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Congestion Management by Phase Shifting Transformer Using Fuzzy Logic Control.

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***Abstract*— This paper introduces Fuzzy logic to the control of phase shifting transformer. Phase shifting transformer is already installed FACTS device in many major countries. It is used for power transfer improvement, reducing cost of transmission system, congestion management, improves stability and many more. In this paper congestion management is discussed using MATLAB software. As load on power transformers is increasing and some transformer gets power congestion. This burden can be taken care by phase shifting transformer and by using Fuzzy logic the controlling of phase shifting transformers is optimized.**

Keywords*— Power Controllers(PC), Fuzzy logic, Phase shifting transformer (PST)

I. INTRODUCTION

The various parameters which can affect the power flow in system of transmission line are mainly phase angle between buses, magnitude of voltage and impedance of the transmission line. Advantages of FACTS controllers are that it can control one or even more than one parameters to enhance performance of power transmission system. FACTS controllers can be used to boost significant performance in the power systems with operating parameters that can be transient and small signal stability, damping out oscillations that occurs in power system, to secure the healthiness power system, management over congestion, minimizing active power loss, voltage profile updation, performance of power system, an efficient power system operations [1]-[3], power systems to be stand with dynamic performances, more power transfer capacity through the lines, and enhancing the loading capability of the power system network[20].

PST injects series voltage in system with the help of shunt transformer. PST can effectively controls the phase angle and does not required another coupling transformer like in case with other FACTS devices[15]-[18]. Voltage is given to primary of boost transformer, which is boosted by boost transformer and given to the system (transmission line). This boost voltage is added in quadrature to the system voltage. That's why this boost transformer is known as quadrature transformer [2]-[6]. If we consider three phase system, same concept will be applied for all three phases, both transformer used will have three windings. PST manufacturer company Siemens developed number of variety in PST which are available for different voltage levels. Various power transformers are connected in the power system. Some transformers rated with lower MVA ratings but as load increases in the system, these transformers gets overloaded and creates congestion in the system[20]-[24]. This congestion of power on power transformers is minimise by the PST. PST performs the tap changing to minimise the congestion. To make this operation in close loop, fuzzy control technique is used. Fuzzy logic tells the degree of truthiness, Which makes decision more accurate for the operation of PST[11].

In the existing system PST is removing the burden on power system but it is not enough to get optimum utilization of power transformer. In paper [1] shows PST improved the power flow but if the load on power system is changing in continuous fashion then how PST should work so that power transformers work in optimum condition is question. This paper shows how the Fuzzy logic control can be used to improve the congestion management and also power transformers can be used under changing load or power condition.

II. PHASE SHIFTING TRANSFORMER

The phase shifting transformer increases active power flow in the system. If E1 is sending end voltage, E2 is receiving end voltage, δ is power angle and XL is line reactance then active power flow is given as:

$$P = \frac{|E_1||E_2|}{X_L}\sin(\delta) \qquad ...(1)$$

Fig.1 shows Thevenin's equivalents of phase shifting transformer which is connected at the two ports of PST[1].

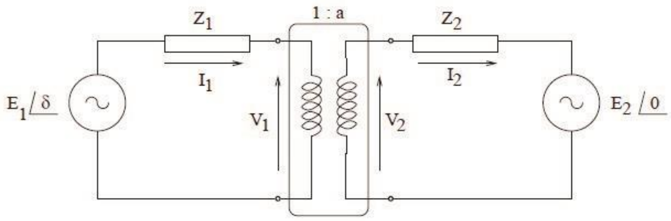

Fig. 1. Phase shifting Transformer connected to network

We can get power flow equation in circuit as

$$P = \frac{E_1 E_2 \sin(\delta+\emptyset)}{(X_L+X_{PST})} \qquad ...(2)$$

Here X_{PST} is the leakage reactance of PST.
here φ is an angle used to shift the phase (positive or negative).

III. PST MODEL IN MATLAB SOFTWARE AND RESULTS

In transmission system of 500 kV/230 kV, Phase shifting transformer is used for congestion management. It essentially consists of B1, B2, B3, B4, B5 buses and they are connected by lines L1, L2, L3. Two transformers banks (Tr1 & Tr2) each of rating 230 kV/500 kV are connected to the system. Plant 1 have rating of 1000 MVA, 13.8 kV and generates 500 MW whereas Plant 2 have rating of 1200 MVA, 13.8 kV and generates 1000MW. Load is connected of 15000 MVA, 500 kV and 200 MW as shown in fig.2.

