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Application of Neuro-Fuzzy Controller for SVC for Improving Transient Stability

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ABSTRACT

In this paper steady-state modeling of Static VAR Compensator (SVC) for power flow studies has been represented and discussed in details. Firing angle model for SVC was proposed to control the voltage at which it is connected. In same manner firing angle model for SVC is proposed with Fuzzy controller to control active power flow of the line to which TCSC is installed. The proposed models take firing angle as state variable in power flow formulation. To validate the effectiveness of the proposed models ANN algorithm was developed to solve power equations in presence of SVC. The Case studies are carried out on 9-bus test system to demonstrate the performance of the proposed models.

Keywords: *SVC, TCSC, Fuzzy Logic, Transient stability*

I. INTRODUCTION

With the rapid development of power system, especially the increased use of transmission facilities due to higher industrial output and deregulation, it becomes necessary to explore new ways of maximizing power transfer in existing transmission facilities, while at the same time maintaining the acceptable levels of the network reliability and stability. On the other hand, the fast development of power electronic technology has made FACTS (flexible AC Transmission System) promising solution of future power system. FACTS controllers such as Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow controller (UPFC) are able to change the network parameters in a fast and effective way in order to achieve better system performance. These controllers are used for enhancing dynamic performance of power systems in terms of voltage/angle stability while improving the power transfer capability and voltage profile in steady-state conditions.

Static VAR Compensator (SVC) and Thyristor Controlled Series Compensator (TCSC) are FACTS controllers based on thyristor controlled reactor (TCRs), the first is a shunt compensator used for voltage regulation which is achieved by controlling the production, absorption and flow of reactive power through the network. The latter is a series compensator, which allows rapid and continuous changes of transmission impedance, controlling power flow in the line and improving system stability. Now, for maximum utilization of any FACTS device in power system planning, operation and control, power flow solution of the network that contains any of these devices is a fundamental requirement, As a result, many excellent research works have been carried out in the literature for developing efficient load flow algorithm for FACTS devices.

II. CONCEPT OF SVC

An SVC is a controlled shunt susceptance (B) which inject reactive power (Q_{net}) into thereby increasing the bus voltage back to its net desired voltage level. If bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power, and the result will be to achieve the desired bus voltage.

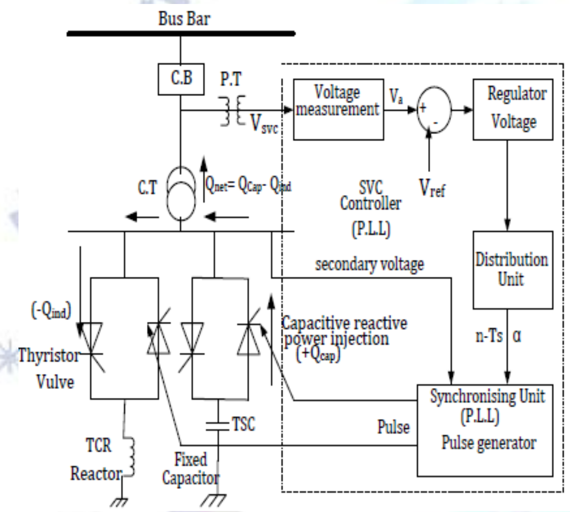

Figure 1: SVC Structure and Control Diagram

The control system consists of,

(a). A measurement system measuring the positive-sequence voltage to be controlled. A Fourier-based measurement system using a one-cycle running average is used.

(b). A voltage regulator that uses the voltage error (difference between the measured voltage V_m and the reference voltage V_{ref}) to determine the SVC susceptance B needed to keep the system voltage constant.

(c). A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs.

(d). A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors. This is shown in Fig. 2.

