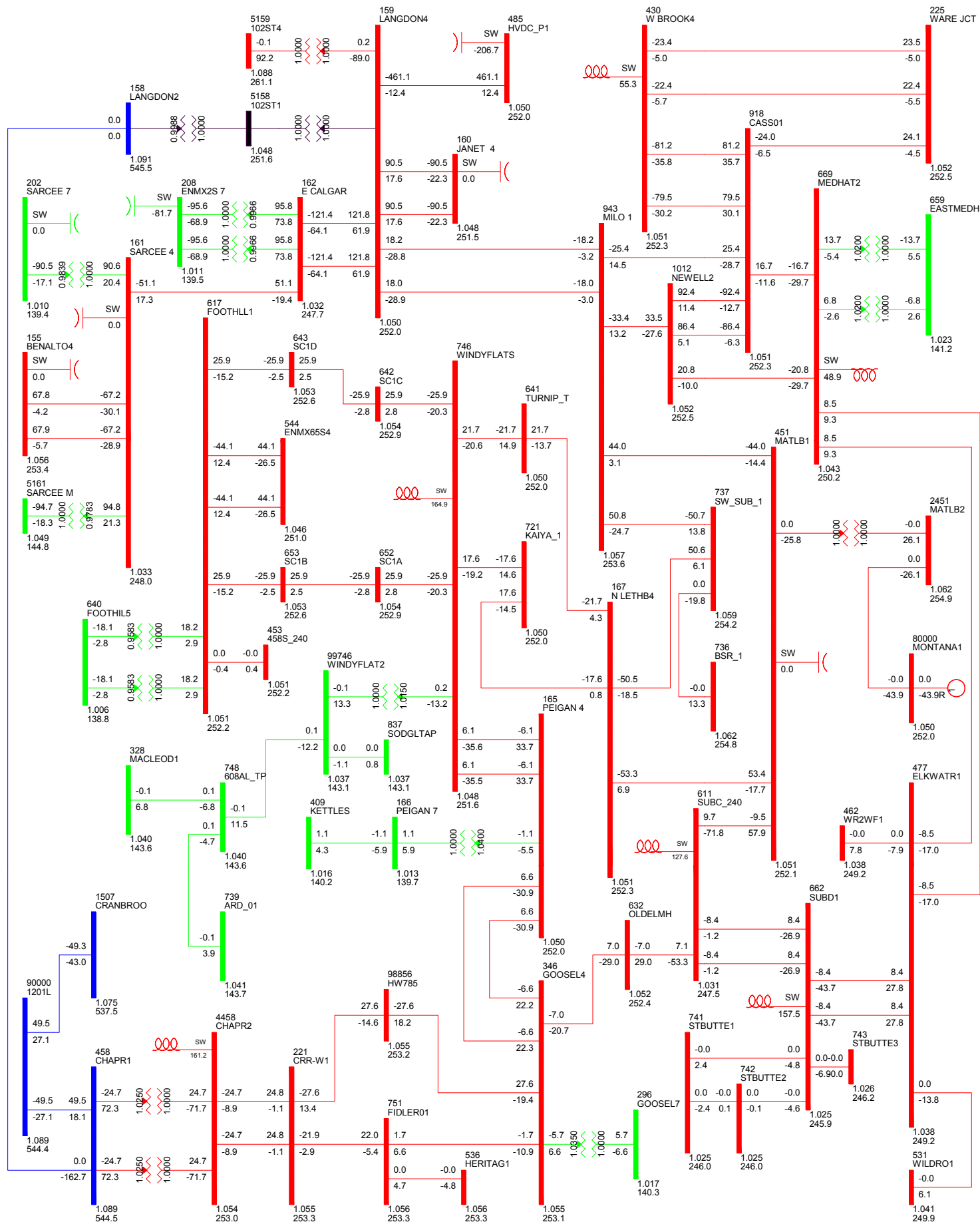


FIG D-W-4: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5S_2017SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: =-34.500 <=-69.000 <=-138.000 <=-240.000 <=-500.000 >500.000

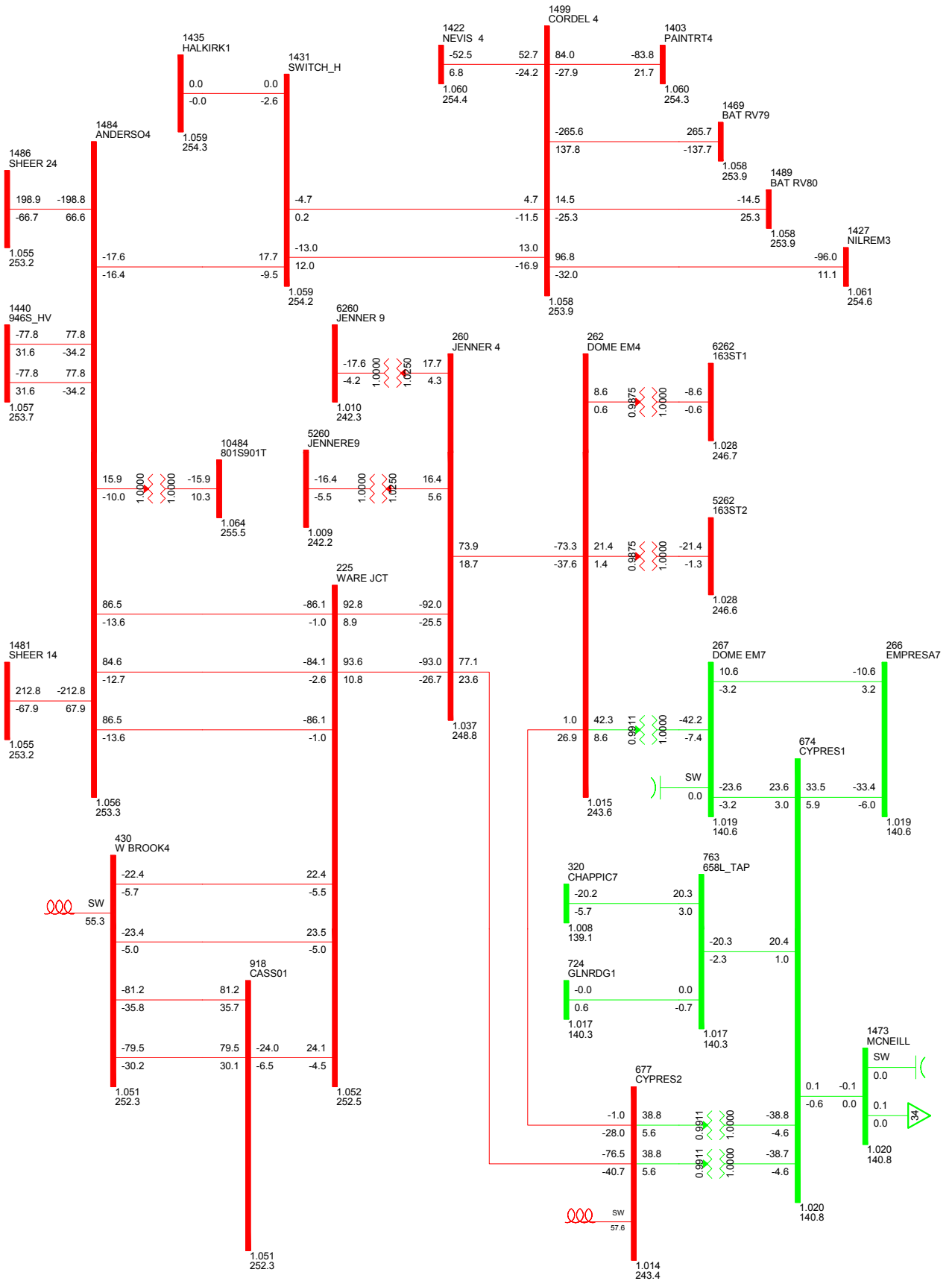


FIG D-E-4: LANGDON 500/240 KV TRANSFORMER 102ST1
 C5S_2017SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

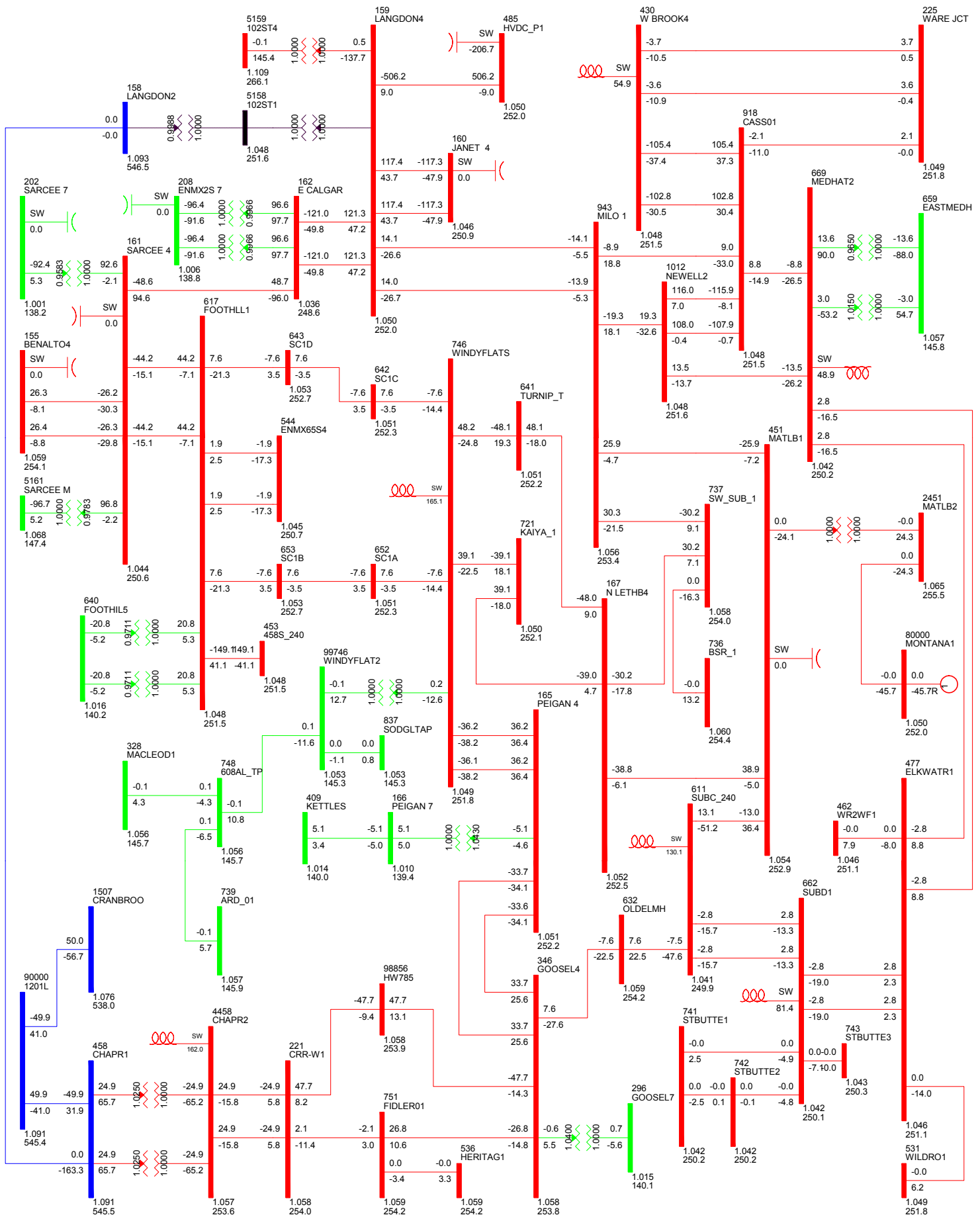


FIG D-W-5: LANGDON 500/240 KV TRANSFORMER 102ST1
 C8_2022SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

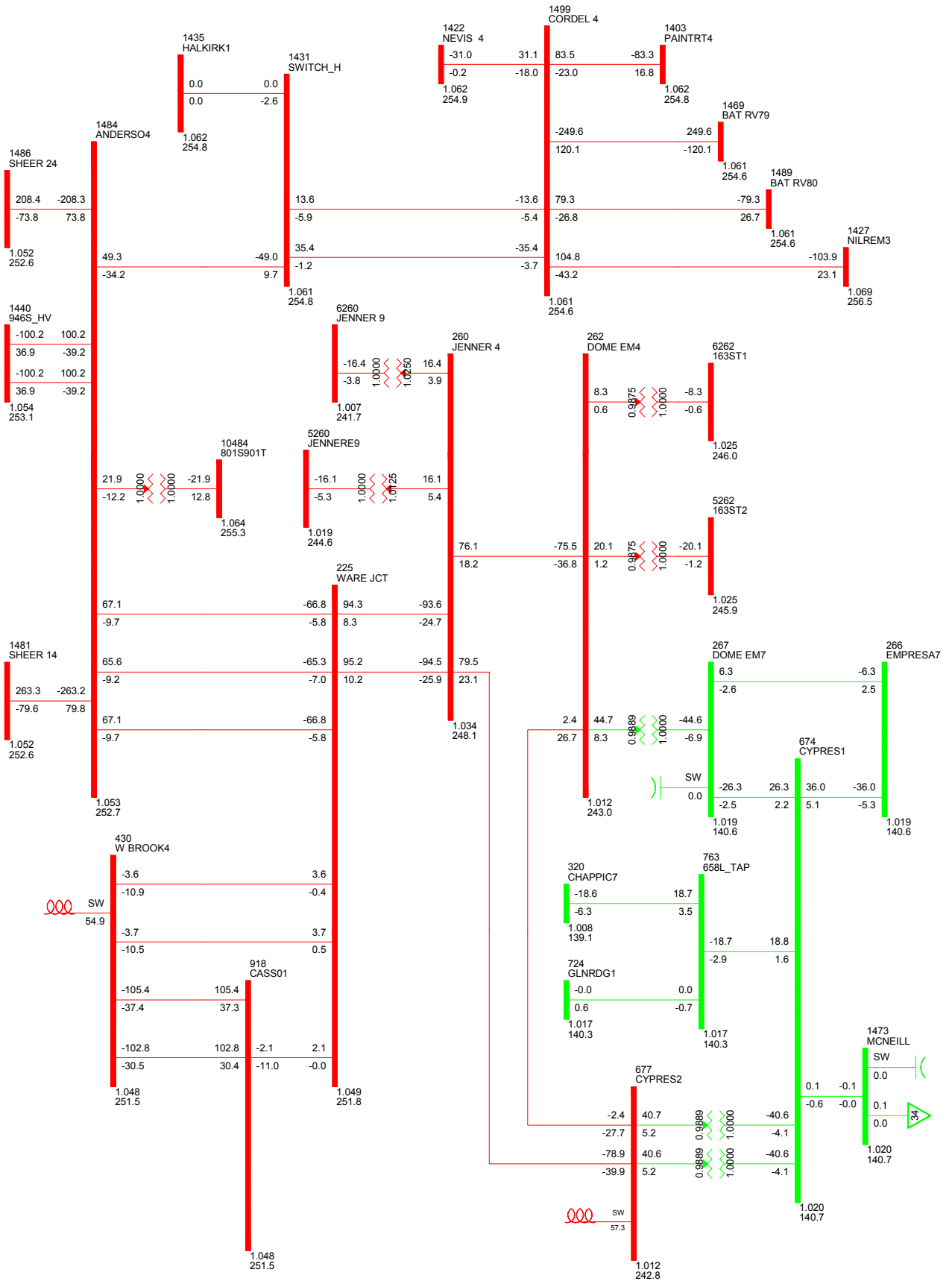


FIG D-E-5: LANGDON 500/240 KV TRANSFORMER 102ST1
 C8_2022SL_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

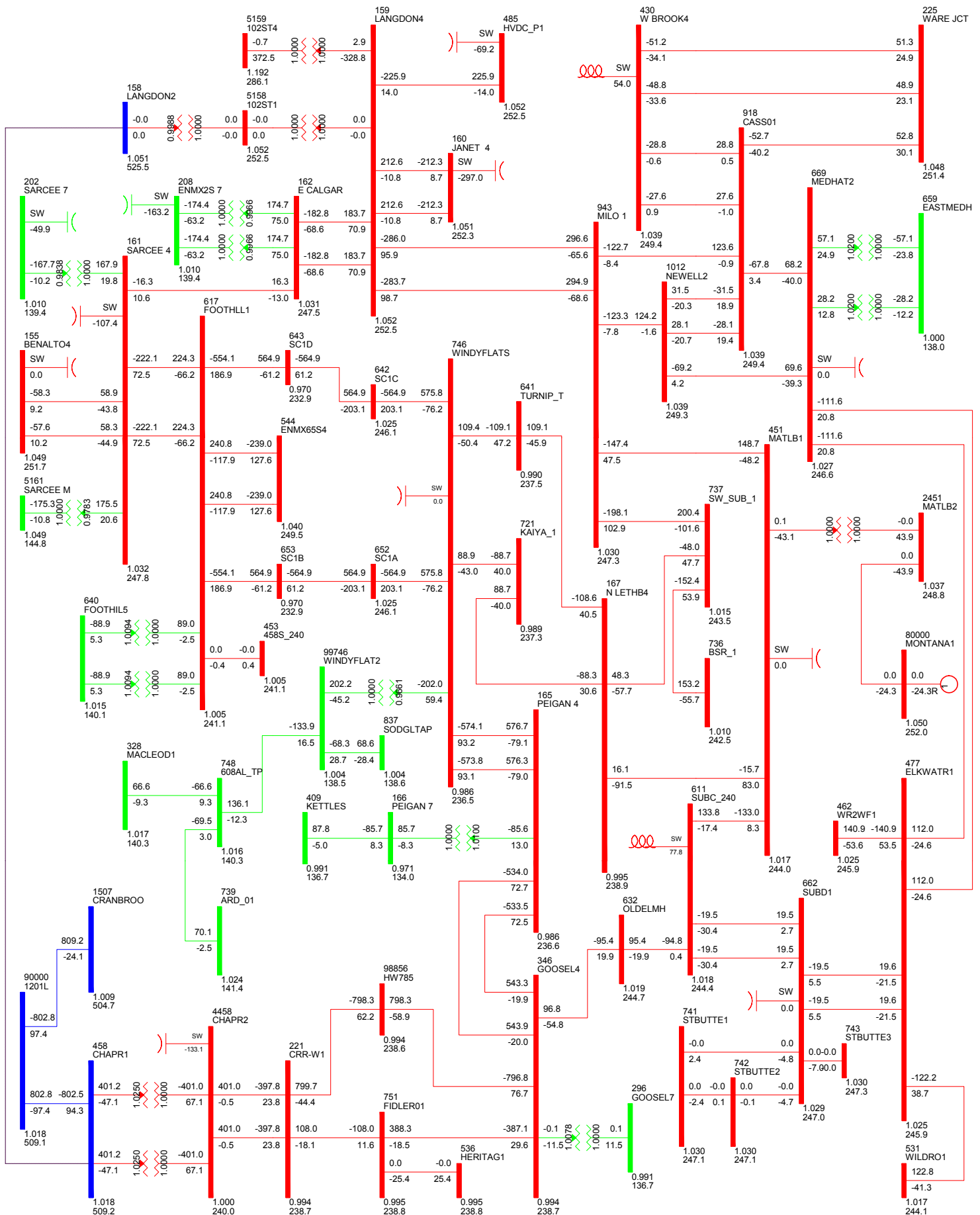


FIG D-W-6: LANGDON2 TO CHAPR1 500 KV LINE
 C11_2017SP_780_0_150_B6_R5

THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kv: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

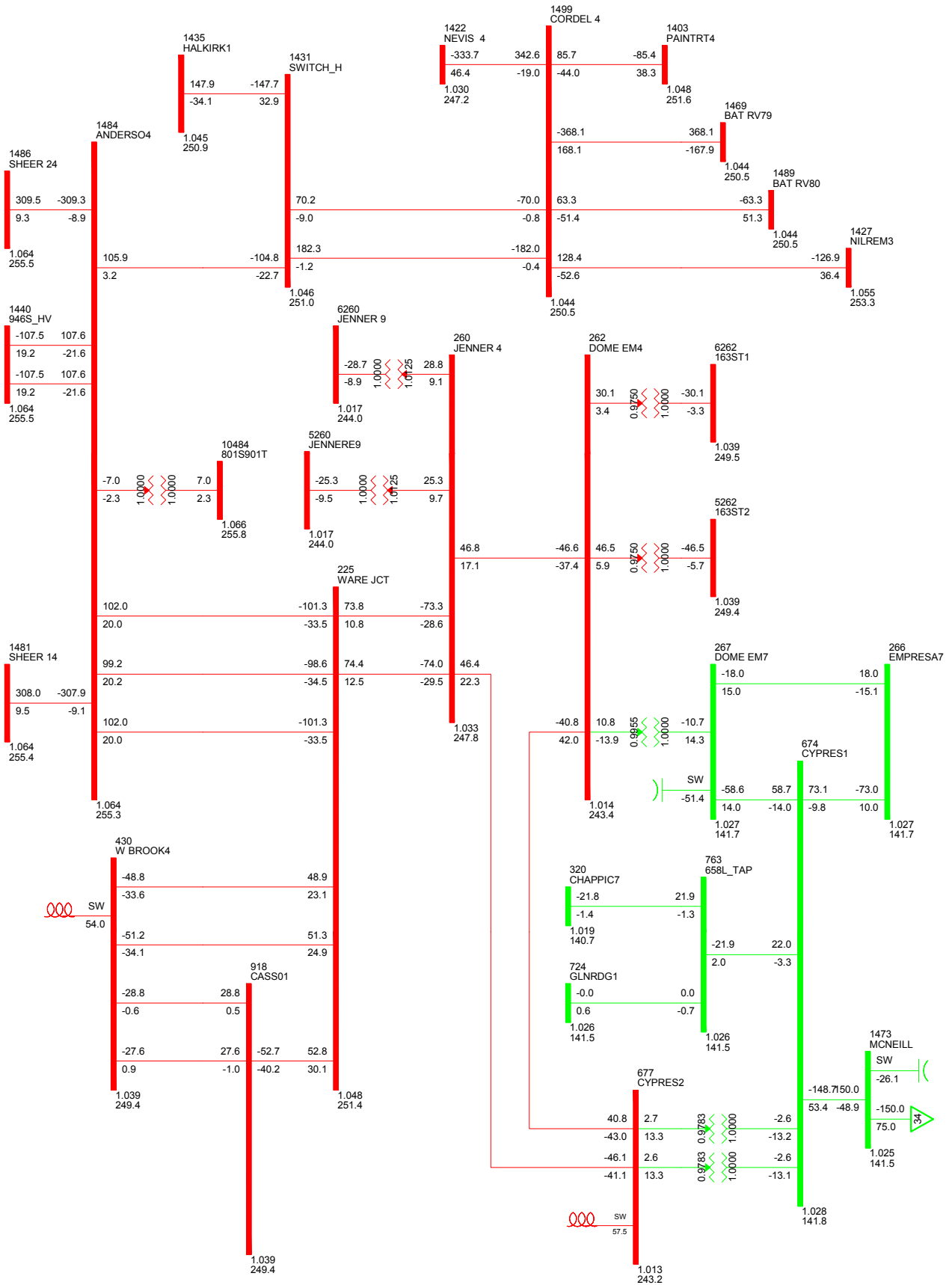


FIG D-E-6: LANGDON2 TO CHAPR1 500 KV LINE
 C11_2017SP_780_0_-150_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: ≤ 34.500=69.000 ≤ 138.000 ≤ 240.000=500.000>500.000

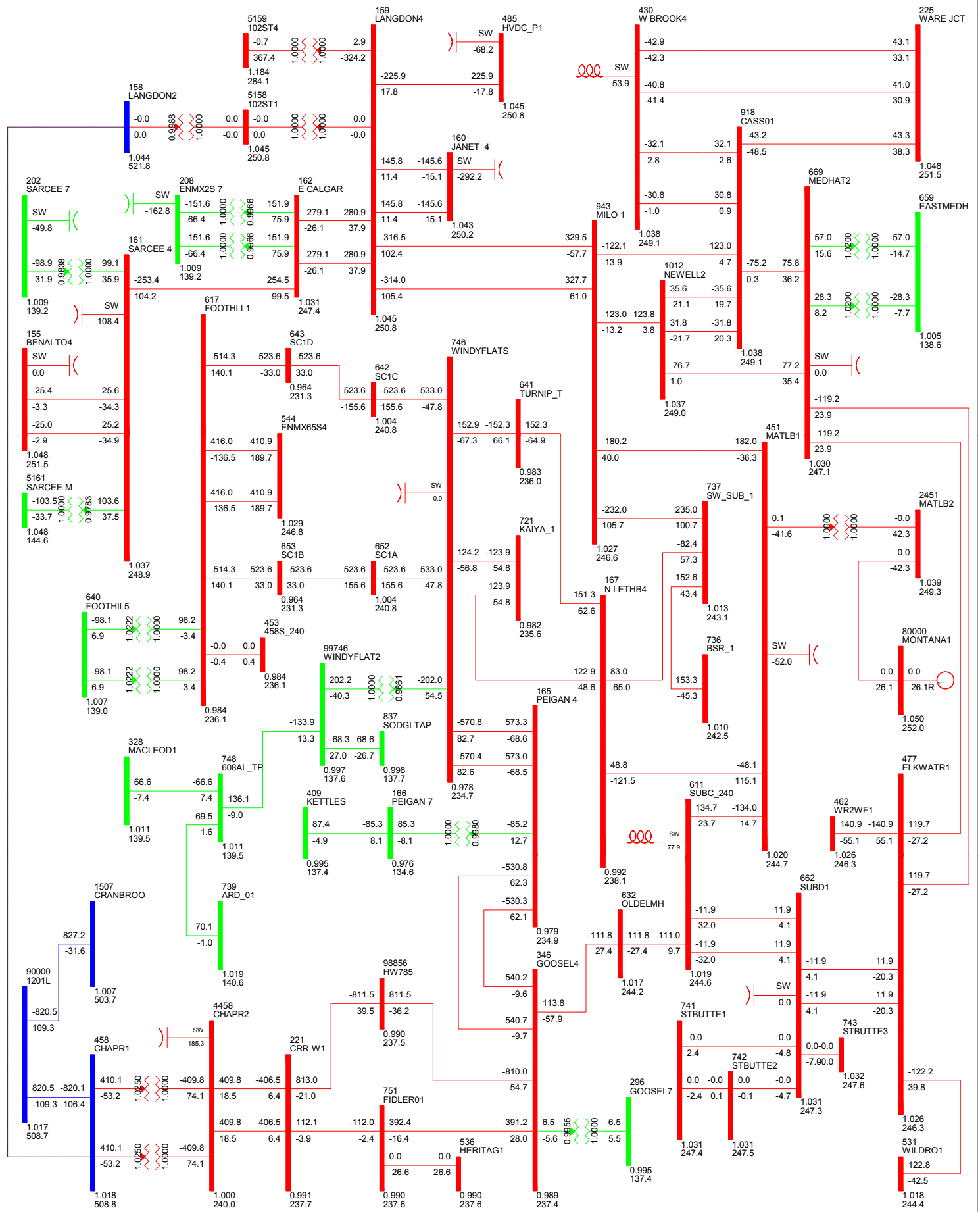


FIG D-W-7: LANGDON2 TO CHAPR1 500 KV LINE
 C11S_2017SP_780_0_150_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

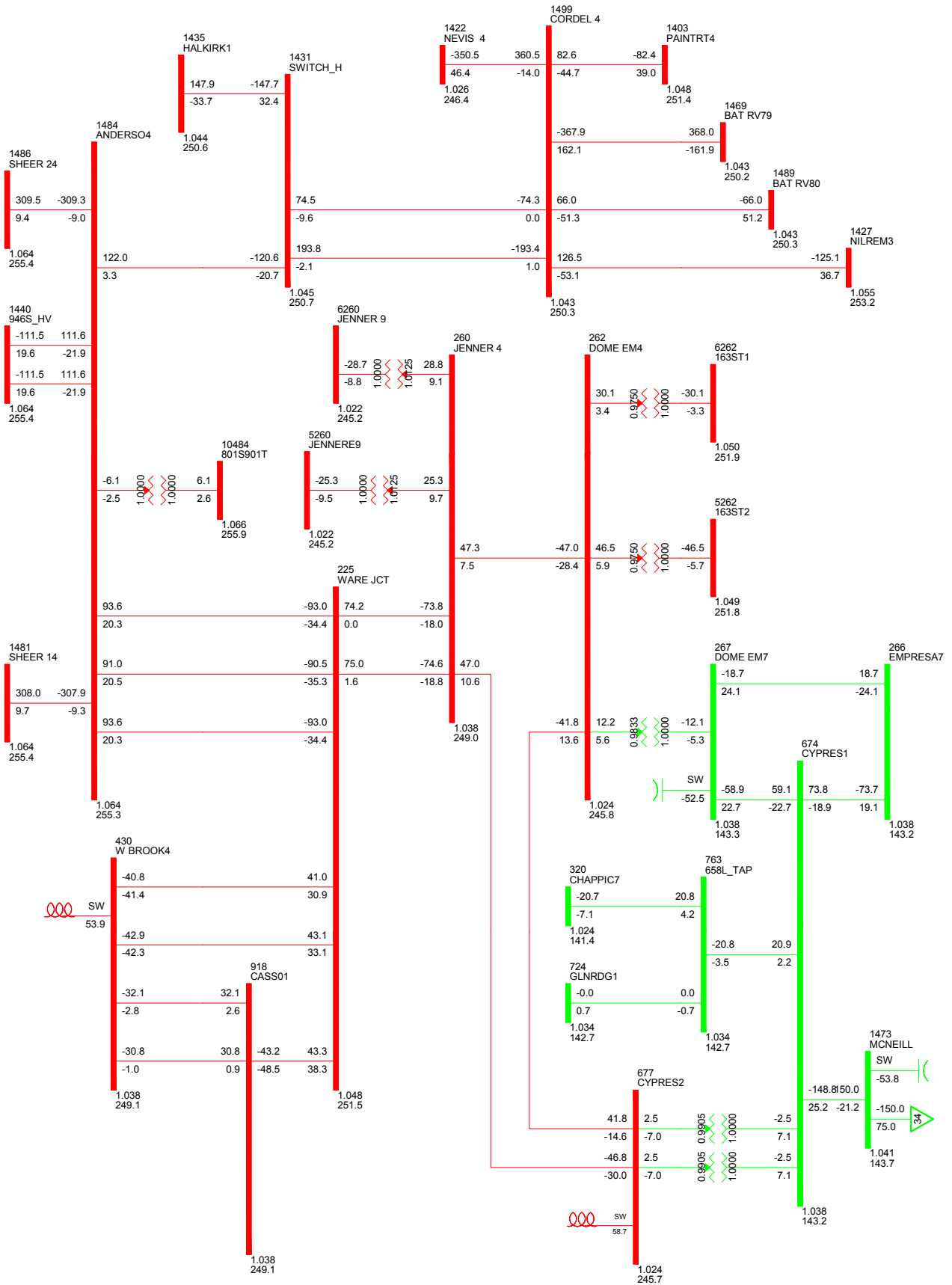


FIG D-E-7: LANGDON2 TO CHAPR1 500 KV LINE
 C11S_2017SP_-780_0_-150_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

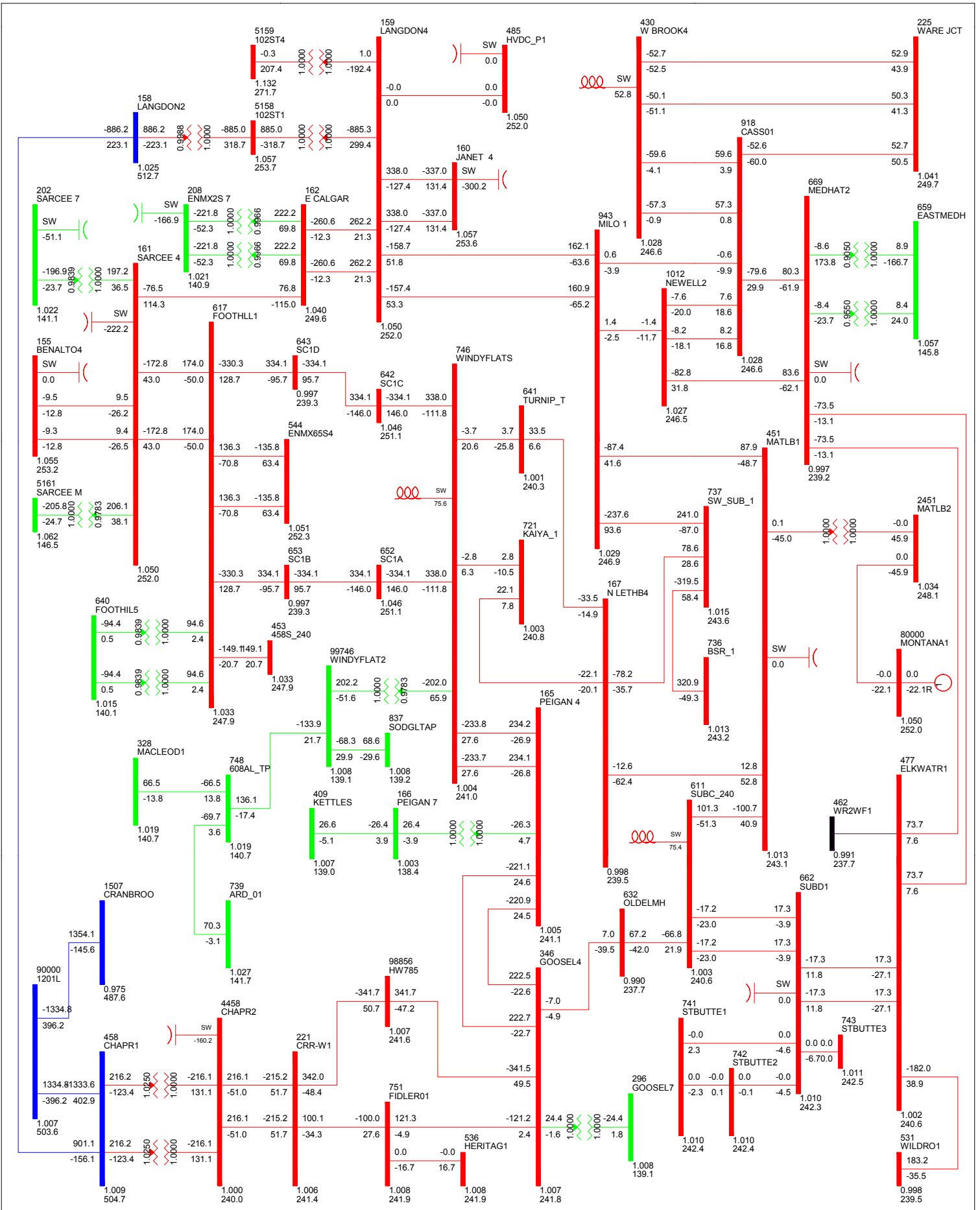


FIG D-W-8: WR2WF1 TO ELKWATR1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

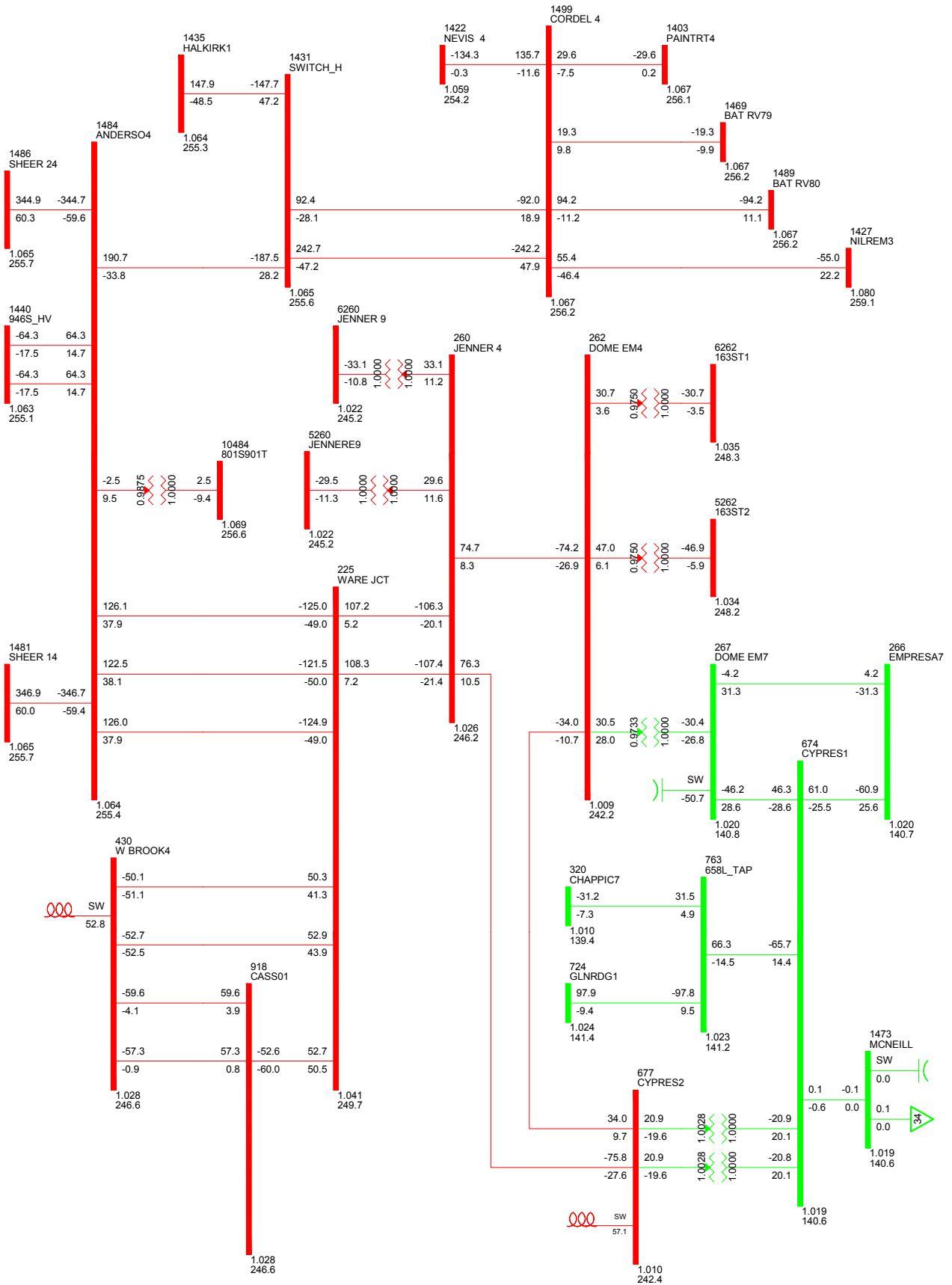


FIG D-E-8: WR2WF1 TO ELKWATR1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

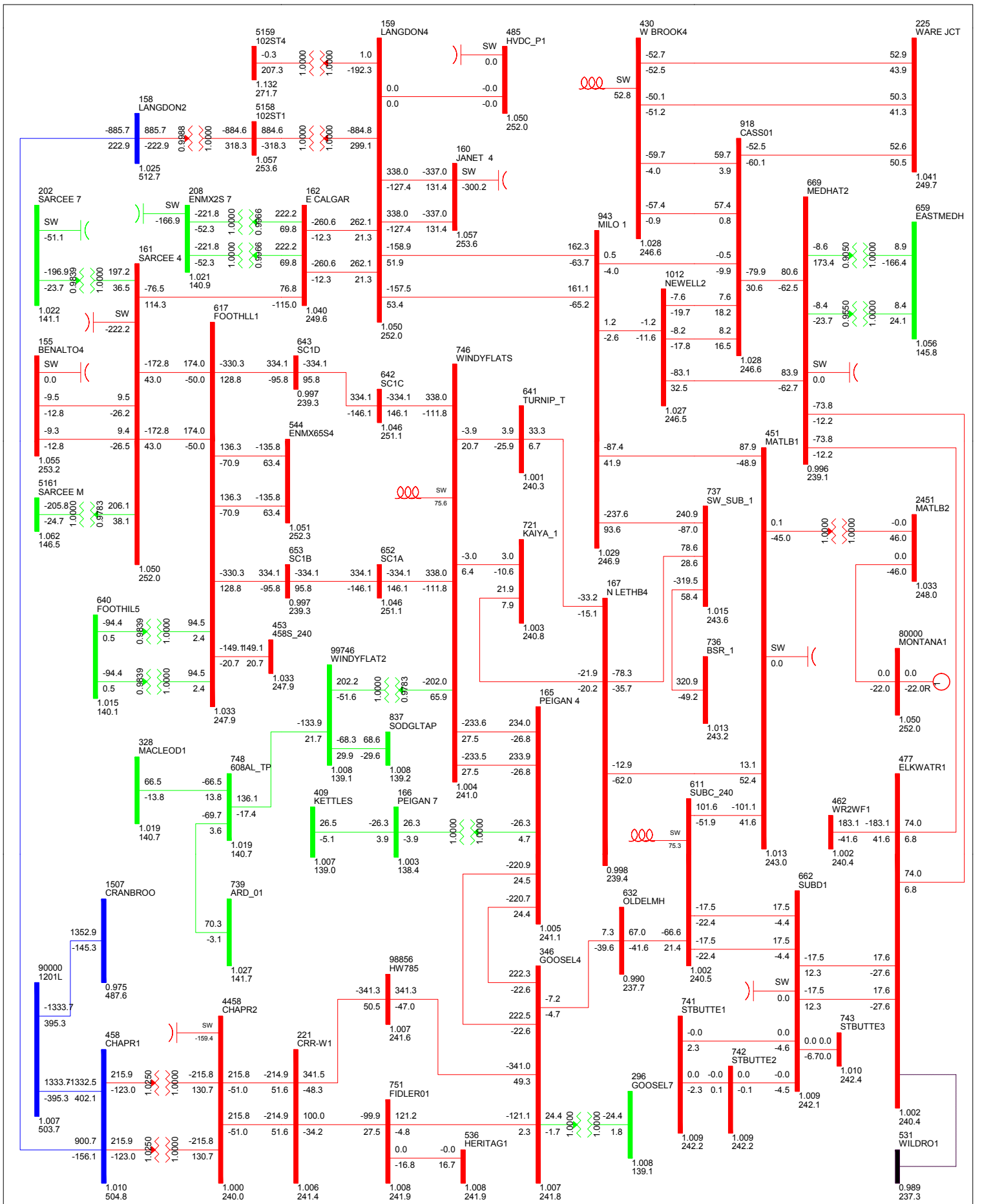


FIG D-W-9: ELKWATR1 TO WILDRO1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

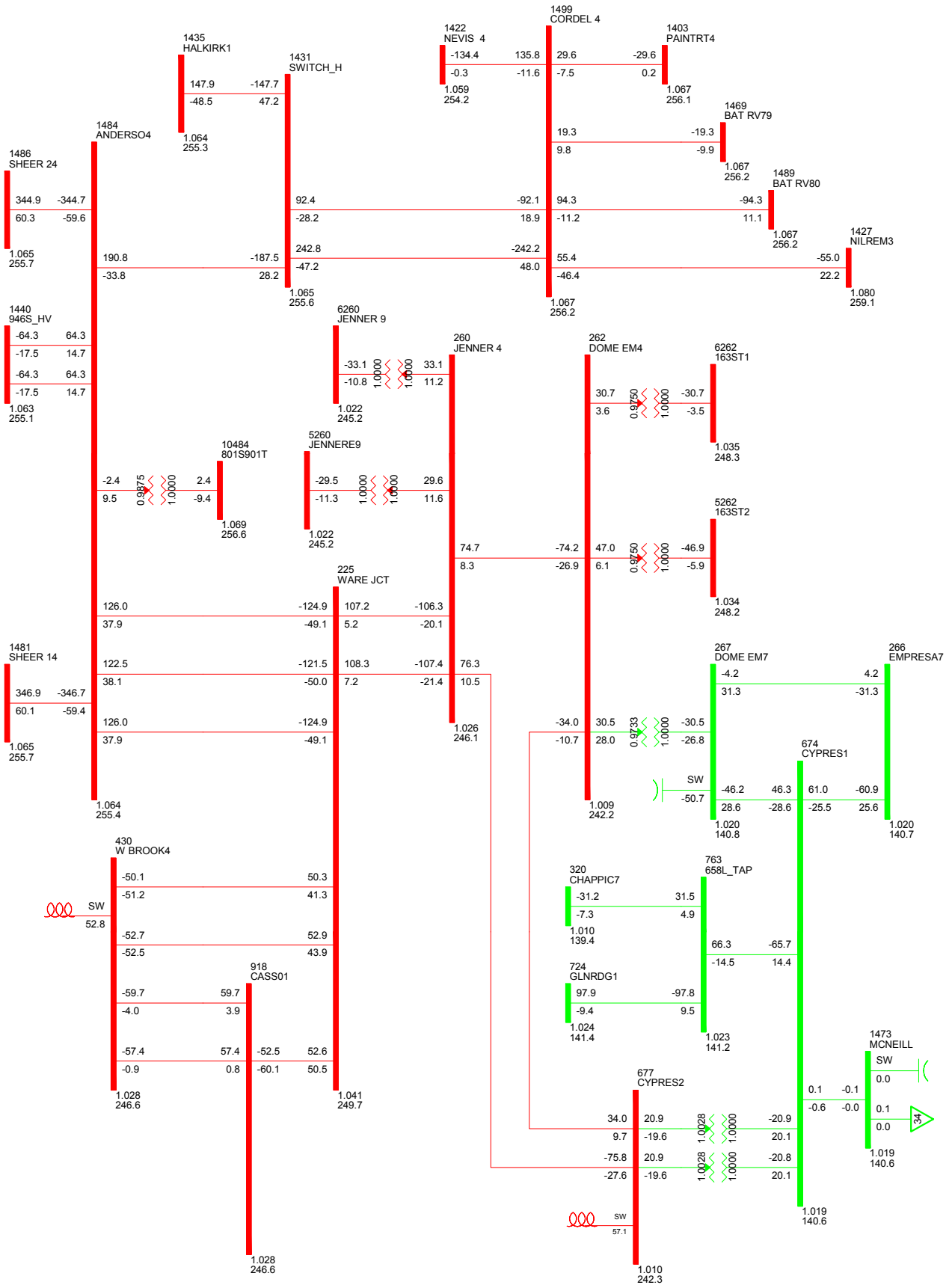


FIG D-E-9: ELKWATR1 TO WILDRO1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

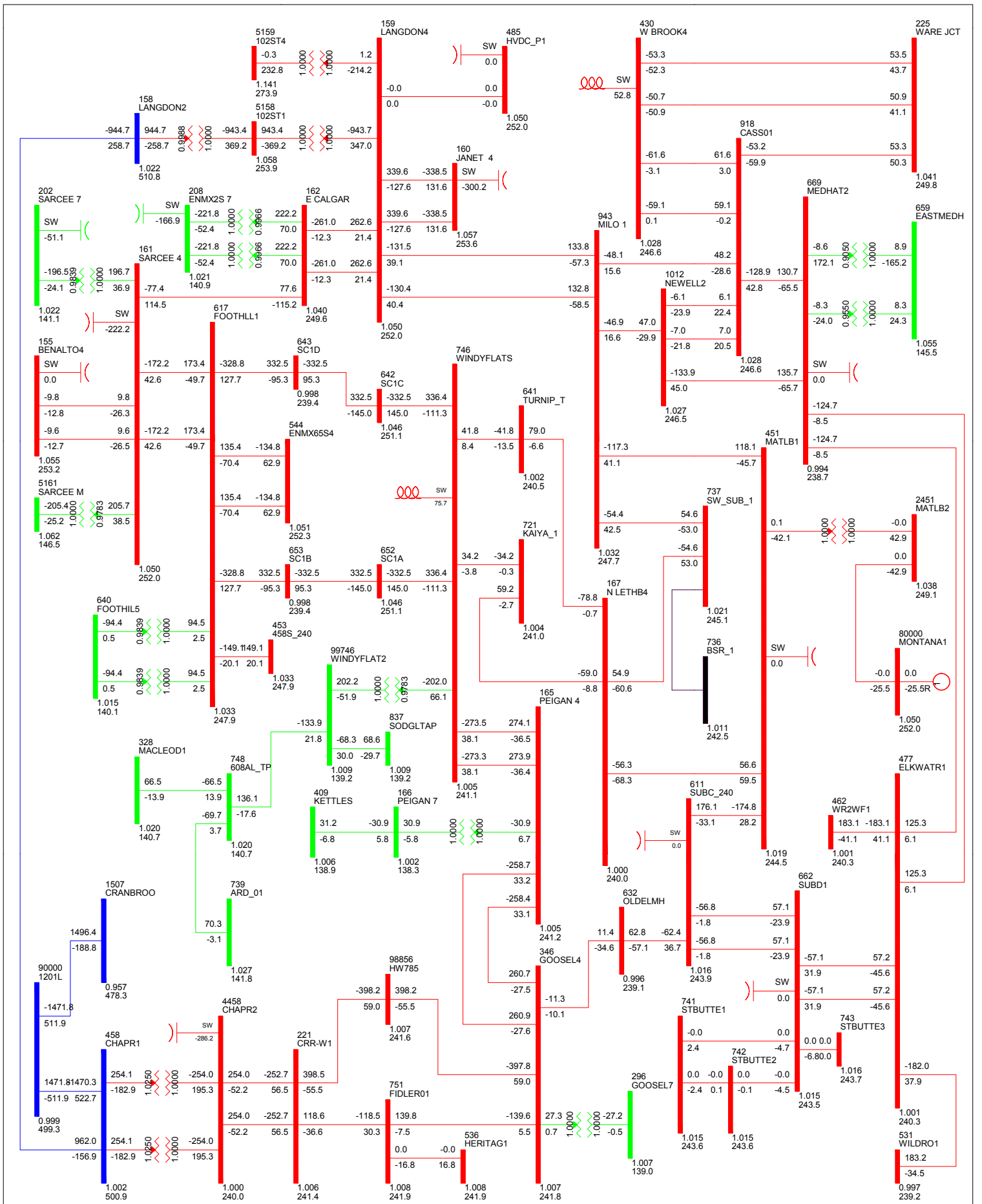


FIG D-W-10: BSR_1 TO SW_SUB_1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

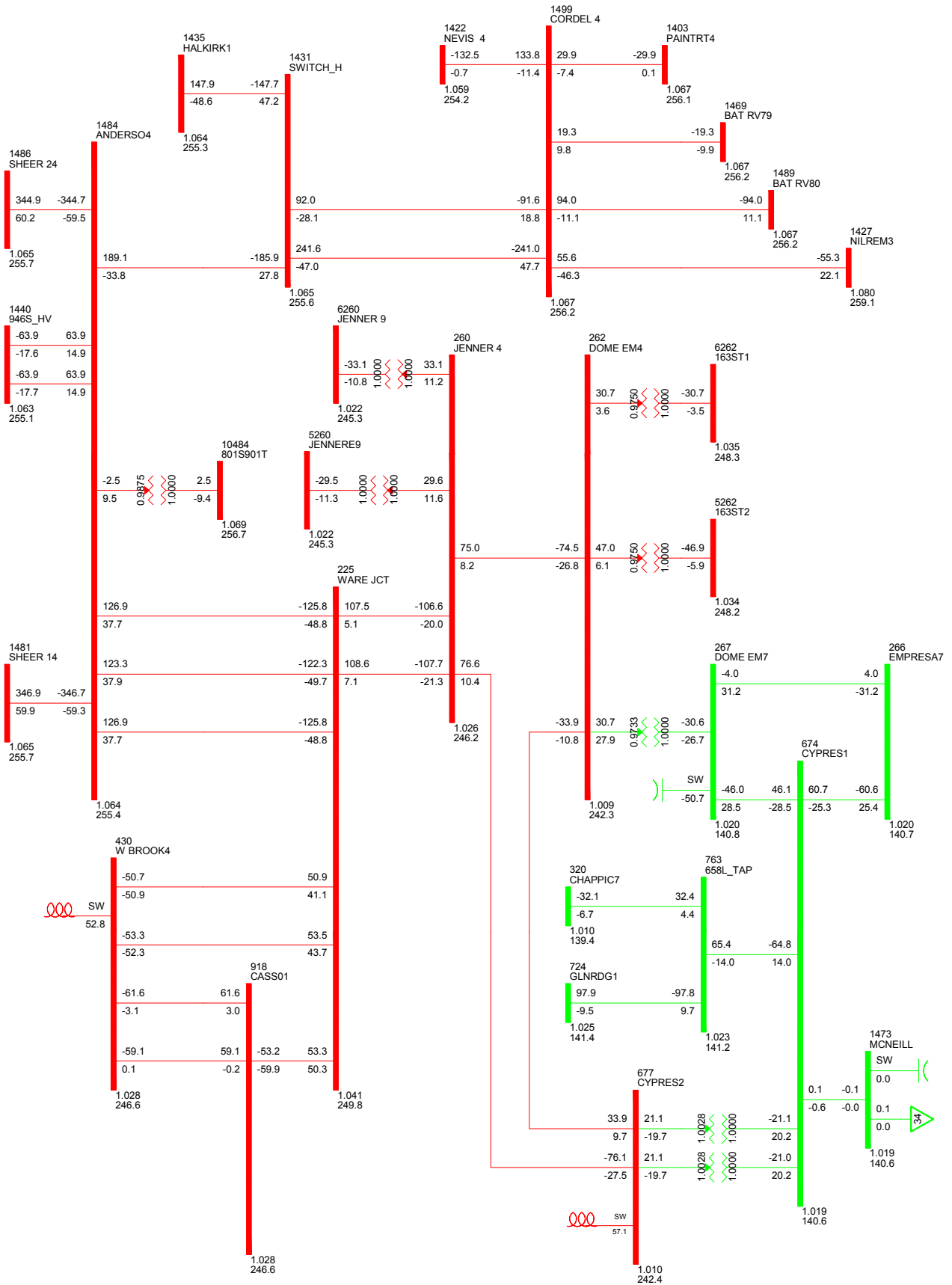


FIG D-E-10: BSR_1 TO SW_SUB_1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

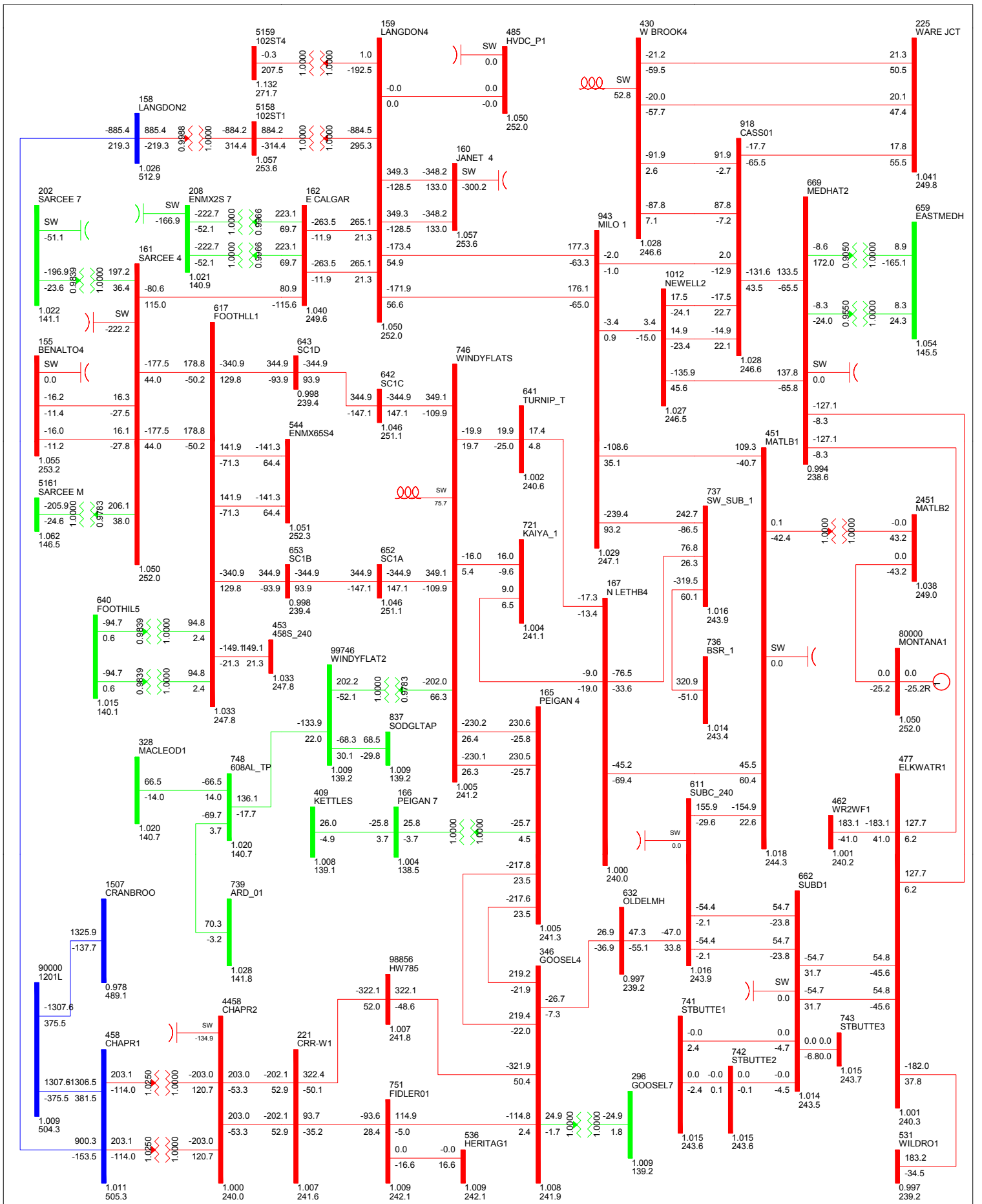


FIG D-W-11: SWITCH_H TO HALKIRKI 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

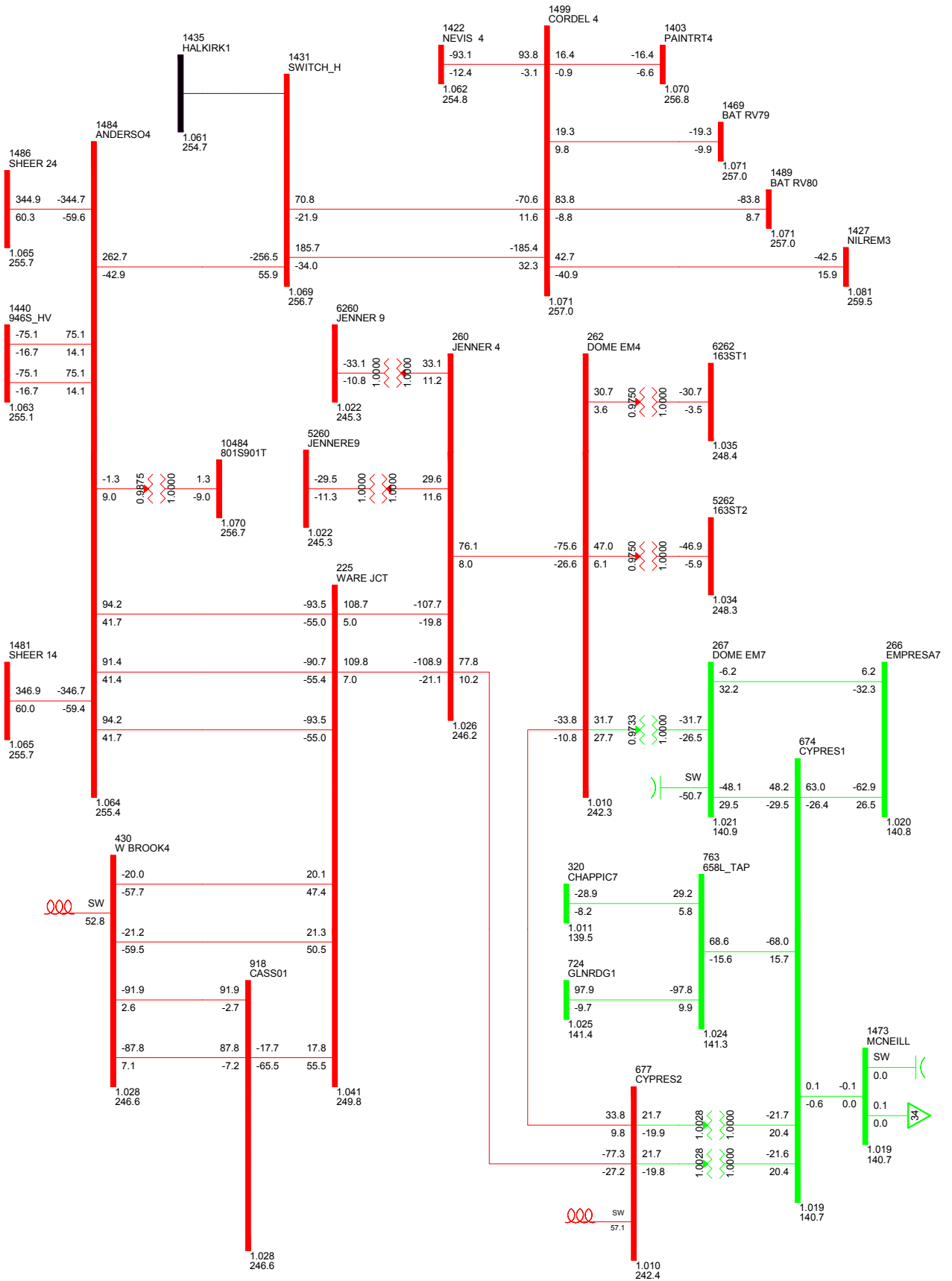


FIG D-E-11: SWITCH_H TO HALKIRK1 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

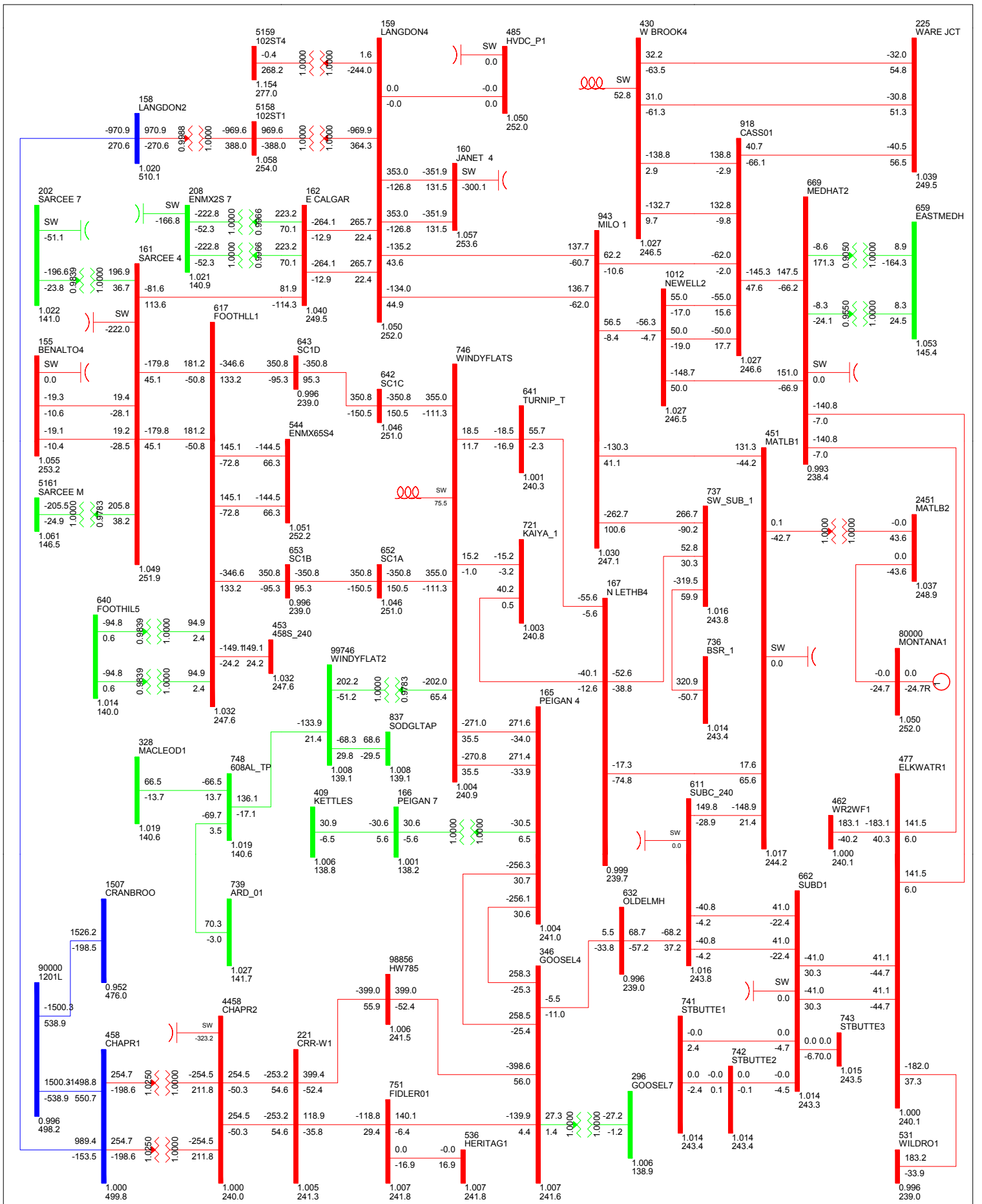


FIG D-W-12: SHEER 14 TO ANDERSO4 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

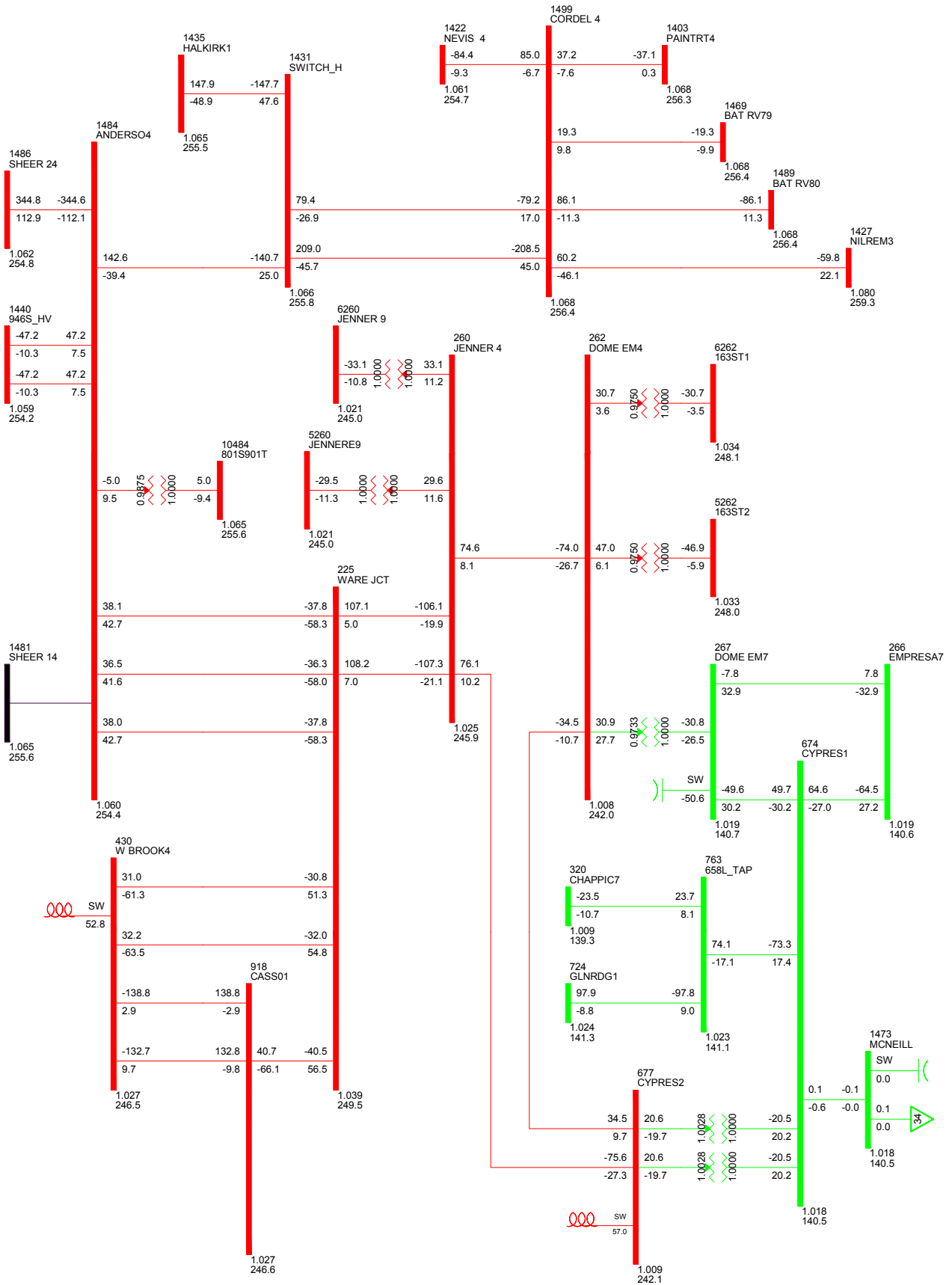


FIG D-E-12: SHEER 14 TO ANDERSO4 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

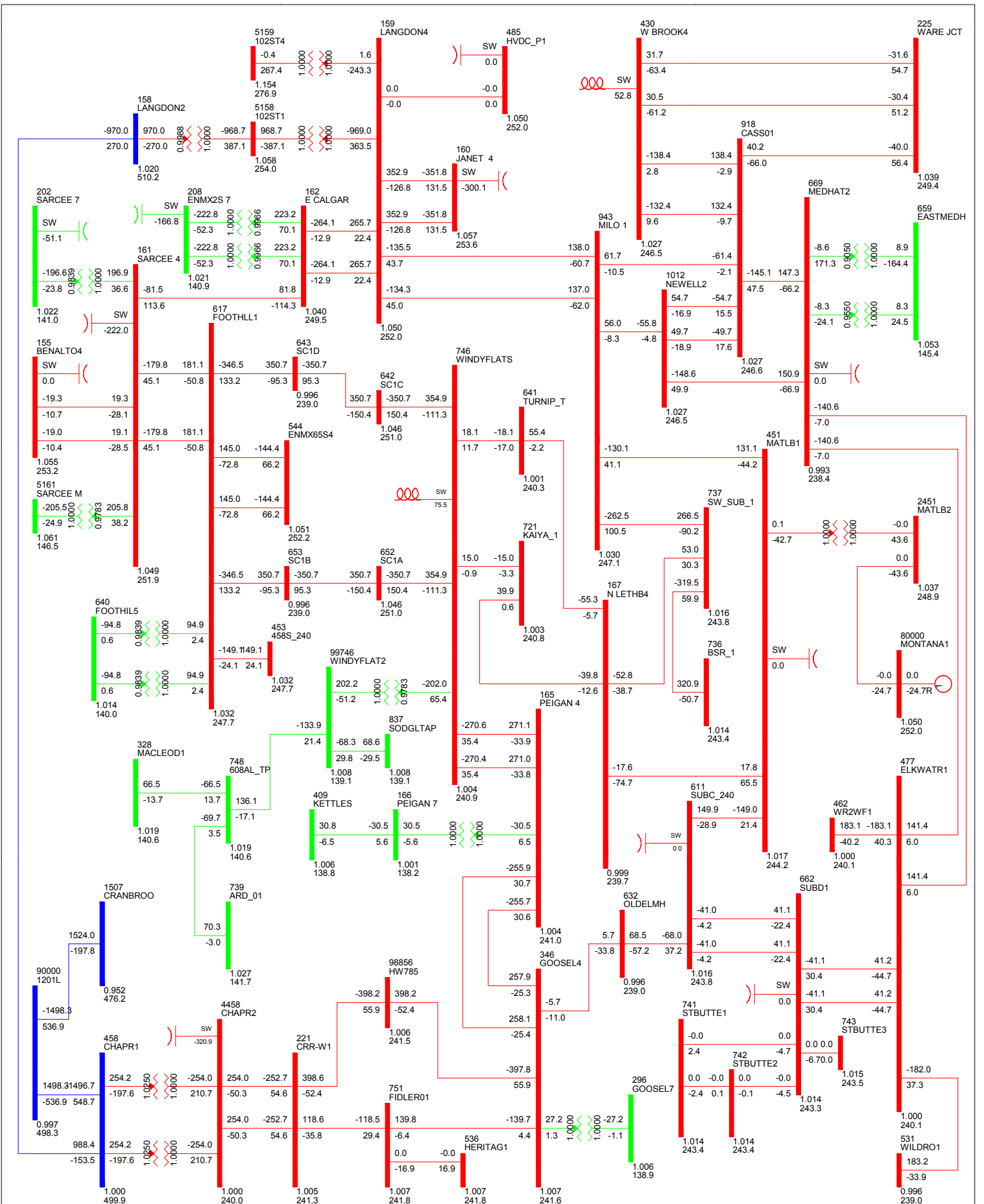


FIG D-W-13: ANDERSON4 TO SHEER 24 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

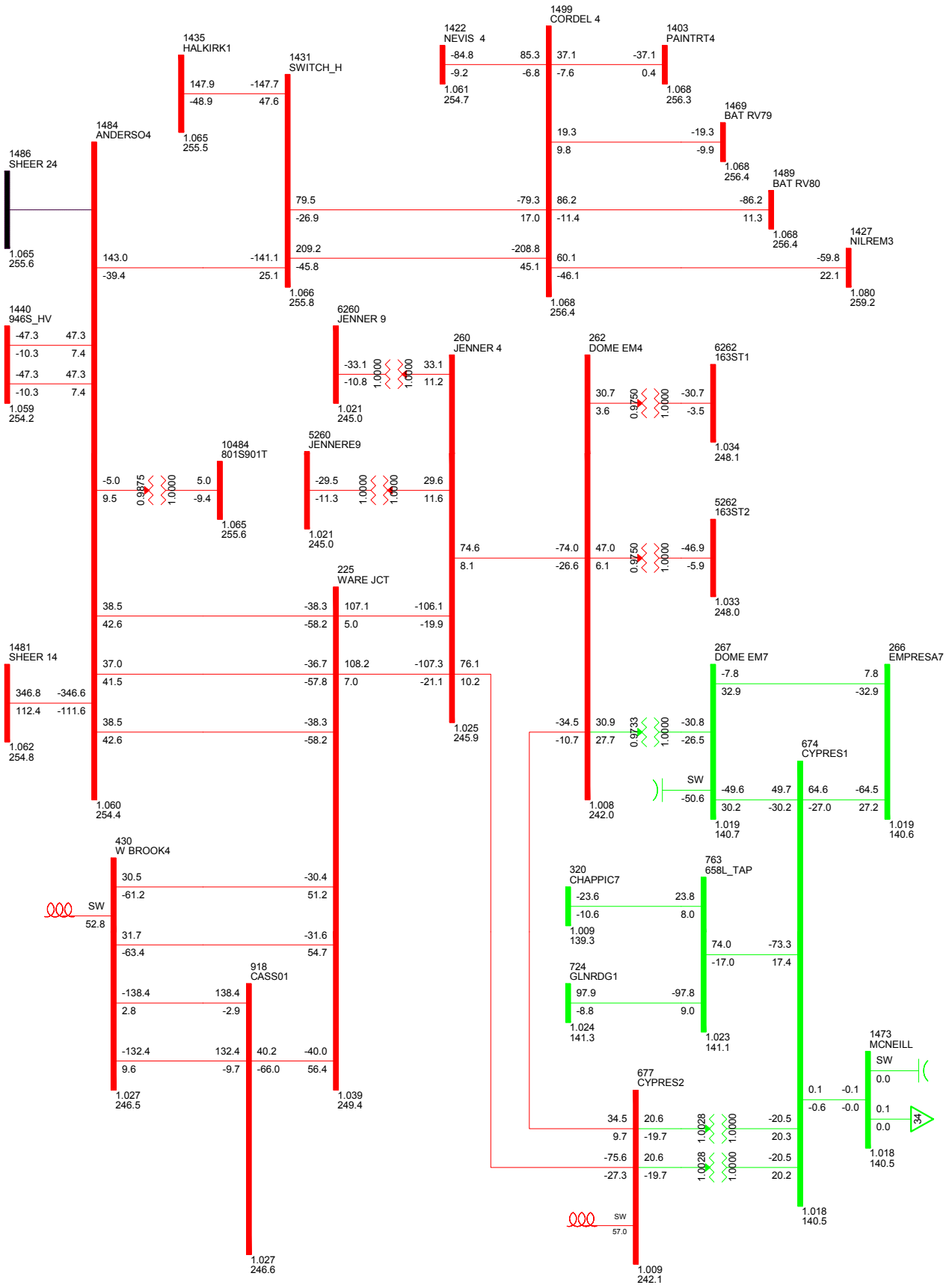


FIG D-E-13: ANDERSON4 TO SHEER 24 240 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 >500.000

