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Transient Stability Analysis of Gas Turbine Power Plant

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***Abstract* — This paper presents the transient stability analysis of electrical power system of gas based open cycle power plant. This power plant has two generators, each having capacity of 297.5 MW. The purpose of the transient stability analysis is to study and examine the ability of the proposed power plant to maintain synchronism with grid when subjected to the various disturbances.**
The main objectives of this analysis is to analyze the suitability of the turbine control as well as excitation control system to obtain desirable performance of the generating sets during sudden loss of load/islanding condition. This analysis will help to determine critical fault clearing time for the different fault locations under the plant maximum loading condition. This critical fault clearing can be used to determine the relay setting and coordination to prevent false tripping. This paper analyses, the behavior of the generators under a severe internal and external fault conditions. The results are tabulated at the end.

Keywords -Transient stability; Industrial plant; Critical clearing time; Acceptance Criteria

I. INTRODUCTION

The power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance. It can be classified into the steady state, transient and dynamic stability. The critical clearing time is defined as maximum time between the initiation of fault and last pole current clearing of the fault leads to stable condition in the network [1].

The fig 1. shows the block diagram of power plant. In this plant, generation of electrical power is at 20 kV, transmission is at 400 kV and auxiliary is at 11/0.415 kV. The auxiliary load list is taken as preliminary data. There are two 297.5 MW generators connected to 20 kV bus which is supplying power to 400 kV grid. Generators are also supplying power to plant auxiliary through 11 kV buses. Fig 2. Shows single line diagram of power plant. The transient stability analysis using the ETAP software is performed for given power plant.

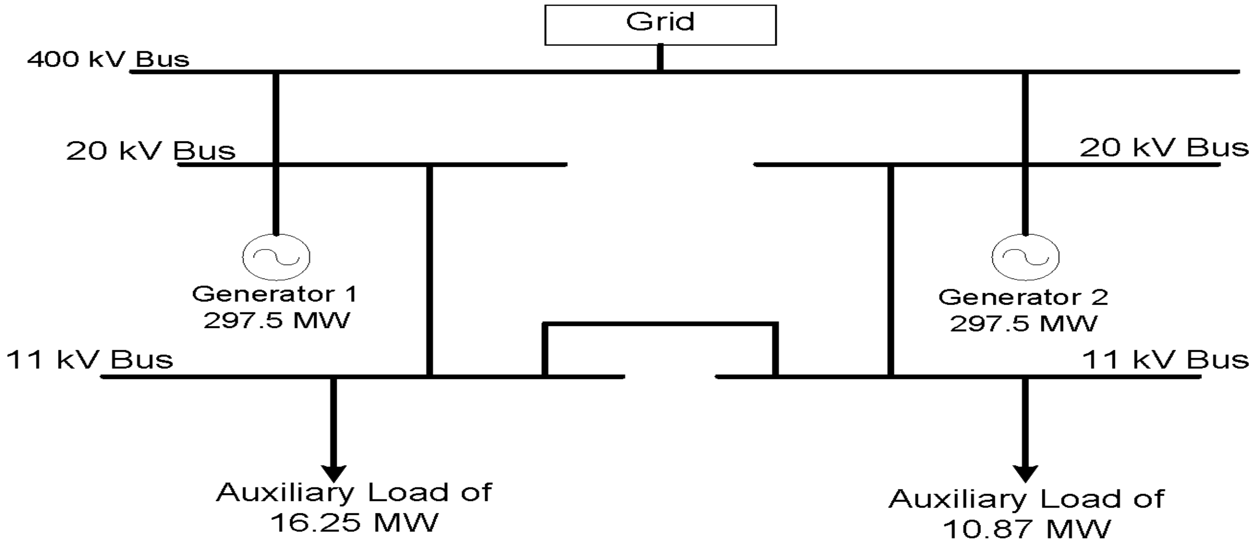

Fig. 1: Block Diagram of Power Plant

II. METHODOLOGY

The behavior of generators of power plant during three phase fault on different locations is simulated in ETAP. The governor, exciter, and PSS suitability for desirable performance of generating sets have been analyzed and critical clearing time for different fault location have been determined.

III. ASSUMPTIONS

- Short circuit MVA of grid is considered as 41292 MVA, based on 63 kA short circuit rating of 400 kV switchyard bus.
- To analyse the worst scenario, a positive tolerance of 15 % on the generator reactance is considered.
- To analyse the worst scenario, unsaturated values of generator reactances are considered.
- To analyse the worst scenario, a positive tolerance on the transformer impedance is considered [2].
- ST1, GT and PSS1A IEEE models are taken for Exciter, Governor, and PSS respectively [3].
- The extent of modelling the individual loads on LV system is restricted to 75 kW motors. All other smaller rated LV loads are modelled as lumped loads. Such lump loads are the combination of the dynamic and static types of the loads.

