International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Optimal design of Power System Stabilizer and Thyristor Controlled Series Compensator-based controllers using Genetic Algorithm

R. Nafeena Abdul Munaf [1*], S. JennathBeevi[2], K. Sarmila Har Beagam[3], M. Bakkiyaraj[4], V. Shanmugasundaram[5]

Submitted: 28/01/2024 **Revised**: 06/03/2024 **Accepted**: 14/03/2024

Abstract: The design of Power System Stabilizer PSS and Thyristor Controlled Series Compensator (TCSC)-based controllers and the increase in power system stability are given and addressed in detail in this article. It is planned that the controllers will be developed both individually and in groups. On a poorly connected power system subjected to a variety of disturbances, the controllers are put to the test. A discussion was held on the simulation findings under various operating conditions. Genetic algorithms (GA) are a familiar algorithm for optimizing systems. This may be used to fix problems in the power system; therefore, it can be used in that sector. GA-based control systems, such as those implemented with PSS, are employed in combination with a control system that has non-controllable transients to provide power system stability and minimize transients within the power system. The system's installed power and voltage levels are first simulated, followed by the application of the new system during faults. The findings demonstrate that the new power grid is more effective than the standard model.

Keywords: *Power System Stabilizer, Thyristor Controlled Series Compensator, Genetic algorithms*

1. Introduction

1.1 Area overview

The receiving and sending end voltages, as well as the line impedance and the phase angle between these voltages, define the transmission rate of electrical power across an electric line. In other words, it is feasible to regulate one or a few of the power variables that have been communicated; in this case, active as well as reactive power flow. Several options, such as a series capacitor or phase shifter, as well as a shunt capacitor, add additional power transfer capacity to the power system. However, in a long-term steady-state operation, these techniques have historically proven to be sluggish but extremely valuable. Transient oscillation is difficult to quell because of its temporal response. Flexible AC transmission systems (FACTS) have recently become possible with recent developments in power electronics. FACTS controllers are capable of quickly regulating the network state and so may be utilized to increase system stability. A key component of the FACTS family is the TCSC, which is extensively utilized in contemporary power systems with longer transmission lines. Power system operation and control tasks such as voltage support, voltage damping, power oscillation suppression, and enhancement of transient stability may be performed by it. Electrochemical oscillations need to be dampened for reliable system functioning. [1]. Many companies utilize power system stabilizers (PSS) to damp out oscillations. Some operating situations require the use of additional effective damping or other effective alternatives, such as PSS. Additional control methods, such as FACTS device stabilizers, have been developed to dampen the rotor modes or inter-area modes of oscillation. However, to get the maximum small-structure vibration and transient response improvement, FACTS controllers must be linked with PSSs.

A stabilizer in the power grid ensures grid stability and minimizes oscillations in the power grid. The electrical grid is experiencing new challenges that might disrupt the grid. As long as there are stability concerns, One of FACTS' technologies, the TCSC has various uses, such as for this particular function [2].

1.2 Power System Stability (PSS)

Stability of the power system means that the system is able to maintain operational equilibrium under normal operating conditions and has the capability of returning to operational equilibrium following a disruption.

1.2.1. Classification of PSS

1.2.1.1. Transient Stability

A power system is temporarily stable in an operating condition that defines a steady state and a (larger) disturbance, and it reaches an appropriate steady state operating condition following this disturbance or succession of disturbances. Examples include short-circuits or generator losses, which might be singular or many.

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[1] *Faculty of Engineering and Technology, Villa College, Maldives*
[2,3] *Department of EEE, B.S.Abdur Rahman Crescent Institute of Science and Technology, Chennai.*
[4] *Department of Mechanical Engineering, Rajalakshmi Institute of Technology, Chennai-600124. ORCID ID: 0000-0001-7917-780X*
[5] *Department of EEE, Sona College of Technology, Salem.*
* *Corresponding Author Email: crescent.research2011@gmail.com*

Nonlinear equations must be utilized when linearized power system equations do not apply.

1.2.1.2. Small signal stability

In steady-state operation, a power system is stable for a specific steady-state operating condition if the following minor disturbances do not disrupt the system. System stability after a minor disruption is characterized as small-signal stability. The majority of stability studies look at the state space equations that characterize the dynamics of the power system.

1.2.1.3. Dynamic Stability

Consider a generator that is working in synchronism to supply huge amounts of active power. If this generator is operated at the leading power factor (-Q) and the load angle approaches 900, the generator loses synchronism due to steady-state instability. Separately, it has been used to define a type of stability that differs from the other kinds. While this word has been defined differently by different writers, as well as as a distinction between groups of analysts in Europe and North America, it has also been used to symbolize other notions. International engineering groups have argued that the stability problem does not warrant using this name.

1.2.2. State Space Representation

Power system behaviour is defined by a series of state equations that are linearized since LFO instability may be modelled with small-signal analysis. To find out the frequency content of inter-area modes of oscillation. Although torsional modes will not be analyzed, the vehicle must nevertheless demonstrate overall torsional performance. To do this, a model that represents the entirety of the power system while allowing the modes of interest to be isolated is required. Mathematical representations have been used to depict the temporal derivatives of both generator and excitation system state equations.

1.2.3. Low frequency Oscillations

To increase the transient stability of the power system, fast-acting static excitation is added with greater system voltages. However, these excitation systems negatively influence tiny signal power system damping. Since loads fluctuate randomly, they pursue these variations and use the resultant change in rotor voltage to modify the terminal voltage, resulting in oscillations in the rotor. They serve to lower the magnitude of electromagnetic and mechanical oscillations between 0.1 and 3.0 hertz. When it comes to creating or locating oscillations, oscillations can be either generated or located in the power system.

