Southwest Power Pool

Impact Study for Generation Interconnection Request GEN – 2004 – 010

SPP Tariff Studies
(#GEN-2004-010)

August 2007

Summary

Black & Veatch performed the following Study at the request of the Southwest Power Pool (SPP) for Generation Interconnection request Gen-2004-010. The request for interconnection was placed with SPP in accordance with SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Pursuant to the tariff, Black & Veatch 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. This study was a re-study of request GEN-2004-010. The re-study was necessary due to the Customer requesting to change from G.E. wind turbines to Clipper wind turbines.

To meet FERC Order 661A provisions for low voltage ride through, the Customer will be required to install at least 60Mvars of 34.5kV capacitor banks within the Customer's wind farm substation as detailed in the Impact Study. The Impact Study found that with the use of the Clipper 2.5MW wind turbines, the installation of a dynamic reactive source (SVC or STATCOM) is not required.

All other Facility requirements that were given in the Facility Study for this request performed in September, 2005 and for the Interconnection Agreement executed in December, 2005 will still apply to this Generation Interconnection request.

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2004-010

SOUTHWEST POWER POOL (SPP)

August 1st, 2007

By

BLACK & VEATCH

Table of Contents

EXECUTIVE SUMMARY

A transient stability study has been performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2004-010 as part of the System Impact Study. The Interconnection Queue Position GEN-2004-010 is a wind farm of 300 MW capacity in Elk County, Kansas. This wind farm would be interconnected into the existing Latham 345kV substation on the Rose Hill – Neosho 345kV transmission line.

Transient Stability studies were conducted with the full output of 300 MW (100%). The wind farm was considered to contain Clipper -2.5 MW turbines.

The 2012 summer load flow case and 2008 winter load flow case together with the SPP MDWG 2006 stability model were used as the base case for the transient stability analysis. The study was performed using PTI's PSS/E program, which is an industry-wide accepted power system simulation program. The wind farm was modeled using the Clipper wind turbine model provided by the manufacturer.

Prior to the transient stability analysis, a power flow analysis was conducted to estimate the amount of additional shunt capacitors that would be needed at the wind farm 34.5 kV collector buses so as to have zero reactive power exchange between wind farm and the grid. It was found that about 60 MVAR capacitors would be needed in the summer peak and winter load case.

Transient Stability studies were conducted with the GEN-2004-010 output at 300 MW (100%) for two scenarios, i.e., (i) summer load and (ii) winter load. eighteen (18) contingencies were considered for each of the scenarios.

GEN-2004-010 generators were found to stay connected to the grid for all the contingencies that were studied. The prior queued project Gen-2002-004 was found to be tripped for contingencies FLT1_3, FLT2_1, FLT3_3, FLT7_3, FLT9_3 and FLT11_3. The Gen-2002-004 project was found to be stable for these contingencies with the voltage and frequency tripping disabled.

The study has not indicated any angular or voltage instability problem due to addition of GEN-2004-010 for the contingencies analyzed in both the scenarios.

If any previously queued projects that were included in this study drop out then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer's project on SPS transmission facilities.

1. INTRODUCTION

This report discusses the results of a transient stability study performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2004-010.

The Interconnection Queue Position GEN-2004-010 is a wind farm of 300 MW capacity in Elk County, Kansas. This wind farm would be interconnected into the existing Latham 345kV substation on the Rose Hill – Neosho 345kV transmission line.The system one line diagram of the area near the Queue Position GEN-2004-010 is shown below.

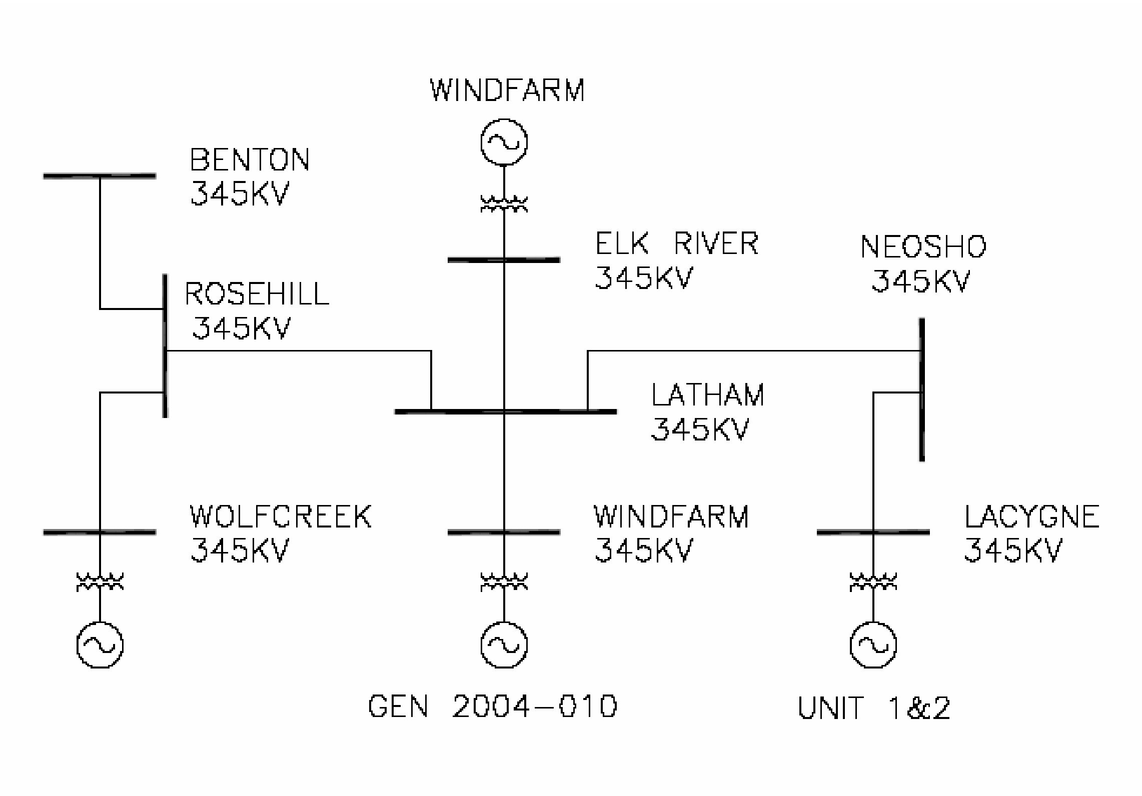


Figure 1: System One Line Diagram near GEN-2004-010

Transient Stability studies were conducted with the full output of 300 MW (100%). The wind farm was considered to contain Clipper -2.5 MW wind turbines in the study.