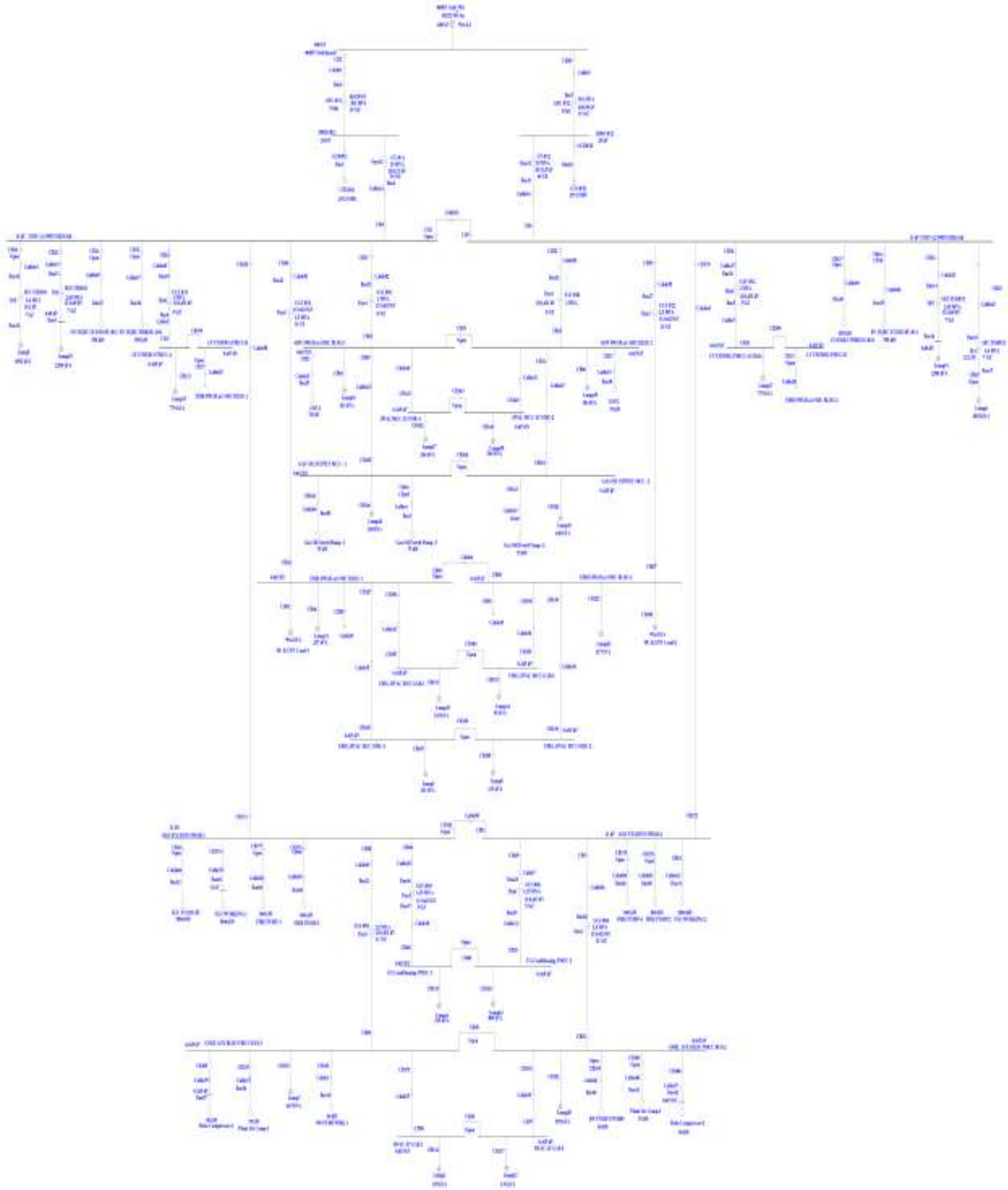

Fig. 2: Single line diagram of the plant.

IV. CASE SCENARIO

To analyse the transient stability analysis following cases are considered.

A. **Determination of critical fault clearing time for 400 kV System faults**

This scenario is simulated to study the behaviour of the generator under a severe external fault condition on the 400 kV systems. To simulate this, a 3 phase fault is created on the 400 kV utility grid bus.

To identify the time limits of stability under such transient condition, various iterations with regards to clearing time of fault are simulated in software to identify the threshold time by which system loses one pole slip (180 degree).

B. **Determination of critical fault clearing time for 20 kV Isolated Phase Bus Duct (IPBD) faults**

This scenario is simulated to study the behaviour of the generator under a severe internal fault condition in the 20 kV Isolated phase bus. To simulate this, a 3 phase fault is created on the 20 kV Isolated phase bus duct (generator bus).

C. Generator behaviour during delayed clearing of 11 kV faults

This scenario is simulated to study the behaviour of the generator under a severe internal fault condition in the 11 kV auxiliary systems. To simulate this, a 3 phase fault is created on the 11 kV bus.

D. **Islanding operation**

This case scenario is simulated to analyse the suitability of the turbine control as well as excitation control system to obtain desirable performance of the generating sets during sudden loss of load/islanding condition.

V. ACCEPTANCE CRITERIA

A. Power Angle for critical clearing time

The critical fault clearing time is identified based on the transient stability limit of the parallel operating generators. The system synchronism is dependent on the relative power angles among the various machines operating in parallel, which in turn is dependent on the fault clearing time. Simulation curves (response curves) showing relative machine power angles are presented to study the dynamics and arrive at a conclusion of the study for each of the cases. A relative power angle variation of 180 degrees or more between generating units due to a transient event has been considered as the criteria for loss of synchronism [4].

B. ***Frequency (Rotor Speed)***

Frequency (rotor speed) monitoring is the widely accepted method to identify the proposed plant stability under various disturbances. A number of cases are simulated to examine the frequency profile of the system.

Acceptable Frequency Variations on 400 kV and 20 kV : ± 5%

If turbine speed exceeds 111% of rated speed, electrical over speed trip will be actuated by turbine protection system.

C. **Voltage Variations**

Acceptable voltage variations for transient condition: ± 10%

VI. RESULTS

A. **Determination of critical fault clearing time for 400 kV System faults**

This scenario is configured to identify the critical fault clearing time for a fault on 400 kV switchyard bus. The results of this case study can be utilized to design and set the 400 kV system protective relays/settings accordingly. Critical fault clearing time from the response curves for 400 kV power plant bus fault is 140 ms. The above critical clearing time of 140 ms is also well supported by the frequency and voltage profile plots. The simulation results for 400 kV System faults at 2 sec for 160 ms and 140 ms is shown in fig.3 to 6.