1.3. Problem Statement

Unstable There have been a number of power system oscillations all around the world in the previous three decades. Systems rely increasingly on their excitation systems as the load increases. As long as further control is provided, synchronizing oscillations remain steady. The synchronizing torque is lower across these weak links, but because each of the systems to be interconnected is heavily linked with each other, the collective inertia of the overall system is also greater. These low-frequency oscillations can be dampened using PSS. Only in situations surrounding the working conditions for which the PSS was intended does the PSS dampen oscillations. When the operating situation changes amatically, tuning has to be done. Phase compensation, such as for tuning the PSS, takes time, and therefore the system's safety may be compromised while that process is in progress.

1.4. Literature Survey

This paper's major contribution is the development of a method for reducing models to simplify the design of damping controllers. In the reduced system, the swinging rate of interest is much lower and shares traits with the model system, including the swinging rate, in the frequency range. An attenuator is built using a simplified version of the original technology. To test the design's validity, nonlinear simulation is used. Reduction may be implemented quickly and is based on the calculation of observability and controllability. A theoretical model of power system damping improvement is presented in this research, which utilizes a concept created for PSS and FACTS device damping coordination (FDSs). A simple linear programming technique is presented to coordinate the team. However, because QR analysis is necessary to apply Eigen analysis, it cannot be used on systems with more than 650-750 states. A case study shows how PSSs and FDSs collaborate to support three geographical areas with 30 stations, 4 SVCs, and 450 states.

The abstract summarizes the main idea of this research as an integrated method using RBFNN and TS fuzzy schemes that incorporate a genetic optimization of parameters [3]. A thyristor-controlled series capacitor (TCSC) linked to a single-machine infinite bus power system is used as a reference for the whole process. Single-neuron architecture and parameter settings are changed in an online way with the TS-fuzzy TS scheme. These rules were determined by a combination of the RMS- or reactive-power error and their derivatives at the TCSC or IPFC bus and apply if they appear at the TCSC or IPFC bus [4]. The new genetic-neuro-fuzzy control system has greater damping performance and a faster critical clearing time than the prior PI and RBFNN controllers [5]. A fundamental structure of the system cuts down on the workload, therefore making it perfect for real-time deployment. This research focuses on how wind energy conversion technology influences power system dynamics. In this work, the authors present the system

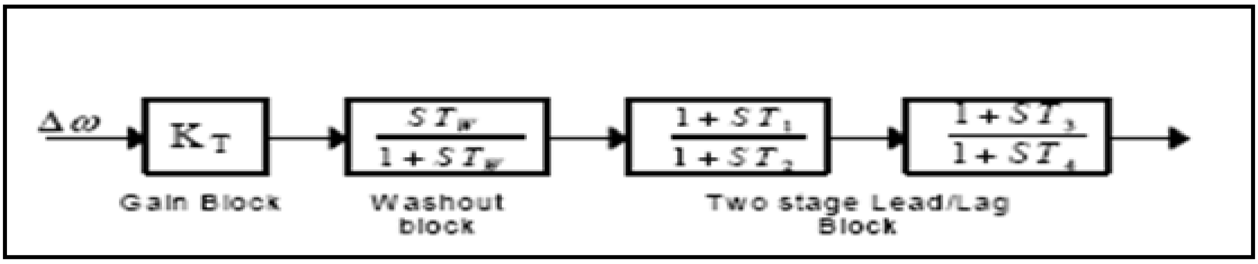


Fig 2. The TCSC Controller

performance of a wind energy conversion system in the context of a power system disturbance that results in voltage sag produced by a short circuit in the power system. During voltage sag, the voltage source converter may still transmit the power from the wind, and in addition, the converter can do a STATCOM function to compensate for reactive power so that system dynamic performance has been enhanced[6].

2. Thyristor Controlled Series Compensator

2.1. Introduction of TCSC

In recent years, FACTS has mostly been used to boost line power transmission, although in the past it was commonly employed to stabilize the system. Fig. 1 shows a circuit schematic of a TCSC. Capacitor bank C, bypass inductor L, and bidirectional thyristors SCR1 and SCR2 make up the TCSC. A method is employed to change the TCSC reactance in response to system control algorithms based on the firing angles of the thyristors. The TCSC may be programmed to operate in either the capacitive or inductive zones to minimize the impacts of steady-state resonance [7].

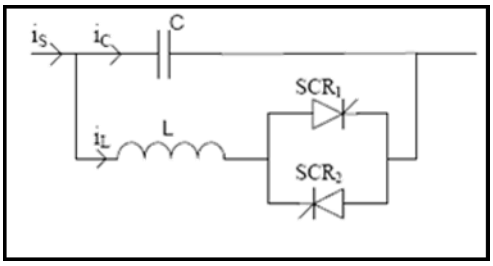


Fig 1. TCSC Circuit Diagram

$$X_{TCSC}(\propto) = \frac{X_c^2}{X_{c-X_l}}\frac{\sigma+\sin(\sigma)}{\pi} + \frac{4X_C^2}{X_C-X_L}\frac{cos^2\left(\frac{\sigma}{2}\right)}{K^2-1}\frac{(K\tan\left(\frac{K\sigma}{2}\right)-tan\left(\frac{\sigma}{2}\right)}{\pi} \qquad (2.1)$$

Where,

X_C = C is the nominal reactance of the fixed capacitor.

