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FUZZY LOGIC CONTROL BASED DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSTEM

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ABSTRACT

For the power quality improvement 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. These devices are used for the transmission system. But now a day's these FACTS devices are used for distribution system and called 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, for power quality improvement in the distribution system, DVR is used with Fuzzy logic controller. There are two different loads are considered. One is linear load and the other is nonlinear load (induction motor). With these loads different fault situations are created and DVR performances are analyzed.

Keywords: power quality, DVR, fuzzy logic controller, multilevel inverter.

1. INTRODUCTION

Power quality is the one of the most important issue in the recent electric power system. The power quality causes serious economic issues for customers, utilities and manufacturers. Some of the main power quality problems are voltage sag, swell, transients, harmonics, and flicker etc [5].

By custom power devices, we refer to power electronic static controllers used for power quality improvement on distribution systems rated from 1 to 38 kV [8]. This interest in the practice of power quality devices (PQDs) arises from the need of growing power quality levels to meet the everyday growing sensitivity of customer needs and expectations [9].

Dynamic Voltage Restorer (DVR) is the one of such power quality device used in power distribution networks. It has lower cost, smaller size and fast dynamic response to the disturbance [6].

N.G. Hingorani explains the concept of custom power [10]. This term describes the quality of power that electric companies and other service providers will offer their customers.

H.P. Tiwari explains the issues and the impact of various factors on performance of Dynamic Voltage Restorer (DVR) [4]. A DVR is connected for series voltage compensation. Voltage sags considerably affects the performance of sensitive loads in the distribution system. The impact of voltage, energy, power, DVR rating, maximum load, power factor, maximum depth and duration of voltage sag, efficiency and losses, harmonics, frequency and transformer on proper functioning of DVR system is studied.

P. RoshanKumar, explains a 3 level flying capacitor Multi Level Inverter cascaded with a flying H-bridge power cell in each of the three phases. This has redundant switching states for generating different pole voltages reduction [2].

Paisan Boonchiaml, explains in detail of load voltage compensation for DVR [7].

A.Teke, presents the design of a fuzzy logic controlled dynamic voltage restorer (DVR) [3]. A new control method for DVR is proposed by combining FL with a SHE PWM inverter.

2. DVR OPERATING PRINCIPLE

The DVR 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.

During undisturbed power supply condition, the DVR 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 DVR 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.

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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 DVR. 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 DVR on the load side, solid-state bypass switches or electromechanical bypass switches must be added as a measure to protect DVR from getting damaged.

3. FUZZY LOGIC CONTROLLER

The basic idea behind FLC is to incorporate the "expert experience" of human operator in the design of the controller in controlling a process whose input - output relationship is described by collection of fuzzy control rules (e.g., IF-THEN rules) involving linguistic variables rather than a complicate dynamic model.

FLC is strongly based on the concepts of fuzzy sets, linguistic variables and approximate reasoning.

A typical architecture of FLC is shown in Figure-1, which is of four principal comprises:

a) A fuzzifier
b) A fuzzy rule base
c) Inference engine
d) A Defuzzifier.

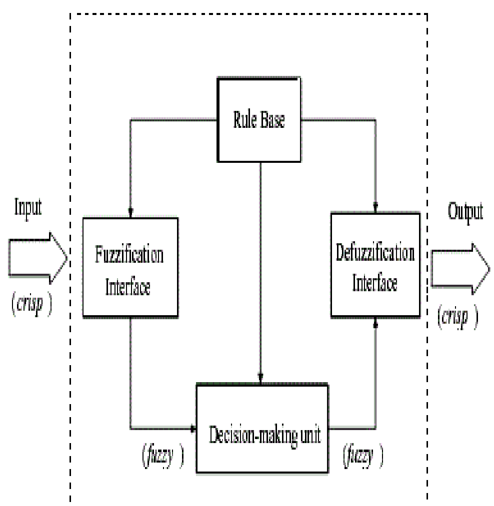

Figure-1. Architecture of FLC.

4. CASCADED MULTILEVEL INVERTER

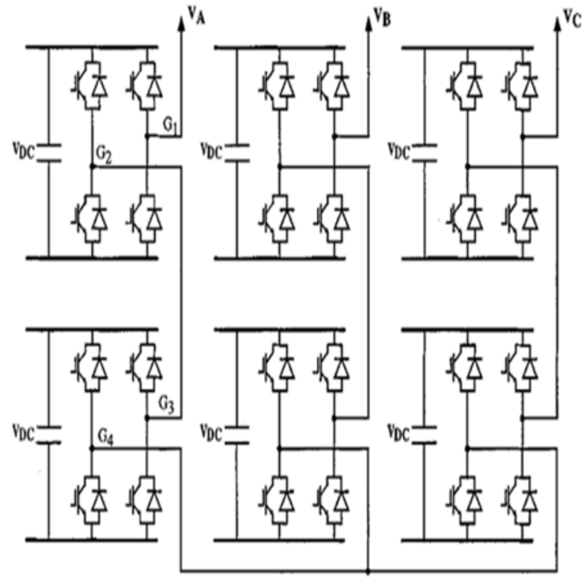

Figure-2. Three-phase 5-level cascaded multilevel inverter (Y-configuration).

