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Introduction the Performance of Dynamic Voltage Restorer (DVR) and Unified power quality conditioner (UPFC) in Power Quality Problems

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Abstract
In energy transmission systems, effective equipments on power control are generally known as Flexible AC Transmission System (FACTS). In addition, the power electronics-based equipment, which are called power conditioners are used to solve power quality problems. Since the topologies of these equipments are similar to those used in FACTS equipment, power conditioners are also called Distribution FACTS (DFACTS). The principal operating modes and applications whichever one of equipment in transmission and distribution system (such as UPFC, and DVR) will be discussed and compared. In this work FACTS based equipment are implemented and the comparative study has been done to underline the special features of each.
The nonlinear load and complexity of control system in industrial processes have triggered the power quality problems in the distribution network. The major aim of power quality enhancing techniques is to maintain a specified voltage magnitude at a desired frequency for sensitive loads irrespective of the fault or conditions in the power distribution network. This is possible only by ensuring an uninterrupted flow of power at proper voltage and frequency levels. As a result of this, the need of custom power devices is felt. But in this work, the main focus is kept only on Introduction the Performance of DVR and UPFC in Power Quality Problems.
***Keywords**: - DVR, UPFC, Flexible AC Transmission System (FACTS), Distribution FACTS (DFACTS)*

I. INTRODUCTION

In energy transmission systems, effective equipments on power control are generally known as Flexible AC Transmission System (FACTS). In addition, the power electronics-based equipment, which are called power conditioners are used to solve power quality problems. Since the topologies of these equipments are similar to those used in FACTS equipment, power conditioners are also called Distribution FACTS (DFACTS). The principal operating modes and applications whichever one of equipment in transmission and distribution system (such as UPFC, and DVR) will be discussed and compared. In this work FACTS based equipment are implemented and the comparative study has been done to underline the special features of each.

The nonlinear load and complexity of control system in industrial processes have triggered the power quality problems in the distribution network. The major aim of power quality enhancing techniques is to maintain a specified voltage magnitude at a desired frequency for sensitive loads irrespective of the fault or conditions in the power distribution network. This is possible only by ensuring an uninterrupted flow of power at proper voltage and frequency levels. As a result of this, the need of custom power devices is felt.

Power quality problem is occurring as a non-standard voltage, current and frequency. The power quality has serious economic implications for customers, utilities and electrical equipment manufacturers. Modernization and automation of industry involves increasing use of computers, microprocessors and power electronic systems such as adjustable speed drives. Integration of non-conventional generation technologies such as fuel cells, wind turbines and photovoltaic with utility grids often requires power electronic inter-faces. The power electronic systems also contribute to power quality problem (generated harmonics). The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipment. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. Due to the harmonics are occurring in the system it causes losses and heating of motor. This work focuses on the key issues in the power quality problems, in the proposed system Voltage sag/Voltage swell occurs due to the three phase fault/ground fault/phase to ground fault in the transmission line and harmonics occurs due to the connection of controlled six pulse converter (rectifier) to the main drive load (nonlinear load). All these factors affect the sensitive load which is connected in parallel to the main drive load. So the proposed system protects the sensitive load by mitigating the harmonics using dynamic voltage restorer technique.

One of the main responsibilities of a utility system is to supply electric power in the form of sinusoidal and currents with appropriate magnitudes and frequency for the customers at the points of common coupling (PCC). Although the generated voltage of synchronous machines in power plants are almost sinusoidal, some unsighted conditions such as lightning and short circuit faults and nonlinear loads cause steady state error or transient voltages and current disturbances. For instance, electric arc furnaces cause voltage fluctuations, power electronic converters generate current harmonics and distort voltage waveforms, and short circuits faults result in voltage sags and swells. On the other hand most customer loads such as computers, microcontrollers and hospital equipment are sensitive and unprotected to power quality disturbances and their proper operation depends on the quality of the voltage that is supplied to them.

