Transient Stability Analysis of Generation and Transmission system of a thermal power plant of Pakistan.

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Abstract: Power system is exposing to various unexpected conditions, which may involve different kinds of faults and sudden load changes. The main reason of these unexpected conditions within power system is its larger size and complicated structure. These accidental conditions may lead to unexpected behavior of power system which may causes instability within the system. The power system must regain its stability after being exposed to various disturbances such as sudden load changes and various faults. In this research paper, the transient stability analysis of generation and high-voltage transmission system of a thermal power plant in Pakistan is performed and analyzed using ETAP software. Three-phase faults are created/developed at different locations and after that, sudden load changed. Transient stability of the system has assessed from the analysis of various system parameters and critical clearing time of the system transients.

NOTE.NPCC (National Power Control Center), WAPDA (Water and Power Development Authority)

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1. Introduction

The desirable operation of any power system is to maintain synchronism and equilibrium between different parts of system and generating units after being subjected to transients. There may be great risk of losing synchronization any time between generating units, and system becomes unstable after transients. The two major types of stabilities are transient stability and steady-state stability [1].

Steady-state stability is the ability of a power system to maintain synchronism and equilibrium after gradual disturbances. Transient stability is the ability of a power system to maintain synchronism and equilibrium after large disturbances. To find out the system withstanding ability to transients, transient stability analysis must be performed [2].

Transient stability is the dominant stability problem and has been considered much of the attention regarding power system stability [3]. The main purpose of transient stability analysis is to find that whether the system regains its equilibrium after the

disturbances. The system planners and operators have a great interest in recovery of a power system from disturbances. The system design should be such that it continuously provides electrical power to utilities without losing stability after being subjected to transients [4].

Transients, such as transmission system faults and sudden load changes, stress the power system in many ways and produce various effects such as frequency transients, voltage and current transients, and inter area oscillations or power swing. For a power system to be stable, all these effects last only for a finite period of time [3]. The system may be stable or unstable after disturbance, depending upon the duration and location of disturbance [5].

Selection of proper protective devices and their rating & specifications is a function of system transient behavior because during transient, the parameters of the system changes largely. If the parameters such as voltage, current and power are

same before fault and after fault, the system will be stable [6].

Transients on a power system lead to variation in power flows, network bus voltages and machines rotor speeds. For a given disturbance, the system may be stable or unstable depending upon disturbance. If a generator remain stable after a disturbance, it may adopt a new state of equilibrium and for that machine, stability conditions will be different from that of previous one [7].

Different forms of system stabilities are frequency-stability, voltage-stability and rotor angle stability. If power system maintain steady voltages at all busses after disturbance then it is called voltage-stability. If power system maintains steady frequency after disturbance then it is called frequency-stability. Rotor angle stability is the ability of synchronous machines to maintain synchronism after disturbance [7].

During transient, the shaft of generator accelerates and decelerates periodically and hence its energy output oscillates with a sinusoidal manner, as a result output electrical power and load angle oscillate in the same manner. In equilibrium point, the mechanical torque is equal to output electrical torque and the system is said to be stable [9].

Authors in [1] have performed transient stability analysis of Tamilnado Generation and transmission line system. The single-line diagram of the mentioned area is created/developed in ETAP software. A three-phase fault is created at some specified bus and as a result of that critical clearing time of transient is studied. Finally transient stability is assessed from rate of change of system frequency, power angle and voltage levels of the busses.

Authors in [2] have performed transient stability analysis of IEEE 9 bus system. A three phase fault is created at different locations, the effect of fault on the system and critical clearing time on the system stability is analyzed.

Various methods are used for transient stability analysis of a power system. In this research paper, the tool used for analysis and simulation are Electrical Transient and Analysis Program (ETAP). Single line diagram of generation and transmission system of a thermal power plant in Mianwali, Pakistan is created/developed, simulated and analyzed in ETAP software for different system transient conditions such as three-phase faults at different locations and sudden load changing. The total duration of transient period, frequency transients, voltage and current transients, power swing and rotor angles are analyzed. Transient stability of the power system of the mentioned area is assessed using these system conditions.

3. Modeling of the system

The single line diagram of the mentioned area is modeled in ETAP as shown in figure. ETAP is chosen as simulation software for transient stability analysis for most of the industrial power system.

The system consists of two main generators, rated 325MW and 340MW. Both generators are connected to a common switchyard after 370MVA and 400MVA transformers respectively. The power of these generating units is transmitted to two separate grid stations naming Daudkhel grid and Ludewala grid at distance of 70km and 125km respectively from generating units as shown in figure. Jinnah Hydal power plant is a small

generating plant delivering 40MW of power (depending upon requirement) to Daudkhel grid station. Ludewala grid station is also connected to Mangla power house. Mangla gives 30-40 MW power (depending upon requirement) to Ludewala grid station.

The important data about load flow, transmission lines, rating and specification of busses and

equipment's has collected from WAPDA and NPCC.

The single-line diagram of the mentioned area is shown in figure below.
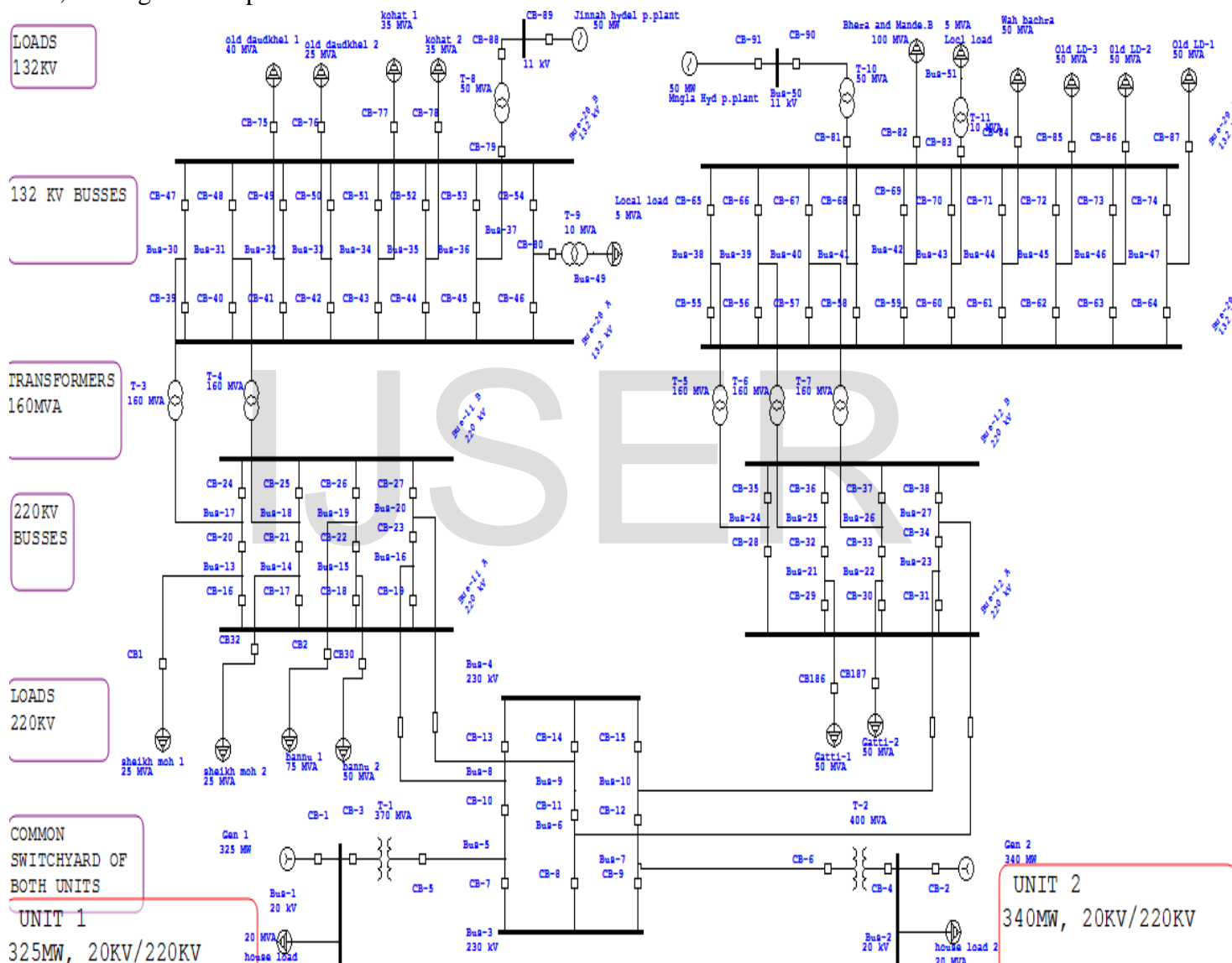
Figure 1: single line diagram of Generation and Transmission system of understudy Thermal Power Plant

4. Transient stability analysis

Transient stability analysis is performed for finding the ability of the mentioned system to regain its steady-state equilibrium state after clearance of disturbances. The purpose is to find the severity of

disturbances, and also it is found that how much the system is affected by the disturbances. The system behavior is checked by the transient stability analysis by exposing the system to disturbances of three-phase faults at different locations and sudden

load changing. There are restricted stability boundaries within which the system supposed to be stable, if those boundaries is crossed, the system becomes instable.

