International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 5, Issue 11, November (2017) www.ijeter.everscience.org

Compensate Reactive Power at Linear & Non-Linear Load with Fuzzy Control of UPFC and STATCOM

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Abstract – In this project we are implementing the power compensation of reactive and regulation of voltage at load side by using STATCOM and UPFC with the combination fuzzy control. Which is utilized for the medium transmission line which is contents of statcom and upfc .here we are developing the fuzzy logic controller which is defined like a human brain to get the better performance. Therefore this test will performed on the medium transmission line which is considerate with both the linear and non linear load at same time. By using the simulation result ,the output and waveform will be observed by the comparsion in between both the devices.

Index Terms – Statcom, UPFC, Reactive Power Compensation, Voltage Stability, Linear Load, Non-Linear Load,fuzzy logic control.

1. INTRODUCTION

According to the recent year in the transmission systems increase in the power line, the energy conservation and stable supply of power is getting to be important. In power transmission power factor drops due to reactive power component of load and transmission line. This may also cause voltage drop due to unexpected load Variations at load side occurs. The function of an AC transmission system is to provide electric power from one end to another at specified voltage, frequency, power factor and waveform. Reactive power Q is exchanged between inductive and capacitive loads in the network.

Therefore according to the reactive power flow which will increase in I2R. Volt-amperes reactive are absorbed by inductive loads and Q for inductive loads is considered positive. Volt-amperes are supplied by capacitance loads and Q for capacitor load is considered negative. The reactive power supplied or absorbed by individual components Varies with the loading, network configuration and with changes in voltage. Voltage stability is refer to maximum power transfer beyond which further increase in load results in reduction in voltage. Higher load Variations results higher reactive power loss and voltage drop in the transmission line.

For regulating voltage reactive power is supplied to the line during heavy loads and is extracted from the line during low loads compensation of reactive power helps in improving steady state and voltage stability. IJSFACTs devices are used to regulate power flows in transmission line by controlling one or all of circuit impedance, magnitude and phase angle difference of voltage across the transmission line.

Among them UPFC is most versatile and reliable device of FACTs family. UPFC consists of a parallel and series branches, each one contains a transformer, power electric converter with turn off capable semiconductor devices and DC circuit. Series inverter is connected to series transformer and shunt inverter is connected to shunt transformer. The real and reactive power in transmission line can be quickly regulated by changing the voltage magnitude and phase angle of converter.

According to the STATCOM is regulating device used on alternating current electricity transmission networks. It is power electronic voltage source converter and can work as either source or sink of reactive AC power to an electricity network. STATCOM provides better reactive power support al low AC voltage than FACTs device, the reactive power from a STATCOM decreases linearly with the AC voltage. This paper indicates a simulation model of medium transmission line which is once considered with linear and non-linear load at time, with STATCOM and UPFC. The UPFC and STATCOM is simulated with the help of Simulink library of MATLAB. The simulation is carried out with these considerations and results are compared.

Mathematical& Simulink Model of UPFC

The UPFC is designed with the help of 12 IGBT and series & shunt connected transformer to the UPFC controller. The PWM Generator circuits are used as the controller circuit of the UPFC. For the measurement of current and voltage, Three Phase voltage current measurement block of Simulation is used.

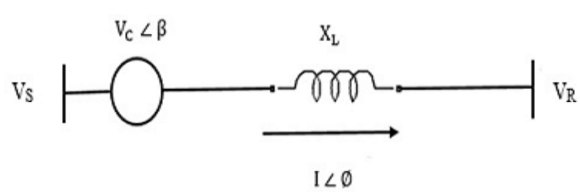


Fig 1 – Mathematical Model of UPFC

$$P_R = P_O \frac{V_{VC}}{X_L} \sin\left(\frac{\delta}{2} + \beta\right) \quad (1)$$

$$-Q_R = Q_O \frac{V_{VC}}{X_L}\cos\left(\frac{\delta}{2}+\beta\right) \quad (2)$$

Here

$$\beta = \frac{\pi}{2} - \frac{\delta}{2} \quad (3)$$

$$P_O = \frac{V^2}{X_L}\sin\delta \quad (4)$$

$$Q_O = \frac{V^2}{X_L}(1-\cos\delta) \quad (5)$$

$$\sin\emptyset = \frac{V_P}{2\sin\frac{\delta}{2}} \quad (6)$$

The gate terminal of each UPFC is connected to individual pulse generator to trigger out the UPFC converter which helps it to simulate at given input source. Both converter has different 3 phase voltage and current measurement blocks with their own 3 phase input source. These blocks are further connected to another blocks which helps in observing the real reactive power absorbed or injected by any of series or shunt converter.

