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AN IMPROVED IUPQC CONTROLLER TO PRODUCE ADDITIONAL GRID VOLTAGE REGULATION USING A STATCOM

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ABSTRACT

The iUPQC is a Unified Power Quality Conditioner in which the series converter emulates a sinusoidal current source and the shunt converter emulates a sinusoidal voltage source. The main causes of a poor power quality are harmonic currents, poor power factor, supply voltage variations, etc. In recent years the demand for the quality of electric power has been increased rapidly. Power quality problems have received a great attention nowadays because of their impacts on both utilities and customers. Voltage sag, swell, momentary interruption, under voltages, over voltages, noise and harmonics are the most common power quality disturbances. This approach provides indirect power quality compensation of the load voltage and the source current. By using this controller, beyond the conventional UPQC power quality features, including voltage sag/swell compensation, the iUPQC will also provide reactive power support to regulate not only the load-bus voltage but also the voltage at the grid-side bus. In other words, the iUPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQC compensations at the load or micro grid side.

1. INTRODUCTION

This paper presents an improved controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in micro grid applications. By using this controller, beyond the conventional UPQC power quality features, including voltage sag/swell compensation, the iUPQC will also provide reactive power support to regulate not only the load-bus voltage but also the voltage at the grid-side bus. In other words, the iUPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQC compensations at the load or micro grid side. Experimental results are provided to verify the new functionality of the equipment. In order to clarify the applicability of the improved iUPQC controller depicts an electrical system with two buses in spotlight, i.e., bus A and bus B. Bus A is a critical bus of the power system that supplies sensitive loads and serves as point of coupling of a microgrid. Bus B is a bus of the microgrid, where nonlinear loads are connected, which requires premium-quality power supply. The voltages at buses A and B must be regulated, in order to properly supply the sensitive loads and the nonlinear loads. The effects caused by the harmonic currents drawn by the nonlinear loads should be mitigated, avoiding harmonic voltage propagation to bus A. The use of a STATCOM to guarantee the voltage regulation at bus A is not enough because the harmonic currents drawn by the nonlinear loads are not mitigated. On the other hand, a UPQC or an iUPQC between bus A and bus B can compensate the harmonic currents of the nonlinear loads and compensate the voltage at bus B, in terms of voltage harmonics, unbalance, and sag/swell. Nevertheless, this is still not enough to guarantee the voltage regulation at bus A. Hence, to achieve all the desired goals, a STATCOM at bus A and a UPQC (or an iUPQC) between buses A and B should be employed. However, the costs of this solution would be unreasonably high. An attractive solution would be the use of a modified iUPQC controller to provide also reactive power support to bus A, in addition to all those functionalities of this equipment, as presented. Note that the modified iUPQC serves as an intertie between buses A and B. Moreover, the microgrid connected to the bus could be a complex system comprising distributed generation, energy management system, and other control systems involving microgrid, as well as smart grid concepts. In summary, the modified iUPQC can provide the following functionalities:

a) “Smart” circuit breaker as an intertie between the grid and the microgrid;
b) Energy and power flow control between the grid and the microgrid (imposed by a tertiary control layer for the microgrid);
c) Reactive power support at bus A of the power system;
d) voltage/frequency support at bus B of the microgrid;
e) Harmonic voltage and current isolation between bus A and bus B (simultaneous grid-voltage and load-current active filtering capability);
f) Voltage and current imbalance compensation.

The functionalities (d)–(f) previously listed were extensively explained and verified through simulations and experimental analysis, whereas the functionality (c) comprises the original contribution of the present work. Depicts, in detail, the connections and measurements of the iUPQC between bus A and bus B. According to the conventional iUPQC controller, the shunt converter imposes a controlled sinusoidal voltage at bus B, which corresponds to the aforementioned functionality.

