System Impact Study for Interconnection of >Omitted Text< 149 MW Generation Facility East of Apache, Oklahoma

Southwest Transmission Planning
(#OAIP 02 001)

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Table of Contents

Executive Summary

(>Omitted Text<) has requested an Impact Study for the interconnection of a wind farm in the Apache, Oklahoma vicinity. The plant will have a maximum output of 149 MW. The proposed facility would be connected to the Southwestern Station-Elgin Jct.-Lawton Eastside Station 138 kV line, and to the Southwestern Station-Hobart Jct. 138 kV line near Carnegie Station. The interconnection plan requires two new 17-mile 138 kV lines to be built, see **Figure 1**. The projected in service date is 2002.

The principal objective of this study is to: 1) identify any system problems associated with the connection of the proposed plant, 2) determine potential system modifications that might be necessary to facilitate the installation of the plant while maintaining system reliability and stability, and 3) estimate the costs associated with those system modifications. The study includes a steady state contingency analysis, a transient stability analysis, and an analysis of whether the interrupting capabilities of the existing circuit breakers in the area are exceeded with the addition of this new generation.

For the purposes of this study, two seasons were studied, the 2003 summer peak and the 2003 winter peak. In both cases the plant's output was exported as follows: 149 MW to Public Service Company of Oklahoma (PSO).

The estimated directly assigned cost of interconnecting the new >Omitted Text< facility to the transmission system is $19.9 million. This cost includes interconnection costs on the American Electric Power (AEP) system, based on steady state analysis and stability analysis. This cost also includes replacements needed for short circuit problems.

The analysis in this document shows that to accommodate a transfer, upgrades will also be required on the AEP 138 kV transmission system to relieve certain criteria violations during contingency operation. Facilities in the western AEP (AEPW) control area found to be overloaded in the transfer cases with the proposed plant addition and not in the base cases were flagged and listed in **Table 1**.

Introduction

>Omitted Text< has requested an Impact Study for the interconnection of a wind farm in the Apache, Oklahoma vicinity, approximately 13 miles south of the PSO's Southwestern Station on the Southwestern Station to Lawton Eastside Station 138 kV circuit. The plant will have a maximum output of 149. The projected in service date is 2002.

The principal objective of this study is to: 1) identify any system problems associated with the connection of the proposed plant, 2) determine potential system modifications that might be necessary to facilitate the installation of the plant while maintaining system reliability and stability, and 3) estimate the costs associated with those system modifications. The study includes a steady state contingency analysis, a transient stability analysis, and an analysis of whether the interrupting capabilities of the existing circuit breakers in the area are exceeded with the addition of this new generation.

The steady-state analysis considers the impact of the new generation on transmission facility loading and transmission bus voltages for outages of single, double, and triple circuit transmission lines, as well as outages of autotransformers, and generators.

The stability analysis shows the effects of the new generation on the transient stability of PSO and surrounding utility generators. Transient stability is concerned with recovery from faults on the transmission system that are in close proximity to generating facilities.

This study also includes a short circuit analysis that determines whether the interruption capabilities of existing circuit breakers are exceeded with the addition of the new generation.

Interconnection Facilities

>Omitted Text< Generation 138 kV Interconnection

The proposed >Omitted Text< wind farm is to be interconnected at transmission facilities located 17 miles from the new >Omitted Text< Switching Station. One connection will be at PSO's new >Omitted Text< Tap 138 kV station located on the Southwestern Station to Lawton Eastside Station 138 kV line. The generator's new >Omitted Text< Switching Station will also be interconnected at transmission facilities located 17 miles away at PSO's new Carnegie 138 kV station located on the Southwestern Station to Hobart Jct. 138 kV line. AEP will construct three new 138 kV stations with a three breaker ring bus in each that will accommodate three 138 kV terminals at >Omitted Text<, Carnegie, and the >Omitted Text< Tap. The new construction will include all metering, protection and SCADA systems. >Omitted Text< will construct and own the generating plant and maintain the equipment including the GSU high-side transformer disconnects at the ownership boundary. AEP will retain ownership and operating authority of the 138 kV interconnects up to the high-side GSU transformer disconnects.

The design and construction of the three new 138 kV stations will meet all AEP specifications for stations. Bus work and disconnect switches will be designed to accommodate the loading requirements, and circuit breakers will be rated to ensure adequate load and fault interrupting capability. Metering equipment will be installed to monitor the plant output and will meet the required accuracy specifications. The estimated cost of the three new >Omitted Text< 138 kV stations is $5,013,000. This estimate does not include the cost of land for the three new stations.

>Omitted Text< Windfarm to new >Omitted Text< 138 kV Station (Located on Southwestern Station to Lawton Eastside Station 138 kV line) 138 kV Circuit

AEP will build a 17-mile, 138 kV circuit connecting >Omitted Text< Windfarm to the >Omitted Text< 138 kV interconnection station located on the Southwestern Station to Lawton Eastside Station 138 kV line. The line shall be supported on single concrete pole structures. The phase conductors shall be 1272 ACSR with shield wire. The cost of the line construction is estimated to be $7,386,829.

>Omitted Text< Windfarm to new Carnegie 138 kV Station (Located on Southwestern Station to Hobart Jct. 138 kV line) 138 kV Circuit

AEP will build a 17-mile, 138 kV circuit connecting >Omitted Text< Windfarm to the Carnegie 138 kV interconnection station located on the Southwestern Station to Hobart Jct. 138 kV line. The line shall be supported on single concrete pole structures. The phase conductors shall be 1272 ACSR with shield wire. The cost of the line construction is estimated to be $7,386,829.

Interconnection Costs

Listed below are the directly assigned costs associated with interconnecting the >Omitted Text< 149 MW generation facility to the transmission system.

AEP SYSTEM IMPROVEMENTS	COST (2002 DOLLARS)
>Omitted Text< Generation 138 kV Interconnection-New >Omitted Text< 138 kV Switching Station near generation site, new >Omitted Text< Tap 138 kV switching station located on the Southwestern Station to Lawton Eastside Station 138 kV circuit, and new Carnegie 138 kV switching station located on the Southwestern Station to Hobart Jct. 138 kV line (Estimate does not include the cost of the land)	$5,013,000
>Omitted Text< Switching Station to new >Omitted Text< Tap 138 kV Station (Located on Southwestern Station to Lawton Eastside Station 138 kV line) 138 kV, 17-mile circuit	$7,386,829
>Omitted Text< Switching Station to new Carnegie 138 kV Station (Located on Southwestern Station to Hobart Jct. 138 kV line) 138 kV, 17-mile circuit	$7,386,829
TOTAL	**$19,786,658**

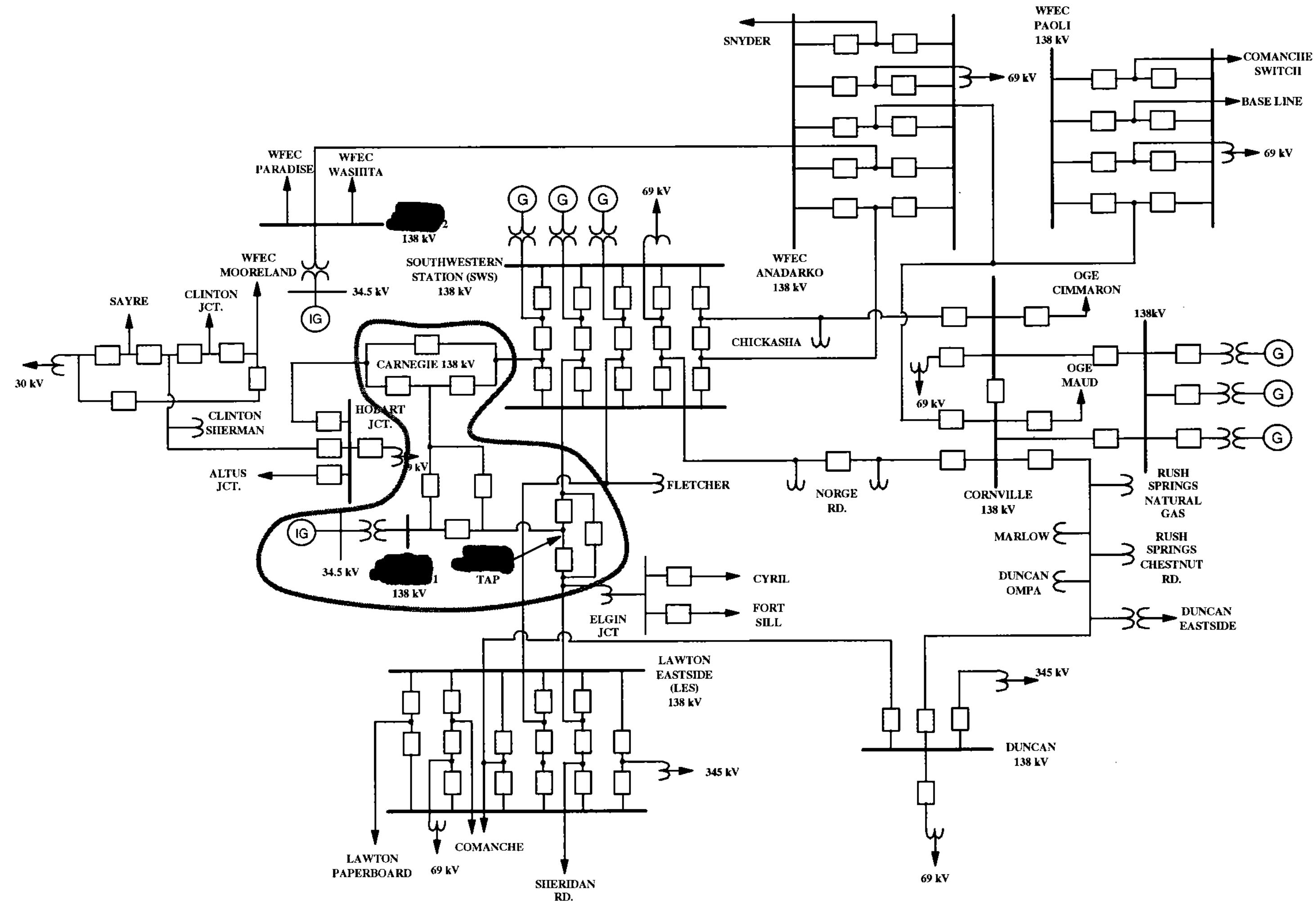


Figure 1: System one-line with [redacted] generation interconnected at new [redacted] 138 kV switching station.

A. Steady State Analysis

Study Methodology

The AEP and Southwest Power Pool (SPP) criteria state that the following conditions be met in order to maintain a reliable and stable system.

1) More probable contingency testing.... must conclude that

   a) All facility loadings are within their emergency ratings and all voltages are within their emergency limits (0.90-1.05 per unit) and
   b) Facility loadings can be returned to their normal limits within four hours

2) Less probable contingency testing.... shall conclude that

   a) Neither uncontrolled islanding, nor uncontrolled loss of large amounts of load will result.

More probable contingency testing is defined as losing any single piece of equipment or multi-circuit transmission lines. Less probable contingency testing involves the loss of any two critical pieces of equipment such as 345 kV autotransformers and generating units or the loss of critical transmission lines in the same right-of-way.

The 2002 series Southwest Power Pool 2003 summer and winter peak base cases were used to model the transmission network and system loads. These cases were modified to reflect known firm point-to-point transmission requests that have been approved.

Per information received from >Omitted Text<, the point of receipt of the generated capacity of the new plant called for 149 MW of the output to be sent to PSO.

Using the created 2003 summer peak model and PTI's PSS/E program, single and select double contingency outages on the SPP system were analyzed to determine the necessary facilities to interconnect the proposed plant to the transmission system. This load flow analysis is described on the following pages.

Next, using the two created models and the ACCC function of PTI's PSS/E program, single and select double contingency outages on the SPP system were analyzed. Facilities in the western AEP (AEPW) control area found to be overloaded in the transfer cases with the proposed plant addition and not in the base cases were flagged and listed in **Table 1.**

Load Flow Analysis

The discussion below is not a summary of all outages or criteria violations. It lists certain key flow results most relevant to the discussion. These load flow analysis results do not include any additions or changes found in the stability analysis or the short circuit analysis.

2003 summer peak base case with generation added at >Omitted Text< under contingency operation With a double contingency of the Tulsa Southeast to Catoosa and the Catoosa to Oneta 138 kV lines, the Fulton Tap line reaches 107% of the emergency rating of the wave trap.

Table 1 – Overloaded SPP Facilities for 03SP. 149 MW transfer to PSO. The upgrades (if available) are included.

Study Year	From -To Area(s)	Branch Over 100% Rate B	Rate B <MVA>	580MW Transfer Case %Loading	Outaged Branch That Caused Overload	Upgrades Required to Relieve Overload
04SP	AEPW-AEPW	FULTONW4 to FULTAP-4	105	107	Tulsa SE to Catoosa and Catoosa to Oneta Double Contingency	Replace 400 A wave trap with 1200 A device

B. Stability Analysis

INTRODUCTION

Per [redacted] request, American Electric Power (AEP) has conducted a stability performance study to evaluate the feasibility of connecting a 149 MW wind farm at a site near Apache, Oklahoma. This report documents the stability performance study.

OVERVIEW OF GENERATION FACILITIES

Figure A.1 of Appendix 1 shows the transmission system configuration in the vicinity of the proposed generaton. The proposed facility would be connected to the Southwestern Station (SWS)–Elgin Jct.-Lawton Eastside Station (LES) 138 kV line, and to the Southwestern Station (SWS)–Hobart Jct. 138 kV line near Carnegie Station with the breaker configuration as shown in Figure A.1. This interconnection plan requires two new 17-mile 138 kV lines, [redacted] tap and [redacted] 1-Carnegie, to be built.

The proposed facility contains (99) 1.5 MW Enron wind turbines for a total output of 149 MW. In this study the wind plant was modeled as one 149 MW induction generator at the [redacted] 1 34.5 kV bus as shown in Figure A.1. The induction generator dynamic modeling data used in the study were provided by [redacted], and are documented in Appendix 2. No dynamic voltage control effect was represented in the study since [redacted] did not provide data for such voltage control action.