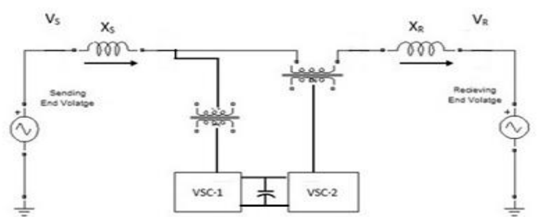
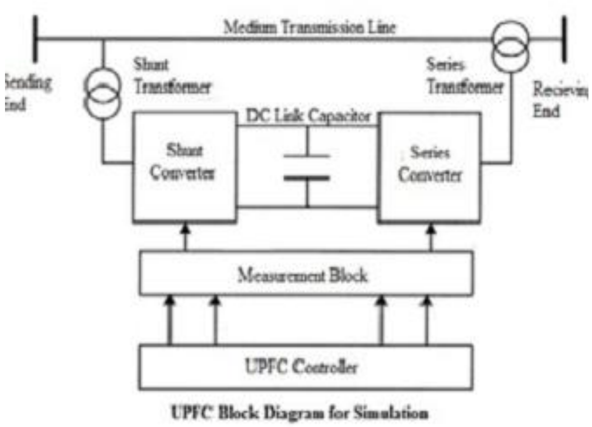


Fig. 2 – Circuit Diagram of UPFC



3 – UPFC Block Diagram for Simulation ER

The UPFC circuit is used here because of its versatile and dynamic nature of controlling real and reactive power from sending to receiving side. On using UPFC with the system we get better results in comparison to other devices and results without devices. The UPFC here designed with the help Simulation through MATLAB. It contains multiple IGBT circuits connected to parallel circuit to each other with a dc capacitor with them. The UPFC is having one transformer in series and other with the shunt connected to the line. The Simulation contains both measurement and control circuit.

2. MATHEMATICAL& SIMULINK MODEL OF STATCOM

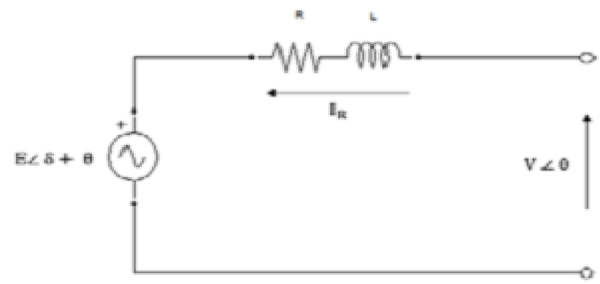


Fig. 4 – Mathematical Model of STATCOM

$$I_r = \frac{V-E}{R+jL} \quad (7)$$

$$E = \frac{\sqrt{2}}{\pi}\int_0^{\pi}\frac{V_{dc}}{2}\sin\theta\, d\theta \quad (8)$$

$$E = \frac{\sqrt{2}}{\pi}V_{dc} \quad (9)$$

$$P = V_{sm}I_{sm}\cos\frac{\delta}{4} \quad (10)$$

$$P = 2\frac{V^2}{X}\sin\frac{\delta}{2} \quad (11)$$

$$Q = VI\sin\frac{\delta}{4} = \frac{4V^2}{X}\left(1-\cos\frac{\delta}{2}\right) \quad (12)$$

The STATCOM is here a combination of shunt transformer, lc Filter and an IGBT Converter fed with the pwm generator. The output of STATCOM is calculated at the Pstat port and results is obtained for absorption or injection of reactive power in STATCOM. The results here are obtained with STATCOM is compared with previous block of power system without STATCOM.

