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Improvement of Power Quality in Transmission System by Hybrid Power Flow Controller (HPFC)

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Abstract : ***The demand of electrical energy is rising across the world. But with that, installation of new generation or transmission system is the matters, constrained by economical and environmental factors. The alternative is to utilize the maximum capacity of existing system by some means. FACTS provides avenue to utilize the maximum capacity of existing system without endangering the stability, security, and performance of system, thus providing efficient utilization of existing system. UPFC is the most versatile FACTS device, which have the best performance characteristics in comparison to other classical controllers. But UPFC is very costly controller because of its configuration, consists of two VSCs. And the topology used in UPFC does not allow it to retrofit the existing equipment like switched capacitor, SVC, TCSC etc. This paper discusses the applicability of "Hybrid Power Flow Controller" (HPFC) as a cost effective and performance equivalent alternative of UPFC. In this paper, two topologies of HPFC are evaluated. Both topologies consist of a reactive power compensator and two VSCs. UPFC is a FACTS device consisting two converters, one is in series and one is in shunt with the line. In first topology of HPFC, the shunt converter of UPFC is substituted by a (presumably existing) switched capacitor, while its series converter is split into two "half sized" ones, installed on each side of the shunt device. And in second topology of HPFC, one of the switching converters of the UPFC is replaced by thyristor controlled variable impedance and other converter of UPFC is split into two "half sized" ones, installed on each side of the series device. Such topological arrangement results in operating characteristics similar to those of the UPFC, while achieving considerable savings in the total required converter MVA ratings*.**

I.INTRODUCTION

The demand is increasing constantly for electrical energy across the world. But with that, installation of new generation and transmission systems are the matters which are constrained by economical and environmental factors. In most cases due to some reasons (like unavailability of right-of –way and area for transmission and generation system), it is not possible to generate electrical energy at the location where it is going to be consumed. So it is the requirement of power system to transmit power from generating stations (large Power generating plants) to the load centers through the transmission system. Electrical energy is generated centrally in bulk amount and transmitted economically with the use of high voltage transmission over a long distance to the consumption point.

To maximize the reliability of electrical supply, to maintain security level of power system and because of some other factors like environment, economic etc, interconnection of transmission systems in various geopolitical and geographic areas is a common practice. This makes the transmission system very large and complex electrical network, consists of generation and consumption areas in hundreds and transmission lines in thousands. For a complex circuit like transmission system, controlling of power flow through the transmission lines is a complicated problem, next important issue with that complex system is to control the voltage at each bus with other performance parameters of the system.

The invention of thyristor in 1970s provides various possible classical means to control power system. Thyristors are semiconductor devices which can be simply use as an unidirectional switches that starts conduction by providing a proper turn-on pulse (gate signal) between gate and cathode terminal of thyristor. Thyristors stops conduction, when current through anode terminal is brought to zero by some means. Mechanical switches (used in devices to control power system's parameters) were replaced by thyristors to solve the problem of switching cycles in mechanical switched. Application of thyristor includes TSC, TCR and thyristor based phase angle regulator and tap changer. Some more novel circuit configurations have emerged by using the property of thyristor to delay the turn on time. This circuit provides continuous control over compensator parameters, which includes SVC, TCSC.

Technological advancements of semiconductor industry advent a new power grade semiconductor device called gate turn-off thyristor (GTO). GTO has the same functional capability to thyristors but it has the ability by which it can be turned off by simply providing a negative gate current to its gate cathode terminals, which make it more versatile semiconductor device in compare to general thyristor. In mid of 1980s, GTO was commercially available, which made it possible to make large current source or voltage source converter. VSCs can generate voltage with full control over its magnitude and phase. In construction of VSC, one side ofVSC consists of switching element like GTO and other side it requires a DC capacitor as a means of voltage support.

The “flexible AC transmission system (FACTS) refers to a concept of power flow control through AC transmission lines using static converters”. The advent of VSCs provides converter based FACTS controller having higher functional capability, includes the series static synchronous compensators (SSSC), advanced static compensator (STATCOM), interline power flow controller (IPFC), and the most versatile FACTS controller “unified power flow controller (UPFC)”.

