Voltage Stability Analysis using PSS in Imo State Nigeria Network

Owolabi Moses Idowu
Electrical Electronics Department,
Federal Polytechnic Nekede, Owerri.
mosesidowu1@gmail.com

Abstract

The action of a power system stabilizer (PSS) is to extend the angular stability limits of a power system by providing a supplementary damping to the oscillation of synchronous machine motors through the generator excitation. PSS controller design, method of combining the PSS with the excitation controller (AVR), investigation of the voltage of the network, how much load in the form of loading parameter are all done in this paper. Power system analysis toolbox (PSAT) was used to analyze the network to compare when PSS is not included and when it is included in the network. The network considered is the Imo state (Eastern part of Nigeria) network. The network consists of three (3) generators and eleven buses. After the simulation, it can clearly be seen that when PSS is not used all the buses were violated running a continuation power flow (CPF) method, but when PSS is added, there is no violation at the point of collapse. The loading factor increased when PSS is added (6.0513pu) as compared to when PSS is not added (1.0561pu). It can be concluded from the result that PSS will greatly improve the existing network both in the area of stabilizing the voltage and also to add more load into the network.

Keywords: Power system stability, Power System Stabilizers (PSS), voltage violation

INTRODUCTION

The tendency of a power system to develop a restoring forces equal to or greater than the disturbance forces to maintain the state of equilibrium is known as stability. If the forces tending to hold machines in synchronism with one another are sufficient to overcome the disturbing forces, the system is said to remain stable.

Disturbances in power systems can cause instabilities that may lead to system shut down. Stabilizing measures or controls are used to improve system performance upon an occurrence of disturbances. Effective amelioration and sustained power system oscillators have presented a major challenge to the electricity supply industry. Considering the stability problem of power systems, it has become very important that an effective stabilizer that could take care of this electromagnetic oscillation in power system is designed. For the purpose of this paper, power system stabilizers are use to investigate the Owerri electrical network (subsection of the Nigerian network).

Literature Review

Power system dynamic performance is improved by the damping of system oscillations. Generally, there are two kinds of power oscillation damping controllers in power systems: PSS and FACTS controllers [1-5]. PSS is widely used in the electric power industry for improve the performance and functions of power systems during normal and abnormal operations. It can increase the system positive damping, improve the steady-state stability margin, and suppress the low-frequency oscillation of the power system [6-12]. Design and application of PSS has been the subject of continuing development for many years. All part of the PSS topics are numerous and various. These are classified as: (a) mathematical modeling and proper signal selection, (b) finding the optimal placement of PSS, (c) coordination between the PSS and the FACTS, (d) the optimal parameters of the controller, and effect of PSS on system stability [13-21]. A field test to adequately assess the oscillation damping effectiveness of the PSS in a multi-generator power plant is presented in [22], which the test allows estimating the location of the dominant open-loop poles from frequency response measurements of the closed-loop multivariable system.

MATERIAL AND METHOD

Power system stabilizer

The basic function of a power system stabilizer is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal(s). To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed deviations. It is well established that fast acting exciters with high gain AVR can contribute to oscillatory instability in power systems. This type of instability is characterized by low frequency (0.2 to 2.0 Hz) oscillations which can persist (or even grow in magnitude) for no apparent reason. This type of instability can endanger system security and limit power transfer. The major factors that contribute to the instability are

- Loading of the generator or tie line
- Power transfer capability of transmission lines
- Power factor of the generator (leading power factor operation is more problematic than lagging power factor operation)
- AVR gain.

A cost efficient and satisfactory solution to the problem of oscillatory instability is to provide damping for generator rotor oscillations. This is conveniently done by providing Power System Stabilizers (PSS) which are supplementary controllers in the excitation systems. The objective of designing PSS is to provide additional damping torque without affecting the synchronizing torque at critical oscillation frequencies. It can be generally said that need for PSS will be felt in situations when power has to be transmitted over long distances with weak AC ties. Even when PSS may not be required under normal operating conditions, they allow satisfactory operation under unusual or abnormal conditions which may be encountered at times. Thus, PSS has become a standard option with modern static exciters and it is essential for power engineers to use these effectively. Substituting of existing excitation systems with PSS may also be required to improve system stability.

