Enhancement of Power Quality by Using Series and Shunt Compensator in Distribution Systems

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Abstract--- This paper presents the design of Unified Power Quality Conditioner which is the integration of series and shunt active power filters. The main purpose of UPQC is to mitigate power quality issues like voltage imbalance, current harmonics etc... For controlling the UPQC fuzzy logic controller is used which also enhances the fast response of the UPQC. The UPQC used in the distribution system is simulated using MATLAB software and obtained results shows that UPQC is the promising solution which deals with both current and voltage imperfections and also THD is measured.

Keywords: - Unified Power Quality Conditioner, Power Quality, Total Harmonic Distortion, Active Power Filter, Fuzzy Logic Controller.

I. INTRODUCTION

Electric power system is considered to be composed of three functional blocks generation, transmission and distribution. For a reliable power system, the generation unit must produce adequate power to meet customer's demand, transmission systems must transport bulk power over long distances without overloading or jeopardizing system stability and distribution systems must deliver electric power to each customer's premises from bulk power systems [13]. Distribution system locates the end of power system and is connected to the customer directly, so the power quality mainly depends on distribution system. The reason behind this is that the electrical distribution network failures account for about 90% of the average customer interruptions [15]. In the earlier days, the major focus for power system reliability was on generation and transmission only as these more capital cost is involved in these. In addition their insufficiency can cause widespread serious consequences for both society and its environment. But now a day's distribution systems have begun to receive more attention for reliability assessment.

Initially for the improvement of power quality or reliability of the system FACTS devices like static synchronous compensator (STATCOM), static synchronous series compensator(SSSC), interline power flow controller (IPFC), and unified power flow controller (UPFC) etc are introduced [17]. These FACTS devices are designed for the transmission system. But now a day's more attention is on the distribution system for the improvement of power quality, these devices are modified and known as custom power devices. The main custom power devices which are used in distribution system for power quality improvement are distribution static synchronous compensator (DSTATCOM), dynamic voltage Restorer (DVR), active filter (AF), unified power quality conditioner (UPQC) etc.

In this paper from the above custom power devices, UPQC is used with fuzzy controller for the power quality improvement in the distribution system [1]. Here two different loads are considered, one is linear load and the other is nonlinear load. Different fault conditions are considered with these loads to analyse the operation of DVR to improve the power quality in distribution system

II. UNIFIED POWER QUALITY CONDITIONER

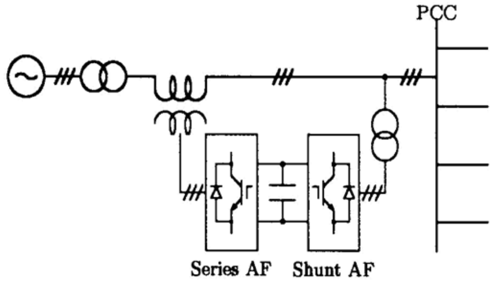

Fig. 1: Basic configuration of UPQC

Fig. 1 shows a basic system configuration of a general UPQC consisting of the combination of a series-active and shunt-active filter [1]. The general UPQC will be installed at substations by electric power utilities in the near future. The main purpose of the series-active filter is harmonic isolation between a sub transmission system and a distribution system. In addition, the series-active filter has the capability of voltage-flicker/imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC). The main purpose of the shunt-active filter is to absorb current harmonics, compensate for reactive power and negative-sequence current, and regulate the dc-link voltage between both active filters.

In this paper, the integration of the series-active and shunt-active filters is called the UPQC, associated with the unified power flow controller which has been proposed by Gyugyi [8]. However, the UPQC for distribution systems is quite different

. The dynamic voltage restorer (UPQC) is one of the most efficient and economic devices to compensate voltage sags [2]. The UPQC 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, UPQCs based on two-level converters are normally used [4] and, therefore, much of the published literature on UPQCs 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.

A. UPQC operating principle

The UPQC 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 UPQC 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 UPQC 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. The required energy during sags has to be supplied by an energy source.

