Performance Evaluation Of TCSC Fuzzy Logic Controller In Transient Stability Analysis

Yellappa. K.
4UB11EPS20
4th Sem, M.Tech (PS)
University B.D.T. College Of Engineering
Davangere-577004

Dr. K. S. Aprameya.
Associate Professor
Dept. of Electrical and Electronics Engineering
University B.D.T. College of Engineering
Davangere-577004

***ABSTRACT* - The main objective of this paper is to stabilize and minimize the fault in the power system using TCSC fuzzy logic controller technique with the help of MATLAB/SIMULINK software. This paper develops the working model of TCSC and investigates the effects of TCSC on synchronous stability and voltage stability improvement by controlling the firing angle of the TCSC through fuzzy logic controller.The main objectives of using FACTS devices are increasing power transfer capacity in transmission lines. If the system stability is maintained or enhanced by Fuzzy based FACTS controllers following the faults, the power transfer may be increased.TCSC is one of the major FACTS devices that may be used to compensate the reactive power of transmission line.**

Keywords - FACTS, TCSC, Fuzzy logic. Thyristor switches,FIS

I. INTRODUCTION

A power transmission network is referred to as a "grid". Multiple redundant lines between points on the network are provided so that power can be routed from any power plant to any load center, through a variety of routes, based on the economics of the transmission path and the cost of power. Much analysis is done by transmission companies to determine the maximum reliable capacity of each line, which, due to system stability considerations, may be less than the physical or thermal limit of the line. The ability of a synchronous power system to return to stable condition and maintain its synchronism following a relatively large disturbance arising from very general situations like switching 'on' and 'off' of circuit elements, or clearing of faults etc. is referred to as the transient stability in power system. Improvement of transient stability is an important topic in the modern power system scenario. It is well known that FACTS technology can control voltage magnitude, phase angle and circuit reactance so it is redistributed in the load flow and regulate bus voltage.FACTS device are more effective for improving total transfer capability and transient stability,

II. FACTS DEVICES

According to the IEEE definition, FACTS is defined as "The flexible AC Transmission System (FACTS) is a new technology based on power electronic devices which offers an opportunity to enhance controllability, stability and power transfer capability of AC Transmission Systems".Power system today are highly complex and the requirements to provide a stable, secure, controlled and economic quality of power are becoming vitally important with the rapid growth in industrial area. To meet the demanded quality of power in a power system it is essential to increase the transmitted power either by installing new transmission lines or by improving the existing transmission lines by adding new devices. Inspired by the way the traditional electro-mechanical system control on the power transmission, researchers and engineers have come up with the power-electronics based FACTS controllers. The FACTS devices form a large group of power electronic based converters designated to enhance controllability and increase power transfer capacity. These devices can be classified into two groups:

1.Thyristor based FACTS devices
2.Converter based FACTS devices

The FACTS devices use conventional thyristors in building the circuit. If the FACTS devices use thyristors without self-turn-off ability, the device is called a thyristor controlled device. If the thyristor in the FACTS device can be turned off by applying appropriate gate voltage, the device is called a thyristor switched device.The TCSC is one of the powerful thyristor based FACTS devices.

III. TCSC MODULE

TCSC(Thyristor controlled series capacitor) is one of the most important and best known FACTS devices. It has been in use for many years to increase line power transfer as well as to enhance system stability. Basically a TCSC consists of three components: capacitor banks C, bypass inductor L and bidirectional thyristors SCR1 and SCR2. The basic module of a TCSC is shown in Fig 1.The firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control algorithm, normally in response to some system parameter variations. According to the variation of the thyristor firing angle or conduction angle, this process can be modeled as a fast switch between corresponding reactance offered to the power system. When the thyristors are fired, the TCSC can be mathematically described as follows:

$$X_{TCSC}(\alpha) = X_C X_L(\alpha) / X_L(\alpha) - X_C$$

Where ; X_{TCSC} = TCSC reactance
X_L = Capacitive reactance
X_C = Inductive reactance
α = firing angle

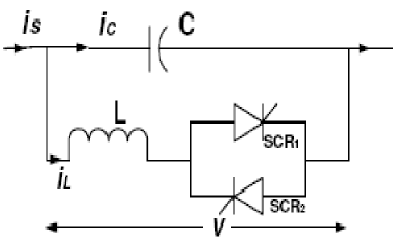

Fig. 1 Schematic Representation Of Tcsc

The TCSC has two operating ranges around its internal circuit resonance:

1.$\alpha_{cmin} \leq \alpha \leq \Pi / 2$ range ,where $X_{TCSC}(\alpha)$ is capacitive

2.$0 \leq \alpha \leq \alpha_{Lmin}$ range , where $X_{TCSC}(\alpha)$ is inductive

The above two relations are shown separately in the fig2.