If the exciter transfer function and the generator transfer function between ΔE_{fd} and ΔT_e were pure gains, a direct feedback of $\Delta\omega_r$ would result in a damping torque component. However, in practice both the generator and the exciter exhibit frequency dependent gain and phase characteristics. Therefore, the PSS transfer function $G_{pss}(s)$ should have appropriate phase compensation circuits to compensate for the phase lag between the exciter input and the electrical torque. In the ideal case, with the phase characteristic of $G_{pss}(s)$ being an exact inverse of the exciter and generator phase characteristics to be compensated, the PSS would result in a pure damping torque at all oscillating frequencies. Figure 3.1 shows the block diagram of the excitation system, including the AVR and PSS. The PSS representation in Figure 3.1 consists of three blocks: a phase compensation block, a signal washout block, and a gain block.

The phase compensation block provides the appropriate phase lead characteristic to compensate for the phase lag between the exciter input and the generator electrical (air-gap) torque. The figure shows a single first-order block. In practice, two or more first-order blocks may be used to achieve the desired phase compensation. In some cases, second-order blocks with complex roots have been used. Normally, the frequency range of interest is 0.1 to 2.0 Hz and the phase- lead network should provide compensation over this entire frequency range.

The phase characteristic to be compensated changes with system conditions; therefore, a compromise is made and a characteristic is acceptable for different system conditions is selected. Generally, some under compensation is desirable so that the PSS, in addition to significantly increase the damping torque, results in a slight increase of the synchronizing torque.

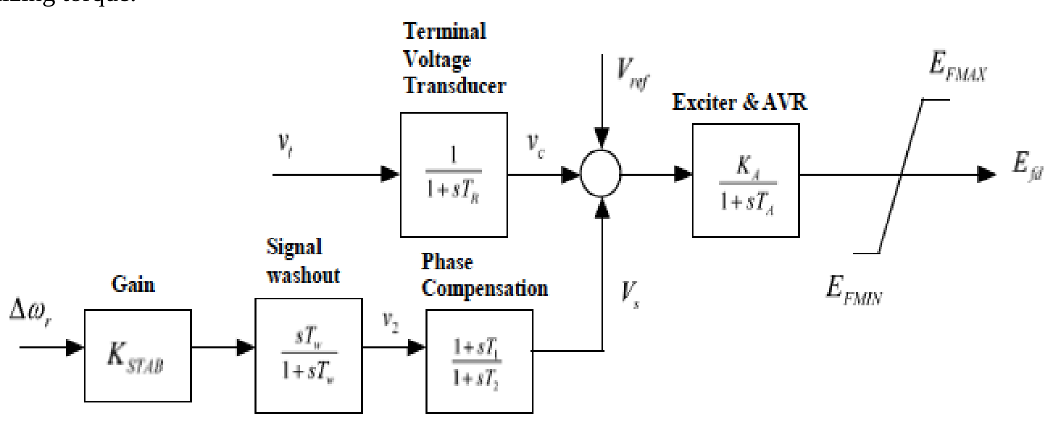

Fig. 1: Block diagram of thyristor excitation system with AVR and PSS

The signal washout block serves as a high-pass filter, with the time constant T_w high enough to allow signals associated with oscillations in ω_r to pass unchanged. Without it, steady changes in speed would modify the terminal voltage. It allows the PSS to respond only to changes in speed. From the view point of the washout function, the value of T_w is not critical and may be in the range of 1 to 20 seconds. The main consideration is that it is long enough to pass stabilizing signals at the frequencies of interest unchanged, but not so long that it leads to undesirable generator voltage excursions during system-islanding conditions.

The stabilizer gain determines the amount of damping introduced by the PSS. Ideally, the gain should be set at a value corresponding to maximum damping; however, it is often limited by other considerations.

