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Addendum to "Dynamic Stability Assessment of Plains & Eastern Clean Line HVDC Project"

Prepared for

Clean Line Energy Partners LLC

Submitted by:
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10/15/2012

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Revision History

Date	Rev.	Description
10/15/2012	0	Initial draft

Contents

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Executive Summary

This report serves as addendum to the originally issued Plains and Eastern stability report titled “Dynamic Stability Assessment of Plains & Eastern Clean Line HVDC Project” that presents the main results of the stability assessment of the Plains & Eastern HVDC project (the Project) connecting the 345 kV Hitchland substation in SPS territory to the 500 kV Shelby substation in TVA territory, for the delivery of 3,500 MW of wind turbine generation.

As a result of the September 26, 2012 discussions of the stability results between Clean Line Energy Partners LLC (Clean Line), SPP Staff, and the potentially affected parties (the Affected Parties,) two additional aspects were identified for further study:

- Evaluation of the transient current increase on key underlying SPP 345 kV lines following the sudden loss of both poles on the 2022 Summer Peak case, with the objective of evaluating the possibility of the protection tripping of these lines.

- Sensitivity to system performance with reduced project generation of 1,750 MW (half of the proposed project wind generation) on 2017 Light Load case

The results presented in this report show that the expected maximum transient currents should not result in the tripping of the affected lines due to actuation of the protection and that the case with reduced generation results in stable responses for both angular and voltage.

Section

1

Introduction

Siemens PTI evaluated the stability performance of Plains & Eastern HVDC project (the Project) designed to transport approximately 3,500 MW of wind turbine generation to the to the 500 kV Shelby substation in TVA from the 345 kV Hitchland substation in SPP

As a result of the discussions of the results with Clean Line Energy Partners LLC (Clean Line) and with a committee made of the potentially affected parties by the Project (the Affected Parties,) two additional aspects were identified for further study:

- Evaluation of the transient current increase on key underlying SPP 345 kV lines following the sudden loss of both poles on the 2022 Summer Peak case, with the objective of evaluating the possibility of the protection tripping of these lines.
- Sensitivity to system performance with reduced project generation of 1,750 MW (half of the proposed project wind generation) on 2017 Light Load case (most severe condition.)

This report serves as addendum to the originally issued Plains and Eastern stability report titled “Dynamic Stability Assessment of Plains & Eastern Clean Line HVDC Project” and it is organized as follows:

Section 1: Introduction (this section)

Section 2: Presents results of the transient current flow analysis for selected contingencies on 2022 Summer Peak case.

Section 3: Presents results of double pole outage on 2017 Light Load case with reduced project generation.

Section

2

Transient Current Flow Analysis

In extreme conditions, such as double pole outages, all the project wind generation, 3798.9 MW (as modeled), flows into the SPP system resulting in increased currents along the lines electrically close to the project. This sudden increase in current peaks might be of interest from protection point of view and this section presents the analysis of the transient current flows along the nearby lines for selected faults.

Table 2-1 shows the selected faults that create significant increase in currents along the lines close to the project. These faults are tested against 2022 Summer Peak case as it is the severe loading condition[1].

Table 2-1 Faults Simulated for the Current Flow Analysis

3 Phase Faults, Normal Clearing			
No	Type	Description	kV
3	3ph, single pole blocked	SPP_PE_HVDC 765097 - TVA_PE_HVDC 765021	345
4	3ph, single pole blocked	TVA_PE_HVDC 765022 - SPP_PE_HVDC 765097	500
68	3ph, both poles blocked	SPP_PE_HVDC 765097 - TVA_PE_HVDC 765021	345
69	3ph, both poles blocked	TVA_PE_HVDC 765022 - SPP_PE_HVDC 765097	500

Figure 2-1 to 2-4 show the transient current flows along the 345 kV lines near by the Hitchland area close to the project for several faults and Table 2-2 shows the peak measured currents following the clearing of the fault (first initial peak at 0.1 sec.),

In this table it can be observed that, for most faults, the maximum transient currents are at or below the lines' nominal current ratings. For Fault # 68 and # 69 for which both poles block, the transient current can be up to 135% the nominal current in the lines connecting the Project to Hitchland II and 120% in the lines Hitchland to Finney, but this peak happens for a few tenths of a second and should not result in operation of the protection; however this will be coordinated with the interconnecting utilities.

[1] See "Steady State Assessment of the Plains and Eastern Clean Line HVDC Project" prepared August 2012 and available at http://www.plainsandeasterncleanline.com/site/page/interconnection-studies

Table 2-2

Monitored 345 kV lines				Nominal Rating		Maximum Transient Current (post fault opening)							
						Fault # 3		Fault # 4		Fault # 68		Fault # 69	
From Bus		To Bus		MVA	I nominal (A)	Amps	% I nominal	Amps	% I nominal	Amps	% I nominal	Amps	% I nominal
765097	SPP_PE_HVDC	523080	HITCHLAND#2	1792	2999	2000	67%	3011	100%	4050	135%	3900	130%
523080	HITCHLAND#2	523097	HITCHLAND_7	1792	2999	500	17%	900	30%	1000	33%	1000	33%
523080	HITCHLAND#2	515375	WWRDEHV7	1792	2999	1000	33%	1400	47%	2500	83%	2500	83%
523080	HITCHLAND#2	523853	FINNEY	1052	1760	700	40%	1300	74%	2100	119%	200	119%