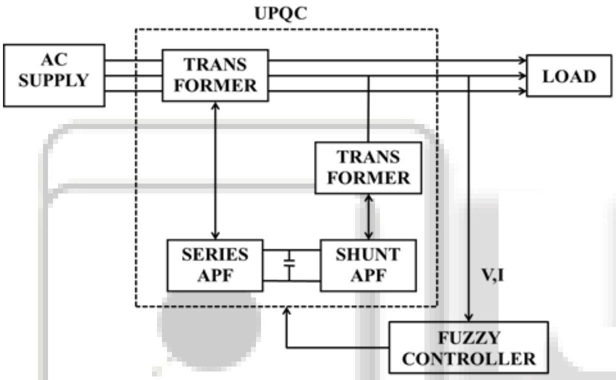

Fig. 2:

The necessary amount of energy that must be delivered by the energy source depends on load MVA requirement, control strategy applied, deepest sag to be protected. Under normal conditions, the short circuit impedance of the injection transformer determines the voltage drop across the UPQC. This impedance must be low and has an impact on the fault current through the VSI on secondary side caused by a short-circuit at load side. The filter design is also affected by the impedance of the injection transformer. In case of fault or over current exceeding the rating of UPQC on the load side, solid-state bypass switches or electromechanical bypass switches must be added as a measure to protect UPQC from getting damaged. [4]

III. PROPOSED 3P4W DISTRIBUTION SYSTEM UTILIZING UPQC

Generally, a 3P4W distribution system is realized by providing a neutral conductor along with three power conductors from generation station or by utilizing a three-phase Δ–Y transformer at distribution level. Fig. 2.1 shows a 3P4W network in which the neutral conductor is provided from the generating station itself, whereas Fig.2.2 shows a 3P4W distribution network considering a Δ–Y transformer Assume a plant site where three-phase three-wire UPQC is already installed to protect a sensitive load and to restrict any entry of distortion from load side toward utility, as shown in Fig.2.3. If we want to upgrade the system now from 3P3W to 3P4W due to installation of recently, the utility service providers are putting more and more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads, to control the power distribution system harmonic pollution. At the same time, the use of sophisticated equipment/load has increased significantly, and it needs clean power for its proper operation. Therefore, in future distribution systems and the plant/load centers, application of UPQC would be common. Fig.2. 4 shows the proposed novel 3P4W topology that can be realized from a 3P3W system. This proposed system has all the advantages of general UPQC, in addition to easy expansion of 3P3W system to 3P4W system.

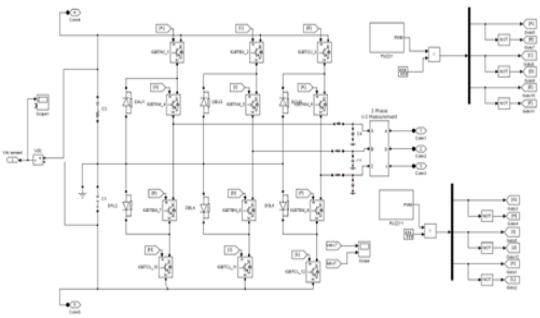

Fig .3: Voltage Source Inverter

Thus, the proposed topology may play an important role in the future 3P4W distribution system for more advanced UPQC based plant/load center installation, where utilities would be having an additional option to realize a 3P4W system just by providing a 3P3W supply. As shown in Fig.2.3, the UPQC should necessarily consist of three-phase series transformer in order to connect one of the inverters in the series with the lineto function as a controlled voltage source. If we could use the neutral of three-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system (Fig. 2.4). The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology [2], [9], [10] or a four-leg voltage-source inverter (VSI) topology for a shunt inverter [2], [11]. In this paper, the four-leg VSI topology is considered to compensate the neutral current flowing toward the transformer neutral point. A fourth leg is added on the existing 3P3W UPQC, such that the transformer neutral point will be at virtual zero potential. Thus, the proposed structure would help to realize a 3P4W system from a 3P3W system at distribution load end. This would eventually result in easy expansion from 3P3W to 3P4W systems.