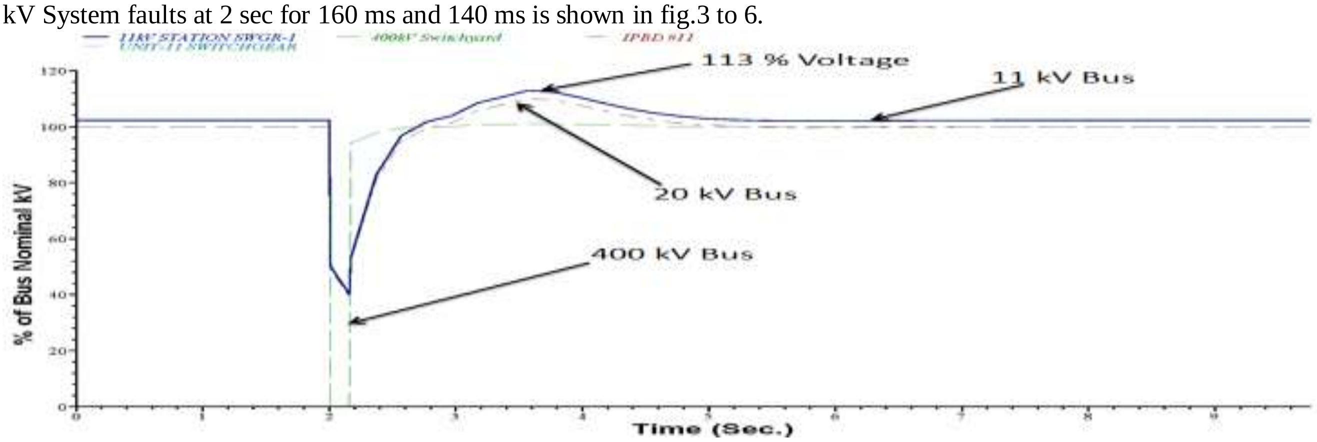

Fig. 3: Bus Voltage at 160 ms of CCT (For 400 kV Fault)

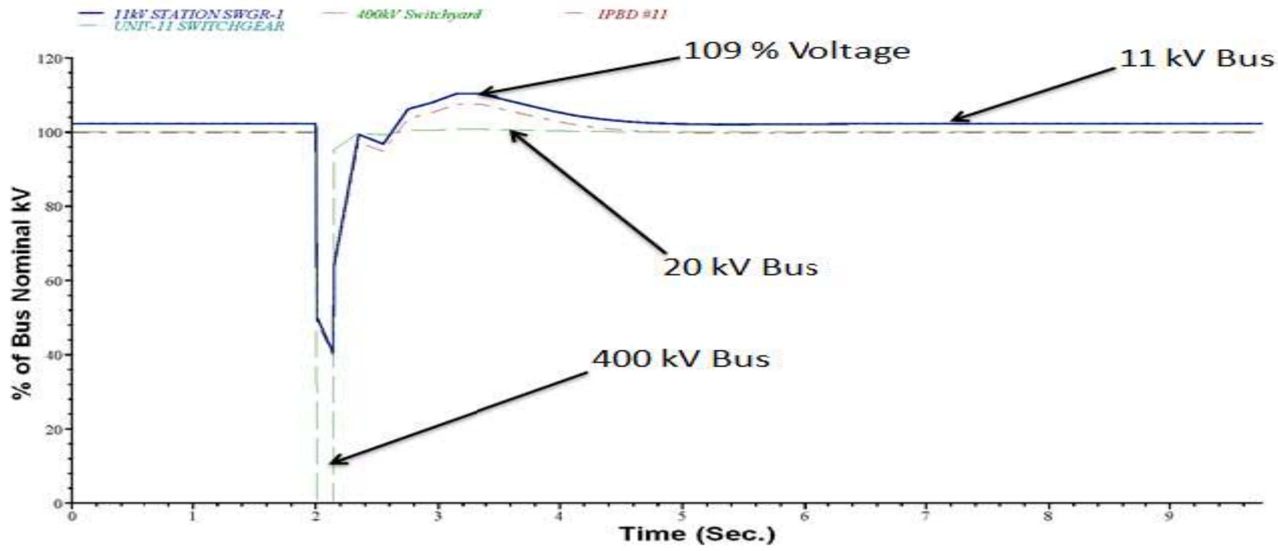

Fig. 4: Bus Voltage at 140 ms of CCT (For 400 kV Fault)