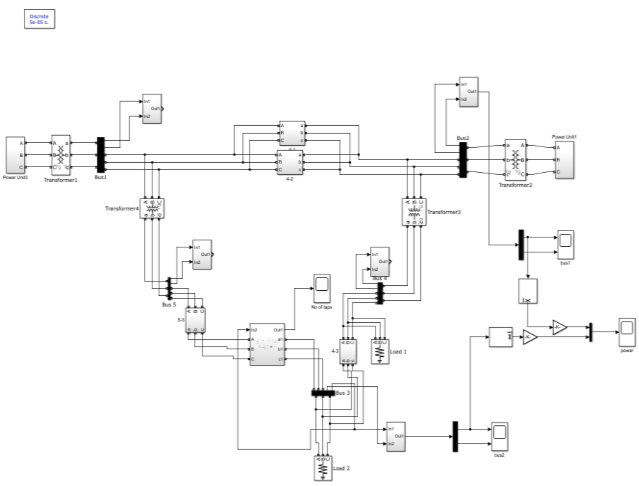

Fig. 2. PST connection to the system

During normal operation 1200 MW power of plant 2 is delivered to 500 kV load via three 400 MVA transformers which are located between buses B4 & B5. Now consider a contingency in which only two transformers (2*400=800 MVA) are connected (between bus B4 & B5). The effect of this, most of generated power (by Plant 2) is to be delivered through transformer bank Tr2. This causes overloading of Tr2 by 99 MVA. This congestion must be overcome to avoid serious consequences.

The PST effectively control the active power flow by directly varying power angle δ.

Fig.3 Below shows PST remove congestion at bus B4 by increasing power flow at bus B3. Phase shift and tap position is as shown in fig.4 . Congestion removed at bus B4 is from 900 MW to 716 MW and power increased at bus B3 is from 580 MW to 760 MW.

The congestion is removed at 23 sec but still power at both buses (B4&B3) is same beyond 35 sec also. This is not desirable. There must be system to detect this condition and also rectify it. Here comes the roll of fuzzy logic controller which simple to understand and widely used method.

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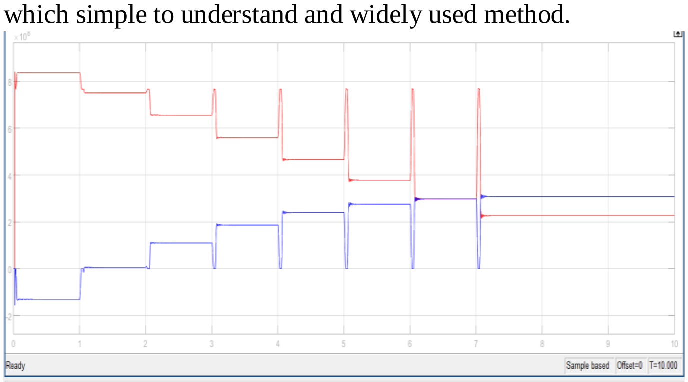


Fig. 3. Active power at buses B3 & B4 without Fuzzy Logic Control

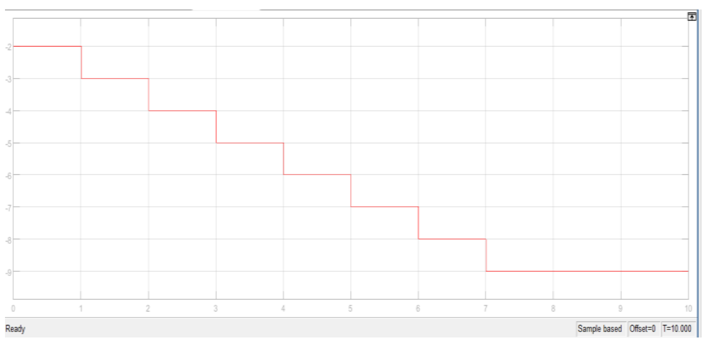


Fig. 4. Different tap position without Fuzzy Logic Control

IV. PST MODEL WITH FUZZY LOGIC CONTROL

In this case consider the contingency is removed means transformer at Tr2 bank is restored then there is no congestion at bus B4. Therefore initial condition must be restored that is use of PST should avoided. This will happen by introducing Fuzzy logic control to control PST as fuzzy logic is used here to act fig.6. Fuzzy logic having two inputs from bus B4. If the contingency happens then congestion occurs at bus B4. Fuzzy logic output controls PST tap positions. PST removes the congestion at bus B4 as shown in fig.7. Now consider the removal of contingency then there is no congestion at bus B4 so fuzzy logic controls PST tap position to increase power flow at bus B4. Now the power flow at buses B4 and B3 has been restored to their initial values shown in fig.7.

