PSSE Dynamic Simulation Study Report

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Contents

List of Figures

Chapter 1

Dynamic Simulation in PSSE

1.1 Introduction

The power system is one of the most complex systems in the world. It is a very high-order multivariable process, operating in a constantly changing environment. Power systems dynamic performance is influenced by a wide array of devices with different response rates and characteristics. Hence system stability must be viewed not as a single problem, but rather in terms of its different aspects.

Power system stability may be broadly classified as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. Instability in a power system may be manifested in many different ways depending on the system configuration and operating mode. In evaluation of stability the concern is the behaviour of the power system when subjected to a disturbance. The disturbance may be small or large.

- **Small disturbances** in the form of load changes take place continually, corresponding to which the generation can be adjusted to meet the required load demand.
- **Large disturbances** are the contingencies/ faults on the system when much of the equipment is lost to disturbance. If such a fault occurs, the device to which the fault has occurred needs to be isolated from the rest of the system causing loss of that equipment, which causes variation in power transfers, machine rotor speeds, and bus voltages in the rest of the connected elements.

Traditionally the stability problem has been one of maintaining synchronous operation. Since power systems rely on synchronous machines for generation of electric power, a necessary condition for satisfactory system operation is that the system remains in synchronism - in step. This aspect of stability is influenced by the dynamics of generator rotor angles.

Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism. The stability problem involves the study of the electromechanical oscillations inherent in power systems. A fundamental factor in this problem is the manner in which the power outputs of synchronous machines vary as their rotor oscillates - Power versus angle relationship. Rotors of all connected synchronous machines must be in synchronism.

Under steady state operation of the power system the mechanical torque input is equal to the o/p electric torque, and the speed of the generator is constant.When the perturbed (in small or large), this equilibrium is upset, an acceleration or deceleration of the rotors occurs.

- Generation controls activated to balance the load and generation to bring back the system to new equilibrium
  - The voltage variations will actuate generator voltage regulators
  - The speed variations will actuate prime mover governers
- Additional voltage support is given by transmission system voltage regulators (reactive power supportive elements)
- The load characteristics may also have influence on the system performance affected by v and f change.
- Individual equipment protectors - may respond to variations affecting system performance

In any given situation, the responses of only a limited amount of equipment may be significant. Hence many assumptions are usually made to simplify the problem and to focus on factors influencing the specific type of stability problem.

In a power system, the change in electric torque of a synchronous machine following a perturbation can be resolved into 2 components.

$$\Delta T_e = T_s \Delta\delta + T_D \Delta\omega$$

System stability depends on existence of both components of torque for each of the synchronous machines

- $T_s\Delta\delta$ - component of torque change in phase with the rotor angle perturbation - synchronising torque component
  - Lack of sufficient synchronising torque results in instability through an **aperiodic drift** - this causes a steady increase in rotor angle due to lack of sufficient synchronizing torque
- $T_D\Delta\omega$ - component of torque in phase with the speed deviation - damping torque component
  - Lack of sufficient damping torque results in **oscillatory instability** - this causes rotor oscillations of increasing amplitude due to lack of sufficient damping torque

Power system stability is a single problem, it is impractical to study it as such. As power system stability takes different forms and can be influenced by a wide range of factors. In this study, power system stability in the small and large are assessed for various disturbances applied. The section 1.2 gives the details regarding the system under study, and cases studied for assessing the small signal and transient stability.

1.2 Study Description

The PSSE study carried out for the SAVNW system investigates the power system stability.

- When disturbance applied is small - Small signal stability study
- When disturbance applied is large - Transient stability study

In order to conduct **Small Signal Stability Study** in PSSE, small variations to Excitor's Vref value and Governor's Gref value are given.

- Excitor Vref variation test
- Governor Gref variation test

For positive and negative variations of Gref and Vref, various outputs are observed at the study bus 211. The various outputs observed are Bus per unit voltages, Bus per unit frequency/ speed deviations, Machine relative rotor angle, Machine electrical power and Machine reactive power.

For the transient stability of the power system, study is carried out in bus 211 of savnw system for faults at bus 201 and bus 206.

