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Faults Analysis in Simulated Two Machine Power System

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Abstract:- With growing complexity of modern power system consists of generators, transformers, transmission and distribution lines etc. The probability of the failure or occurrence of abnormal condition is more on power lines. Short circuit and other abnormal conditions often occur on a power system. The heavy current associated with short circuit is likely to cause damage to equipment if suitable protective relays and circuit breakers are not provided for the protection of each section of the power system. The basic electrical quantities which are likely to change during abnormal conditions are current, voltage, phase-angle and frequency. In this report, at first, the power system stability and the causes of symmetrical and unsymmetrical fault has been discussed briefly and later on the three phase two machine power system model has been simulated to find out the critical clearing time graphically for all the types of fault. On comparisons of critical clearing time on the synchronous generator and asynchronous motor parameters with respect to all the faults and make conclusion about the severe fault, also find out the stabilize time of all mechanical and electrical parameters after fault is landing.

Keywords:- Asynchronous Machine, MATLAB, Protective Devices, Synshronous Machine, Three Phase Power.

I. INTRODUCTION

The power system networks are continuously expanding over wide geographical area with increased number of interconnection to meet the rapid growth in the demand of electricity. The transmission and distribution networks are main carriers of electrical power.

An electrical power system consists of generators, transformers, transmission and distribution lines etc. Short circuits and other abnormal conditions often occur on a power system. The heavy current associated with short circuits is likely to cause damage to equipment if suitable protective relays and circuit breakers are not provided for the protection of each section of the power system. Short circuits are usually called faults by power engineers. Basically, the failure of conducting path due to a break in a conductor is a type of fault.

If a fault occurs in an element of a power system, an automatic protective device is needed to isolate the faulty element as quickly as possible to keep the healthy section of the system in normal operation. The fault must be cleared within a fraction of a second. If a short circuit persists on a system for a longer, it may cause damage to some important sections of the system. A heavy short circuit current may cause a fire. It may spread in the system and damage a part of it. The system voltage may reduce to a low level and individual generators in a power station or groups of generators in different power stations may lose synchronism. Thus, an uncleared heavy short circuit may cause the total failure of the system.

A protective system includes circuit breakers, transducers and protective relays to isolate the faulty section of the power system from the healthy sections. The function of a protective relay is to detect and locate a fault and issue a command to the circuit breaker to disconnect the faulty element. It is a device which senses abnormal conditions on a power system by constantly monitoring electrical quantities of systems, which differ under normal and abnormal conditions. The basic electrical quantities which are likely to change during abnormal conditions are current, voltage, phase-angle (direction) and frequency. Protective relays utilize one or more of these quantities to detect abnormal conditions on a power system.

II. POWER SYSTEM STABILITY

Power system stability can be defined as "*the ability of an electric power system, operating at a given initial operating condition, to regain a state of operating equilibrium after being subjected to a disturbance, with most system variables bounded so that practically the entire system remains intact".*

If following a disturbance the power system remains stable, it may reach a new equilibrium state with the system integrity preserved. The power system stability can be broadly classified into three types.

- Rotor Angle Stability
- Frequency Stability
- Voltage Stability

Frequency and voltage stability can be further categorized into short term and long term stability. Voltage stability may be classified into large disturbance and small disturbance voltage stability.
This categorically comes under the short term and the long term stability respectively.