DYNAMICS BASE CASE

A western AEP dynamics base case representing 2002 summer peak load conditions for the SPP portion of the AEP System was used for this study. This dynamics case was assembled using data from the 2002 SPP Dynamics Database. The new [redacted] generating facility totaling 149 MW was added to the case using data and configuration information provided by [redacted] and their equipment vendors as shown in Appendix 2. An identical [redacted] 149 MW wind farm, located at the same site, is proposed for connection into the Western Farmers Energy Cooperative (WFEC) system, and was also included in the case as shown in Figure A.1.

TESTING CRITERIA

AEP transient stability criteria for 138 kV connected generation facilities shown in Table 4.1 are used in time domain simulations to evaluate the stability performance of a proposed generation facility.

The testing criteria described in Table 4.1 specify the conditions and events for which stable operation is required. In addition to transient stability performance, satisfactory damping of generating unit post-disturbance power oscillations is required. For each simulated disturbance, the resulting transmission system response is analyzed to assess the impact of the disturbance scenarios on the proposed generators and the surrounding system.

Table 4.1

AEP 138 kV Stability Disturbance Testing Criteria

Prefault System Condition	Fault Disturbance Scenario
All Facilities In Service	3A. Permanent single phase to ground fault with three-phase breaker failure. Fault cleared by backup breakers 3B. Permanent 3-phase fault with unsuccessful HSR (high speed reclosing), if applicable. Fault cleared by primary breakers. 3C. 3-phase line opening without fault.
One Facility Out of Service	3D. Permanent 3-phase fault with unsuccessful HSR, if applicable. Fault cleared by primary breakers. 3E. 3-phase line opening without fault

STUDY SCOPE

The dynamic simulations were conducted for selected event scenarios and post-contingency network configurations described in Table 5.1. Note: First two letters of the case designation refer to the criterion listed in Table 4.1 (e.g., case 3A-1 represents criterion 3A of Table 4.1).

Table 5.1

Event Scenarios and Post-Contingency Network Configurations

Case	Prior Condition (Lines out of service)	Disturbance	Faulted Circuit	Fault Location	Comments
3A-1	All facilities in service	Perm SLG fault W/1 ph CB failure	[redacted]p-SWS 138 kV	[redacted]n tap	Primary breaker opens in 5 cycles. Breaker fails at [redacted] tap 138 kV. Backup breaker opens 12 cycles following fault initiation clearing [redacted] tap-Elgin Jct.-LES 138 kV line.
3A-2			[redacted]tap-Elgin Jct.-LES 138 kV		Primary breaker opens in 5 cycles. Breaker fails at [redacted] tap 138 kV. Backup breaker opens 12 cycles following fault initiation clearing SWS[redacted]n tap 138 kV line.
3A-3			Carnegie-SWS 138 kV	Carnegie	Primary breaker opens in 5 cycles. Breaker fails at Carnegie 138 kV. Backup breaker opens 15 cycles following fault initiation clearing Blue Canyon 1-Carnegie and Carnegie-Hobart Jct. 138 kV lines.
3B-1		Perm 3 ph fault with no HSR	[redacted]ap-SWS 138 kV	[redacted]n tap	Fault time 5 cycles.
3B-2			Blue Canyon tap-Elgin Jct.-LES 138 kV		
3B-3			[redacted]1- [redacted] tap 138 kV	[redacted]n 1	Fault time 3.5 cycles.
3B-4			[redacted] 1-Carnegie 138 kV		
3B-5			SWS-Carnegie 138 kV	SWS	Fault time 5 cycles.

Case	Prior Condition (Lines out of service)	Disturbance	Faulted Circuit	Fault Location	Comments
3B-6			SWS-Anadarko 138 kV		
3B-6$_{HSR}$	All facilities in service	Perm 3 ph fault with unsuccessful HSR	SWS-Anadarko 138 kV	SWS	Fault time 5 cycles. Unsuccessful HSR time 0.1 seconds.
3B-7			Carnegie – Hobart Jct. 138 kV	Carnegie	Fault time 5 cycles. Unsuccessful HSR time 0.5 seconds.
3B-8		Perm 3 ph fault with no HSR	SWS-Cornville 138 kV	SWS	Fault time 5 cycles.
3B-9			SWS-Fletcher-LES 138 kV		
3B-10		Perm 3 ph fault with unsuccessful HSR	LES-Duncan-Comanche 138 kV	LES	Fault time 5 cycles. Unsuccessful HSR time 0.1 seconds.
3D-1	[redacted] tap -Elgin Jct.-LES 138 kV	Perm 3 ph fault w/no HSR	[redacted] 1-Carnegie 138 kV	[redacted] 1	Fault time 3.5 cycles.
3D-2	[redacted] 1-Carnegie 138 kV		[redacted]tap-SWS 138 kV	[redacted] tap	Fault time 5 cycles.
3D-3			[redacted]tap-Elgin Jct.-LES 138 kV		
3D-4	[redacted] 1- [redacted] tap 138 kV		SWS- Carnegie 138 kV	SWS	
3D-5	SWS- Carnegie 138 kV		[redacted] 1- [redacted] tap 138 kV	[redacted] 1	Fault time 3.5 cycles.
3D-6	[redacted] 1- [redacted] tap 138 kV	Perm 3 ph fault with unsuccessful HSR	Carnegie – Hobart Jct. 138 kV	Carnegie	Fault time 5 cycles. Unsuccessful HSR time 0.5 seconds.

STABILITY SIMULATION RESULTS

The stability performance study results are presented in Appendix 3 and are summarized in Table 6.1. Appendix 3 contains the plots of:

- speed deviation and terminal voltage for the proposed [redacted] generating units and [redacted] units connected to WFEC system
- speed deviation plots for nearby existing generators: WFEC Anadarko, AEP Comanche Station, and Southwestern Station and
- [redacted] 1, SWS, LES, and Anadarko 138 kV bus voltages.

Transient stability performance of the cases with no prior outage was, with some exceptions, found to be acceptable. The results of Cases 3B-3 and 3B-4 with primary fault clearing time of 5 cycles (not shown in this report) indicate transient instability. However, Table 6.1 results show that both cases are stable with primary fault clearing time of 3.5 cycles. Therefore, it is recommended that the primary fault clearing time at [redacted] 1, [redacted] tap, and Carnegie Stations be 3.5 cycles. Furthermore, due to the lack of stability margin in Case 3B-3 it is recommended that the primary fault clearing time at [redacted] 1 be reduced to 3 cycles.

The simulation results of Case 3B-6 with HSR (shown in Appendix 3), and results of Cases 3B-5, 3B-8 and 3B-9 with HSR (not shown in this report) indicate transient instability. However, as indicated in Table 6.1, Cases 3B-5, 3B-6, 3B-8 and 3B-9 without HSR are transiently stable. Therefore HSR must be disabled on every 138 kV line going out of the SWS station.

Table 6.1

Stability Performance Study Results

Case	Generation (MW)	Transient Stability	Oscillatory Stability
3A-1	149MW	Stable	Satisfactory
3A-2		Stable	Satisfactory
3A-3		Stable	Satisfactory
3B-1		Stable	Satisfactory
3B-2		Stable	Satisfactory
3B-3		Marginally Stable	Satisfactory
3B-4		Stable	Satisfactory
3B-5		Stable	Satisfactory
3B-6		Stable	Satisfactory
$3B\text{-}6_{HSR}$		Unstable	N/A
3B-7		Stable	Satisfactory
3B-8		Stable	Satisfactory
3B-9		Stable	Satisfactory
3B-10		Stable	Satisfactory
3D-1		Stable	Satisfactory
3D-2		Unstable	N/A
3D-3		Unstable	N/A
3D-4		Unstable	N/A
3D-5	100MW	Unstable	N/A
	90 MW	Marginally Stable	Satisfactory
3D-6	149 MW	Unstable	N/A

Table 6.1 results indicate that following the outage o[redacted] 1-Carnegie 138 kV line (Cases 3D-2 and 3D-3), [redacted] 1-[redacted] tap 138 kV line (Cases 3D-4 and 3D-6), or SWS- Carnegie 138 kV line (Case 3D-5), the [redacted] plant generation will have to be curtailed. Other contingency conditions, not considered in this study, may also require curtailment. The results of Case 3D-5 indicate that the largest expected curtailment would be approximately 60 MW. The studies necessary to determine all curtailment conditions and levels will be extensive and are not attempted here. If the proposed facility is built, the required levels of curtailment will be determined in the follow-up stability study by AEP after the final project data is received.

SUMMARY

- This stability performance study was conducted to evaluate the feasibility of connecting a 149 MW wind farm at a site near Apache, Oklahoma. The interconnection plan consists of two new 17-mile 138 kV lines, [redacted]

[redacted] tap and [redacted] 1-Carnegie, and nine new circuit breakers at [redacted] 1, [redacted] tap and Carnegie Stations as shown in Figure A.1.

- The wind plant was modeled as one 149 MW induction generator at the [redacted] 1 34.5 kV bus as shown in Figure A.1. No dynamic voltage control effect was represented in the study since [redacted] did not provide data for such voltage control action. The study should be revisited, if representation of voltage control action as a user-defined PSS/E model is made available by [redacted].

- The study results show that from a stability perspective, the proposed [redacted] generation plant totaling 149 MW may be accommodated at the proposed location. However,

  1) The primary fault clearing times at [redacted] 1, [redacted] tap, and Carnegie Stations, should be 3.5 cycles. Furthermore, due to the lack of transient stability margin, it is recommended that the primary fault clearing time at [redacted] 1 Station be reduced to 3 cycles.
  2) The [redacted] generation will have to be curtailed under certain contingency conditions. The largest expected curtailment would be approximately 60 MW.
  3) HSR must be disabled on every 138 kV line going out of the SWS station

- If the proposed generation project is built, follow-up stability studies by AEP will be required based on dynamics data and modeling for the proposed generating units that have been revised to reflect equipment commissioning tests and field settings.

- This study addresses the impact of the proposed generation independent of any other merchant generation additions to the AEP System in the vicinity with the exception of those that have executed an Interconnection Agreement or those that have requested an unexecuted Interconnection Agreement be filed with FERC. If an Interconnection Agreement for a new generation facility in the general vicinity is executed or significant transmission network changes occur within AEP or adjacent systems, prior to the execution of an Interconnection Agreement for this facility, then a new study would be required to reassess the impact of this generation addition, and the study results contained in this report would no longer be valid.

Appendix 1

[redacted] Generation

Configuration of Proposed Facility

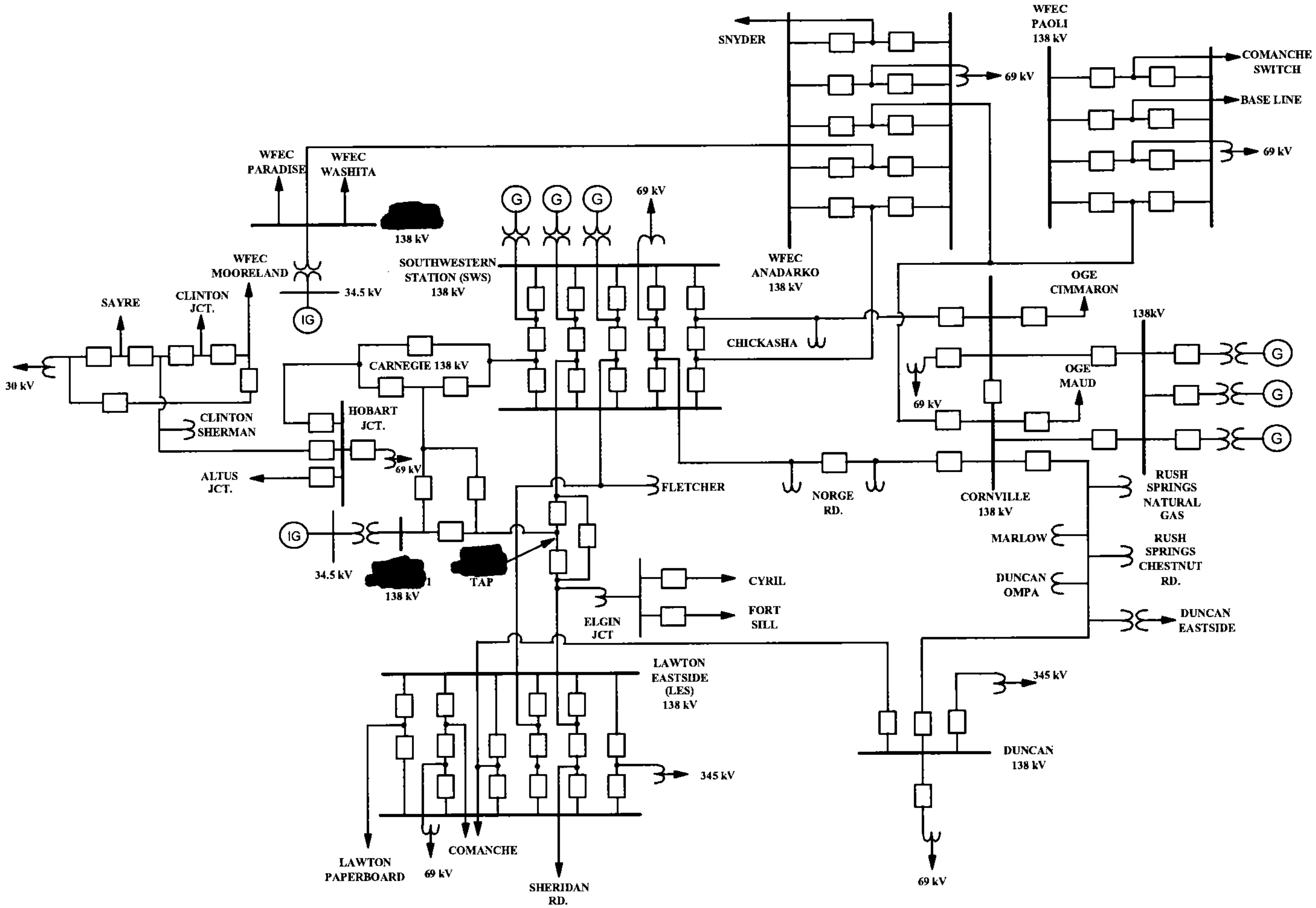


Figure A.1

Transmission Facilities in the Vicinity of the [redacted] Proposed Plant

Appendix 2

[redacted] Generation

Dynamics Data

Induction Generator

Table A.1 CIMTR3

Induction Generator Model

Value	Description
1.2116	T' (>0) (sec)
0.0300	T'' (>0) (sec)
5.0400	Inertia, H
3.2924	X
0.3001	X'
0.2011	X'
0.0907	X_l
1	E1 (≥0)
0.1000	$S(E_1)$
1.2000	E2
0.4000	$S(E_2)$
0	Switch
1	SYN-POW, mechanical power at synchronous speed (>0). Used only to start machine, otherwise ignored.