2. STABILITY STUDY CRITERIA

The 2012 summer load flow and 2008 winter load flow cases together with the SPP MDWG 2006 stability model were used as the base case for the transient stability analysis. These models were provided by SPP.

Using Planning Standards approved by NERC, the following stability definition was applied in the Transient Stability Analysis:

“Power system stability is defined as that condition in which the difference of the angular positions of synchronous machine rotor becomes constant following an aperiodic system disturbance.”

Disturbances such as three phase and single phase line faults were simulated for a specified duration and the synchronous machine rotor angles were monitored for their synchronism following the fault removal.

The ability of the wind generators to stay connected to the grid during the disturbances and during the fault recovery was also monitored.

3. SIMULATION CASES

Transient Stability studies were conducted with the GEN-2004-010 output at 300 MW for (i) 2012 summer and (ii) 2008 winter load flow cases.

Table 1 indicates the contingencies which were studied for each of the two cases.

Fault Number	Fault Definition
FLT13PH	Three phase fault on the Rose Hill to Latham Switching Station 345 kV line, near Latham, with one shot reclosing after 300 cycles.
FLT21PH	Single phase fault on the Rose Hill to Latham Switching Station 345 kV line, near Latham, with one shot reclosing after 300 cycles.
FLT33PH	Three phase fault on the Latham Switching Station to Neosho 345kV line, near Neosho, with one shot reclosing after 300 cycles.
FLT41PH	Single phase fault on the Latham Switching Station to Neosho 345kV line, near Neosho, with one shot reclosing after 300 cycles.
FLT53PH	Three phase fault on the Neosho to Morgan, 345kV line, near Mid-line bus, with one shot reclosing

	after 300 cycles.
FLT61PH	Single phase fault on the Neosho to Morgan, 345kV line, near Mid-line bus, with one shot reclosing after 300 cycles.
FLT73PH	Three phase fault on the Rose Hill to Wolf Creek 345 kV line, near Rose Hill, with one shot reclosing after 300 cycles.
FLT81PH	Single phase fault on the Rose Hill to Wolf Creek 345 kV line, near Rose Hill, with one shot reclosing after 300 cycles.
FLT93PH	Three phase fault on the Rose Hill to Benton 345 kV line, near Benton, with one shot reclosing after 60 cycles.
FLT101PH	Single phase fault on the Rose Hill to Benton 345 kV line, near Benton, with one shot reclosing after 60 cycles.
FLT113PH	Three phase fault on the Benton to Wichita 345 kV line, near Wichita, with one shot reclosing after 60 cycles.
FLT121PH	Single phase fault on the Benton to Wichita 345 kV line, near Wichita, with one shot reclosing after 60 cycles.
FLT133PH	Three phase fault on the Benton - Midian 138 kV line, near Midian, with one shot reclosing after 25 cycles.
FLT141PH	Single phase fault on the Benton - Midian 138 kV line, near Midian, with one shot reclosing after 25 cycles.
FLT153PH	Three phase fault on the Midian to Butler 138 kV line, near Butler, with one shot reclosing after 25 cycles.
FLT161PH	Single phase fault on the Midian to Butler 138 kV line, near Butler, with one shot reclosing after 25 cycles.
FLT173PH	Three phase fault on the Rose Hill to Weaver 138 kV line, near Weaver, with one shot reclosing after 25 cycles.
FLT181PH	Single phase fault on the Rose Hill to Weaver 138 kV line, near Weaver, with one shot reclosing after 25 cycles.

Table 1: Study Cases

In all of the simulations, the fault duration was considered to be 5 cycles except 138 kV network where the fault duration is 7 Cycles. One shot re-closing into the fault was also considered in the study with the re-closure dead time of 25 cycles for 138 kV lines and 300 cycles and 60 cycles for the 345 kV lines.

4. SIMULATION MODEL

The customer requested to use Clipper Wind turbine. The Clipper turbines have four separate output shafts, each feeding a 650 kW permanent magnet synchronous generator. The following are the main electrical parameters of the Clipper 2.5 MW wind turbine are set to.

Rated Power : 2.5 MW
Apparent Power : 2.5 MW

The models of the Wind Farm equipment such as generators, transformers and cables were added to the base case for the purpose of this study. The equivalent generators of the wind farm were based on the number of collector circuits shown on the Customer provided single line diagram. Figure 2 shows the one line diagram of GEN-2004-010 modeled.

Table 2 provides the number of Clipper 2.5 MW wind generators modeled as equivalents at each collector buses of the wind farm.

