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Transient Stability Control of Power System with Windmill Interaction

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Abstract: ***This paper presents a transient stability analysis for power system with wind farm interaction for different types of large perturbations such as three phase fault in power system. Power system integrated with wind mill may be exposed to various large disturbances such as three phase faults, short circuit faults etc, the unbalance caused by these faults can be addressed with the help of a power system stabilizer. This paper analyses the integrated power system grid with and without Power system stabilizer. The above mentioned conditions are realized by a simulation model in PSCAD and this simulation model is ran for results for a three phase fault in three phase circuit for different fault lasting durations.***

Keywords: PSCAD, Power system stability, power system stabilizer, transient stability, wind energy conversion systems.

1. Introduction

The modern power systems are extensively interconnected, as it provides operating flexibility, economy and reliability. Power system interconnection presents several benefits but along with that it also has some drawbacks. Due to interconnection power system may lead to various problems such as small signal stability, large signal stability, power quality, voltage fluctuations, power system unbalance, power system shut downs etc. As the interconnection has become a common practice now to meet the ever increasing demand of electricity, possible stability issues have also become significant.

Wind power demand in power systems is exceedingly mounting around the world as it is the most significant of all existing renewable energy sources present as of today. It offers several benefits such as pollution free electric power, cost friendly compared to other available renewable energy sources and short gestation time requisite for setting up wind mills. Wind flow is a great substitute to fossil fuels for electricity production as it is available in abundance and has no unpleasant environmental effect and it is competitively economical in comparison to conventional power generation if social and environmental costs are taken into account [1]-[9].

The exchange of power in the integrated system depends on angular separation between the rotors of the machines of generating units, during the synchronization of integrated system, generating units may be subjected to some sudden variations and there may be a probability that these variations may excite relative angular swings between synchronous machines which is already present in the system and doesn't die down out with time. These swings may further be triggered or enhanced by perturbations such as continuous load changes, three phase faults etc. these phenomena may hinder system stability at small scale or at large scale. Hence when interconnection is carried out damping controller such as a power system stabilizer is required [1]-[12].

The aim of this paper is to present a transient stability analysis of power system integrated with wind mill with and without a power system stabilizer for large disturbances such as a three-phase fault during synchronization and operation. This paper is organized as follows. In section 1 the paper was introduced. In section 2 an overview of power system stability and its types are described. In section 3 the power system stabilizer structure is presented. In section 4 the simulation model of power system integrated with wind mill is presented & discussed. In section 5 results and graphs obtained from simulation by PSCAD is presented & discussed. Finally, in section 6 the conclusions are summarized.

2. Power System Stability

Power system stability is that property of a power system that facilitates it to stay put in state of operating equilibrium under normal operating state and to reclaim an acceptable status of equilibrium after being exposed to a perturbation [11]-[17].

Types of power system stability:
- Rotor angle stability
- Voltage stability

Angular stability can further be subcategorized mainly into the following types:
- Small signal stability
- Transient stability

2.1 Rotor angle stability

Rotor angle stability is that property of a power system comprises of interconnected synchronous machines that facilitates it to stay put in synchronism when the system is exposed to miniature perturbations. These instability tribulations involve problems of electromechanical swings, which are inherent in power systems and may affect amount of power produced by synchronous machines and the interchange power between machines [11]–[17].

2.2 Small signal stability

Small signal stability is that property of a power system that facilitates it to uphold synchronism under miniature perturbations [11]-[17].

2.3 Transient stability

Transient stability is that property of a power system that facilitates it to preserve synchronism when exposed to large perturbations. In other words it is the ability of power system to retain its stability under large disturbances such as three phase faults, large load changes, short circuits, switching surges etc [11], [17].