For a three-phase system, the output voltage of the three cascaded inverters can be connected in either wye (Y) or delta (Δ) configurations. For example, a wye-configured 5-level converter using a Cascaded Multilevel Inverter (CMI) with separated capacitors is illustrated in the Figure-2.

5. PROPOSED SYSTEM

In distribution systems to regulate the voltage custom power devices may be used and it improves the power quality at the consumer side. In this paper DVR is used, which is connected in series to the distribution system through coupling transformer which is shown in Figure-3.

The DVR consists of energy storage device and voltage source converter. Here hybrid multilevel inverter is used with the five level output voltage with Selective Harmonic Elimination Pulse Width Modulation (SHEPWM) technique to decrease the harmonics since power electronics devices are used. Whenever voltage sag or swell occurs in the distribution side to maintain the load, voltage is injected in series, which is controlled by fuzzy logic controller.

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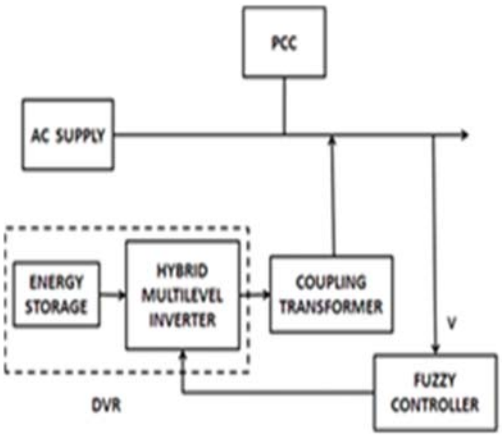

Figure-3. DVR with Fuzzy controller.

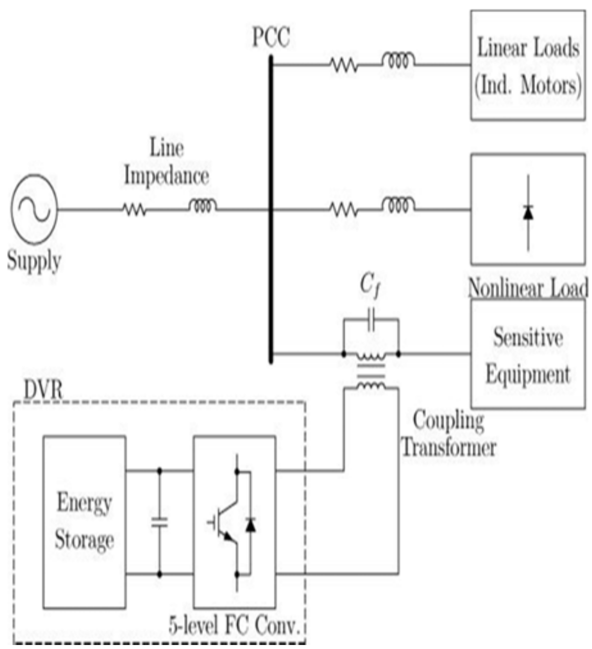

Figure-4. Block diagram of proposed system.

6. SIMULATION MODEL OF DVR

The simulation diagram Figure-5 consists of DVR which is connected to the distribution system through the coupling transformer. The DVR consists of hybrid multilevel inverter and the energy storage system with the fuzzy logic controller which is used to control the injection of voltage in series across the distribution systems during voltage sags and swells.

By using source voltage generator voltage sags and voltage swells are created for the time period of 0.6 to 1.5 seconds.

