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PI Controlled SVC for Power System Stability

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ABSTRACT

This paper introduces the SVC (Static VAR Compensator) design that is remotely controlled by the PI (Proportional Integral) controller for adjusting the voltage stability and damping effect of the line power system. The parameters of the PI controller have been designed using the Ziegler-Nichols close loop tuning technique. In the analysis, all single phase and three phase (L-L) faults are found. In this article, the power system network is known to be recreated by the phasor simulation process and the system is replicated throughout two phases; SVC is not yet remotely controlled and SVC controlled by the PI controller. The simulation result shows that when SVC is introduced into the model, the parameters of the structure end up stable at that stage. Once again, if SVC is remotely controlled by the PI operator, the parameters of the system at that stage will be stable in the quicker direction than without the controller. It has been mentioned that the SVC scores are only 50 MVA with controllers and 200 MVA without controllers. Along these lines, SVC and PI controls are more feasible to improve the reliability of the voltage and maximize the power transmission capability of the power system. Fluctuations of the power system can be minimized by the controllers in addition to the fluctuations without controllers. So, with the PI controller, the performance of the system is greatly improved.

Key words : Proportional integral, static VAR compensator, voltage regulation, stability.

1. INTRODUCTION

Improvements to the reliability of the power system are important for a large-scale project. The AC transmission system has different limits, allocated stable limits and variable limits [1]-[4]. Power system consists of some synchronous machines operating in synchronous mode. It is necessary for the stability of the power system to maintain culminating synchronism under all steady state conditions. At the moment when the disruption arises in the process, the system puts up a force that renders it natural and secure.

The tendency of the power system to yield to its usual or healthy state of affairs after being disrupted is called stability [5]. Disturbance of the system could be of different kinds, such as quick changes in load, unexpected short-circuit between line and surface, line-to-line fault, all three line faults, shifting, and so on.

The stability of the process is essentially based on the behavior of the synchronous devices owing to the disturbing effect. For the most part, the reliability of the power system is divided in two groups, based on the severity of the disturbances: Steady state stability - It alludes to the capacity of the system to recover its synchronism (speed and frequency of all the system are same) after moderate and little unsettling influence which happens because of slow power ups and downs. Steady-state stability is divide up into two sorts:

(a) Dynamic stability-Specifies the stability of the system in order to achieve its stable condition after a little disturbance (disturbance occurs only for 10 to 30 seconds). It's otherwise called small signal stability. This is mainly due to variations in the rate of load and production. Static stability - It alludes to the stability of the system that gets without the guide (advantage) of automatic control devices, for example, governors and voltage regulators.

(b) Transient stability-Defined as the capacity of the power system to revert to its normal conditions after a significant disruption. Big disruptions arise in the network due to sudden load withdrawal, line flipping operation; system failure, sudden line outage, and so on.

Transient stability is regulated when the current transmission and generation device is configured. The swing equation depicts the conduct of the synchronous machine in the midst of transient disturbances.

The transient and steady-state disturbances that occur in the power system are shown in the diagram below. These disturbances lessen the synchronism of the machine, and the system becomes unstable.

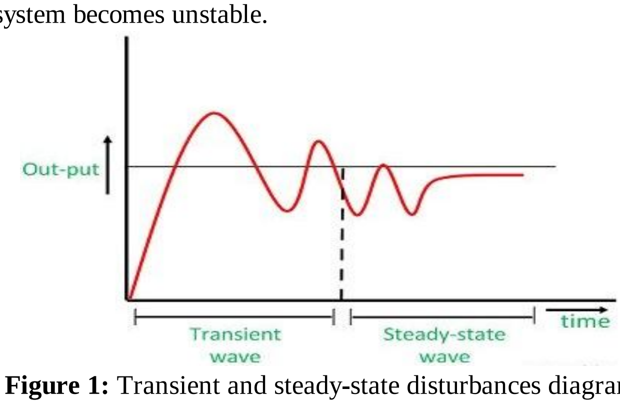


Figure 1: Transient and steady-state disturbances diagram [1]

2. LITERATURE REVIEW

SVC is essentially a shunt mounted static var generator / load whose output is balanced in accordance with commercial capacitive or inductive current in order to keep or control particular power system variables; usually the controlled parameter is the SVC bus voltage. SVC is used to provide fast-acting, reactive power protection to high-voltage transmission networks in order to enhance the reliability and performance of electrical services. On the other side, SVC can also contribute to the development of the voltage profiles in the transient state [6]-[10].