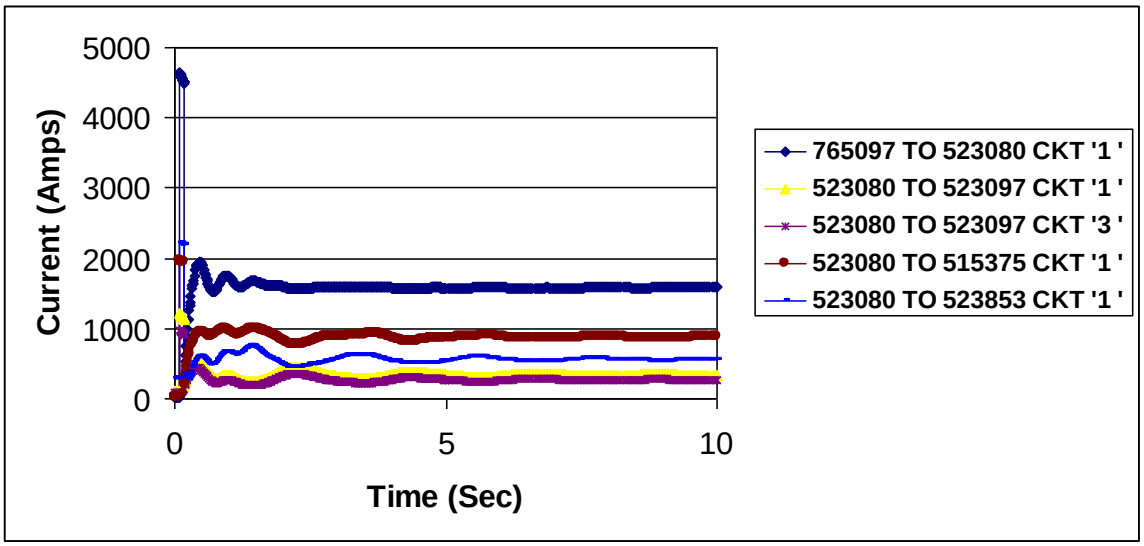

Figure 2-1 Fault # 3 – 2017 Light Load

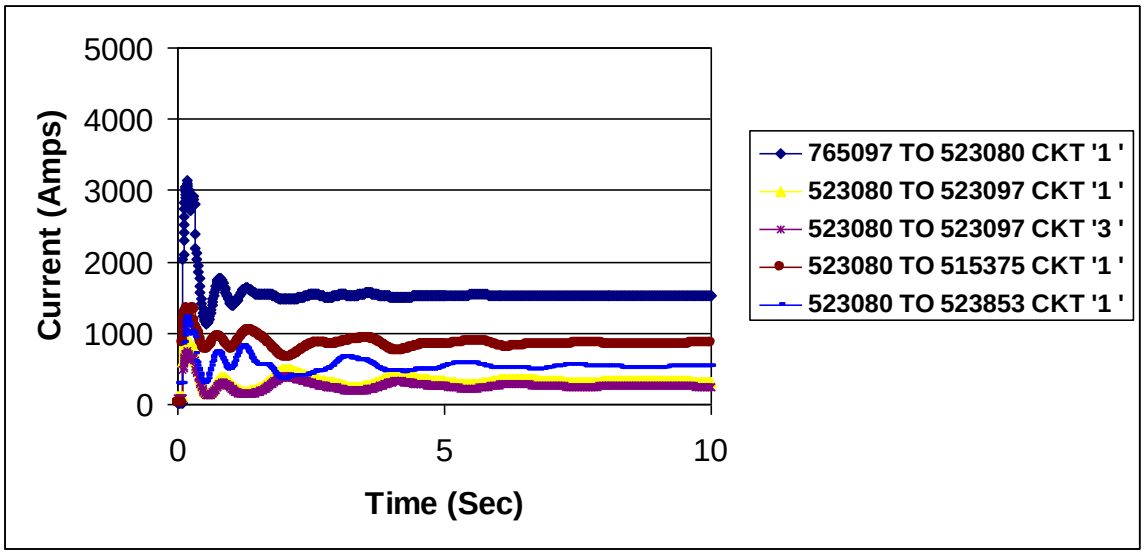

Figure 2-2 Fault # 4 – 2017 Light Load

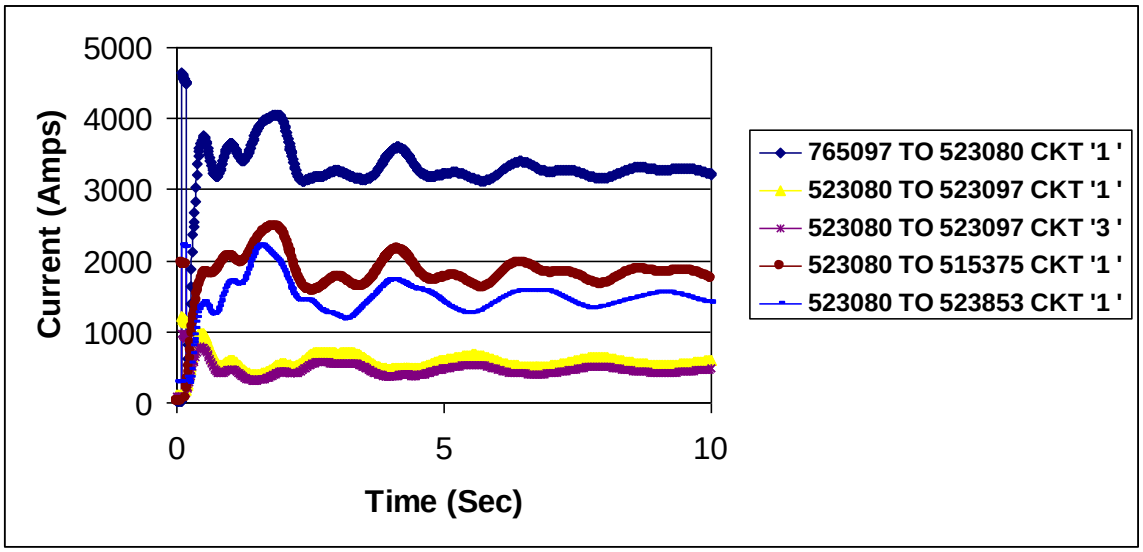

Figure 2-3 Fault # 68 – 2017 Light Load

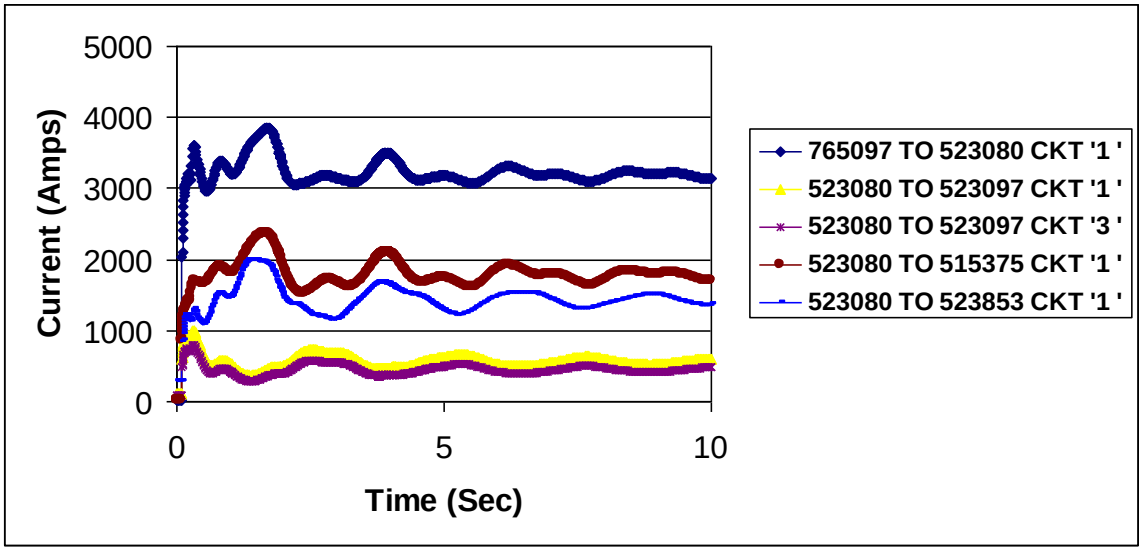

Figure 2-4 Fault # 69 – 2017 Light Load

Section

3

Sensitivity Case of 1750 MW Project Generation

A sensitivity case of reduced project wind generation of 1,750 MW (half of originally studied 3,500 MW of wind generation) injections in to Shelby substation (TVA) was developed to study the project impacts with reduced wind generation. The load flow case with 3798.9 MW of project generation was modified by turning-off approximately half of the generation as opposed to reduce the dispatched generation while keeping the same installed capacity. Table 3-1 shows the dispatched generation after modifying the load flow case with reduced installed capacity.

Figure 3-1 shows the updated project generation where the units connected by dotted lines indicate turned-off units. Also note that the synchronous condenser is turned off since the installed capacity of wind is reduced almost by half, resulting in short circuit ratio of higher than 2. The reactive compensation at both converter stations is 1,100 MVAr (4x275)

