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DECIDING OPTIMAL LOCATION FOR PLACING FACTS DEVICES [UPFC, IPQC, DPFC] USING BANG-BANG CONTROL TECHNIQUE

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ABSTRACT

This paper discusses about the problems that arise in the transmission of power. Sag, swell, voltage fluctuation, harmonic losses etc are the problems in the transmission of power. In this paper we are focusing on the harmonic losses. Distributed Power Flow Controller, Unified Power Flow Controller and Improved Power Quality Controller are the three FACTS devices which are considered in this project. These FACTS devices are used in between the IEEE 14 bus system individually for locating the FACTS devices to calculate the real and reactive power. The devices are placed based on the better efficiency of the devices along the IEEE 14 bus system and the harmonics are reduced. The three FACTS devices are compared and they are placed based on the better efficiency of the devices.

Index terms- Optimal location, Unified Power Flow Controller (UPFC), Improved Power Quality Controller (IPQC), Distributed Power Flow Controller (DPFC)

1. INTRODUCTION

Electric power distribution network is playing an essential role in power system planning. This type of power systems has a major function to serve distributed customer loads along a feeder line; therefore under competitive environment of electricity market service the electric energy transfer must not be interrupted and at the same time they must provide reliable, stable and high quality of electric power. FACTS covers several systems based on power electronics for AC power transmission and distribution. FACTS are the family of devices which can be used in series, in shunt and in some cases both as series and shunt. Series capacitor (SC), Thyristor controlled series capacitor (TCSC) and STATCOM have important applications in transmission and distribution. SVC and SC are the devices which have been utilised for a long time. Real and reactive power are not stable in the devices which were used earlier and had less efficiency. Advanced FACTS devices like UPFC (Unified Power Flow Controller, DPFC (Distributed Power Flow Controller, IPQC(Improved Power Quality Controller) are implemented in this paper. Shunt series connections are present in DPFC and UPFC. IPQC has only the series connection. There are many benefits of the FACTS devices which can be attained in AC systems. Minimized transmission losses, Minimized environmental impact, Improved power quality, Improved power system stability and availability, Improved power transmission capability are the benefits of the FACTS devices. These devices are more reliable and have high efficiency and has direct control over real and reactive power flow.

2. DEVICES DESCRIPTION

Advanced FACTS devices like UPFC, IPQC and DPFC are used. It provides fast dynamic reactive power support and voltage control and hence reduces the financial cost.

A. Unified Power Flow Controller

UPFC is most comprehensive flexible ac transmission system. The schematic diagram of UPFC is as shown in Fig. 1. It consists of a series and a shunt converter connected by a common dc link capacitor and can simultaneously perform the function of transmission line real/reactive power flow control in addition to UPFC bus voltage/shunt reactive power control.

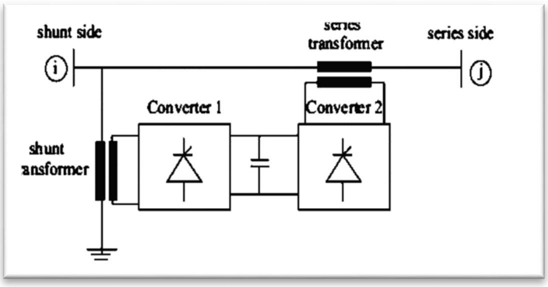

Fig.1. Schematic diagram of UPFC

The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter of the UPFC controls the transmission line real/reactive power flows by injecting a series voltage of adjustable magnitude and phase angle.

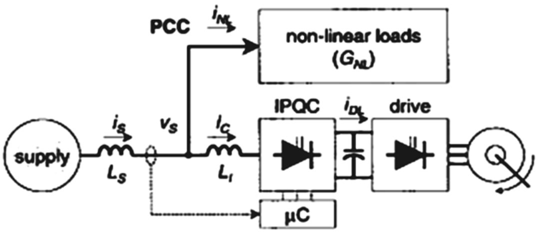

Fig. 2 Schematic diagram of IPQC

IPQC improves the harmonic content of the supply current, displacement power factor, supply current balance, and can serve as a four-quadrant active rectifier for motor drives and other dc-link loads.

b. Distributed Power Flow Controller

The DPFC is derived from the Unified Power Flow Controller (UPFC). The schematic diagram of DPFC is as shown in Fig. 3. The DPFC can be considered as a UPFC with an eliminated common dc link.