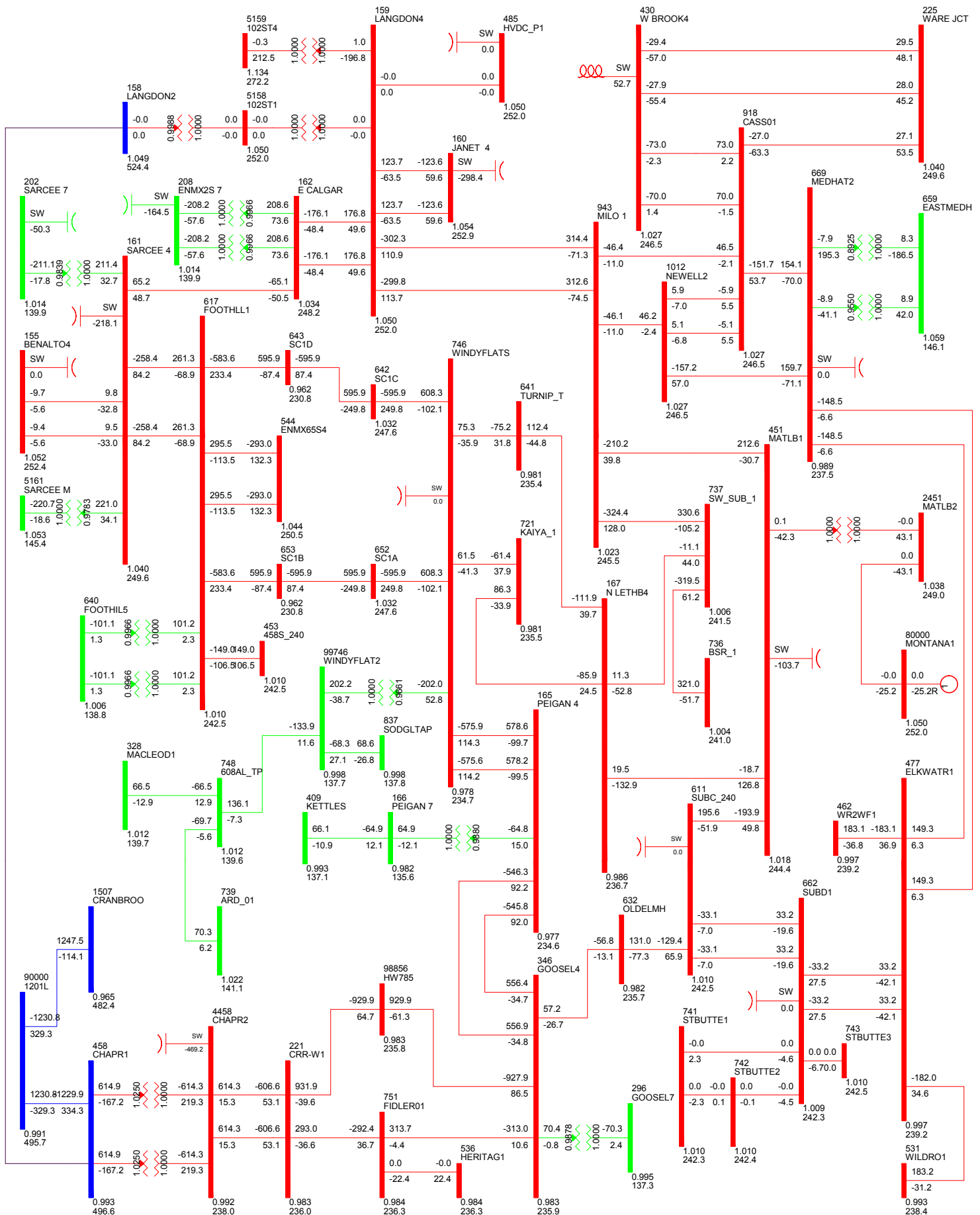


FIG D-W-14: LANGDON2 TO CHAPR1 500 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

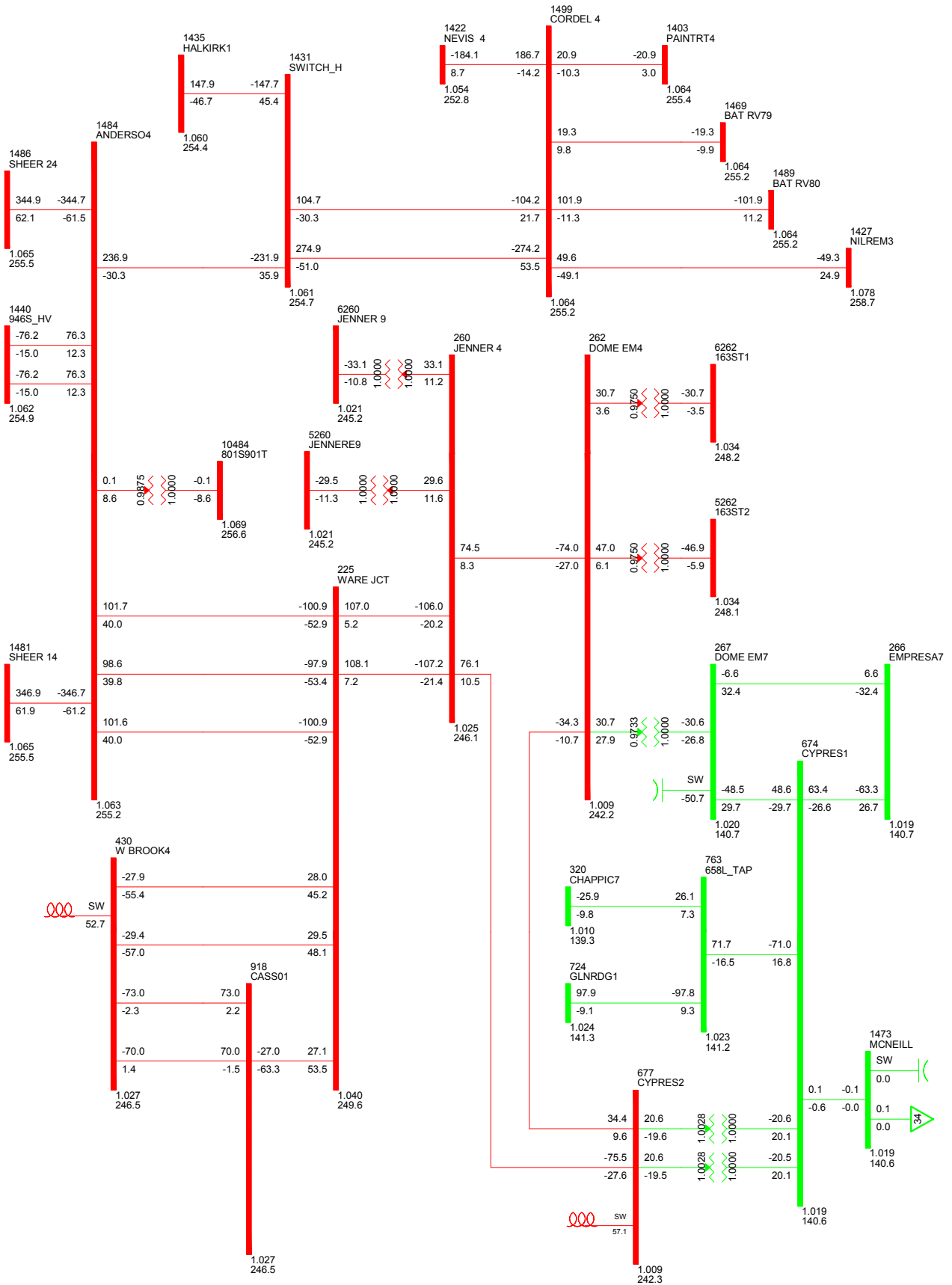


FIG D-E-14: LANGDON2 TO CHAPR1 500 KV LINE
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=240.000<=500.000>500.000

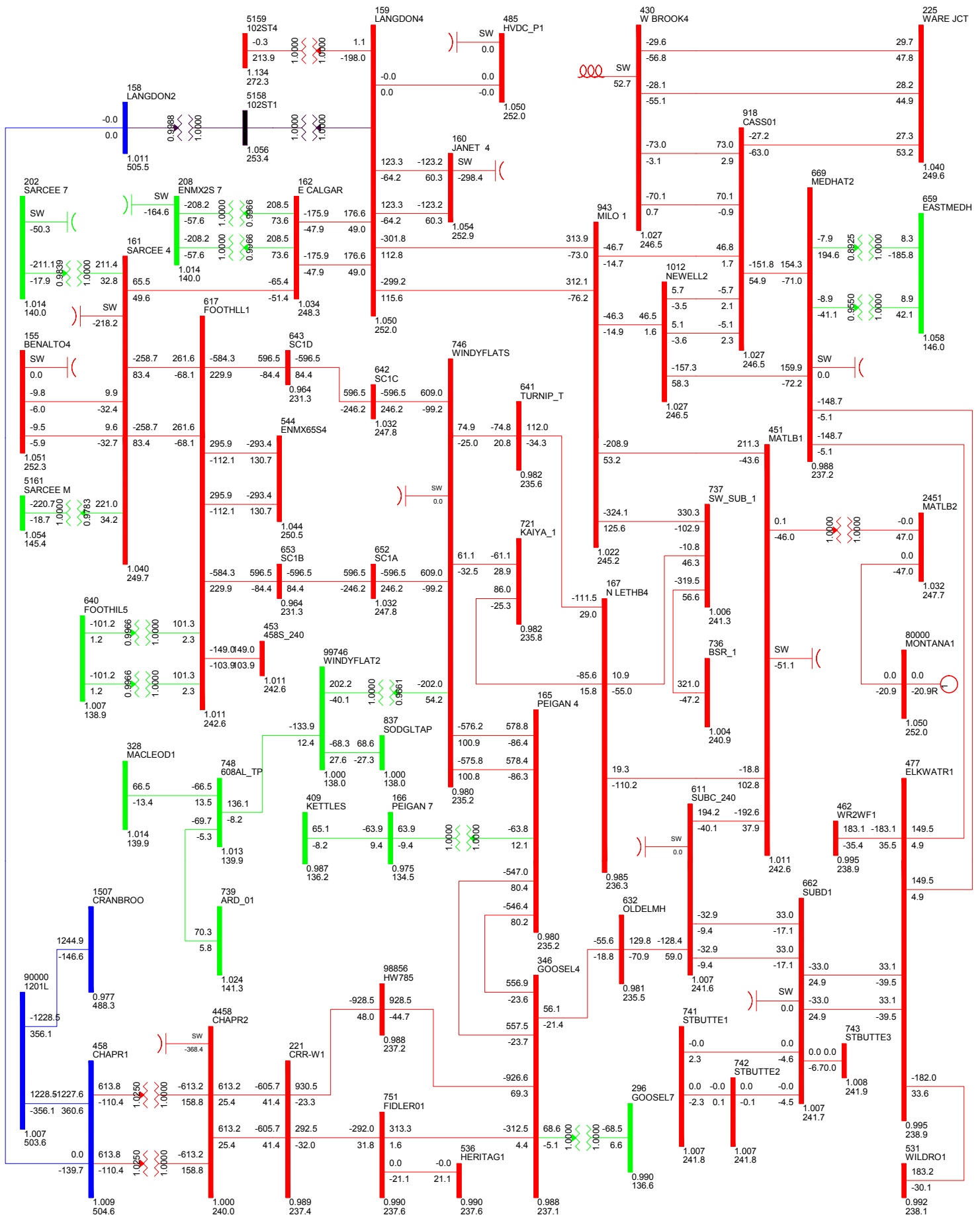


FIG D-W-15: LANGDON 500/240 KV TRANSFORMER 102ST1
 C12_2022SP_-1200_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

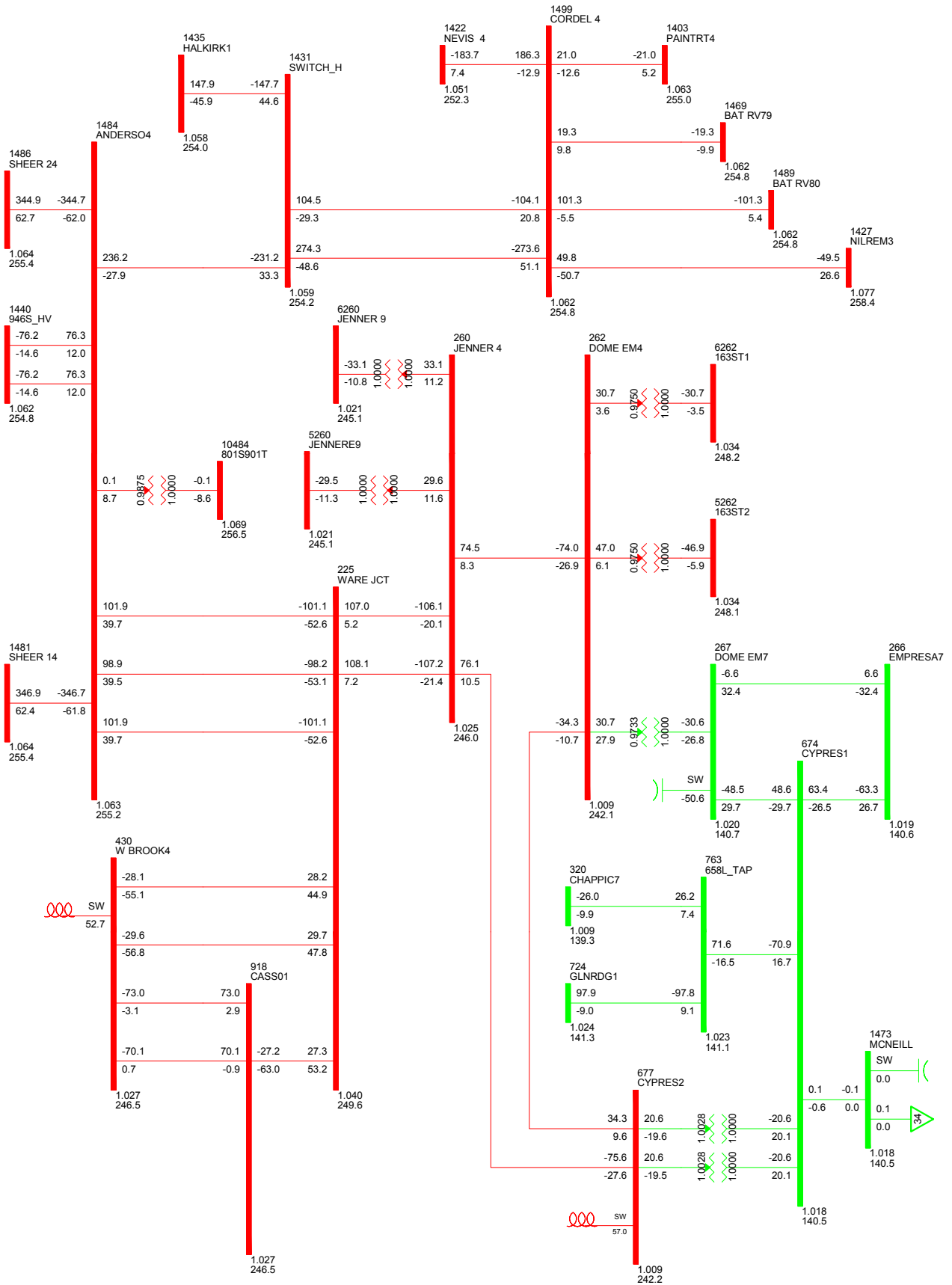


FIG D-E-15: LANGDON 500/240 KV TRANSFORMER 102ST1
 C12_2022SP_-1200_0_0_B6_R5
 THU, AUG 30 2012 15:59

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

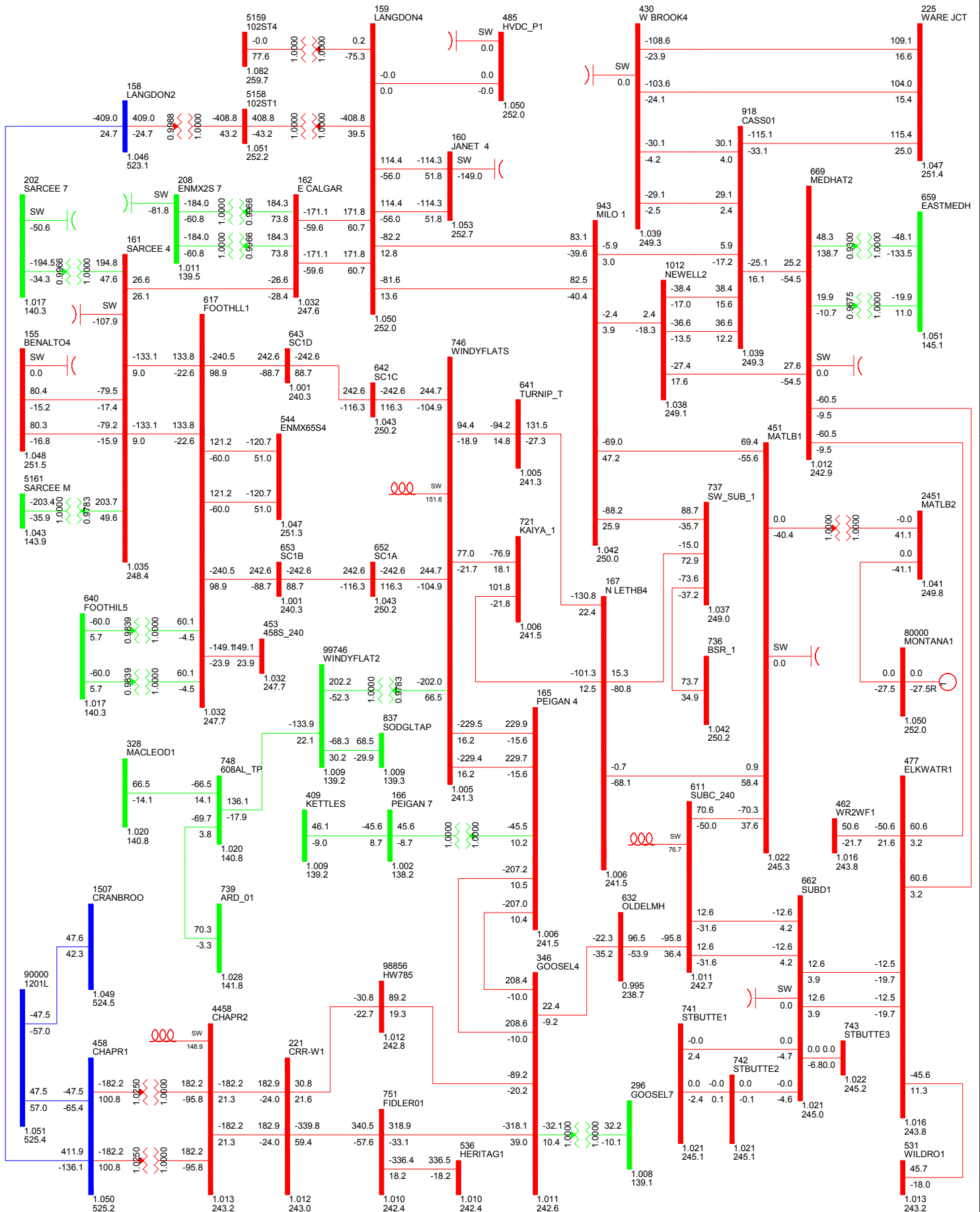


FIG D-W-16: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 15:59

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

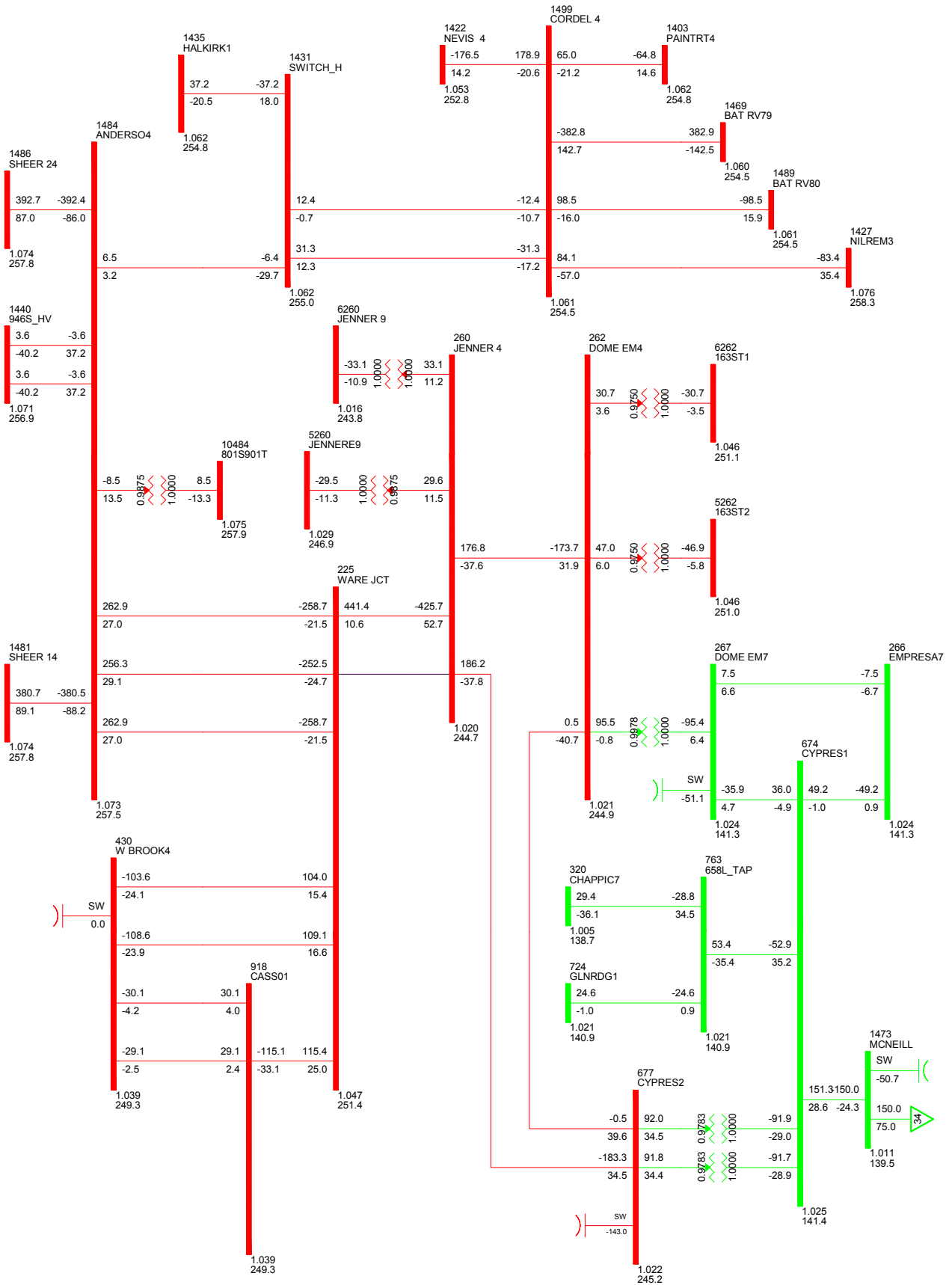


FIG D-E-16: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

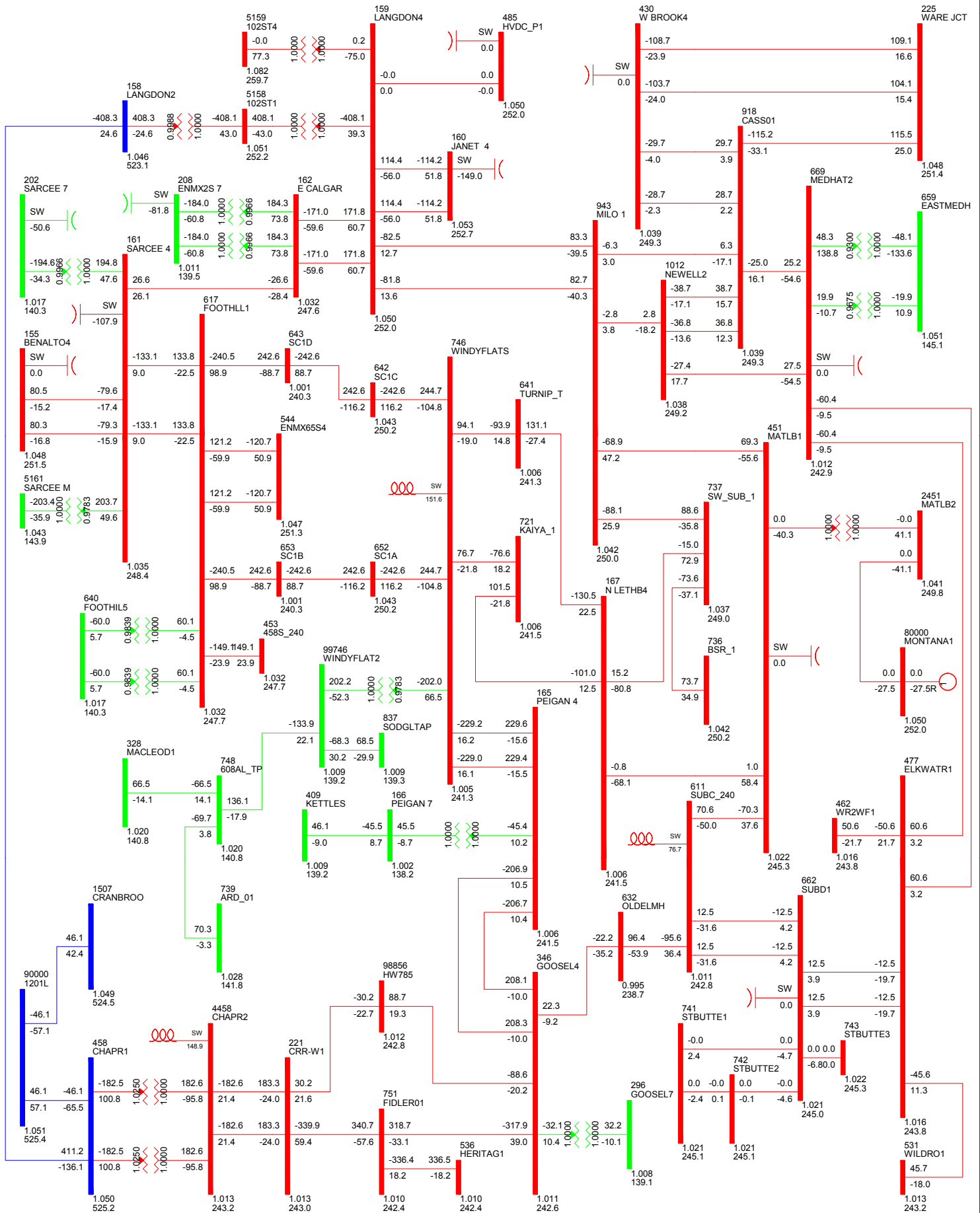


FIG D-W-17: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

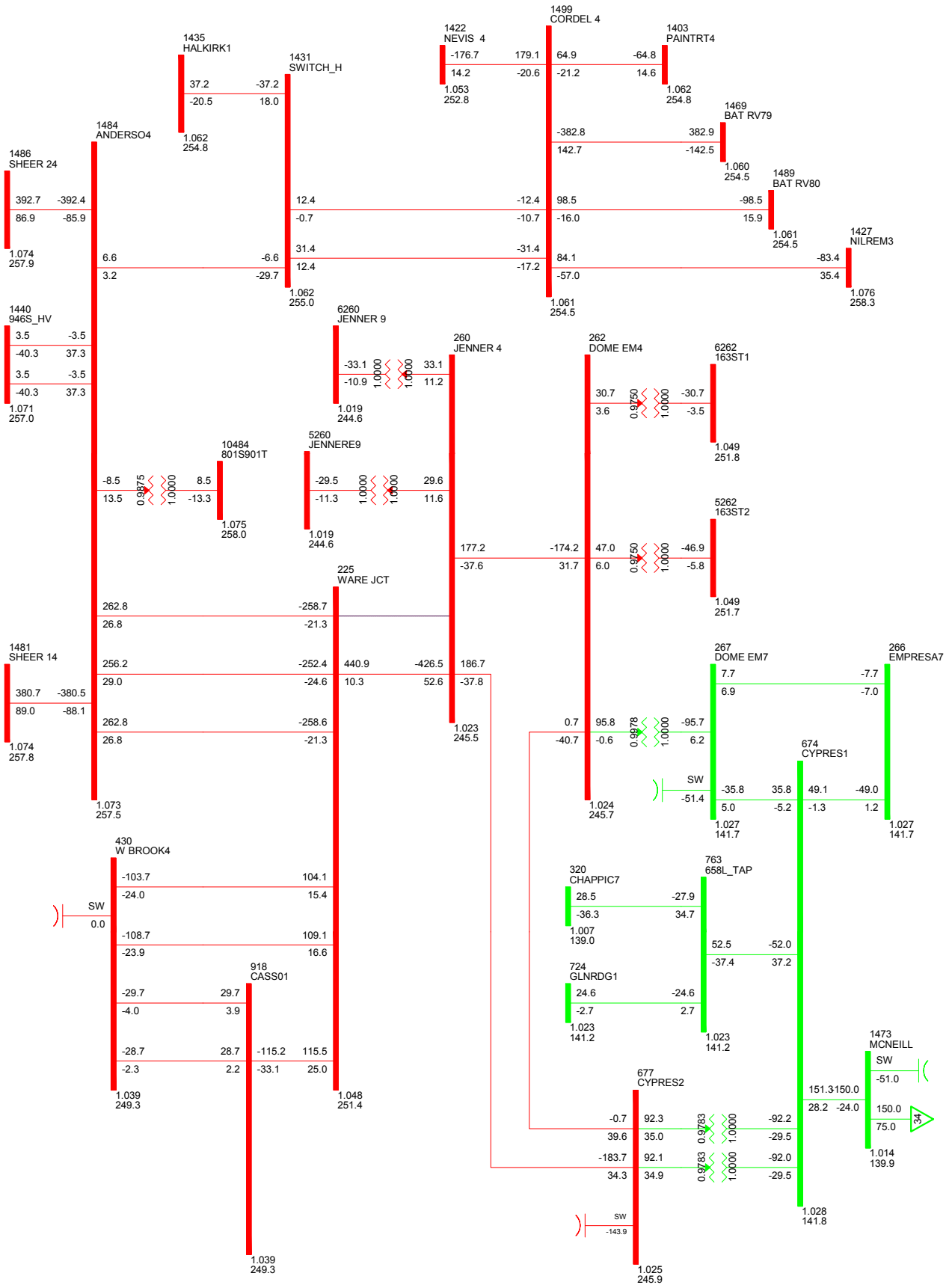


FIG D-E-17: WARE JCT TO JENNER 4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

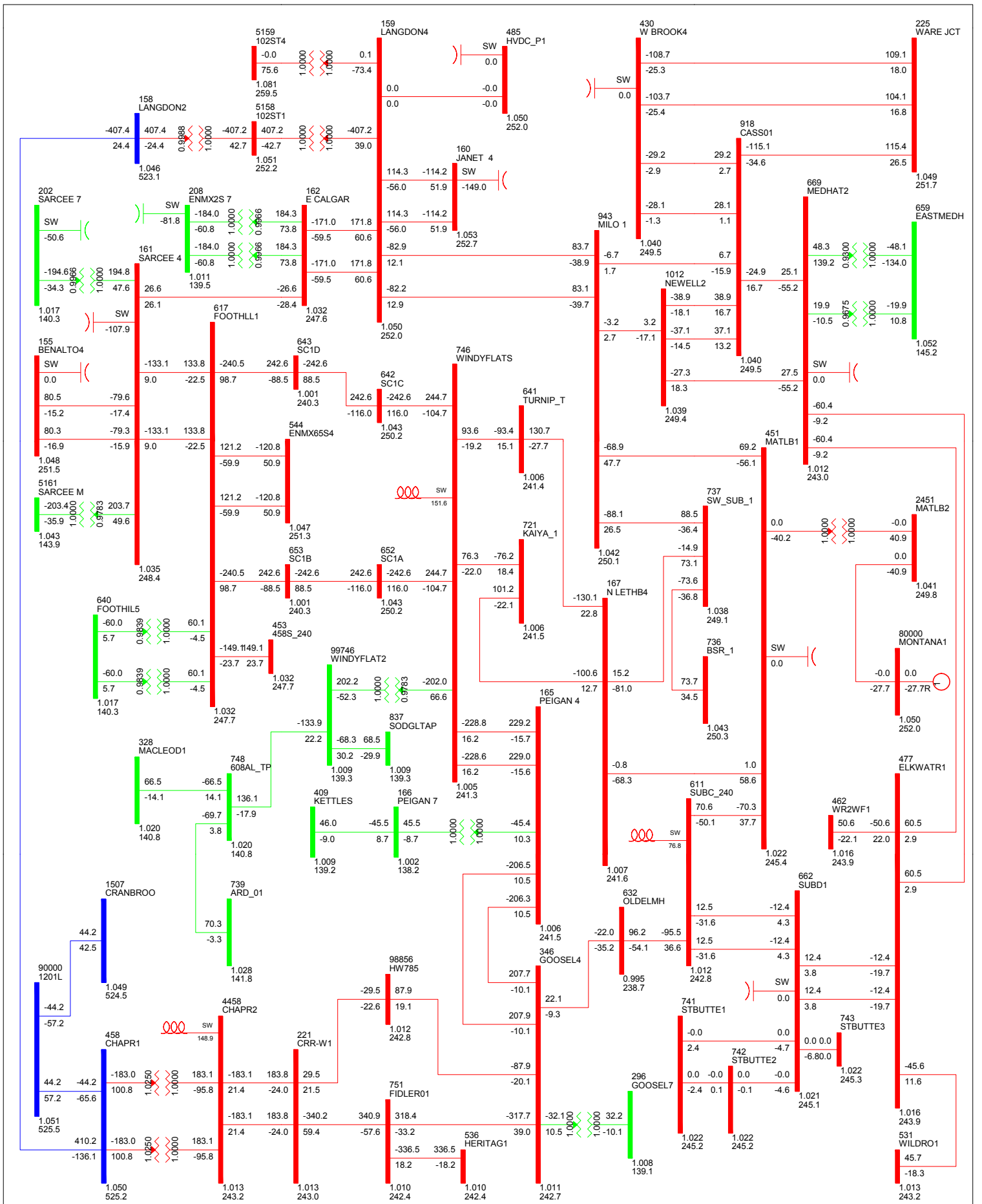


FIG D-W-18: JENNER 4 TO DOME EM4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

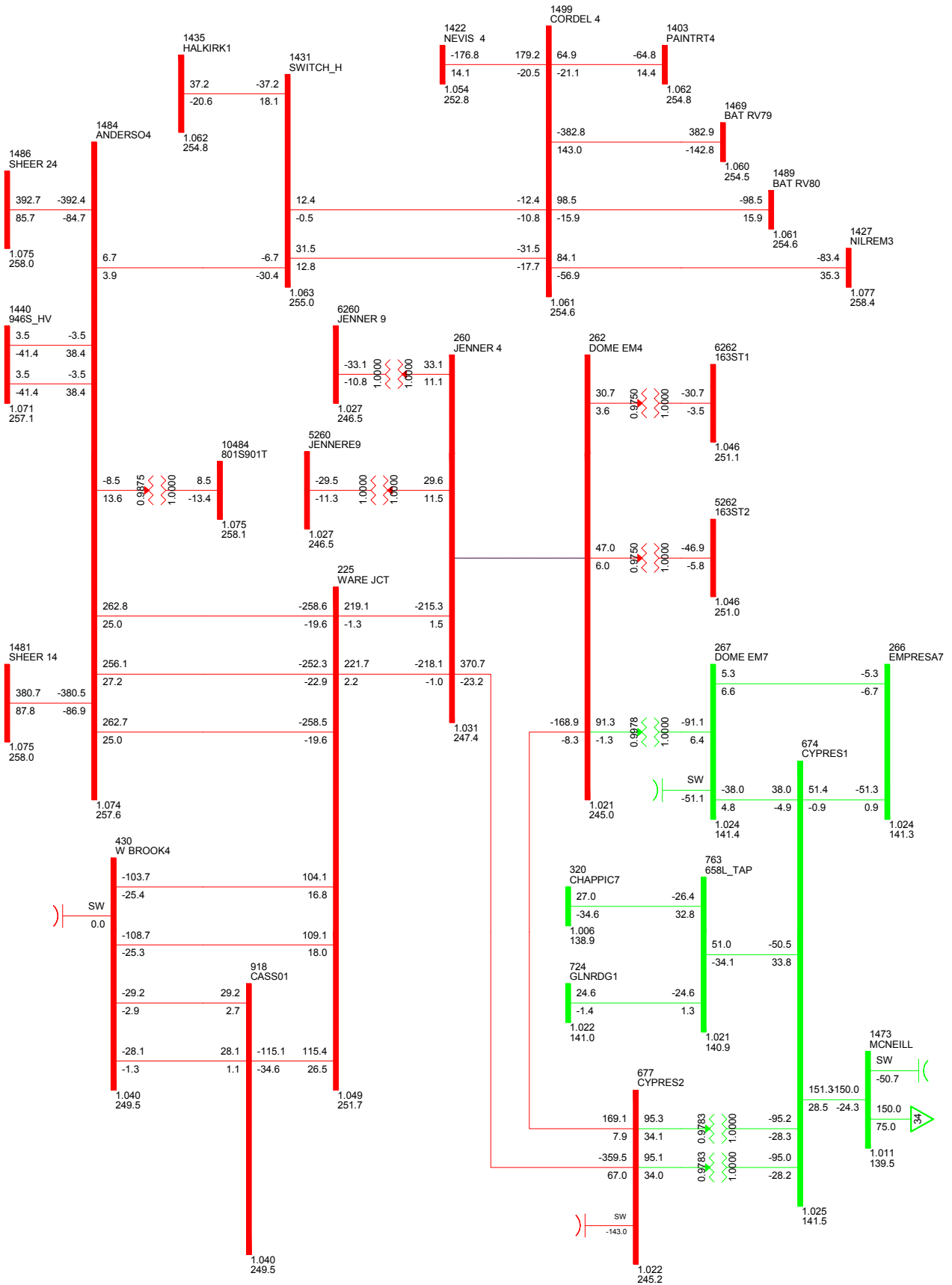


FIG D-E-18: JENNER 4 TO DOME EM4 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

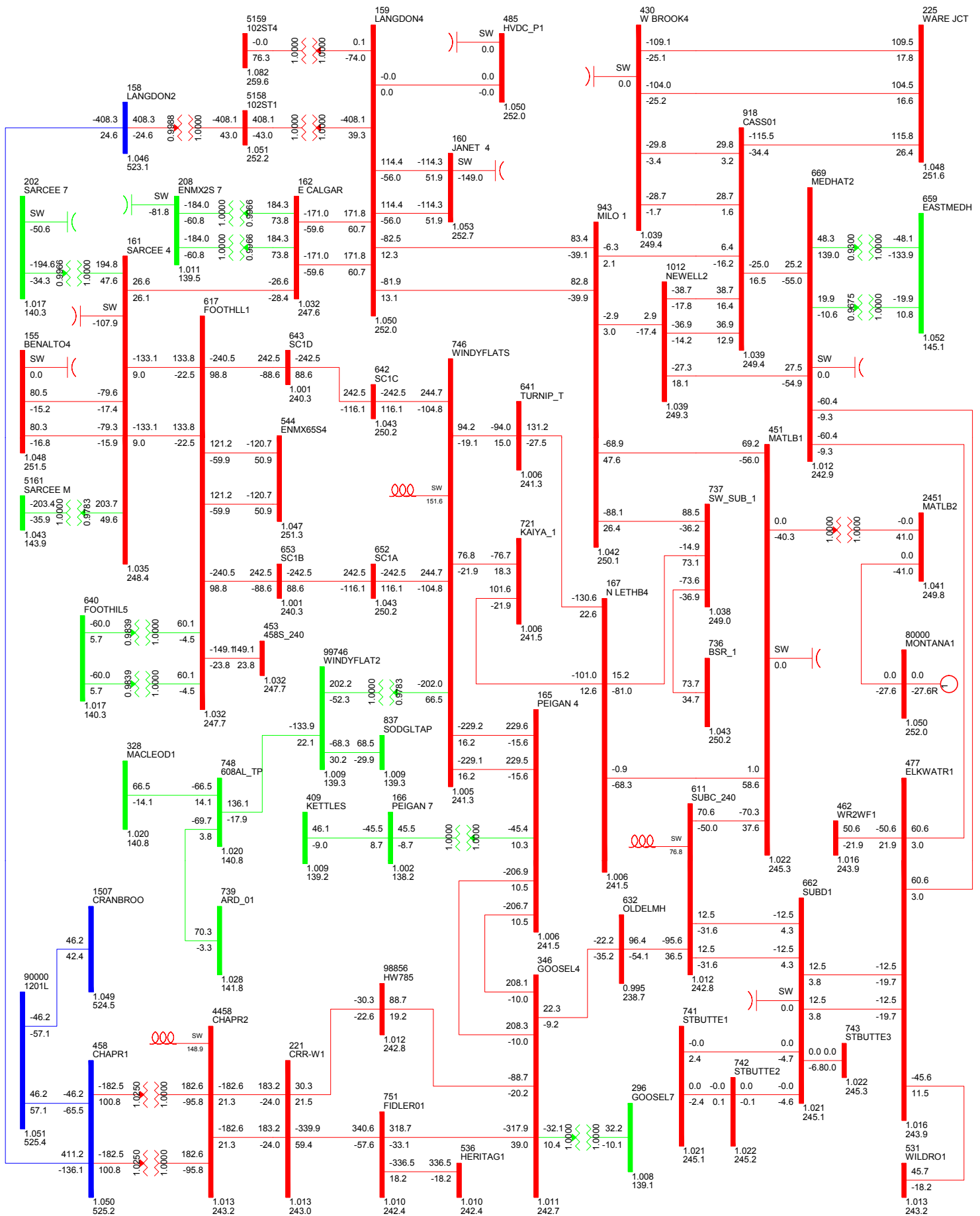


FIG D-W-19: JENNER 4 TO CYPRES2 240 KV LINE
 C13_2022SP_0_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

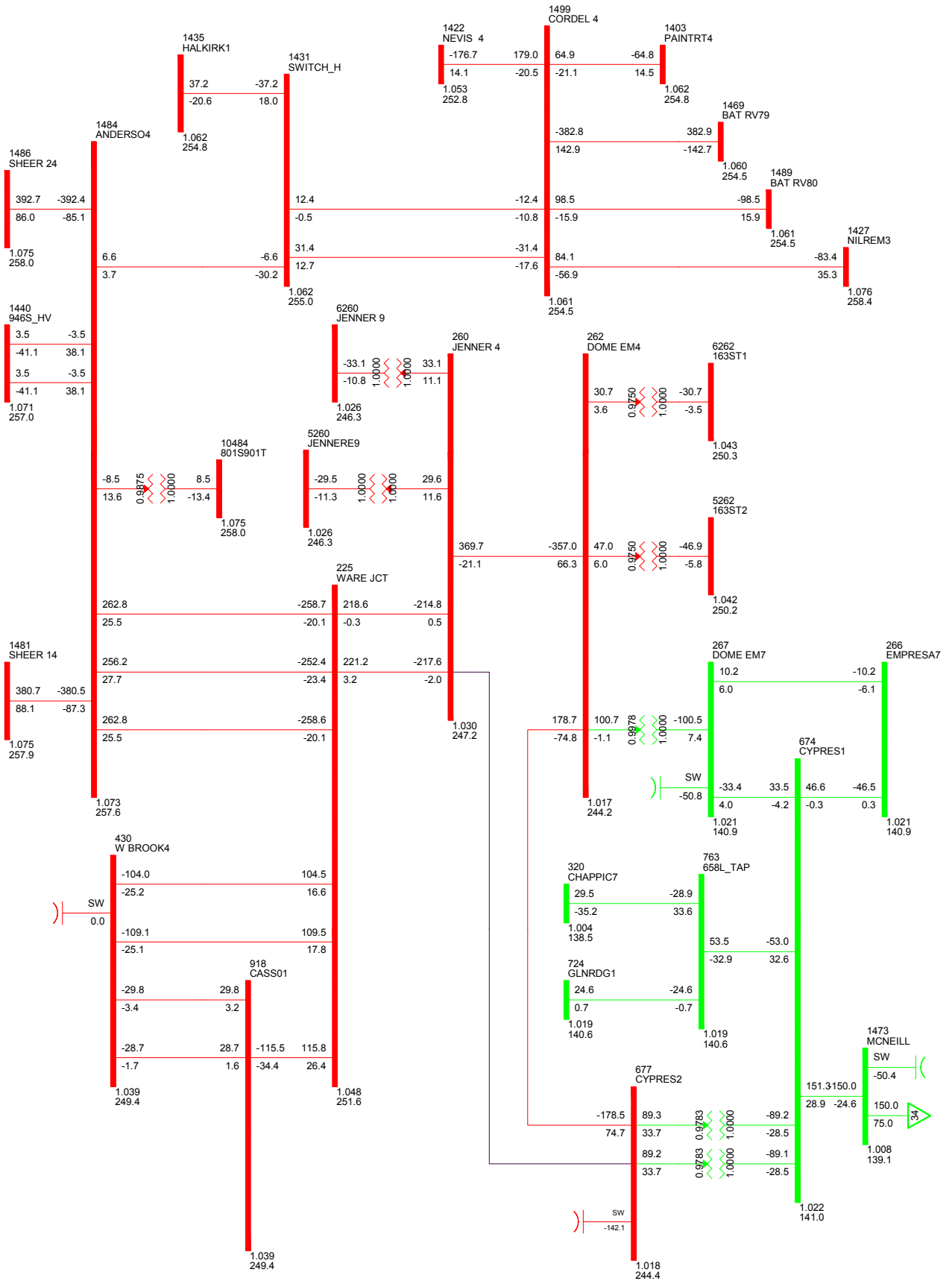


FIG D-E-19: JENNER 4 TO CYPRES2 240 KV LINE
 C13_2022SP_0_150_B6_R6
 THU, AUG 30 2012 16:00

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

Table B-5: Reactive Case – Category C5 Plot List

Figure #	Contingency	Scenario
Fig E-W-1 Fig E-E-1	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C3_2015SP_0_0_0
Fig E-W-2 Fig E-E-2	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C6_2017SP_0_0_0
Fig E-W-3 Fig E-E-3	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C6S_2017SP_0_0_0
Fig E-W-4 Fig E-E-4	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C9_2022SP_0_0_0
Fig E-W-5 Fig E-E-5	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C10_2015SP_-780_0_0
Fig E-W-6 Fig E-E-6	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C11_2017SP_-780_0_-150
Fig E-W-7 Fig E-E-7	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C11S_2017SP_-780_0_-150
Fig E-W-8 Fig E-E-8	944L & 951L (Jenner to Ware Junction Double Circuit Line) with loss of Jenner 240/138 kV transformer and Ware Junction to Anderson 950L	C12_2022SP_-1200_0_0
Fig E-W-9 Fig E-E-9	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C3_2015SP_0_0_0
Fig E-W-10 Fig E-E-10	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C6_2017SP_0_0_0
Fig E-W-11 Fig E-E-11	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C6S_2017SP_0_0_0
Fig E-W-12 Fig E-E-12	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C9_2022SP_0_0_0
Fig E-W-13 Fig E-E-13	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C10_2015SP_-780_0_0
Fig E-W-14 Fig E-E-14	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C11_2017SP_-780_0_-150
Fig E-W-15 Fig E-E-15	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C11S_2017SP_-780_0_-150
Fig E-W-16 Fig E-E-16	1002L & 1011L (Jenner to Cypress and Jenner to Dome Empress Double Circuit Outage) with loss of Jenner 240/138 kV transformer	C12_2022SP_-1200_0_0

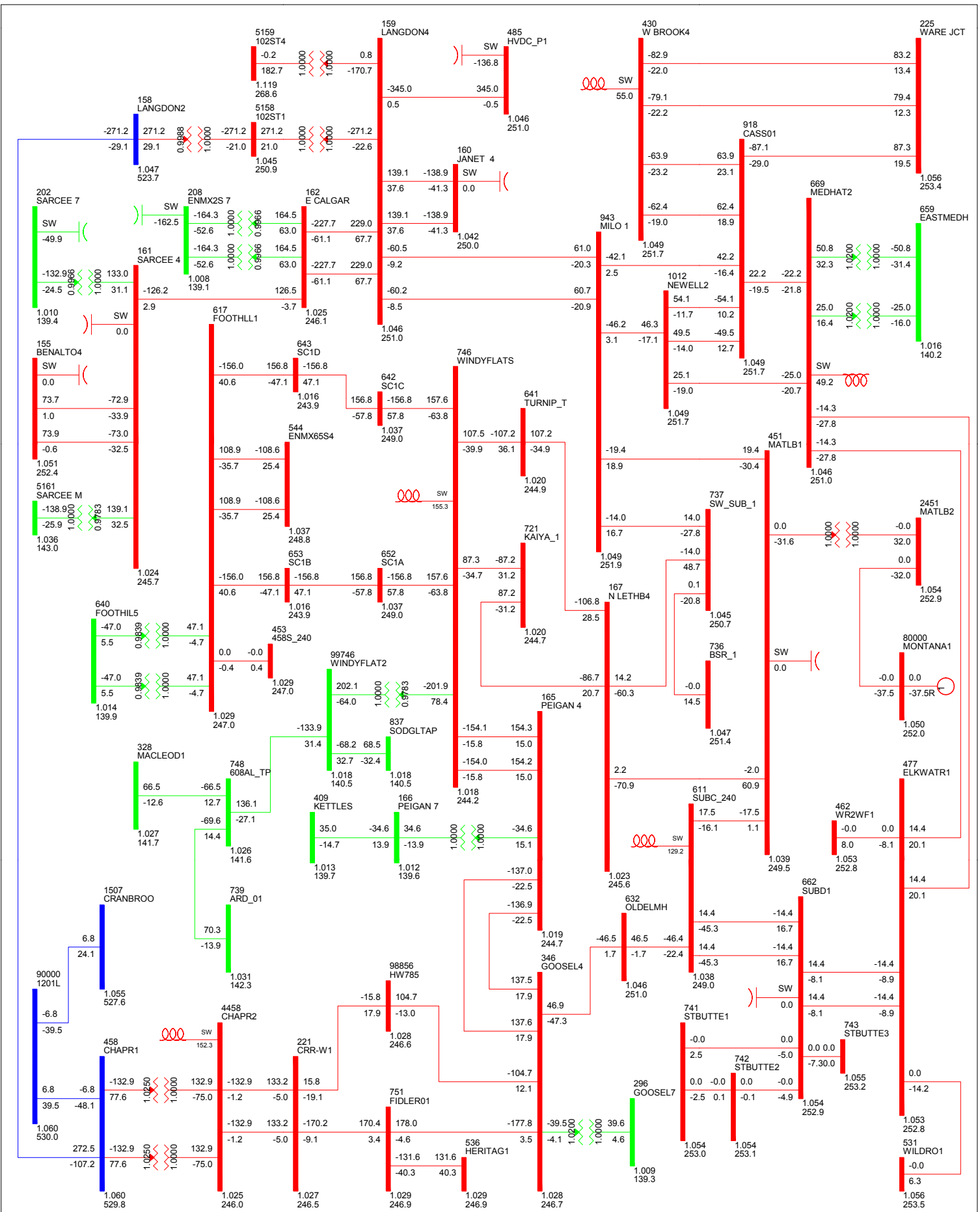


FIG E-W-1; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C3_2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34,500 <=69,000 <=138,000 <=240,000 <=500,000 >500,000

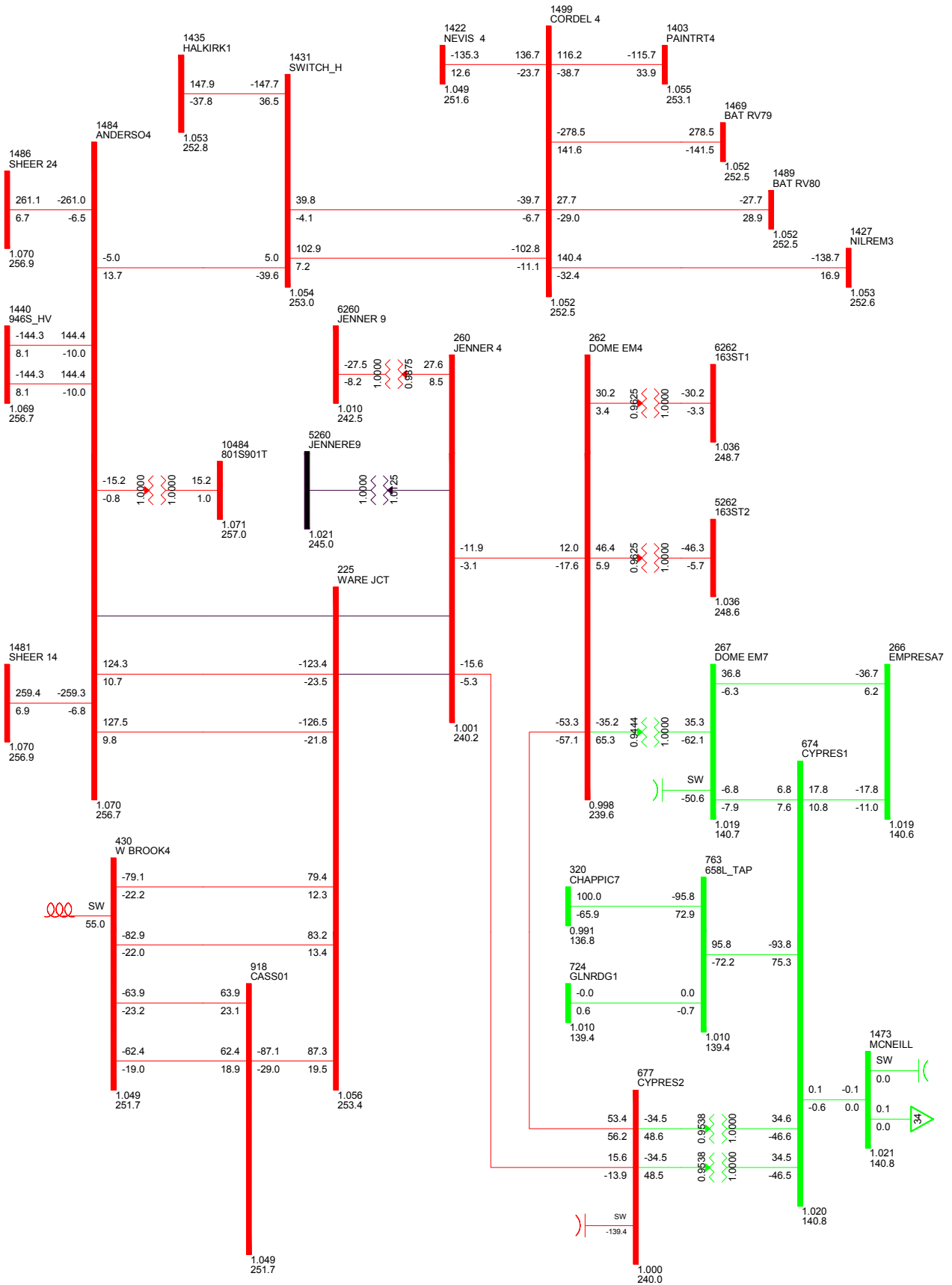


FIG E-E-1; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C3 2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

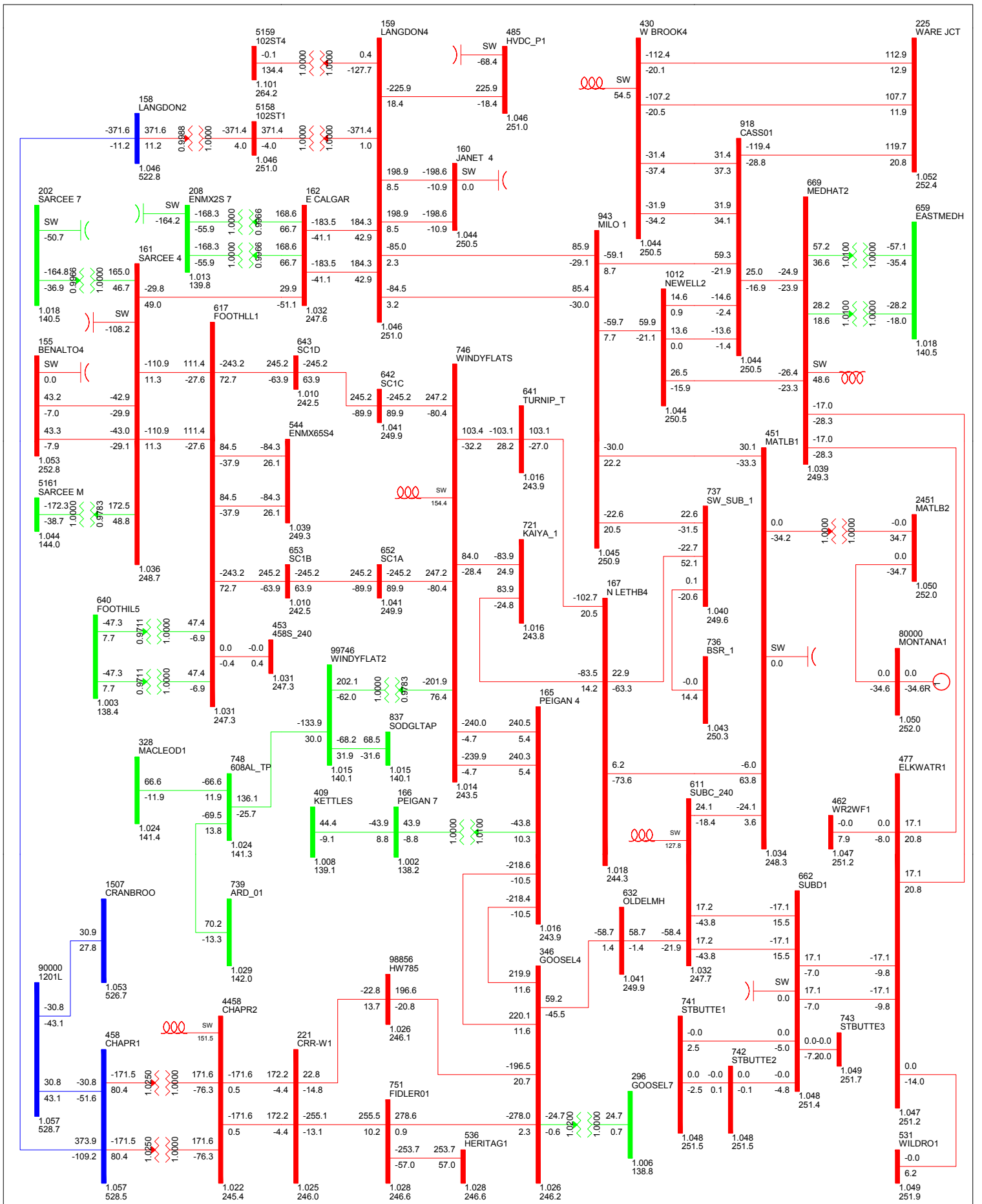


FIG E-W-2; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C6.2017SP.0.0.0_B6 R5
 THU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

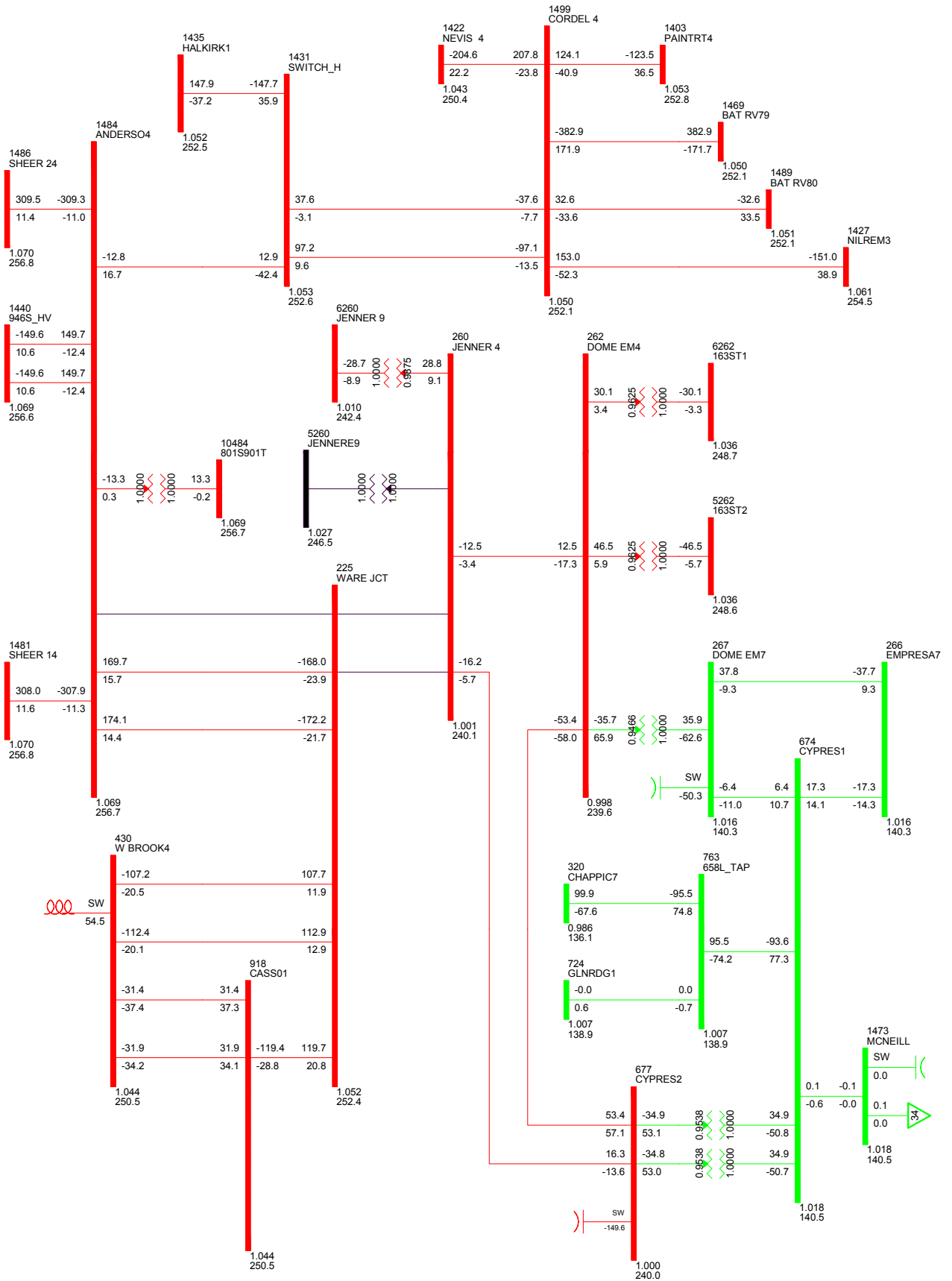


FIG E-E-2; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C6 2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

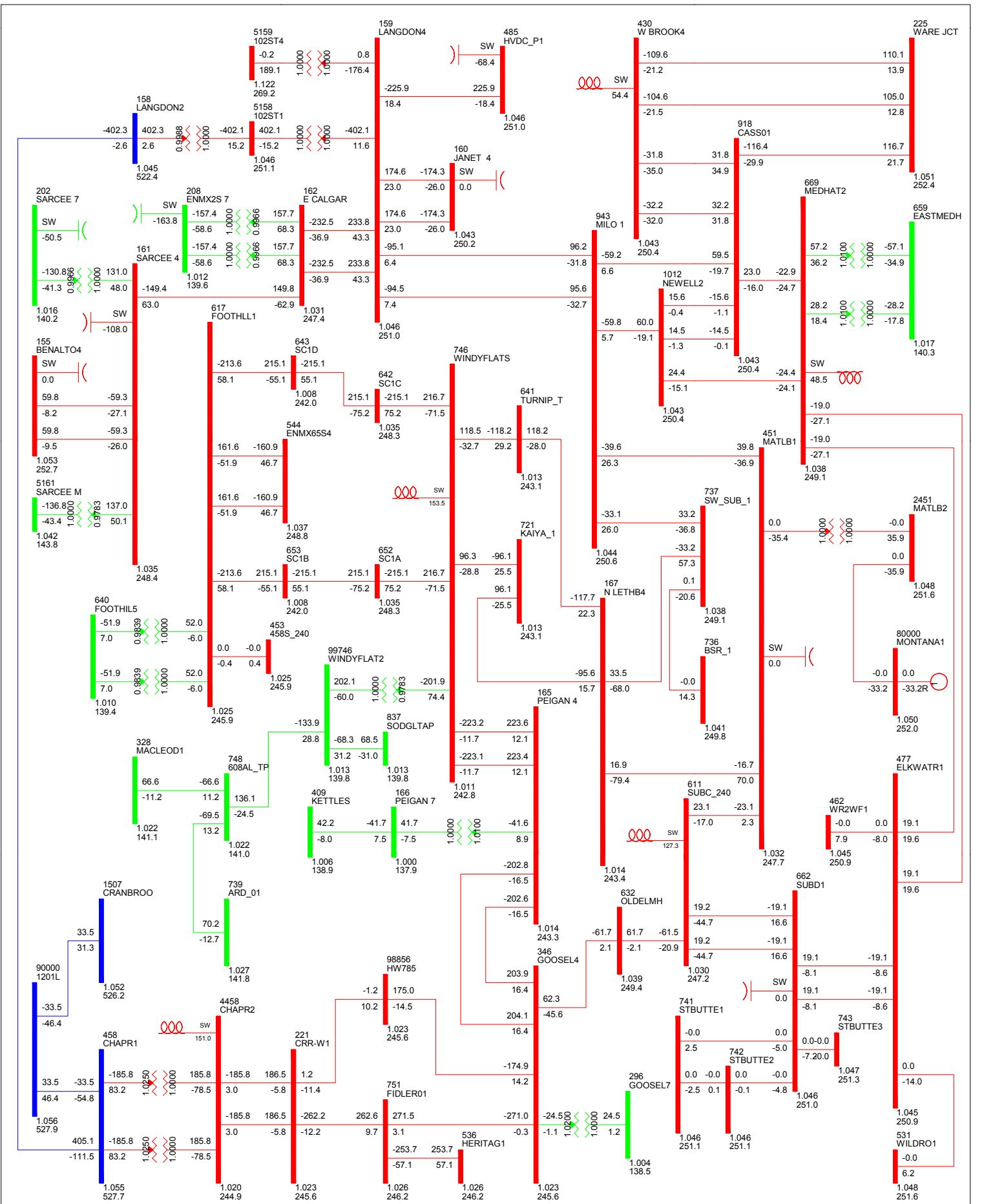


FIG E-W-3; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 CBS_2017SP_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

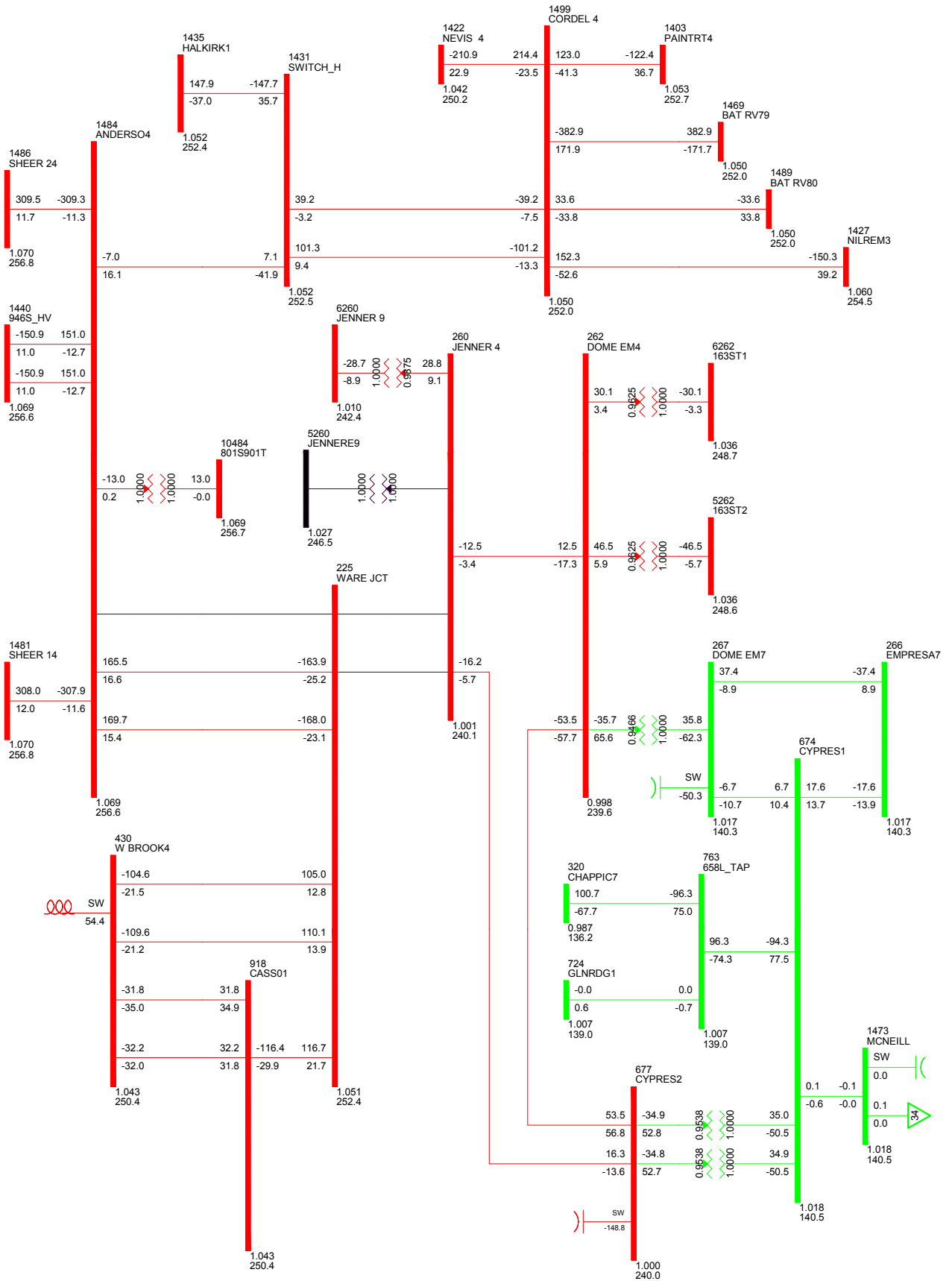


FIG E-E-3; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C6S_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

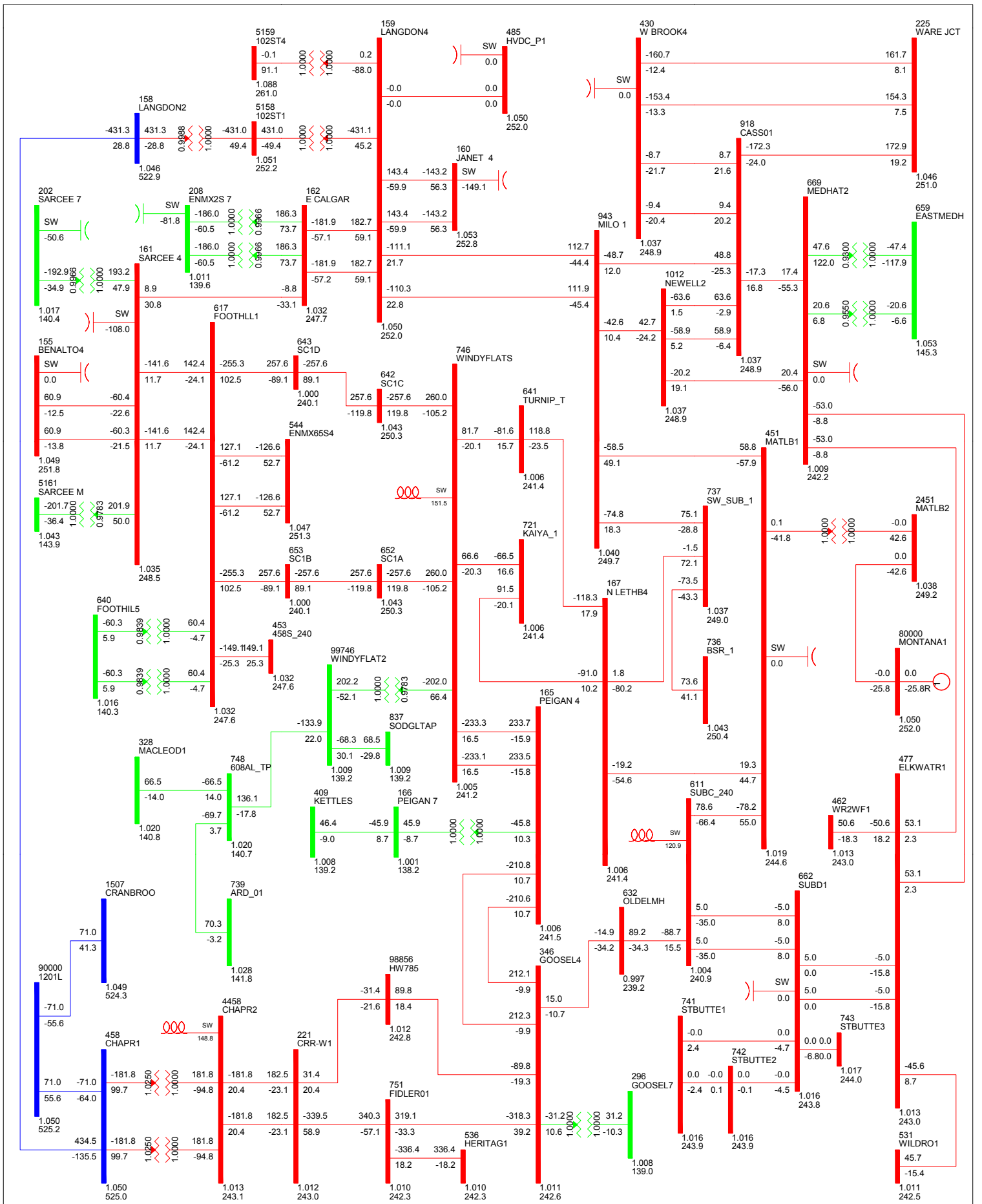


FIG E-W-4; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANS
 C9.2022SP.0.0.0_B6 R5
 THU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

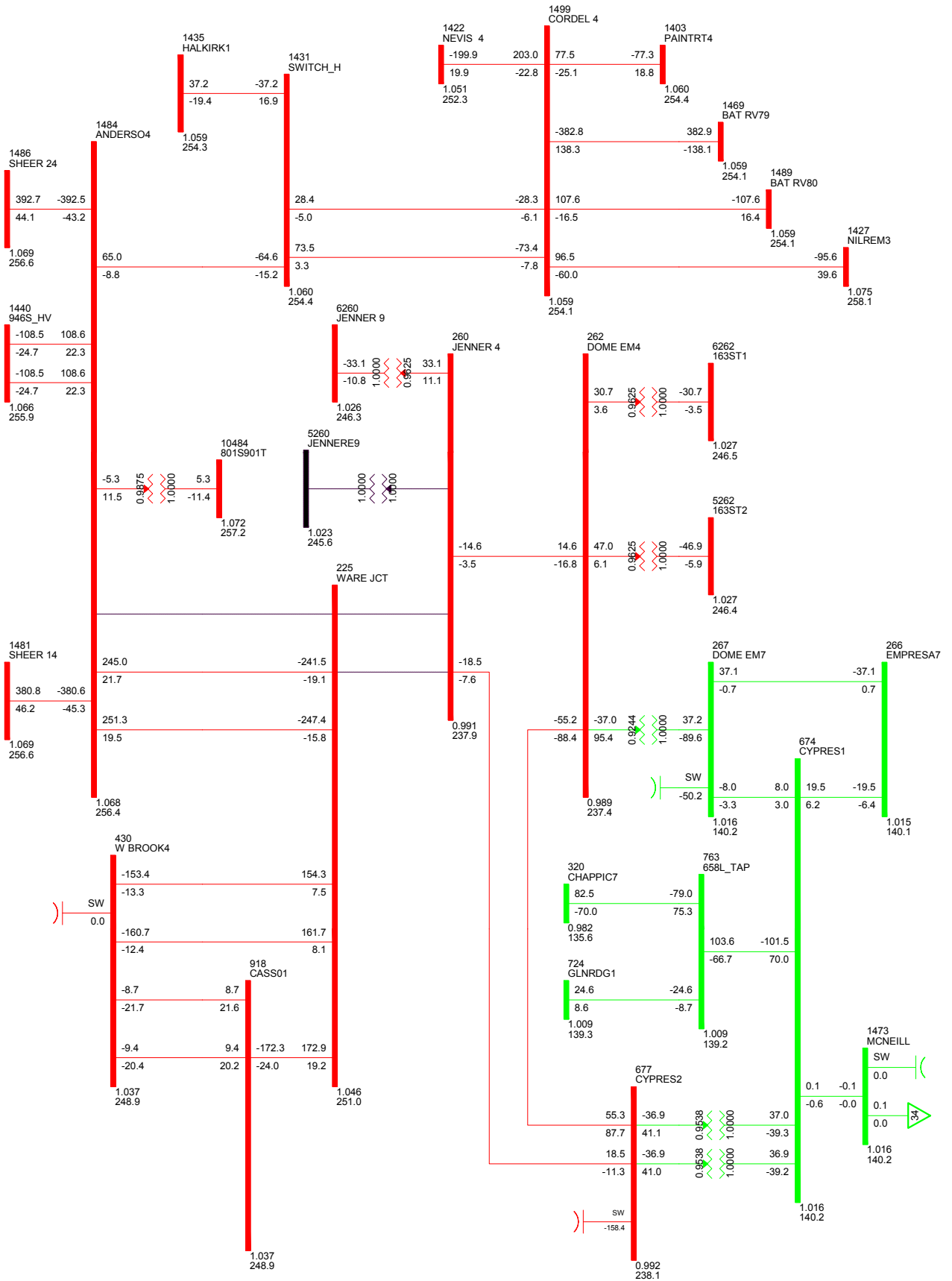


FIG E-E-4; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C9 2022SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: ≤ 34.500=69.000 ≤ 138.000 ≤ 240.000=500.000>500.000

