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Review on Power Quality Issues

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Abstract-This paper introduces the terminology and various issues related to power quality from the patron perspective. The application of power electronics to power transmission system for the benefit of utilities called FACTS Devices and power distribution system for the benefit of a customer or group of customers is called Custom power. The FACTS devices like Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) and Custom power devices like Distribution Static compensator (DSTATCOM), Dynamic voltage restorer (DVR) and Unified power quality conditioner (UPQC) are discussed. Comprehensive results are presented to assess the working of some FACTS and Custom power device as a potential custom power solution. Simulation was carried out with matrix converter based UPFC by using MATLAB/SIMULINK software and the results are reviewed.

KEYWORDS: **FACTS, STATCOM, SSSC, UPFC, DSTATCOM, DVR, UPQC.**

I. INTRODUCTION

Classically, the aim of the electric power system is to generate electrical energy and to deliver this energy to the end-user equipment at an acceptable voltage. One of the most common power quality problems is voltage sag. Voltage sag is a reduction in the RMS voltage in the range of 0.1 to 0.9p.u for duration greater than half a main cycle and less than one minute. There are different ways to mitigate voltage sag, swell and interruptions in distribution system. A custom power specification may include provisions for (i) no power interruption (ii) Tight Voltage regulation including short duration sags or swells (iii) Low harmonic voltage and (iv) Acceptance of fluctuating and non linear loads without effect on terminal voltage[1][2]. These devices are connected either in shunt or in series or in combination of both. The series connected device is DVR which is used to inject a voltage of desired amplitude, frequency and phase between point of common coupling and the load in series with the grid voltage. The shunt-connected device is the DSTATCOM which is used to dynamically inject a current of desired amplitude, frequency and phase into the grid. Similarly UPQC configuration consists of series and shunt converters connected to the same DC link, in which shunt converter and one side of the series converter is connected to series transformer same node [3][4]. To achieve these objectives the custom power devices were simulated, sample wave forms are analyzed for better understanding, thus polluting the voltage for other customers. The chapter II explains about the basic classification of custom power devices and chapter III elaborates the results of voltage variations with FACTS and custom power device compensation.

II. CLASSIFICATION OF CUSTOM POWER DEVICES

Custom power devices can be classified into two main categories [5], first one being network configuring type and the other is compensating type. The former one changes the configuration of the power system network for power quality enhancement. The devices widely used in this category are SSCL (Solid State Current Limiter), SSCB (Solid State Circuit Breaker) and SSTS (Solid State Transfer Switch). SSCL is a IGBT based device that inserts an inductor in series with a power system and limits the fault current and once the fault is cleared the inductor is removed from the circuit. SSCB acts as a protection device which isolates the fault circuit from the system. SSTS performs rapid transfer of the load from a fault line to an alternative line to protect a sensitive load. All these devices use self commutating principle like GTO’s or IGCT’s. Therefore, these devices are called solid-state devices [6][7][8]. The compensating type devices are mainly used for active filtering, load balancing, power factor correction and voltage regulation. The compensating devices are DVR, DSTATCOM and UPQC. DSTATCOM has a similar structure as that of STATCOM in the transmission system and is connected in shunt with the power system. DVR is a series connected device which injects a rapid series voltage to compensate the supply voltage. UPQC is a similar structure to that of UPFC which injects series voltage and shunt current to the system [4].

A. DISTRIBUTION STATIC SYNCHRONOUS COMPENSATOR(DSTATCOM)

The DSTATCOM configuration consists of a two level Voltage Source Converter (VSC), a dc energy storage device and a coupling transformer connected in shunt with the ac system. Fig. 1 shows that the schematic representation of the DSTATCOM [4]. The VSC converts the dc voltage across the capacitance which is coupled to the ac system through the reactance of the coupling transformer. Suitable adjustment of the storage device is used to convert d.c. into a set of three phase ac output voltages in phase and magnitude of the DSTATCOM output voltage, allow which allows effective control of real and reactive power exchanges between the DSTATCOM and the ac system[9][10].

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for distinct purposes [10] [14].