- Bus fault at bus 201, applied at 2 seconds, and following next step actions (never cleared, cleared after 0.15 seconds, cleared after 0.50 seconds, cleared after 0.75 seconds)
- Bus fault at bus 206, applied at 2 seconds, never cleared

For the above studied cases, the various outputs observed are Bus per unit voltages, Machine relative rotor angle, Machine electrical power and Machine reactive power.

Chapter 2

Small Signal Stability Study

2.1 Introduction

Small signal (or small disturbance) stability is the ability of the power system to maintain synchronism under small disturbances. Such disturbances occur continuously on the system because of small variations in loads and generations. The disturbances are considered sufficiently small for linearization of system equations to be permissible for purpose of analysis. Instability that may result can be of two types.

- Steady increase in rotor angle due to lack of synchronizing torque
- Rotor oscillations of increasing amplitude due to lack of sufficient damping torque

The nature of system response to disturbances depends on a number of factors including

- Initial operating condition
- Transmission system strength
- Type of generation excitation controls used

For a generators without AVRs (ie with constant field voltage) instability is due to lack of synchronizing torque and results in instability in non-oscillatory mode. When AVRs are present, the small-disturbance stability problem is one of ensuring sufficient damping of system oscillations with instability through increasing oscillations.

2.2 Simulation Results in PSSE

In order to conduct the small signal stability study in PSSE small changes in Vref of excitor control and Gref of governor control are given. Two sets of waveforms are observed

- Excitor Vref variation test
  - Flat Start without any disturbance
  - Vref increased by 0.03 PU
  - Vref decreased by 0.03 PU
- Governor Gref variation test
  - Flat start without any disturbance
  - Governor reference - Gref increased by 0.01
  - Governor reference - Gref decreased by 0.01

Flat start test without applying any disturbance shows steady generator voltage, real and reactive power flow, relative angle and speed deviation from nominal value to be constant. In case of the small disturbance by increasing Vref it was observed that the Bus voltage, machine electrical power and machine reactive power was increased. The machine relative rotor angle is decreased from the base case steady state value. In case of the small disturbance by decreasing Vref, it was observed that the bus voltage, machine electrical power and machine reactive power was decreased from the base case steady state value. The relative machine rotor angle is increased from the base case steady state value . In both cases of Vrefs considered, the transient variation in the beginning is not problematic, and have tolerable values and settles within reasonable time to give new steady state values for observed variables. In both cases the deviation of speed from base case steady state speed was observed to be very minimal.