3. Power System Stabilizer

Power system stabilizer is basically used in a power system to augment the system stability by further improving damping of oscillations. Besides improving damping PSS should not apply changes in the system in steady state condition when it is not required. Different components of power system stabilizer are shown in Figure 1 below in the structure diagram of PSS:

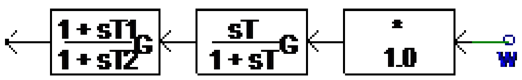

Figure 1: Structure of PSS

PSS input signal is generally taken from a filter, which generally is represented by a 1st order transfer function. Washout Circuit ensures no operation of PSS in steady state condition.

Washout circuit is represented by transfer function $\frac{sT}{1+sT}$ which has unity gain for high frequency and for low frequency gain of the transfer function is zero hence it passes the transient signals and blocks the steady state values and so limits operation of PSS in steady state condition. Compensator provides lead-lag phase shift to the input signal. Limiter limits the PSS operation i.e. ensures that PSS doesn't alter reference value of Automatic Voltage Regulator beyond a limit [18]-[24].

4. Line Diagram of Simulation Model in PSCAD

In this paper an integrated system is realized as shown in Figure 2 in PSCAD by connecting two three-phase voltage source components modeling two 132 kV generators at two buses of 4-bus system, in which one generator is an ideal source and the other is with some load angle. These buses are connected by a 200 KM long transmission line forming a power system grid. Wind mill generator is connected at another bus with one of the generators via a step up transformer for generated power transfer. In the simulation model a power system stabilizer is introduced as damping controller, the synchronous generator connected to the wind mill turbine has an exciter connected for excitation control, this exciter offers option to connect or disconnect the PSS for simulating integrated system response with and without PSS.

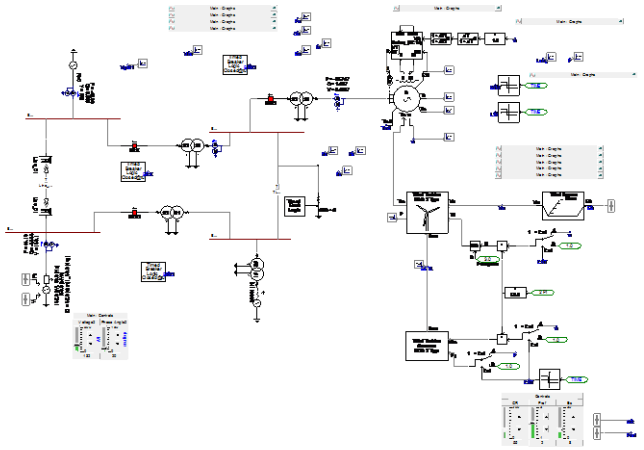

Figure 2: Line Diagram of Simulation Model in PSCAD

5. Results & Discussions

The simulation model of integrated power grid is simulated using PSCAD for transient stability. The integrated system's transient stability is analysed by creating a three-phase fault and by observing the system behaviour under effect of this transient with and without PSS. Simulation in PSCAD is ran for 30 seconds for analysing the changing behaviour of power system integrated with wind mill under the presence of a three phase faults for different fault lasting durations and various results obtained for the integrated system are as under:

5.1 When there is a three phase fault at time 10.0 s and the fault duration is 0.1s

The changes in integrated system behavior are analyzed by creating a three phase fault at 10 sec and for the duration of 0.1 sec.

5.1.1 Plot of Grid voltage

Plot of Grid voltage (kV) against time (sec) at steady state condition before the application of fault is obtained by simulation as under:

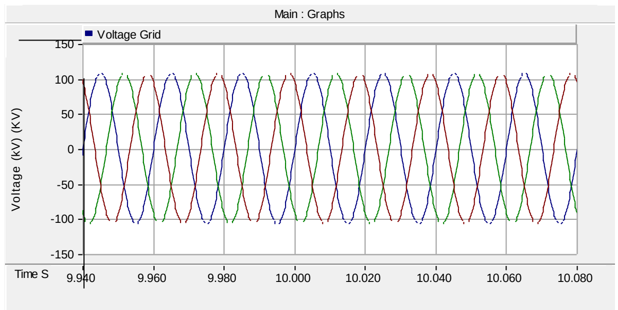

Figure 3: Grid voltage (kV) against time (sec) for steady state condition

5.1.2 Plot of Voltage

Plot of Voltage (kV) against time (sec) obtained by simulation is shown in Figure 4 depicts the changes in Grid Voltage in kV against time when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.1 sec:

