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REDUCTION OF SUB-SYNCHRONOUS RESONANCE BY USING PSO BASED PI DAMPING CONTROLLER

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ABSTRACT

When a series compensated long transmission lines connects to a steam-turbine generator, it results in the unfavorable phenomenon called as sub-synchronous resonance (SSR). This effect results in the damage of the turbine shaft which is very dangerous. This paper mainly deals with the reduction of oscillations resulting from SSR in order to protect the steam turbine. Hence sufficient damping controllers should be employed to protect the system to go out of synchronism. For this, simple TCSC and TSSC alone are not sufficient and hence we are going for the PID damping controllers along with the Distributed Static Series Capacitors (DSSC) in order to damp out the oscillations quickly. In this paper, the PID controlled damping controllers are employed along with the DSSC to make the system stable and the simulations are carried out in MATLAB/SIMULINK

KEYWORDS: PSO, DSSC, SSR, PI damping controller.

INTRODUCTION

Tremendous growth in the demand of the electricity lead to the increase in the power system networks as well as the increase in the electrical long transmission lines. Whenever the long transmission lines are used in the power system network, inductive reactance will be injected into the lines which lead to the drop in the voltage at the receiving end and hence this reactive voltage is to be compensated. For compensating the inductive reactance, series capacitors are widely used which are available with low cost, easy to maintain and easy to install. By using these series capacitors, the power transfer capability is increased, and also the steady state stability can be enhanced. Hence, they became very popular. But, when these series capacitors are employed in the system, an adverse effect known as Sub-Synchronous resonance occurs in the turbines which even lead to the damage of the turbine shaft.

Sub-Synchronous is a phenomenon, in which when the natural Impedance loading of the transmission lines equals to the system generator frequency in the event of disturbance, the generator may experience severe torsional oscillations and finally it may go into instability and because of this high speed, the generator shaft will experience huge stress and it will get damage.

In order to avoid this Sub-Synchronous effect[1], suitable damping controllers should be installed to prevent the system from collapse.

There are many damping controllers have been proposed using TSSC, GCSC[7] and other FACTS devices[2,6]. These controllers[3-5] must reduce the oscillations. In fact these devices should not make the system to go out of stability. And also when the system is subjected to sudden and large disturbance, some of the auxiliary controllers are unable to damp out the oscillations and in return they will inject negative sequences in the power system and the generator will go out of stability even faster. So, a proper care must be taken in designing the controllers for the damping controllers. A suitable controller will improve the stability of the system and an improper controller will make the system as unstable one.

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Hence, when a fault occurs in the power system, the generator will act according to it automatically. At that time, the behavior of the power system is non-linear. Hence, the damping controllers that are designed should work in non-linear model so as to attenuate the oscillations of the turbine.

The Distributed static Synchronous Capacitor is a new concept derived from the Static Synchronous Series Compensator (SSSC) in which the reliability of the system is more than SSSC and also due to the distributed in nature, easy to install, maintain and also the cost incurred is low. Hence, now a day's these are becoming very popular in nature. So, DSSC is used in this paper for the compensation.

For the designing of the non-linear damping controllers, simple TSSC or TCSC controllers are non-sufficient as their behavior will not change non-linearly in fault conditions of the power system. Hence, some auxiliary components should be added to the system in order to get the required feature. So, we are going for the implementation of the PI damping controller along with DSSC to make the system more stable.

Mainly this paper presents the behavior of the PI controller in damping out the oscillations in the fault period. In this paper, a comparative study between the system under fault condition has been studied and the system under the fault with the PI controller has been studied. And the simulation results are compared.

ANALYSIS OF THE IEEE SBM MODEL OF POWER SYSTEM NETWORK

The network taken in this model is IEEE SBM model included with the DSSC components. The fig.1 gives the single line diagram of the power system network connected with the DSSC modules.

A single generator of 700MVA, 22KV, 60Hz, 3600RPM is connected to infinite bus through the DSSC modules and one transformer and two long transmission lines.