X_L = Connected to the inductor L is C's inductive reactance.

σ = 2(π − α) = TCSC controller Conduction angle.

k = $\sqrt{\frac{X_C}{X_L}}$ = ratio of compensation.

2.2. TCSC Controller Model

This study employs a standard lead-lag structure as a TCSC controller. A graphical representation of the TCSC controller model's structure is provided in Fig. 2. The design uses a gain block, a signal washout block, and a two-stage phase correction block. This block cancels the phase difference between the input and the output signals. Washout blocks are used to process high-frequency signals, which help to maintain oscillations in the input signal. The suggested TCSC controller is designed to implement an input signal, which is the speed deviation Δω, and to provide an output, which is the change in conduction angle Δσ.

2.2.1. Gain Block

The Gain Block is the damping block that governs the amount of compression and rebound applied to the device. Damping rotor oscillations is a crucial contributor to this effect. With an increase in stabilizer gain, the damping increases. Increasing the oscillations and making the situation worse is possible if incorrect levels of stabilizer gain are used.

2.2.2. Washout Block

To filter out the field voltage's variations in speed, the washout block acts as a high-pass filter. The suggested TCSC controller is in charge of the speed deviation (Δω) and hence regulates the change in conduction angle (Δσ).

$Transfer\ function\ of\ washout =$ (sT-W)/(1+sT-W) (2.2)

2.2.3. Dynamic compensator

This circuit adjusts for the phase difference between the input and output signals. In order to compensate for the block delays, additional phase lead circuits are required in the machine model's forward route.

3. Power System Stabilizer

3.1. Introduction

The effect of a high-gain AVR on transient stability is potent. Such a fast-acting excitation mechanism might cause unwanted rotor damping resulting from tiny, random load variations [8]. Because low-frequency electromechanical oscillations are created in the synchronous machine, low-frequency mechanical oscillations are also produced in the synchronous machine. The low-frequency rotor oscillations that are found in interconnecting ties or long transmission lines can also be detected in power system links, such as circuit interconnections and transmission lines. The PSS reduces generator rotor oscillations by providing supplementary stabilizing signals to control the excitation of the generator. To attenuate rotor speed variations, the stabilizer must provide an equal and opposite component of electrical torque.

The following criteria can be used to select a control signal for PSS:

(i) The signal must be measured and produced from local observations.

(ii)When designing a PSS signal system, the following must be done: The system must be able to withstand noise, and the design must be robust. This indicates that in order to prevent increasing the noise, lead compensation must be maintained to a minimum.

(iii)The input signals to the PSS can be any of the following: shaft speed, bus frequency, actual power, and accelerating power. Any control signals previously listed as 'possible influences on rotor speed or possible influences on rotor frequency' or 'possible influences on electrical power' are found locally. Zero crossing detection may be used to measure the bus frequency signal's period. A Hall-effect transducer may be used to extract the power signal.

Measurement of shaft speed is simple, and hence it is frequently employed. You may get the speed signal using a toothed wheel that is placed on the shaft of a transducer. Instead, it may be generated by the internal voltage angle. It is of critical importance to emphasize that the PSS serves the express purpose of increasing overall network power transmission. For the PSS to be able to work effectively when the system is put under significant amounts of stress, it must also be stable.

3.2. PSS Model

The purpose of the PSS is to dampen rotor oscillations. Fig. 3 depicts the gain, washout, lead-lag, and limitation blocks of a digital signal processor. A typical construction for PSS is shown below, and it is commonly used. The PSS is a single-input (speed)-single-output (stabilizer signal to exciter) system employed in the feedback path. The important blocks in a PSS Dynamic compensator, Washout circuit and Stabilizer gain.

3.2.1. Dynamic Compensator

The PSS should provide an electrical torque in phase with the rotor speed variation to moderate rotor oscillations. To compensate for the block delays, additional phase lead circuits are required in the machine model's forward route. Also known as a lead-lag stage, the lead compensator helps to balance the delay of the previous stage. It is composed of phases of lead lag.

$Transfer\ function\ of$ of Compensators $= \frac{(1+sT_1)}{(1+sT_2)}$ (3.1)

Where,

T_1, T_2 =Time constants of Compensators

3.2.2. Washout Circuit

To reduce steady state bias in the output of PSS, the washout circuit is supplied. Only changes in the input signal, not the Dc offset, are anticipated to be handled by the PSS.

$Transfer\ function\ of$ of washout $= \frac{sT_W}{1+sT_W}$ (3.2)

Washout blocks are used to stop variations in speed from affecting the voltage in the recording or playing field. For signals indicative of rotor speed oscillations to remain undisturbed, the magnitude of the washout time constant (Tw) should be substantial. The time constant (Tw) should be between 1 and 2 seconds to dampen out local patterns of oscillation.

3.2.3. Stabilizer Gain

The stabilizer gain Kpss, which may be described as a damping control, has a major influence on the amount of rotor oscillation. The optimal value of gain is examined over a wide range of values, and a specific value is selected. When the stabilizer gain increases, the damping increases. Increasing the oscillations and making the situation worse is possible if incorrect levels of stabilizer gain are used.