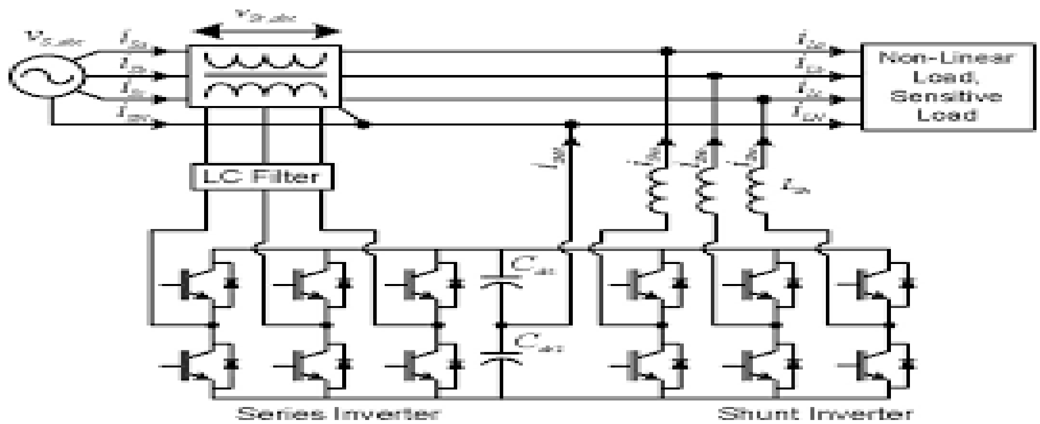


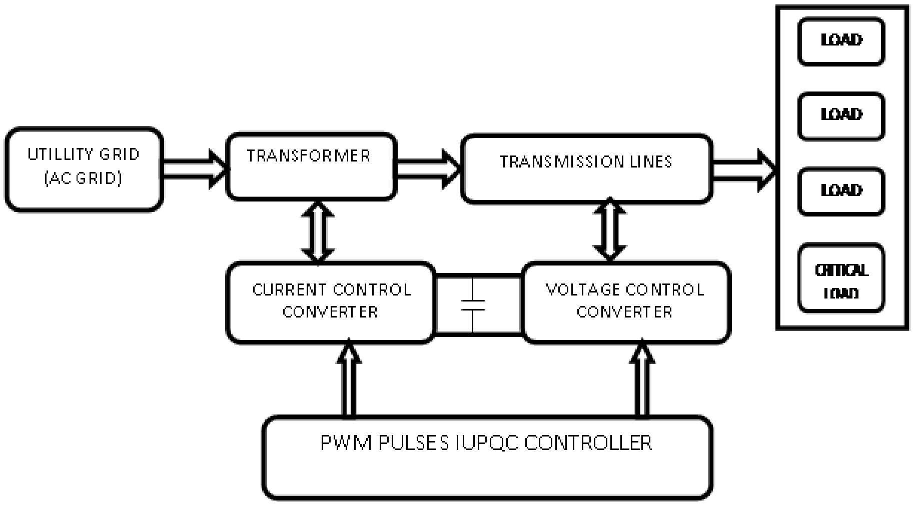
Fig.1 proposed circuit diagram

As a result, the shunt converter has no further degree of freedom in terms of compensating active- or reactive-power variables to expand its functionality. On the other hand, the series converter of a conventional iUPQC uses only an active-power control variable *p*, in order to synthesize a fundamental sinusoidal current drawn from bus A, corresponding to the active power demanded by bus B.

If the dc link of the iUPQC has no large energy storage system or even no energy source, the control variable *p* also serves as an additional active-power reference to the series converter to keep the energy inside the dc link of the iUPQC balanced. In this case, the losses in the iUPQC and the active power supplied by the shunt converter must be quickly compensated in the form of an additional active power injected by the series converter into the bus B. The STATCOM has been used widely in transmission networks to regulate the voltage by means of dynamic reactive power compensation.

