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TRANSIENT STABILITY ENHACENMENT USING MATRIX CONVERTER BASED UPFC WITH INTELLIGENT CONTROLLING TECHNIQUES

Sk. Salma[1]*, K. Radha Rani[2]
**[1]PG Scholar, Dept of EEE, R.V.R & J.C. College of Engineering (Autonomous), Guntur, India*
[2]Associate Professor, Dept of EEE, R.V.R & J.C. College of Engineering (Autonomous), Guntur, India
**[1] sk.salma1991@gmail.com ; [2]korrapati_radharani@yahoo.com*

****Corresponding Author: -***
Email: sk.salma1991@gmail.com

Abstract: -
This paper presents a matrix converter based UPFC for enhancing the transient stability. Conventional methods use a twostep based UPFC (DC-AC-DC). In the proposed model the conventional UPFC is replaced by a Matrix Converter which is controlled with two different controllers which include fuzzy logic controller and the other with an added integrator which is referred to be a HYBRID fuzzy logic controller. In this paper, the working of matrix converter based UPFC with the two controller techniques under certain disturbances is observed using the MATLAB software and the results are verified.

Keywords: - *UPFC, Matrix Converter, Transient Stability, Fuzzy controller.*

I. INTRODUCTION

In developing countries like India there is a high demand for electricity and it is rising day by day. Modern power system network consists of interconnected generating plants, transmission lines, transformers and a variety of loads. When the loads connected to the long transmission lines are increased, then the stability of the system especially transient stability becomes a serious limiting factor. The ability of the system to maintain in a stable condition after being subjected to large disturbances such as faults and switching of lines is defined as the transient stability [1]-[2].

This transient stability problem requires evaluation of a power system's ability to withstand disturbances while maintaining the quality of service. The general methods for enhancing the transient stability include reduction in system transfer reactance, circuit breakers and fast acting exciters. With the developing technologies in the high power semiconductor devices and their control features, enhancing the power system stability has become feasible with various types of FACTS (Flexible AC Transmission Systems) controllers.

The purpose of FACTS devices is to provide fast control of active and reactive power through a transmission line. The unified power-flow controller (UPFC) is one of the members of the FACTS family with attractive features as it can independently control many parameters.

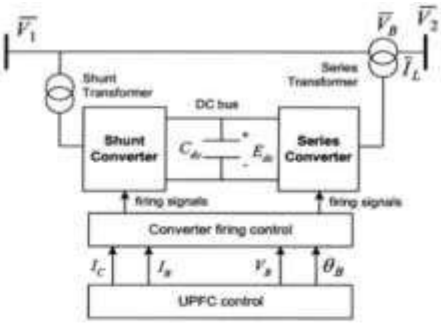

Fig 1: Block diagram of UPFC

So, it includes the combined properties of two devices which include static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC). These two are the devices that offer an alternative mean to damp the power system oscillations [3]. Thus, for a conventional UPFC device the selection of the input signals and the adopted control strategy is important to damp power oscillations in an effective and robust manner. UPFC can be used to change the line flow by means of fast controllers, such that the thermal limits are not violated and hence the losses are also minimized .It also includes the increase in stability margin without violating specified power dispatch.

UPFC is a combination of shunt compensator and series compensator which are connected via a common DC link, to allow the bi-directional flow of real power between their output terminals and is allowed to provide simultaneous real and reactive power compensation. Two voltage source inverters (VSI) are provided for the operation which consists of a common DC link provided by a DC storage capacitor. There is a significant impact of the ratings of this DC link capacitor bank on the cost and physical size of the UPFC. The capacitor is sized depending on the specified ripple voltage, typically 10% of the nominal voltage. The design of this DC link capacitor is the main drawback for maintaining the desired ripple[4]. Also the capacitor life span used in this is small when compared to that of AC capacitor of same rating. Hence the life and reliability of the voltage source inverter is limited only[5]. To overcome these limitations, a matrix converter (MC) is employed in place of UPFC which replaces the classical AC/DC and DC/AC converter structure with dc link capacitor by a matrix converter. The matrix converter has several advantages such as reduced THD, less number of switches, bidirectional power flow, etc., Also matrix converters potentially have much longer life span and are more reliable, because of the absence of the DC link capacitor.

There are different control strategies to control the series voltage magnitude, angle and the shunt current magnitude [6]-[8]. In the proposed model the advanced version of control strategies is used which is the fuzzy logic controller. The performance is compared with one more controller which includes an integrator to fuzzy logic controller that is referred as Hybrid fuzzy logic controller.