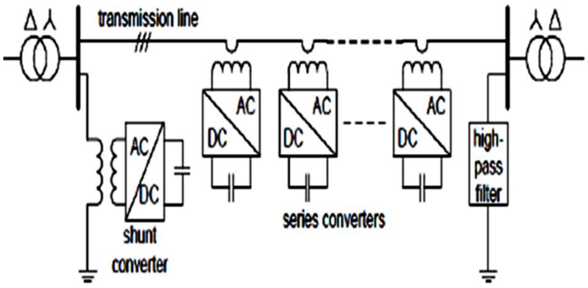

Fig. 3 Schematic diagram of DPFC

The active power exchange between the shunt and series converters, which is through the common dc link in the UPFC, is now through the transmission lines at the third-harmonic frequency. The DPFC employs the distributed FACTS (D-FACTS) concept, which is to use multiple small size single phase converters instead of the one large size three phase series converter in the UPFC.

3. BANG-BANG CONTROL TECHNIQUE

Bang-Bang controller (ON-OFF controller),also known as Hysteresis controller are the switches which acts as a feedback controller between the two states. It is the most common residential thermostat. It is a variable structure controller which is used in heavy side function in discrete form. The representation of the grid interfacing inverter control is as shown in the Fig. 2. Neutral current of the load is compensated using the fourth leg of the inverter. The main aim of the proposed approach is to regulate the power at PCC during the following conditions:

1. $P_{RES} = 0$
2. $P_{RES} <$ total load power (P_L)
3. $P_{RES} >$ total load power (P_L)

while performing the power management operation.

$$I_{dc2} = P_{inv} / V_{dc} = P_G + P_{loss}/V_{dc} \qquad (1)$$

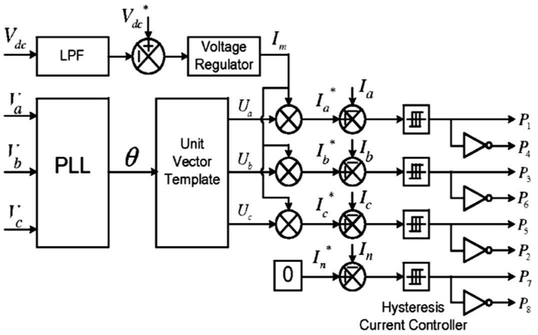

Fig. 4 Block diagram representation of Grid-interfacing inverter control

If PCC is non linear or unbalanced or the combination of both when connected to the load, then the approach compensates the harmonics, unbalance, and neutral current. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balanced resistive load to the grid. The multiplication of the action current component (I_m) with unity grid voltage vector templates (U_a, U_b and U_c) generates the reference grid currents (I_a^*, I_b^* and I_c^*). The reference grid neutral current (I_n^*) is set to zero, being the instant sum of balanced grid currents. The grid synchronizing angle obtained from phase locked loop (PLL) is used to generate unity vector template as