The mechanical power generating system consists of one Low Pressure turbine (LP), one High Pressure Turbine (HP), one generator, and an exciter system.

The level at which the compensation given by the series capacitor is set as 52%. Here, two incidents have been considered.

1. The power system under the fault condition without any damping controller in which fault has been occurred after a time period of 3sec and the same is cleared after a time period of 0.168sec.
2. The power system under the fault with the implementation of the PID damping controller

The fig.1 represents the IEEE SBM model of the power system network with two transmission lines incorporated with the DSSC modules, generator and turbine sets.

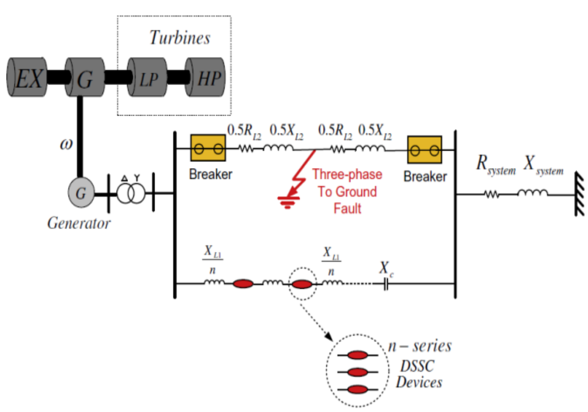

Fig1: DSSC connected to SBM model of the IEEE

DESIGN OF THE DSSC MODULES

DSSC [11,12] is a single-phase model of the SSSC. But, the DSSC can be implemented for three-phases in order to get the proper power flow in the transmission lines and to maintain the symmetry of the transmission lines. Each module is suspended from the line and also it will replace the insulating clamp and hence there is a reduction in the extra insulation.

Fig.2 represents the DSSC module schematic diagram in which all the components of DSSC are present. It mainly consists of current transformer (CT) to give back the feedback signal, one processing unit serves as controller, a single turn transformer to inject the voltage into the transmission line, a single phase inverter to generate the sinusoidal voltage. The capacitor placed will maintain constant DC voltage of the DC bus of the inverter. Harmonics are eliminated through the LC filter circuit and the power losses in the inverter circuit are compensated by absorbing the active power from the transmission line.

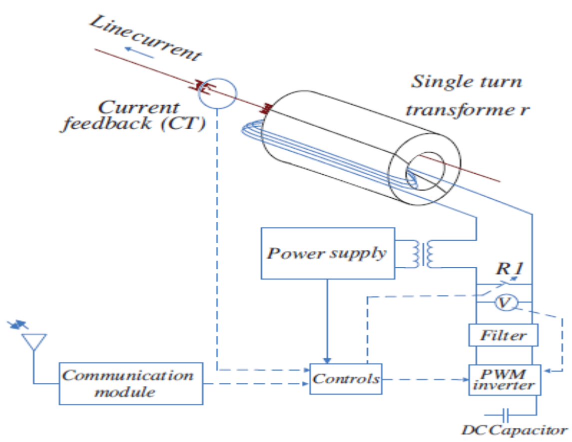

Fig.2: Schematic of the DSSC module

The power line communication system sends corresponding signals to the gradual changes in the transmission line when subjected to fault. The CT is of single turn and hence the current handled by the inverter is very less. So, power loss in the inverter is significantly low. And also the cost incurred for the inverters is low, they are also smaller in size.

CONTROLLER DESIGN TO SUPPRESS TORSIONAL OSCILLATIONS

The DSSC modules are linked to the series compensated transmission lines to reduce the torsional oscillations due to SSR. The main function of the DSSC is to inject the voltage in quadrature with the line current in order to control the active power in the transmission line. The DSSC modules even perform much better if they are supplied with the extra controllers and with the algorithms [8]. Further, the particle swarm optimization algorithm [9-10] is used in designing the conventional damping controller to optimize the system parameters.