X, X', X'', X_l, H are in pu, machine MVA base of (99X1.5MW/0.9pf) = 167 MVA.

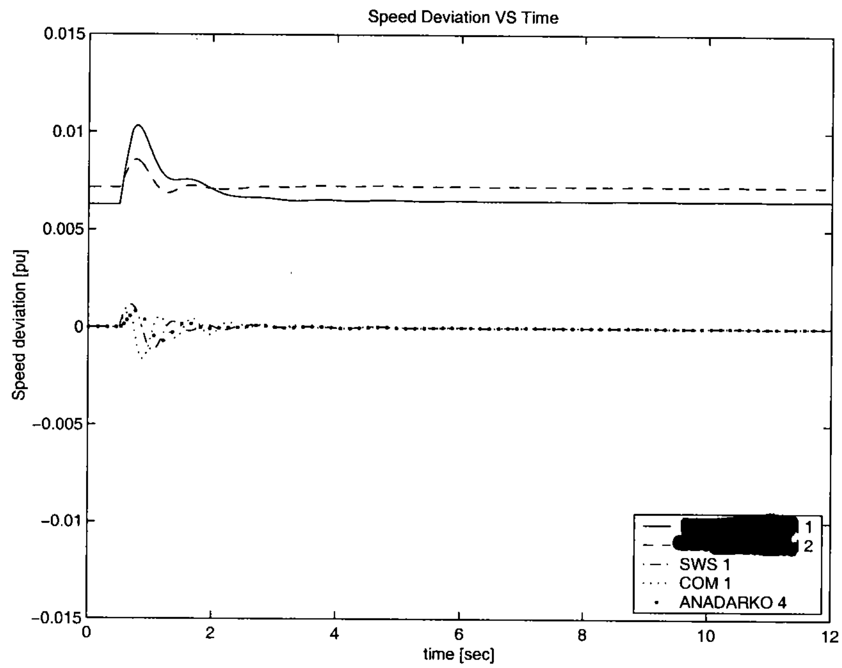
Wind turbine unit transformer 0.575/34.5 kV impedance = 6% on 167 MVA base.

Appendix 3

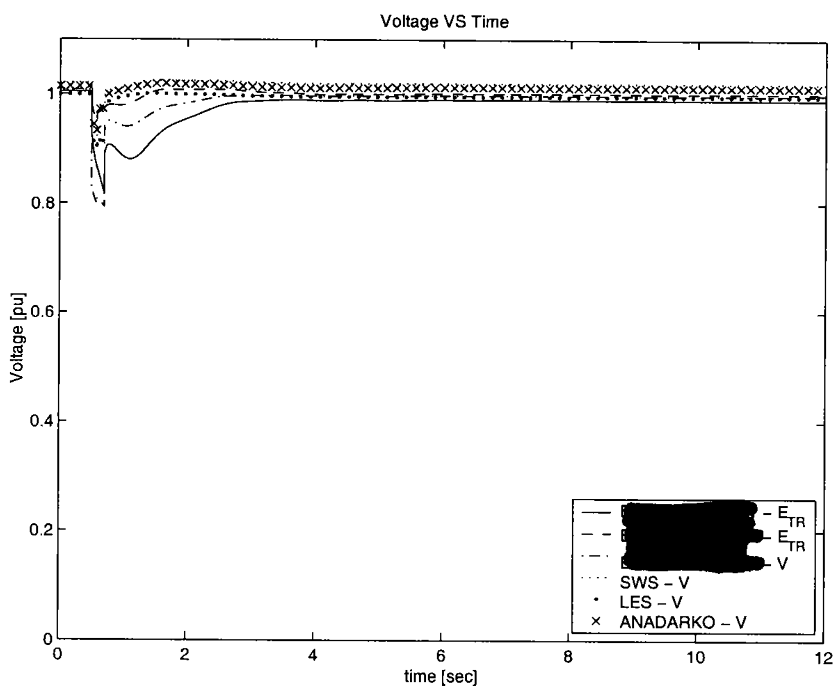
Results –

Individual Case Plots

Case 3A-1

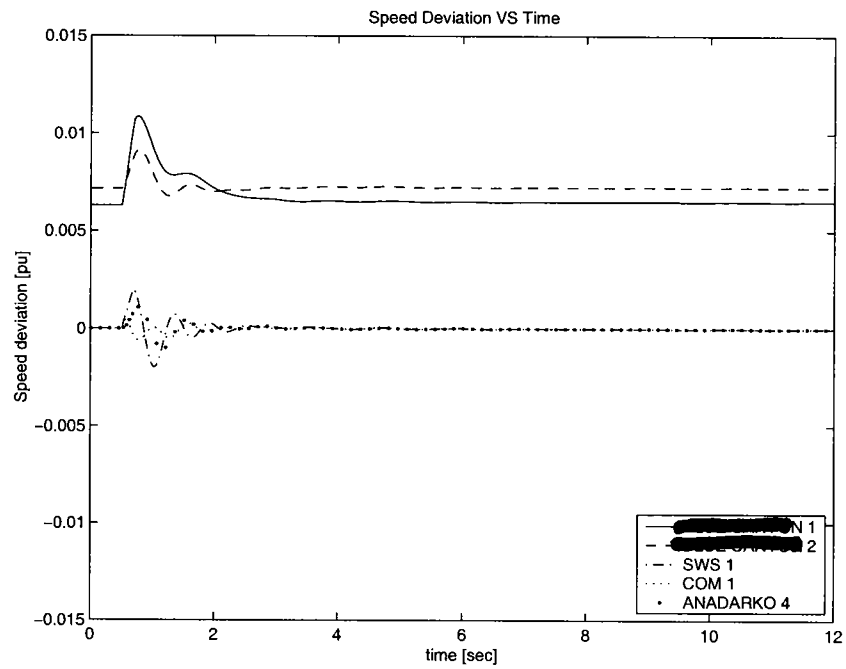


Speed Deviation VS Time
Speed deviation [pu]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4



Voltage VS Time
Voltage [pu]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
time [sec]
[redacted] - E_TR
[redacted] - E_TR
[redacted] - V
SWS - V
LES - V
ANADARKO - V

Case 3A-2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0.005
0
-0.005
-0.01
-0.015
0
2
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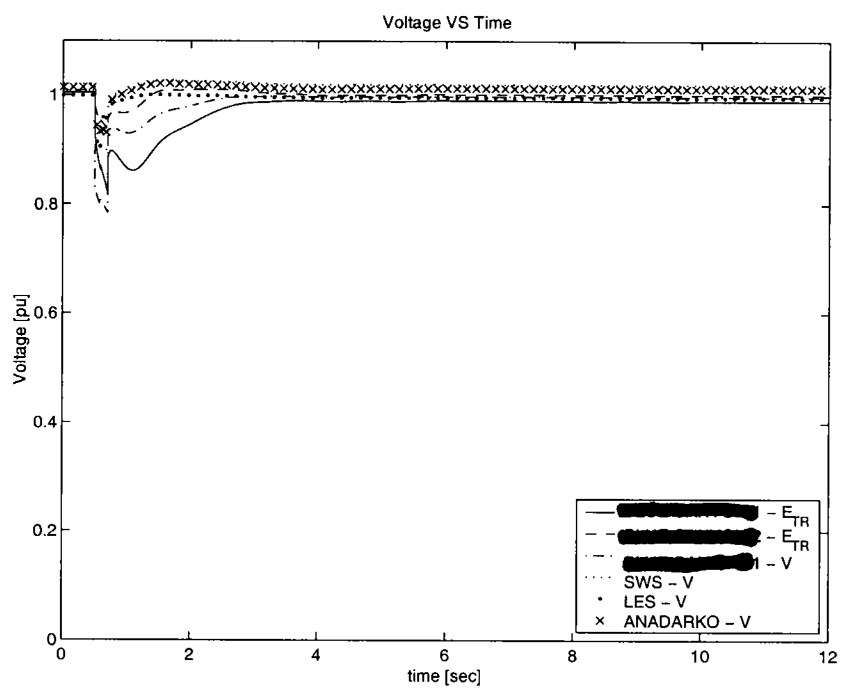
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4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0
0
2
4
6
8
10
12
time [sec]
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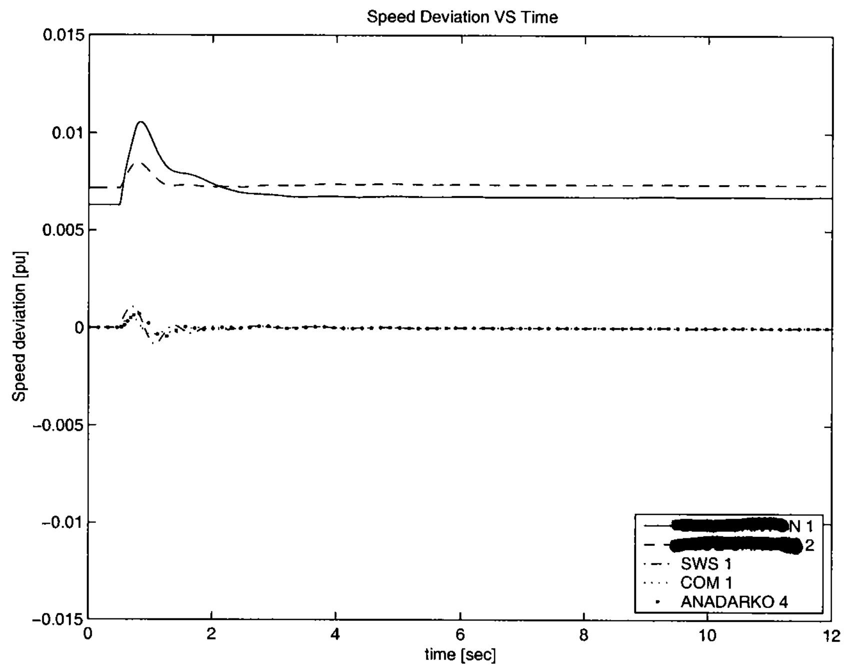
[redacted] - E_{TR}
[redacted] - V
SWS - V
LES - V
ANADARKO - V

Case 3A-3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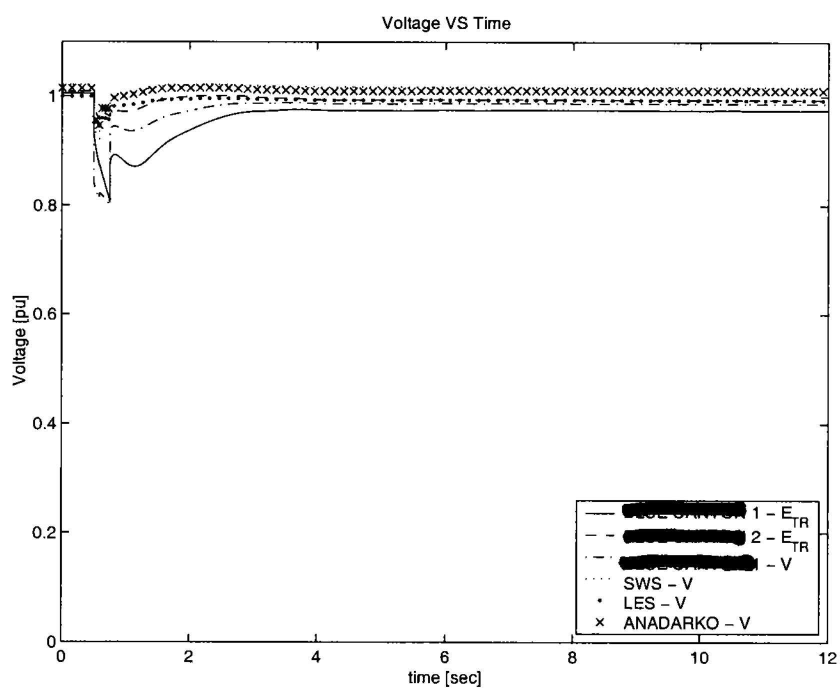
[redacted] 2
SWS 1
COM 1
ANADARKO 4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time [sec]
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0
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4
6
8
10
12
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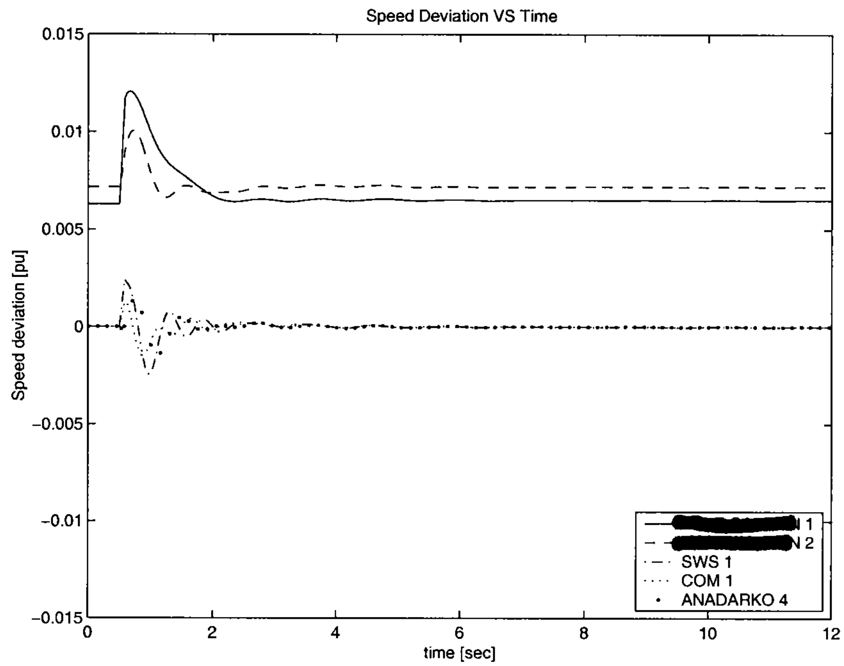
[redacted] - V
SWS - V
LES - V
ANADARKO - V

