

# Simulation and Analysis of Cascade Tripping & Islanding Detection

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**Abstract** – Cascading failure occurs when an initial disturbance in power system propagates to cause blackouts. Large cascading failure is not frequent, but they have large risk due to their large loss of revenue. When a power system is subjected to large disturbances control actions need to be taken to steer the system away from severe results and to limit the extent of the disturbance. Analysis of cascading and islanding is divided into two steps (a) Detection of major disturbances leading to cascading events, which includes steady state, transient and dynamic analysis. (b) Adaptive Islanding scheme to develop a fast accurate assessment for detection of timing for conducting controlled islanding scheme that prevents cascading phenomena.

**Index Terms** – Cascading, Steady State Analysis, Transient Analysis, Adaptive Islanding Scheme

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## I. INTRODUCTION

The basic requirement of the power system network is continuous operation without losing the system stability. As the demand for power more and more increasing the systems are going to connect to each other. This interconnection increases the system capacity, as well as the system, become more and more complex. Due to system disturbances and sudden system load changes may make the system unstable or synchronism of the interconnected system may lose. This loss of synchronism results in to "cascade tripping" of the system. This "CASCADE TRIPPING" results into large blackouts, too. So various remedy should apply to make system stable against such sudden disturbances.

When there is a heavy short circuit/disturbance in the grid, the frequency drops and the generators in the system may undergo transient behavior, resulting in out of step and hence tripping. This phenomenon may result in a series of tripping, causing cascade tripping of generators. Hence, the system will be going into the instability region. Hence, proper action should be taken to prevent such tripping and make the system to operate into its stability margin. This paper divided into two part:

1) To find the major reasons behind the cascade tripping.

2) After finding the reasons fast action islanding is done to prevent such events.

### 1.1 Cascade Tripping

The phenomenon of tripping generators in series is called Cascade Tripping. At steady state, the operating system should have the capability of tolerating the loss of any one element in the system (N-1), such as a generator, transmission line or critical load (Nedic, et. al., 2006).

When a disturbance occurs, the electrical torque output of the generator is no longer equal to the mechanical torque input. Therefore, machines move away from equilibrium governed by the swing equation of generators that is described by:

$$\frac{2H}{\omega_0} \frac{d^2\delta}{dt^2} = T_m - T_e$$

If the disturbance is small, oscillations could be eliminated by the action of controls such as exciters, governors and power system stabilizers.

## 1.2 Phenomena leading to cascade tripping

When there is a heavy short circuit/disturbance in the grid, the frequency drops and the generators in the system may undergo transient behavior, resulting in out of step and hence tripping (Nedic, et. al., 2006).

These phenomena may result in series of tripping, causing cascade tripping of generators. When the generator is running at full load, it operates at some load angle  $\delta_1$ . If the load is increased abruptly, either due to excessive load or fault the generator slows down, and if it is working within its transient stability limit, the rotor of the generator will regain synchronism at a new load angle  $\delta_2$ , higher than  $\delta_1$ .

But if the poles of which have slipped beyond the transient limit, the generator will **continue to slow down and stability is lost**. In this way cascading may be occurred and a large system may be affected due to these unwanted events and it will result in system blackout if proper step will not be taken in time.

Here, below a flow chart has been drawn that will give a brief idea about the cascade tripping (Nedic, et. al., 2006), (Baldick et. al., 2008).

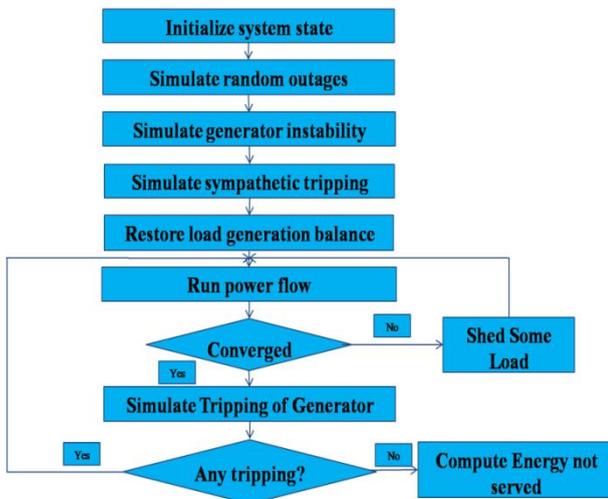


Figure 1 Flow chart of Cascade tripping (Nedic, et. al., 2006)

