POWER QUALITY IMPROVEMENT IN SINGLE DISTRIBUTION SYSTEM USING RENEWABLE ENERGY BSAED ON UNIFIED POWER QUALITY CONTROLLER (UPQC)

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ABSTRACT

Voltage sags result in unwanted operation stops and large economic losses in industrial applications. A Unified Power Quality Controller (UPQC) is a power-electronics-based device conceived to protect high-power installations against these events. However, the design of a UPQC control system is not straightforward and it has some peculiarities. First of all, a UPQC includes a resonant (LC) connection filter with a lightly damped resonance. Secondly, the control system of a UPQC should work properly regardless of the type of load, which can be linear or non-linear, to be protected. In order to improve the utilization rate and power quality of distributed new energy power generation technology and, to solve the voltage fluctuation problem in the operation of the distributed photovoltaic storage and grid-connected system. This project proposes a control strategy based on UPQC (Unified Power Quality Controller) for operation of distributed photovoltaic storage and grid-connected. The remaining photovoltaic output energy is stored in energy storage via active bridge to reduce the waste of photovoltaic power To compensate the output voltage fluctuation of photovoltaic grid-connected inverter, the UPQC was connected to the energy storage. And PI controller parameters of the UPQC are optimized by ANFIS algorithm, realize the recovery of output voltage fluctuation of the photovoltaic grid-connected inverter. The advantages of the proposed control strategy are demonstrated using simulations, and the results show that the proposed strategy can ensure the quality of PV output voltage in the photovoltaic storage and grid connected. PV based UPQC system is comprised of PV System with low and high power DC-DC boost converter, PWM voltage source inverter, series injection transformer and semiconductor switches. Simulation results proved the capability of the proposed UPQC in mitigating the voltage sag, swell and outage in a low voltage distribution system.

Keyword : - *UPQC, SMC, PI Controller*

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1. INTRODUCTION

Most downtimes in industry are due to voltage sags. Unfortunately, it is difficult to immunize equipment against these voltage events and, if the sag lasts for a long time, equipment shutdown is inevitable. Uninterruptible power supplies (UPSs) are often used for protecting sensitive loads against voltage sags. UPSs are widely applied to protect low-power loads such as computers or small electronic loads. They replace the grid when a voltage sag takes place and, when the voltage level recovers, loads are gently reconnected to the grid. However, a UPS has to deliver all the power consumed by the protected loads during a sag. This means that a UPS requires large batteries to protect loads against long-duration voltage sags and, consequently, its application is greatly restricted by the size and cost of batteries. A Unified Power Quality Controller (UPQC) is conceived to protect sensitive loads. against voltage sags and swells.

This device is connected in series with an electrical distribution line and, typically, it consists of a voltage source converter (VSC), a DC capacitor, a coupling transformer, batteries, and an AC filter. When voltage sag takes place, a UPQC injects the required voltage in series with the feeding line and the load voltage remains unchanged. The main advantage of UPQCs is that only a portion of the power consumed by the load is supplied from the batteries. This means that batteries can be made much smaller than in a typical UPS and cost can be reduced. These reductions in battery size and cost make UPQCs very attractive for high-power applications where a UPS may be infeasible. A series-connected power-electronics device that was able to restore the voltage of a load under distorted grid conditions. AC–DC converter was used to maintain the DC voltage constant so that no additional energy storage elements were required. The main task of a UPQC is to control the load voltage. Therefore, a control scheme is commonly adopted. UPQCs are sometimes controlled by using open-loop techniques. Stability is guaranteed with this control technique if the plant is stable (alwaysthe case for a UPQC).

1.1 Control Techniques

Open-loop control techniques were applied to control a UPQC, obtaining a fast transient response. However, performance was poor if the AC filter included a capacitor because of the LC filter resonance. In most cases, UPQCs are controlled by using a feedback control scheme. Additionally, the current consumed by the sensitive load can be added as a feed-forward signal. Feedback control provides accurate reference tracking provided the closed-loop plant is stable.

However, UPQC feedback control can be difficult because

(a) the load modifies the plant dynamics and

(b) the LC filter resonance is difficult to damp with a controller based on a single loop.

If the controller is applied in natural magnitudes or in a stationary RF (*ab*), decoupling equations are not required. However, a resonant controller is needed to achieve zero steady-state error for the fundamental component. By far, the most common alternative is to use an SRF because the fundamental components of all magnitudes are constant values in steady state. Therefore, a proportional-integral (PI) controller is enough to track balanced voltage sags, although the dq-axis dynamics are coupled.