Case 3B-1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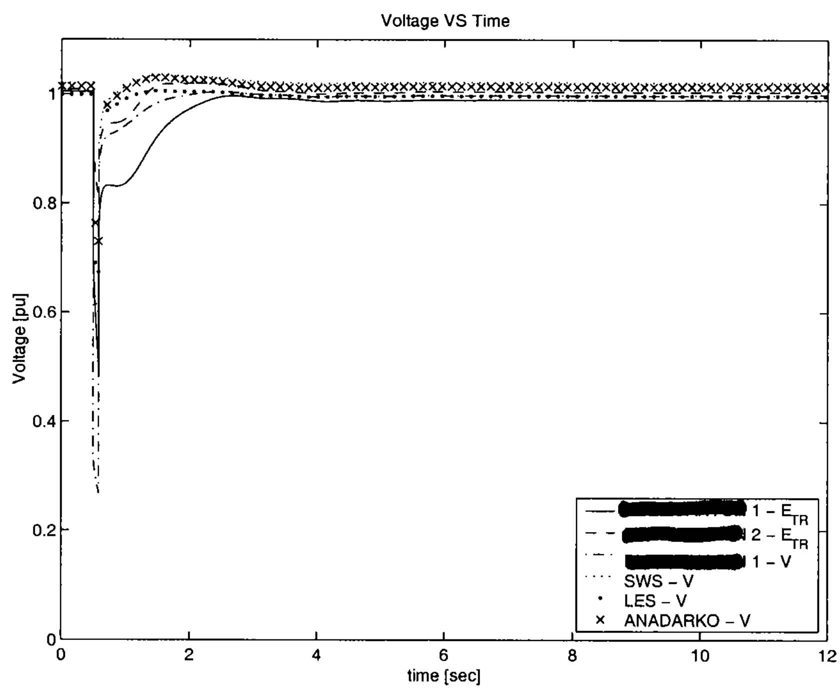
COM 1
ANADARKO 4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time [sec]
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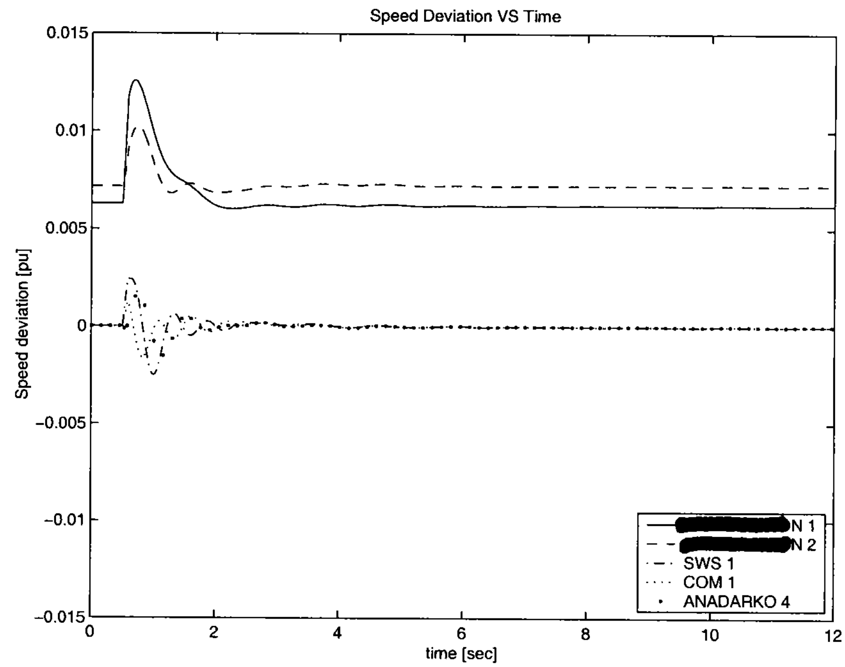
LES - V
ANADARKO - V

Case 3B-2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0.005
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Speed deviation [pu]
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12
time [sec]
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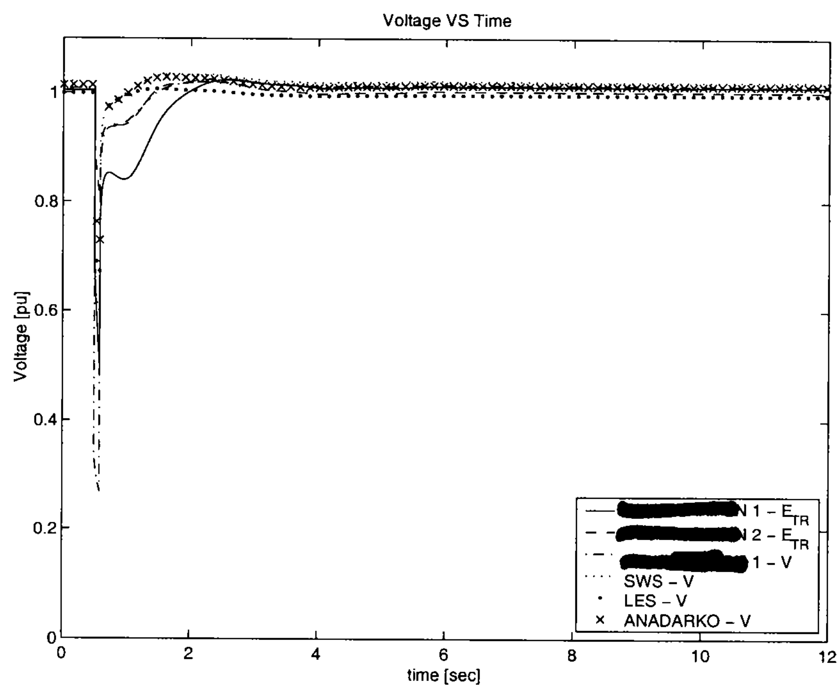
SWS 1
COM 1
ANADARKO 4


Voltage VS Time
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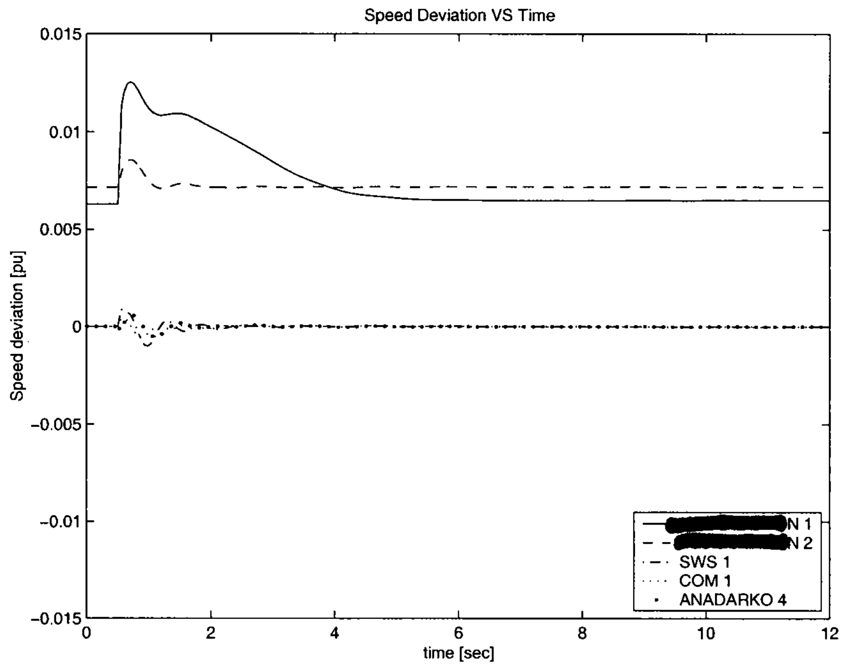
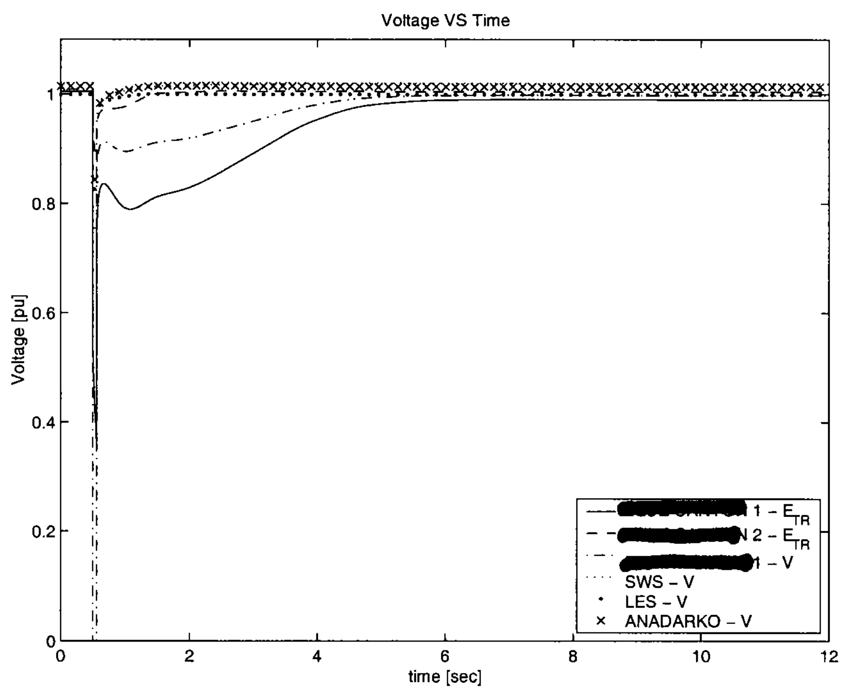
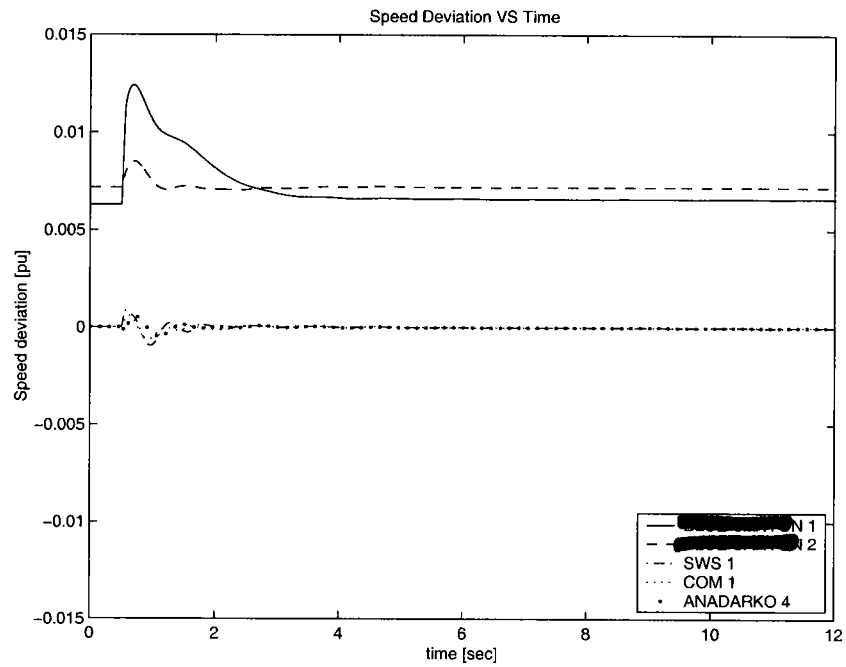
0.8
0.6
0.4
0.2
0
Voltage [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_{TR}
[redacted] 2 - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

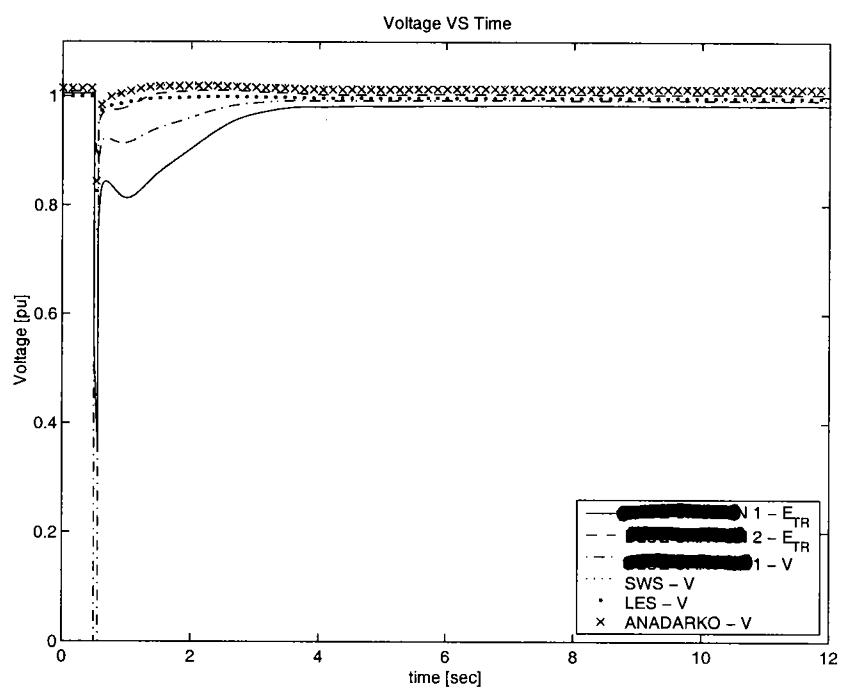
Case 3B-3


Speed Deviation VS Time
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Speed deviation [pu]
0
2
4
6
8
10
12
time [sec]
[redacted]N 1
[redacted]N 2
SWS 1
COM 1
ANADARKO 4