## II. ISLANDING

Controlled separation may be used to prevent a major disturbance in one part of an interconnected system from propagating into the rest of the system and causing a severe system breakup. Whenever there is a disturbance in the system it may result in loss of a major transmission line carrying a large amount of power or loss of significant amount of generation. The instability is usually characterized by sudden changes in tie line power. If such a situation can be detected in time and this information is used to initiate corrective actions, severe system upsets

can be averted. The instability is detected by monitoring sudden change in power flow through specific transmission circuits, change of bus voltage angle, the rate of power change, and circuit breaker auxiliary contacts. Here is the flow chart for the particular islanding detection (Demetriou, et. al., 2018).

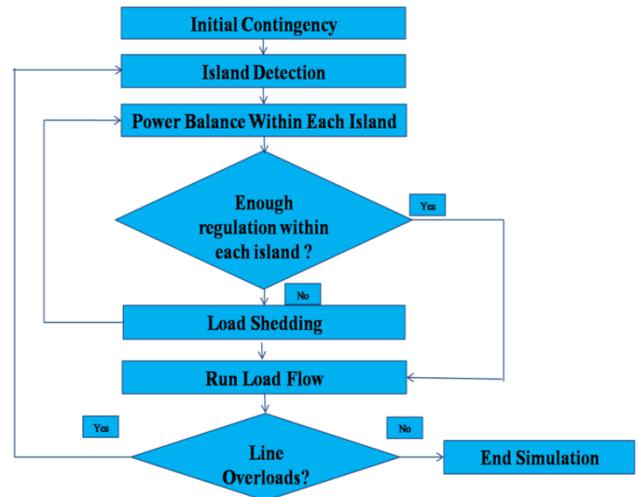


Figure 3 flow chart of the island (Zaag, et. al., 2007)

### 2.1 Where to Island?

The island formed should satisfy the following conditions (a) Coherent generators should stay on one island and (b) the load/generation imbalance of each island should be minimized. The first requirement is to form slow coherent generators. The balance between mechanical torque and electrical torque is upset and some generators tend to swing together against other groups of generators i.e. generator with similar swing patterns must stay in one island. Otherwise, separating power angles between different generator groups in a single island will affect transient stability recovery. This would then reduce the efficiency of the controlled islanding scheme. Another important requirement is to minimize the overall power imbalance of the created islands for the purpose of minimizing the impact of tripping multiple transmission lines on the system. The third requirement is that the number of lines to be tripped should as few as possible, for the purpose of easy restoration (Ahmed, et. al., 2003).

### 2.2 When to Island?

The issue focuses to determine the timing accurately for a controlled separation. The transient stability scheme is used to determine whether certain contingencies can initiate severely unstable swings and cause cascading events. This is a post-disturbance prediction approach, which collects transient system state variables as predictors after the disturbance. The predictors selected are all

from transient voltage phase angles at high voltage buses (Demetriou, et. al., 2018)

For every state variable, six data points are defined.

- The first data point is the phase angle at the fault clearance time.
- The second data point is the angle value 4 cycles later.
- The third is the one 8 cycles after the fault clearance.
- The fourth data point is calculated as the angular velocity between the first two data points.
- The fifth variable is the angular velocity between the second and third voltage phase angles.

Finally, the last variable is defined to be the acceleration from the first three angle values.

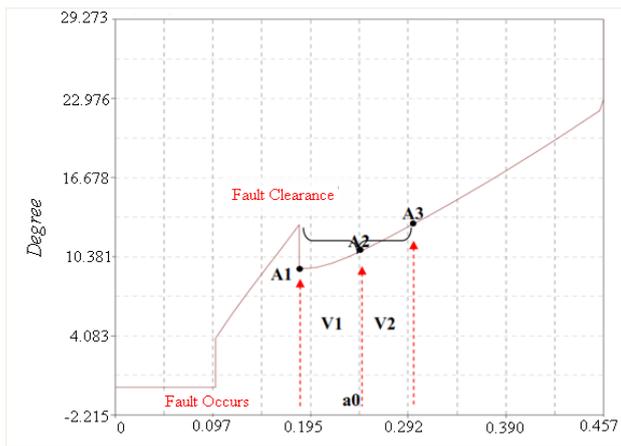


Figure 2 Case study for when to island

### III. INTRODUCTION TO ETAP

ETAP stands for Electrical Transient and Analysis Program.