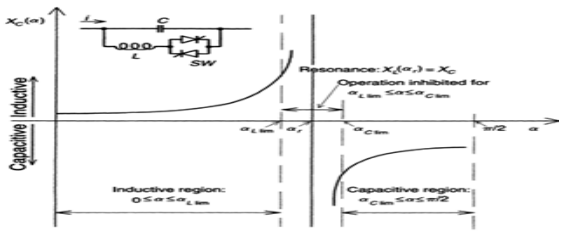

FIG.2 TCSC Characteristic curve

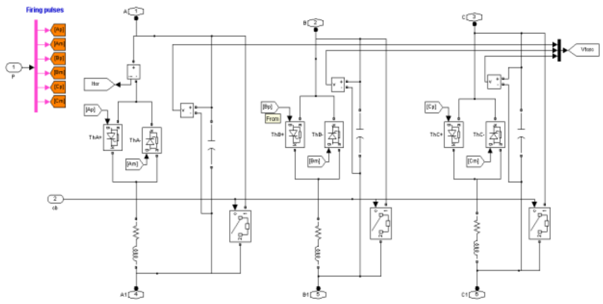

Fig. 3 TCSC circuit diagram

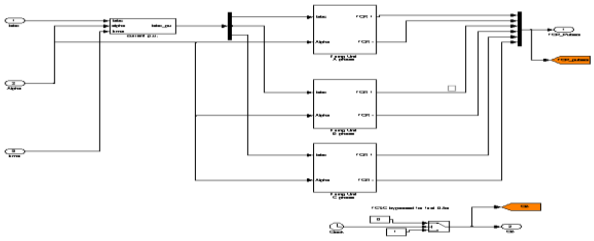

Fig. 4 TCSC firing circuit diagram

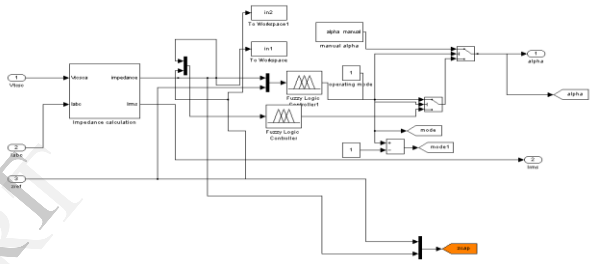

Fig. 5 TCSC impedence calculation network

The system designed can be split into three modules TCSC circuit module, firing circuit module and the TCSC impedence calculation module. The three modules are shown in fig 3,fig4 and fig 5.In this paper, fuzzy control method is used for controlling TCSC thyristors firing angle, in order to improve damping of power oscillations .

IV. FUZZY LOGIC CONTROLLER

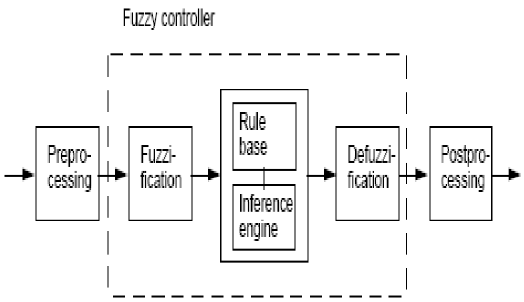

Fig.6 Fuzzy Logic Controller Block Diagram

A fuzzy control system is a control system based on fuzzy logic—**a** mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively). Fuzzy logic is widely used in machine control. Fuzzy logic was first proposed by Lotfi A. Zadeh in a 1965 paper. He elaborated on his ideas in a 1973 paper that introduced the concept of "linguistic variables", which in this paper equates to a variable defined as a fuzzy set. Fuzzy set allows us to use fuzzy sets in order to make computers more 'intelligent'. A straight way to generalize this concept, is to allow more values between 0 and 1. The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed. Some studies have shown that fuzzy logic performs better when compared to conventional PI controller.There are specific components characteristic of a fuzzy controller to support a design procedure. In the block diagram shown in fig.6 the controller is between a pre-processing block and a post-processing block.