4.1. Three phase fault at different location

4.1.1. Three phase fault at BUS-11B

At the time interval before t=0.5 sec, BUS-11B is supposed to be in normal and equilibrium position. A three-phase fault is assumed to be occurred on

bus-11A at time t=0.5 sec. At time t=0.6 sec; the fault is removed. Different plots are as shown.
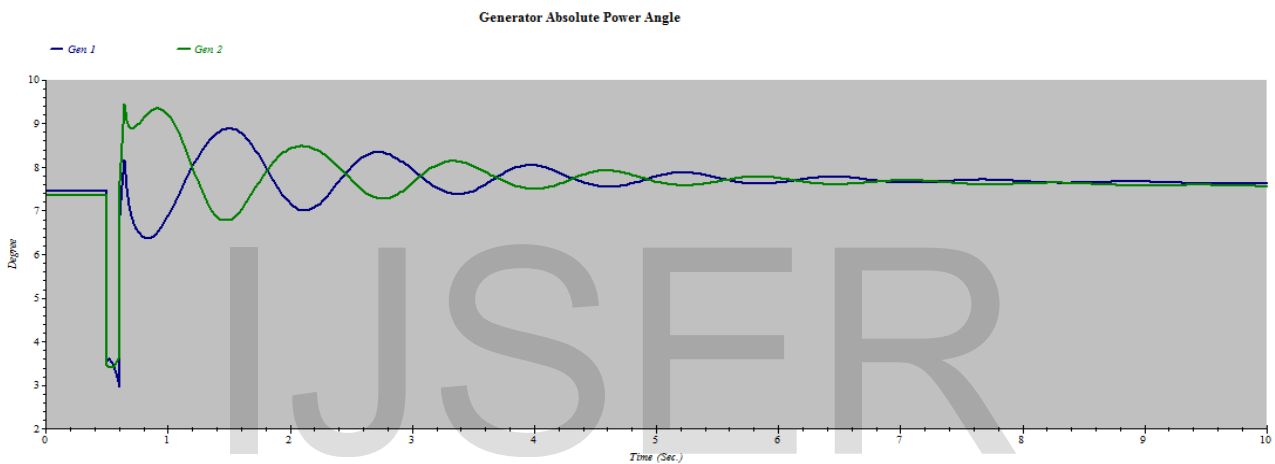
Figure 2: Generator absolute power angle
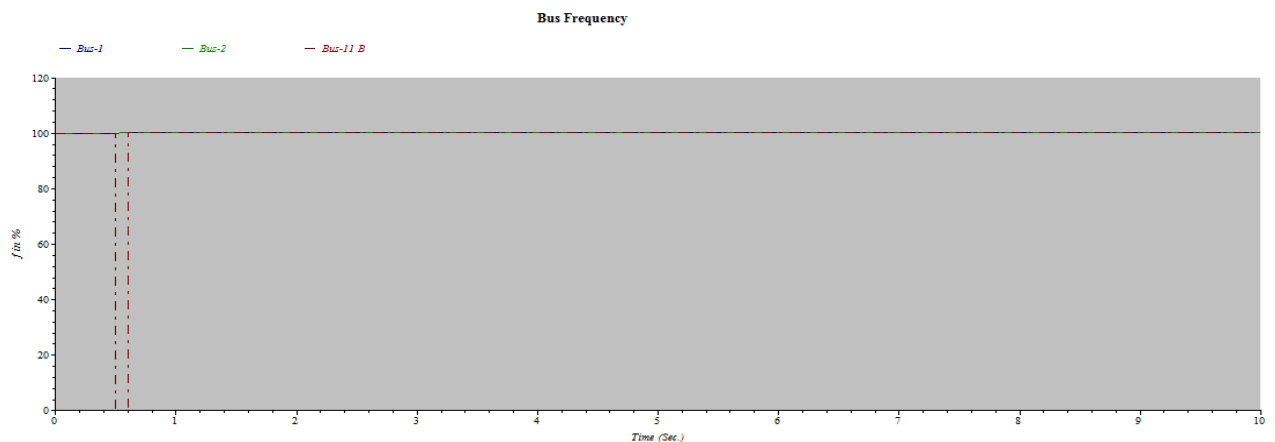
Figure 3: Bus frequency in percent
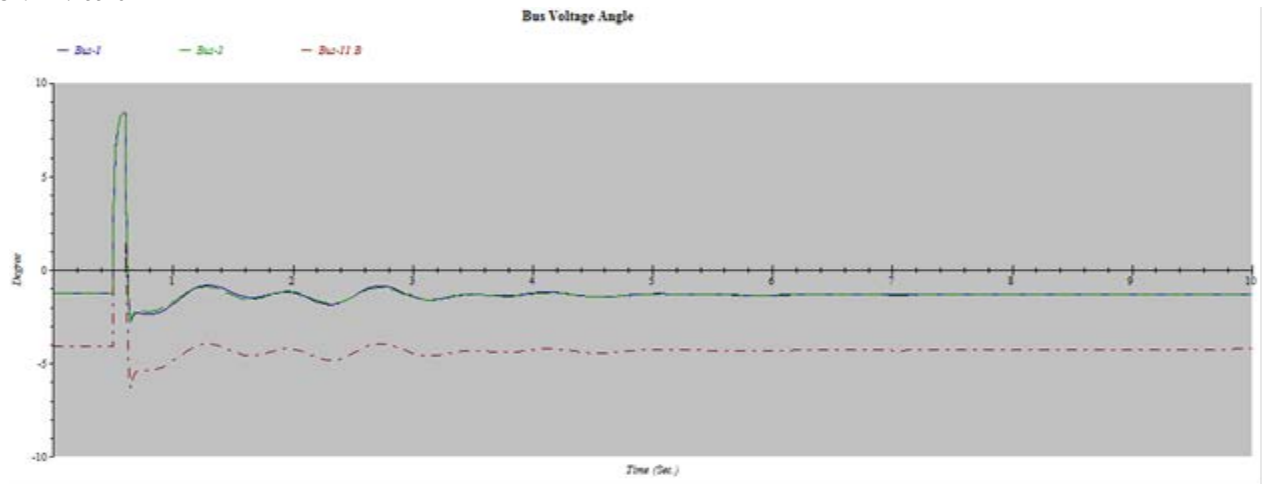
Figure 4: Bus voltage angle
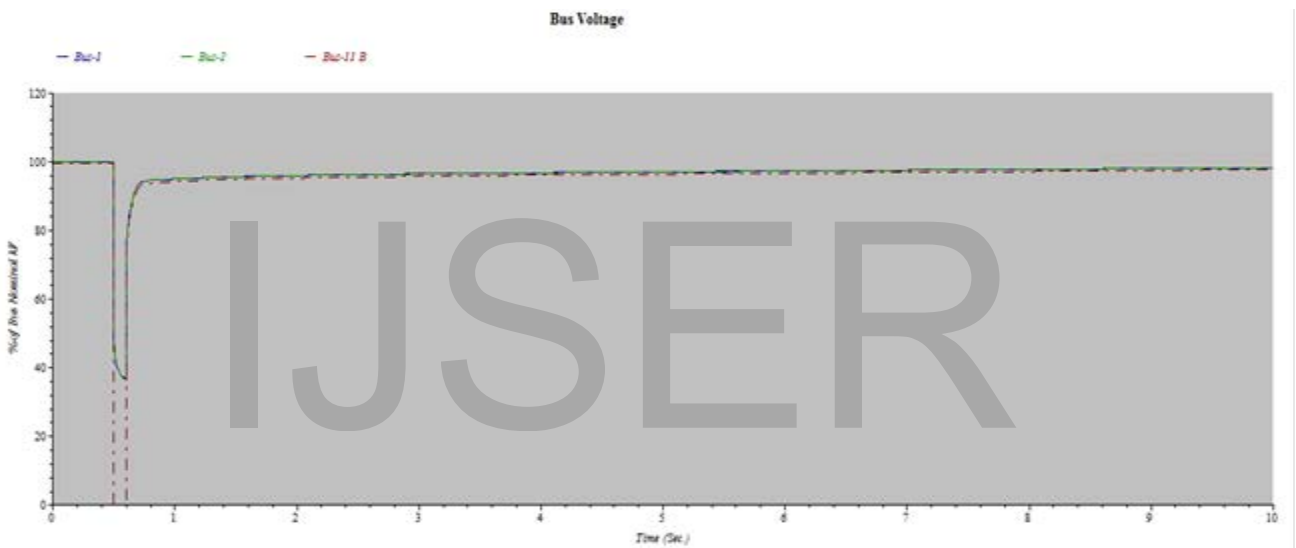
Figure 5: Bus voltage
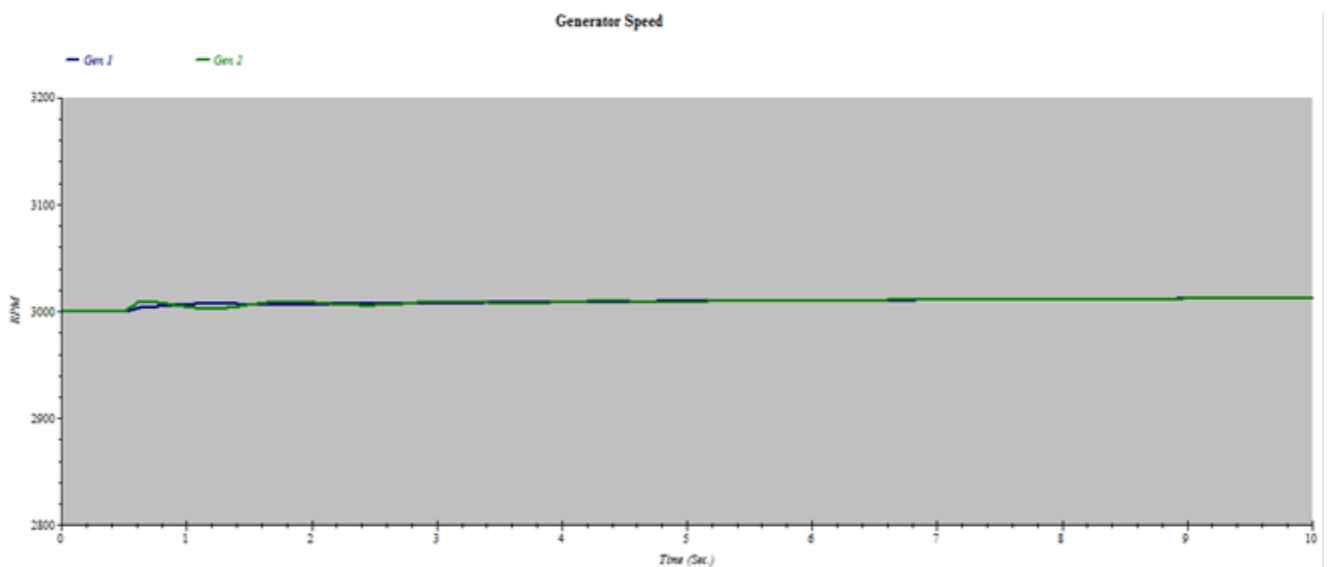
Figure 6: Generator speed.
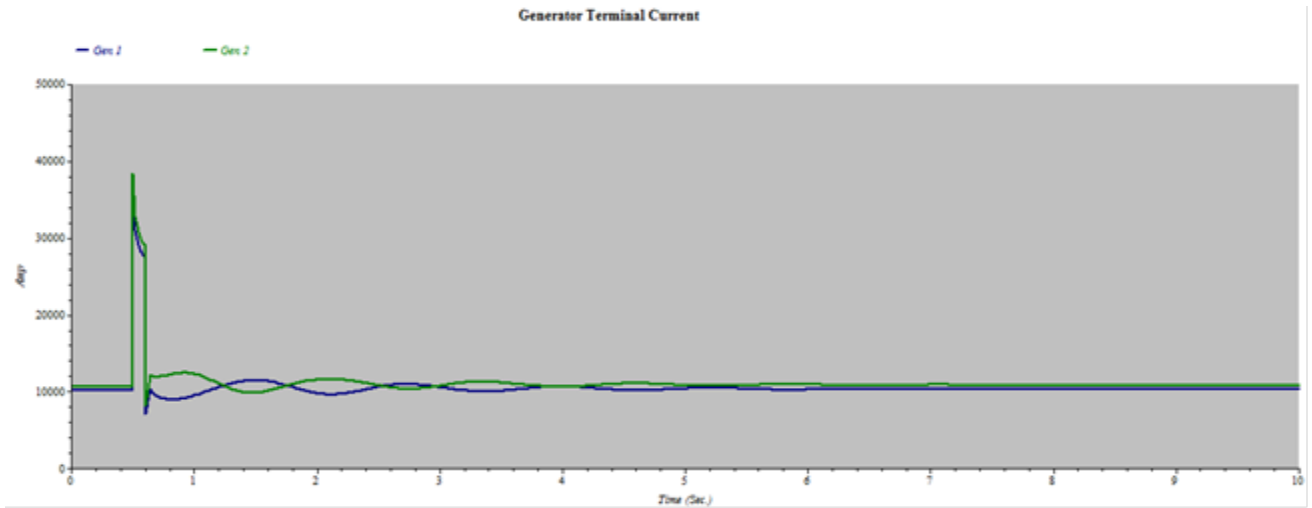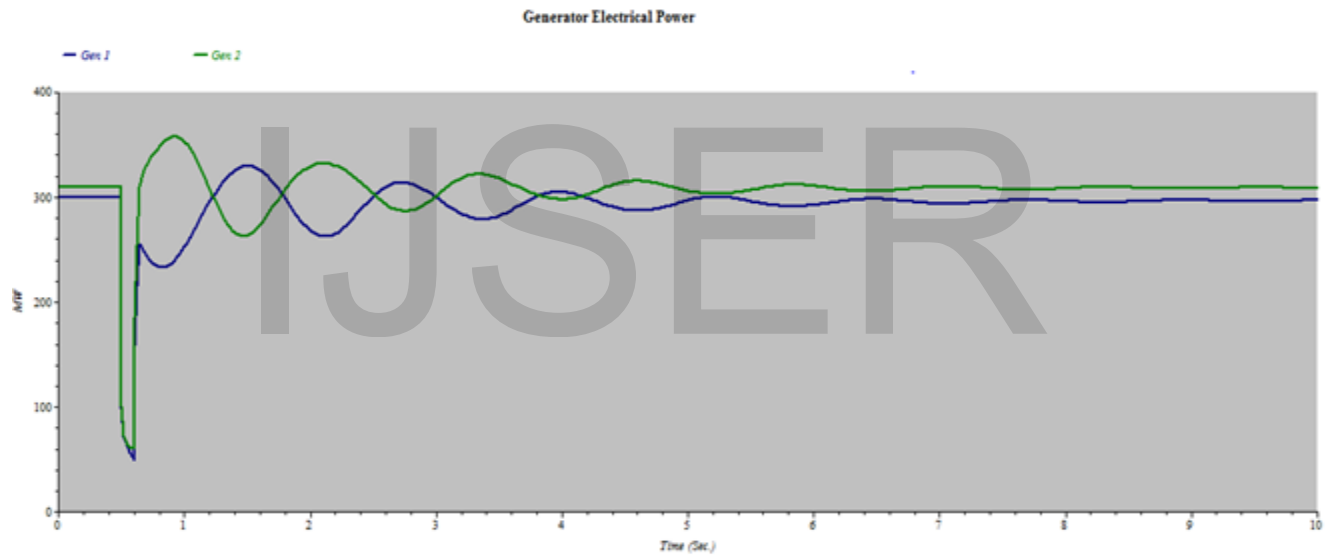