1) Voltage regulation and compensation of reactive power;
2) Correction of power factor;

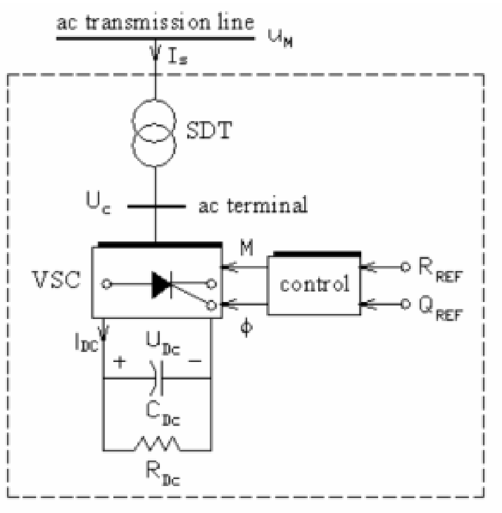

Figure. 1 Schematic diagram of Distribution Static Synchronous Compensator

3) Elimination of current harmonics.

The relation "(1)" shows that the shunt injected current (I_{sh}) corrects the voltage sag by adjusting the voltage drop across the system impedance Z_{TH}. The value of I_{sh} can be controlled by adjusting the output voltage of the converter.

$$I_{SH} = I_L - I_S = I_L - \frac{V_{TH} - V_L}{Z_{TH}} \qquad (1)$$

B. DYNAMIC VOLTAGE RESTORER (DVR)

The DVR is a powerful controller that is commonly used for alleviation of voltage sag at the point of common connection. The DVR employs the same blocks as that of DSTATCOM, with slight modification of connecting the coupling transformer in series with the ac system, as shown in Fig. 2. The main functions of DVR are [6][9][10] :

(i)Reactive Power Compensation
(ii)Voltage Regulation
iii)Compensation for Voltage Sag and Swell
(iv)Unbalance Voltage Compensation (for 3-phase systems)

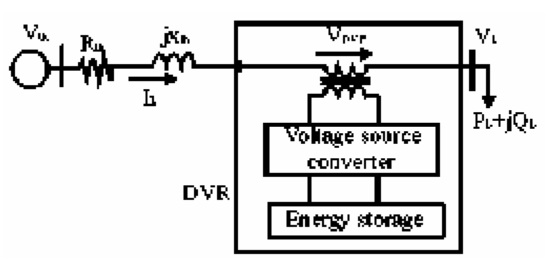

Figure. 2 Schematic diagram of Dynamic Voltage Restorer

The VSC generates a three phase ac output voltage which is controllable in phase and magnitude [16]. This voltage is injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference.

C. UNIFIED POWER QUALITY CONDITIONER (UPQC)

UPQC allows the alleviation of voltage and current disturbances that could affect sensitive electrical loads while compensating the load reactive power. UPQC consists of combined series and shunt active power filters. Fig. 3 and fig. 4 shows the schematic representation of UPQC and UPFC. The main function of UPQC includes

(i) Reactive Power Compensation.
(ii)Voltage Regulation.
(iii)Compensation for voltage sags and swells.
(iv)Unbalance compensation for current and voltage (for a 3-phase systems).
(v)Neutral Current Compensation (for a 3-phase 4-wire systems).