This sensitivity was implemented on 2017 Light Load case and tested for a three phase fault in the lines connecting the Project's HVDC Converter to Hitchland II 345 kV substation, followed by a double pole outage. This fault was found to be the most severe condition tested during the study[2].

Appendix A shows the corresponding stability plots, where it can be observed that the system is stable; all units remain online, oscillations are well damped and voltages remain within acceptable ranges.

Table 3-1 Project WTG with Reduced Installed Capacity and Reactive Limits

Bus	Type	# Units	Pgen	Pmax	Qmin	Qmax	Mbase	Pgen/Pmax
999984	3	265	830.6	954	-411	551	1060	87%
999985	4	460	1001.5	1150	-552	552	1288	87%
			1832	**2104**			**2348**	

[2] It is the same fault that showed an unstable voltage performance in the case of 3,500 MW of injection into the TVA, where the project generation had to be reduced by 800 MW to ensure the study area stability

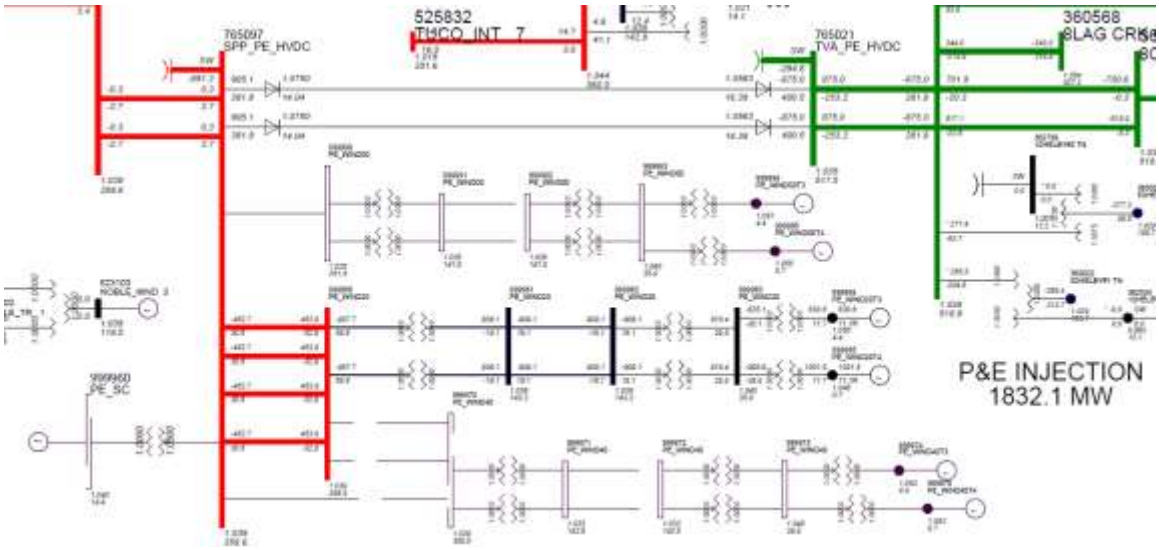

Figure 3-1 Reduced Project Wind Generation – Dotted lines showed turned off units

Appendix

A

Double Pole Outage Stability Plots – 2017 Light Load Case with 1750 MW Project Wind Generation

3PH RECTIFIER AC BUS 345 KV BOTHPOLES BLOCK * FLT68-3PH 5 CY
MDWG 2017L WITH 2010 MMWG 2016L; FOR DYN
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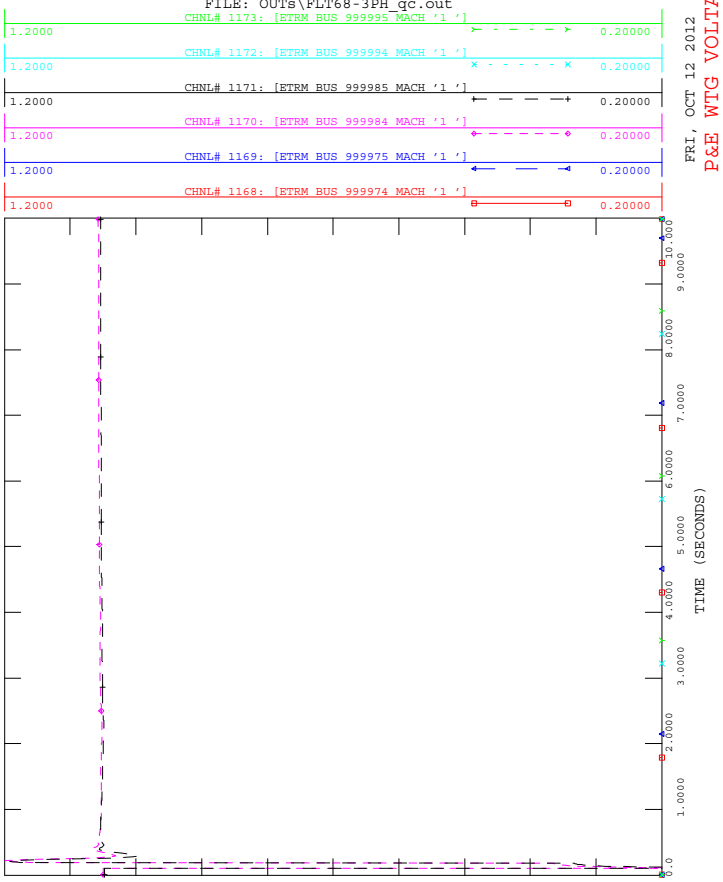
P&E WTG VOLTAGES