Figure 7: Generator terminal current
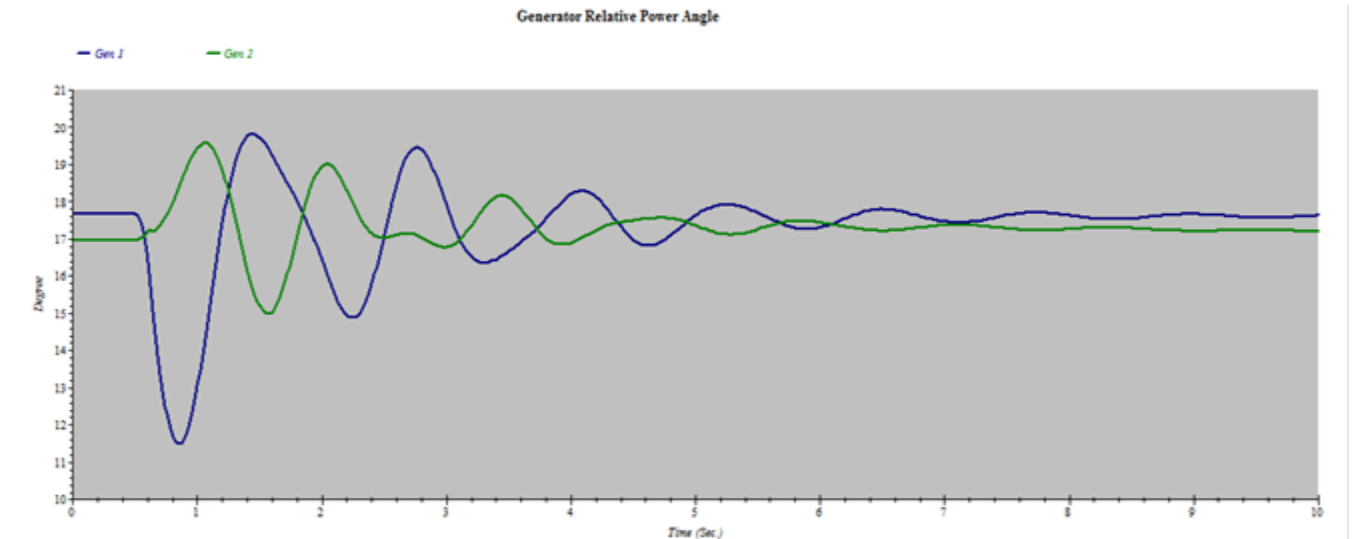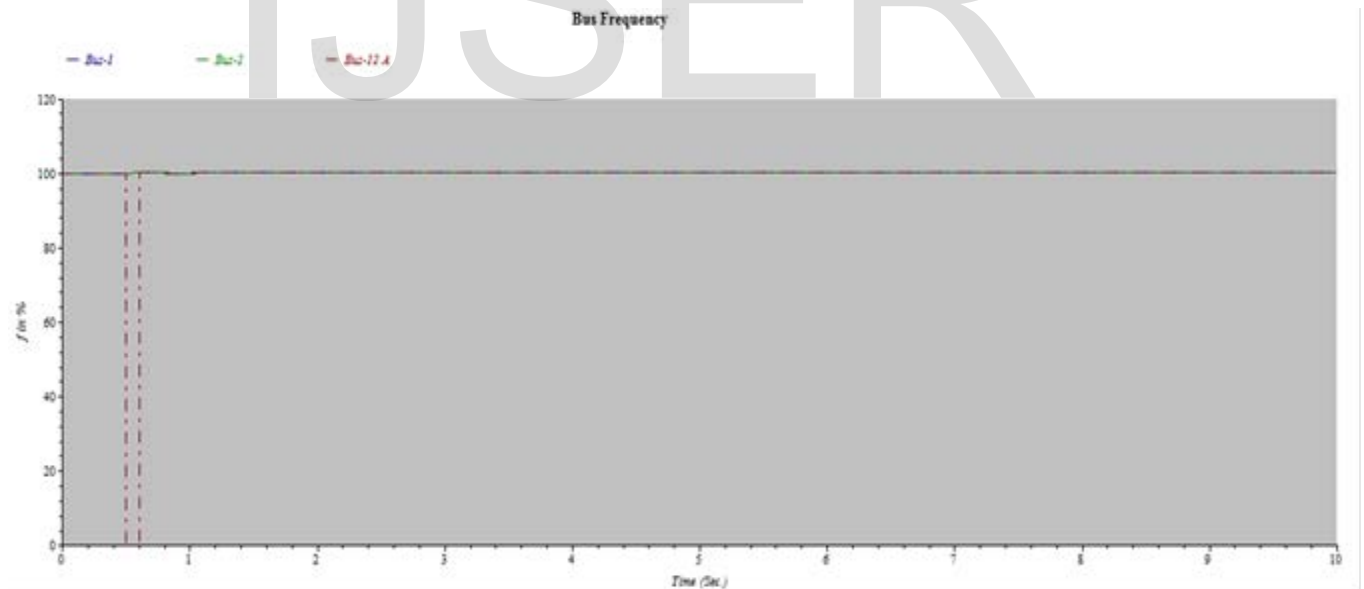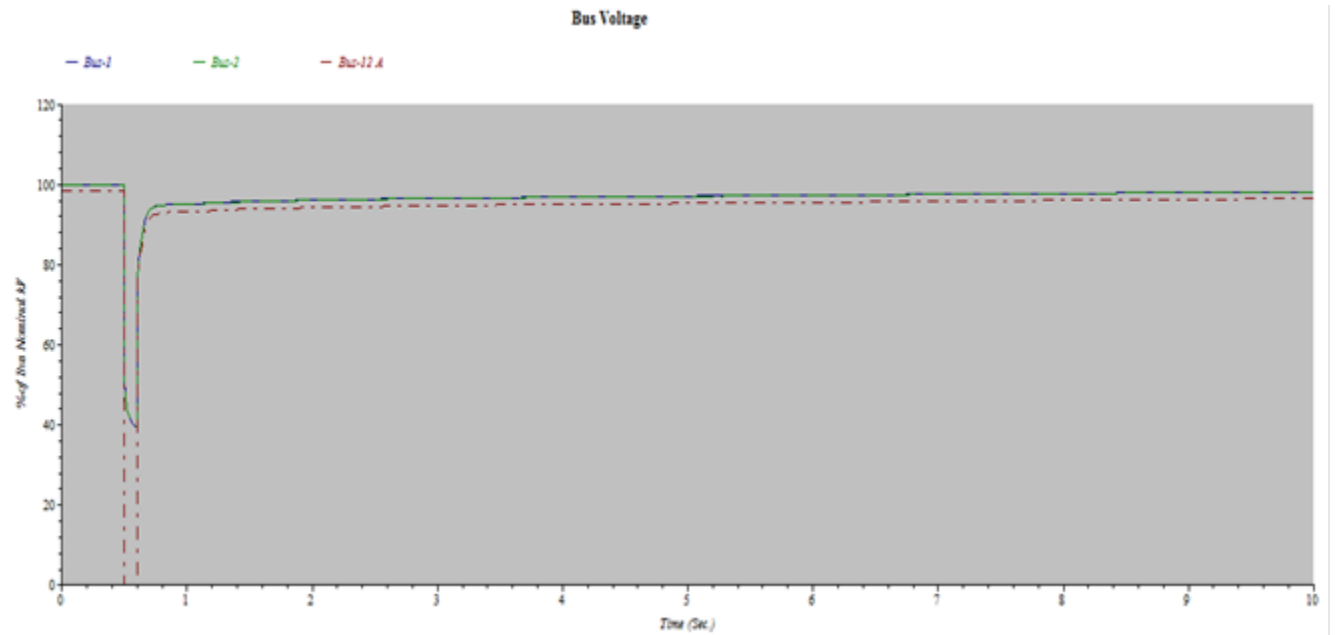