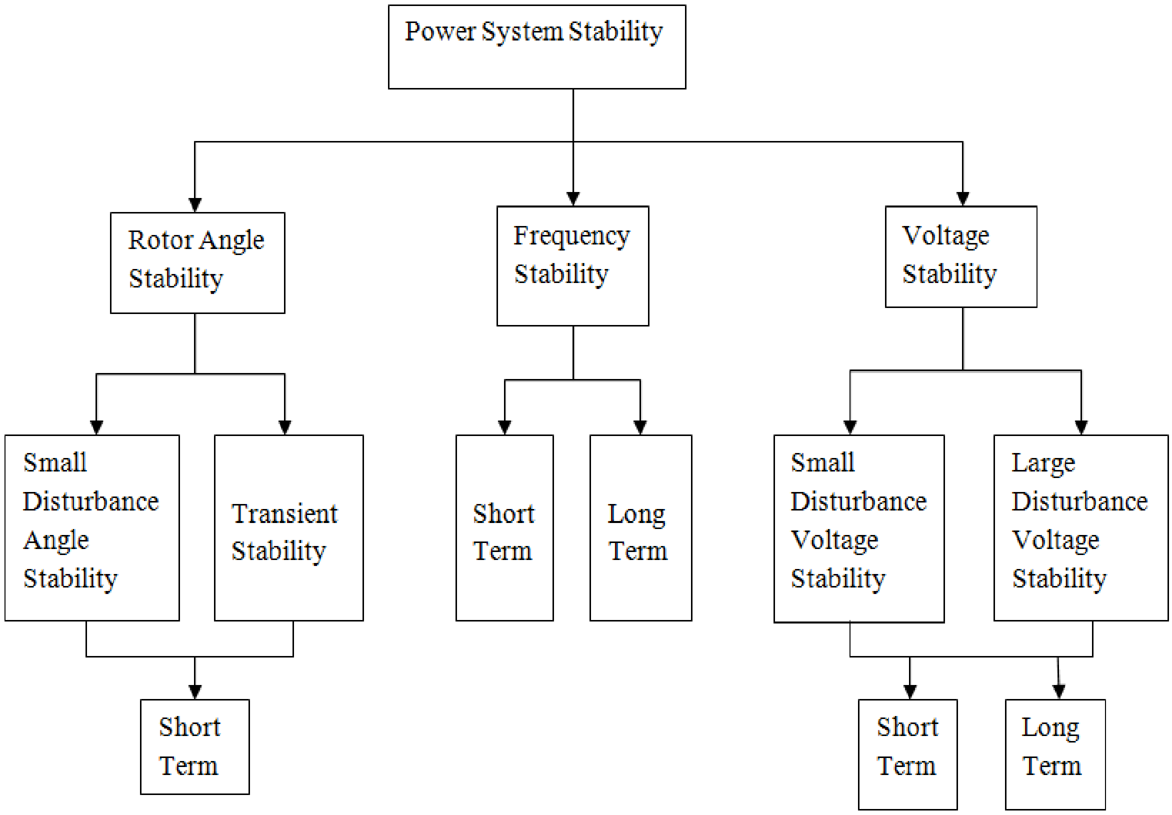


Fig.1 Classification of Power System Stability

III. POWER QUALITY PROBLEMS

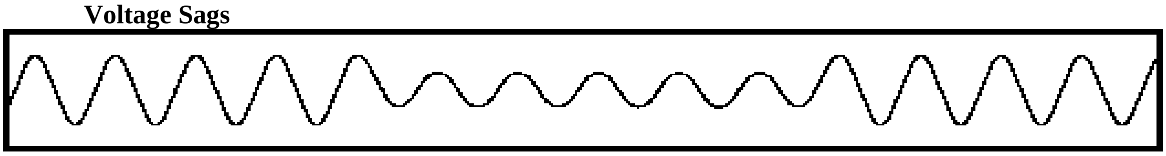
Transmission lines are often subjected to many kinds of faults, such as

- Single phase-to-earth
- Double phase-to-earth
- Phase to phase (two phase)
- Three phase with or without the earth

Some of the causes of these faults are storms, insulation breakdown with age, operating beyond its capacities, improper maintenance etc. The faults are generally detected and faulty sections are isolated by protective relays. However, to minimize the downtime and to improve the reliability. It is very important to identify the fault location as quickly as possible.

A power quality audit can help determine the causes of one's problems and provide a well-designed plan to correct them. The findings will be included in a report outlining problems found during the audit and recommend solutions. Many businesses and organizations rely on computer systems and other electrical equipment to carry out mission-critical functions, but they aren't safeguarding against the dangers of an unreliable power supply. The power quality problems are as follows.

i) Voltage Sags

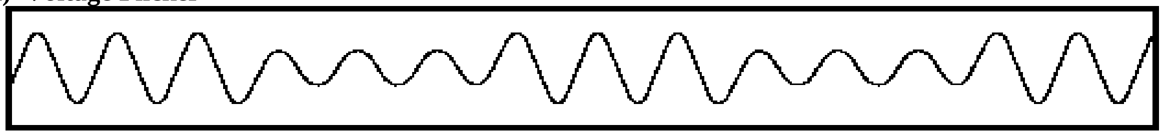


Voltage sags are the most common power problem encountered. Sags are a short-term reduction in voltage (that are 80-85% of normal voltage), and can cause interruptions to sensitive equipment such as adjustable-speed drives, relays, and robots. Sags are most often caused by fuse or breaker operation, motor starting, or capacitor switching. Voltage sags typically are non-repetitive, or repeat only a few times due to re-closer operation. Sags can occur on multiple phases or on a single phase and can be accompanied by voltage swells on other phases.

ii) Power Interruptions

Power interruptions are zero-voltage events that can be caused by weather, equipment malfunction, re-closer operations, or transmission outages. Interruptions can occur on one or more phases and are typically short duration events, the vast majority of power interruptions are less than 30 seconds.

iii) Voltage Flicker



Voltage flicker is rapidly occurring voltage sags caused by sudden and large increases in load current. It is most commonly caused by rapidly varying loads that require a large amount of reactive power such as welders, rock-crushers, sawmills, wood chippers, metal shredders, and amusement rides. It can cause visible flicker in lights and cause other processes to shut down or malfunction.

iv) Power Surges

A power surge takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off. Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss.

v) High-Voltage Spikes

High-voltage spikes occur when there is a sudden voltage peak of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on electronic systems can include loss of data and burned circuit boards.

vi) Switching Transients

Switching transients take place when there is an extremely rapid voltage peak of up to 20,000 volts with duration of 10 microseconds to 100 microseconds. Switching transients take place in such a short duration that they often do not show up on normal electrical test equipment. They are commonly caused by machinery starting and stopping, arcing faults and static discharge. In addition, switching disturbances initiated by utilities to correct line problems may happen several times a day. Effects can include data errors, memory loss and component stress that can lead to breakdown.

vii) Frequency Variation

A frequency variation involves a change in frequency from the normally stable utility frequency of 50Hz.This may be caused by erratic operation of emergency generators or unstable frequency power sources. For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shutdown.

viii) Electrical Line Noise

Electrical line noise is defined as Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) and causes unwanted effects in the circuits of computer systems. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms. RFI, EMI and other frequency problems can cause equipment to lock-up, and data error or loss.

ix) Brownouts

A brownout is a steady lower voltage state. An example of a brownout is what happens during peak electrical demand in the summer, when utilities can't always meet the requirements and must lower the voltage to limit maximum power. When this happens, systems can experience glitches, data loss and equipment failure.

x) Blackouts

A power failure or blackout is a zero-voltage condition that lasts for more than two cycles. It may be caused by tripping a circuit breaker, power distribution failure or utility power failure. A blackout can cause data loss or corruption and equipment damage.

