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Transient stability for IEEE 14 bus power system using power world simulator

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Transient stability for IEEE 14 bus power system using power world simulator

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Abstract: Nowadays, demand for electricity is increasing every single day. This is due to the deep requirements in current economy. Generating electricity is an important element to ensuring a system operates in good condition and not being affected. At the same time, some problems have arisen as a phenomenon of transient stability. Hence, analysis needs to be done to control energy stability in rivalling current demand. Power system stability can be further divided into 3 sub-analysis starting with rotor angle stability which is the ability of synchronous machines of an interconnected power system to remain in synchronism after being subjected to a disturbance, voltage stability which is the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance and also frequency stability which the ability of a power system to maintain steady frequency following a severe system disturbance resulting in a significant imbalance between generation and load. This analysis is used the IEEE Bus System 14 and analyzed using Power World Simulator (PWS) software. The variations in power angle, bus voltage and system frequency were studied with the help of three-phase balanced fault. Fast fault clearing times were analysed for a three-phase balanced fault in order to re-establish the stability of the system. Furthermore, impact of fault location on system was also computed to observe whether it affected the stability of the systems.

1. Introduction

Stability of a power system is the ability of the system itself to return and become normal. In other words, stability is referring to the ability of the system to operating in stable conditions after having been subjected to a form of disturbance. Besides, instability is referring to a situation where contain a loss of synchronism or falling out of step. In addition, stability is the likelihood of a power system to develop recovering forces in order to maintaining the state of equilibrium [1]. If the forces are capable to hold the machines in synchronism between one another are adequate to overcome the disturbing forces, the system is expected to remain in stable condition.

The studies of stability in power system is conducted in order to determine the suitable relaying system, critical fault clearing time of circuit breaker, critical clearing angle, auto reclosing time tcr, voltage level and also transfer capability between system. The effect of instability will result the machines does not work at synchronous speed anymore. This complication will tend to swing the voltage, power and current drastically. It could damage the loads by receiving electric supply from the instable system [2].

The stability in power system is referring to the ability of a system to return back to its normal condition after being subjected to a disturbance. For the initial, the generator has generated the power in a synchronism operation with a bus as both of them have same frequency, voltage and phase sequence. The stability of the system can be defined by the ability of the system to return to steady state condition without losing synchronism. Power system stability is classified into Steady State, Transient and Dynamic Stability [3]. Figure 1 shows the diagram of classified Power system stability.

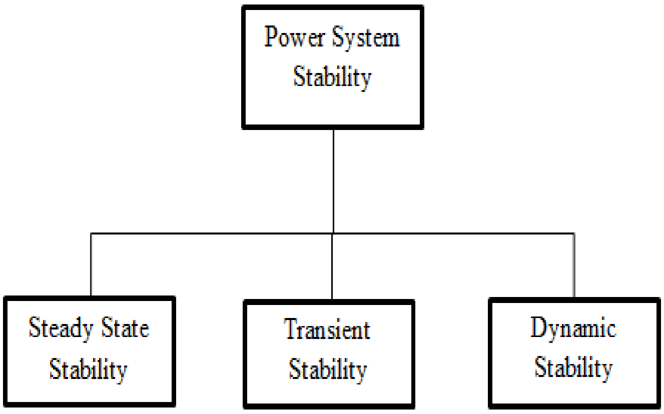

Figure 1. Power System Stability

2. Methodology

The IEEE-14 bus system as shown in Figure 2 is taken for simulation of transient stability. System model is implemented and executed in PWS which consists of 14 buses, 5 generators, 5 transformers and 11 constant impedance loads. The parameter of generator and synchronous condenser data, bus data, transformer data, and branch data were filled in the system for a running method. Next, a three-phase balanced fault is used to perform a transient stability analysis. A fault which gives rise to equal fault currents in the lines with 120-degree displacement is known as three phase fault or symmetrical fault.

For the first analysis, which is to analyse the relationship between rotor angle with respect to time clearing fault, a three-phase balanced fault has been located at a transmission line between bus 1 and bus 2. At 50% location from the near end of transmission line, the fault has been subjected and occurred at 1.0 second. After 1.033 seconds, the fault has been cleared and the result were taken from the graph obtain by the plot options. The simulation is carried out by using different time clearing fault which is 1.05, 1.15, and 1.16 seconds respectively. In addition, the simulation was repeated with the different plot to observe the variation of bus voltage, and also frequency of the system.