4. Optimization with Genetic Algorithm

4.1. Formulation of Problem

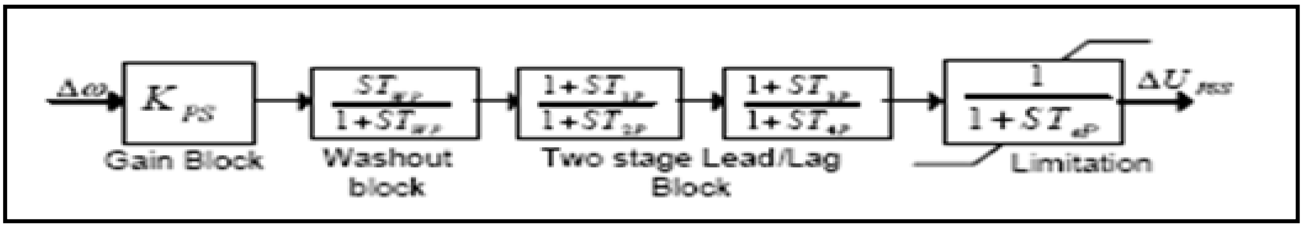


Fig 3. Structure of PSS

4.1.1. Controller Structure of PSS and TCSC

A common lead-lag structure is utilized in this work as a PSS and TCSC controller structure, which is chosen because of its ease of implementation. The TCSC controller's structure is represented in Fig. 4

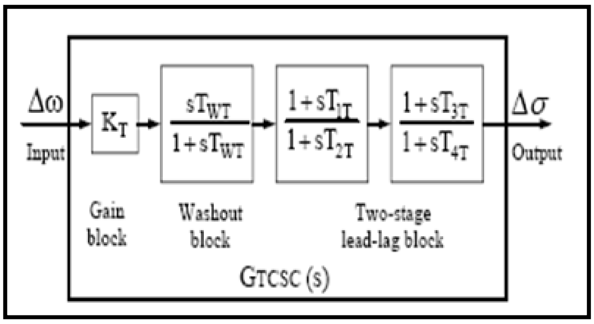


Fig 4. Structure of the TCSC Controller

One gain block with KT gain, one signal washout, and two-stage phase correction blocks are shown in the diagram. Using this block, you may verify that the input and output signals are in sync with each other. The output would also change if the input were to change constantly. Since the washout function is not important, the value of TWT may be anything between 5 and 30 seconds. The dampening torque that is provided by the TCSC may be regarded as being in two parts: half is direct torque and half is via gear torque.

When the first portion, KP, is applied to the generator's electromechanical oscillation loop, it is referred to as the direct damping torque. The indirect damping torque, designated KQ and KV, is applied to the generator's field channel through the indirect damping torque bus.

$$\Delta T_{Dt} = T_D \omega_O \Delta\omega \cong K_P K_T K_D \Delta\omega \qquad (4.1)$$

where,

TDt is denoted as the damping torque coefficient, and the transfer functions of the PSS and the TCSC controller are

$$U_{PSS} = K_P\left(\frac{sT_{WP}}{1+sT_{WP}}\right)\left(\frac{1+sT_{1P}}{1+sT_{WP}}\right)\left(\frac{1+sT_{3P}}{1+sT_{4P}}\right)y \qquad (4.2)$$

$$U_{TCSC} = K_T\left(\frac{sT_{WT}}{1+sT_{WT}}\right)\left(\frac{1+sT_{1T}}{1+sT_{2T}}\right)\left(\frac{1+sT_{3T}}{1+sT_{4T}}\right)\mathrm{y} \qquad (4.3)$$

UT contains the output signals from the two controllers, TCSC and PSS, which are fed to U TCSC and U PSS. In this form, the TWT and TWP washout time constants and the T2T, T4T, T2P, and T4P time constants are often provided. In the current study, TWT is equal to TWP, T2T is equal to T4T, and T2P is equal to T4P. The controller acquires knowledge and patience, as well as the time constants T1T, T3T, T1P, and T3P. The suggested TCSC stabilizer has an input signal in the form of speed deviation Δω, and an output in the form of a change in the conduction angle Δσ. Delta σ = 0 and XEff = XT+XL-XTCSC(α0) while in steady state. Series compensation is applied to dampen system oscillations while things are changing rapidly. When measuring dynamic circumstances, the effective reactance XEff will be calculated as XT+XL-XTCSC(α), where (σ = σ0+Δσ) and (σ=2(π-α), α0 and σ0) are the starting values of firing and conduction angle respectively.

4.1.2. Objective Function

The TCSC controller's main objective is to minimize the oscillations in the power system once a disturbance occurs. The variation in the generator rotor angle (Δδ), rotor speed (Δω), and accelerating power (ΔPa) are all caused by the oscillations in the machine. The objective can be formulated as the minimization of:

$$\mathrm{J}=\left(F_{1,}F_{2,}F_3\right) \qquad (4.4)$$

Where

$$F_1 = \Sigma \int_0^{t_1} [\Delta\delta(t,X)]^{2dt}$$

$$F_2 = \Sigma \int_0^{t_1} [\Delta\omega(t,X)]^{2dt}$$

$$F_3 = \Sigma \int_0^{t_1} [\Delta P_a(t,X)]^{2dt}$$

The expression above shows how the settings of the TCSC controller are going to be reduced and how long the simulation period is going to be. T1, T2, and KT are indicated by the letters X. Although T1 = T3, and T2 = T4, T1 fluctuation will lead to rotor speed, accelerating power, and rotor angle change. Rotor angle oscillations are measured by F1, accelerating power oscillations are measured by F2, and rotor oscillations are measured by F3. Thus, varying the rotor angle, speed, and accelerating power will alter the shape of the J curve and lead to an overall reduction in J. Using a genetic algorithm, we have been able to reduce the size of the J function [9].

