Impact Study for Generation Interconnection Request GEN – 2004 – 015

SPP Coordinated Planning
(#GEN-2004-015)

June 2005

Summary

Pterra Consulting performed the following Study at the request of the Southwest Power Pool (SPP) for Generation Interconnection request Gen-2004-015. The request for interconnection was placed with SPP in accordance SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Pursuant to the tariff, Pterra Consulting was asked to perform a detailed Impact Study of the generation interconnection request to satisfy the Impact Study Agreement executed by the requesting customer and SPP.

Pterra Consulting

Report No. R119-05

"Feasibility and Impact Study for Generation Interconnection Request GEN-2004-015"

Submitted to

The Southwest Power Pool

June 2005

Pterra

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Report No. R119-05

"Feasibility and Impact Study for Generation Interconnection Request GEN-2004-015"

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1 Executive Summary

<OMITTED TEXT> (Customer) has requested the Southwest Power Pool (SPP) to conduct a generator interconnection feasibility and impact study through the SPP Tariff for new Frame-7 170 MW combustion turbine (CT) connected to the existing Mustang substation as shown in Figure 1.

For the feasibility study:

Load flow analysis was conducted with and without the study project to identify the proposed generator's impact on the local area. For the contingency tests, SWPS was monitored for overloads that are greater than base case overloads + 3% and voltage below 0.9 pu and have a drop greater than 3% of the base case.

The minimum cost of interconnecting the Customer project is estimated at $0 for SWPS's interconnection Network Upgrade facilities listed in Table 1. At this time, the cost estimates for the Direct Assignment facilities have not been defined by the Customer. These interconnection costs do not include any cost that may be associated with short circuit analysis. These costs likewise do not include all costs associated with the deliverability of the energy to final customers. Such costs are determined by separate studies if the Customer requests transmission service through SPP's OASIS.

For the impact study:

Eighteen (18) contingencies were considered for the transient stability simulations which included three phase faults as well as Single-phase line faults on the 115 kV and 230 kV substations nearby the study project. Single-phase line faults were simulated by applying a fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

Table 5 shows the list of simulated contingencies. The table also shows the fault clearing time and the time delay before re-closing for all the study contingencies. The stability simulation shows that the study plant would not degrade the stability performance of the system. The impact study finds that the study project addition shows stable performance of the SPP system for the contingencies tested on the supplied base cases.

2 Project Overview

<OMITTED TEXT> (Customer) has requested the Southwest Power Pool (SPP) to conduct a generator interconnection feasibility and impact study through the SPP Tariff for new Frame-7 170 MW combustion turbine (CT) connected to the existing Mustang substation as shown in Figure 1. This CT will be interconnected using a set of new 230 kV breakers and switches in accordance with the proposed one-line. The existing substation is owned by SWPS (d/b/a Xcel Energy). The customer has asked for a load flow and Impact study case of 100% MW.

Three base cases were used in the study: 2006 summer peak, 2006 winter, and 2009 Summer Peak. Each base case was modified to include the study plant with the total MW dispatched against existing plants in the SPP system maintaining current area interchange totals. Dispatch for existing generation was provided by SPP.

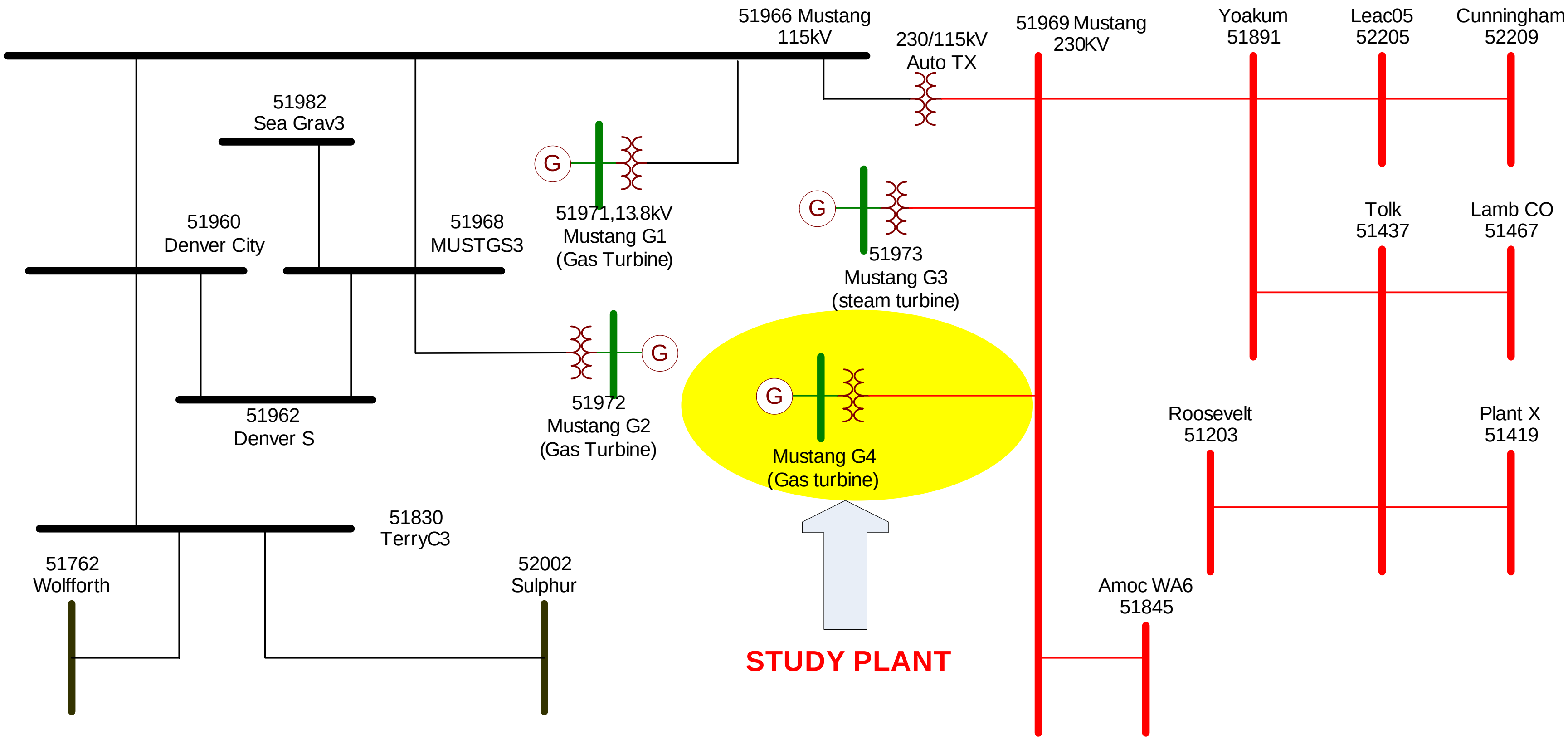


Figure 1 One-Line Diagram Showing the 170 MW Study Plant and the Nearby Substations

3 Feasibility Study

3.1 Interconnection Facilities

The Feasibility Study assesses the practicality and costs involved to incorporate the study project into the SPP Transmission System. The analysis is limited to load flow analysis of the more probable contingencies within the Transmission Owner's control area and key adjacent areas.