Nowadays, the STATCOM is largely used for voltage regulation, whereas the UPQC and the Iupqc have been selected as solution for more specific applications. The iUPQC approach, the series converter behaves as a controlled sinusoidal current source and the shunt converter as a controlled sinusoidal voltage source. This means that it is not necessary to determine the harmonic voltage and current to be compensated, since the harmonic voltages appear naturally across the series current source and the harmonic currents flow naturally into the shunt voltage source. This paper proposes an improved controller, which expands the iUPQC functionalities. This improved version of iUPQC controller includes all functionalities of those previous ones, including the voltage regulation at the load-side bus, and now providing also voltage regulation at the grid-side bus, like a STATCOM to the grid. Experimental results are provided to validate the new controller design.

2. BLOCK DIAGRAM



Fg.2.General block diagram

Mainly three significant control approaches for IUPQC can be found to control the sag on the system: 1) active power control approach in which an in-phase voltage is injected through series inverter , popularly known as IUPQC-P; 2) reactive power control approach in which a quadrature voltage is injected, known as UPQC-Q; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, which is known as VA min. The VA loading in IUPQC-VA min is determined on the basis of voltage sag, may not be at optimal value. The voltage sag/swell on the system is one of the most important power quality problems in distribution.

3. MODULE DESCRIPTION

A. UNIFIED POWER QUALITY CONDITIONER (UPQC)

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The main advantage of the UPFC is to control the active and reactive power flows in the transmission line. If there are any disturbances or faults in the source side, the UPFC will not work. The UPFC operates only under balanced sine wave source. The controllable parameters of the UPFC are reactance in the line, phase angle and voltage. The UPFC concept was described in 1995 by L. Gyugyi of Westinghouse. [1] The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system.

B. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

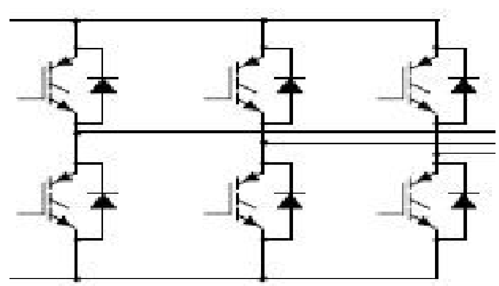
A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. It is inherently modular and electable. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; conversely, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of a static VAR compensator (SVC), mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).

C. POWER QUALITY

Power quality determines the fitness of electric power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electric power distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised. While "power quality" is a convenient term for many, it is the quality of the voltage—rather than power or electric current—that is actually described by the term. Power is simply the flow of energy and the current demanded by a load is largely uncontrollable.

D. SERIES INVERTER AND SHUNT INVERTER

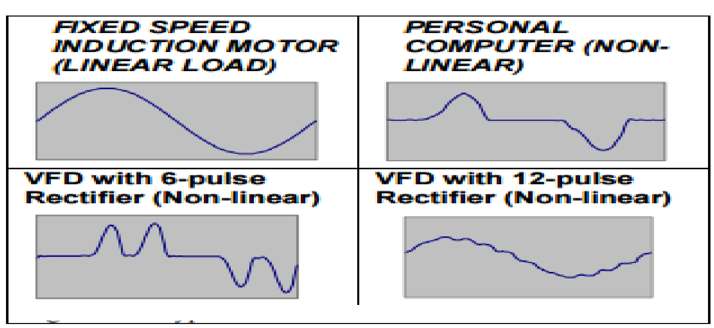
The circuit is basically an extension of the H-bridge-style single-phase inverter, by an additional leg. The control strategy is similar to the control of the single-phase inverter, except that the reference signals for the different legs have a phase shift of 120° instead of 180° for the single-phase inverter. Due to this phase shift, the odd triple harmonics (3rd, 9th, 15th, etc.). To compensate for this voltage reduction, the fact of the harmonics cancellation is sometimes used to boost the amplitudes of the output voltages by intentionally injecting a third harmonic component into the reference waveform of each phase leg.



Fg.4.Series and shunt Inverter

E. NON-LINEAR LOAD:

A load is considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads connected to it.



