VOLTAGE STABILITY ANALYSIS USING PSS IN IMO STATE NETWORK

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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 presented 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. Simulation results show that when PSS is not used all the buses were violated running a continuation power flow (CPF) method, but when PSS was added , there was 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 withstanding additional load in the network.

Keywords: Power System Stability, Power System Stabilizers (PSS), Voltage Violation.

1.0 INTRODUCTION

The tendency of a power system to develop a restoring force 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 occurrence of disturbances. Effective amelioration of sustained power system oscillations has 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 stabilizer is use to investigate the Owerri electrical network (subsection of the Nigerian network).

2.0 LITERATURE REVIEW

The major difficulties by Chen and Malik (2008)) approach are the requirement of all state information, which is hard to realize in practice and the polytopic vertices used in the design are determined by a trial and error procedure. These limitations are overcome by Soliman et al (2008). Robust output feedback PSS design using LMI approach is considered in this paper. The design of output feedback controller that achieves robust pole clustering while minimizing an $H\infty$ performance criterion has been derived resulting in new BMI conditions and provides good transient response specifications and good performance for all expected operating conditions.
Taguchi method has been employed to solve economic dispatch problems by Liu and Cai (2005) and optimal power flow of power systems by Bounou M. (1995). The proposed PSS provides better damping over a wide range of operating conditions. Finally, it can be concluded that the Taguchi principle can be effectively employed to achieve an intrinsic robustness in the PSS parameters against variations in operating conditions.

The proposed coordinated PSS/AVR design by (Dysko et al (2010) procedure is established within a frequency-domain framework and serves as a most useful small-signal complement to established large-signal transient simulation studies.

The PSS designed using conventional method performs well around the nominal operating condition. However, its performance degrades as the system becomes more loaded (Sheetekela (2010)). Breeder Genetic Algorithm PSS (BGAPSS) performs slightly better than the GA-PSS. GA however has some limitations such as premature convergence, difficulties in selecting optimal genetic operators as well as the high computational capacity required in solving complex optimization problems. In order to deal with some of the limitations, BGA was proposed by (Greene (2005)). This paper uses a slightly different version of BGA known as adaptive mutation BGA.

The method proposed by Gurunath (2010)) for the PSS design is based on the conventional design technique as described by Larsen and Swann (1981) and Kundur et al (1989). However, as opposed to a conventional stabilizer design, the system dynamics are linearized by taking the secondary bus voltage of the step-up transformer as reference instead of the infinite bus (Nambu and Ohsawa (1996)).

The transient stability of a power system is a nonlinear property and cannot be understood and properly addressed using linear analysis. Nonlinear controller, inspired and designed using the nonlinear Hopf bifurcation theory, can give great insight into understanding and improving the transient stability margins of the power system. Hopf bifurcation (HB) is a nonlinear theory that is useful in explaining some of those phenomena (Nayfeh et al (1998)). Existence of HB in a system can be inferred using the linearized model of the system. This has been used, for instance, by Mithunalantha et al (2010). A new technique based on PSO was proposed to optimize the parameters settings of CPSS is developed and Simulation results show the effectiveness and robustness of the proposed OPSS over CPSS.

The Bacteria Foraging Algorithm, BFA has been reported by Mishra et al (2009). A new procedure for improving BFA called Smart BFA is a modification of the classical BFA and is applied for tuning the PSS coefficients in a multi machine power system. Due to having the bacteria conduction at a smart direction, the cost function decrease is better than the classical BFA and the speed convergence is also increased (Gustavo et al (2011)). In all past researches of classic BFA, only the social intelligence of bacteria is considered.

Recent work combining nonconvex, nonsmooth optimization with the use of concepts of pseudo-spectra for the design of low order controllers including robustness requirements is suited to the design of power system stabilizers (Gustavo et al (2011)). In this paper the PSS design is based on nonconvex, nonsmooth optimization. The use of concepts of pseudo-spectra for the design of low order controllers including robustness requirements is explained by Burke et al (2006).

3.0 MATERIAL AND METHOD

3.1 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 1 shows the block diagram of the excitation system, including the AVR and PSS. The PSS representation in Figure 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 that 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.