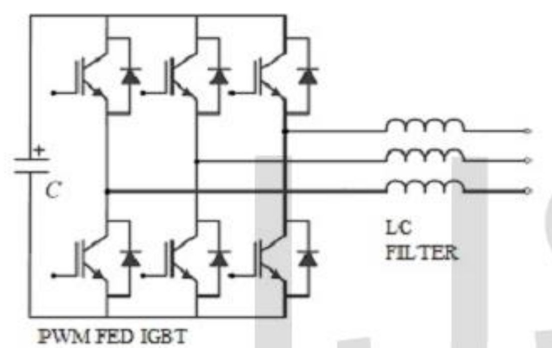


Fig 5 – Circuit Diagram of STATCOM

The capacitor voltage can be adjusted by controlling the phase angle difference between line voltage and vsc voltage. If the phase angle of line voltage is taken as a reference, the phase angle of vsc voltage is the same as the firing angle of vsc. The dc voltage decreases and reactive power flows into STATCOM, if the firing angles are slightly advanced. Conversely, if the firing angles are slightly delayed, the dc voltage increases and STATCOM supplies reactive power to the bus.

Simulation model of medium transmission line is constructed in Simulink Library of MATLAB. The simulink is once considered with linear and non-linear load in medium transmission line with UPFC and STATCOM. The DC capacitor is here used for the source of the Voltage Source Converter. The DC source helps to provide the active power is helpful by using the capacitor. There is DC Capacitor connected parallel with the IGBT circuits, the transformer dc voltage source is calculated with K modulation gain and α is the phase angle for the injected voltage.

By controlling the firing angles of Voltage Source Converter, the voltage stability and control of reactive power injected or absorbed can be control. The Iq component of the source current is strongly correlated to the reactive power which is used as the reference Iq in the PI controller that produces the modulation index of the PWM controller.

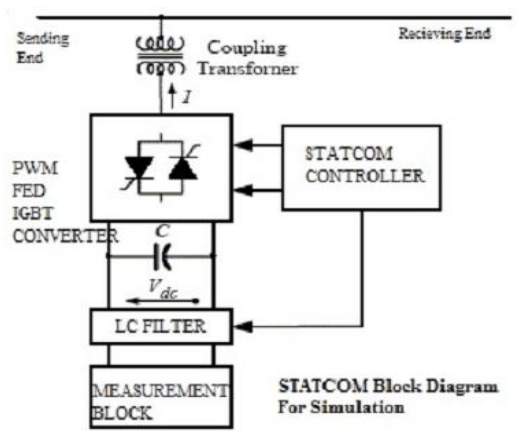


Fig. 6 – STATCOM Block Diagram for Simulation

The Voltage Source Converter of STATCOM is here constructed with 3 arms IGBT Bridge, here each IGBT is connected parallel to diode. The output of the converter is triangular sine wave. Also a dc capacitor is connected in parallel to provide the input voltage source. A subsystem is connected here which is build up with the pwm generator circuit inside. The output of pwm generator is here given to IGBT input one with and other without not gate.

3. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

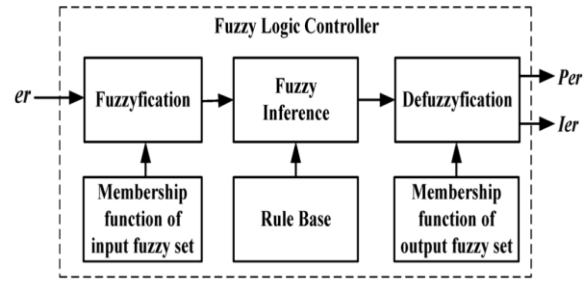


Fig.7.Fuzzy logic controller

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

TABLE: Fuzzy Rules

e / $\dot{e}$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Fuzzification: Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The Partition of fuzzy subsets and the shape of membership CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor.In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset. The input error for the FLC is given as

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \quad (13)$$

$$CE(k) = E(k) - E(k-1) \quad (14)$$

Inference Method: Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, „height" method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output