One of the key reasons behind the implementation of SVC is to enhance dynamic voltage regulation and thus maximize the loadability of the device. An extra stabilization signal and added control lay over on the SVC voltage control loop can induce system oscillation damping, as described in [11]-[13].

a) In the voltage control mode (the voltage is governed withi the boundaries as described below);

b) In the VAR control mode (the SVC susceptance is retained constant).

From V-I curve of SVC in Figure 2 [14],

V = Vref + Xs·I: In regulation range (-Bcmax < B < Bcmax)

V = I/Bcmax: SVC is fully capacitive (B = Bcmax)

V = 1/Blmax : SVC is fully inductive (B = Blmax)

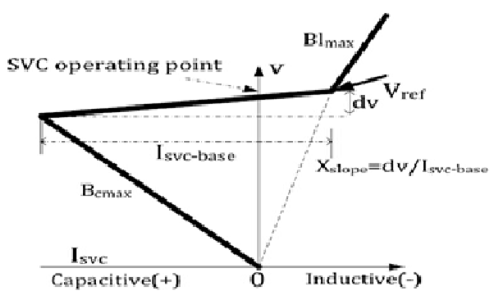


Figure 2: Steady state (V-I) characteristic of a SVC [14]

3. METHODOLOGY

3.1 PI Controller Tuning Process

The method of choosing the parameters of the controller to conform with the output requirements is called the tuning of the controller. The bulk of controls are on-site, several dissimilar sorts of tuning rules were suggested in the literature [15]. The PI (Proportional Integral) controller parameters have been developed by the Ziegler-Nichols close loop tuning system.

The PI controller has two term control signal [15],

$$u(t) = K_p e(t) + \frac{K_p}{T_i}\int e(t)\,dt \qquad (1)$$

In Laplace Form,

$$\frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i s}\right) \qquad (2)$$

For decide on the appropriate controller constraints, Ziegler-Nichols close loop Tuning method [15] is described below. At first, the constraint is designated in proportional action (see Figure 3) to obtain critical gain value Kcr. Ti = ∞ and Td = 0. The conforming period Pcr are experimentally defined (see Figure 4). The parameters values of Kp and Ti should set agreeing to below formula:

$$K_p = 0.6\,K_{cr} \quad and \quad T_i = 0.5\,P_{cr}$$

PI controller parameters is tuned by Ziegler – Nichols method [15] gives,

$$G_c(s) = K_p\left(1 + \frac{1}{T_i s}\right) \qquad (3)$$

$$G_c(s) = 0.6\,K_{cr}\left(1 + \frac{1}{0.5\,P_{cr} s}\right) \qquad (4)$$

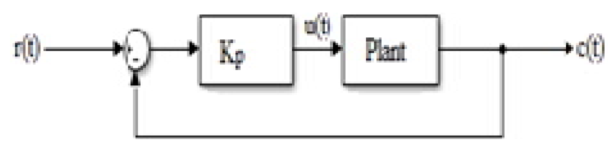


Figure 3: PI controller in proportional action

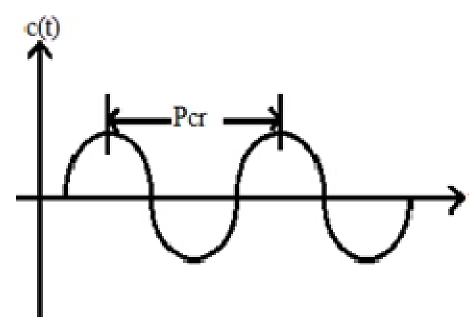


Figure 4: Determination of sustained oscillation (Pcr)

3.2 Modelling of Power System with SVC

This case in this section highlights the design of a complex transmission system comprising 2-hydraulic power plants. SVC used to improve transient stabilization and damping of power system fluctuations. The phasor simulation technique can be utilized. A single line diagram speaks to a basic 500 kV transmission system is exposed in Figure 5.