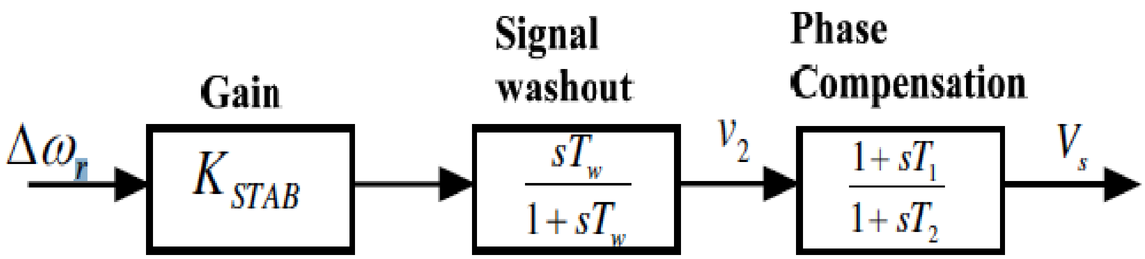

Figure 2: Block diagram of PSS

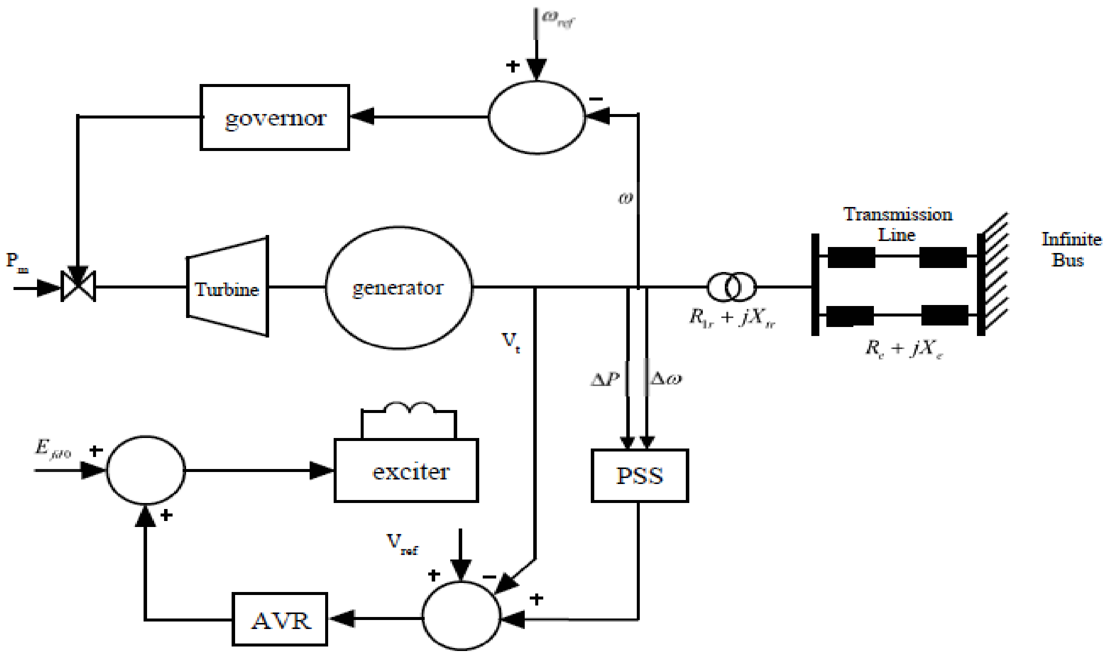

Figure 3: Power system configuration with PSS

Imo state network

The Imo state network is eleven bus with three generators network. The generators are two 60MW coming from Alaoji 1 and Alaoji 2, and 40MW coming from Afam power plant. The diagram of the network with MATLAB Simulink is presented in the figure below;