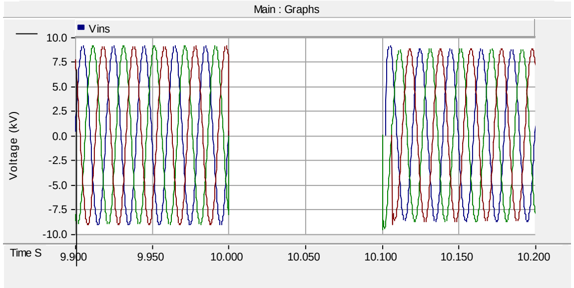

Figure 4: Voltage (kV) against time (sec) for a 3-phase fault of 0.1 sec duration

5.1.3 Plot of Fault current

Plot of Fault current (kA) against time (sec) obtained by simulation is shown in Figure 5 depicts the Fault current (kA) in the grid against time (sec) for the three phase fault of 0.1 sec duration:

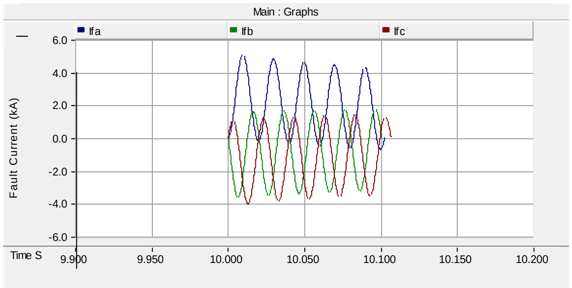

Figure 5: Fault current (kA) against time (sec) for 0.1 sec

5.1.4 Plot of Active power

Plot of Active power against time (sec) with and without PSS, obtained by simulation is shown in Figure 6 depicts the changes in Active power against time (sec) with and without PSS when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.1 sec. Changes in Active power with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be observed from the below plot that at t = 10 sec, there is no magnitude difference in Active power oscillations but at t = 12 sec, oscillations in Active power are from 2 to 2.8 without PSS and from 2 to 2.5 with PSS, which depicts decease in magnitude of oscillation by 37.5%. At t = 14 sec, oscillations are from 2 to 2.4 without PSS and from 2 to 2.1 with PSS, which shows oscillation decrement by 75%. At 15 sec the decrement is almost 100%.

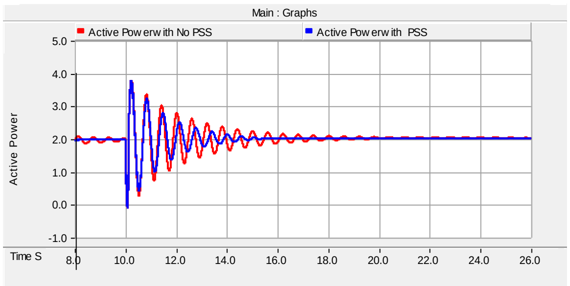

Figure 6: Active power against time (sec) for a 3-phase fault of 0.1 sec duration with and without PSS

5.1.5 Plot of Machine Electrical torque

Plot of Machine Electrical torque (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 7 depicts the changes in Machine Electrical torque (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec at lasted for the duration of 0.1 sec. Changes in Machine Electrical torque with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be observed from the below plot that at t = 10 sec, there is no magnitude difference in oscillations but at t = 12 sec, oscillations are from 1 to 1.50 without PSS and from 1 to 1.25 with PSS, which depicts decease in magnitude of oscillation by 50%. At t = 14 sec, oscillations are from 1 to 1.25 without PSS and from 1 to 1.12 with PSS, which shows oscillation decrement by 52%. At 15 sec the decrement is almost 100%.

