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MITIGATION OF SUBSYNCHRONOUS RESONANCE IN SERIES COMPENSATED WIND FARM USING UPFC AND ANN WITH BACK PROPAGATION ALGORITHM

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***Abstract*—** FACTS devices have shown effective functionalities in promoting the system operation security and service reliability.UPFC Versatile of FACTS controllers, yield simultaneous control of all basic power system parameters. Subsynchronous Resonance has been identified as a serious problem for conventional turbine Generators due to the application of series capacitors. Moreover Wind turbine generators are also susceptible to Subsynchronous oscillations and other resonant interactions. Artifical Neural Network(ANN) using Back propagation Algorithm can be used with promising results as it has good ability of Non-linear mapping with self organization and self learning capability,it also requires less computational time and ANN is trained to store solution without excessive memory storage requirements.UPFC joined with artificial neural network could respond and damp both Subsynchronous resonance and Subsynchronous oscillations respectively. It has been demonstrated in MATLAB/Simulink and shown with better damping of oscillations.

I INTRODUCTION

Series compensated long transmission lines in order to improve power transmission networks are in the power of great importance [1]. Series compensation of transmission lines, decreasing the normal load impedance by increasing the electrical length of the line, had a notable impact in promoting stable and improves voltage [2].Compensated in such networks, electrical networks and modes of interaction between states leads to a phenomenon harmful to the mechanical shaft of the turbine generator under synchronous oscillations (SSR) is [3].Sub-synchronous resonance phenomenon often occurs in series with the capacitor compensated systems. SSR oscillation phenomenon is that it occurs in the range of electrical and mechanical oscillations gradually increases, and the turbine rotor - Generator simultaneously is that the fluctuations it is not controlled and proper protection, these fluctuations can lead to fatigue or even broken rotor axis [2]. WIND power based generation has been rapidly growing world wide during past decade[4]. In order to transmit large amounts of wind power over long distances, system planners may often add series compensation to existing transmission systems for enhanced power transfer capability. Subsynchronous Resonance (SSR) has been identified as a problem for conventional turbine generators due to the application of series capacitors [5], [6].Wind turbine generators may also susceptible to subsynchronous oscillations or other resonant interactions [7],[8].

Series capacitors have been extensively used as a very effective means of increasing power transfer capability of transmission system[1]. This is due to partially compensating the reactance of the transmission lines. However, the use of series capacitors may lead to the phenomenon of subsynchronous resonance. Under a disturbance, series capacitors may excite subsynchronous oscillations, when electrical resonant frequency of the network is close to natural torsional mode frequency of turbine-generator shaft[2]. Under such circumstance the shaft will oscillate at this natural frequency. This oscillation might grow to uncertain limit in seconds resulting in shaft fatigue and possibly damage and failure[2]. Therefore, there is a need to investigate and analyse Subsynchronous resonance when planning inclusion of series capacitors for new or existing power system. Subsynchronous resonance is categorized in three categories, induction generator effect, torsional interaction and torque amplification. In all aspects, subsynchronous resonance is due to the interaction of a series capacitor with turbine-generator.

II SUBSYNCHRONOUS RESONANCE AND SUBSYNCHRONOUS OSCILLATIONS

WIND power based generation has been rapidly growing world-wide during the recent past. In order to transmit large amounts of wind power over long distances, system planners may often add series compensation to existing transmission systems for enhanced

power transfer capability. Subsynchronous Resonance (SSR) has been identified as a problem for conventional turbine generators due to the application of series capacitors [2], [3].Wind turbine generators may also be susceptible to subsynchronous oscillations or other resonant interactions [4],[5]. However, not much information is available in literature about such interaction possibilities. Subsynchronous resonance is a phenomenon in which the resonant frequency of the turbine generator shaft coincides with a natural resonant frequency of the electrical system such that there is a sustained, cyclic exchange of energy between the mechanical shaft and the electrical system. This exchange of energy results in torsional stress on the turbine generator shaft that can lead to severe damage. In extreme cases, the shaft can actually fracture. Subsynchronous resonance (SSR) is a dynamic phenomenon of interest in power systems that have certain special characteristics. Subsynchronous resonance is an electric power system condition where the electric network exchanges energy with a turbine generator at one or more of the natural frequencies of the combined system below the synchronous frequency of the system.[2]
The definition includes any system condition that provides the opportunity for an exchange of energy at a given subsynchronous frequency.