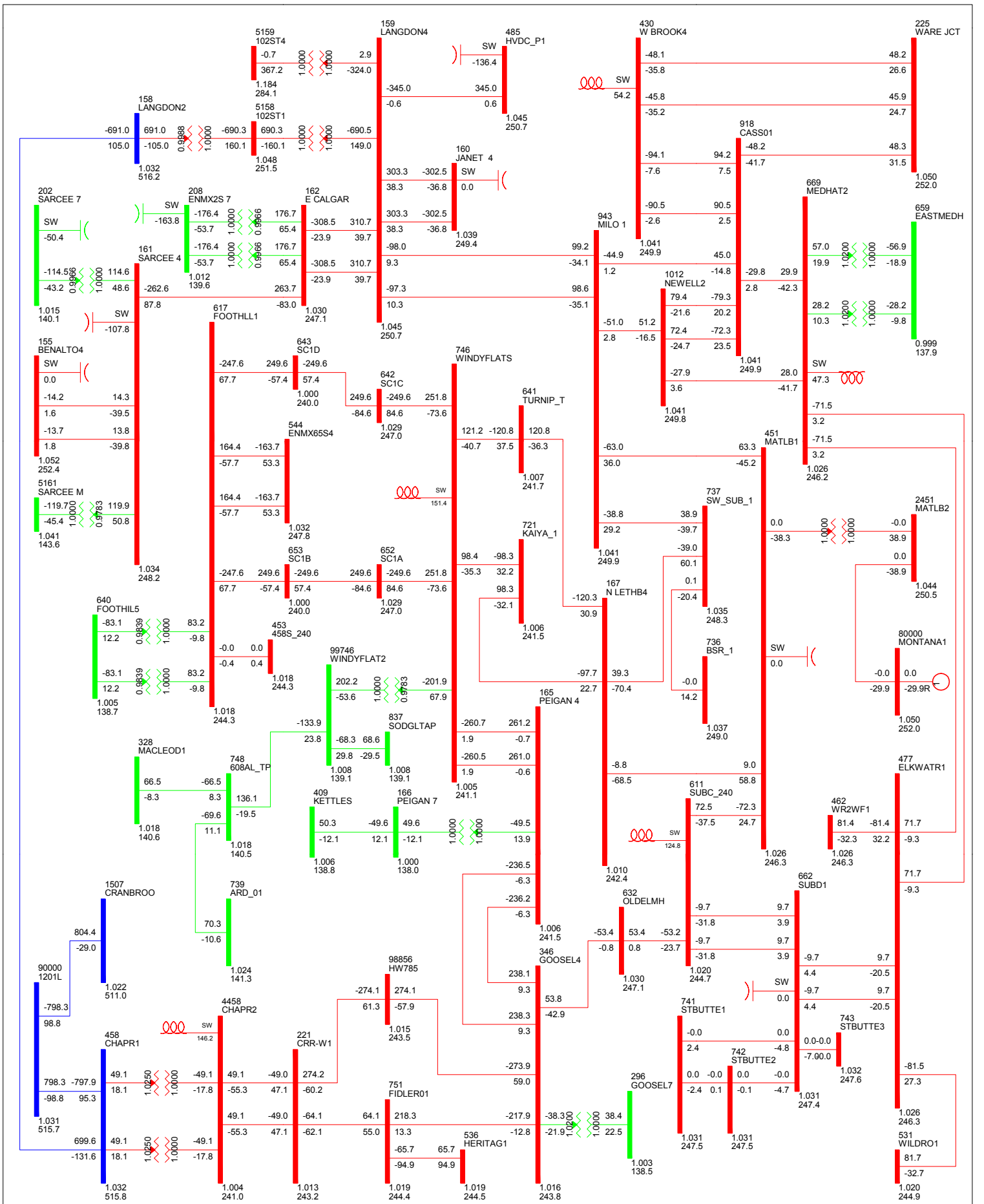


FIG E-W-5; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C10_2015SP -780_0_0_B6_R5
 TRU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

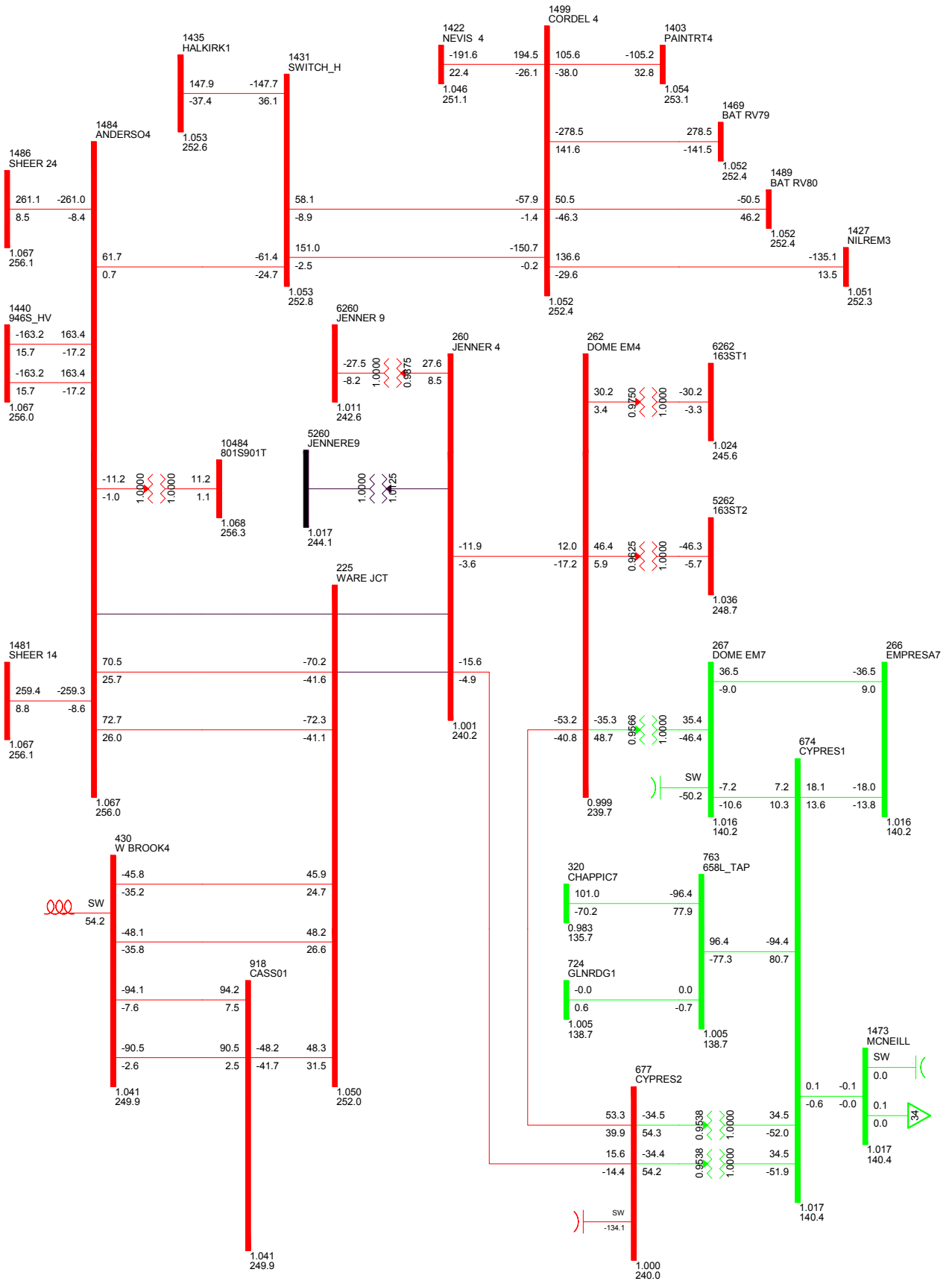


FIG E-E-5; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C10_2015SP -780_0_0_B6_R5
 TRU, AUG'30 2012' 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500>=69.000 <=138.000 <=240.000 <=500.000 >500.000

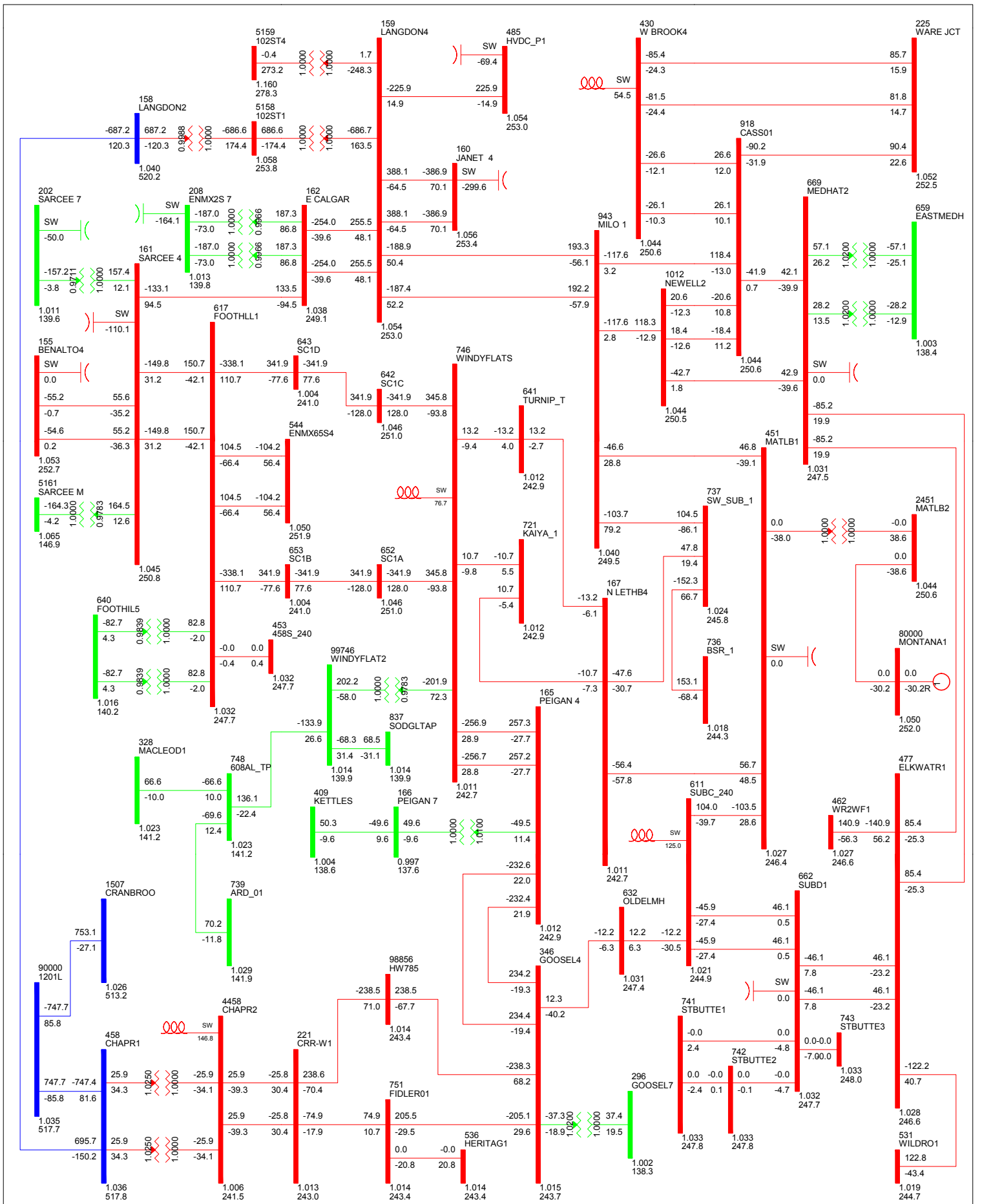


FIG E-W-6; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C11_2017SP -780_0 -150_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

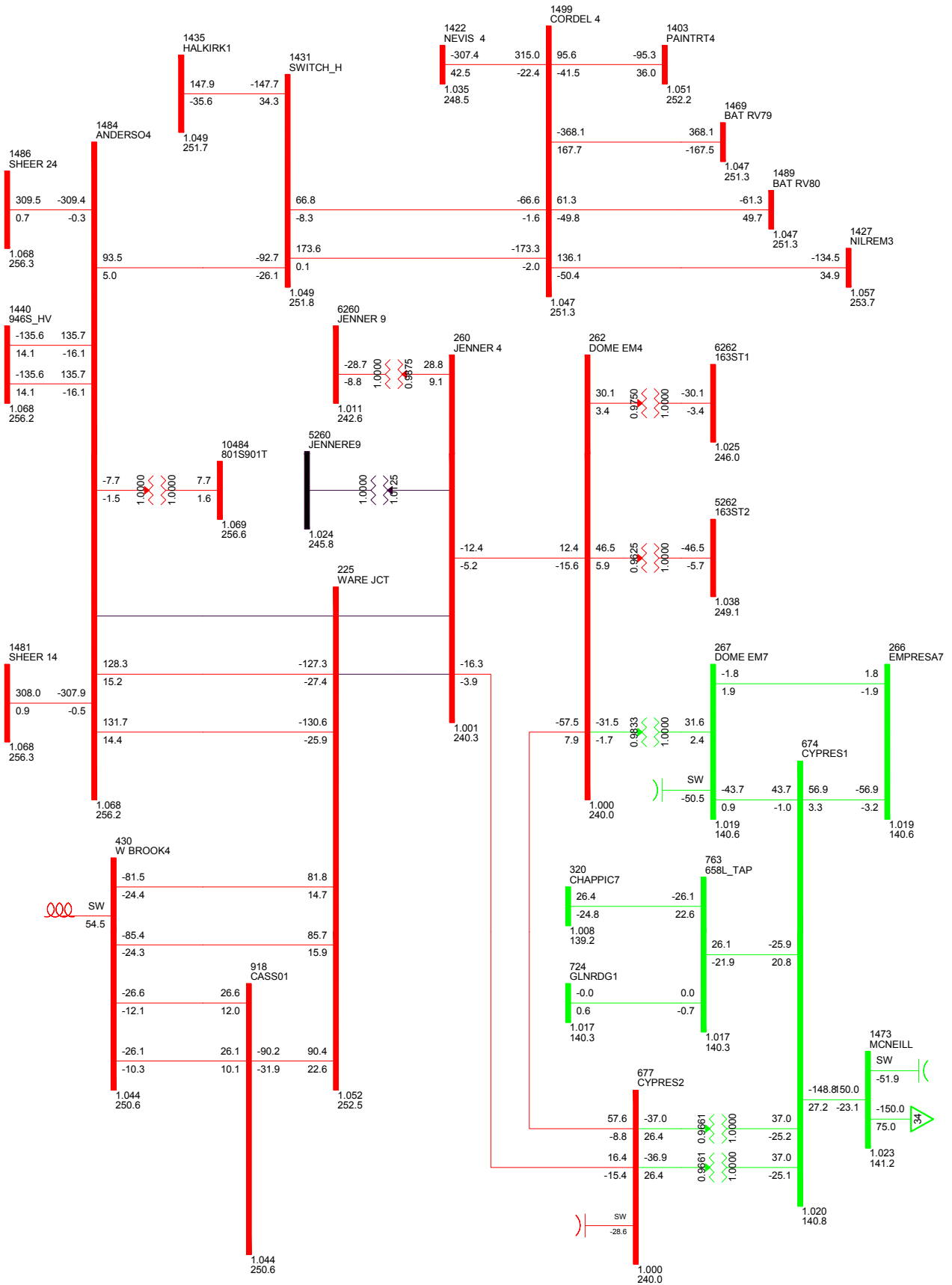


FIG E-E-6; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C11 2017SP -780_0_-150_B6_R5
 THU, AUG 30 2012 16:01

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: ≤ 34.500=69.000 ≤ 138.000 ≤ 240.000=500.000>500.000

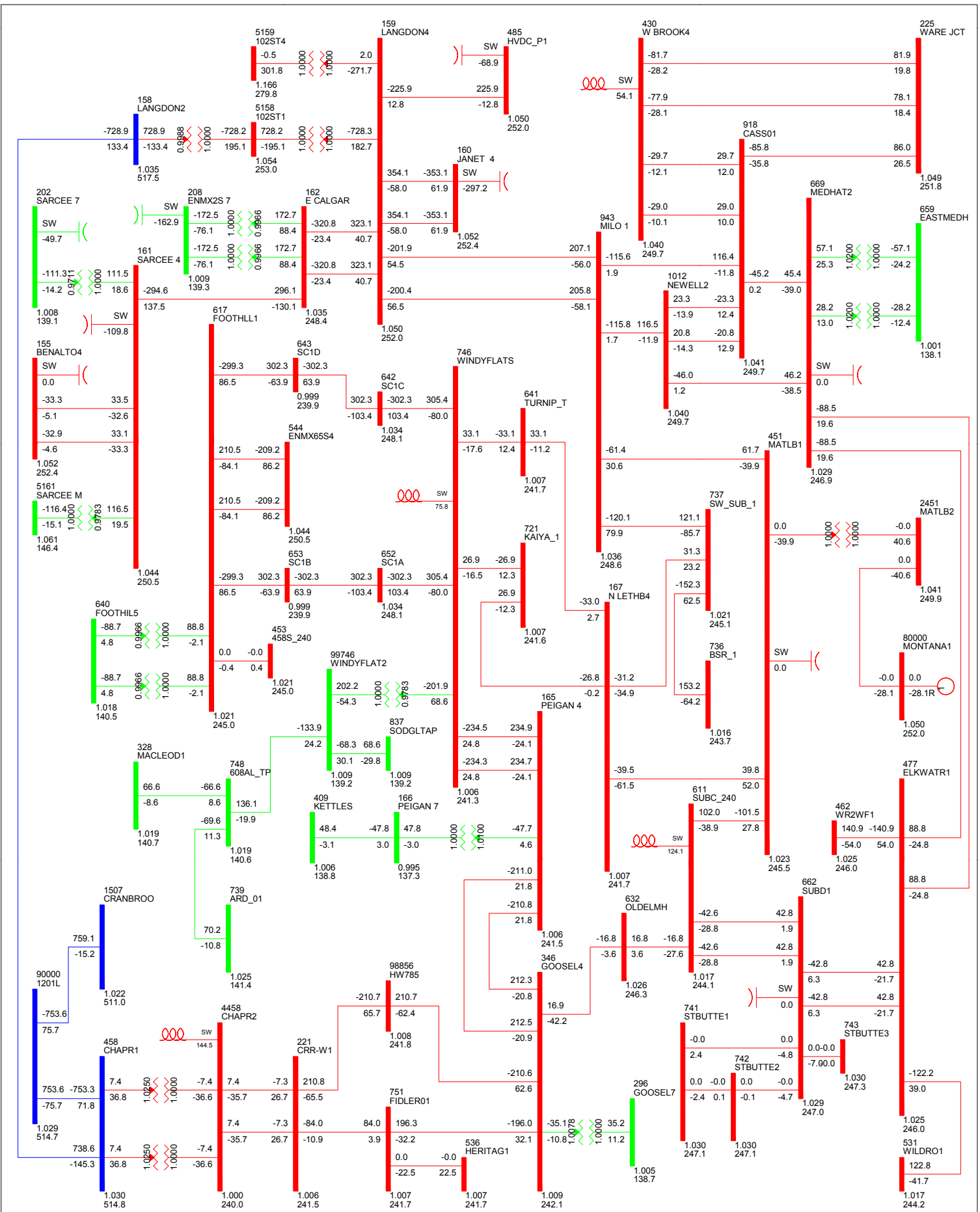


FIG E-W-7; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C11S_2017SP -780.0 -150_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

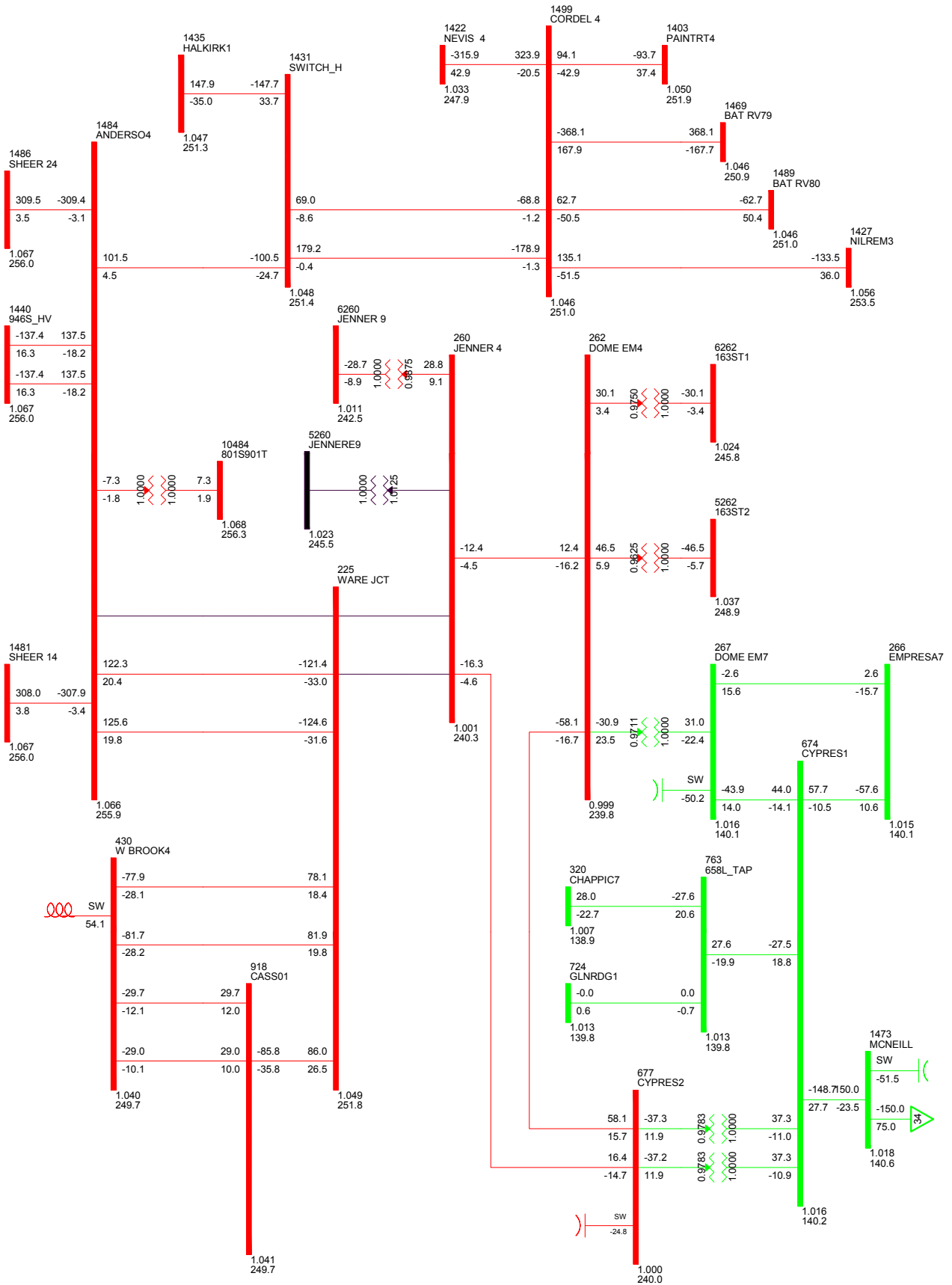


FIG E-E-7; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C11S_2017SP -780_0 -150_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

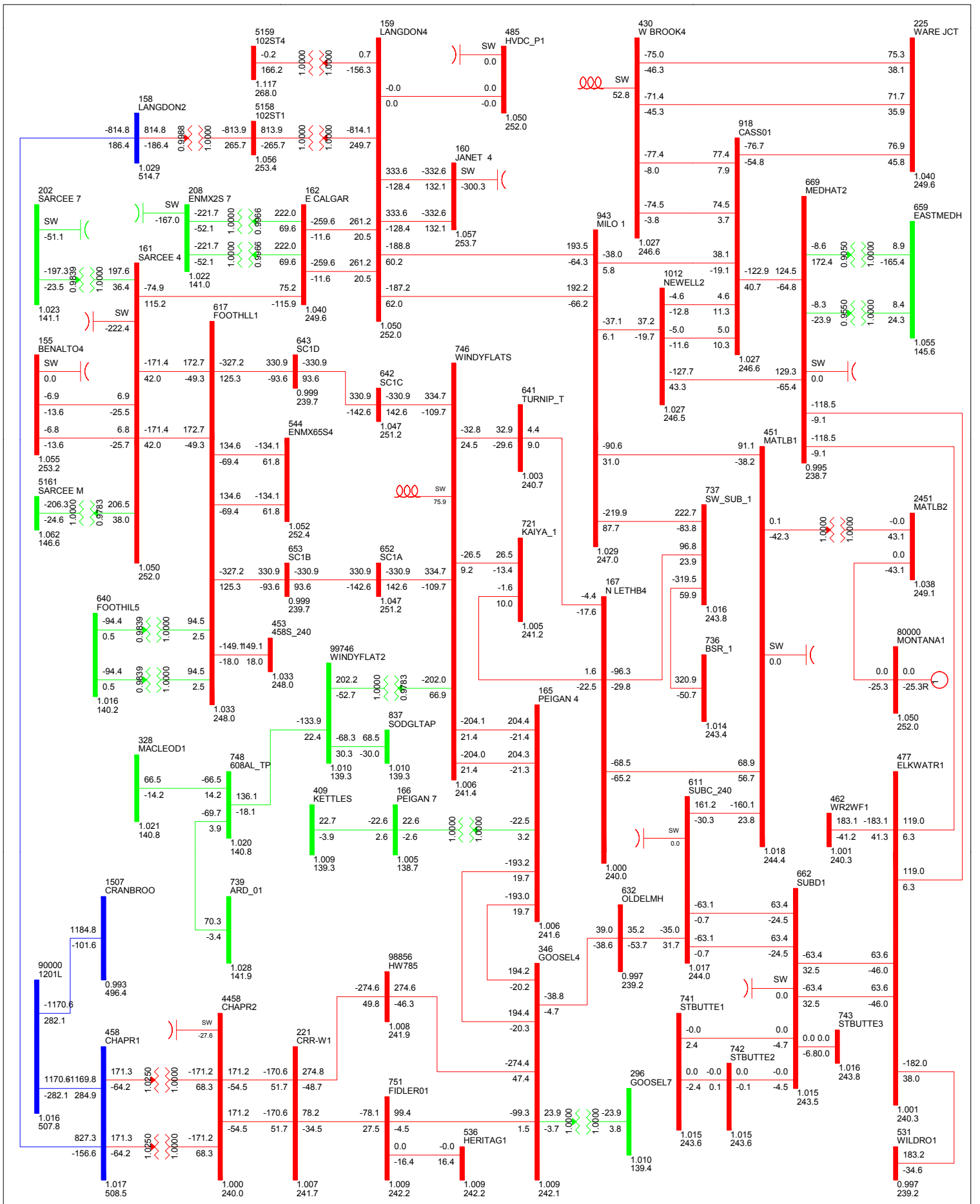


FIG E-W-8; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C12_2022SP_-1200_0_0_B6 R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

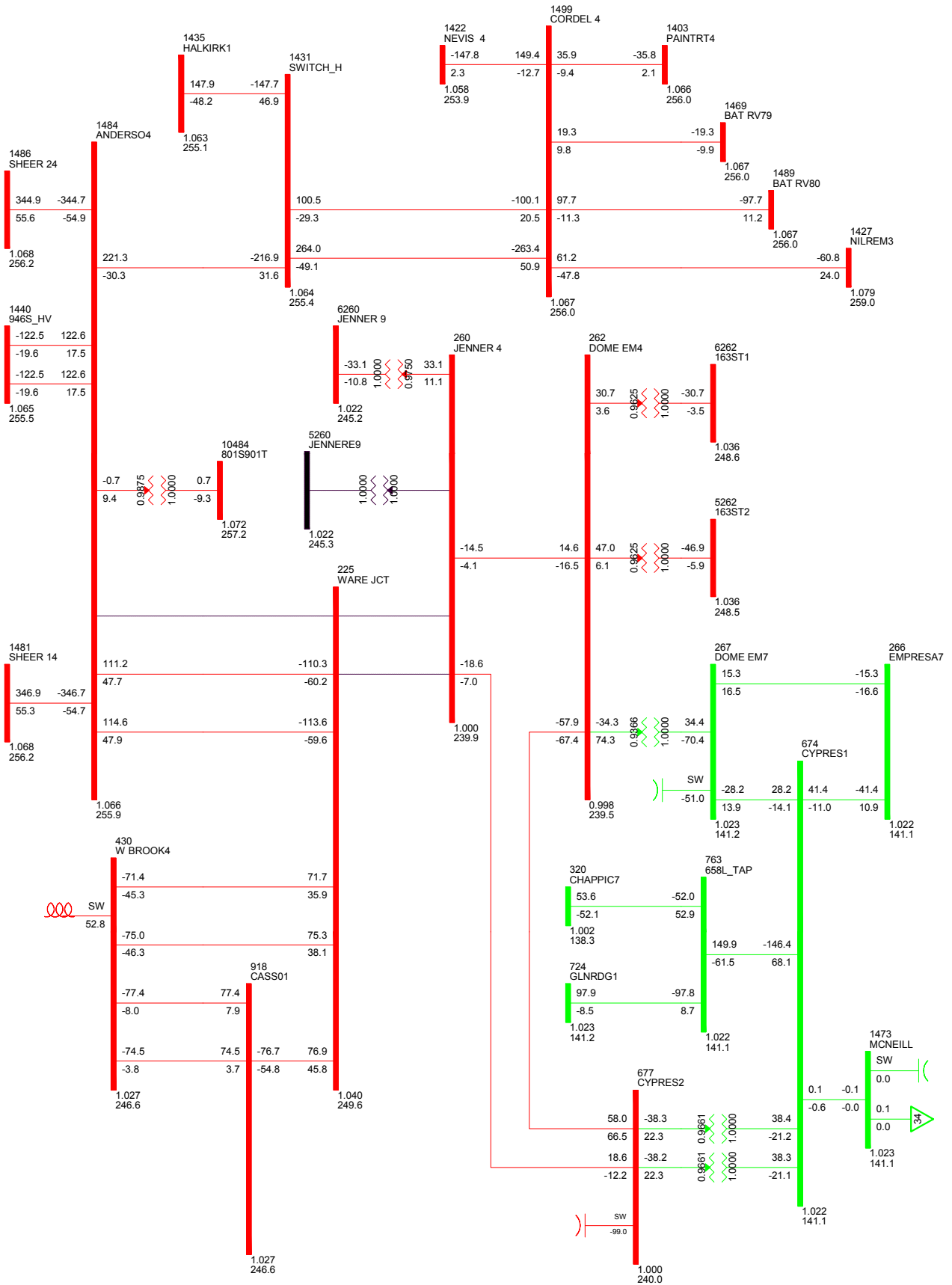


FIG E-E-8; 944L & 951L WITH LOSS OF JENNER 240/138 KV TRANSF
 C12_2022SP -1200_0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

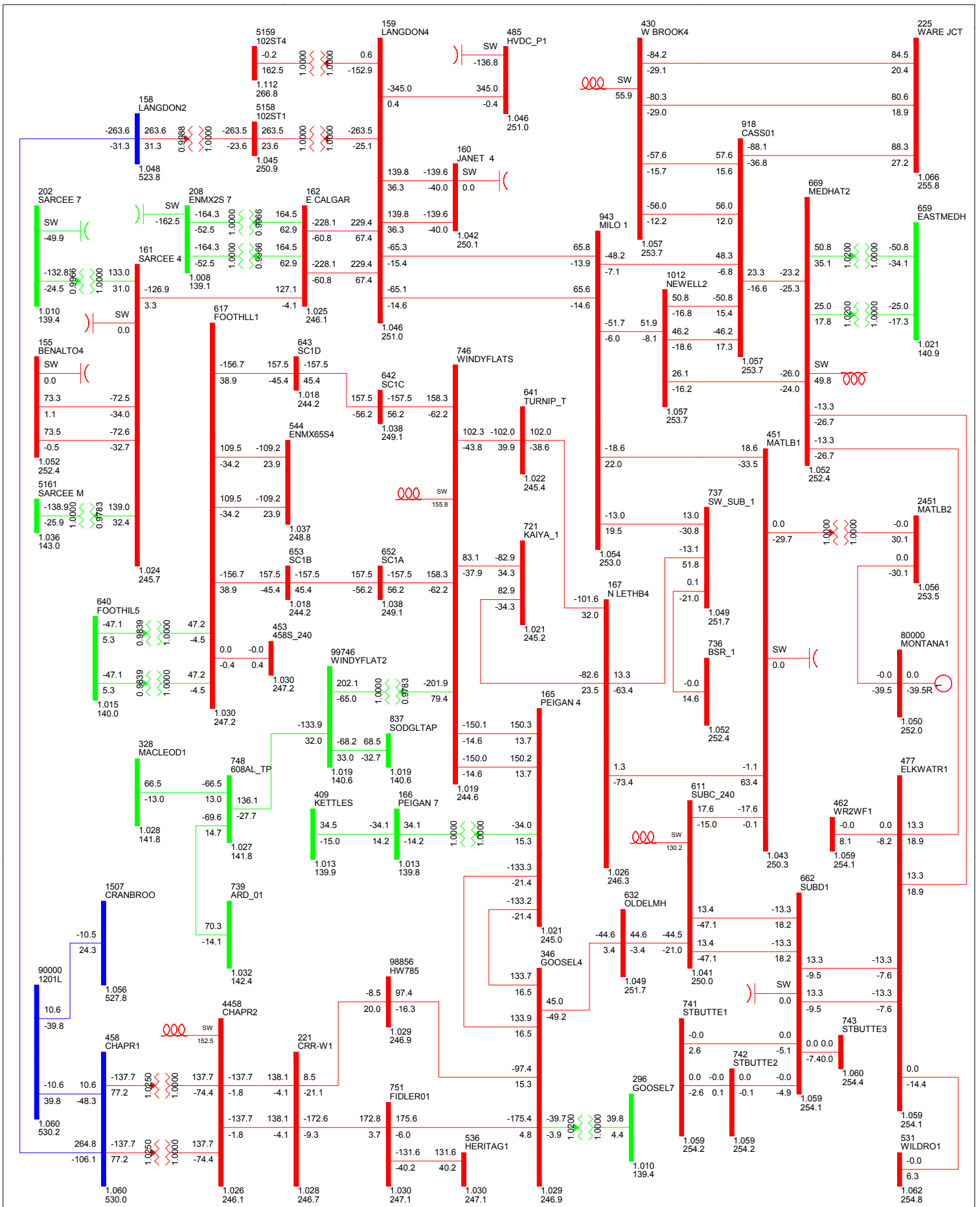


FIG E-W-9; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRAN
 C3 2015SP_0_0_0_B6 R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=-34.500 <=-69.000 <=-138.000 <=-240.000 <=-500.000 >500.000

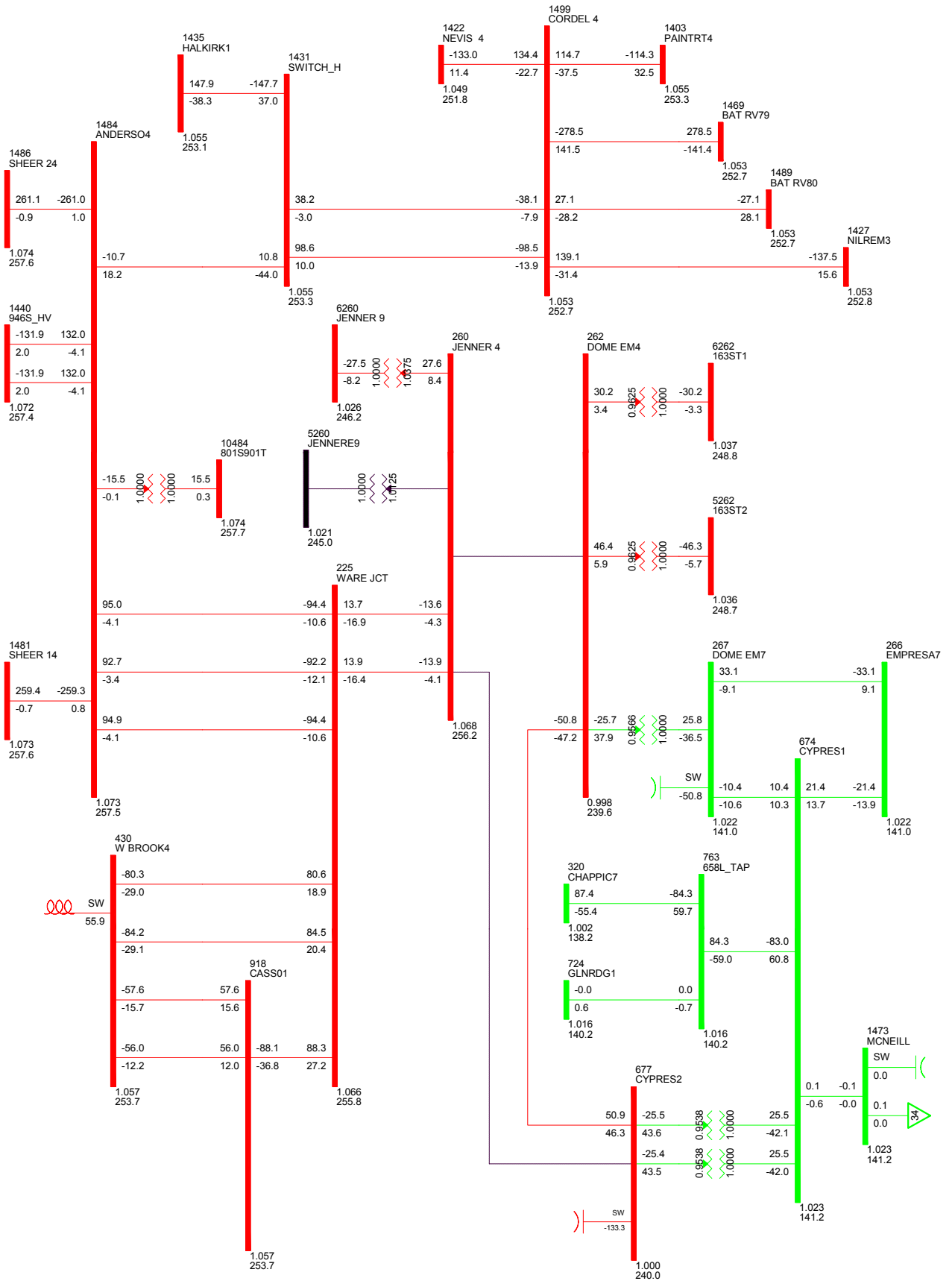


FIG E-E-9; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRAN
 C3_2015SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000<=500.000>500.000

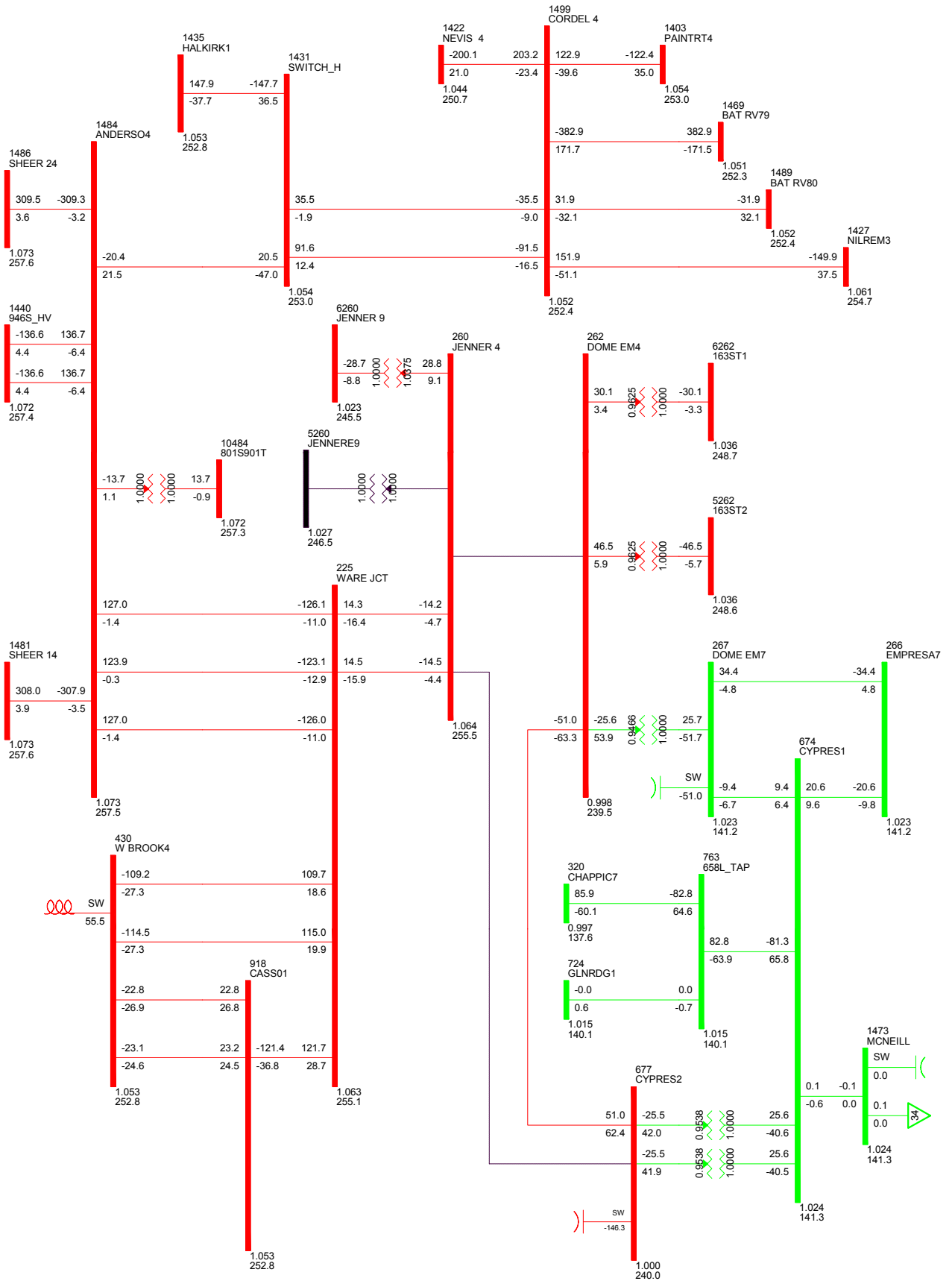


FIG E-E-10; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C6 2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 >500.000

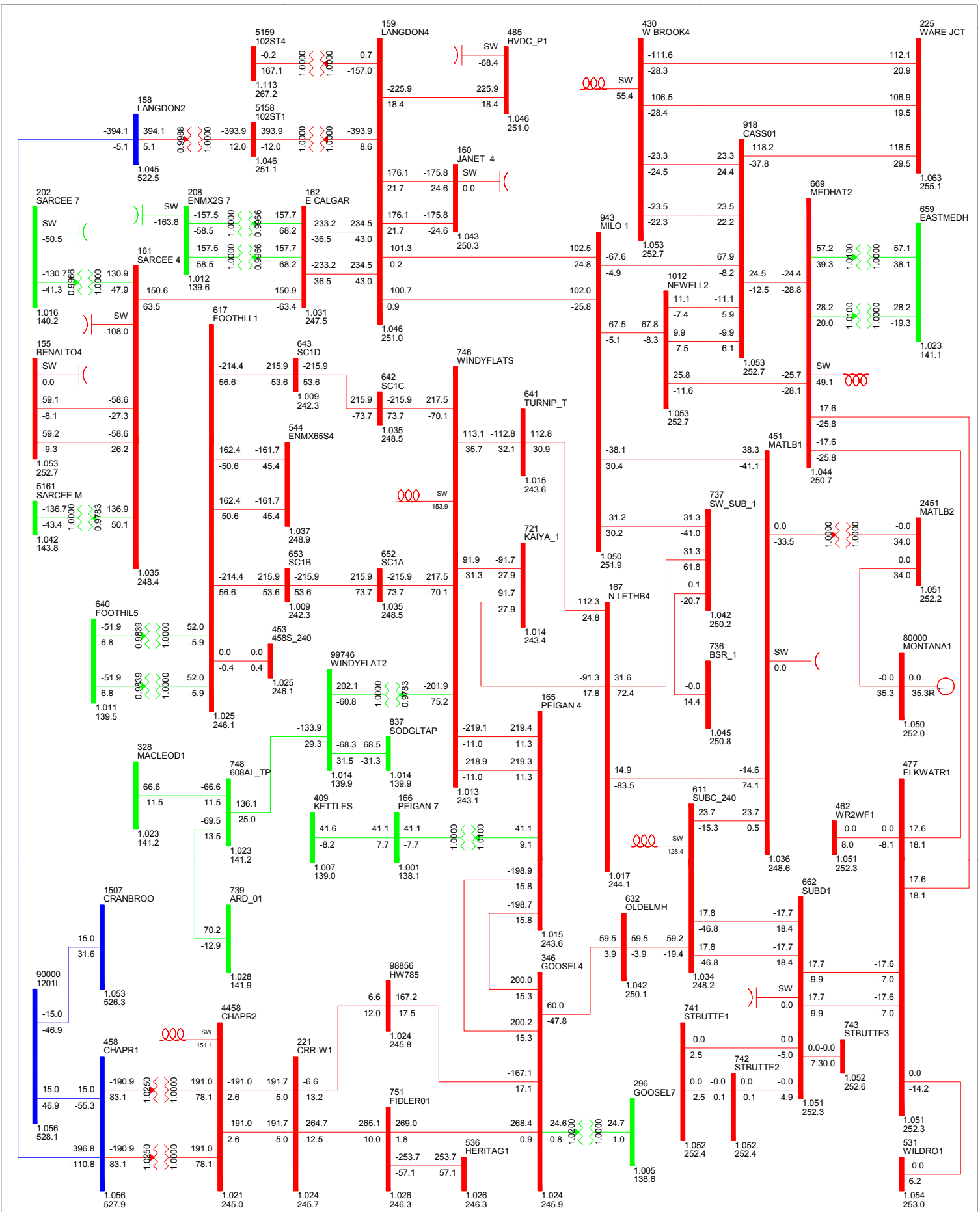


FIG E-W-11; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 CGS_2017SP_0.0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

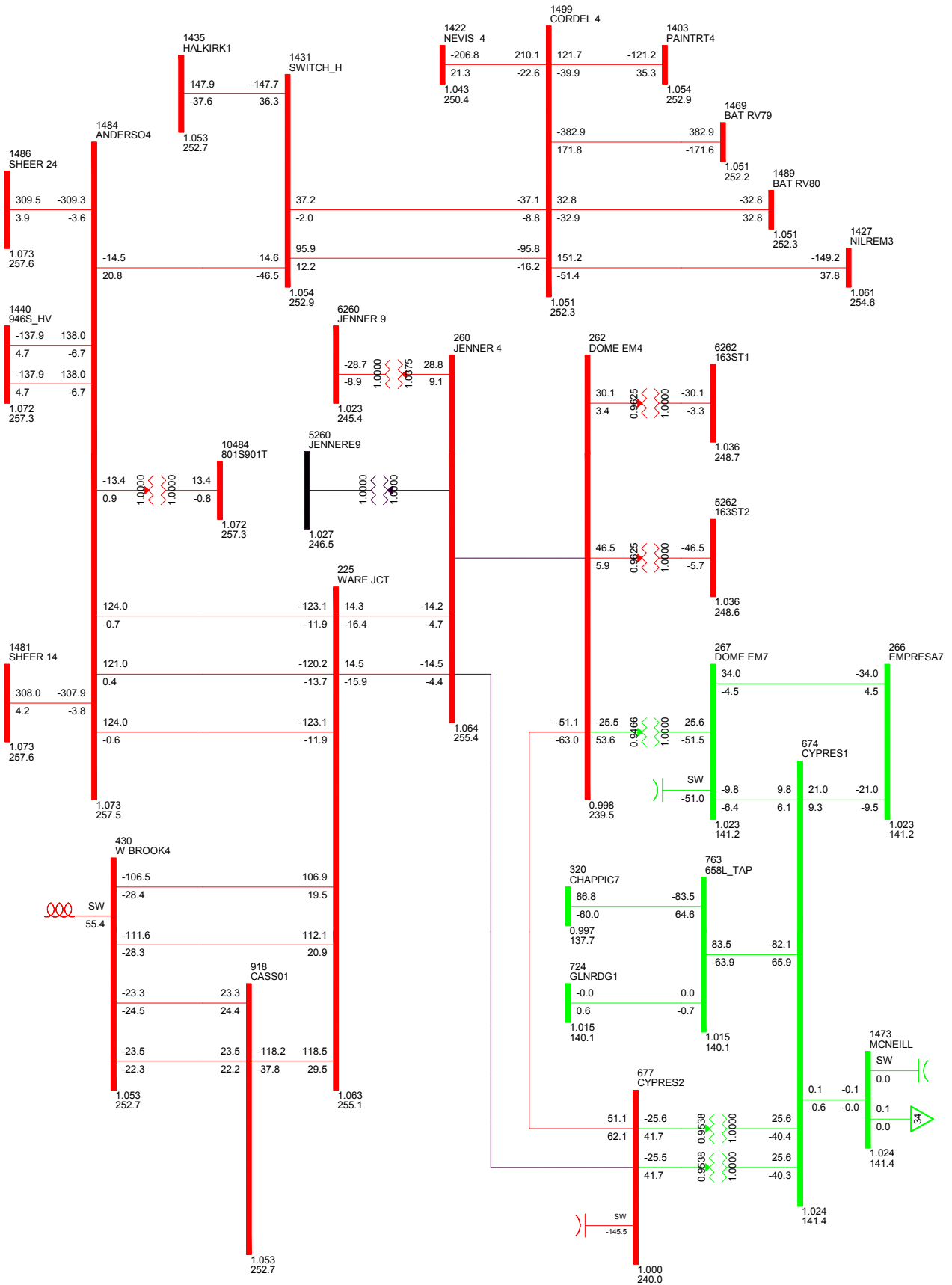


FIG E-E-11; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C6S_2017SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

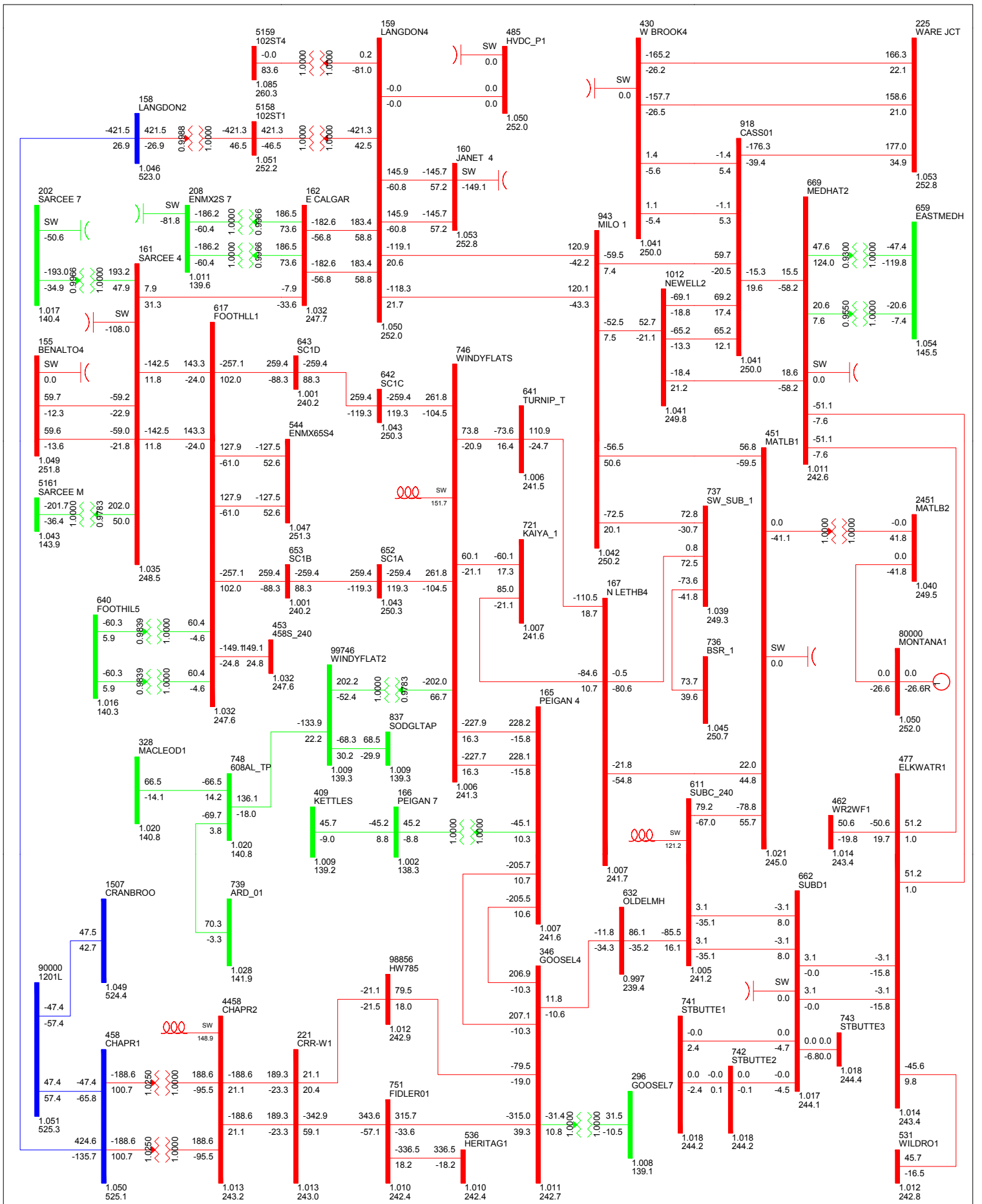


FIG E-W-12: 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C9 2022SP 0 0 0 B6 R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

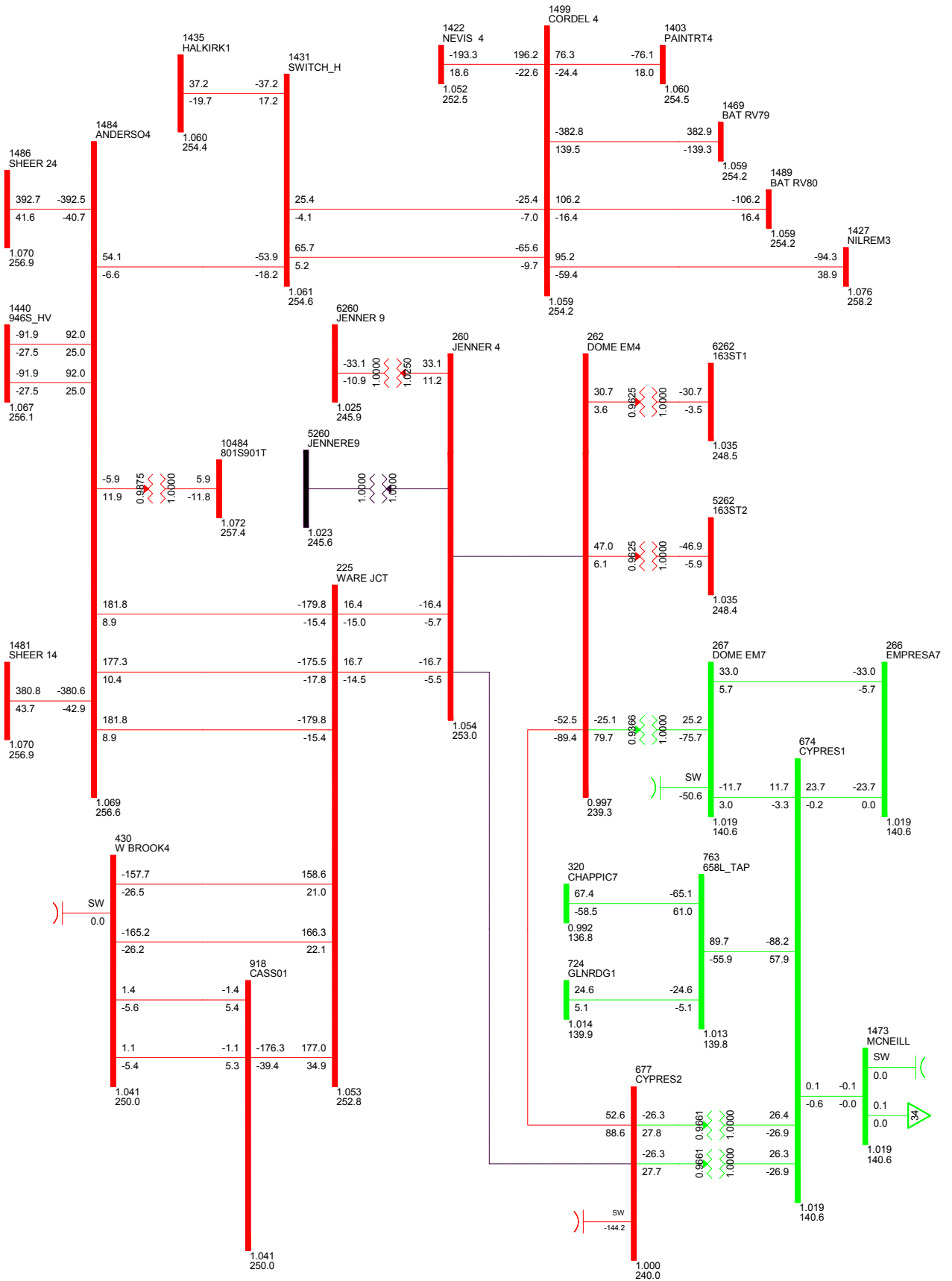


FIG E-E-12; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C9_2022SP_0_0_0_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <math>V < 240.000</math> <math>240.000 <= V < 250.000</math> $V > 250.000$

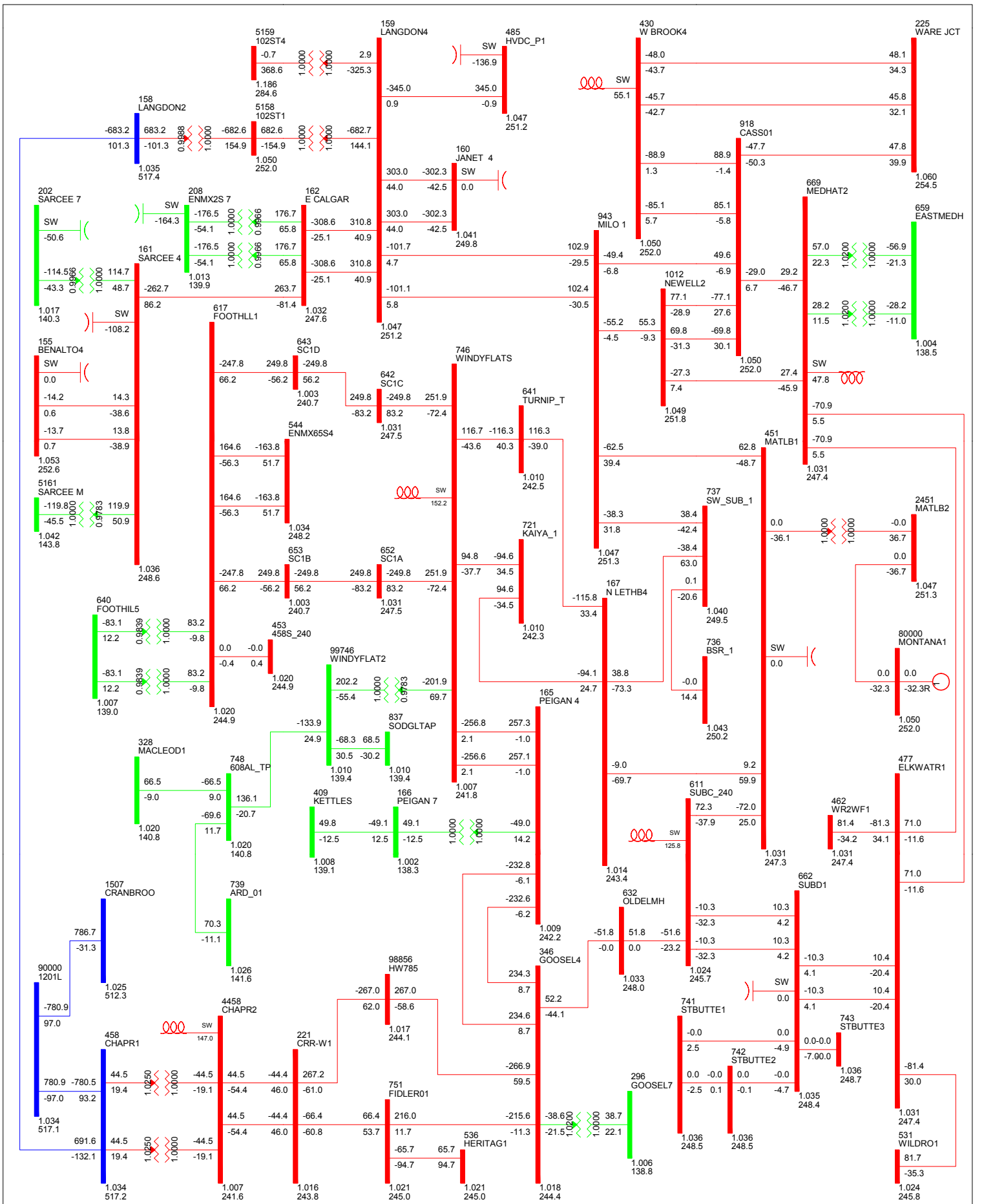


FIG E-W-13; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C10_2015SP_780_0_0_B6_R5
 TRU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

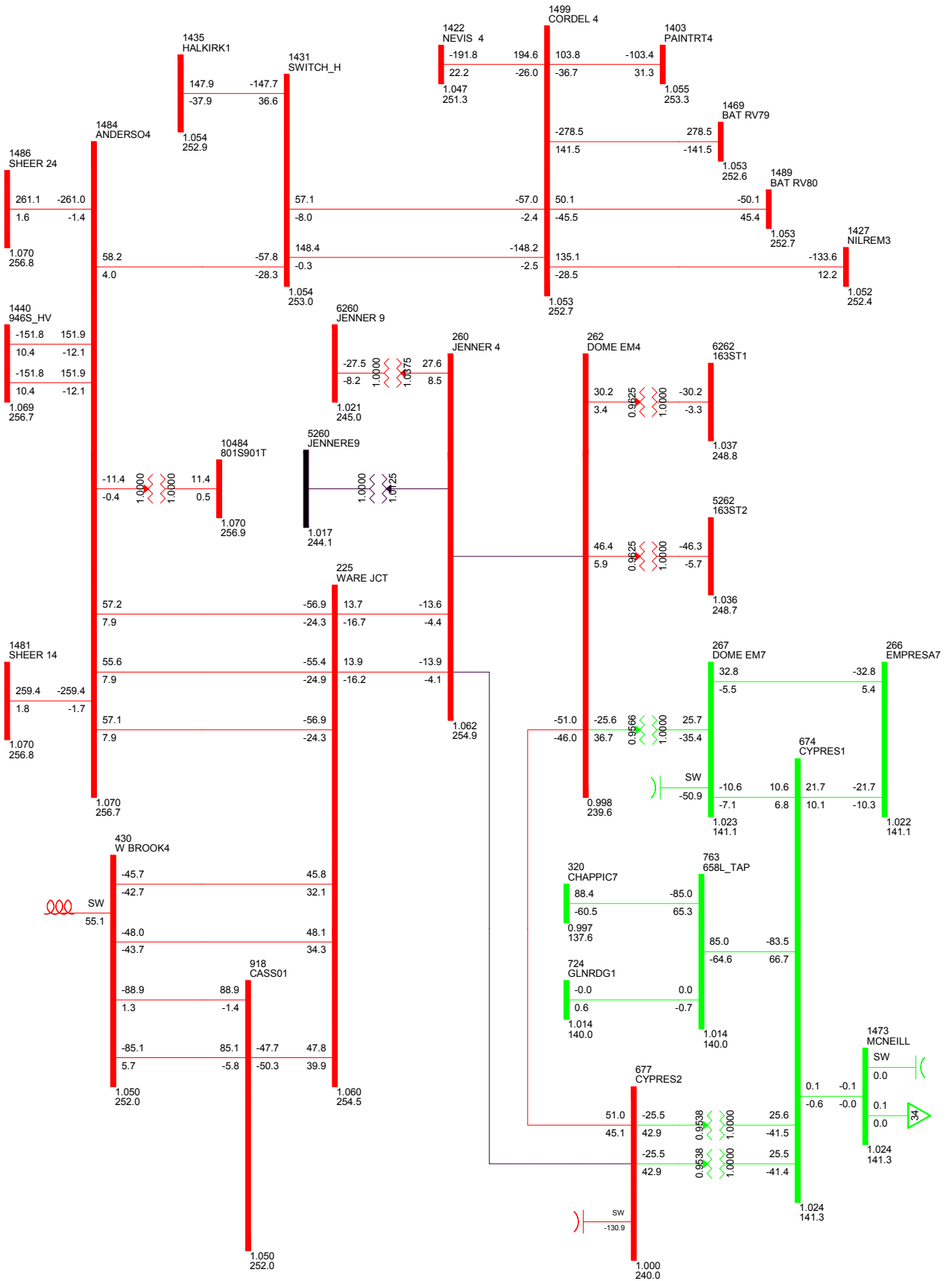


FIG E-E-13; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C10_2015SP_-780_0_0_B6_R5
 TRU, AUG 30 2012 16:02

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

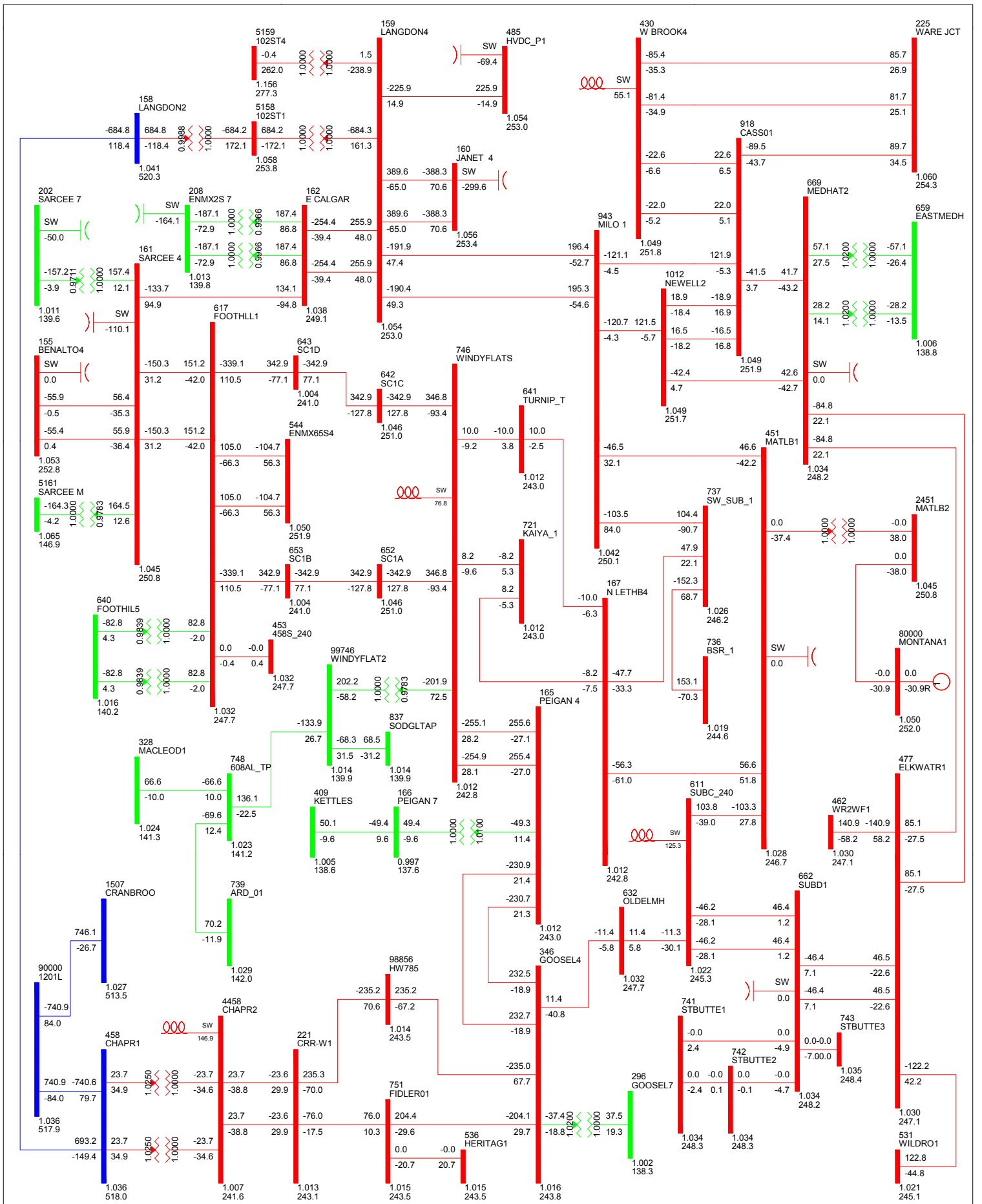


FIG E-W-14: 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C11_2017SP -780_0 -150_B6_R5
 THU, AUG 30 2012 16:02

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

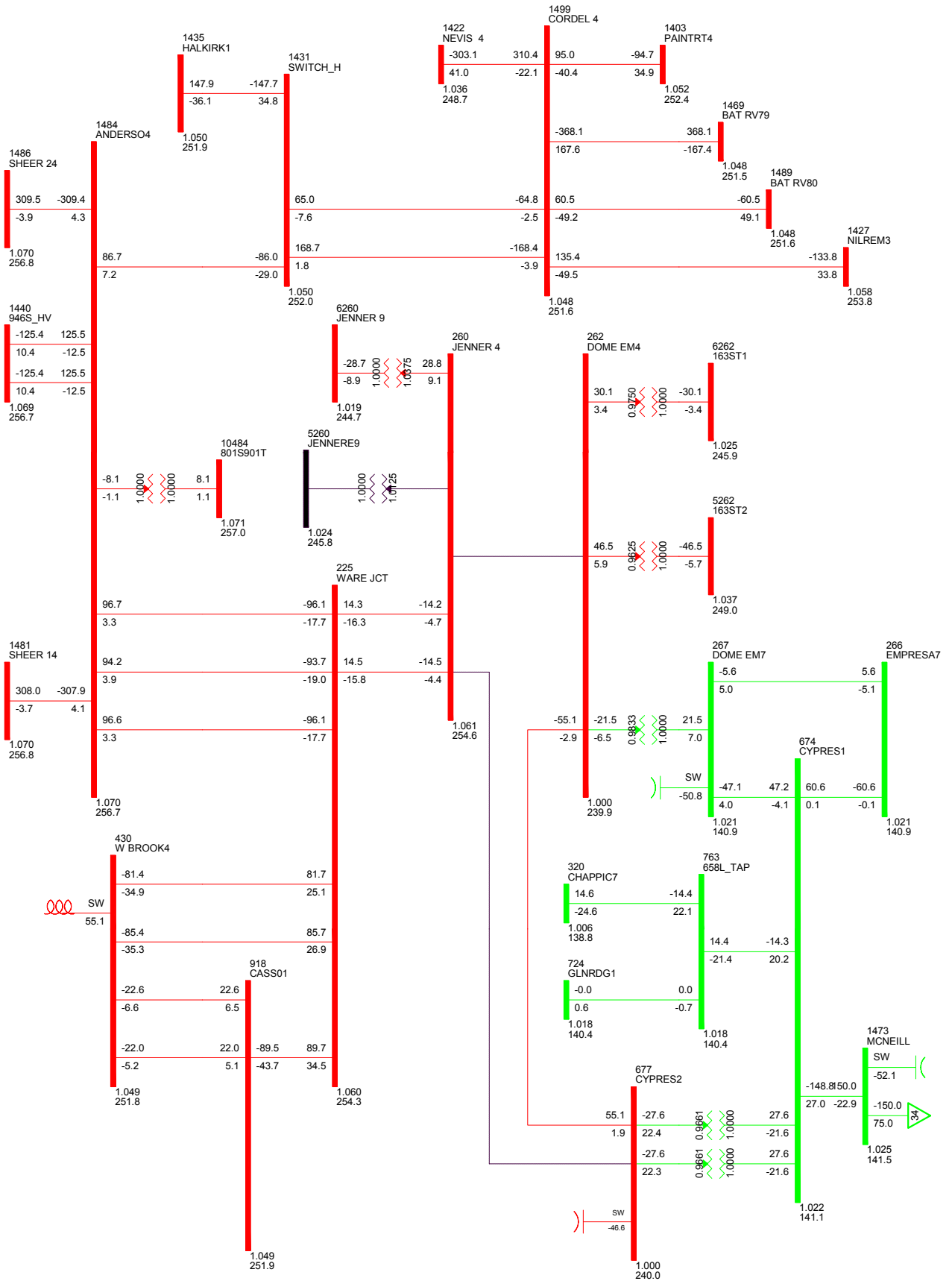


FIG E-E-14; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C11 2017SP -780.0 -150.86 R5
 THU, AUG 30 2012 16:03

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500<=69.000 <=138.000 <=240.000 <=500.000 >500.000

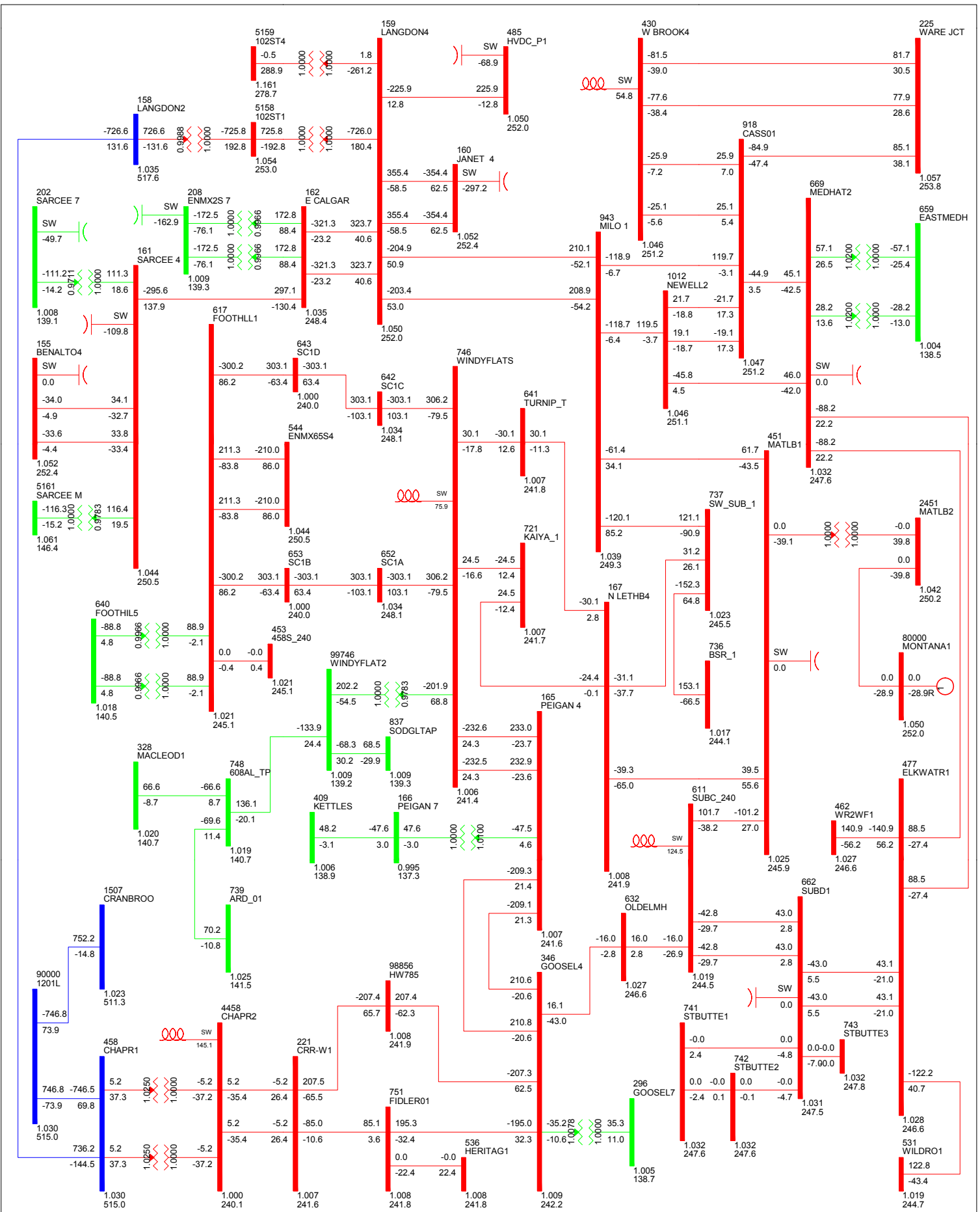


FIG E-W-15; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C11S_2017SP -780_0 -150_B6_R5
 THU, AUG 30 2012 16:03