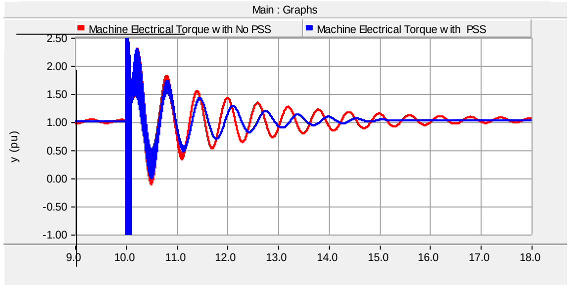

Figure 7: Machine Electrical torque (pu) with and without PSS for a 3-phase fault of 0.1 sec duration with and without PSS

5.1.6 Plot of Speed of generator

Plot of Speed of generator (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 8 depicts the changes in Speed of generator (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.1 sec. Changes in Speed of generator with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can observed from the below plot that at t = 10 sec, there is no magnitude difference in oscillations but at t = 12 sec, oscillations are from 1 to 1.0080 without PSS and from 1 to 1.0062 with PSS, which depicts decease in magnitude of oscillation by 22.50%. At t = 14 sec, oscillations are from 1 to 1.0030 without PSS and from 1 to 1.0012 with PSS, which shows oscillation decrement by 60%. At 15 sec the decrement is almost 100%.

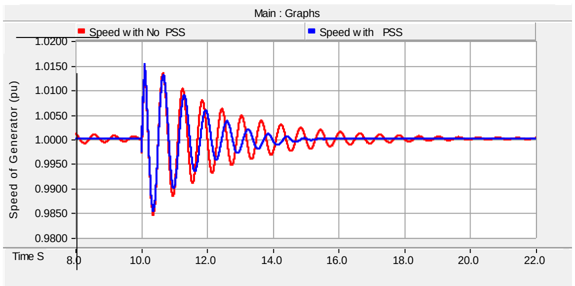

Figure 8: Speed of generator (pu) against time (sec) for a 3-phase fault of 0.1 sec duration with and without PSS

5.2 When there is a three phase fault at time 10.0 s and the fault duration is 0.2s

The changes in integrated system behavior are analyzed by creating a three phase fault at 10 sec and this time with 0.1 sec increase in the fault duration i.e. system analyzed under the effect of fault for 0.2 sec.

5.2.1 Plot of Voltage

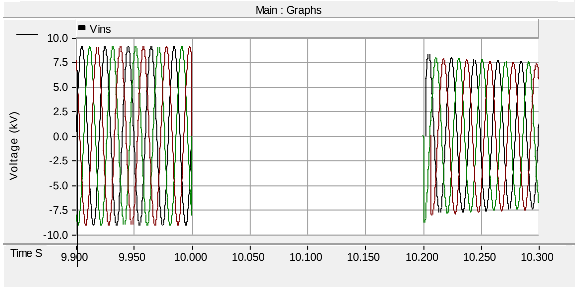

Figure 9: Voltage (kV) against time (sec) for a 3-phase fault of 0.2 sec duration

Plot of Voltage (kV) against time (sec) obtained by simulation is shown in Figure 10 depicts the changes in Grid Voltage in kV against time when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.2 sec:

5.2.2 Plot of Fault current

Plot of Fault current (kA) against time (sec) obtained by simulation is shown in Figure 10 depicts the Fault current (kA) in the grid against time (sec) for the three phase fault of 0.2 sec duration.