II. PROPOSED MODEL

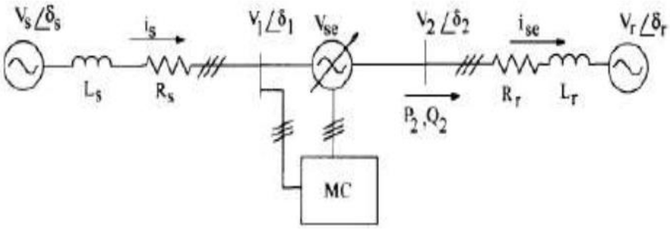

Fig 2: MC placed as UPFC in the system

In the above figure 2, the voltages at sending end and receiving end are represented with Vs and Vr. The voltages at the two buses are considered to be V1 and V2. The Matrix Converter is connected between two buses via series and shunt coupling transformers. The Transmission line also includes the line parameters Rs, Ls and Rr, Lr representing the resistance and inductances at the sending end and receiving end respectively. The series voltage injected to the transmission line by the matrix converter to maintain the required active and reactive power flow is represented by Vse. The active and reactive powers at bus 2 are indicated by P2 & Q2. The power supply and transformers used in the system modelling are considered to be ideal. Delta (δ), which is used as a controlling parameter for stabilizing the oscillations, is the phasor difference between both the bus voltages.

III.MATRIX CONVERTER

The input voltage can be directly converted to AC voltage in a one step process with the help of a matrix converter, instead of converting that voltage into a DC voltage as inverters. This matrix converter has smaller size, high efficiency, long life span, and also the input current harmonics are also reduced than inverters. They have high enough potential for realizing the above mentioned demands.

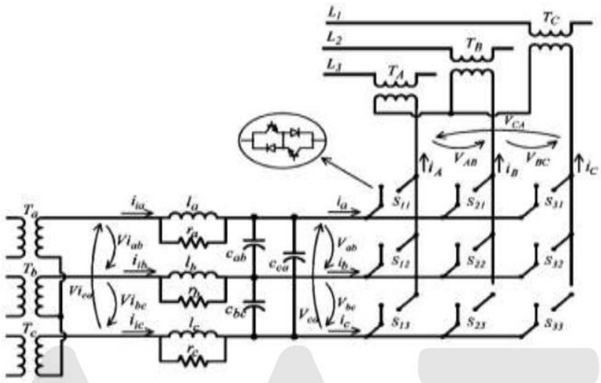

Fig 3: Matrix converter based UPFC

The matrix converter has an array of bidirectional switches; here each switch is connected between one input terminal and one output terminal. The switches can be connected to any of the three input phases to any of the three output phases. The normalized currents (in per unit) that flow through the transmission line are obtained using Standard axis transformation [9]-[11] where d and q represent the direct and quadrature axis.

$$\frac{d(i_{sed})}{dt} = -\frac{R_r}{L_r} i_{sed} + \omega i_{seq} + \frac{1}{L_r}[v_{2d} - v_{rd}]$$
$$\frac{d(i_{seq})}{dt} = -\frac{R_r}{L_r} i_{seq} - \omega i_{sed} + \frac{1}{L_r}[v_{2q} - v_{rq}]$$

IV. CONTROLLING TECHNIQUES

In the proposed model fuzzy logic controller and the other controller with added integrator for enhancing the stability is used.

A. Fuzzy Basics

One of the important branches of computer science or engineering is Fuzzy logic which belongs to the class of artificial intelligence [12]-[13]. Lotfi Zadeh is the inventor of Fuzzy Logic. He has classified computing in to “soft computing,” or approximate computation and “hard computing,” or precise computation. Fuzzy logic is a problem-solving control system methodology which uses IF-THEN rules. It can be implemented in software, hardware, or a combination of both. Fuzzy Logic provides a simple path to arrive at a definite conclusion based upon ambiguous, noisy, imprecise, vague, or missing input information. Fuzzy Logic uses linguistic terms in natural languages and provides foundation for approximate reasoning with imprecise propositions. In classical logic, a proposition used is either “TRUE”, denoted by 1, or “FALSE”, denoted by 0. Fuzziness includes uncertainty. A membership value of zero implies that the corresponding element is definitely not an element of the referred fuzzy set. A membership function of unity means that the corresponding element is definitely an element of referred fuzzy set. A grade of membership greater than zero and less than unity corresponds to a non-crisp (or fuzzy) membership of the fuzzy set. A fuzzy set “A”, is formally given by its membership function μÃ (x).

There are different types of fuzzy sets. They are (a) Trapezoidal, (b) Triangular, (c) Gaussian and (d) Bell shaped

B. Fuzzy Inference

Two major types of fuzzy rules exist:

- Mamdani fuzzy rules and
- Takagi-Sugeno fuzzy rules.