Collector Bus	**No. of generators aggregated**
EQ1N	1
EQ1N2	1
EQ2N1	6
EQ2N2	4
EQ3N1	7
EQ3N2	3
EQ4N1	6
EQ4N2	3
EQ5N1	8
EQ5N2	3
EQ6N1	7
EQ6N2	2
EQ6N3	1
EQ7N1	7

EQ7N3	3
EQ8N1	8
EQ8N2	1
EQ8N3	1
EQ9N1	6
EQ9N2	2
EQ9N3	2
EQ10N1	8
EQ10N2	2
EQ11N1	4
EQ11N2	3
EQ11N3	1
EQ12N1	6
EQ12N2	2
EQ12N3	2
EQ13N1	2
EQ13N2	8

Table 2: Equivalent Generators with Clipper 2.5 MW Turbines

The Customer provided the wind turbine feeder conductor types, lengths and impedance values. Line charging is negligible for the length of cables considered in the study and so was not included. Table 3 indicates the transmission line parameters, as provided by the Customer, were used in the model for the underground lines within the Wind Farm:

Conductor Size	**Resistance (Ohms per 1000 ft)**	**Reactance (Ohms per 1000 ft)**
1/0	0.2173	0.055
4/0	0.1070	0.049
1000 kcmil	0.0280	0.037
500 kcmil	0.0470	0.042

Table 3: Cable impedance per 1000 feet

The Customer also provided the following substation transformer's impedance:

Transformer Impedance: 9.0 % at 167 MVA

The wind farm was modeled using the Clipper wind turbine model available in PSS/E. The base case power flow diagram for the project GEN-2004-010 is shown in Figure 2. The prior queued project Gen-2002-004 (201 MW) is also included in the study model.

Prior to the transient stability analysis, a power flow analysis was conducted to estimate the amount of additional shunt capacitors that would be needed at the wind farm 34.5 kV collector buses so as to have zero reactive power exchange between wind farm and the

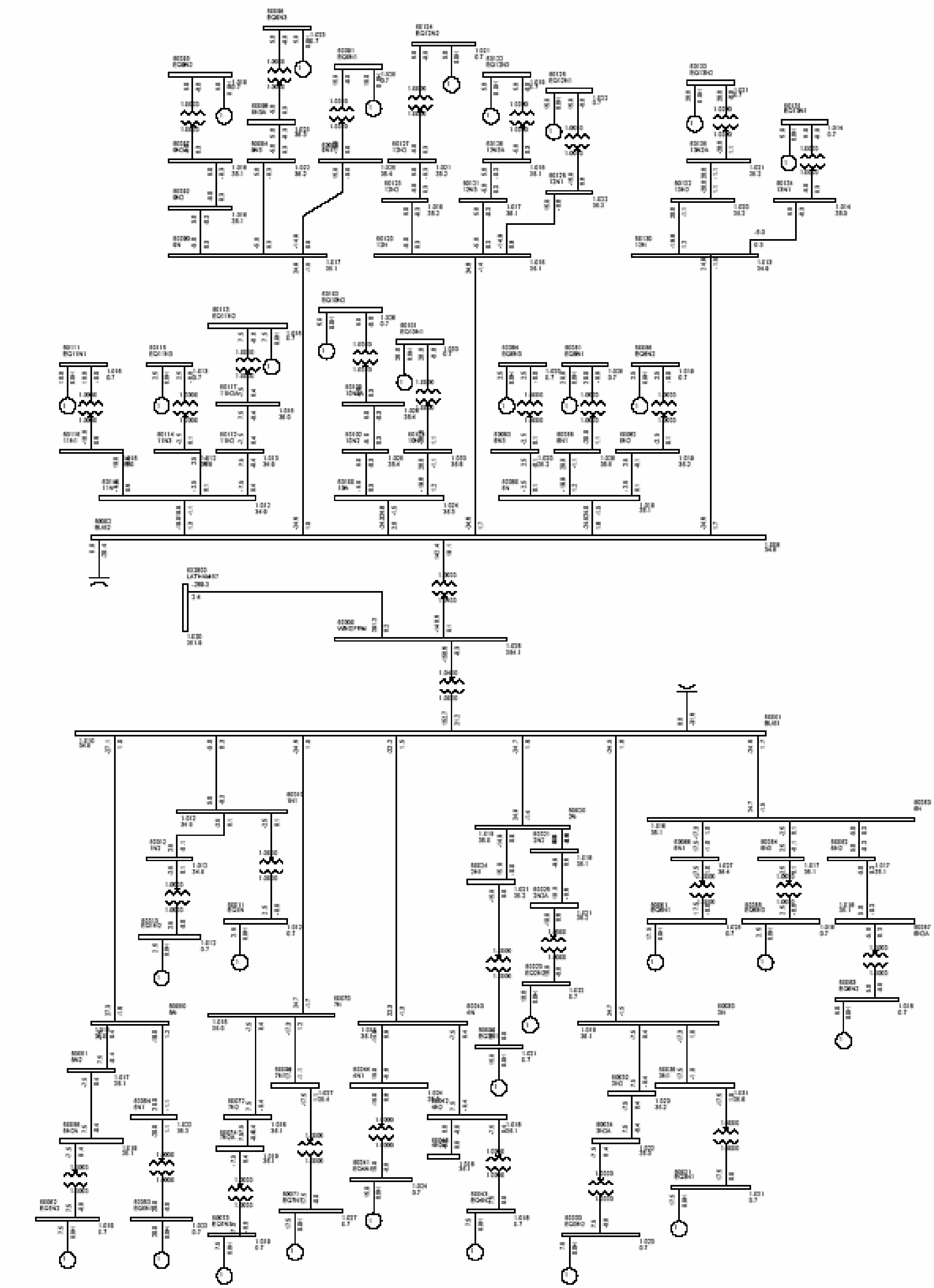


Figure 2: 100% Power Flow Base Case for GEN-2004-010

grid. It was found that about 60 MVAR capacitors would be needed in the summer case and winter case.

5. STUDY ASSUMPTIONS

The following assumptions were made in the Study:

1. The wind speed over the entire wind farm was assumed to be uniform and constant during the study period.
2. From the wind turbine data sheets the protection settings were used as and are shown in Figures 3.
3. The other generators in the SPP control area were scaled down to accommodate the new generation as indicated in Table 5.