The expression above shows how the settings of the TCSC controller are going to be reduced and how long the simulation period is going to be. T1, T2, and KT are indicated by the letters X. Despite the fact that T1 = T3 and T2 = T4, T1 fluctuation will result in rotor speed, accelerating power, and rotor angle changes. Rotor angle oscillations are measured by F1, accelerating power oscillations are measured by F2, and rotor oscillations are measured by F3. Thus, varying the rotor angle, speed, and accelerating power will alter the shape of the J curve and lead to an overall reduction in J. Using a genetic algorithm, we have been able to reduce the size of the J function.

4.2. Simulation Diagram of PSS Model

4.2.1. Circuit Elucidation

The test system is comprised of two symmetrical regions that are connected by two 230 kV wires that are 220 kilometers in length. The building was particularly built to research massive interconnected power networks to examine low-frequency electromechanical oscillations. Despite its tiny size, it closely models genuine operating systems. The facilities have two identical round rotor generators, each of which is rated at 20 kV/900 MVA. There are equal parameter values for all the synchronous machines, except for inertias, which are 6.5 seconds per area in area 1 and 6.175 seconds per area in area 2. Furthermore, it is believed that all sites utilize similar thermal plant speed regulators and fast static exciters with a 250-gain [1,2].

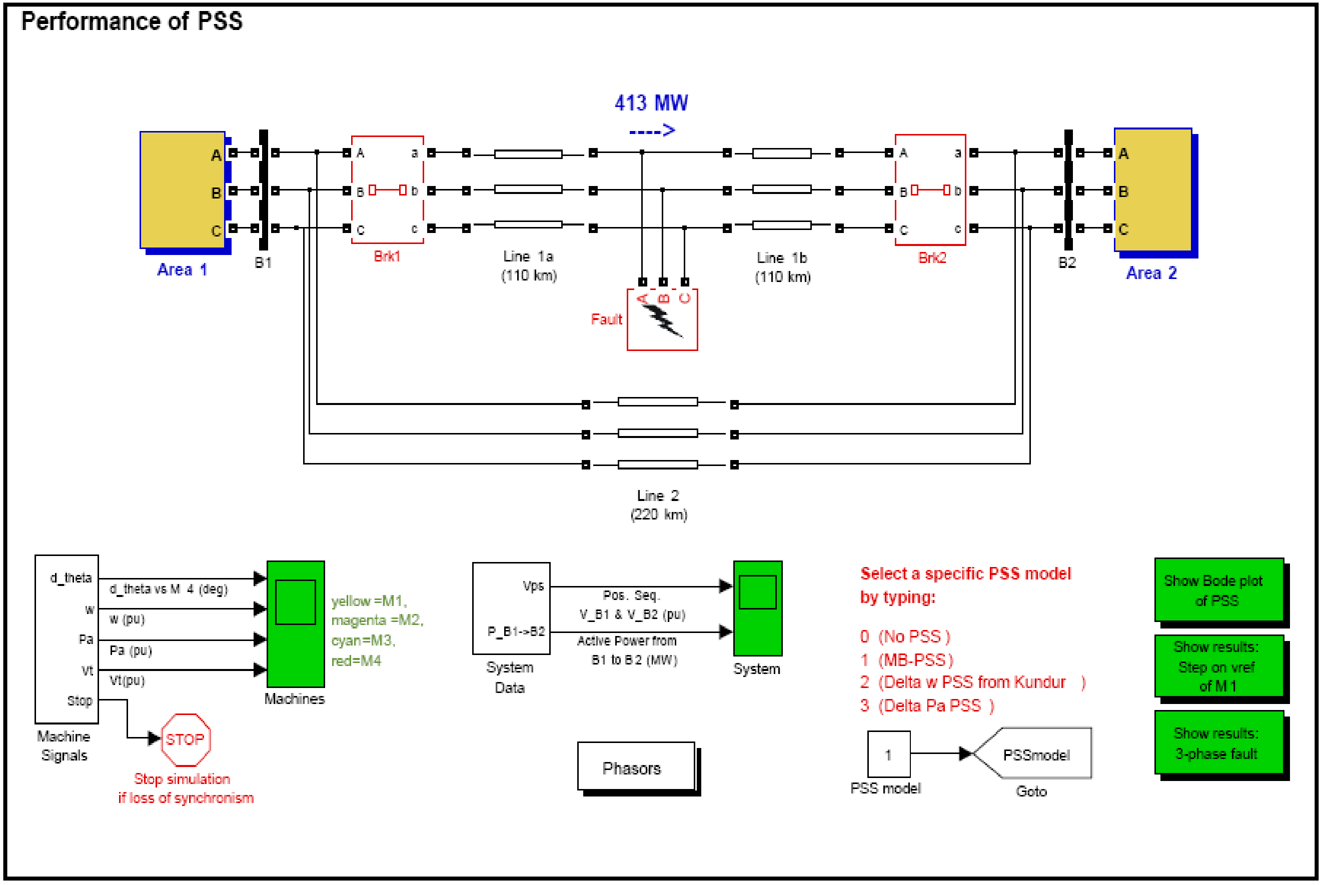


Fig 5. Performances of PSS

4.2.2. Demonstration

4.2.2.1. Small scale signal analysis of the systems

To get an early, fundamental knowledge of the network's behavior, we may simulate the system's open-loop reactions to a 7% magnitude pulse, which occurs 15 times during the duration of the pulse at the voltage reference of M1. To make sure the line fault is deactivated, go to the "Fault" device and change the transition time's vector's multiplication factor from 1 to 100. Simulations commence when the "machine" and "system" scopes are opened on the main diagram. All signals exhibit instability resulting from an unmodeled oscillation.