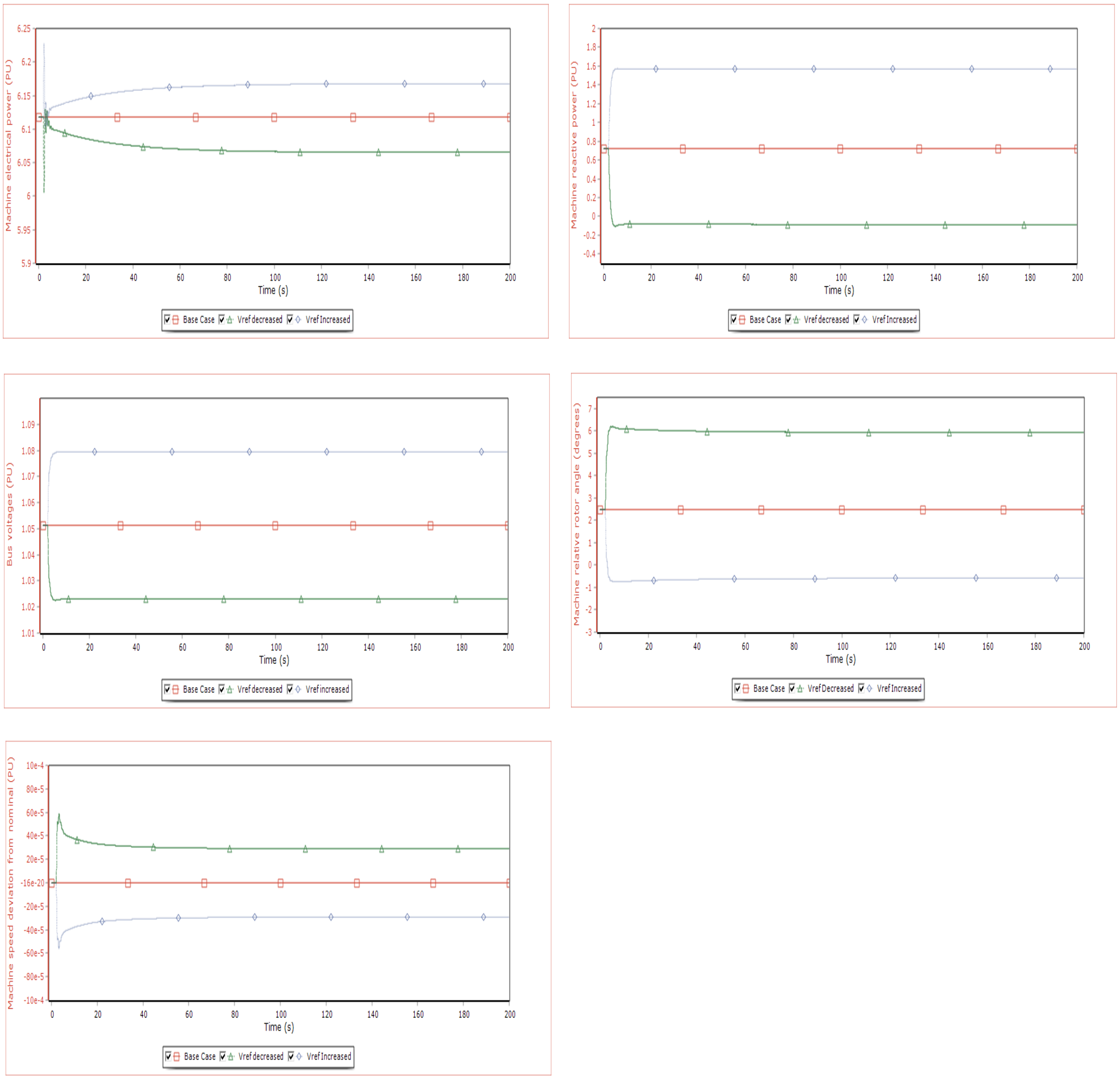

Figure 2.1: Outputs observed for Vref test cases

When governor reference is increased, it increases the mechanical power input to the generator. Correspondingly the machine electrical power and the reactive power increases. The relative machine rotor angle is increased from the base case steady state value. The bus voltage is decreased. When governor reference is decreased, it decreases the mechanical power input to the generator. Correspondingly the machine electrical power and the reactive power decreases. The relative machine rotor angle is decreased from the base case steady state value. The bus voltage is increased.

Similar to the tested Vref scenarios, in case of Gref scenarios, the transient variation in the beginning is not problematic and have tolerable values and settles within reasonable time to give new steady state values for observed variables. The deviation of speed from present flat rate speed was observed to be very minimal. Implying the minimal change in the frequency.