II. HYBRID POWER FLOW CONTROLLER

A. Topologies used for HPFC

Fig. 2.1 shows the typical application of “hybrid power flow controller”, which is installed between two electrical areas connected by a transmission line. As shown in fig. 2.1, HPFC’s first topology consists of a the static VAr compensator (SVC) which works as a shunt connected variable susceptance at center and two VSCs connected in series with the transmission line by means of coupling transformers on each side of SVC. The main advantage of the HPFC topology in comparison to other known FACTS controllers like UPFC is that it can be used to retrofit existing equipment. Therefore, the point of installation of HPFC is an important issue and which will often be dictated by the location of existing equipment (usually HPFC is installed at the location already have reactive power compensators like SVC, TCSC etc) and in general it will be at some distance from strong voltage bus within the transmission line. The converters (VSCs) are connected through a common DC link like UPFC. By using the virtue of converters, the magnitude and angle of supplied voltage can be control, by which active power flow and the reactive power exchanged with the line can be simultaneously and independently controlled. The static VAr compensator (SVC) used in topology is coordinated with the control of converters to supply the bulk of total required reactive power.

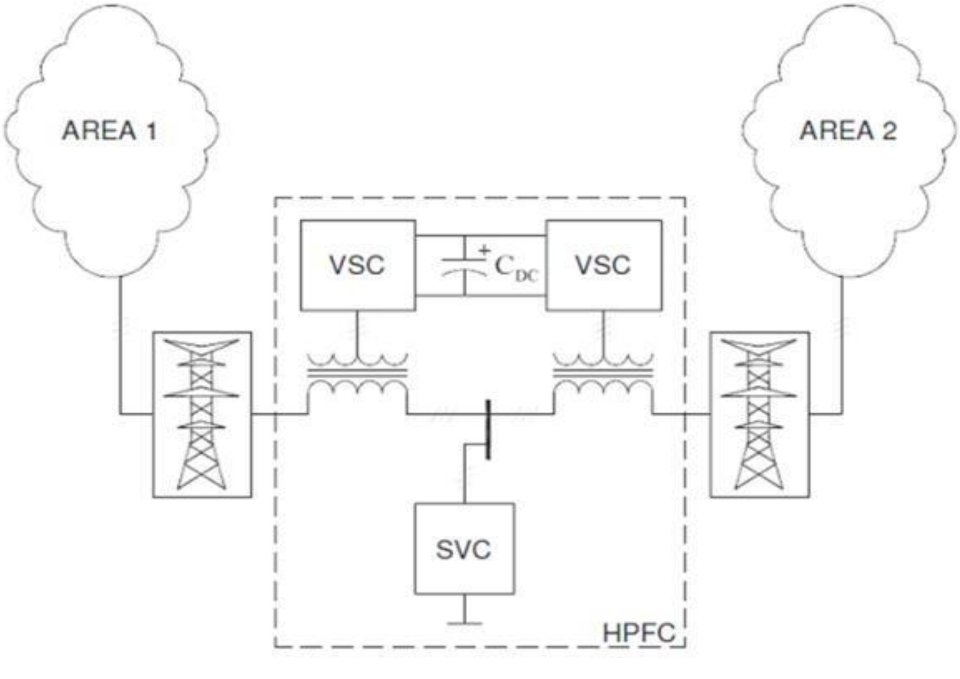


Figure 2.1: Topology-1 for Hybrid Power Flow Controller (HPFC1)

The second topology for HPFC is shown in fig 2.2, which is the dual topology of above topology. With some simple circuit transformations the second topology of HPFC can be obtained. In circuit transformations, let the static VAr compensator (SVC) is replaced by two half sized shunt connected current source converter (CSC). And two series connected voltage sources are combined and replaced by a variable reactance. Similar to first topology, the CSCs

