

Transient Stability Improvement of the Power Systems

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ABSTRACT

During the last few decades, electrical power demand enlarged significantly whereas power production and transmission expansions has been brutally restricted as a result of restricted resources as well as ecological constrains. Consequently, many transmission lines have been profoundly loading so the stability of power system became as Limiting factor for transferring electrical power. So, maintaining a secure and stable operation of the electric power networks is deemed an important and challenge issue. transient stability of a power system has been gained a considerable attention from researchers due to its importance. Therefore, this paper sheds light on a substantial number of the adopted techniques, including an increase in inertia constant of generator, shunt capacitor, reduction reactance of the transmission line to achieve this purpose. A 7-Machine CIGRE system has been considered a case study. Matlab package has been employed to implement this study. The simulation results show that the transient stability of the respective system enhanced considerably with these techniques.

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1. INTRODUCTION

Currently, electricity demand has significantly increased and a current electrical power system becomes a complicated network of the transmissions lines which interconnect the power stations to the main points of loads in the whole power system to provide consumers with the required power. The complex power networks cause some technical issues such as stability problem [1]. Power system stability of current big interrelated systems is considered a key issue for secure system operation. It is worth mentioning that current major shutdowns across the world prone to system instability, even in advanced and protected systems, elucidate the difficulties facing stable operation of electrical power systems [1-3]. In this regard, power system stability can be defined as the ability of system to return to normal operation condition after being exposed to some kinds of interruptions [4]. Power stability can be divided into several categories such as frequency voltage, rotor angle stability and voltage stability [5,6]. Many researches have been done to assess stability of the power system and then enhance it, especially transient stability which is deemed as one of the significant aspects that have to be taken in consideration in the recent power systems. Several techniques have been proposed to enhance the transient stability of the modern power systems, including Flexible AC Transmission systems (FACTS), and distributed generation units (DG) [7].

This paper presents the different technique of the enhancement of transient stability of the above-mentioned power system based on using shunt capacitor, an increase in inertia constant of generator, and decreasing the transmission line reactance as explained in the second part. The simulation code has been

implemented in the Matlab environment. it has been tested on the single line diagram and data of 225-kV, 7-machine CIGRE system (in pu on a 100 MVA base).

2. STABILITY ENHANCEMENT TECHNIQUES

Transient stability improvement can be achieved by adopting one of the following method:

2.1. Inertia Constant of Generator

Inertia of machine can be defined as a kinetic energy that stored in moving parts of the machines at the synchronous speed per-unit MVA machine rating. It represents a rate of its deceleration or acceleration which indicates rate of change in the rotor angle. It is worth mentioning that the higher the inertia, the slower the rate of change in angle. This decreases the kinetic energy gained during fault; so accelerating area is decreased [8].

2.2. Shunt Capacitor

Connect capacitors are connected in more than one bus to supply specific amount of reactive power. This is because the main reason of occurring disturbances is the lack of reactive power thereby injecting reactive power will improve the stability of the system as well as it increase the load carrying capability of the transmission line [9].

2.3. Reduction of the Transmission Line Reactance

This technique involves reducing the reactance of the transmission lines and that plays an important role in improving the power transferred and the stability of the system because the transferred apparent power proportional inversely with the reactance according to the equation below:

$$P = \frac{V_1 \times V_2}{X} \sin \delta$$

3. SYSTEM STRUCTURE

The single line diagram and data of 225-kV, 7-machine CIGRE system (in pu on a 100 MVA base) are given in the appendix. this system consists of 10 buses which include one slack bus, six PV buses, and three load buses, single line diagram and data of 225-kV, 7-machine CIGRE System as shown in Figure 1.

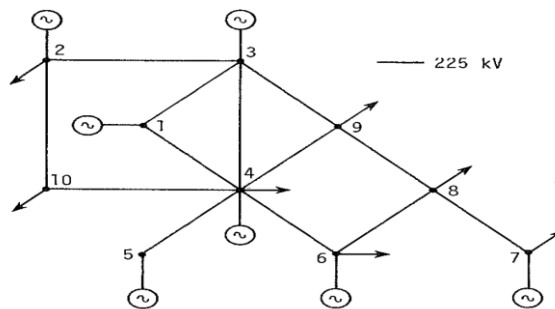


Figure 1. Single line diagram and data of 225-kV, 7-machine CIGRE System

4. SIMULATION RESULTS

In this section, different techniques are considered to evaluate the impact of each method on the transient stability of a 7-machine CIGRE system.