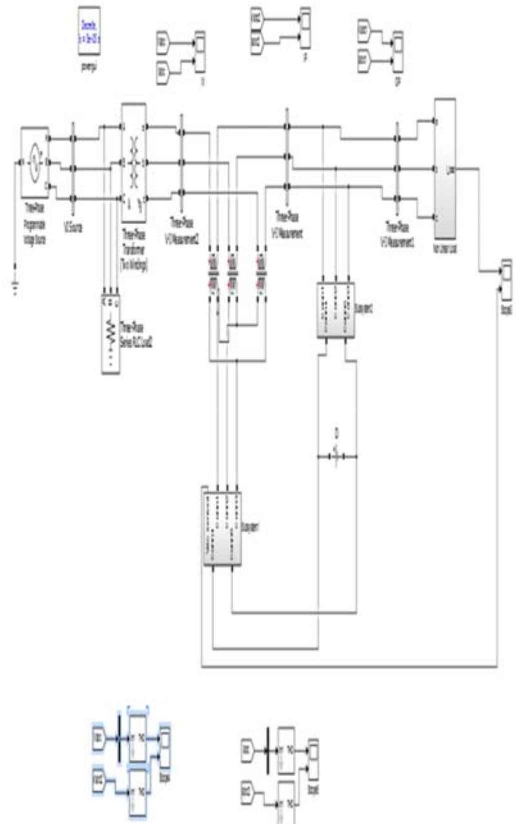

Figure-5. Simulink model of DVR.

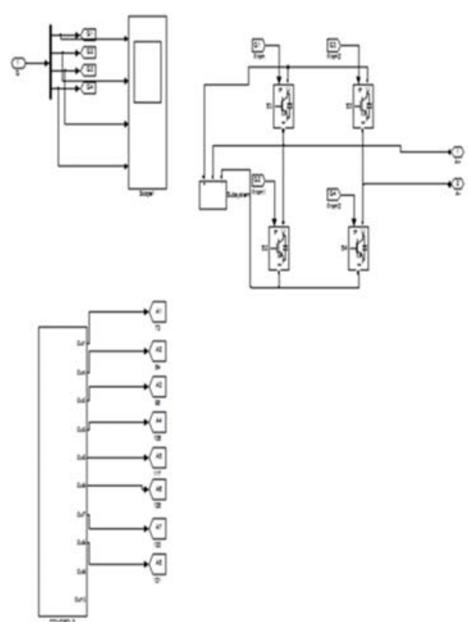

Figure-6. Simulink model of Hybrid multilevel inverter.

Figure-6 shows the hybrid multilevel inverter of a phase which is three level h-bridge multilevel inverter

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hybrids with a flying capacitor for each cell for the 3 phases. This inverter enables the use of single energy storage system for the production of multilevel output. In this inverter the capacitor voltages are balanced by using the switching strategies which is done by pulse width modulation technique. This inverter uses IGBT switches which got a very low on-state voltage drop. In each phase, the switches S1, S2, S3, S4 and S1, S2, S3, S4 are operated in complementary manner. The output voltage is based on the switching states that decide the path of the current flow. The capacitor voltages remain unaffected while producing the voltages Vdc and 0.

7. SIMULATION RESULTS

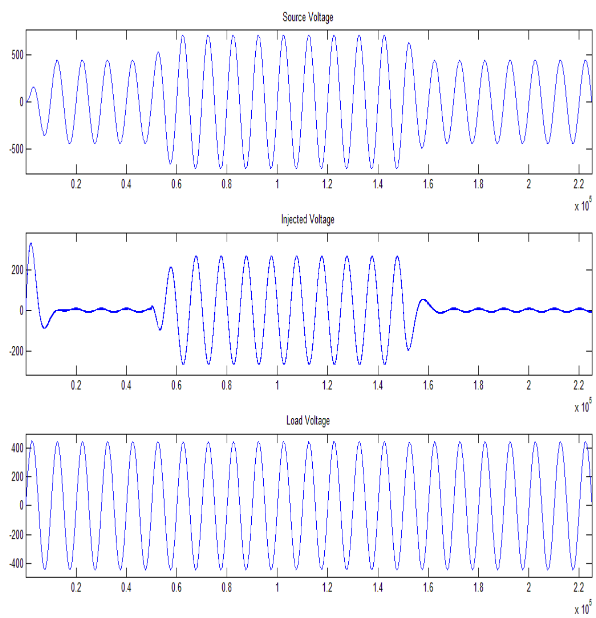

Figure-7. Voltage waveforms for phase 1.

The above Figure-7 shows the voltage waveforms for phase 1 source voltage, injected voltage and load voltage. In the first waveform voltage swell is produced between time periods of 0.6 to 1.5 seconds, which is mitigated by injecting voltage by DVR and the amount of injection is controlled by fuzzy logic controller in second waveform and in the third waveform because of injected voltage the load voltage waveform is compensated during the faulted time period and hence the power quality is maintained by mitigating the voltage swells.