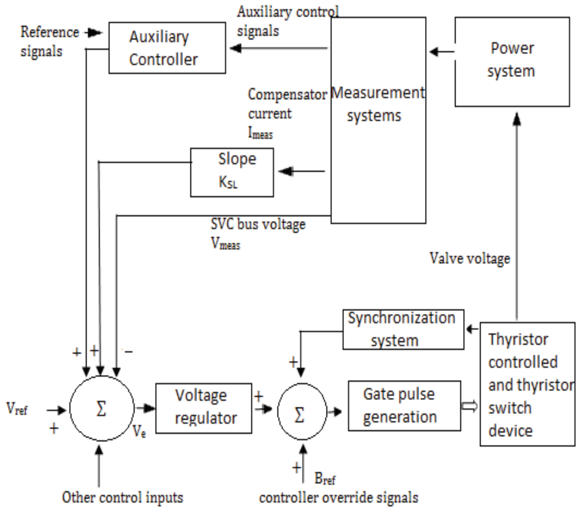

Figure 2: SVC Control Structure

The control system diagram of general SVC with TSC-TSR configuration is shown in fig 2, and also incorporating of voltage regulator and the measurement of reactive power is Regulator processes and ensures that measured input Variables must produce an output signal which is equivalent to the reactive-power compensation. Then the measured Variables are compared with the reference voltage signal, denoted by V_{ref}, and the error evolved is used an input signal for the controller. Then the output of controller generates a PU susceptance signal, which is shown by B_{ref}, and is then used to reduce undesired error signal to zero in the steady-state operation, generated signal is then transferred into a gate-pulse generation.

Fuzzy Controller:

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 3. Generally, the FLC is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

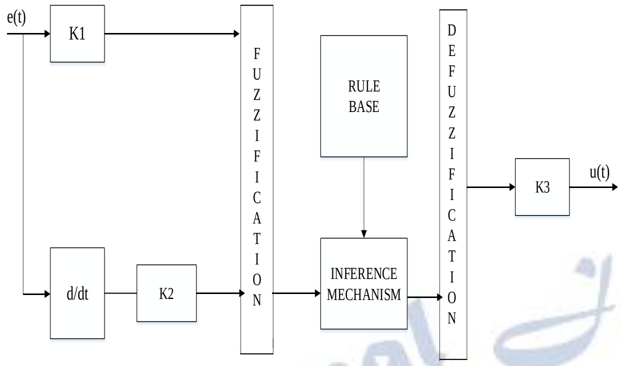

Figure 3: basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3.The numbers of rules are formed as 9. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the output as maximum value of input.

Artificial Neural Networks

Figure 4 shows the basic architecture of artificial neural network, in which a hidden layer is indicated by circle, an adaptive node is represented by square. In this structure hidden layers are presented in between input and output layer, these nodes are functioning as membership functions and the rules obtained based on the if-then statements is eliminated. For simplicity, we considering the examined ANN 14 have two inputs and one output. In this network, each neuron and each element of the input vector p are connected with weight matrix W.

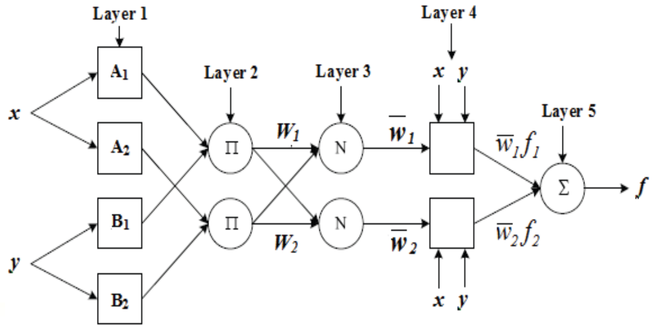

Figure 4: ANN architecture for a two-input multi-layer network

Where the two crisp inputs are x and y, the linguistic variables associated with the node function are Ai and Bi. The system has a total of five layers are shown in Figure 4.