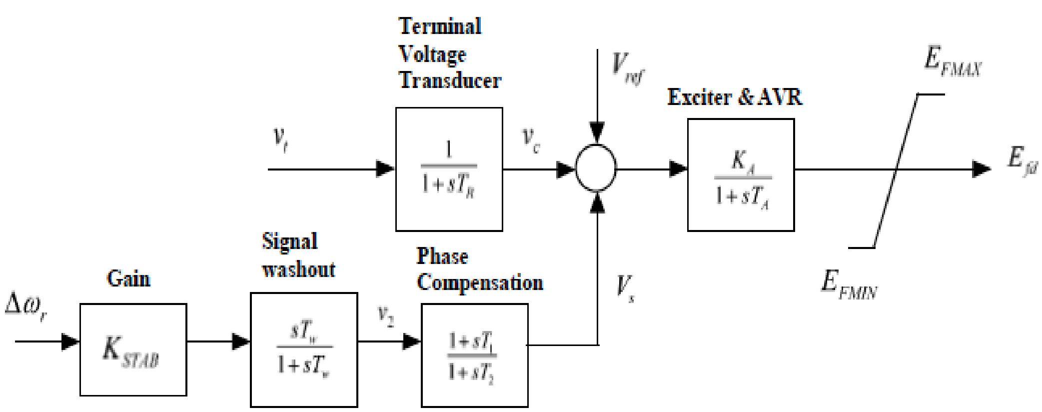

Figure 1: Block diagram of Thyristor Excitation System with AVR and PSS.

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. The block diagram of the PSS is shown in figure 2, while figure 3 shows the power system configuration with PSS.

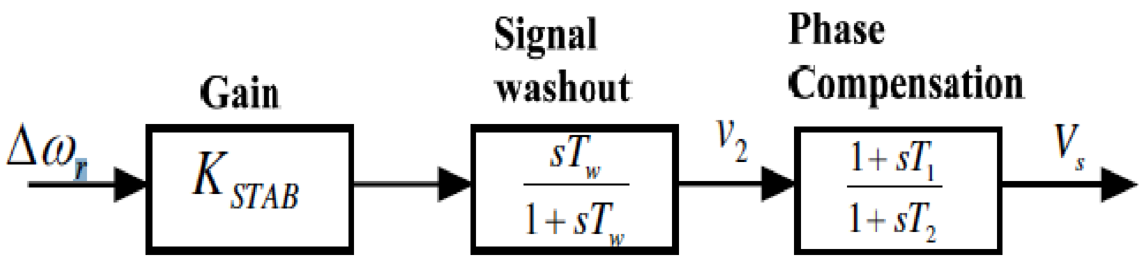

Figure 2: Block Diagram of PSS

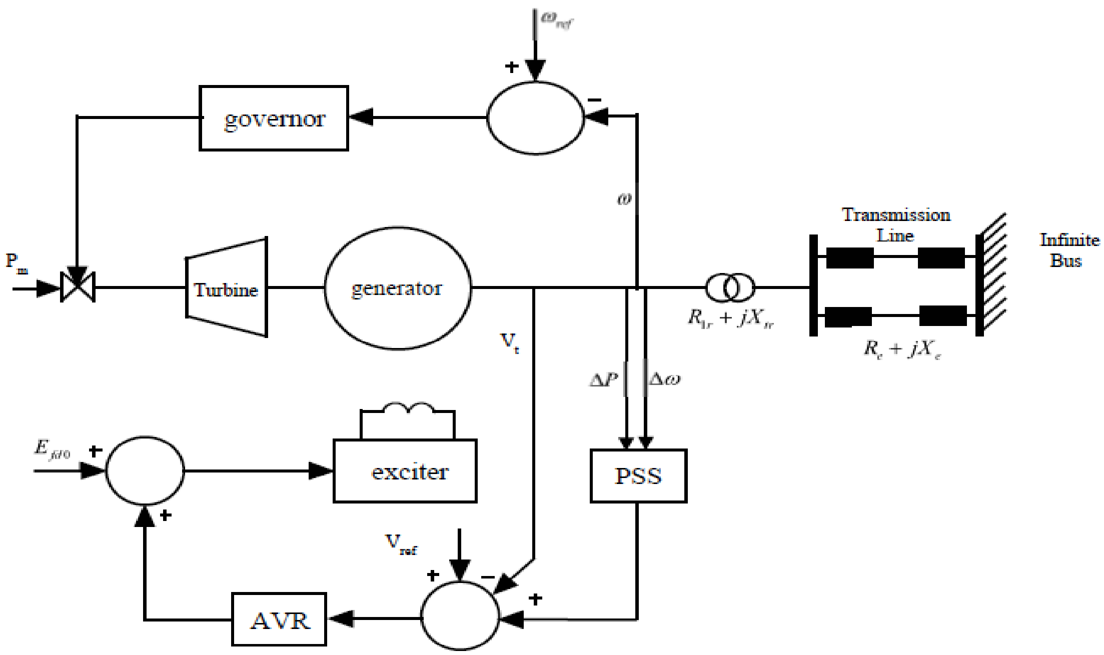

Figure 3: Power System Configuration with PSS.