Fg.5.Non-linear load

A. RESULT ANALYSIS

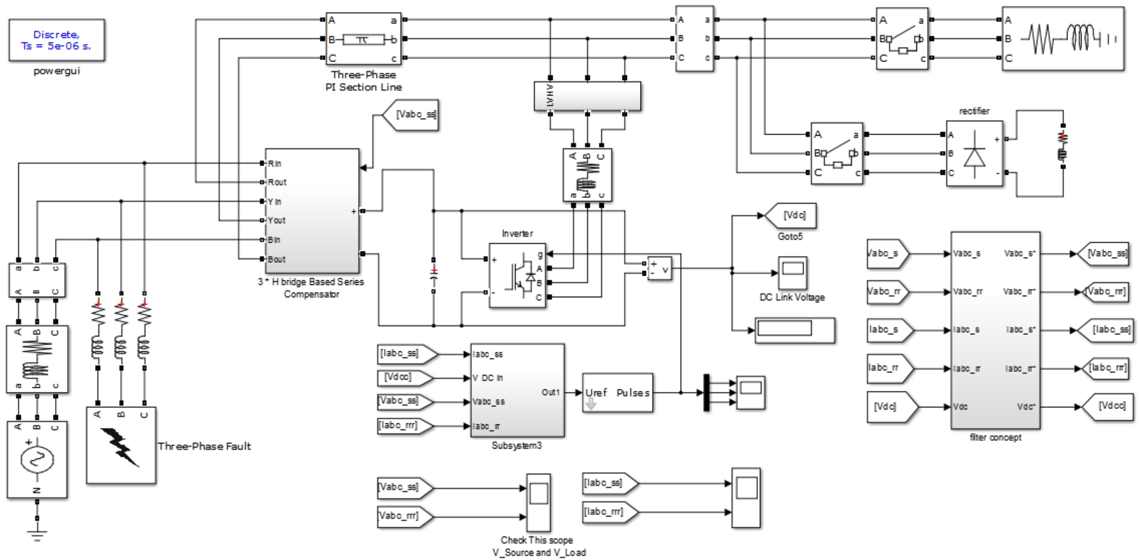


Fig.6. Simulation Diagram

In figure 7 and 8 shows the simulation diagram and graph of the compensate voltage during power quality proplem. In the graph results shows the exact output waves of the series and shunt converter. The simulation and experimental results confirm to verify the feasibility of the proposed converter. The simulation and output waveform s are done by MATLAB software.