Case 1: Normal situation

A 7-machine CIGRE System has been tested at the normal situation to evaluate transient stability. In this situation, it has been noticed that the system maintains the stability as long the circuit breaker working on the removal of the damaged bus from the system as soon as possible. This has been observed by increasing the clearing time from 0.05s to 0.39115 that represents critical clearing time of the fault. During the bounded period, the system keeps its stability as shown in the Figure 2:



Figure 2. Swing curves for a stable situation

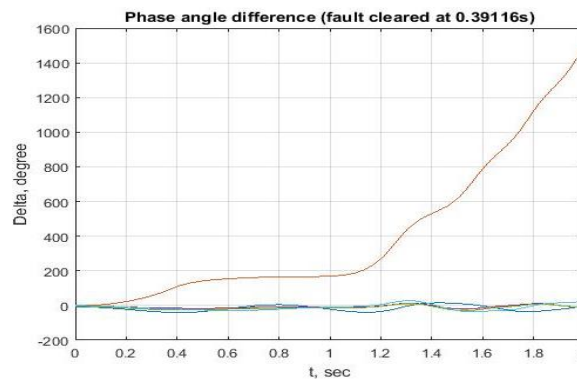


Figure 3. Swing curves for an unstable situation

From the Figure 3, it has been observed that 0.39115s is regarded as critical time of system and 0.39116 is unstable time. In the second part, some techniques will be applied to increase the clearing time to Long as possible to improve the stability of the system.

Case2: an increase in inertia constant of generator (H)

This method is classified as one of the main techniques for improving the transient stability of the power systems. In fact, when the inertia becomes higher that makes the rate of change in angle slower. The gain of kinetic energy depends directly on angle rate change. Therefore, when the rate decreases, the gained kinetic energy during fault will also decrease then accelerating area reduces so the system stability remains with the desirable level [10]. During our practical, we found that our original system stays stable until clearing time equal 0.39115 second then it became unstable at $t_{cl} = 0.39116$ second without changing or adding anything as shown the photos in Figure 4.

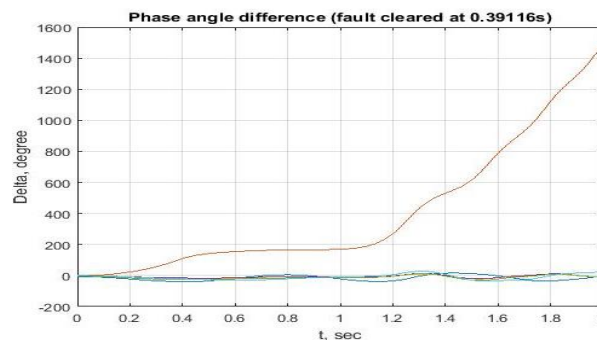


Figure 4. Swing curves for an unstable situation

Now, we multiplied the inertia of all generators by two and check again the tc for the system. We found that the system stayed stable in this situation until $t_{cl}=0.5531$ second then it became unstable at $t_{cl}= 0.5532$ second and the Figure 5-6.

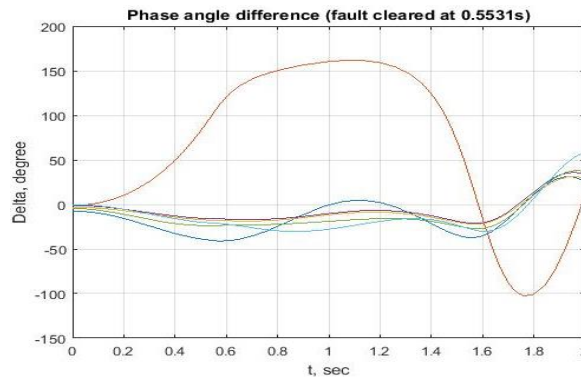


Figure 5. Swing curves for an unstable situation

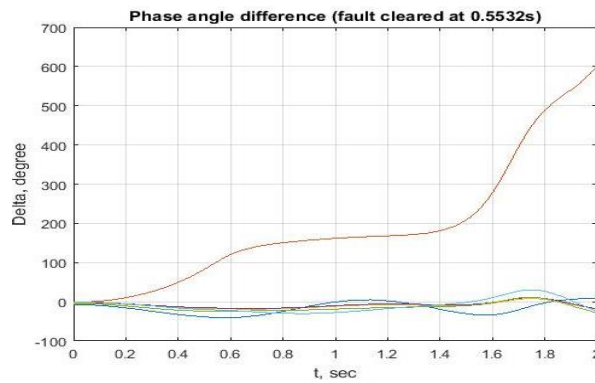


Figure 6. Swing curves for an unstable situation

Moreover, we multiplied the inertia of the generators by three and repeat the above steps. It is observed that the the system remains stable untill $t_c= 0.6774$ second then be unstable when $t_c= 0.6775$ second as shown in the Figure 7-8.