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 KV: <=-34.500 <=-69.000 <=-138.000 <=-240.000 <=-500.000 >500.000

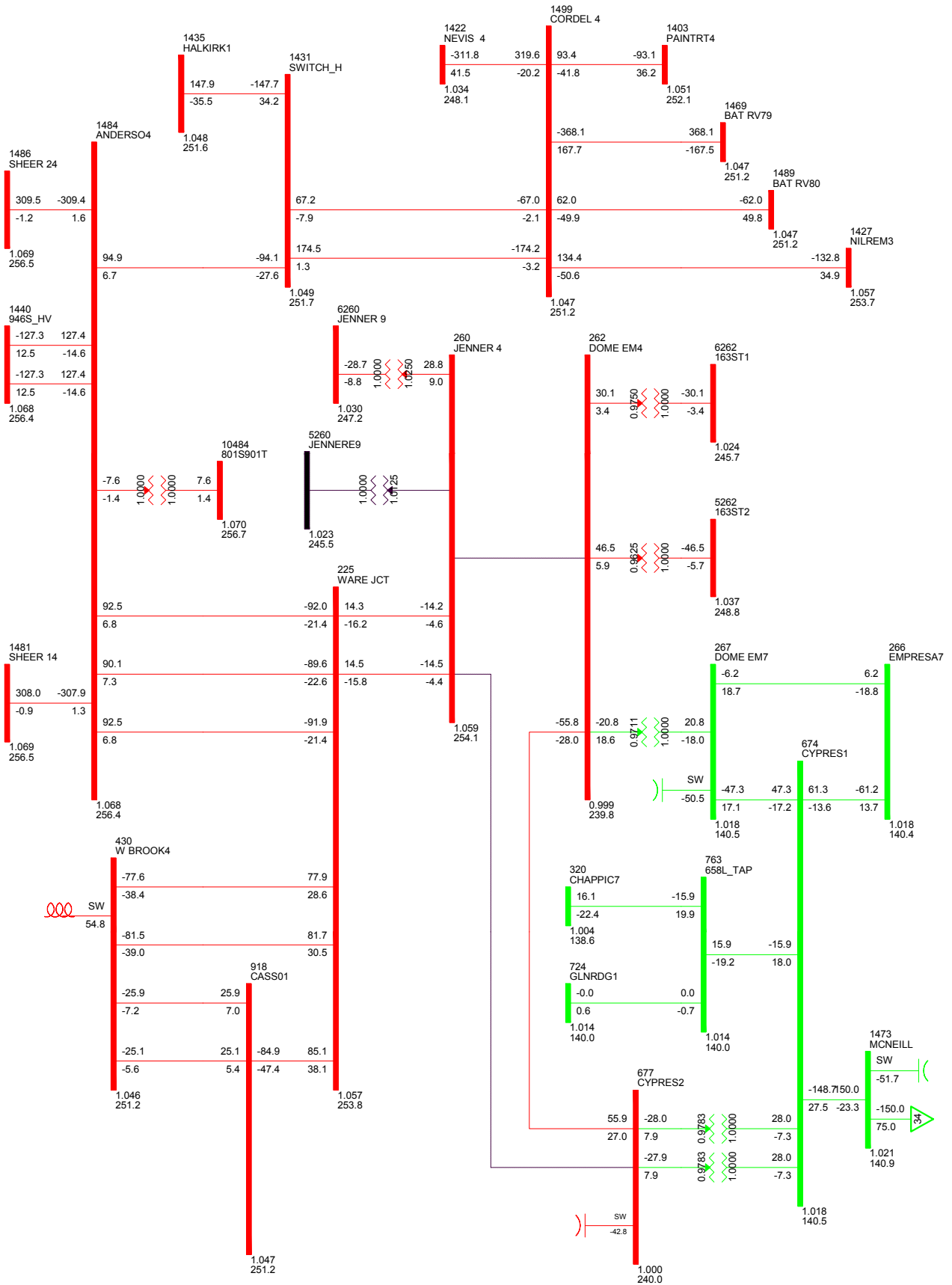


FIG E-E-15; 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C11S_2017SP -780_0 -150_B6_R5
 THU, AUG 30 2012 16:03

South Reactive Study East (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <math>=< 34.500</math>=69.000 <math><= 138.000</math> <math><= 240.000</math>=500.000>500.000

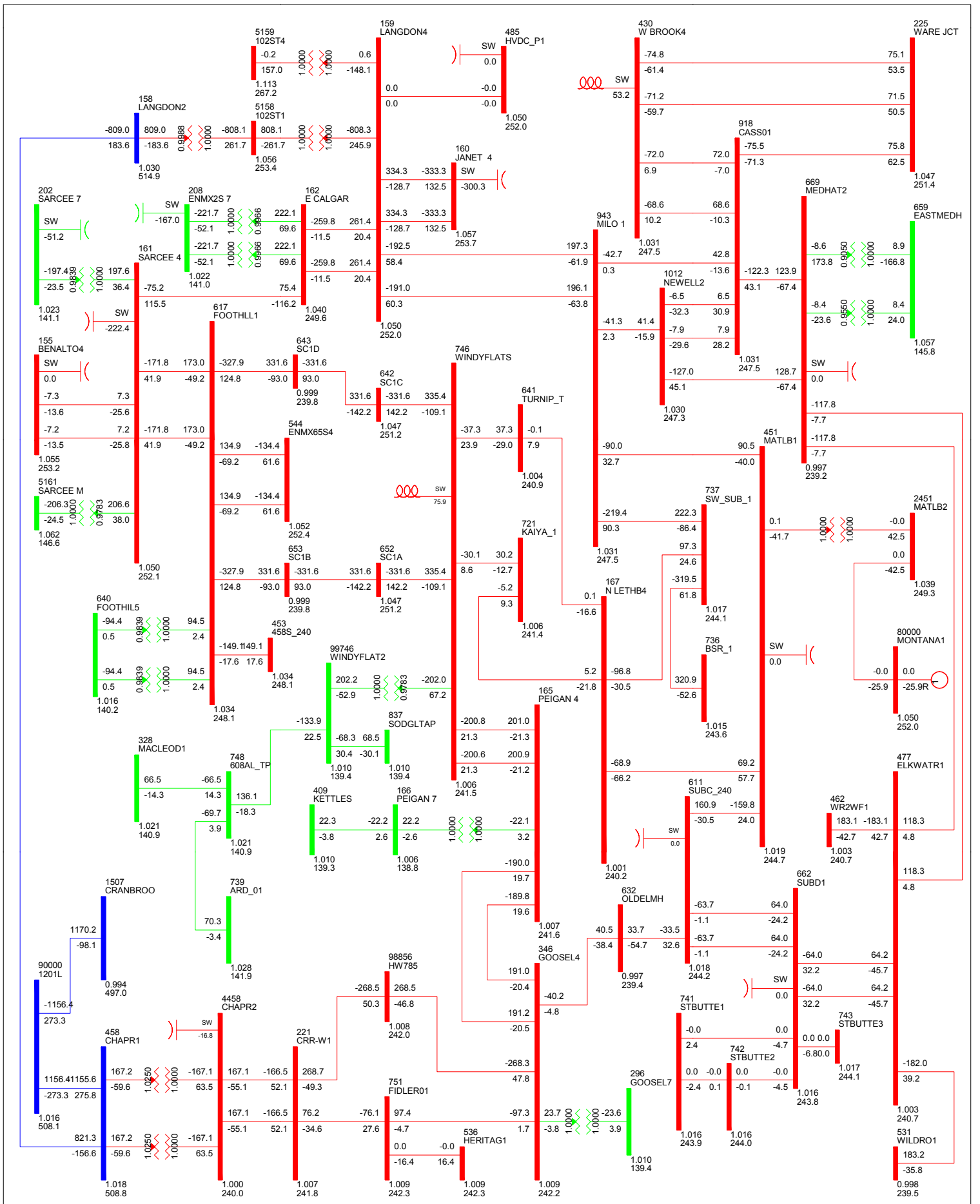


FIG E-W-16: 1002L & 1011L WITH LOSS OF JENNER 240/138 KV TRA
 C12_2022SP_-1200_0_0_B6 R5
 THU, AUG 30 2012 16:03

South Reactive Study West (Reactive Cases)

Bus - VOLTAGE (kV/PU)
 Branch - MW/Mvar
 Equipment - MW/Mvar
 kV: <=34.500 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

Appendix C
Dynamic Stability Fault Descriptions and Diagrams

List of Tables

Table C-1: Category B Dynamic Stability Fault Descriptions

Table C-2: Category C5 Dynamic Stability Fault Descriptions

Table C-3: Cypress Area Reduced Set Dynamic Stability Fault Descriptions

Table C-1: Category B Dynamic Stability Fault Descriptions

Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)
B01	CRBR_CHPR	Cranbrook - Chapel Rock 500 kV	3ph fault at Cranbrook on Cranbrook - Chapel Rock 500 kV line	
			trip Cranbrook 500 kV breaker	4
			trip Chapel Rock 500 kV breaker	5
B02	CRBR_CHPR	Cranbrook - Chapel Rock 500 kV	3ph fault at Chapel Rock on Cranbrook - Chapel Rock 500 kV line	
			trip Chapel Rock 500 kV breaker	4
			trip Cranbrook 500 kV breaker	5
B03	CHPR_XFMR500	Chapel Rock 500/240 kV Transformer	3ph fault at Chapel Rock 500/240 kV Transformer	
			trip Chapel Rock 500 kV breaker	4
			trip Chapel Rock 240 kV breaker	5
B04	CHPR_CRW1	Chapel Rock - Castle Rock Ridge 240 kV	3ph fault at Chapel Rock on Chapel Rock - Castle Rock Ridge 240 kV line	
			trip Chapel Rock 240 kV breaker	5
			trip Castle Rock Ridge 240 kV breaker	6
B05	CHPR_CRW1	Chapel Rock - Castle Rock Ridge 240 kV	3ph fault at Castle Rock Ridge on Chapel Rock - Castle Rock Ridge 240 kV line	
			trip Castle Rock Ridge 240 kV breaker	5
			trip Chapel Rock 240 kV breaker	6
B06	CHPR_LAND	Chapel Rock - LANGDON 500 kV	3ph fault at Chapel Rock on Chapel Rock - LANGDON 500 kV line	
			trip Chapel Rock 500 kV breaker	4
			trip LANGDON 500 kV breaker	5
B07	CHPR_LAND	Chapel Rock - LANGDON 500 kV	3ph fault at LANGDON on Chapel Rock - LANGDON 500 kV line	
			trip LANGDON 500 kV breaker	4
			trip Chapel Rock 500 kV breaker	5
B08	LAND_XFMR500	LANGDON 500/240 kV Transformer	3ph fault at LANGDON 500/240 kV Transformer	
			trip LANGDON 500 kV breaker	4
			trip LANGDON 240 kV breaker	5
B09	LAND_XFMR240	LANGDON 500/240 kV Transformer	3ph fault at LANGDON 500/240 kV Transformer	
			trip LANGDON 240 kV breaker	4
			trip LANGDON 500 kV breaker	5
B10	PEIG_GOLK	PEIGAN - Goose Lake 240 kV	3ph fault at PEIGAN on PEIGAN - Goose Lake 240 kV line	
			trip PEIGAN 240 kV breaker	5
			trip Goose Lake 240 kV breaker	6
B11	PEIG_WIDF	PEIGAN - WINDY FLATS 240 kV	3ph fault at PEIGAN on PEIGAN - WINDY FLATS 240 kV line	
			trip PEIGAN 240 kV breaker	5
			trip WINDY FLATS 240 kV breaker	6
B12	PEIG_WIDF	PEIGAN - WINDY FLATS 240 kV	3ph fault at WINDY FLATS on PEIGAN - WINDY FLATS 240 kV line	
			trip WINDY FLATS 240 kV breaker	5
			trip PEIGAN 240 kV breaker	6
B13	WIDF_KAIY	WINDY FLATS - KAIYA 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - KAIYA 240 kV line	
			trip WINDY FLATS 240 kV breaker	5
			trip KAIYA 240 kV breaker	6
B14	WIDF_KAIY	WINDY FLATS - KAIYA 240 kV	3ph fault at KAIYA on WINDY FLATS - KAIYA 240 kV line	
			trip KAIYA 240 kV breaker	5
			trip WINDY FLATS 240 kV breaker	6
B15	KAIY_NLEB	KAIYA - North Lethbridge 240 kV	3ph fault at KAIYA on KAIYA - North Lethbridge 240 kV line	
			trip KAIYA 240 kV breaker	5
			trip North Lethbridge 240 kV breaker	6
B16	KAIY_NLEB	KAIYA - North Lethbridge 240 kV	3ph fault at North Lethbridge on KAIYA - North Lethbridge 240 kV line	
			trip North Lethbridge 240 kV breaker	5
			trip KAIYA 240 kV breaker	6
B17	WIDF_XFMR240	WINDY FLATS 240/138 kV Transformer	3ph fault at WINDY FLATS 240/138 kV Transformer	
			trip WINDY FLATS 240 kV breaker	5
			trip WINDY FLATS 138 kV breaker	6
B18	WIDF_TURP	WINDY FLATS - Turnip 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Turnip 240 kV line	
			trip WINDY FLATS 240 kV breaker	5
			trip Turnip 240 kV breaker	6
B19	NLEB_TURP	North Lethbridge - Turnip 240 kV	3ph fault at North Lethbridge on North Lethbridge - Turnip 240 kV line	
			trip North Lethbridge 240 kV breaker	5
			trip Turnip 240 kV breaker	6
B20	WIDF_SCPA	WINDY FLATS - Series Compensator A 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Series Compensator A 240 kV line	
			trip WINDY FLATS 240 kV breaker	5
			trip Series Compensator A 240 kV breaker	6
B21	FHIL_SCPB	FOOTHLL - Series Compensator B 240 kV	3ph fault at FOOTHLL on FOOTHLL - Series Compensator B 240 kV line	
			trip FOOTHLL 240 kV breaker	5
			trip Series Compensator B 240 kV breaker	6

Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)
B22	WIDF_SCPC	WINDY FLATS - Series Compensator C 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Series Compensator C 240 kV line	
			trip WINDY FLATS 240 kV breaker	5
			trip Series Compensator C 240 kV breaker	6
B23	FHIL_SCPD	FOOTHLL - Series Compensator D 240 kV	3ph fault at FOOTHLL on FOOTHLL - Series Compensator D 240 kV line	
			trip FOOTHLL 240 kV breaker	5
			trip Series Compensator D 240 kV breaker	6
B24	MATL_SUBC	Matl - Sub C 240 kV	3ph fault at Matl on Matl - Sub C 240 kV line	
			trip Matl 240 kV breaker	5
			trip Sub C 240 kV breaker	6
B25	MATL_SUBC	Matl - Sub C 240 kV	3ph fault at Sub C on Matl - Sub C 240 kV line	
			trip Sub C 240 kV breaker	5
			trip Matl 240 kV breaker	6
B26	SUBC_OLMH	Sub C - Old Medicine Hat 240 kV	3ph fault at Sub C on Sub C - Old Medicine Hat 240 kV line	
			trip Sub C 240 kV breaker	5
			trip Old Medicine Hat 240 kV breaker	6
B27	SUBC_OLMH	Sub C - Old Medicine Hat 240 kV	3ph fault at Old Medicine Hat on Sub C - Old Medicine Hat 240 kV line	
			trip Old Medicine Hat 240 kV breaker	5
			trip Sub C 240 kV breaker	6
B28	OLMH_GOLK	Old Medicine Hat - Goose Lake 240 kV	3ph fault at Old Medicine Hat on Old Medicine Hat - Goose Lake 240 kV line	
			trip Old Medicine Hat 240 kV breaker	5
			trip Goose Lake 240 kV breaker	6
B29	SUBC_SUBD	Sub C - Sub D 240 kV	3ph fault at Sub C on Sub C - Sub D 240 kV line	
			trip Sub C 240 kV breaker	5
			trip Sub D 240 kV breaker	6
B30	SUBC_SUBD	Sub C - Sub D 240 kV	3ph fault at Sub D on Sub C - Sub D 240 kV line	
			trip Sub D 240 kV breaker	5
			trip Sub C 240 kV breaker	6
B31	SUBD_STBU	Sub D - STBUTTE3 240 kV	3ph fault at Sub D on Sub D - STBUTTE3 240 kV line	
			trip Sub D 240 kV breaker	5
			trip STBUTTE3 240 kV breaker	6
B34	CYPR_JENN	Cypress - JENNER 240 kV	3ph fault at Cypress on Cypress - JENNER 240 kV line	
			trip Cypress 240 kV breaker	5
			trip JENNER 240 kV breaker	6
B35	CYPR_JENN	Cypress - JENNER 240 kV	3ph fault at JENNER on Cypress - JENNER 240 kV line	
			trip JENNER 240 kV breaker	5
			trip Cypress 240 kV breaker	6
B36	JENN_DOME	JENNER - Dome Empress 240 kV	3ph fault at JENNER on JENNER - Dome Empress 240 kV line	
			trip JENNER 240 kV breaker	5
			trip Dome Empress 240 kV breaker	6
B37	JENN_DOME	JENNER - Dome Empress 240 kV	3ph fault at Dome Empress on JENNER - Dome Empress 240 kV line	
			trip Dome Empress 240 kV breaker	5
			trip JENNER 240 kV breaker	6
B38	CYPR_DOME	Cypress - Dome Empress 240 kV	3ph fault at Cypress on Cypress - Dome Empress 240 kV line	
			trip Cypress 240 kV breaker	5
			trip Dome Empress 240 kV breaker	6
B39	CYPR_DOME	Cypress - Dome Empress 240 kV	3ph fault at Dome Empress on Cypress - Dome Empress 240 kV line	
			trip Dome Empress 240 kV breaker	5
			trip Cypress 240 kV breaker	6
B40	CYPR_XFMR240	Cypress 240/138 kV Transformer	3ph fault at Cypress 240/138 kV Transformer	
			trip Cypress 240 kV breaker	5
			trip Cypress 138 kV breaker	6
B41	DOME_XFMR240	Dome Empress 240/138 kV Transformer	3ph fault at Dome Empress 240/138 kV Transformer	
			trip Dome Empress 240 kV breaker	5
			trip Dome Empress 138 kV breaker	6
B42	CYPR_MCNL	Cypress - Mc Neil 138 kV	3ph fault at Cypress on Cypress - Mc Neil 138 kV line	
			trip Cypress 138 kV breaker	6
			trip Mc Neil 138 kV breaker	24
B43	CYPR_MCNL	Cypress - Mc Neil 138 kV	3ph fault at Mc Neil on Cypress - Mc Neil 138 kV line	
			trip Mc Neil 138 kV breaker	6
			trip Cypress 138 kV breaker	24
B44	CYPR_DOME	Cypress - Dome Empress 138 kV	3ph fault at Cypress on Cypress - Dome Empress 138 kV line	
			trip Cypress 138 kV breaker	6
			trip Dome Empress 138 kV breaker	24

Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)
B45	CYPR_DOME	Cypress - Dome Empress 138 kV	3ph fault at Dome Empress on Cypress - Dome Empress 138 kV line	
			trip Dome Empress 138 kV breaker	6
			trip Cypress 138 kV breaker	24
B46	CYPR_EMPR	Cypress - Empress 138 kV	3ph fault at Cypress on Cypress - Empress 138 kV line	
			trip Cypress 138 kV breaker	6
			trip Empress 138 kV breaker	24
B47	CYPR_EMPR	Cypress - Empress 138 kV	3ph fault at Empress on Cypress - Empress 138 kV line	
			trip Empress 138 kV breaker	6
			trip Cypress 138 kV breaker	24
B48	CYPR_658L	Cypress - 658L_TAP 138 kV	3ph fault at Cypress on Cypress - 658L_TAP 138 kV line	
			trip Cypress 138 kV breaker	6
			trip 658L_TAP 138 kV breaker	24
B49	GLEN_658L	Glenridge - 658L_TAP 138 kV	3ph fault at Glenridge on Glenridge - 658L_TAP 138 kV line	
			trip 658L_TAP 138 kV breaker	6
			trip Glenridge 138 kV breaker	24
B50	CHAP_658L	Chappice - 658L_TAP 138 kV	3ph fault at Chappice on Chappice - 658L_TAP 138 kV line	
			trip Chappice 138 kV breaker	6
			trip 658L_TAP 138 kV breaker	24
B51	DOME_EMPR	Dome Empress - Empress 138 kV	3ph fault at Dome Empress on Dome Empress - Empress 138 kV line	
			trip Dome Empress 138 kV breaker	6
			trip Empress 138 kV breaker	24
B52	DOME_EMPR	Dome Empress - Empress 138 kV	3ph fault at Empress on Dome Empress - Empress 138 kV line	
			trip Empress 138 kV breaker	6
			trip Dome Empress 138 kV breaker	24
B53	ANDE-WARE	Anderson - Ware JCT 240 kV	3ph Fault at Anderson on Anderson to W J 240 kV line	
			trip Anderson 240 kV breaker	5
			trip Ware JCT 240 kV breaker	6
B54	WBRO-CASS	West Brooks - Cassils 240 kV	3ph Fault at West Brooks on West Brooks to Cassils 240 kV line	
			trip West Brooks 240 kV breaker	5
			trip Cassils 240 kV breaker	6
B55	CASS-BOWM	Cassils - Bowmanton 240 kV	3ph Fault at Cassils on Cassils to Bowmanton 244S	
			trip Cassils 240 kV breaker	5
			trip Bowmanton 240 kV breaker	6
B56	TINC-CORD	Tincherbray - Cordel 240 kV	3ph Fault at Tincherbray on Tincherbray 401S to Cordel 755S 240 KV line 9L xx	
			trip Tincherbray 240 kV breaker	5
			trip Cordel 240 kV breaker	6
B57	HTHF-NEWE	HTHFIELD -NEWELL HVDC line	Loss of EATL HVDC line	
			trip HTHFIELD 500 kV breaker	4
			trip NEWELL 240 kV breaker	5

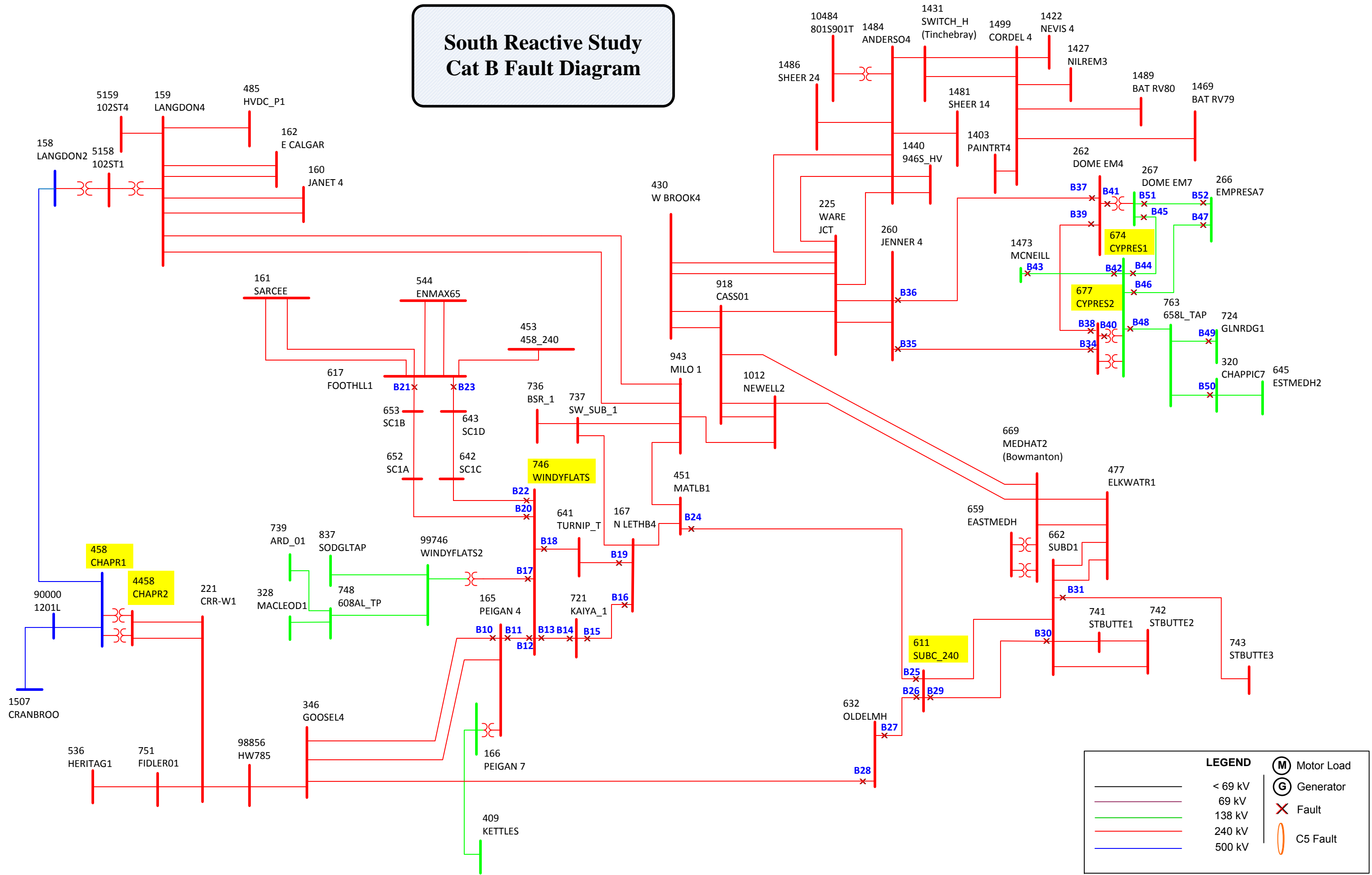
Table C-2: Category C5 Dynamic Stability Fault Descriptions

Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)
C501	CHAP-CRW1	Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	3ph fault at Chapel Rock on Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	
			trip Chapel Rock 240 kV breakers	5
C502	CRW1-CHAP	Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	trip Castle Rock Ridge 240 kV breakers	7
			3ph fault at Castle Rock Ridge on Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	
C503	LANG-ECAL	LANGDON - ECALGAR 240 kV Double Circuit lines	trip Castle Rock Ridge 240 kV breakers	5
			trip Chapel Rock 240 kV breakers	7
C504	ECAL-LANG	LANGDON - ECALGAR 240 kV Double Circuit lines	3ph fault at LANGDON on LANGDON - ECALGAR 240 kV Double Circuit lines	
			trip ECALGAR 240 kV breakers	5
C505	LANG-MILO	LANGDON - MILO 240 kV Double Circuit lines	trip LANGDON 240 kV breakers	7
			trip MILO 240 kV breakers	5
C506	MILO-LANG	LANGDON - MILO 240 kV Double Circuit lines	3ph fault at LANGDON on LANGDON - MILO 240 kV Double Circuit lines	
			trip MILO 240 kV breakers	5
C507	LANG-JANE	LANGDON - JANET 240 kV Double Circuit lines	trip LANGDON 240 kV breakers	7
			trip JANET 240 kV breakers	5
C508	JANE-LANG	LANGDON - JANET 240 kV Double Circuit lines	3ph fault at JANET on LANGDON - JANET 240 kV Double Circuit lines	
			trip JANET 240 kV breakers	5
C509	944-951_A	JENNER - WARE JCT 240 kV Double Circuit line	trip LANGDON 240 kV breakers	7
			trip JENNER 240 kV breakers	5
C510	944-951_B	WARE JCT - JENNER 240 kV Double Circuit lines	trip JENNER 275ST1 240/25 kV 3-winding transformer	6
			trip WARE JCT 240 kV breakers	6
C511	1002-1011_A	DOME EMPRESS - JENNER 240 kV Double Circuit lines	3ph fault at WARE JCT on WARE JCT - JENNER 240 kV Double Circuit lines	
			trip WARE JCT 240 kV breakers	5
C512	1002-1011_B	JENNER - DOME EMPRESS 240 kV Double Circuit lines	trip JENNER 240 kV breakers	6
			3ph fault at JENNER on JENNER - DOME EMPRESS 240 kV Double Circuit lines	
			trip JENNER 240 kV breakers	5
			trip JENNER 275ST1 240/25 kV 3-winding transformer	6
			trip DOME EMPRESS 240 kV breakers	6

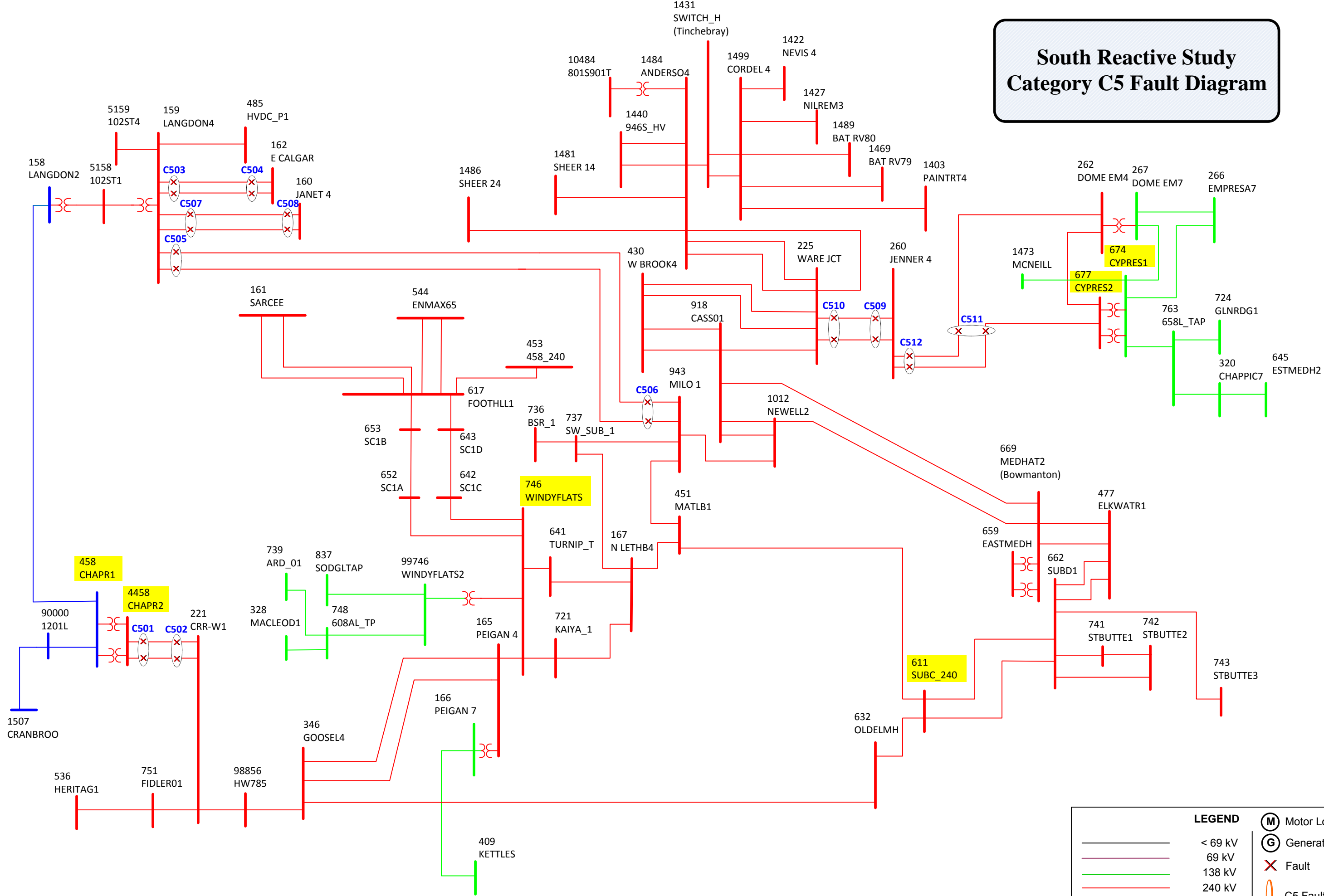
Table C-3: Cypress Area Reduced Set Dynamic Stability Fault Descriptions

Fault Name	Fault Location	Description	Clearing Time (Cycles)
Cypress - Dome	Cypress - Dome 138kV	3-ph fault at Cypress on Cypress - Dome 138kV line	
		Trip Cypress 138kV Breaker	8
		Trip Dome 138kV Breaker	8
Cypress - Empress	Cypress - Empress 138kV	3-ph fault at Cypress on Cypress - Empress 138kV line	
		Trip Cypress 138kV Breaker	8
		Trip Empress 138kV Breaker	8
Cypress - Jenner	Cypress - Jenner 240kV	3-ph fault at Cypress on Cypress - Jenner 240kV line	
		Trip Cypress 240kV Breaker	6
		Trip Jenner 240kV Breaker	6
Cypress - Glenridge	Cypress - Glenridge - Chapprice Lake 138kV	3-ph fault at Cypress on Cypress - Glenridge - Chapprice Lake 138kV line	
		Trip Cypress 138kV Breaker	8
		Trip Glenridge 138kV Breaker	8
Cypress - McNeil	Cypress - McNeil 138kV	3-ph fault at Cypress on Cypress - McNeil 138kV line	
		Trip Cypress 138kV Breaker	8
		Trip McNeil 138kV Breaker	8
Dome - Empress	Dome - Empress 138kV	3-ph fault at Dome on Dome - Empress 138kV line	
		Trip Dome 138kV Breaker	8
		Trip Empress 138kV Breaker	8

South Reactive Study Cat B Fault Diagram



South Reactive Study Category C5 Fault Diagram



LEGEND	
	< 69 kV
	69 kV
	138 kV
	240 kV
	500 kV
	Motor Load
	Generator
	Fault
	C5 Fault

Appendix D
Dynamic Stability Results and Plots

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Table D-2: C3X Dynamic Stability Results

Table D-3: C12 Dynamic Stability Results

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Table D-1: C3 Dynamic Stability Results

Table D-2: C3X Dynamic Stability Results

Table D-3: C12 Dynamic Stability Results

Table D-4: C9 Dynamic Stability Results - 2022 SP with 161 MVar SVC @ Cypress

Table D-5: C9X Dynamic Stability Results - 2022 SP with 161 MVar SVC @ Cypress

Table D-1: C3 Dynamic Stability Results

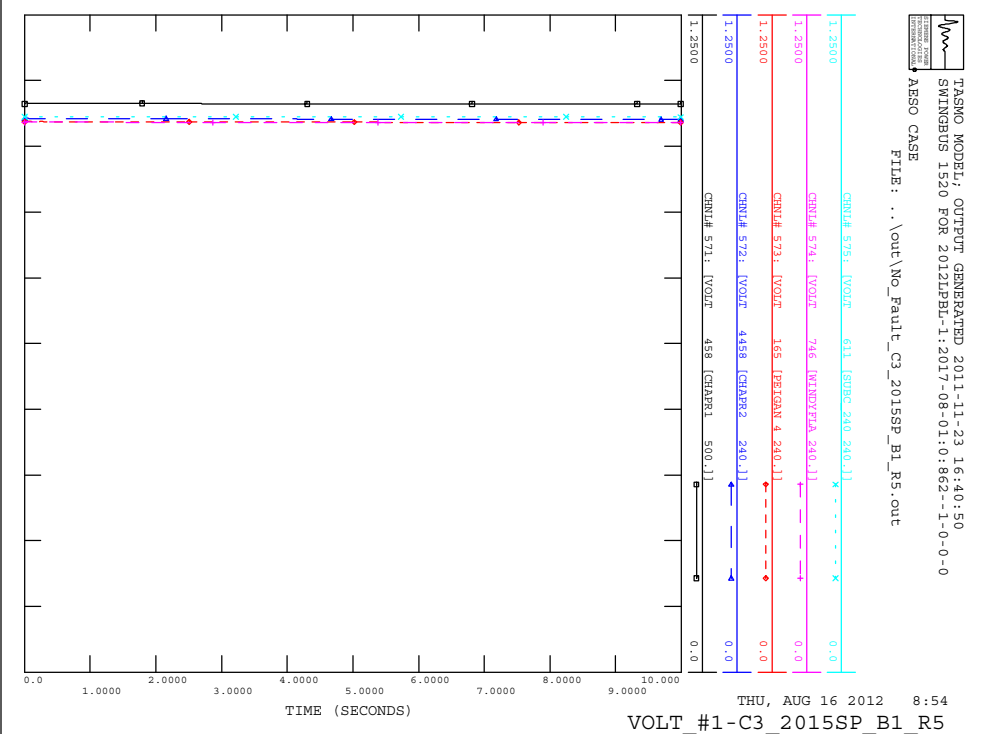
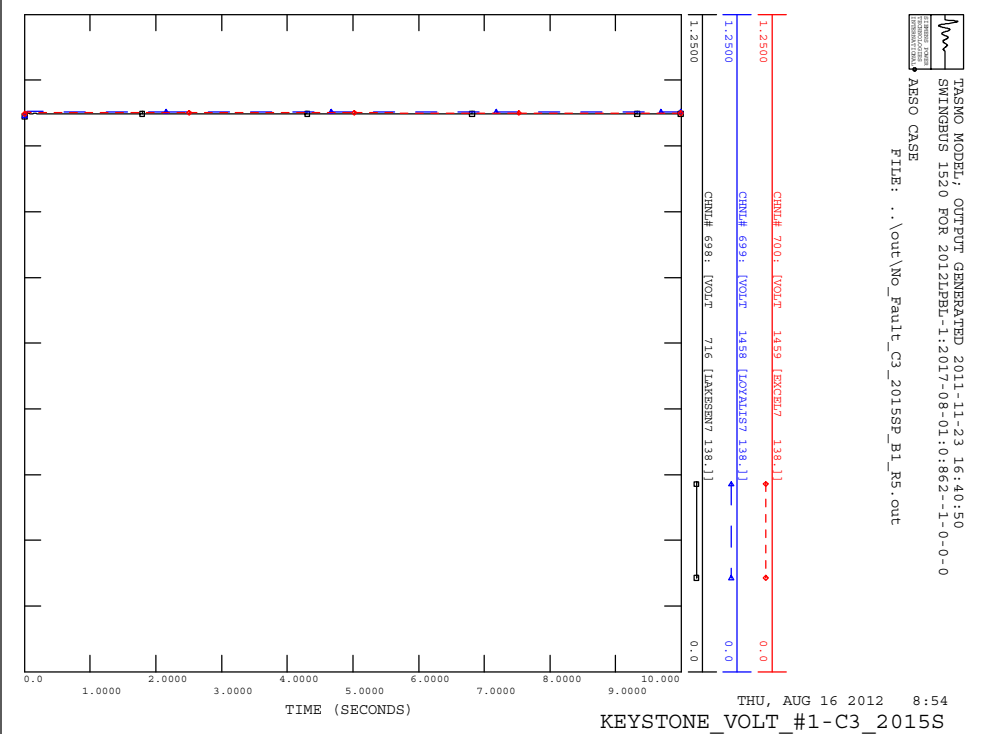
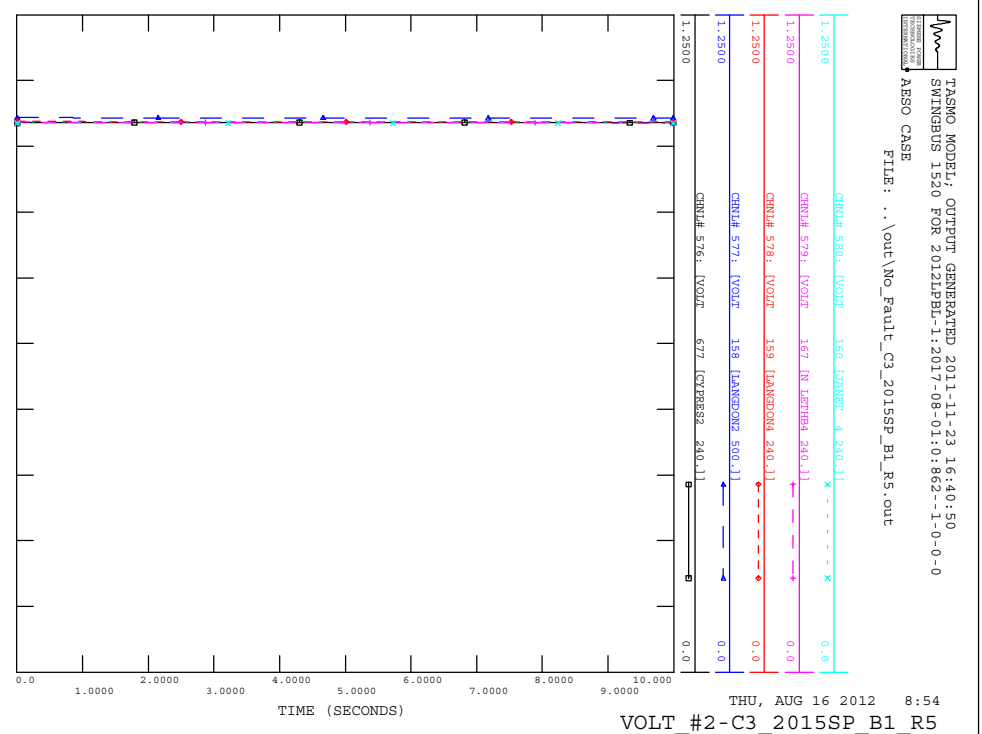
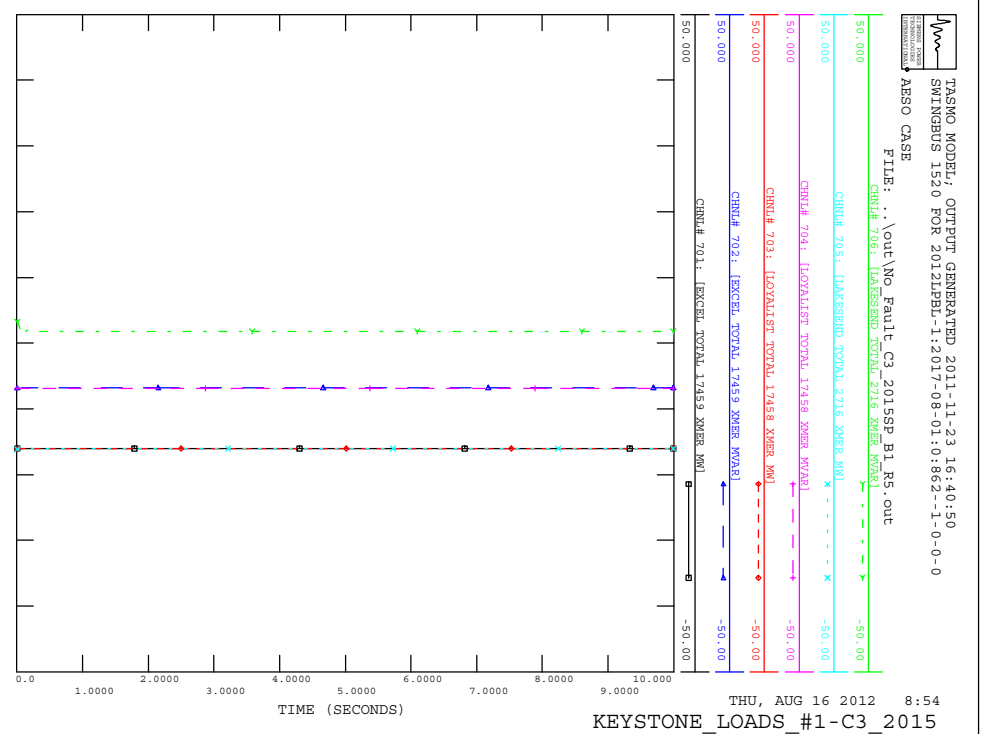
Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)	Observation	Load Shed
	No Fault				System Stable	
Category B						
B03	CHPR_XFMR500	Chapel Rock 500/240 kV Transformer	3ph fault at Chapel Rock 500/240 kV Transformer		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Chapel Rock 500 kV breaker	4		
			trip Chapel Rock 240 kV breaker	5		
B04	CHPR_CRW1	Chapel Rock - Castle Rock Ridge 240 kV	3ph fault at Chapel Rock on Chapel Rock - Castle Rock Ridge 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Chapel Rock 240 kV breaker	5		
			trip Castle Rock Ridge 240 kV breaker	6		
B05	CHPR_CRW1	Chapel Rock - Castle Rock Ridge 240 kV	3ph fault at Castle Rock Ridge on Chapel Rock - Castle Rock Ridge 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Castle Rock Ridge 240 kV breaker	5		
			trip Chapel Rock 240 kV breaker	6		
B06	CHPR_LAND	Chapel Rock - LANGDON 500 kV	3ph fault at Chapel Rock on Chapel Rock - LANGDON 500 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Chapel Rock 500 kV breaker	4		
			trip LANGDON 500 kV breaker	5		
B07	CHPR_LAND	Chapel Rock - LANGDON 500 kV	3ph fault at LANGDON on Chapel Rock - LANGDON 500 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 500 kV breaker	4		
			trip Chapel Rock 500 kV breaker	5		
B08	LAND_XFMR500	LANGDON 500/240 kV Transformer	3ph fault at LANGDON 500/240 kV Transformer		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 500 kV breaker	4		
			trip LANGDON 240 kV breaker	5		
B09	LAND_XFMR240	LANGDON 500/240 kV Transformer	3ph fault at LANGDON 500/240 kV Transformer		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 240 kV breaker	4		
			trip LANGDON 500 kV breaker	5		
B10	PEIG_GOLK	PEIGAN - Goose Lake 240 kV	3ph fault at PEIGAN on PEIGAN - Goose Lake 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip PEIGAN 240 kV breaker	5		
			trip Goose Lake 240 kV breaker	6		
B11	PEIG_WIDF	PEIGAN - WINDY FLATS 240 kV	3ph fault at PEIGAN on PEIGAN - WINDY FLATS 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip PEIGAN 240 kV breaker	5		
			trip WINDY FLATS 240 kV breaker	6		
B12	PEIG_WIDF	PEIGAN - WINDY FLATS 240 kV	3ph fault at WINDY FLATS on PEIGAN - WINDY FLATS 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5		
			trip PEIGAN 240 kV breaker	6		
B13	WIDF_KAIY	WINDY FLATS - KAIYA 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - KAIYA 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5		
			trip KAIYA 240 kV breaker	6		
B14	WIDF_KAIY	WINDY FLATS - KAIYA 240 kV	3ph fault at KAIYA on WINDY FLATS - KAIYA 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip KAIYA 240 kV breaker	5		
			trip WINDY FLATS 240 kV breaker	6		
B15	KAIY_NLEB	KAIYA - North Lethbridge 240 kV	3ph fault at KAIYA on KAIYA - North Lethbridge 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip KAIYA 240 kV breaker	5		
			trip North Lethbridge 240 kV breaker	6		
B16	KAIY_NLEB	KAIYA - North Lethbridge 240 kV	3ph fault at North Lethbridge on KAIYA - North Lethbridge 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip North Lethbridge 240 kV breaker	5		
			trip KAIYA 240 kV breaker	6		

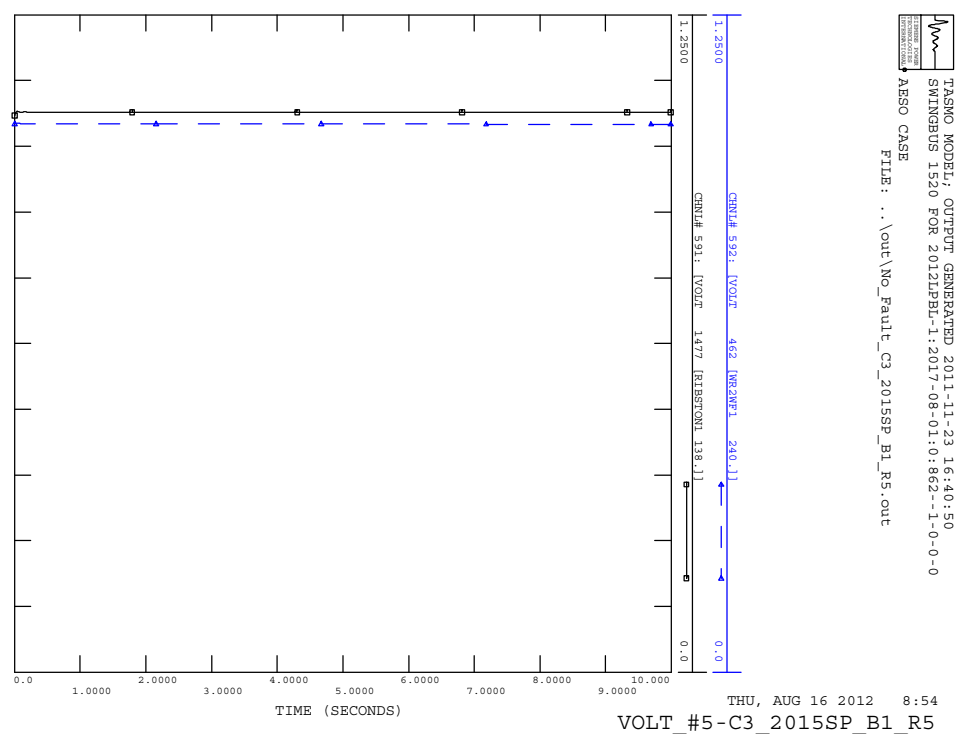
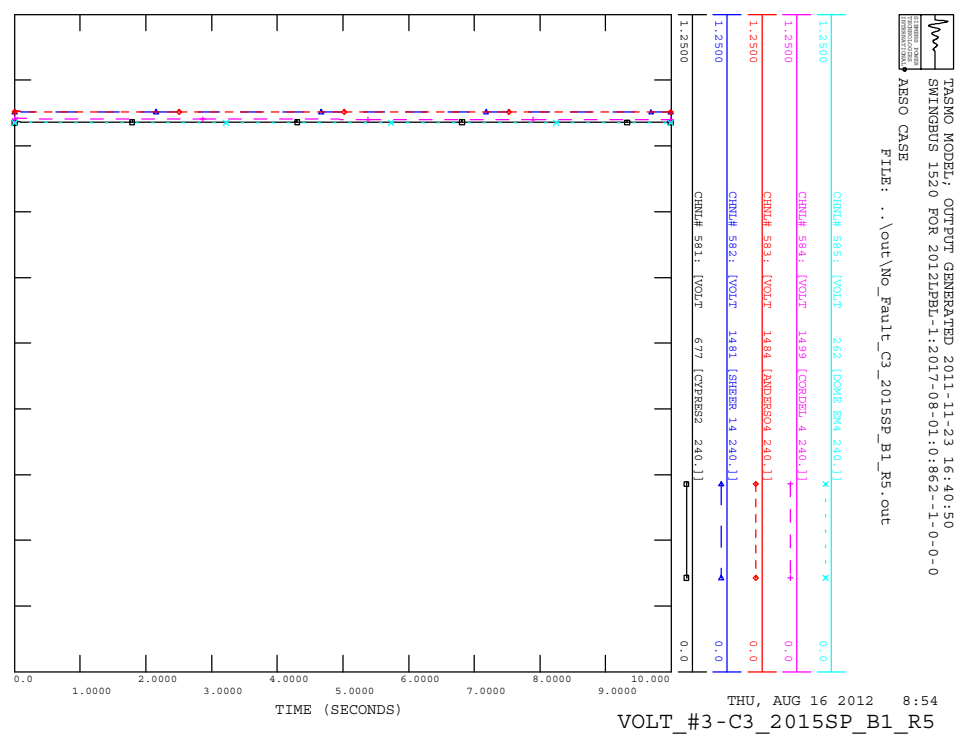
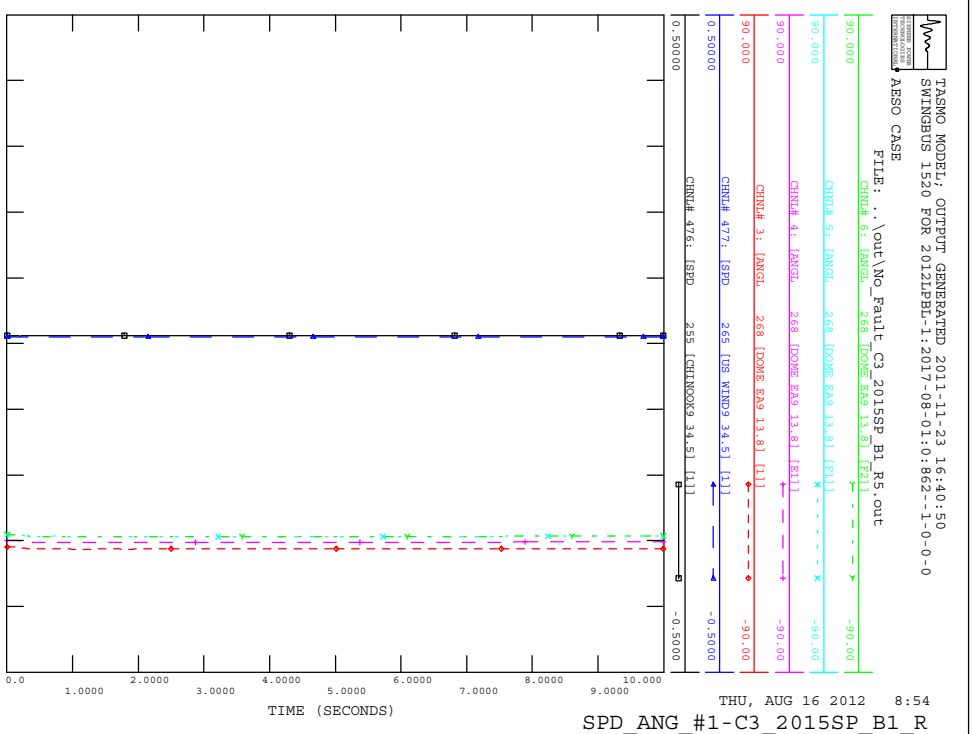
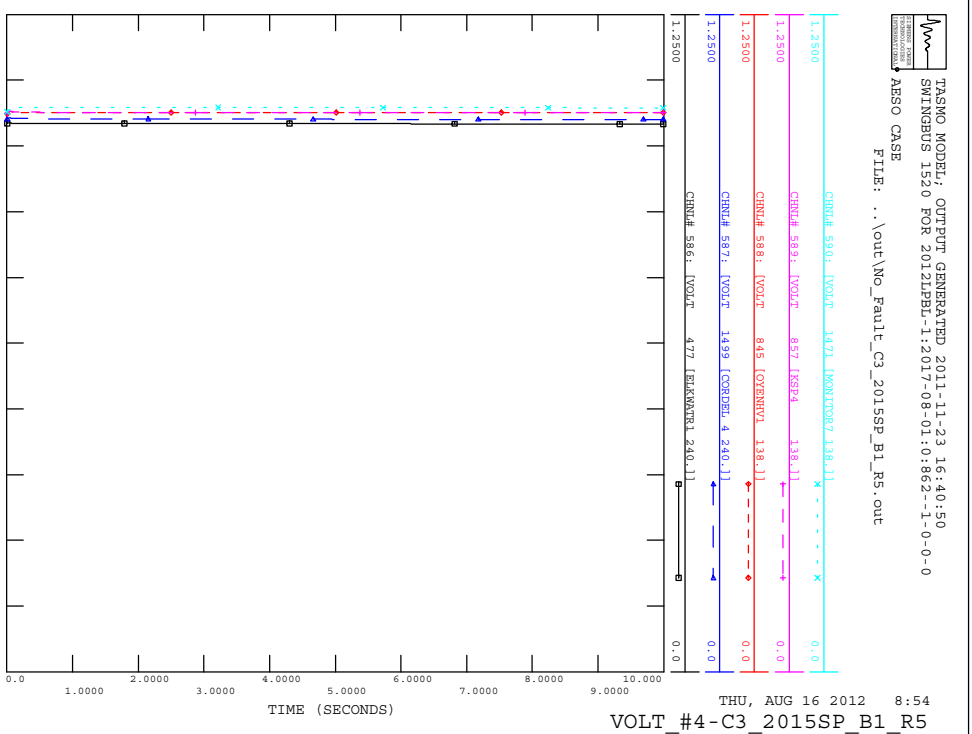
Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)	Observation	Load Shed
B17	WIDF_XFMR240	WINDY FLATS 240/138 kV Transformer	3ph fault at WINDY FLATS 240/138 kV Transformer		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5	Out-of-Step (Isolated by Fault): [5329] McLeod D1, [12358, 13358] Soderglen 1+2, [4735, 4740] Ardenville, [66328, 67328] Macleod G1+G2	
			trip WINDY FLATS 138 kV breaker	6		
B18	WIDF_TURP	WINDY FLATS - Turnip 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Turnip 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5		
			trip Turnip 240 kV breaker	6		
B19	NLEB_TURP	North Lethbridge - Turnip 240 kV	3ph fault at North Lethbridge on North Lethbridge - Turnip 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip North Lethbridge 240 kV breaker	5		
			trip Turnip 240 kV breaker	6		
B20	WIDF_SCPA	WINDY FLATS - Series Compensator A 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Series Compensator A 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5		
			trip Series Compensator A 240 kV breaker	6		
B21	FHIL_SCPB	FOOTHLL - Series Compensator B 240 kV	3ph fault at FOOTHLL on FOOTHLL - Series Compensator B 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip FOOTHLL 240 kV breaker	5		
			trip Series Compensator B 240 kV breaker	6		
B22	WIDF_SPCPC	WINDY FLATS - Series Compensator C 240 kV	3ph fault at WINDY FLATS on WINDY FLATS - Series Compensator C 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip WINDY FLATS 240 kV breaker	5		
			trip Series Compensator C 240 kV breaker	6		
B23	FHIL_SCPD	FOOTHLL - Series Compensator D 240 kV	3ph fault at FOOTHLL on FOOTHLL - Series Compensator D 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip FOOTHLL 240 kV breaker	5		
			trip Series Compensator D 240 kV breaker	6		
B24	MATL_SUBC	Matl - Sub C 240 kV	3ph fault at Matl on Matl - Sub C 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Matl 240 kV breaker	5		
			trip Sub C 240 kV breaker	6		
B25	MATL_SUBC	Matl - Sub C 240 kV	3ph fault at Sub C on Matl - Sub C 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Sub C 240 kV breaker	5		
			trip Matl 240 kV breaker	6		
B26	SUBC_OLMH	Sub C - Old Medicine Hat 240 kV	3ph fault at Sub C on Sub C - Old Medicine Hat 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Sub C 240 kV breaker	5		
			trip Old Medicine Hat 240 kV breaker	6		
B27	SUBC_OLMH	Sub C - Old Medicine Hat 240 kV	3ph fault at Old Medicine Hat on Sub C - Old Medicine Hat 240 kV line		System Stable	
			trip Old Medicine Hat 240 kV breaker	5		
			trip Sub C 240 kV breaker	6		
B28	OLMH_GOLK	Old Medicine Hat - Goose Lake 240 kV	3ph fault at Old Medicine Hat on Old Medicine Hat - Goose Lake 240 kV line		System Stable	
			trip Old Medicine Hat 240 kV breaker	5		
			trip Goose Lake 240 kV breaker	6		
B29	SUBC_SUBD	Sub C - Sub D 240 kV	3ph fault at Sub C on Sub C - Sub D 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Sub C 240 kV breaker	5		
			trip Sub D 240 kV breaker	6		
B30	SUBC_SUBD	Sub C - Sub D 240 kV	3ph fault at Sub D on Sub C - Sub D 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Sub D 240 kV breaker	5		
			trip Sub C 240 kV breaker	6		
B31	SUBD_STBU	Sub D - STBUTTE3 240 kV	3ph fault at Sub D on Sub D - STBUTTE3 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Sub D 240 kV breaker	5		
			trip STBUTTE3 240 kV breaker	6		
B34	CYPR_JENN	Cypress - JENNER 240 kV	3ph fault at Cypress on Cypress - JENNER 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 240 kV breaker	5		
			trip JENNER 240 kV breaker	6		

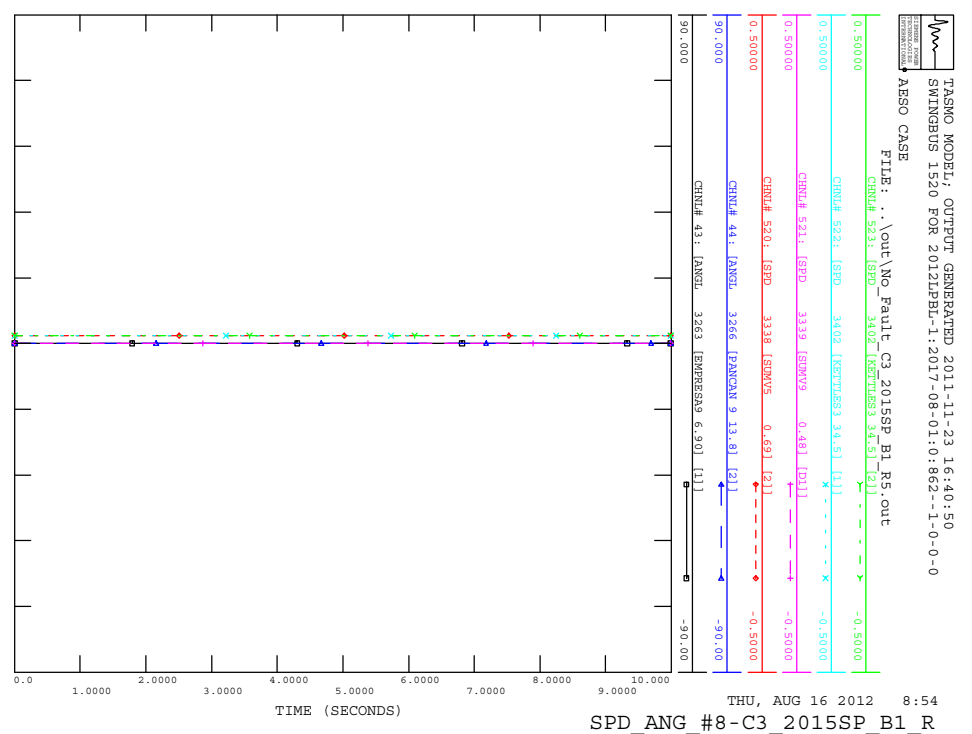
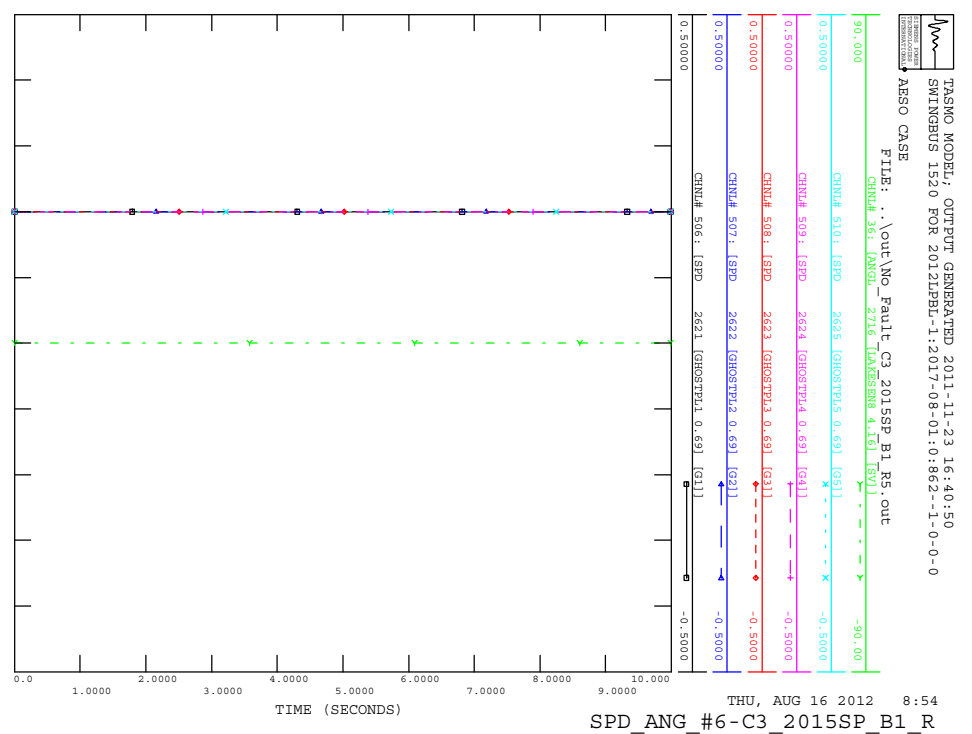
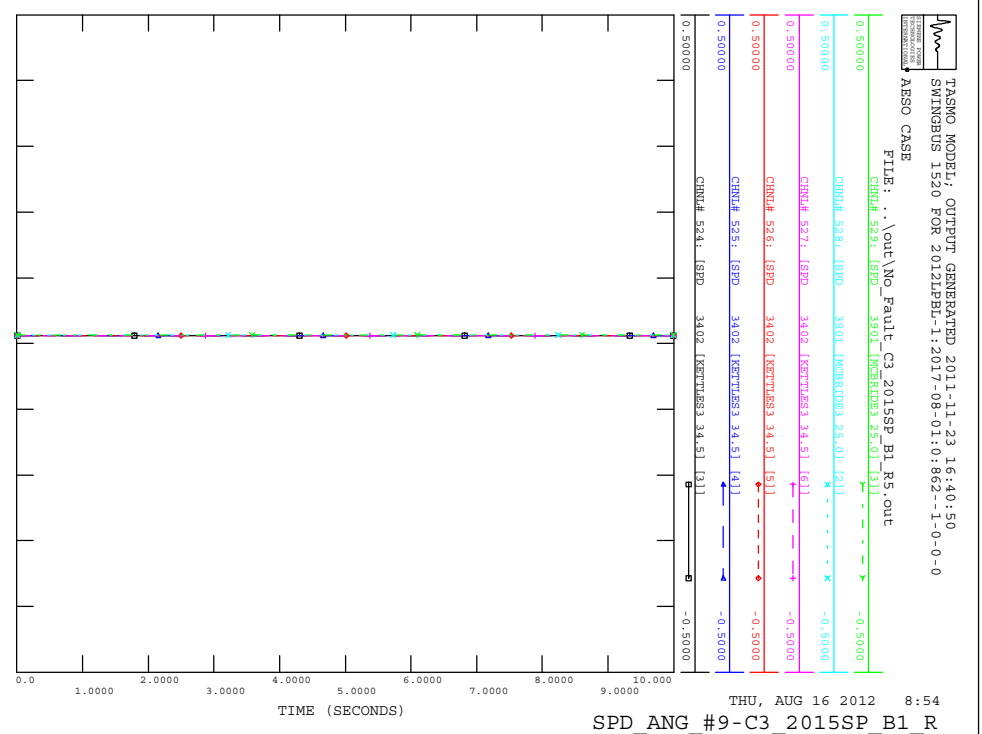
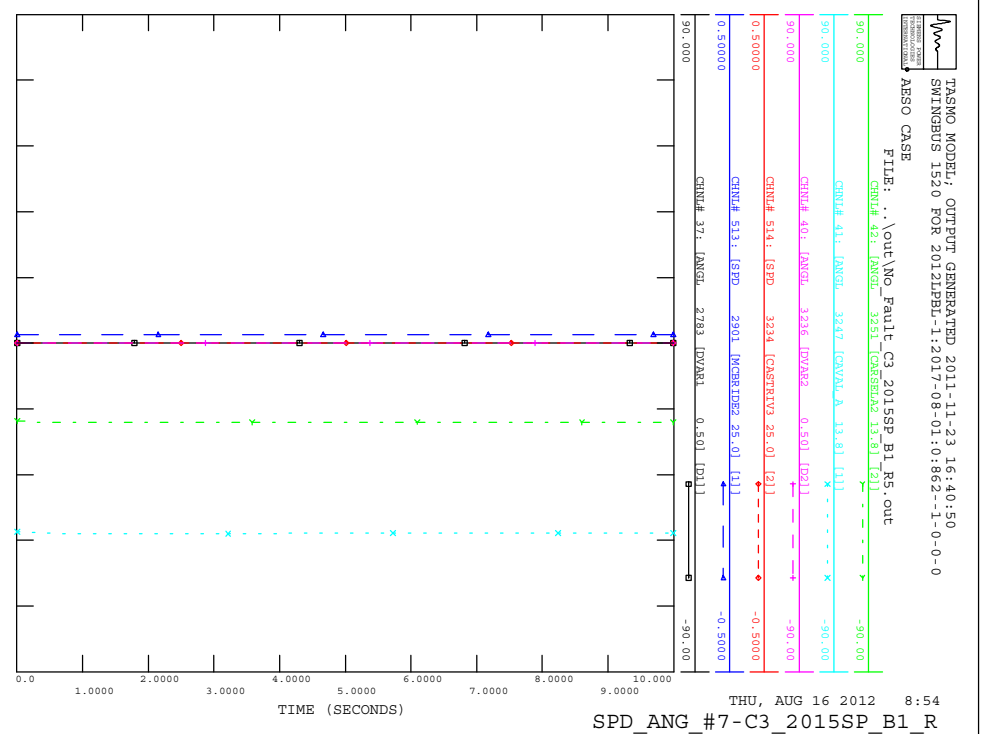
Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)	Observation	Load Shed
B35	CYPR_JENN	Cypress - JENNER 240 kV	3ph fault at JENNER on Cypress - JENNER 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip JENNER 240 kV breaker	5		
			trip Cypress 240 kV breaker	6		
B36	JENN_DOME	JENNER - Dome Empress 240 kV	3ph fault at JENNER on JENNER - Dome Empress 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip JENNER 240 kV breaker	5		
			trip Dome Empress 240 kV breaker	6		
B37	JENN_DOME	JENNER - Dome Empress 240 kV	3ph fault at Dome Empress on JENNER - Dome Empress 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Dome Empress 240 kV breaker	5		
			trip JENNER 240 kV breaker	6		
B38	CYPR_DOME	Cypress - Dome Empress 240 kV	3ph fault at Cypress on Cypress - Dome Empress 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 240 kV breaker	5		
			trip Dome Empress 240 kV breaker	6		
B39	CYPR_DOME	Cypress - Dome Empress 240 kV	3ph fault at Dome Empress on Cypress - Dome Empress 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Dome Empress 240 kV breaker	5		
			trip Cypress 240 kV breaker	6		
B40	CYPR_XFMR240	Cypress 240/138 kV Transformer	3ph fault at Cypress 240/138 kV Transformer		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 240 kV breaker	5		
			trip Cypress 138 kV breaker	6		
B41	DOME_XFMR240	Dome Empress 240/138 kV Transformer	3ph fault at Dome Empress 240/138 kV Transformer		System Stable Out-of-Step (Isolated by fault): [289] DOME EM9 1+2, [288] DOME EC9 1	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Dome Empress 240 kV breaker	5		
			trip Dome Empress 138 kV breaker	6		
B42	CYPR_MCNL	Cypress - Mc Neil 138 kV	3ph fault at Cypress on Cypress - Mc Neil 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 138 kV breaker	6		
			trip Mc Neil 138 kV breaker	24		
B43	CYPR_MCNL	Cypress - Mc Neil 138 kV	3ph fault at Mc Neil on Cypress - Mc Neil 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Mc Neil 138 kV breaker	6		
			trip Cypress 138 kV breaker	24		
B44	CYPR_DOME	Cypress - Dome Empress 138 kV	3ph fault at Cypress on Cypress - Dome Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 138 kV breaker	6		
			trip Dome Empress 138 kV breaker	24		
B45	CYPR_DOME	Cypress - Dome Empress 138 kV	3ph fault at Dome Empress on Cypress - Dome Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Dome Empress 138 kV breaker	6		
			trip Cypress 138 kV breaker	24		
B46	CYPR_EMPR	Cypress - Empress 138 kV	3ph fault at Cypress on Cypress - Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 138 kV breaker	6		
			trip Empress 138 kV breaker	24		
B47	CYPR_EMPR	Cypress - Empress 138 kV	3ph fault at Empress on Cypress - Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Empress 138 kV breaker	6		
			trip Cypress 138 kV breaker	24		
B48	CYPR_658L	Cypress - 658L_TAP 138 kV	3ph fault at Cypress on Cypress - 658L_TAP 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Cypress 138 kV breaker	6		
			trip 658L_TAP 138 kV breaker	24		
B49	GLEN_658L	Glenridge - 658L_TAP 138 kV	3ph fault at Glenridge on Glenridge - 658L_TAP 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip 658L_TAP 138 kV breaker	6		
			trip Glenridge 138 kV breaker	24		
B50	CHAP_658L	Chappice - 658L_TAP 138 kV	3ph fault at Chappice on Chappice - 658L_TAP 138 kV line		System Stable	
			trip Chappice 138 kV breaker	6		
			trip 658L_TAP 138 kV breaker	24		
B51	DOME_EMPR	Dome Empress - Empress 138 kV	3ph fault at Dome Empress on Dome Empress - Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Dome Empress 138 kV breaker	6		
			trip Empress 138 kV breaker	24		

