A Comparative Analysis of FACTS Devices for Power Quality Improvement

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Abstract: According to a recent study, the load demand is rapidly increasing, causing more problems such as imbalance in the power system. Power electronics have major and essential role in the transmission, distribution and utilization of electricity and have the ability to process electricity potentially and economically. Although, the nonlinear operation of electrical devices introduces two important factors to the power system. They produce harmonics and affect the power factor of the system. Due to the uneven load, the system faces insufficient power consumption and affects the power quality. This requires system enhancements and is achieved by providing the adequate power transfer and power compensation to improve system performance. All of this can be done with FACTS devices. Some of the more advanced systems in this family are UPQC and DPFC. This paper compares how much system performance improves with and without these devices in balanced and unbalanced conditions using Simulink.

Keywords: Load Demand, Harmonics, Power Factor, Power Quality, Power Compensation, Flexible Alternating Current Transmission System (FACTS), Unified Power Quality Conditioner (UPQC), Distributed Power Flow Controller(DPFC).

1 Introduction

Power quality (PQ) is an important factor that influences the power system and all levels of electricity consumers [1]. A power quality issue is defined as "a voltage, current, or frequency fluctuation in the power grid resulting in system or equipment failure." The development of devices which integrate power electronics has a major impact on the quality of power which are consumed by the devices. Switched Mode Power Supplies (SMPS), Voltage and Current Regulators, Lamps which consumes low power, Arc Welders, etc., are just a few wide ranges of applications for power electronic devices. The load or equipment creates harmonics that disturbs the modern power distribution system.

Due to the interest growing in using renewable energy sources for power generation, distribution networks are prone to power quality issues. In this context, both the power industry and the electrical end users are increasingly concerned about the quality of their electricity. Customers

ITSPWC 2022, May 14-15, Karur, India

DOI 10.4108/eai.14-5-2022.2318894

demand higher levels of power quality than the current that power grids provide. Therefore, the quality of power should be maintained at a higher level using various techniques which are available.

Active power filters (APFs) have been proposed as useful tools for enhancing the quality of power. Active power filters are classified as series or shunt based on the following criteria: Series APFs are frequently used to eliminate voltage-based distortion, whereas shunt Active Power filter which are implemented to reduce current-based distortion. UPQC is a fusion of a shunt and a series active power filter. UPQC reduces current and voltage-related distortion simultaneously and independently[2-3]. In UPQC, the configuration is linked by a DC link, whereas in DPFC, it is linked by transmission lines.

2 Proposed System

The power quality issues such as current and voltage fluctuations, presence of harmonics etc., are will be eliminated by using the custom power devices. These problems are eliminated by using the appropriate compensation techniques. For the purpose of compensation various types of converters are used. In various techniques single to multi converters are used. These converters are connected in series or in parallel. In advanced systems two active power filters, here voltage source converters are used, in that one is connected in series which compensates all the voltage related power quality issues, The other one will be connected in parallel which compensates the current and the harmonics. Dynamic voltage Restorer (DVR) is the voltage source converter which acts as the voltage compensator[4-5]. STATCOM or Static compensator is the one which is connected parallelly to the system. An external energy storage system is provided to the system which provides the necessary voltage for compensation when the sag occurs, during the voltage rise the energy storage system will be recharged through the voltage source converters[6-9]. The voltage source converters have to be triggered in the time sag or swell, which is controlled by the PI controller, PWM control system or with any other suitable controlling unit. Fig. 1 represents the generalized block diagram of the system.