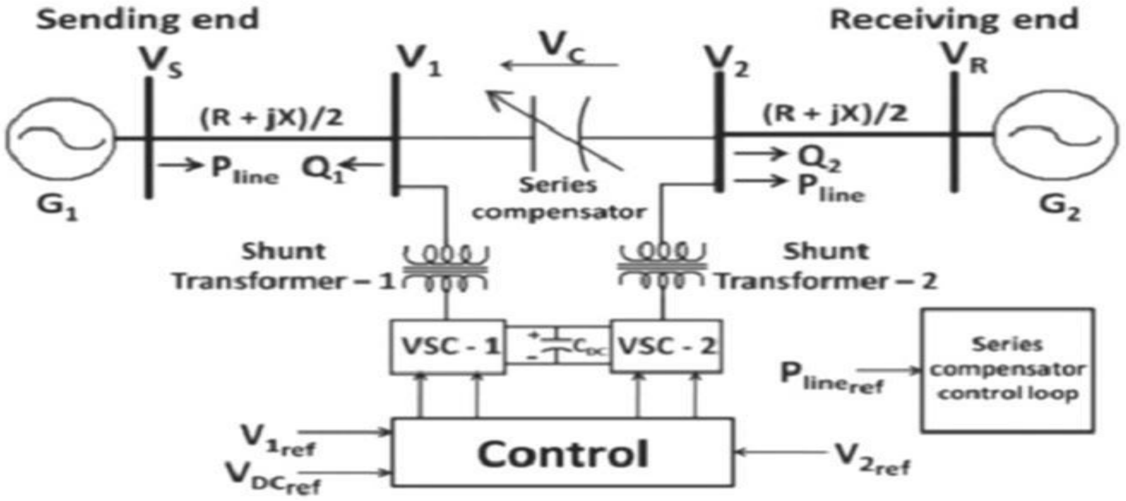


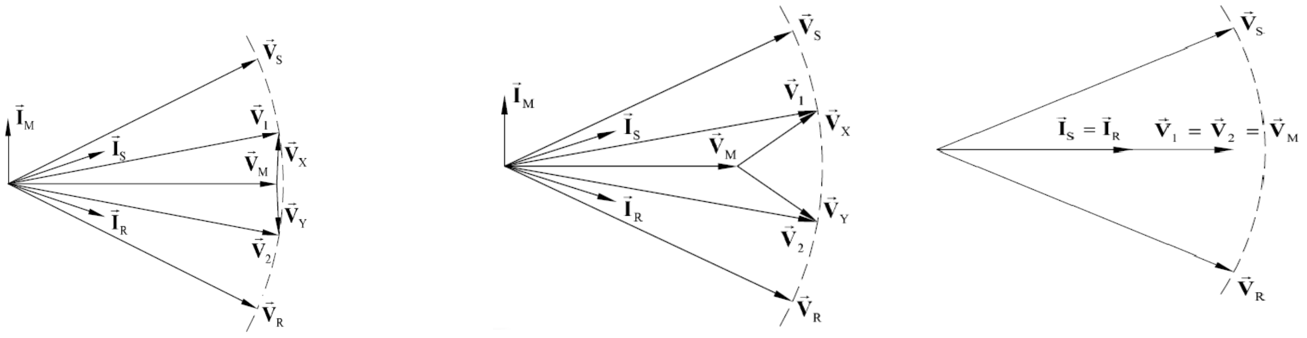
Figure 2.3: Topology-3 for Hybrid Power Flow Controller (HPFC2)

are coupled through a common DC link, and hence exchange of active power is possible.

The basic comparison between these topologies of HPFC with the topology used for UPFC gives the important features of new circuit. In brief, the shunt converter used in topology of UPFC is replaced by a classical shunt (SVC) or series (TCSC) compensator, and the series converter used in topology of UPFC is replaced by two half sized converters, which are installed on each side of the classical compensators (SVC or TCSC). Because of these topologies a considerable saving in total required converters rating is possible, consequently these topologies gives rise to retrofit application.

A. Functional Capability of HPFC Just like UPFC, HPFC can also independently and simultaneously control the real power and reactive power flow through the transmission line. If HPFC is not installed between two area shown in fig 2.1, the natural power flow through the line is given by:

Where, IV_SI = Magnitude of sending end voltage, V_R = Magnitude of receiving end voltage,
δ = Power angle ($\delta = \delta S - \delta R$)



(a) (b) (c)

Figure 2.4: HPFC phasor diagram (a) BM control reduces converter voltage (b) reduced power flow (c) natural power flow

III. SIMULATION MODEL AND RESULT

The simulation model of Single machine to infinite bus system (SIMB) without any controller is shown in fig 3.1. The SIMB in simulation model consists of two synchronous machines, interconnected through transformers, transmission line and a load of 5000 MW. The detailed data of SIMB are given in the Appendix. The power measurement, voltage measurement and machine performance parameter blocks are present in model.