IV. CAUSES AND EFFECTS OF POWER QUALITY PROBLEMS

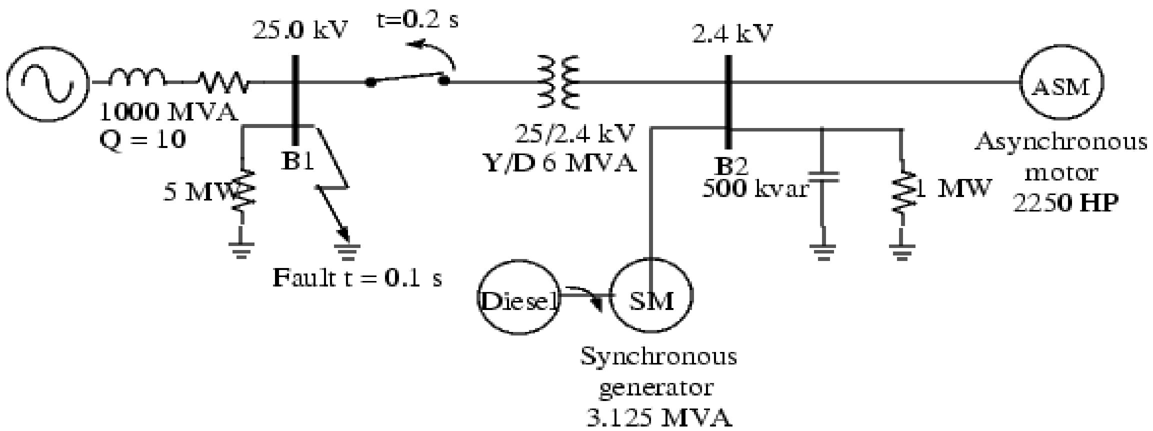
POWER PROBLEMS	CAUSES	EFFECTS
Voltage Spikes and Surges	**Lightning, Utility grid switching, Heavy industrial equipment**	**Equipment failure, System lock-up, Data corruption, Data loss**
Electrical Noise	**Arc Welders etc..., Switch mode power supplies, Fault clearing devices, Ground not dedicated or isolated**	**Data corruption, Erroneous command functions, Loss of command functions, Improper wave shapes etc...**
Harmonics	**Switch mode power supplies, Nonlinear loads**	**High neutral currents, Overheated neutral conductors, Overheated transformers, Voltage distortion, Loss of system capacity**
Voltage Fluctuations	**Brownouts, Unstable generators, Overburdened distribution systems, Start-up of heavy equipment**	**System lock-up, System shutdown, Data corruption, Data Loss, Reduced performance, Loss of system control**
Power Outage & Interruptions	**Blackouts, Faulted or overload, conditions, Back-up generator start-up**	**System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control**
Stable AC from DC source	**DC power plant available, Remote areas**	**Unavailable AC power**
Emergency power source transfer, Peak shave power	**Back-up generator start-up, Power interruption transfer of utility source**	**System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control**
Distribution Systems and Power quality questions	**Lack of understanding of system problems or coordination**	**Unstable distribution system, Lost productivity and profitability.**
High energy cost / Power factor correction	**Need for energy savings and pay back for equipment investment.**	**Lost profits increased cost.**

V. TWO MACHINE POWER SYSTEM

A two machine power system is simulated using MATLAB- SIMULINK to find the critical clearing time for the different types of fault then using information from their suitable waveform, it is observed that which one are most severe fault and the effects of fault on machine's parameters.

1. Power System Study

The two-machine power system under study is shown in this single line diagram.



This system consists of a plant (bus B2), simulated by a 1 MW resistive load and a motor load (ASM) fed at 2400 V from a distribution 25 kV network through a 6 MVA, 25/2.4 kV transformer, and from an emergency synchronous generator/diesel engine unit (SM). The 25 kV network is modeled by a simple R-L equivalent source (short-circuit level 1000 MVA, quality factor X/R = 10) and a 5 MW load. The asynchronous motor is rated 2250 HP, 2.4 kV, and the synchronous machine is rated 3.125 MVA, 2.4 kV. Initially, the motor develops a mechanical power of 2000 HP and the diesel generator is in standby, delivering no active power. The synchronous machine therefore operates as a synchronous condenser generating only the reactive power required to regulate the 2400 V bus B2 voltage at 1.0 p.u. At t = 0.1 sec., A fault occurs on the 25 kV system, causing the opening of the 25 kV circuit breaker at t = 0.2 s, and a sudden increase of the generator loading. During the transient period following the fault and islanding of the motor-generator system, the synchronous machine excitation system and the diesel speed governor react to maintain the voltage and speed at a constant value.

1.2 MATLAB-SIMULINK Diagram

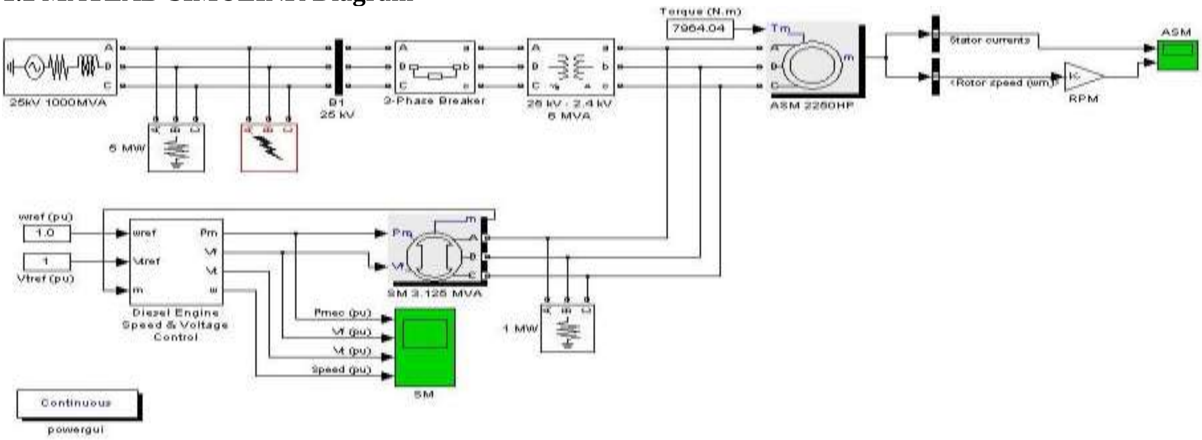


Fig.2 MATLAB SIMULINK model of two machine power system

2. Load Flow and Machine Initialization

In order to start the simulation in steady state with sinusoidal currents and constant speeds, all the machine states must be initialized properly.