In the proposed model Mamdani fuzzy rule base is used. The basic structure of Fuzzy Logic Controller is as the following

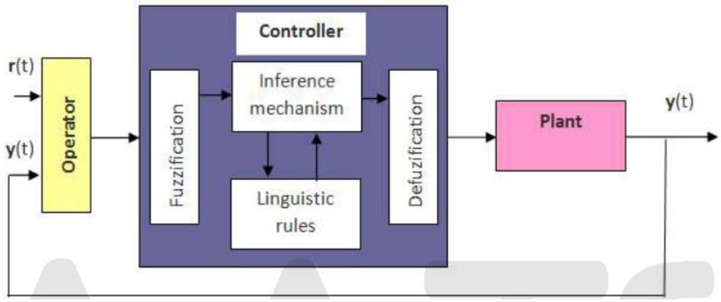

Fig 4: Block diagram of Fuzzy Controller

C. Defuzzification

The process of changing the linguistic terms or variables into crisp values is known as Defuzzification process. Generally Centroid method is used for Defuzzification. The matrix converter based UPFC is controlled with the following controlling techniques,

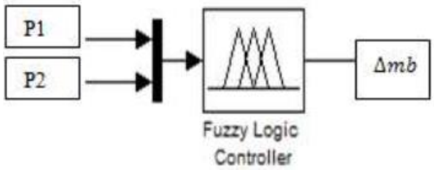

Fig 5(a): Proportional Fuzzy Logic controller

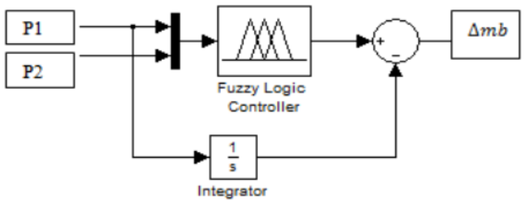

Fig 5(b): Hybrid Fuzzy Logic controller

Fuzzy rules used for the simulations are,

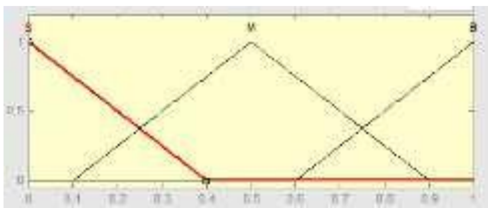

Fig 6 (a): Membership Functions for Power P1