ETAP is a most comprehensive analysis software for design, simulation and operation and automation of Generation, Distribution and industrial power systems. ETAP is developed under an established quality assurance program and is used worldwide as a high impact software (Raveendran and Tomar, 2012).

As an integrated enterprise solution, ETAP extends to Real-time intelligent power management system to monitor, control, automate, simulate and optimize the operation of power systems.

### IV. SIMULATION AND RESULT

To understand the effect of cascading on our system behavior we simulated one system using ETAP simulator. This will lead how the system stability will affect and what will the behavior of system generators and buses due to such unwanted events (Raveendran and Tomar, 2012) (Nedic, et. al., 2006)

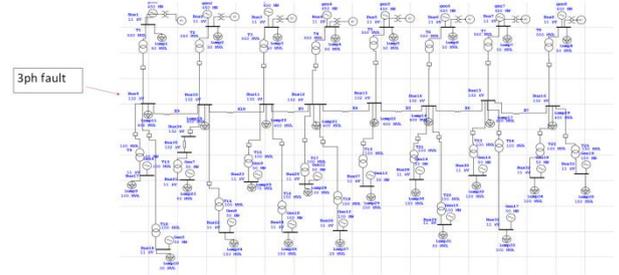


Figure 4 3ph fault in a single line diagram of 132kV lines developed using ETAP software

A system contains 23 generators, 33 buses and 31 lump loads. For various events the load flow analysis will be carried out than similarly for all the faulty conditions transient stability will be carried out and the resultant tables and graphs will be observed (Raveendran and Tomar, 2012)

Table 1 Frequency relay event list

Time (Sec)	Event	Device ID	Action
1	1	Line 1	3phfault
5.56	Freq. relay	CB2	Open
5.91	Freq. relay	CB1	Open
16.7	Freq. relay	CB4	Open
16.72	Freq. relay	CB5	Open
16.72	Freq. relay	CB3	Open
16.8	Freq. relay	CB6	Open
16.85	Freq. relay	CB7	Open
16.88	Freq. relay	CB8	Open