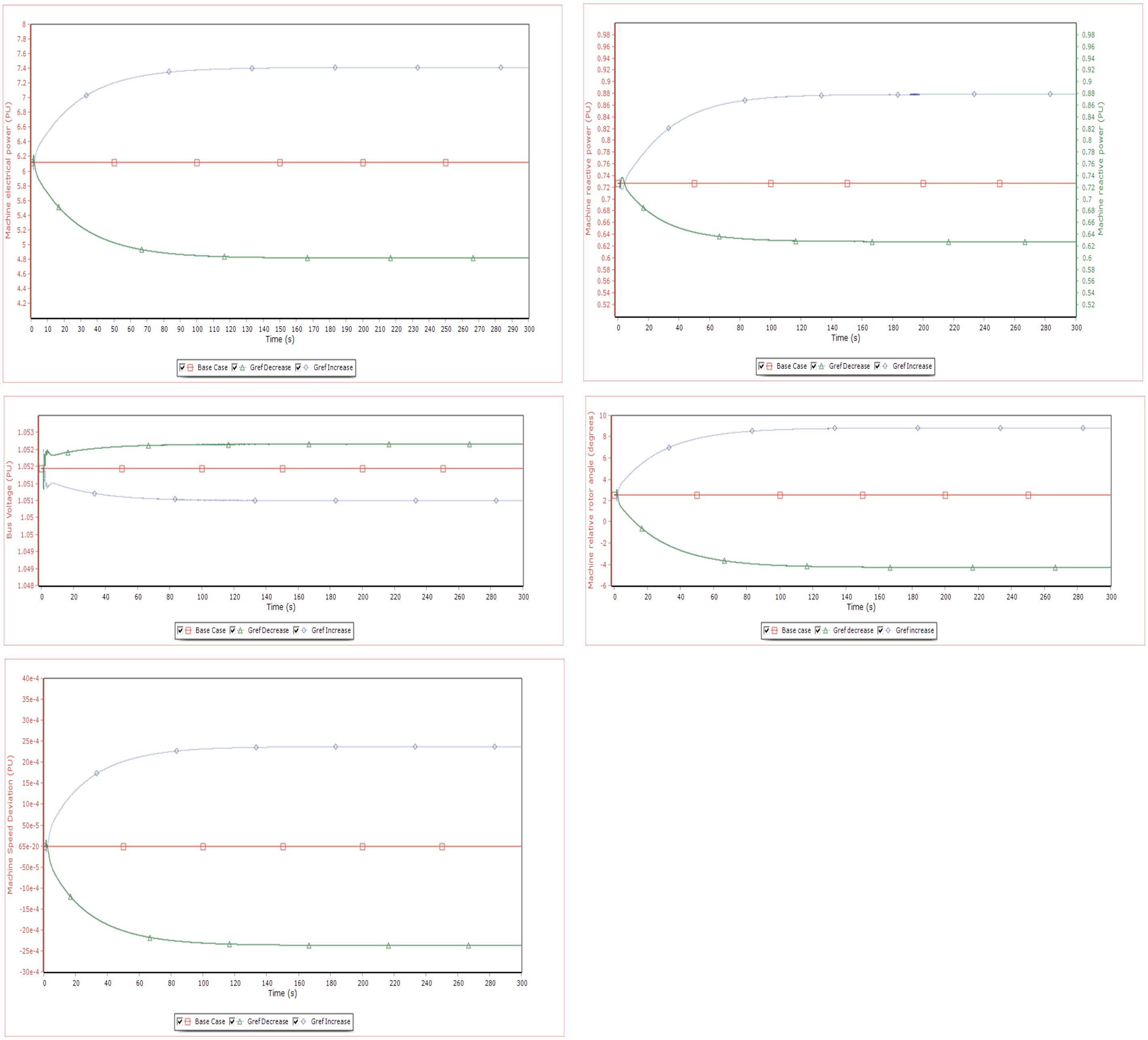

Figure 2.2: Outputs observed for Gref test cases

Chapter 3

Transient Stability Study

3.1 Introduction

Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance such as a fault on transmission facilities, loss of generation, or loss of a large load. The system response to such disturbances involves large excursions of generator rotor angles, power flows, bus voltages, and other system variables. Stability is influenced by the nonlinear characteristics of the power system. If the resulting angular separation between the machines in the system remains within certain bounds, the system maintains synchronism.

3.2 Simulation Results in PSSE

For the transient stability of the power system, study is carried out in bus 211, savnw system for 5 cases.