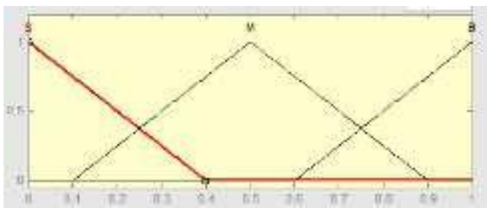

Fig 6 (b): Membership functions for Power P2

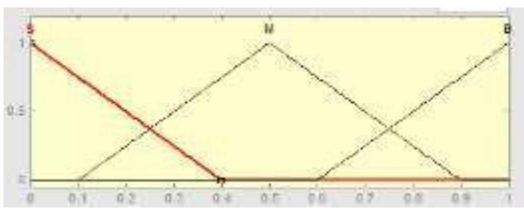

Fig 6 (c): Membership Functions for modulating signal

TABLE I: FUZZY RULE BASE

S=Small M=Medium B=Big

$P1$	$P2$	Δm_b
S	S	B
S	M	M
S	B	S
M	S	B
M	M	M
M	B	S
B	S	M
B	M	S
B	B	S

V. **SIMULATION DIAGRAM**

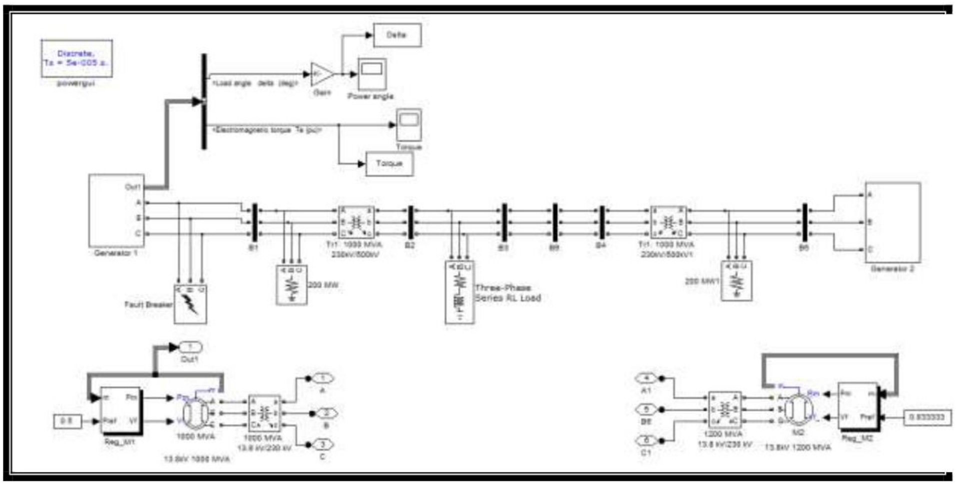

Fig 7: Simulation Diagram for two Generator bus and without operation of Matrix converter based UPFC

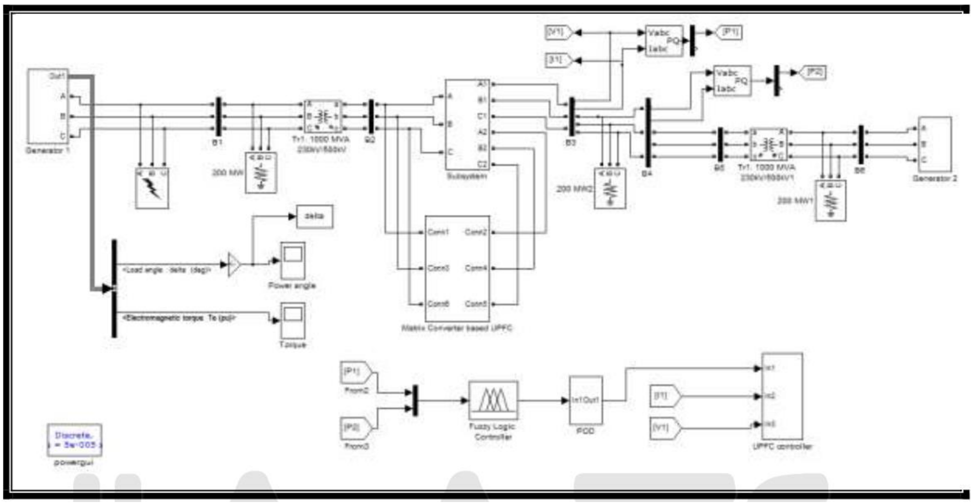

Fig 8(a): Simulation Diagram for two Generator bus and with operation of proportional fuzzy based Matrix converter

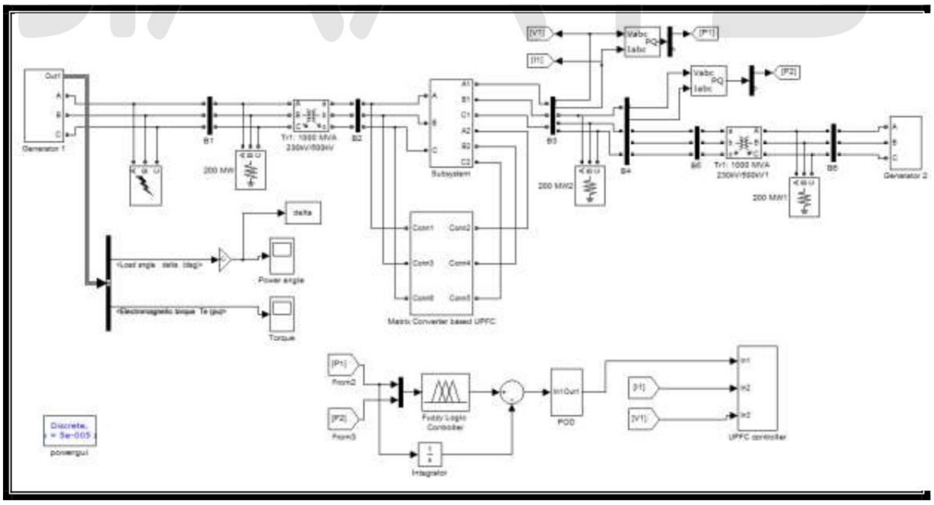

Fig 8(b): Simulation Diagram for two Generator bus and with operation of Hybrid fuzzy based Matrix converter