The set of FC rules are derived from

$$u=-[\alpha E + (1-\alpha)*C] \quad (15)$$

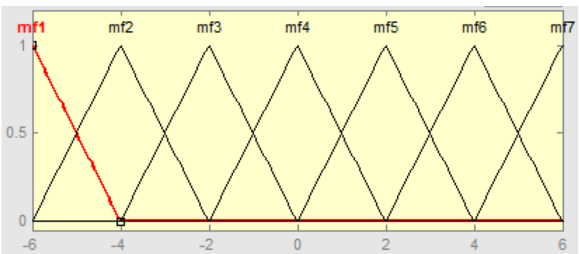


Fig 8 input error as membership functions

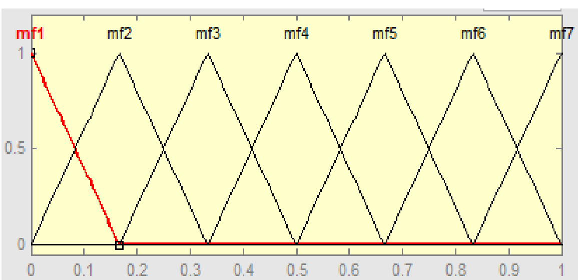


Fig 9 change as error membership functions

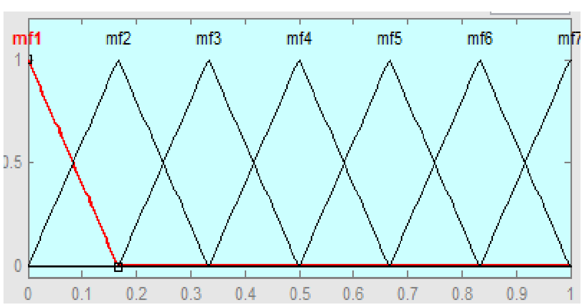


Fig.10 output variable Membership functions

Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable.

4. RESULTS AND DISCUSSIONS

In this section, the simulation is tested at linear and non linear load connected to the medium transmission line. The system is connected once with UPFC and STATCOM to the medium transmission line. The simulation is carried out on Simulink platform of MATLAB

Sr. No	Configuration Name	Configuration Code
	At Linear Load	
1	Without FACTS in Linear Load	WFL
2	With STATCOM in Linear Load	SL
3	With UPFC in Linear Load	UL
	At Non-Linear Load	
4	Without FACTS in Non-Linear Load	WFNL
5	With STATCOM in Non-Linear Load	SNL
6	With UPFC in Non-Linear Load	UNL

Linear Load

The system is connected to linear load at medium transmission line once at UPFC and STATCOM. The results observed and comparison is carried out between both devices. The values of reactive power and load voltage is carried in below.

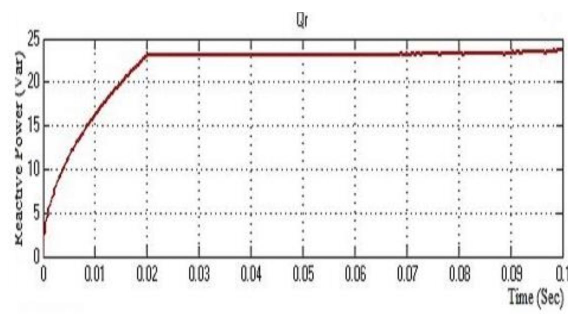


Fig. 11 – Reactive Power of Medium Transmission line at Linear Load with STATCOM (SL)

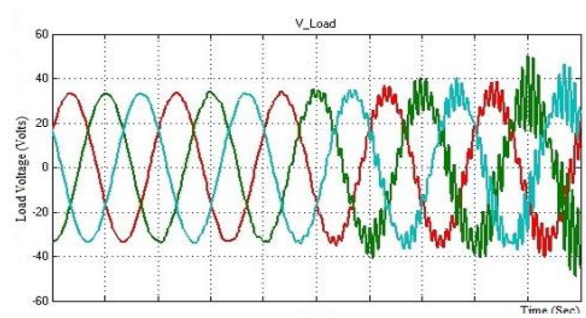


Fig. 12– Load Voltage of Medium Transmission Line at Linear Load with STATCOM (SL)

By controlling firing angle of IGBT converter, the voltag stability and reactive power can be control.