The location of fault happen was also been considered whereby the critical time before the system losing a synchronism will be different due to location factors. With the same method of previously analysis, a three-phase balanced fault is now located at the middle of transmission line between bus 5 and bus 6, and also between bus 7 and bus 8 respectively. The comparative is made on which location of fault is more critical for transient stability. In this case, the maximum time allowed for clear fault is taken by considering each location of fault applied. The variation of bus voltage, and also frequency of the system has been plotted for each simulation.

The next analysis was performed to evaluate the impact of fault location on system whether it affected the stability of the systems. From the previous analysis, the same simulation was conducted with different location in percentage of fault at transmission line. Starting from near end to far end, which is from 0% to 100%, ten different location of fault on transmission lines has been selected to be simulated and the maximum time of clearing fault which is allowed to maintain the stability of the system is taken. The maximum time of clearing fault allowed by each location of transmission line are recorded in table to be discussed.

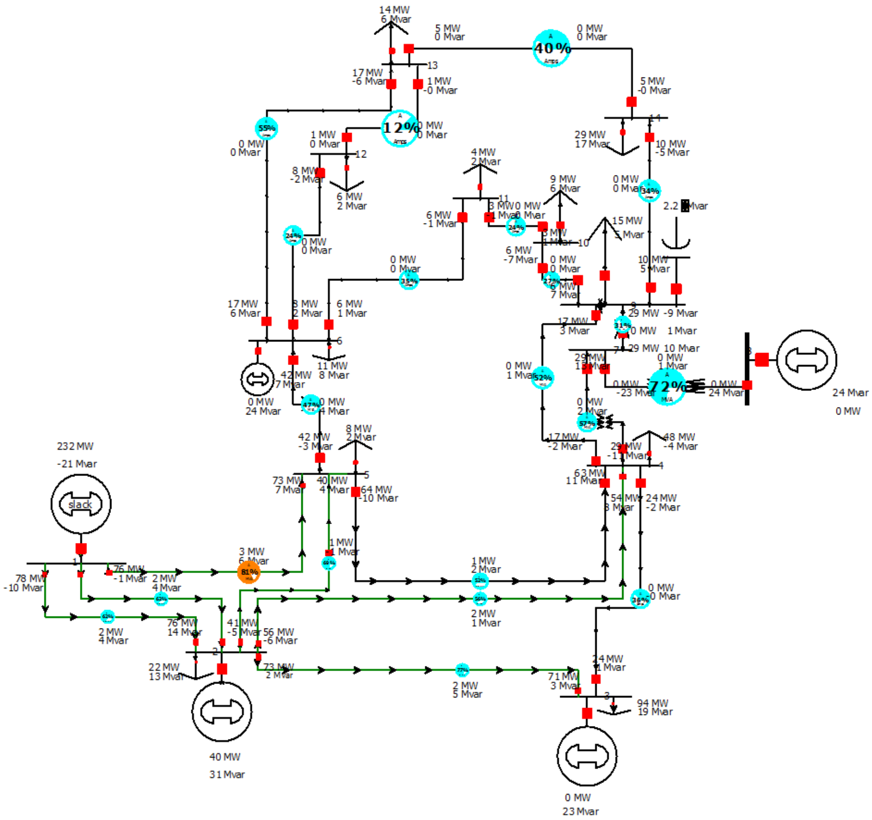

Figure 2. IEEE 14 Bus Systems

3. Results and Discussions

There are some results that has been obtained during the simulation of this research.

Bus Voltage (pu) versus Time

The bus voltage of all 14 bus were observed with the same fault location and certain time of fault clearing time to analyses the voltage stability of each bus. The first simulation has been setting for 1.05 seconds of fault clearing time. The result shown in Figure 3 clearly describe that the initial voltage in per unit (p.u) falls dramatically from the average value of 1.05 p.u to 0.23 p.u after being subjected to a three phase balanced fault. When the fault is cleared at 1.05 seconds, the voltage returns to increase rapidly and begin to raise the voltage back to initial normal state. At time = 6.7 seconds, the voltage bus (p.u) return to initial setting voltage.

With the same parameter, the next simulation is performed with a critical clearing time at 1.13 seconds. Figure 4 shows the duration of time required to return the voltage back to initial value were increase following the increasing of time clearing fault. After fault has been cleared at 1.13 seconds, the voltage of the bus starting to increase and it only reach to the normal value at 10 seconds.