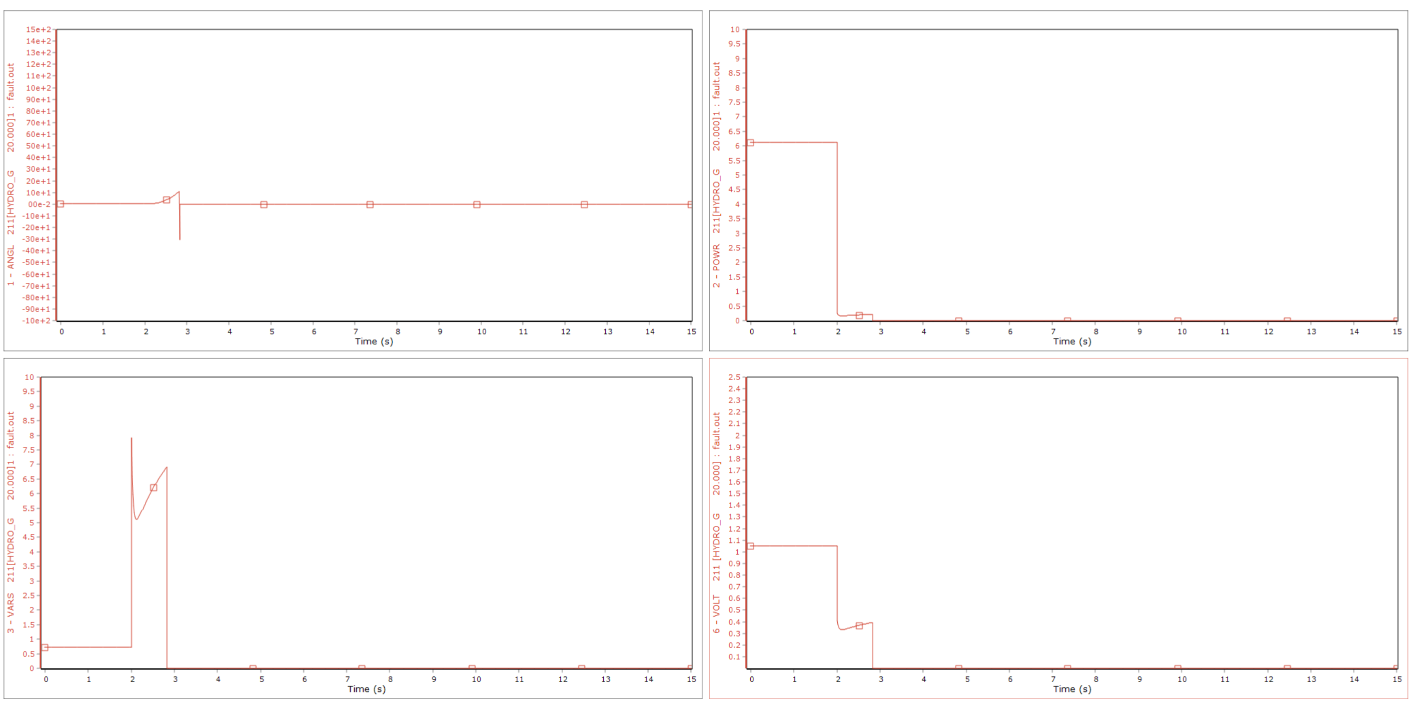

Figure 3.1: Bus fault at bus 201, applied at 2 seconds, never cleared

- Bus fault at bus 201, applied at 2 seconds, never cleared
- Bus fault at bus 201, applied at 2 seconds, cleared after 0.15 seconds
- Bus fault at bus 201, applied at 2 seconds, cleared after 0.50 seconds

- Bus fault at bus 201, applied at 2 seconds, cleared after 0.75 seconds
- Bus fault at bus 206, applied at 2 seconds, never cleared

The bus at 201 is connected to the HV side of the transformer of the studied generator bus. It is also connected to a tie line from Area 1. A fault at this bus can be very critical.

For a fault at bus 201, applied at 2 seconds, never cleared - the system became unstable. In this case, the generator at the studied bus tripped at a time of 2.8334 seconds, i.e., after 0.8334 seconds after the application of the fault as can be seen from Figure 3.1. Since the bus 201 was tripped after 0.8334 seconds, 3 more cases are considered for the bus fault at 201 with fault clearings at times 0.15 seconds, 0.50 seconds and 0.75 seconds respectively.