Figure 8: Generator electrica power

Figure 9: Generator relative power angle

4.1.2. Three phase fault at BUS-12A

At the time interval before t=0.5 sec, BUS-12A is supposed to be in normal and equilibrium position. A three-phase fault is assumed to be occurred on bus-11A at time t=0.5 sec. At time t=0.6 sec, the fault is removed. Different plots are as shown.
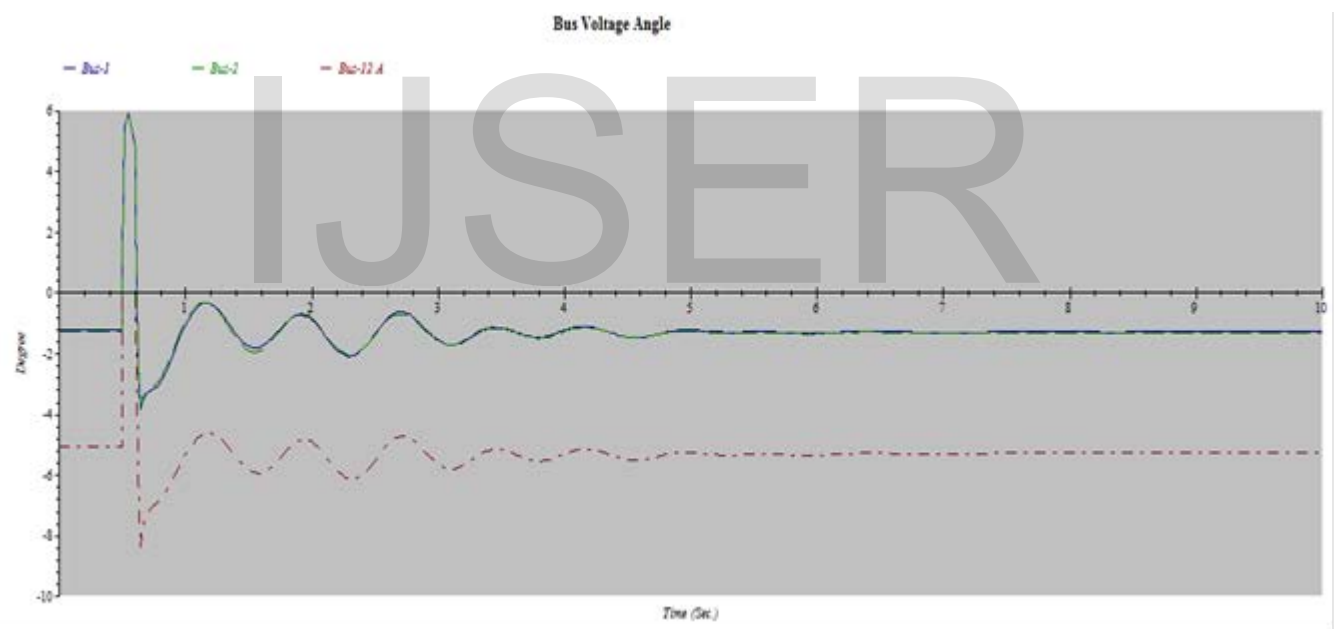