After setting the next duration of time clearing fault to 1.16 seconds, the bus voltage was identified losing out of synchronism. Even though the fault has been cleared, the voltages are tending to be unstable as the duration of time required to clear the fault has reached the limit. From Figure 5 shows the voltage of all 14 bus falls down after fault occurred at 1.0 second. After the fault has been cleared, the voltage become unstable with the maximum amplitude reach 0.9 V and then falling back to 0.05 seconds. This unstable voltage behavior is continuously and it can be concluded that more time taken to clear the fault, the higher the possibility of the bus voltage to running out of stability.

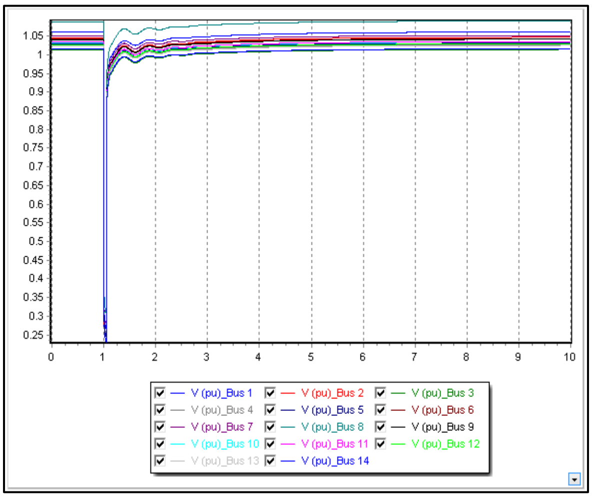

Figure 3. Voltage bus (p.u) 14 bus system versus time with clearing time 1.05 seconds

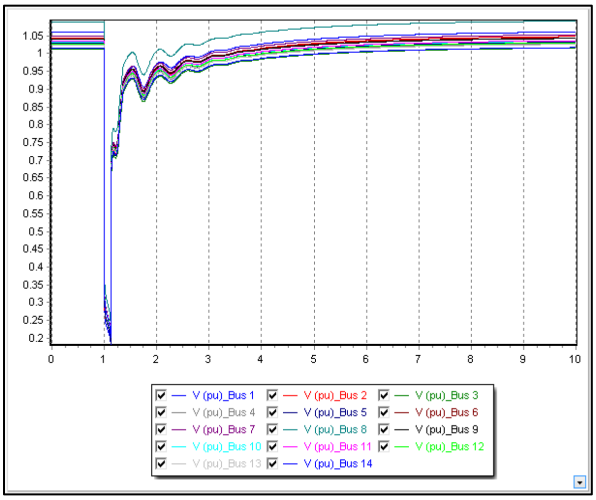

Figure 4. Voltage bus (p.u) 14 bus system versus time with clearing time 1.13 seconds

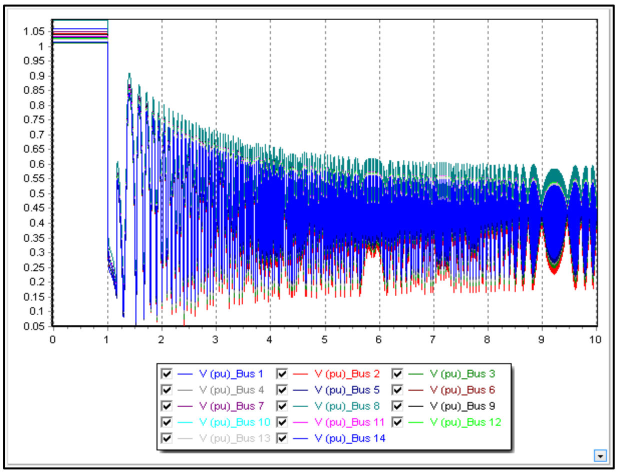

Figure 5. Voltage bus (p.u) 14 bus system versus time with clearing time 1.16 seconds

Bus Frequency versus Time

The third simulation was done to observe the relationship between the frequencies of bus with respect to time after fault happen. With the different duration of fault happen, the analysis has been made whether the frequency is maintaining on operating Hz after being subjected to a fault.

Firstly, fault has been setting to happen at 1.0 second the frequency of the bus was suddenly increase from the normal operating at 60 Hz to 61 Hz by referring to Figure 6. After the fault has been cleared at 1.033 seconds, the frequency falls to 60.15 Hz. At 1.1 seconds, the frequency starts to increase logarithmically until maximum endpoint, 61.2 Hz at 6 seconds before it decreases back to synchronize operating Hz after 150 seconds.