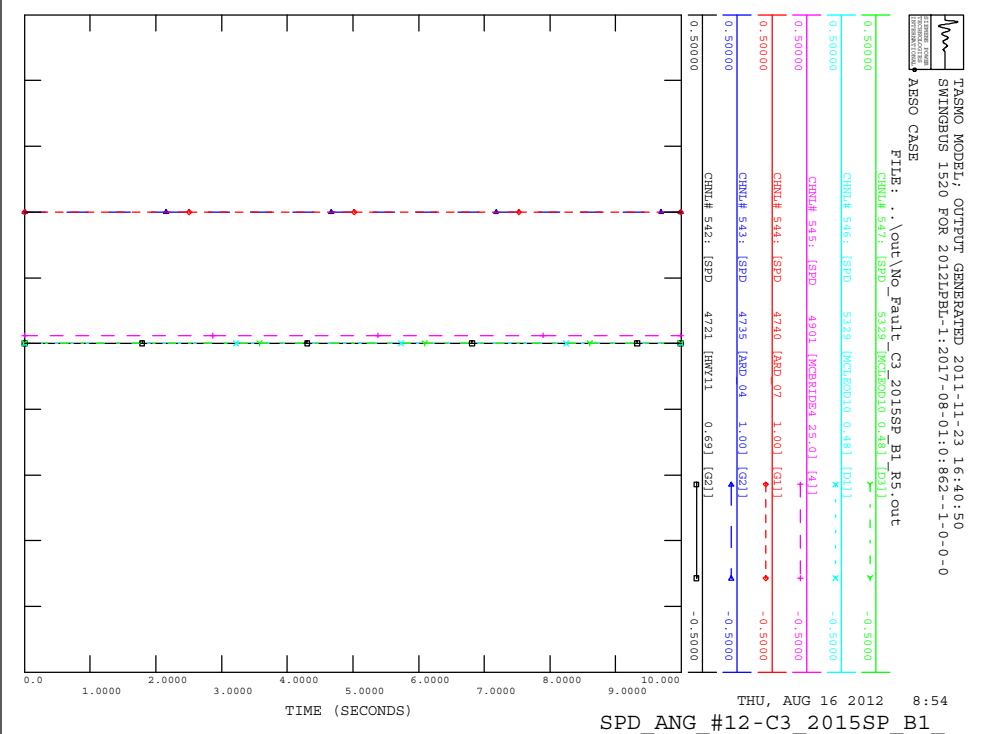
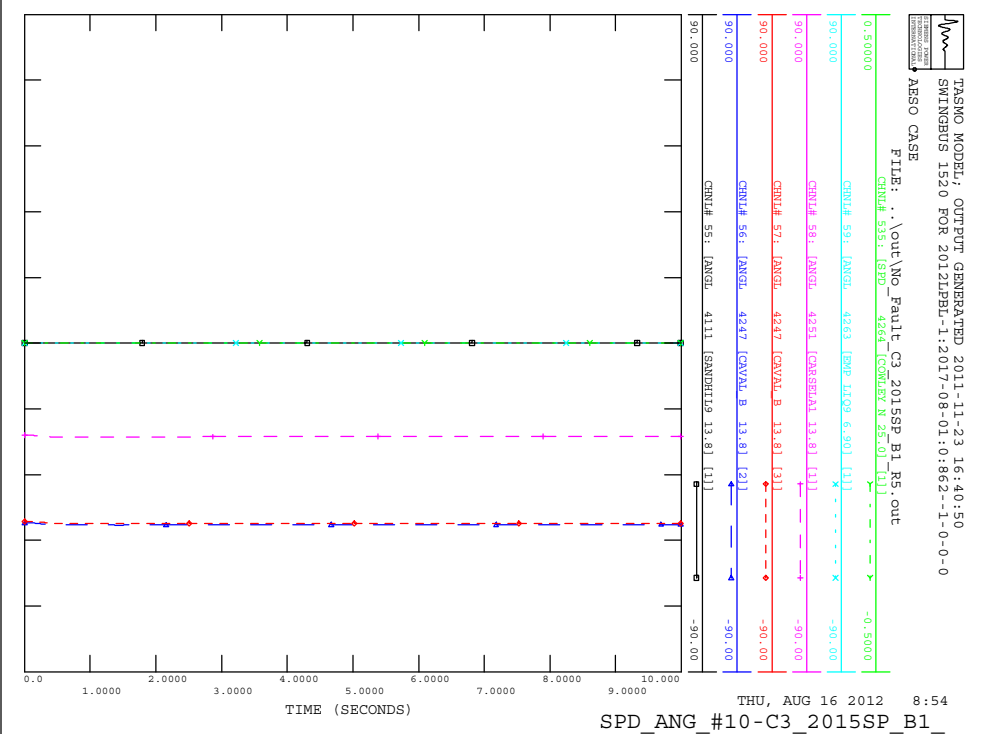
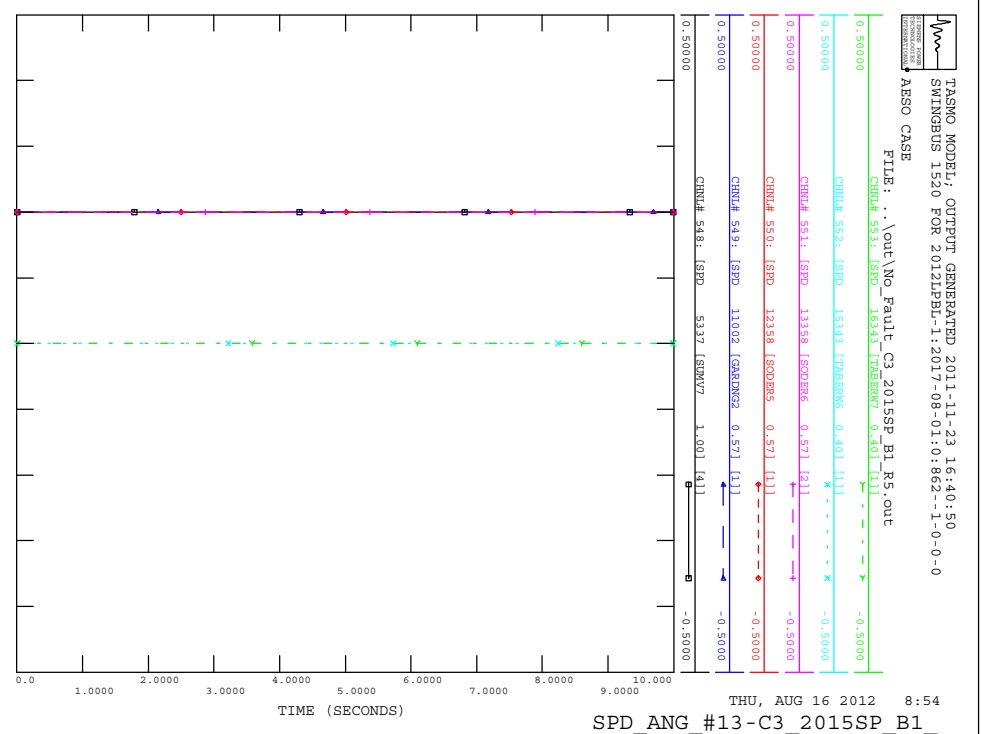
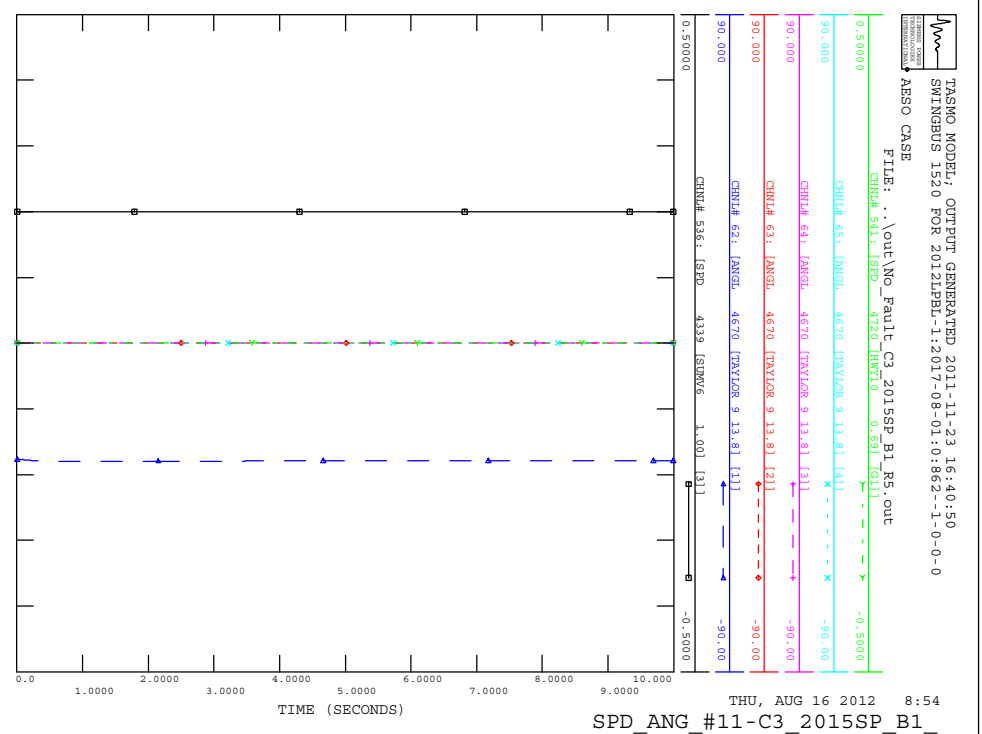
Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)	Observation	Load Shed
B52	DOME_EMPR	Dome Empress - Empress 138 kV	3ph fault at Empress on Dome Empress - Empress 138 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Empress 138 kV breaker	6		
			trip Dome Empress 138 kV breaker	24		
B53	ANDE-WARE	Anderson - Ware JCT 240 kV	3ph Fault at Anderson on Anderson to W J 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip Anderson 240 kV breaker	5		
			trip Ware JCT 240 kV breaker	6		
B54	WBRO-CASS	West Brooks - Cassils 240 kV	3ph Fault at West Brooks on West Brooks to Cassils 240 kV line		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip West Brooks 240 kV breaker	5		
			trip Cassils 240 kV breaker	6		
B55	CASS-BOWM	Cassils - Bowmanton 240 kV	3ph Fault at Cassils on Cassils to Bowmanton 244S		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip Cassils 240 kV breaker	5		
			trip Bowmanton 240 kV breaker	6		
B56	TINC-CORD	Tincherbray - Cordel 240 kV	3ph Fault at Tincherbray on Tincherbray 401S to Cordel 755S 240 KV line 9L xx		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip Tincherbray 240 kV breaker	5		
			trip Cordel 240 kV breaker	6		
B57	HTHF-NEWE	HTHFIELD -NEWELL HVDC line	Loss of EATL HVDC line		System Stable	
			trip HTHFIELD 500 kV breaker	4		
			trip NEWELL 240 kV breaker	5		

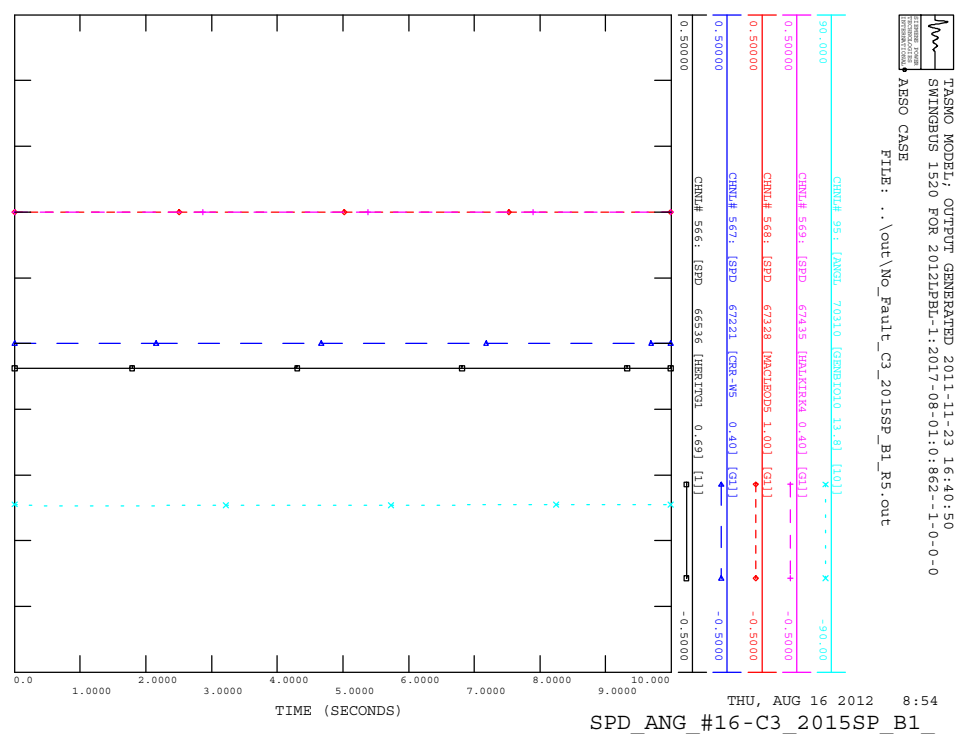
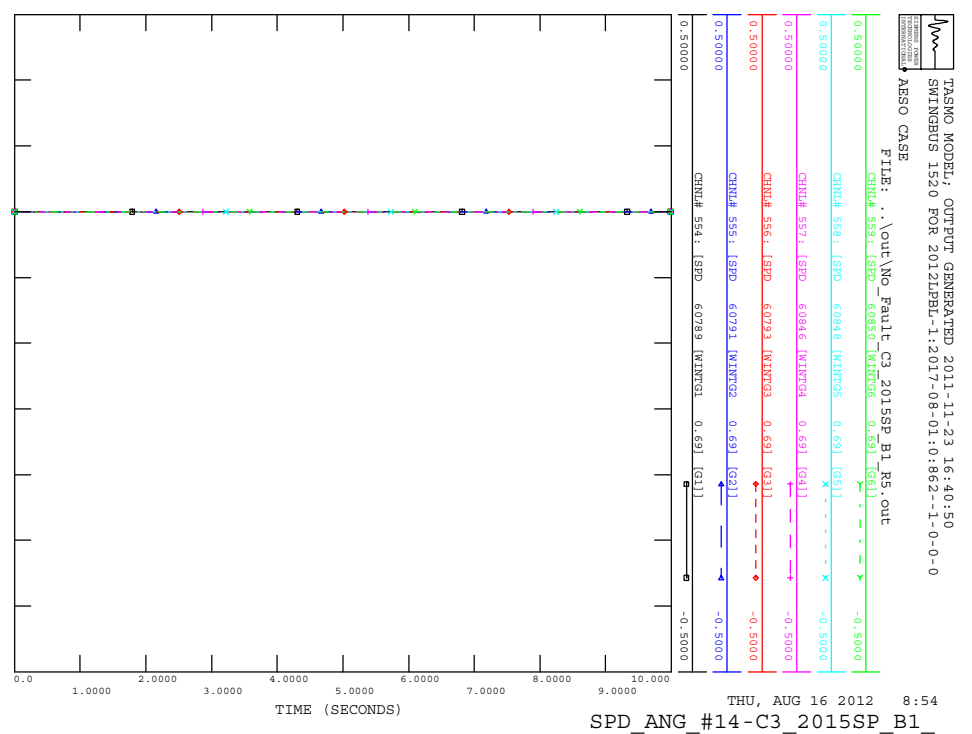
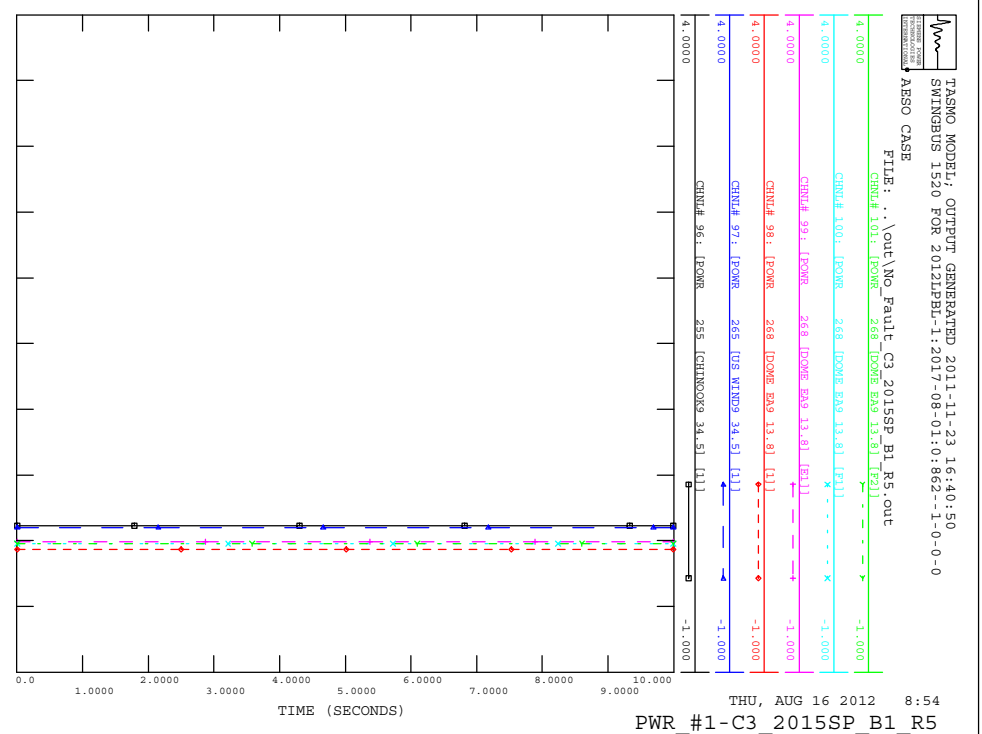
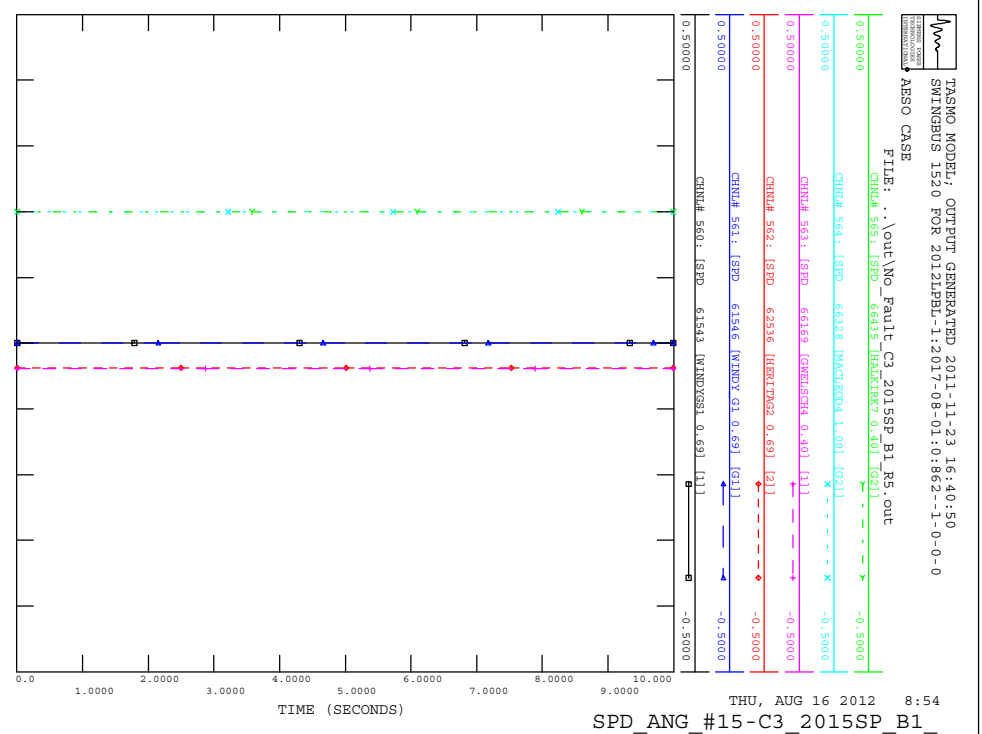
Fault ID	Fault Name	Fault Location	Description	Clearing Time (Cycles)	Observation	Load Shed
Category C5						
C501	CHAP-CRW1	Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	3ph fault at Chapel Rock on Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Chapel Rock 240 kV breakers	5		
			trip Castle Rock Ridge 240 kV breakers	7		
C502	CRW1-CHAP	Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines	3ph fault at Castle Rock Ridge on Chapel Rock - Castle Rock Ridge 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip Castle Rock Ridge 240 kV breakers	5		
			trip Chapel Rock 240 kV breakers	7		
C503	LANG-ECAL	LANGDON - ECALGAR 240 kV Double Circuit lines	3ph fault at LANGDON on LANGDON - ECALGAR 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 240 kV breakers	5		
			trip ECALGAR 240 kV breakers	7		
C504	ECAL-LANG	LANGDON - ECALGAR 240 kV Double Circuit lines	3ph fault at ECALGAR on LANGDON - ECALGAR 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip ECALGAR 240 kV breakers	5		
			trip LANGDON 240 kV breakers	7		
C505	LANG-MILO	LANGDON - MILO 240 kV Double Circuit lines	3ph fault at LANGDON on LANGDON - MILO 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 240 kV breakers	5		
			trip MILO 240 kV breakers	7		
C506	MILO-LANG	LANGDON - MILO 240 kV Double Circuit lines	3ph fault at MILO on LANGDON - MILO 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip MILO 240 kV breakers	5		
			trip LANGDON 240 kV breakers	7		
C507	LANG-JANE	LANGDON - JANET 240 kV Double Circuit lines	3ph fault at LANGDON on LANGDON - JANET 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip LANGDON 240 kV breakers	5		
			trip JANET 240 kV breakers	7		
C508	JANE-LANG	LANGDON - JANET 240 kV Double Circuit lines	3ph fault at JANET on LANGDON - JANET 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip JANET 240 kV breakers	5		
			trip LANGDON 240 kV breakers	7		
C509	944-951_A	JENNER - WARE JCT 240 kV Double Circuit line	3ph fault at JENNER on JENNER - WARE JCT 240 kV Double Circuit line		Voltage Collapse at Cypress, Dome Empress	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip JENNER 240 kV breakers	5		
			trip JENNER 275ST1 240/25 kV 3-winding transformer	6		
C510	944-951_B	WARE JCT - JENNER 240 kV Double Circuit lines	3ph fault at WARE JCT on WARE JCT - JENNER 240 kV Double Circuit lines		Voltage Collapse at Cypress, Dome Empress	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip WARE JCT 240 kV breakers	5		
			trip JENNER 275ST1 240/25 kV 3-winding transformer	6		
C511	1002-1011_A	DOME EMPRESS - JENNER 240 kV Double Circuit lines	3ph fault at DOME EMPRESS on DOME EMPRESS - JENNER 240 kV Double Circuit lines		System Stable	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459
			trip DOME EMPRESS 240 kV breakers	5		
			trip JENNER 240 kV breakers	6		
C512	1002-1011_B	JENNER - DOME EMPRESS 240 kV Double Circuit lines	3ph fault at JENNER on JENNER - DOME EMPRESS 240 kV Double Circuit lines		Voltage Collapse at Cypress, Dome Empress	50.00 PERCENT OF INITIAL LOAD SHED AT BUS 17459 and 2716
			trip JENNER 240 kV breakers	5		
			trip JENNER 275ST1 240/25 kV 3-winding transformer	6		
			trip DOME EMPRESS 240 kV breakers	6		

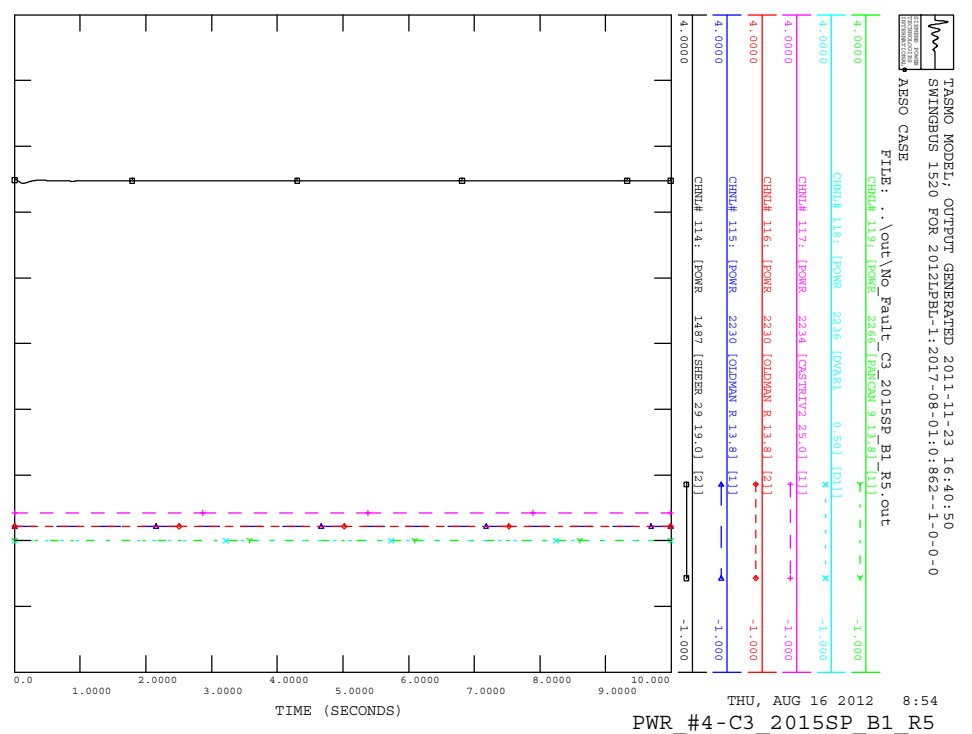
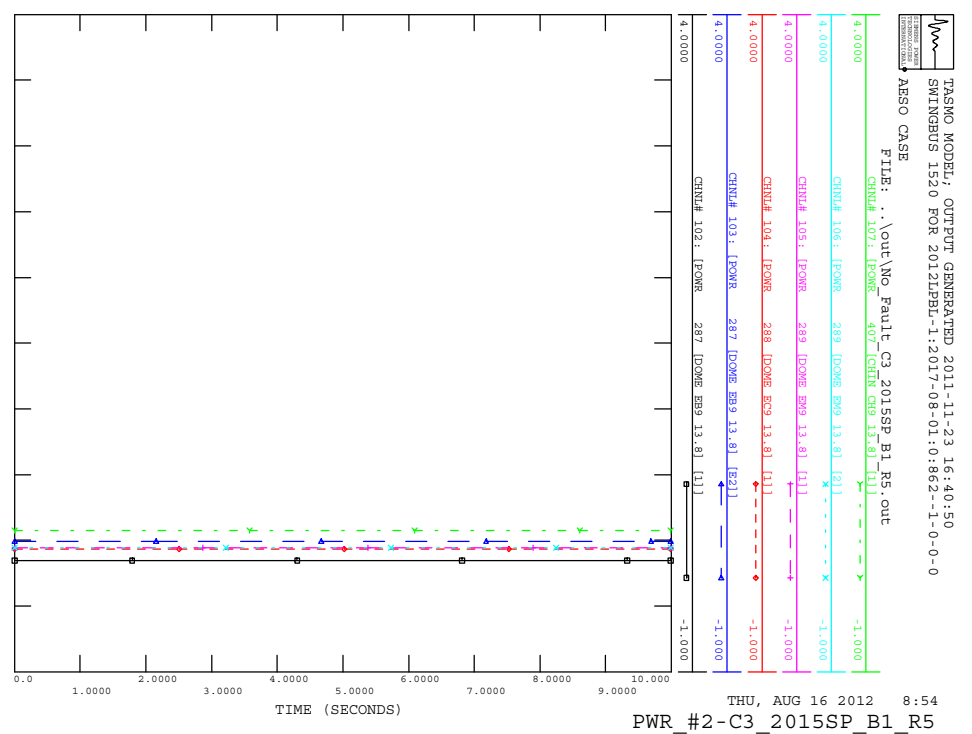
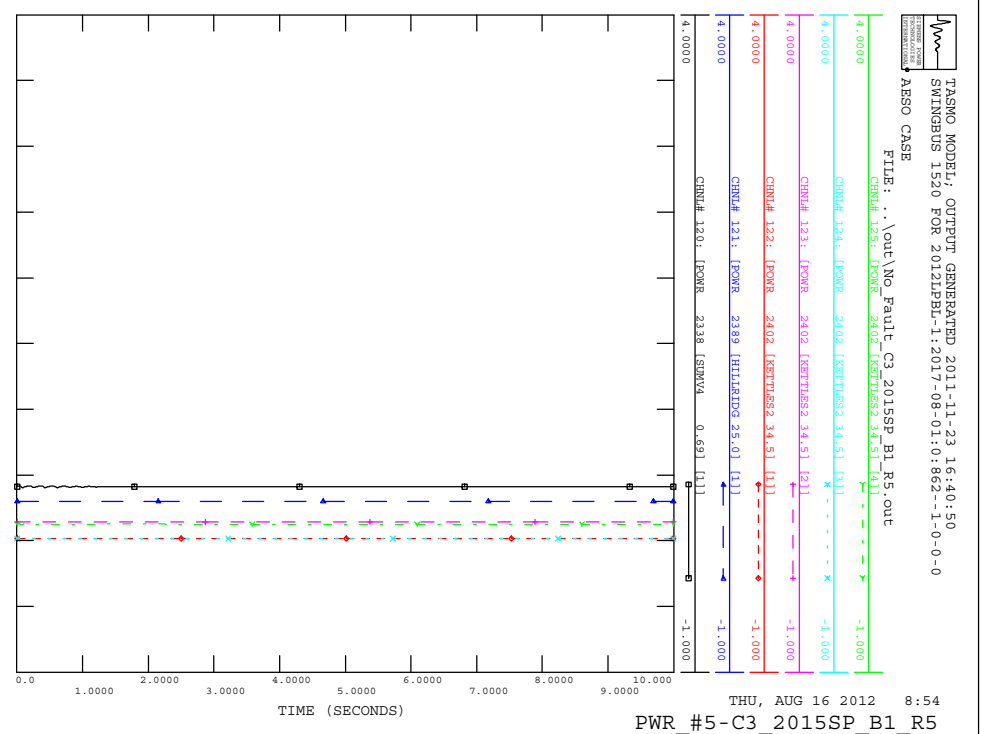
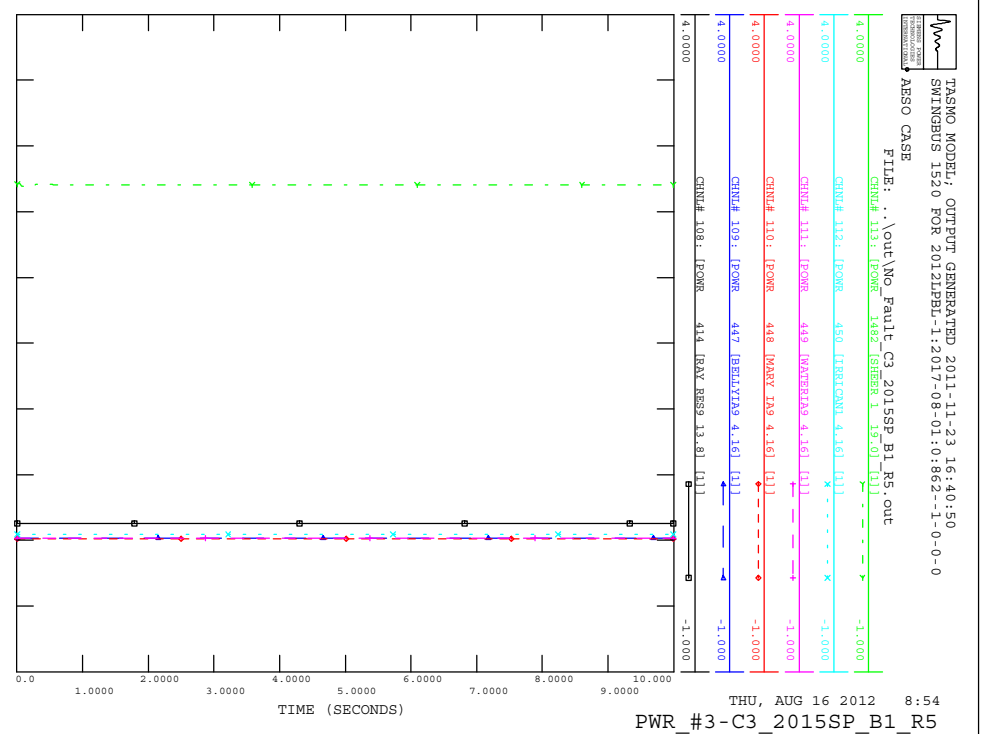


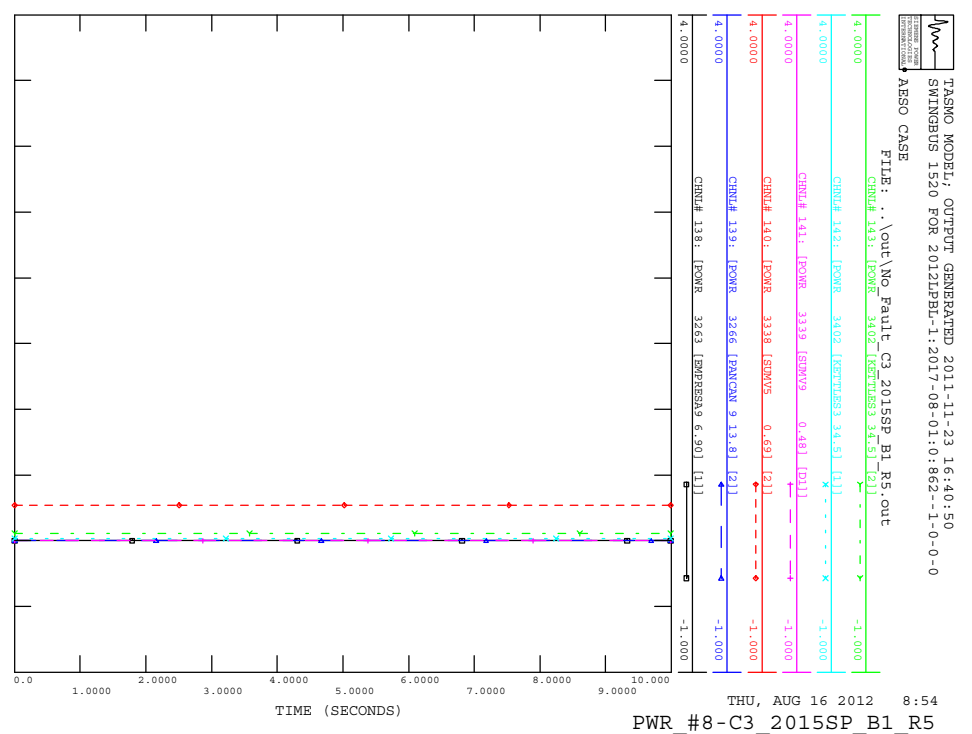
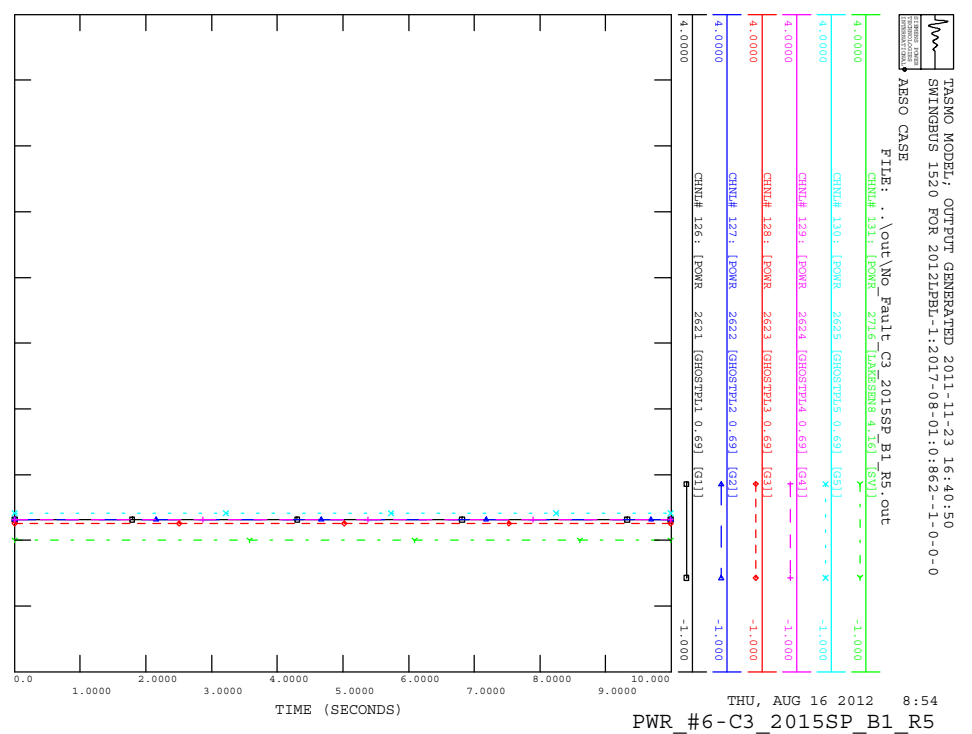
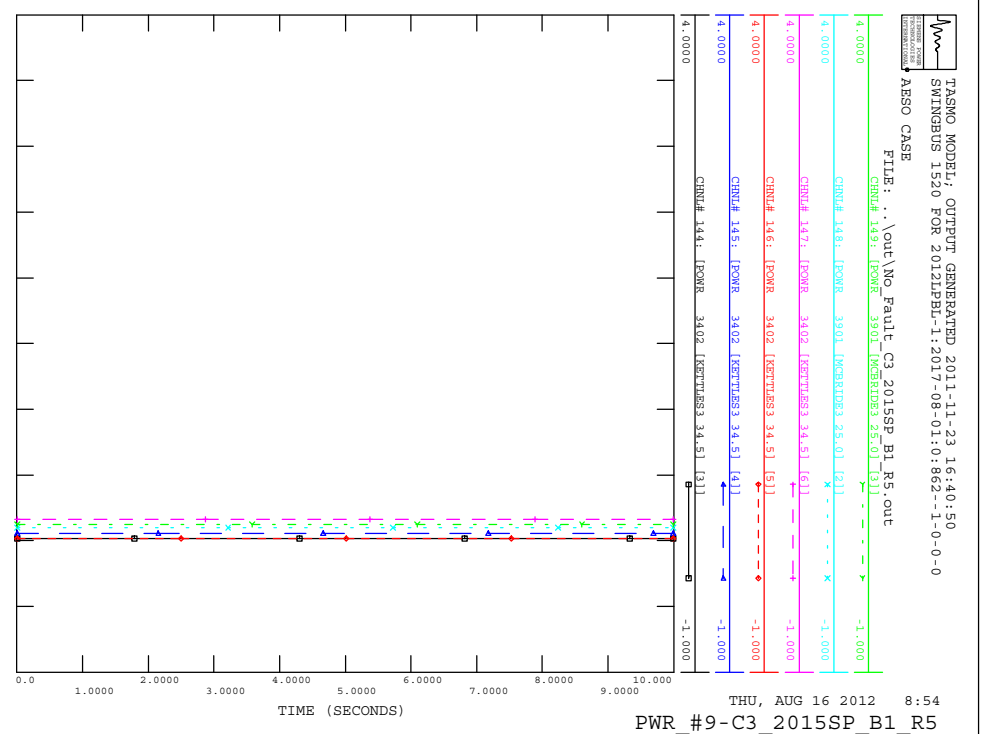
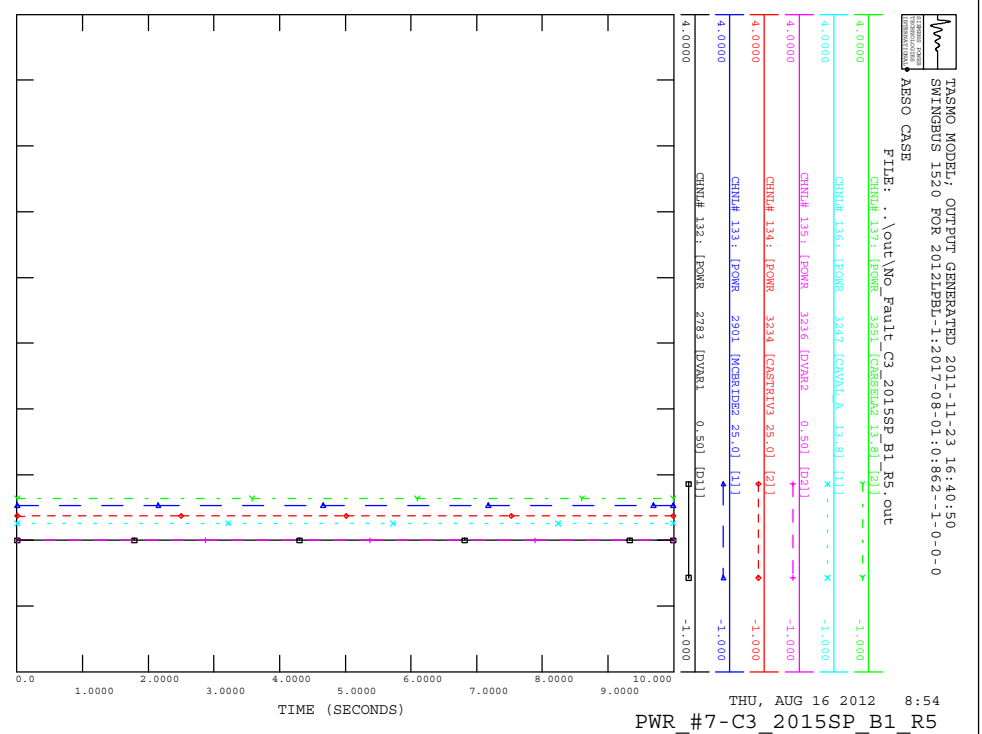


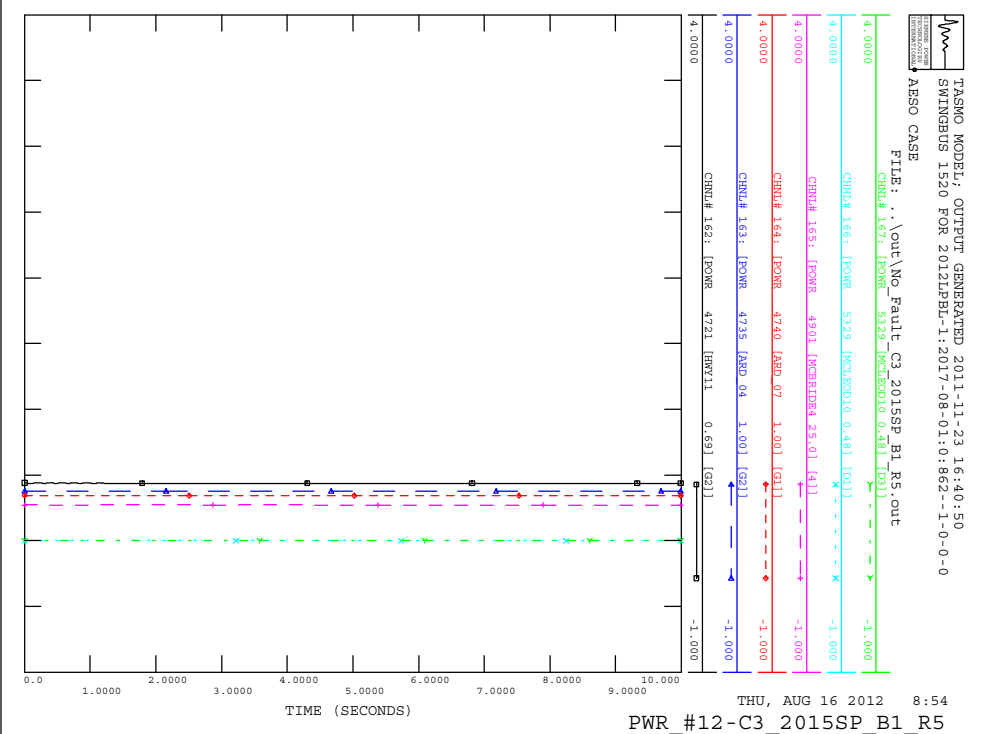
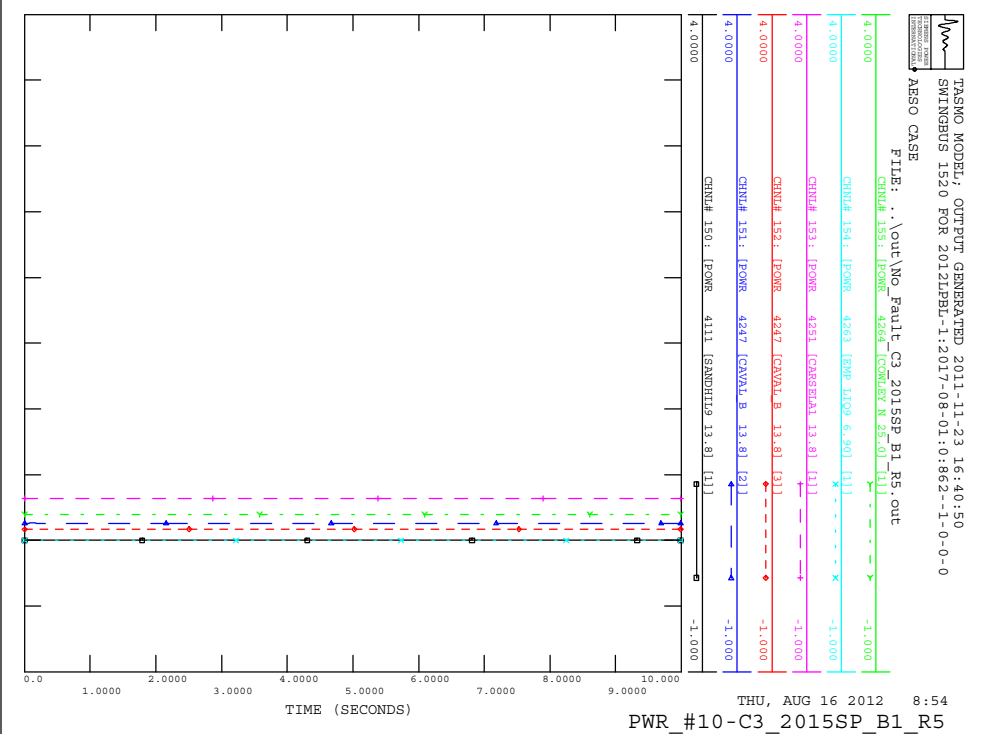
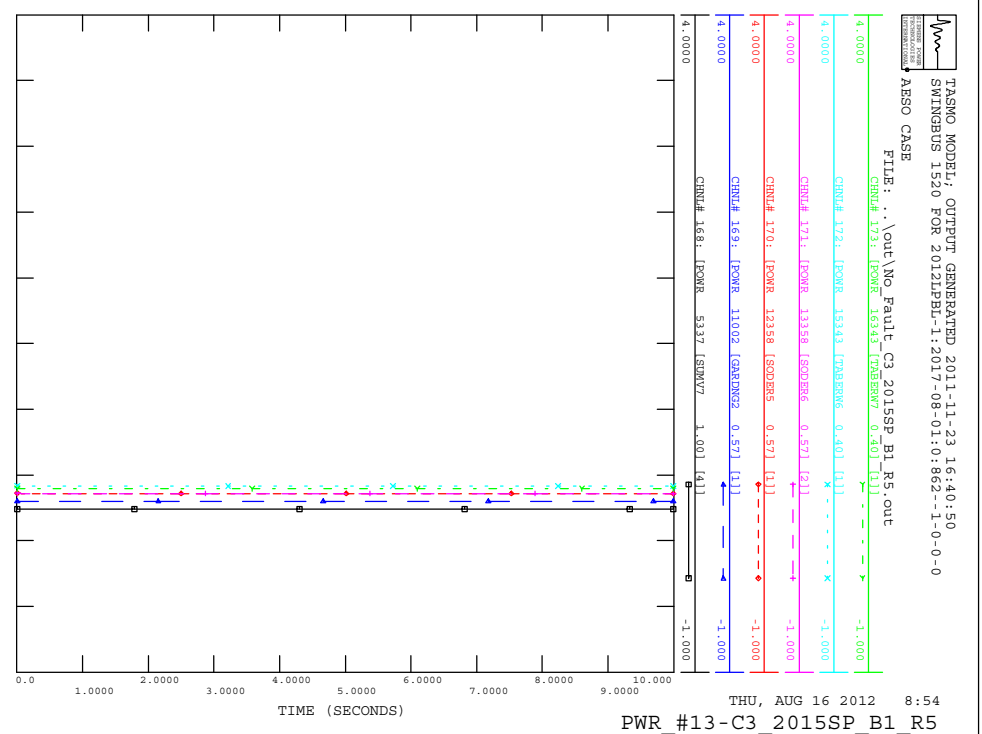
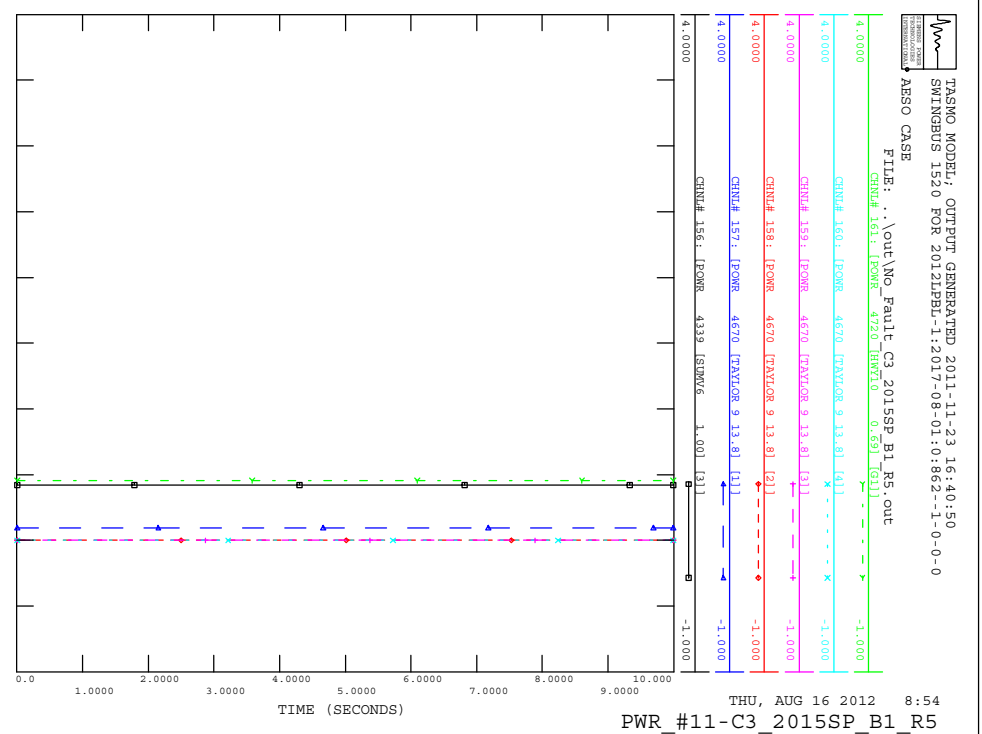


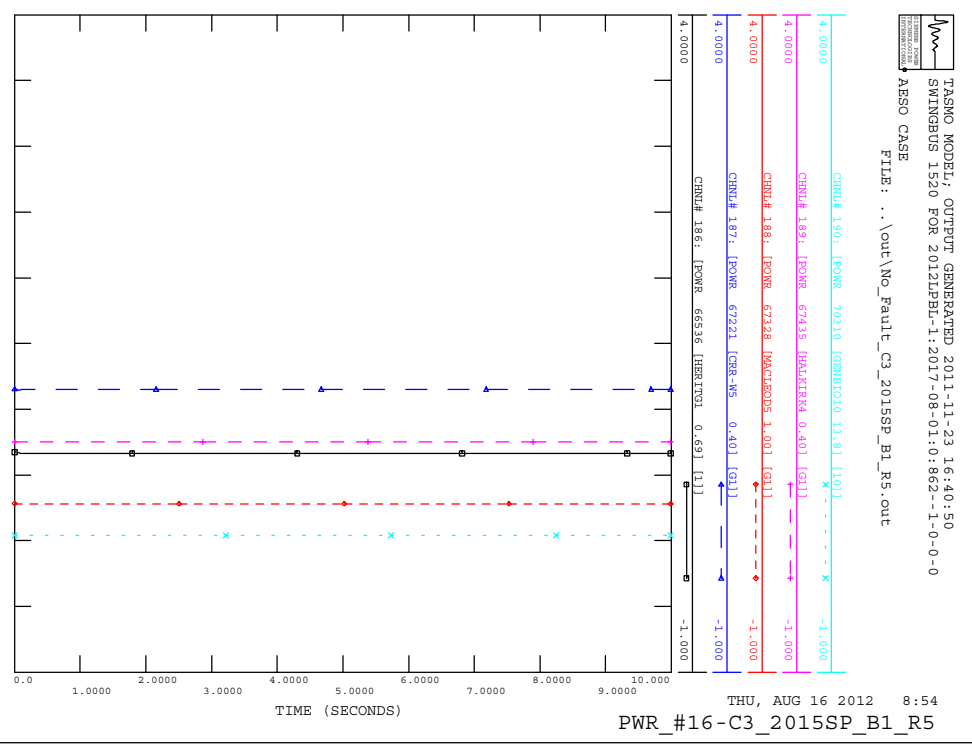
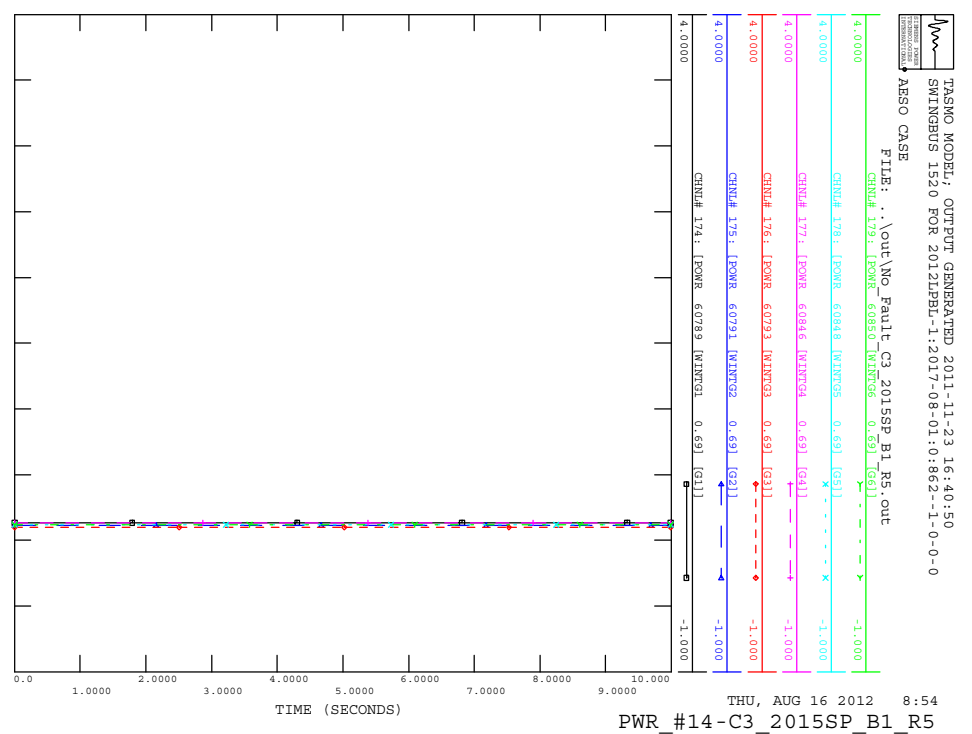
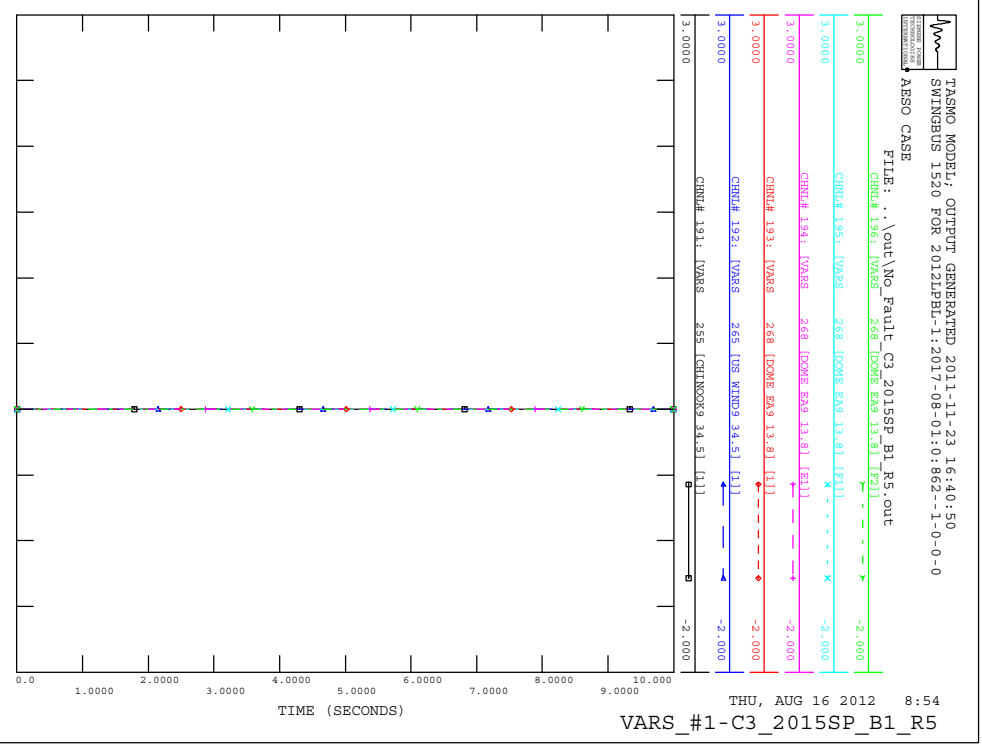
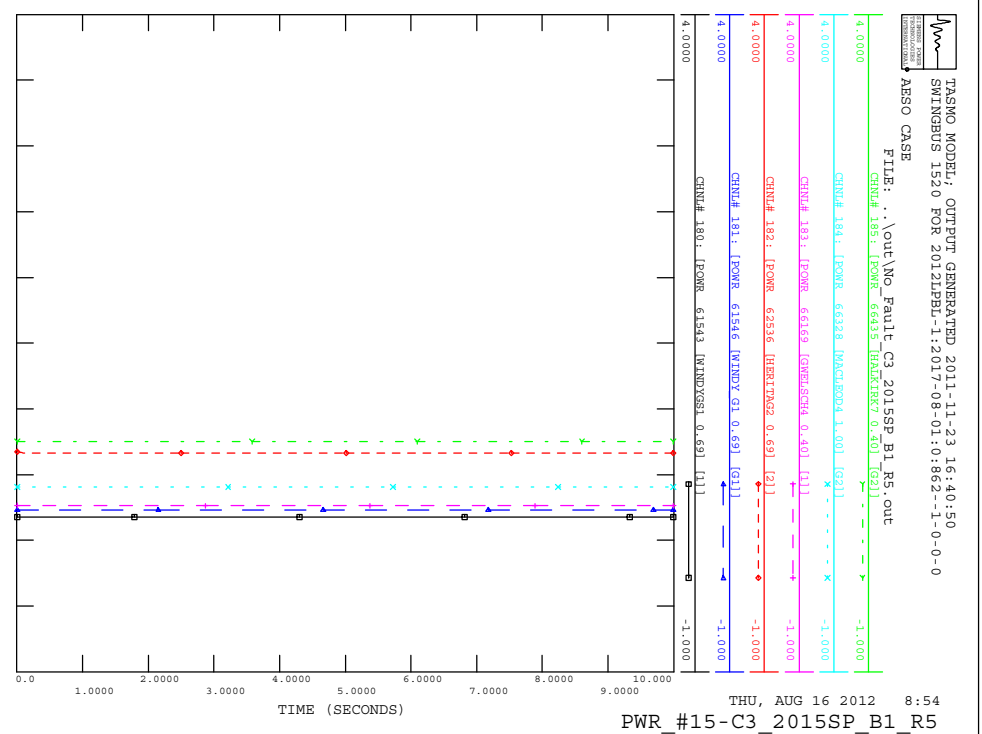


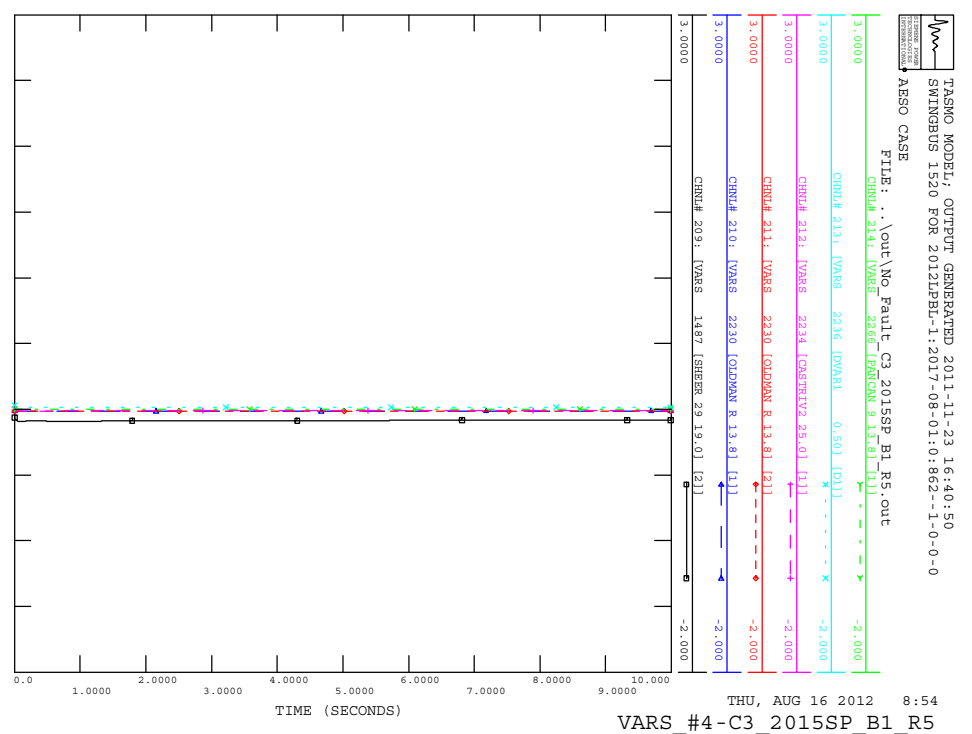
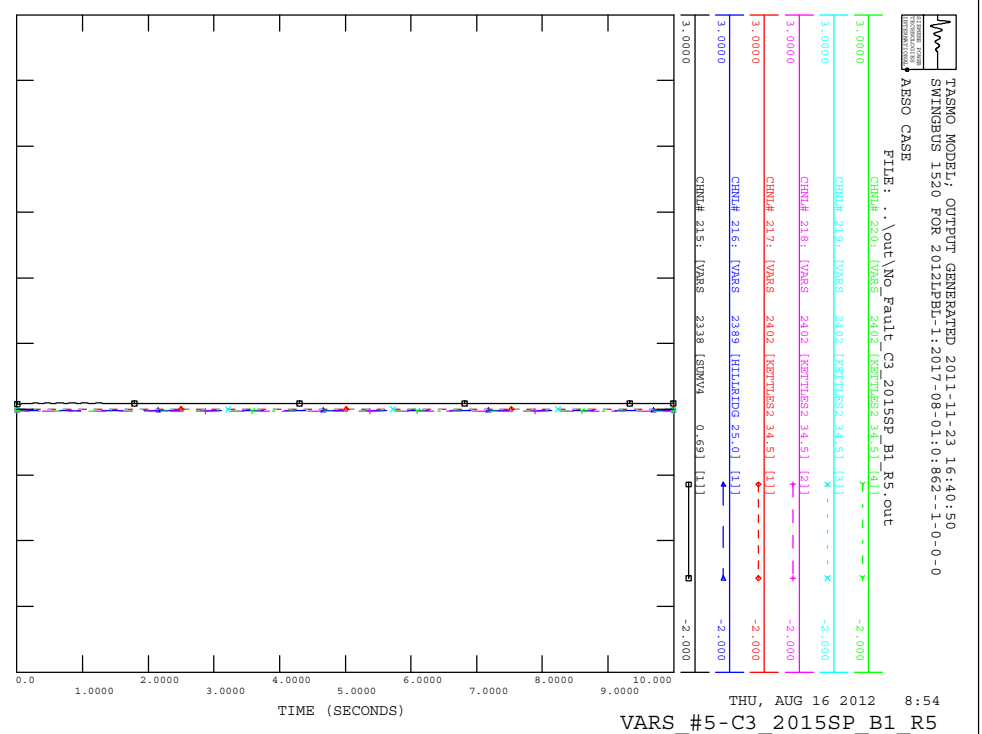
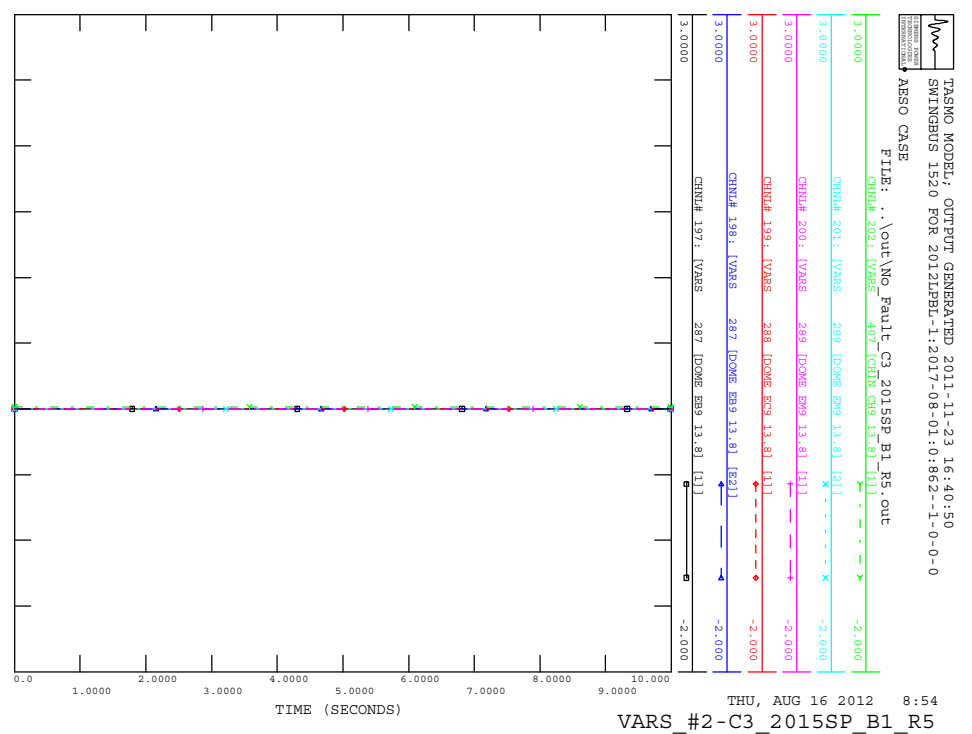
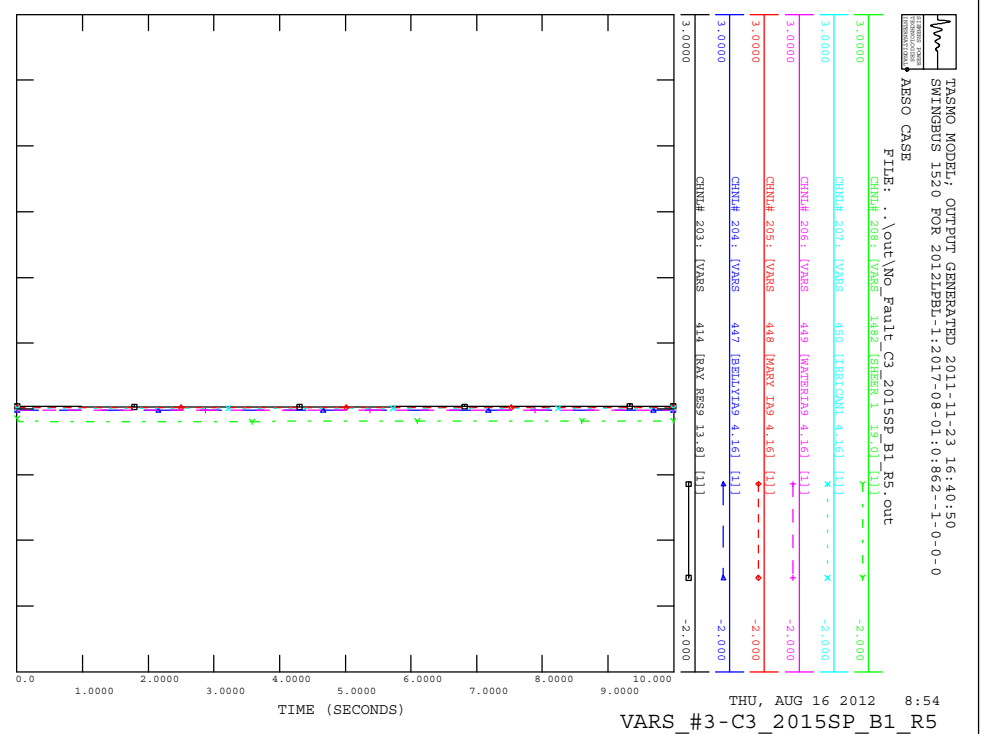


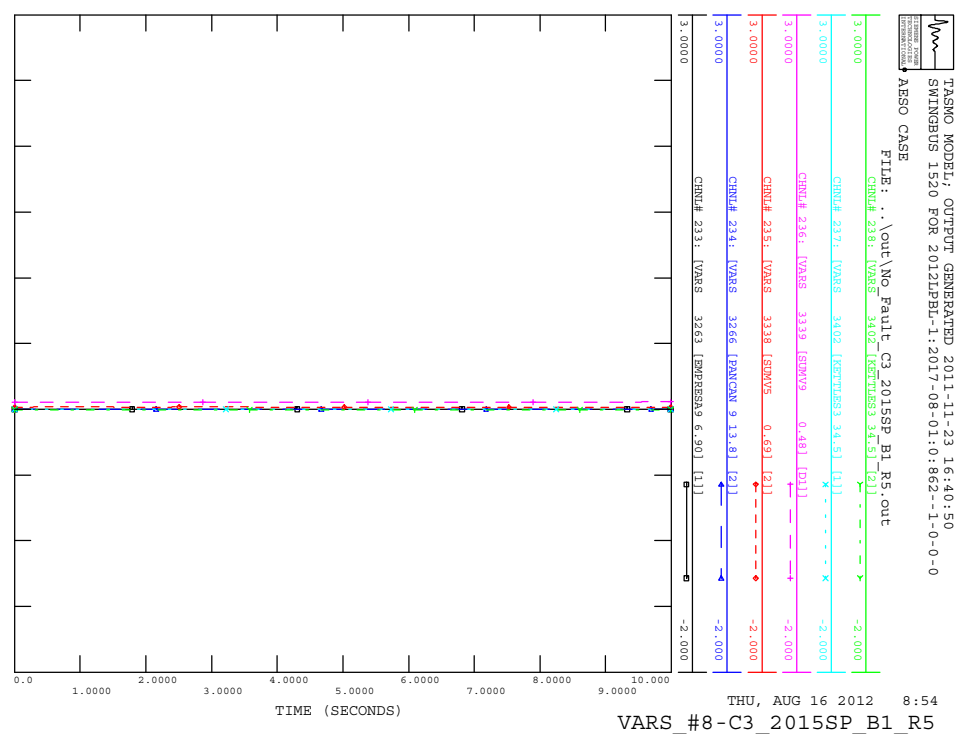
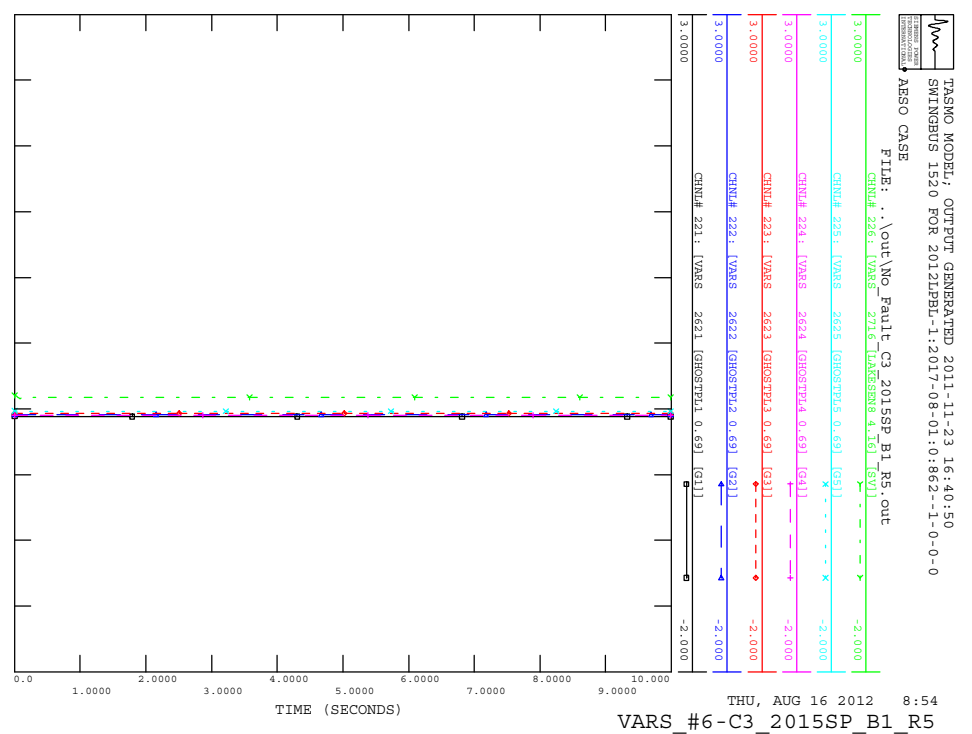
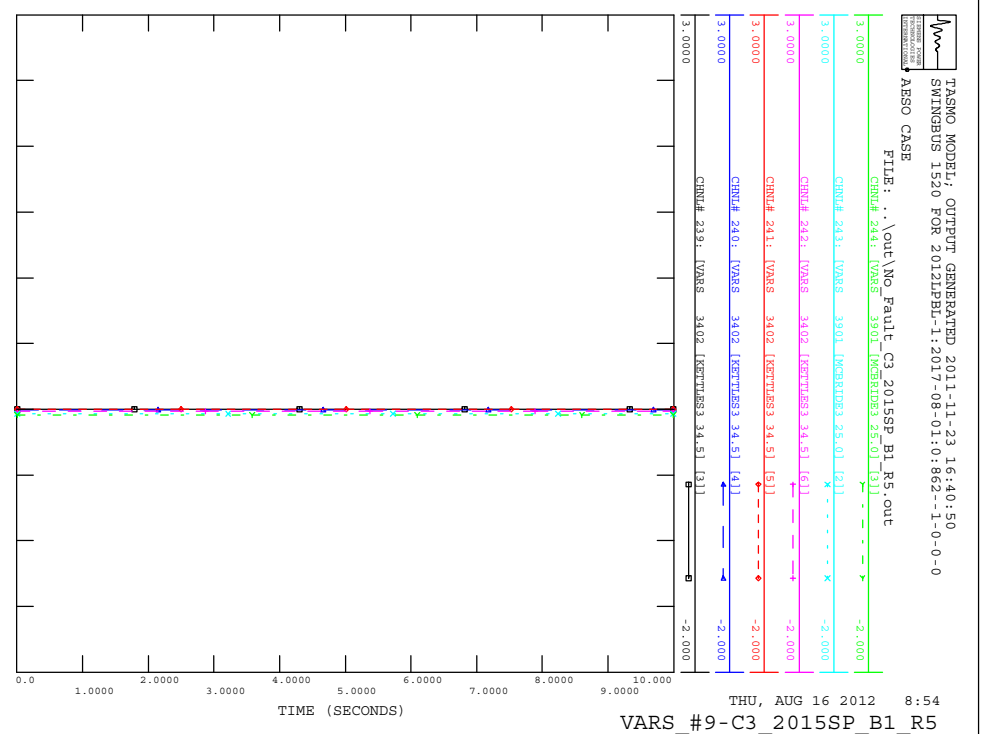
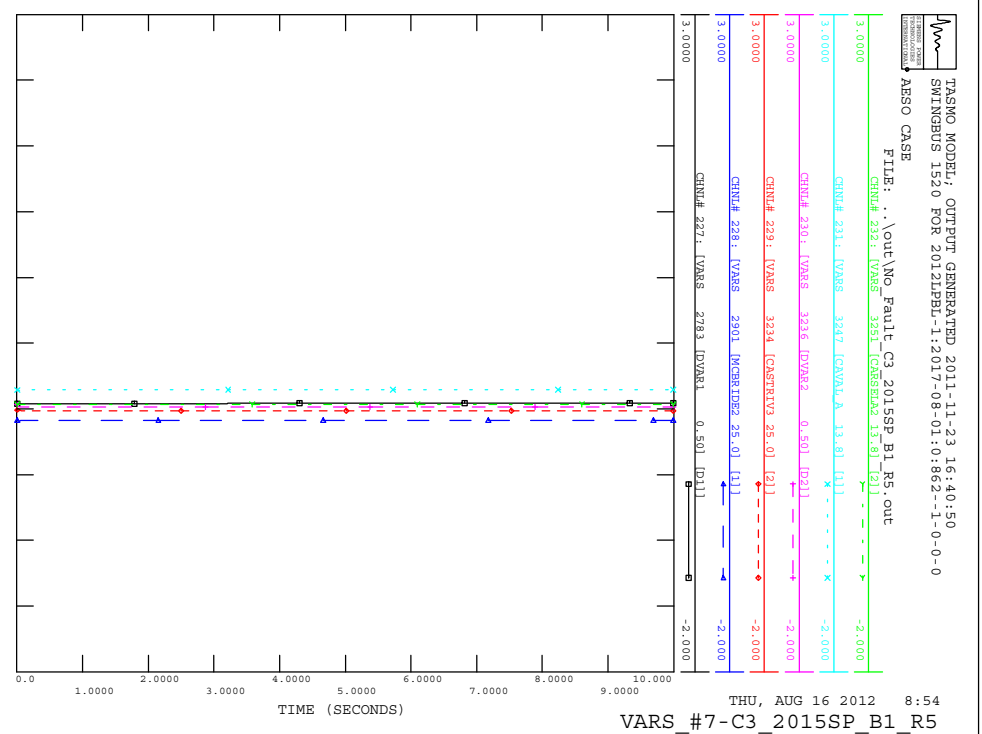