- Graph of frequency response at various buses

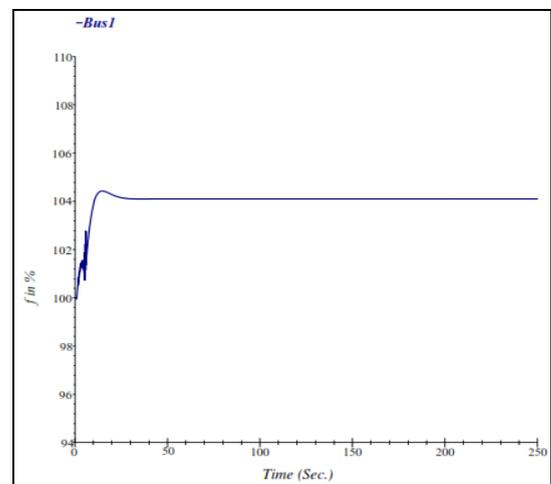


Figure 5 Frequency response at bus 1

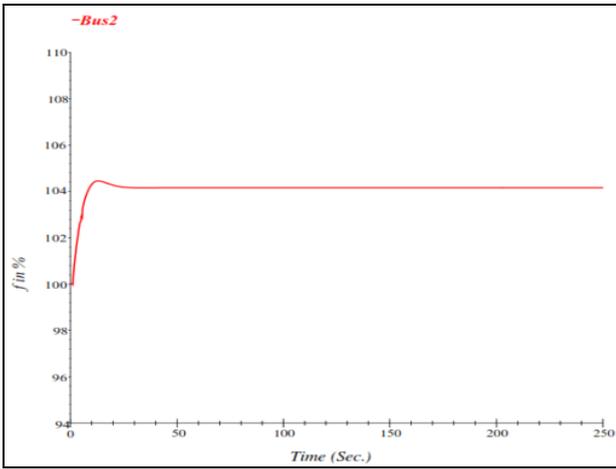


Figure 6 Frequency response at bus 2

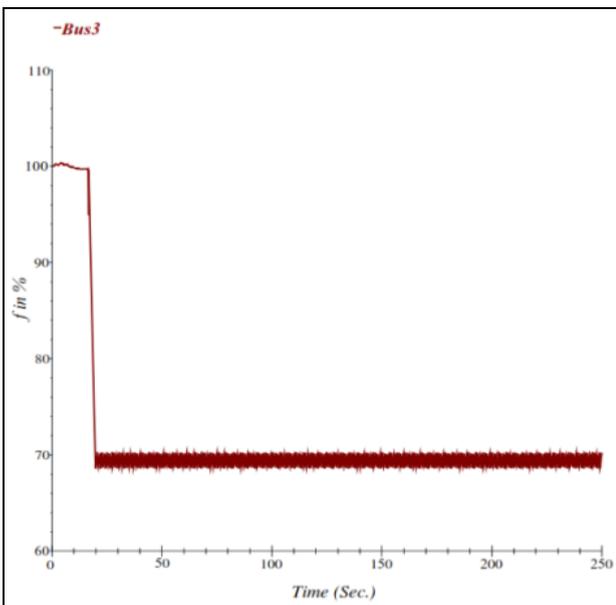


Figure 7 Frequency response at bus 3

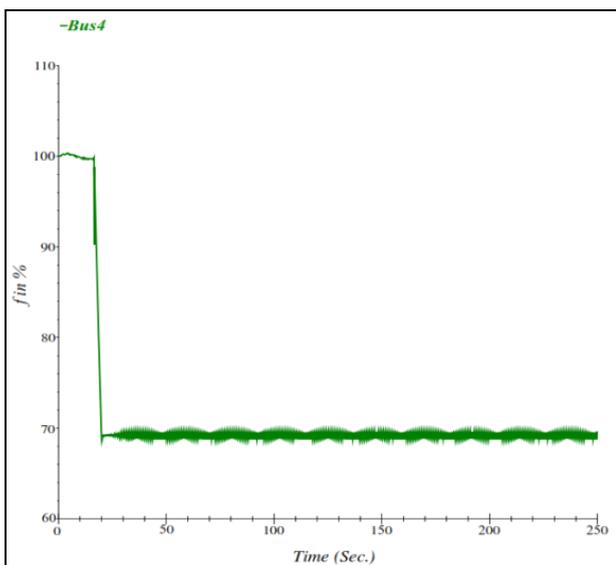


Figure 8 Frequency response at bus 4

• Generator power angle variation

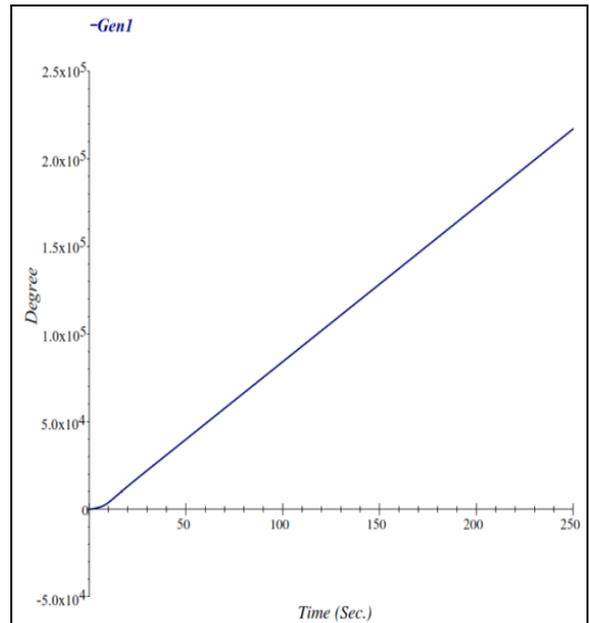


Figure 9 Power angle variation of Gen 1

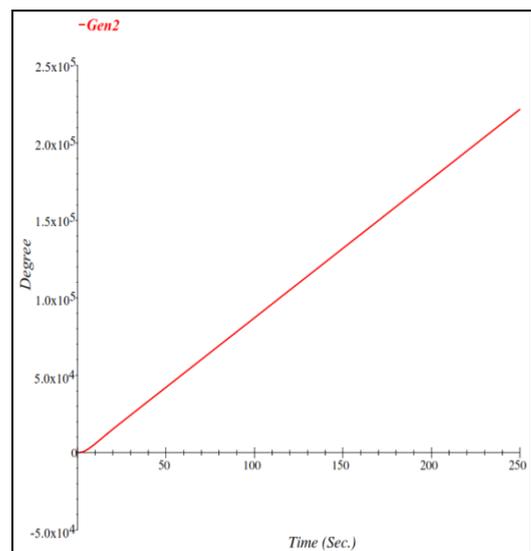


Figure 10 Power angle variation of Gen 2

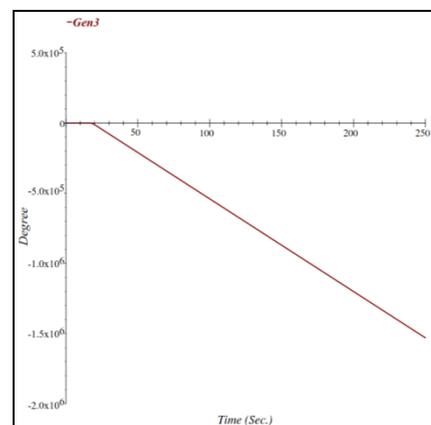


Figure 11 Power angle variation of Gen 3

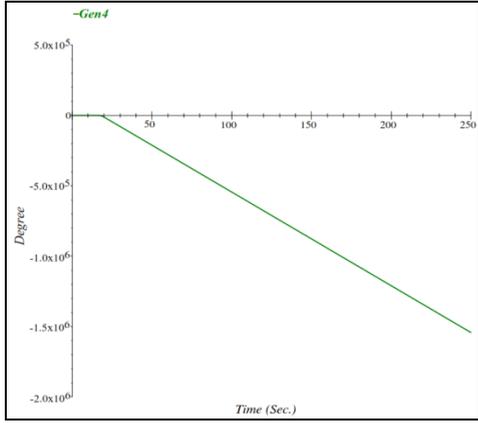


Figure 12 Power Angle variation of Gen 4

Hereby observing these output graphs, when the fault occurs at transmission line and the protective system lead to operating and due to such events, the generators lost its synchronism and this phenomenon will lead to the cascading events (Raveendran and Tomar, 2012) (Baldick et. al., 2008)

