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# Design of PSS Based Static VAR Compensator Using Fuzzy Controller

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**Abstract:**
Power system stability is always given a high priority in the design of power systems. It could be defined generally as a property of the power system, which gives it the ability to remain in equilibrium state or regain that state after occurrence of disturbance. Low frequency oscillations are detrimental to the goals of maximum power transfer and optimal power system security. A contemporary solution to this problem is the addition of power system stabilizers which acts as supplementary controllers in the power systems. The Power System Stabilizers (PSS) are designed to enhance damping of power system oscillations in order to extend power transfer limits of the system. Met heuristic algorithms such as particle swarm optimization, firefly algorithm and harmony search are now becoming powerful methods for solving many tough problems. A new metaheuristic method, the Bat Algorithm, was proposed based on the echolocation behavior of bats. It intends to combine the advantages of existing conventional algorithms into the new bat algorithm. It is a more powerful and promising algorithm. The results have been demonstrated by simulation in MATLAB.

**Index Terms:**
Power system stability, Power System Stabilizers, SMIB.

## I.INTRODUCTION:

Electrical energy has become a major form of energy for end use consumption today. To make electric energy generation and transmission more economic and reliable, the trend in electric power production is towards an interconnected network of transmission lines linking generators and loads into large integrated systems. Power system stabilizer (PSS) is used in the auxiliary feedback to provide supplementary damping to the system to damp these low frequency oscillations on the rotor. The PSS, also referred to as conventional PSS (CPSS), is made of gain stage K, a high pass filter and the lead – lag compensators, with $T_1 – T_4$ as time constants. These parameters require fine tuning at a set of operating conditions, usually nominal, in order to improve the system damping. As the power system is extremely nonlinear, operating conditions are constantly changing. Therefore, the CPSS's parameters may not provide adequate performance and may need to be returned. In most real applications of EAs, computational complexity is a prohibiting factor. In fact, this computational complexity is due to fitness function evaluation. Fitness approximation is one of the solutions to overcome this difficulty. However, seemingly simple EA can solve often complex problems; therefore, there may be no direct link between algorithm complexity and problem complexity. A possible limitation of many evolutionary algorithms is their lack of a clear genotype-phenotype distinction. In nature, the fertilized egg cell undergoes a complex process known as embryogenesis to become a mature phenotype. This indirect encoding is believed to make the genetic search more robust (i.e. reduce the probability of fatal mutations), and also may improve the resolvability of the organism.

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Such indirect (aka generative or developmental) encodings also enable evolution to exploit the regularity in the environment. And gene expression programming successfully explores a genotype-phenotype system, where the genotype consists of linear multigenic chromosomes of fixed length and the phenotype consists of multiple expression trees or computer programs of different sizes and shapes. In artificial intelligence, an evolutionary algorithm (EA) is a subset of evolutionary computation, a generic population-based met heuristic optimization algorithm. An EA uses mechanisms inspired by biological evolution, such as reproduction, mutation recombination and selection. Candidate solutions to the optimization problem play the role of individuals in a population, and the fitness function determines the environment within which the solutions "live" (see also cost function). Evolution of the population then takes place after the repeated application of the above operators. Artificial Evolution (AE) describes a process involving individual evolutionary algorithms. EAs are individual components that participate in an AE.

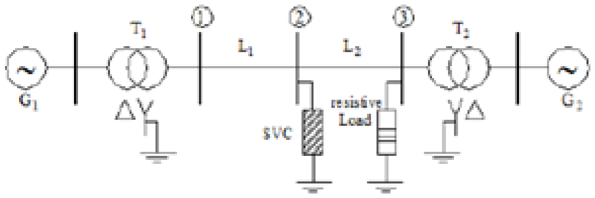


**Fig 1. Single line diagram of the power system under study**

## II. Power System Stability and Single Machine Infinite Bus System

### A. Small Signal Stability:

Small-signal stability is the ability of the power system to maintain synchronous operation when subjected to small disturbances. Since the disturbance is considered to be small, the equations that describe the resulting dynamics of the system may be linearized. Small signal stability on the other hand is concerned with the system response to small changes and is fundamental requirement for the satisfactory operation of power systems. Usually the problem is one of the ensuring sufficient damping of system oscillations. Small signal stability can be analyzed by linearizing the system about an equilibrium point represented by a steady state operating condition. This allows the use of powerful analytical tools of linear systems to determine the stability characteristics, which aid in the design of corrective controls.

