International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 6, Issue 09, PP. 275-279, September 2019
https://www.ijew.io/
https://doi.org/10.34259/ijew.19.609275279

Mitigating Low Frequency Oscillations in Interconnected Power System

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Received: 20 August, Revised: 26 August, Accepted: 05 September

***Abstract*—** Low frequency oscillations are one of the major causes which reduce the capabilities of power system. Low frequency oscillations (LFO) have taken the attention of engineers therefore different techniques are introduced. This paper will help out to damp low frequency oscillations using one of the best and effective technique i.e. Power system stabilizer (PSS). Since among various techniques power system stabilizer has taken the attention by working effectively to damp low frequency harmonics. The model will is implemented using Simulink and the graphical results are analyzed and compared. The system efficiency is improved up to 82%, by employing power system stabilizer.

***Keywords*—** LFO, PSS, Harmonics, AVR.

I. Introduction

Interconnected arrangement is used for power systems which make it complicated and complex. Due to interconnection systems constantly variations are experienced in generation, transmission and distribution of electric power. The main problem of interconnected power system stability is low frequency oscillations. As stability is the prime goal in electric power system [1]. Constantly complications occurring in power system have initiate curiosity for developing best and effective solution for PSS to damp out LFO. Largely interconnected power system causes the system spontaneously affected by very low frequencies. In oscillatory mode electromechanical oscillations are called as weak damping, ranging 0.2-0.3Hz, and if once they started, they continue for long time period. In some cases they leave a severe effect on system, like they continue to grow which cause system separation and limits the power transfer if bold steps are not followed to damp LFO or small signal stability.

The tendency of synchronous machine of interconnected power system to remain run & step and synchronized with each other after being perturbed by small disturbance is known as small signal stability. This stability depends on the skill of maintaining equilibrium between electromechanical and mechanical torques connected to power systems [2]. The perturbation followed by change in electromechanical torque of synchronous machine can be resolved by two components "synchronizing torque component in phase with rotor angle deviation" and "a damping torque component in phase with speed deviation". LFOs are generator rotor angle oscillations having frequency 0.2-0.3 Hz or 0.1- 2.0 Hz (generally) and they are classified according to their source of oscillations. In earliest age of power system development the oscillations were almost zero (non-observable) this was due to close connection of generators and loads. But now days due to increase demand, electric power systems are installed farthest from load. Due to which power is transmitted through long transmission line which increase the power oscillations [3][4]..The basic cause of oscillations is the difference between the demand and generation. Therefore to maintain power system stability, PSS are used.

Power system stability [5] is the ability of an electric power system, for a given initial operating condition, to regain astate of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. PSS [6,7] is a controller device which is installed in synchronous machine to damp LFO. The working principle of PSS [8, 9] is to add damping to generator rotor oscillations by controlling its excitation by using auxiliary stabilizing signals or it can explain as PSS [10] is aid for damping oscillations via modulations of excitation system of generators. For damping purpose stabilizer produces electrical torque on rotor which is in phase with speed variations. This control is beneficial for large power transfers [11,12]. However, in certain conditions when the negative damping effects of PSS on rotor occur then the power system instabilities arises. The reason behind negative damping effects is that PSS [13,14] is tuned around steady- state operating point. And at this operating point the damping effect is only valid for small excursions. At severe disturbances this may happen that PSS cause the generator under its control to lose synchronism in an attempt to control its excitation field [15].

Thus, the aim of this paper is to damp the unrequired low frequency oscillations. Since LFOs are harmful for power system stability. Therefore the latest and updated technique is used i.e. power system stabilizer. There are many phases from which the signals are passed and due to which LFOs are extracted from the power system.

II. PROBLEM STATMENT

Power production with good quality is the main objective of every power utility company so that their generation, transmission, distribution of electrical power is efficient and the consumers are satisfied. Most of the power systems suffers from various unwanted internal generators effects such as production of low frequency oscillations and harmonics. This is due the difference between the rotor angle and the pole. To overcome this hazardous problem, we proposed a solution to which is a control system that will sense the synchronous generator transient response and will provide feedback signal to reduce the low frequency oscillations and make the system stable. By employing this method, the overshoot will be reduced and the response will be approximately smooth.

III. METHODOLGY

The block diagram of PSS is shown in Figure 1. to understanding the structure. It contains washout

filter, gain block, phase compensator block and input signal.