3 Block Diagram

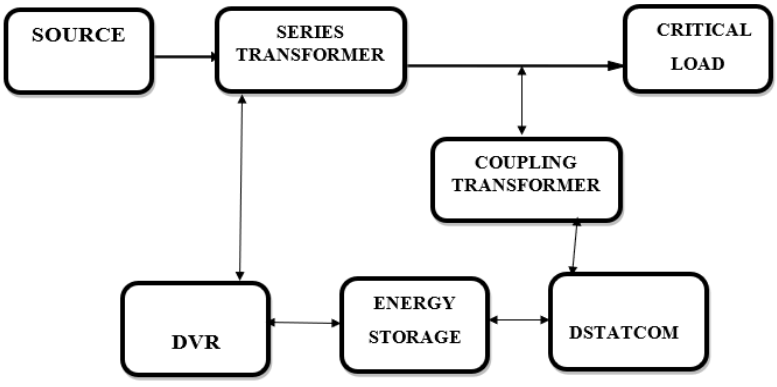

Fig. 1. Block Diagram of the Proposed System

4 Materials and Methods

4.1 Static Synchronous Series Compensator (SSSC)

SSSC is one of the latest power transmission series adjustment FACTS devices. Because it could produce a virtually sinusoidal voltage in a variable and controllable manner, it's also known as a synchronous voltage source [10-11]. The transmission line is in series with the amplitude and phase angle. The voltage which is injected is nearly perpendicular to the current in the line. Inverter losses are due to the feed voltage that is in phase with the grid current. Many injected voltages are orthogonal to the line current, resulting in inductive reactance or capacitive reactance in series with the transmission line. The electrical flow in the transmission line is affected by variable reactance. Fig. 2 is the configuration of Static Synchronous Series Compensator.

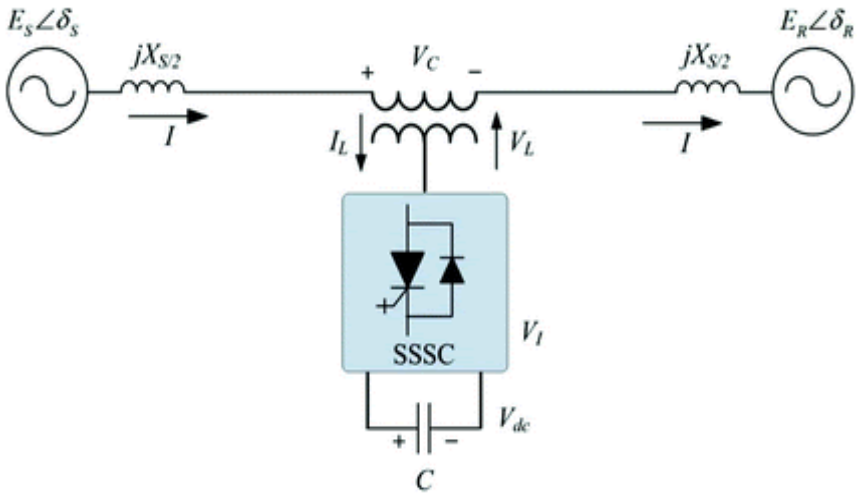

Fig. 2. Configuration of SSSC

4.2 Unified Power Quality Conditioner (UPQC)

The Unified Power Quality Conditioner (UPQC) is a versatile active power controller that takes into account both harmonics and reactive power [3], which has gained popularity in recent years. UPQC (Unified Power Quality Conditioner) is an advanced version of UPFC (Unified Power Flow Controller). The speed and accuracy with which the compensation signal is obtained determines how well UPQC performs. The UPQC reduces harmonics and feeds reactive power to the grid, resulting in a nearly one-to-one power factor improvement [12-13]. The UPQC is made up of active parallel and active series filters that are connected via a DC bus. The active shunt filter in the UPQC serves as a current source for the shunt transformer, delivering transient current. The active series filter serves as a voltage source for the series transformer, providing a compensatory voltage. Fig. 3 shows the schematic diagram of UPQC.

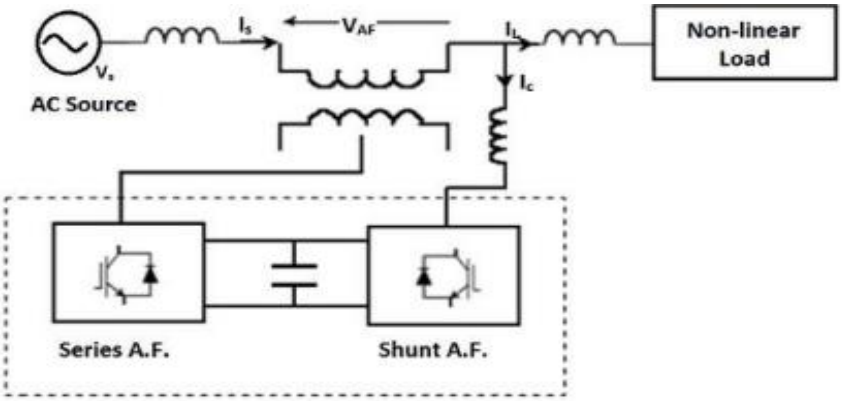

Fig. 3. Configuration of UPQC

4.3 Distributed Power Flow Controller (DPFC)

The DC link capacitor is removed in the DPFC system, and the active power is exchanged utilizing the 3rd harmonic current. The versatility of Series and Shunt Converters is increased by eliminating the common DC Power Supply[14-15]. Each DPFC converter is self-contained, with its own DC coupling capacitor to generate the requisite DC voltage. A shunt and DC linked converter circuit converter is used in the DPFC control. The most essential technology is that which provides dynamic Power between converters without a DC connection. Between the shunt AC connector and the device's converter, which is the transmission line, the DPFC has a common connection. The converter's AC port can be used to interchange dynamic power inside the scheme which are shown in Fig. 4.