Figure 10: Bus frequency

Figure 11: Bus voltage
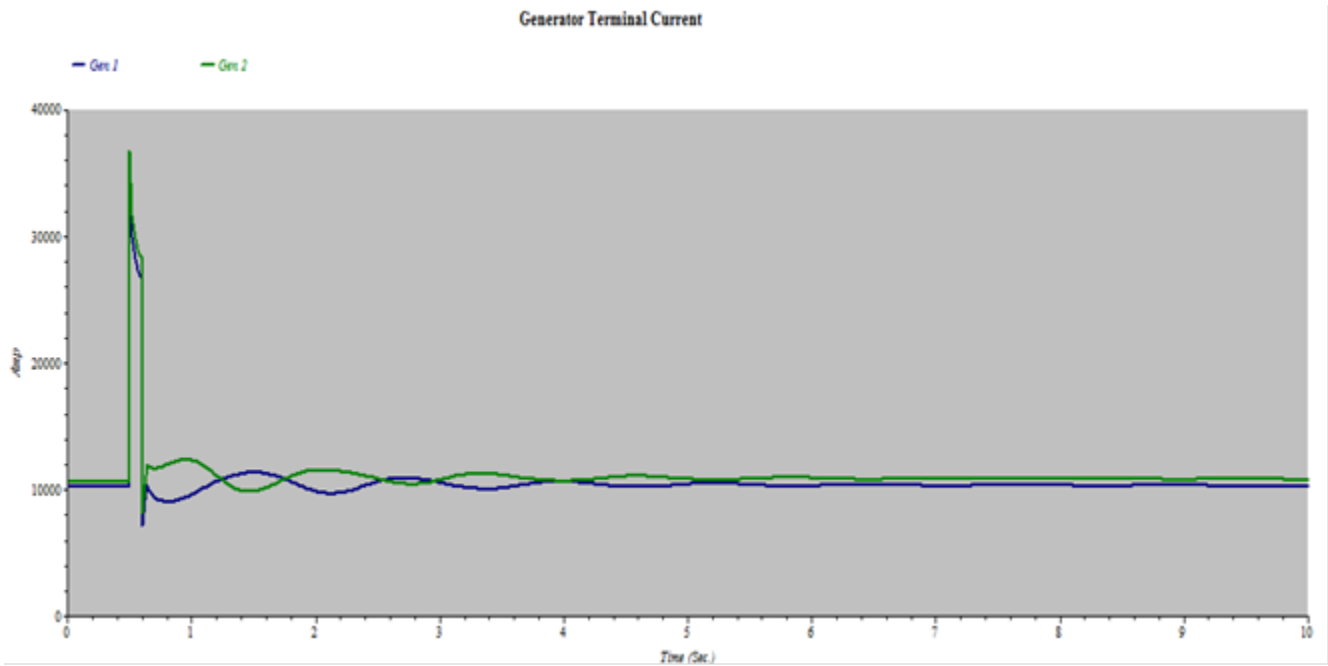

Fugure 12: Bus voltage angle
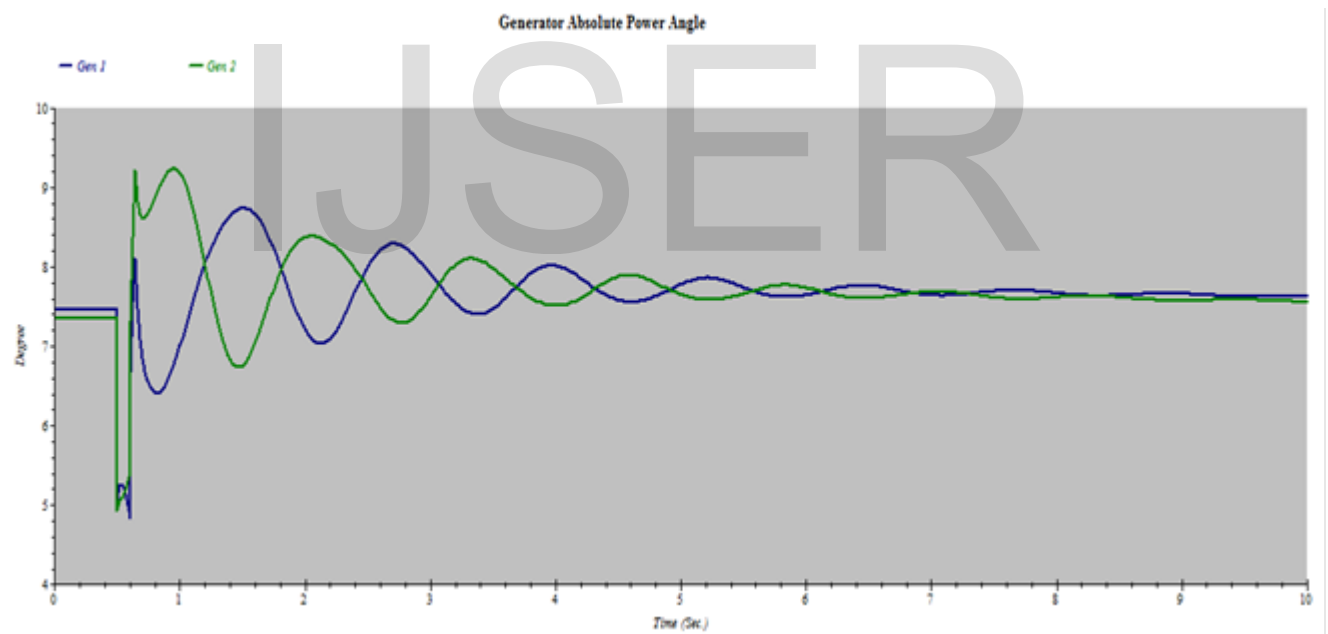
Figure 13: Generator terminal current

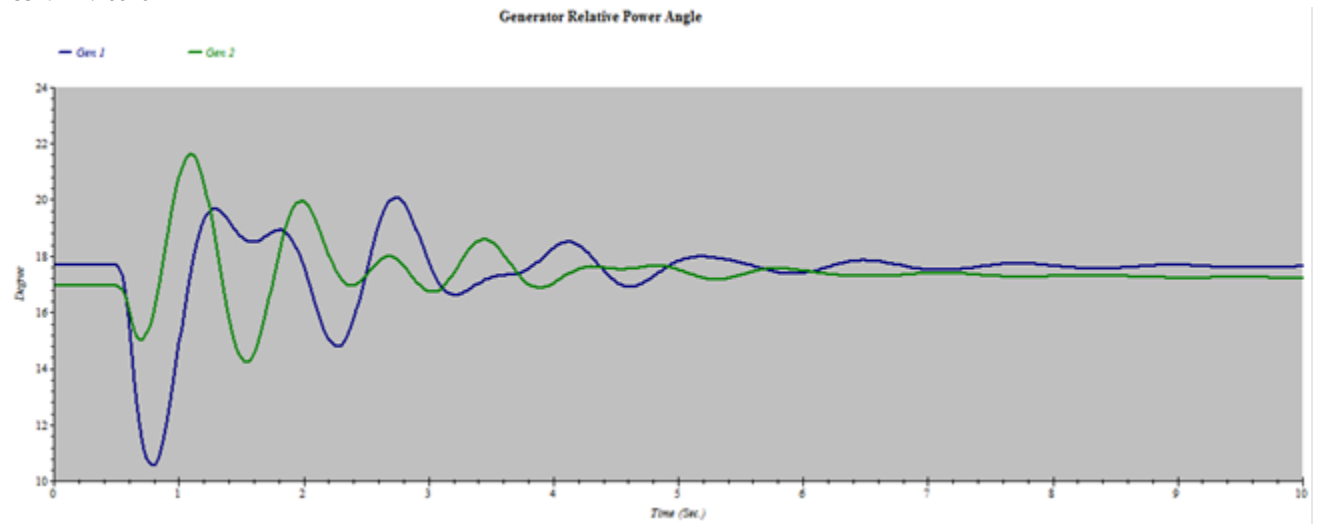Figure 14: Generator absolute power angle
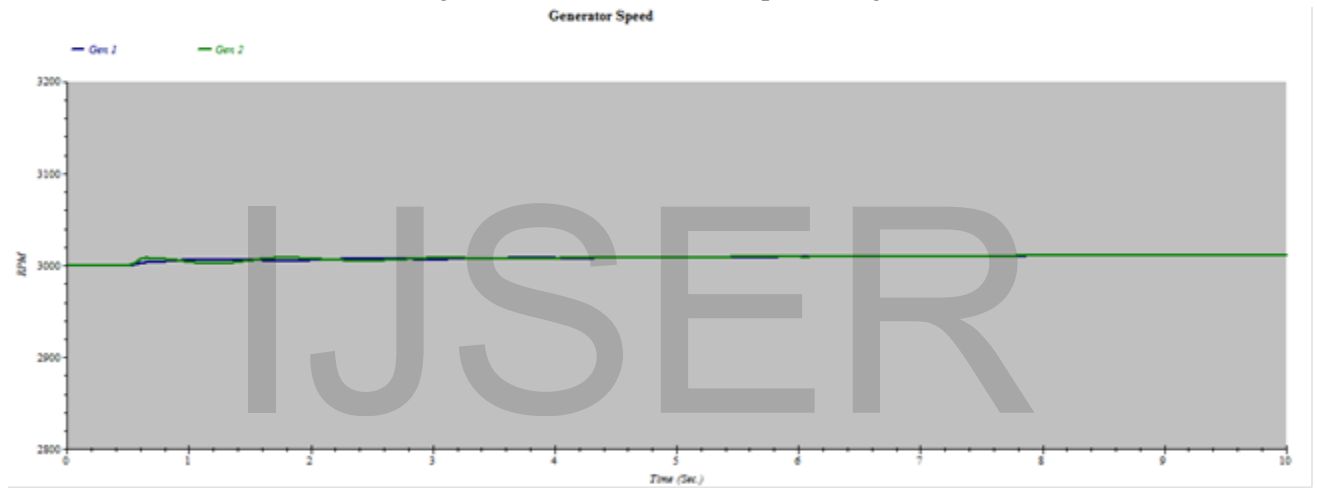
Figure 15: Generator relative power angle

Figure 16: Generator speed

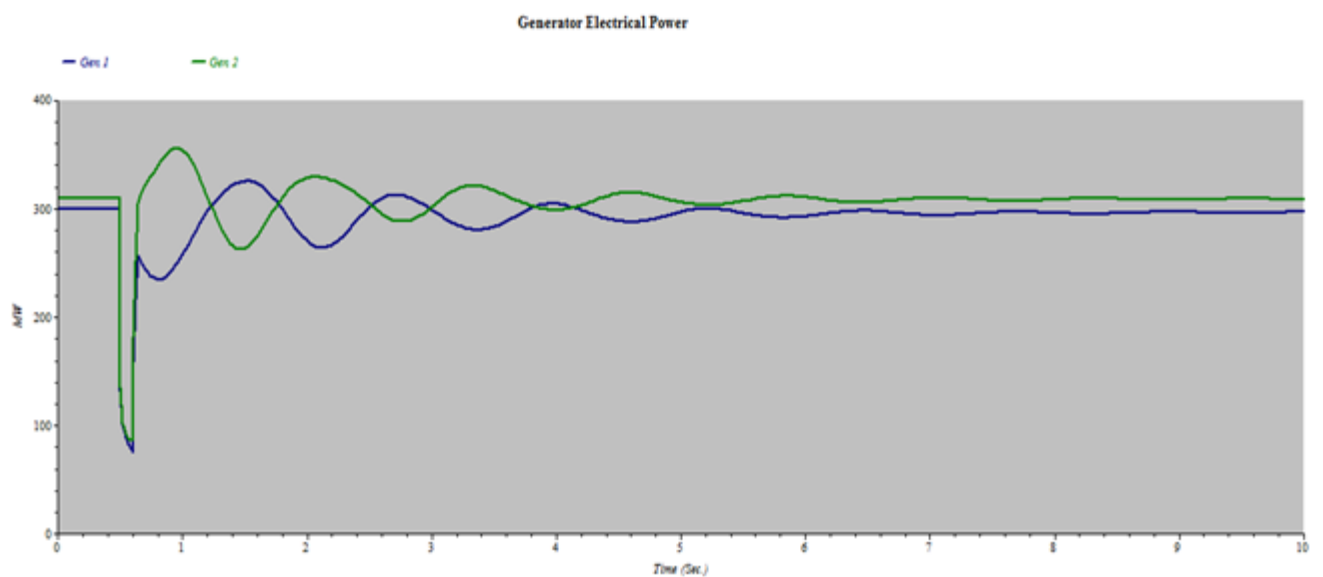Figure 17: Generator electrical power

From the above waveforms it is clear that the system regains its stability after clearance of fault at time t=7 sec. The faulty bus has zero voltage and frequency at the time of fault and comes back to normal voltage and frequency after clearance of fault as shown in figures 3, 10,5,11.

The regular generator current of generator 1 and generator 2 at pre-fault is 10500 and 11000 ampere. During fault, the current is about five times higher than normal currents. The generator currents regain their normal values after the clearance of fault as shown in figure 7,13.

At the time of fault, the rotor angles of generators severely disturbed. The equilibrium is upset between electrical and mechanical torque because of which some machines temporarily run faster and some runs slower causing the power swing between generators as shown in figure 8, 17. At time t=7 or 8 sec, after disturbance, the equilibrium is restored and the system regains its steady-state operation as shown in figure 2, 9, 14, 15.

Disturbances in the power system cause variation in generator RPM also. At time t=0.5 sec, the RPM of generators disturbed, the rotors of some of the generators accelerate and some decelerate. At time t=7 0r 8 sec, the rotor steady down to its equilibrium position and the system achieves its steady-state operation. The system is said to be stable at time t=7 sec.

4.1.3 Three phase fault at transmission lines

At the time interval before t=0.7 sec, there is no fault on transmission line. A three-phase fault is assumed to be occurred on transmission line at time t=0.7 sec. At time t=0.8 sec; the fault is cleared.