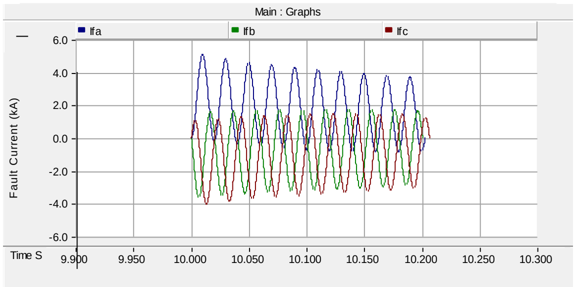

Figure 10: Fault current (kA) against time (sec) for 0.2 sec

5.2.3 Plot of Active power

Plot of Active power against time (sec) with and without PSS, obtained by simulation is shown in Figure 11 depicts the changes in Active power against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.2 sec. Changes in Active power with PSS is depicted by blue plot and changes without PSS is depicted by red plot, where it can be observed from the below plot that at t = 10 sec, there is no magnitude difference in oscillations but at t = 12 sec, oscillations are from 2 to 4.1 without PSS and from 2 to 3.2 with PSS, which depicts decease in magnitude of oscillation by 42.85%. At t = 14 sec, oscillations are from 2 to 3.0 without PSS and from 2 to 2.45 with PSS, which shows oscillation decrement by 55%. At 17 sec the decrement is almost 100%.

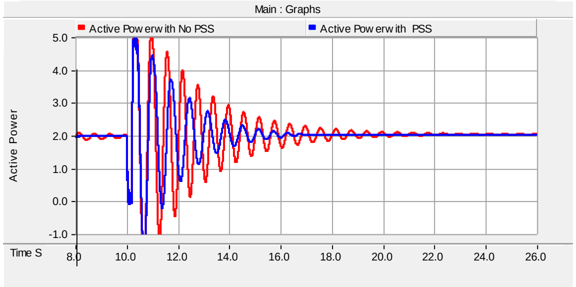

Figure 11: Active power against time (sec) for a 3-phase fault of 0.2 sec duration with and without PSS

5.2.4 Plot of Machine Electrical torque

Plot of Machine Electrical torque (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 12 depicts the changes in Machine Electrical torque (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec at lasted for the duration of 0.2 sec. Changes in Machine Electrical torque with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be observed from the below plot that at t = 10 sec, there is no magnitude difference in oscillations but at t = 12 sec, oscillations are from 1 to 2.2 without PSS and from 1 to 1.70 with PSS, which depicts decease in magnitude of oscillation by 41.67%. At t = 14 sec, oscillations are from 1 to 1.50 without PSS and from 1 to 1.25 with PSS, which shows oscillation decrement by 50%. At 17 sec the decrement is almost 100%.

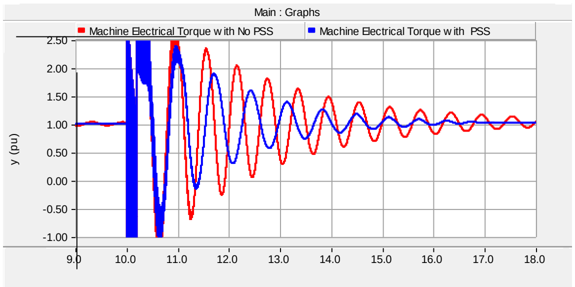

Figure 12: Machine electrical torque (pu) against time (sec) for a 3-phase fault of 0.2 sec duration with and without PSS

5.2.5 Plot of Speed of generator

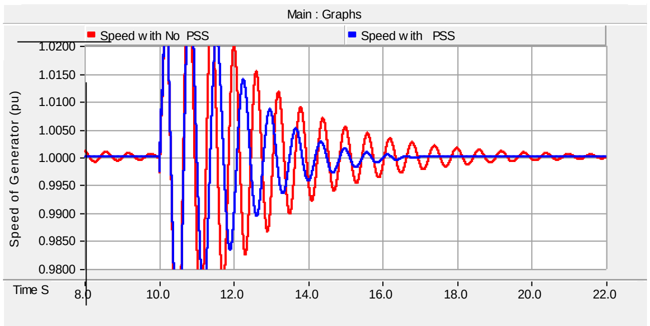

Figure 13: Speed of Generator with and without PSS against time (sec) for a 3-phase fault of 0.2 sec duration with and without PSS