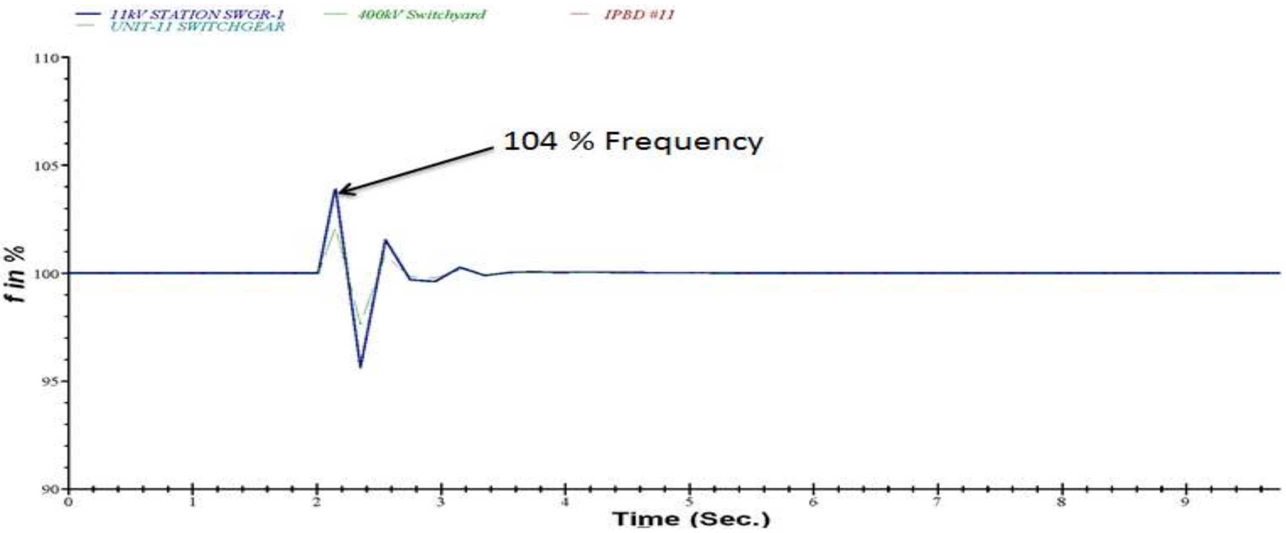

Fig. 5: Bus Frequency at 140 ms of CCT (For 400 kV Fault)

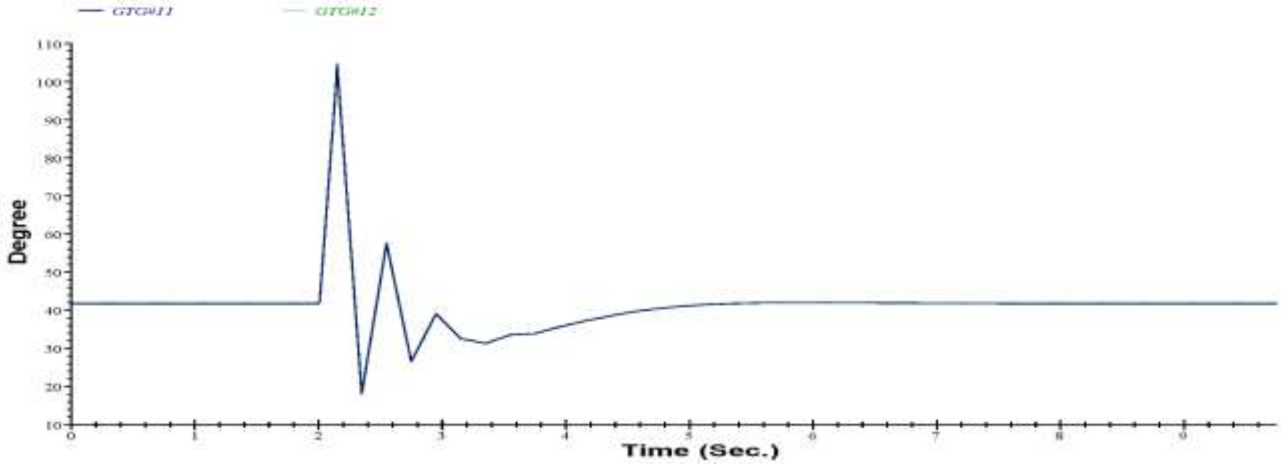

Fig. 6: Relative Power Angle at 140 ms of CCT (For 400 kV Fault)

B. Determination of critical fault clearing time for 20 kV IPBD faults

This scenario is configured to identify the critical fault clearing time for a fault on 20 kV Isolated Phase bus. The results of this case study can be utilized to design and set the 20 kV system protective relays/settings accordingly. Critical fault clearing time from the response curves for 20 kV power plant bus fault is 140 ms. The above critical clearing time of 140 ms is also well supported by the frequency and voltage profile plots. For 160 ms voltage and frequency limits are violated. The simulation results for 20 kV System faults at 2 sec for 140 ms is shown in fig.7 to 11.