2.1 Load flow with the following parameters:

SM (Synchronous Generator)

- Terminal Voltage ─ 2400 V_{rms}
- Active Power ─ 500 kW

ASM (Asynchronous Motor)

- Mechanical Power ─ 2000*746 W (Rating of 2000 HP where 1 HP equals to 746 W)

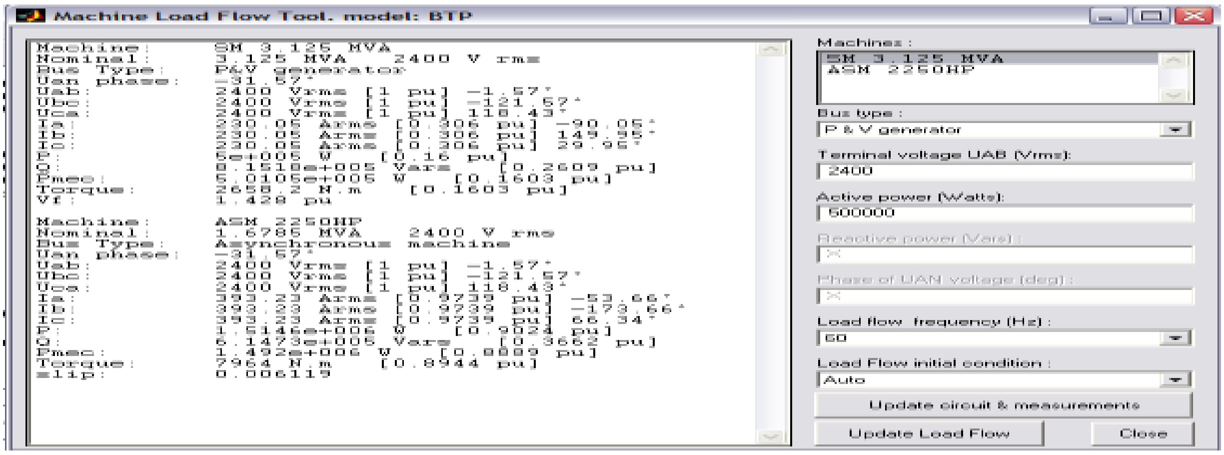


Fig.3 Machine Load Flow Tool Model

From here we get value of torque 7964 N-m and entered in the constant block connected at the ASM torque input.

2.2 Machine Initialization

To start the simulation in steady state, the states of the Governor & Diesel Engine and the Excitation blocks are initialized according to the values calculated by the load flow. In the Governor & Diesel Engine subsystem, the initial mechanical power has been set to 0.0002701 p.u. In Excitation block the initial terminal voltage and field voltage have been set respectively to 1.0 and 1.427 p.u.

3. Simulated Graph

The following graph of simulated two machine power system for synchronous generator and asynchronous motor in terms of mechanical parameters and electrical parameters with respect to time in different cases of faults.

The initial parameters are considered as follows.

- Circuit Breaker operation time = 0.2 sec.
- Fault time = 0.1 sec.

Steady state simulation initial conditions from Load Flow (Powergui)

3.1 Three Phase Fault (LLL- fault)

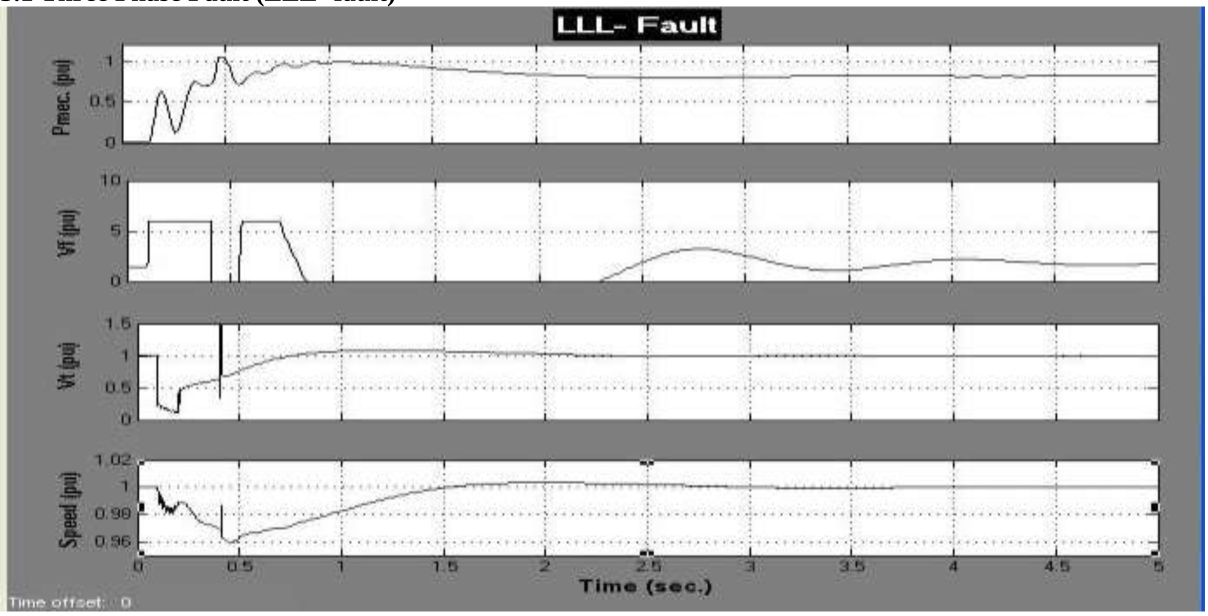


Fig.4 Graph of Synchronous Generator's parameters in three phase fault

Observation:

During the fault, the terminal voltage drops to about 0.2 p.u. with more fluctuation at 0.4 sec., and the excitation voltage hits the limit of 6 p.u. After fault clearing and is landing, the SM mechanical power quickly increases from its initial value of 0 p.u. to 1 p.u. and stabilizes at the final value of 0.82 p.u. required by the resistive and motor load (1.0 MW resistive load + 1.51 MW motor load = 2.51 MW = 2.51/3.125 = 0.80 p.u.). After 3 seconds the terminal voltage stabilizes close to its reference value of 1.0 p.u.