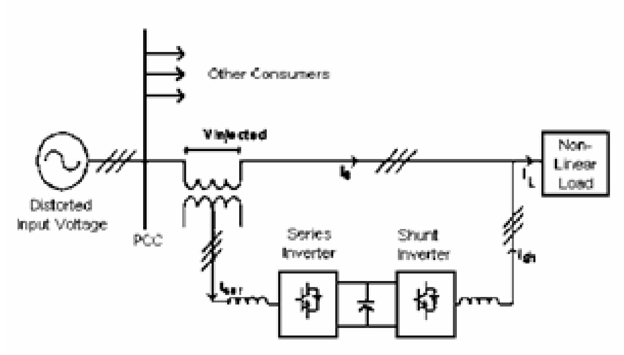

Figure. 3 Schematic diagram of Unified Power Quality Conditioner

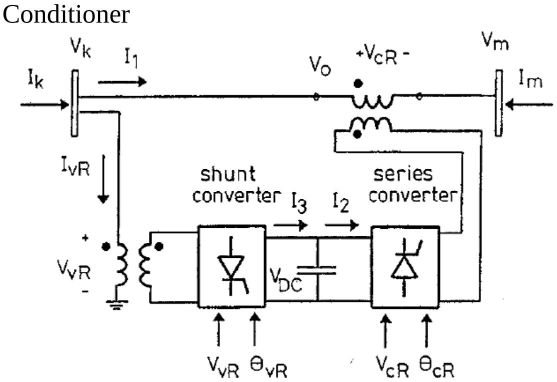

Figure. 4 Schematic diagram of Unified Power Flow Controller

III. RESULTS AND DISCUSSIONS

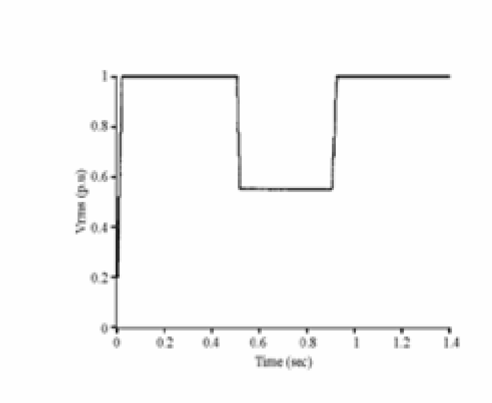

Figure. 5 Uncompensated RMS Voltage at load point without DSTATCOM

Sample simulation results for voltage sags and swells using DSTATCOM [11] are reviewed from figure. 5 to figure. 8. The figure. 5 shows the uncompensated line with voltage variations due to single line to ground fault which occurs at load point. The RMS voltage falls from 1p.u to 0.5p.u and remains in same condition for a duration of 0.4sec and it restored to the level of 1p.u after clearing the fault.

But the compensated system with the help of DSTATCOM has the ability to maintain same level during fault and restored condition as shown in figure. 6.

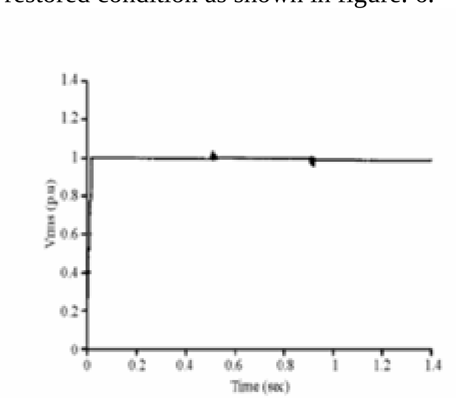

Figure. 6 Compensated Voltage RMS at load point with DSTATCOM

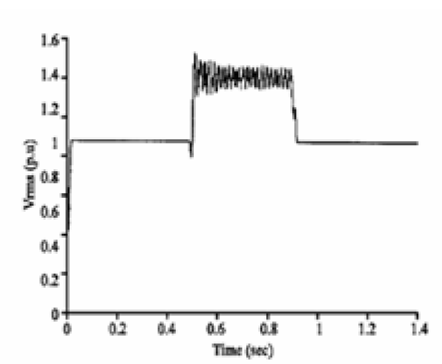

Figure. 7 Voltage Swell at load point without DSTATCOM

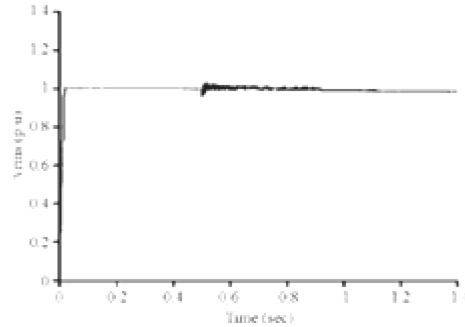

Figure. 8 Alleviated voltage swell at load point with DSTATCOM

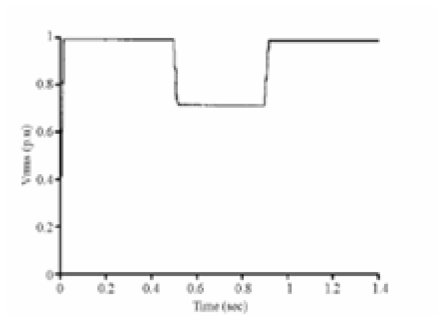

Figure. 9 Voltage sag at load point without DVR

In figure. 9 shows the simulation result of voltage sag at load point without DVR. In Figure. 10 shows the alleviated voltage sag at load point with the inclusion of DVR into the system.

In figure. 11 shows that there is a voltage swell due to either switching on capacitor banks or switching off major loads if the system doesn't have compensating device (DVR).

In figure. 12 shows a system having compensating device maintains same level of RMS voltage even if it has sudden change in the system loading conditions.