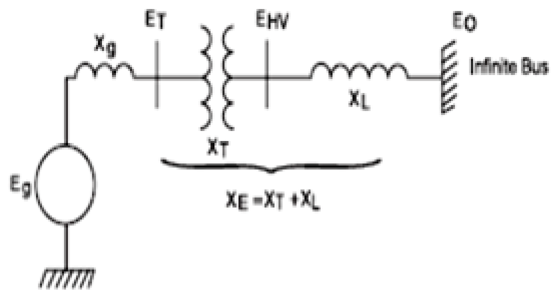


**Fig 2.1 Single machine system**

The algebraic equations of the stator are

$$E'_q + x'_d i_d = v_q \quad (2.1)$$

$$-x_q i_q = v_d \quad (2.2)$$

The complex terminal voltage can be expressed as,

$$v_Q + jv_D = (v_q + jv_d)e^{j\delta} = (i_q + ji_d)(R_e + jx_e)e^{j\delta} + E_b\angle 0$$

$$(v_q + jv_d) = (i_q + ji_d)(R_e + jx_e) + E_b e^{-j\delta} \quad (2.3)$$

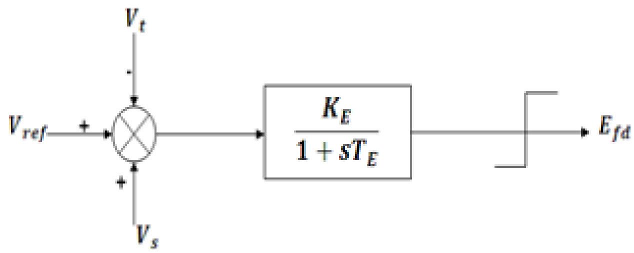


**Fig 2.2 Excitation system**

Separating real and imaginary parts of Eq. (2.3) can be expressed as

$$v_q = R_e i_q - x_e i_d + E_b \cos\delta \quad (2.4)$$

$$v_d = R_e i_d - x_e i_q - E_b \sin\delta \quad (2.5)$$

Substituting Eqs (2.4) and (2.5) in Eqs. (2.1) and (2.2), we get,

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$$\begin{bmatrix} (x'_d+x_e) & -R_e \\ -R_e & -(x_q+x_e)\end{bmatrix}\begin{bmatrix} i_d \\ i_q\end{bmatrix} = \begin{bmatrix} E_b\cos\delta - E'_q \\ -E_b \text{Sin}\delta\end{bmatrix} \qquad (2.6)$$

### B. System Representation

The system block diagram, consisting of the representation of the rotor swing equations, flux decay and excitation system, is obtained by combining the component blocks shown in Figs. 2.4 to 2.6. The overall block diagram is shown in Fig. 2.3.

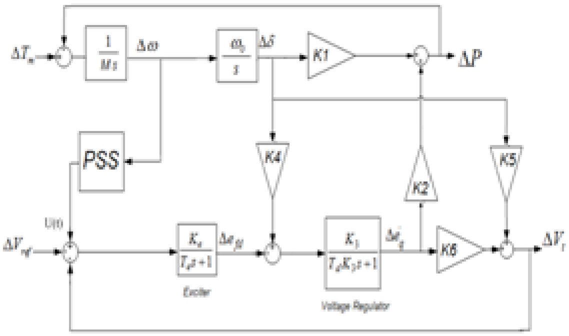


Fig 2.3 Overall block diagram of system

## III. Circuit Description:

A 1000 MW hydraulic generation plant (machine M1) is connected to a load centre through a long 500 kV, 700 km transmission line. The load centre is modelled by a 5000 MW resistive load. The load is fed by the remote 1000 MW plant and a local generation of 5000 MW (machine M2). The system has been initialized so that the line carries 950 MW which is close to its surge impedance loading (SIL = 977 MW). In order to maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200-Mvar Static Var Compensator (SVC). Notice that this SVC model is a phasor model valid only for transient stability solution. The SVC does not have a Power Oscillation Damping (POD) unit. The two machines are equipped with a Hydraulic Turbine and Governor (HTG), Excitation system and Power System Stabilizer (PSS). These blocks are located in the two 'Turbine and Regulator' subsystems. Two types of stabilizers can be selected: a generic model using the acceleration power (Pa= difference between mechanical power Pm and output electrical power Peo) and a Multi-band stabilizer using the speed deviation (dw). The stabilizer type can be selected by specifying a value (0=No PSS 1=Pa PSS or 2= dw MB PSS) in the PSS constant block. During this Demo you will apply faults on the 500 kV system and observe the impact of the PSS and SVC on system stability.