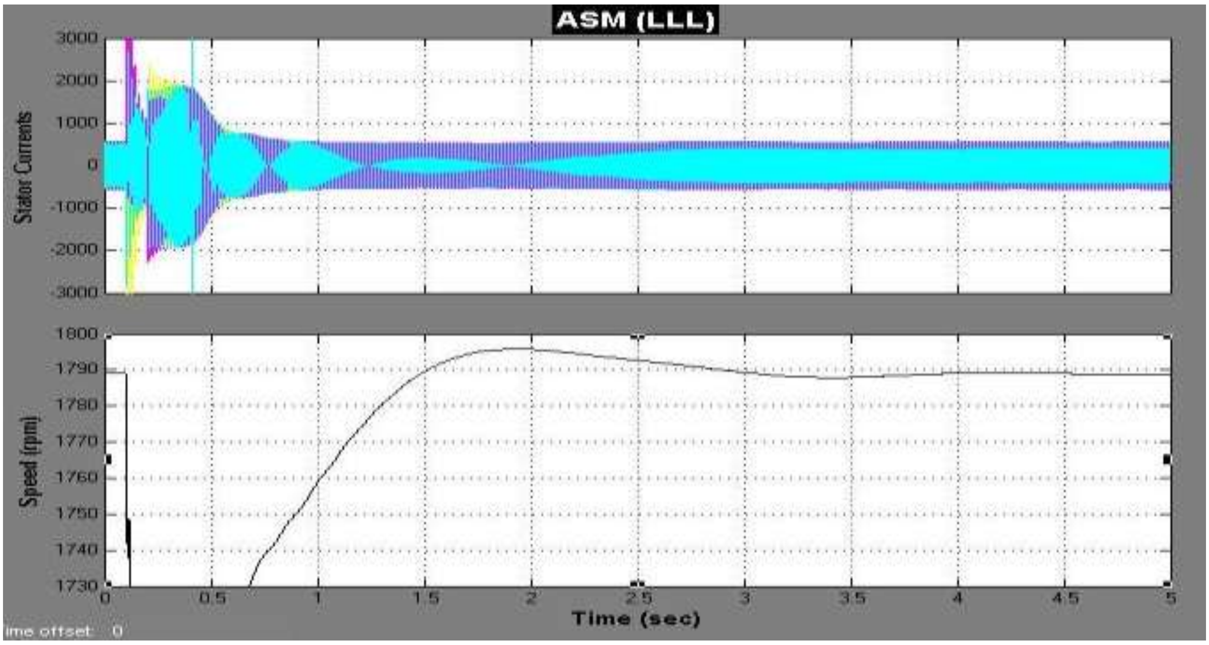


Fig.5 Graph of Asynchronous Motor's parameters in three phase fault

Observation:

The motor speed temporarily decreases from 1789 rpm to more down of 1730 rpm, and then recovers close to its normal value after 3 seconds. The stator currents fluctuate drastically on fault occurs at 0.1 sec. and maintains its normal condition after 2 sec.

3.2 Three Phase to Ground Fault (LLL- G fault)

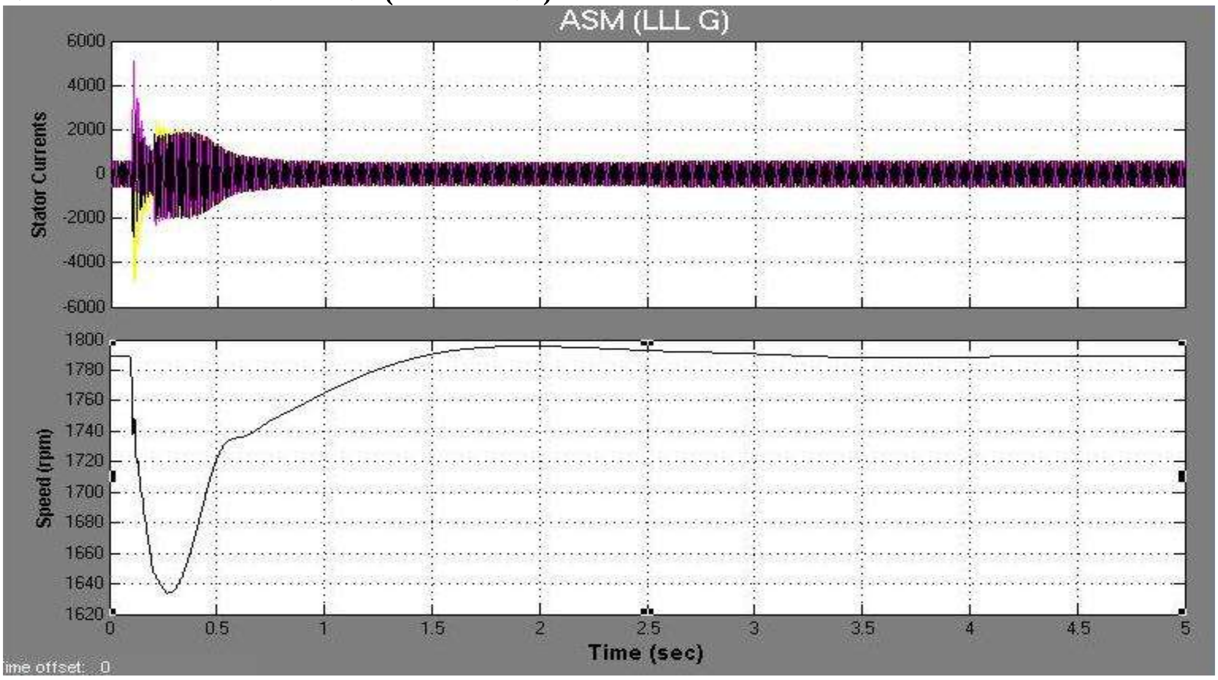


Fig.6 Graph of Asynchronous Motor's parameters in three phase to ground fault

Observation:

The motor speed temporarily decreases from 1790 rpm to 1630 rpm, and then recovers close to its normal value after 3 seconds. The stator currents fluctuate drastically on fault occurs at 0.1 sec. and maintains its normal condition after 1 sec.