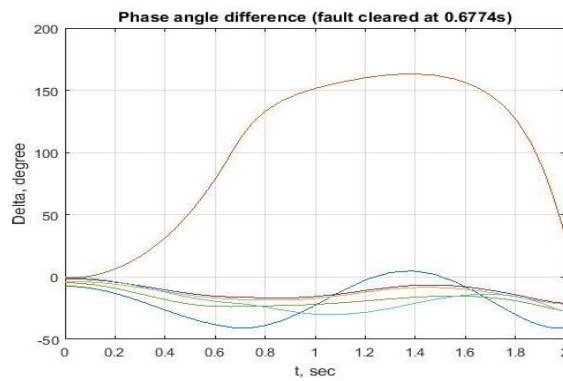


Figure 7. Swing curves for an stable situation

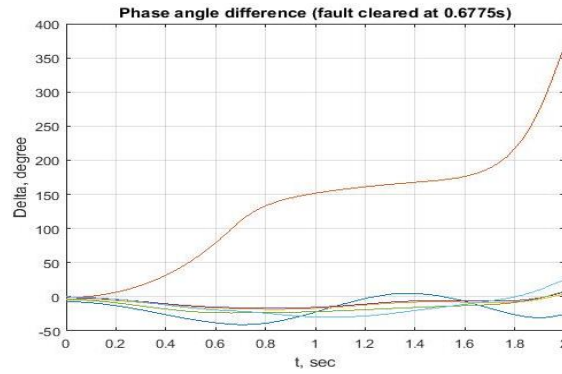


Figure 8. Swing curves for an unstable situation

Case3: Connecting Shunt Capacitor

In this case, shunt capacitor is connected in two different places to evaluate its impact on the system. Firstly, two capacitors are connected to the system one on the bus 8 with 80 Mvar and the other is 60 Mvar on the bus 10. In this case, the system remained stable until $t_c=0.39319$ second and be unstable at $t_c=0.3932$ second as shown in the Figure 9-10.

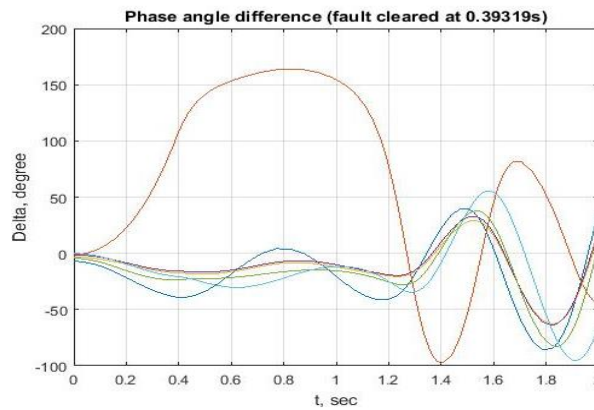


Figure 9. Swing curves for a stable situation

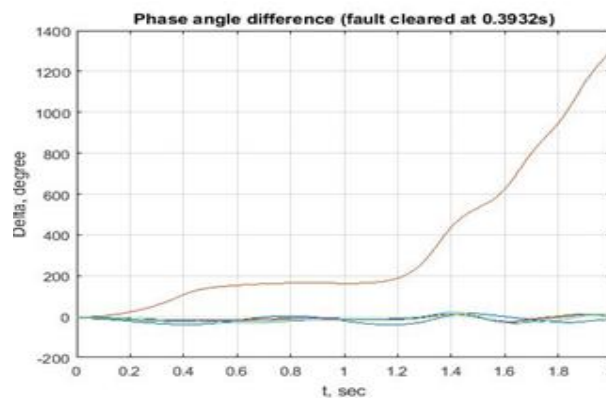


Figure 10. Swing curves for an unstable situation

Secondly, the amplitude of the injected reactive power had be increased from 80 Mvar to 100 Mvar on bus 8 and from 60 Mvar to 80 Mvar on bus 10, then the system stayed stable until $t_c=0.39387$ second and became unstable at $t_c= 0.39388$ second as shown in Figure 11-12.

