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FUZZY BASED DPFC FOR DAMPING POWER SYSTEM OSCILLATIONS

R.Surendra Naik, S.Ravindra, Dr.P.Hari Krishna Prasad

***Abstract*— A new control scheme to improve the stability of a system by optimal design of distributed power flow controller (DPFC) based stabilizer is presented in this paper. The paper demonstrates the basic module, steady state operation, mathematical analysis, and current injection modeling of the DPFC.**

The purpose of the work reported in this paper is to design an oscillation damping controller for DPFC to damp low frequency electromechanical oscillations. A damping controller is provided to improve the damping of power system oscillations. Through damping controller an electrical torque in phase with speed deviation is to be produced in order to improve the damping of the system oscillation. Here the proposed fuzzy supplementary controller is used for damping oscillations. Results demonstrate that DPFC with the proposed model can more effectively improve the dynamic stability and enhance the transient stability of power system compared to without fuzzy logic based damping controllers.

I. INTRODUCTION

Because of the power demand grows dramatically, and extension in transmission and generation is restricted with the rigid environmental constraints and the limited availability of resource. However, this causes the power systems to be operated near their stability limits. Moreover, interconnection between remotely power systems results rise to low frequency oscillations in the range of 0.2–3 Hz. These oscillations may keep growing in magnitude until loss of synchronism results, if not well damped [1]. In order to minimize this problem, power system stabilizers (PSSs) have been successfully used to damp these low frequency oscillations. However, PSSs may unfavorably affect on the voltage profile, may result in leading power factor, and may be unable to control oscillations cause by large disturbances [2]. The idea of FACTS technology is to increase controllability and to optimize the utilization of the existing power system capacities using the reliable and high-speed power electronic devices instead of mechanical controllers [3].

The opportunities arise through the ability of FACTS devices to control the parameters of transmission systems, which includes the series/shunt impedances, phase angle and damping of oscillations at various frequencies below the rated frequency. These constraints cannot be overcome otherwise, while maintaining the required system stability, by mechanical means without decreasing the transmission capacity [4]. By proving added flexibility, FACTS controllers can enable a line to carry power closer to its ratings. The DPFC recently presented in [5, 6] is a powerful device within the FACTS family, which provides much lower cost and higher reliability than conventional FACTS devices. It is derived from the UPFC [7] and has the same capability of simultaneously adjusting all the parameters of the power system: line impedance, transmission angle, and bus voltage magnitude.

The DPFC eliminates the common DC link between the shunt and series converters, instead of one large three-phase converter, the DPFC employs multiple single phase converters (distributed-FACTS concept) as the series compensator, as shown in Fig. 1.

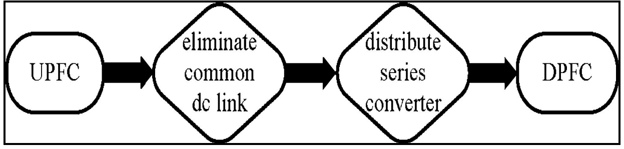

Fig 1: Schematic diagram of DPFC

Two approaches are applied to the UPFC to increase the reliability and to reduce the cost; they are as follows. First, eliminating the common dc link of the UPFC and second distributing the series converter, as shown in Fig 2. By combining these two approaches, the new FACTS device—DPFC is achieved.

By introducing the two approaches outlined in the previous section (elimination of the common DC link and distribution of the series converter) into the UPFC, the DPFC is achieved. Similar as the UPFC, the DPFC consists of shunt and series connected converters. The shunt converter is similar as a STATCOM, while the series converter employs the DSSC concept, which is to use multiple single-phase converters instead of one three-phase converter.

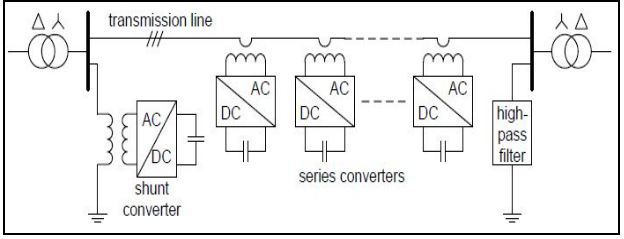

Fig. 2 DPFC configuration

Each converter within the DPFC is independent and has its own DC capacitor to provide the required DC voltage.