This is possible only by ensuring an uninterrupted flow of power at proper voltage and frequency levels. As a result of this, FACTS devices and Custom power devices are introduced to electrical system to improve the power quality of the electrical power. With the help of these devices we are capable to reduce the problems related to power quality. There are many types of Custom Power devices. Some of these devices include Active Power Filters (APF), Surge Arresters (SA). Battery Energy Storage Systems (BESS), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid State Fault Current Limiter (SSFCL), Solid-State Transfer Switches (SSTS), Static VAR Compensator (SVC), Distribution Series Capacitors (DSC), Dynamic Voltage Restorer (DVR), Distribution Static synchronous Compensators (DSTATCOM) and Uninterruptible Power Supplies (UPS), Unified power quality conditioner (UPFC). But in this work, the main focus is kept only on DVR and UPFC to performance.

II. LITERATURE SURVEY

Power quality is a comprehensive term that squeezes all features related with amplitude, phase and frequency of the voltage and current waveforms existing in a power circuit. Poor power quality may result from transient conditions accumulate in the power circuit or from the non-linear loads. Power distribution systems ought to deliver their customers with an associate degree uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude level and frequency, but the distribution systems, have several nonlinear loads, which significantly affect the quality of power supplies [1-4].

The concept of custom power was introduced by **N.G.Hingorani [**5]. The term custom power means the utilization of power electronic controllers for distribution systems. The custom power devices will increases the quality and reliability of the power that is delivered to the customers. Customers are increasingly demanding more exigent quality in the power supplied by the electrical company Mahesh Singh et. al. demonstrated that power quality measures can be applied both at the user end and also at the utility level. The work identifies some important measures that can be applied at the utility level without much system upset. Parag Nijhawan and Rajan Sharma [7] focused on power quality improvement with DSTATCOM on feeders feeding field oriented controlled induction motor drive as load. In this paper, role of DSTATCOM to improve power quality of distribution network under normal operating and fault conditions is investigated.

III. METHODOLOGY

Dynamic Voltage Restorer

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses. The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

A power electronic converter based series compensator that can protect critical loads from all supply side disturbances other than outages is called a dynamic voltage restorer. The restorer is capable of generating or absorbing independently controllable real and reactive power at its AC output terminal. [8] This device employs solid-state power electronic switches in a pulse-width modulated (PWM) inverter structure. It injects a set of three-phase AC output voltages in series and synchronism with the distribution feeder voltages. The amplitude and phase angle of the injected voltages are variable thereby allowing control of the real and reactive power exchange between the device and the distribution system. The DC input terminal of the restorer is connected to an energy Source or an energy storage device of appropriate capacity. The reactive power exchanged between the restorer and the distribution system is internally generated by the restorer without AC passive reactive components. The real power exchanged at the restorer output AC terminals is provided by the restorer input DC terminal from an external energy source or energy storage system. The dynamic voltage restorer (DVR) is one of the most efficient and economic devices to compensate voltage sags [2]. The DVR is basically a voltage-source converter in series with the ac grid via an interfacing transformer, conceived to mitigate voltage sags and swells [3]. For low-voltage applications, DVRs based on two-level converters are normally used [4] and, therefore, much of the published literature on DVRs deals with this kind of converter. Nevertheless, for higher power applications, power- electronic devices are usually connected to the Medium-voltage (MV) grid the use of two-level voltage converters becomes difficult to justify owing to the high voltages that the switches must block.

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. The function of the DVR will inject the missing voltage in order to regulate the load voltage from any disturbance due to immediate distort of source voltage. A dynamic voltage restorer (DVR) is a solid state inverter based on injection of voltage in series with a power distribution system.

The DC side of DVR is connected to an energy source or an energy storage device, while its ac side is connected to the distribution feeder by a three-phase inter facing injection transformer. A single line diagram of a DVR connected power distribution system. Since DVR is a series connected device, the source current, is same as load current. DVR injected voltage in series with line such that the load voltage is maintained at sinusoidal nominal value.

It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage Harmonics compensation, reduction of transients in voltage and fault current limitations. The Injection/Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side.

In a three-phase system, either three single-phase transformer units or one three phase transformer unit can be used for voltage injection purpose. The injection transformer comprises of two side voltages namely the high voltage side and low voltage side. The three single transformers can be connected with star/open star winding or delta/open star winding. The latter does not permit the injection of the zero sequence voltage. The choice of the injection transformer winding depends on the connections of the step down transformer that feeds the load. If a D/Y connected transformer is used, there is no need to compensate the zero sequence voltages.