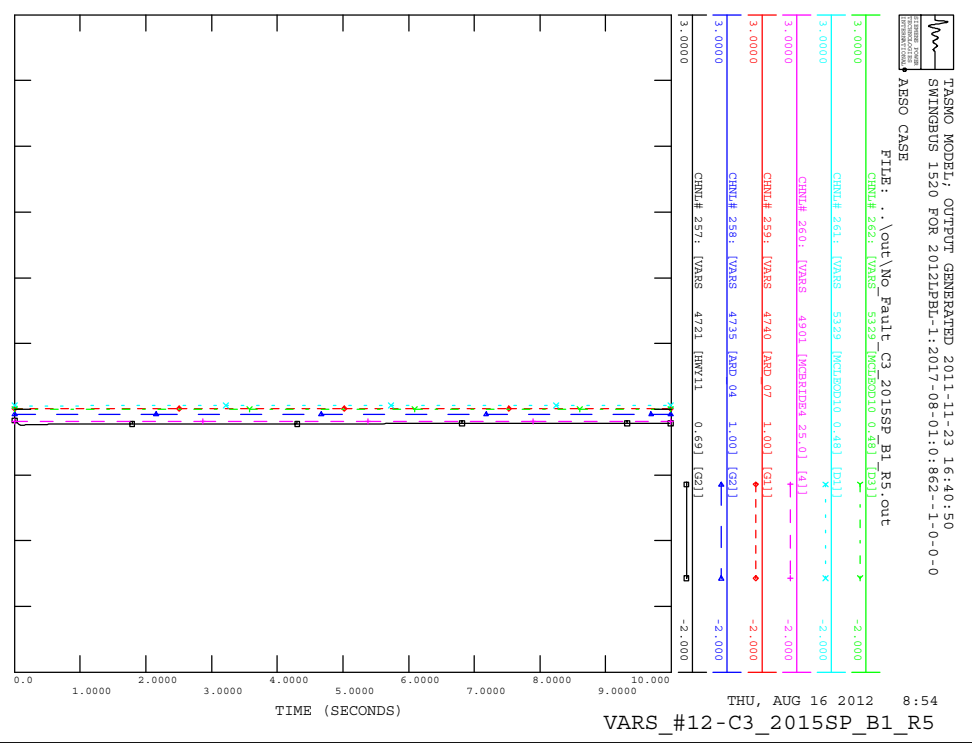
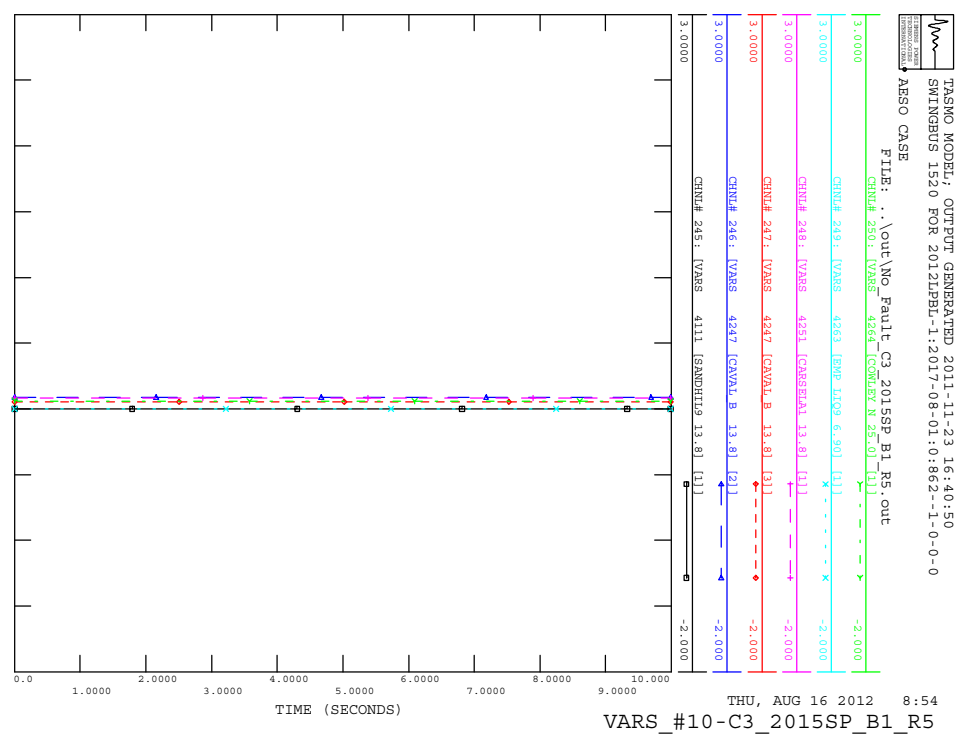
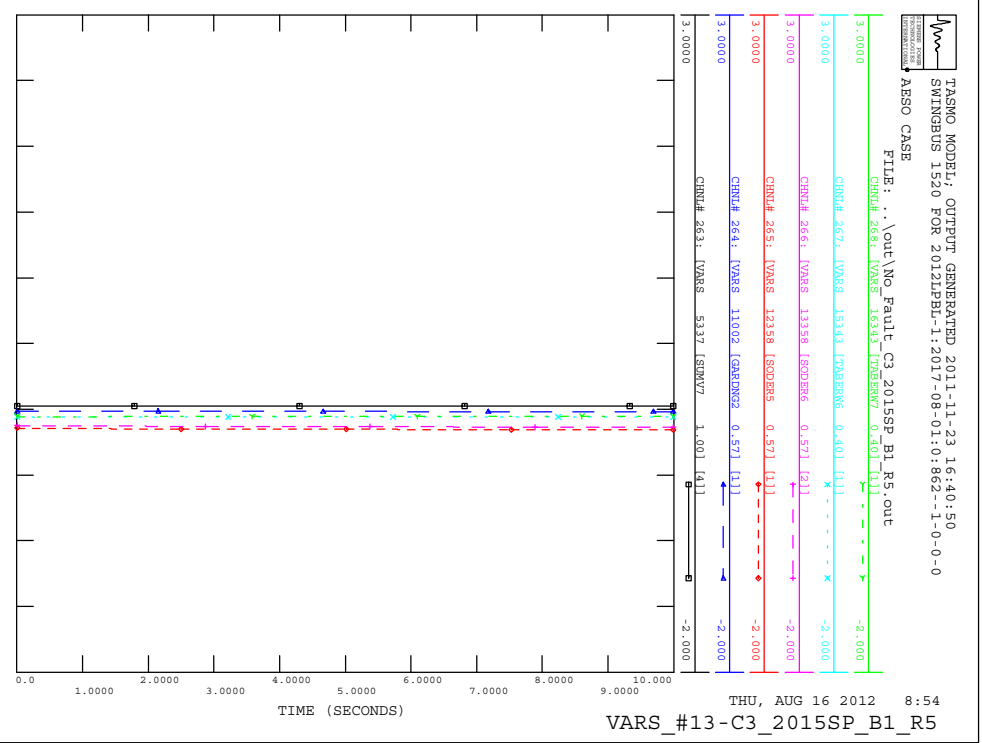
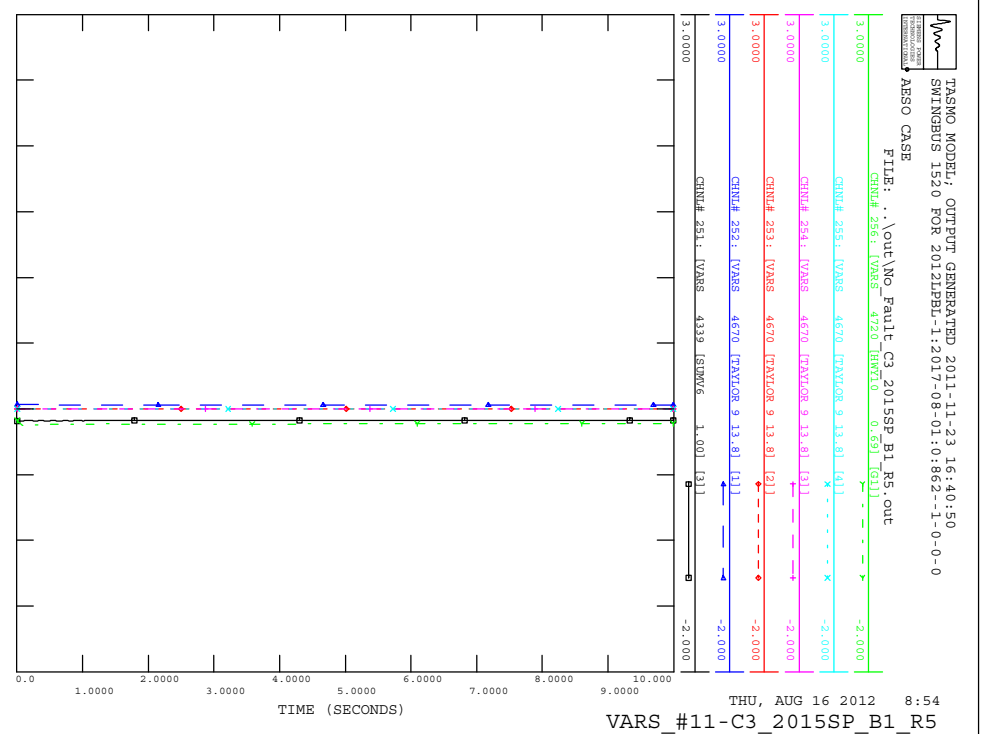


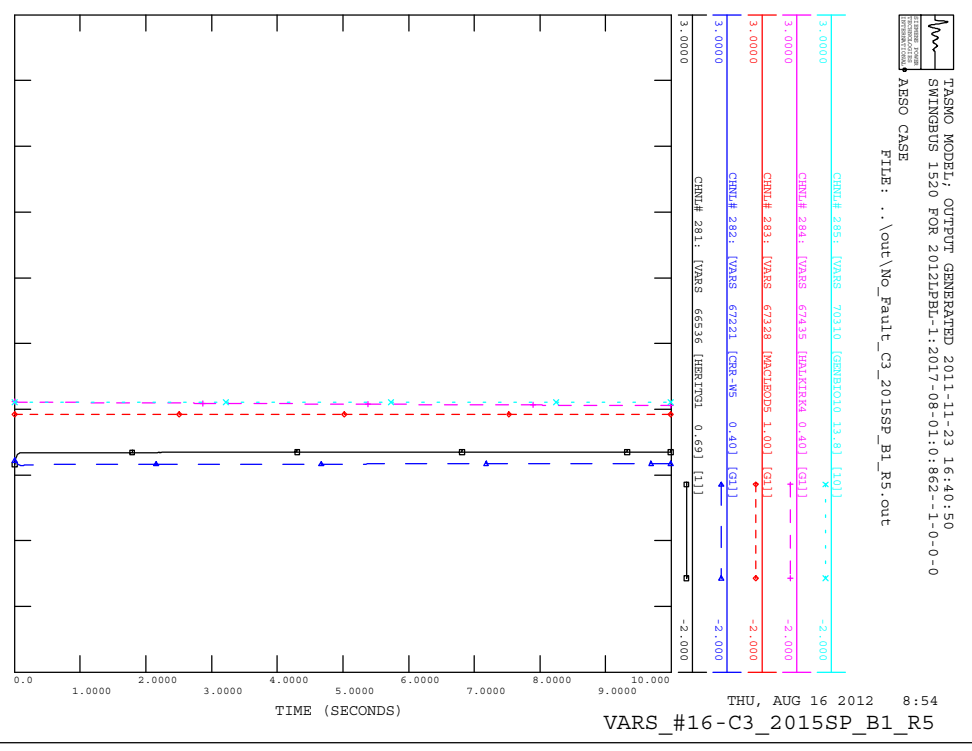
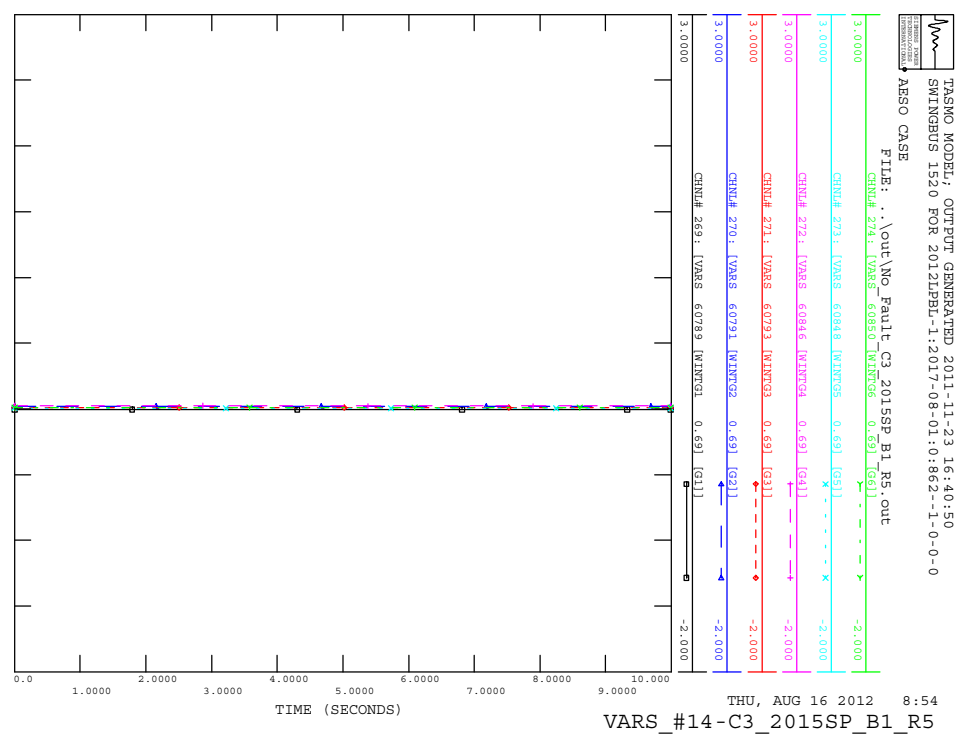
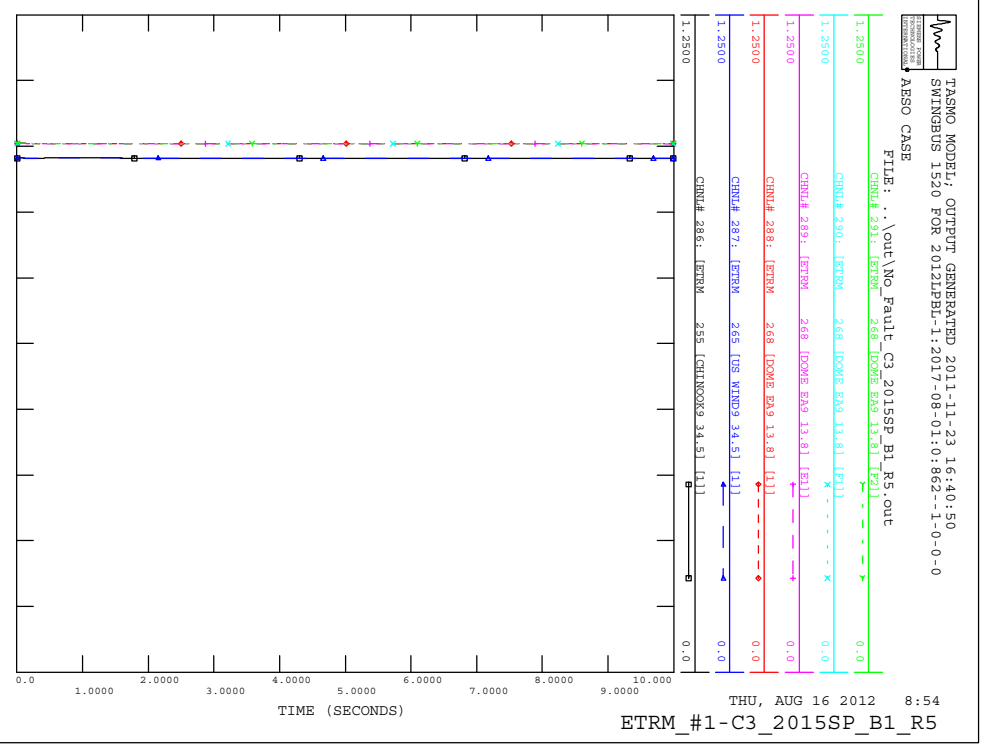
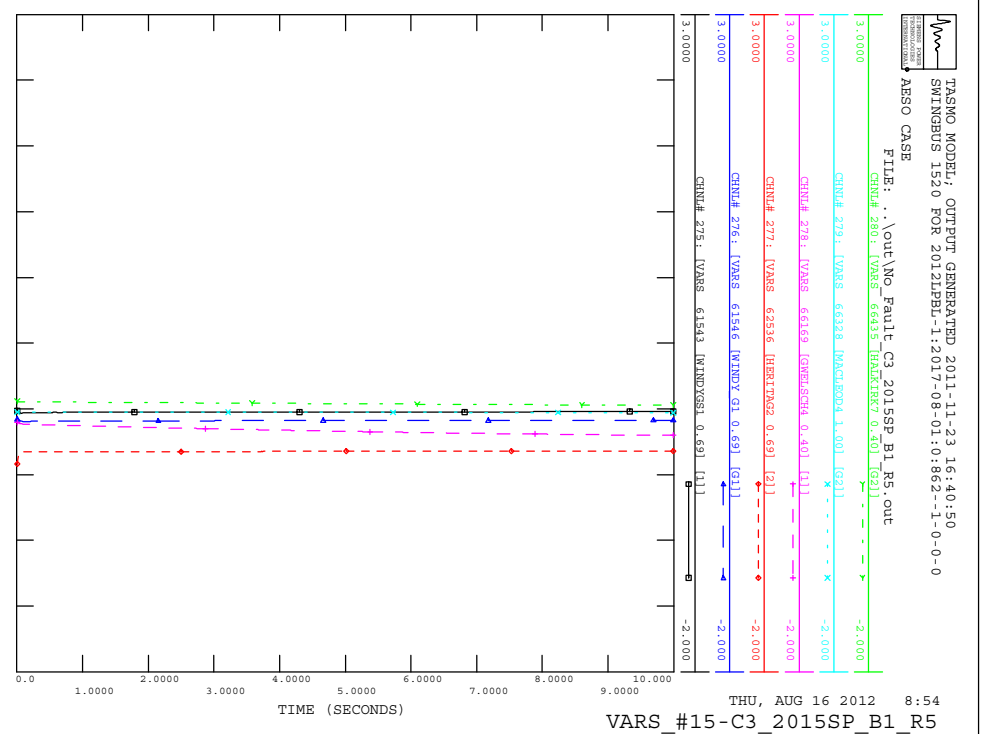


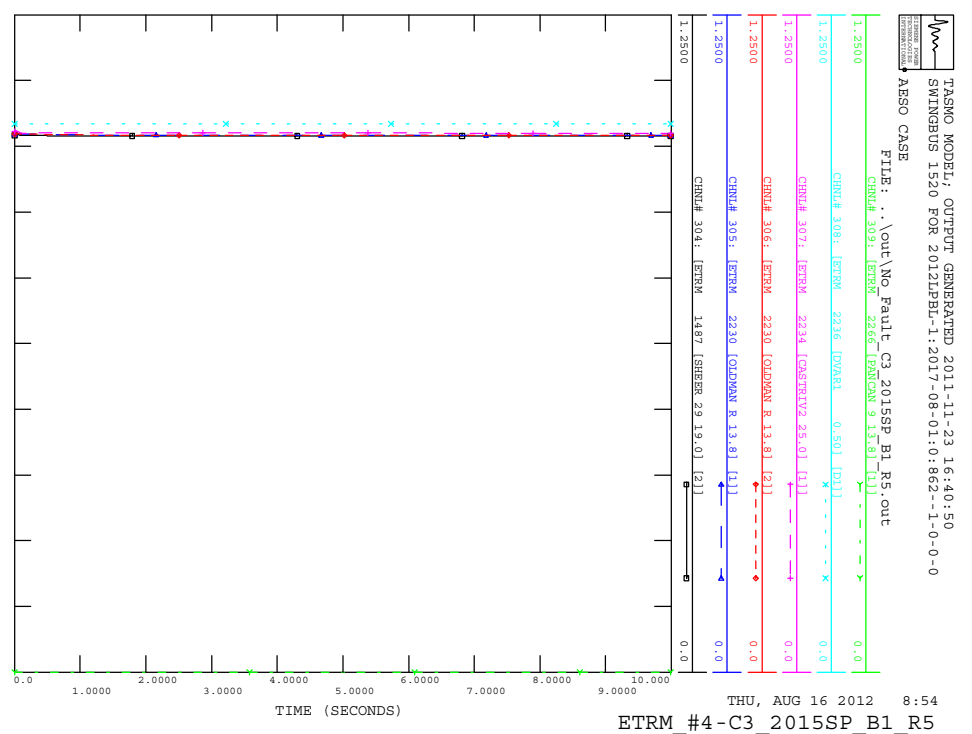
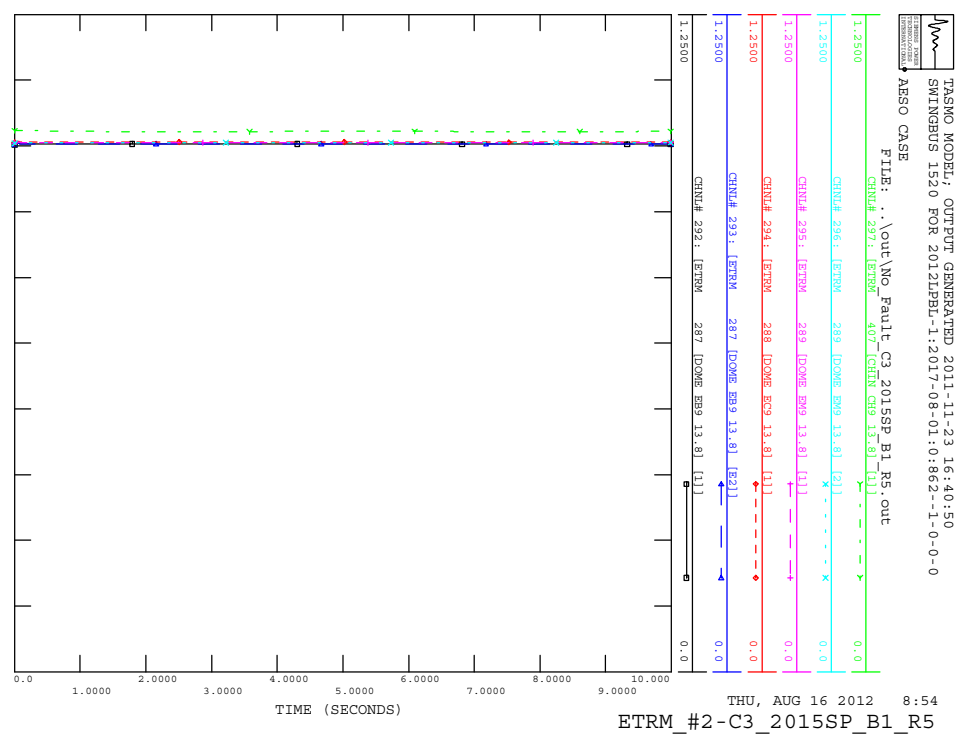
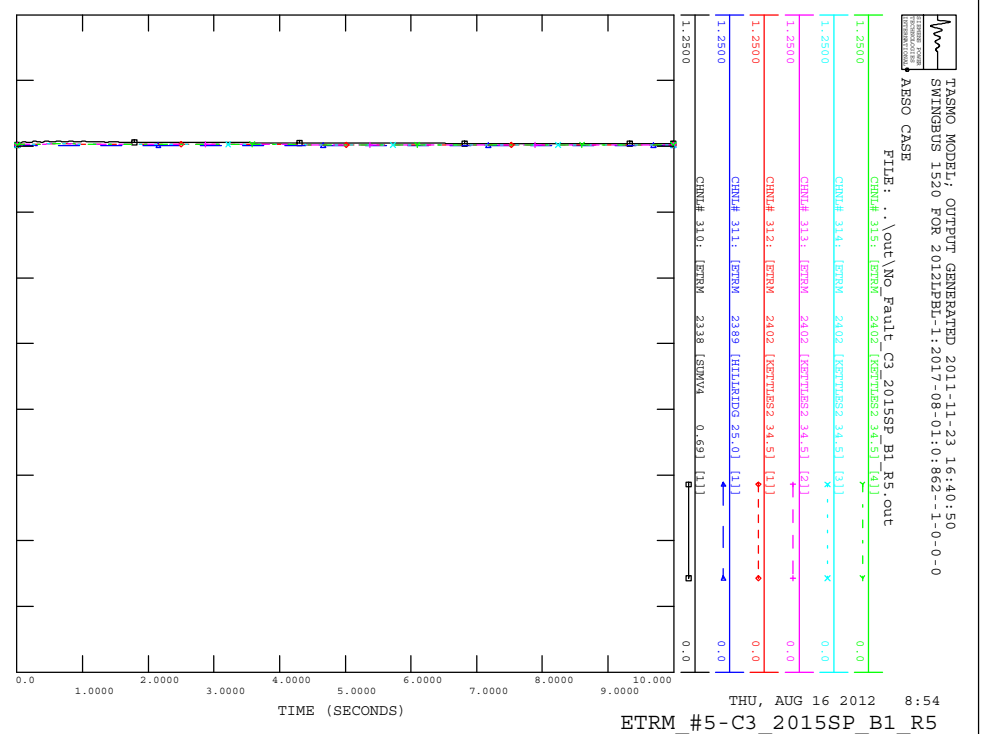
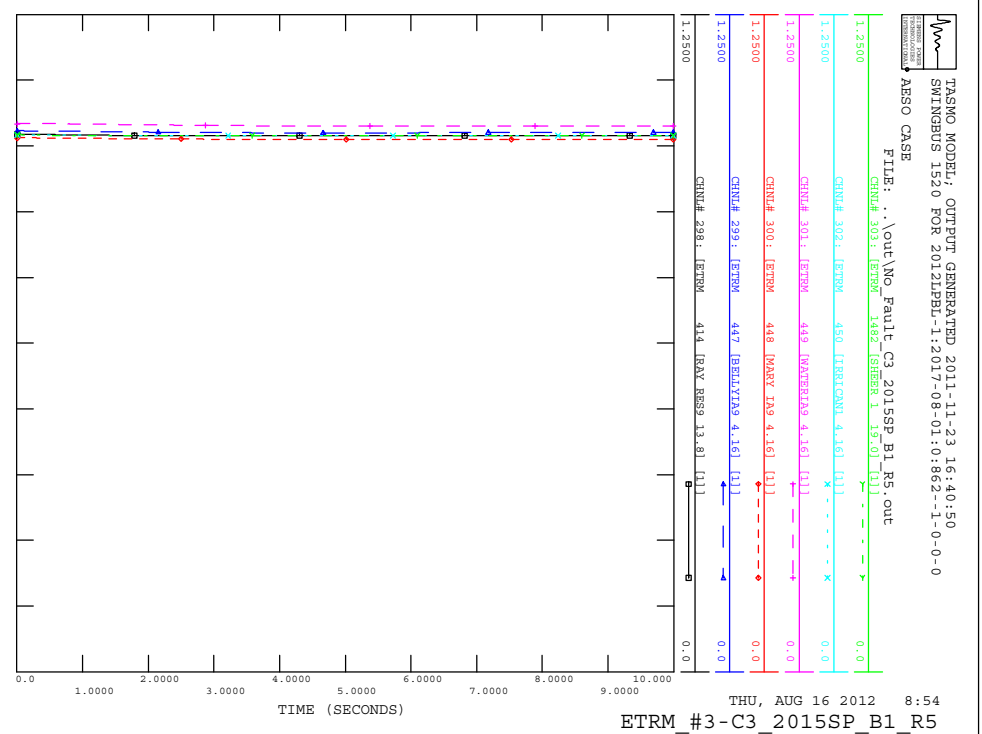


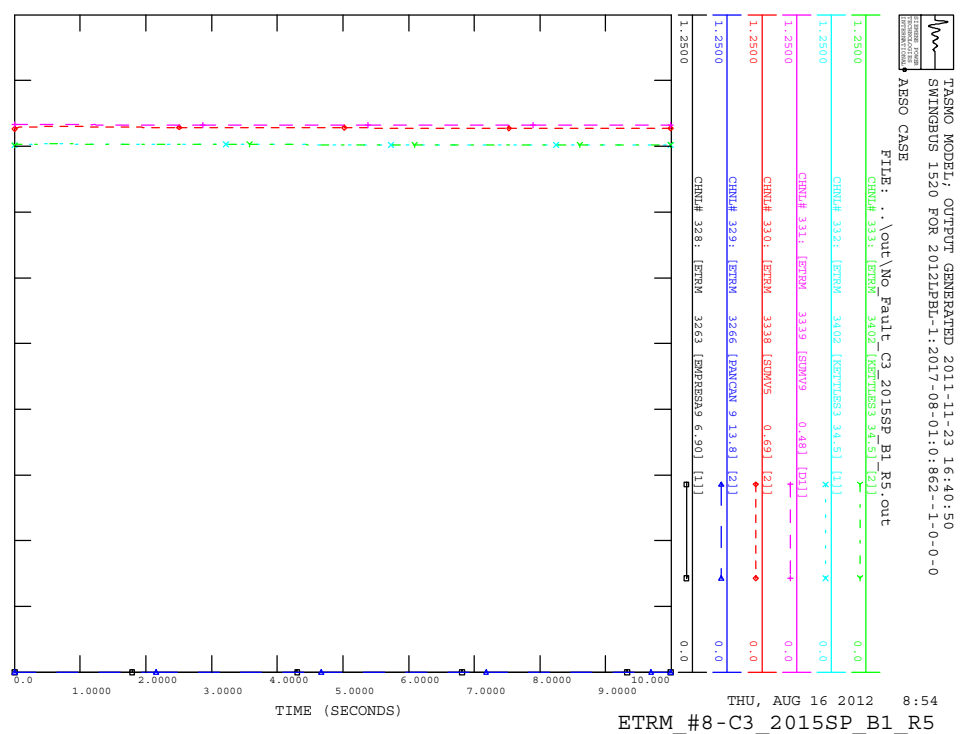
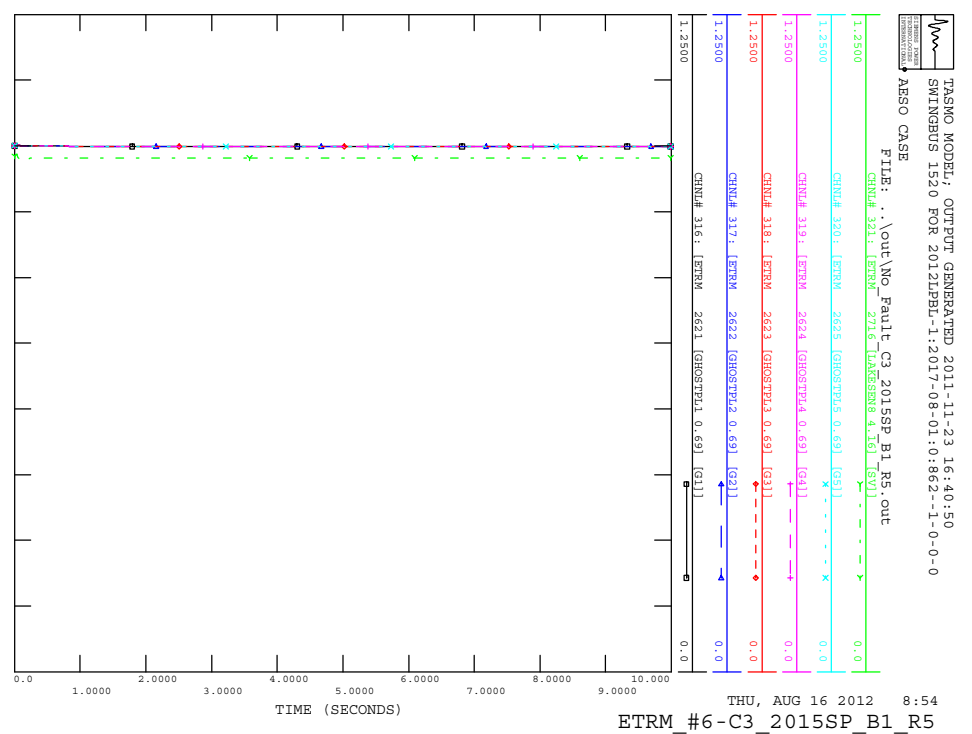
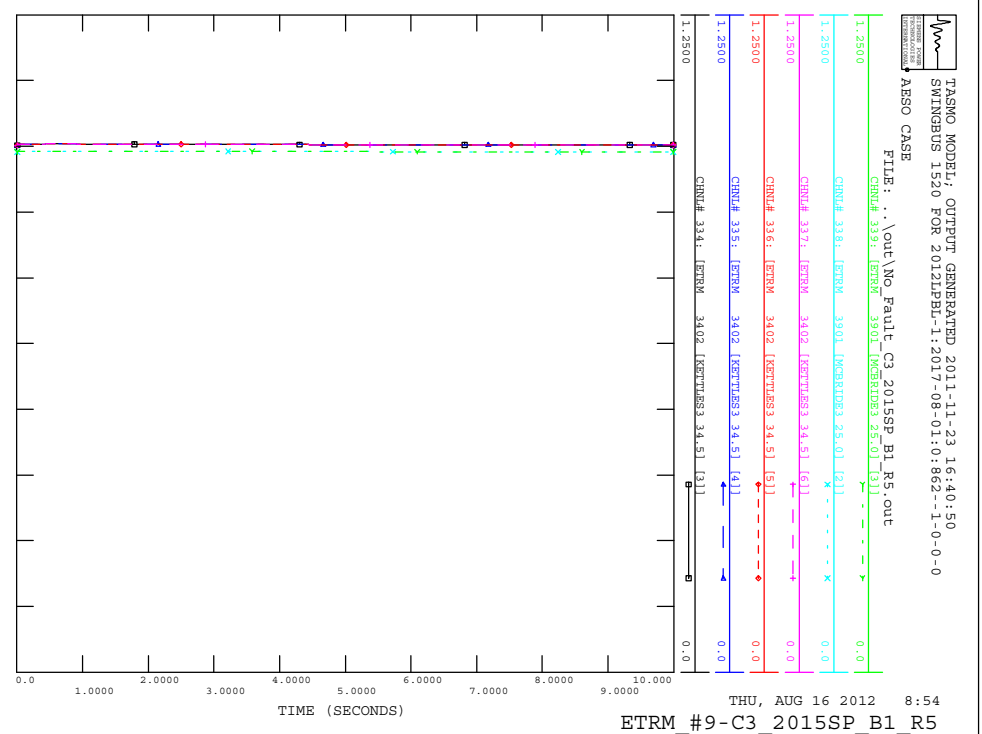
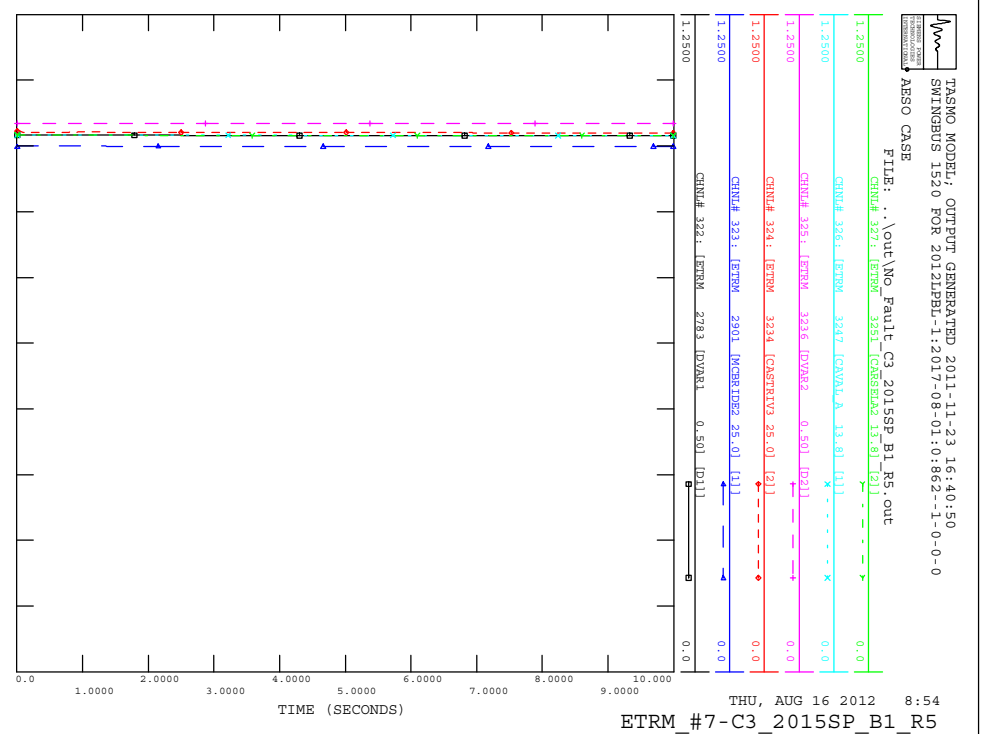


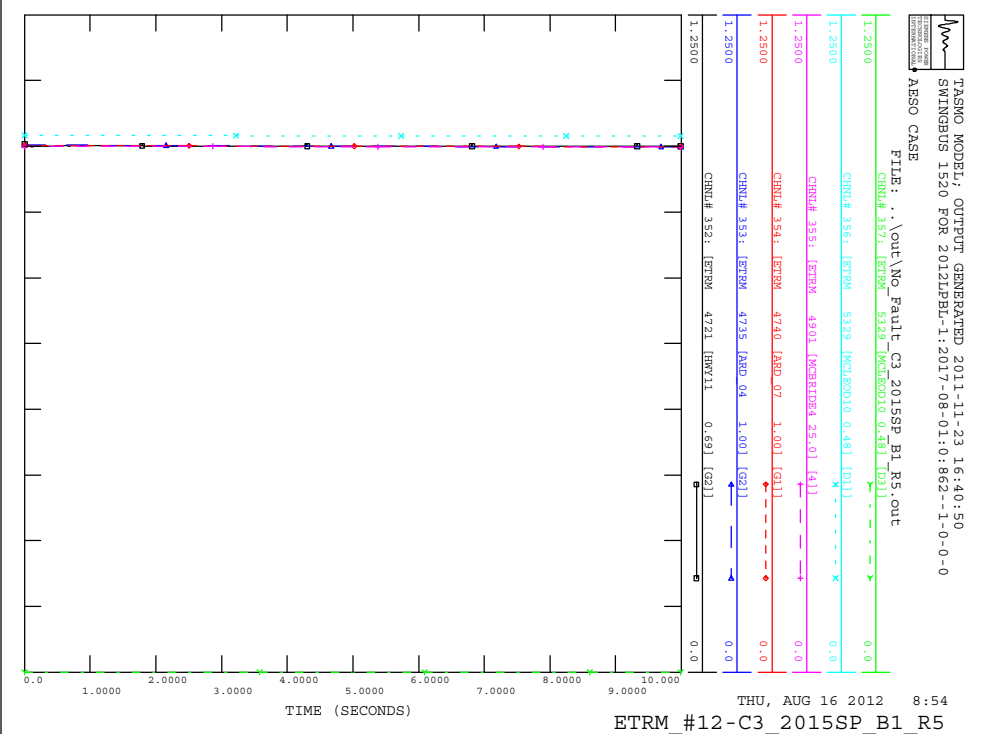
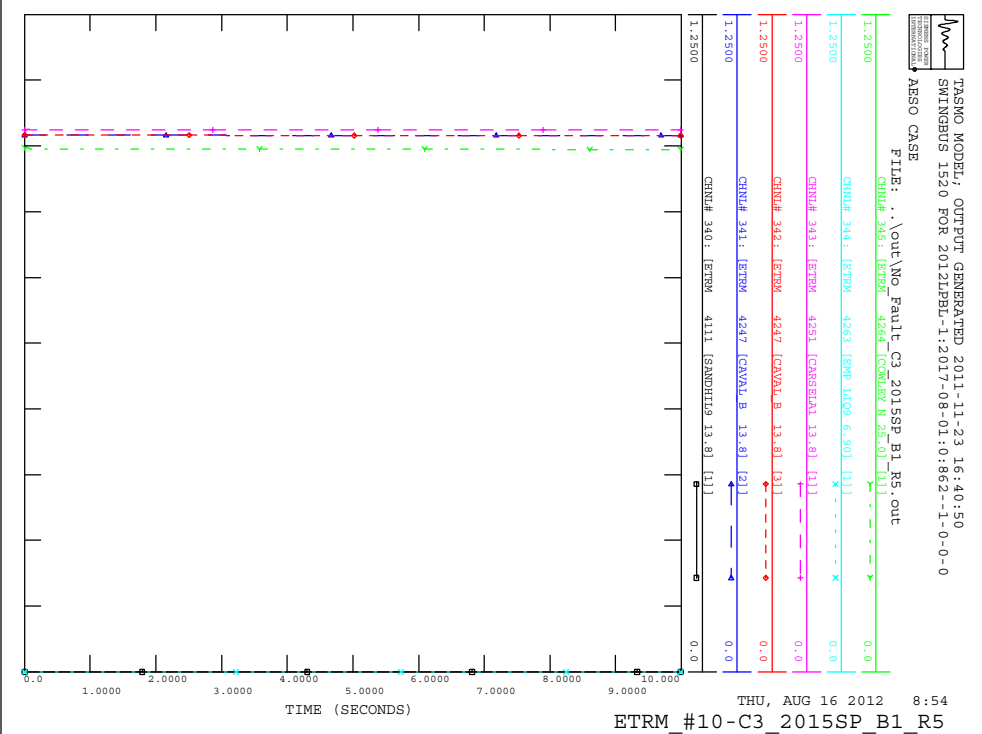
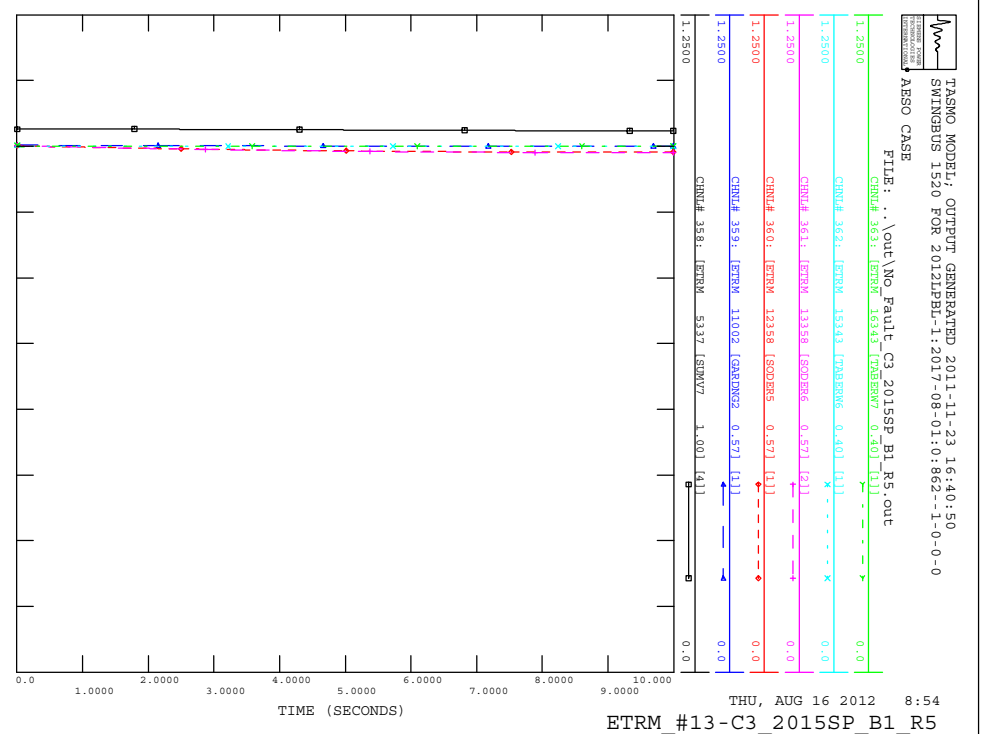
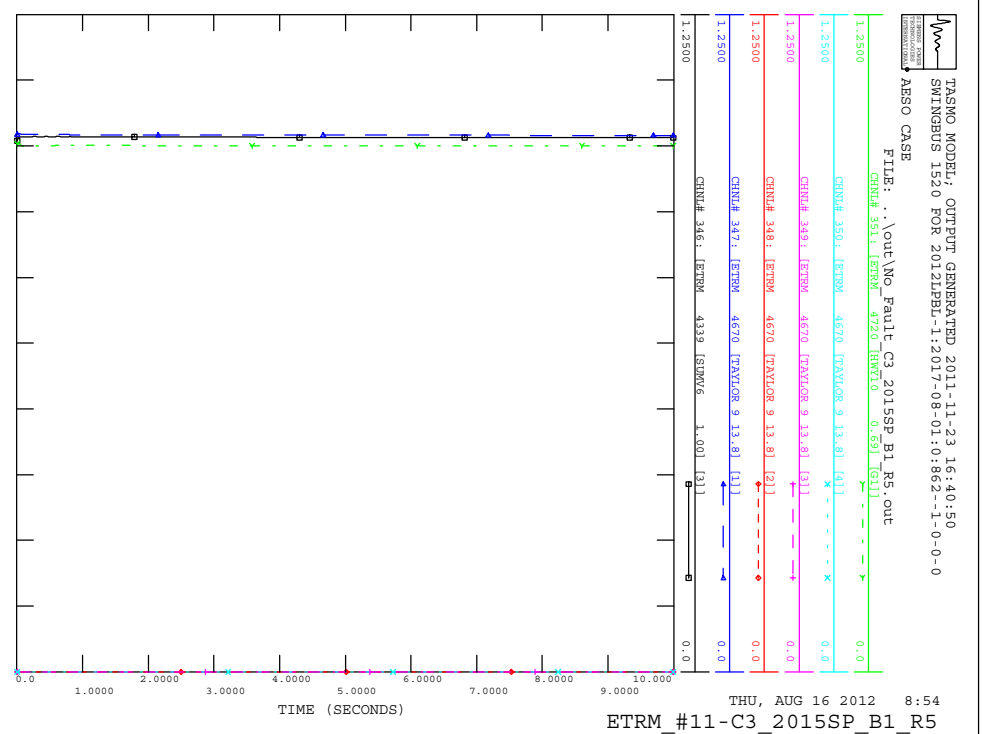


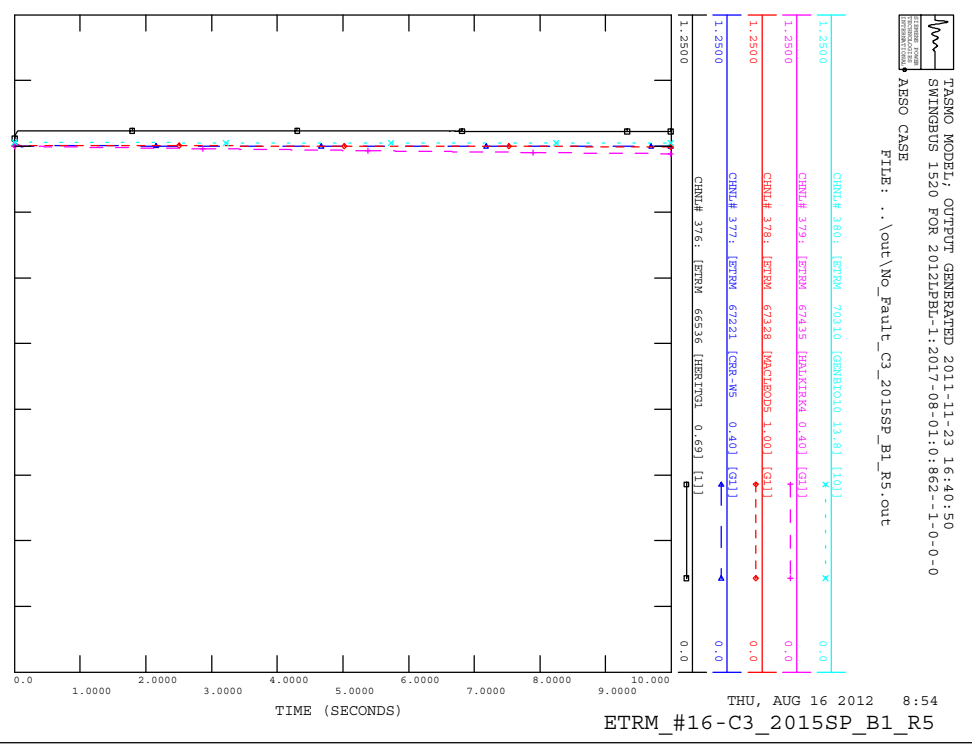
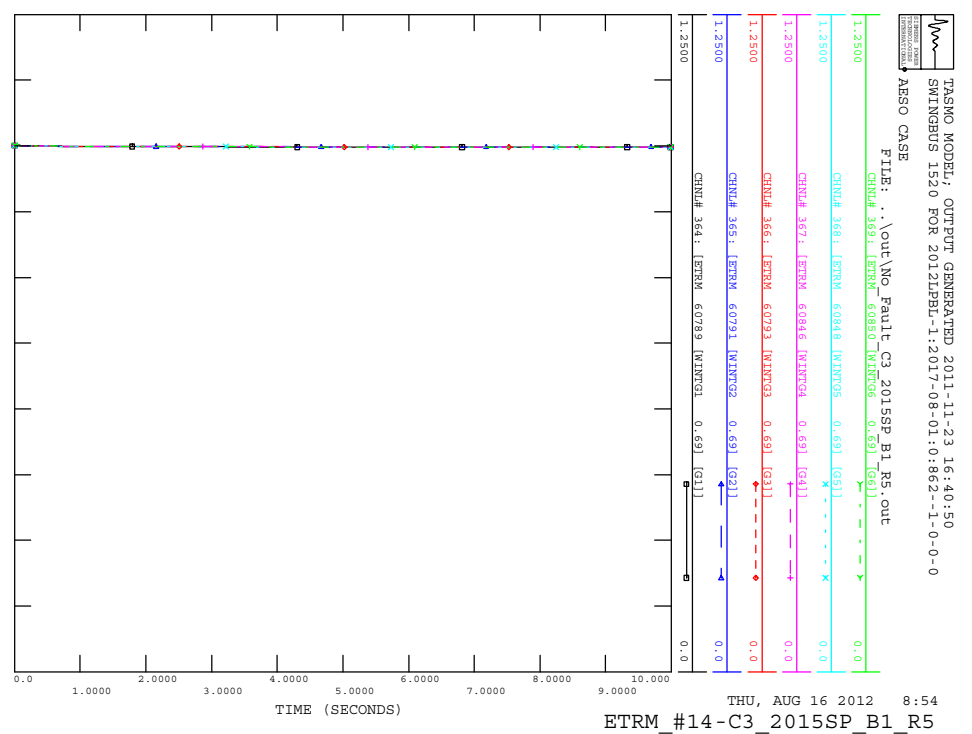
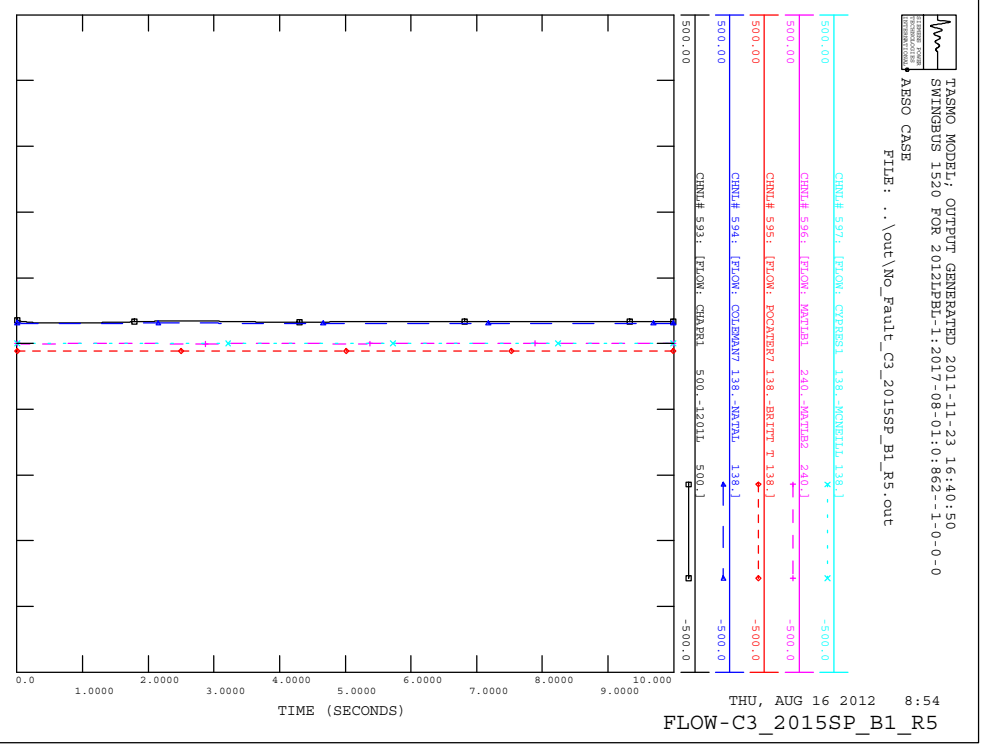
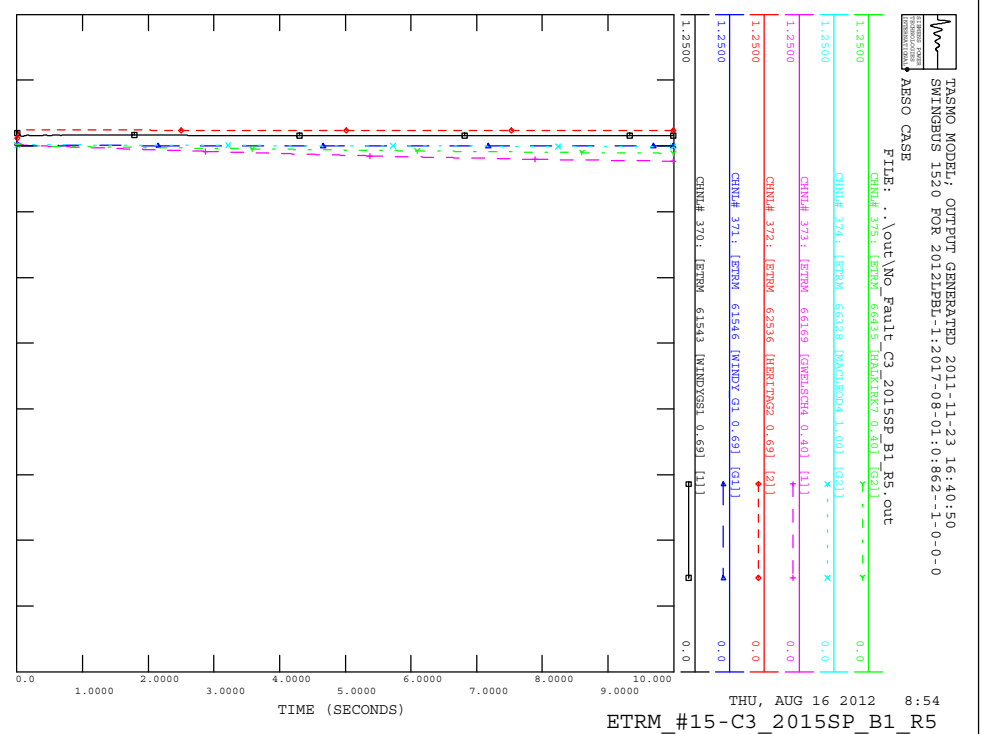


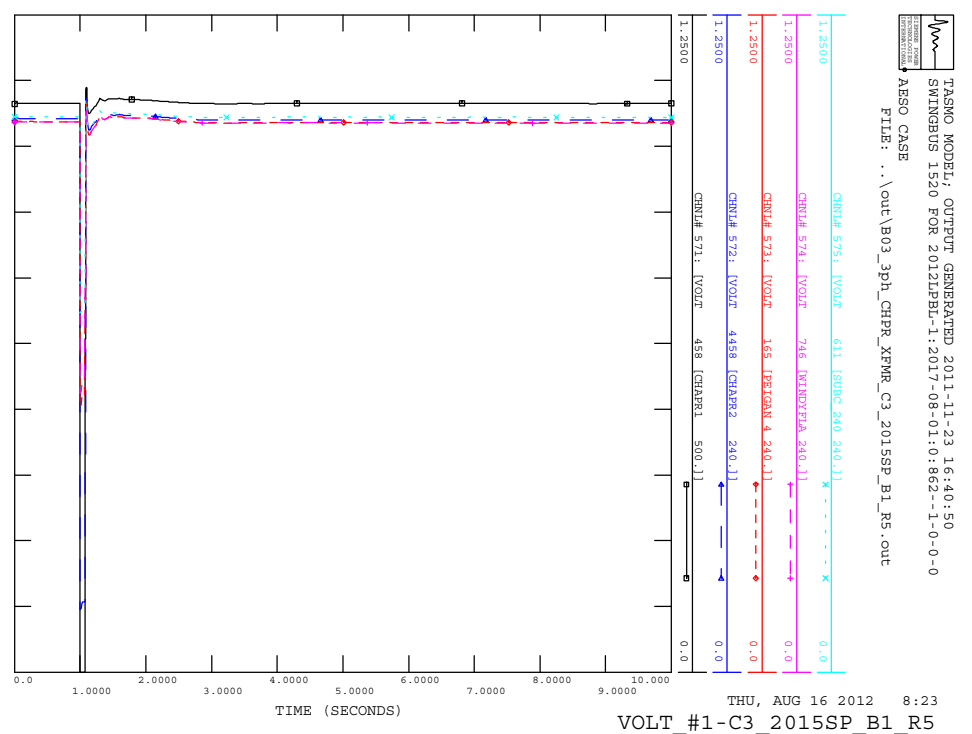
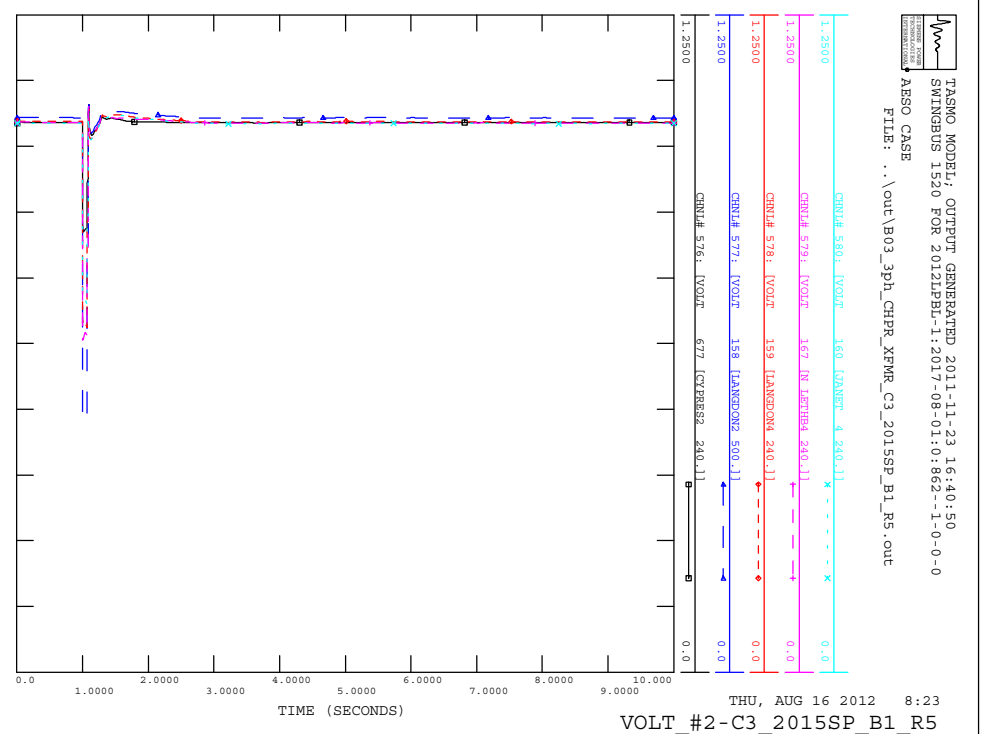
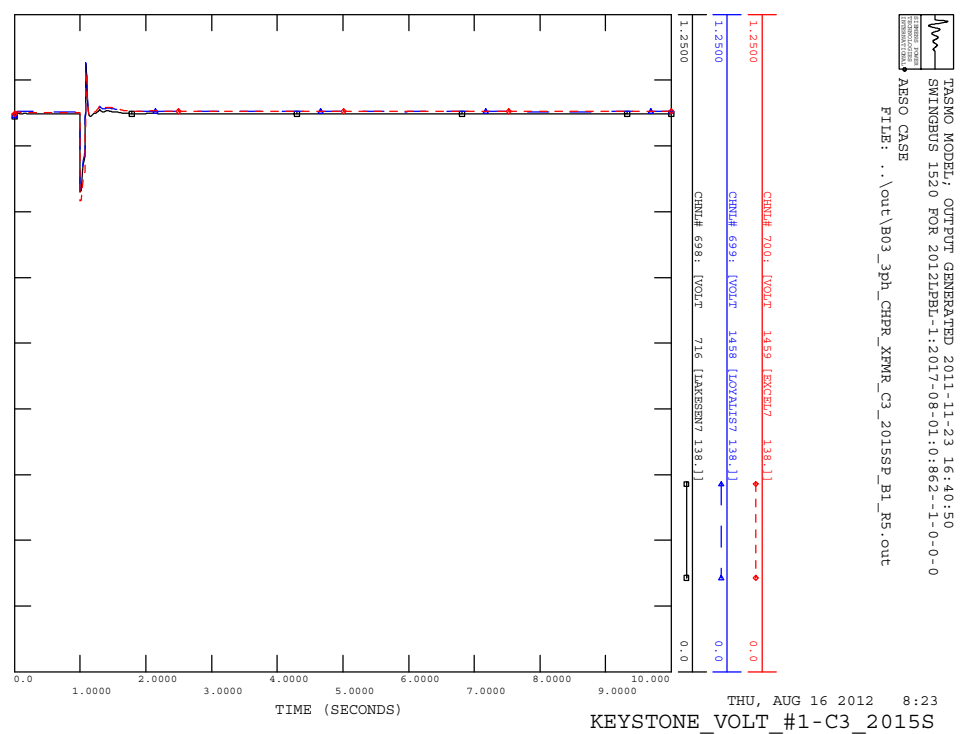
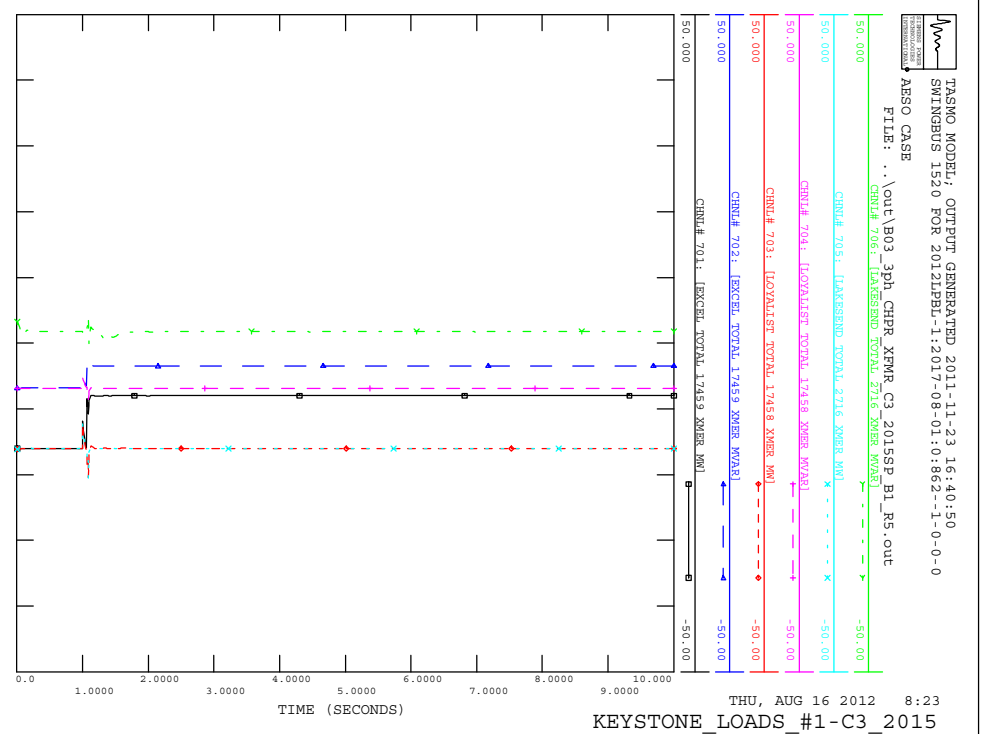


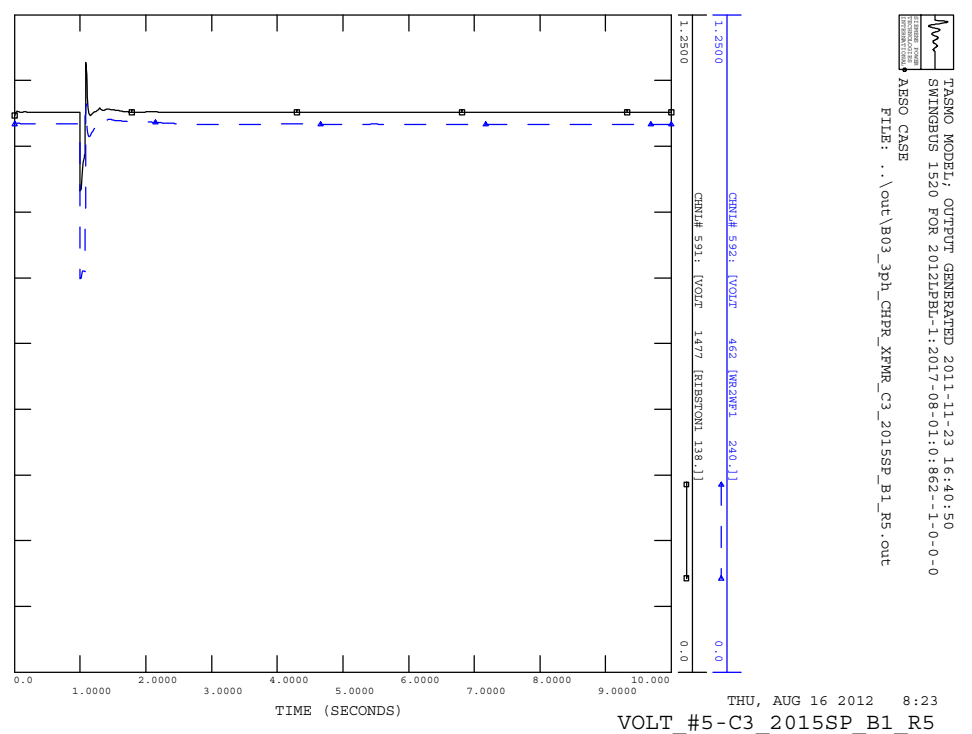
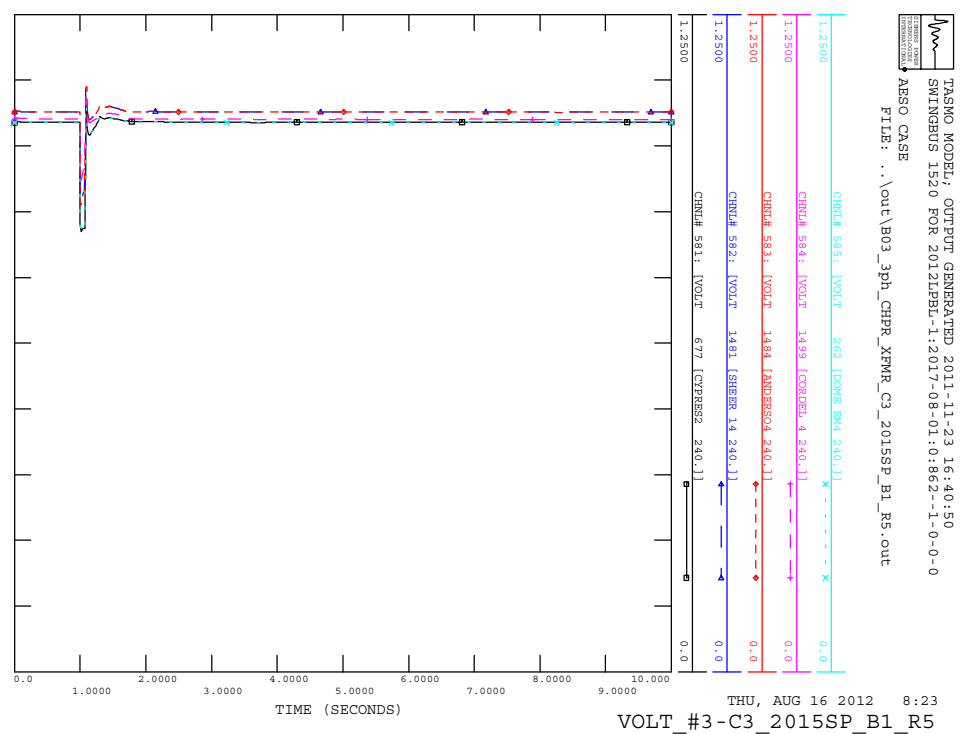
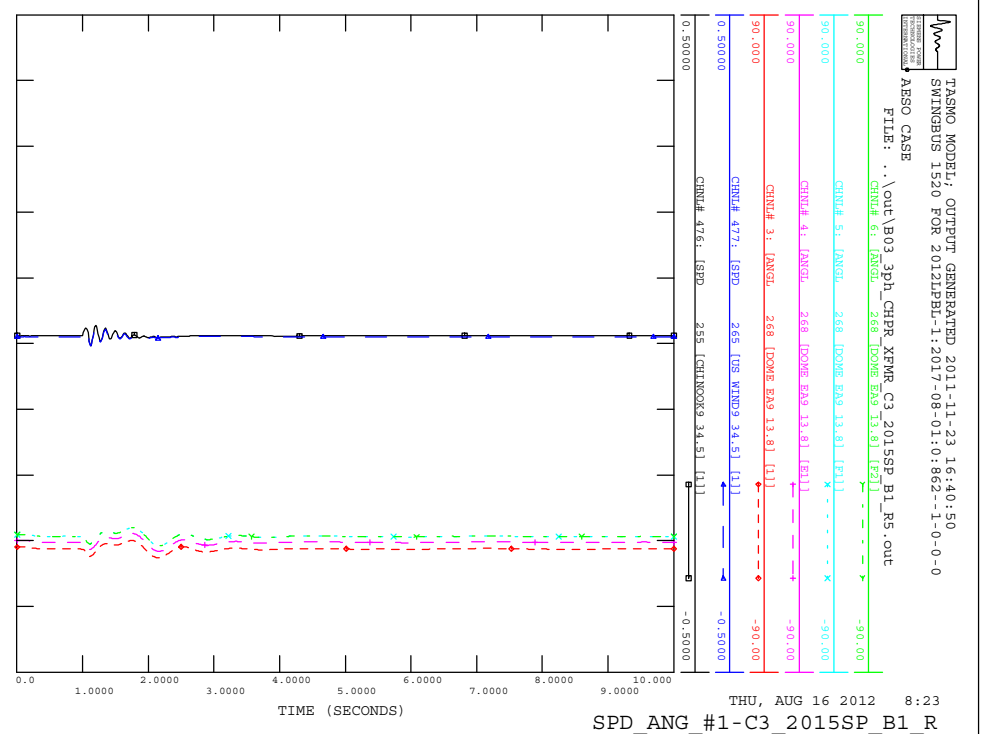
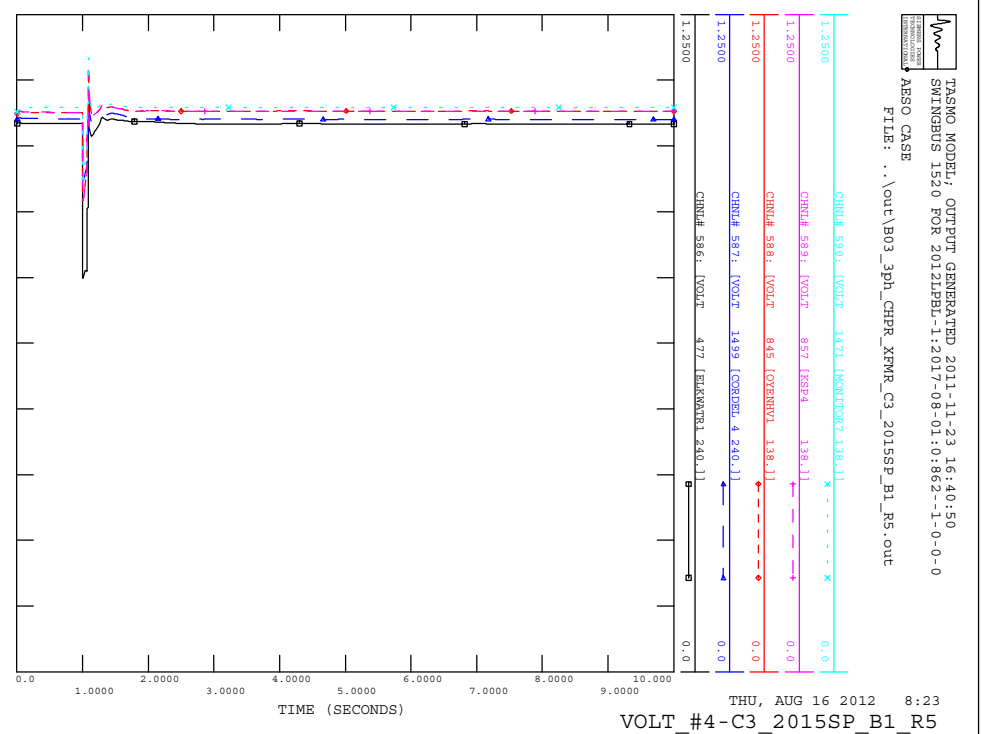