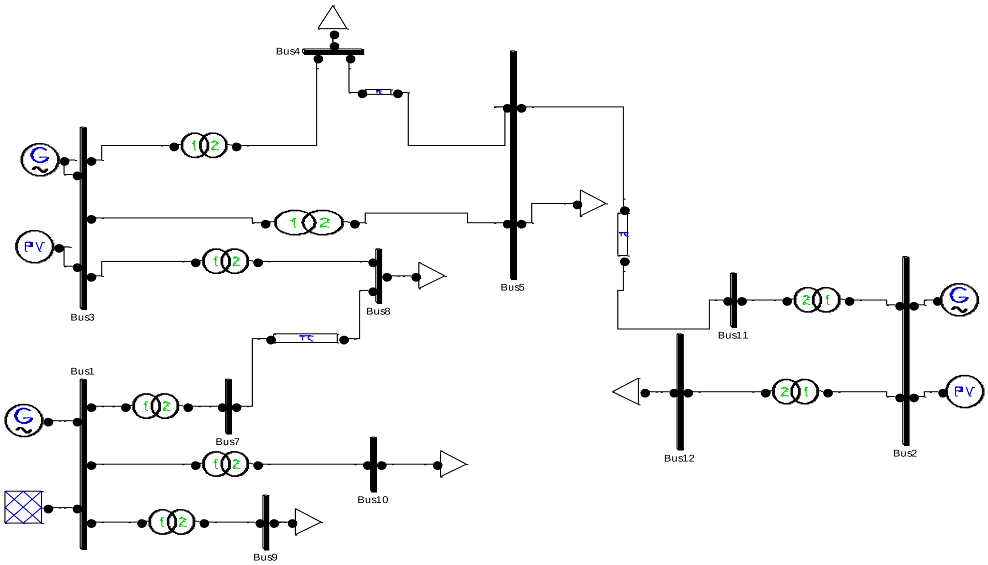

Figure 4: MATLAB SIMULINK describing Owerri network without PSS

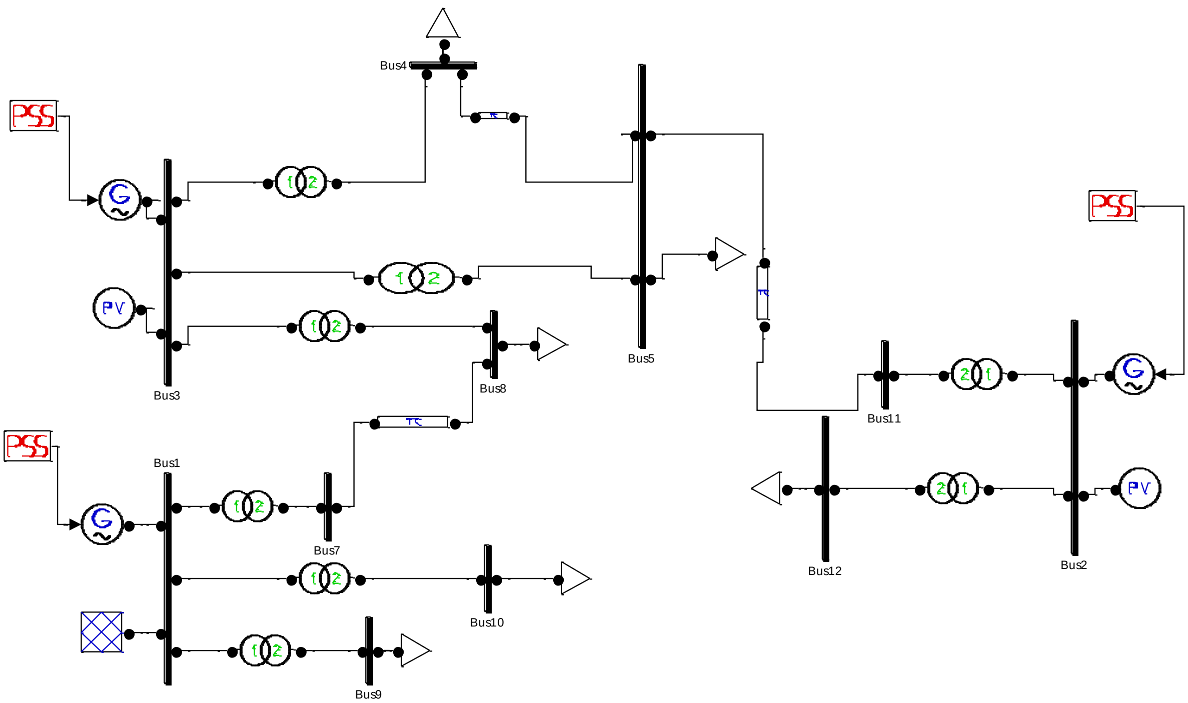

Figure 5: MATLAB SIMULINK describing Owerri network with PSS

RESULTS

Table 1: Results for the MATLAB simulation

Type	Voltage violation	Maximum loading	Real power losses	Reactive power losses
Without PSS	All buses	1.0561	0.00703	0.10156
With PSS	1	6.2257	0.00508	0.07989