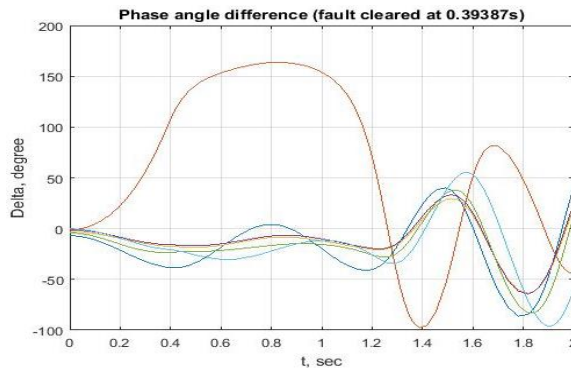


Figure 11. Swing curves for a stable situation

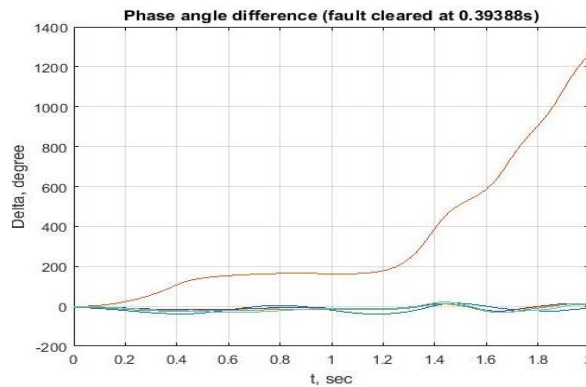


Figure 12. Swing curves for an unstable situation

Case4: Reduction of the transmission line reactance

In this case, two different scenarios has been done to assess the influence of reactance reduction on the system stability. The first case involves reducing the reactances between bus 2 to 10 and bus 1 to 4 to the half of their values. Then, the t_{cl} increases to 0.39326 second and the system is stable after that it became unstable at $t_c=0.39327$ second as described in the Figures 13-14.

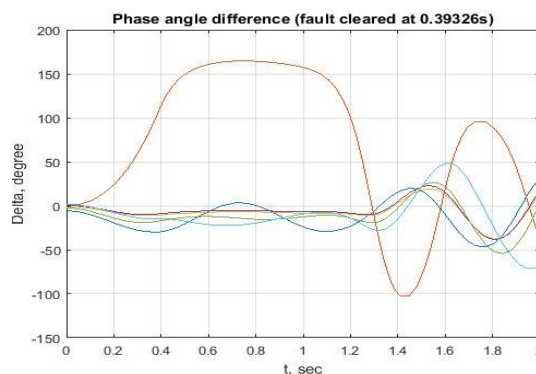


Figure 13. Swing curves for a stable situation

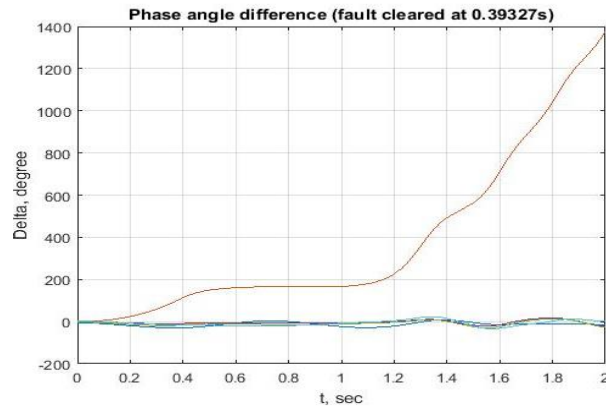


Figure 14. Swing curves for an unstable situation

In the second case, the same reactance which was used in the first case are used here a but multiplied by 0.25 instead of 0.5. it shows that the system is able to remain stable up to $t_c = 0.39642$ second and then it will be unstable at $t_c = 0.39643$ second as shown in Figure 15-16.