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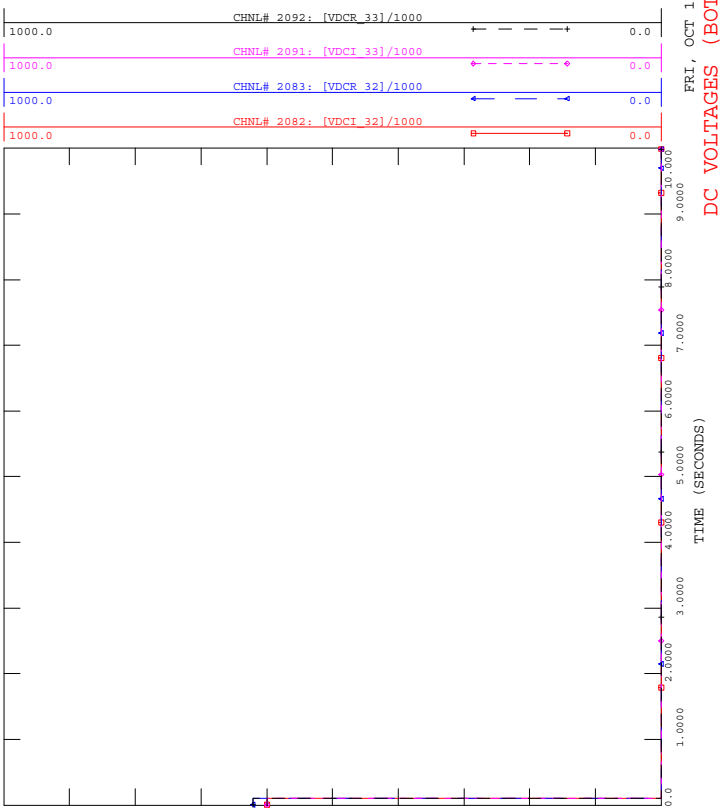
DC VOLTAGES (BOTH POLES)



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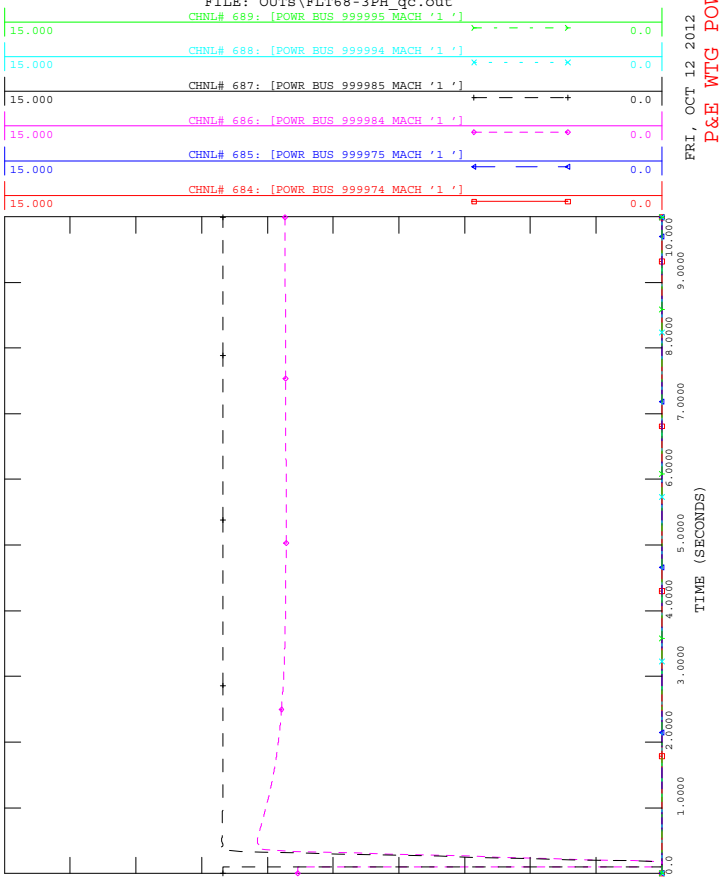
P&E WTG POWERS



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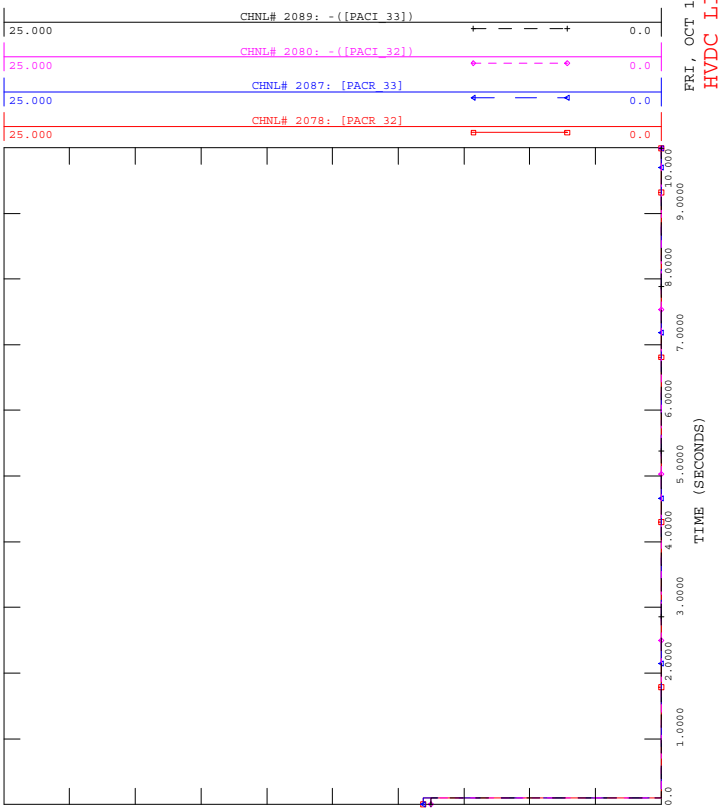
HVDC LINE FLOWS