A 1000 MW hydraulic power system (M1) is attached to a 500 kV load center which adds up to 350 km of transmission line. A resistive load of 5000 MW is shown as a load core. The remote 1000 MVA plant and the local generation 5000 MVA plant M2) feed the load. The load stream was carried out on this process with the M1 plant producing 950 MW, so the M2 plant produces 4046 MW. The line conveys 944 MW, which is opened to the charging of the surge impedance (SIL= 977 MW). In order to keep system stability during failures, the transmission line [10] at its base is protected by a 200MVAR SVC. SVC do not have a controller feature. Parameters for computer and SVC have been omitted from [16].

To order to uphold system stability during errors, the transmission line at its inside is balanced via a 200MVAR SVC. The two computers were fitted with an HTG (Hydraulic Turbine and Governor), an excitation unit, and a PSS (Power System Stabilizer). The other unit is a swing generator. PSS is used as part of this design to apply damping to the rotor movements of the synchronous device by regulating the excitation current. Some disruptions which arise in the power system due to a fault that can contribute to electromechanical fluctuations in the electrical generators. These fluctuating movements must be dampened to preserve the stability of the system and reduce the risk of synchronization.

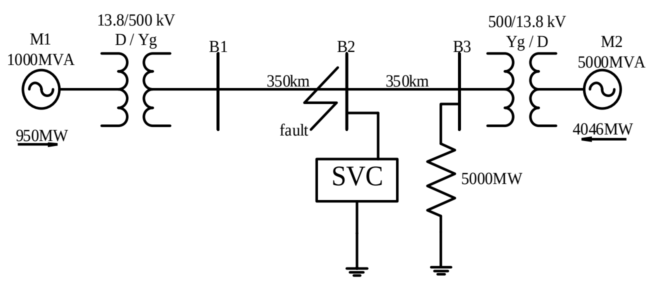


Figure 5: Single line diagram of 2-machine power

3.3 Design of PI Controller

The proposed PI controller constraints has been designed by using Ziegler – Nichols tuning technique.

$K_{cr} = 53.899$ and $P_{cr} = 6.294$

$$K_p = 0.45\, K_{cr} = 0.45\,(53.899) = 24.25455$$

$$T_i = 0.83\, P_{cr} = 0.83\,(6.294) = 5.22402$$

$$Gc(s) = K_p\left(1 + \frac{1}{T_i s}\right) = 0.45\, K_{cr}\left(1 + \frac{1}{0.5\, P_{cr} s}\right) = 24.25455\left(1 + \frac{1}{5.22402 s}\right) = 24.25455\left(\frac{s + 0.1914}{s}\right)$$

Through faults angular speed deviation (dω) of the devices, mechanical power (pm), line voltage and current are adjusted. So, dω and pm are taken as input parameters for improving the performance of SVC operated by newly designed PI controllers are therefore taken as input parameters for fast and high-performance processors.

4. RESULTS

4.1 Simulation Results

The load flow result of the above model is determined and the effects of the simulation are shown below. Two forms of faults: single line to ground fault and three phase fault (line to line) are known.

4.2 Single Line to Ground Fault

Think through a 1-phase fault happened at 0.1s and circuit breaker is opened at 0.2s (4-cycle fault). If SVC (without controller) is applied, settling time for voltage at Bus 1 is at 1.9186s (see Figure 6(a)), settling time for voltage at Bus 2 is at 0.9870s (see Figure 6(c)), settling time for voltage at Bus 3 is at 0.2064s (see Figure 6(e)). Settling time is at 2.4188s for power (see Figure 6(g)).

Next, the simple SVC is replaced by PI controlled SVC. For the duration of fault, machines speed deviation (dω) and mechanical power deviation (pm) at all times monitored by PI controller. Settling time for voltage at Bus 1 is at 2.0698s (see Figure 6(a)), settling time for voltage at Bus 2 is at 2.0118s (see Figure 6(c)), settling time for voltage at Bus 3 is at 0.2035s (see Figure 6(e)). Settling time is at 2.5721s for power (see Figure 6(g)). PI reduces damping of power system fluctuation.