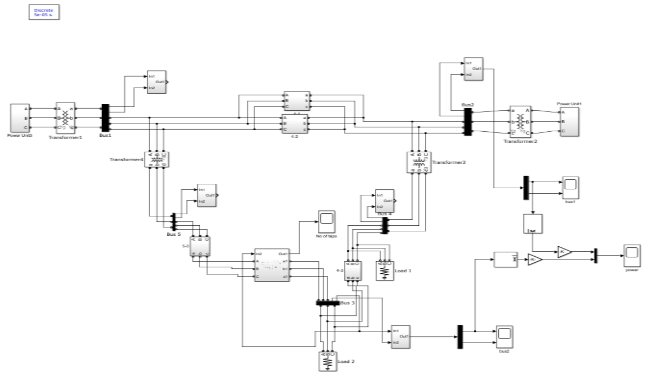


Fig. 5. PST connection with fuzzy logic control

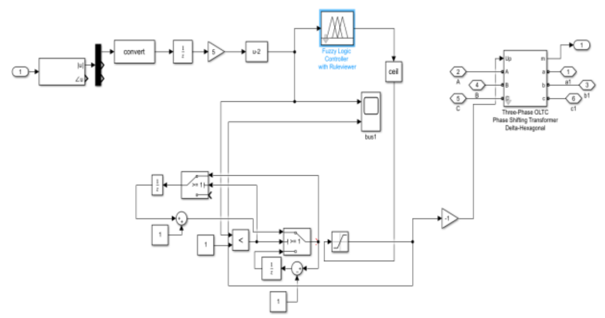


Fig. 6. PST connection with fuzzy logic control

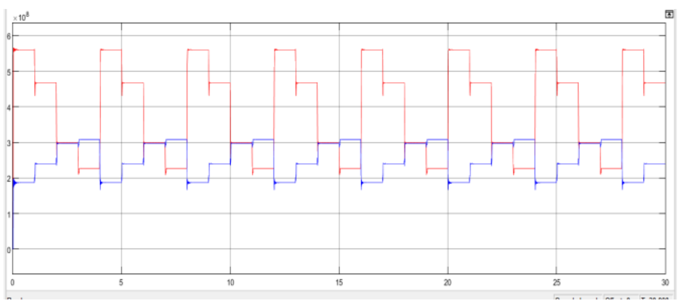
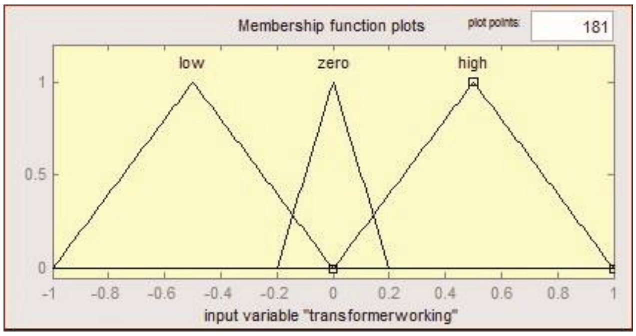
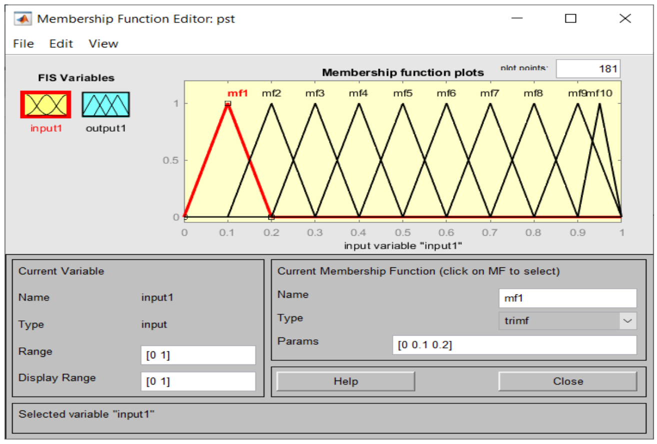


Fig. 7. Power flow at busses B3&B4 with fuzzy logic control

Fuzzy logic having two inputs, one is power at bus B4 and other is healthy condition of all transformers at transformer bank Tr2. In fig.8, a&b are the inputs, c is output, d is surface view of rules and e is rules for fuzzy logic control. If any transformer is not working then only fuzzy logic examine whether the power at bus B4 is at particular level or not. If the power is beyond particular level then fuzzy logic changes the tap position of PST so that congestion get removed, and if transformer bank Tr2 is get restored then fuzzy logic again changes the tap position of PST which is normal condition of the system. In this way fuzzy logic acts as effective control method for PST to remove congestion at particular bus shown in fig.6.