IV. CONTROL SYSTEM

The aim of the control system is to maintain voltage magnitude at the point where a sensitive load is connected, under system disturbances. The harmonics is generated in the load terminals using six pulse converters with fixed firing angle are connected to the main drive non linear load which is parallel to the sensitive load [3]. Voltage sag is created at load terminals via a three phase fault. The above voltage problems are sensed separately and passed through the sequence analyzer. The control system of the general configuration typically consists of a voltage correction method which determines the reference voltage that should be injected by UPQC and the VSI control which is in this work consists of PWM with Fuzzy controller [4]. The controller input is an error signal obtained from the reference voltage and the value of the injected voltage.. Non-Linear control methods comprising the Artificial Neural Networks (ANN), the Fuzzy Logic (FL) and the Space Vector (SV) controllers Although feedback controllers are popular, they Require load and source tracking, whereas feed-foreword controllers are much simpler yet open-looped, there is no Feedback from the load voltage or current.

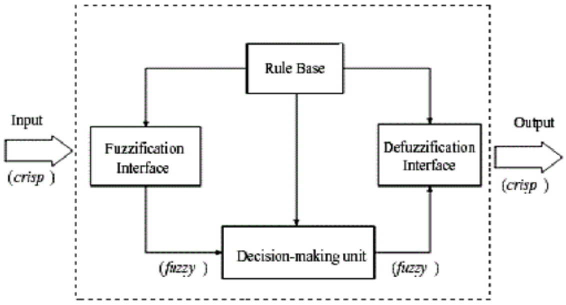

Figure. 3 Architecture of FLC

Fig. 4:

Unlike Boolean logic, fuzzy logic allows states (membership values) between 0 or 1. Its major features are the use of linguistic variables rather than numerical variables. Linguistic variables, defined as variables whose values are sentences in a natural language (such as small and big), may

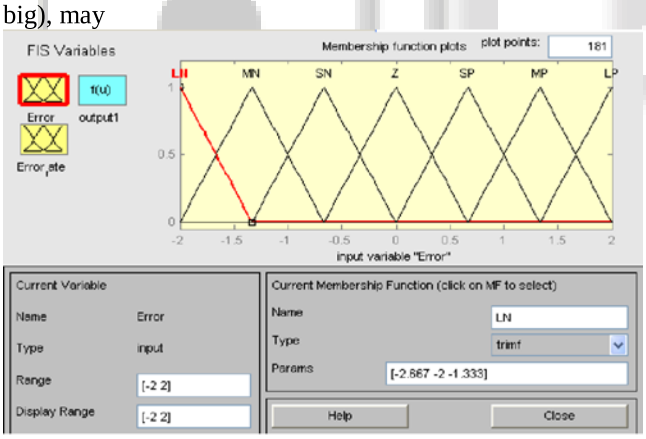

Fig. 5: Membership functions of fuzzy controller

Be represented by fuzzy sets [6]. The general structure of an FLC is represented in Figure 3 and comprises four principal components, a fuzzification interface which converts input data into suitable linguistic values; a knowledge base which consists of a data base with the necessary linguistic definitions and control rule set; a decision making logic which, simulating a human decision process, infers the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions; and a defuzzification interface which yields a nonfuzzy control action from an inferred fuzzy control action.. The process also same as before except the controller now is Fuzzy Logic. The FL controller consists of three linguistic variables from input which is; Negative (N), Zero (Z) and Positive (P). Each parameter from linguistic variables for error signal for delta error, there are three linguistic variables, Negative (N), Zero (Z) and Positive (P).