IV. DESIGN PROCEDURE OF FLC

Fuzzy controller Design process involves 3 steps:
1.Fuzzification
2. Fuzzy rules
3. Defuzzification

The FIS Editor GUI tool allows to edit the fuzzy inference system, such as the number of input and output variables, the defuzzification method used, and so on .The fig7 shows the FIS Editor with two input variable blocks, one output variable block and a Mamdani FLC block.The designing process is carried out with the help of MATLAB.

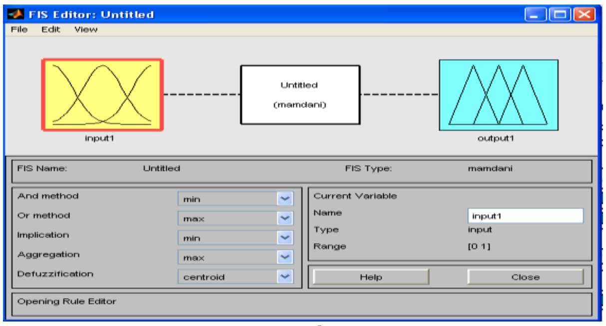

FIG.7 FIS Editor

Fuzzification:The method used for fuzzification shown in fig8 is called Sugeno, method of fuzzy inference. The first two parts of the fuzzy inference process involves fuzzifying the inputs and applying the fuzzy operator. The Sugeno output membership functions are either linear or constant.A typical rule in a Sugeno fuzzy model has the form

If Input1= x and Input2= y, then Output is $z = ax + by + c$

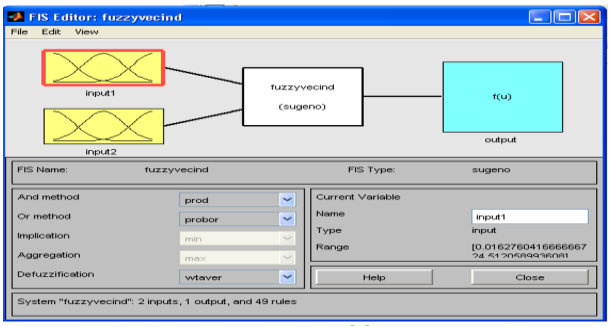

Fig. 8 Sugeno Model

Fuzzy rules :TheFuzzy rules shown in fig9 and fig10 are defined to reduce the error in the system after analyzing the function of controller. For each fuzzy value there are seven membership functions, so 49 combinations of impedence are possible. Membership functions are used to convert the fuzzy values between 0 and 1.There is an output for each of the membership functions and the linguistic label can be determined by using IF–THEN fuzzy rules in the following form:

If reference impedence is in1mf1 and impedence deviation is in2mf2 then fuzzy output is out1mf1.

Where in1mf1 and in2mf2 and out1mf1 are fuzzy subsets.