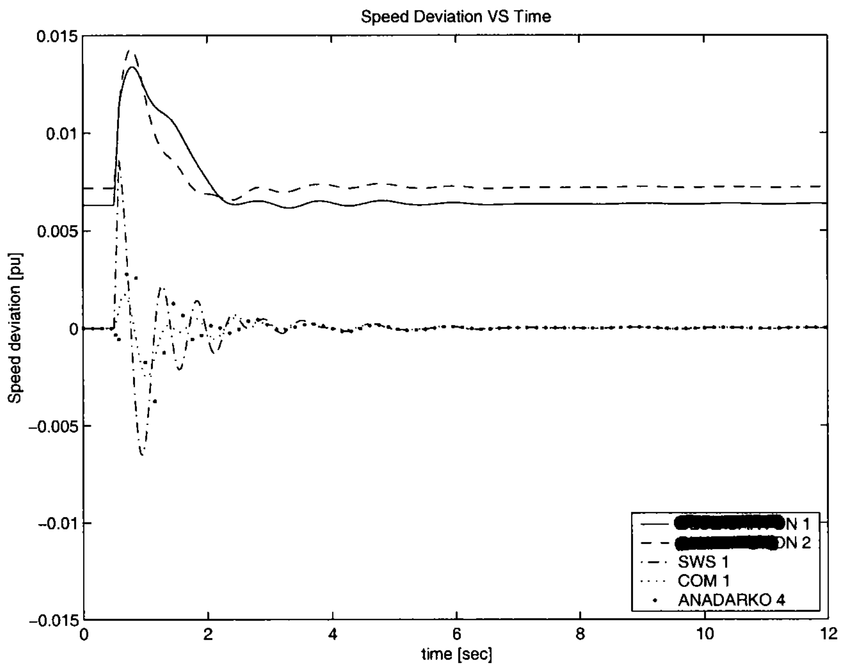

Voltage VS Time
1
0.8
0.6
0.4
0.2
0
Voltage [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_{TR}
[redacted] 2 - E_{TR}
[redacted]1 - V
SWS - V
LES - V
ANADARKO - V

Case 3B-4

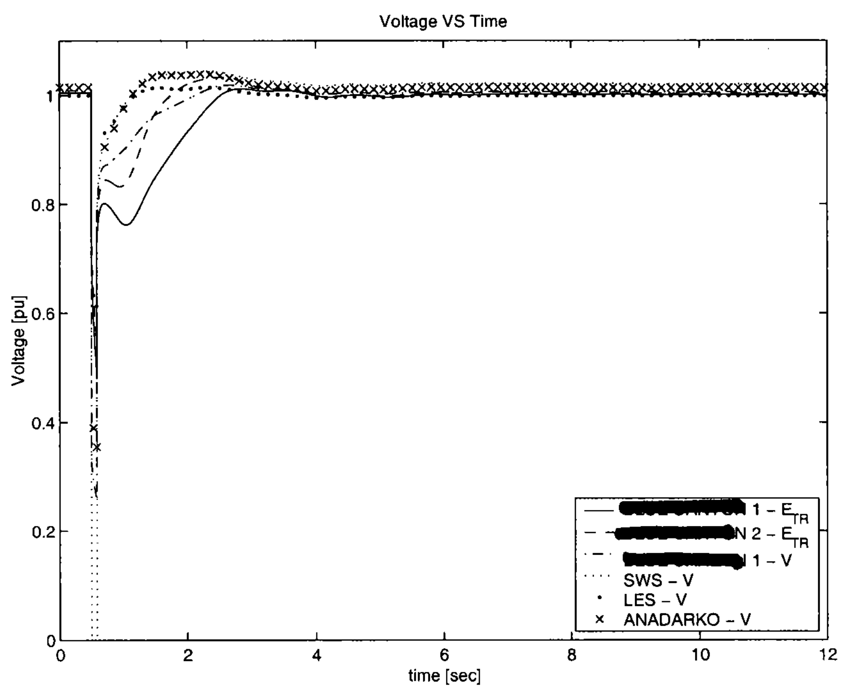

Speed Deviation VS Time
Speed deviation [pu]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4


Voltage VS Time
Voltage [pu]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_{TR}
[redacted] 2 - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

Case 3B-5

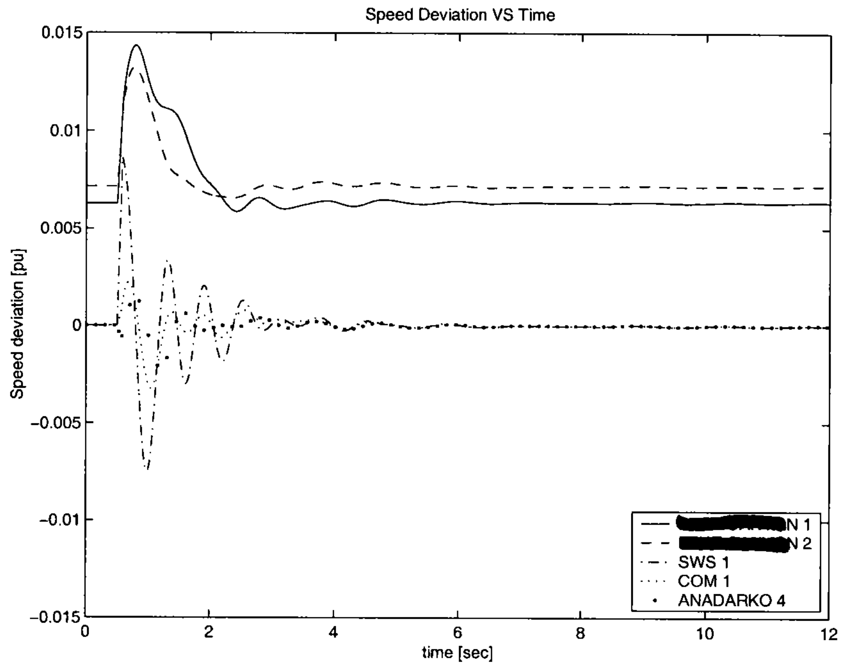


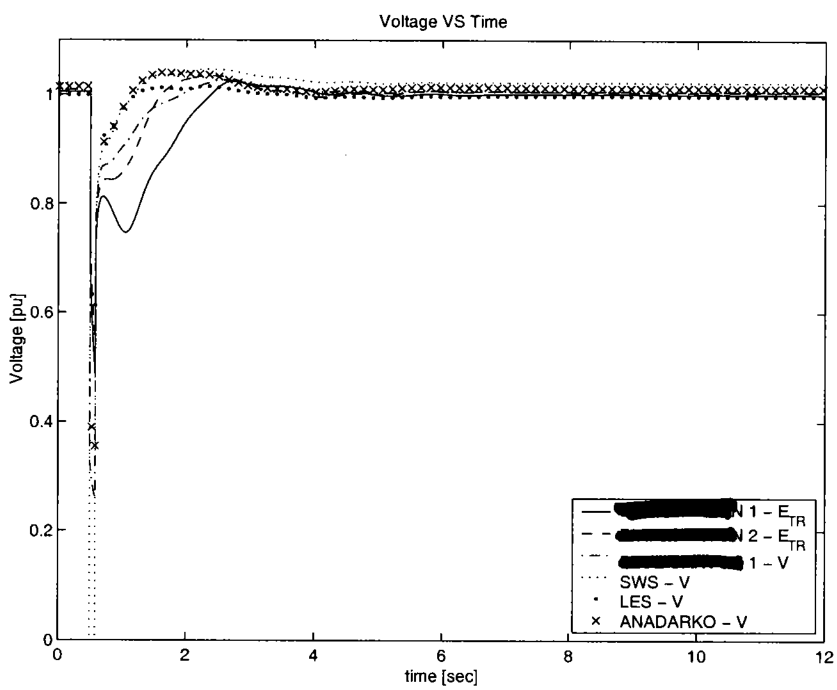
Speed Deviation VS Time
Speed deviation [pu]
time [sec]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
[redacted]N 1
[redacted]N 2
SWS 1
COM 1
ANADARKO 4



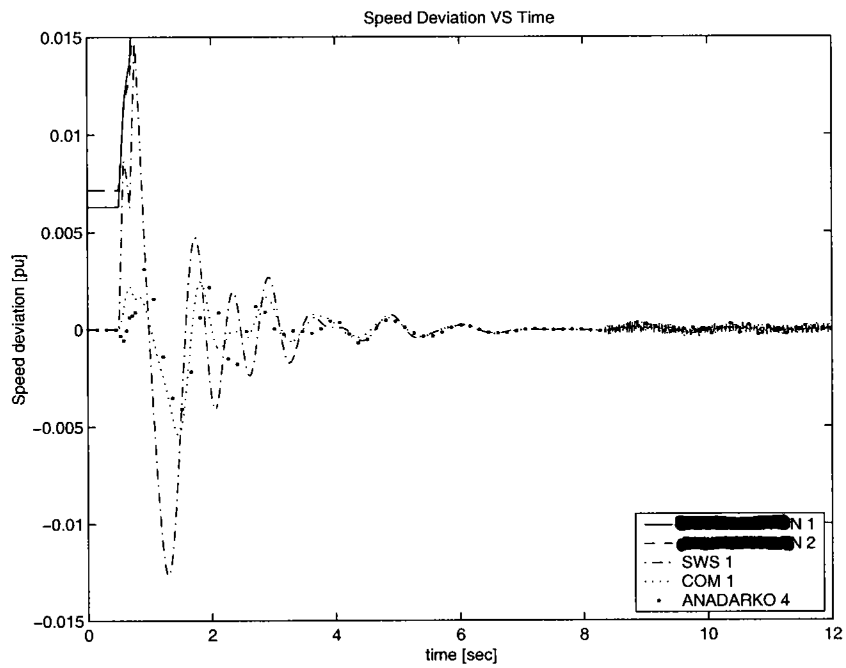
Voltage VS Time
Voltage [pu]
time [sec]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
[redacted] 1 - E_{TR}
[redacted]N 2 - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

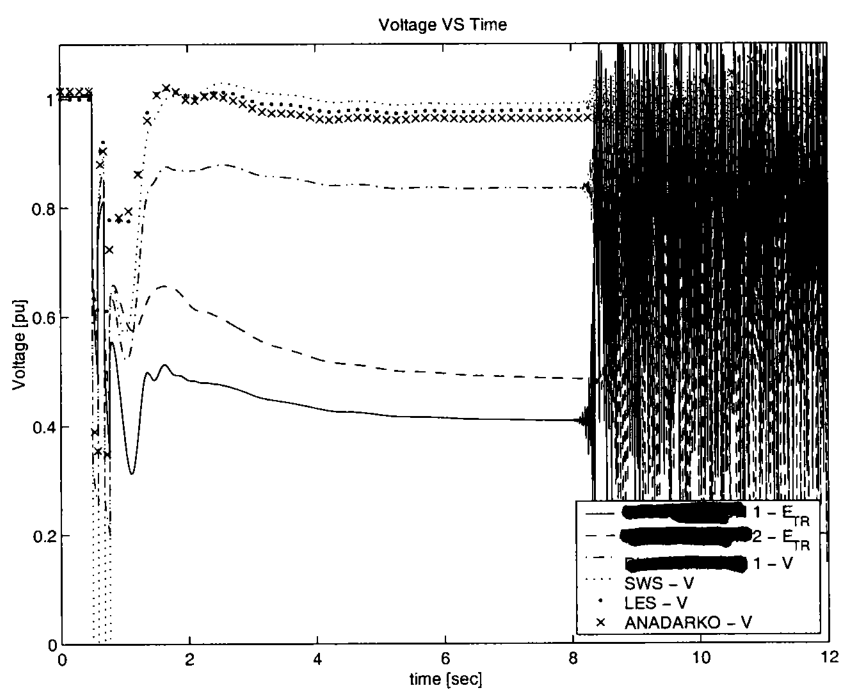
Case 3B-6 (without HSR)



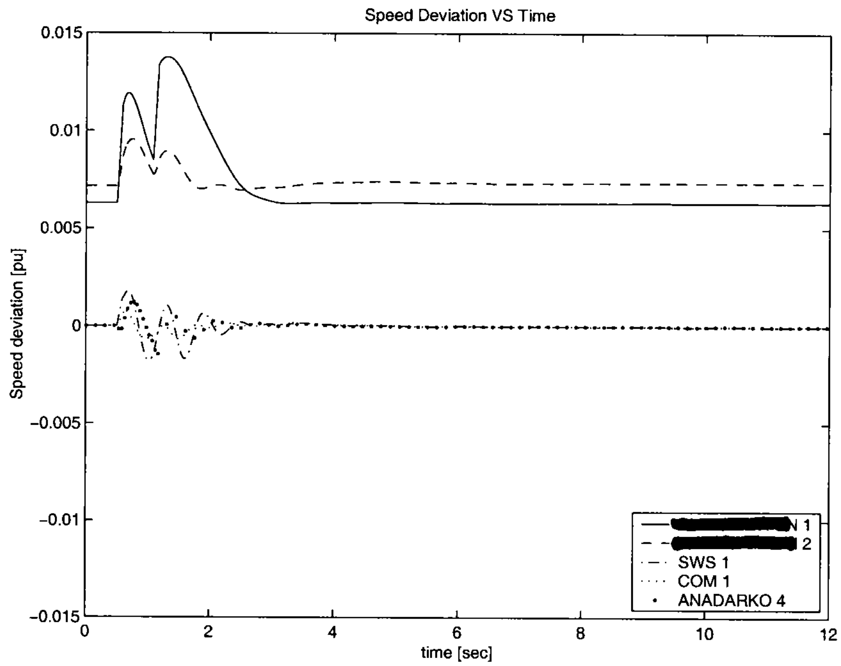


Case 3B-6 (with HSR)