Different plots as a result of disturbance are as shown below.
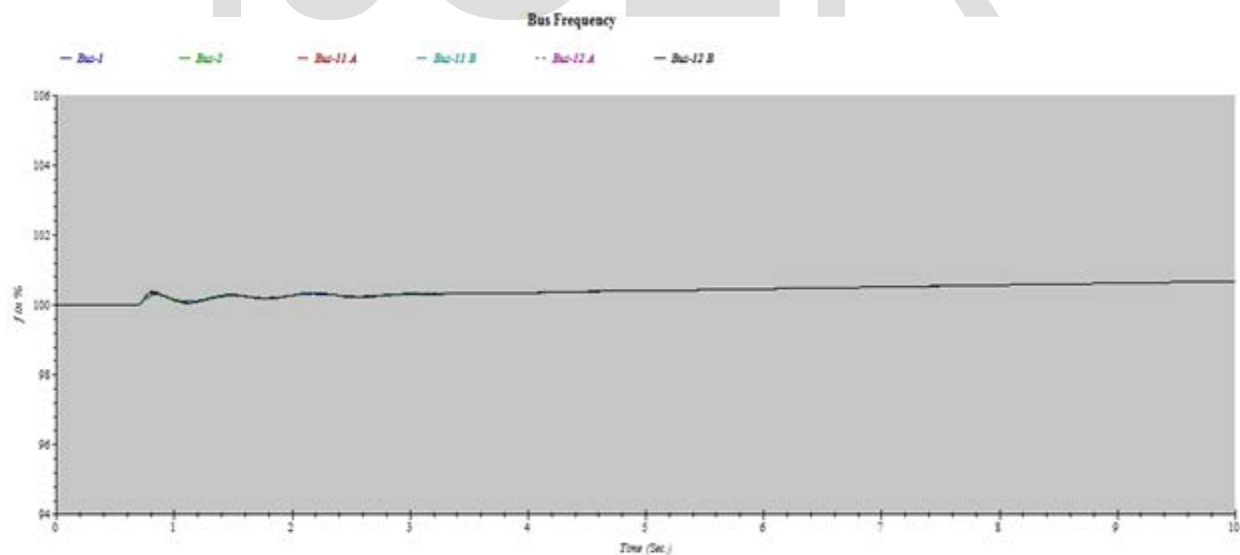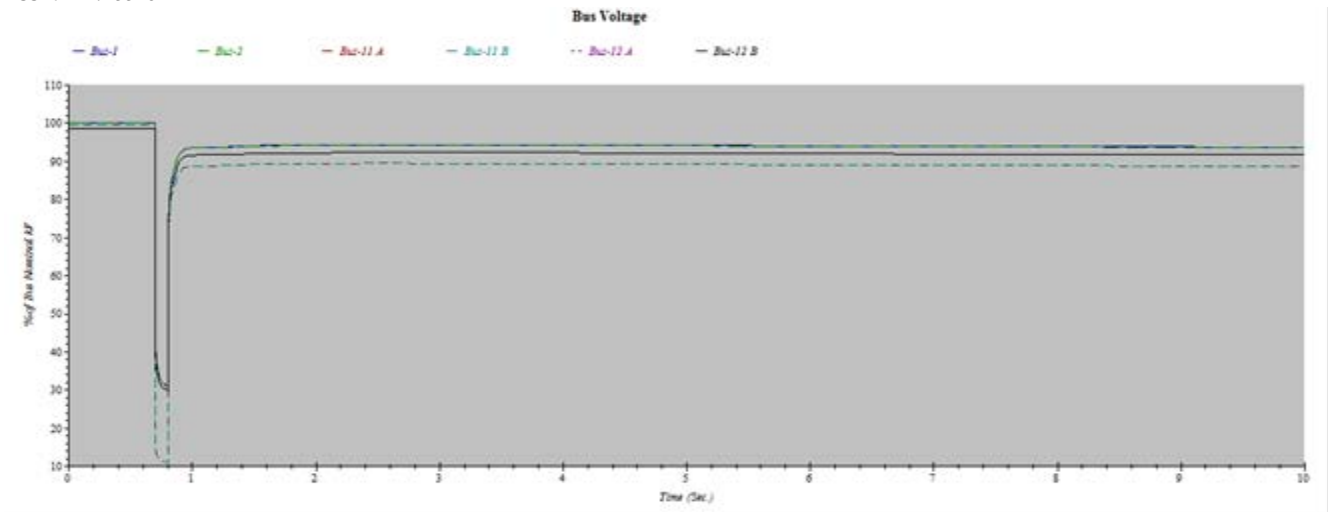

Figure 18: Bus frequency

Figure 19: Bus voltage

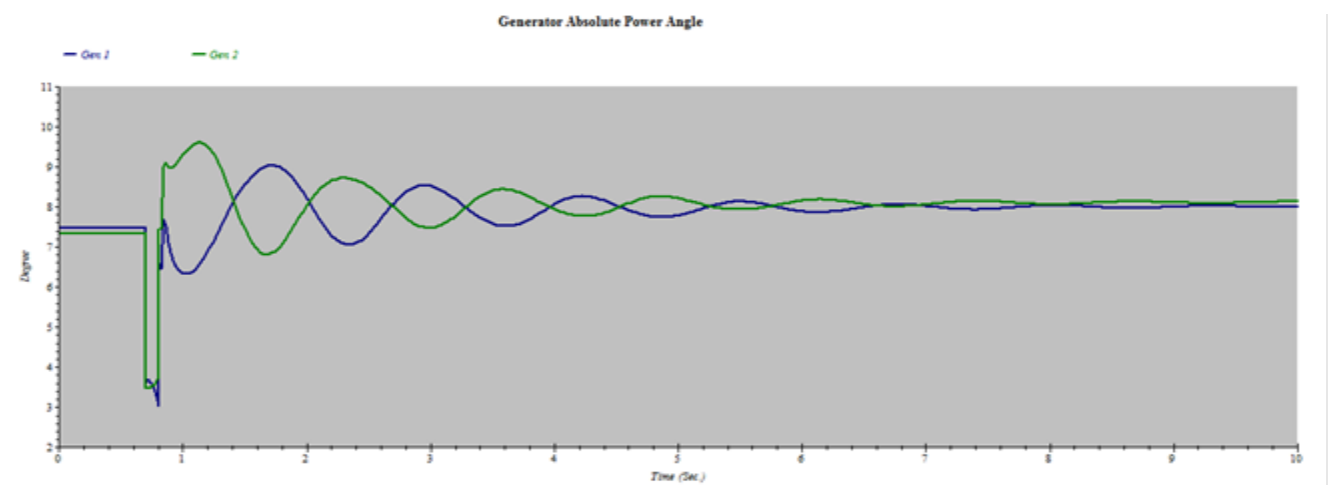Figure 20: Bus voltage angle
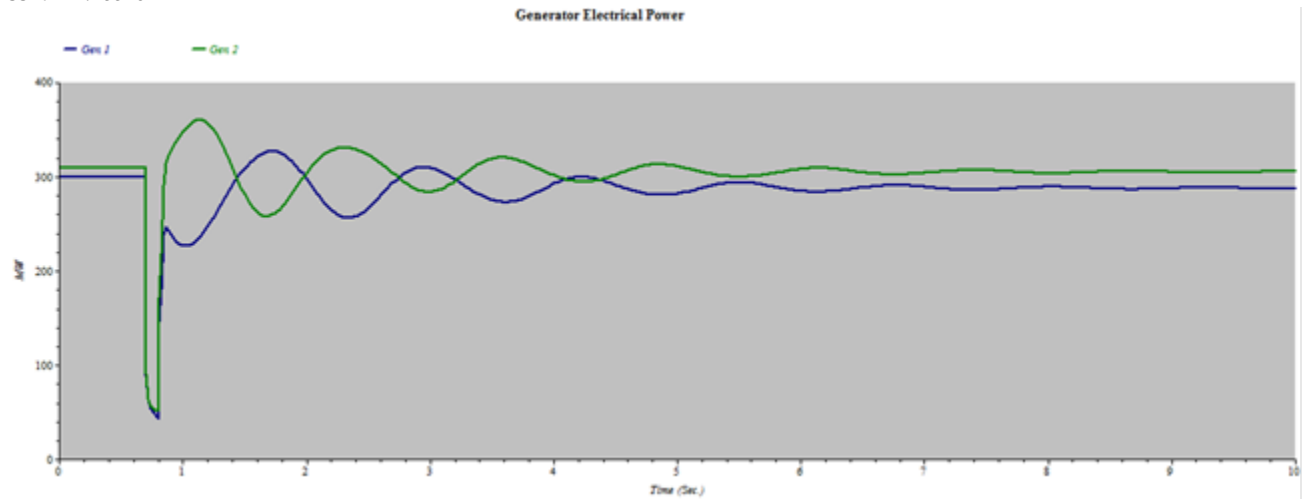