III.UNIFIED POWER FLOW CONTROLLER(UPFC)

The Unified Power Flow Controller (UPFC) is a typical FACTS (Flexible AC Transmission Systems) device that is the most sophisticated and complex power electronic equipment and has emerged for the control and optimization of power flow and also to regulate the voltage in electrical power transmission system. This project propose the mitigation SSR and oscillations by placing UPFC in the transmission line with suitable controllers[10].

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link[10].

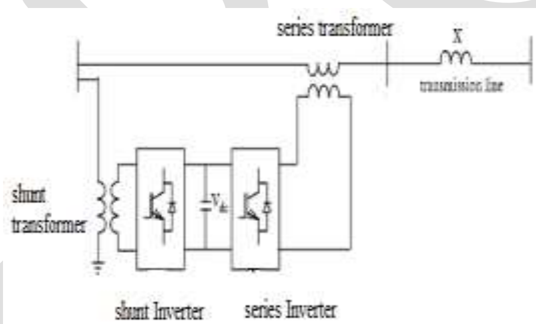


Fig:1 Schematic Diagram of UPFC

The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system. The UPFC can provide simultaneous control of all basic power system parameters (transmission voltage, impedance and phase angle). The controller can fulfill functions of reactive shunt compensation, series compensation and phase shifting meeting multiple control objectives[7].

UPFC consists of two inverters connected back to back with DC link capacitor as shown in. One inverter is connected in shunt and the other in series with the transmission line. Such an arrangement allows for all the three functions namely series, shunt and phase angle compensation to be unified in one unit[8].

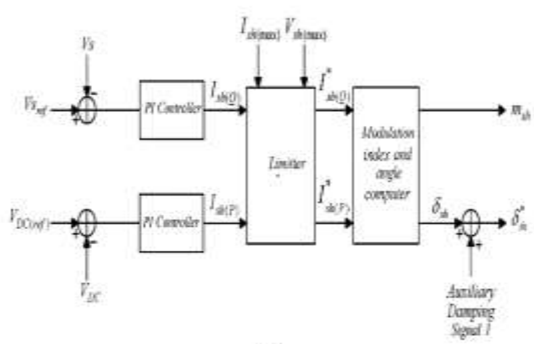
Shunt Inverter is connected to a shunt transformer and the series inverter is connected to a series transformer. It is readily seen that the inverter connected to the shunt transformer can perform the function of a variable reactive power source similar to that of shunt compensator. In addition, the shunt inverter can charge the DC link capacitor.

Series inverter can provide series or phase angle compensation by injecting a series voltage of proper phase relationship. In the case of series compensation, series inverter can function independent of the shunt inverter , as series inverter supplies consumes only reactive power and does not have any real power exchange with shunt inverter. In such case the DC link capacitor voltage will ideally be constant.

IV. EXISTING SYSTEM

UPFC with SSD(Subsynchronous Resonance damping controller)

The UPFC control system , does not provide, by itself, the essential damping of oscillations since its primary mission is to regulate the bus voltage and to control the power flow in corresponding transmission line. However, the UPFC controllable signals including $m_{sh,\delta sh,,}m_{se}$ and δ_{se}, can be modulated in a desired way to provide some other ancillary duties such as SSD, power oscillation damping, etc. In order to achieve an effective damping of SSR, from the reference[14] its understood that it is indispensible to apply synchronized tuning of UPFC with auxiliary SSD controllers. Fig. 3 presents two controllers which are respectively granted to shunt and series branch control systems. Two controllers depicted by Fig. 3 generate auxiliary signals for the main control circuits shown in Fig. 2. Referring to Fig. 2, with the aim of achieving effective damping of oscillations, the output of SSD controller is utilized to modulate δ_{sh} in shunt converter. In contrast, the output of SSD controller in conjunction with the series branch is devised to regulate,,m_{se} with the aim of providing the proper damping. As illustrated in Fig. 3 a gain block, a washout filter, and a lead-lag compensator comprise the building blocks of a SSD controller. Δ_w signifies the angular frequency difference and is speculated as the feedback input signal [14]. The design process for each SSD controller is such that an additional electrical torque, which is in phase with the speed deviation, it would be produced to improve the damping of oscillations [15]. The gain settings for SSDs are determined such that a desired damping ratio for the subsynchronous oscillations is generated. Also a washout filter is included suitably to eliminate the effect of SSDs in steady-state power conditions. Herein, a trial-and-error approach has been applied for tuning the different parameters of SSDs through the simulation studies to achieve the best damping performance. However, intelligent and heuristic algorithms might be employed as well. The generated output signals by auxiliary SSD controllers are utilized to adjust the reference settings of UPFC in order to realize the SSD objective. For the sake of comprehensive studies, three different control strategies are considered. In the first attempt, only the SSD controller is added to the shunt inverter control system. In the second trial, a single SSD controller is designed and added to the series inverter control system. Finally, it is deemed that two SSD controllers for both shunt and series inverter control systems are operating simultaneously. In this case, the total capability of UPFC could be realized.