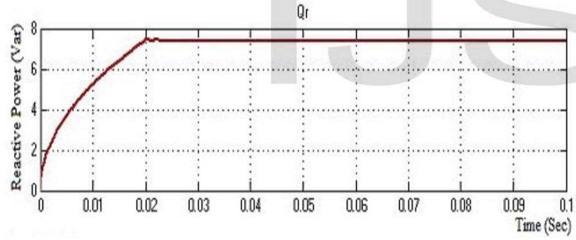


Fig. 13 - Reactive Power of Medium Transmission line at Linear Load with UPFC (UL)

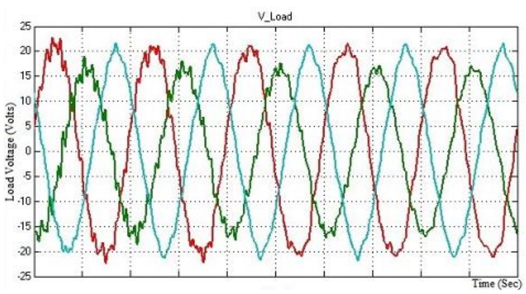


Fig. 14 - Load Voltage of Medium Transmission Line at Linear Load with UPFC (UL)

At Non-Linear Load

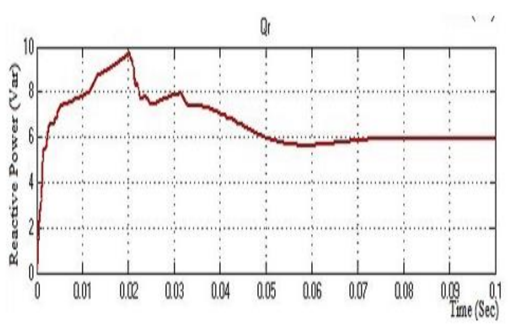


Fig. 15 - Reactive Power of Medium Transmission line at Non-Linear Load with STATCOM (SNL)

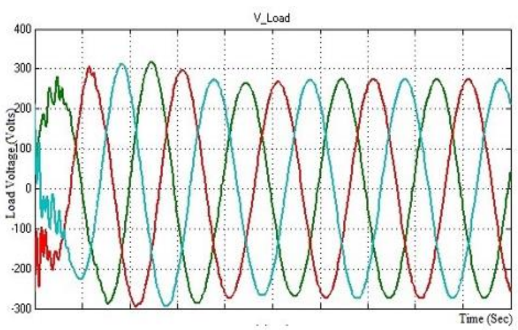


Fig. 16 - Load Voltage of Medium Transmission Line at Non-Linear Load with STATCOM (SNL)

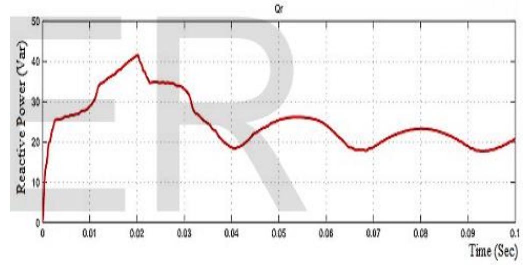


Fig. 17 - Reactive Power of Medium Transmission line at Non-Linear Load with UPFC (UNL)

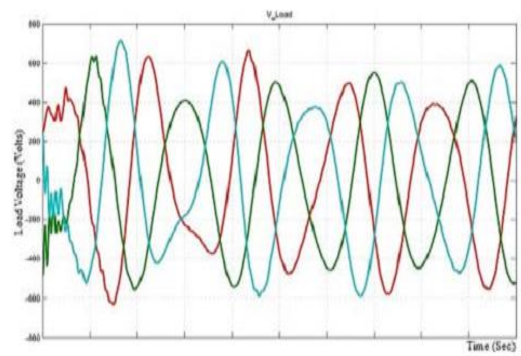


Fig. 18 - Load Voltage of Medium Transmission Line at Linear Load with UPFC (UNL)

Firing angle is inversely proportional to the reactive power at receiving end. The sine wave of load voltage and current is occurred due to sine triangular PWM which is given to gate of IGBT's.