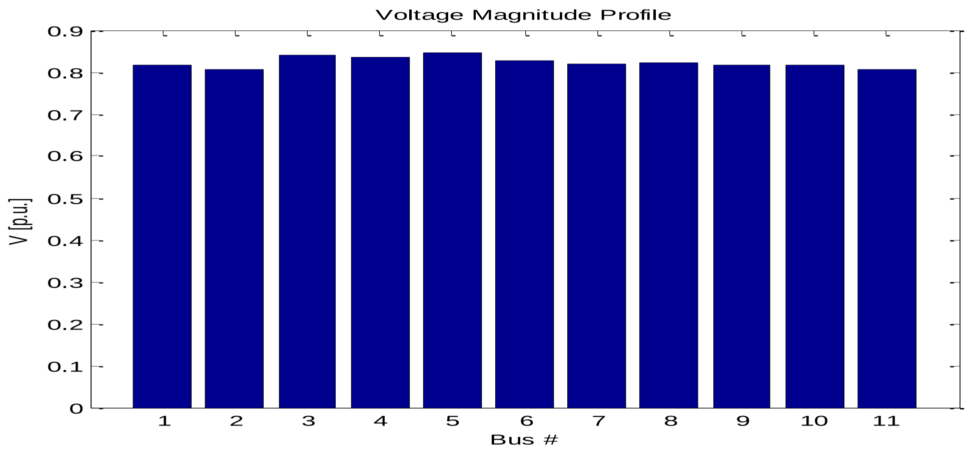

Figure 6: Voltage profile of Owerri network without PSS

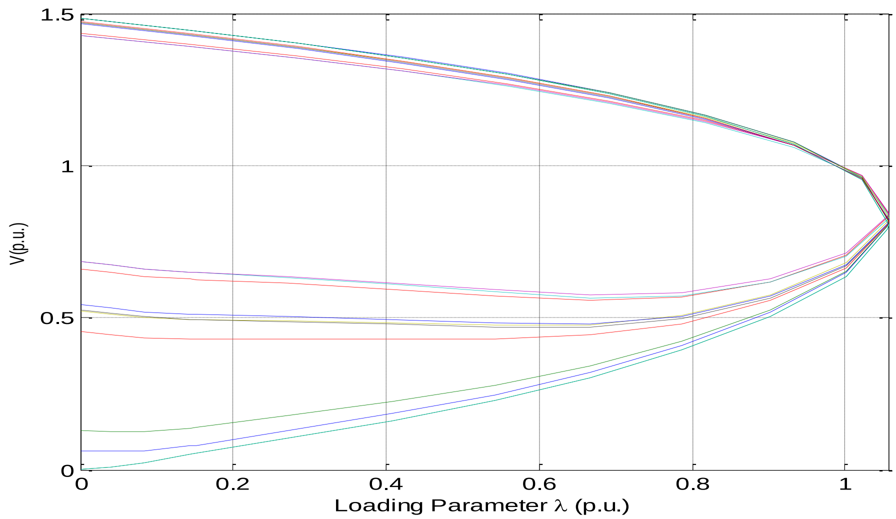

Figure 7: P-V curve of Owerri network without PSS

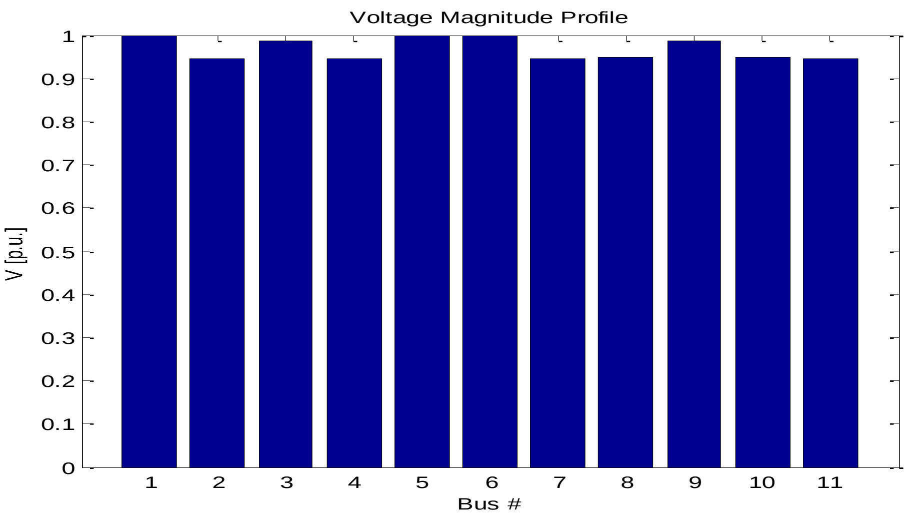

Figure 8: Voltage profile of Owerri network with PSS

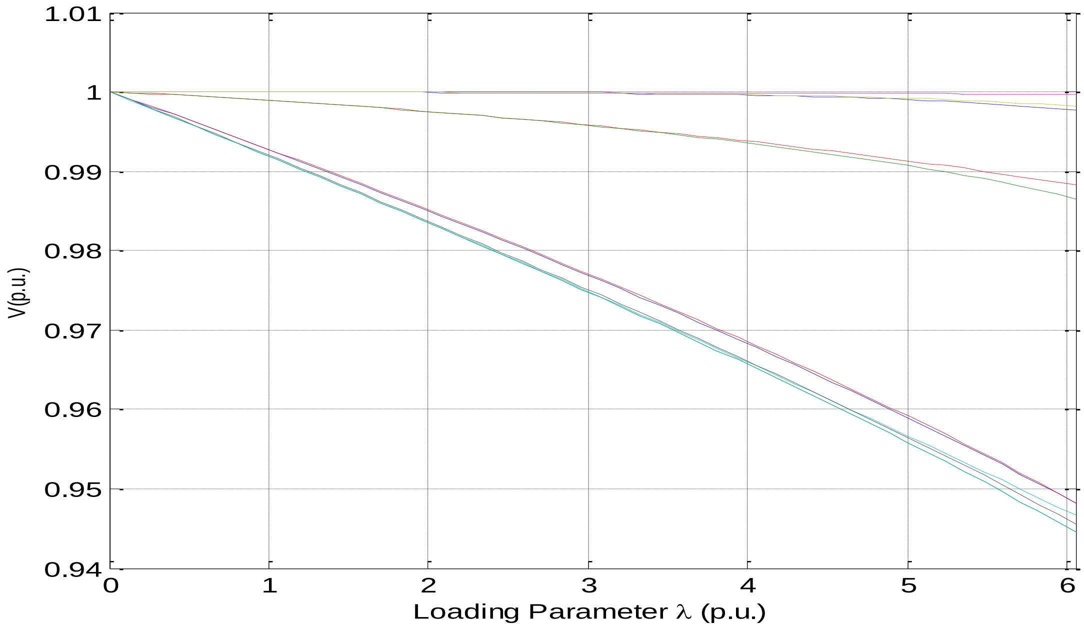

Figure 9: P-V curve of Owerri network with PSS

After subjecting the network to continuation power flow analysis, according to the result gotten in table 1, it can be seen that when PSS is not used all the buses are violated (below 0.95p.u.) while when PSS is used only one bus is violated. Also, without PSS the real and reactive power losses are 0.17793 pu and 0.10156pu respectively and with PSS 0.00508pu and 0.07989pu respectively. The maximum loading for the analysis of the network without and with PSS can be seen to 1.1061pu and 6.2257pu.

CONCLUSION

Power system stabilizers are very essential tools for the improvement of the Nigeria power system as using Owerri network as a case study. From the simulation conducted, it can be concluded that power system stabilizers can be used to improve the network so much as it was noticed in the P-V curve which shows that as load continues to increase, it will not affect the system much with the aid of PSS and losses will also be minimized. This also implies that more load can be added to the network when PSS is used as seen in the loading factor which is far greater when PSS is used.

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