The Feasibility Study is intended to identify attachment facilities and other direct assignment facilities needed to accept power into the grid at the interconnection receipt point. Gen-2004-015 would be interconnected to the Mustang 230 kV substation owned by SWPS (d/b/a Xcel Energy).

Table 1: Direct Assignment Facilities

Facility	Estimated Cost to Customer
Customer – Add the following at Mustang substation:	
• Step-up transformer 18/230 kV, 115/213.8 MVA	*
• 230 kV PTs	*
• Auxiliary service transformer 230/4.16 kV, 12/16/20 MVA	*
• Two new 230 kV breakers	*
• Autotransformer 230/115 kV, 150 MVA	*
Total	*

*Note: * Estimate of cost to be determined by Customer*

Table 2: Required Interconnection Network Upgrade Facilities

Facility	Estimated Cost
None	$0

Table 3: Network Constraints

Facility
None

Note: (1) Network Upgrade description will be determined at the request of the Customer.

Table 4: Contingency Analysis Results

Facility	Model and Contingency	Facility Loading[1]	Bus Voltage	ATC (MW)	Date Required
None	N/A	N/A	N/A	N/A	N/A

Note: When transmission service associated with this interconnection is evaluated, the loading of the facilities listed in this table may be greater due to higher priority reservations. If the loading of a facility is higher, the level of ATC will be lower.

3.2 Power Flow Analysis

Load flow analysis was conducted with and without the study project to identify the study project's impact on the local area. In the power flow, the 170 MW study plant was added to the base case as a new source delivering to the Mustang 230 kV bus.

The results of load flow analysis include power flow and voltage magnitudes under probable contingency conditions. The results of the load flow study are used to identify equipment overloads and voltage impacts that may be encountered due to the addition of new generation. Probable contingencies comprise of single contingencies in the study area and their impact on transmission elements in the monitored area.

Three base cases were used in the study: 2006 summer peak, 2006 winter, and 2009 Summer Peak. There are no prior queued projects. The study project is dispatched only into SPP member SWPS. For the contingency tests, SWPS is monitored. Overloads that are greater than base case overloads + 3% and voltage below 0.9 pu and have a drop greater than 3% of the base case, are checked in the results.

3.3 Methodology

The SPP criteria applied to the Feasibility Study states that: "The transmission system of the SPP region shall be planned and constructed so that the contingencies as set forth in the Criteria will meet the applicable NERC Planning Standards for System Adequacy and Security – Transmission System Table 1, and its applicable standards and measurements."

The analysis was conducted by assessing single contingencies in SWPS using power flows. This is consistent with the more probable contingency testing criteria mandated by NERC and the SPP.

3.4 Conclusion

The minimum cost of interconnecting the Customer project is estimated at $0 for SWPS's interconnection Network Upgrade facilities listed in Table 1. At this time, the cost estimates for the Direct Assignment facilities have not been defined by the Customer.

These interconnection costs do not include any cost that may be associated with short circuit analysis. The required interconnection costs listed in Table 1 and other upgrades associated with Network Constraints listed in Table 3 do not include all costs associated with the deliverability of the energy to final customers. These costs are determined by separate studies if the Customer requests transmission service through SPP's OASIS.

[1] % Rate B.

4 Impact Study

4.1 Objective

The objective of the impact study is to determine the impact on system stability of connecting the proposed GEN-2004-015 combustion turbine to SPP's 230 kV transmission system. Three base cases were provided by SPP for the stability simulations: 2006 Summer Peak, 2006 Winter, and 2009 Summer Peak.

4.2 The Study Plant Model

The customer provided generator model of the study plant as shown in Appendix A. The plant was dispatched against the existing plant in the system maintaining current area interchange totals. Dispatch for existing generation was provided by SPP.

4.3 Contingencies Simulated

Eighteen (18) contingencies were considered for the transient stability simulations which included three phase faults as well as Single-phase line faults on the 115 kV and 230 kV substations nearby the study project. Single-phase line faults were simulated by applying a fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

Table 5 shows the list of simulated contingencies. The table also shows the fault clearing time and the time delay before re-closing for all the study contingencies.

Figure 2 provides a diagram to better visualize the fault locations in the Stability Simulations.

The 20 second "no fault" runs were performed prior to running the contingencies listed in Table 5, and the results shows flat machines angle performance.

Appendix B provides sample plots for Contingency #3, 3-phase fault for the 2006 Summer Peak case.

4.4 Conclusion

The stability simulation shows that the study plant would not degrade the stability performance of the system. The impact study finds that the study project addition shows stable performance of the SPP system for the contingencies tested on the supplied base cases.