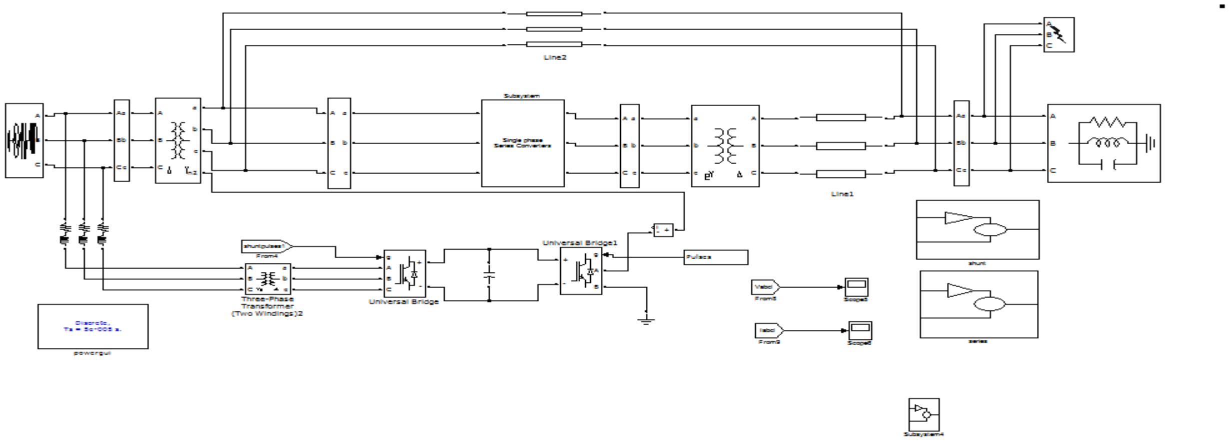
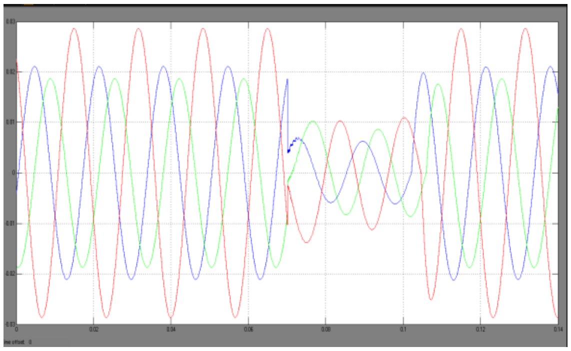


Fig .3.1: HPFC Simulink model for single machine connected to infinite bus with PID controller

The performance parameters of SMIB, which includes rotor angle deviation, rotor speed, and terminal voltage and load angle for both machines, are shown in fig 3.1. Which shows the deviation of machine parameters, so the performance of SMIB without any controller.



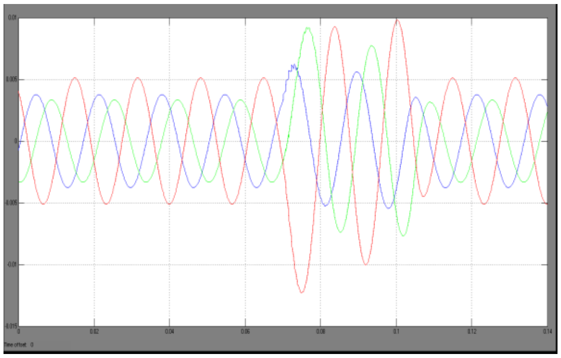
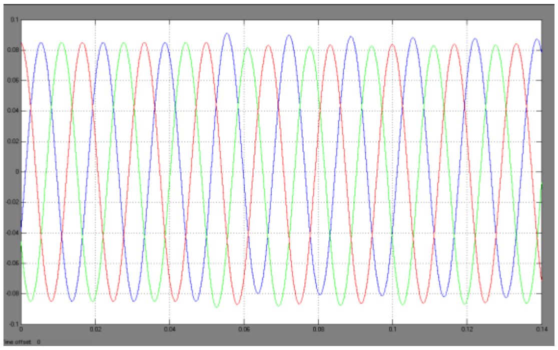


Fig.3.2:Three phase voltage sag without HPFC-PID Fig.3.3: Three phase current swell without HPFC-PID

Fig 3.1 shows the simulation model of SMIB with HPFC2, its controllers and other modules are also shown in fig 3.1. The model of HPFC2 consists of two shunt connected converter (VSC), so the performance of SMIB without any controller.