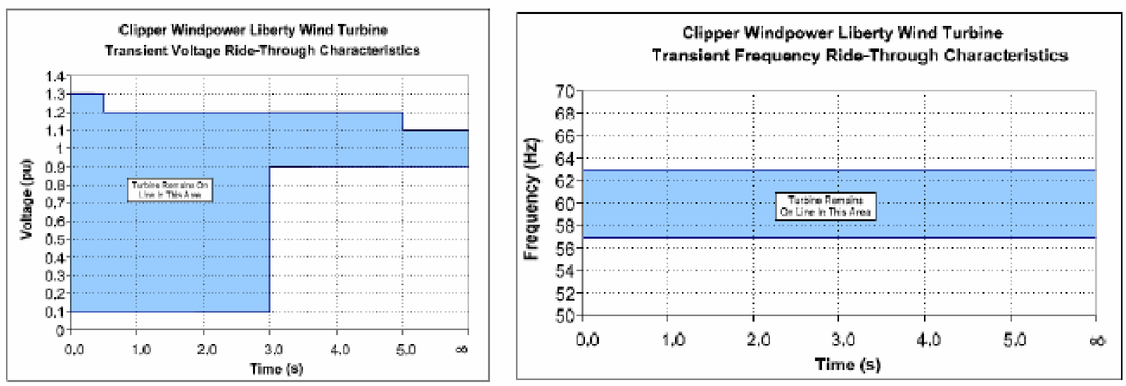


Figure 3: Protective Settings for voltage and frequency.

Scenario	Generation within SPP	
	Summer	Winter
Without the Wind Farms	40224	27543
GEN-2004-010 at 100% output with the prior queued projects	39924	27243

Table 5: SPP Dispatches

6. SIMULATION RESULTS

Initial simulation was carried out without any disturbance to verify the numerical stability of the model and was confirmed to be stable.

Table 6 provides the summary of the stability studies for GEN-2004-010.

Fault Number	Summer Load	Winter Load
FLT13PH	PQ	PQ
FLT21PH	PQ	PQ
FLT33PH	PQ	PQ
FLT41PH	- -	- -
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	PQ	PQ
FLT81PH	- -	- -
FLT93PH	PQ	PQ
FLT101PH	- -	- -
FLT113PH	PQ	PQ
FLT121PH	- -	- -
FLT133PH	- -	- -
FLT141PH	- -	- -
FLT153PH	- -	- -
FLT161PH	- -	- -
FLT173PH	- -	- -
FLT181PH	- -	- -

UV : GEN-2004-010 Tripped due to low voltage
OV : Tripped due to high voltage
UF : Tripped due to low frequency
OF : Tripped due to high frequency
S : Stability issues encountered
- - : Wind Farm did not trip
PQ : Prior queued project Gen-2002-004 tripped

Table 6: Stability Study Results Summary

GEN-2004-010 generators were found to stay connected to the grid for all the contingencies that were studied.

The prior queued project Gen-2002-004 was found to be tripped for FLT1_3, FLT2_1, FLT3_3, FLT7_3, FLT9_3 and FLT11_3. The Gen-2002-004 was found to be stable for these contingencies with the voltage and frequency tripping disabled.

Figure 3 and 4 show the summer peak response for FLT1_3PH and FLT3_3PH respectively. Figure 5 and 6 show the summer peak response for FLT1_3PH and FLT3_3PH with the voltage and frequency tripping disable for Gen-2002-004.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position GEN-2004-010 consisting of Clipper 2.5 MW wind turbines with its output at 300 MW. The study was conducted for two different power flow scenarios, i.e., one for summer peak and one for winter peak.

GEN-2004-010 generators were found to stay connected to the grid for all the contingencies that were studied. The prior queued project Gen-2002-004 was found to be tripped for FLT1_3, FLT2_1, FLT3_3, FLT7_3, FLT9_3 and FLT11_3. The Gen-2002-004 was found to be stable for these contingencies with the voltage and frequency tripping disabled.

The study has not indicated any angular or voltage instability problem due to addition of GEN-2004-010 for the contingencies analyzed in both the scenarios.

If any previously queued projects that were included in this study drop out then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer’s project on SPS transmission facilities.

Disclaimer

If any previously queued projects that were included in this study drop out, then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer’s project on SPS transmission facilities. Since this is also a preliminary System Impact Study, not all previously queued projects were assumed to be in service in this System Impact Study. If any of those projects are constructed, then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer’s project on SPS transmission facilities. In accordance with FERC and SPP procedures, the study cost for restudy shall be borne by the Interconnection Customer.