### Demonstration

**Note:** Before starting the demo, open the Powergui block and notice that 'Phasor simulation' has been checked. The phasor solution is much faster than the 'standard' detailed solution. In this solution method, the network differential equations are replaced by a set of algebraic equations time. This allows transient stability studies of multimachine systems, as illustrated below.

### A. Load Flow and machine initialization:

In order to start the simulation in steady-state you must first initialize the synchronous machines and regulators for the desired load flow. Note that the system has already been initialized. If you are familiar with the Load Flow procedure you can skip this item and proceed to step 2. In the Powergui menu, select 'Load Flow and Machine Initialization'. A new window appears. The machine M1 'Bus type' should be already initialized as 'PV generator', indicating that the load flow will be performed with the machine controlling its active power and its terminal voltage. Machine M2 will be used as a swing bus for balancing the power. Check that the following parameters are specified for

### M1 and M2:

M1: type = PV Terminal voltage (Vrms) = 13800 Active Power = 950e6 M2: type = Swing bus Terminal voltage (Vrms) = 13800 Active power guess = 4000e6 Then press the 'Update Load Flow' button. Once the load flow has been solved , the actual machine active and reactive powers, mechanical powers and field voltages will be displayed. If you look in the hydraulic turbine and governor (HTG) and Excitation system contained in the two Regulator subsystems, you will notice that the initial mechanical power and field voltage have also been automatically initialized by the

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Load Flow. The reference mechanical powers and reference voltages for the two machines have also been updated in the two constant blocks connected at the HTG and excitation system inputs: Pref1=0.95 pu (950 MW), Vref1=1pu; Pref2=0.8091 pu (4046 MW), Vref2=1 pu.

**B. Single-phase fault - Impact of PSS - No SVC**:

Open the SVC dialog box and notice that the SVC is set to operate in 'Var control (fixed susceptance)' mode with Bref = 0. Setting Bref to zero is equivalent to putting the SVC out of service. Verify also that the two PSS (Pa type) are in service (value=1 in the PSS constant block) Start the simulation and observe signals on the 'Machines' scope. For this type of fault, the system is stable without SVC. After fault clearing, the 0.8 Hz oscillation is quickly damped. This oscillation mode is typical of interarea oscillations in a large power system. First trace on the 'Machine' scope shows the rotor angle difference d_theta1_2 between the two machines. Power transfer is maximum when this angle reaches 90 degrees. This signal is a good indication of system stability.

If d_theta1_2 exceeds 90 degrees for a too long period of time, the machines will loose synchronism and the system goes unstable. Second trace shows the machine speeds. Notice that machine 1 speed increases during the fault because during that period its electrical power is lower than its mechanical power. By simulating over a long period of time (50 seconds) you will also notice that the machine speeds oscillate together at a low frequency (0.025 Hz) after fault clearing. The two PSS (Pa type) succeed to damp the 0.8 Hz mode but they are not efficient for damping the 0.025 Hz mode. If you select instead the Multi-Band PSS (value=2 in the PSS constant block) you will notice that this stabilizer type succeeds to damp both the 0.8 Hz mode and the 0.025 Hz mode. You will now repeat the test with the two PSS out of service (value=0 in the PSS constant block). Restart simulation. Notice that the system is unstable without PSS.

You can compare results with and without PSS by double clicking on the 2nd blue block on the right side.

**C. Three-phase fault - Impact of SVC - two PSS in service:**

You will now apply a 3-phase fault and observe the impact of the SVC for stabilizing the network during a severe contingency. Put the two PSS (Pa type) in service (value=1 in the PSS constant block. Reprogram the 'Fault Breaker' block in order to apply a 3-phase-to-ground fault. Verify that the SVC is in fixed susceptance mode with Bref = 0. Start the simulation. By looking at the d_theta1_2 signal, you should observe that the two machines quickly fall out of synchronism after fault clearing. In order not to pursue unnecessary simulation, the Simulink® 'Stop' block is used to stop the simulation when the angle difference reaches 3*360degrees. Now open the SVC block menu and change the SVC mode of operation to 'Voltage regulation'. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.009 pu). The chosen SVC reference voltage corresponds to the bus voltage with the SVC out of service. In steady state the SVC will therefore be 'floating' and waiting for voltage compensation when voltage departs from its reference set point.