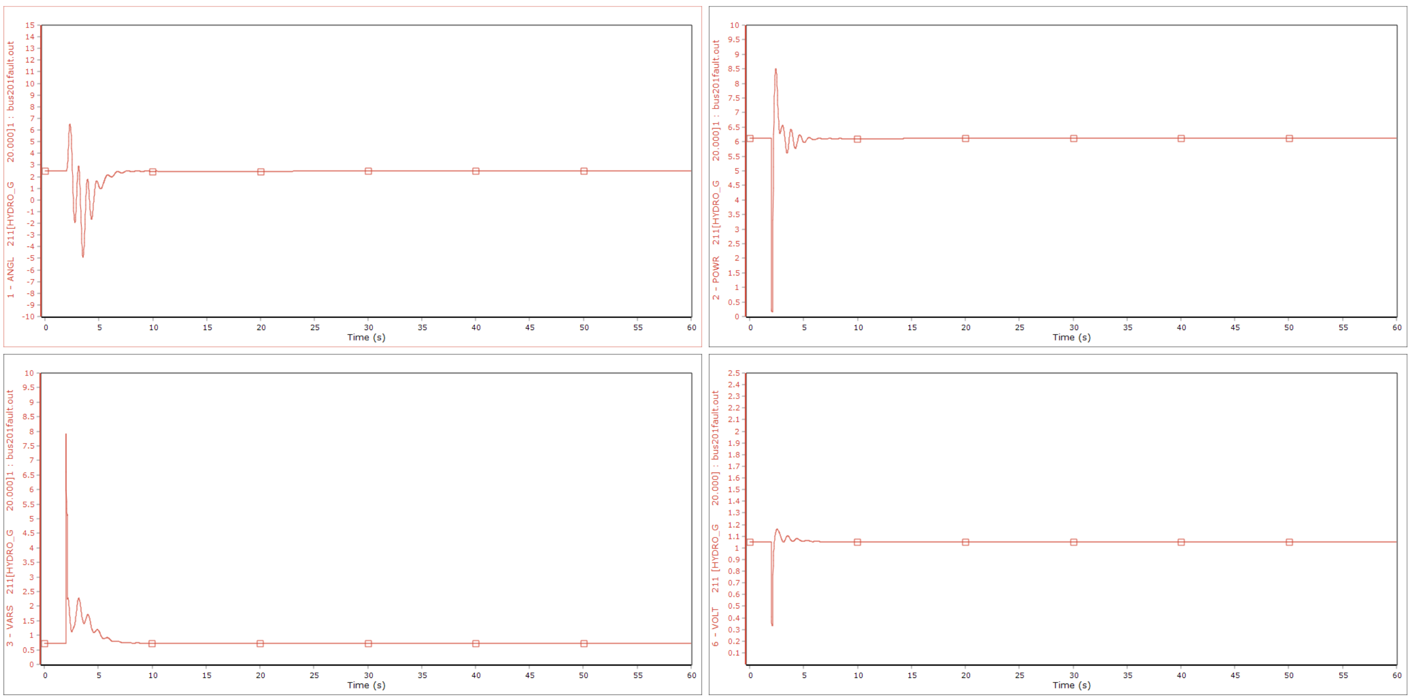

Figure 3.2: Bus fault at bus 201, applied at 2 seconds, cleared after 0.15 seconds

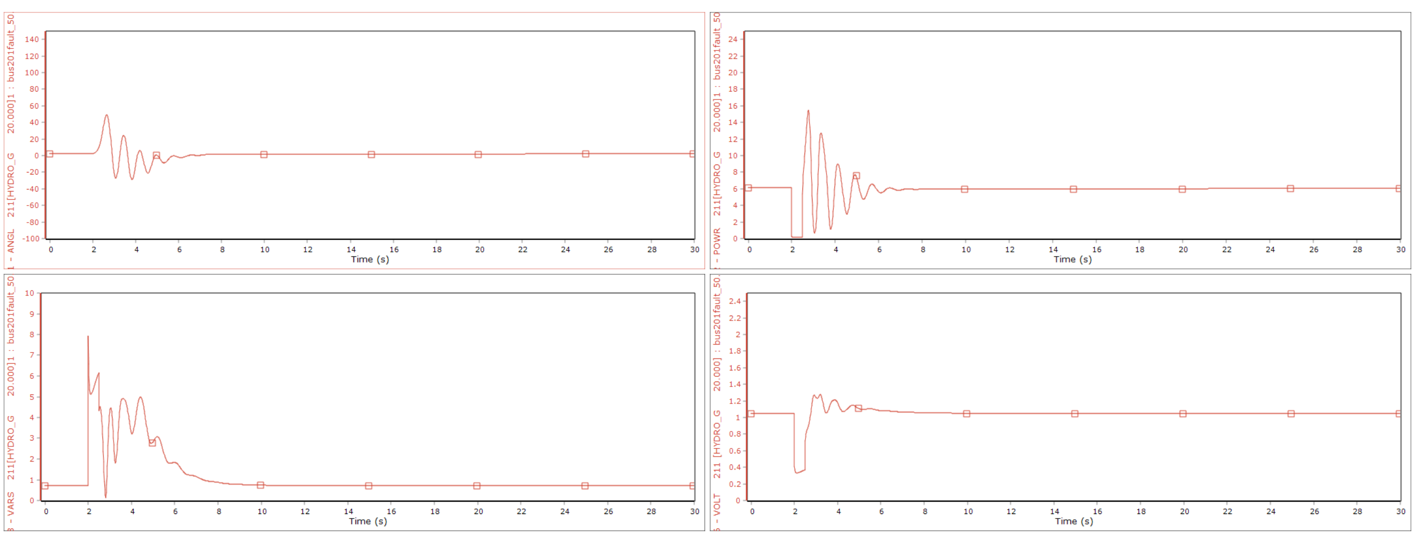

Figure 3.3: Bus fault at bus 201, applied at 2 seconds, cleared after 0.5 seconds