Cascading blackouts become more likely as a power system become stressed. As load increases average blackout size increases very slowly. Islanding is the last line of defense to stabilize the whole power system, which provides a promising control strategy for system operators under extreme conditions. Once properly designed, it can save a large amount of load from being shed and effectively stop the cascading events.

Here we created several islands for the same transmission line fault the resultant graphs for the bus's frequency response and generator power angle and reactive power are as under (Baldick et. al., 2008).

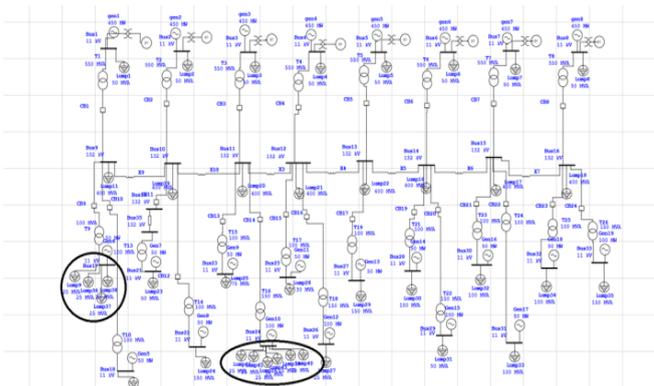


Figure 13 Island after 3ph fault using a single line diagram of 132kV lines developed using ETAP software