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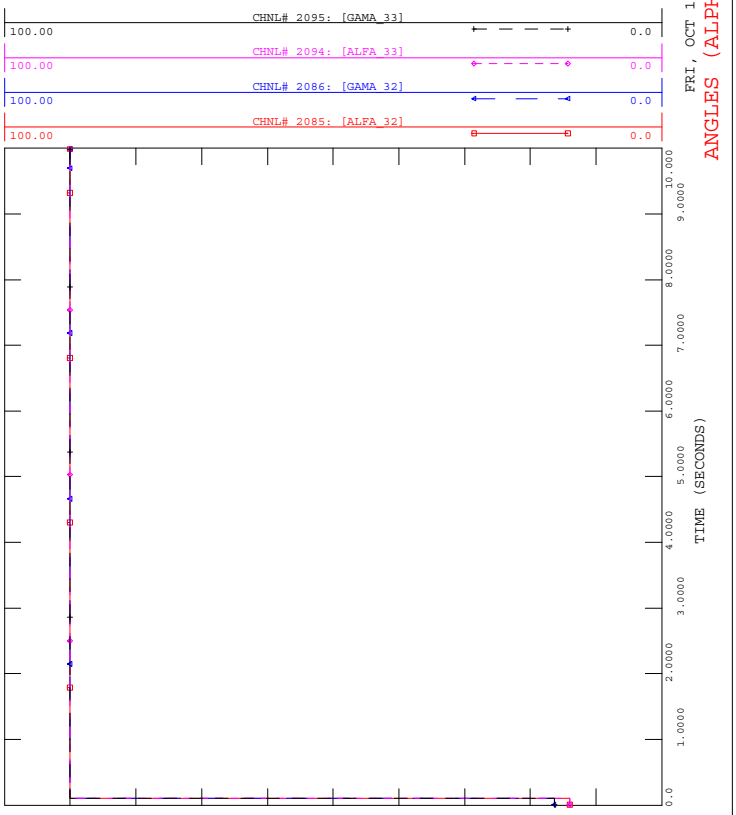

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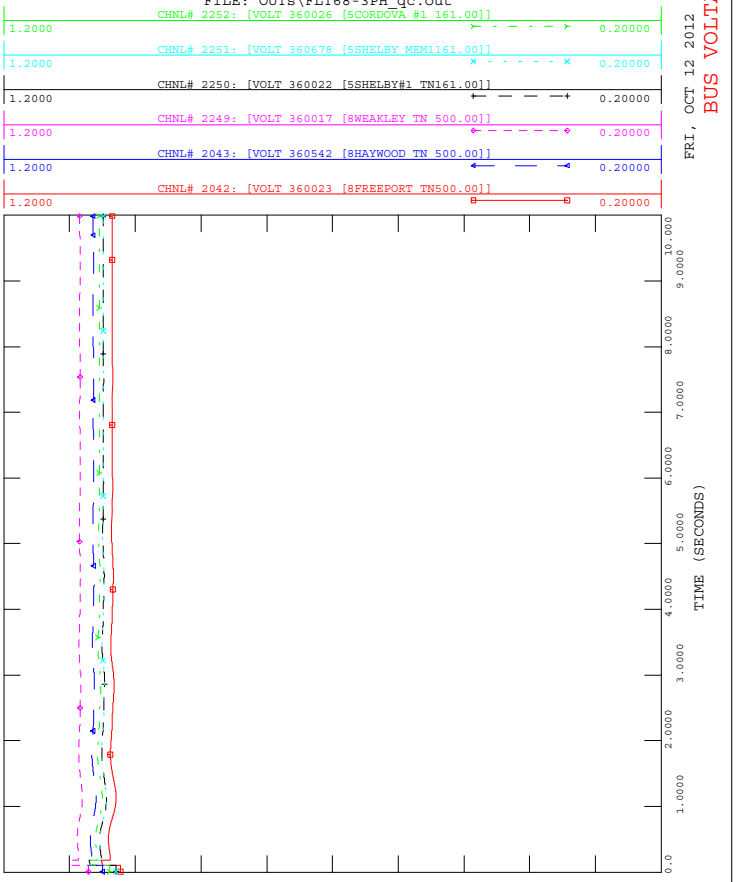

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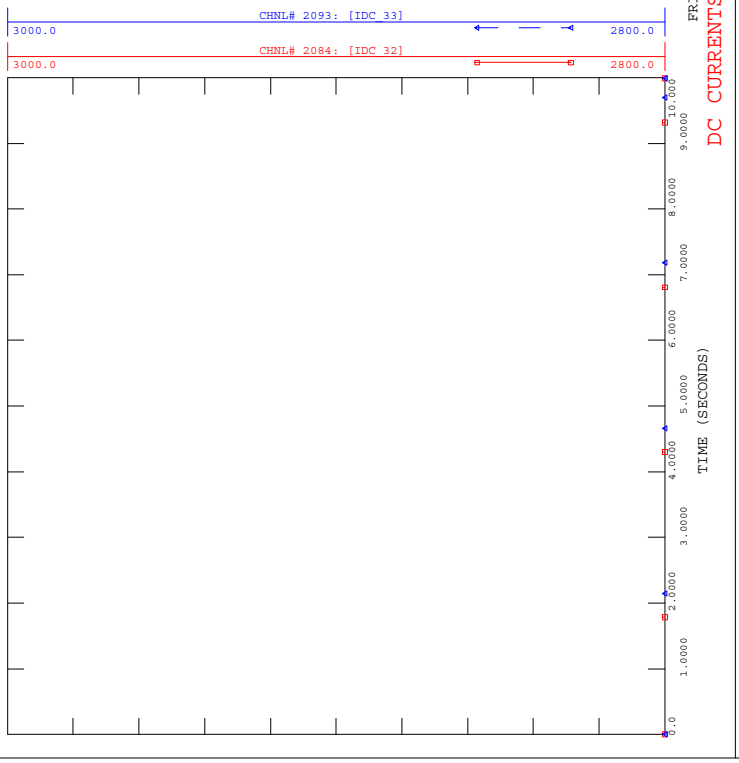