3.1 Imo State Network

The Imo state network has eleven buses 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 figures 4 and 5 below;

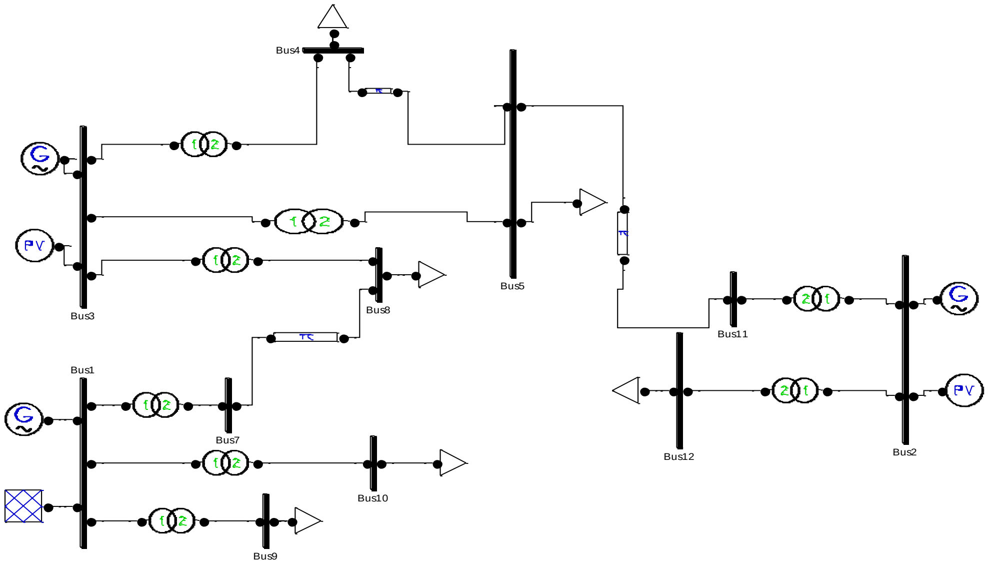

Figure 4: MATLAB SIMULINK Describing Owerri Network without PSS

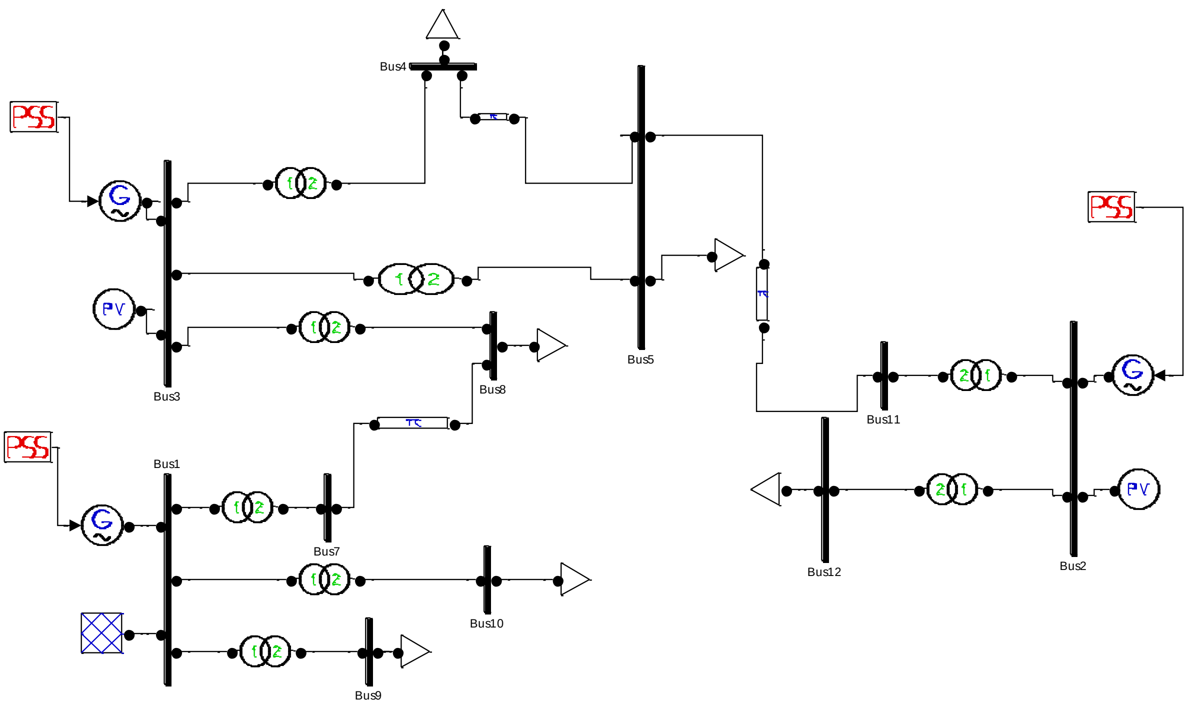

Figure 5: MATLAB SIMULINK Describing Owerri Network with PSS

4.0 RESULTS and ANALYSIS

After subjecting the network to continuation power flow analysis, according to the result gotten in Table 1, it can be seen that when PSS was not used, all the buses were violated (below 0.95p.u.) as shown in figure 6, while when PSS was used only one bus was violated as shown in figure 8. 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 as seen in table 1. The maximum loading for the analysis of the network without and with PSS was found to be 1.1061pu and 6.2257pu respectively as shown in figure 7 and figure 9.

Table 1: Results for the MATLAB simulation

Type	**Voltage violation**	**Maximum loading (p.u.)**	**Real power losses (p.u.)**	**Reactive power losses (p.u.)**
Without PSS	All buses	1.0561	0.00703	0.10156
With PSS	1	6.2257	0.00508	0.07989