A higher transformer winding ratio will increase the primary side current, which will adversely affect the performance of the power electronic devices connected in the VSI. To evaluate the performance of the DVR the rating of the injection transformer is an important factor that need to be considered due to the compensation ability of the DVR is totally depend on its rating .The DVR performance is totally depend on the rating of the injection transformer , since it limits the maximum compensation ability of the DVR.

Simulation Model of DVR Test System

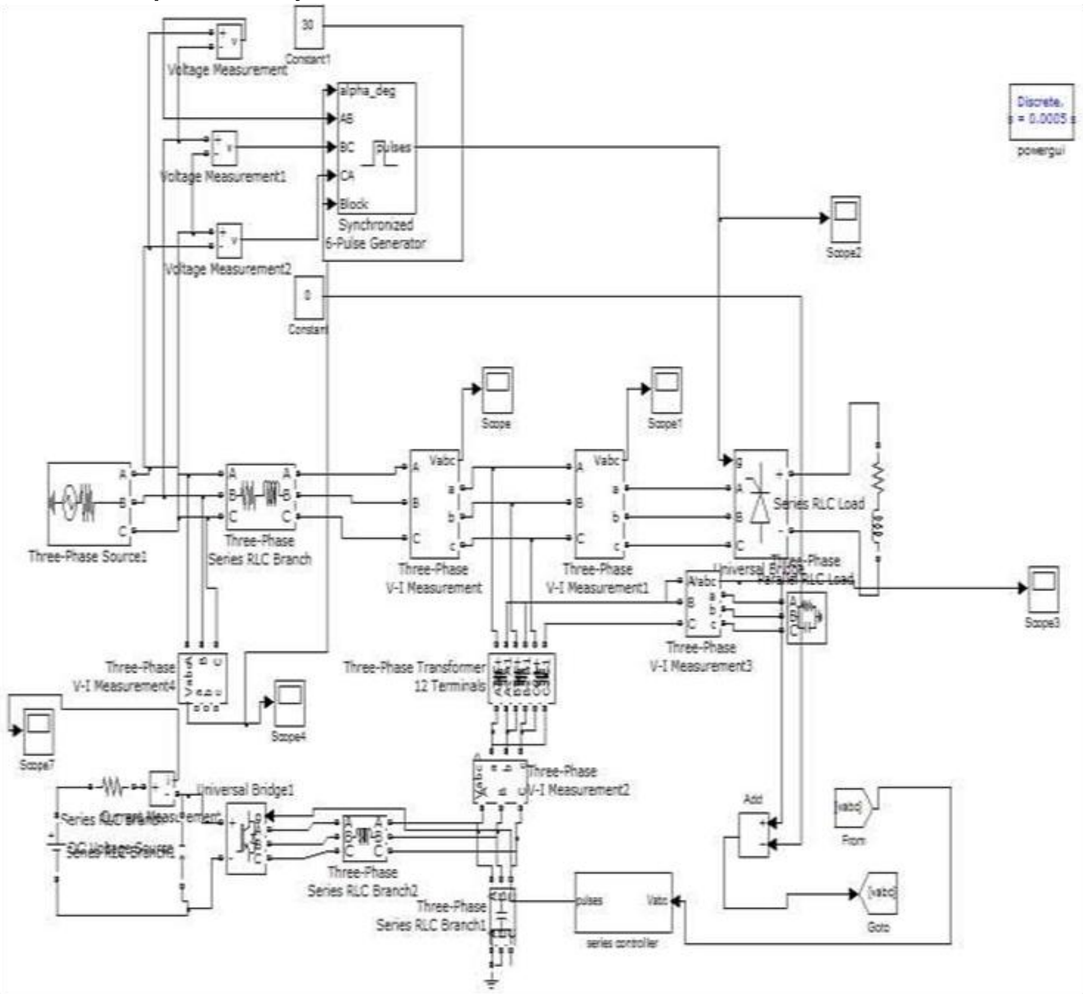

Figure 1: Simulation Model of DVR

Unified Power Flow Controller (UPFC) It is a FACTS device which is installed for the support of electricity networks which have poor power factor and voltage regulation also, commonly it is use for the stabilization of voltage and to improve power factor of that network. It is a voltage source converter based device, which can work as reactive power source or as a sink.