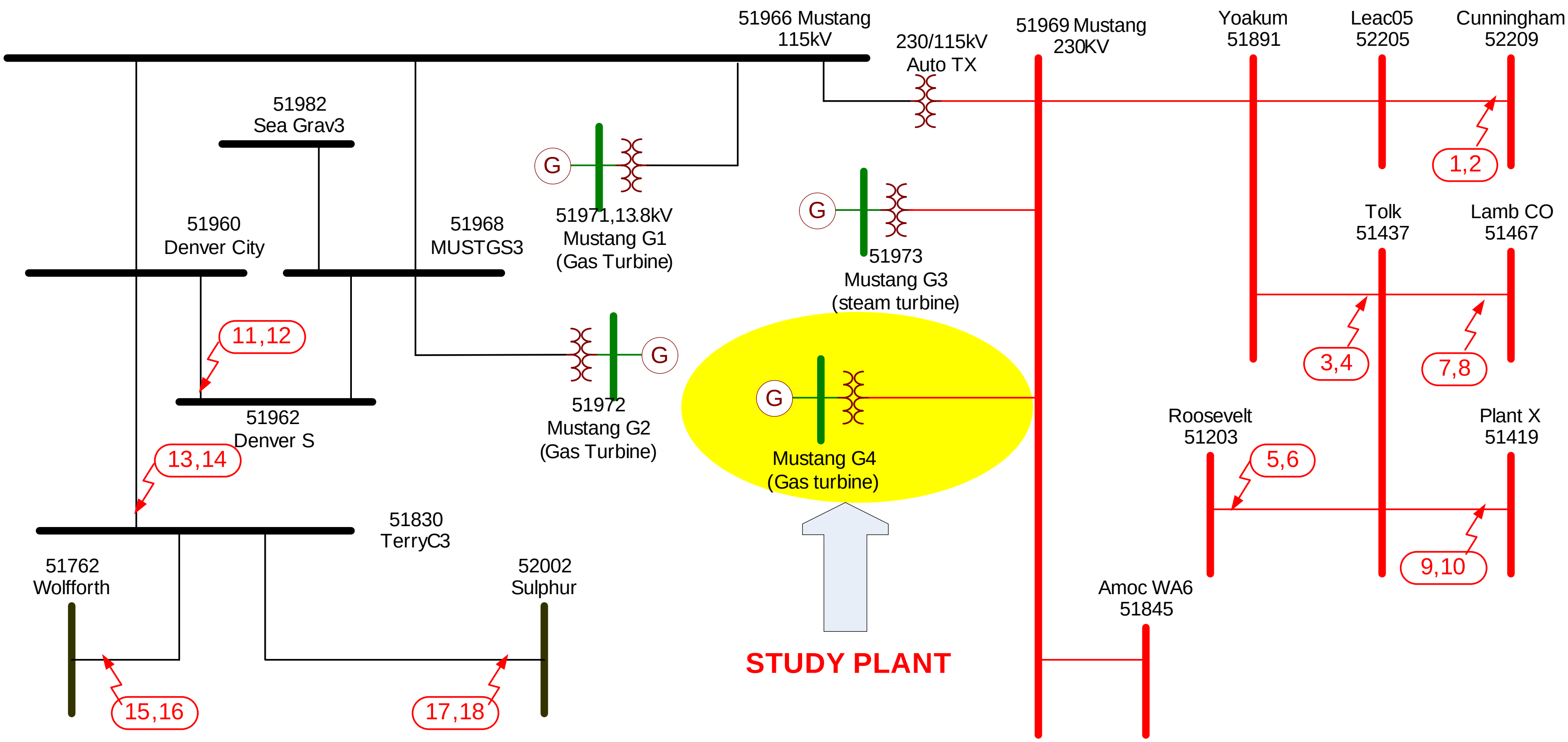


Figure 2 One Line Diagrams Showing the Fault Location on the 115 kV and 230 kV Transmission lines nearby the Study Plant

Table 5 List of Contingencies and Results Summary for Impact Study

Legend:
-- : System shows stable performance
S : Stability issues encountered
UV : Tripped due to low voltage

Cont. No.	***Cont.Name***	***Description***	***<u>Case-1:</u> 2006 Summer Peak***	***<u>Case-2:</u> 2006 Winter Case***	***<u>Casse-3:</u> 2009 Summer Peak***
1	FLT13PH	3-phase fault on the Cunningham (52209) to Yoakum (51891) 230 kV line near Cunningham. a. Apply Fault at the Cunningham bus (52209) b. Clear Fault after 5 cycles by removing the line from Cunningham (52209) to Yoakum (51891). c. Wait 30 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
2	FLT21PH	*Single phase fault and sequence like Cont. No. 1*	--	--	--
3	FLT33PH	3-phase fault on the Tolk (51437) to Yoakum (51891) 230 kV line near Tolk a. Fault on the Tolk (51437) to Yoakum (51891) 230 kV line near Tolk b. Apply fault at the Tolk bus (51437). c. Clear fault after 5 cycles by removing the 230 kV line from Tolk (51437) to Yoakum (51891). d. Wait 30 cycles, and then re-close the line in (b) into the fault. e. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
4	FLT41PH	*Single phase fault and sequence like Cont. No. 3*	--	--	--
5	FLT53PH	3-phase fault on the Roosevelt (51203) to Tolk (51437) 230 kV line near Roosevelt. a. Apply Fault at the Roosevelt bus (51203).	--	--	--

Cont. No.	*Cont.Name*	*Description*	***Case-1:** 2006 Summer Peak*	***Case-2:** 2006 Winter Case*	***Casse-3:** 2009 Summer Peak*
		b. Trip the line after 5 cycles by removing the line from Roosevelt (51203) to Tolk (51437. c. Wait 30 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.			
6	FLT61PH	*Single phase fault and sequence like Cont. No. 5*	--	--	--
7	FLT73PH	3-phase fault on the Lamb Co. bus (51467) to Tolk (51437) 230 kV line, near Lamb Co. a. Apply fault at the Lamb Co. bus (51467). b. Clear fault after 5 cycles by tripping the line from Lamb Co. bus (51467) to Tolk (51437). c. Wait 30 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
8	FLT81PH	*Single phase fault and sequence like Cont. No. 7*	--	--	--
9	FLT93PH	3-phase fault on the Tolk (51437) to Plant X (51419) 230 kV line, near Plant X. a. Apply fault at the Plant X bus (51419). b. Clear fault after 5 cycles by tripping the line from Tolk (51437) to Plant X (51419). c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
10	FLT101PH	*Single phase fault and sequence like Cont. No. 9*	--	--	--
11	FLT113PH	3-phase fault on the Denver S. (51962) to Denver City (51960) 115 kV line, near Denver S. a. Apply fault at the Denver S. bus (51962). b. Clear fault after 5 cycles by tripping the line Denver S. (51962) to Denver City (51960).	--	--	--

Cont. No.	*Cont.Name*	*Description*	***Case-1:** 2006 Summer Peak*	***Case-2:** 2006 Winter Case*	***Casse-3:** 2009 Summer Peak*
		c. Wait 20 cycles, and then re-close line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.			
12	FLT121PH	*Single phase fault and sequence like Cont. No. 11*	--	--	--
13	FLT133PH	3-phase fault on the Denver City (51960) to Terry Co. (51830) 115 kV line, near Terry Co. a. Apply fault at the Terry Co. bus (51830). b. Clear fault after 5 cycles by tripping the line from Denver City (51960) to Terry Co. (51830). c. Wait 20 cycles, and then re-close line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
14	FLT141PH	*Single phase fault and sequence like Cont. No. 13*	--	--	--
15	FLT153PH	3-phase fault on the Terry Co. (51830) to Wolfforth (51762) 115 kV line, near Wolfforth. a. Apply fault at the Wolfforth bus (51762). b. Clear fault after 5 cycles by tripping the line from Terry Co. (51830) to Wolfforth (51762). c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	--	--
16	FLT161PH	*Single phase fault and sequence like Cont. No. 15*	--	--	--
17	FLT173PH	3-phase Fault on the Terry Co. (51830) to Sulphur Springs (52002) 115 kV line near Sulphur Springs. a. Apply fault at the Sulphur Springs bus (52002). b. Clear fault after 5 cycles by tripping the line from Terry Co. (51830) to Sulphur Springs (52002). c. Wait 20 cycles, and then re-close the line in (b) back into the fault.	--	--	--