Comparison of Load voltage and Reactive Power of Medium Transmission Line at Linear and Non-Linear Load

At Linear Load

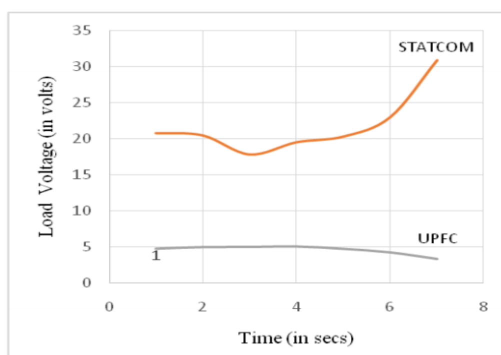


Fig. 19 - Load Voltage Characteristics with UPFC and STATCOM at Linear Load

When the load varies, the value of sending end reactive power also decreases. Also due to load variations the sending end reactive power decreases which also affects the sending end reactive power, which finally results in increase in power transfer capability and voltage stability at receiving end.

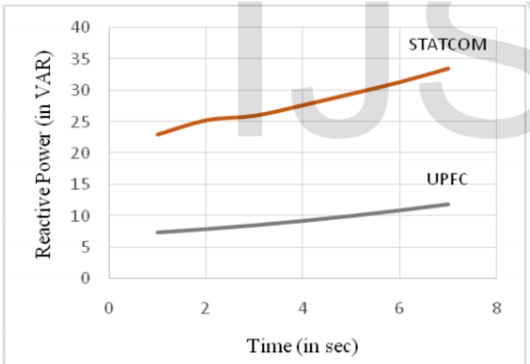


Fig. 20 – Reactive Power Characteristics with UPFC and STATCOM at Linear Load

At Non-Linear Load

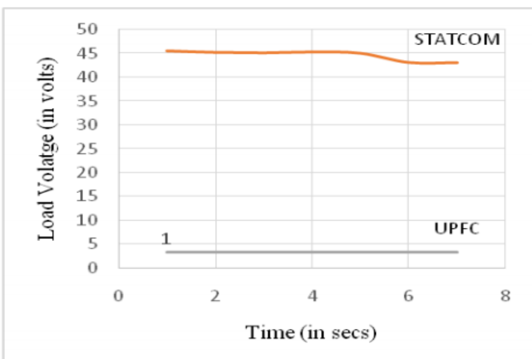


Fig. 21 - Load Voltage Characteristics with UPFC and STATCOM at Non-Linear Load

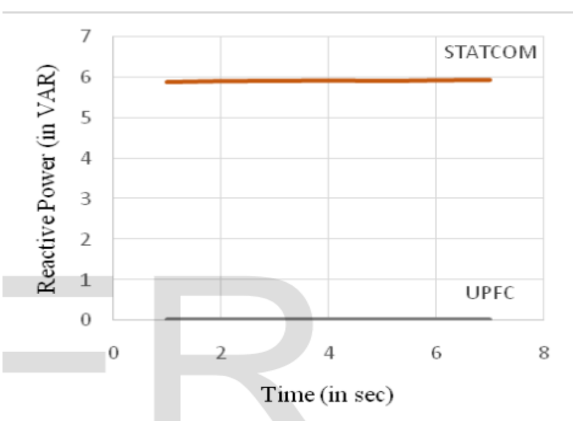


Fig. 22 - Reactive Power Characteristics with UPFC and STATCOM at Non-Linear Load

5. CONCLUSION

In this project we are observing the linear load of the transmission line with the UPFC which is represented in the fig :16 which will have the results of reactive and power compensatiuon with the load voltage.therefore when the load reactive power reduces then sending end reactive power losses will also reduces. By using fuzzy logic controller we can get the better performance because it works like a human brain. by using the STATCOM it is is observed that the sending end reactive power losses will be reduces.therefore UPFC is the better in the place of STATCOM. by utilizing the UPFC we can increases the power transfer capability and the thermal capability of transmission line.

Sr. No.	At Linear Load		At Non-Linear Load	
	Reactive Power Losses	Load Voltage Losses	Reactive Power Losses	Load Voltage Losses
STATCOM	23.06 VAR	20.82 V	5.894 VAR	45.51 V
UPFC	**7.37**VAR	4.729 V	0.016 VAR	3.296 V

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