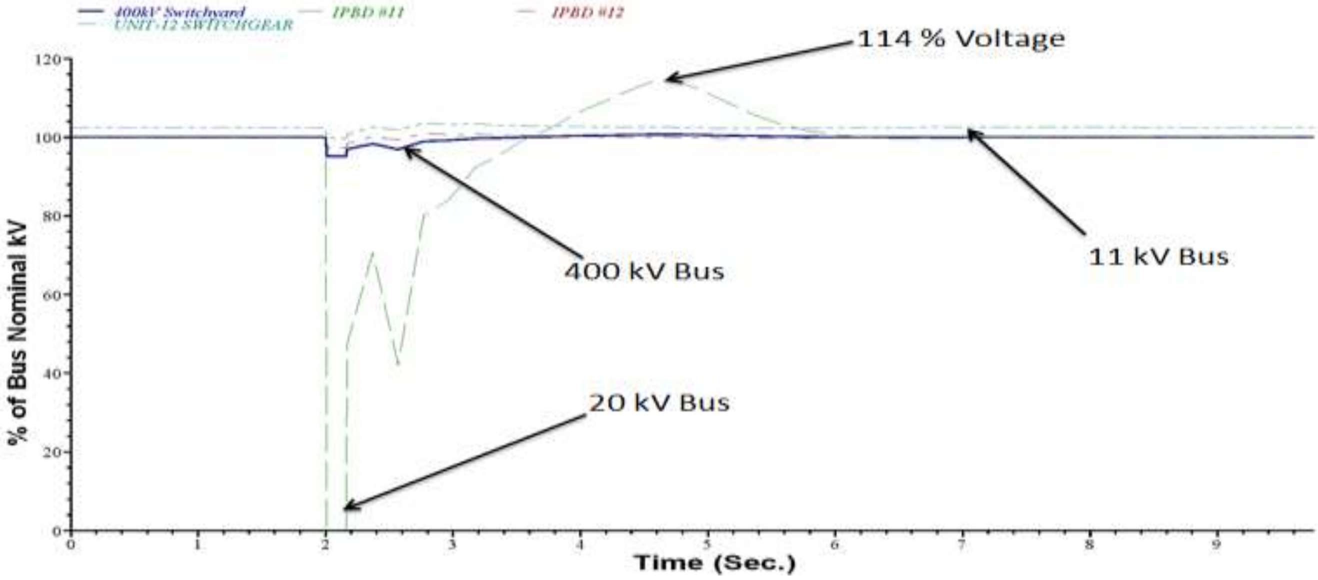

Fig. 7: Bus Voltage at 160 ms of CCT (For 20 kV Fault)

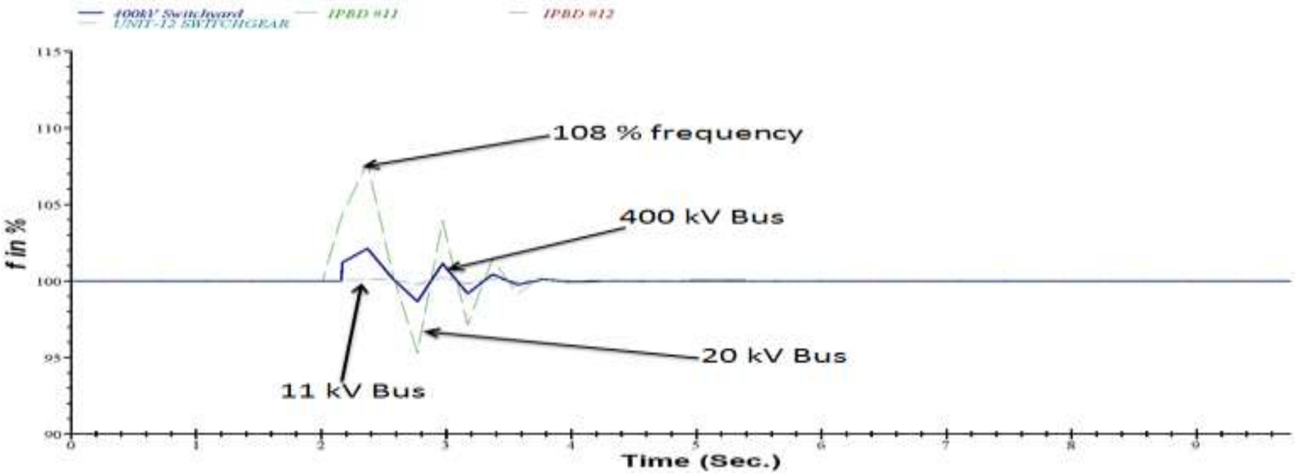

Fig. 8: Bus Frequency at 160 ms of CCT (For 20 kV Fault)

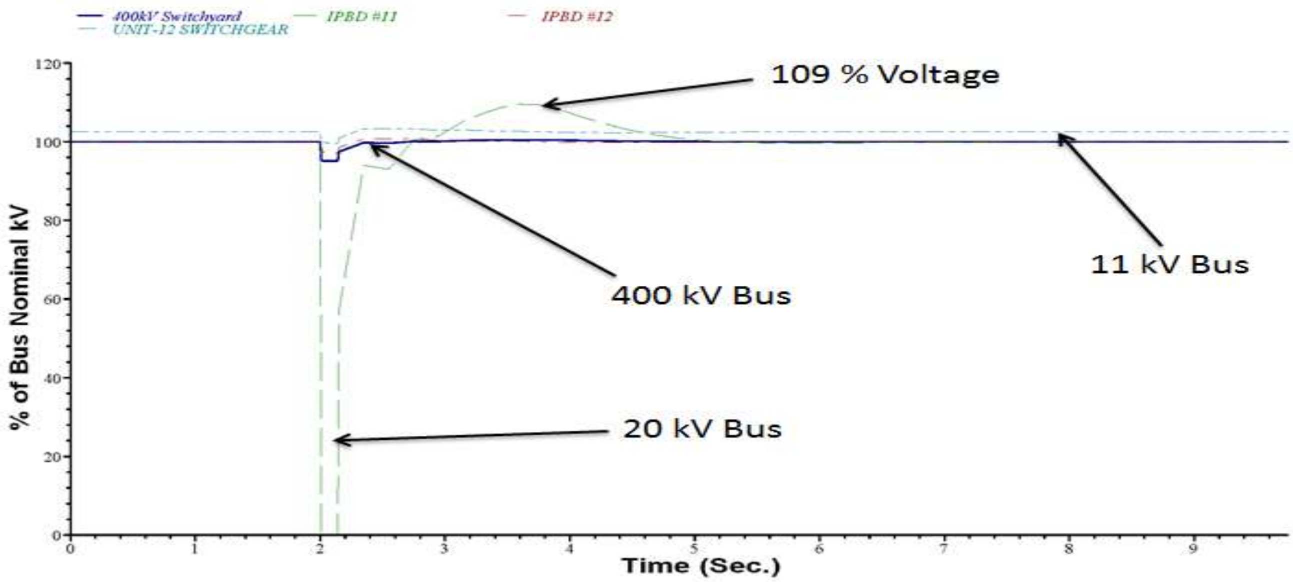

Fig. 9: Bus Voltage at 140 ms of CCT (For 20 kV Fault)