Figure 3 : System Responses with 100% output of GEN-2004-010 for FLT1-3PH

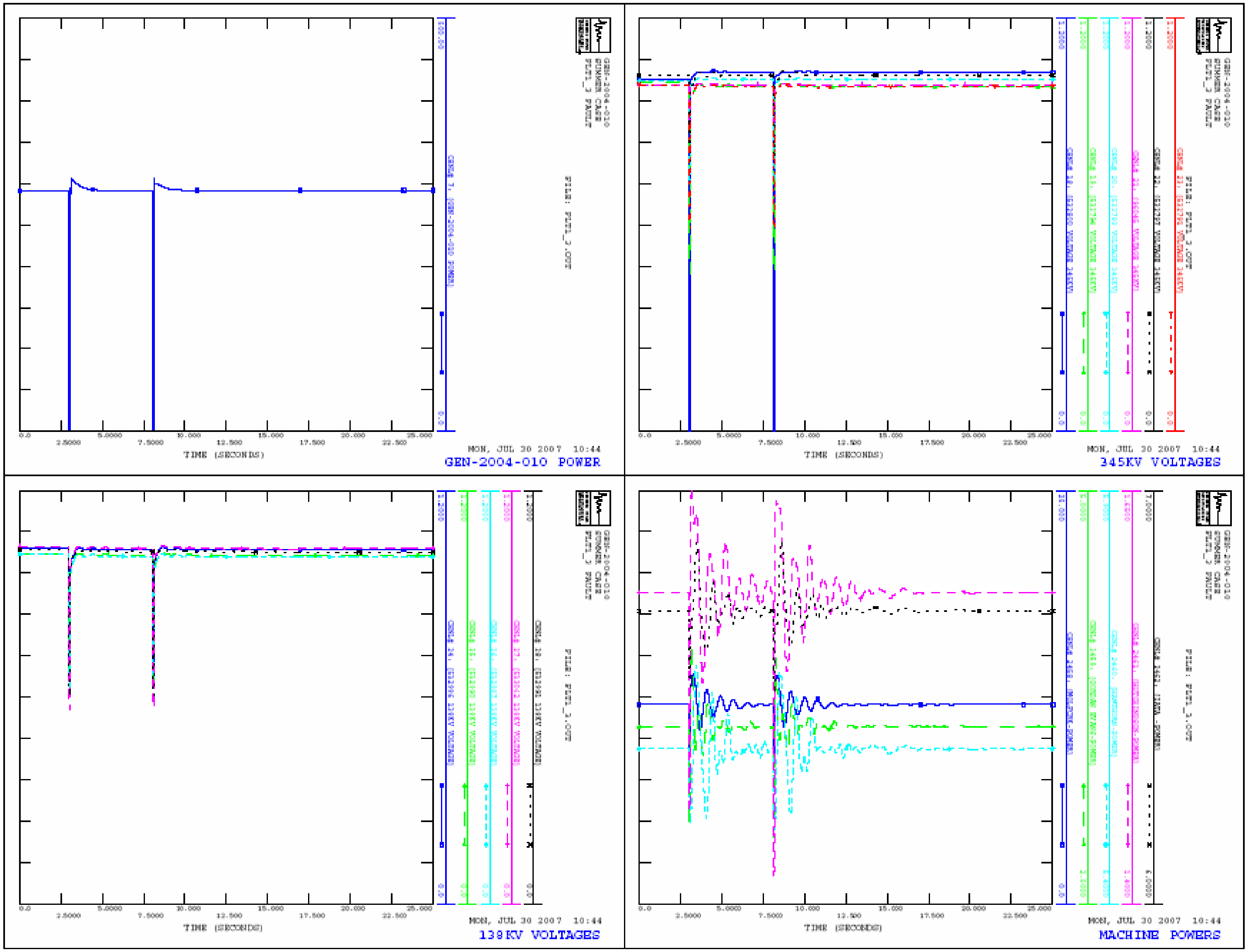
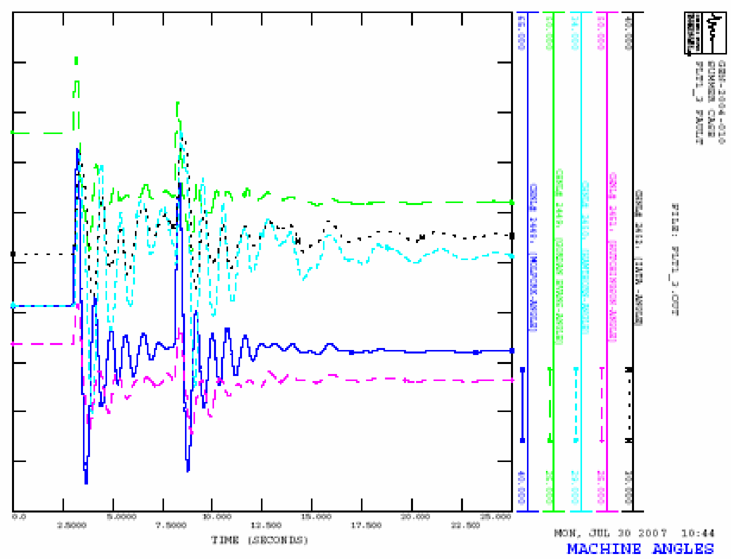


Figure 3 : System Responses with 100% output of GEN-2004-010 for FLT1-3PH (Cont'd)