Figure 21: Generator absolute power angle

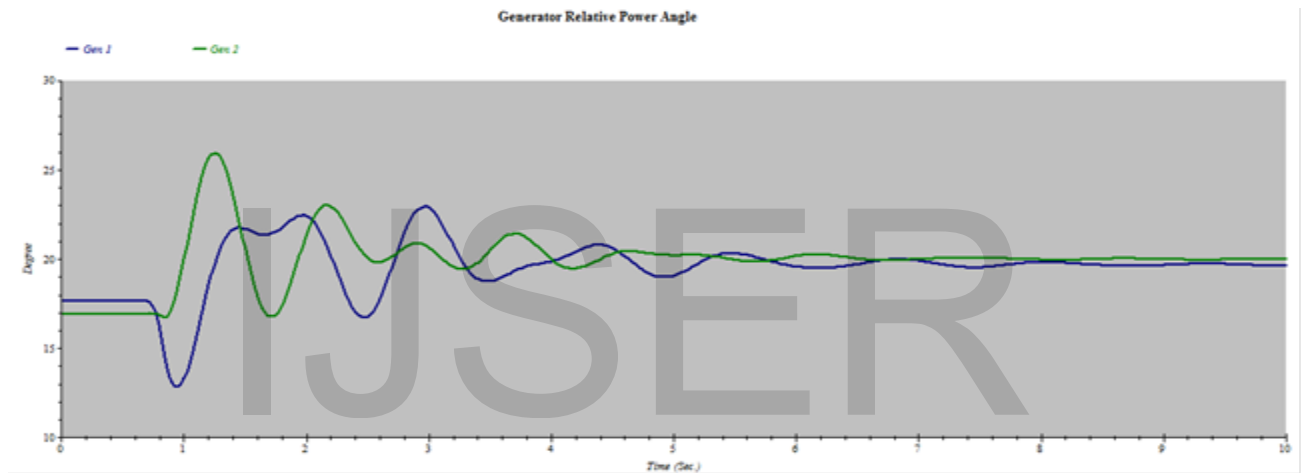Figure 22: Generator electrical power

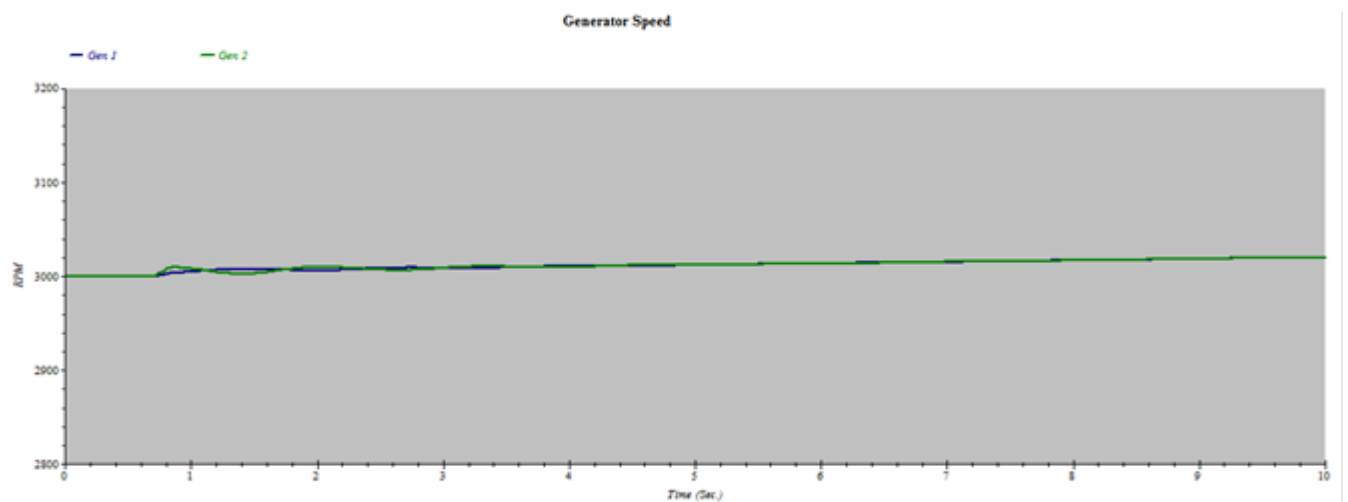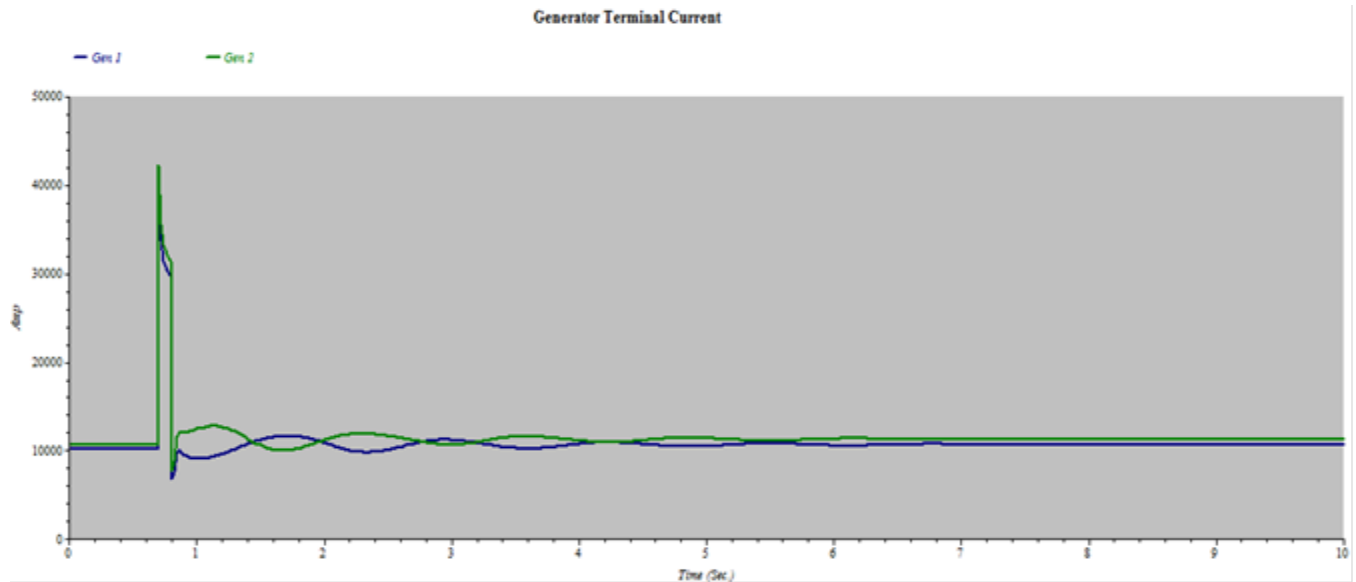Figure 23: Generator relative power angle

Figure 24: Generator speed

Figure 25: Generator terminal current

From the above waveforms it is clear that the system regains its stability after clearance of fault at time t=7sec. The busses regain their normal frequency and voltages after the clearance of fault as shown in figure 17, 18.

The normal generator current of generator 1 and generator 2 at pre-fault is 10500 and 11000 ampere. During fault, the current is 43000 and 38000, many times higher than regular currents. The generator currents regain their normal values at time t=7 sec, after the clearance of fault as shown in figure 24.

At the time of fault, the rotor angles of generators severely disturbed. The equilibrium is upset between electrical and mechanical torque because

of which some machines temporarily run faster and some runs slower causing the power swing between generators as shown in figure 21. At time t=7 or 8 sec, after disturbance, the equilibrium is restored and the system regains its steady-state operation as shown in figures.

Disturbances in a power system cause variation in generator RPM also. At time t=0.7 sec, the RPM of generators disturbed, the rotors of some of the generators accelerate and some decelerate. At time t=7 0r 8 sec, the rotor steady down to its equilibrium position and the system achieves its steady-state operation. The system is said to be stable at time t=7 sec as shown in figure 23.

4.2. Sudden load changes

Abrupt load changes produce disturbance, which may cause loss of synchronism and the system becomes instable. Because of Sudden load changes, the rotors of some of the generators on the system tends to increase in speed, and some are tended to decrease and after some time, all the rotors comes to equilibrium position and system regain its stability after some oscillation. If the disturbance cause by

the sudden load changes is too high, the rotors of generators may lose its synchronous speed because over speed or under speeds.

For disturbances caused by sudden load changes, the circuit breakers connecting OLD DAUDKHEL (CB-15 and CB-16) lines are assumed to be opened. A sudden loss of 70 MW load is assumed to be

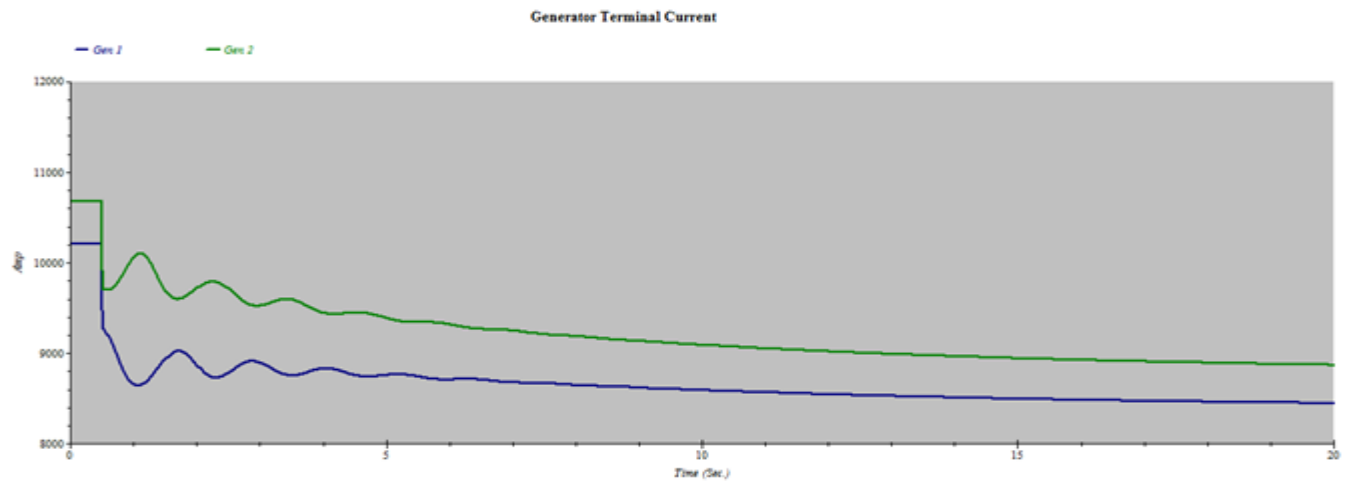occurred within the system. The waveforms are as   shown.