4.3 Three Phase Fault (Line – Line)

If SVC (without controller) is applied, settling time for voltage at Bus 1 is at 2.8470s (see Fig. 6(b)), settling time for voltage at Bus 2 is at 1.8369s (see Fig. 6(d)), settling time for voltage at Bus 3 is at 0.5445s (see Fig. 6(f)). Settling time is at 2.7631s for power (see Fig. 6(h)).

Next, the simple SVC is switched by PI controlled SVC. During fault, Machines speed deviation (dω) and mechanical power deviation (pm) at all times observed by PI controller. Settling time for voltage at Bus 1 is at 3.0569s (see Figure 6(b)), settling time for voltage at Bus 2 is at 2.5302s (see Figure 6(d)), settling time for voltage at Bus 3 is at 0.2063s (see Figure 6(f)). Settling time is at 2.9661s for power (see Figure 6(h)). PI reduces damping of power system oscillation.

5. DISCUSSION

From the results obtain, percentage overshoot can be reduced by adding the simple PI controller. During 1 phase fault, percentage overshoot for voltage at Bus 1 reduced from 26.4131% to 18.1555%, at Bus 2 reduced from 16.7984% to 12.5976% and at Bus 3 reduced from 5.2878% to 4.9973 %. Meanwhile, for power, reducing to 41.1526% from 46.1633%. During 3 phase fault, percentage overshoot for voltage at Bus 1 reduced from 16.9781% to 16.5235%, at Bus 2 reduced from 15.1245% to 13.7407% and at Bus 3 reduced from 7.5132% to 7.4725 %. Meanwhile, for power, reducing to 52.8457% from 51.1336%.

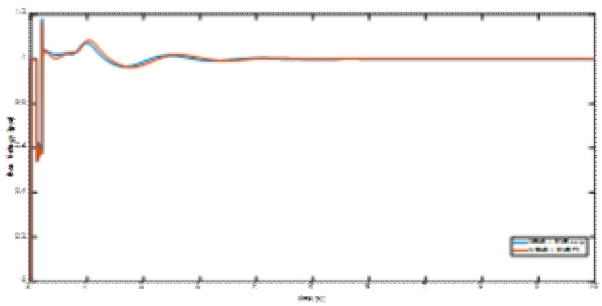
Other than that, PI controlled SVC also improve output value nearly to its desired value compared to SVC without controller. Table 1 and Table 2 show the voltage and power value for 1 phase fault and 3 phase fault respectively.

Table 1: Output value during 1 phase fault

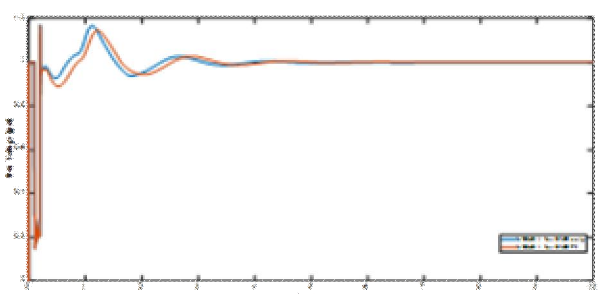
Output Value	SVC Only	SVC PI
V at Bus 1	0.9988 p.u	1 p.u
V at Bus 2	1.003 p.u	1.008 p.u
V at Bus 3	0.9921 p.u	0.9924 p.u
Power	943.9 MW	944.4 MW

Table 2: Output value during 3 phase fault

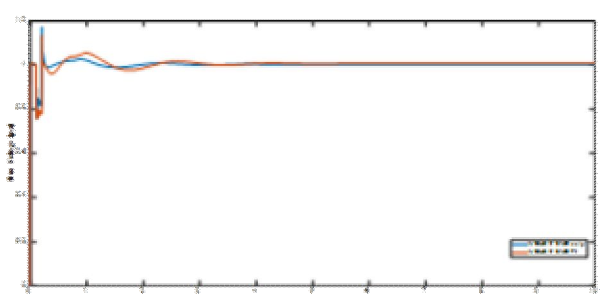
Output Value	SVC Only	SVC PI
V at Bus 1	0.9988 p.u	0.9999 p.u
V at Bus 2	1.003 p.u	1.008 p.u
V at Bus 3	0.9921p.u	0.9923 p.u
Power	943.9 MW	944.1 MW