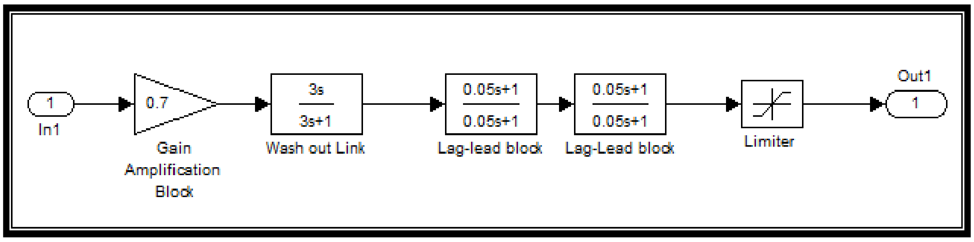

Fig 9: Simulation Diagram for Power oscillations Damping

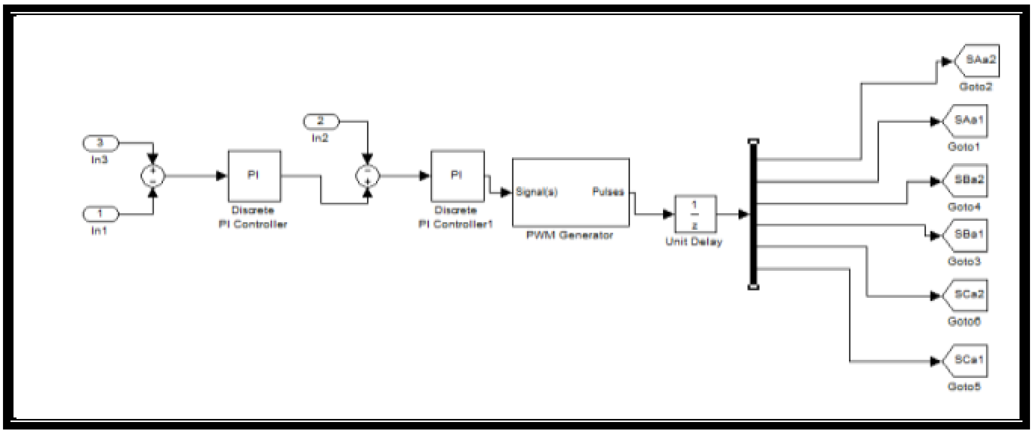

Fig 10: Simulation Diagram for UPFC Controller

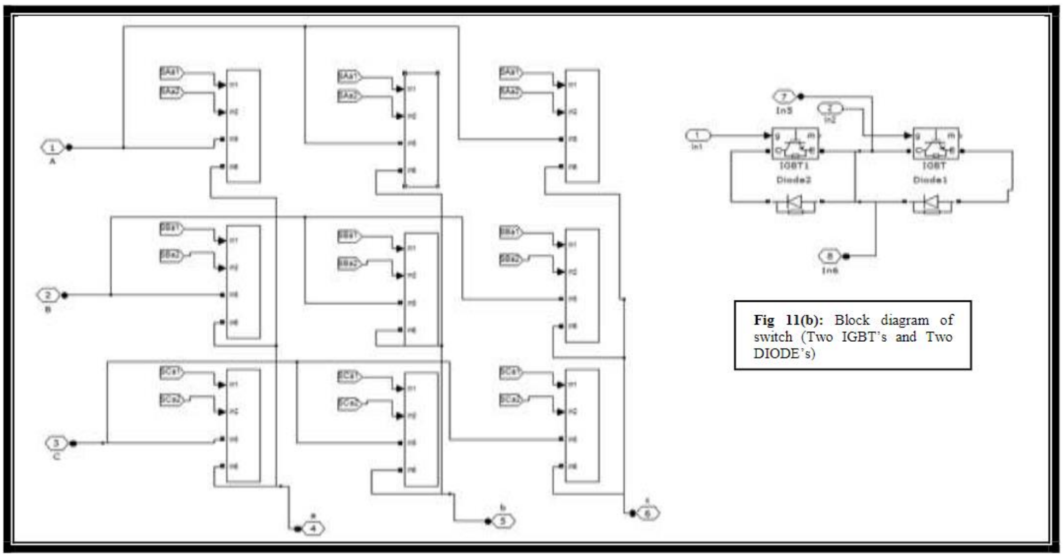

Fig 11(b): Block diagram of switch (Two IGBT's and Two DIODE's)

Fig 11(a): Simulation Diagram for Matrix converter based UPFC

VI. SIMULATION RESULTS

The system performance is analyzed placing the fault at sending end generator. Fault is made to occur at 0.01 sec and cleared at 2 sec.