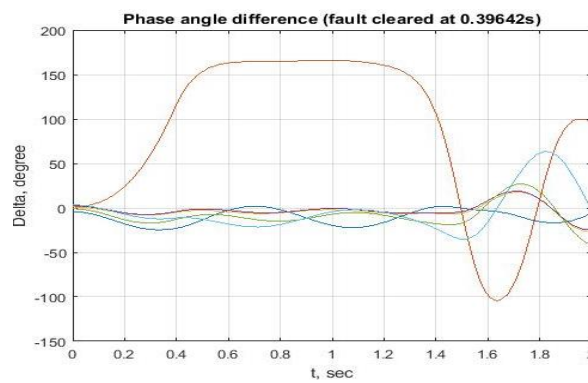


Figure 15. Swing curves for a stable situation

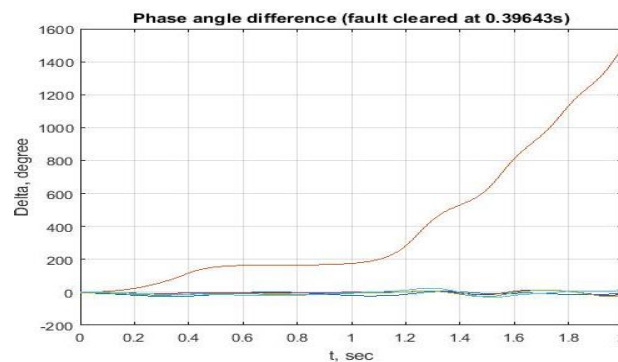


Figure 16. Swing curves for an unstable situation

From these three methods, it can be seen that the first method (by increasing the inertia of the generators) is much better than the other two because it increases clearing time very high as compared with other two strategies.

5. CONCLUSION

This paper has been dedicated to assess the transient stability of 7-Machine system. It shows that the system retains its stability as long the circuit breaker working on the exclusion of the damaged bus from the respective system as soon as possible. In order to comprehend this case, A 7-Machine system has been taken as a sample. It has been found that system loses its stability at 0.39116 s. Then three techniques have been used to improve stability effectively and proves that practically. The adopted strategies includes increasing generator inertia constant, connecting shunt capacitor, and decreasing the reactance of the transmission lines. It should be clear that increasing generator inertia constant is found the best way to achieve this purpose where the clear time goes up to 0.6774s.

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APPENDX

Bus Data of the 7-machine CIGRE System

| Bus # | V (pu) | P _{Load} (MW) | Q _{Load} (MVar) | P _{gen} (MW) | Q _{min} (MVar) | Q _{max} (MVar) |
|-------|--------|------------------------|--------------------------|-----------------------|-------------------------|-------------------------|
| 1 | 1.060 | | | --Swing-- | -200 | 200 |
| 2 | 1.000 | 200 | 120 | 120 | -200 | 200 |
| 3 | 1.040 | | | 256 | -200 | 200 |
| 4 | 1.015 | 650 | 405 | 300 | -200 | 200 |
| 5 | 1.055 | | | 230 | -200 | 200 |
| 6 | 1.020 | 80 | 30 | 160 | -200 | 200 |
| 7 | 1.010 | 90 | 40 | 175 | -200 | 200 |
| 8 | | 100 | 50 | | | |
| 9 | | 230 | 140 | | | |
| 10 | | 90 | 45 | | | |

Generator Data of the 7-machine CIGRE System

| Gen # | Resistance (pu) | Transient Reactance (pu) | Inertia Constant (H) |
|-------|-----------------|--------------------------|----------------------|
| 1 | 0 | 0.074 | 11.35 |
| 2 | 0 | 0.118 | 7.75 |
| 3 | 0 | 0.062 | 14.31 |
| 4 | 0 | 0.049 | 17.98 |
| 5 | 0 | 0.074 | 11.35 |
| 6 | 0 | 0.071 | 12.76 |
| 7 | 0 | 0.087 | 10.71 |

Line Data of the 7-machine CIGRE System

| -BETWEEN- BUSES | | ---IMPEDANCE--- | SHUNT ADMIT. |
|--------------------|----|-----------------|-----------------|
| | | R (P.U) | X (P.U) |
| 1 | 3 | 0.0098 | 0.0484 |
| 1 | 4 | 0.0098 | 0.0484 |
| 2 | 3 | 0.0450 | 0.1237 |
| 2 | 10 | 0.0164 | 0.0638 |
| 3 | 4 | 0.0118 | 0.0780 |
| 3 | 9 | 0.0115 | 0.0553 |
| 4 | 5 | 0.0039 | 0.0197 |
| 4 | 6 | 0.0075 | 0.0197 |
| 4 | 9 | 0.0488 | 0.1916 |
| 4 | 10 | 0.0164 | 0.0652 |
| 6 | 8 | 0.0188 | 0.0628 |
| 7 | 8 | 0.0118 | 0.0740 |
| 8 | 9 | 0.0488 | 0.1916 |