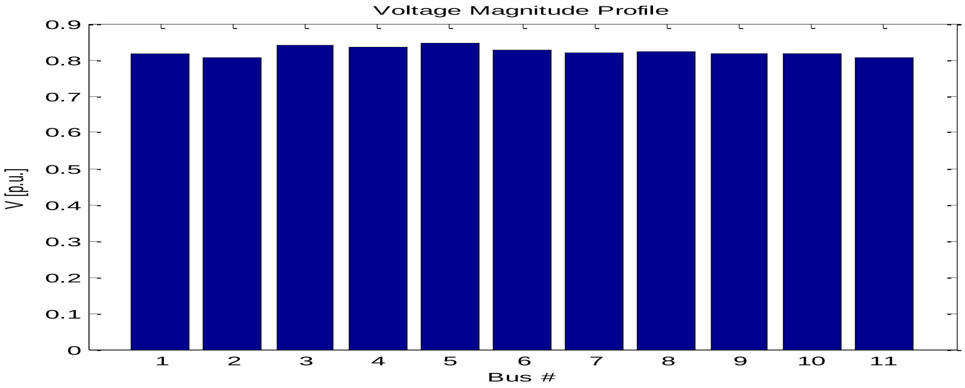

Figure 6: Voltage Profile of Owerri Network without PSS

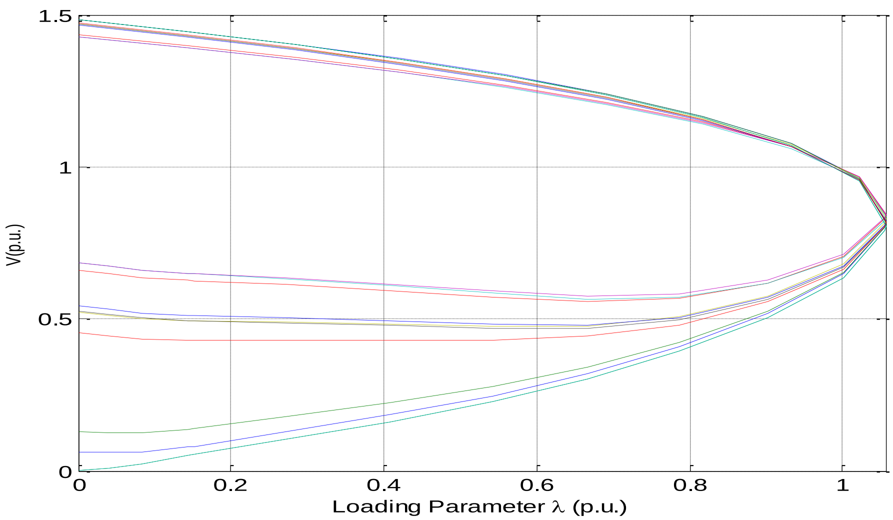

Figure 7: P-V curve of Owerri network without PSS

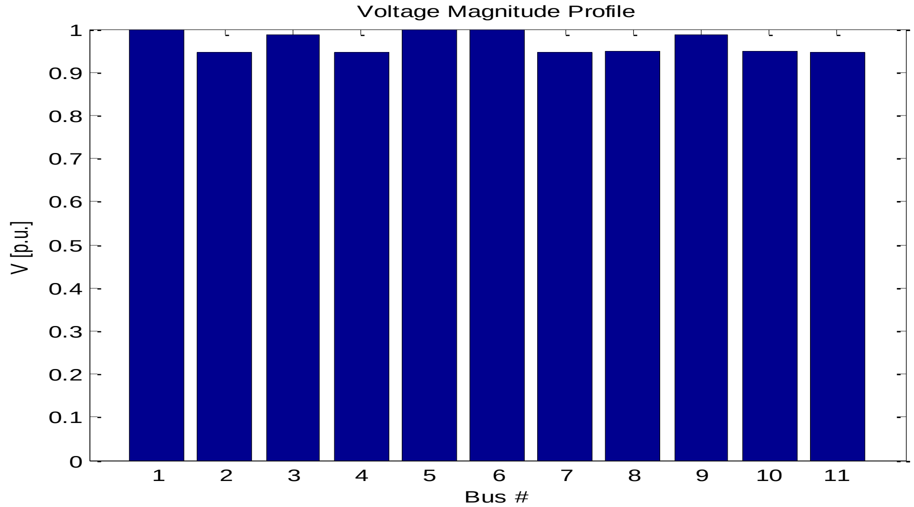

Figure 8: Voltage profile of Owerri network with PSS

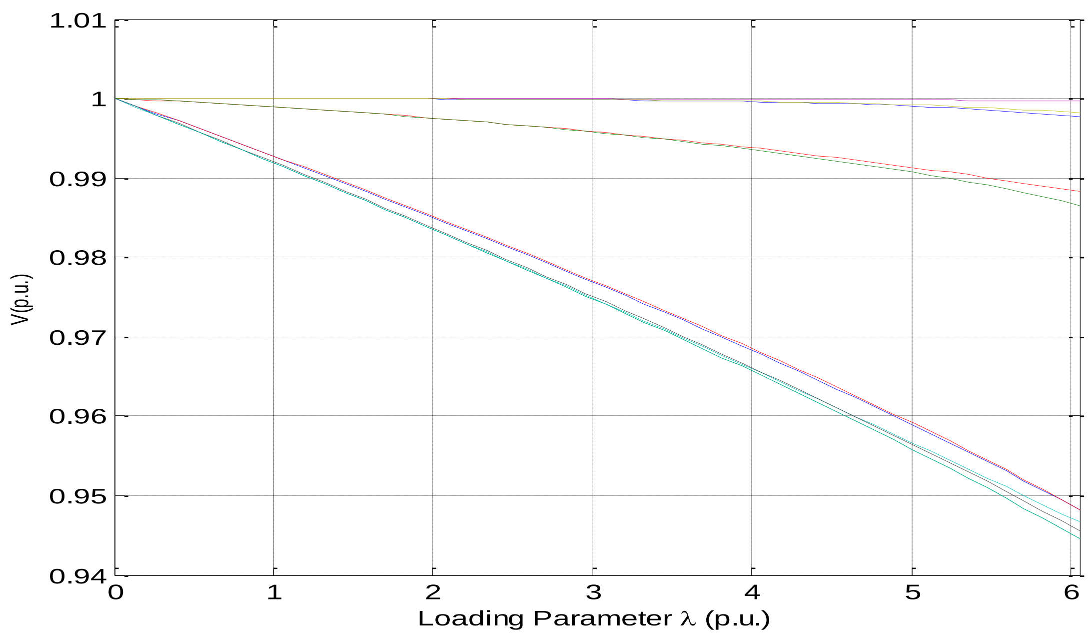

Figure 9: P-V curve of Owerri network with PSS

CONCLUSION

Power system stabilizers are very essential tools for the improvement of the Nigeria power system having used Owerri network as a case study. The simulation demonstrated 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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