In the PSO algorithm, the trajectory of the velocity of each particle s altered in the search space. The best objective function is derived from all over the particles and is considered as Pb. And the overall best value of the objective function is obtained by the particle at time is represented as Gb and these can be calculated by using the below formula.

$$V_{id}(t)= w \times V_{id}(t-1) + C_1 r_1 \times (P_{id}(t-1)-X_{id}(t-1)) + C_2 r_2 \times (P_{gt}(t-1) - X_{id}(t-1))$$

$$X_{id}(t)= X_{id}(t-1) + C\, V_{id}(t)$$

Where, X_{id} is the i^{th} particle position at time'*t*' and v_{id} is the i^{th} particle velocity at time'*t*'. The positive constants C_1 and C_2 are responsible for alteration of velocity of the particle towards their respective best values. Random constants r1 and r2 are the two random constants between '0' and '1' and 'c' is a factor which can modify the velocity of the particle to next position in the next iteration. In the designing of controller, model is followed as shown in fig.3

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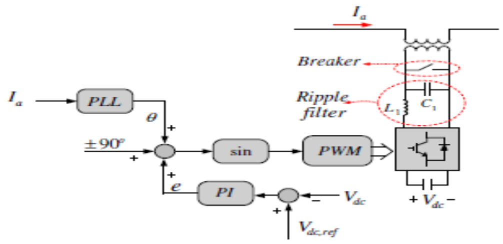

Fig.3: Schematic control circuit for DSSC

In the above schematic circuit, Phase Locked loop is used for generating the synchronization signal 'Θ'. The signal coming from the PI controller adds up with the 'Θ' and the resulting signal will be given to the inverter circuit through PWM component.

Now, designed circuit is ready for simulation and is to be simulated using the MATLAB.

SIMULATION RESULTS

The simulation is to be carried out in the MATLAB. The simulation circuit with the fault and without any damping controller is shown in the fig.4.

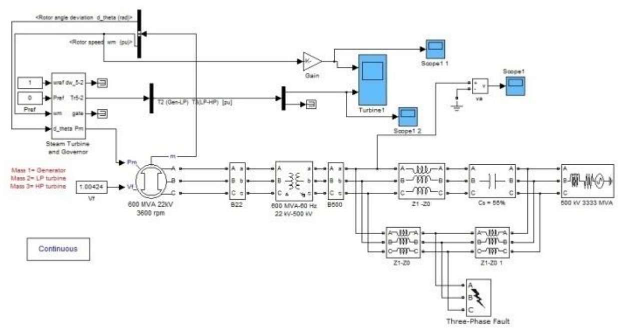

Fig.4: IEEE SBM without any controller under fault

In this model, the fault is created after a time period of 3sec and is cleared after 0.168sec. When this occurs, there is a significance change in torque and speed of the generator at which the impedance of the system coincides with the natural frequency of the transmission system. When the system is subjected to the fault, the change in the torque characteristics of the turbine is shown in Fig.5 and the change in the speed of the turbine is shown in the Fig.6.

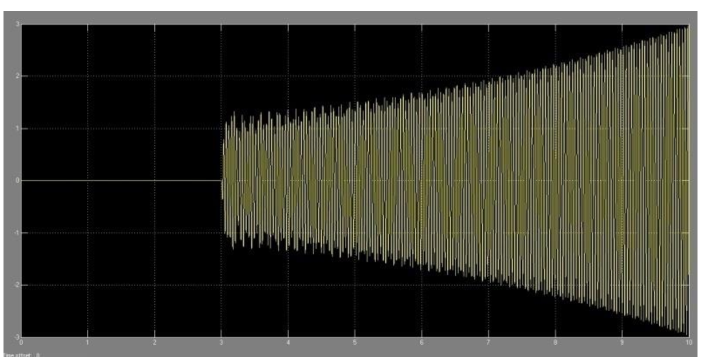

Fig.5: Torque characteristics of IEEE SBM system without any damping controller under fault