In addition, a phase-locked loop (PLL) is needed to synchronize with the grid voltage. An alternative controller was implemented by using time-varying phasors that did not require a PLL and made it possible to independently control each phase. However, the transient response was slower when compared to other control algorithms because the phasors needed to be estimated. The simplest solution to damp the resonance is to add a resistor close to the AC capacitor, but this increases losses. A multi-loop control scheme like the one depicted in Figure 1c is a classical solution to damp resonances: first, the current through the filter inductor (il) is controlled by the inner AC-current controller, and, secondly, the load voltage (ul) is controlled by the AC-voltage controller. With this control scheme, the resonance can be actively damped and no extra passive elements are required.

Nevertheless, extra measurements are required. A UPQC can also be controlled by using a single control loop. For instance controlled a UPQC with an LC filter by applying a PID controller and a fast transient response with a reduced overshoot was obtained. However, the load voltage quality deteriorated when loads were non-linear. Alternatively, Roncero-Sánchez et al. damped the resonance by applying a PI controller plus a notch filter tuned at the resonant frequency: the notch filter simplified the PI controller design, but the result was not robust against variations in the system parameters.

1.2 Power Quality Problems

SOURCES AND EFFECTS OF POWER QUALITY PROBLEMS:

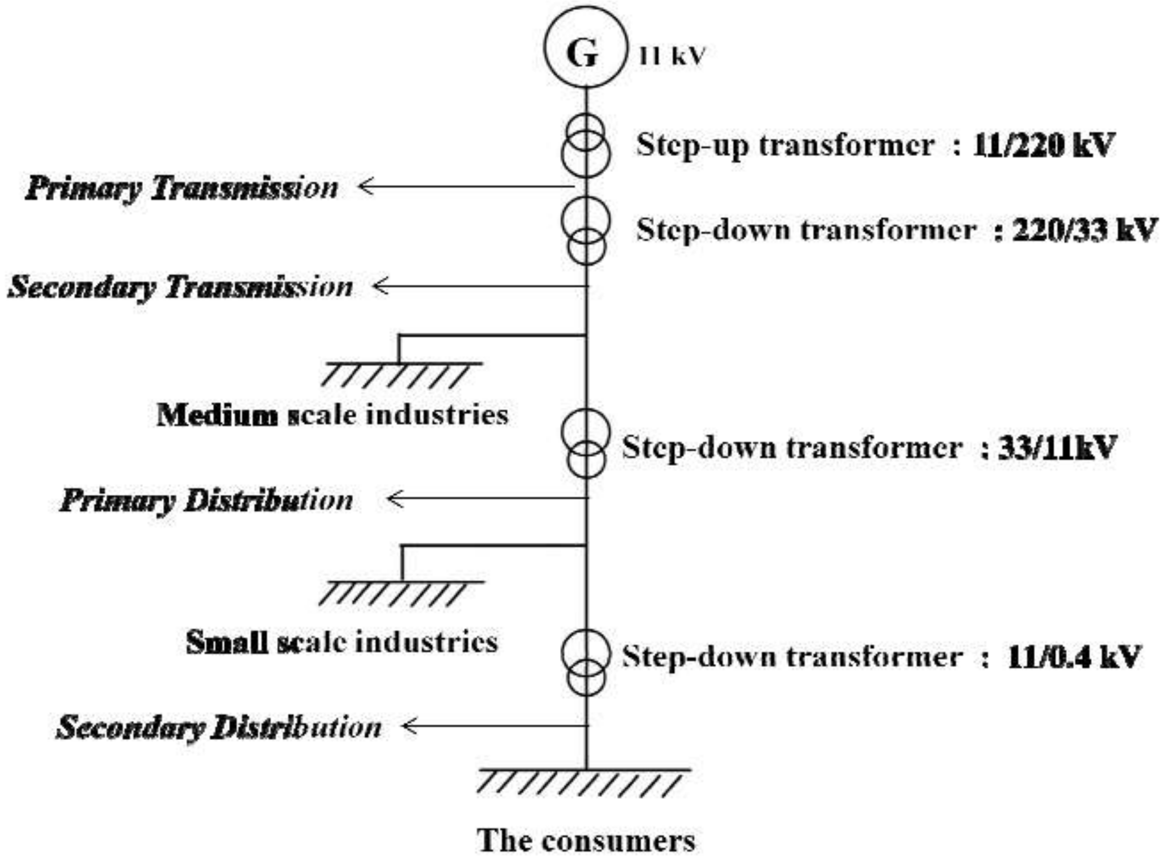

Fig. 1.1 Single line diagram of power

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up produce power quality problems. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