The frequency response of various Buses

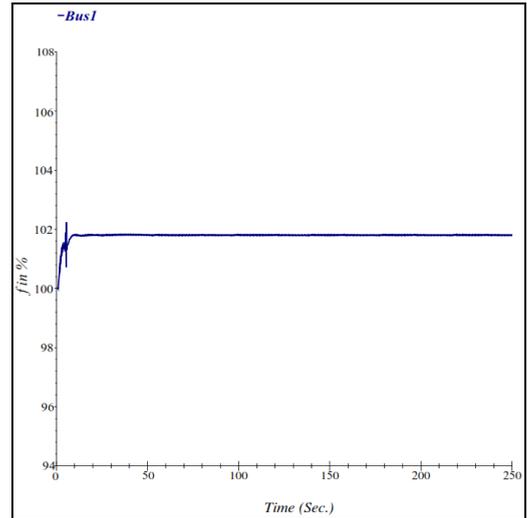


Figure 14 Frequency variation at bus 1

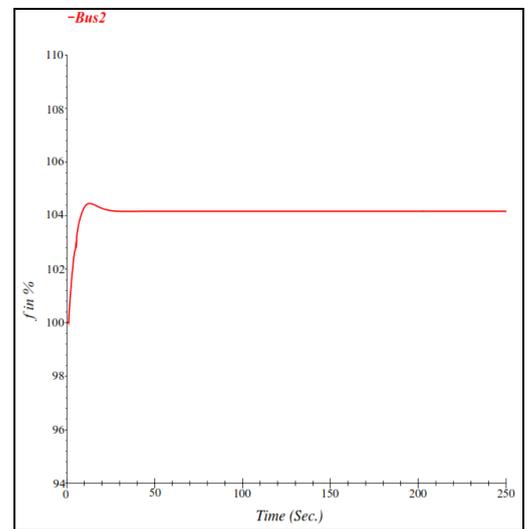


Figure 15 Frequency variation at bus 2

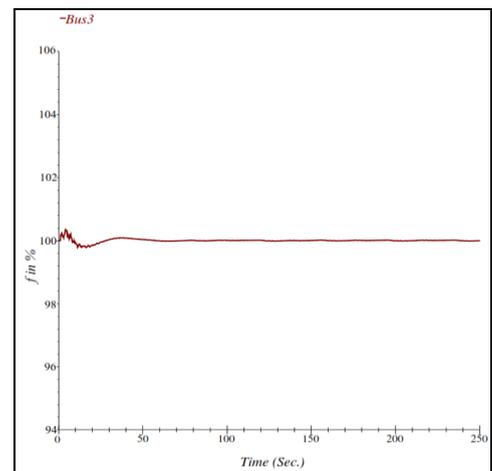


Figure 16 Frequency variation at bus 3

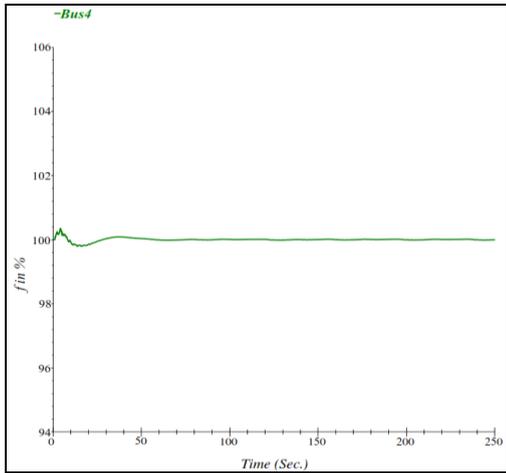


Figure 17 Frequency variation at bus 4

- Generator power angle

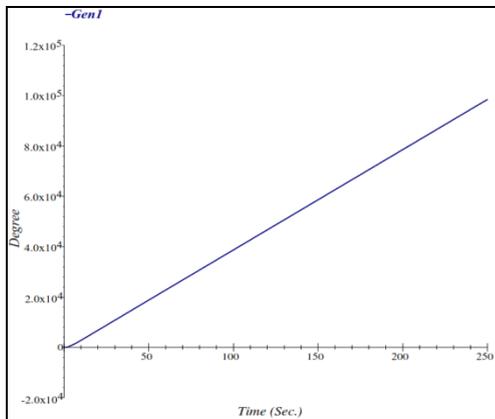


Figure 18 Generator power angle of Gen 1

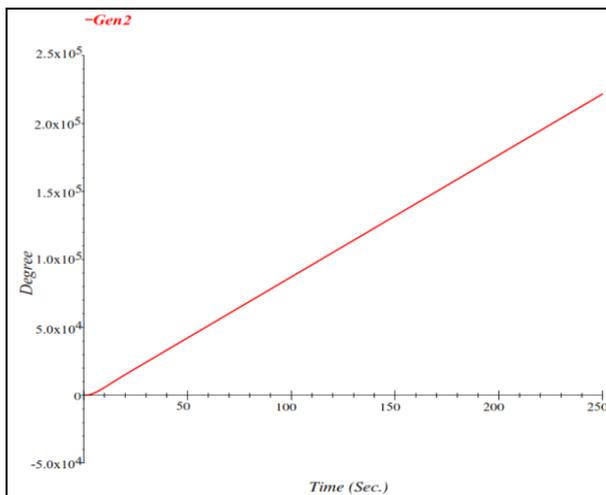


Figure 19 Generator power angle of Gen 2

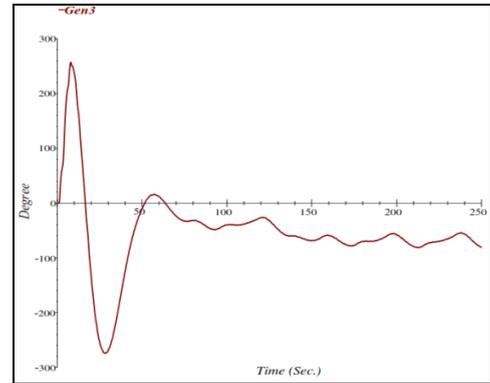


Figure 20 Generator power angle of Gen 3

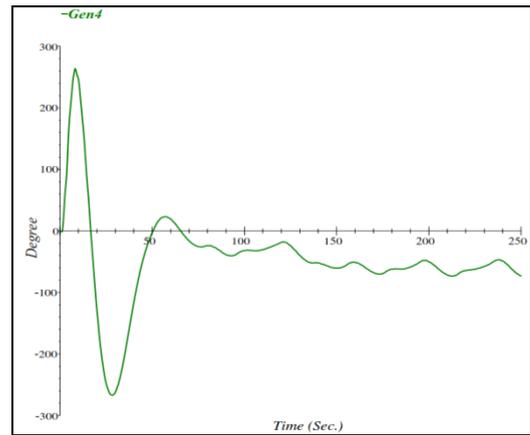


Figure 21 Generator power angle of Gen 4