Cont. No.	***Cont.Name***	***Description***	***<u>Case-1:</u> 2006 Summer Peak***	***<u>Case-2:</u> 2006 Winter Case***	***<u>Casse-3:</u> 2009 Summer Peak***
		d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.			
18	FLT181PH	*Single phase fault and sequence like Cont. No. 17*	--	--	--
19	FLT193PH	3-phase Fault on Yoakum 230 kV bus (51891) to Mustang (51969) a. Apply fault at the Yoakum 230 kV bus (51891) b. Clear fault after 5 cycles by tripping the 230kV line from Yoakum (51891) to Mustang (51969). c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.	--	Simulated only for 2006 Summer	Simulated only for 2006 Summer
20	FLT201PH	*Single phase fault and sequence like Cont. No. 19*	--	Simulated only for 2006 Summer	Simulated only for 2006 Summer

Appendix A

Generator Data for the Study Plant

DWG NO	SH	REV
Preliminary	2	-

ESTIMATED GENERATOR DATA

Customer:	**-99999**
Station/Project:	
Generator Number:	**337X306**
Generator Type:	**7FH2 LU**

GENERATOR RATING

Data for Proposal No/Electrical Design: F297T20B   Sep 2 2004

ATB 2 170000 kVA 3600 RPM 18000 Volts 0.9 PF 42 psig 52 °C Gas 153000 kW 5452 Amps
250 Field Volts 3500 Ft Alt 0.66 SCR 60 Hz 3 Phase WYE Connection

Exciter Rating

Type Static

370 kW 250 Volts 1480 D.C.Amps   Field Amps @ Generator rated Load 1267

Total temperatures are guaranteed not to exceed:	**Insulation Class**		**Temperature Rise**
Stator coils: 100 °C by embedded detector	Armature	F	B
Field coils 110 °C by Resistance	Field class	F	B
Collector Gas Rise 20 °C by RTD			

Cooling water Requirements @ Generator Rating (C901 - Data)

(Data not applicable for Open Ventilated Units. Air cooled OV units, values will be shown as –99999)

Generator Output:	170000	Kva
Loss to Coolers:	1137 Kw	
Inlet Water Temperature:	46.1 °C	
Outlet Cold Gas Temperature	52 °C	
Coolant	50% Propylene Glycol / 50% Water	
Maximum Fouling Factor:	0.0005	1/(btu / (hours*footsquared*F))
Total Water Flow Required:	1860 GPM	(total for all coolers)
Coolant temperature Max	51.7 °C	
Head Loss Per Cooler:	20.6 Feet of Water	
Maximum Operating Pressure:	125 psig	
	8.6184	bar

Dielectric tests (Between coils and ground, 50/60 hertz AC for 1 min)

Stator 37000V

Rotor 2460V

GENERAL ELECTRIC COMPANY	SIZE	CAGE CODE	DWG NO
GE POWER GENERATION SCHENECTADY, NY	A		**Preliminary**
DRAWN: Q PIERSON			
ISSUED: Q PIERSON	SCALE		SHEET 2

SIZE	DWG NO	SH	REV
A	Preliminary	3	-

REACTANCES (Per Unit):	Direct Axis		Quadrature Axis	
Saturated Synchronous	X_{dv}	1.53	X_{qv}	1.44
Unsaturated Synchronous	X_{di}	1.53	X_{qi}	1.44
Saturated Transient	X'_{dv}	0.17		
Unsaturated Transient	X'_{di}	0.19	X'_{q}	0.365
Saturated Sub transient	X''_{dv}	0.11	X''_{qv}	0.11
Unsaturated Sub transient	X''_{di}	0.145	X''_{qi}	0.145
Saturated Negative Sequence	X_{2v}	0.11		
Unsaturated Negative Sequence	X_{2i}	0.145		
Saturated Zero Sequence	X_{0v}	0.09		
Unsaturated Zero Sequence	X_{0i}	0.09		
Saturated Leakage Reactance	X_{lv}	0.1		
Unsaturated Leakage Reactance	X_{li}	0.11		

FIELD TIME CONSTANTS (Seconds @ 125 °C)

Open Circuit	T'_{d0}	7	T'_{q0}	0.51
Three Phase Short Circuit Transient	T'_{d3}	0.7	T'_{q}	0.13
Line To Line Short Circuit Transient	T'_{d2}	1.2		
Line To Neutral Short Circuit Transient	T'_{d1}	1.5		
Short Circuit Sub transient	T''_{d}	0.026	T''_{q}	0.026
Open Circuit Sub transient	T''_{d0}	0.04	T''_{q0}	0.086

ARMATURE DC COMPONENT TIME CONSTANTS (Seconds@ 100 °C)

Three Phase Short Circuit	T_{a3}	0.39
Line To Line Short Circuit	T_{a2}	0.39
Line To Neutral Short Circuit	T_{a1}	0.32

ARMATURE WINDING SEQUENCE RESISTANCES (Per Unit)

Positive	R_1	0.0021
Negative	R_2	0.0147
Zero	R_0	0.0079

Reactance, Resistance and Time Constant data may be interpreted per IEEE 115, section VII.

The base reactance ("UNIT") is calculated by the armature kV squared / MVA.

Base reactance = 1.9059 Ohms

Rotor Short-Time Thermal Capacity, $(I_2)^2t$	10 s
Turbine-Generator Combined Inertia Constant, H	6.697 kW-s/kVA
Three Phase Armature Winding Capacitance	0.8171 µF
Armature Winding DC Resistance (Per Phase)	0.0017 Ω (100 °C)
Field Winding DC Resistance	0.1942 Ω (125 °C)
Field Current At Rated Kva, Armature Voltage, & PF	1267 A
Field Current At Rated Kva, Armature Voltage, 0 PF Lagging	1571 A

(For Systems Study Only - Not Allowable Operating Point)

GENERAL ELECTRIC COMPANY GE POWER GENERATION SCHENECTADY, NY	SIZE A	CAGE CODE	DWG NO **Preliminary**
DRAWN: Q PIERSON			
ISSUED: Q PIERSON	SCALE		SHEET 3

SIZE	DWG NO	SH	REV
A	Preliminary	4	-

MACHINE SATURATION DATA

S/1.0 = 0.068 — Machine saturation may be calculated from the data of curves A and B of

S/1.2 = 0.5806 — "ESTIMATED SATURATION AND SYNCHRONOUS IMPEDANCE CURVES".