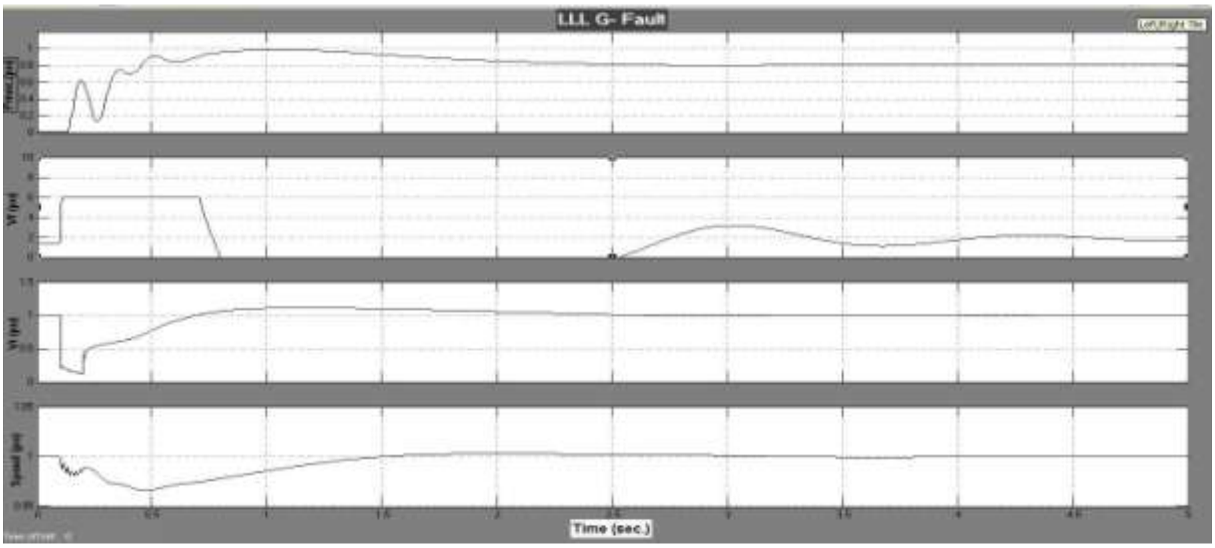


Fig.7 Graph of Synchronous Generator's parameters in three phase to ground fault

Observation:

During the fault, the terminal voltage drops to about 0.2 p.u. with less fluctuation, and the excitation voltage hits the limit of 6 p.u. After fault clearing and is landing, the SM mechanical power quickly increases from its initial value of 0 p.u. to 1 p.u. and stabilizes at the final value of 0.82 p.u. required by the resistive and motor load (1.0 MW resistive load + 1.51 MW motor load = 2.51 MW = 2.51/3.125 = 0.80 p.u.). After 3 seconds the terminal voltage stabilizes close to its reference value of 1.0 p.u.