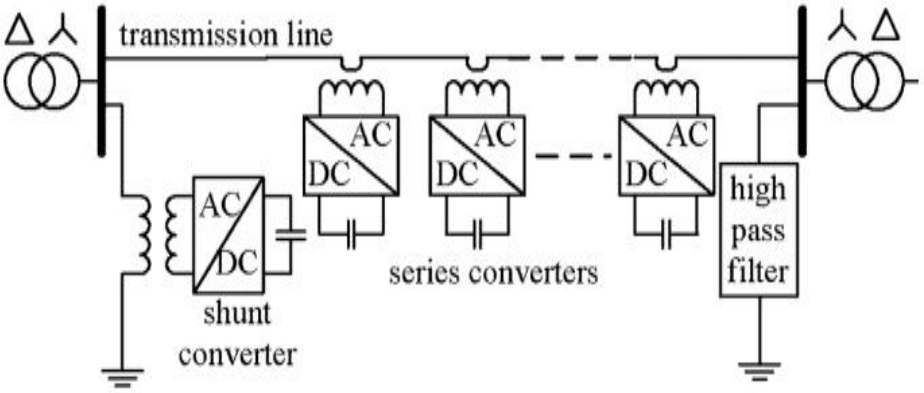

Fig. 4. Configuration of UPFC

5 Simulation Models

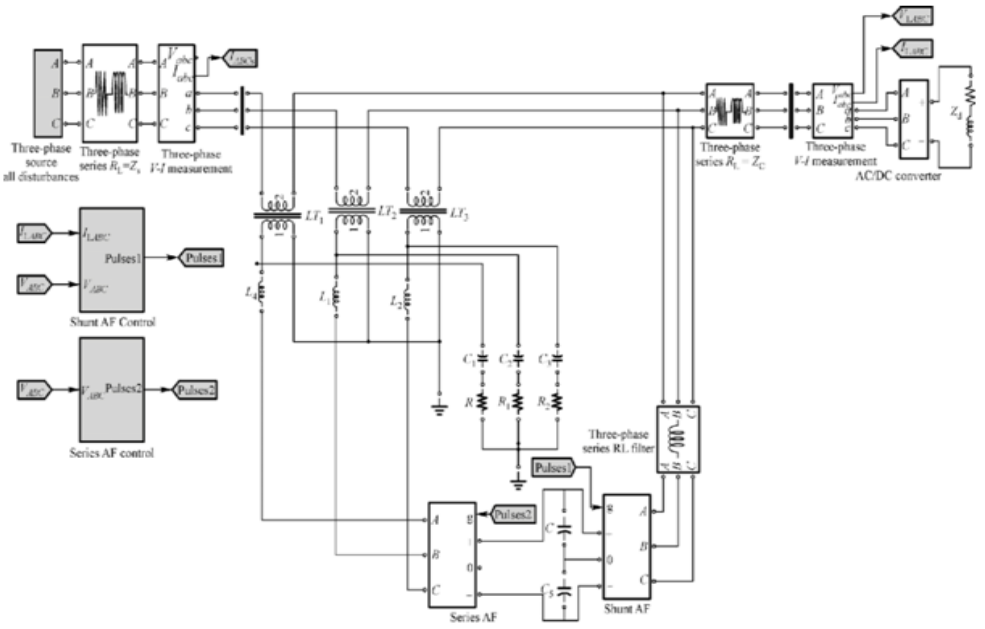

Fig. 5. Simulation model of UPQC

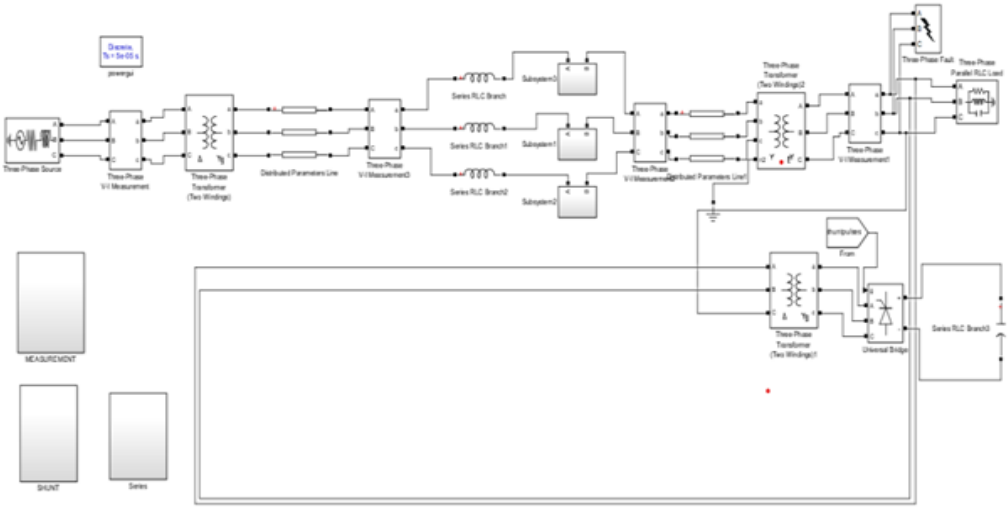

Fig. 6. Simulation model of DPFC

6 Results And Discussion

The proposed systems and techniques are simulated in the MATLAB SIMULINK software. The input Fig. 7 to the system was the waveform with the power quality issues which are established by the unbalanced loads or with the disturbance generator. After the compensation of the power with the help of DVR and STATCOM the output Fig. 8 of the system is obtained in the load terminal.

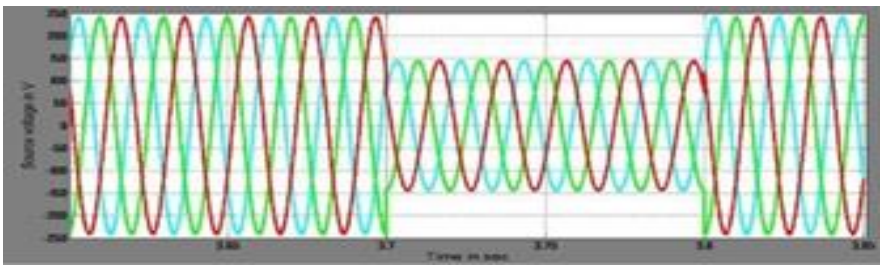

Fig. 7. Source voltage with sag

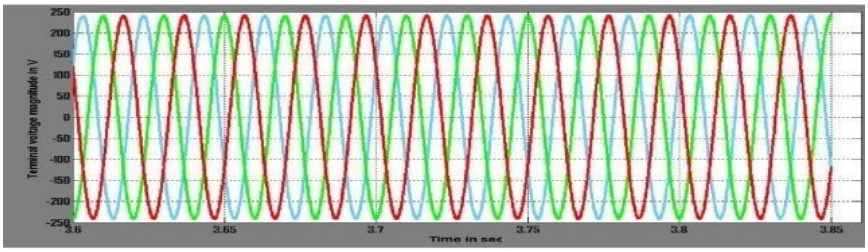

Fig. 8 Terminal voltage with DPFC

Table 1. Comparison of FACTS Devices

FACTS Devices	Settling Time (in seconds)	THD (%)	Transient Stability
SSSC	11	10.2	High
UPFC	0.6	7.58	Medium
UPQC	0.08	5.43	High
DPFC	0.05	4.60	High

According to the simulations the results are tabulated in Table 1 and it shows that DPFC has very short settling time than other FACTS devices and the current harmonic distortion has the value of 4.6% which is good value when compared to other custom power devices. The both UPQC and DPFC has high transient stability.

7 Conclusion

Each Custom Power gadget has its own advantages and disadvantages. Perhaps the prominent solutions for high power sensitive loads is UPQC and DPFC. UPQC and DPFC are preferred over others for a variety of reasons. UPQC and DPFC are much more adaptable than single inverter systems. They can correct for both source voltage disturbances and load current unbalance and distortion, whereas all other devices can only adjust for current or voltage distortion. According to the simulation results, the DPFC has a lower THD value than the UPQC. As a result, with the help of DPFC, the power quality is increased to the highest level compared to other FACTS devices.

8 Future Work

In the future, performance tests were done in various compensating techniques with different control strategy and methods, possibilities on real time prototyping and testing in live wires, integrating these techniques with the non-conventional energy transmissions such as in photovoltaic system, wind mill etc., Therefore the continuous and standard quality of power will be obtained through all means of energy resources. Further it extends and improved by using artificial neural networks and many more things.

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