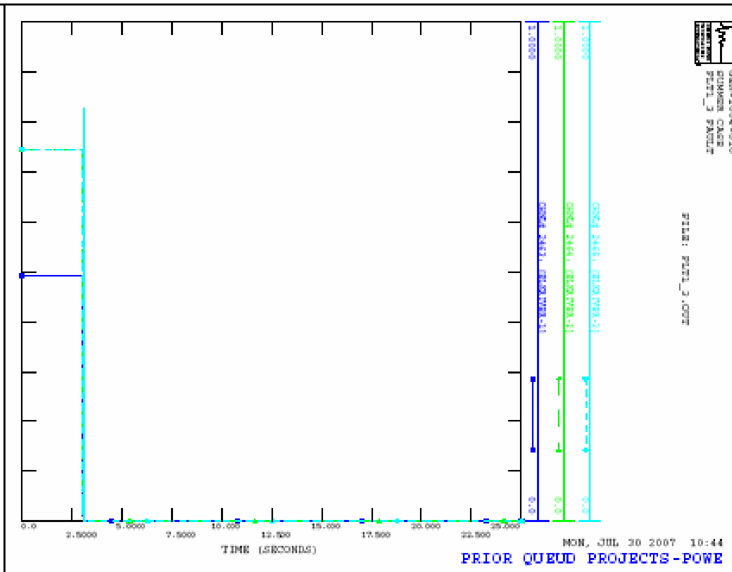


Figure 4 : System Responses with 100% output of GEN-2004-010 for FLT3-3PH

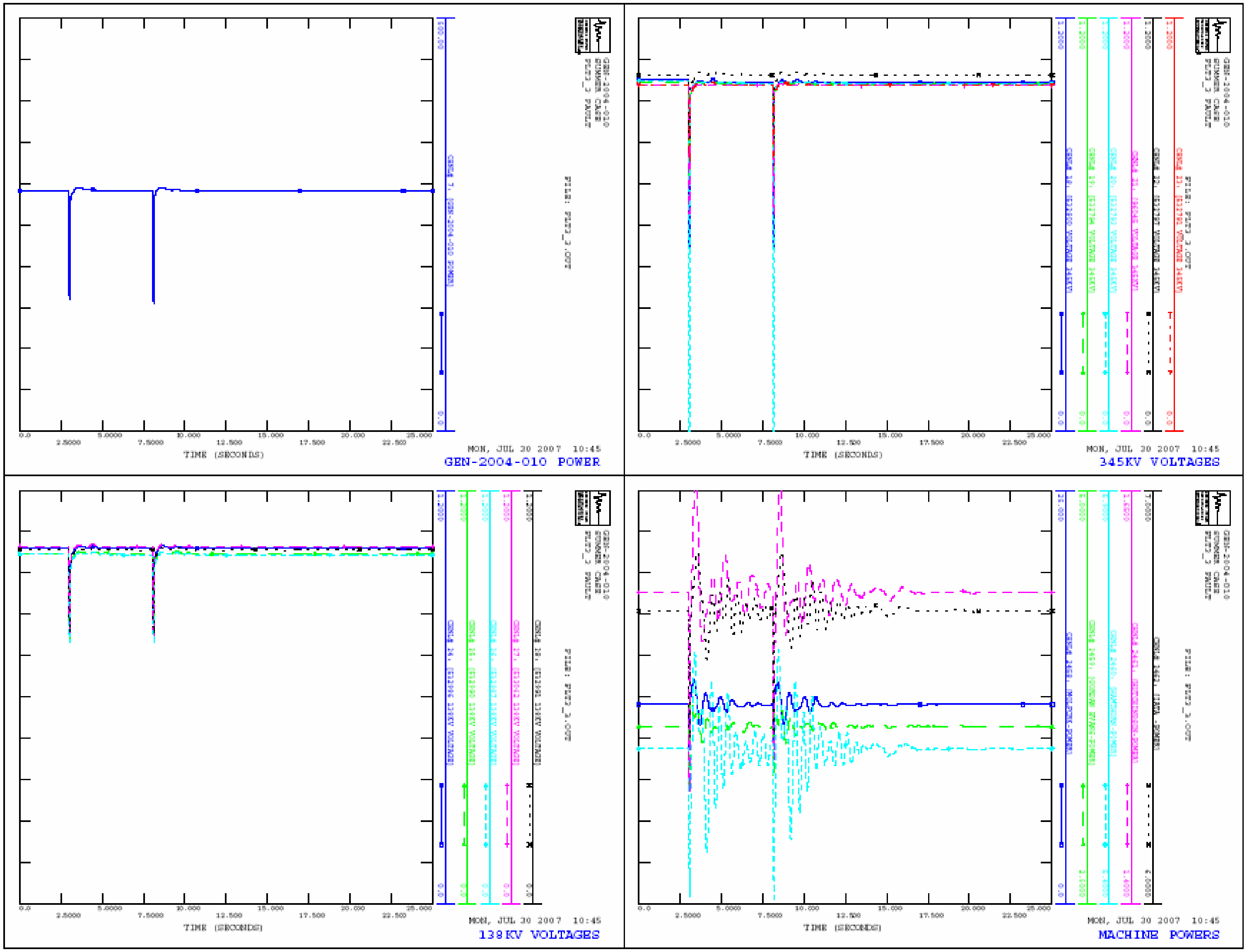
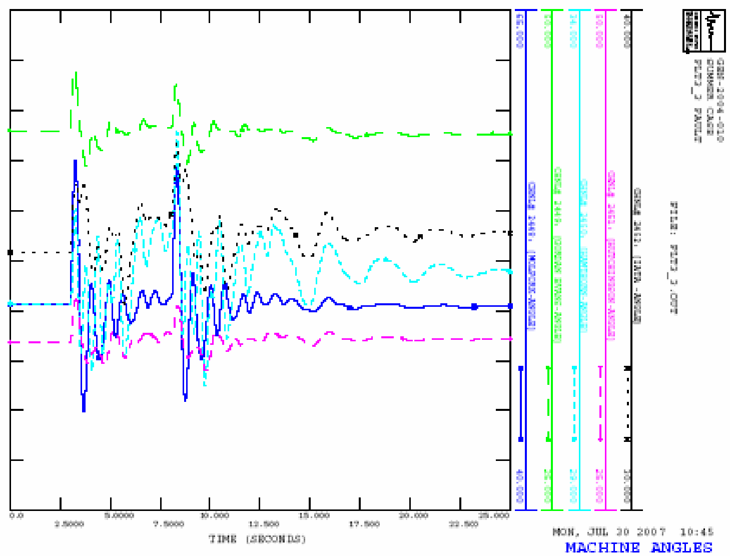


Figure 4: System Responses with 100% output of GEN-2004-010 for FLT3-3PH (Cont..)