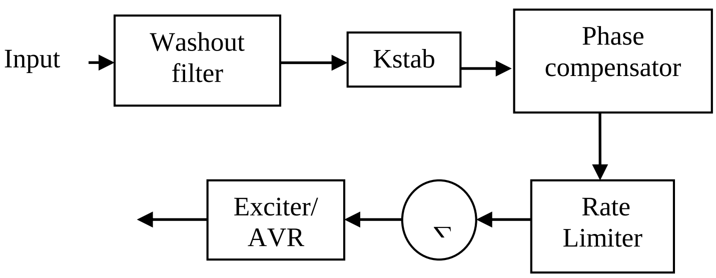

Figure 1: Block Diagram of PSS

A. *Washout filter:*

Washout filter works as high pass filter, with time constant Tw, which is high enough and allow signal to pass unchanged which are associated with oscillations in wr. It is important because without it steady variations in speed would modify the terminal voltage. It allows PSS to react only to make changes in speed. According to washout function, the Tw value isn't critical and it may ranges from 1 to 20 seconds. It diminishes dc component present in input signal.

B.Gain block:

The stabilizer gain finds the amount of damping introduced by PSS. The value of gain should be set according to maximum damping (ideally) but it is often limited by other considerations. Generally its value is set between 2 to 10.

C. *Phase compensator block:*

Phase compensation provides appropriate phase-lead characteristics to compensate the phase-lag between the exciter input and generator torque.

D. *Input signal:*

Input signals that have been identified as valuable include deviations in rotor speed ($\Delta\omega$), the frequency (Δf), the electrical power (ΔPe) and the accelerating power (ΔPa). Since main function of PSS is to control rotor oscillations. In this paper speed signal is used as input signal.

E.Exciter /AVR:

Automatic voltage regulator (AVR) is connected PSS and it inject signal at summing junction. AVR with PSS is connected to generator to control its terminal voltage by adjusting excitation voltage at rotor side of it. To evaluate performance of PSS SMIB is used (single machine infinite bus), which will explain later. Generator connected with AVR and PSS is connected to infinite bus by transmission line and some disturbances are produced to create oscillations in power system.

F. *Rate limiter:*

PSS output requires limits in order to prevent conflicts with AVR actions during load rejection. The AVR acts to reduce the terminal voltage while it increases the rotor speed and bus frequency. Thus, PSS is compelled to counteract and produce more positive output .the negative and positive limit should be around the AVR set point to avoid any counteraction. The positive limit of PSS output voltage contributes to improve transient stability in first swing during fault. The negative limit appears to be very important during the backswing of rotor.

The system is designed and simulated using Simulink and the analysis is performed. The Power System Stabilizer is incorporated with the synchronous generator as feedback element. The rest of power system comprised of three phase Transmission lines, RLC Loads, Transformers, SPDT Switches and Scopes. The results of the system response is observed with and without power system stabilizer. Both results are compared graphically and the conclusion is obtained by analyzing those figures. The algorithm of the project is illustrated below which indicate the step by step sequence of the power system stabilizer operation during transient state.

IV. FLOW CHART

The algorithm for power system stabilization is depicted in the flow chart as shown in fig. 2. First the system is run and then the synchronous generator response is determined. This response is compared with ideal variables and when the system response is unstable then the PSS feedback run and optimizes the parameters. After the response gets smooth and stable, the whole results are displayed on scope windows.