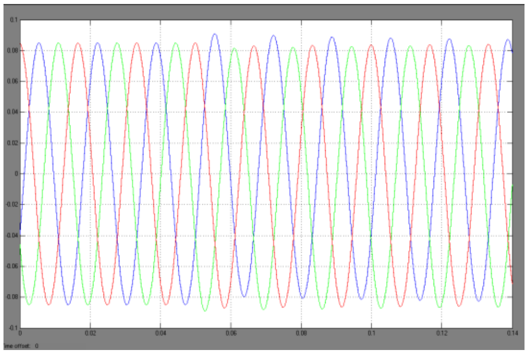


Fig.3.4: Three phase voltage sag with HPFC-PID Fig.3.5: Three phase current swell with HPFC-PID

The performance parameters of two machines system with HPFC1 is shown in fig 3.4. Which shows the deviation of machine parameters, so the performance of SMIB with HPFC1.

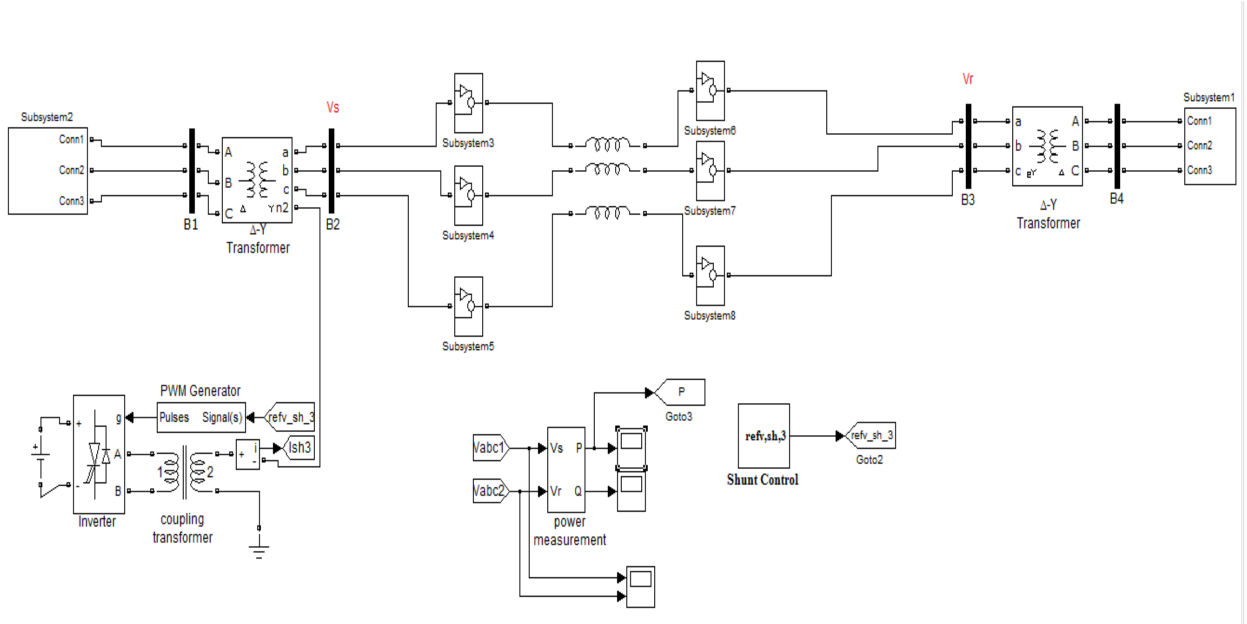


Fig .3.6: HPFC Simulink model for Two Machine System with PID controller

Fig 3.6 shows the simulation model of TMS with HPFC, its controllers and other modules are also shown in fig 3.7. The model of HPFC consists of two converters (VSC), one is series connected and other one is shunt connected.