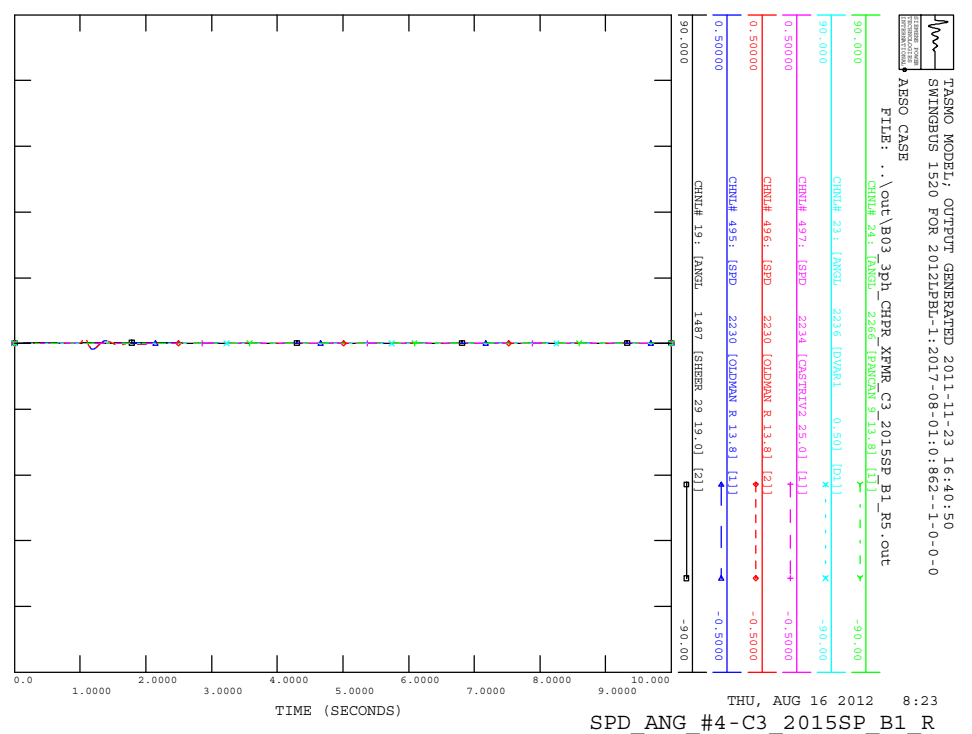
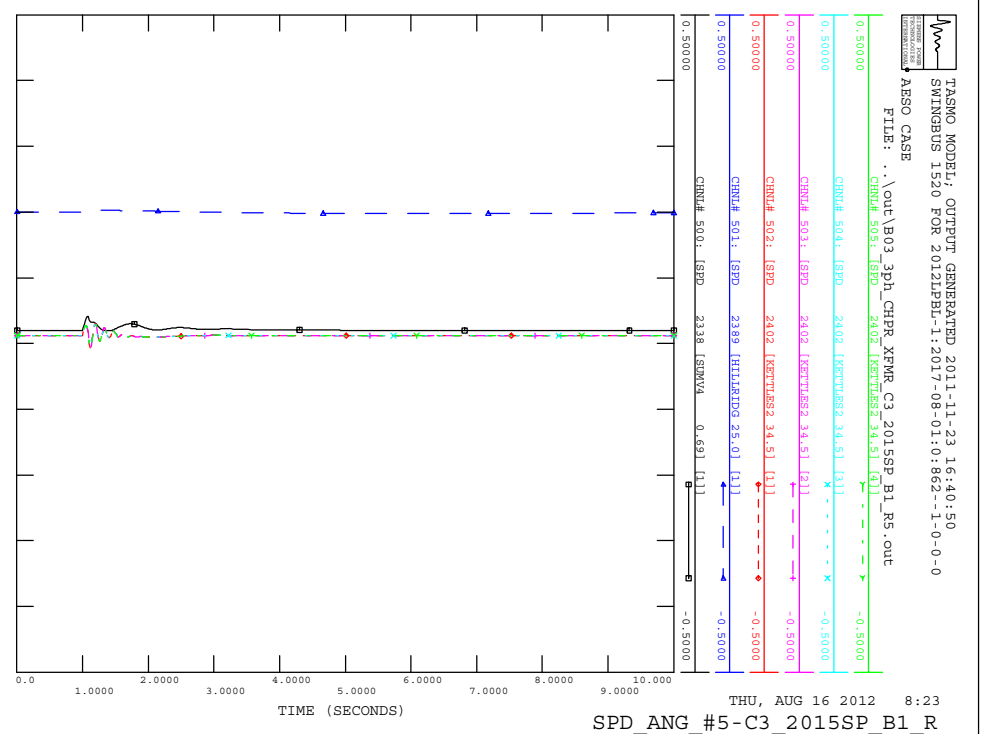
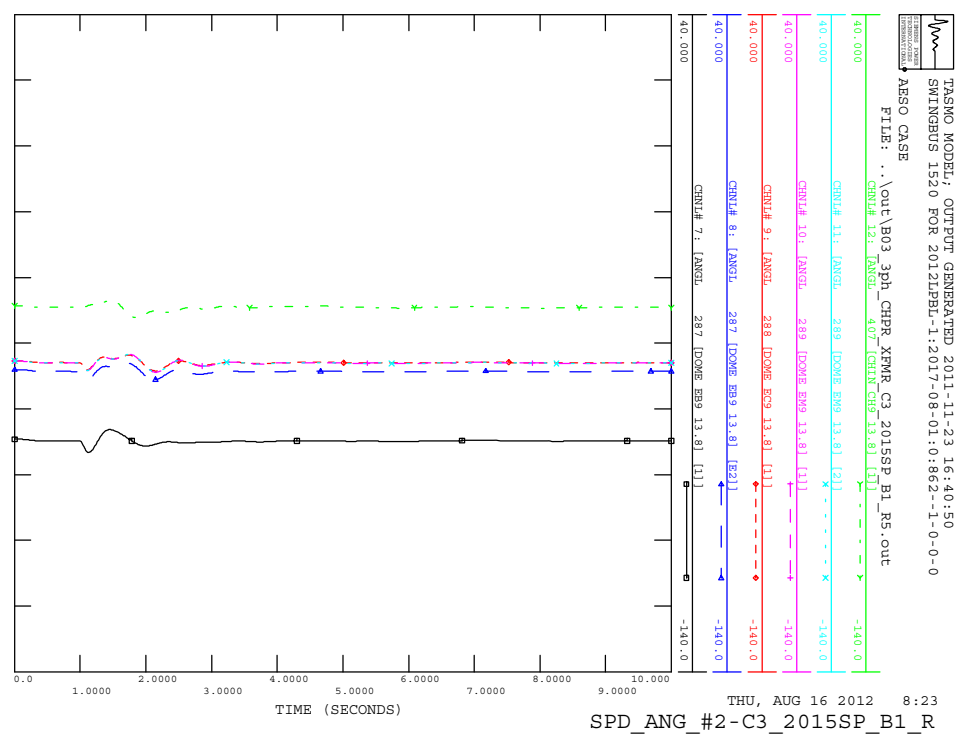
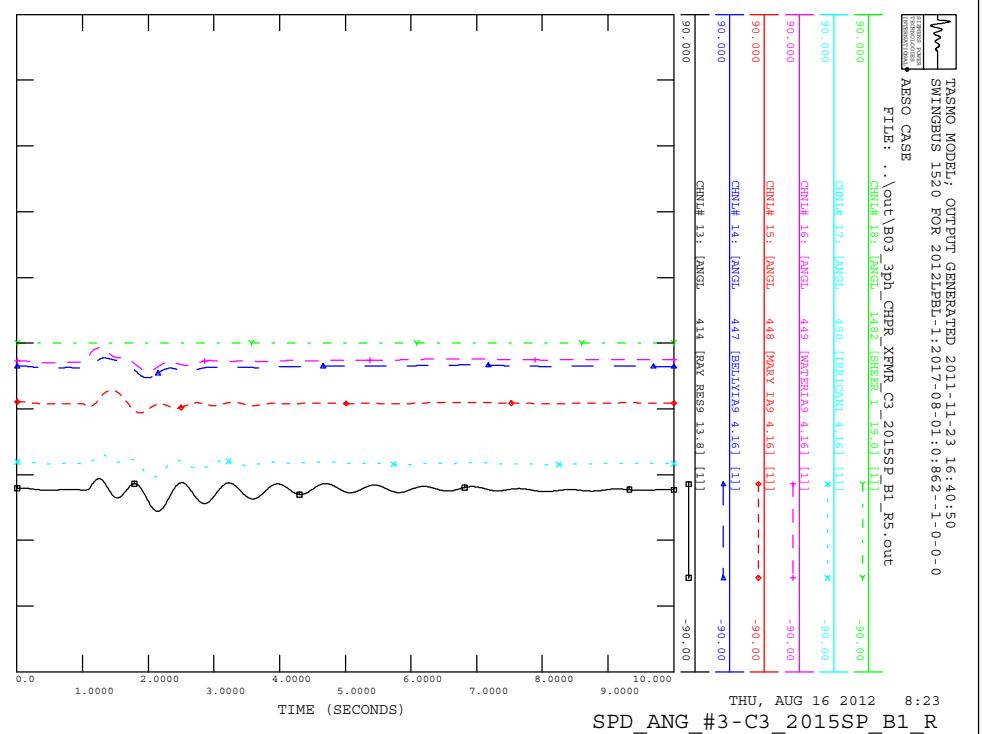


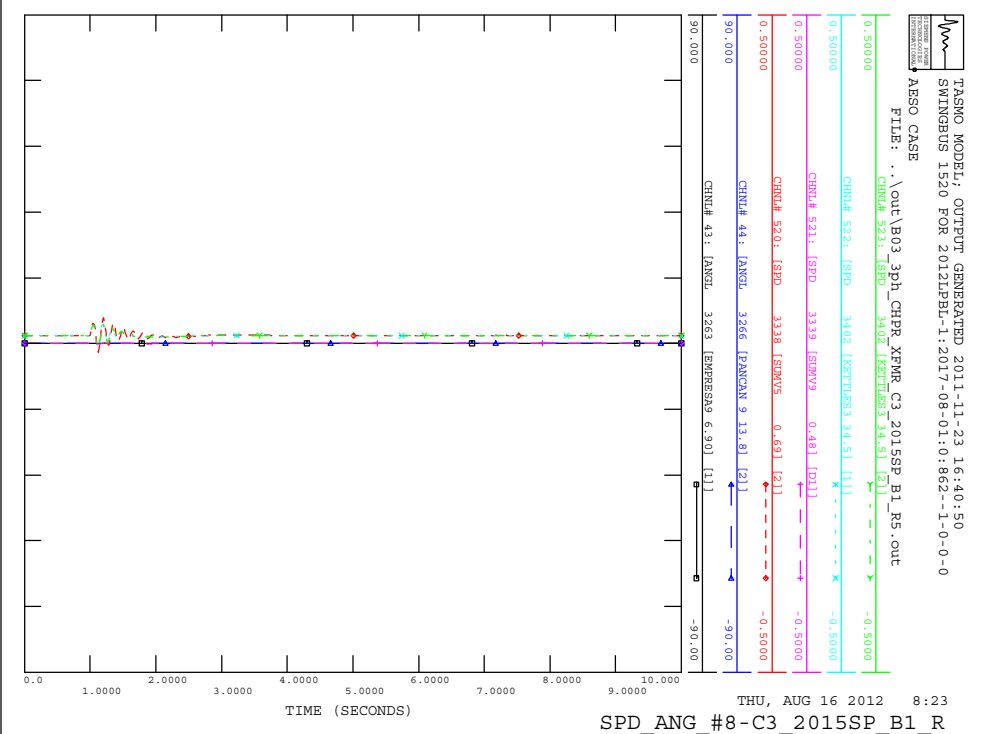
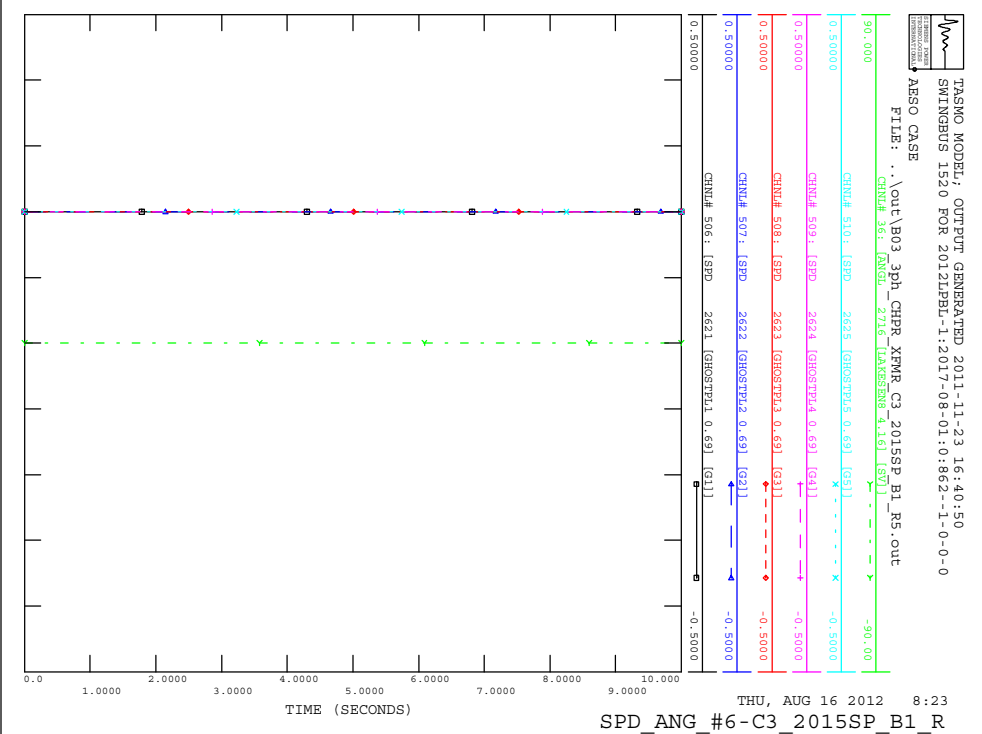
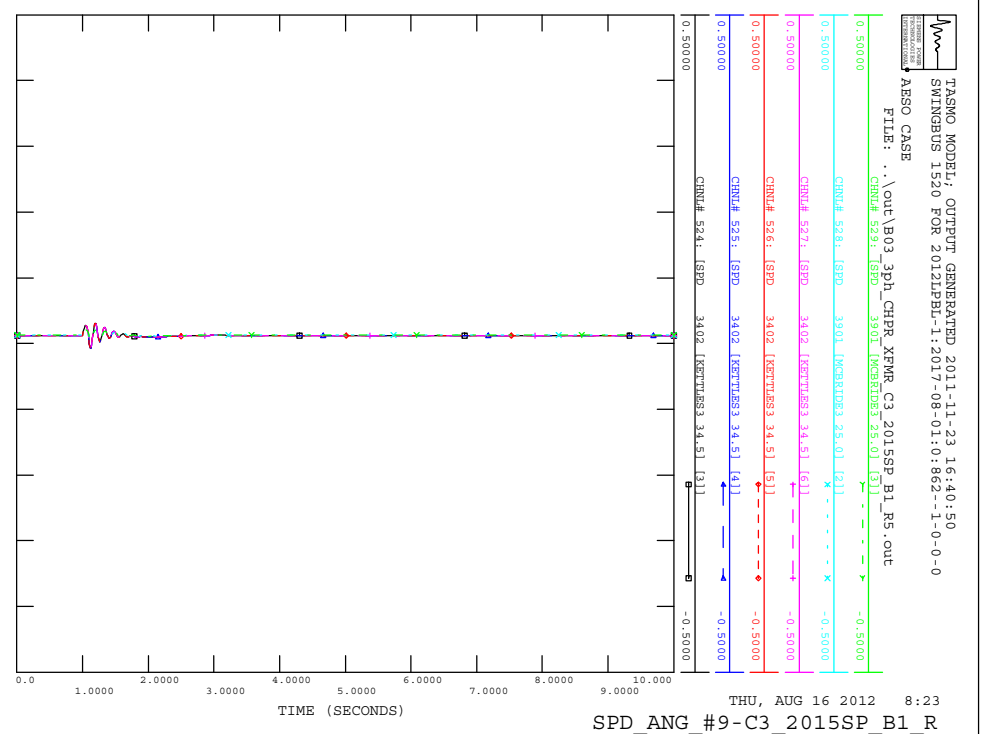
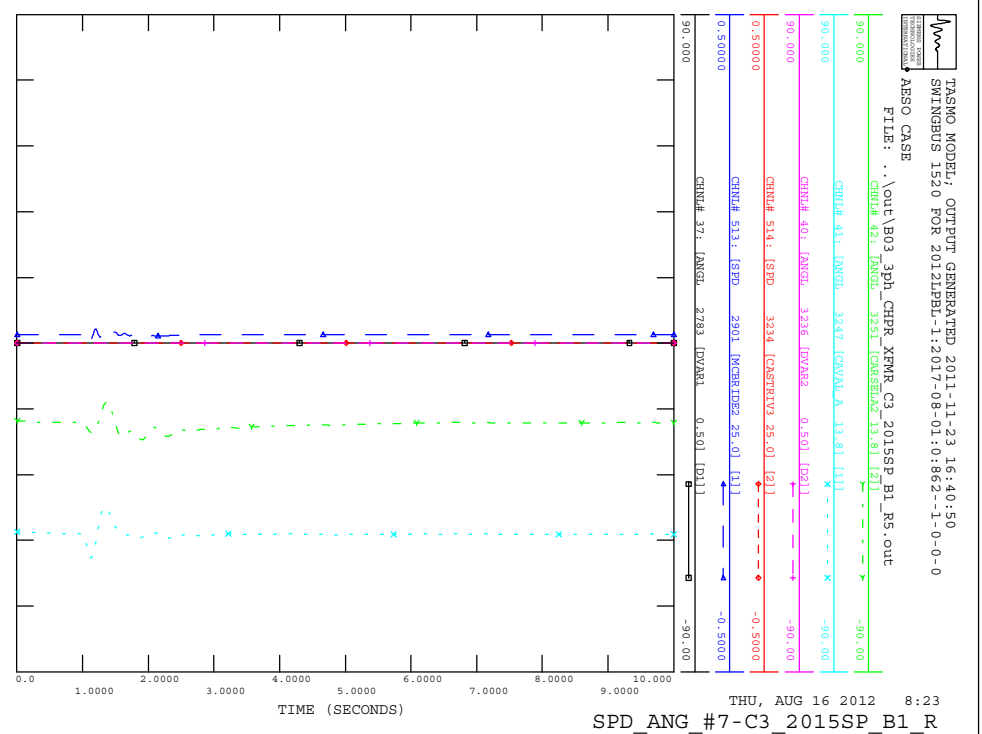


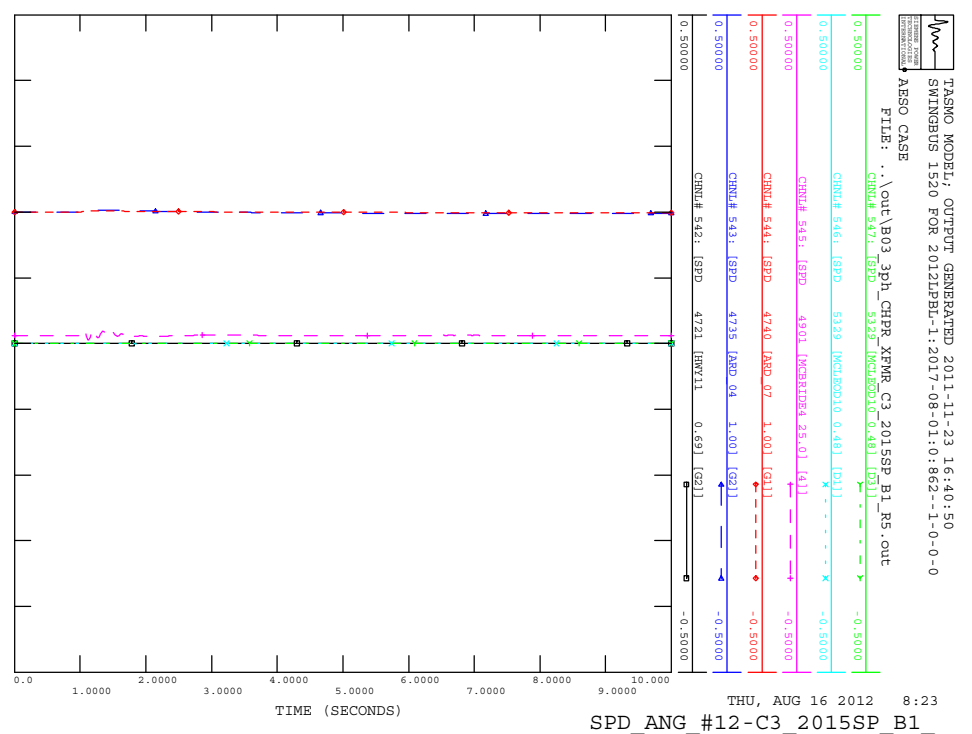
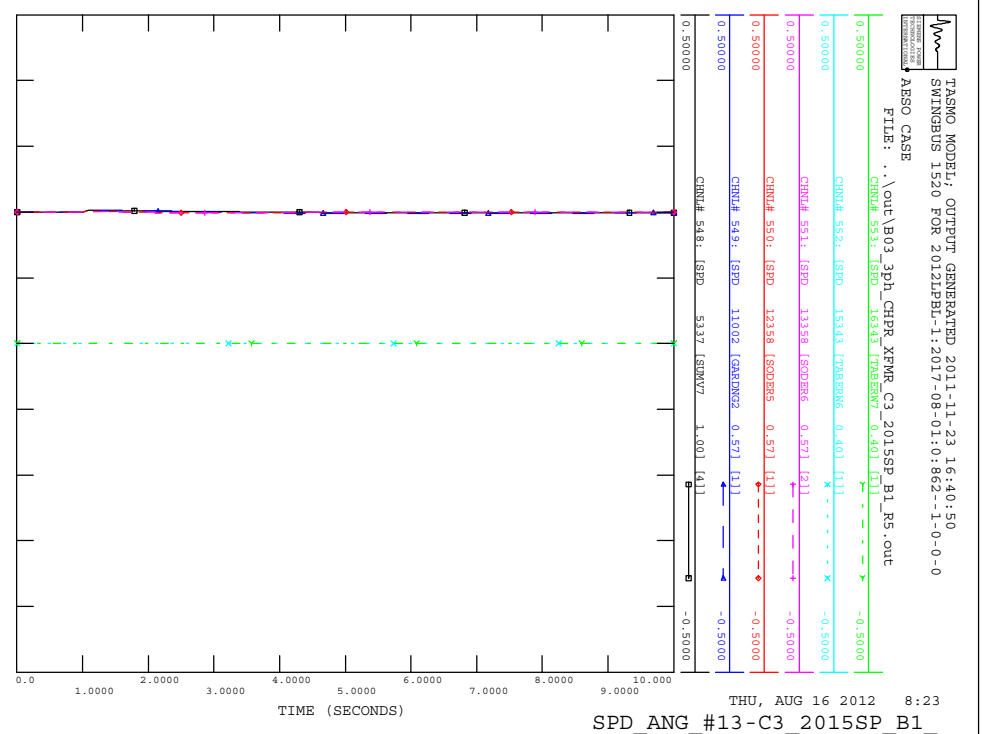
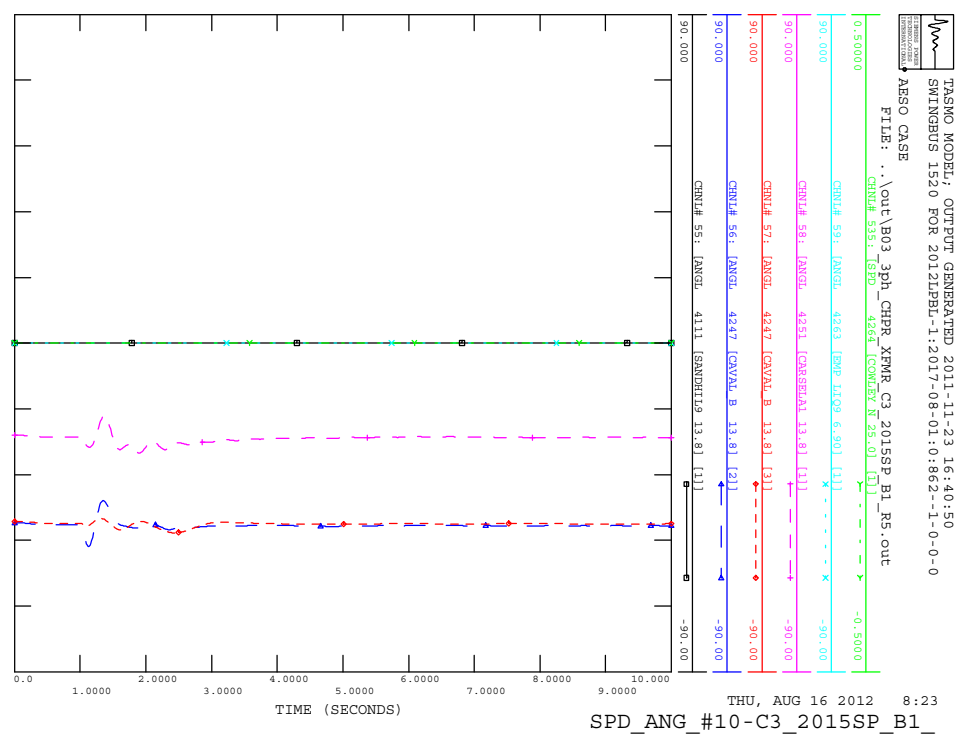
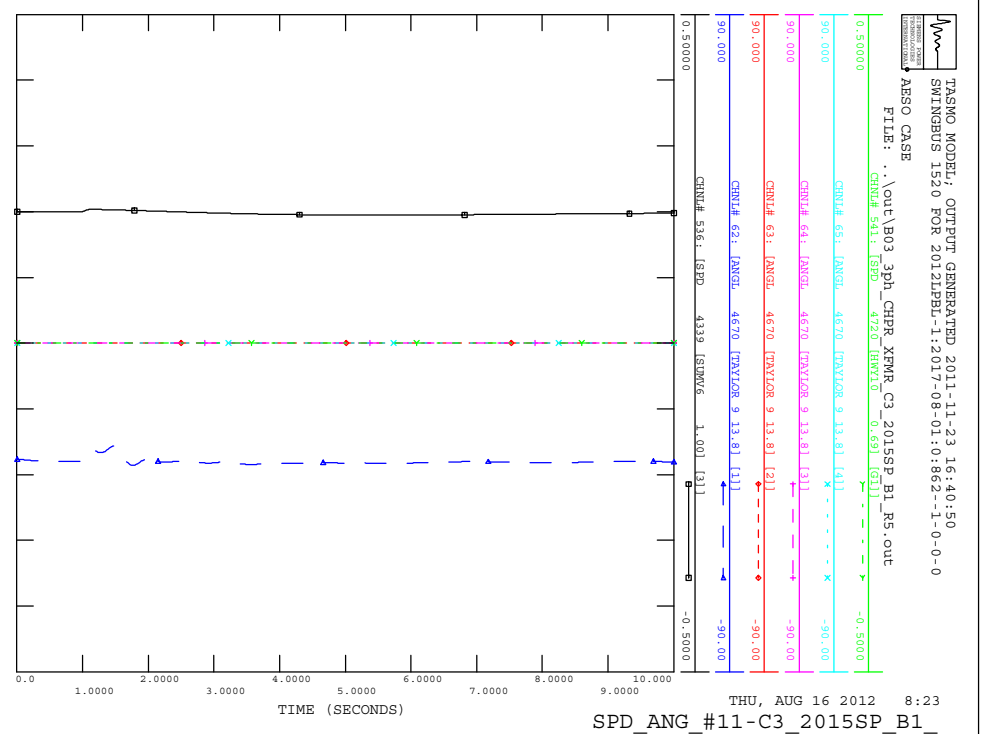


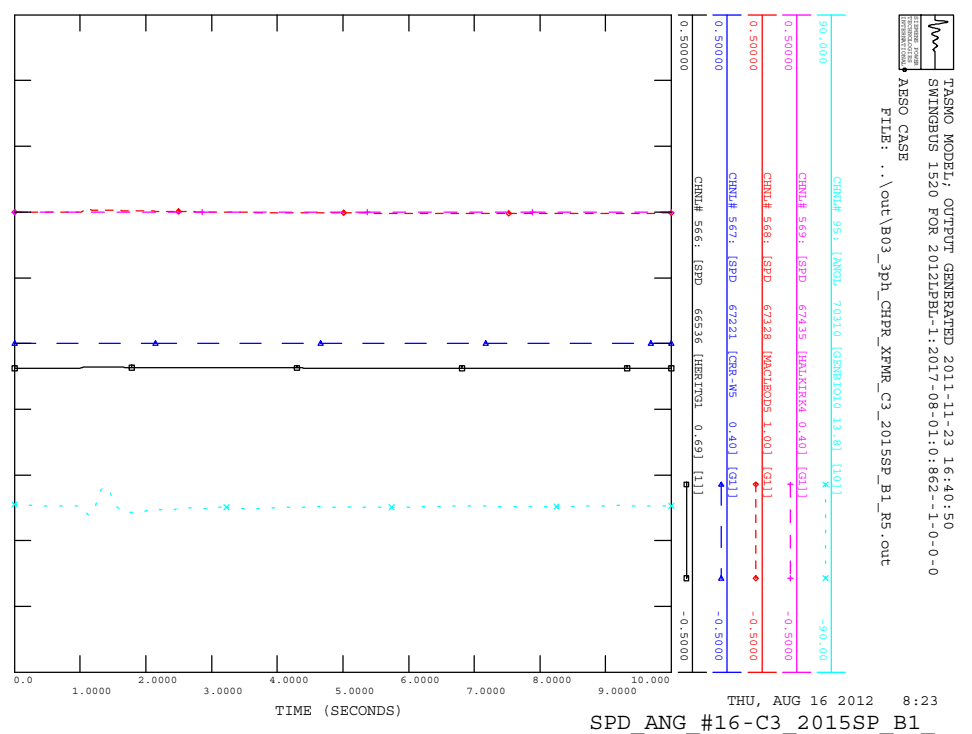
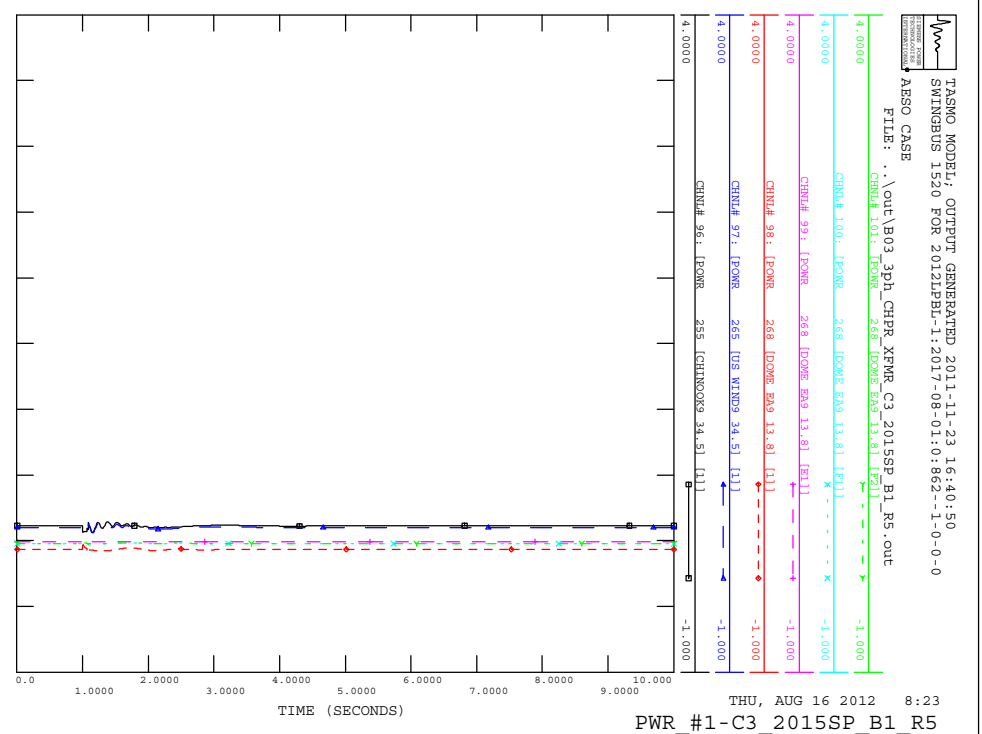
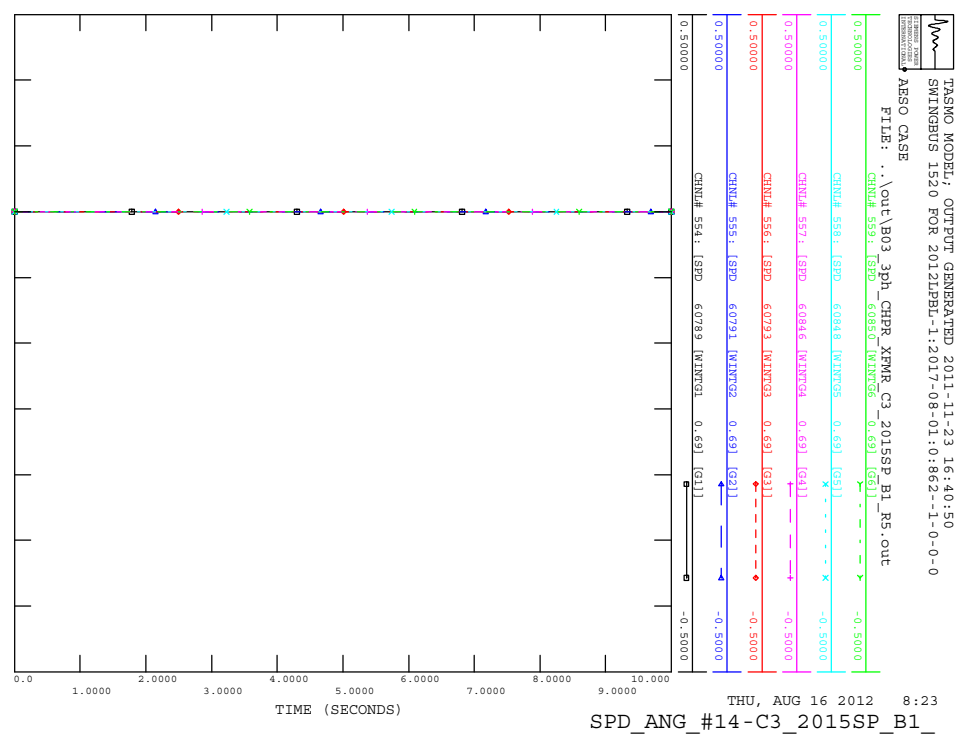
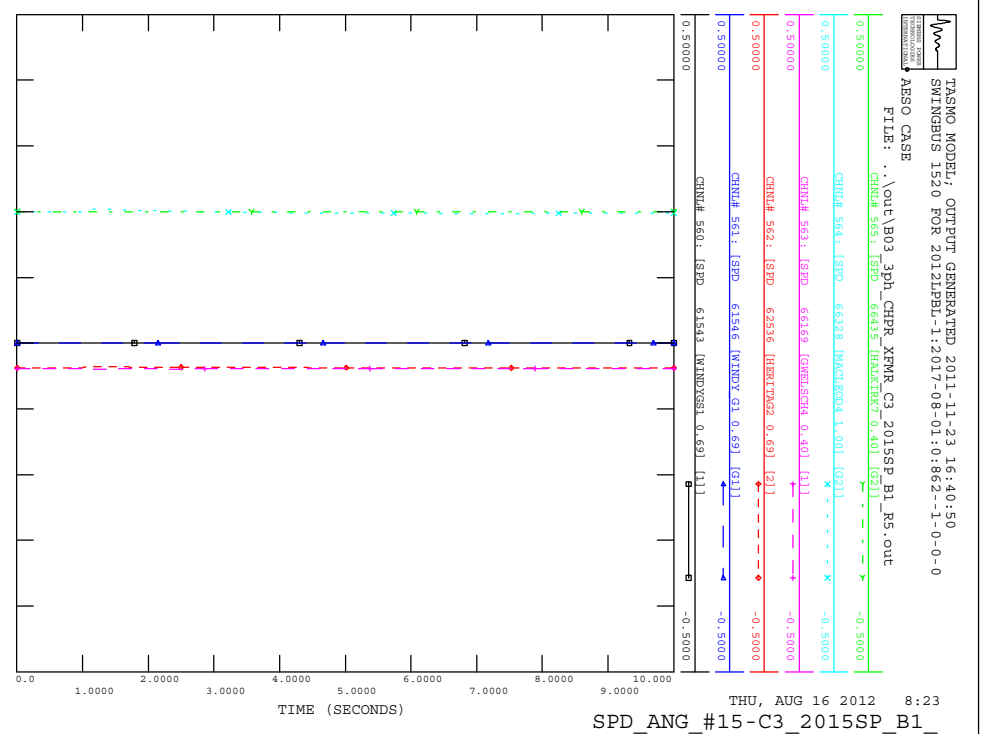


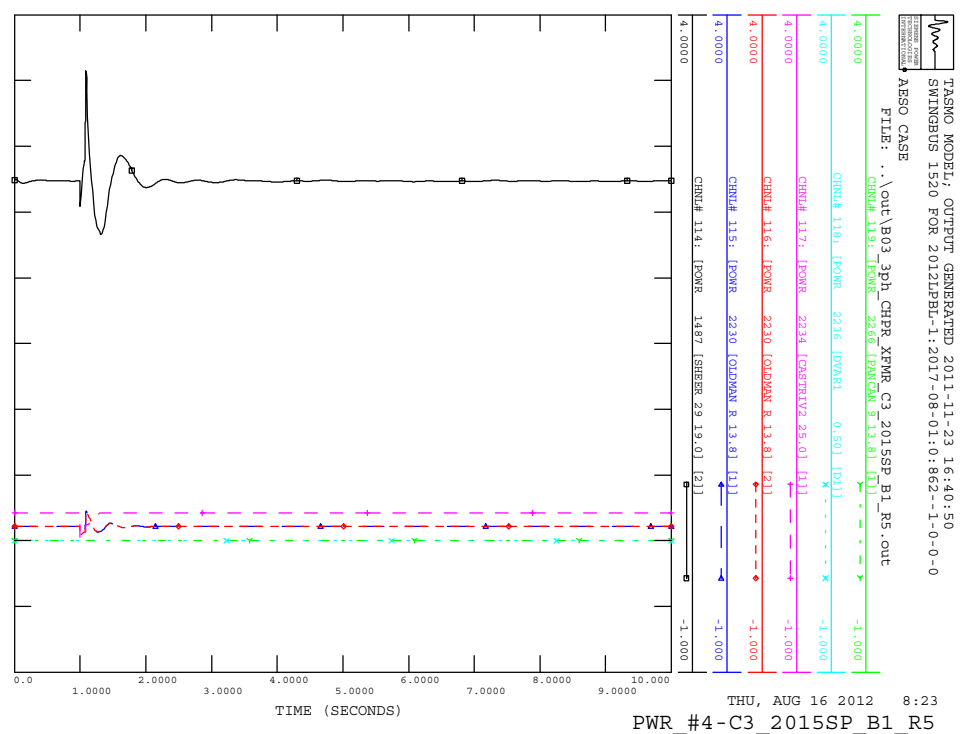
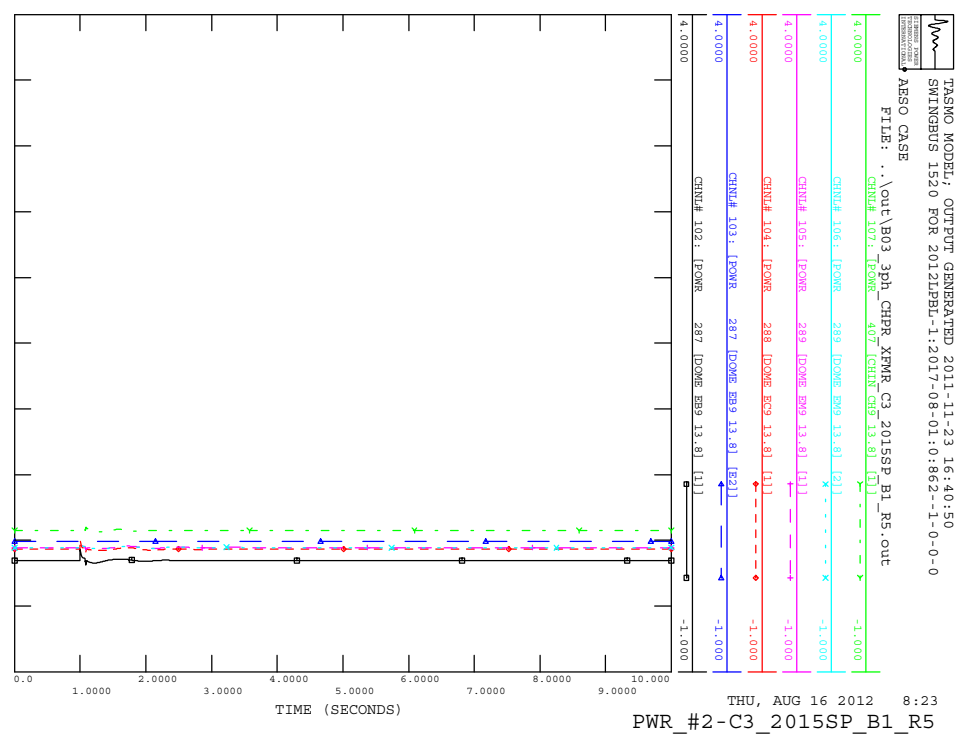
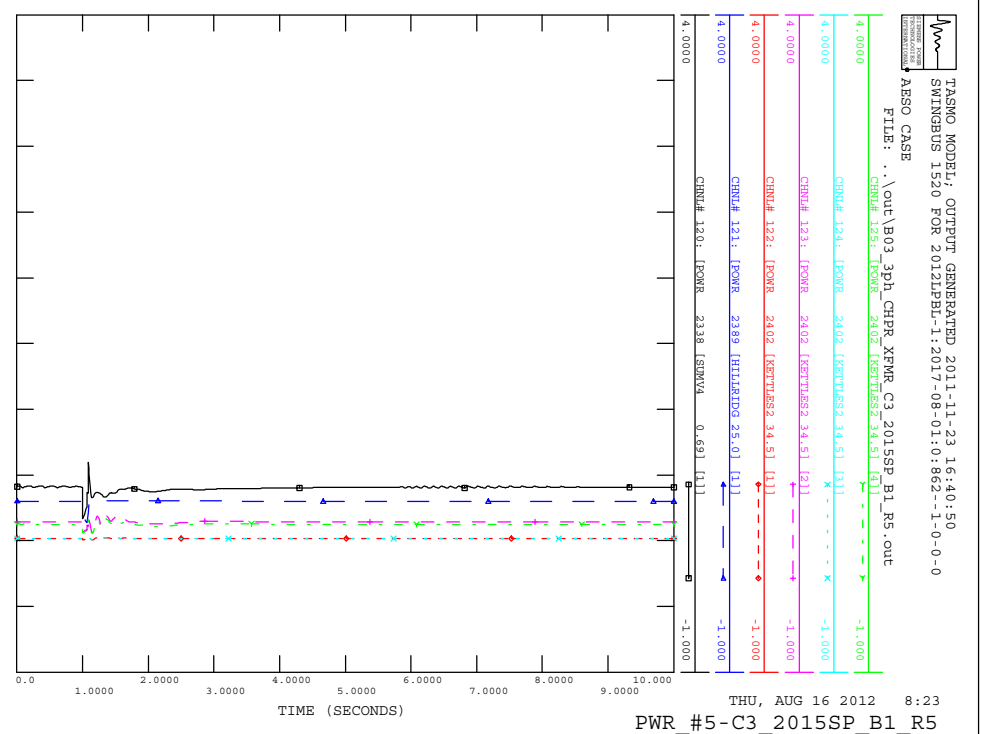
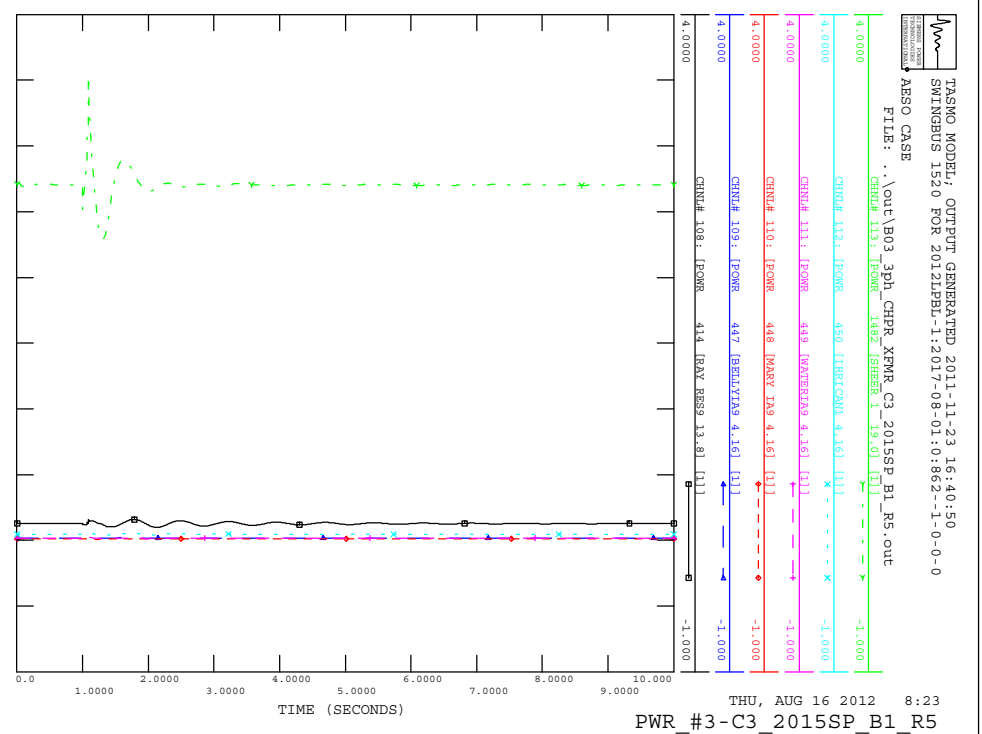


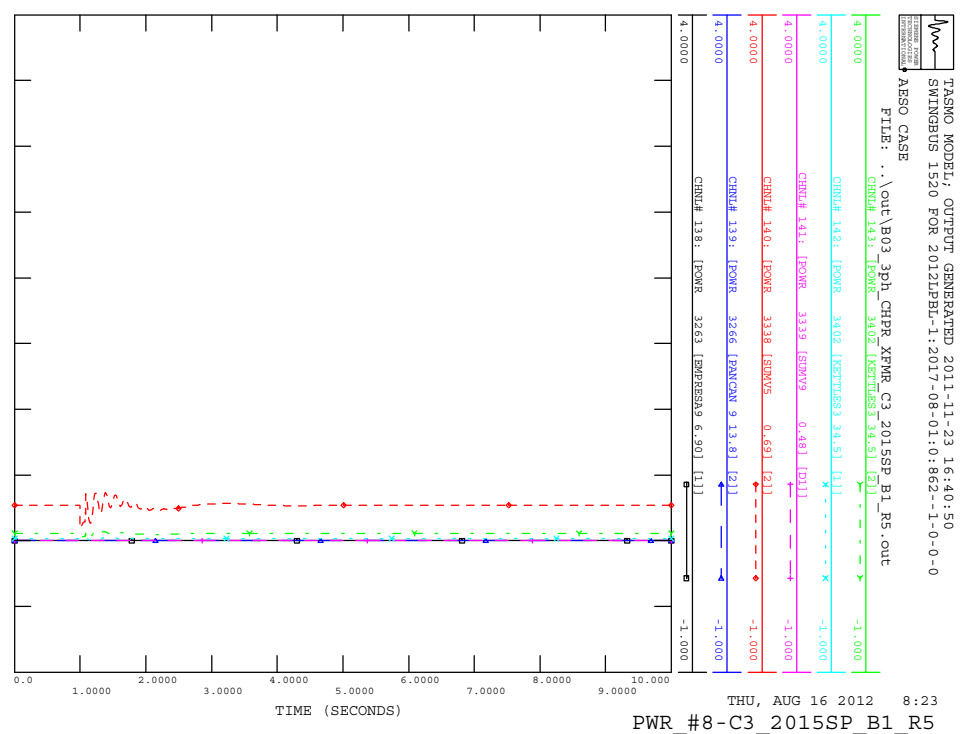
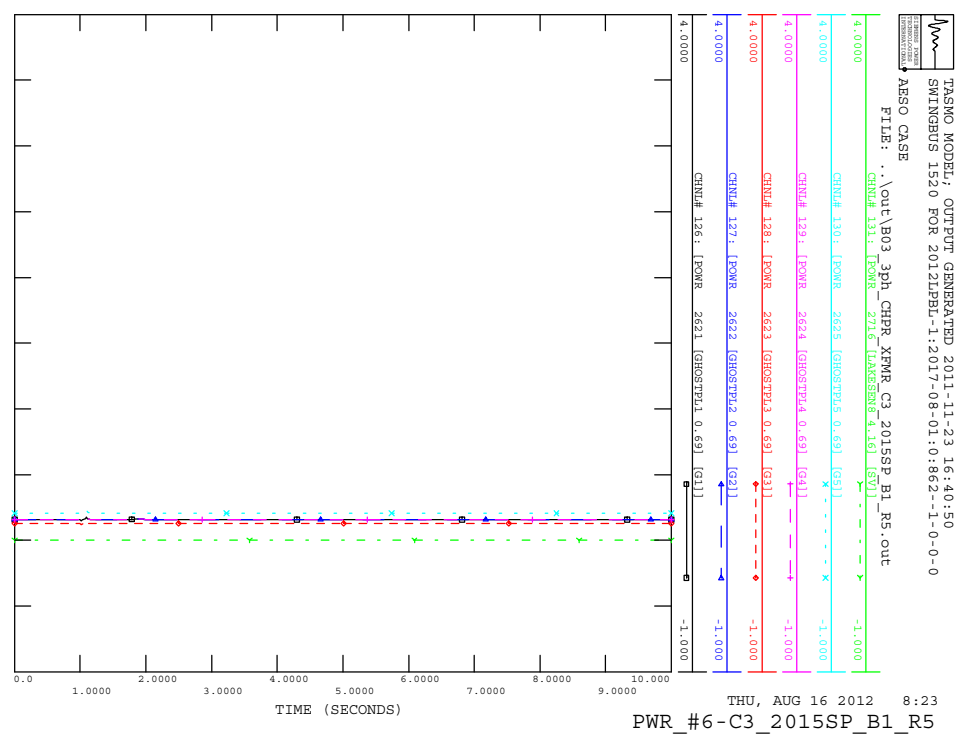
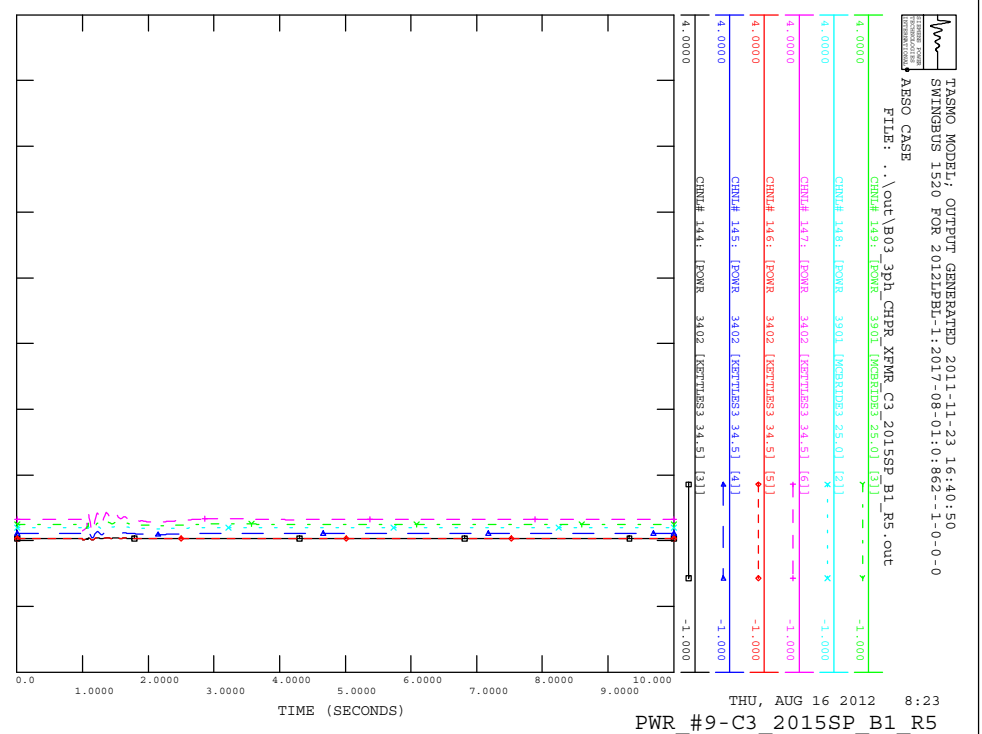
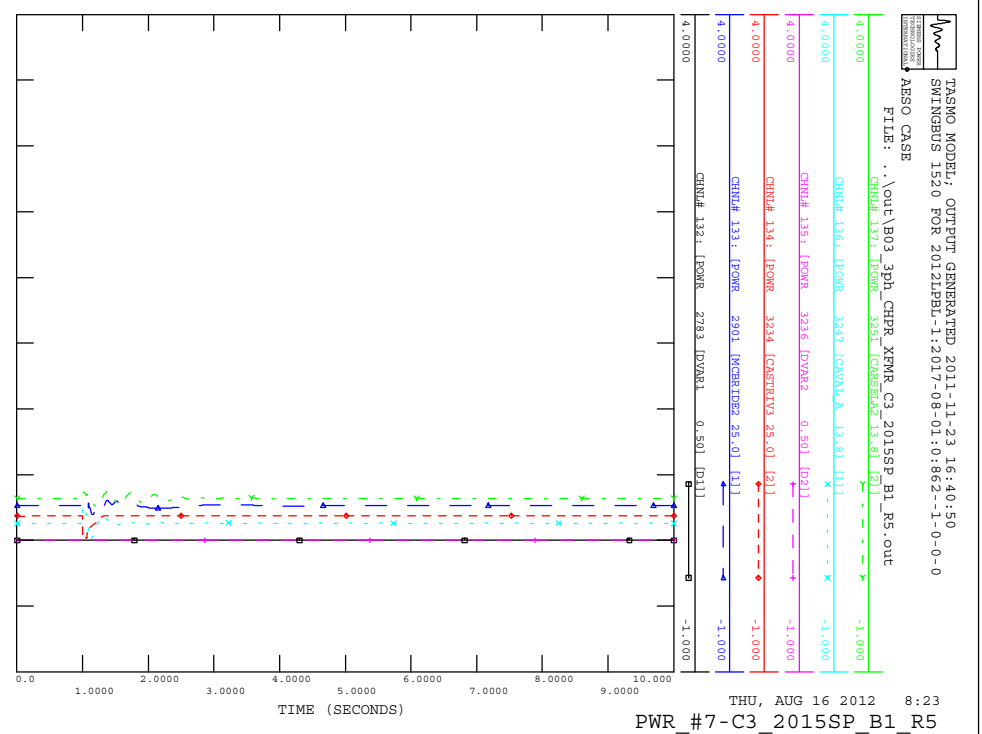


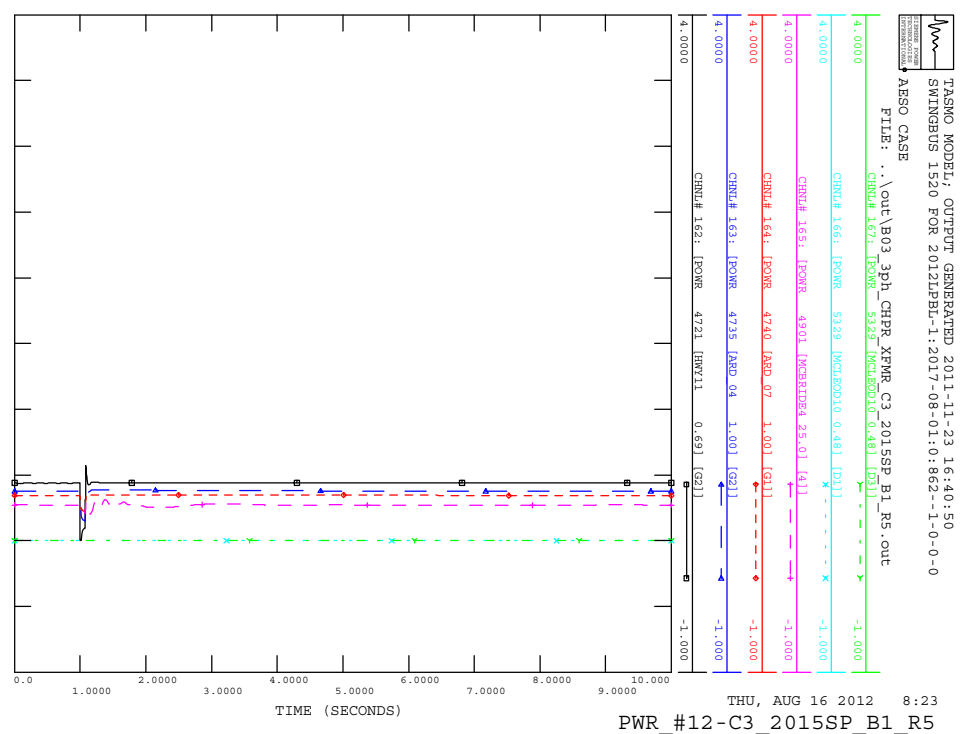
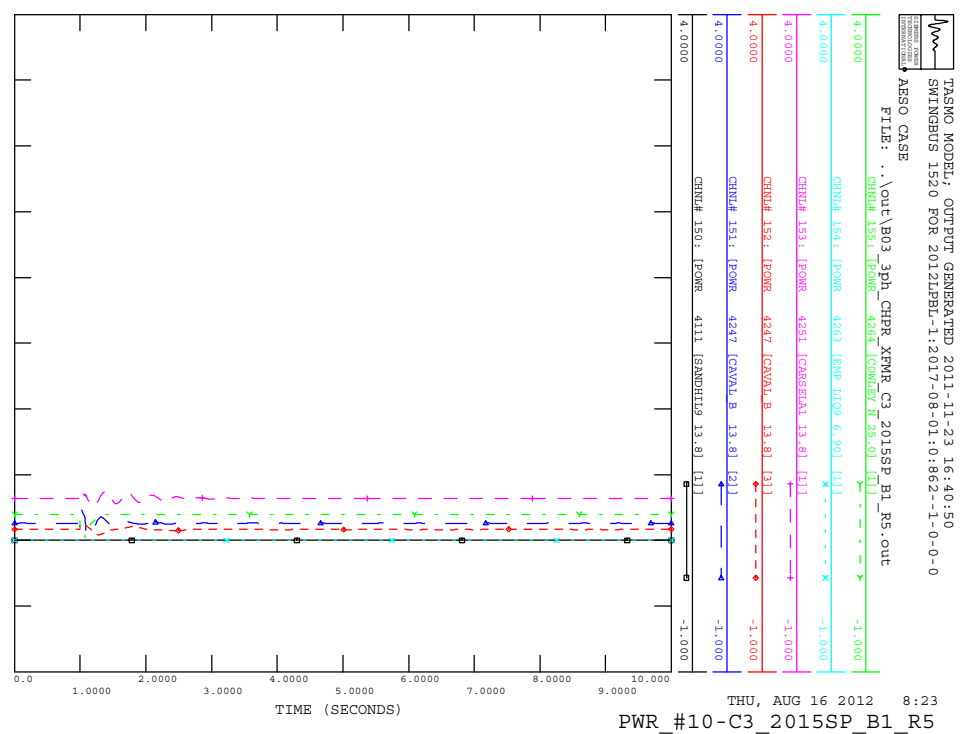
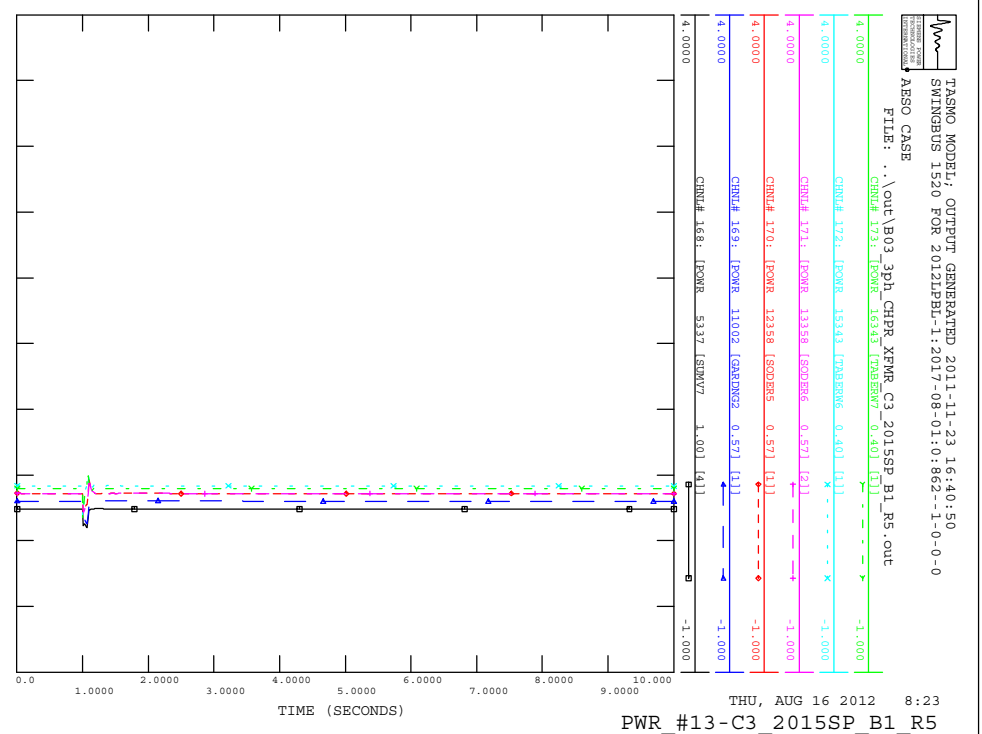
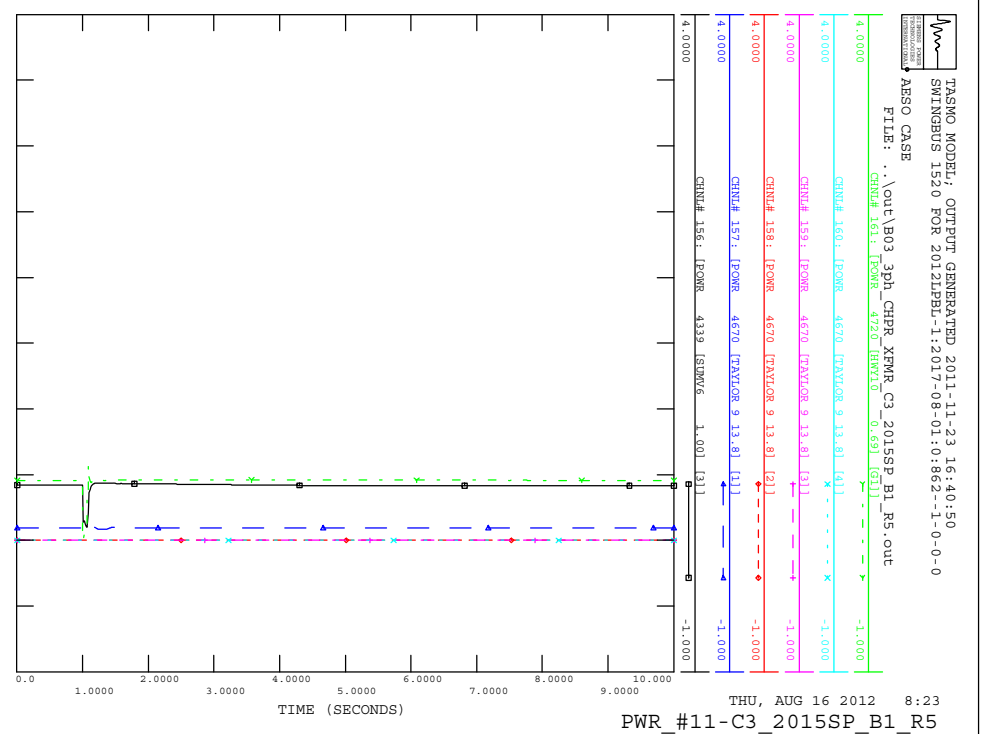


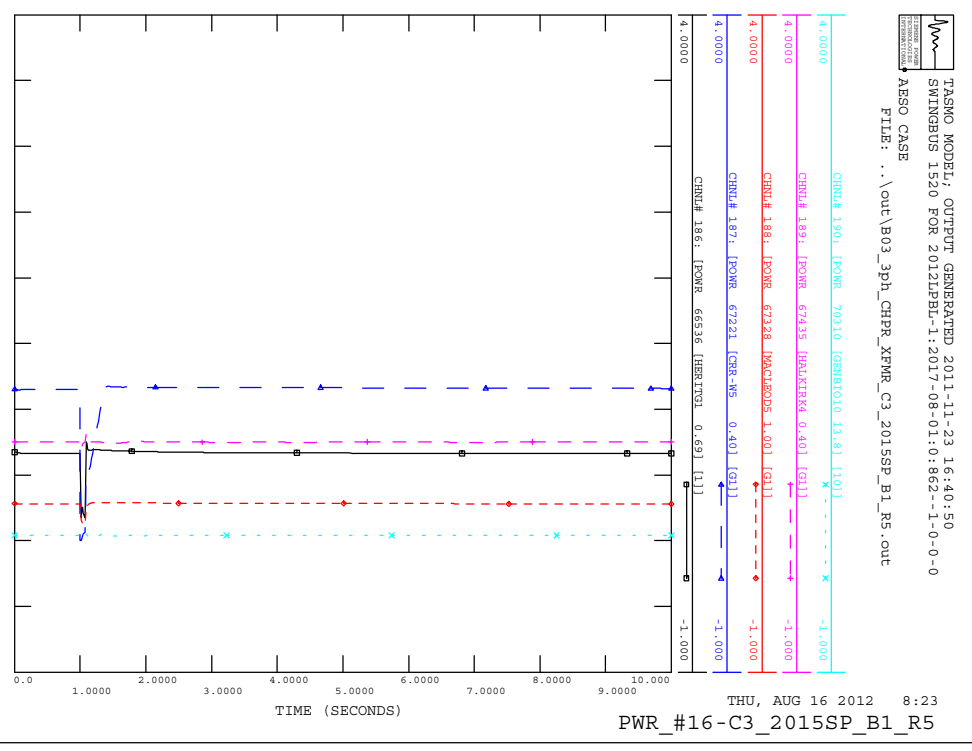
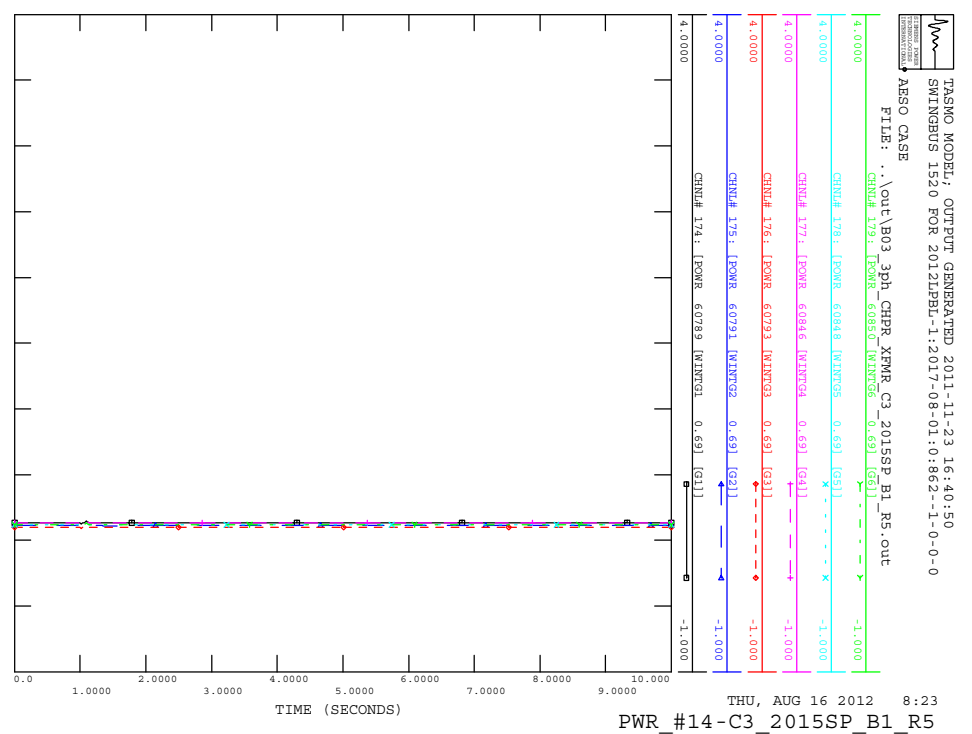
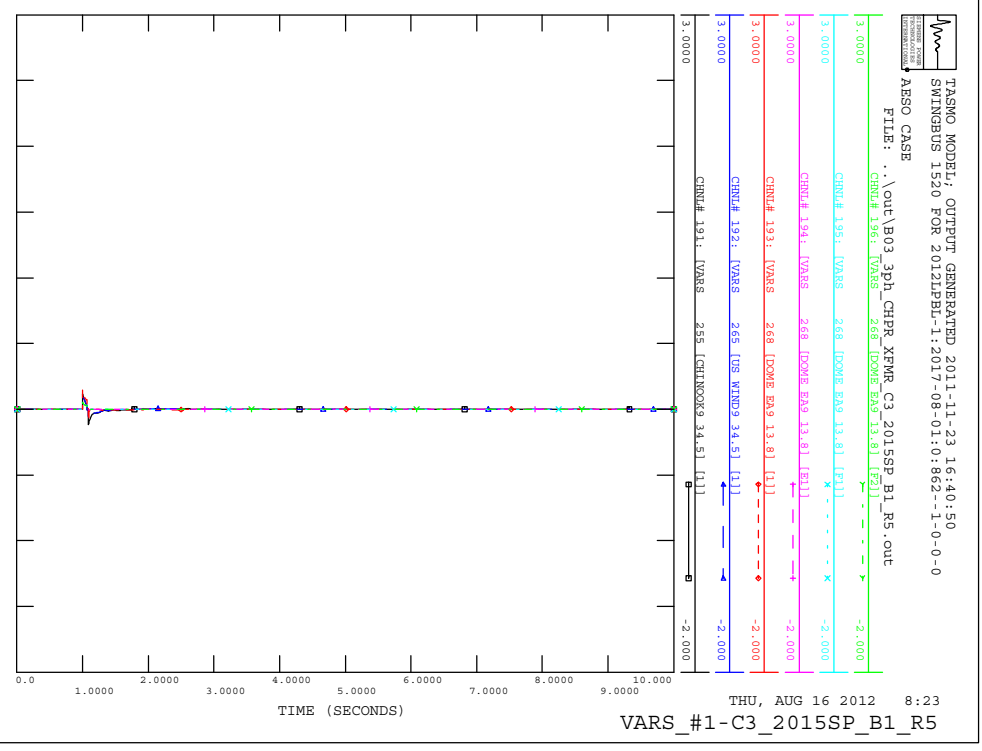
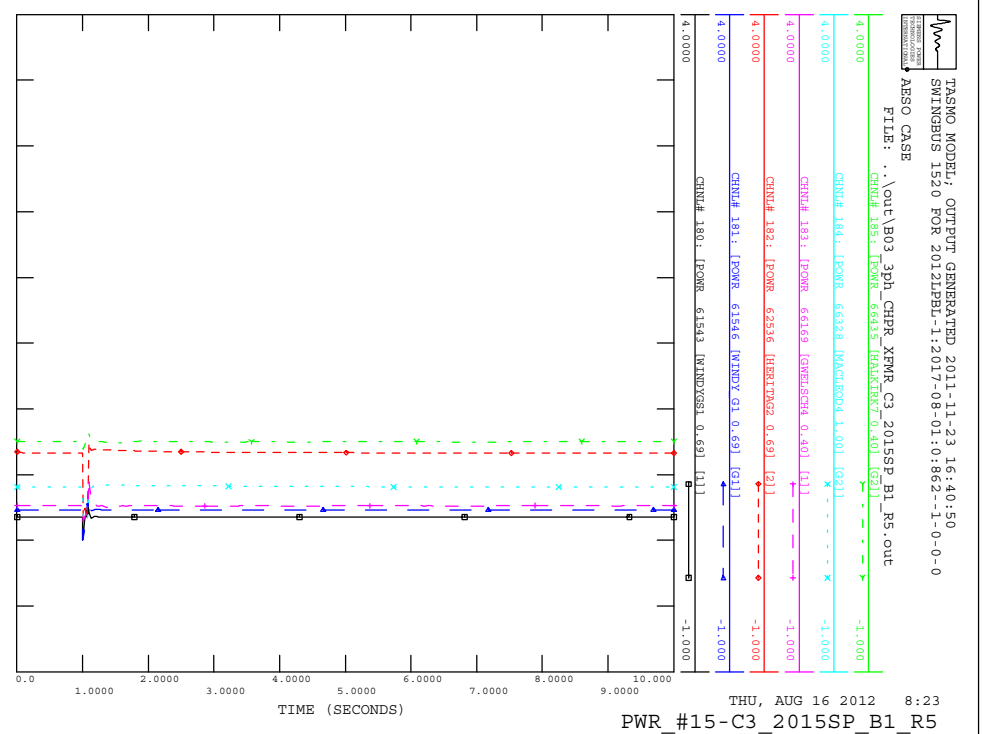


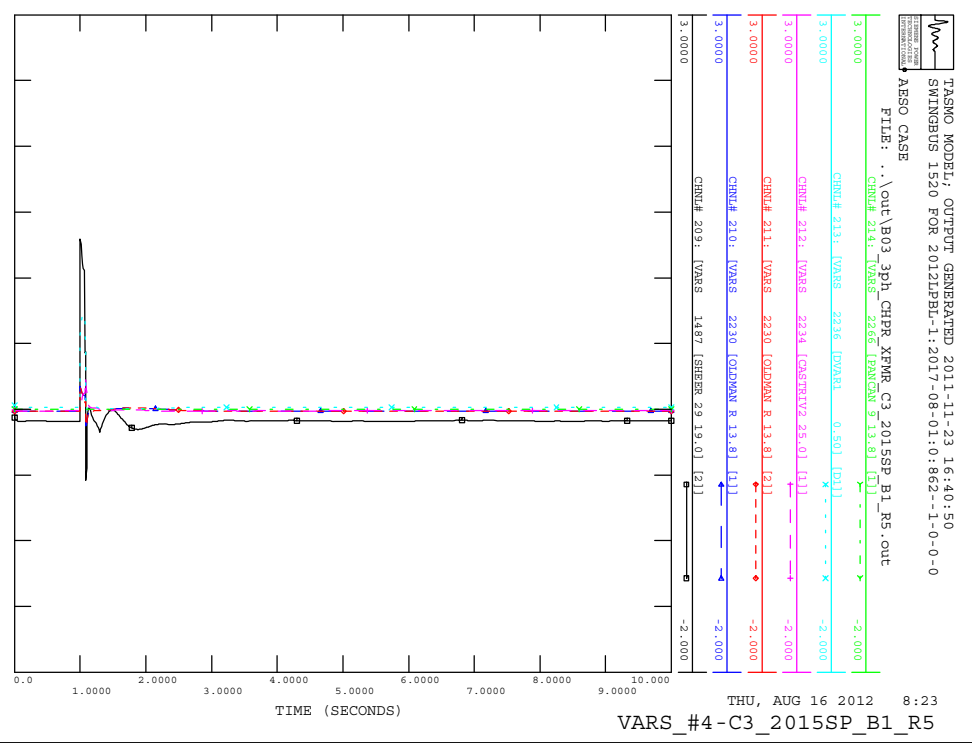
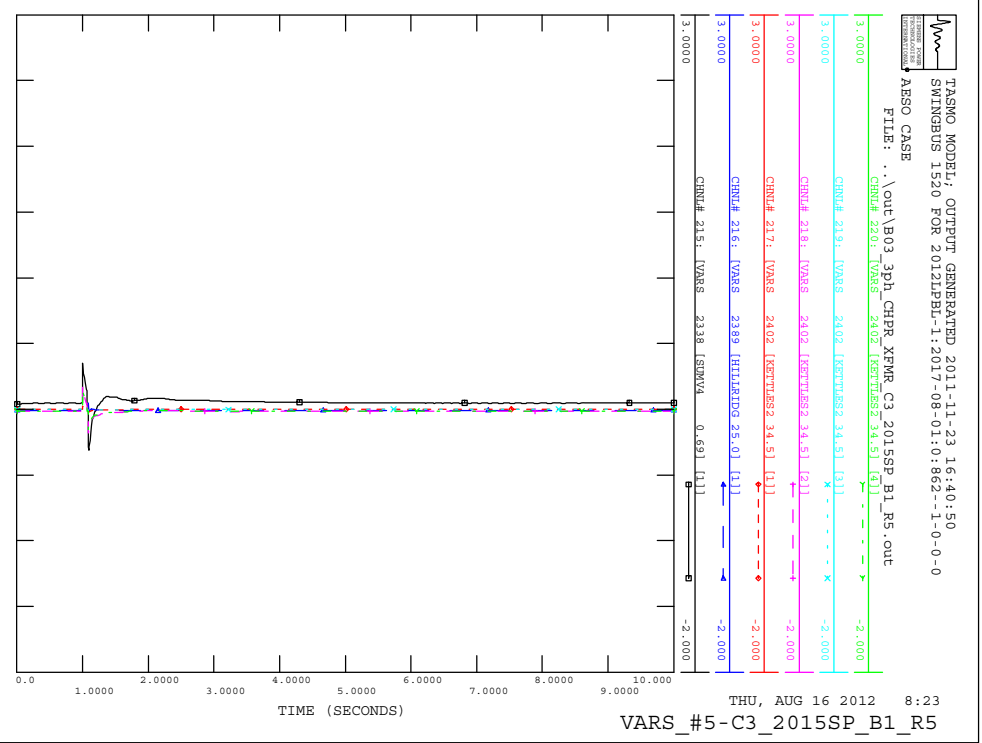
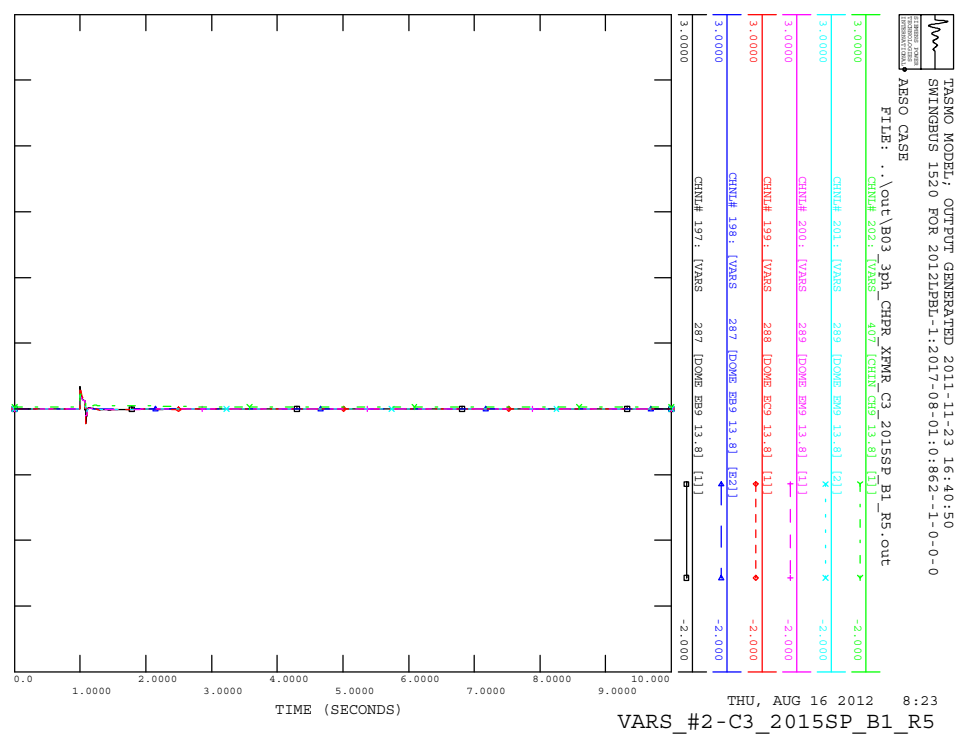
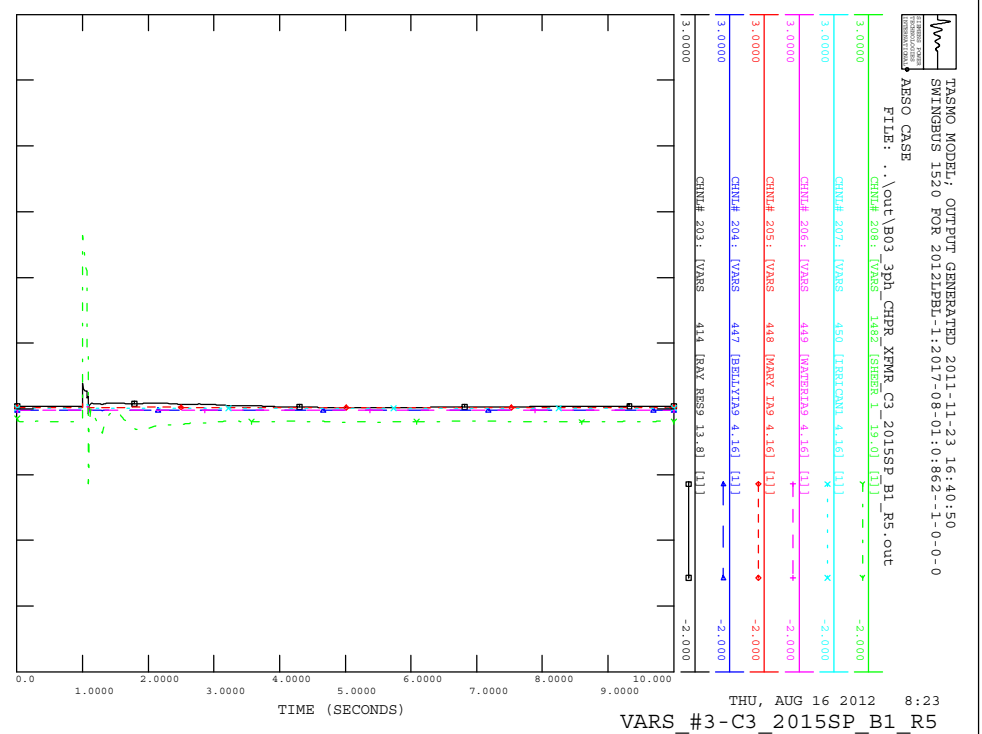