3.3 Phase – Phase to Ground Fault (LL-G fault)

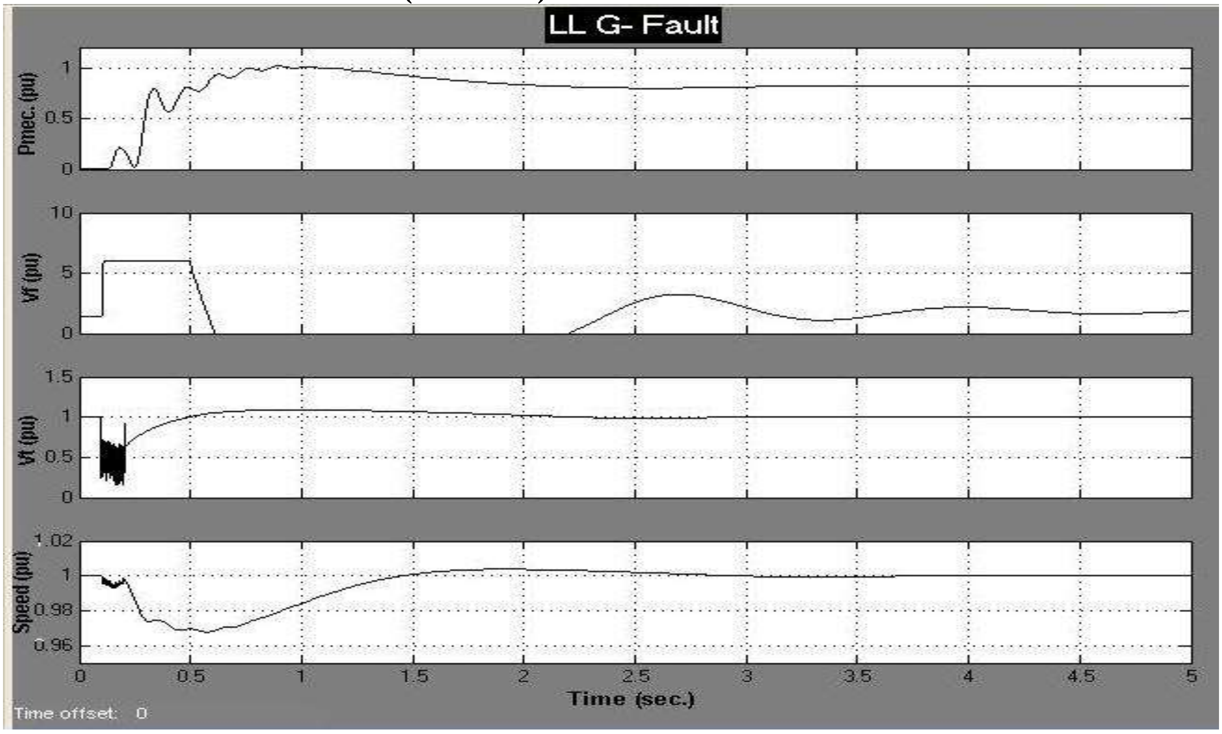


Fig.8 Graph of Synchronous Generator's parameters in phase−phase to ground fault

Observation:
During the fault, the terminal voltage drops to about 0.2 p.u. with more fluctuation for short duration, and the excitation voltage hits the limit of 6 p.u. After fault clearing and is landing, the SM mechanical power quickly increases from its initial value of 0 p.u. to 1 p.u. and stabilizes at the final value of 0.82 p.u. required by the resistive and motor load (1.0 MW resistive load + 1.51 MW motor load = 2.51 MW = 2.51/3.125 = 0.80 p.u.). After 3 seconds the terminal voltage stabilizes close to its reference value of 1.0 p.u.

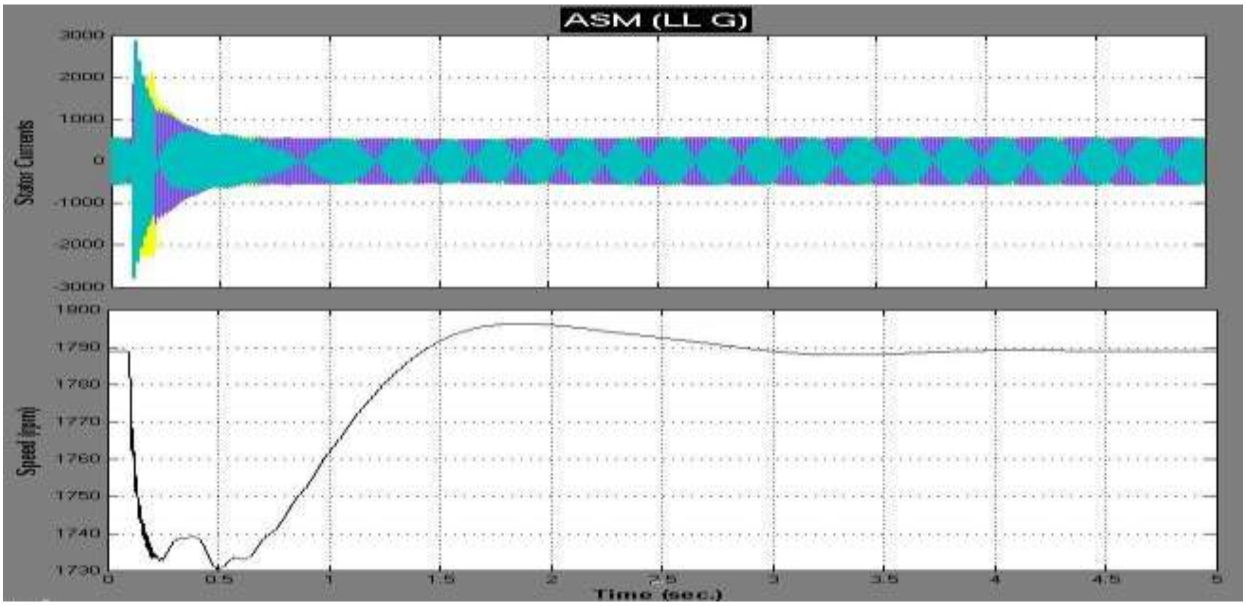


Fig.9 Graph of Asynchronous Motor's parameters in phase−phase to ground fault

Observation:
The motor speed temporarily decreases from 1790 rpm to 1735 rpm with fluctuation up to 0.5sec, and then recovers close to its normal value after 3 seconds. The stator currents fluctuate drastically on fault occurs at 0.1 sec. and maintains its normal condition after 1 sec.