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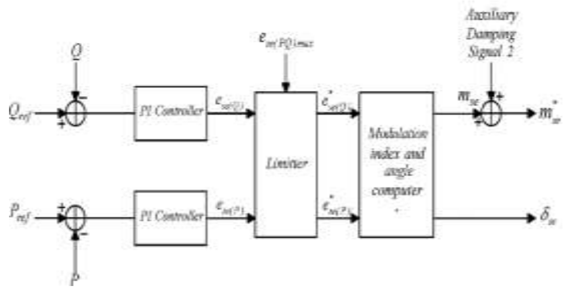


(b)Fig 2: Block Diagram of the UPFC control system (a)shunt inverter controller(b)series inverter controller

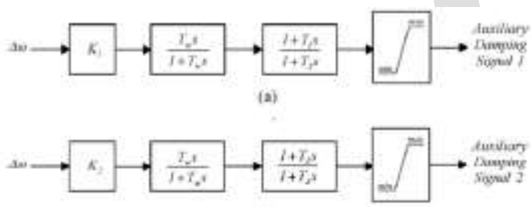


Fig 3:SSD controller (a) for shunt branch (b) for series branch.

V.PROPOSED SYSTEM

UPFC WITH ARTIFICAL NEURAL NETWORK

A neural network is a machine that is designed to model the way in which the brain performs a particular task. The network is implemented by using electronic components or is simulated in software on a digital computer. A neural network is a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing experimental knowledge and making it available for use.Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques[16]. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyse.

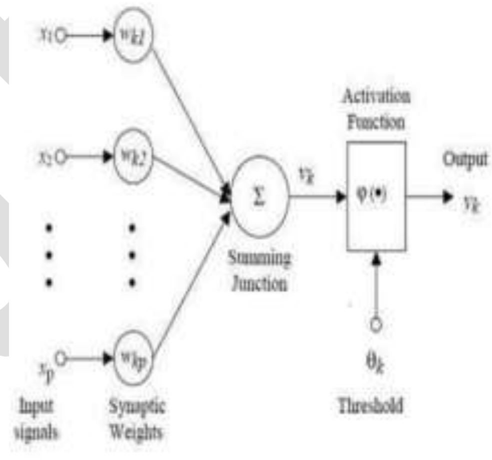
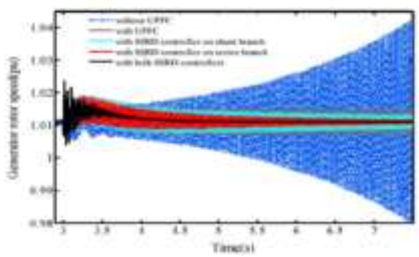


Fig 4: Model of an ANN

This expert can then be used to provide projections given new situations of interest and answer "what if" questions. Before the ANN can be used to adapt the controller gains in real time, it is necessary to determine a proper set of values for the connection weights .The process of reaching the connection weights is normally carried out off-line and is usually referred to as the training process. In the training process, we first compile a set of training patterns and store these training patterns in the training set. Each training pattern

comprises a set of input data and the corresponding output data. A training pattern set of training patterns, which cover a wide range of operating conditions, is finally used to train the desired ANN. It should be noted that we use two hidden layers. Main purpose of ANN is used for the reducing the error in the system, for that we are going to use training data method. In this method, we have to give both input values and desired output value for estimating the weight values, in that initial value taken as a random value[17].
UPFC is the most widely used FACTS device to control the power flow and to optimize the system stability in the transmission line. The ANN is usually made up of sigmoidal activation function neurons and back propagation is normally used to train the network either on-line or off-line. In order to train a neural network to determine the network weights and most important of all is learning to talk. Training a neural network depends on the network type. Another smart way to reduce oscillations about the synchronous oscillations can be reduced by using a neural network[18] . Usefulness of artificial neural networks are able to solve problems of power systems. They are able to input and output of a power system using constant learning process and no need to do the programming of complex .