Plot of Speed of generator (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 13 depicts the changes in Speed of generator (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.2 sec. Changes in Speed of generator with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be observed from the below plot that at t = 10 sec, there is no magnitude difference in oscillations but at t = 12 sec, oscillations are from 1 to 1.0200 without PSS and from 1 to 1.0140 with PSS, which depicts decease in magnitude of oscillation by 30%. At t = 14 sec, oscillations are from 1 to 1.0090 without PSS and from 1 to 1.0050 with PSS, which shows oscillation decrement by 44.44%. At 17 sec the decrement is almost 100%.

5.3 When there is a three phase fault at time 10.0 s and the fault duration is 0.3s

The changes in integrated system behavior are analyzed by creating a three phase fault at 10 sec and again by increasing the duration of fault by 0.1 sec i.e. this time the integrated system analyzed under the effect of fault duration of 0.3 sec.

5.3.1 Plot of Voltage

Plot of Voltage (kV) against time (sec) obtained by using simulation is shown in Figure 14 depicts the changes in Grid Voltage in kV against time when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.3 sec:

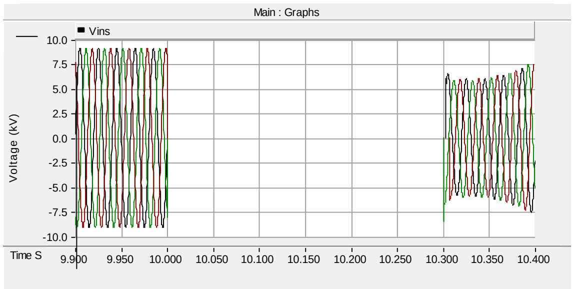

Figure 14: Grid voltage (kV) against time (sec) for a 3-phase fault of 0.3 sec duration

5.3.2 Plot of Fault current

Plot of Fault current (kA) against time (sec) obtained by simulation is shown in Figure 15 depicts the Fault current (kA) in the grid against time (sec) for the three phase fault of 0.3 sec duration:

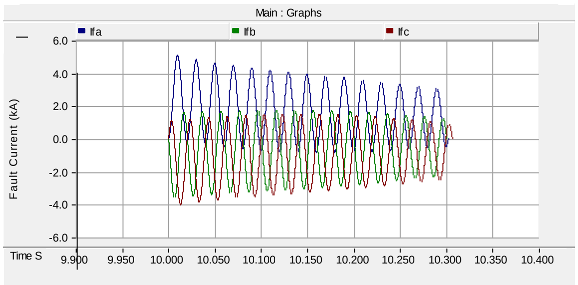

Figure 15: Fault current (kA) against time (sec) for 0.3 sec

5.3.3 Plot of Active power

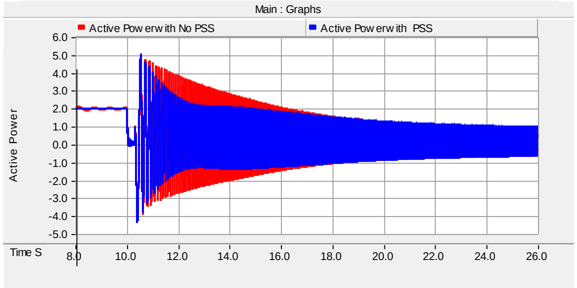

Figure 16: Active power against time (sec) for a 3-phase fault of 0.3 sec duration with and without PSS

Plot of Active power against time (sec) with and without PSS, obtained by simulation is shown in Figure 16 depicts the changes in Active power against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec and lasted for the duration of 0.3 sec. Changes in Active power with PSS is depicted by blue plot and changes without PSS is depicted by red plot, where it can be observed from the below plot that between t = 10 to 11 sec, there is no significant magnitude difference in oscillations but at t = 12 sec, oscillations are from 2 to 4 without PSS and from 2 to 2.5 with PSS, which depicts decease in magnitude of oscillation by 75%. At t = 14 sec, oscillations are from 2 to 2.9 without PSS and from 2 to 2.1 with PSS, which shows oscillation decrement by 88.89%. At 18 sec PSS seize to damp oscillations.