$$U_a = Sin(\theta) \tag{2}$$

$$U_b = Sin(\theta - 2\mu/3) \tag{3}$$

$$U_c = Sin(\theta + 2\mu/3) \tag{4}$$

4. BLOCK DIAGRAM DESCRIPTION

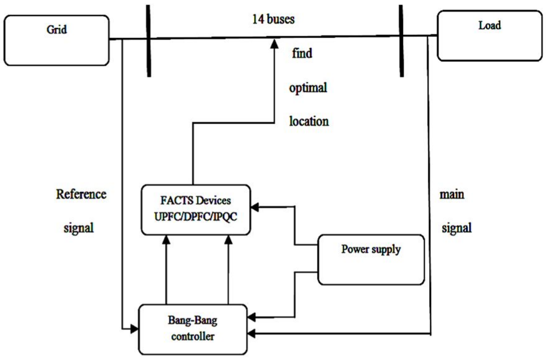

Fig. 5 Block diagram

In a normal transmission line from grid to the load side the location of the fault can be found out by optimal location of the FACTS devices. 14 bus system is connected in between the grid and the load. The output from the grid is taken as the reference signal and the signal from the load side are given as the input to the Bang-Bang control technique. The signals which are given as the input are compared with each other and if there is a difference between the two signals then the pulse will be generated and given to the FACTS devices to trigger the pulses. FACTS device will act immediately and the optimal location can be found out in a 14 bus system and the devices can be placed in proper location. Separate power supply is given for bang-Bang control technique and FACTS devices.

5. SIMULATION

MATLAB version 8.002 (2012-(b)) is used. Advanced FACTS devices are used in IEEE 14 bus system to find the optimal location of the FACTS devices. Bang-Bang control technique is used for the hysteresis control of the devices i.e. UPFC, IPQC and DPFC. Optimal location of the devices are found out easily and the devices are placed at the suitable location. Bang-Bang control technique is used because of its simplicity of implementation. Also besides fast response current loop, the method does not need any knowledge of the load parameters.

A. With DPFC

DPFC is placed in between the IEEE 14 bus system and the simulation for with and without DPFC. The MATLAB model of with DPFC are as shown in fig 6.

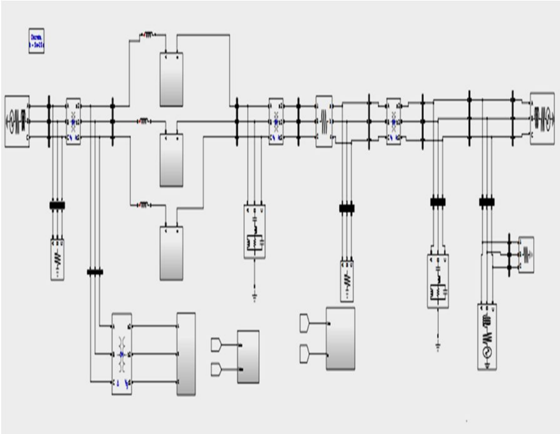

Fig. 6. With DPFC

B. With IPQC

IPQC is placed in between the IEEE 14 bus system. The simulation is performed with and without IPQC. The MATLAB model of with IPQC as shown in figure 7. The optimal location of IPQC is found out and they are placed at a proper location and the better efficiency of the device is found out.

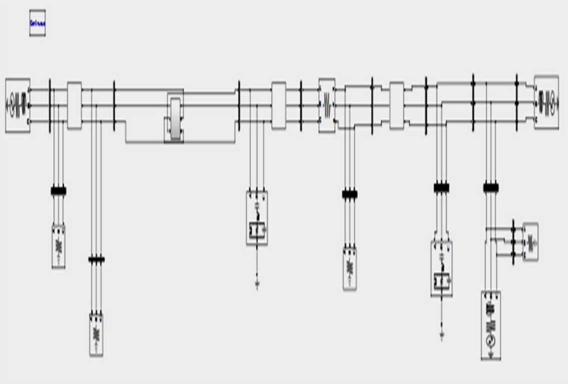

Fig. 7 With IPQC

C. With UPFC

UPFC is testes in IEEE 14 bus system. the optimal location of the UPFC is found out and it is placed in a proper location. The efficiency of the devices are found out. The simulink model of UPFC are as shown in the fig 8.