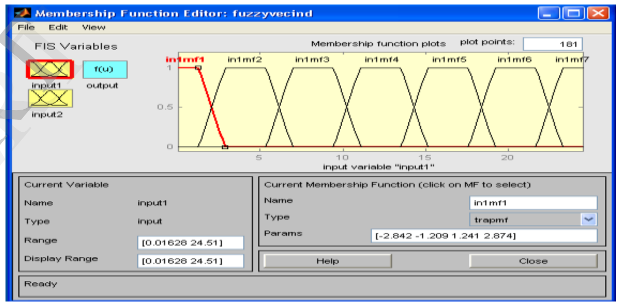

Fig .9 Membership Function For First Input

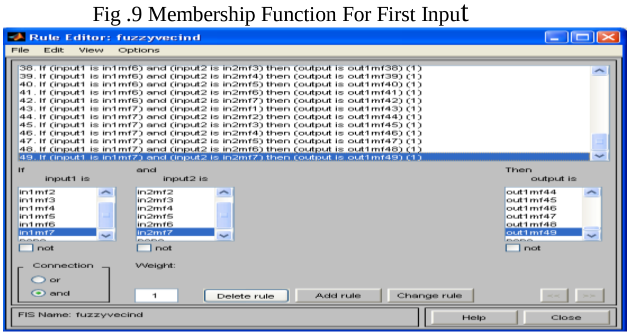

Fig 10.Initializing The Fuzzy Rule

Rule Viewer :The Rule Viewer in fig11allows you to interpret the entire fuzzy inference process at once. The Rule Viewer also shows how the shape of certain membership functions influences the overall result, Because it plots every part of every rule, The Rule Viewer shows one calculation at a time and in great detail.

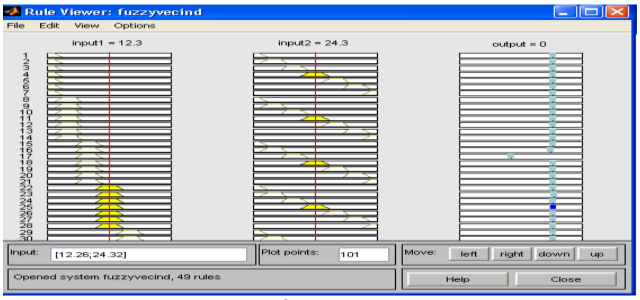

Fig. 11 Rule Viewer

Defuzzification:The defuzzification Converts the fuzzy output of the inference engine to crisp single membership functions analogous to the ones used by the fuzzifier.One of the commonly used defuzzifying methods is Centroid of area (COA) or centroid method.The waveforms obtained after defuzzification are shown in the fig12 and fig13.

V. PERFORMANCE ANALYSIS

As shown in the power and impedence waveforms in fig12 and fig13,the firing of the thyristors can be observed and a considerable improvement is also observed an the impedence values.

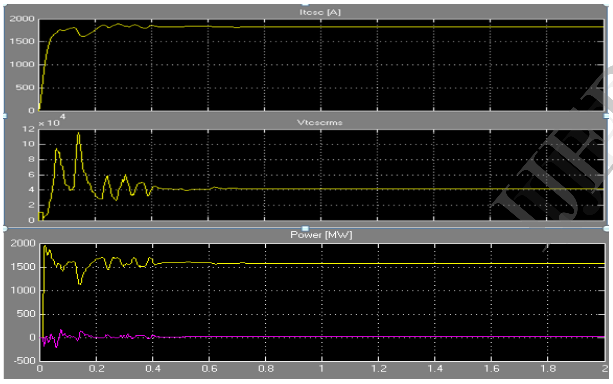

Fig. 12 Power Wavforms

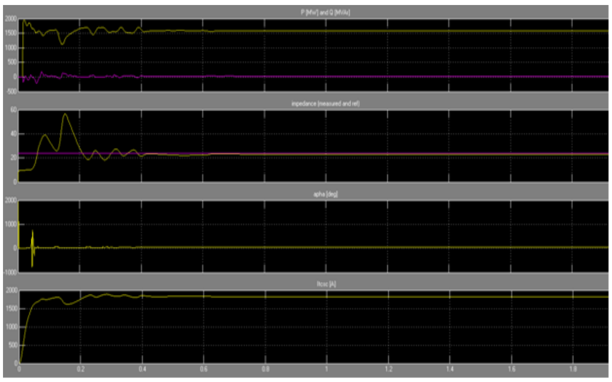

Fig. 13 Impedence Wavforms

VI. CONCLUSION

The purpose of this paper ,as seen, was to suggest another control approach, based on a modified version of Fuzzy Controller, for TCSC to control and stabilise the power system. Simulation results showed that, the proposed method is very robust gives satisfactory performance. To evaluate the usefulness of FLC, we performed the computer simulation for a two machine four bus system. We analysed the response of the TCSC with fuzzy controller. In spite of the easy implementation of traditional "PI" controller, its response is not so good for the two machine four bus system used for simulation in this paper. The improvement is remarkable when controls with Fuzzy logic are used, obtaining a better dynamic response from the system. This is seen with clarity in the power and impedence waveforms. Simulation results showed that the performance of the FLC is better than conventional PI controller.

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