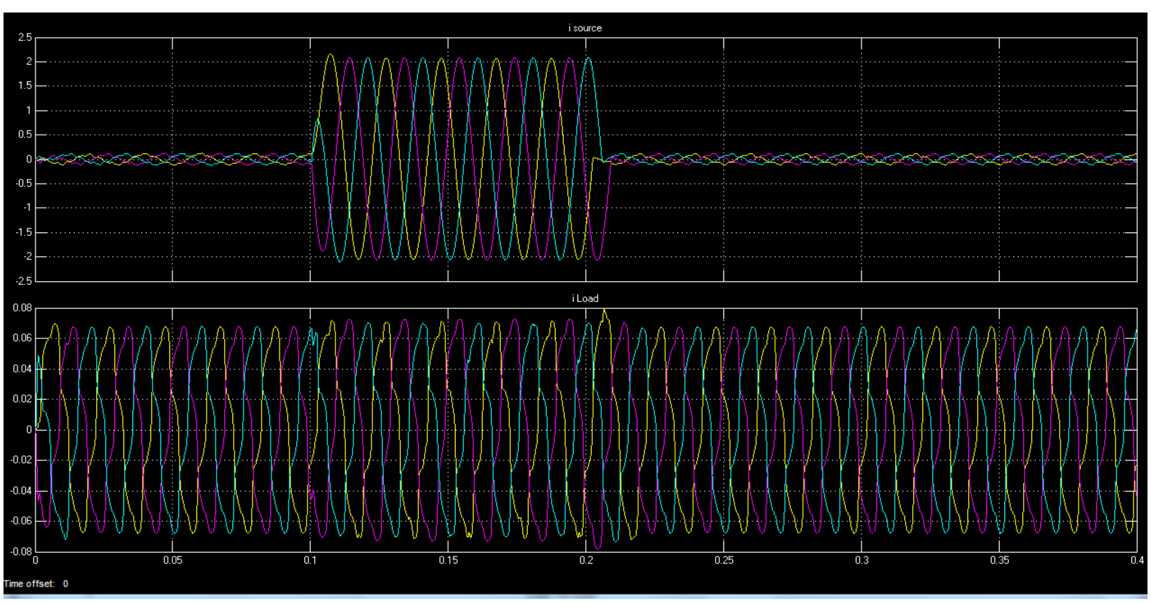


Fig.7. Simulation Graph

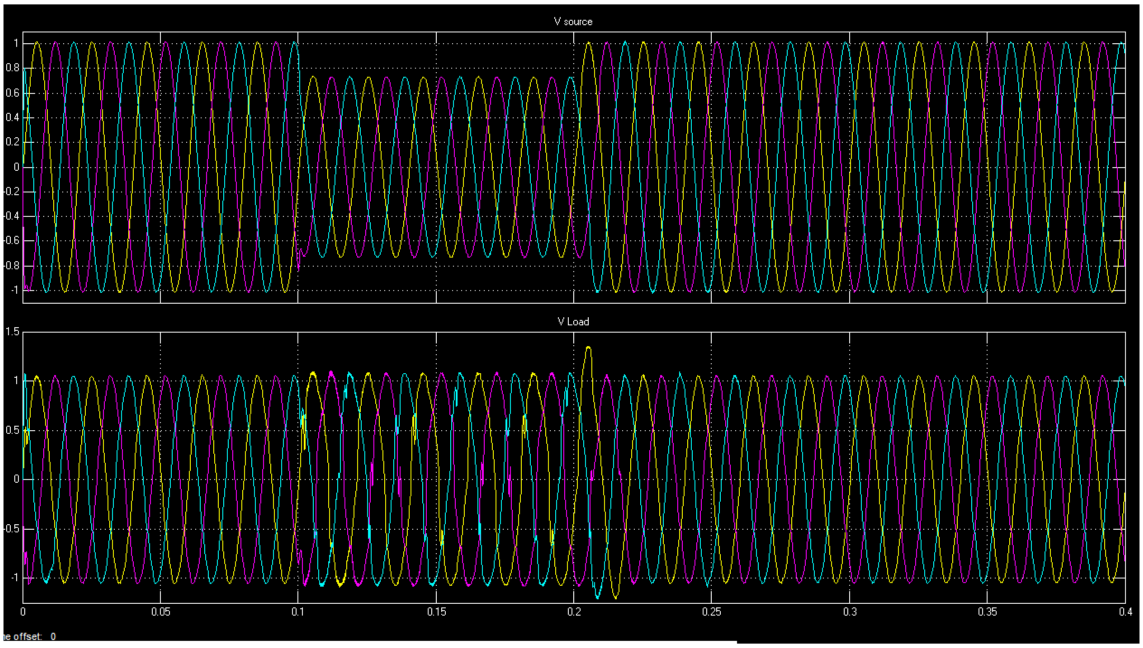


Fig.8. Simulation Graph

CONCLUSION

The paper illustrates the operation and control of an interline unified power quality conditioner (IUPQC). An effective PLL based control technique is used for IUPQC to detect and extract the PQ disturbances in power system. Each phase of Series and Shunt Compensator are investigated independently with PLL based controller. Custom power devices like DVR, DSTATCOM, and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the distribution system, there is a choice to choose particular custom power device with specific compensation. Unified Power Quality Conditioner (UPQC) is the combination of series and shunts APF, which compensates supply voltage and load current imperfections in the distribution system. A simple control technique based on unit vector templates generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The simulation results show that the input voltage harmonics and current harmonics caused by nonlinear load can be compensated effectively by the proposed control strategy. The closed loop control schemes of direct current control, for the proposed UPQC have been described.

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