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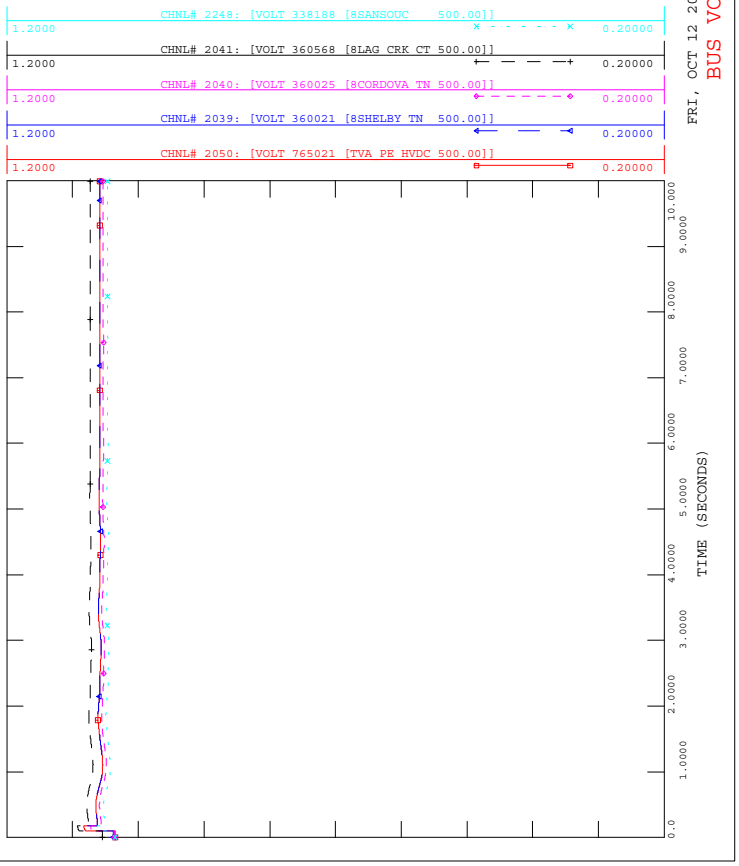

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CHNL# 2231: [VOLT 531451 [MINGO 7 345.00]]
CHNL# 2230: [VOLT 531465 [SETAB 7 345.00]]
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TIME (SECONDS)

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CHNL# 2222: [VOLT 523309 [MOORE CNTY 6230.00]]
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CHNL# 2030: [VOLT 523097 [HITCHLAND 7345.00]]
CHNL# 2048: [VOLT 523080 [HITCHLND#2 7345.00]]
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CHNL# 2037: [VOLT 532796 [WICHITA7 345.00]]
CHNL# 2036: [VOLT 539801 [THISTLE 7 345.00]]
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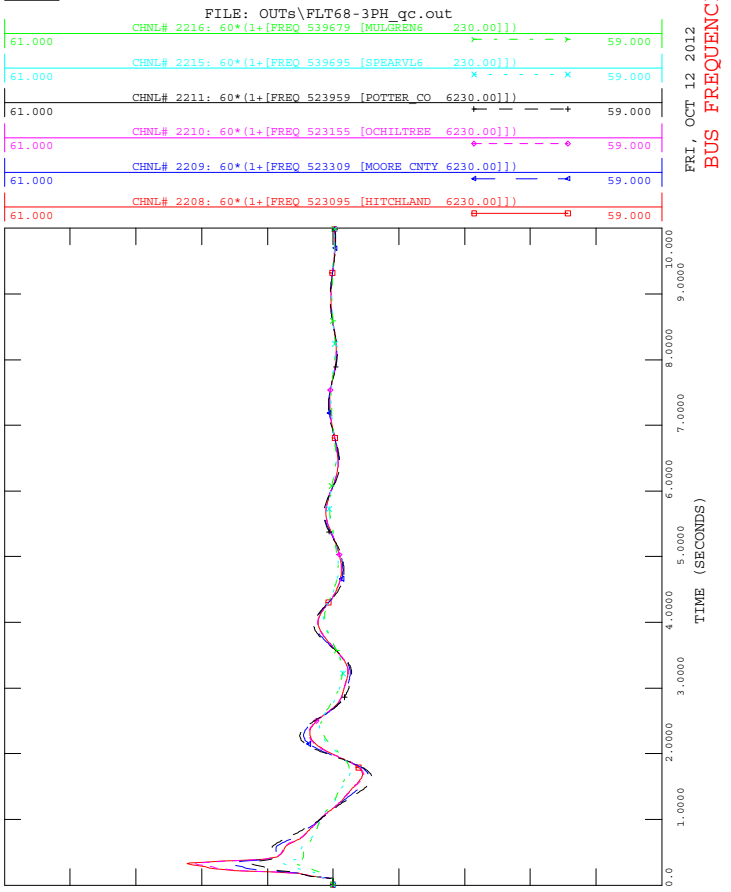

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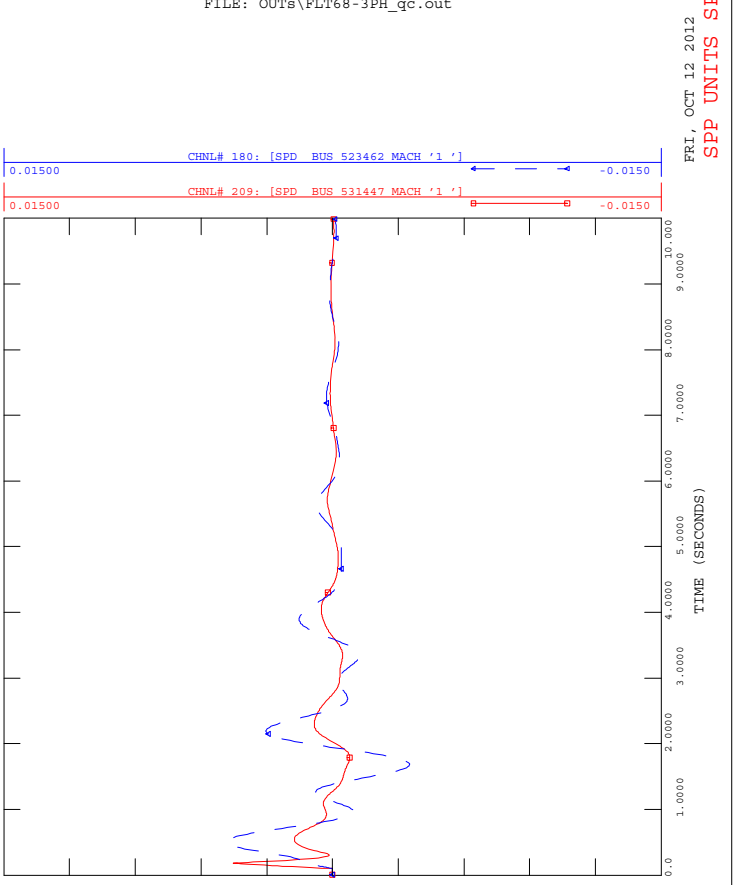