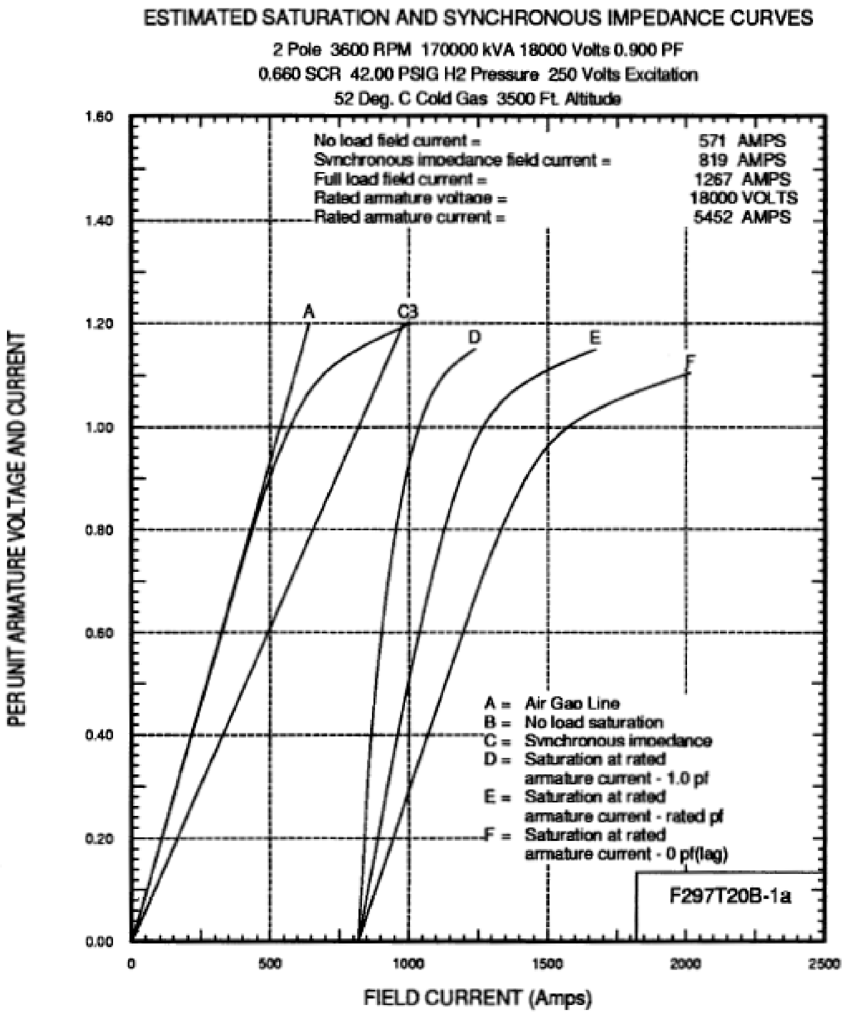
"S/1.0" is the field amp difference from B to A divided by the field amp of A at 1.0 pu voltage.

X/R RATIO

X/R = 126 — X/R ratio equals "XPP/DV" * base reactance / armature DC resistance at 100 C

GE POWER GENERATION — GENERAL ELECTRIC COMPANY, SCHENECTADY, NY	SIZE A	CAGE CODE	DWG NO Preliminary
DRAWN: Q PIERSON			
ISSUED: Q PIERSON	SCALE		SHEET 4

SIZE	DWG NO	SH	REV
A	Preliminary	5	-



GENERAL ELECTRIC COMPANY	SIZE	CAGE CODE	DWG NO
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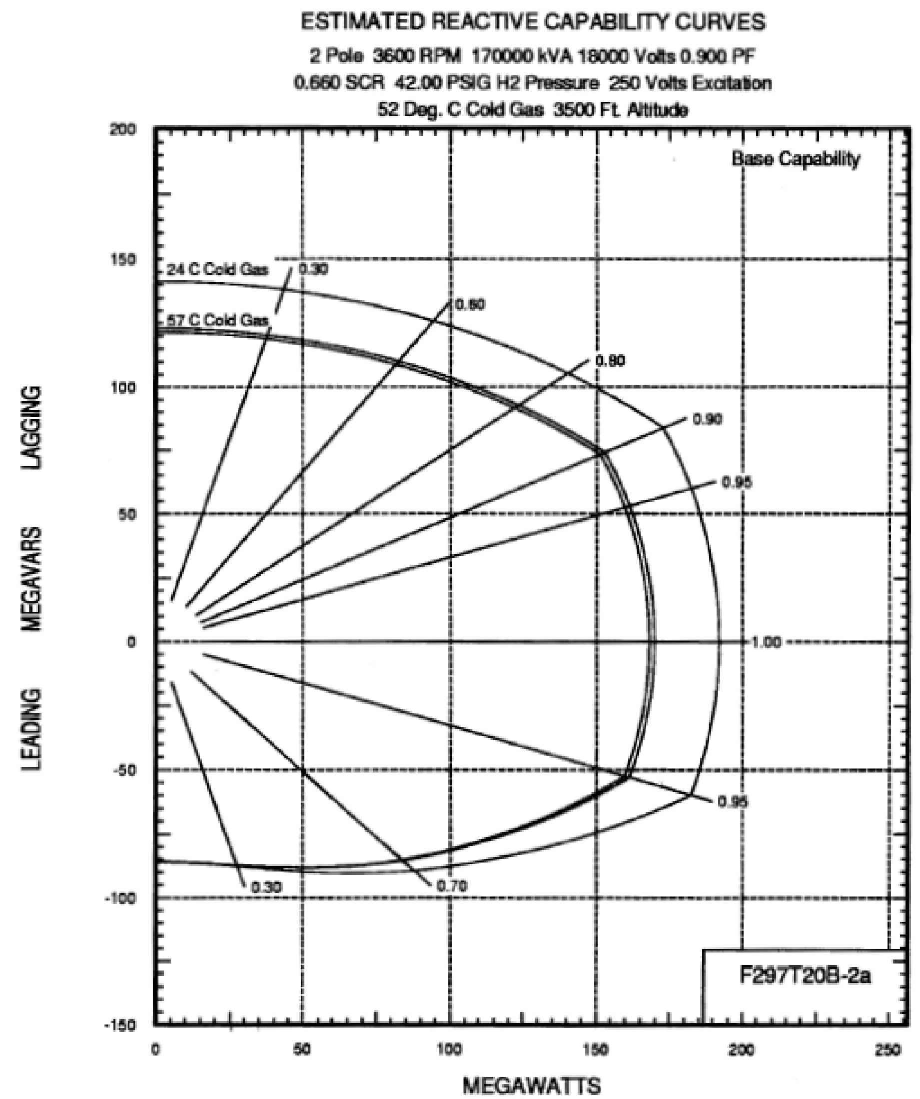
DRAWN Q PIERSON			
ISSUED Q PIERSON	SCALE		SHEET 5