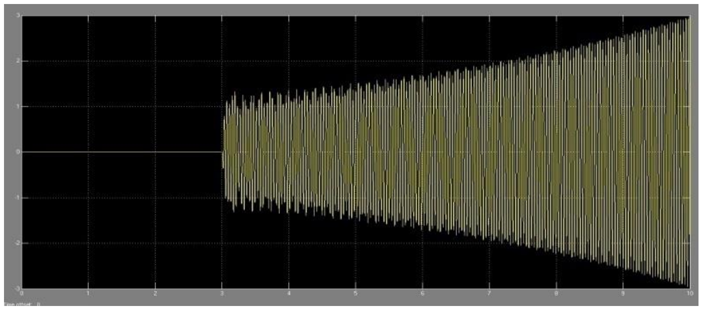

Fig.6: Speed characteristics of IEEE SBM system without any damping controller under fault

From the above simulation results, we can clearly see that when the impedance of the system coincides with the natural impedance loading of the transmission network, the speed of the turbine is going out of control and at the same time the torque is also uncontrolled.

Because of this, there is a necessity to implement a damping controller in the network to reduce the oscillations and also to protect the system from damage. So, we are going for the PID controller to control the system damping oscillations. The schematic circuit model of the IEEE SBM model under the fault with the PID damping controller is shown in below figure.

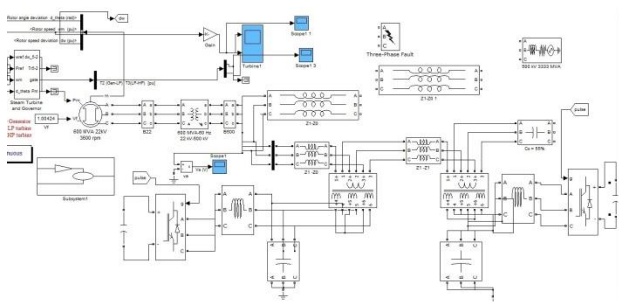

Fig.7: IEEE SBM with controller under fault

In the above circuit the PI controller is implemented to damp out the oscillations due to SSR. Now, the output torque for the system under the fault condition is shown in fig.8 and the output speed of the turbine is shown in fig.9

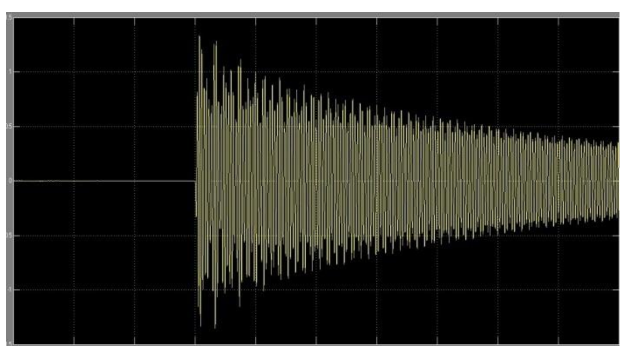

Fig.8: Output torque characteristics with damping controller under the fault

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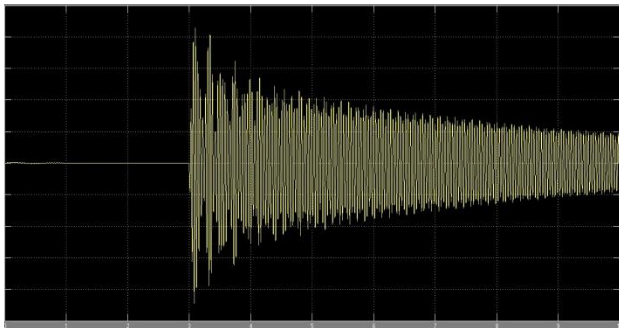

Fig.9: Output speed characteristics with damping controller under the fault

From the output characteristics, we can say that when the system is subjected to the fault, because of the controller, sufficient damping is injected into the system hence, the speed is getting controlled and so the torque.

CONCLUSION

This paper deals about the implementation of the PSO based PI damping controller for the reduction of the oscillation of the torque and the speed under fault conditions. And also the simulation results for the proposed controller are presented. As the implementation of damping controller will make the system more versatile to the fault occurrences and makes the system to be more stable against the fault conditions and also the turbine and the other components of the system will be protected.

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