For a fault at bus 201, cleared after 0.15 seconds - even though the voltage value for this fault went less than 0.4 PU, the generator at bus 211 had a ride through this low voltage, and the generator did not trip, and when the fault was cleared the system recovered and was able to attain steady state operation as can be seen from Figure 3.2.

For a fault at bus 201, cleared after 0.50 seconds - even though the voltage value for this fault went less than 0.4 PU, the generator at bus 211 had a ride through this low voltage and did not trip, and when the fault was cleared at 0.50 seconds, there were very high oscillations but the system recovered and was able to attain steady state operation. As can be seen from the Figure 3.3 both synchronizing torque and damping torque was sufficient enough to bring the system back to stability.

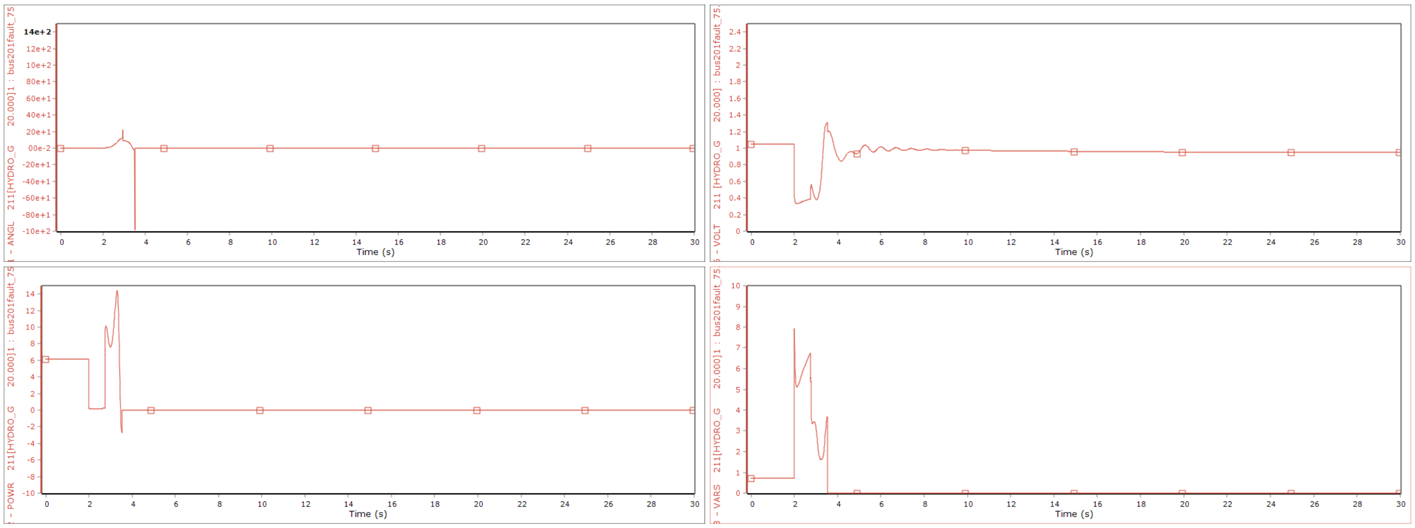

Figure 3.4: Bus fault at bus 201, applied at 2 seconds, cleared after 0.75 seconds

For a fault at bus 201, cleared after 0.75 seconds - even though it was cleared before 0.8334 seconds as observed in case 1, the studied generator at bus 211 tripped. It was observed that the voltage value for this bus went less than 0.4 PU as in previous cases. When the fault was cleared after 0.75 seconds. As can be seen from the Figure 3.4, insufficient synchronizing torque caused the instability and tripping of the generator at the studied bus 211.