The best protection for sensitive loads from sources with inadequate quality is shunt series connection i.e. unified power flow controller (UPFC). Recent research efforts have been made towards utilizing unified power flow controller (UPFC) to solve almost all power quality problems for example voltage sag, voltage swell, voltage outage and over correction of power factor and unacceptable levels of harmonics in the current and voltage.

The UPFC can provide simultaneous control of all basic power system parameters transmission voltage, impedance and phase angle. The controller can full functions of reactive shunt compensation, series compensation and phase shifting meeting multiple control objectives. From a functional perspective, the objectives are met by applying a boosting transformer injected voltage and an exciting transformer reactive current. The injected voltage is inserted by a series transformer.

Besides transformers, the general structure of UPFC contains also a "back to back" AC to DC voltage source converters operated from a common DC link capacitor, **Figure 1**. First converter (CONV1) is connected in shunt and the second one (CONV2) in series with the line.

The shunt converter is primarily used to provide active power demand of the series converter through a common DC link. Converter 1 can also generate or absorb reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line. Converter 2 provides the main function of the UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via a voltage source, **Figure 2**.

The reactance xs describes a reactance seen from terminals of the series transformer and is equal to (in p.u. base on system voltage and base power).

$$x_S = x_k r_{max}^2 (S_B/S_S)$$

Where xk denotes the series transformer reactance, r_{max} the maximum per unit value of injected voltage magnitude, SB the system base power, and SS the nominal rating power of the series converter.

The UPFC injection model is derived enabling three parameters to be simultaneously controlled. They are namely the shunt reactive power, Qconv1, and the magnitude, r, and the angle, of injected series voltage Vse. The series connected voltage source is modeled by an ideal series voltage Vse which is controllable in magnitude and phase, that is, Vse = rV kej where 0 < r < r r max.

The basic configuration of UPFC is shown in **Figure 2**. The main purpose of a UPFC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In other words, the UPFC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems.

The UPFC, therefore, is expected as one of the most powerful solutions to large capacity sensitive loads to voltage flicker/imbalance. Unified Power Flow Controller (UPFC) for non-linear and a voltage sensitive load has following facilities:

It eliminates the harmonics in the supply current, thus improves utility current quality for nonlinear loads. UPFC provides the VAR requirement of the load, so that the supply voltage and current are always in phase, therefore, no additional power factor correction equipment is necessary.

UPFC maintains load end voltage at the rated value even in the presence of supply voltage sag. The voltage injected by UPFC to maintain the load end voltage at the desired value is taken from the same dc link, thus no additional dc link voltage support is required for the series compensator.

The UPFC consists of two three phase inverters connected in cascade in such a manner that Inverter I is connected in series with the supply voltage through a transformer inverter II is connected in parallel with the load.

The main purpose of the shunt compensator is to compensate for the reactive power demanded by the load, to eliminate the harmonics and to regulate the common dc link voltage. The series compensator is operated in PWM voltage controlled mode. It injects voltage in quadrature advance to the supply voltage (current) such that the load end voltage is always maintained at the desired value. The two inverters operate in a coordinated manner.

The UPFC functions by injecting three single phase AC voltages in series with the three phase incoming network voltages during sag, compensating for the difference between faulty and nominal voltages. All three phases of the injected voltages are of controllable amplitude and phase. Three pulse-width modulated (PWM) voltage source inverters (VSI) fed from a DC link supply the active and reactive power as shown in the figure 1.

During undisturbed power supply condition, the UPFC operates in a low loss standby mode. In the normal operation mode (no sag) the low voltage side of the booster transformer is shorted either by solid state bypass switch or by switching one of the inverter legs and it functions as a short-circuited current transformer. Since no VSI switching takes place, the UPFC produces conduction losses only.

These losses should be kept as low as possible so as not to cause steady state power loss. Harmonics produced by the operation of VSI must be reduced to an acceptable limit defined by proper filtering scheme.

Modulation scheme used on the VSI switches has also impact on the harmonics produced. Operation of the UPFC demands proper power rating of the series and shunt branches. The rating should enable the UPFC carrying out pre-defined power low objective. The low chart of Figure shows algorithm for UPFC rating.

The algorithm starts with definition of the series transformer short circuit reactance, xk, and the system base power, SB. Then, the initial estimation is given for the series converter rating power, SS, and the maximum magnitude of the injected series voltage, rmax. The effective reactance of the UPFC seen from the terminals of the series transformer, (xS), can be determined in the next step.