To reach another steady-state equilibrium point, if the two tie-lines are opened and set to "Brk1" and "Brk2," set breakers "Brk1" and "Brk2" to the open position. Post-contingency networks are sometimes referred to as post-contingency networks because it is possible to establish them in the Machine and Load-Flow Initialization window in the Power GUI. In area 1, the two local modes remain relatively unchanged with regard to frequency and damping, while the inter-area mode shifts to a much lower frequency, and the damping is negative.

4.2.2.2. PSS Tuning

To provide a virtually flat phase response from 0.1 Hz to 5 Hz, the MB-PSS parameters may be varied to adjust the center frequency and gain of each band. The Delta has the Kundur PSS settings with the addition of a transducer time constant of 15 ms. This result furthers the proof that it is not suitable for multi-unit power plants that have either quicker local or inter-machine modes. Delta Pa PSS has a significant phase advance at low frequencies (90 degrees), which has a destabilizing impact. The DC rejection (washout) provided by the Delta-W PSS is inadequate, giving attenuation five times lower than that of the MB-PSS [10]. Fig. 5 represents the performance measure of PSS.

4.2.2.3. Small scale -Signal Performance Assessment

All PSSs help stabilize the unstable system naturally. With two ties in the inter-area mode damping, performance is improved. The MB-PSS inter-area mode has a damping performance of 50 Hz and a damping response of 0.30 Hz, and the performance is 0.36 Hz; the delta values are 50 Hz and 0.35 Hz, respectively; the inter-area-mode damping performance with two ties has a damping response of 43 Hz and a damping performance of 23 Hz [11].

4.2.2.4. Large Signal Performance and Robustness Assessment

Performance in a PSS must go beyond simple small-signal performance. Other requirements of equal importance include strong performance in the face of significant fluctuations and high stability under fluctuating operating circumstances. It is possible to mimic the system's response to a three-phase fault that was cleared in eight cycles by opening the circuit breakers "Brk1" and "Brk2." The PSS can provide a seamless transition into this new highly stressed working point, but only if all the tie-lines are employed. The comparison symbol is always visible. Demonstrate a problem: a 3-phase fault [13]. While the Delta W PSS and the Delta Pa PSS each experience a loss of synchronism, the MB-PSS maintains stability. Both of them suppress the oscillation of the power transmission rather effectively. However, whereas the Delta w PSS takes too long to recover the terminal voltage, the MB-PSS has a closed-loop oscillation frequency that is lower; this is a poor side consequence of an inefficient washout. Also, with the MB-PSS, the power acceleration isn't as sharp as with other PSSs. Multi-objective-based algorithms will give better performance for these simulations.

4.3. Simulation Results

Fig. 6 and 7 gives the frequency response of PSS and damping of oscillations for different operating conditions like MB-PSS with simplified setting conventional delta (from Kundur) and conventional delta Pa.

4.4 Simulation Diagram of TCSC Model

Simulations are done using MATLAB to test the damping capabilities of the PSS and TCSC controllers on electric power system electromechanical oscillations. These figures depict the simulation models and outcomes of the simulation.

4.4.1. Phasor TCSC Model

The TCSC thyristor-based testing system in the library is comparable to this phasor system. In contrast to the thyristor model, the phasor model (Fig.8) assumes fundamental-frequency impedances but omits transients, and therefore it is not as accurate. However, the phasor model is far simpler, and the simulation run speed is greatly enhanced. In steady-state, the model exactly matches the reactions of the study participants.