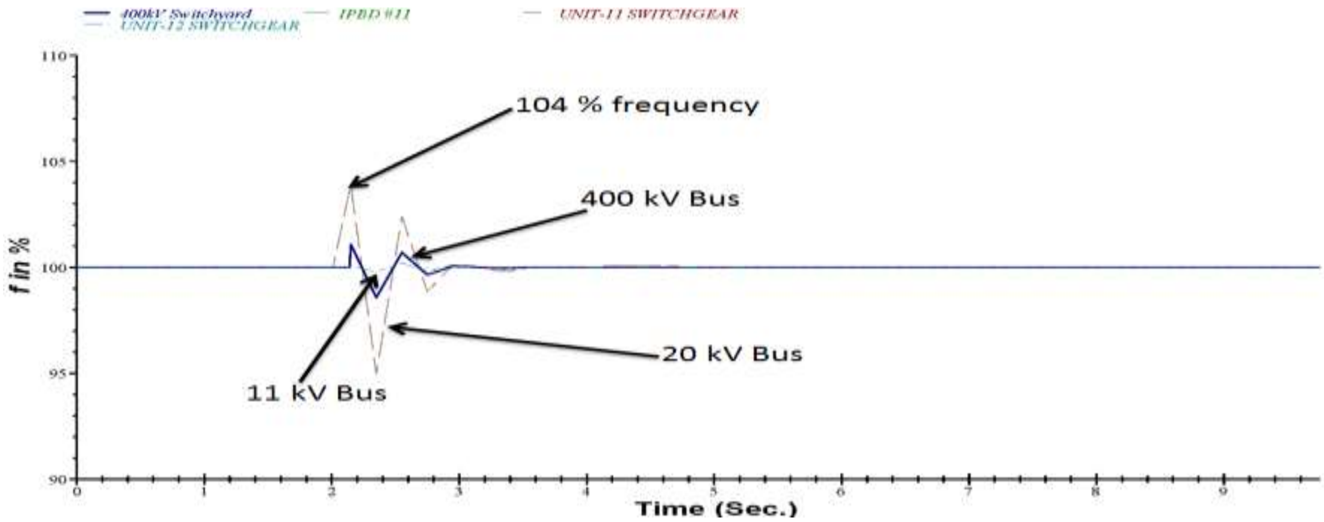

Fig. 10: Bus Frequency at 140 ms of CCT (For 20 kV Fault)

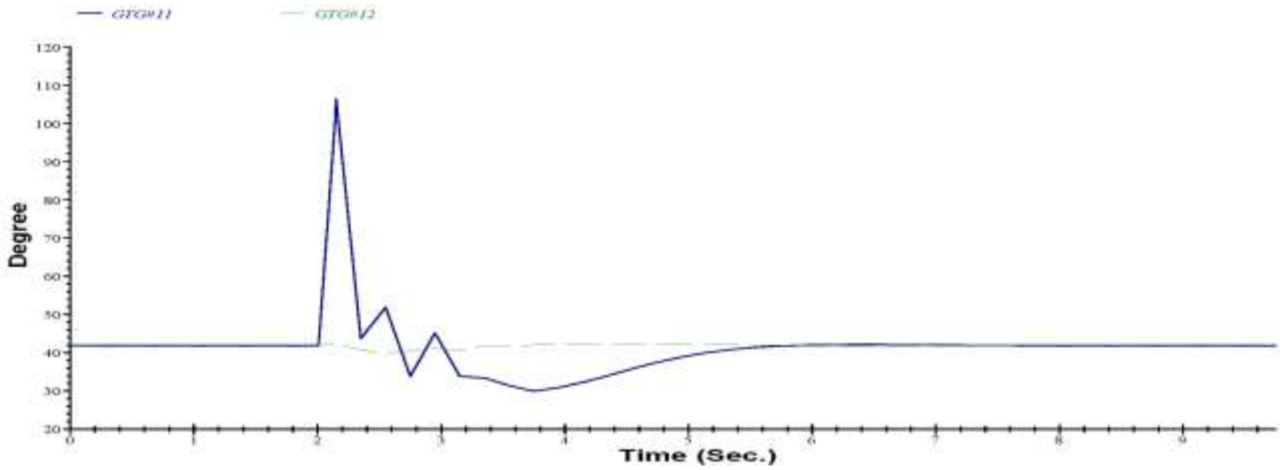

Fig. 11: Relative Power Angle at 140 ms of CCT (For 20 kV Fault)

C. Generator behaviour during delayed clearing

This scenario is configured to identify the response of generator sources under delayed clearance of fault at 11 kV Unit Switchgear–1. The fault current magnitude of such 11 kV fault is not as severe as fault on 400 kV system, however to simulate the worst condition, the delayed clearance of such 11 kV faults is simulated. From the study results, it is observed that even the delayed clearance of faults with a typical time delay of 1 sec does not affect the stable operation of the generating sets. Furthermore, fault on 11 kV Unit Switchgear-1 does not affect the stability of bus voltage of 11 kV Unit Switchgear-2. The simulation results for 11 kV System faults at 2 sec for 1000 ms is shown in fig.12 to 14.