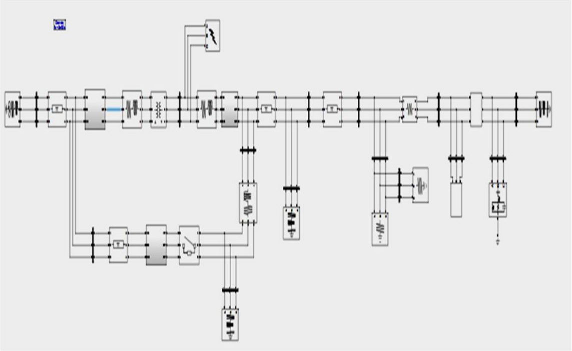

Fig. 8 With UPFC

6. SIMULATION RESULTS

A. DPFC

i) With DPFC

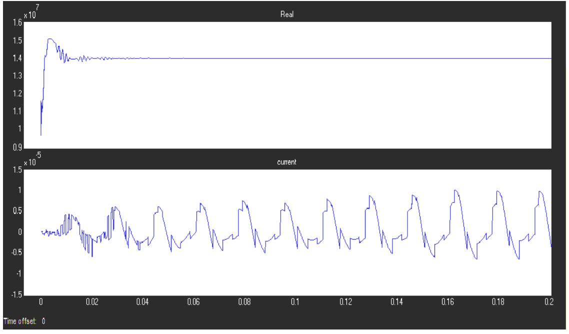

Fig. 9 Real and reactive power with DPFC

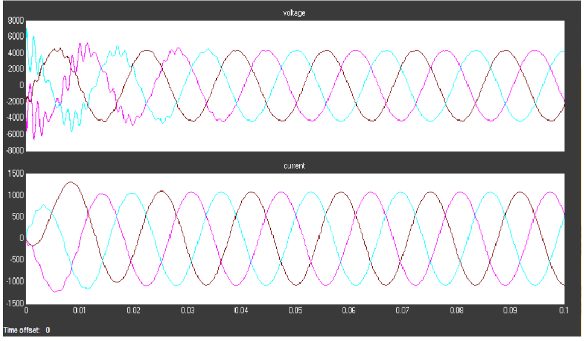

Fig. 10 Voltage and current waveform with DPFC

ii) Without DPFC

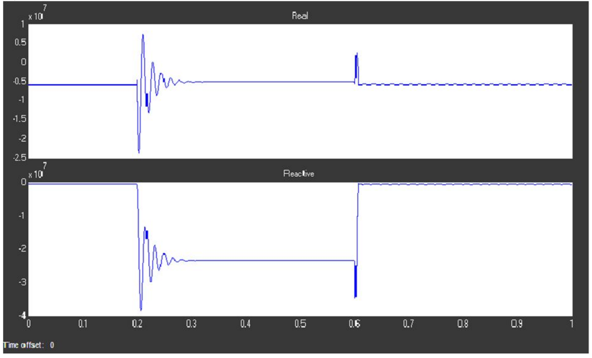

Fig. 11 Real and reactive power without DPFC

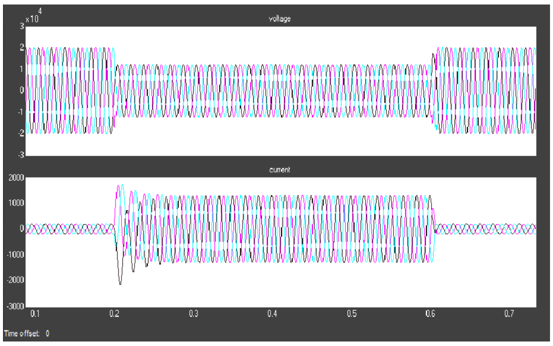

Fig 12 Voltage and current without DPFC

B. IPQC

i) With IPQC

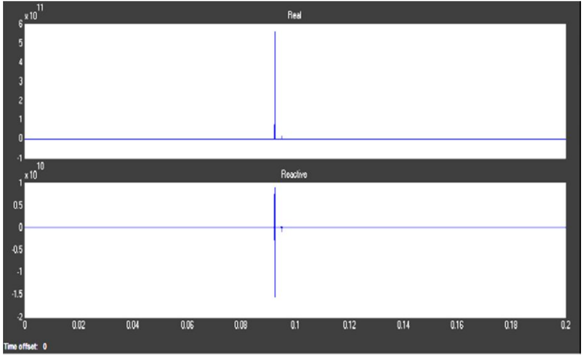

Fig 13 Real and reactive power with IPQC

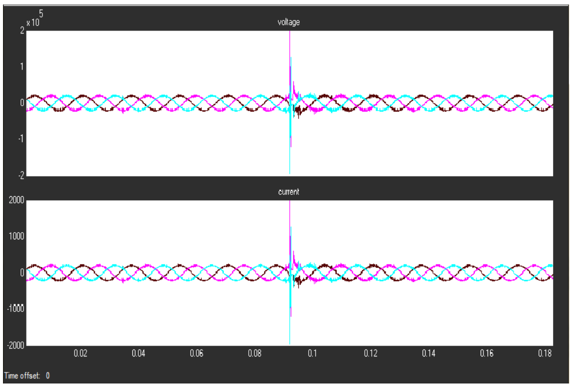

Fig 14 Voltage and current with IPQC

ii) Without IPQC

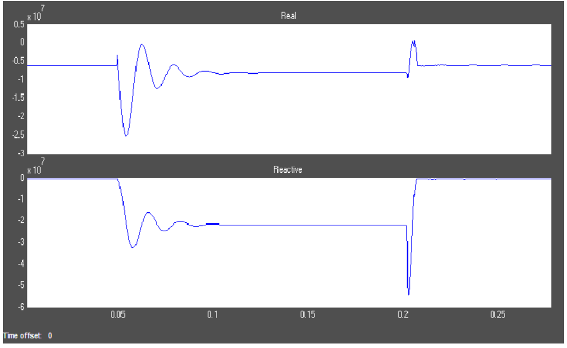

Fig 15 Real and reactive power without IPQC

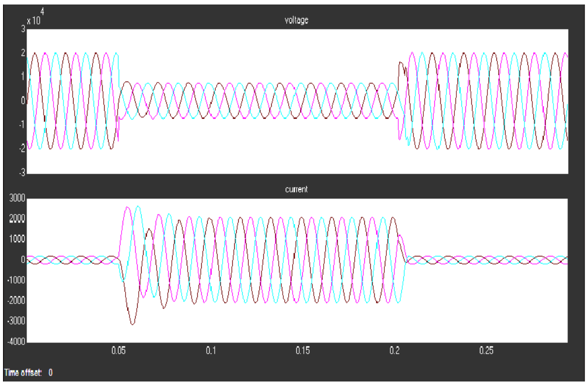

Fig 16 Voltage and current without IPQC

C. UPFC

i) With UPFC

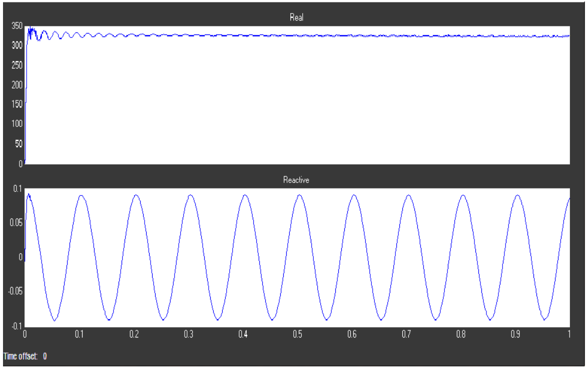

Fig 17 Real and reactive power with UPFC

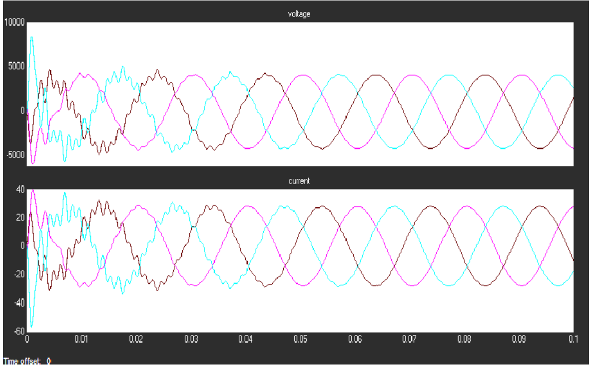

Fig 18 Voltage and current with UPFC

ii) Without UPFC

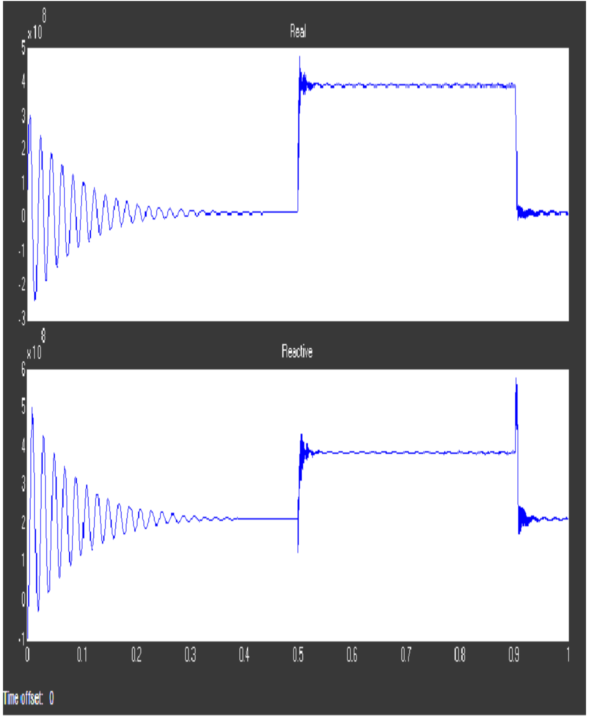

Fig 22 real and reactive power without UPFC

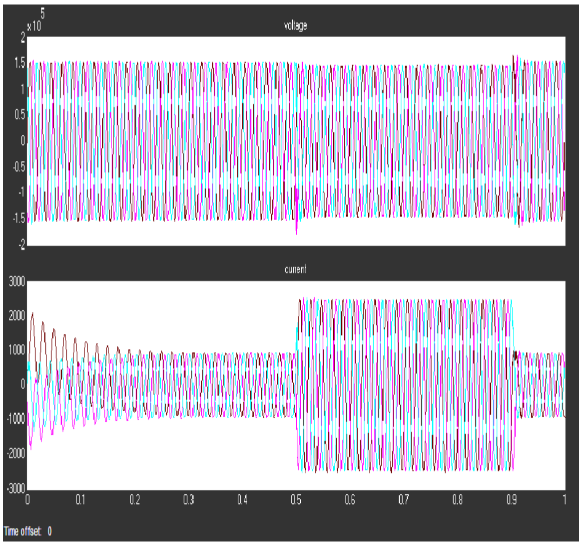

Fig 23 voltage and current without UPFC

VII TABULATION