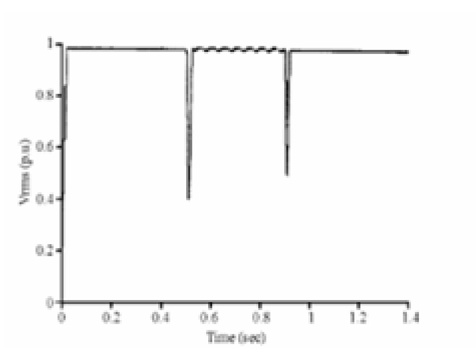

Figure. 10 Alleviated voltage sag at load point with DVR

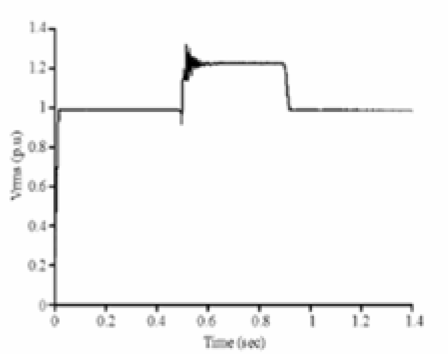

Figure. 11 Voltage Swell in RMS at load point without DVR

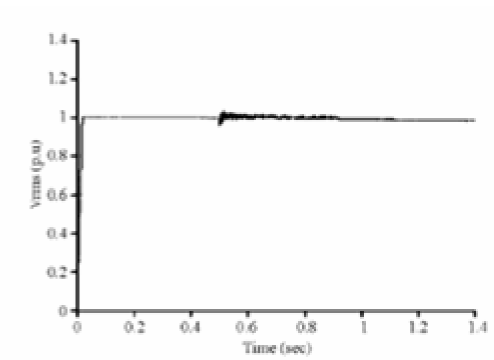

Figure. 12 Alleviated Voltage swell in RMS at load point with DVR

Simulation was carried out with the help of MATLAB/Simulink software for alleviation of voltage sag at load point using Matrix Converter based UPFC as shown in figure. 13. and figure. 14 shows matrix converter arrangements for the implementation of UPFC for voltage current compensation at load point.

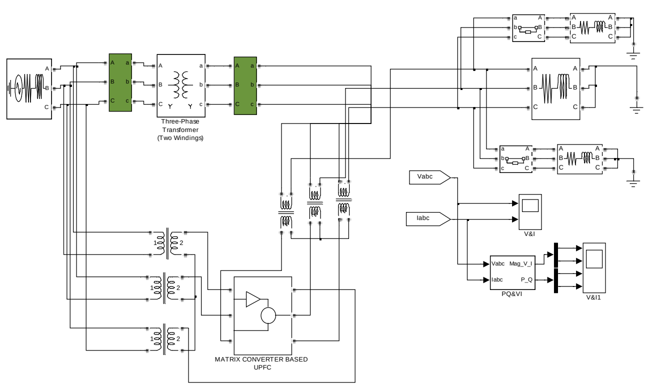

Figure. 13 Closed loop control of Matrix Converter based UPFC

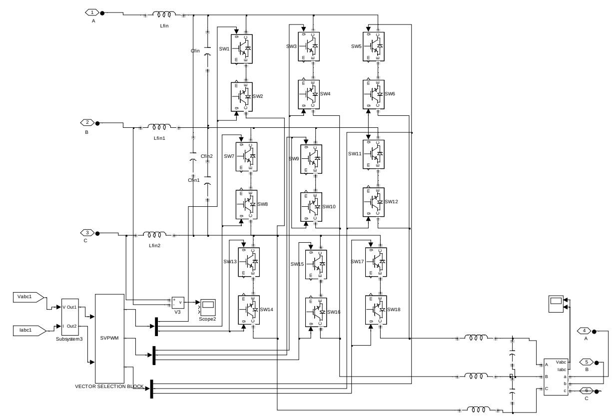

Figure. 14 Matrix converter arrangements which is used in the implementation of UPFC

In figure. 15 shows the simulation results of source current without UPFC and we can observe that there is a reduction in current of all the three phases.