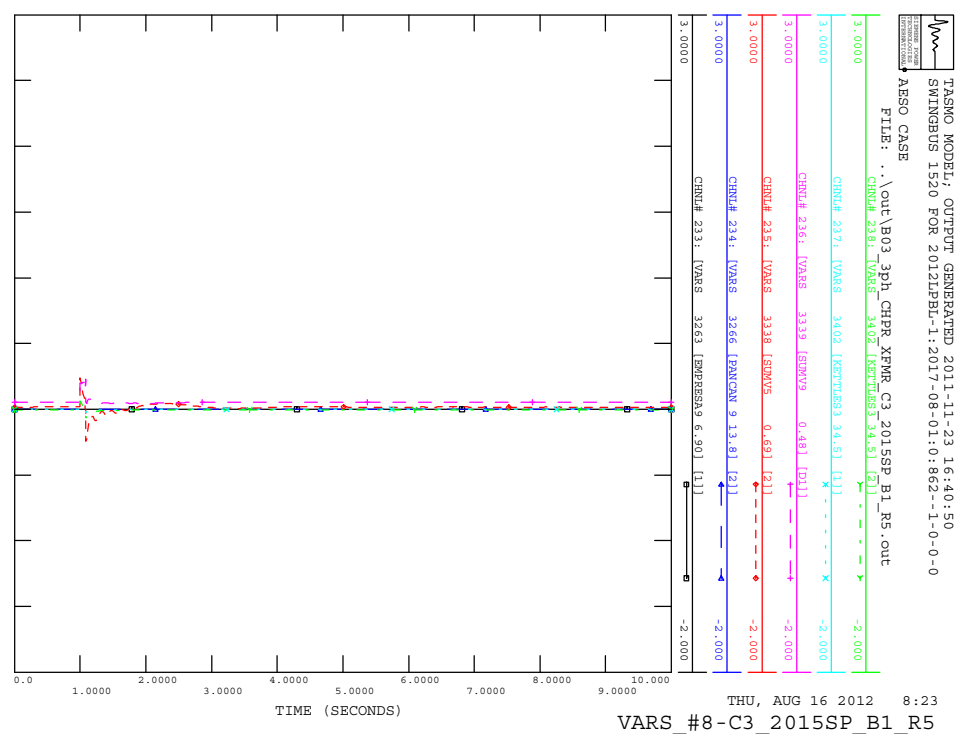
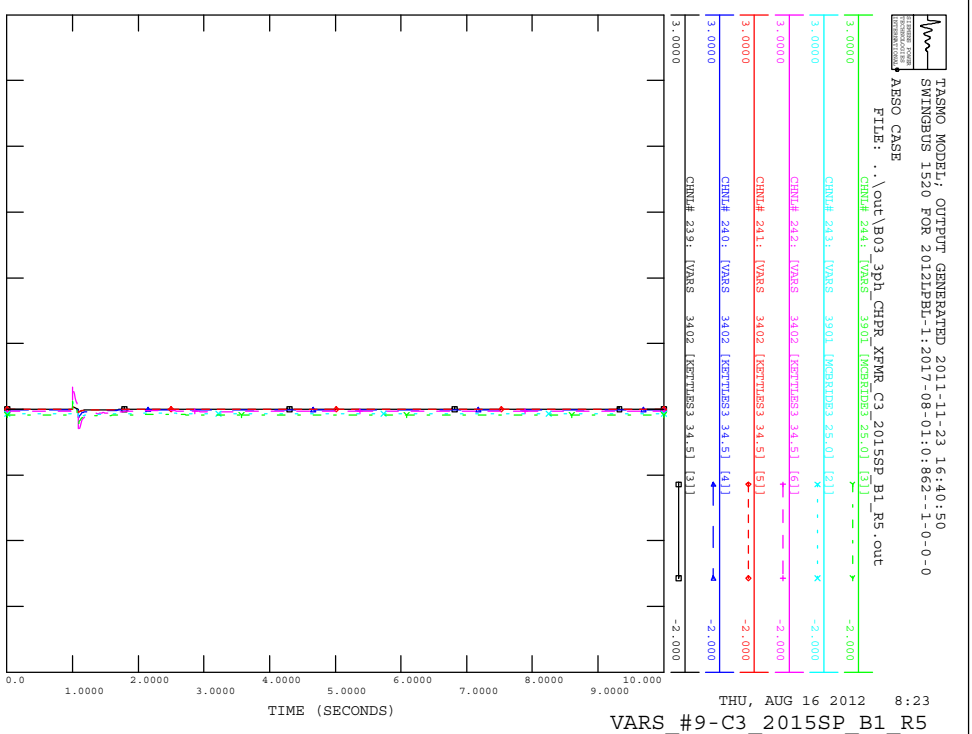
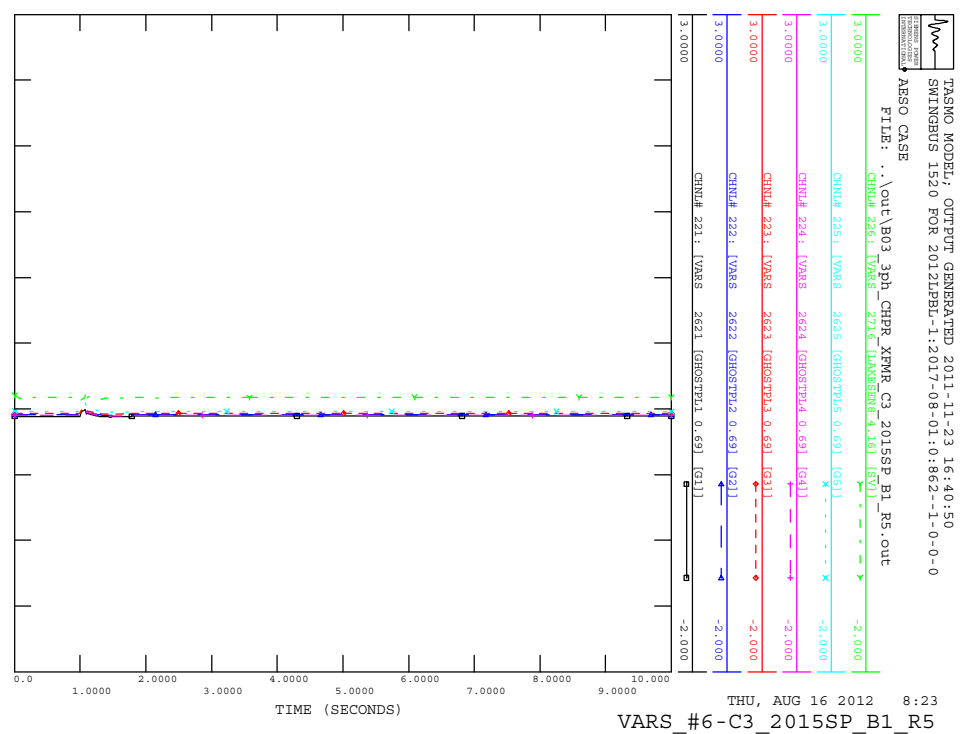
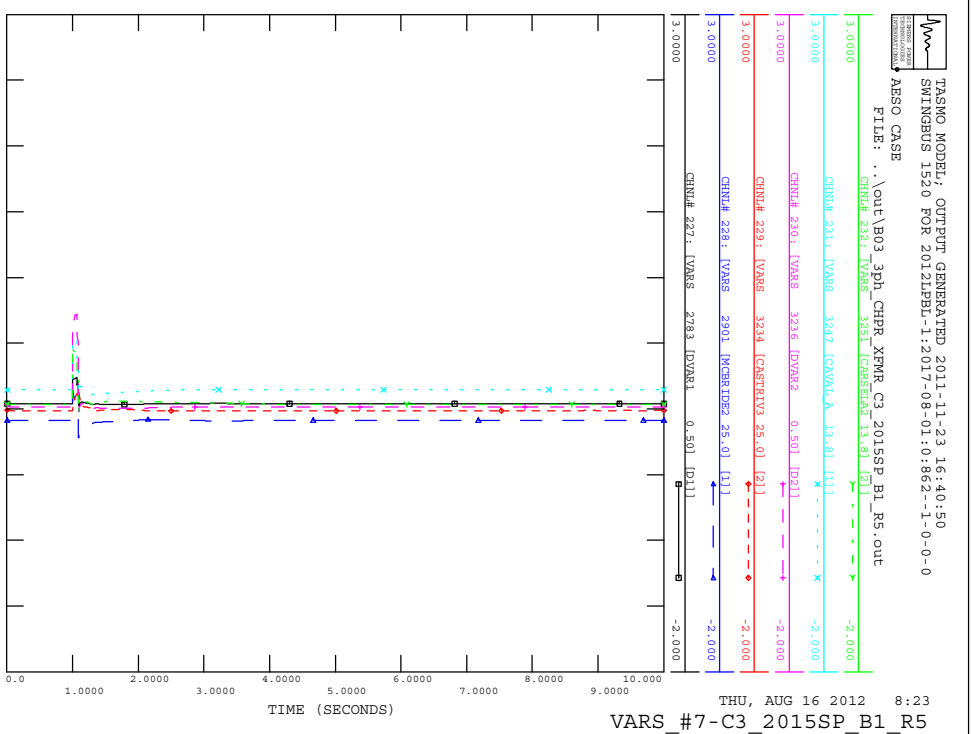


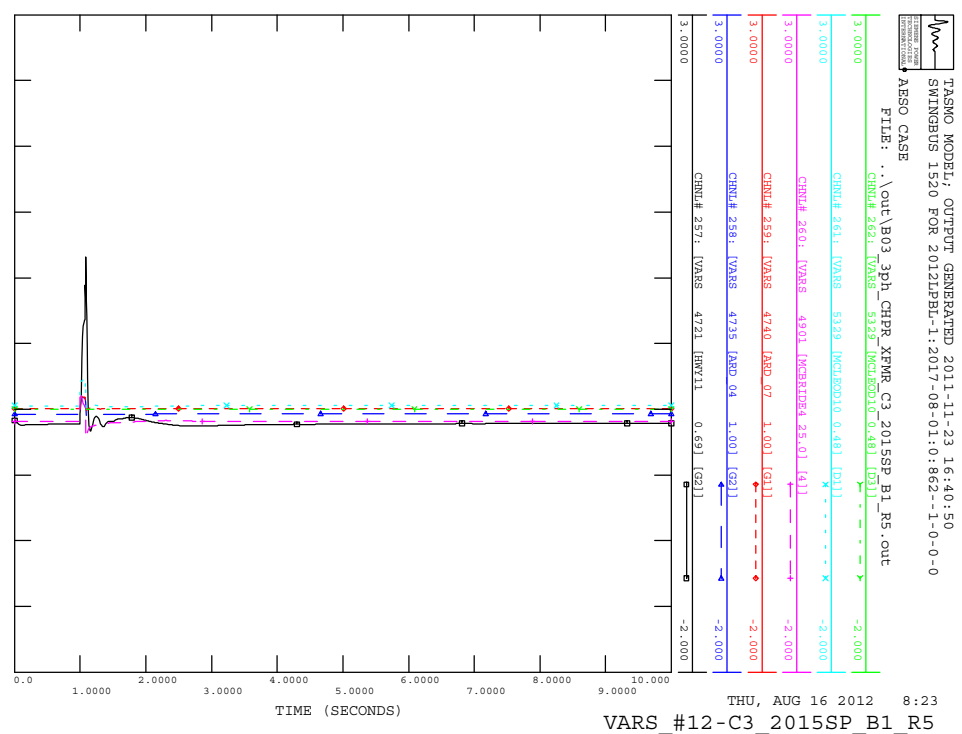
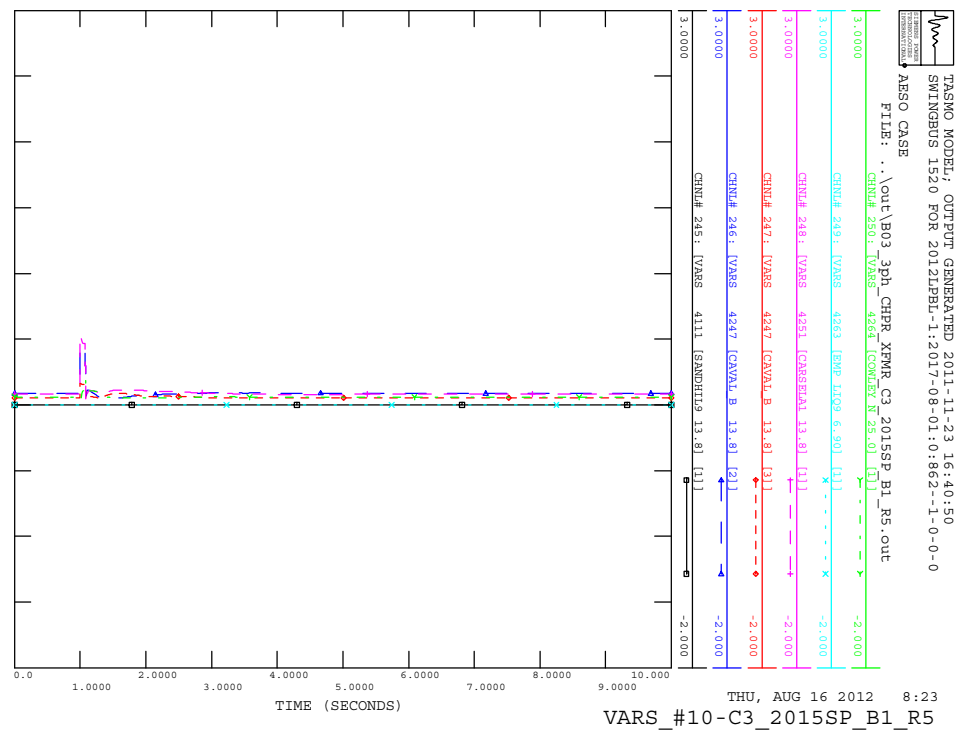
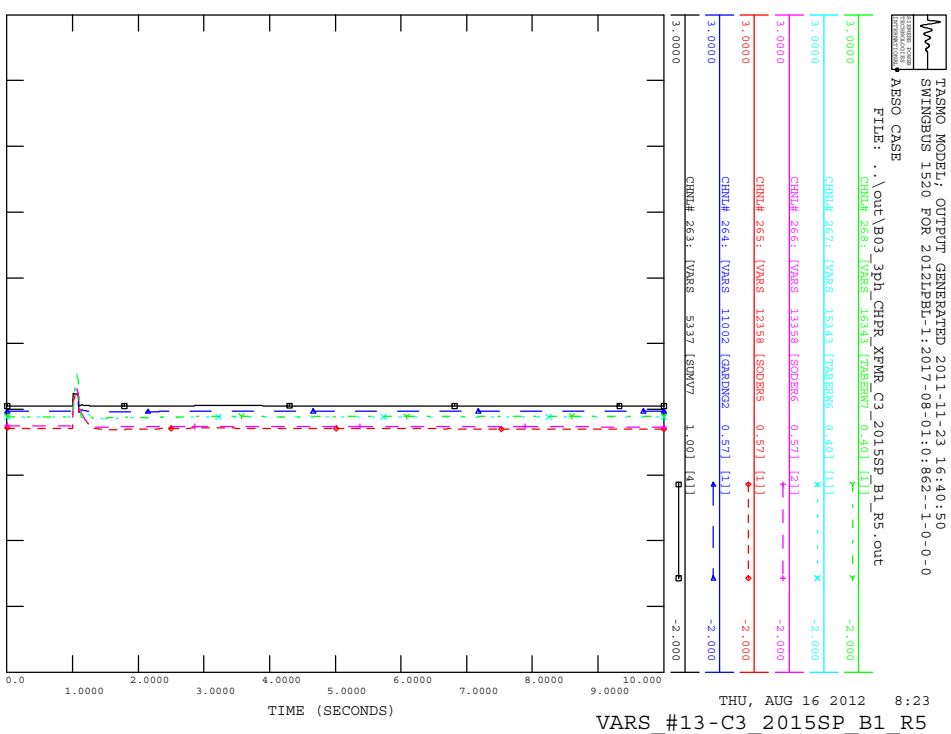
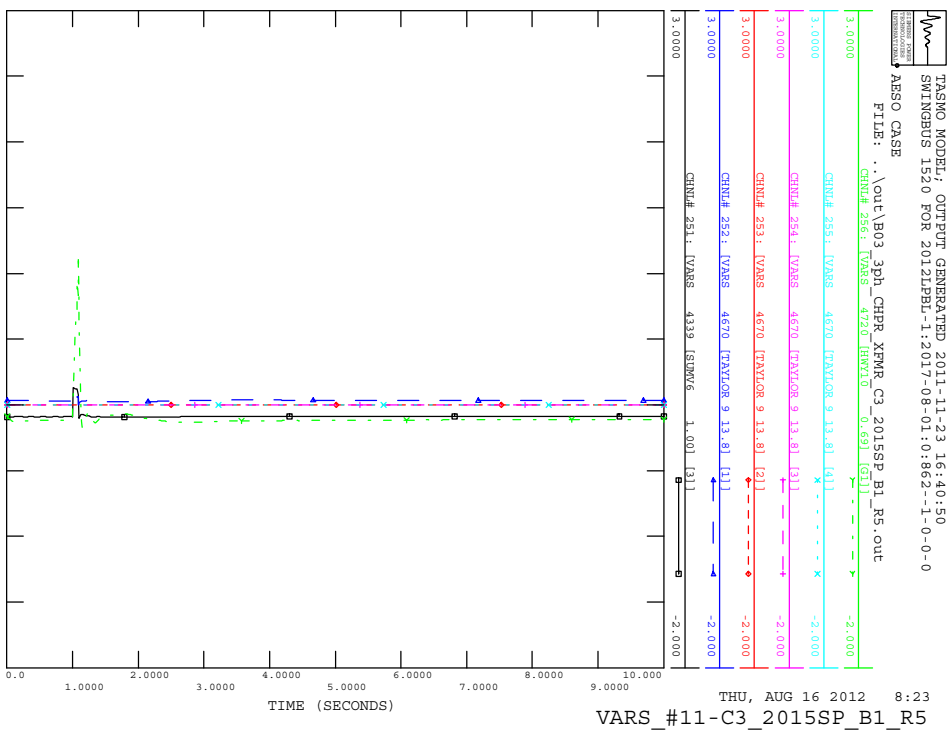


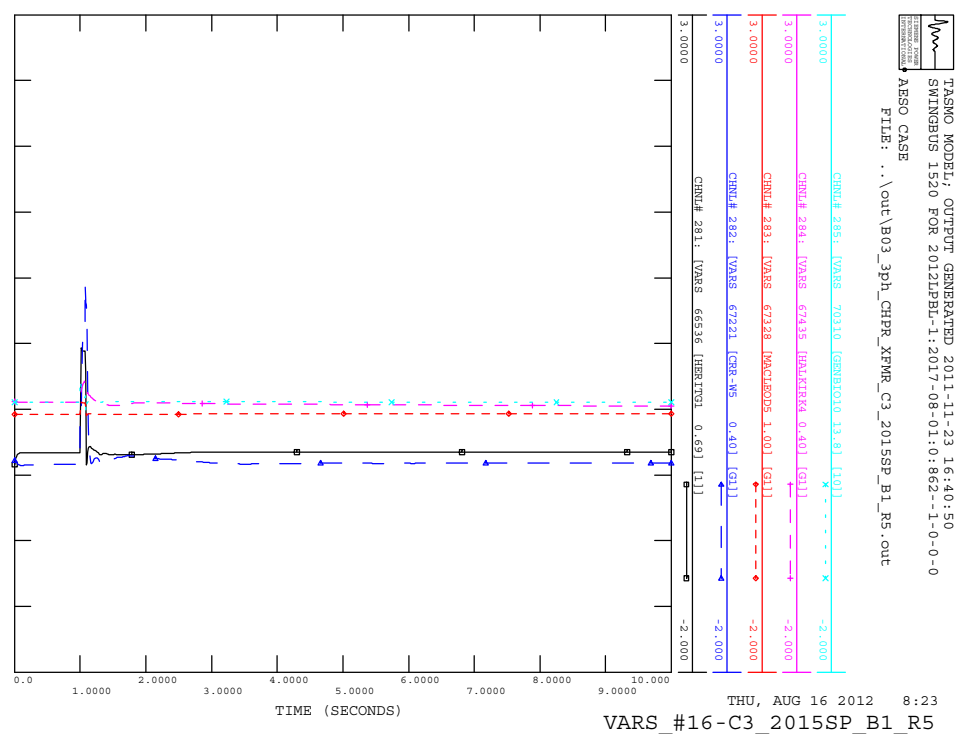
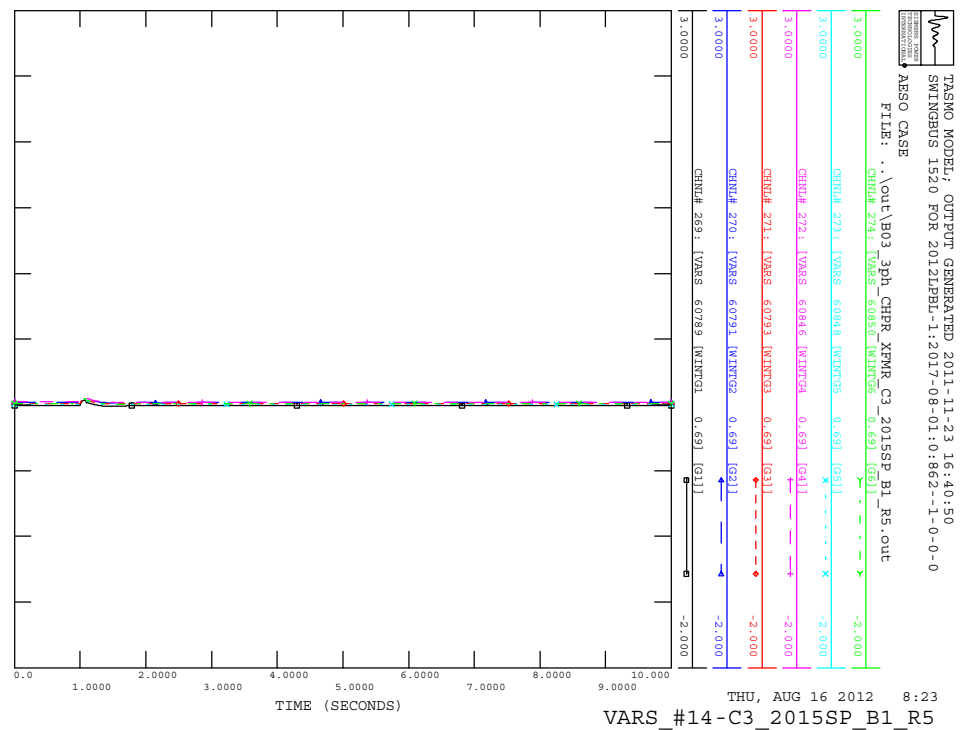
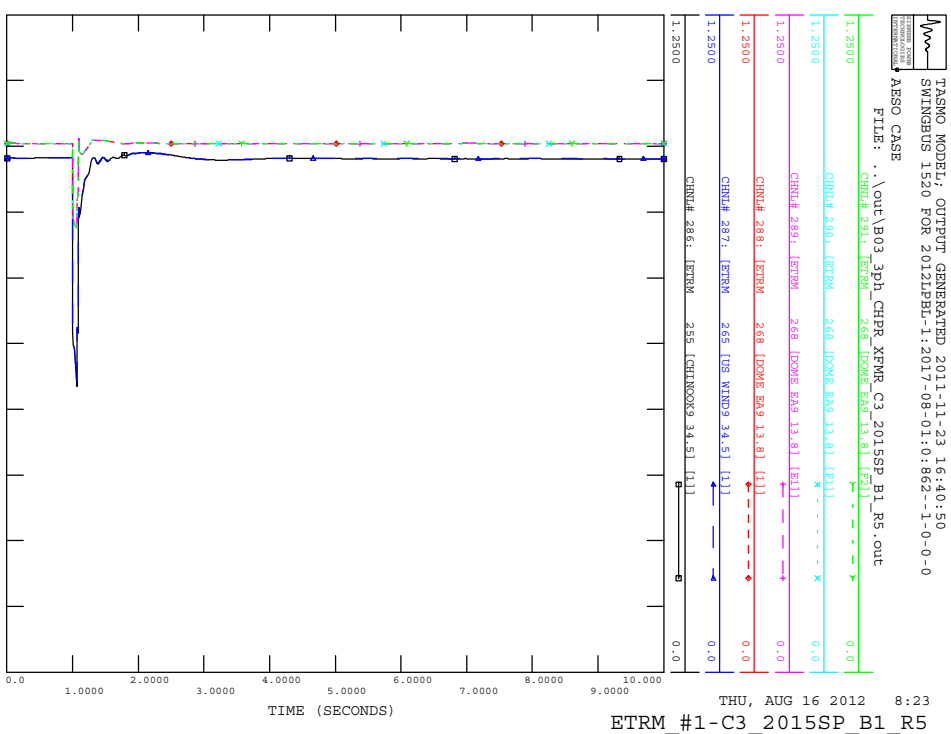
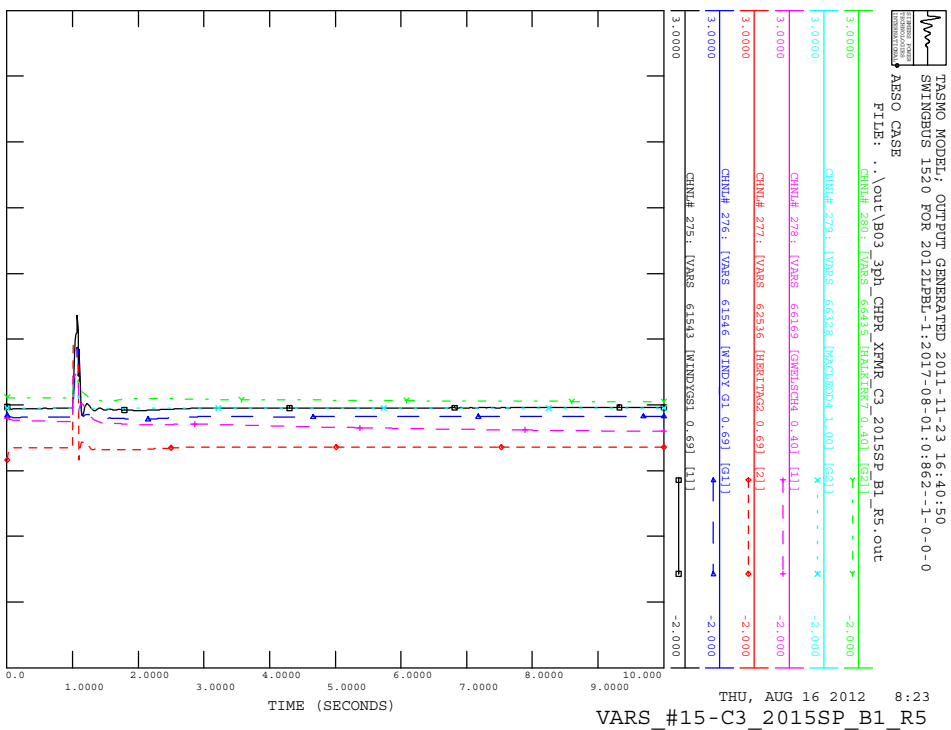


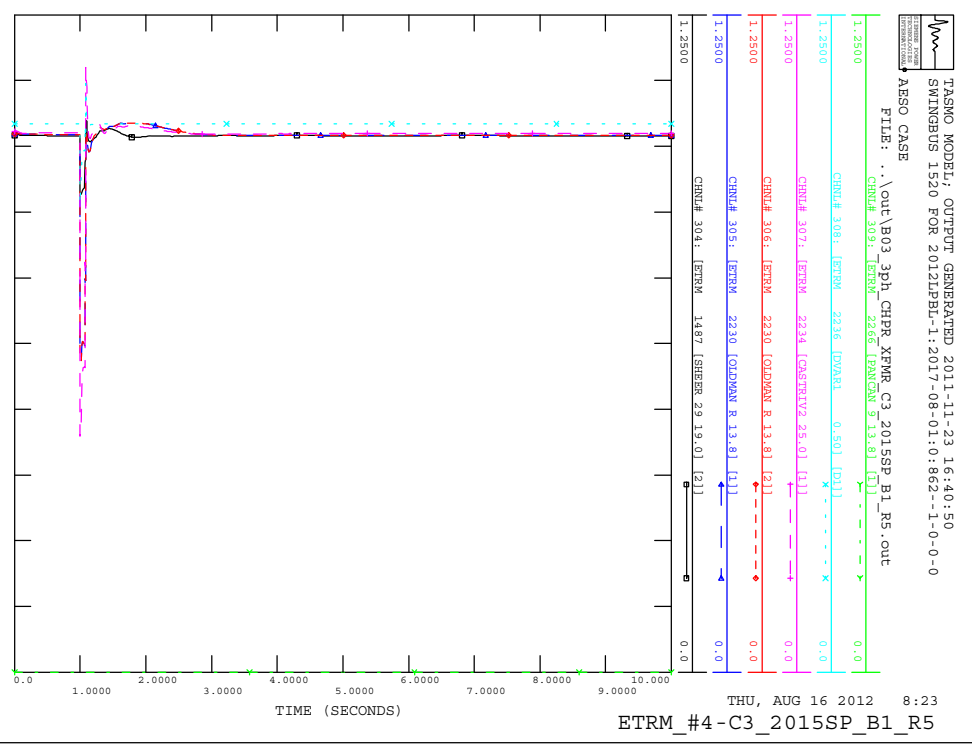
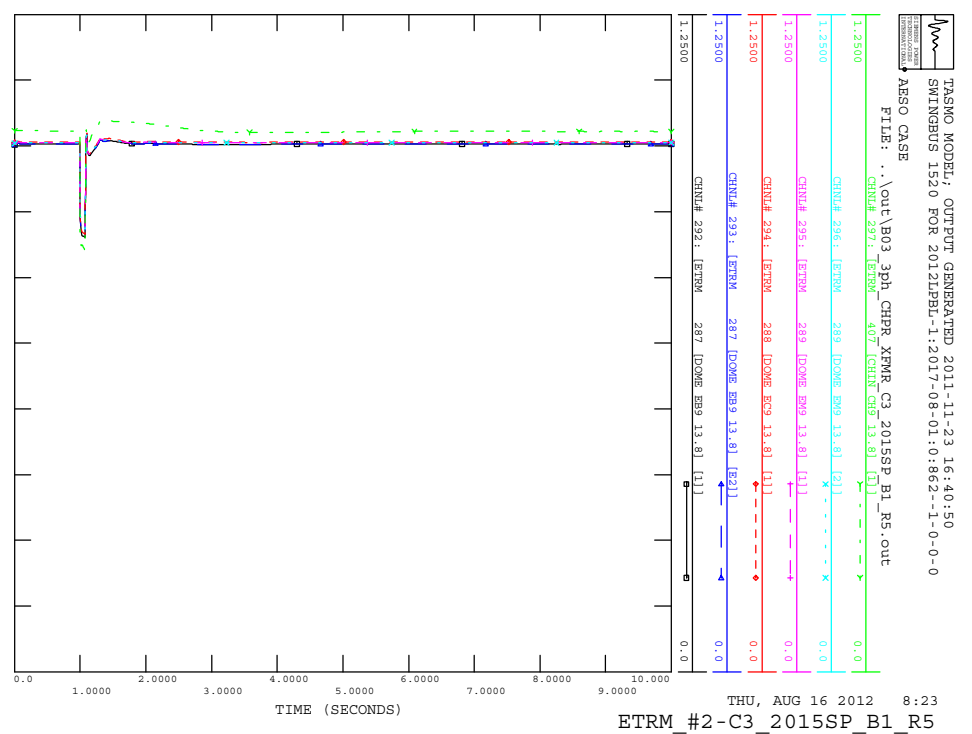
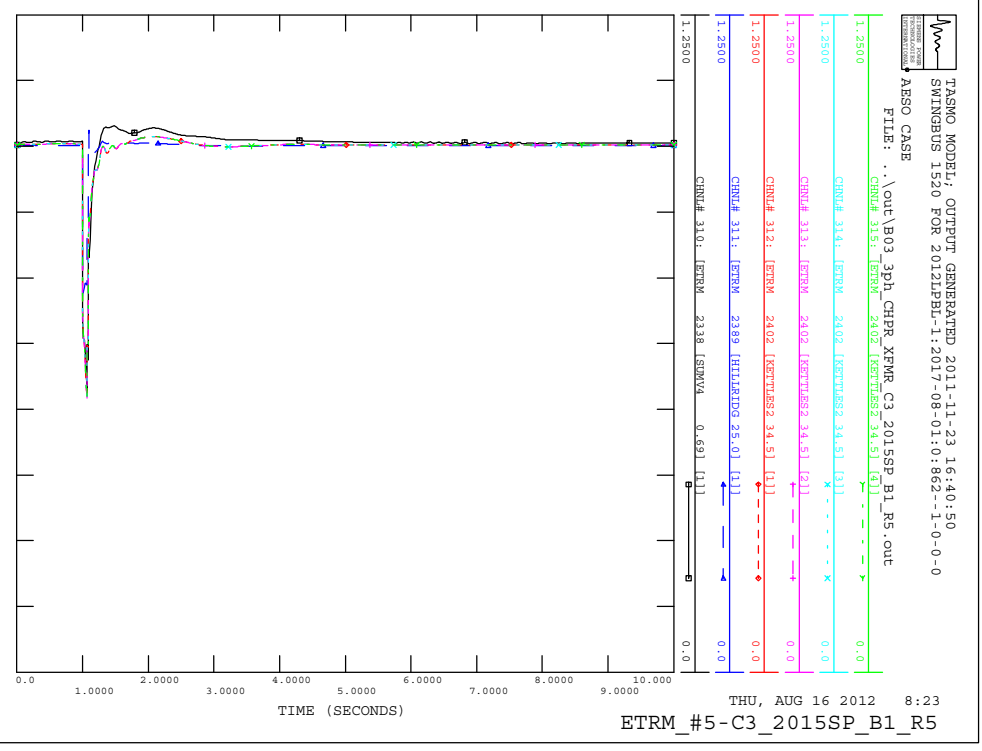
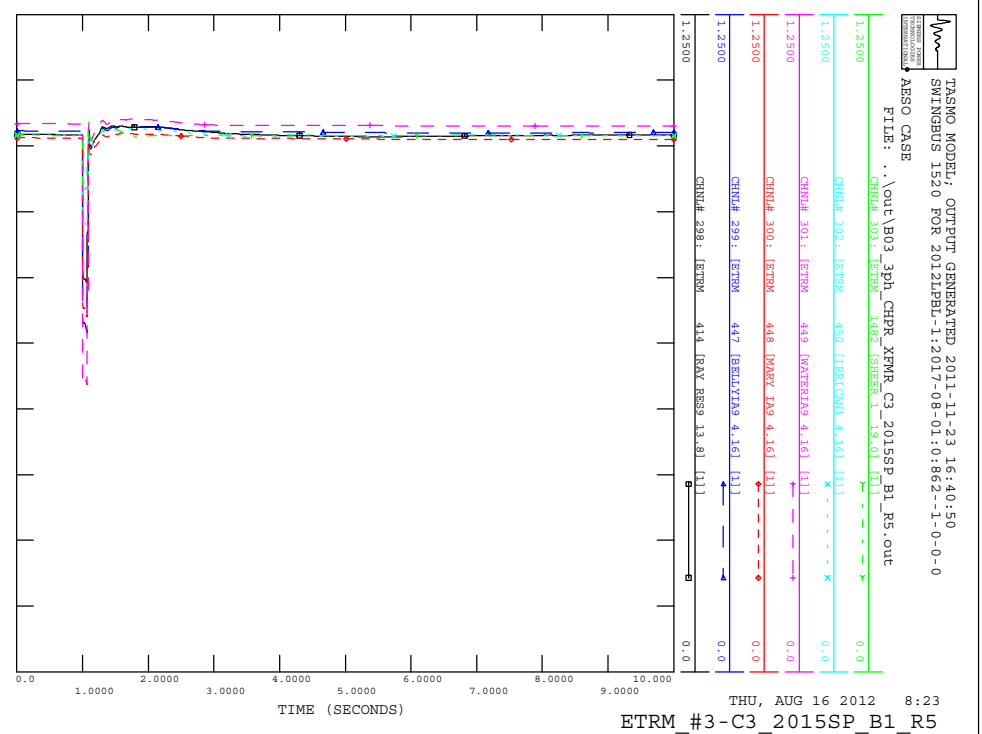


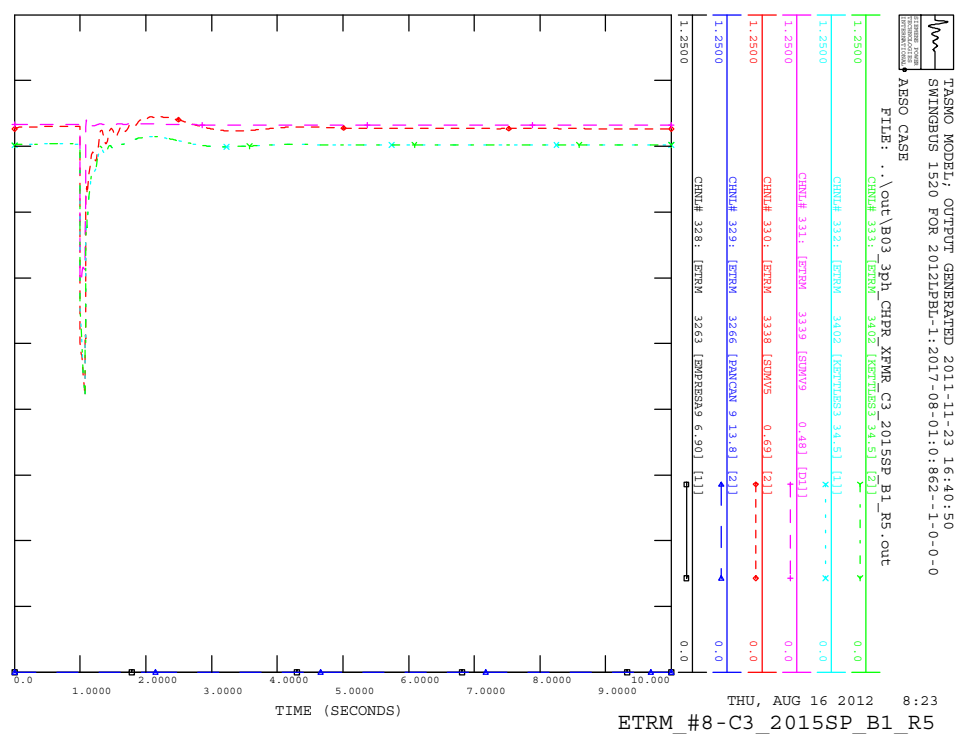
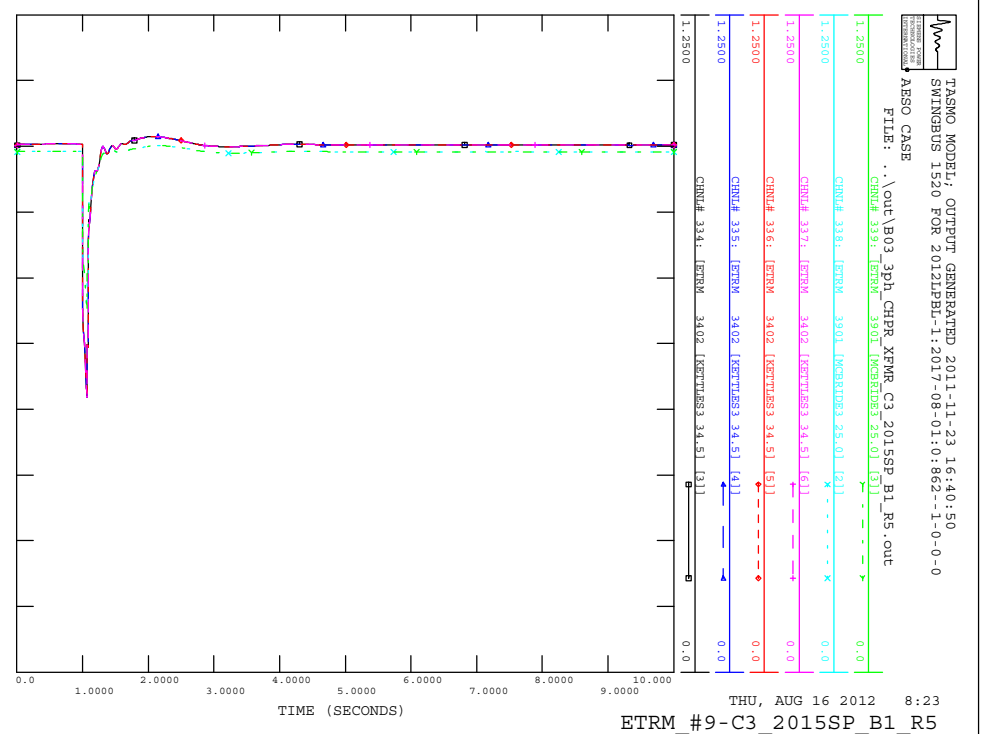
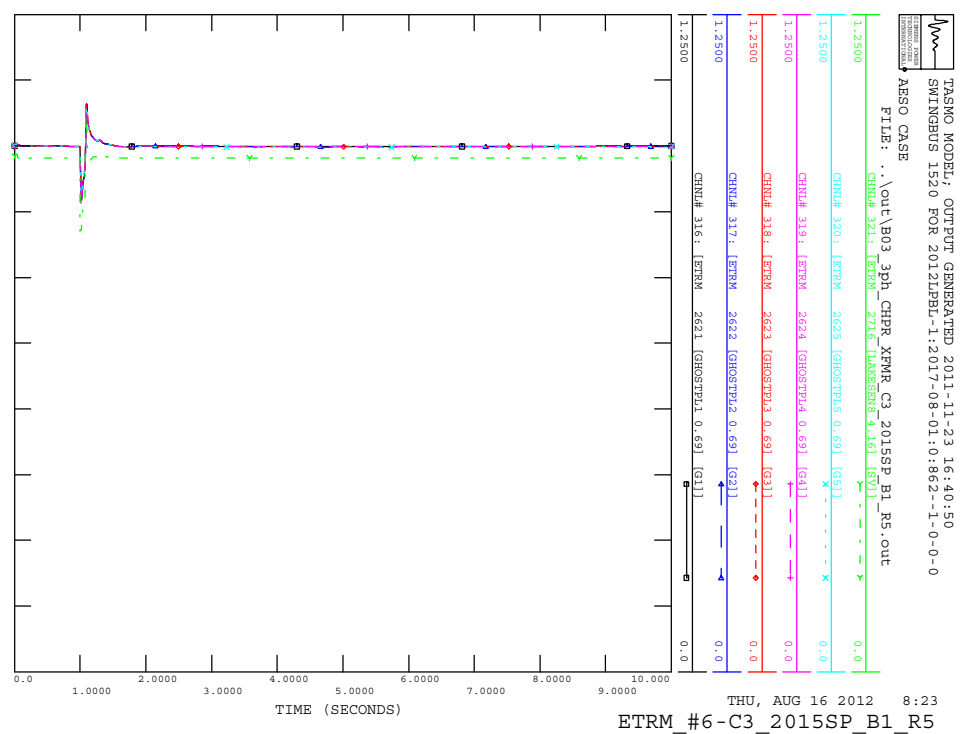
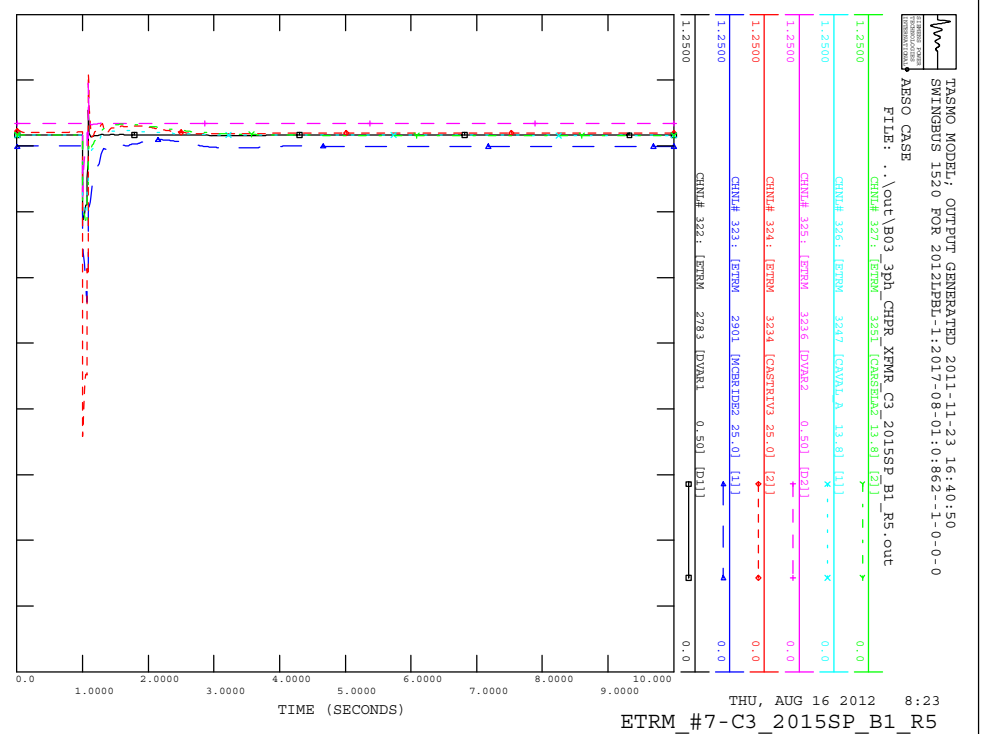


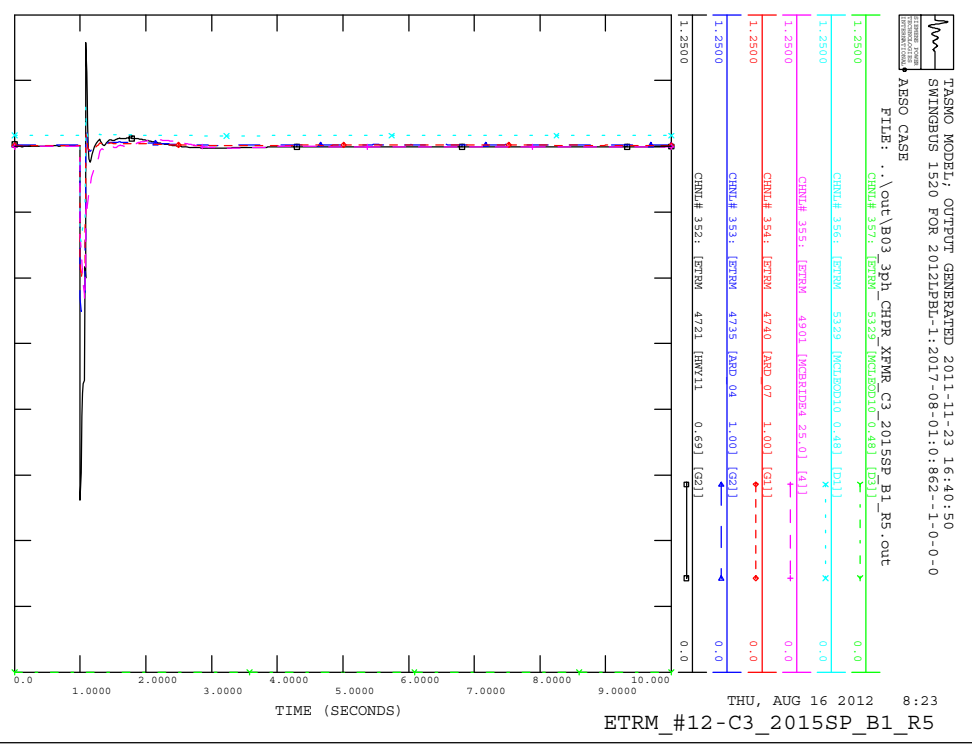
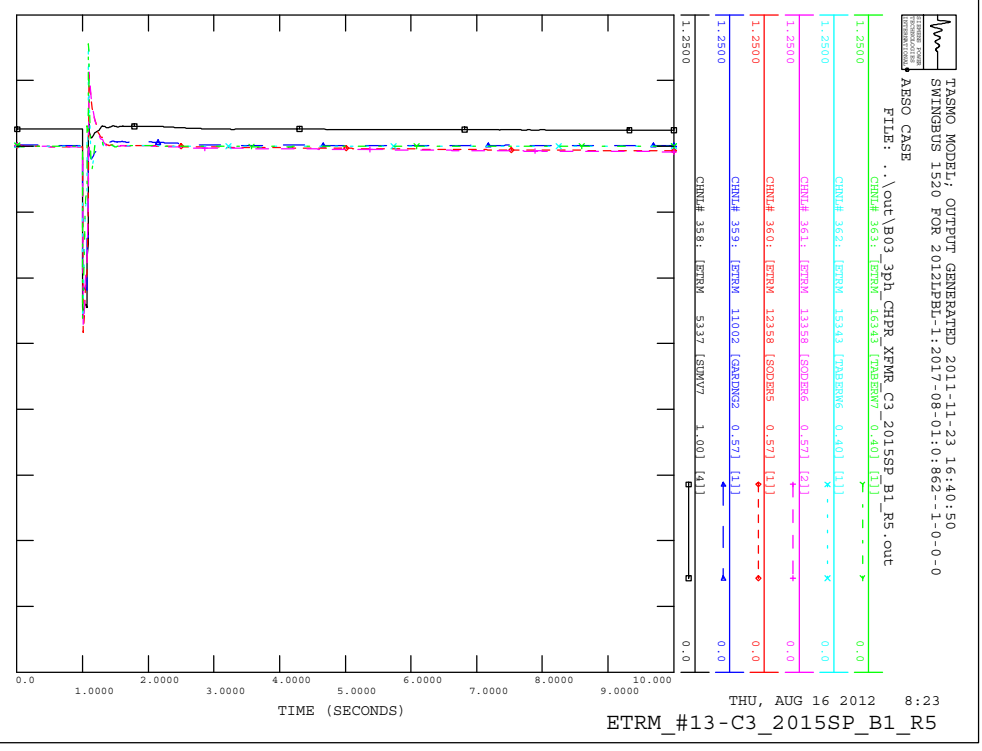
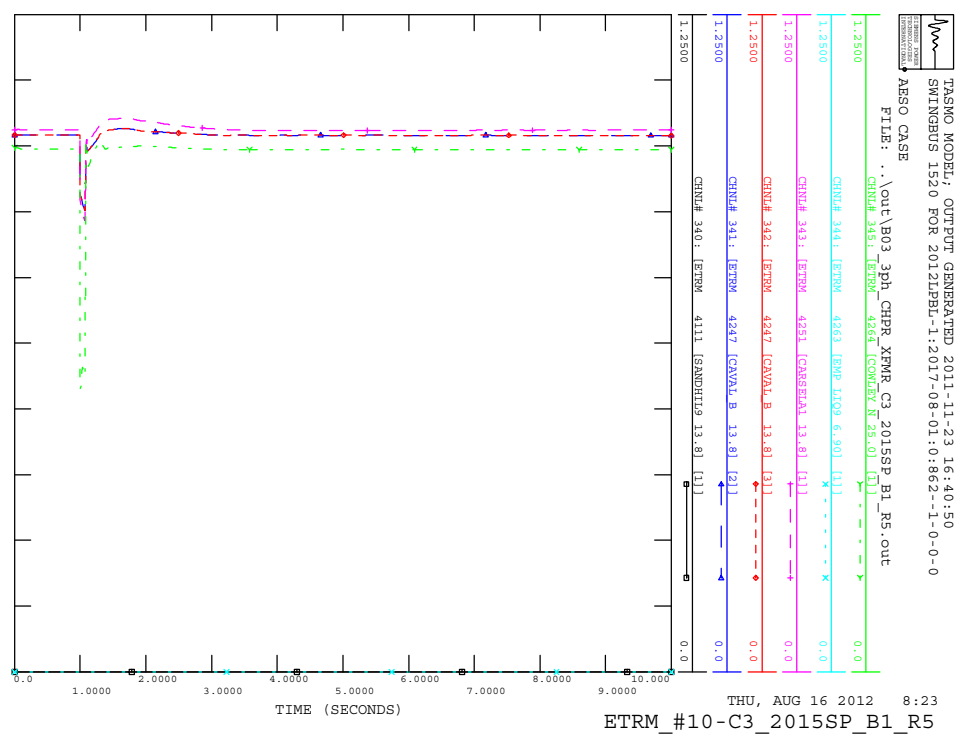
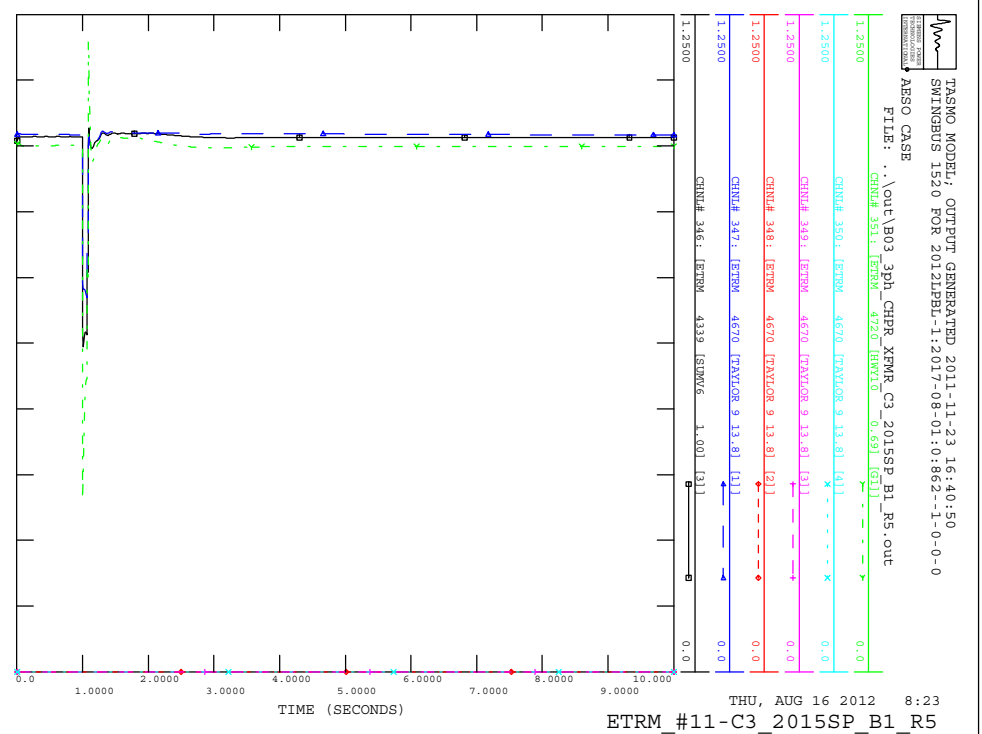


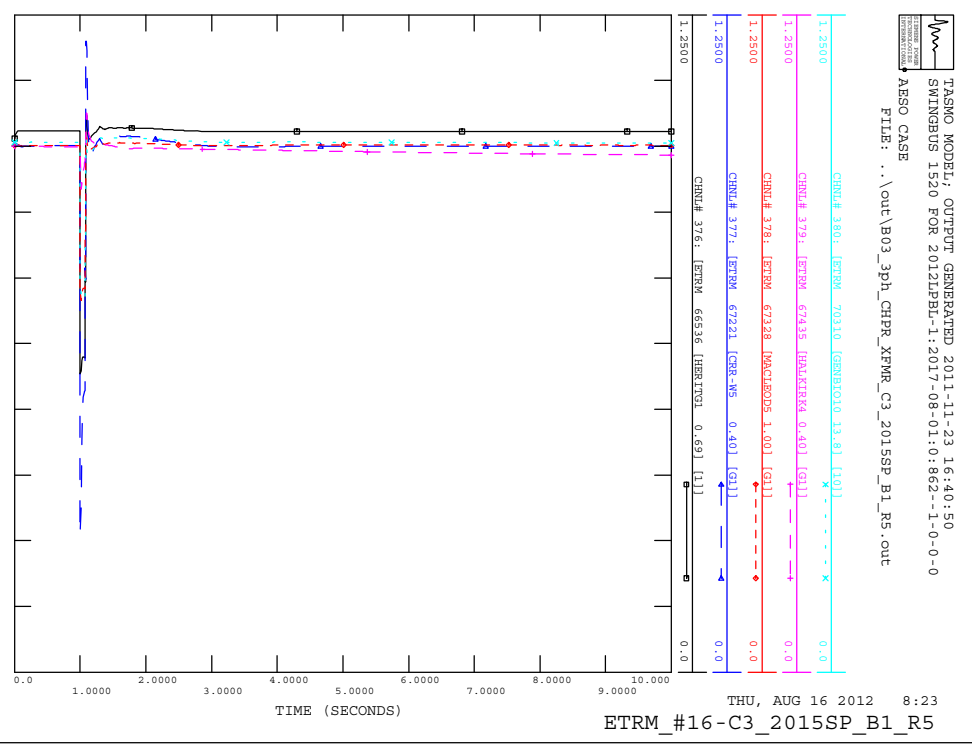
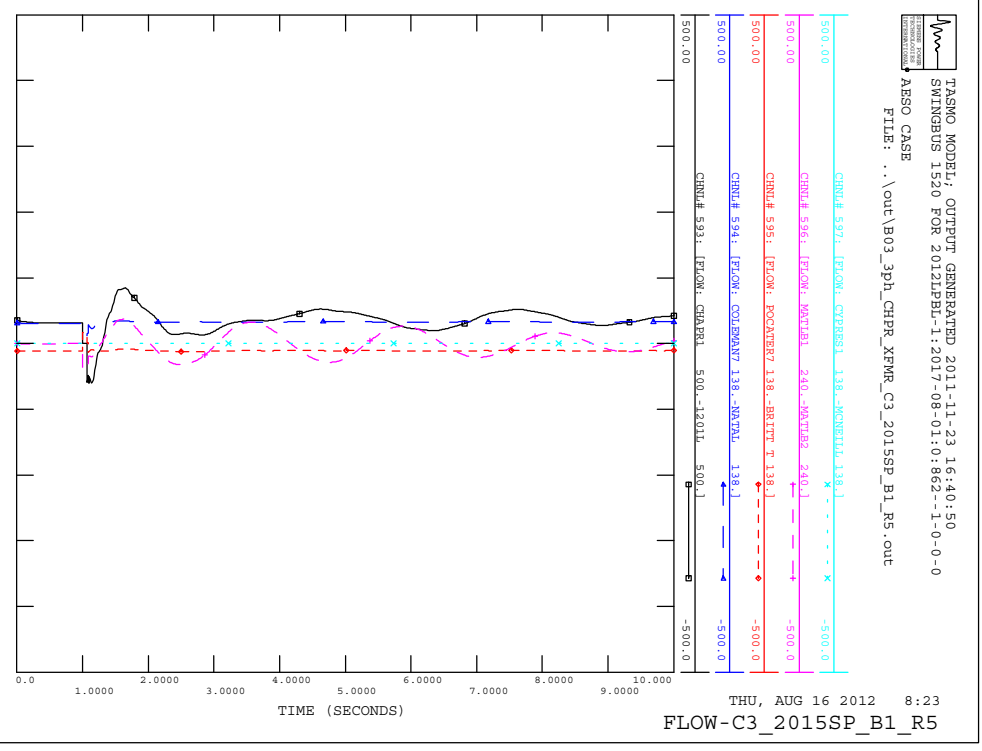
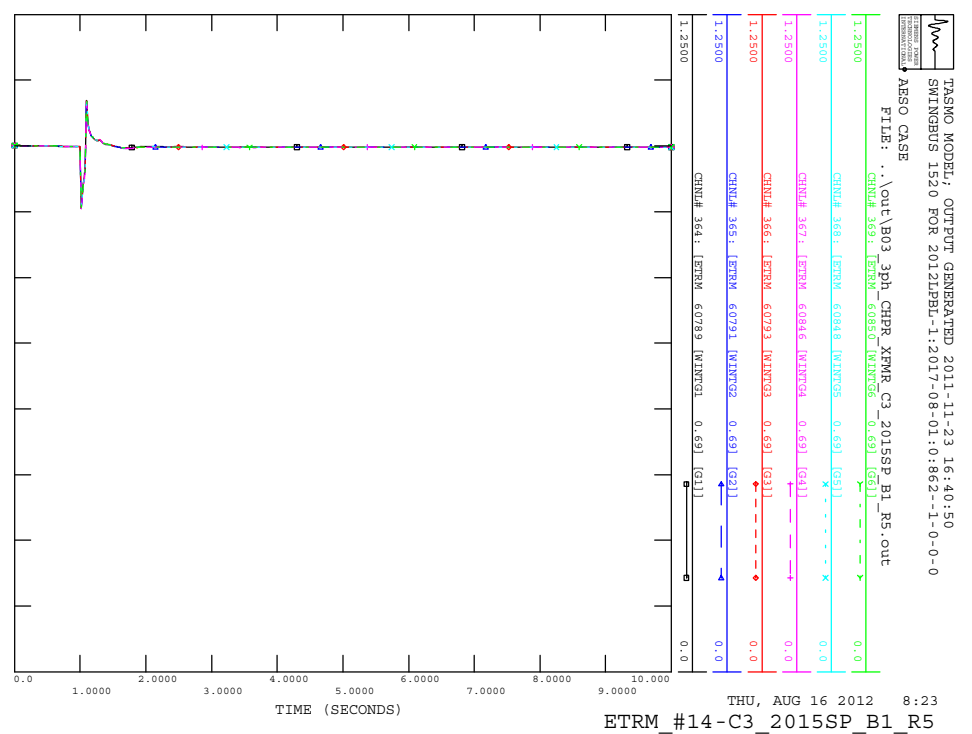
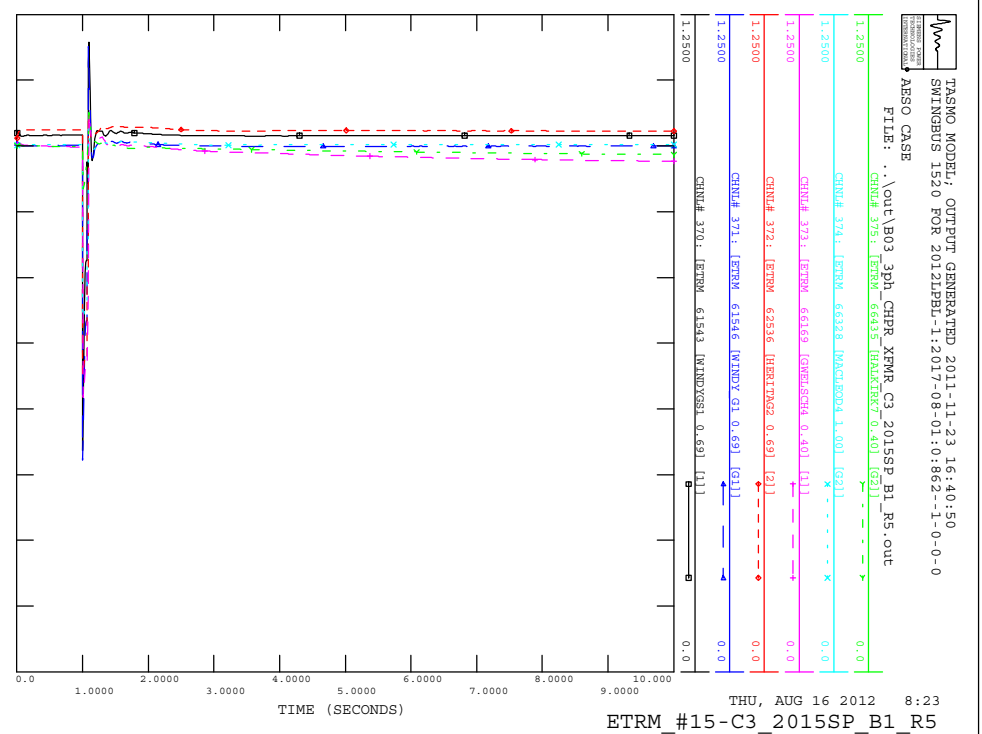


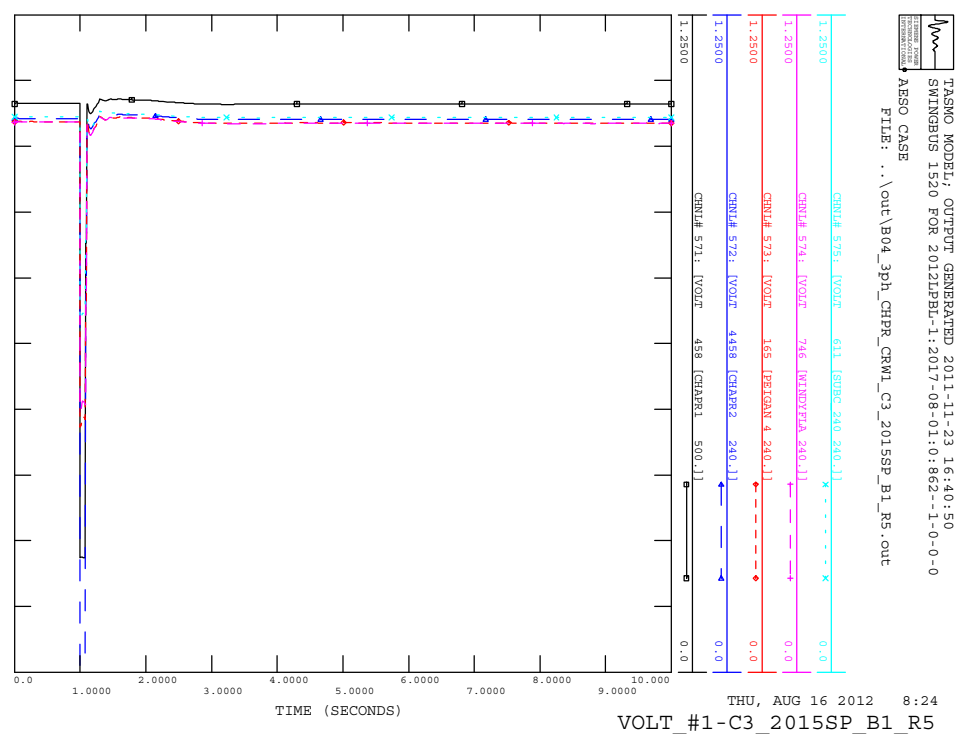
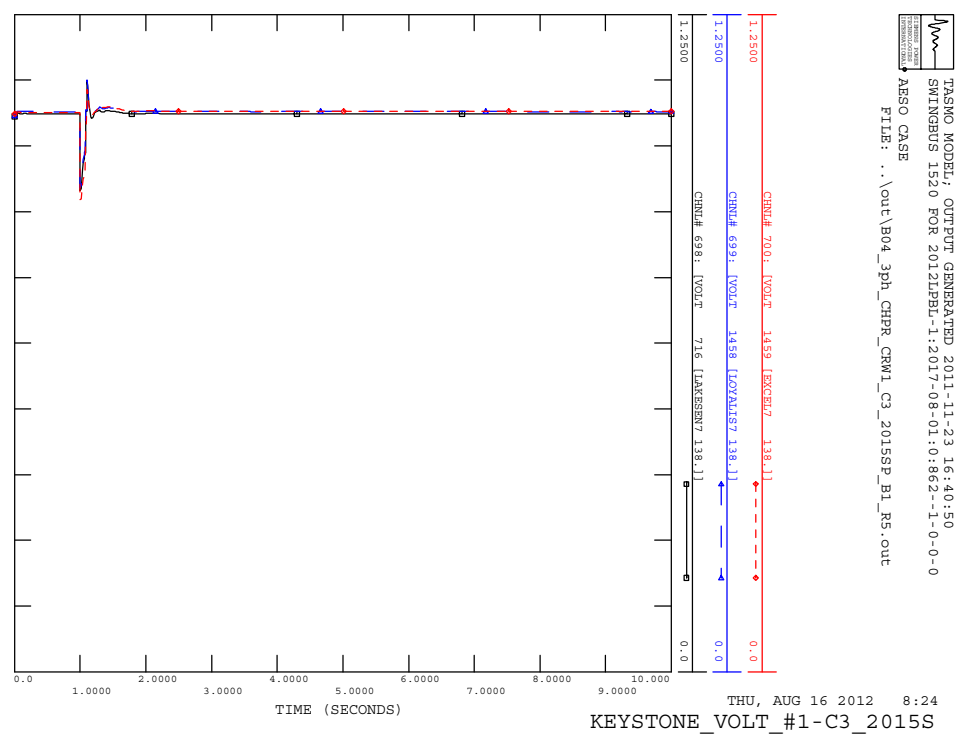
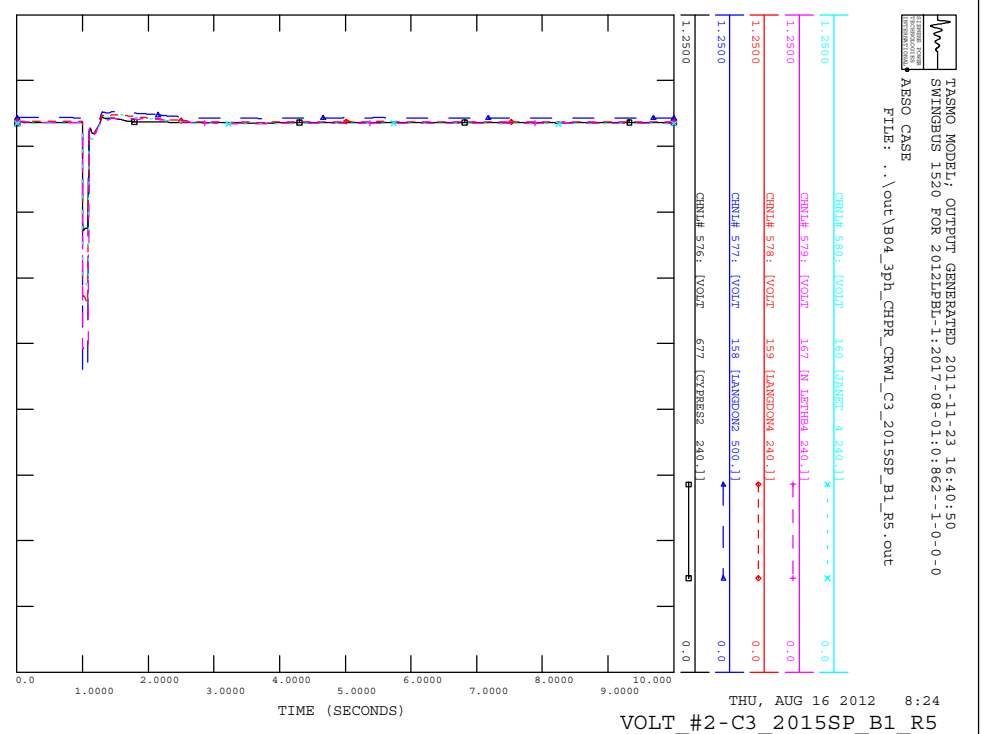
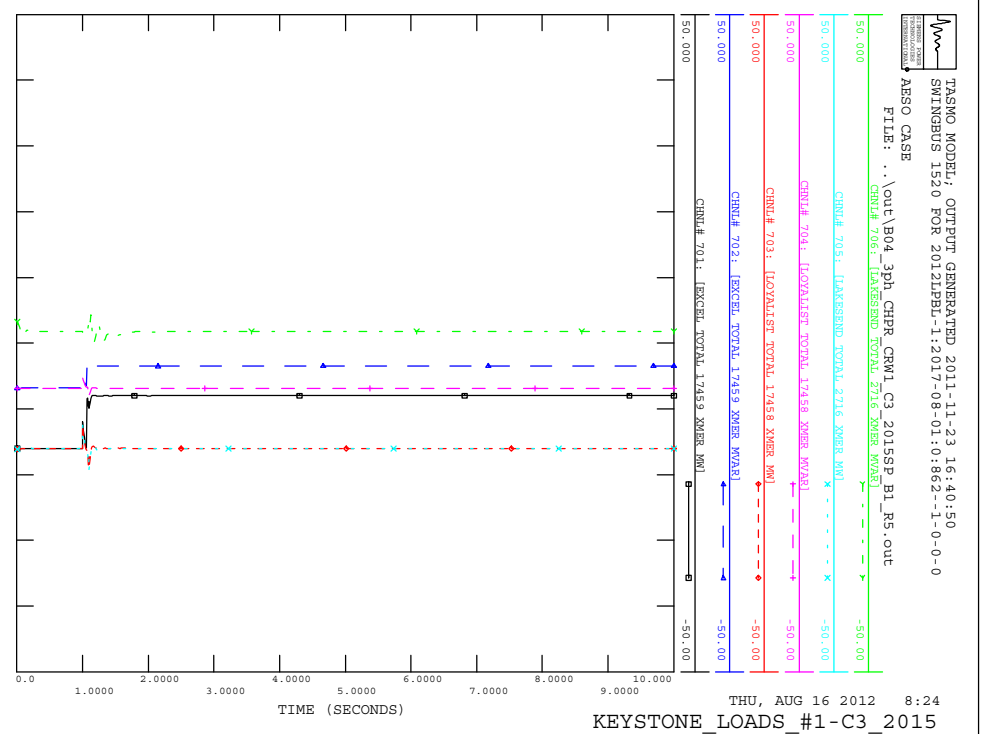












TASKO MODEL, OUTPUT GENERATED 2011-11-23 16:40:50
SWINBUS 1520 FOR 2012LPBL-1:2017-08-01:0:862--1-0-0-0
FILE: ..\out\B04_3ph_CHPR_CRW1_C3_2015SP_B1_R5.out
ABSO CASE

TASKO MODEL, OUTPUT GENERATED 2011-11-23 16:40:50
SWINBUS 1520 FOR 2012LPBL-1:2017-08-01:0:862--1-0-0-0
FILE: ..\out\B04_3ph_CHPR_CRW1_C3_2015SP_B1_R5.out
ABSO CASE

TASKO MODEL, OUTPUT GENERATED 2011-11-23 16:40:50
SWINBUS 1520 FOR 2012LPBL-1:2017-08-01:0:862--1-0-0-0
FILE: ..\out\B04_3ph_CHPR_CRW1_C3_2015SP_B1_R5.out
ABSO CASE

TASKO MODEL, OUTPUT GENERATED 2011-11-23 16:40:50
SWINBUS 1520 FOR 2012LPBL-1:2017-08-01:0:862--1-0-0-0
FILE: ..\out\B04_3ph_CHPR_CRW1_C3_2015SP_B1_R5.out
ABSO CASE