SIZE	DWG NO	SH	REV
A	Preliminary	6	-



GENERAL ELECTRIC COMPANY	SIZE	CAGE CODE	DWG NO
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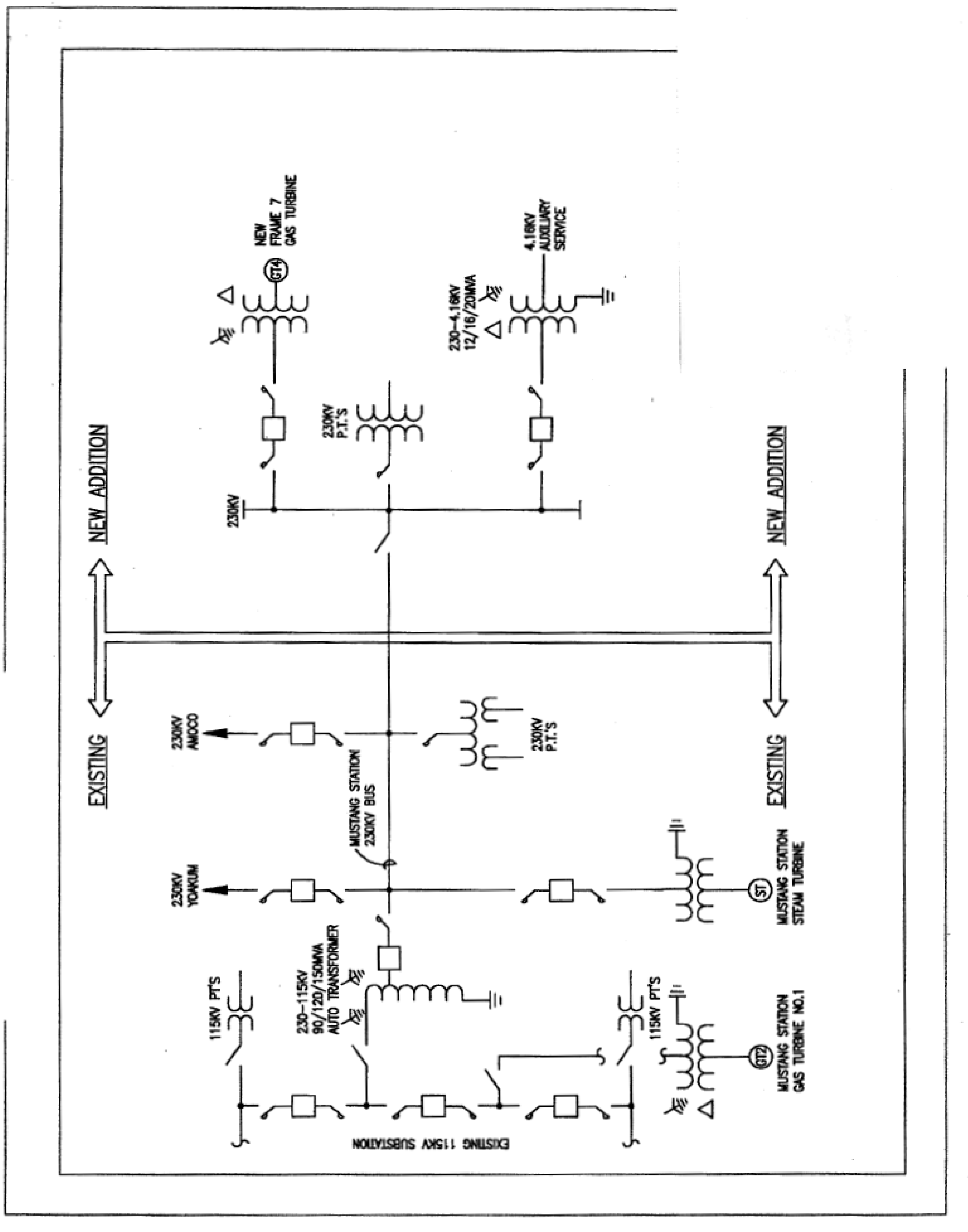
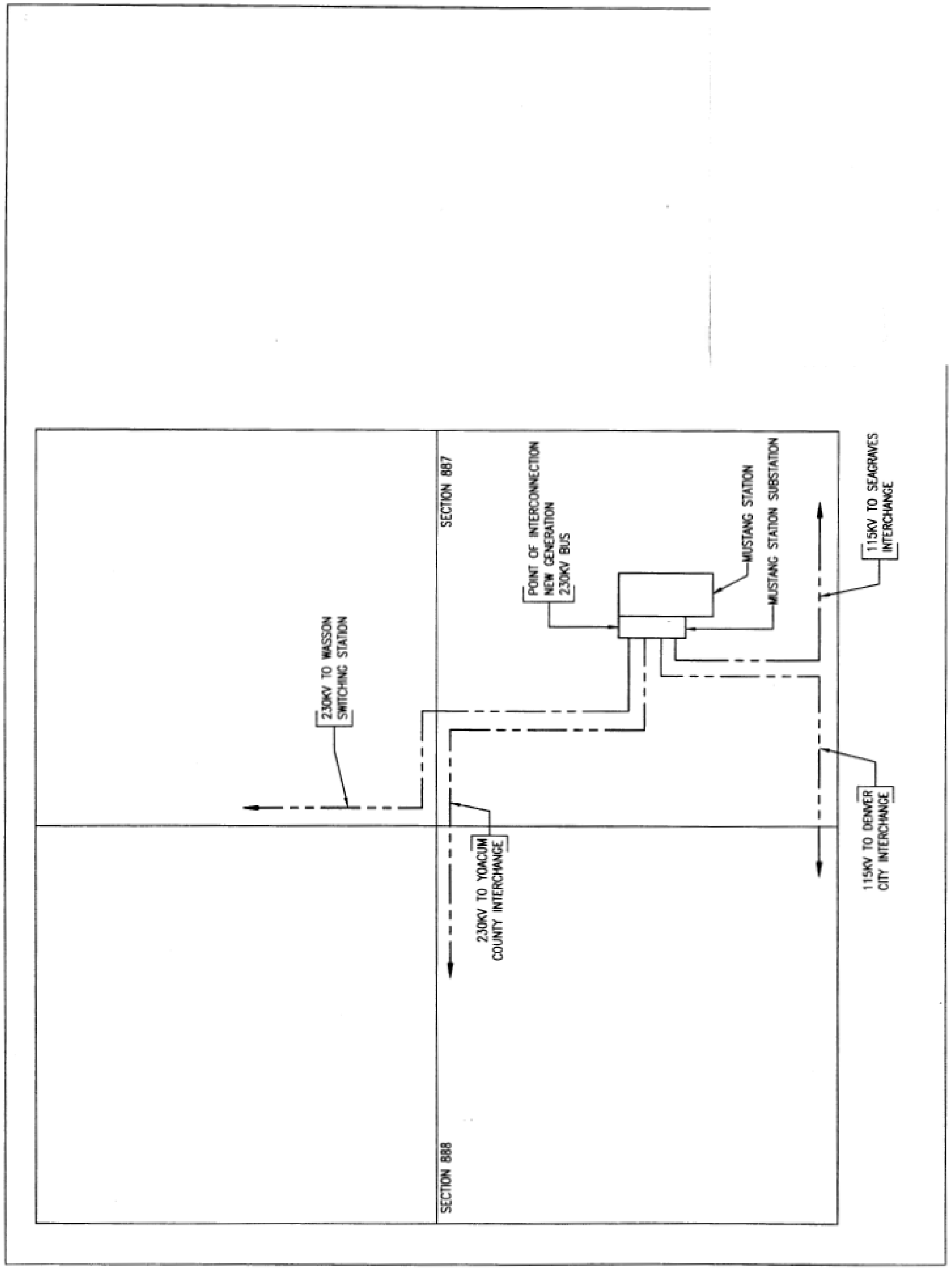
DRAWN Q PIERSON			
ISSUED Q PIERSON	SCALE		SHEET 6