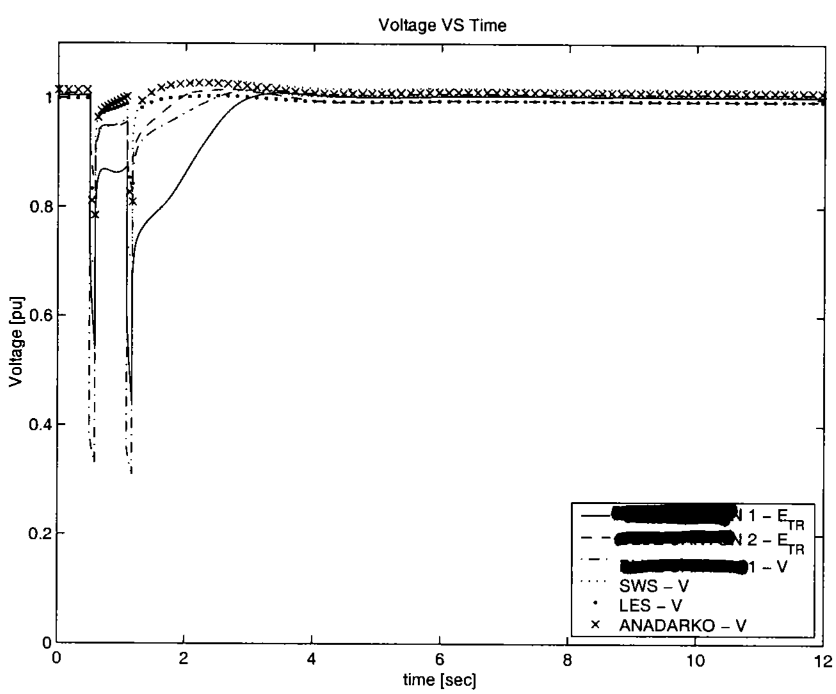




Case 3B-7

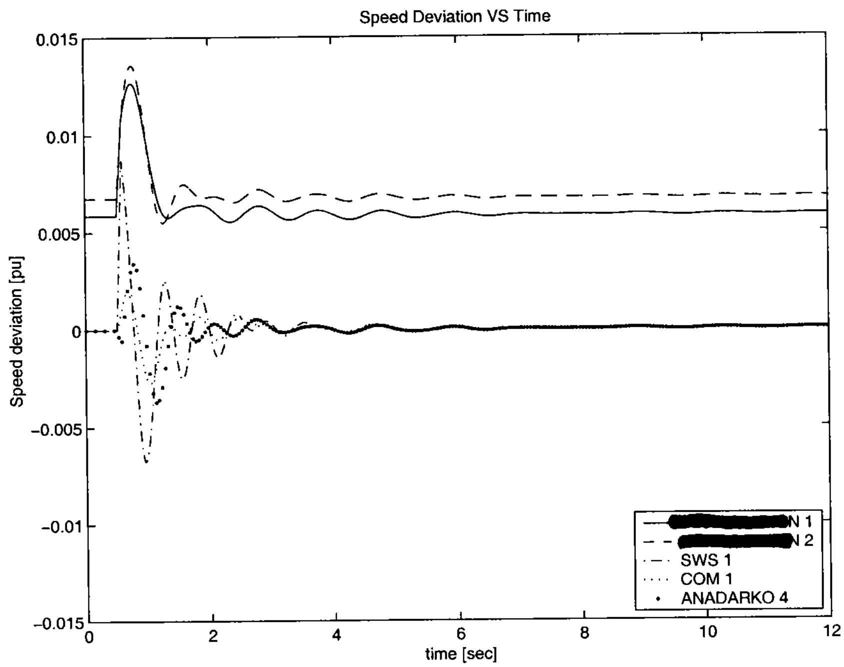


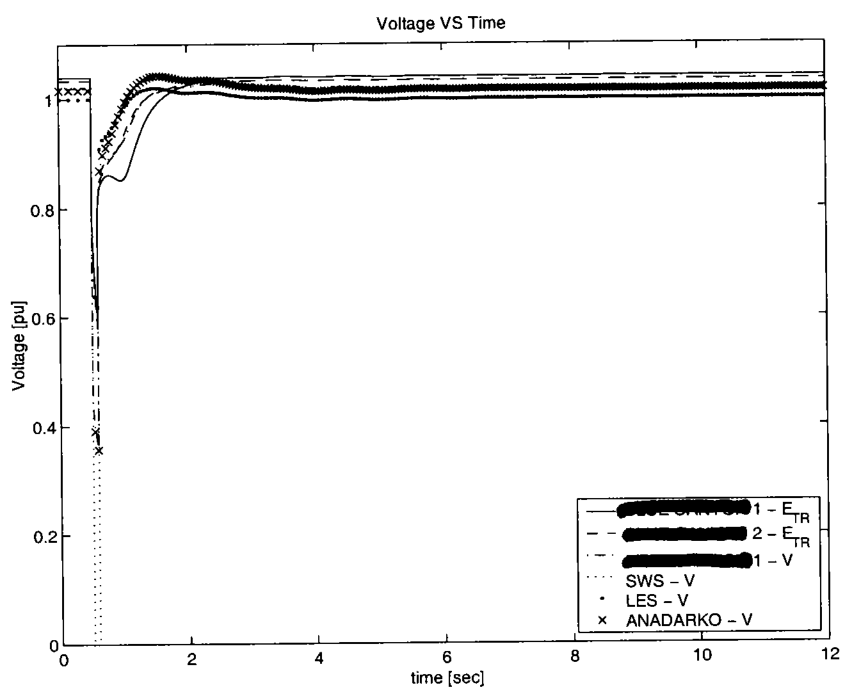
Speed Deviation VS Time
Speed deviation [pu]
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4



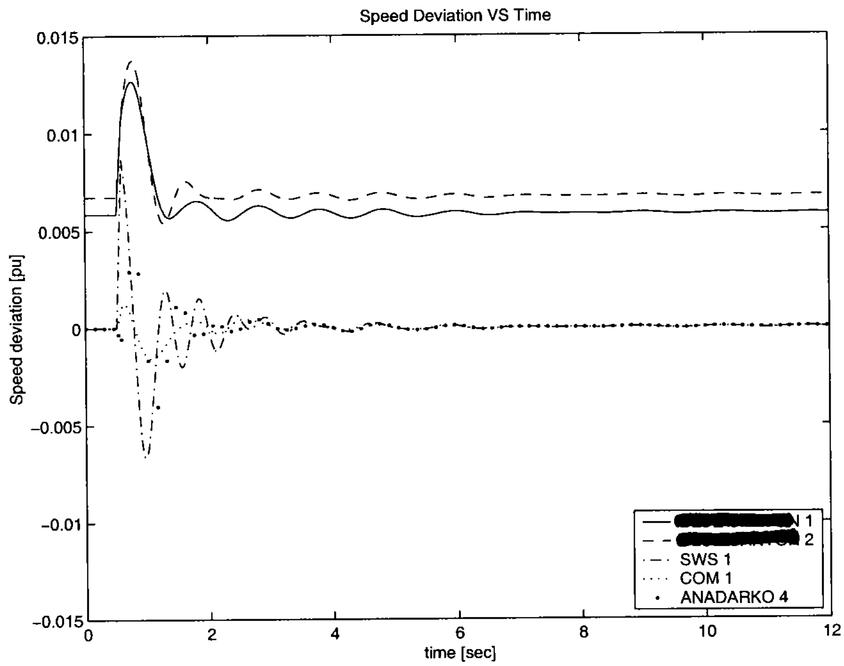
Voltage VS Time
Voltage [pu]
time [sec]
[redacted] 1 - E_{TR}
[redacted] 2 - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

Case 3B-8

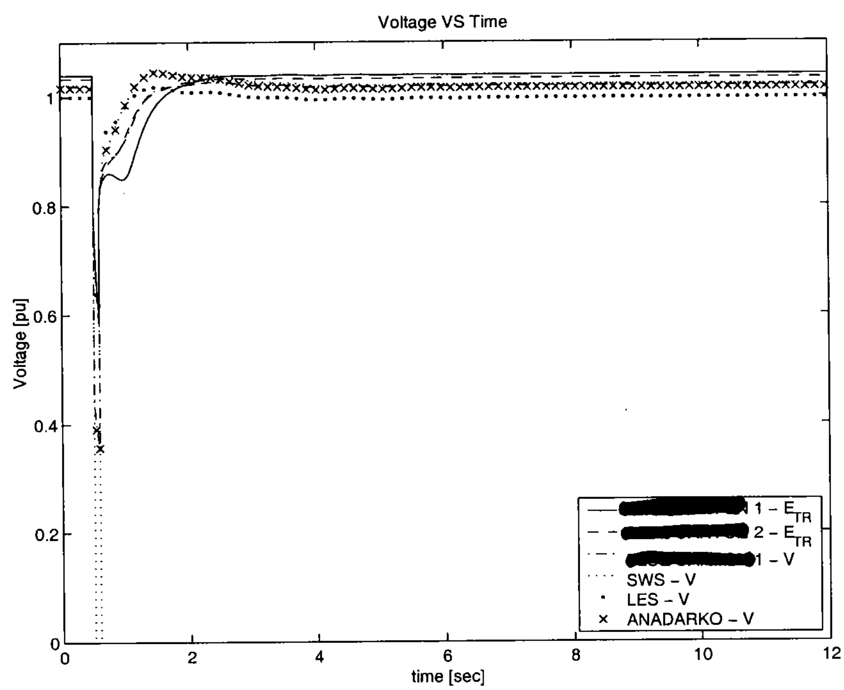

Speed Deviation VS Time
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Speed deviation [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4


Voltage VS Time
1
0.8
0.6
0.4
0.2
0
Voltage [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_TR
[redacted] 2 - E_TR
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

Case 3B-9

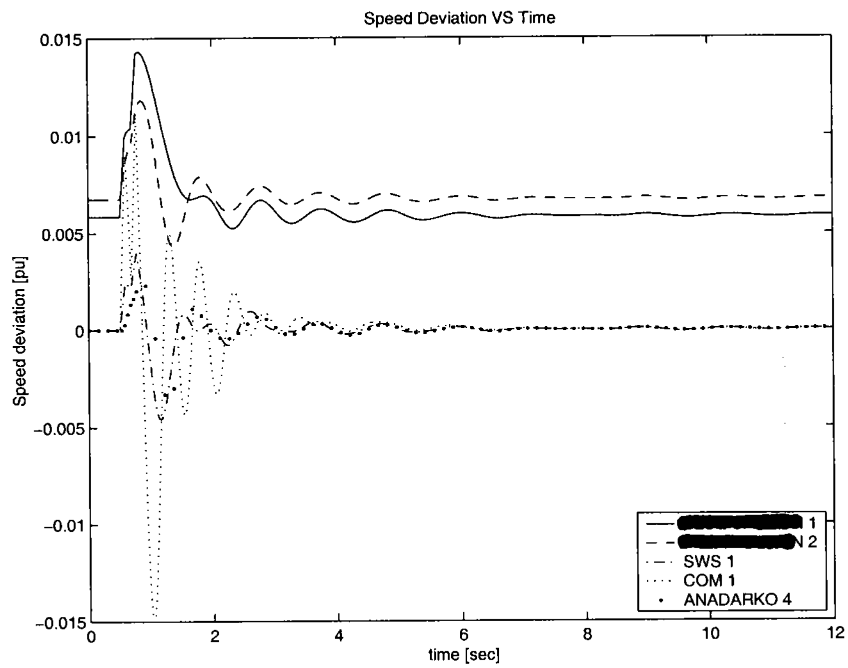


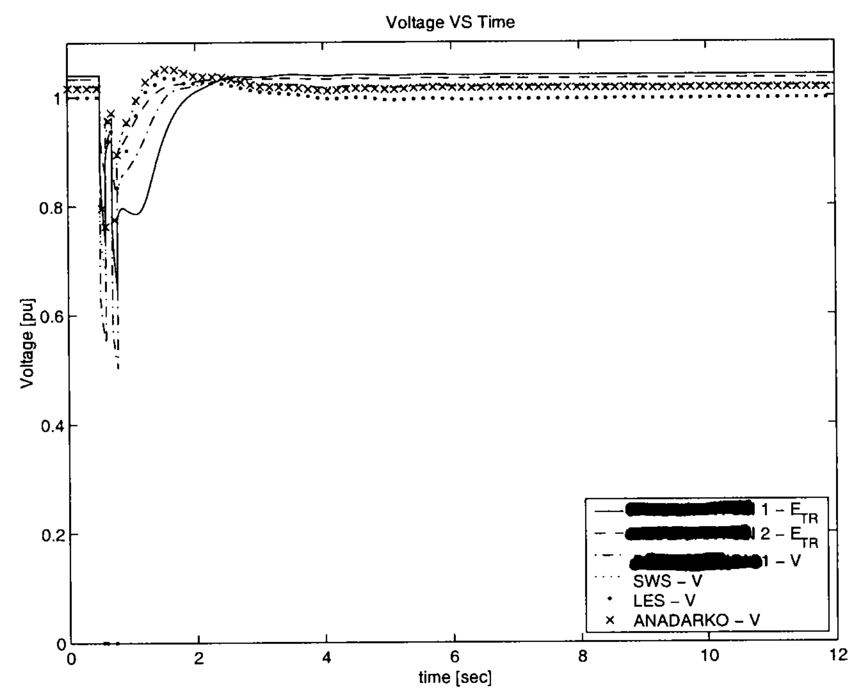
Speed Deviation VS Time
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Speed deviation [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4



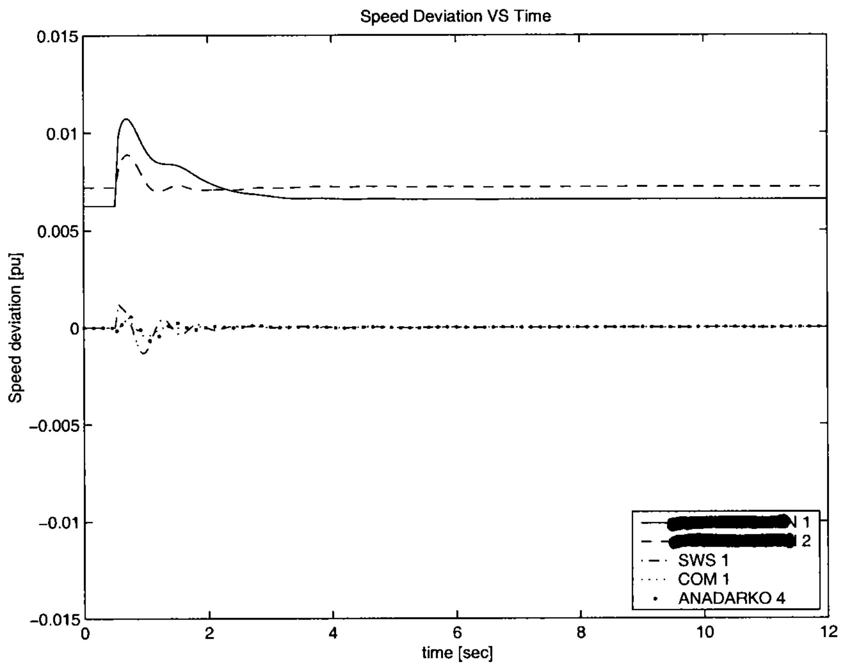
Voltage VS Time
1
0.8
0.6
0.4
0.2
0
Voltage [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_TR
[redacted] 2 - E_TR
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