TABLE 1

Values for the FACTS devices along the 14 bus system

Bus	DPFC				UPFC				IPQC			
	V	I	Real	Reactive	V	I	Real	Reactive	V	I	Real	Reactive
1	1.85×10^{4}	410	9×10^{6}	6.6×10^{6}	1.5×10^{5}	1600	1.5×10^{7}	3.5×10^{8}	2×10^{4}	240	7×10^{6}	1×10^{5}
2	4360	100	5×10^{5}	2×10^{5}	1.15×10^{4}	180	2.8×10^{6}	1.5×10^{6}	5000	40	2.5×10^{5}	1.5×10^{5}
3	4400	100	5×10^{5}	1.7×10^{5}	2800	28	1.15×10^{5}	5.75×10^{-4}	1×10^{4}	100	2×10^{5}	1×10^{5}
4	1100	300	3.2×10^{5}	3.6×10^{5}	1.27×10^{5}	750	0.5×10^{7}	1.4×10^{8}	1×10^{5}	100	0.5×10^{7}	1×10^{6}
5	3×10^{5}	600	2.77×10^{7}	3.5×10^{5}	2000	20	6.5×10^{4}	3×10^{-4}	6000	600	2×10^{6}	0.5×10^{7}
6	3×10^{4}	300	1.4×10^{7}	0.5×10^{-5}	2×10^{4}	4.6×10^{5}	2×10^{4}	4.6×10^{5}	4×10^{4}	600	2.5×10^{7}	0.5×10^{7}
7	7800	2400	2.85×10^{7}	2×10^{6}	1.5	150	325	0.1	4×10^{4}	400	1.5×10^{7}	4×10^{-9}
8	7800	4.0	200	4.5×10^{7}	1.5	100	325	1×10^{-11}	1×10^{4}	250	3×10^{7}	2×10^{6}
9	7800	2440	2.9×10^{7}	1.9×10^{6}	1.5	150	325	2×10^{-12}	1×10^{4}	4	0.5×10^{4}	5×10^{4}
10	7800	820	2.62×10^{6}	9.28×10^{6}	4000	0.04	248	0.1	1×10^{4}	2300	2.9×10^{7}	2×10^{6}
11	7800	78	9.2×10^{5}	1×10^{-7}	4000	3.4	2×10^{4}	6743	8000	80	10×10^{5}	5×10^{5}