A. Power angle simulation output without using Matrix converter based UPFC

a) LLL-G Fault

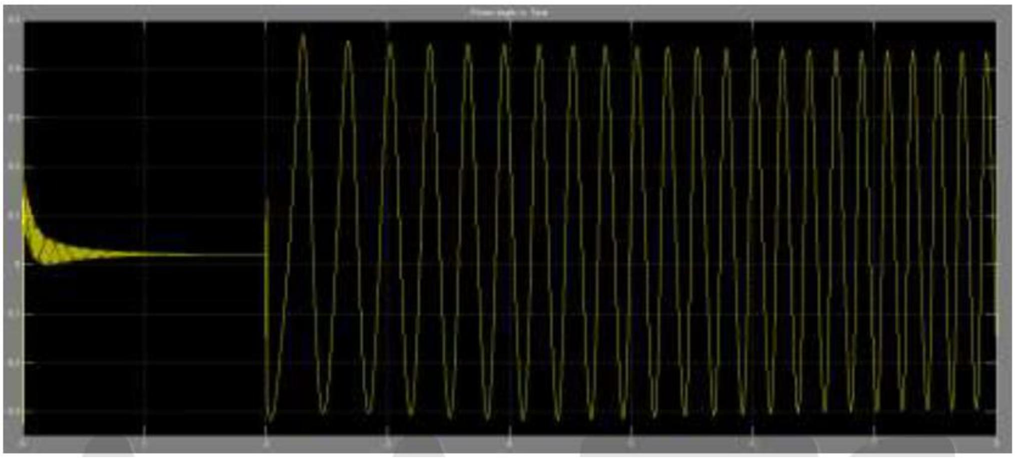

Fig 12: Power angle vs. Time curve for LLL-G Fault

b) L-G Fault

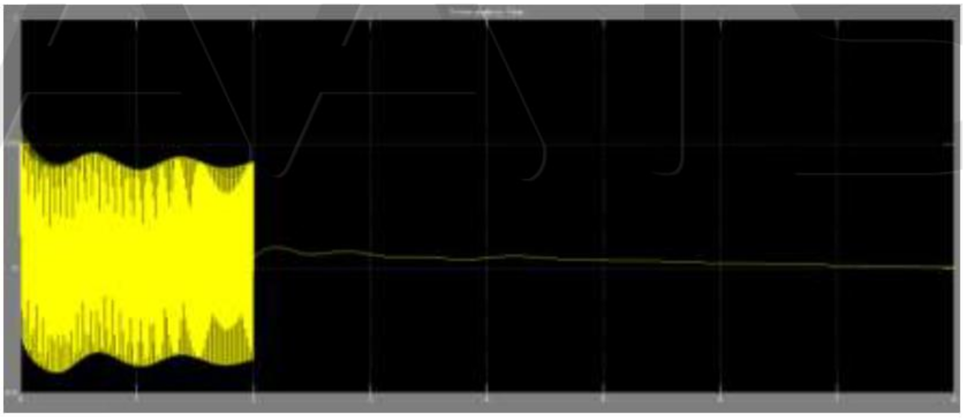

Fig 13: Power angle vs. Time curve for L-G Fault

c) L-L Fault

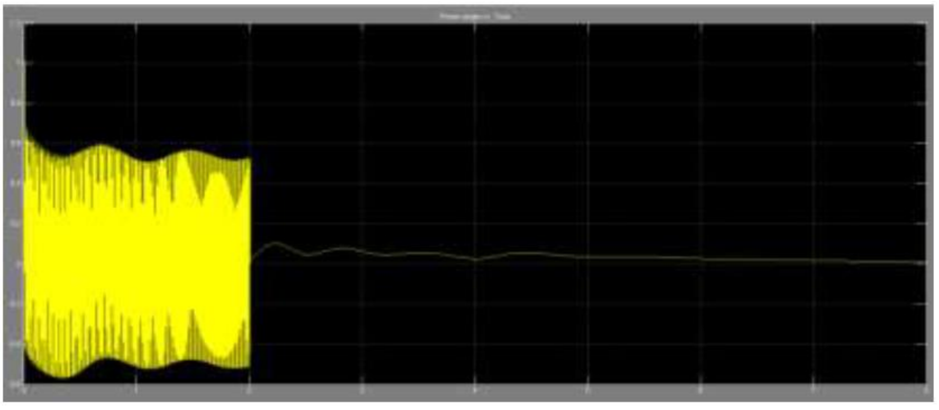

Fig 14: Power angle vs. Time curve for L-L Fault

B. Power angle simulation output with Matrix converter based UPFC using proportional FLC technique

a) LLL-G Fault

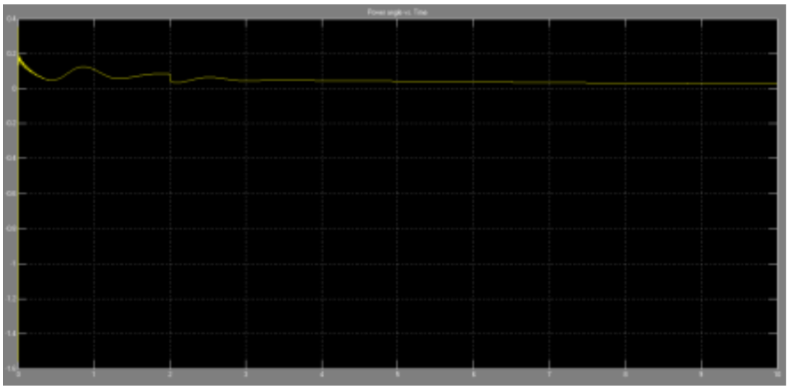

Fig 15: Power angle vs. Time curve for LLL-G Fault

b) L-G Fault

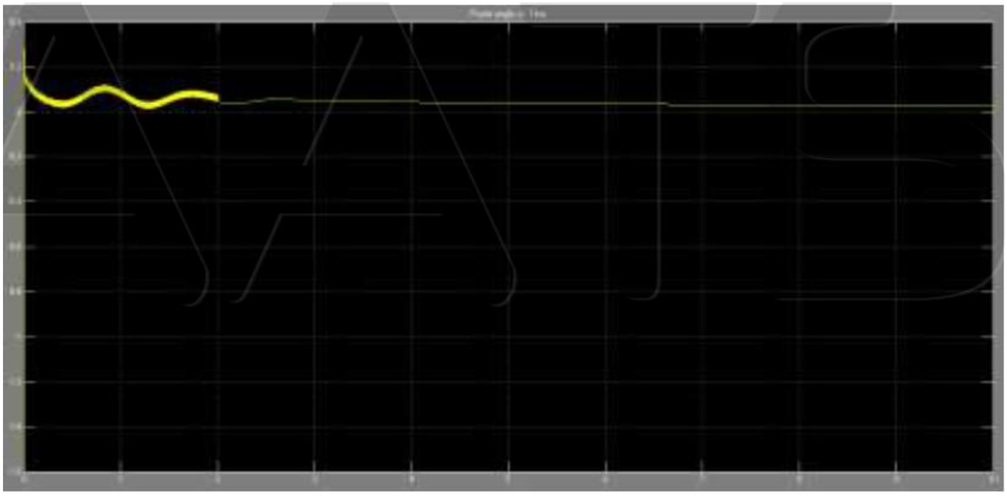

Fig 16: Power angle vs. Time curve for L-G Fault

c) L-L Fault

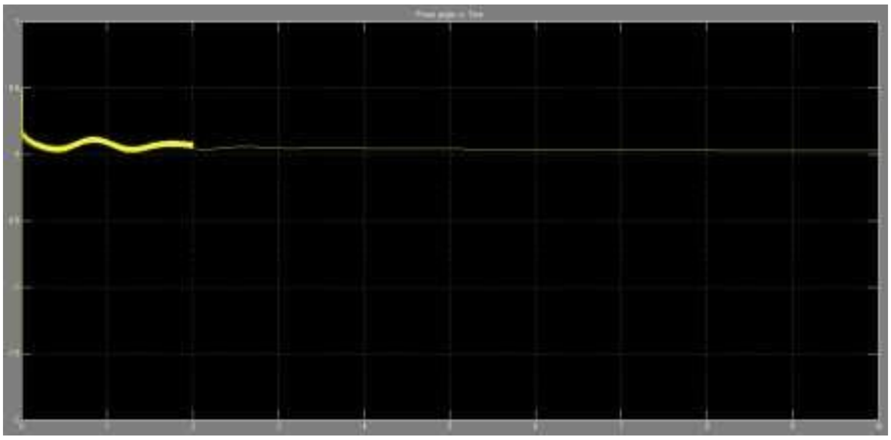