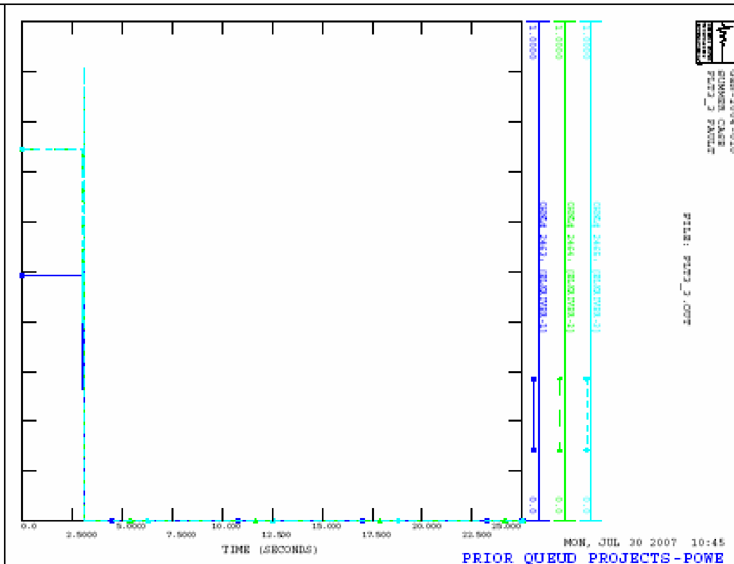


Figure 5: System Responses with 100% output of GEN-2004-010 for FLT1-3PH with Frequency and voltage tripping disabled for Gen-2002-004

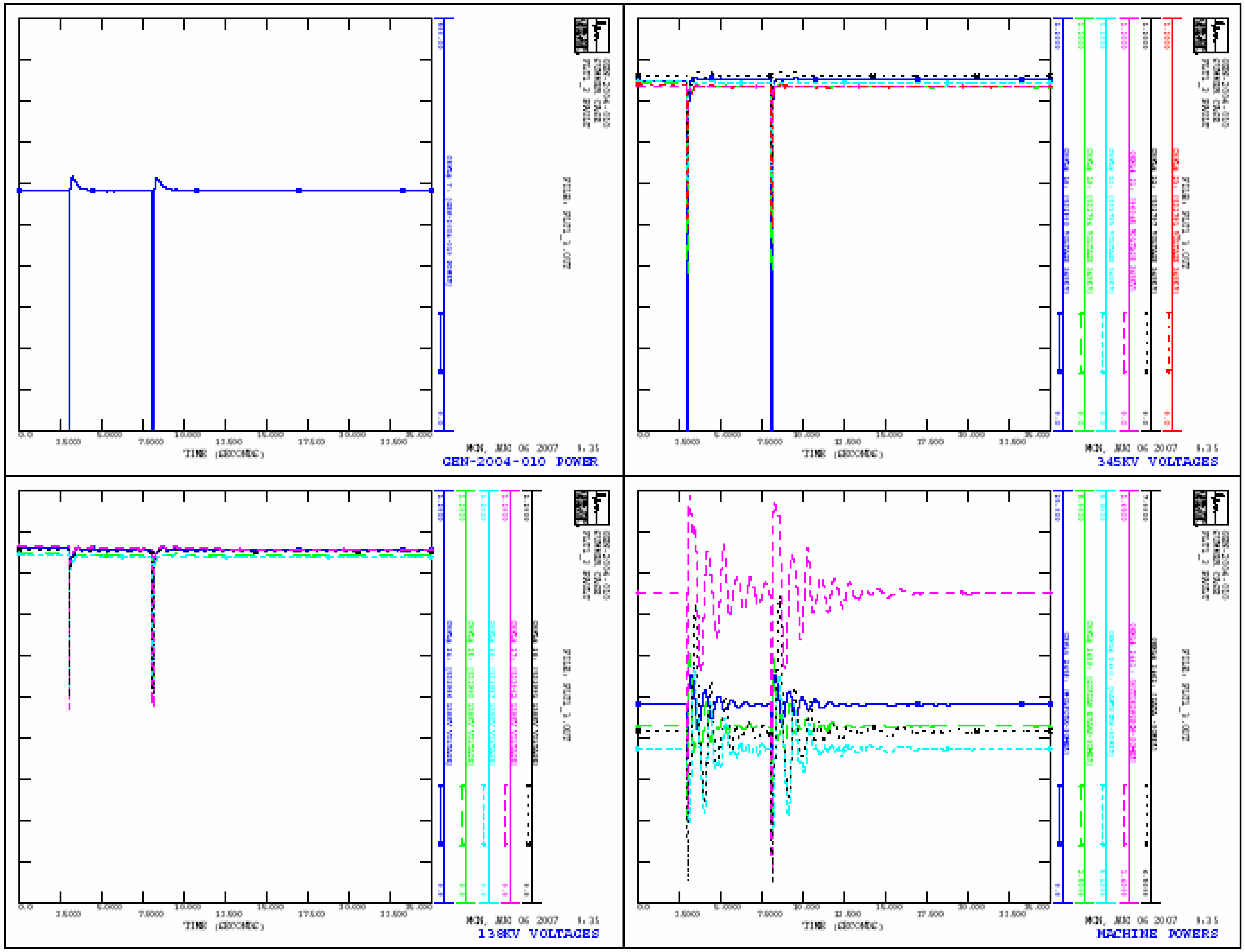


Figure 5: System Responses with 100% output of GEN-2004-010 for FLT1-3PH with Frequency and voltage tripping disabled for Gen-2002-004 (Cont..)