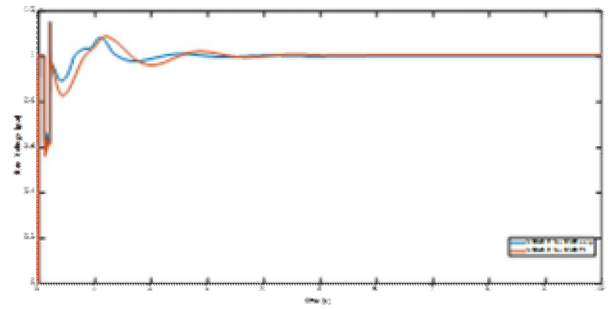
(a)



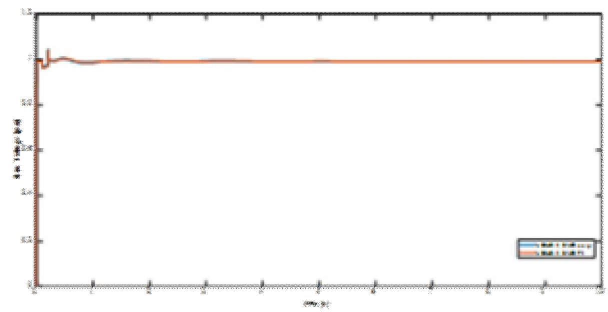
(b)



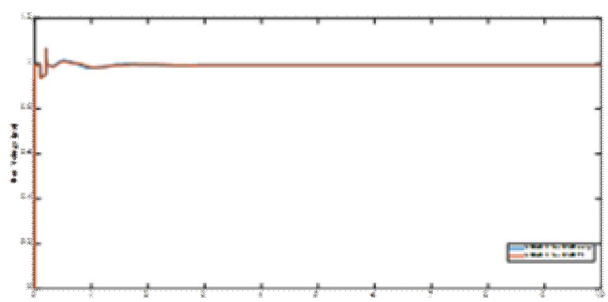
(c)



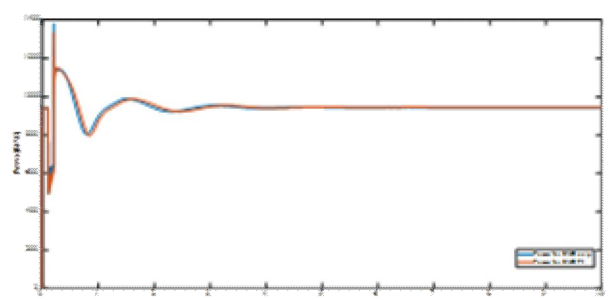
(d)



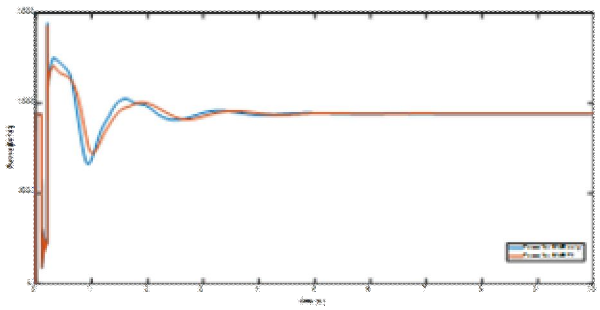
(e)



(f)



(g)



(h)

Figure 6: (a) V Bus 1 for 1phase fault. (b) V Bus 1 for 3phase fault. (c) V Bus 2 for 1phase fault. (d) V Bus 2 for 3phase fault. (e) V Bus 3 for 1phase fault. (f) V Bus 3 for 3phase fault. (g) Power for 1phase fault. (h) Power for 3phase fault

6. CONCLUSION

PI controller is cheapest and efficient controllers in order to enhance power system stability. Two types of faults which is 1 phase and 3 phase fault are used to test performance of PI for SVC in a large scale power system model. In other hand, PI controller can handle a robust interconnected power system efficiently and can damped out all types of oscillation. Ziegler Nichols method is properly and easily tuning method used in order to tuning PI, so that can be highly suitable as SVC controller. Only change of machines angular speed deviation and mechanical power deviation can be observed by this proposed controller. A new controller can be designed so that it can monitor every network parameters such as change of bus voltage, current, machines angular speed deviation, mechanical power deviation, etc.

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