After extended the fault until been cleared at 1.15 seconds, the maximum endpoint of frequency also increases to 73 Hz at 10 seconds while the frequency is only reach its normal operating Hz after 250 seconds. From Figure 7, it can be concluded that the more time taken to clear the fault, the lower the possibility of the frequency to return back to it synchronize operating Hz. For more clearly, Figure 8 describes that frequency off all 14 bus were totally out of synchronism after the fault been cleared at 1.16 seconds.

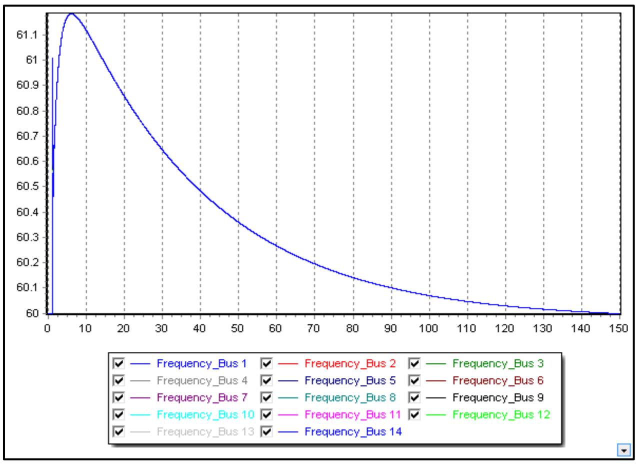

Figure 6. Frequency 14 bus system versus time with clearing time 1.033 seconds

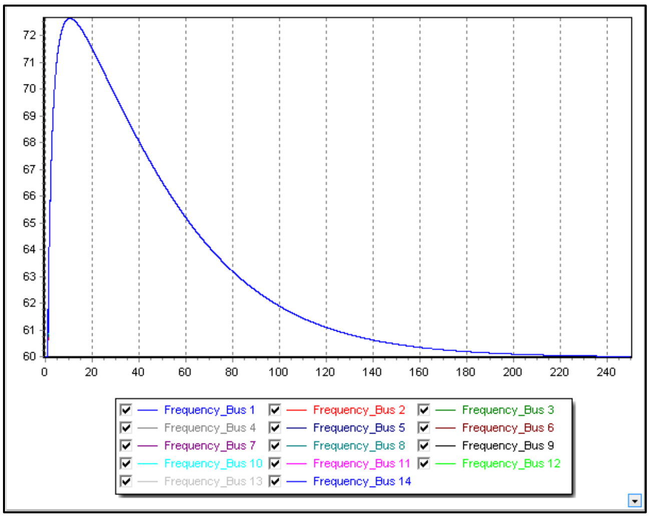

Figure 7. Frequency 14 bus system versus time with clearing time 1.15 seconds

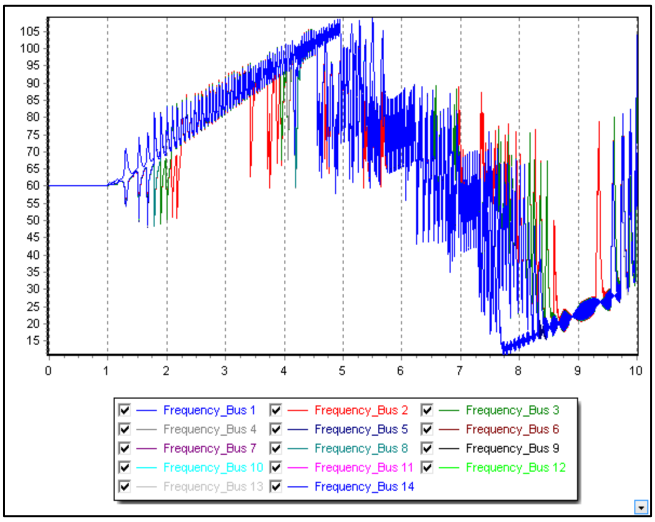

Figure 8. Frequency 14 bus system versus time with clearing time 1.16 seconds

4. Summary

The designed IEEE 14-bus system consists of 14 buses, 5 generators, 5 transformers and 11 loads. Transient stability analysis has been divided by three sub-analyses which is rotor angle stability, bus voltage stability, and frequency stability with respected to fault clearing time. In this analysis work, load flow studies are performed to analyse the transient stability of system. It can be concluded that Power system should be a very low critical clearing time to operate the relays. If the faulty section has been isolated within very short time, the system can maintain the stability otherwise it will go out of synchronism. Thus, the protection system provided for the system should have fast response. Besides, the impact of three-phase balanced fault location on system are clearly shows that the stability of the system is also dependent on location of the fault occurred. According to this analysis, fast fault clearing and fault location factors can be adopted for system stability.

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