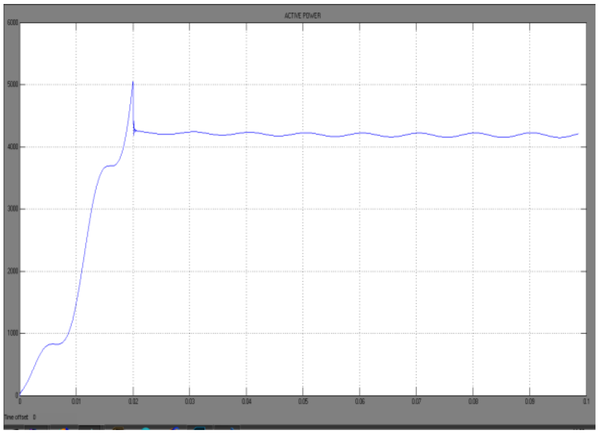


Fig.3.7.Active power without HPFC-POD

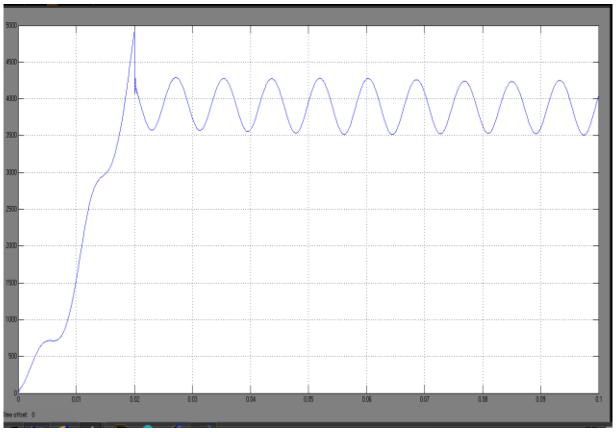


Fig.3.8.Active power with HPFC-POD

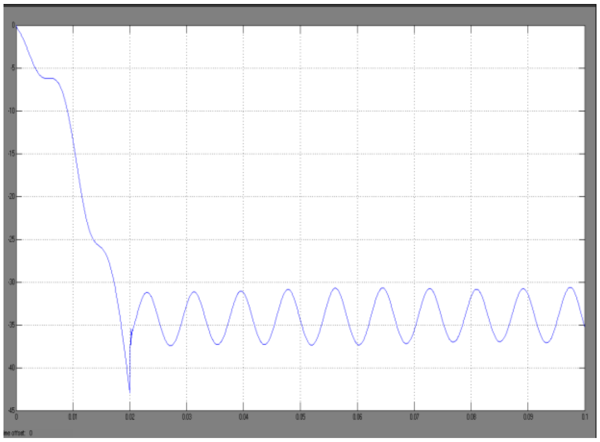


Fig.3.9.Reactive power without HPFC-POD

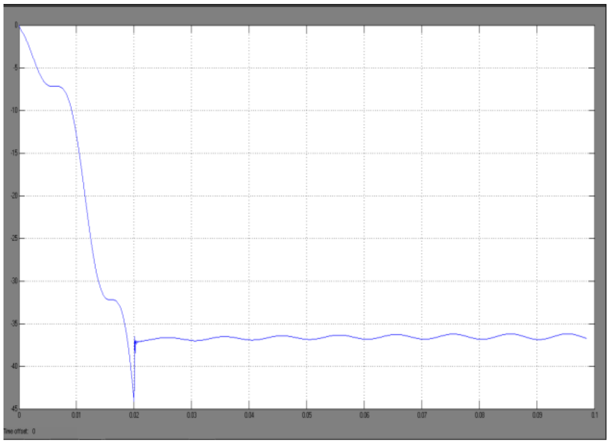


Fig.3.10.Reactive power with HPFC-POD

Fig 3.6 shows the simulation model of TMS with HPFC2, its controllers and other modules are also shown in fig 3.6. The model of HPFC2 consists of two shunt connected converter (VSC), and a passive element (TCSC) in series The rating of converters and passive component used in HPFC. The performance parameters of two machines system with UPFC is shown in fig 3.8. Which shows the deviation of machine parameters, so the performance of TMS with UPFC.

IV. CONCLUSION

In this work, the performance of "Hybrid power flow controller" has been analyzed. In this work two topologies are used for HPFC, labeled as HPFC1 and HPFC2. The aim of in this work is to model the HPFC for improving the performance of power system using MATLAB/SIMULINK software and compared to UPFC device.

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