As shown, besides the key components - shunt and series converters, a DPFC also requires a high pass filter that is shunt connected to the other side of the transmission line and a Y–Δ transformer on each side of the line. The reason for these

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R.Surendra Naik, P.G Student (PS), EEE Department
QIS College of Engineering and Technology, Ongole, India
S.Ravindra, Associate Professor, EEE Department
QIS College of Engineering and Technology, Ongole, India
Dr.P.Hari Krishna Prasad, Prof of EEE Department
QIS College of Engineering and Technology, Ongole, India

extra components will be explained later. The unique control capability of the UPFC is given by the back-to-back connection between the shunt and series converters, which allows the active power to freely exchange. To ensure the DPFC has the same control capability as the UPFC, a method that allows active power exchange between converters with an eliminated DC link is required.

II. DAMPING CONTROLLER

A damping controller is provided to improve the damping of power system oscillations. Through damping controller an electrical torque in phase with speed deviation is to be produced in order to improve the damping of the system ioscillation.

Fuzzy logic based DPFC damping Controller

Here the proposed fuzzy supplementary controller block diagram is given in fig 3. In fact this Fuzzy Logic controller with 2 inputs and one output. The speed deviation is considered as the input to the damping controller. The structure of fuzzy supplementary controller is shown in fig 3.

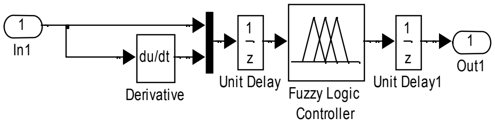


Fig 3: Fuzzy Supplementary Controller

Though the fuzzy controller accepts these inputs, it has to convert them into fuzzified inputs before the rules can be evaluated and fired. To accomplish this we have to build one of the most important and critical blocks in whole fuzzy controllers, the knowledge base. It consist of two more blocks namely the data and the rule base [8].

Data base

it consists of the membership function for input variables (X1) and (X2) described by the following linguistic variables:

For(X1):

- Positive (P)
- Negative (N)

For(X2);

- Negative (N)
- Near Zero (NZ)
- Positive (P)

For output variable (damping signal) described by the following linguistic variables:

- Positive (P)
- Positive Small (PS)
- Near Zero (NZ)
- Negative Small (NS)
- Negative (N)

The "Gaussian membership functions" are used as membership function for the input variables and "triangular membership functions" for output variables [8]. Figures 4-6 illustrate these in detail, indicating the range of all the variables.

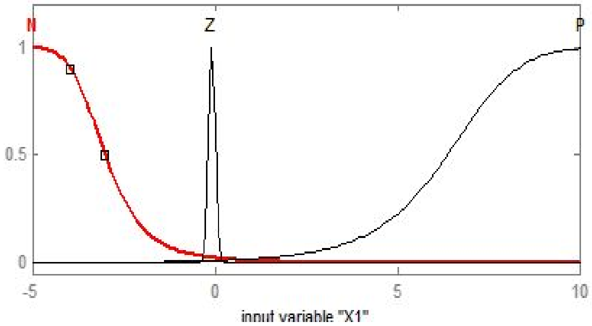


Fig 4: Membership function of input (X1)

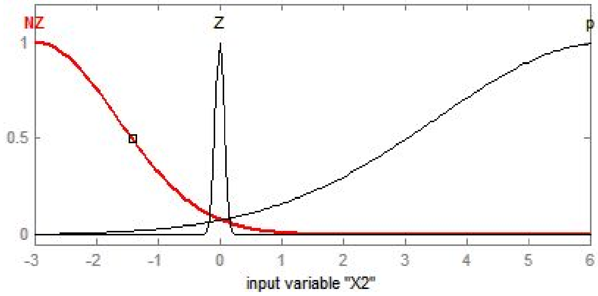


Fig 5: Membership function of input (X2)