VI .SIMULATION RESULT



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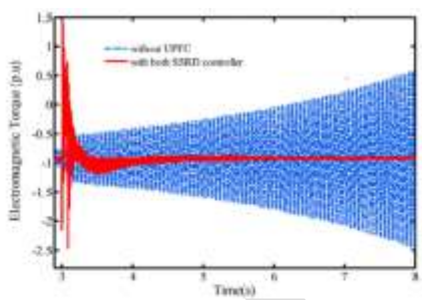

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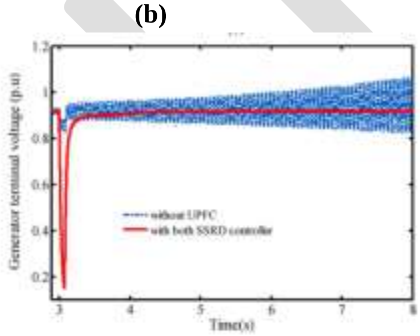
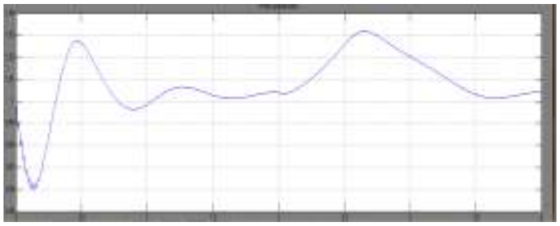


(c)

Fig 5: SSR mitigation using UPFC and SSD controller (a) generator rotor speed (b) electromagnetic torque (c) generator terminal voltage



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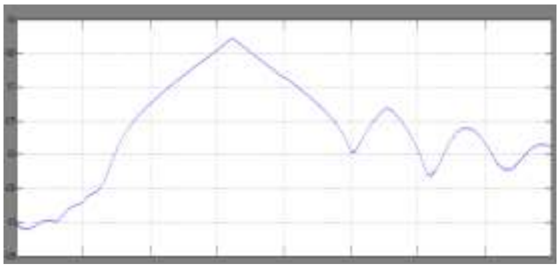
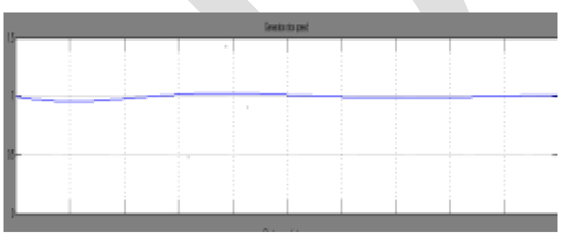


(b)

(c)

Fig 6 : Oscillations in (a)Generator rotor speed (b)Electromagnetic torque (c) Generator voltage without using UPFC

Fig 6(a),(b) displays oscillations in generator rotor speed, electromagnetic torque. Referring to Fig 6(a),(b) it is observable that, in contrast to the instability for the case without UPFC, the UPFC even with no specific controller prevents divergent SSR oscillations but the damping performance is, however, very poor.



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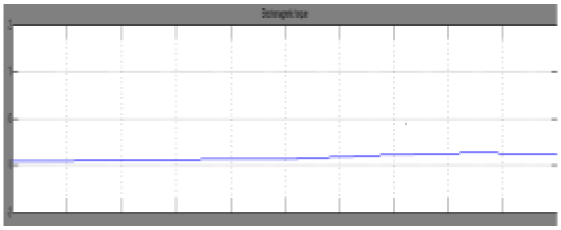

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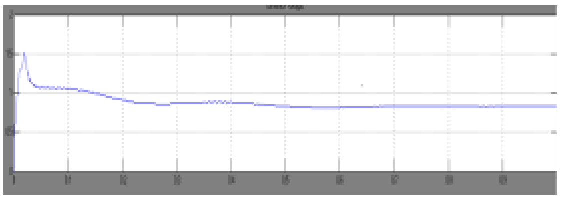

(c)

Fig 7: SSR mitigation using UPFC and Artifical Neural Network (a) Generator rotor speed (b) Electromagnetic torque (c) Generator terminal voltage

VII. CONCLUSION

The proposed work presented a comprehensive approach for mitigating SSR and damping subsynchronous oscillations. The main cause of the Production of SSR is the Series Compensation. The study served a rather comprehensive exploration on the SSR mitigating effect yielded by the UPFC utilization in the transmission system with suitable intelligent controller. Artifical neural network should not only improve the performance of the UPFC but also it should not cause any instability in the system. The study demonstrated that UPFC with artificial neural network can simultaneously achieve SSR mitigation and subsynchronous oscillation damping.

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