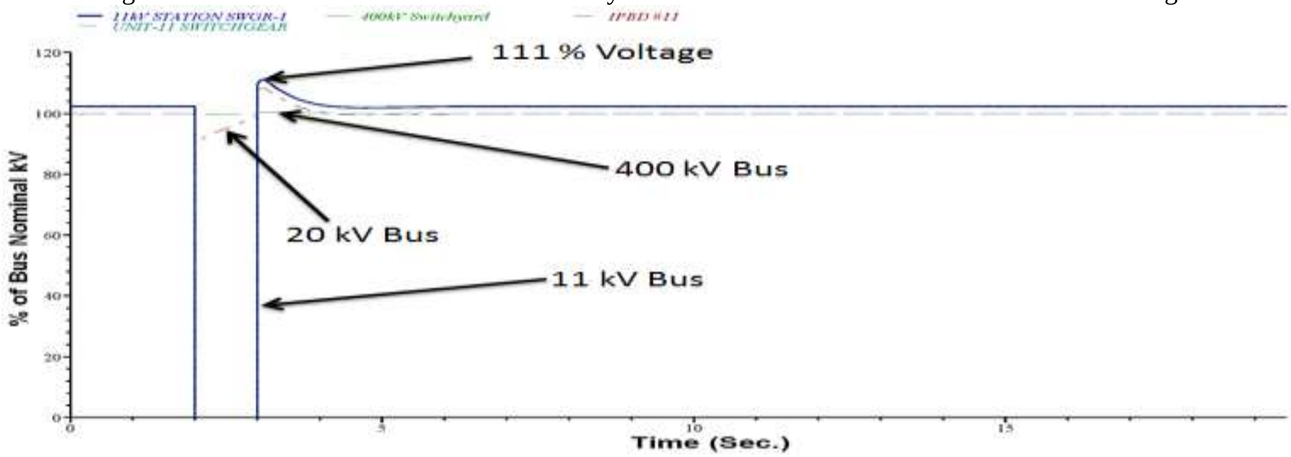

Fig. 12: Bus Voltage at 1 sec of CCT (For 11 kV Fault)

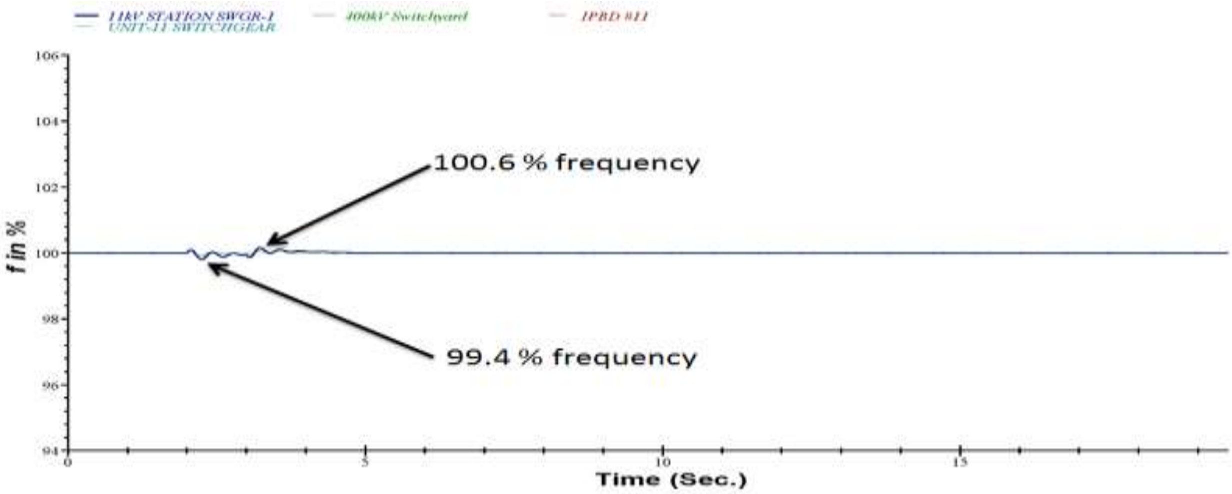

Fig. 13: Bus Frequency at 1 sec of CCT (For 11 kV Fault)

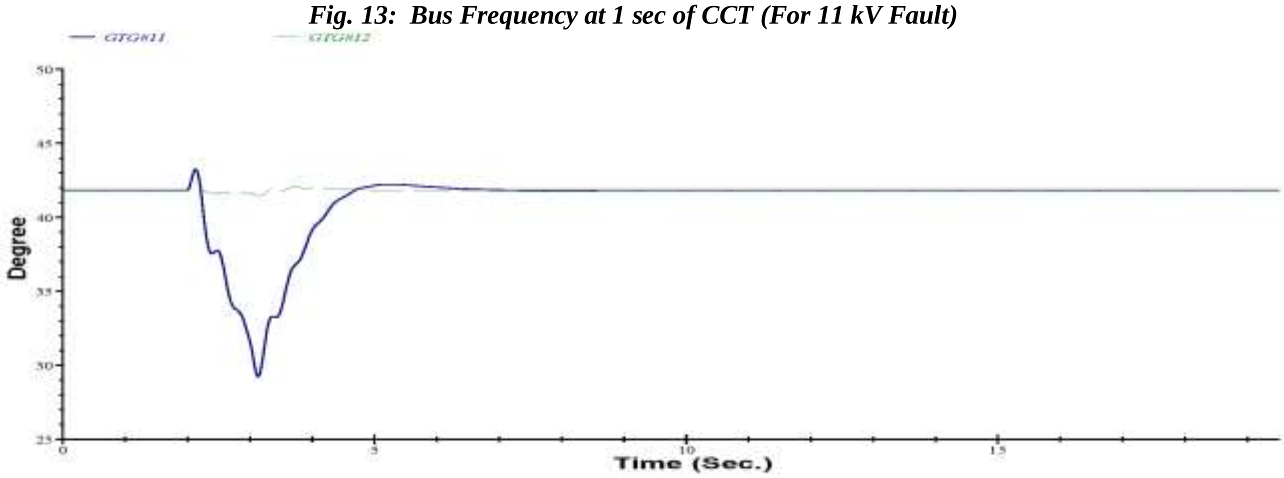

Fig. 14: Relative Power Angle at 1 sec of CCT (For 11 kV Fault)

D. Islanding Operation

This scenario is simulated to observe the response when generator is subjected to sudden loss of maximum continuous load. The primary response of the power plant with respect to frequency and voltage at generator buses are analysed in this study. This case also identifies the suitability of the generators to adopt sudden change from full load to house load under island mode of operation.