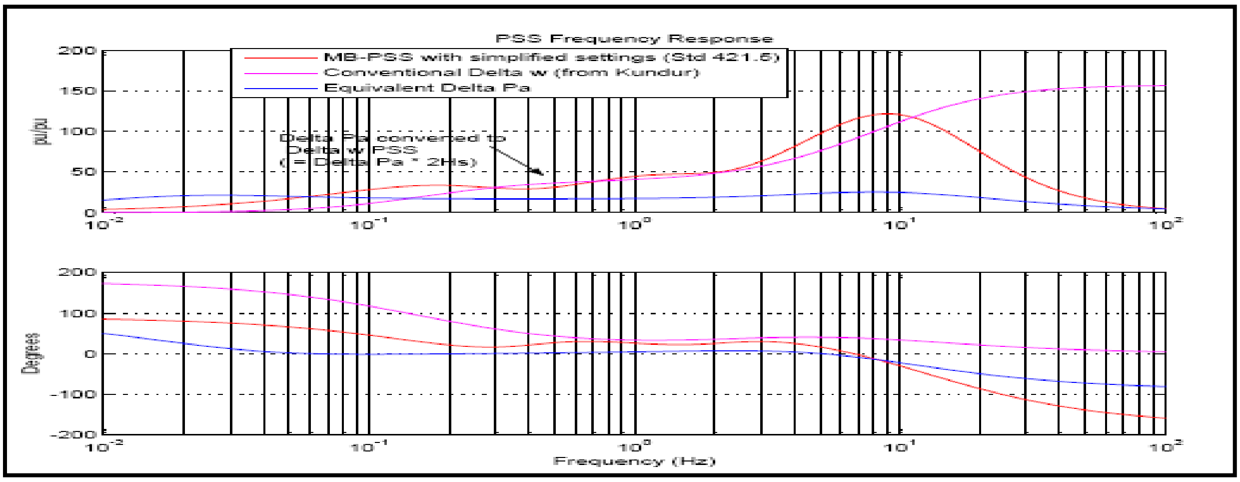
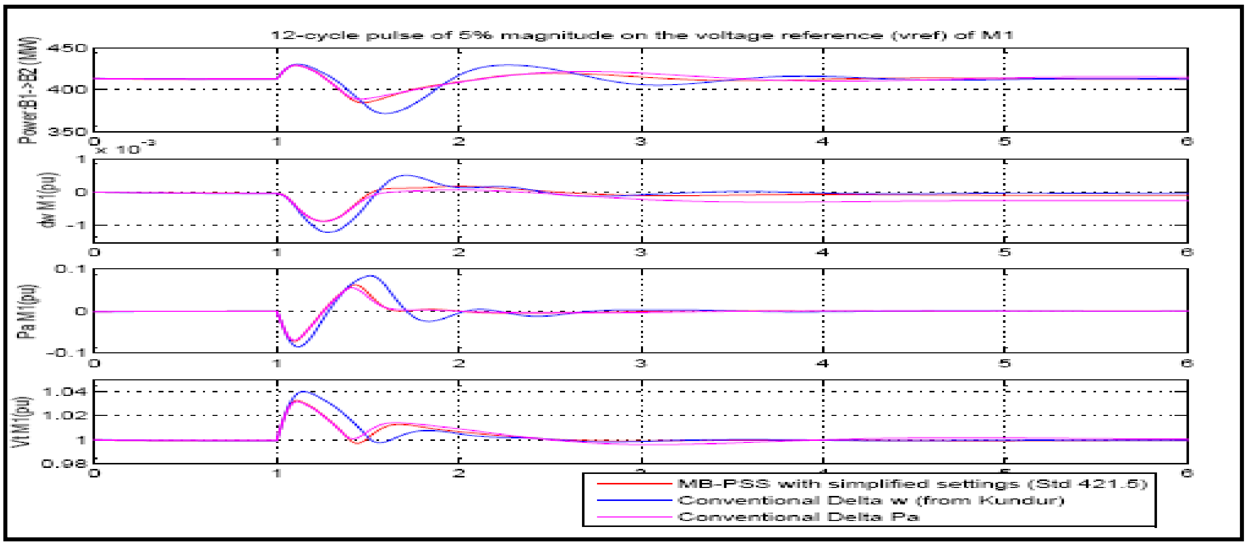


Fig 6. Frequency responses of PSS



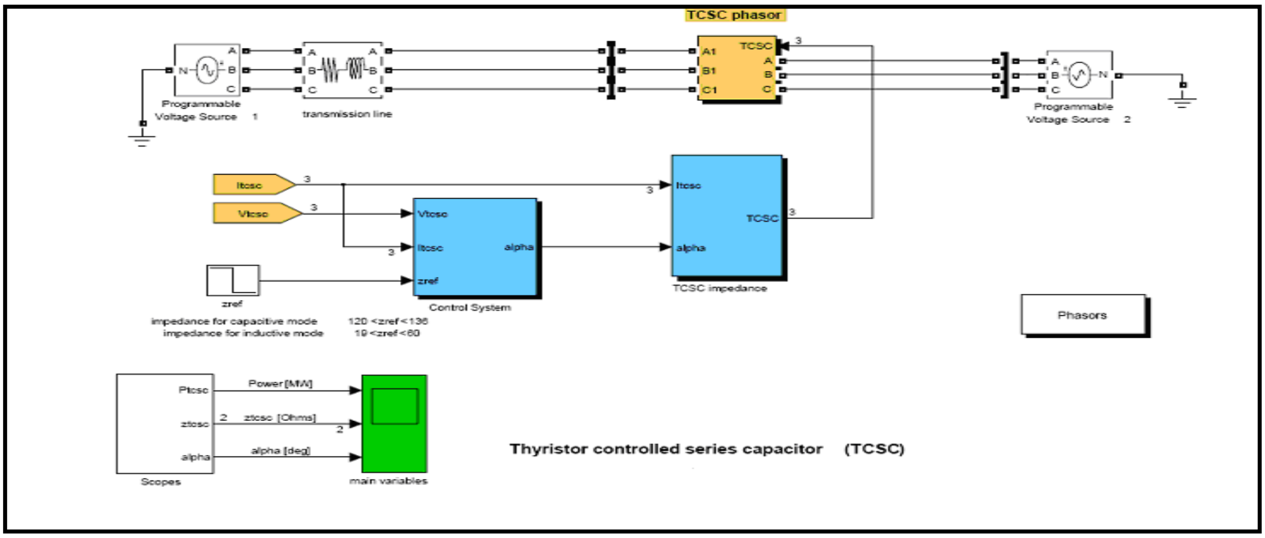


Fig 8. Phasor TCSC Model

4.4.2. Circuit Description

To increase power transfer, a TCSC is put on a 550 kV, long transmission line. Without the TCSC, the power transfer is about 110 MW, as demonstrated when the TCSC is bypassed at the beginning of the simulation. Equivalent impedance at the fundamental frequency is used to mimic the TCSC's behavior as a voltage source. Only the capacitors are present; the nominal compensation is 75 percent (discharge angle of 900). The TCSC has a natural oscillation frequency of 165 Hz, which is 2.9 times the fundamental frequency.

Capacitive and inductive modes are rarely utilized, although the TCSC may be operated in any one. The operation is restricted to a firing angle range of 49° to 69°. With firing angles of 69–90 degrees, the capacitive mode is achieved. If the firing angle is decreased, the amount of power that is transferred increases, and the impedance values in capacitive mode are about 120–136 Ohm. This power transmission range is calculated to be between 490 and 830 MW" (100 percent to 110 percent compensation). Compared with 110 MW of power transfer, TCSC increases the amount of power transfer by 20%. Corresponding to a power transfer level of approximately 100–85 MW. When operating in inductive mode, the amount of power sent over the line is less. For a constant firing angle, the same limitations apply. Fig. 9 represents the simulation of TCSC results.