By observing the above results, we can see the behavior of the system generators by Controlled separation. It may be used to prevent a major disturbance in one part of an interconnected system from propagating into the rest of the system and causing a severe system breakup (Pahwa, et. al., 2012).

After islanding, the load rich islands need to incorporate a load shedding scheme. The load shedding scheme operates and drops the required amount of load as a result of which frequency recovers in an island formed. Loads with high reactive power absorption are more suitable to shed in order to prevent a voltage collapse. Load shedding represents the solution used to avoid voltage collapse or overloads cascade on a wide area electrical network after all other resources have been exhausted (Pahwa, et. al., 2012)

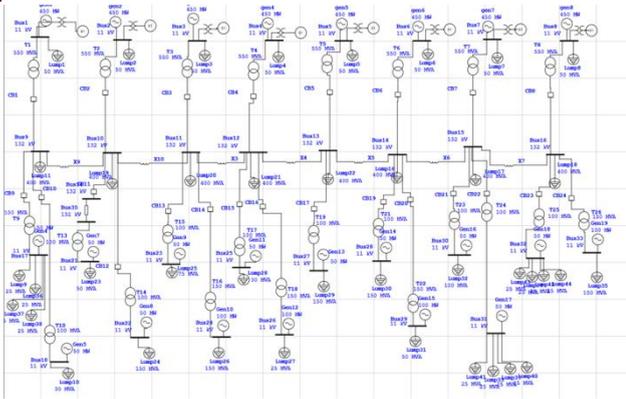


Figure 22 Load shedding after islanding using single line diagram of 132kV lines developed using ETAP software