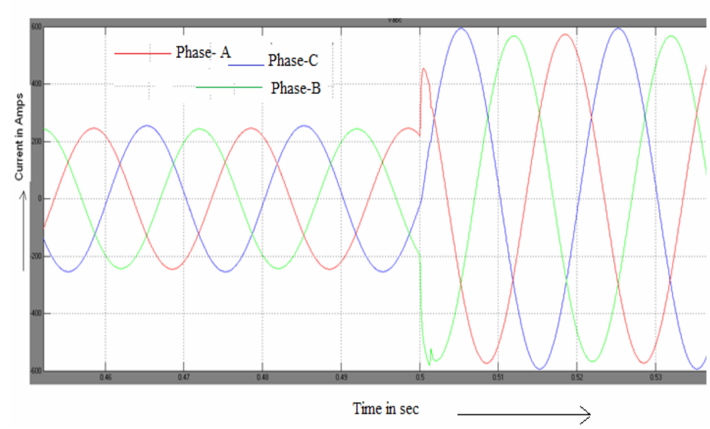

Figure. 15 Source Current without UPFC

In figure. 16 shows the compensating current with the inclusion of UPFC into the system.

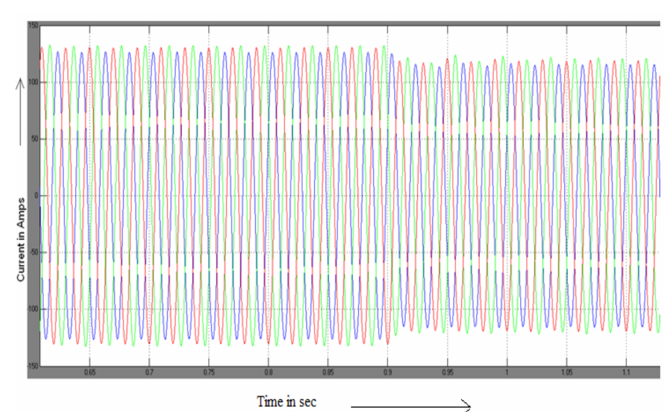

Figure. 16 Output of UPFC Current

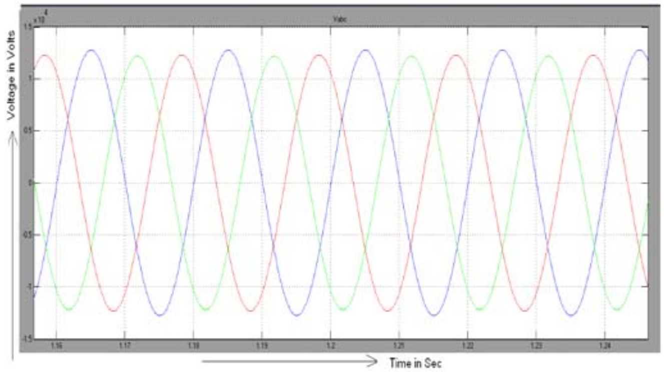

Figure. 17 Source Voltage at load point with UPFC

In figure. 17 and figure. 18 shows the source voltage and current with the inclusion of UPFC into the system.

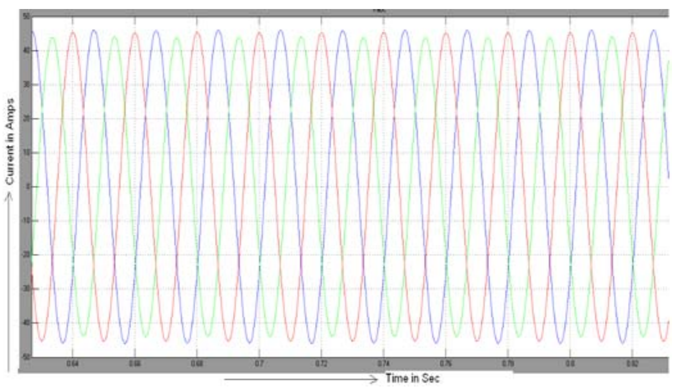

Figure. 18 Source Current after compensation

IV. CONCLUSIONS

This paper presents the power quality problems such as voltage sags, swells and interruptions. The mitigation of power quality problems using some FACTS and custom power devices are studied. The simulation results show that the DVR provides excellent voltage regulation capabilities and DSTATCOM provides excellent current regulation capabilities in distribution system.

Simulation was carried out by using matrix converter based UPFC with Space Vector PWM technique which gives an excellent compensation of voltage and current. We were able to observe from the study that the capacity for power compensation and voltage regulation depends mainly on two factors: the rating of the dc storage device and the characteristics of the coupling transformer. These two factors determine the maximum value of sag alleviation that a DVR can provide. The SSTS is a suitable device for screening selected load points against faulted conditions, but it requires an alternative feeder being available and it is overcome by custom power devices.

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