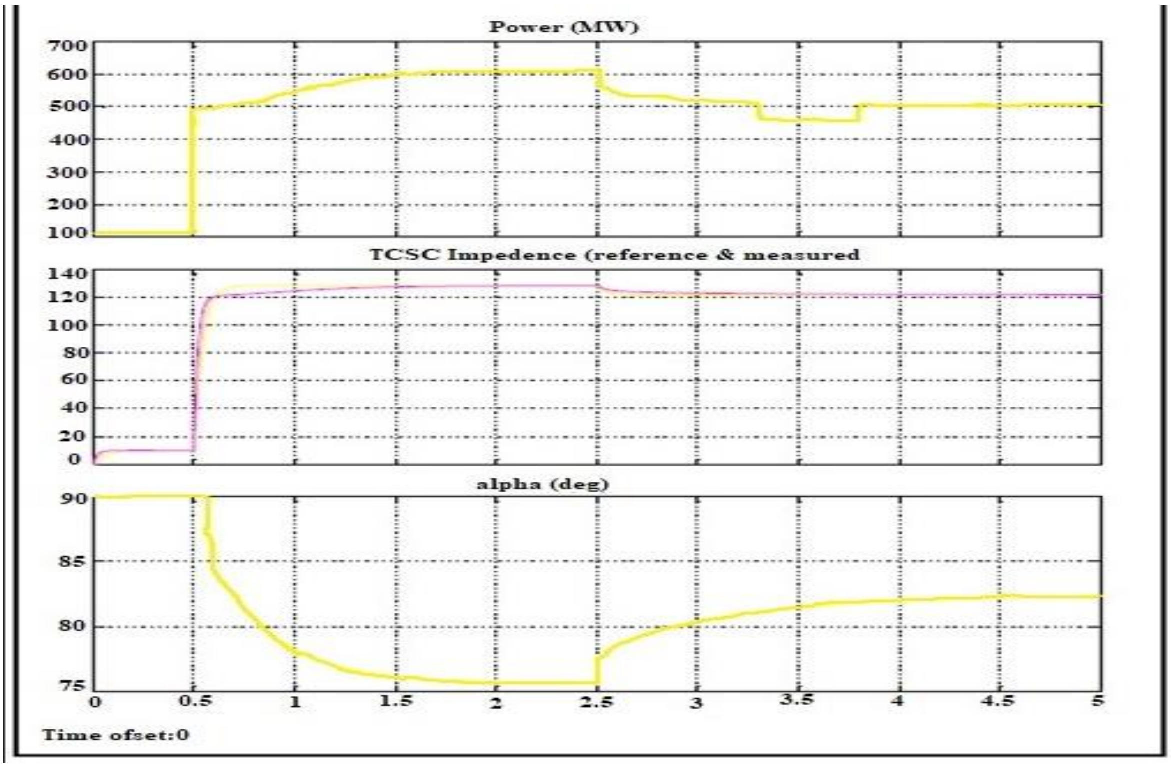


Fig 9. Simulation results of TCSC main variables

4.4.2.1. TCSC Control

The TCSC uses voltage and current feedback for calculating the TCSC impedance when it is in constant impedance mode. The reference impedance affects the power level, although a power control mode that uses reference impedance values could also be implemented.

Each operating mode uses a PI controller, which is distinct from the main controller. It utilizes a phase-lead compensator in the capacitive mode, too. Additional controllers have an adaptive control loop that increases the controller's ability to work under a wide variety of conditions. System-induced variation in gain can be compensated for with controller gain scheduling [12-13].

4.4.3. Demonstration

Examine the waves created on the main variable scope block to see how the simulation runs. Power is transferred at 110 MW until the first 0.5 seconds after the circuit breaker is bypassed. Power transmission is increasing at 0.5 seconds into TCSC when the impedance is raised to 128 ohms. To keep the lowest possible switching disturbance on the line, the TCSC begins with alpha (the angle between 90 and 0) at 90 degrees. A multimachine system can be demonstrated for better performance [14].

4.4.4. Dynamic Response

In response to a 5% variation in the impedance reference, an impedance change of 2.5 seconds occurs. According to the response, TCSC allows impedance tracking as well as the settling time to be measured. The source voltage is reduced to 4% at 3.3 seconds, after which it is returned to 1 p.u. at 3.8 seconds. With these disturbances factored in, the TCSC's impedance remains constant. TCSC reaction time is anywhere between 200 ms and 300 ms. The transient reaction should be modeled with phasor models, not using the thyristor-based model [15].

5. Conclusions

Both separately and in a coordinated manner, the controllers are created. A controller is tested on power systems with low connectivity to deal with different kinds of disruptions. The simulation results were displayed in the demonstration. An optimization problem has been created and a genetic algorithm has been applied to seek out the best controller settings, and their performances are evaluated concerning the stabilizer capabilities of the traditional power system. The PSS can provide a seamless transition into this new highly stressed working point, but only if all the tie-lines are employed. The comparison of performance demonstrated a 3-phase fault problem. All PSSs help stabilize the unstable system naturally. With two ties in the inter-area mode damping, performance is improved. The inter-area-mode damping performance with two ties has a damping response of 40 Hz and a damping performance of 22 Hz.

The authors declare no conflicts of interest.

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