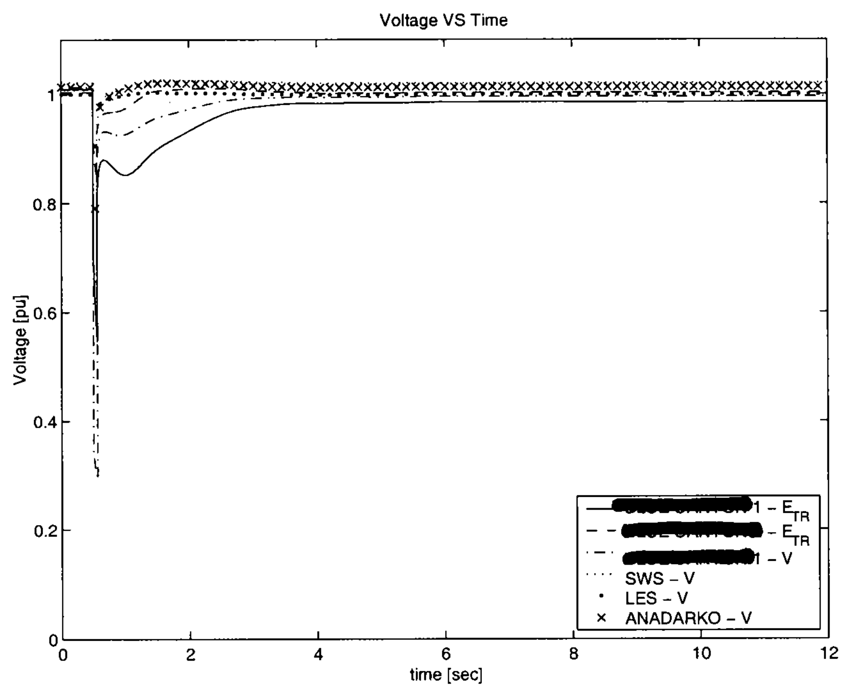
Case 3B-10


Speed Deviation VS Time
Speed deviation [pu]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4

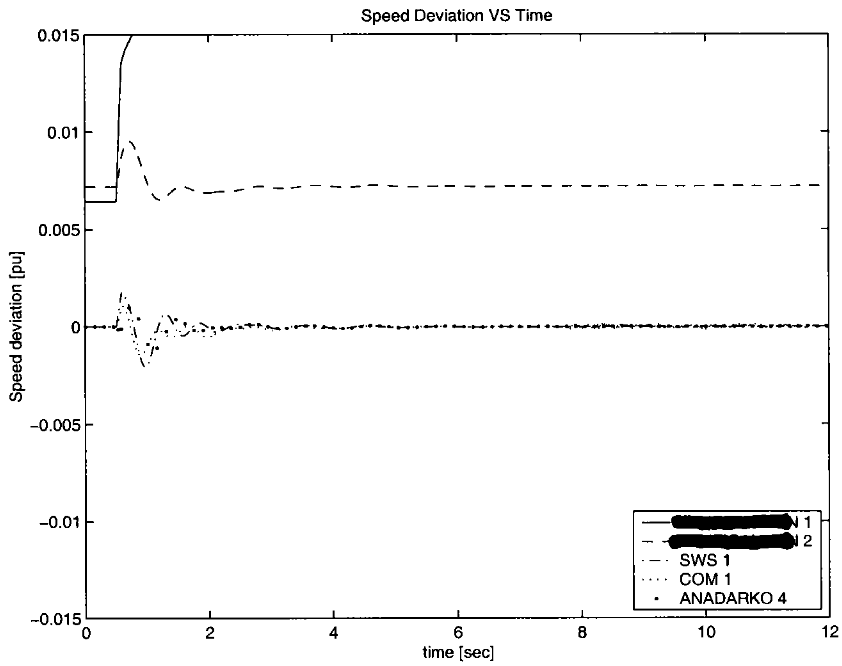

Voltage VS Time
Voltage [pu]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
time [sec]
[redacted] 1 - E_{TR}
[redacted] 2 - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

Case 3D-1

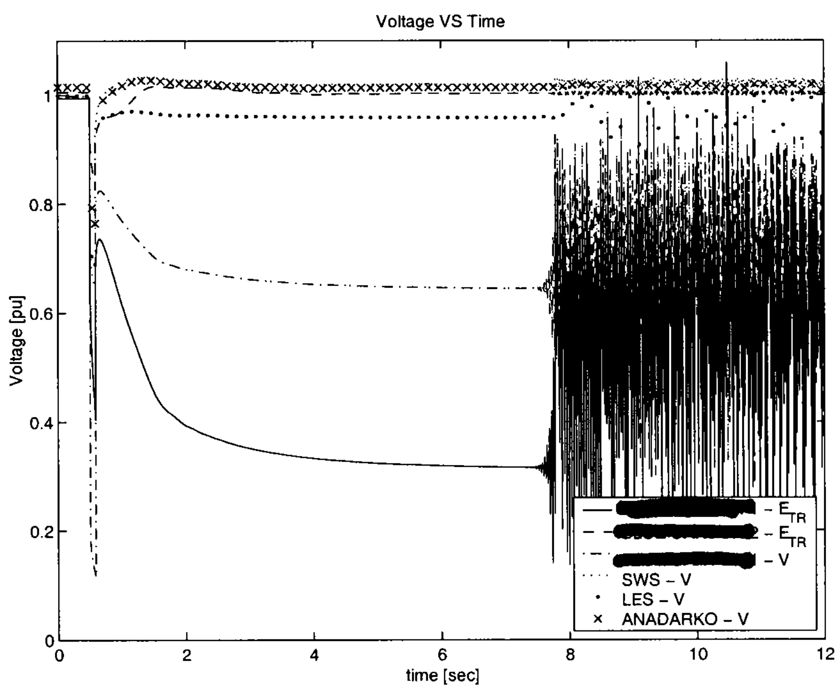

Speed Deviation VS Time
Speed deviation [pu]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4


Voltage VS Time
Voltage [pu]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
time [sec]
[redacted]1 - E_{TR}
[redacted] - E_{TR}
[redacted]1 - V
SWS - V
LES - V
ANADARKO - V

Case 3D-2

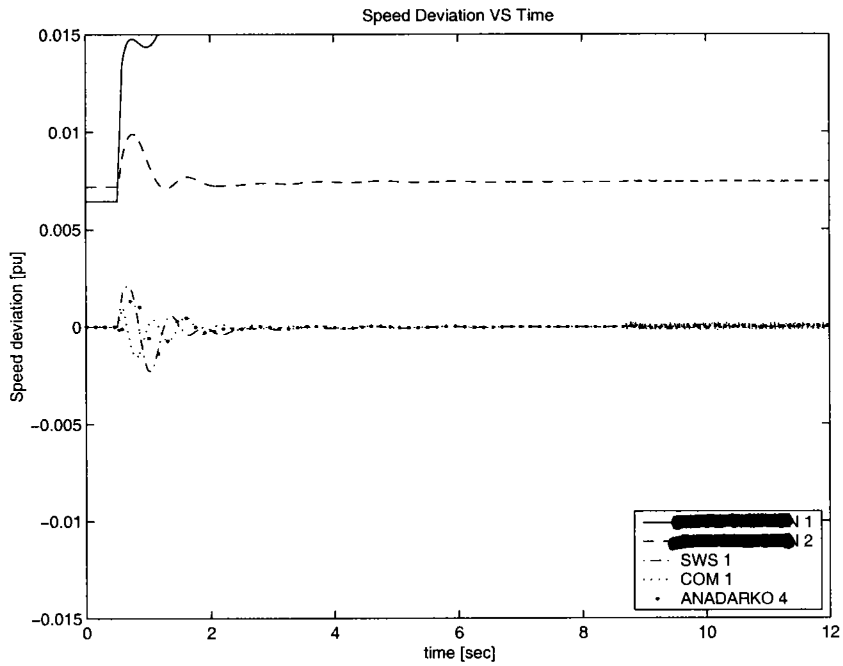


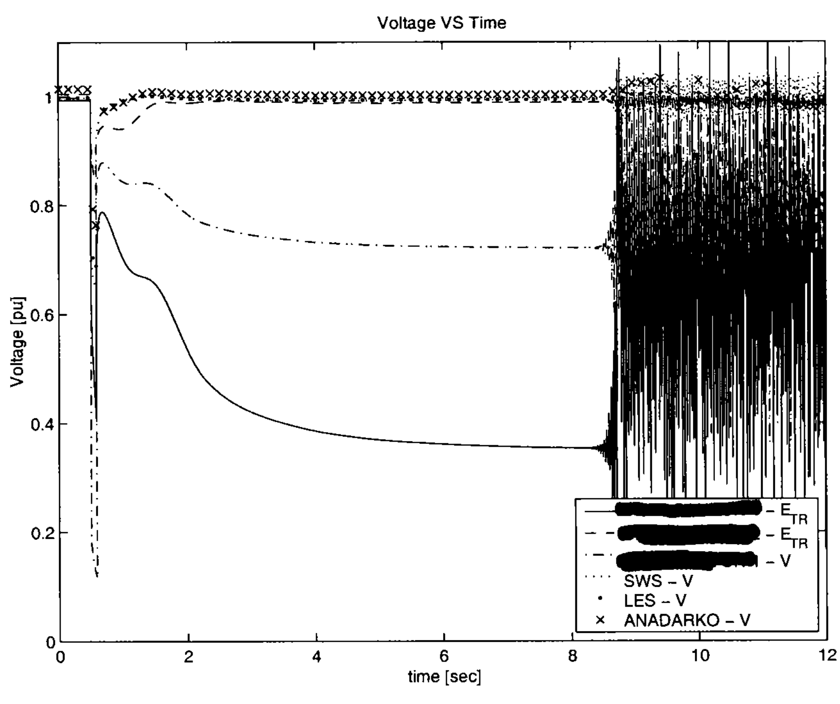
Speed Deviation VS Time
Speed deviation [pu]
time [sec]
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
2
4
6
8
10
12
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4



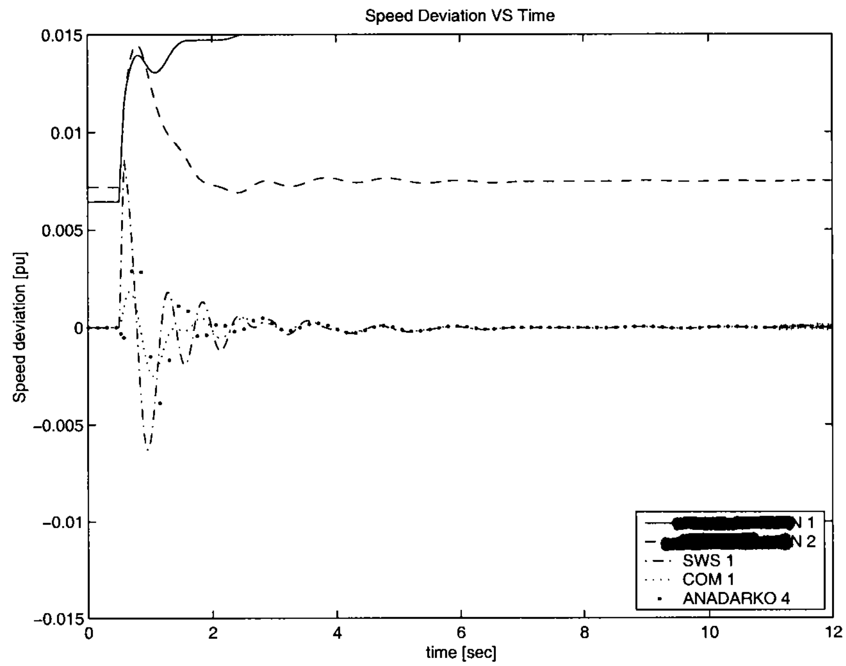
Voltage VS Time
Voltage [pu]
time [sec]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
[redacted] - E_{TR}
[redacted] - E_{TR}
[redacted] - V
SWS - V
LES - V
ANADARKO - V

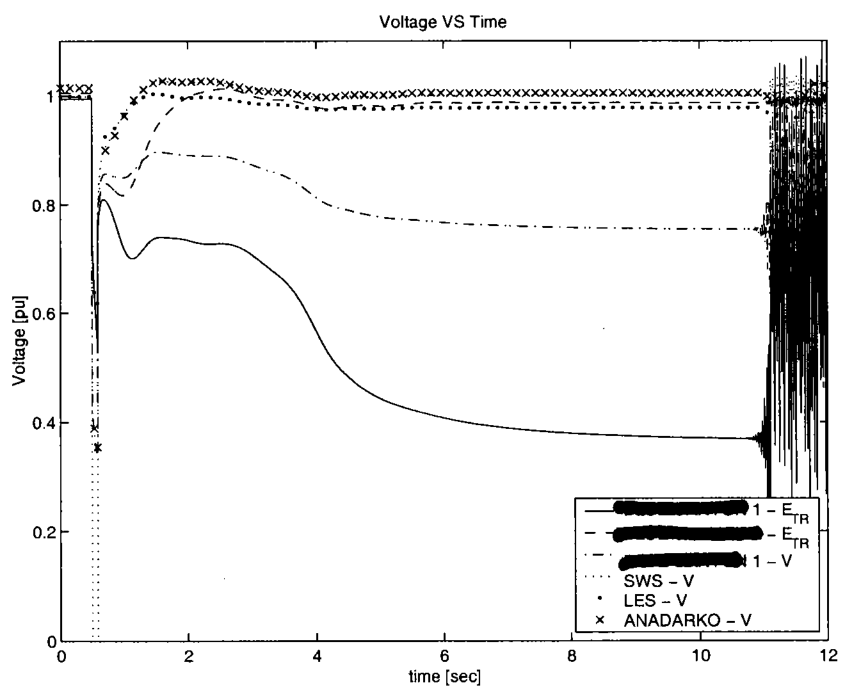
Case 3D-3


Speed Deviation VS Time
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Speed deviation [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4