Further, post event, Generator terminal voltage is violating the voltage variation limit but due to AVR action voltage variation comes to acceptable limit within very short period of time. Hence the generator terminal voltage will be controlled to rated terminal voltage. The results of this case study can be utilized to design and set over voltage relay setting to prevent false tripping. A simulation result for this case is shown in fig.15 to 16.

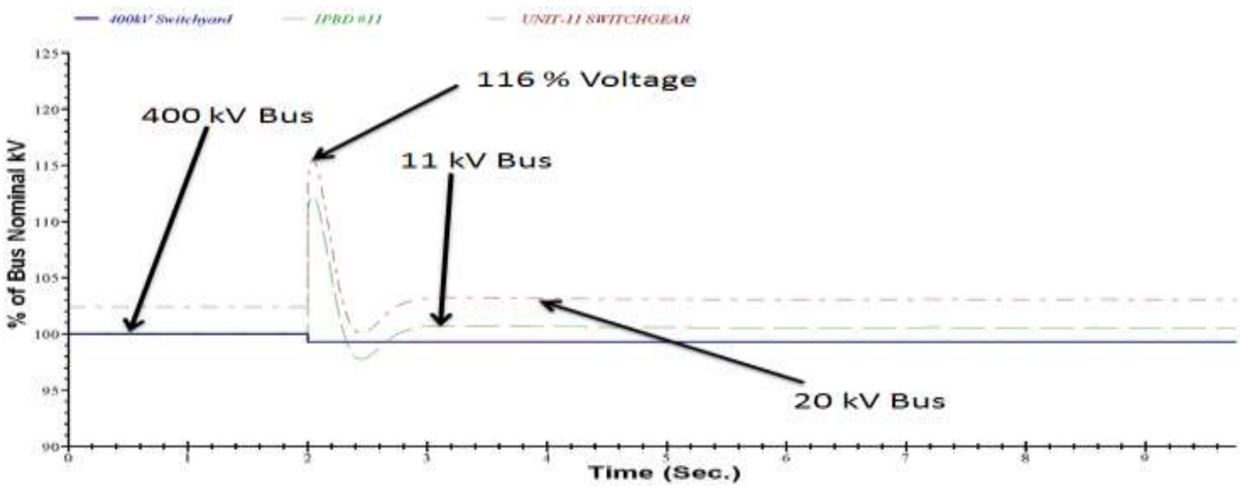

Fig. 15: Bus Voltage (For Islanding Operation at 2 sec)

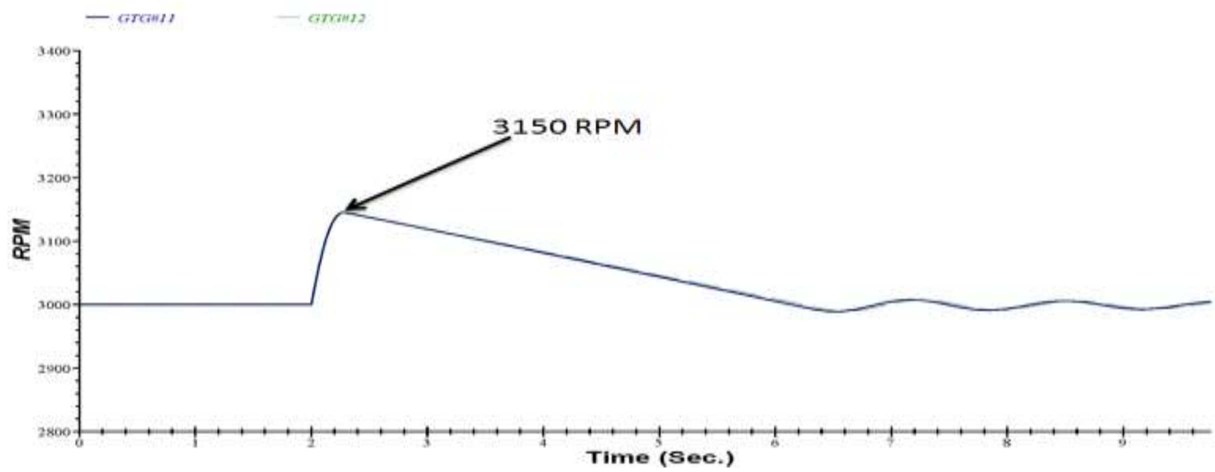

Fig. 16: Generator Speed (For Islanding Operation at 2 sec)

Table 1. Result Summary Table

Operation	CCT in ms	Stability	Remarks
400 kV Fault	160	Unstable	Voltage limit violation
	140	Stable	Within limit
20 kV Fault	160	Unstable	Voltage & Frequency limit Violation
	140	Stable	Within limit
11 kV Fault	1000	Stable	Required Suitable Relay Setting
Islanding	-	Stable	Required Suitable Relay Setting

VIII. CONCLUSION

In this paper, a comprehensive transient stability analysis for proposed power system of gas based power plant has been completed. Following points have been concluded.
Governor, Exciter and PSS models are suitable to obtain desirable performance of the generating sets during sudden loss of load/house load condition.
Values of Critical Clearing Time for different cases can be utilized to design and set system protective relay settings which will help in prevention of false tripping and improves stability of the proposed power system of power plant.
Behavior of generators under a severe internal and external fault condition is desirable.

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