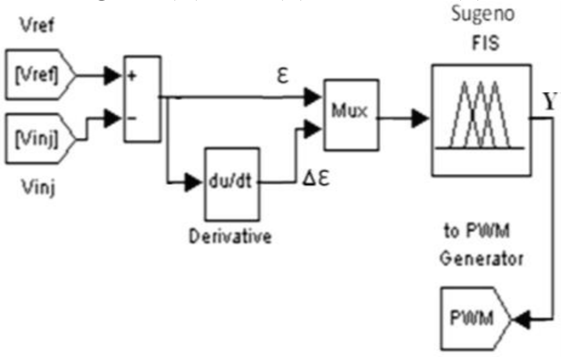

Fig. 6: Fuzzy controller in simulation

V. SIMULATION, RESULTS AND DISCUSSION

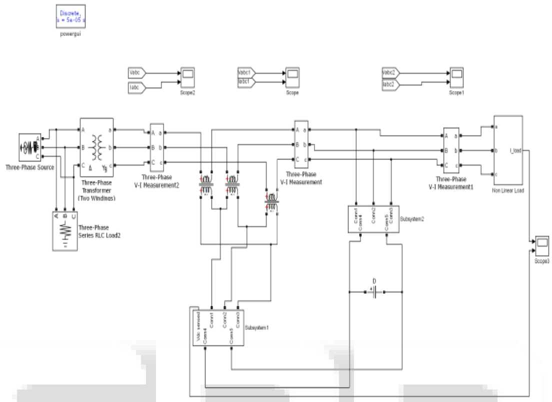

Fig. 7: Simulation digram of the UPQC connected n distribution systems

The above figure 5 shows the simulation diagram of UPQC which is connected to the distribution system.

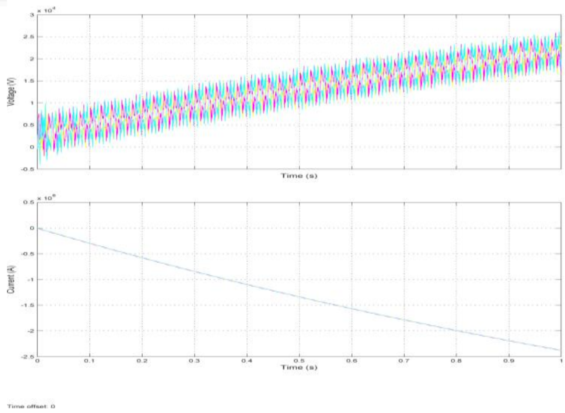

Fig. 8: Voltage and current waveforms due to non lnear load

The above waveform shows the distorted voltage and current waveform due to the non linear load behaviour. Also the harmonic content is veryhigh.

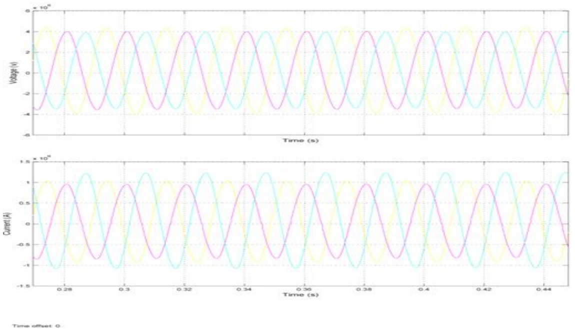

Fig. 9: load voltage

The above results shows the compensated voltage and current which is compensated by the UPQC which is connected to the distribution system.

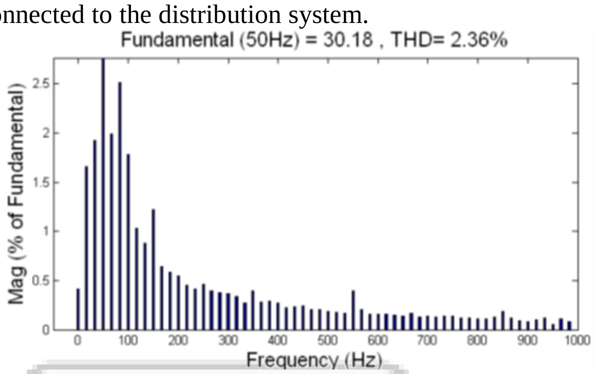

Fig. 10:

The THD before the system connected to UPQC was 30.18%after the compensation the THD is made 2.36% .

VI. CONCLUSION

Nowadays, reliability and quality of electric power is one of the most discuss topics in power industry, The simulation results shows that the distorted and unbalanced load currents and voltage seen from the utility side act as perfectly balanced and are free from distortion. Here we can absorb the power quality problems like voltage and current unbalanced and reduced the total harmonic distortion (THD). The result indicates that the load voltage and current is improved within few seconds using UPQC when faults occur in distribution system which shows the UPQC's excellent performance and the control system in order to protect sensitive equipment from PQ disturbances.

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