2. Basic Configuration of UPQC

The general configuration of the UPQC consists of:

i. An Injection/ Booster transformer
ii. A Harmonic filter
iii. Storage Devices
iv. A Voltage Source Converter (VSC)
v. DC charging circuit
vi. A Control and Protection system

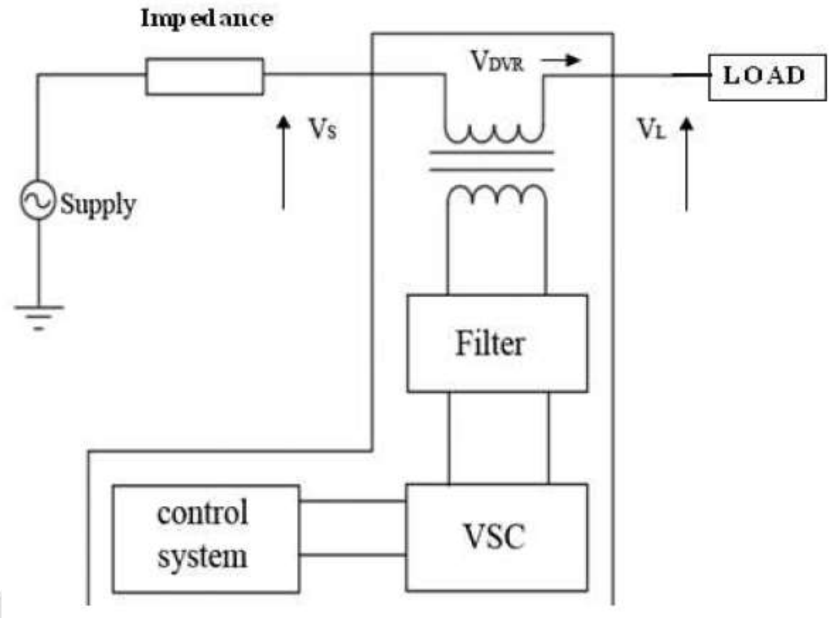

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Fig. 2.1: Schematic diagram of UPQC

2.1 Injection/ Booster transformer

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. Its main tasks are:

- It connects the UPQC to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.
- In addition, the Injection / Booster transformer serves the purpose of isolating the load

from the system (VSC and control mechanism).

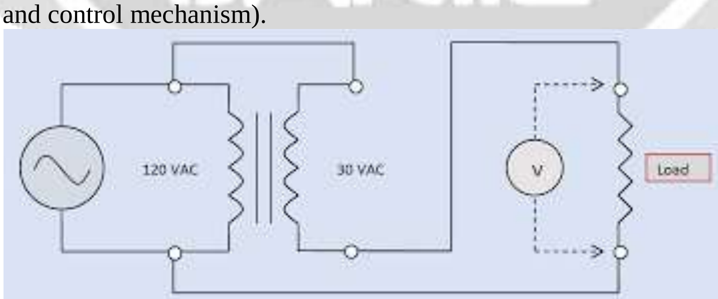

Fig. 2.2:Circit Diagram of Boost Transformer

2.2 Voltage Source Inverter

A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle.

In the UPQC application, the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing. There are four main types of switching devices:

Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Each type has its own benefits and drawbacks.

The IGCT is a recent compact device with enhanced performance and reliability that allows building VSC with very large power ratings. Because of the highly sophisticatedconverter design with IGCTs, the UPQC can compensate dips which are beyond the capability of the past UPQCs using conventional devices.

The purpose of storage devices is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages. The different kinds of energy storage devices are Superconductive magnetic energy storage (SMES), batteries and capacitance.

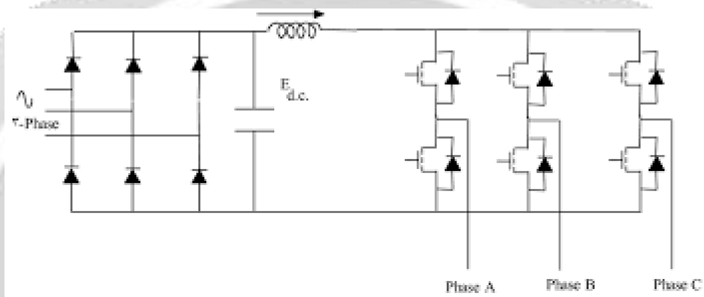

Fig. 2.3: Schematic diagram of UPQC

3. OPERATING MODES OF UPQC

The basic function of the UPQC is to inject a dynamically controlled voltage VUPQC generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The UPQC has three modes of operation which are: protection mode, standby mode, injection/boost mode.