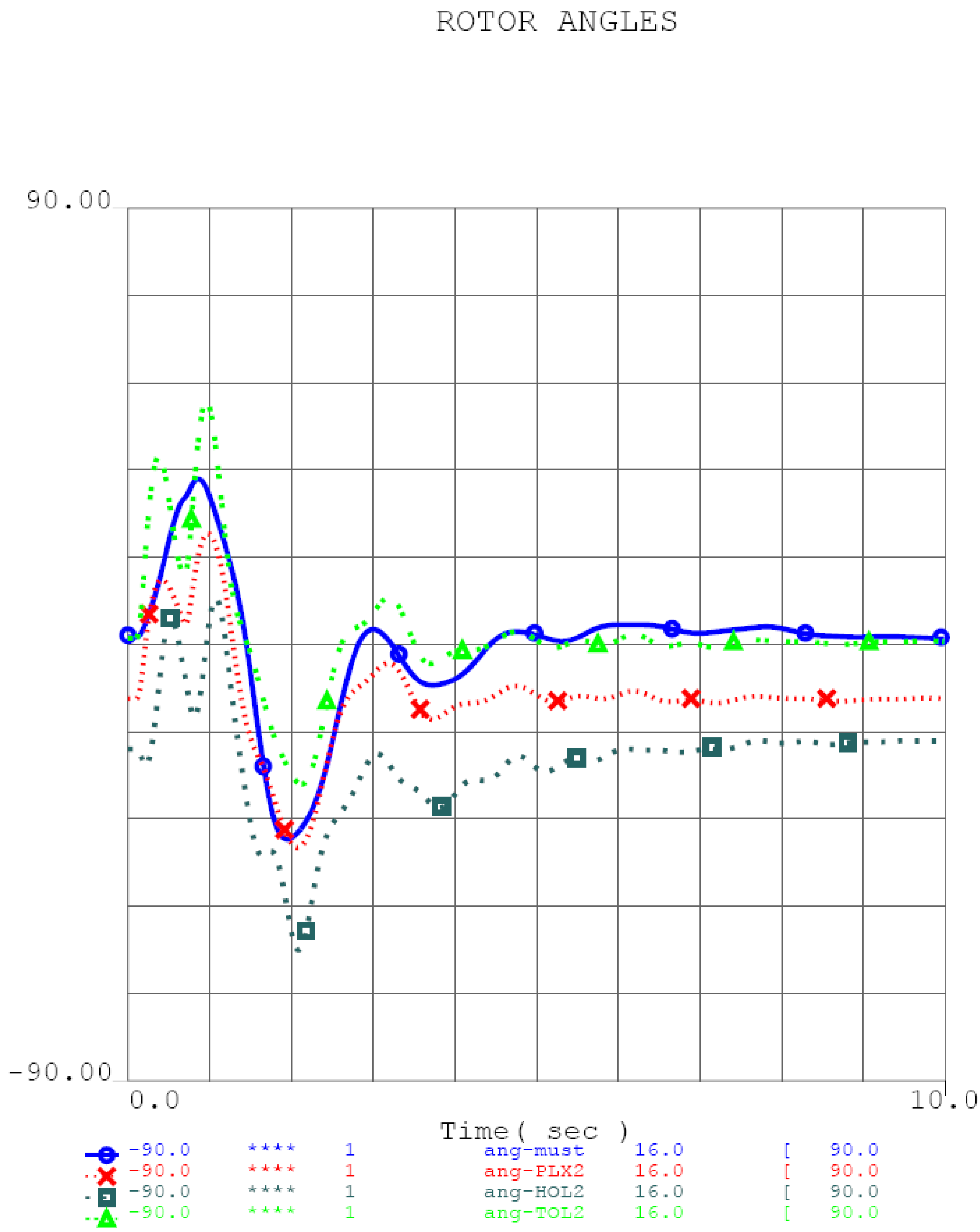
NEW ADDITION
EXISTING
NEW FRAME 7 GAS TURBINE
GT4
230KV
230KV P.T.'S
230-4.16KV 12/16/20MVA
4.16KV AUXILIARY SERVICE
230KV AMOCO
230KV YOAKUM
MUSTANG STATION 230KV BUS
230KV P.T.'S
MUSTANG STATION STEAM TURBINE
ST
230-115KV 90/120/150MVA AUTO TRANSFORMER
115KV PT'S
115KV PT'S
GT2
MUSTANG STATION GAS TURBINE NO.1
EXISTING 115KV SUBSTATION


SECTION 887
230KV TO WASSON
SWITCHING STATION
POINT OF INTERCONNECTION
NEW GENERATION
230KV BUS
MUSTANG STATION
MUSTANG STATION SUBSTATION
115KV TO SEAGRAVES
INTERCHANGE
115KV TO DENVER
CITY INTERCHANGE
230KV TO YOACUM
COUNTY INTERCHANGE
SECTION 888

Appendix B – Sample Plots

The following plots are included for sample only, the complete plots for all contingencies listed in Table 5 are provided in a CD-ROM