III. MATLAB SIMULATION AND RESULTS

The system is connected as a loop type, consisting of five buses (B1,B2,B3,B4 and B5) interconnected by transmission lines (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2. Line L1 is used as double circuit line for increasing the power transfer capability by lowering the inductance of line. Two power plants are being located on the 230-kV system so as to generate total 2200 MW which is to be transmitted to a 500-kV 15000-MVA and to 200-MW load which is connected at bus B3. An excitation system, a power system stabilizer (PSS) and a speed regulator is included in the plant model.

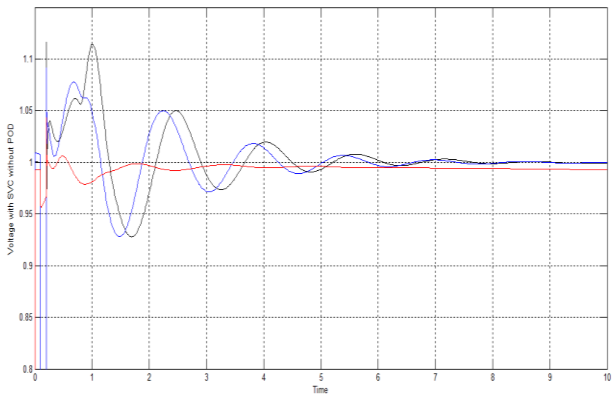

Figure 5: Bus voltage profile in a grid connected DG with SVC and without controller under L-L fault

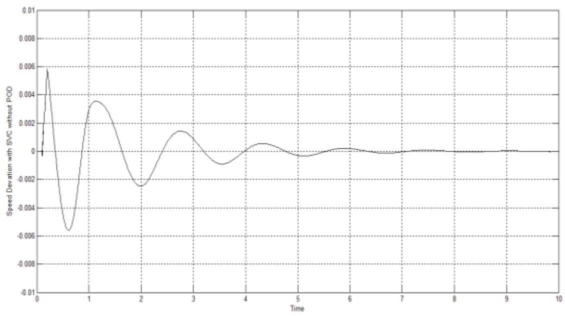

Figure 6: Bus voltage profile in a grid connected DG with SVC and with fuzzy controller

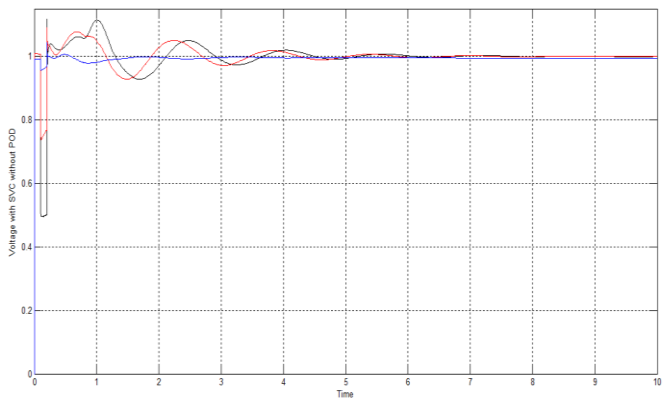

Figure 7: Bus voltage profile in a grid connected DG with SVC and with ANN controller

IV. CONCLUSION

The paper summarized the following points, mainly quality, reliability and stability issues get generated with the Inter-connection of many distributed generation system in Grid. Power stability issues like voltage frequency and load angle Variation in DG connections. An advanced control device is required for the connection of distributed generation in a network; control device should have a property to secure high reliability and stability of the power system. In this paper, SVC mechanism is controlled with fuzzy logic and ANN based controller. This controller along with SVC improves the voltage profile and the transient stability of buses connected with grid occurred. The designed controller is tested on a 3 machine 5 bus Simulink model in MATLAB. The Simulation tests are performed on buses terminal voltage. The ability of designed controller in contrast with the conventional SVC can be seen that the fuzzy and Ann based controller has enhanced the transmission line power stability during the disturbances whereas the ANN controller provides reliable and stable working.

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