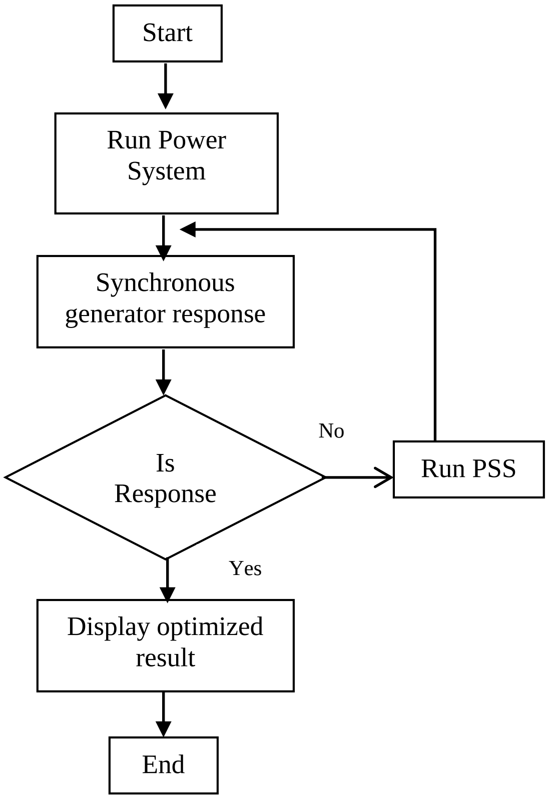

Figure 2 Flow chart of the PSS

V. RESULTS

Following are results of models and their results without PSS and with PSS. Figure: 3 shows the synchronous generator response is obtained without using the PSS Controller. It can be clearly seen in the above Simulink model that the switch is open which is installed between synchronous generator and PSS. The results are obtained on scope windows.

Figure: 4 scope windows show the rotor deviation angle, output active power, output reactive power and stable voltage level from Excitation system. The results show that the rotor deviation angle increases from zero which is undesired. The output active power is variable and is not smooth. Same is the case for the reactive power and stable voltage level

Figure:5 shows switch is now closed which connects the synchronous generator and feedback system. The results are depicted on the scope which shows much improvement all the parameters.

Figure: 6 describes that the rotor deviation angle is near to zero which is desired. The output active power is also smooth which is suitable for loads. Same is the case for reactive power and stable voltage levels. From these graphical results it is clear that by using PSS, the performance of power system and its efficiency improves to the required level.

CONCLUSION

This paper is proposed for the development of a model to overcome the unstable behavior during transient state. The PSS compensator filter out all the unnecessary effects and the improved response is obtained. The results comparison shows that the synchronous generator response oscillatory and increases with time which moves into unstable region of operation. The rotor deviation angle increases from zero to onward which produces the harmonics. Also the output active power is variable which is not desired to the end loads. Similarly, the reactive power shows variable and not constant. On the other hand, by employing Power system stabilizer in feedback with the generator, the system responses show a better and stable behavior. The rotor deviation angle is almost zero as well as the active and reactive power values. Therefore, it is concluded that PSS play an important role for improving power system stability.