3.4 Phase to Ground Fault (LG fault)

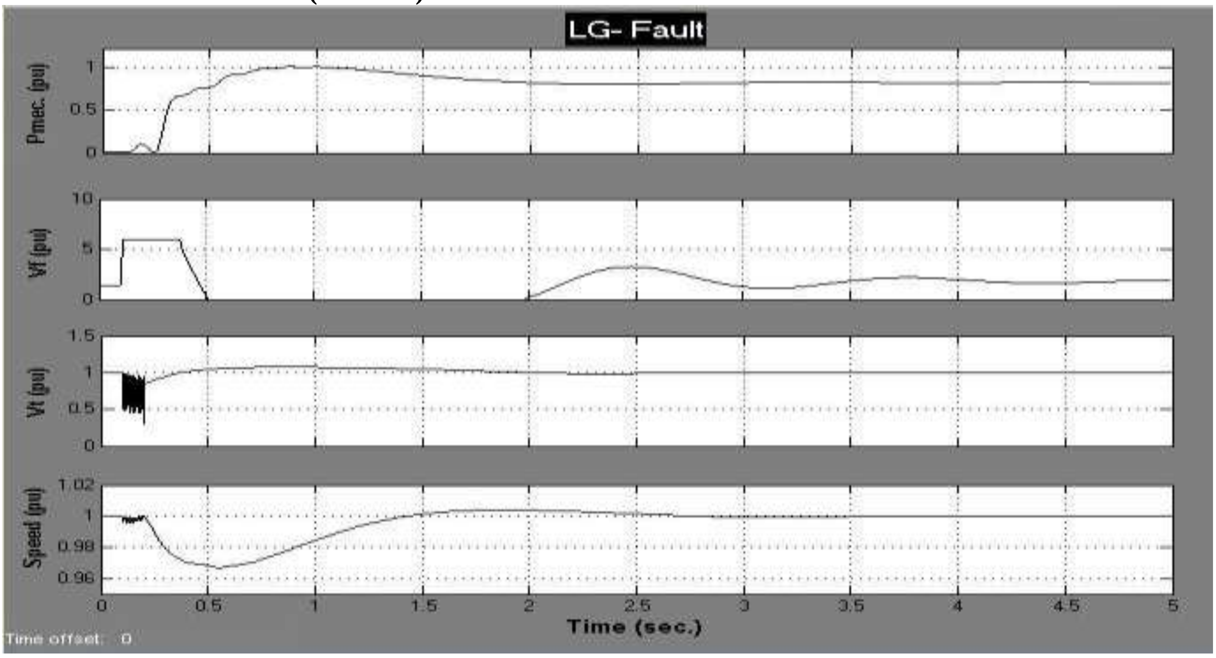


Fig.10 Graph of Synchronous Generator's parameters in phase to ground fault

Observation:

During the fault, the terminal voltage drops to about 0.5 p.u. with more fluctuation for short interval of time, and the excitation voltage hits the limit of 6 p.u. After fault clearing and is landing, the SM mechanical power quickly increases from its initial value of 0 p.u. to 1 p.u. and stabilizes at the final value of 0.82 p.u. required by the resistive and motor load (1.0 MW resistive load + 1.51 MW motor load = 2.51 MW = 2.51/3.125 = 0.80 p.u.). After 3 seconds the terminal voltage stabilizes close to its reference value of 1.0 p.u.

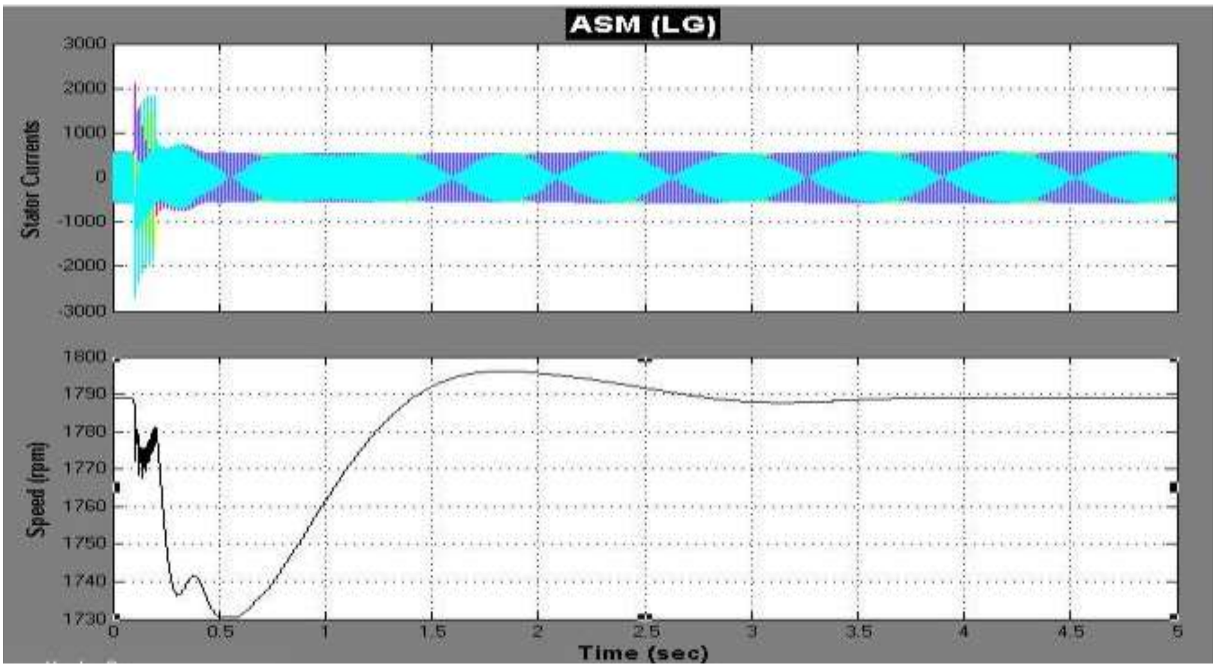


Fig.11 Graph of Asynchronous Motor's parameters in phase to ground fault

Observation:

The motor speed temporarily decreases from 1790 rpm to 1770 rpm with some fluctuation for short duration then again decreases to 1730 up to 0.5 sec., and then recovers close to its normal value after 3 seconds. The stator currents fluctuate drastically on fault occurs at 0.1 sec. and maintains its normal condition after 1 sec.

VI. CONCLUSION

In case of synchronous generator, on occurring the fault, the terminal voltage drops to some extent of duration with more fluctuation in case of thee phase fault as comparison of all unsymmetrical fault and stabilizes close to its reference value of 1.0 p.u. Whereas the excitation voltage hits the some certain value, which is same for all the faults. After the fault clearing and is landing, the mechanical power quickly increases from its value of 0 p.u. to 1 p.u. and stabilizes at the final value of 0.82 p.u. required by the resistive and motor load.

In case of asynchronous motor, the motor speed temporarily decreases from 1790 rpm to more down in case of three phase fault as comparison of all the fault, but in phase to ground fault the little bit fluctuation is occurred towards down for short duration , and then recovers close to its normal value after 3 seconds. The stator currents fluctuate drastically on fault occurs at 0.1 sec. and maintains its normal condition after 1 sec.

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