- ***2006 Summer Peak Plot, Contingency # 3, 3-phase fault.***



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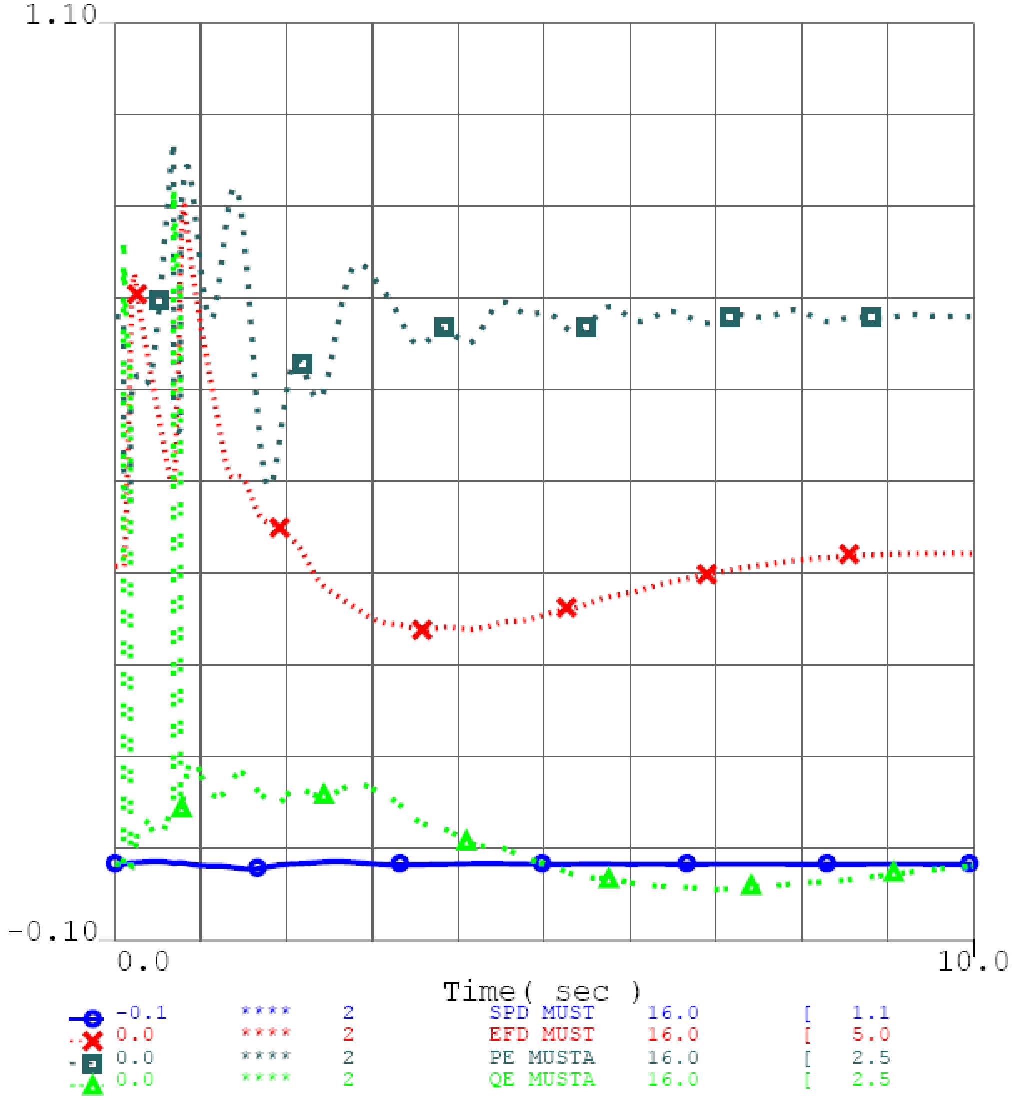
STUDY PLANT



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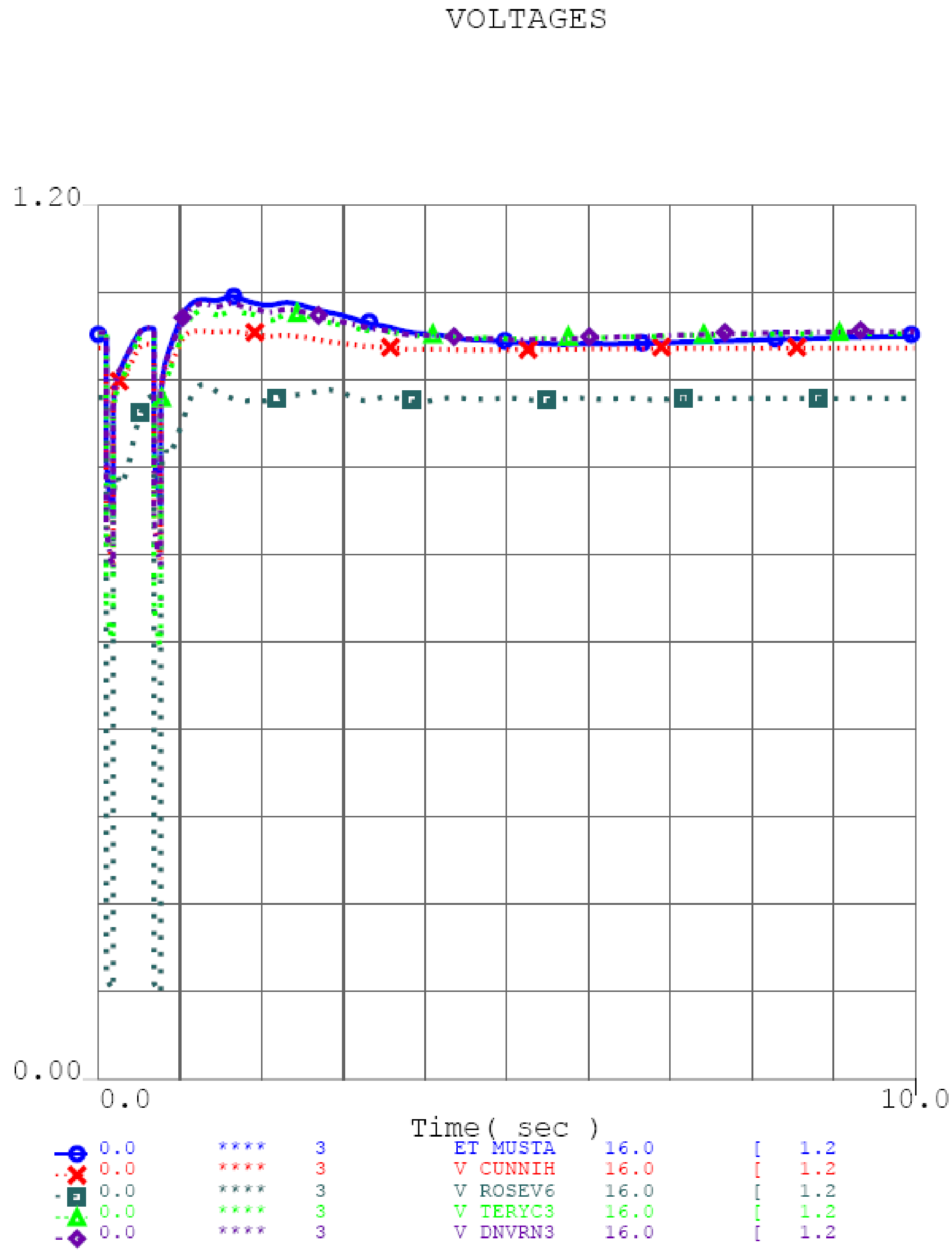

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