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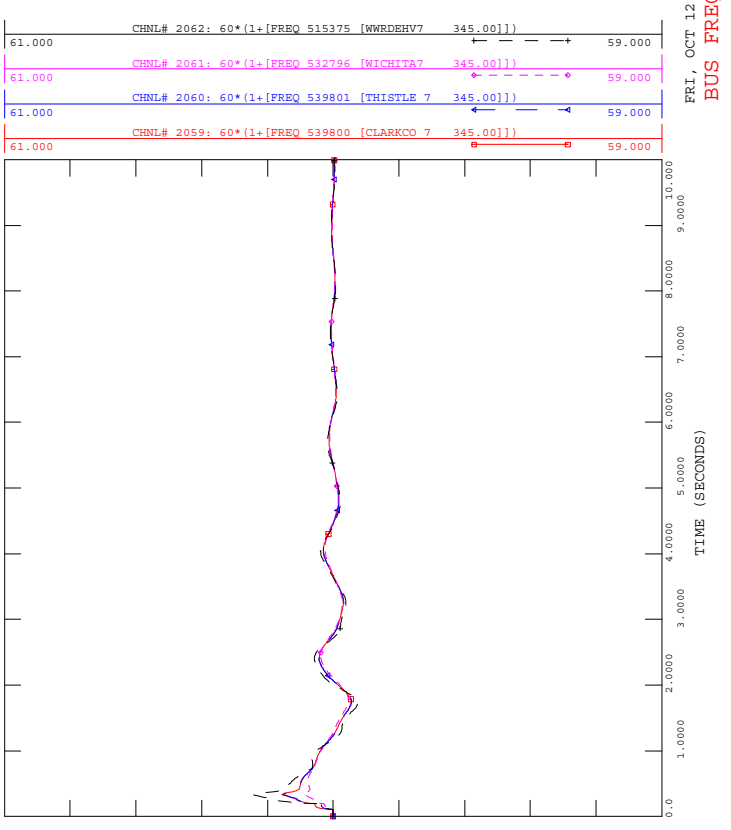

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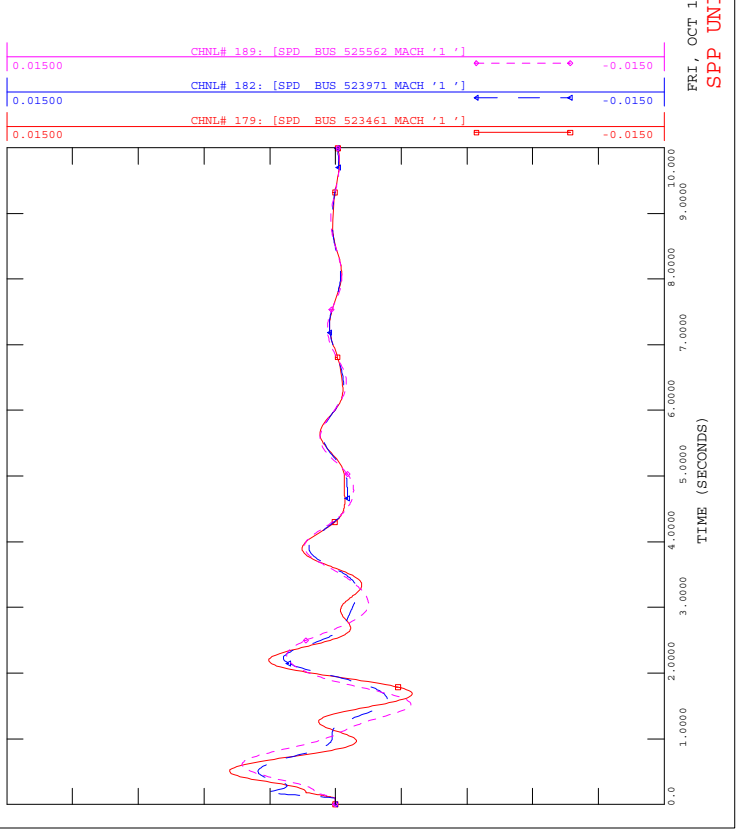
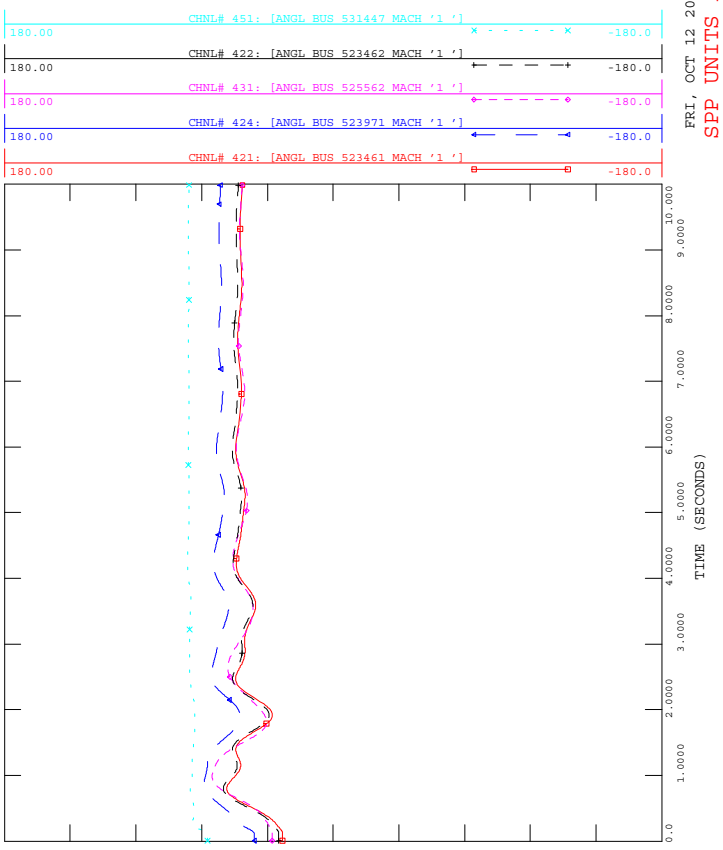


3PH RECTIFIER AC BUS 345 KV BOTHPOLES BLOCK * FLT68-3PH 5 CY
MDWG 2017L WITH 2010 MMWG 2016L; FOR DYN
3PH_HITCHLAD_CONV_345KV_BOTHPOLE_BLOCK