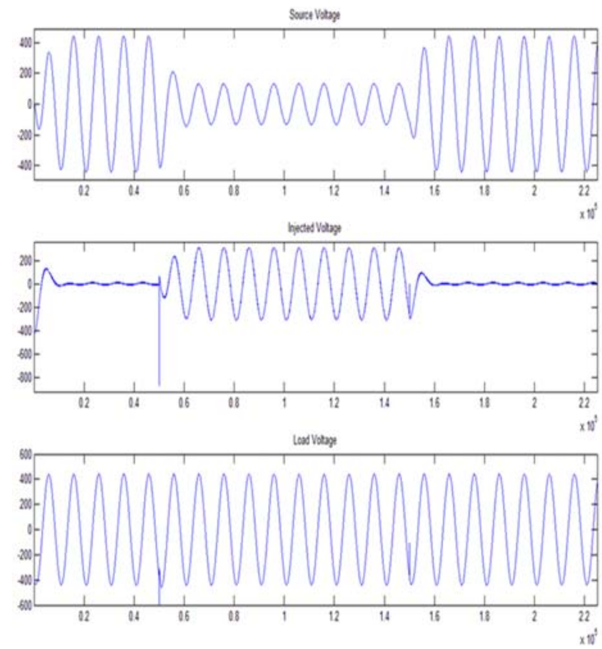

Figure-8. Voltage waveforms for phase 2.

The above Figure-8 shows the voltage waveforms for phase 2 source voltage, injected voltage and load voltage.

In the first waveform voltage sag is produced between time periods of 0.6 to 1.5 seconds which is mitigated by injecting voltage by DVR and the amount of injection is controlled by fuzzy logic controller in second waveform and in the third waveform because of injected voltage the load voltage waveform is compensated during the faulted time period and hence the power quality is maintained by mitigating the voltage sags.

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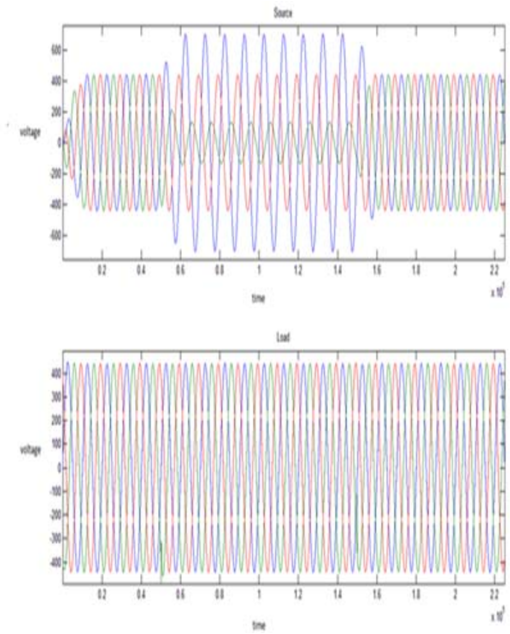


Figure-9. Three phase source and load voltage.

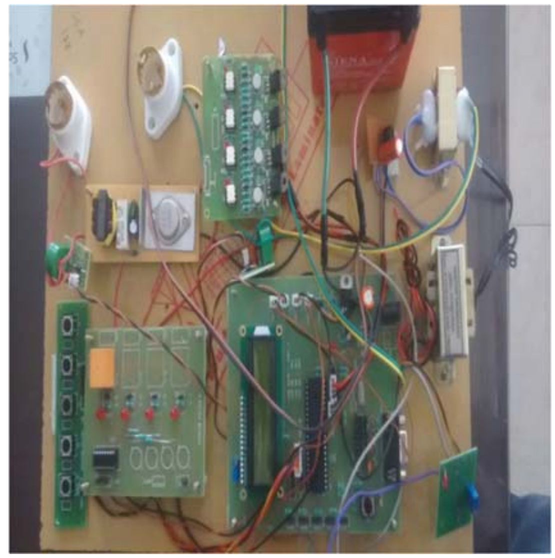
The above Figure-9 shows the source voltage and load voltage of three phases.

In the first waveform the distribution side voltage is produced with voltage sags and swells during the time periods of 0.6 to 1.5 seconds in two phases and in the second waveform by using DVR the dc supply stored in the energy storage system is converter into ac by the multilevel inverter and injected during the faulted voltage into the distribution system by series injection of voltage thereby the load voltage is compensated and hence the power quality is maintained at the consumer end.

8. SYSTEM DATA

Supply Voltage	240V
Series transformer turns ratio	1:2
DC link Voltage	120V
Filter Inductance	0.5mH
Filter capacitance	1µF
Load resistance	200 Ohm
Load inductance	200mH

9. HARDWARE SETUP



CONCLUSIONS

In this paper Dynamic Voltage Restorer (DVR) is used to overcome the voltage sag and swell with the use of hybrid multilevel inverter is presented to improve the Power Quality. This is proved by MATLAB simulation results. The result indicates that the load voltage is improved within few seconds using DVR when faults or any disturbance occur in distribution system which shows the DVR's excellent performance and the control system in order to protect sensitive equipment from PQ disturbances.

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