Simulation Model of UPFC Test System

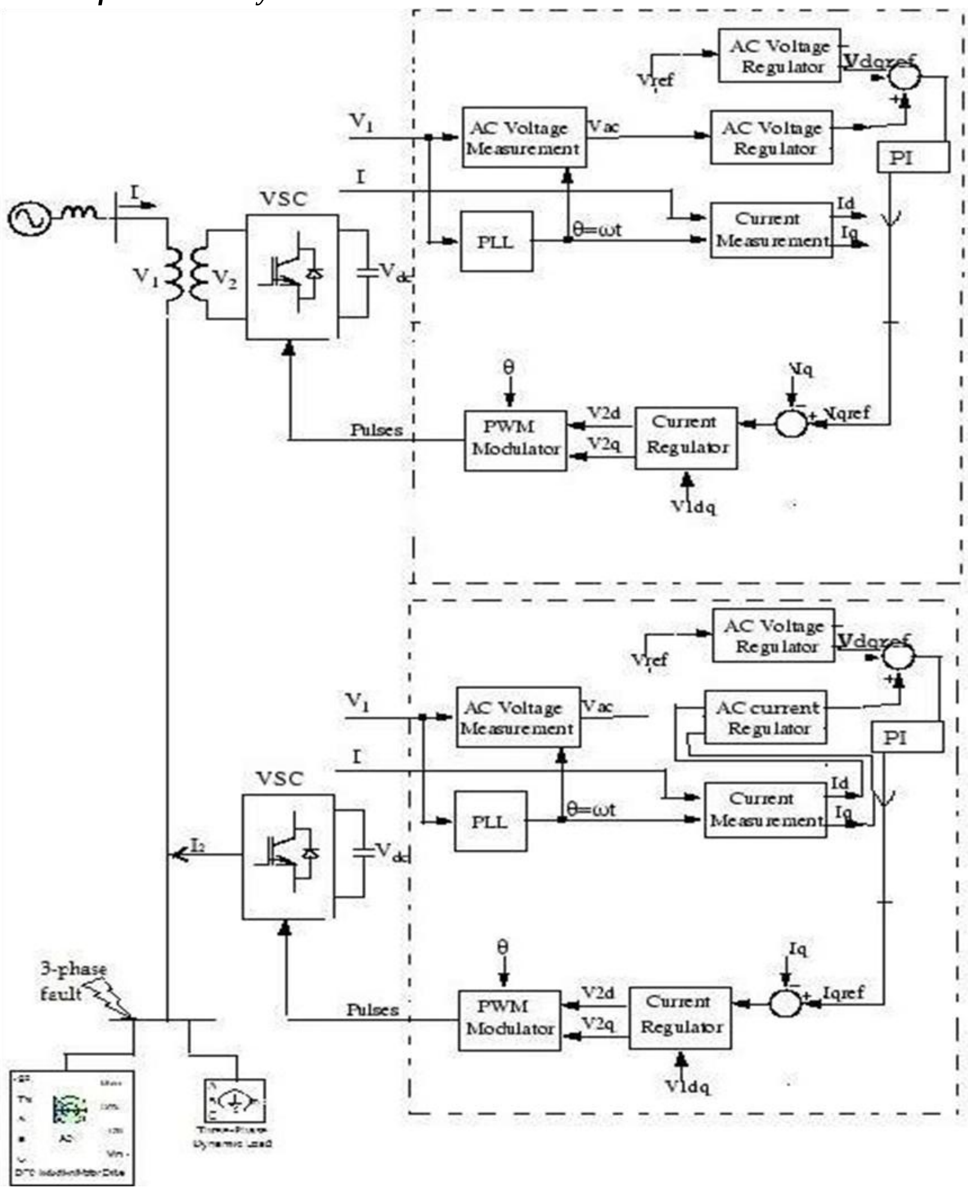

Figure 2: Simulation Model of UPFC

IV. RESULT AND CONCLUSION

This work has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Comparative analysis of compensation techniques of custom power electronic devices DVR and UPFC are presented and compared for same parameters. The design and applications of DVR and UPFC for voltage sags and comprehensive results we proposed.

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