FILE: OUTs\FLT68-3PH_qc.out

FRI, OCT 12 2012 7:03

SPP UNITS ANGLES

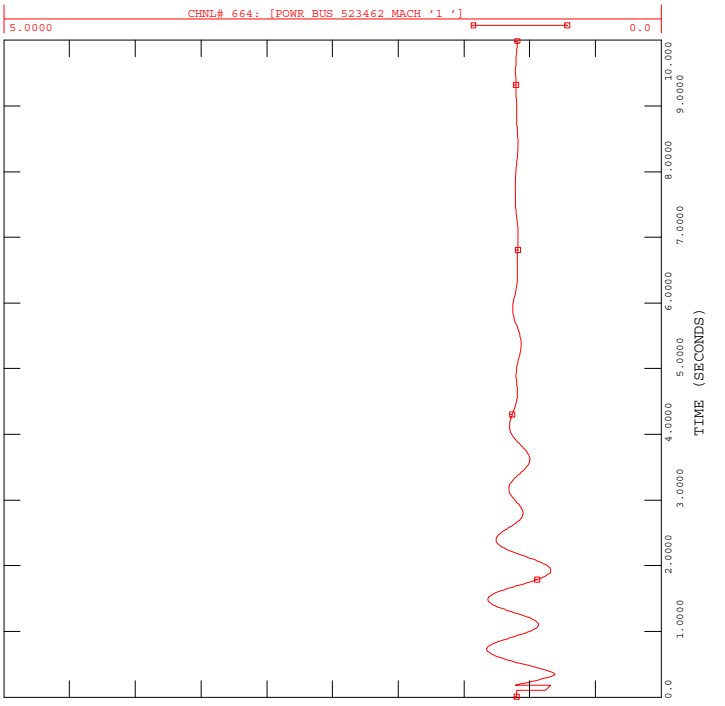


3PH RECTIFIER AC BUS 345 KV BOTHPOLES BLOCK * FLT68-3PH 5 CY
MDWG 2017L WITH 2010 MMWG 2016L; FOR DYN
3PH_HITCHLAD_CONV_345KV_BOTHPOLE_BLOCK

FILE: OUTs\FLT68-3PH_qc.out

FRI, OCT 12 2012 7:03

SPP UNIT POWERS



3PH RECTIFIER AC BUS 345 KV BOTHPOLES BLOCK * FLT68-3PH 5 CY
MDWG 2017L WITH 2010 MMWG 2016L; FOR DYN
3PH_HITCHLAD_CONV_345KV_BOTHPOLE_BLOCK

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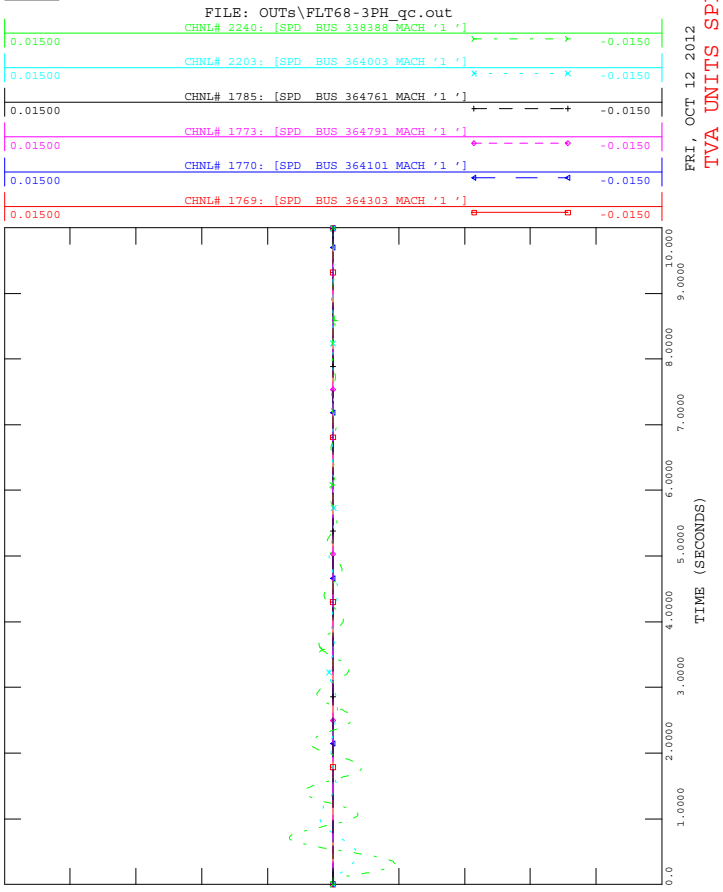
TVA UNITS SPEED



3PH RECTIFIER AC BUS 345 KV BOTHPOLES BLOCK * FLT68-3PH 5 CY
MDWG 2017L WITH 2010 MMWG 2016L; FOR DYN
3PH_HITCHLAD_CONV_345KV_BOTHPOLE_BLOCK

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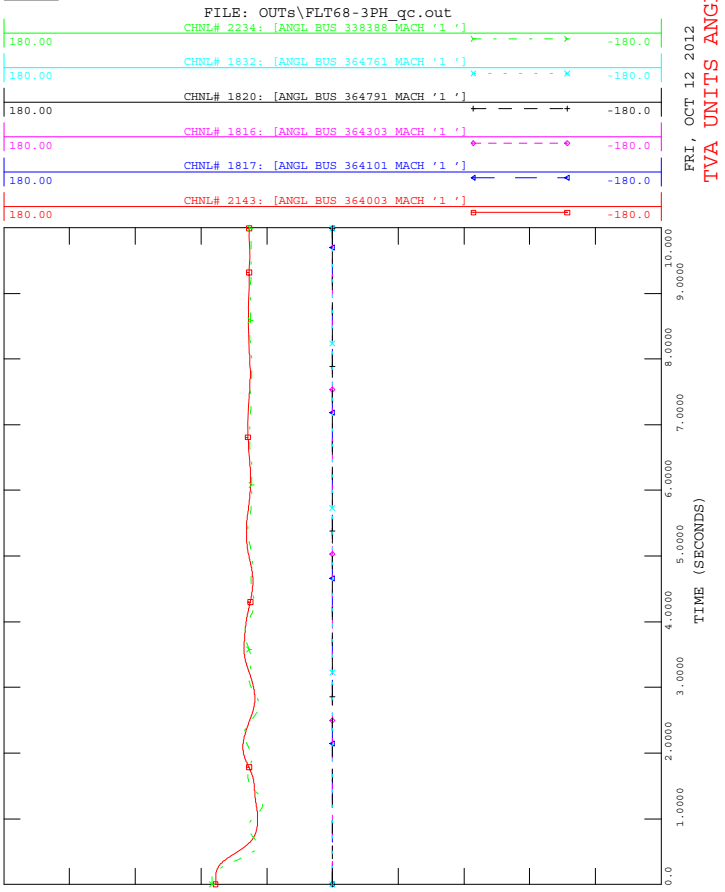
TVA UNITS ANGLES



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