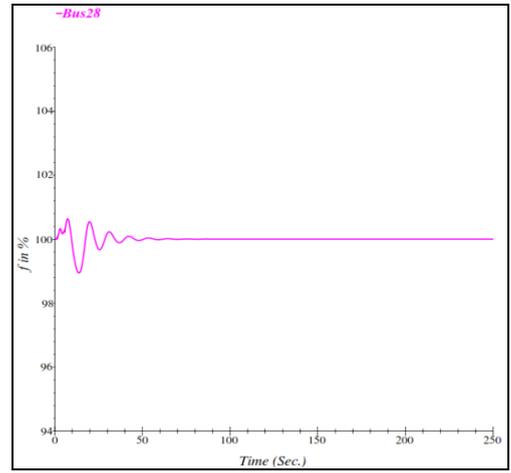


Figure 25 Frequency response at bus 28

- Result: Frequency response

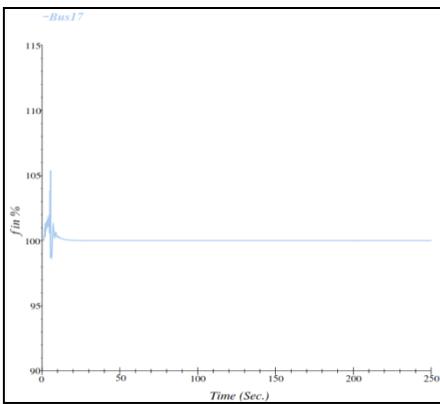


Figure 23 Frequency response at bus 17

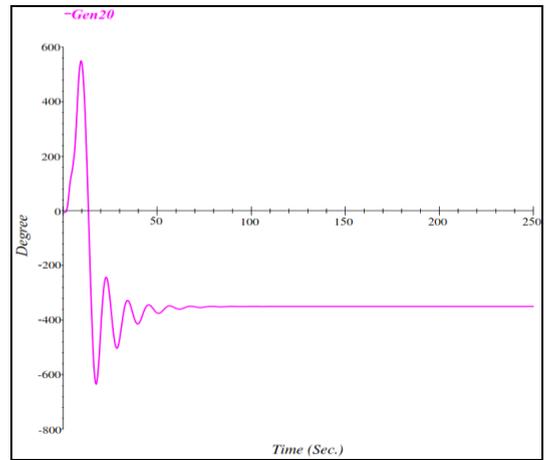


Figure 28 Generator power angle of Gen 20

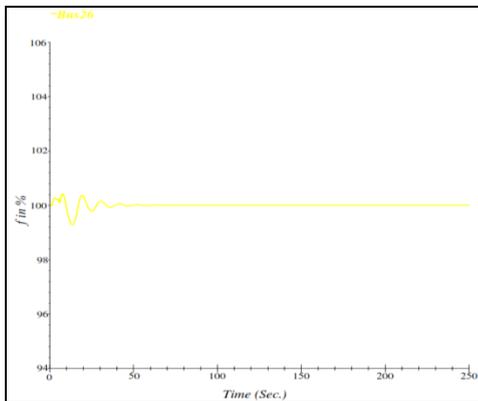


Figure 24 Frequency response at bus 26

- Generator power angle

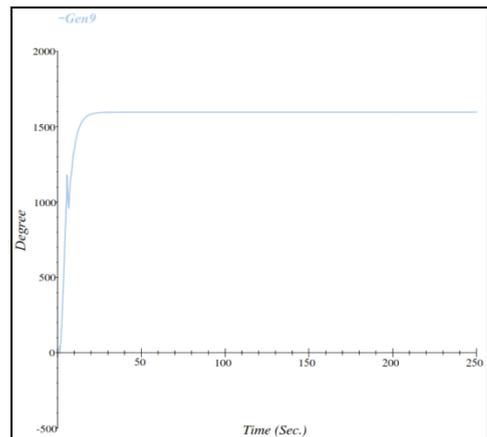


Figure 26 generator power angle of Gen 9

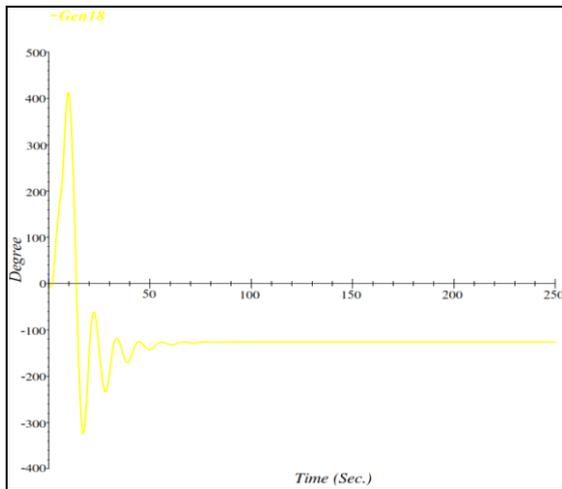


Figure 27 Generator power angle of Gen 18

## V. CONCLUSION

In this project various cases are taken to check the system stability by solving swing equation and also the transient stability analysis is carried out for various fault clearing time and by that the importance for the fault clearing time is explained.

In the second part by simulating a particular model of how the cascade tripping will occur and what will be its consequences on the system components will be explained briefly.

In the third part, the islanding and load shedding is carried out as the remedy for the cascading. Islanding is the last option for cascading events. Here, where and when to island is done is explained and for the same faulty system by doing the islanding system behavior will explain and will show the improvement for the generators and buses of the particular system.

By doing proper load shedding the system which has been islanded will work properly or not is explained and system voltage balance is maintained or not is verified.

## VI. ACKNOWLEDGMENT

The satisfaction that comes with successful completion of a task would be but incomplete without the mention of the people who made it possible it gives us immense pleasure to acknowledge all those who have extended their valuable guidance and magnanimous help. The success of any work depends upon the dedication, Sincerity and hard work. It also requires some ingredients such as motivation, guidance, encouragement and time.

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