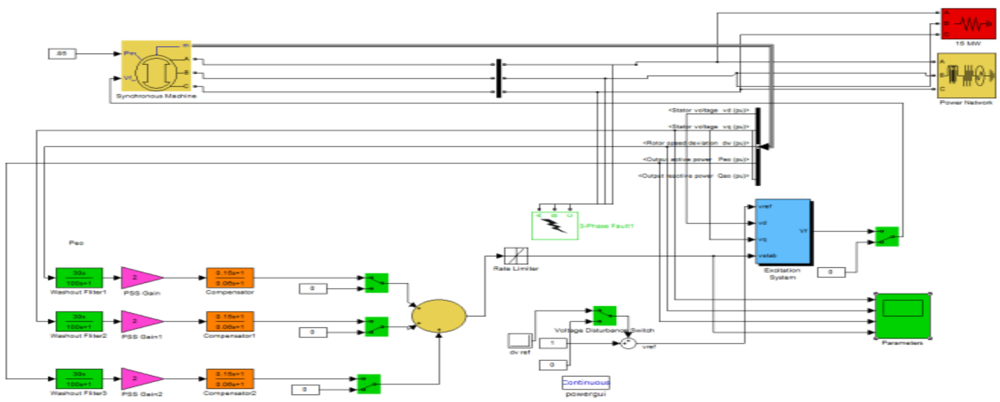

Figure: 3 Simulink Model without Power System Stabilizer Feedback

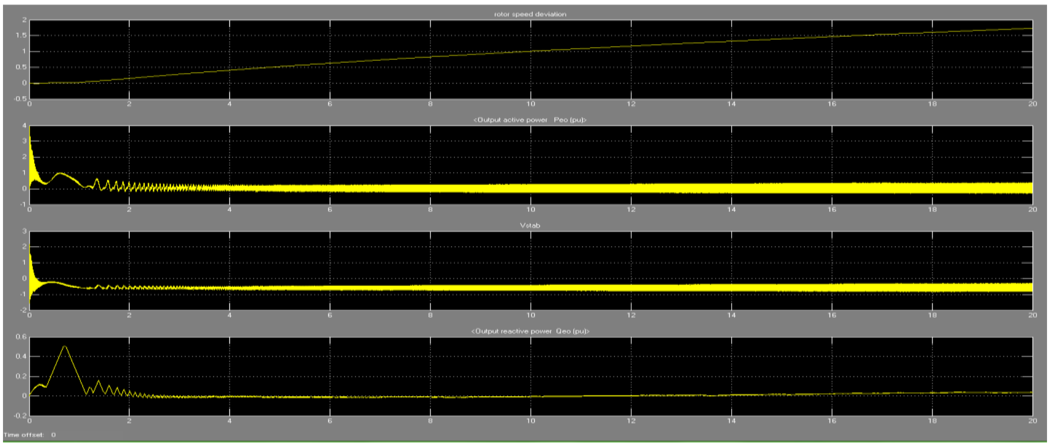

Figure: 4 Simulink Model without Power System Stabilizer Feedback Result

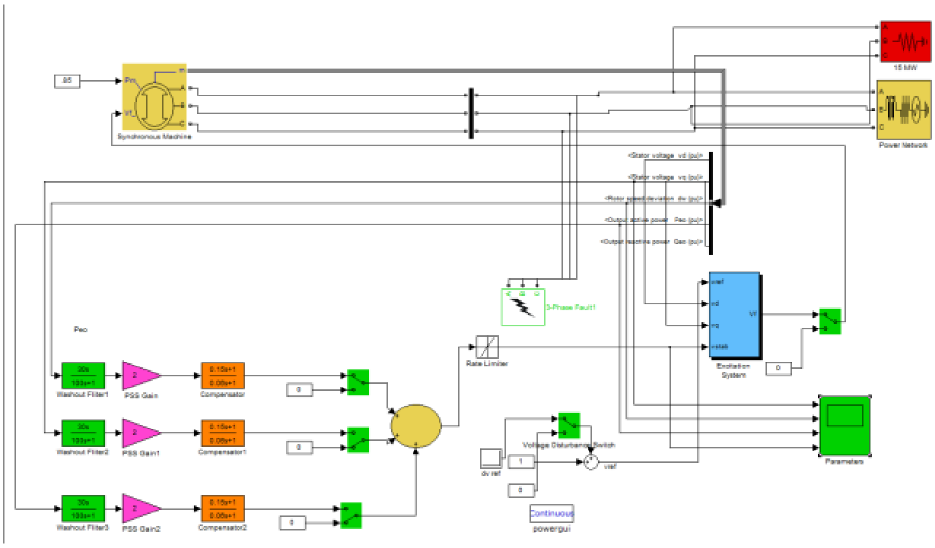

Figure: 5 Simulink Model with Power System Stabilizer

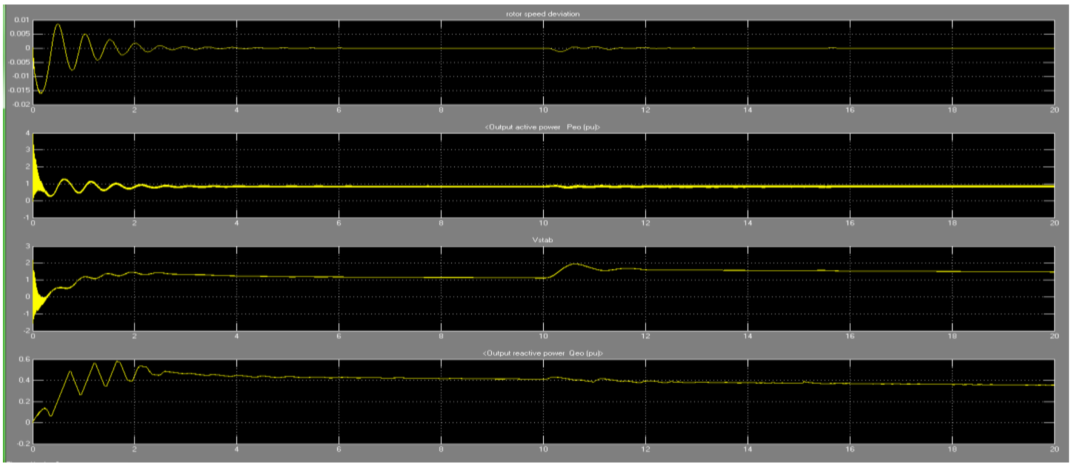

Figure: 6 Simulink Model with Power System Stabilizer

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