a



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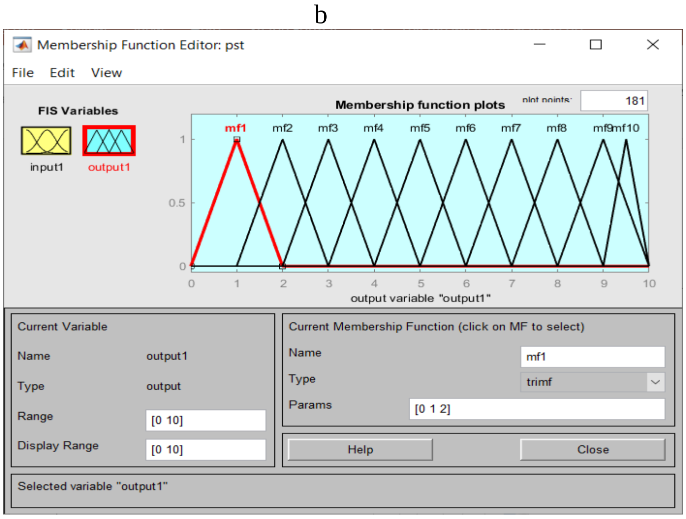
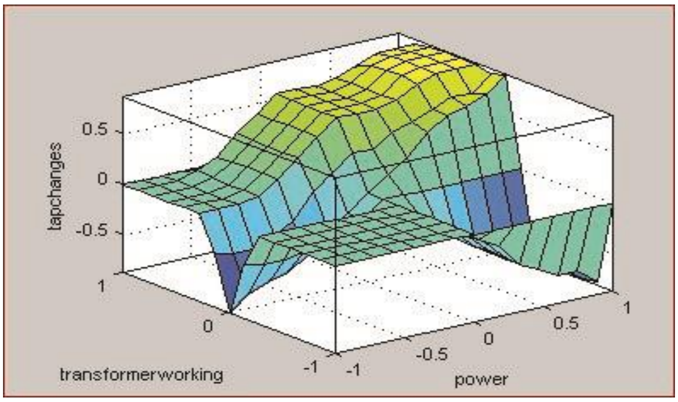


c



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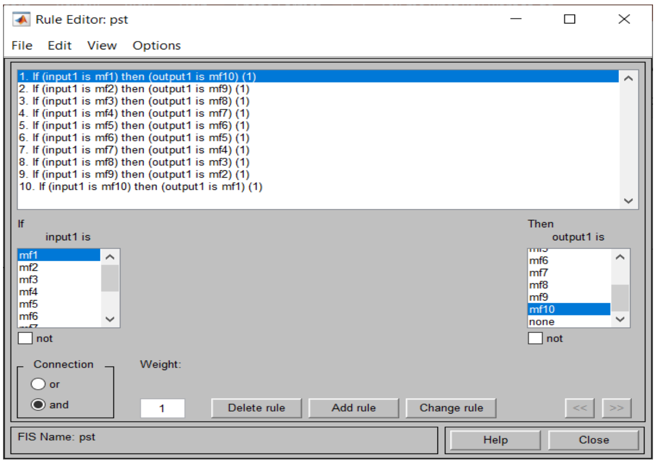

e

Fig. 8. Fuzzy logic with Input and output command

Fuzzy logic control have rules in which 10 conditions are provided which analyzes the system parameters and creates response in the form of tap positions. Fig.9 shows the phase shift and tap position of PST by fuzzy logic. Simulation time is up to 30 secs to see the effect of fuzzy logic control.

Therefore with the help of fuzzy logic, PST removes the congestion and also bring back the system to normal condition after removal of congestion.

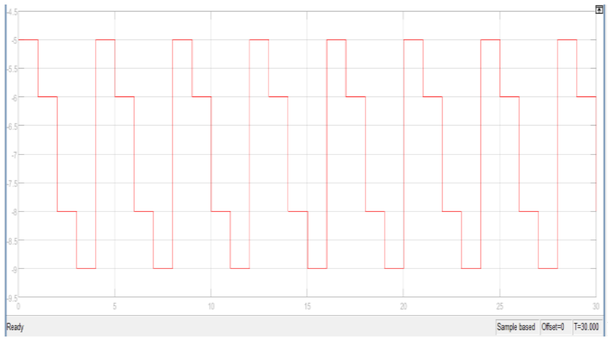

Fig . 9. Tap position of PST with fuzzy logic control

V. CONCLUSIONS

The paper has discussed the problem of modern power system. Burdon is increasing as power demand rises hence increasing power generation. This brings congestion in the power system and PST is the solution which is installed in almost every major country. The paper discussed PST principle and its effect on power system active power flow. Two cases discussed out of in first case only PST is connected to the system and its simulation results clarifies that PST control active power flow during congestion. But after removal of congestion it is not bringing back to normal condition of power system. In second case fuzzy logic is implemented and simulation results clears that Fuzzy logic not only removes the congestion but after restoration of fault at transformer bank Tr2 , brings back the system to normal condition where no phase shift is required.

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