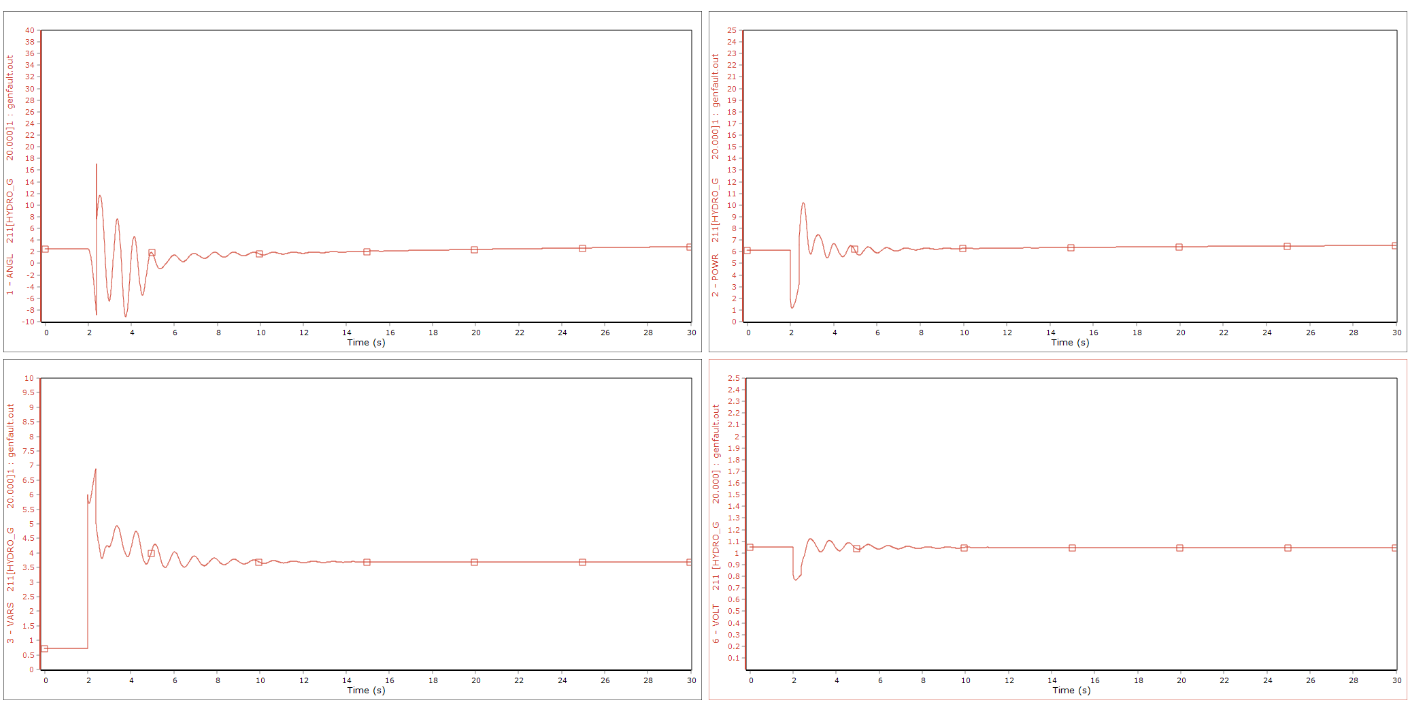

Figure 3.5: Bus fault at bus 206, applied at 2 seconds, never cleared

The bus 206 is connected to a generator - criticality of a loss of generator depends on the initial conditions of the system including how much load is connected to it and if the loads can be compensated for this generation loss from other resources in the system. As seen from Figure 3.5, it was observed for a fault at bus 206, never cleared, after oscillations, the system attained steady state operation.

Chapter 4

Conclusions

In this study stability of the savnw system for small disturbances for small signal stability and large signals for transient stability was investigated.

It was found that for small disturbances, for the tested cases the system is stable. In all the tested cases, the transient variation in the beginning is not problematic, and have tolerable values and settles within reasonable time to give new steady state values for observed variables at bus 211.

For large disturbances, for the observed cases, the system stability depended on fault clearing time, location of the occurrence of the fault. For the transient stability study, it was found that for the same fault at bus 201, systems ability to come back to stable operation depended on the time at which the fault was cleared.

References

This study report was developed by referening Power System Stability and Control - Prabha S. Kundur and, PSSE user manuals PAGV2 and POM.