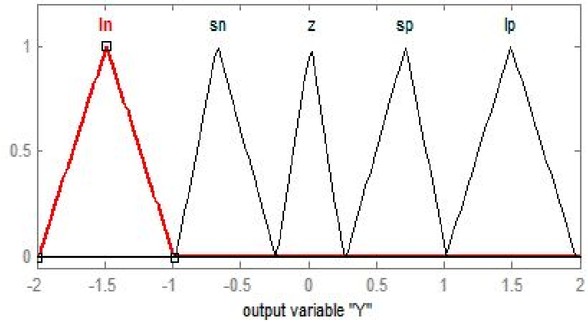


Fig 6: Membership function of output

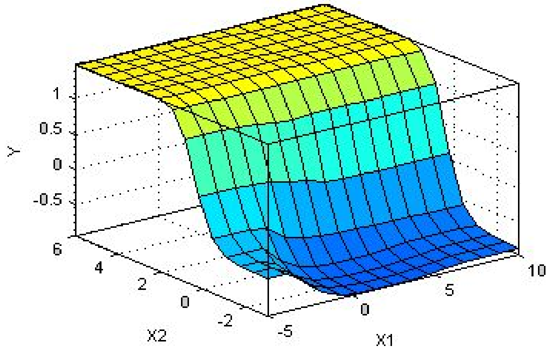


Fig 7: Output coefficients verses two inputs

Rule base

The other half of the knowledge base is the rule base, which consists of, all the rules formulated by experts. It also consists of weights, which indicate the relative importance of the rules among themselves and indicates the influence of a particular rule over the net fuzzified output. The next section specifies the method adopted by the inference engine, especially the way it uses the knowledge base consisting of the described data base and rules base [8]. Plot of inputs versus output, base rule base, is shown in fig.7.

III. Methodologies adopted in fuzzy inference engine

Though we have mentioned many methodologies in evaluating the various expressions like fuzzy union (OR operation), fuzzy intersection (AND operation, etc, with varying degree of complexity, we in our fuzzy scheme use the most widely used methods for evaluating such expressions. The function used for evaluating OR is "MAX"), which is nothing but the maximum of the 2 operands, i.e,

MAX(X1, X2) =X1 if X!>X2
=X2 if X1<X2

Similarly, the AND is evaluated using "MIN" function which is defined as the minimum of the two operands, i.e,

MIN(X1, X2) =X1 if X!>X2
=X2 if X1<X2

Another important point to note here is that in the present research paper, we have assigned equal importance to all the rules in the rule base, i.e., all the weights are equal and this is indicated in the fuzzy rules table 1 in the parenthesis against each rule[8].

De-fuzzification method

The de-fuzzification method followed in our study is the "center of area method or "gravity method". This method is discussed in [8].

IV. SIMULATION RESULTS

The proposed control scheme for DPFC is evaluated by computer simulation in MATLAB/Simulink. The details of simulation model are depicted in fig.8.

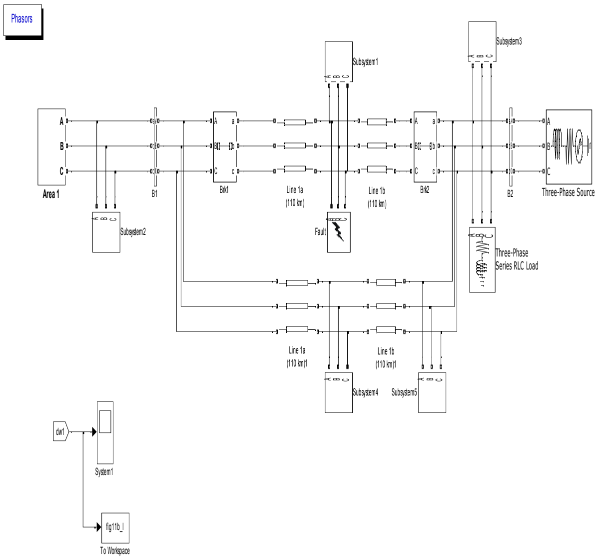
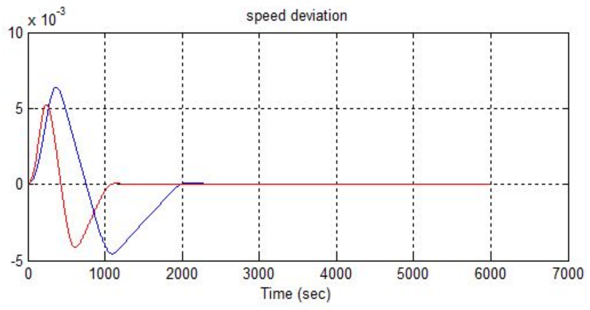
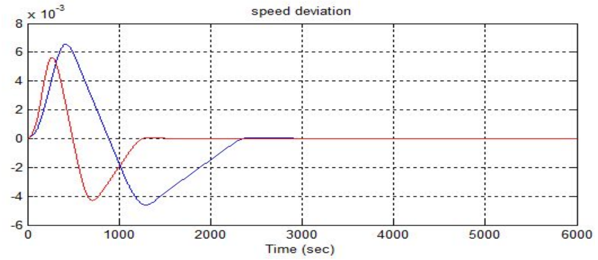


Fig.8: SMIB with DPFC built with MATLAB/Simulink.