3.1 Protection mode

If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the UPQC will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

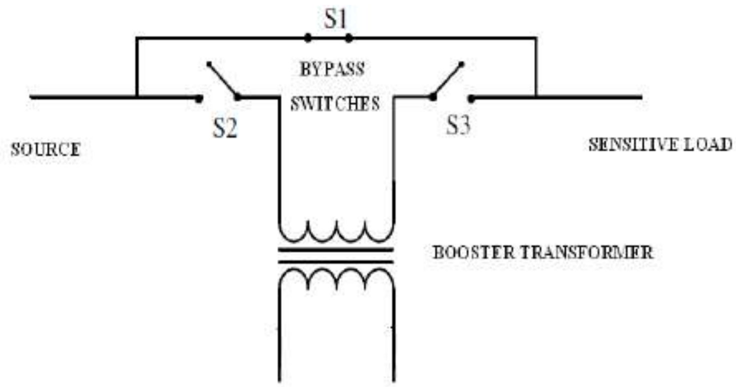

Fig.3.1: Protection Mode(creating another path for current)

3.2 Pre-sag/dip compensation method

The pre-sag method tracks the supply voltage continuously and if it detects any disturbances in supply voltage it will inject the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method. In this method the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions

$$V_{DVR} = V_{prefault} - V_{sag}$$

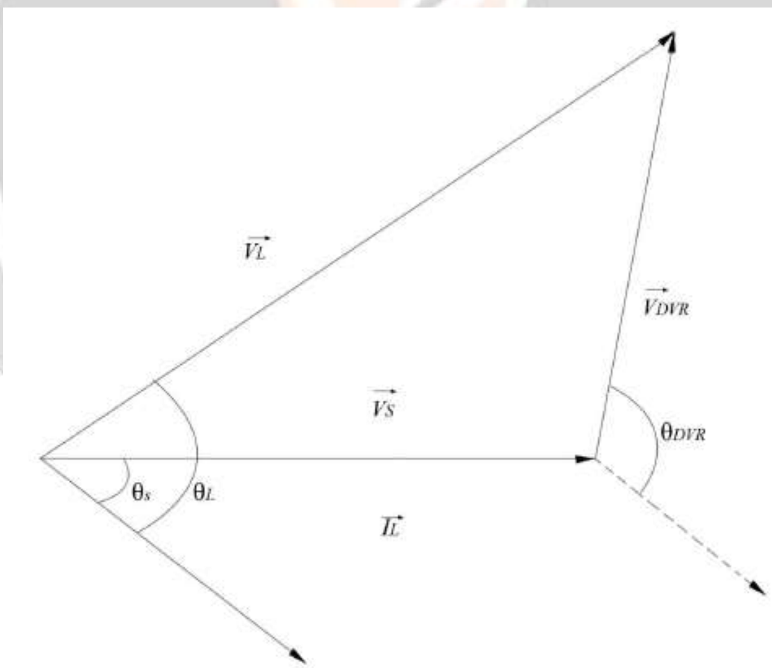

Fig. 3.4 Pre-sag compensation method

3.3 In-phase compensation method

This is the most straight forward method. In this method the injected voltage is in phase with the supply side voltage irrespective of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied.

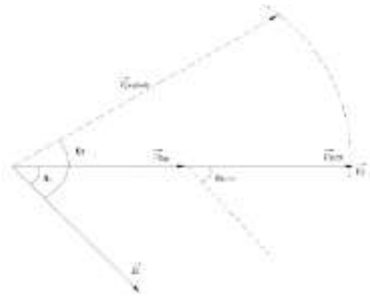

Fig -3.4: In-phase compensation method

One of the advantages of this method is that the amplitude of UPQC injection voltage is minimum for a certain voltage sag in comparison with other strategies. Practical application of this method is in non-sensitive loads to phase angle jump.

4. CONCLUSIONS

This paper has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Compensation techniques of custom power electronic devices UPQC was presented. The design and applications of UPQC for voltage sags and comprehensive results were presented. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. Design and implementation of solar energy-based three phase UPQC, using fuzzy logic controlled novel boost inverter, for mitigation of deep voltage sags, swells and an interruption affecting the sensitive equipment connected on low voltage distribution side, has been proposed. The proposed model of UPQC has been simulated in Matlab/Simulink. The proposed UPQC system model utilizes solar energy stored in the battery for mitigation of voltage sags, swells and interruptions hence result in huge cost saving for consumer side and reduces the payback period of the UPQC system. It stores the solar energy in separate back up for night time utilization purpose rather than drawing energy from the grid which minimizes the usage of grid energy and increases the reliability of UPQC for the consumer. Further fuzzy logic controlled novel boost inverter improves overall efficiency and dynamic performance of the UPQC system.

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