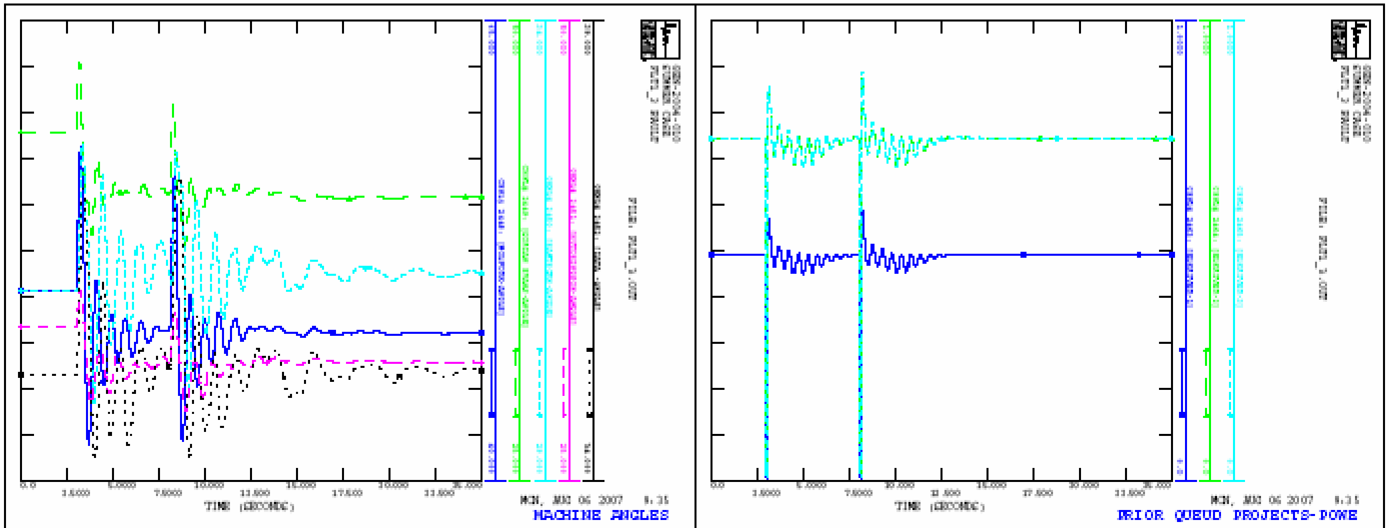


Figure 6: System Responses with 100% output of GEN-2004-010 for FLT3-3PH with Frequency and voltage tripping disabled for Gen-2002-004

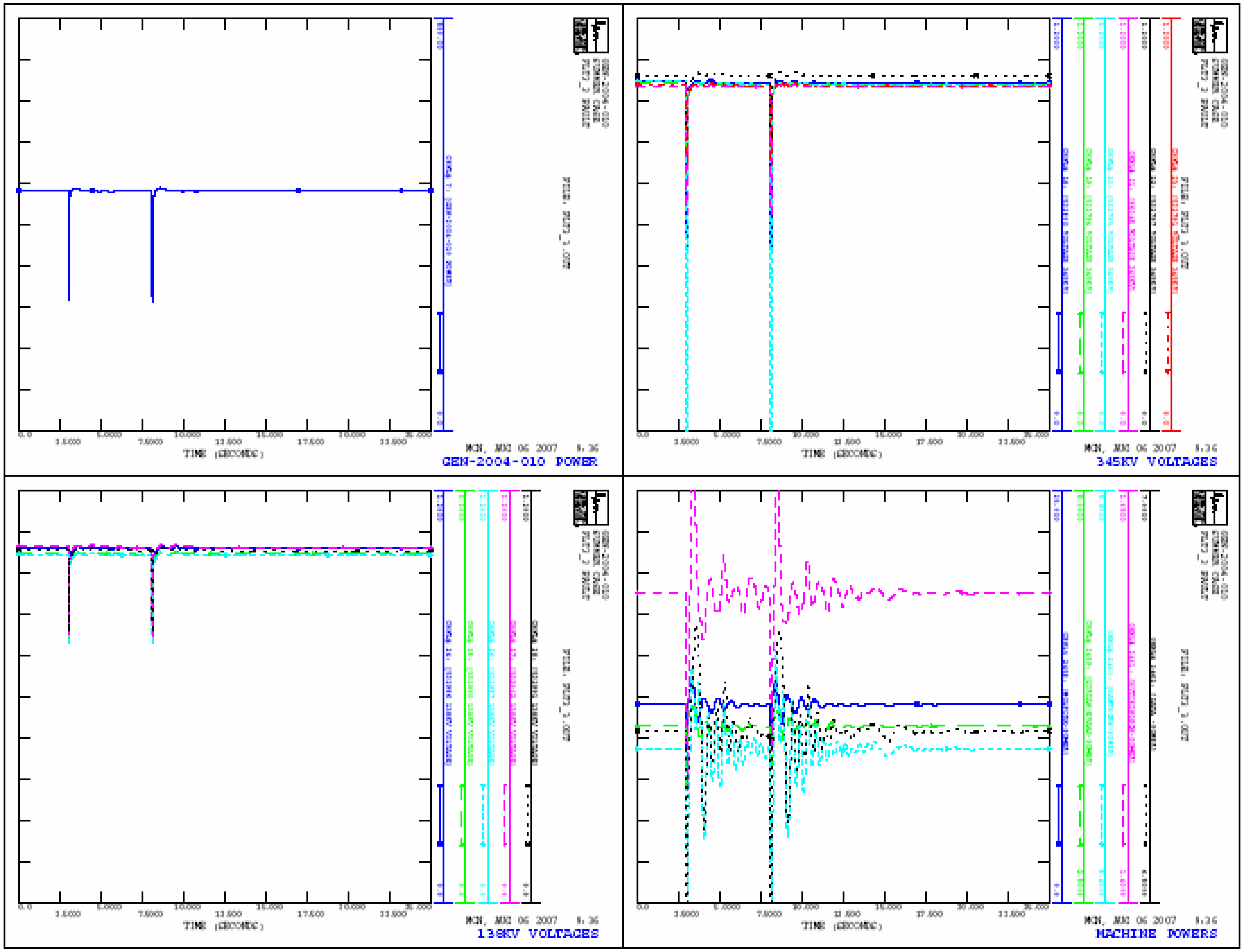


Figure 6: System Responses with 100% output of GEN-2004-010 for FLT3-3PH with Frequency and voltage tripping disabled for Gen-2002-004 (Cont..)