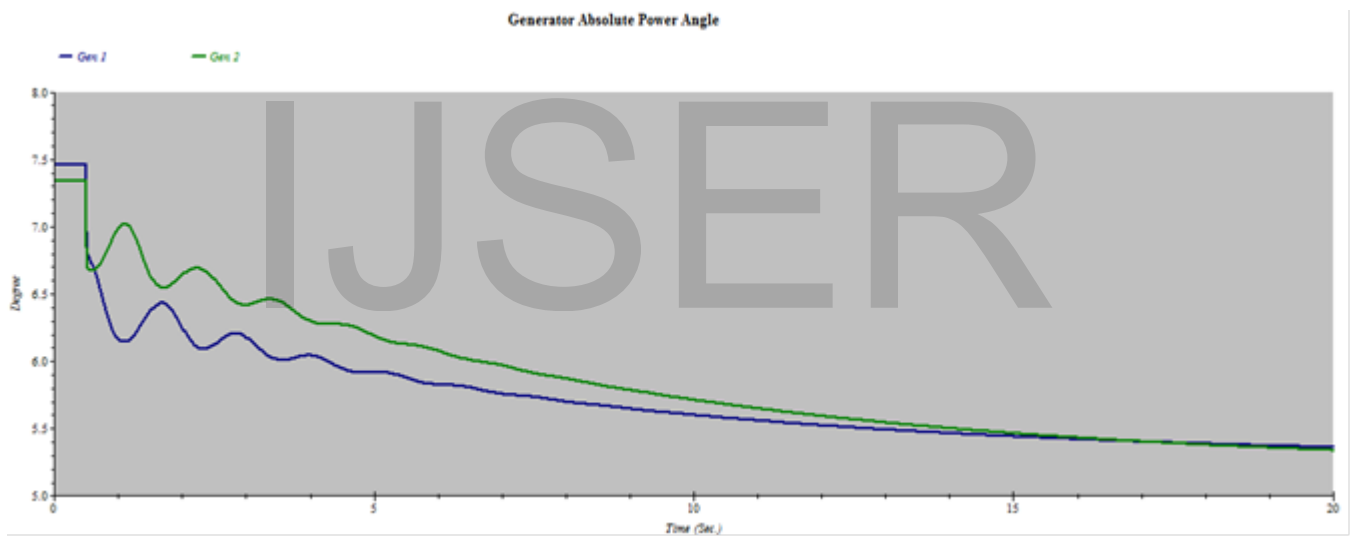Figure 26: Generator terminal current

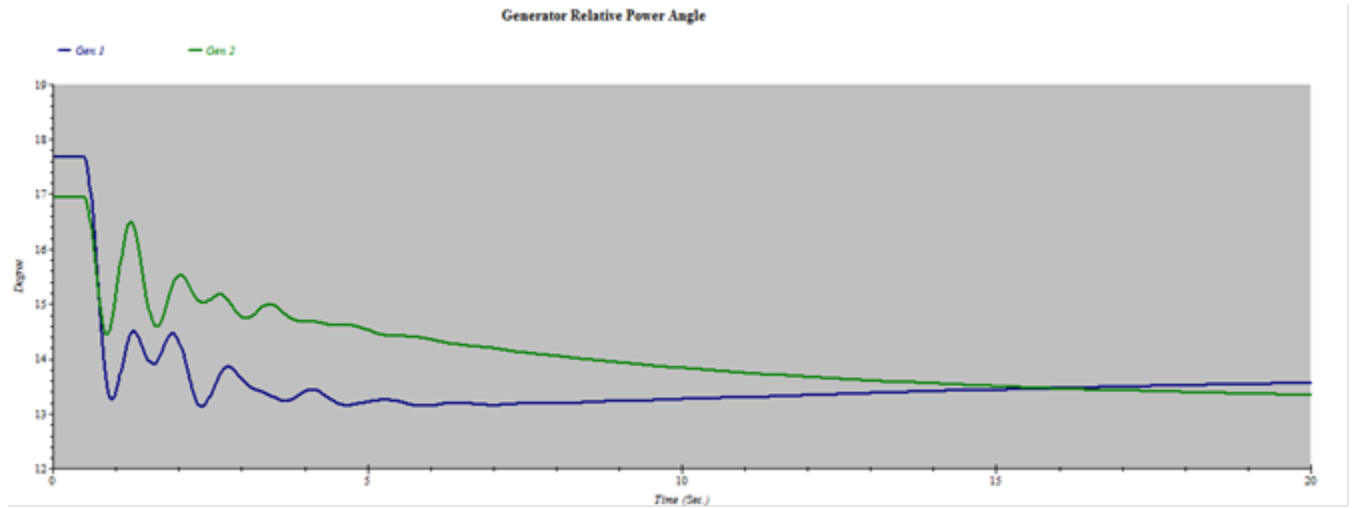

Figure 27: Generator absolute power angle

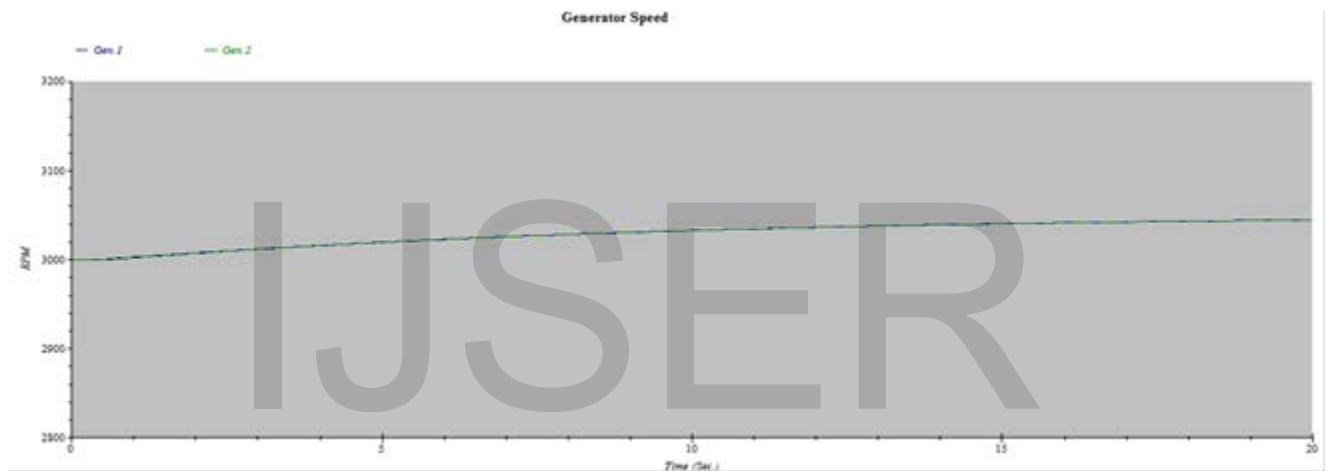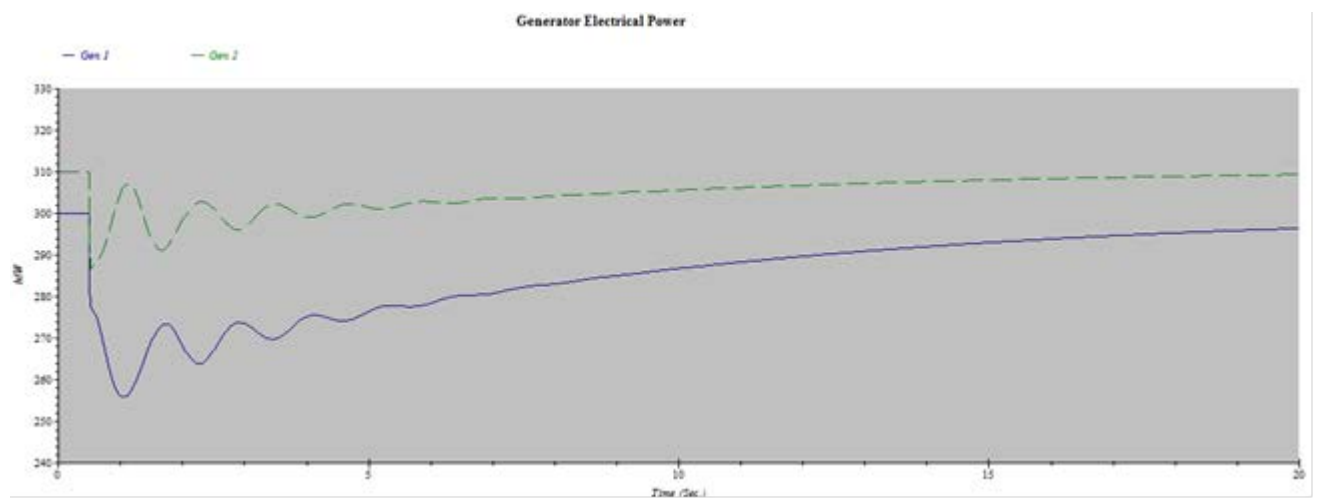Figure 28: Generator relative power angle

Figure 29: Generator speed

Figure 30: Generator electrical power

From the above waveforms it is clear that the system regains its stability after disturbance at time t=15 sec.

The normal generator current of generator 1 and generator 2 before disturbance is 10500 and 11000 ampere. When sudden load loss occurs, the generator currents also decrease after some transients as shown in figure 25.

At the time of sudden loss of load, the rotor angles of generators severely disturbed. The equilibrium is upset between electrical and mechanical torque because of which some machines temporarily run faster and some runs slower causing the power swing between generators as shown in figure 29. At time t=15 sec, after disturbance, the equilibrium is restored and the system regains its steady-state operation as shown in figure 26, 27.

Disturbances in a power system cause variation in generator RPM also. At time t=0.5 sec, the RPM of generators disturbed, the rotors of some of the generators accelerate and some decelerate. At time t=15 sec, the rotor steady down to its equilibrium position and the system achieves its steady-state operation. The system is said to be stable at time t=15 sec.

5. Conclusion

In this research paper, transient stability of generation and transmission system of a thermal power plant in district Mianwali, Pakistan has been studied. The parameters such as rate of change of system frequency, power angle, bus voltage levels, current levels of each generator and power swings are considered for analysis. The performance of the proposed system has been analyzed in ETAP software. The recovery time of the power system from transient (the critical clearing time) and effects caused by the faults has been studied from transient stability analysis. The system transient stability assessed with the aforementioned system information. This research work helps to find the ratings and specifications of protective equipment's for any type of transients. This research work is useful in future expansion planning, designing and up gradation of power system and gives an important data for system operators, planners and designers.

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