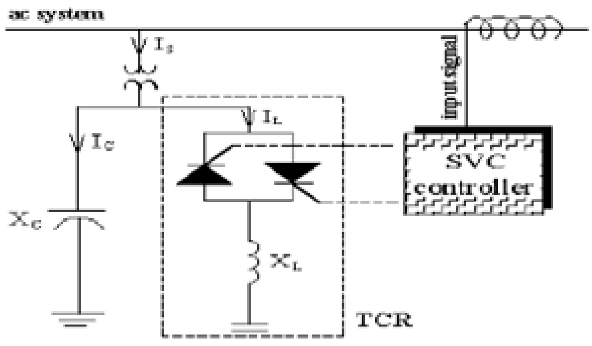


Fig. 3. Stractutre of static var compensator

**IV. Fuzzy logic controller**

**Introduction to Fuzzy Logic:**

The logic of an approximate reasoning continues to grow in importance, as it provides an in expensive solution for

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controlling know complex systems. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vacuum cleaner etc. Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D. Player etc. and so on in last decade, fuzzy controllers have convert adequate attention in motion control systems. As the later possess non-linear characteristics and a precise model is most often unknown. Remote controllers are increasingly being used to control a system from a distant place due to inaccessibility of the system or for comfort reasons. In this work a fuzzy remote controllers is developed for speed control of a converter fed dc motor. The performance of the fuzzy controller is compared with conventional P-I controller.

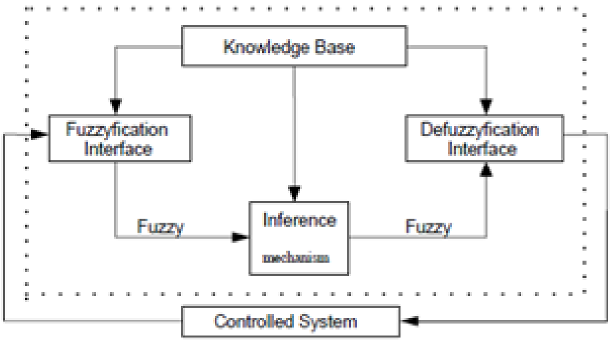


Fig 4 Fuzzy controller

TABLE I SYSTEM PARAMETERS

| Components | Values |
|---|---|
| transmission line | resistance per unit length= 0.01755 Ω/km |
| | inductance per unit length= $0.8737\times10^{-3}$ H/Km |
| | capacitance per unit length= $13.33\times10^{-9}$ F/Km |
| | length= 350 Km |
| machine $G_1$ | $X_d$=1.305, $X_q$=0.474, $X'_d$=0.296, $X''_d$=0.252, $X''_q$=0.243, $X_L$=0.18 |
| $T_1$ | 1000MVA, 13.8KV/500KV, 60Hz |
| $T_2$ | 5000MVA, 13.8KV/500KV, 60Hz |
| surge impedance loading | 977 MW |
| SVC | Rating of SVC=±200 MVar<br>Voltage regulator $K_i$=300<br>Droop $X_s$=0.3 |
| reference voltage | 1.009 pu |