12	4000	1000	3.7×10^{6}	6×10^{6}	1000	10	1.5×10^{4}	3.6×10^{5}	1×10^{4}	80	2×10^{5}	4×10^{-3}
13	1.85×10^{4}	185	5×10^{6}	0.25×10^{-6}	1000	0.5	8×10^{-4}	766	2.5×10^{4}	250	6×10^{6}	1×10^{-9}
14	7800	2400	2.6×10^{7}	1.175×10^{7}	4000	28	1.7×10^{5}	150	8000	2300	2.6×10^{7}	13×10^{6}

The value of current, voltage, real and the reactive power is as shown in the table 1. The fault time with FACTS devices and without FACTS devices are as shown in table 2 and table 3.

Table 2

Fault time with FACTS device

FAULT TIME IN WITH FACTS DEVICE		
DEVICE	**STARTING**	**ENDING**
DPFC	0	0.04
UPFC	0	0.05
IPQC	0.090	0.095

Table 3

Fault time without FACTS device

FAULT TIME WITHOUT FACTS DEVICES		
DEVICE	**STARTING**	**ENDING**
DPFC	0.2	0.6
UPFC	0.5	0.9
IPQC	0.05	0.2

Fault time with and without the FACTS devices are observed and the starting and ending time are noted. The devices will be placed according to the better efficiency for minimizing the fault.

Table 3 Placement of devices

BUS NO.	DPFC	UPFC	IPQC
1	11th bus	9th bus	13th bus
2	13th bus	8th bus	7th bus
3	6th bus	3rd bus	12th bus
4	3rd bus	5th bus	9th bus
5	2nd bus	7th, 10th bus	1st, 3rd bus
6	5th bus	7th, 10th bus	1st, 3rd bus
7	4th bus	14th bus	2nd bus
8	9th bus	13th bus	11th bus
9	7th bus	11th bus	4th bus
10	12th bus	12th bus	8th, 10th bus
11	1st bus	6th bus	8th, 10th bus
12	10th bus	2nd bus	13th bus
13	14th bus	4th bus	5th, 6th bus
14	8th bus	1st bus	5th, 6th bus

8. CONCLUSION

In this paper appropriate model development of flexible ac transmission systems (FACTS) shunt-series controllers for multiobjective optimization is shown and also a multiobjective optimization methodology to find the optimal location of FACTS shunt-series controllers are presented. When power is transmitted in a long transmission line some losses will occur. The FACTS devices are used to reduce the losses. Bang-Bang controller is used. Bang- Bang controller compares the reference signal and main signal. If there is a difference between the reference signal and the main signal then the signal is given to the FACTS devices. FACTS devices which are placed on the transmission line acts on it and maintains the real and reactive power. Advanced FACTS devices have both the shunt and the series connections to filter the losses. The devices are compared with each other and the suitable place is found out and the devices are placed by finding the optimal location along the transmission line.

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