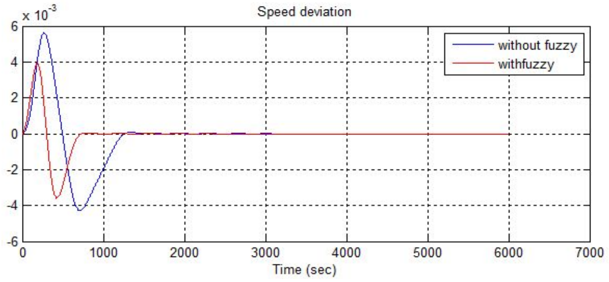
Here, it is considered a 6-cycle three-phase fault occurred at t=1 s at the middle of the one transmission line cleared by permanent tripping of the faulted line. The speed deviation of generator at nominal load, light, and heavy loading conditions due to designed controller by fuzzy logic controller are shown in fig 9.Also Fig 10 shown the generator out power, internal voltage variation, and excitation voltage deviation for nominal load condition respectively. These figures obviously show the good damping effect of the supplementary controller.



a) Nominal load

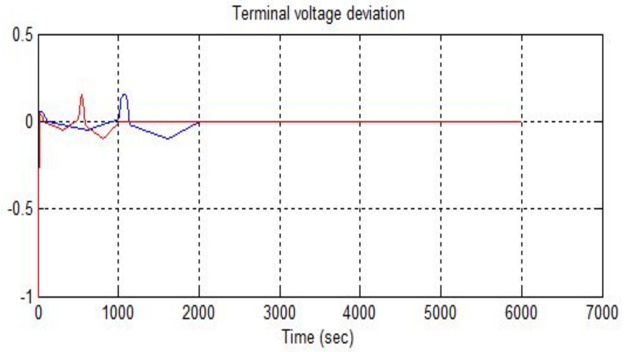


b) Light load

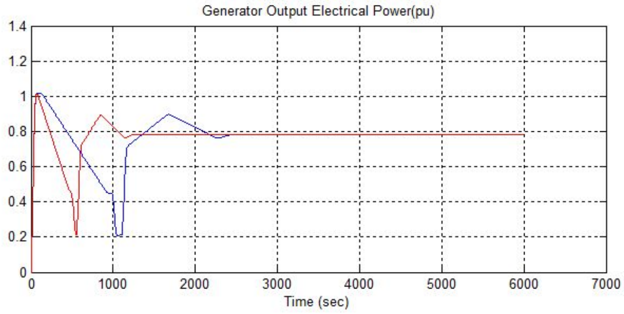


c) Heavy load

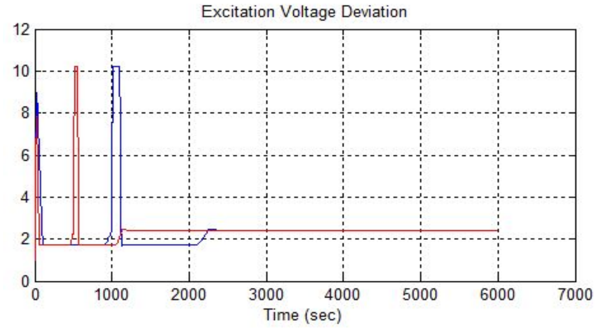
Fig.9 Dynamic response for speed deviation at a) Nominal b) Light and c) Heavy loading conditions



a) Terminal Voltage deviation



b) Generator output power



c) Excitation voltage deviation

Fig.10: a) Terminal Voltage deviation, b) Generator output power and c) Excitation voltage deviation

CONCLUSION

In this study, the DPFC as new FACTS device that to can regulate line active and reactive power flow of the transmission line and provide enough damping to system oscillation modes. Here the proposed fuzzy supplementary controller is used for damping oscillations. The results have shown that the proposed model can effectively damp power system oscillations.

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