## V Simulation

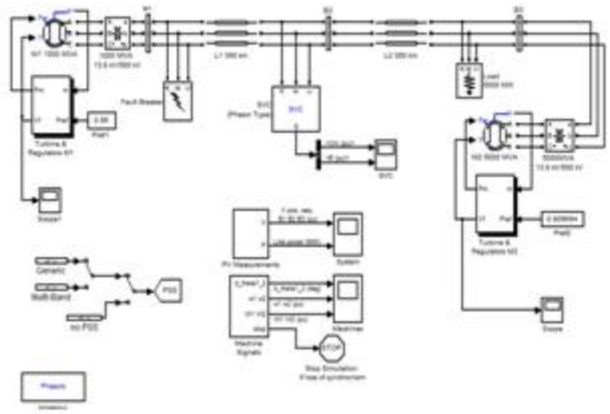

Fig 5.1 Simulation diagram svc PSS under single phase fault

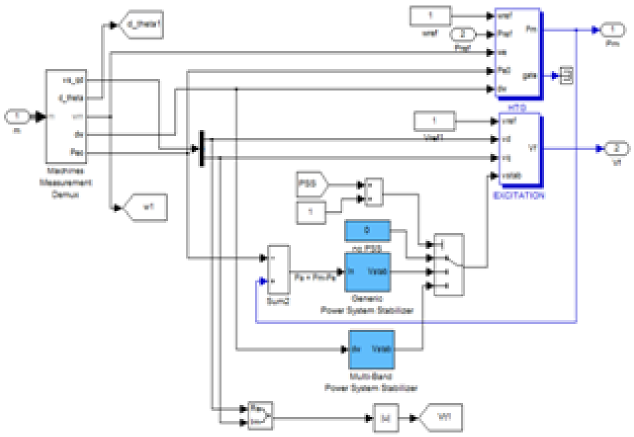

Fig 5.2 PSS control without controller

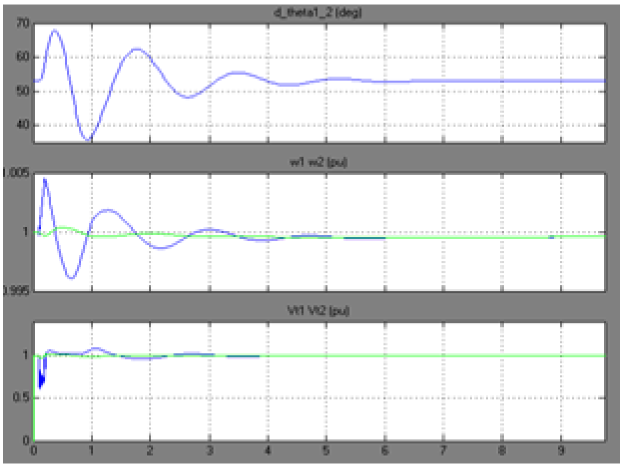


Fig 5.3 Terminal voltage under single phase fault

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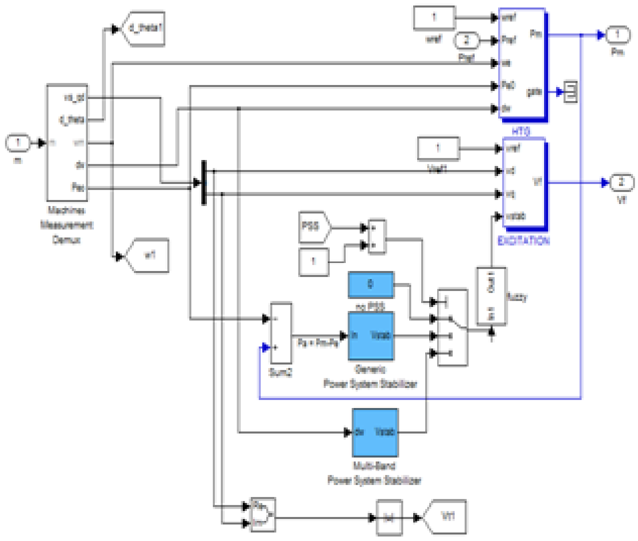


Fig 5.4 PSS control with fuzzy controller

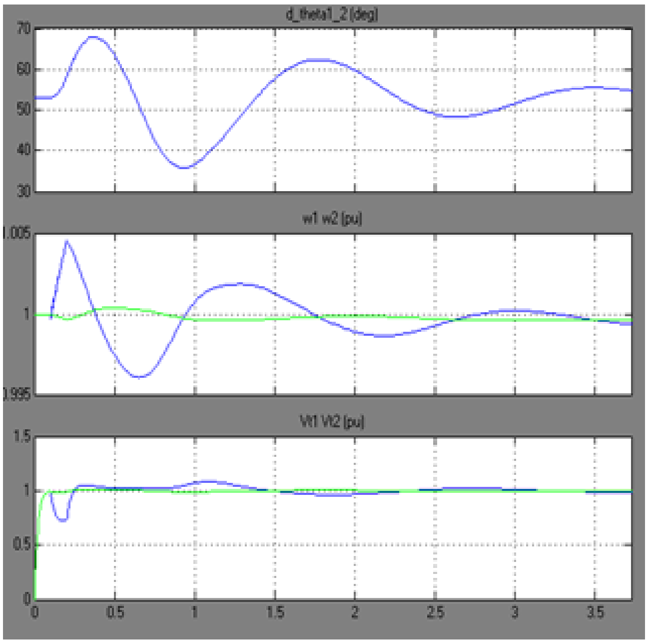


Fig 5.5 Terminal voltage compensation using fuzzy controller

## VI. CONCLUSION:

In this paper, the influence of PSS on a single machine connected to infinite bus system was investigated. The design of Power System Stabilizer is done. Static var compensator is used for transient stability improvement. PSS and FACTS devices can help the damping of power system oscillations.

This study deals with demonstration of transient stability enhancement using PSS and SVC through MATLAB Simulink. For the simulation, different loading conditions with different fault locations in the two-machine power system using the PSS and SVC are consideredThe magnitude of terminal voltage can be reduced under fault using fuzzy region selector.

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