Fig 17: Power angle vs. Time curve for L-L Fault

C. Power angle simulation output with Matrix converter based UPFC using hybrid FLC technique

a) LLL-G Fault

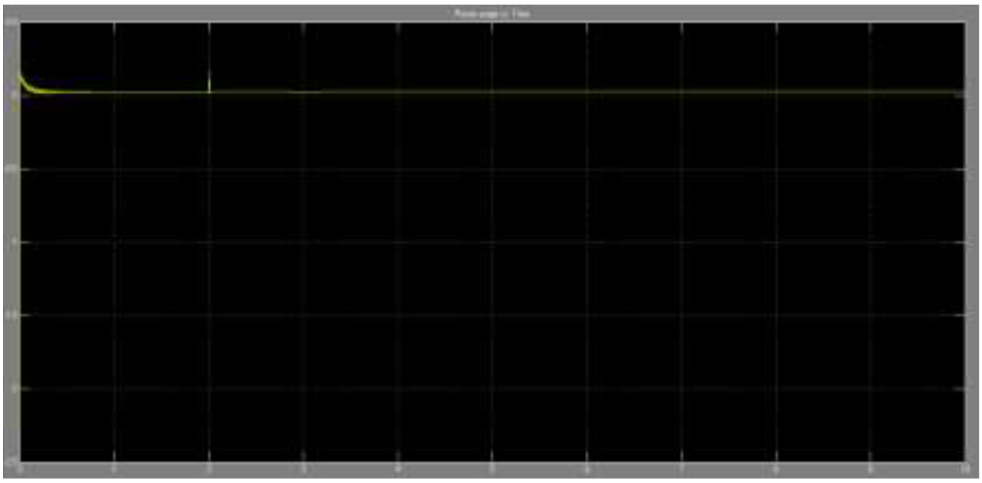

Fig 18: Power angle vs. Time curve for LLL-G Fault

b) L-G Fault

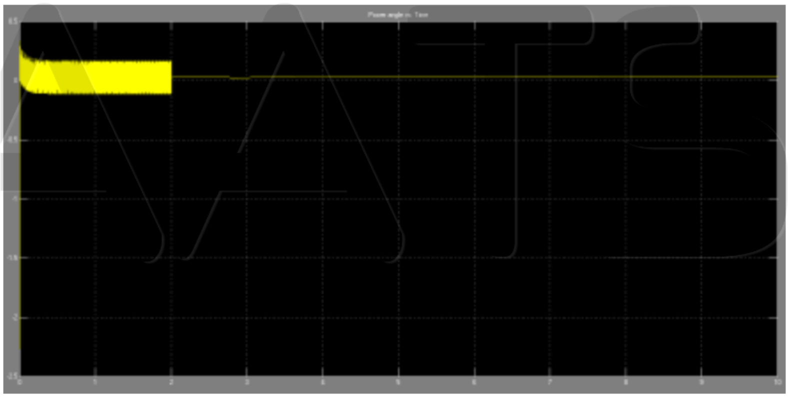

Fig 19: Power angle vs. Time curve for L-G Fault

c) L-L Fault

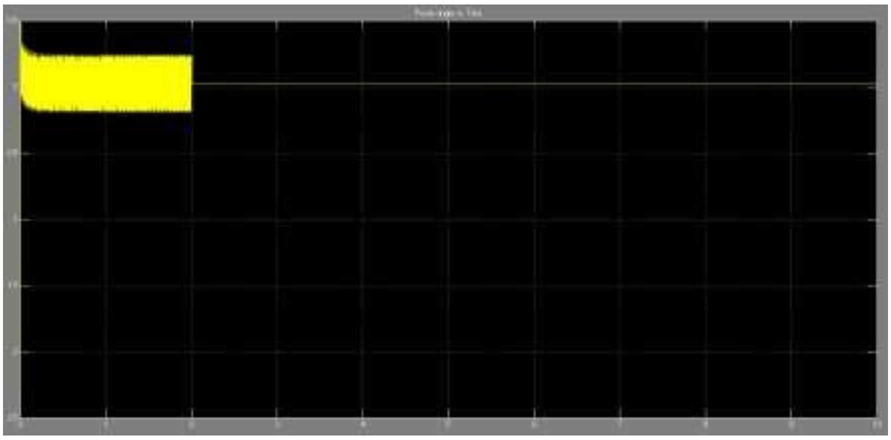

Fig 20: Power angle vs. Time curve for L-L Fault

TABLE II: COMPARISON OF RESULTS

Type of Fault	**Without Matrix converter**	**With Proportional Fuzzy based Matrix converter**	**With Hybrid Fuzzy based Matrix converter**
	Settling Time(Ts) in seconds	Settling Time(Ts) in seconds	Settling Time(Ts) in seconds
LLL-G Fault	1.5997e+005	5.3306e+004	4.0162e+004
L-G Fault	1.2839e+005	4.0079e+004	4.0132e+004
L-L Fault	1.1534e+005	4.0137e+004	4.0065e+004

VII. CONCLUSION

In this paper, the UPFC has been simulated with Matrix converter based UPFC along with two different controlling techniques. The MATLAB Simulink software has been used to observe the results. The main aim was to design a UPFC that enables the power system to track the reference signals precisely, to adjust itself for uncertainties and disturbances and at the same time to increase the overall performance of the converters with reduced cost and losses .From the obtained results it can be observe that the matrix converter based UPFC gives highly flexible operation and transient stability is improved with the used controlling techniques.

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