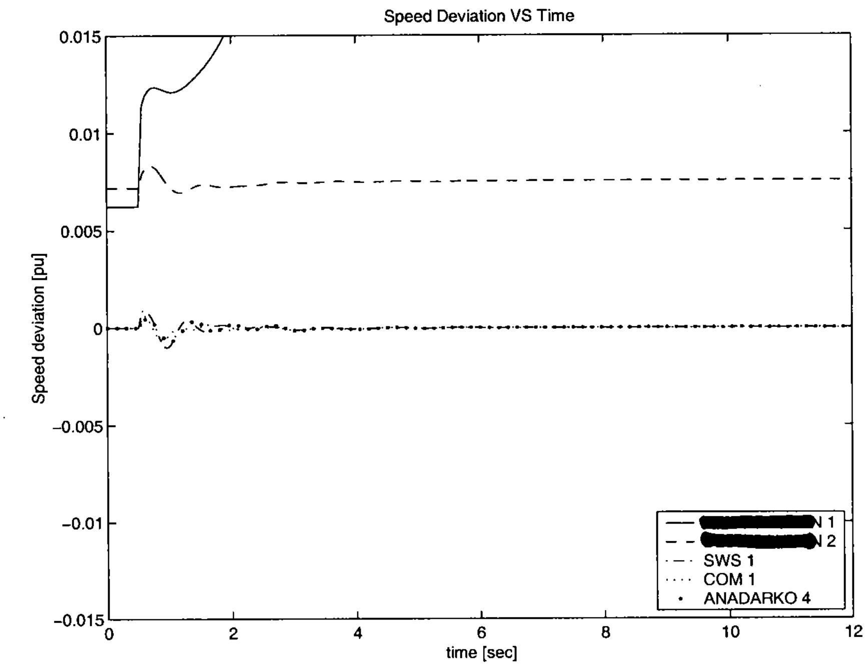

Voltage VS Time
1
0.8
0.6
0.4
0.2
0
Voltage [pu]
0
2
4
6
8
10
12
time [sec]
[redacted] - E_{TR}
[redacted] - E_{TR}
[redacted] - V
SWS - V
LES - V
ANADARKO - V

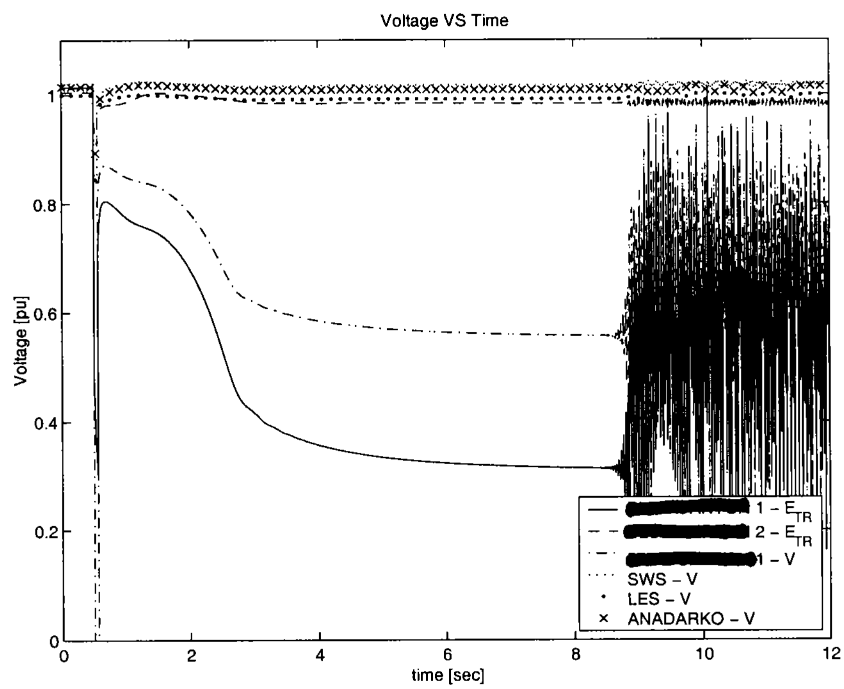
Case 3D-4


Speed Deviation VS Time
Speed deviation [pu]
time [sec]
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
0
2
4
6
8
10
12
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4

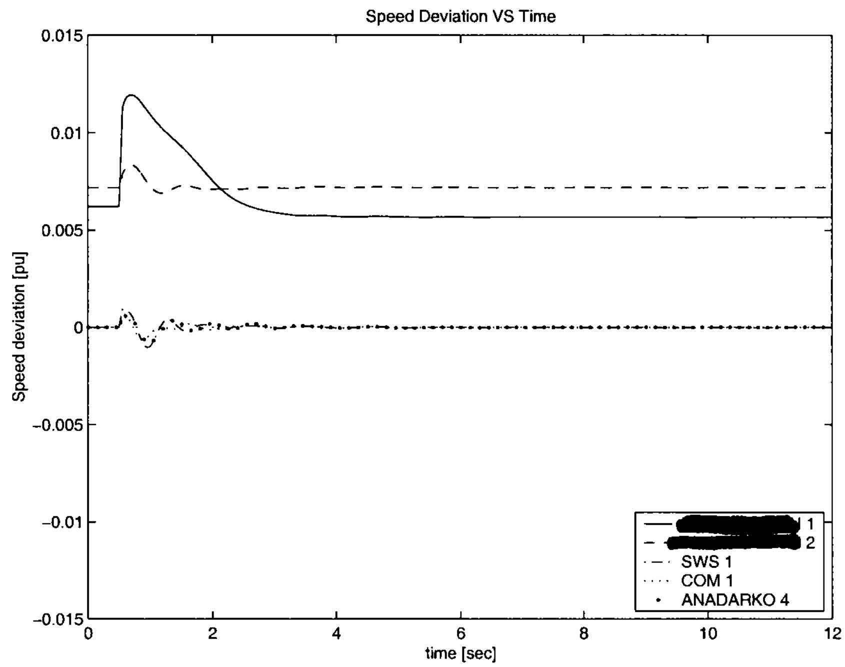

Voltage VS Time
Voltage [pu]
time [sec]
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
[redacted] 1 - E_{TR}
[redacted] - E_{TR}
[redacted] 1 - V
SWS - V
LES - V
ANADARKO - V

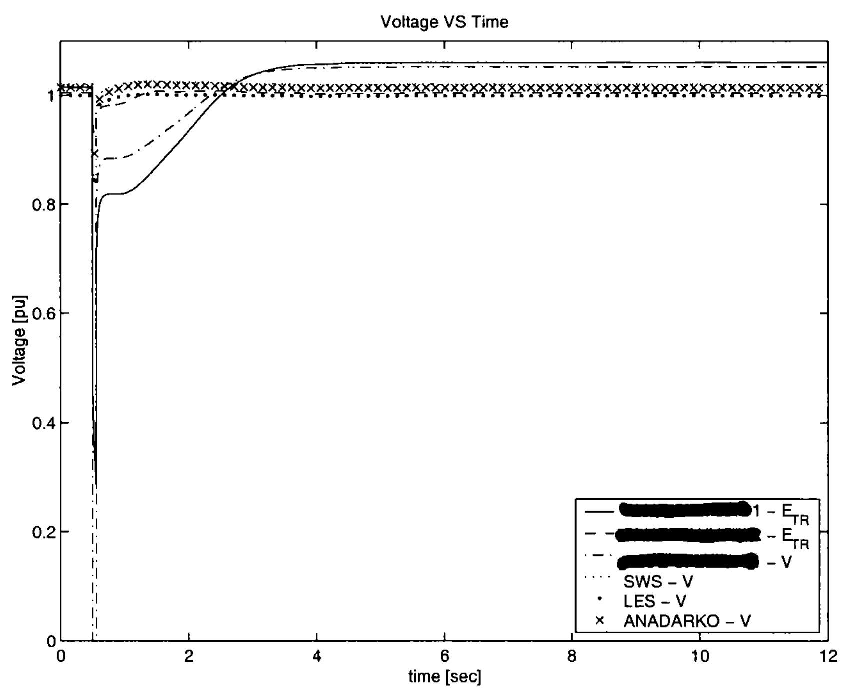
Case 3D-5 (P_{gen} = 100 MW)



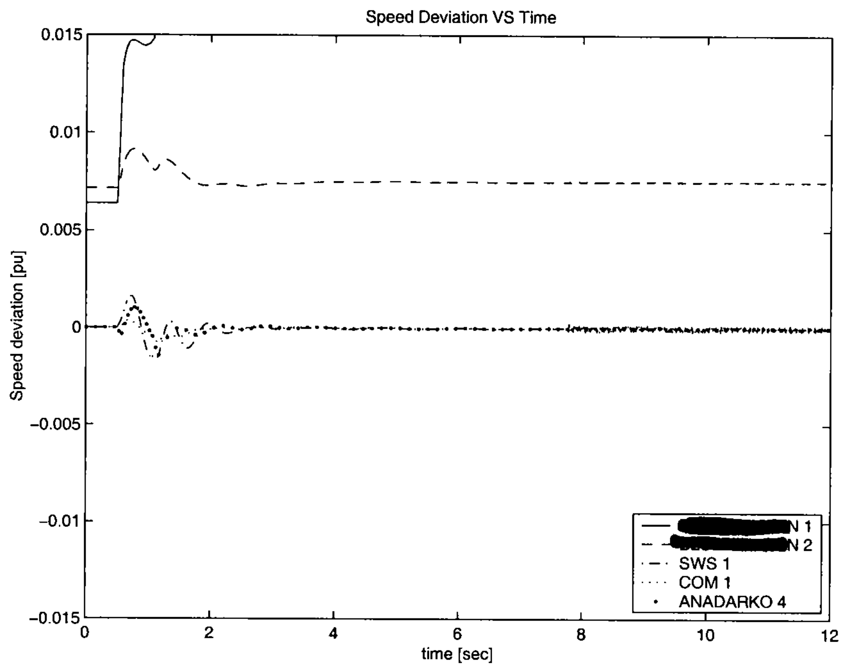


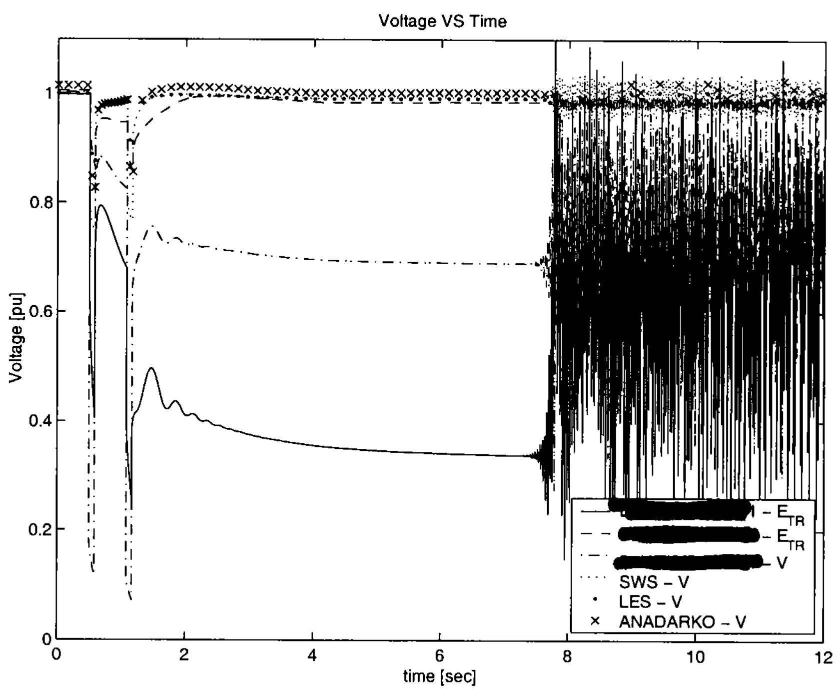
Case 3D-5 (P_{gen} = 90 MW)





Case 3D-6


Speed Deviation VS Time
Speed deviation [pu]
time [sec]
[redacted] 1
[redacted] 2
SWS 1
COM 1
ANADARKO 4


Voltage VS Time
Voltage [pu]
time [sec]
[redacted] - E_{TR}
[redacted] - E_{TR}
[redacted] - V
SWS - V
LES - V
ANADARKO - V

C. Short Circuit Analysis

Scope

The subject of this study is the >Omitted Text< proposed 149 MW wind farm near Apache, Oklahoma. >Omitted Text< will tap the Public Service Company of Oklahoma (PSO) Southwestern Station - Elgin Jct. - Lawton Eastside (81-825) 138 kV line near Apache and the Southwestern Station – Hobart Jct. (81-819) 138kV line near Carnegie. Two approximately 17-mile 138kV lines from >Omitted Text< to the above proposed taps will have to be constructed. The purpose of this study is to assess the impact of the addition of the proposed generation on the available fault current in the PSO system, and to determine whether or not the interrupting rating of PSO circuit breakers, circuit switchers, and power fuses would be exceeded as a result of the addition.

The software used to study the >Omitted Text< proposed plant near Apache has the ability to calculate ANSI X/R ratios for bus and close in faults and to perform breaker rating study in batch mode for determining the short-circuit duty imposed on circuit-interrupting devices. The base short-circuit case used was a Southwest Power Pool (SPP) 2005 case. This case includes prior IPP generation and related system improvements. This case was modified for the additional system change requirements for the injection of 149 MW of generation by >Omitted Text<, into the PSO transmission system.

>Omitted Text< 149 MW Case Model Data

The following facilities were modeled in the short circuit case to determine the impact of 149 MW on available short circuit levels:

- The >Omitted Text< 138 kV generating facility comprised of a single 149 MW generator.
- Approximately seventeen miles of 138 kV line from the >Omitted Text< station to a tap on the PSO Southwestern Station - Elgin Jct. - Lawton Eastside (81-825) 138 kV line near Apache.
- Approximately seventeen miles of 138 kV line from the >Omitted Text< station to a tap on the PSO Southwestern Station – Hobart Jct. (81-819) 138kV line near Carnegie.

Method

The batch short-circuit and breaker rating program was then used to place a three-phase-to-ground and a single-phase-to-ground close in fault on each transmission line connected to each breaker modeled in the short-circuit case. For each breaker, the worst-case fault current level was compared to the breaker rating. This was performed with the above facilities excluded and then performed again with the above facilities included for comparative purposes.

Conclusion

It is standard practice for AEP to recommend replacing a circuit breaker when the current through the breaker for a fault exceeds 100% of its interrupting rating with recloser de-rating applied, as determined by the ANSI/IEEE C37.5-1979, C37.010-1979 & C37.04-1979 breaker rating methods.

In the PSO system, no equipment was found to exceed their interrupting capability after the addition of the >Omitted Text<'s 149 MW generation and related facilities.