5.3.4 Plot of Machine Electrical torque

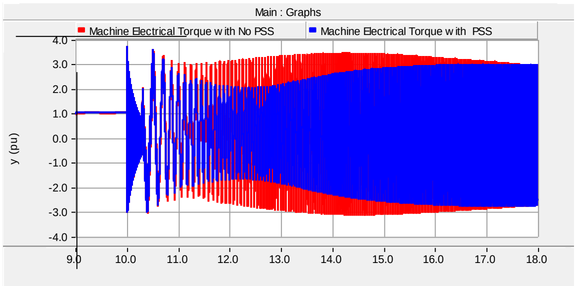

Figure 17: Machine electrical torque (pu) against time for a 3-phase fault of 0.3 sec duration with and without PSS

Plot of Machine Electrical torque (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 17 depicts the changes in Machine Electrical torque (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec at lasted for the duration of 0.3 sec. Changes in Machine Electrical torque with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be observed from the below plot that between t = 10 to 11 sec, there is no significant magnitude difference in oscillations but at t = 12 sec, oscillations are from 1 to 3 without PSS and from 1 to 2.1 with PSS, which depicts decease in magnitude of oscillation by 40%. At t = 14 sec, oscillations are from 1 to 3.5 without PSS and from 1 to 2.5 with PSS, which shows oscillation decrement by 40%. At 17.5 sec PSS seize to damp oscillations.

5.3.5 Plot of Speed of generator

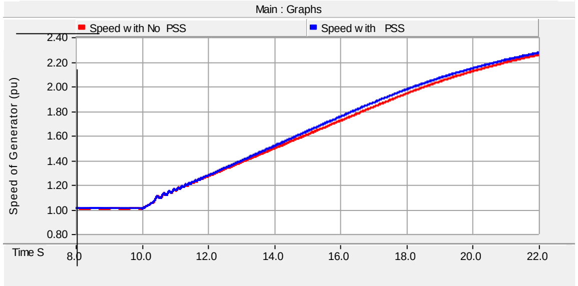

Figure 18: Speed of generator (pu) against time (sec) for a 3-phase fault of 0.3 sec duration with and without PSS

Plot of Speed of generator (pu) time (sec) with and without PSS, obtained by simulation is shown in Figure 18 depicts the changes in Speed of generator (pu) against time (sec) with and without a PSS when the integrated system is subjected to a three phase fault starting at 10 sec at lasted for the duration of 0.3 sec. Changes in Speed of generator with PSS is depicted by blue curve and changes without PSS is depicted by red curve, where it can be seen that even in the presence of PSS transient oscillations don't damp out and increases continuously.

6. Conclusions

The behaviour of power system integrated with wind mill is analysed for a three phase fault with different lasting durations with the help of simulation in PSCAD. For transient stability analysis of integrated system a three-phase fault of duration 0.1 second is introduced at t = 10 sec in the three-phase circuit and the integrated model is simulated with and without power system stabilizer, from the simulation results obtained it is observed that transients don't die down completely in the system without PSS but with PSS transient oscillations damped out in 5 sec of operation. Similar results are obtained with fault duration of 0.2 seconds that transients don't die down completely in the system without PSS but with PSS transient oscillations damped out in 7 sec of operation, it is also observed that with the PSS, magnitude of oscillations significantly decreased. In the end when duration of fault is increased to 0.3 seconds at t = 10 sec in the three-phase circuit and the integrated model is simulated with and without power system stabilizer, from the simulation results it is observed that although the magnitude of oscillations decreased with PSS but the transients don't die down completely in the system with or without PSS.

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Author Profile

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