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SINGLE-PHASE TO THREE-PHASE UNIFIED POWER QUALITY CONDITIONER APPLIED IN SWER ELECTRIC POWER DISTRIBUTION GRIDS

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Abstract— This paper deals with the deployment of a local three-phase four-wire (3P4W) electrical power distribution system (EPDS), using a single- to three-phase unified power quality conditioner (UPQC) topology, called UPQC-1Ph-to-3Ph. The topology is indicated for applications in rural or remote areas in which, for economic reasons, only EPDS with single-wire earth return are accessible to the consumer. Since the use of three-phase loads is increasing in these areas, access to a three-phase distribution system becomes preponderant. By adopting a dual compensation strategy, the proposed UPQC-1Ph-to-3Ph is able of draining from the single-phase electrical grid a sinusoidal current and in phase with the voltage, resulting high-power factor. Furthermore, the system is also able to suppress grid voltage harmonics, as well as to compensate for other disturbance, such as voltage sags. Thus, a 3P4W system with regulated, balanced, and sinusoidal voltages with low-harmonic contents is provided for single- and three-phase loads. An analysis of the power flow through the series and parallel converters is performed in order to aid the designing of the power converters. Experimental results are presented for validating the proposal, as well as evaluating the static and dynamic performances of the proposed topology.

I. INTRODUCTION

System Overview

Electrical power distribution systems (EPDS) with single-wire earth return (SWER) have been commonly adopted as a solution for electrical power supplying. This is due to the fact that the reduction of costs in the distribution of energy to serve large territorial extensions with low demographic densities is an important requirement, since lower installation and maintenance costs are achieved.

Other alternatives are the use of energy distribution by means of two conductors (phase-to-neutral) without earth return, or even using two-phase systems (phase-to-phase). Considering these alternatives, capital investments for the realization of SWER distribution grid facilities installations are still lower. The capital investments for the realization of SWER distribution grid facilities installations are still lower. In this system, the three-phase four-wire electrical power distribution system, using a single-

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to three-phase unified power quality conditioner topology, called UPQC-1Ph-to-3Ph is used.

This topology is indicated for applications in rural or remote areas in which, for economic reasons, only EPDS with single wire earth return are accessible to the consumer. Since the use of three-phase loads is increasing in these areas, access to a three-phase distribution system becomes preponderant. By adopting a dual compensation strategy, the proposed UPQC is able of draining from the single-phase electrical grid a sinusoidal current and in phase with the voltage, resulting high power factor. Furthermore, the system is also able to suppress grid voltage harmonics, as well as to compensate for other disturbances, such as voltage sags.The demand for electrical energy in single-phase rural distribution grids has considerably increased in the last decades.It is possible to notice an increasing need to use three-phase distribution grids to meet the demand for electrical energy in rural areas due to changes in the characteristics of the loads.Thus this project deals with local three-phase four-wire power distribution system, indicated for applications in rural or remote areas where three-phase distribution grids are not accessible.It was conceived based on unified power quality conditioner functionalities. With serial and parallel filtering capability, two inverter topologies were used to compose the UPQC-1Ph-to-3Ph.Thereby, the single-phase series converter was deployed using a half-bridge inverter, while the three-phase parallel converter was implemented using a 3-Leg split capacitor inverter.Using the dual compensation strategy, the proposed system was able of feeding linear and non-linear three-phase loads acting with universal active filtering capability. In addition, a procedure was presented that allows the dimensioning the power structures of the series and parallel converters, under various operating conditions of the utility grid and the load.

Electrical Power Distribution System(EPDS)

Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage used by lighting, industrial equipment or household appliances. Often several customers are supplied from one transformer through secondary distribution lines. Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level. Electric power distribution only became necessary in the 1880s when electricity started being generated at power stations. Before that electricity was usually generated where it was used. The first power distribution systems installed in European and US cities were used to supply lighting: arc lighting running on very high voltage (around 3000 volts) alternating current (AC) or direct current (DC), and incandescent lighting running on low voltage (100 volt) direct current. Both were supplanting gas lighting systems, with arc lighting taking over large area and street lighting, and

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incandescent lighting replacing gas for business and residential lighting.

Due to the high voltages used in arc lighting, a single generating station could supply a long string of lights, up to 7-mile (11 km) long circuits. Each doubling of the voltage would allow the same size cable to transmit the same amount of power four times the distance for a given power loss. Direct current indoor incandescent lighting systems (for example the first Edison Pearl Street Station installed in 1882), had difficulty supplying customers more than a mile away due to the low 110-volt system being used throughout the system, from the generators to the final use. The Edison DC system needed thick copper conductor cables, and the generating plants needed to be within about 1.5 miles (2.4 km) of the farthest customer to avoid excessively large and expensive conductors.

Unified Power Quality Conditioner (UPQC) Topology

In today's world there is great importance of electrical energy as it is the most famous from of energy and all are massively relying on it. Without supply of electricity life cannot be imagined. At the same time the quality and continuousness of the electric power supplied is also very important for the efficient functioning of the end user equipment. Many of the commercial and industrial loads require high quality undisturbed and constant power. Thus maintaining the qualitative power is topmost important in today's world. Due to power electronics devices there is serious effect on quality and continuousness of electric supply. Because of power electronics devices there is uninterrupted power supply, flicker, harmonics, voltage fluctuations e.t.c. There is also PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there is reactive power disturbances and harmonics in power distribution system. It is very essential to overcome this type of problems as its effect may increase in future and cause adverse effect. Traditionally passive filters were used for reactive power disturbances and harmonics generation but there are many problems with them like they are large in size, resonance problem, effect of source impedance on performance. Active Power Filters are used for power quality enhancement. Active power filters can be classified according to system configuration. Active power filters are of two types series and shunt. Combining both series APF & shunt APF we get a device known as UPQC. UPQC eliminates the voltage and current based distortions together. A Shunt APF eliminates all kind of current problems like current harmonic compensation, reactive power compensation, power factor enhancement. A Series APF compensates voltage dip/rise so that voltage at load side is perfectly regulated. The Shunt APF is connected in parallel with transmission line and series APF is connected in series with transmission line. UPQC is formed by combining both series APF and shunt APF connected back to back on DC side.

II. SYSTEM ANALYSIS

Existing System

The use of medium and high power three-phase voltage inverters involved in modern

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automated systems also justifies the need for three-phase grids in rural areas. Therefore, the presence of a local three-phase energy distribution system in areas that make use of the SWER distribution system becomes more and more indispensable. For this purpose, several solutions and/or configurations of single-phase-to-three-phase (1Ph-to-3Ph) converters have been addressed in the literature.These include 1ph-to-3Ph four-wire converters, which are able of supplying three-phase and single-phase. Dedicated to feed three-phase three-wire loads and integrating the functioning of the unified power quality conditioner (UPQC), the 1Ph-to-3Ph converter presented performs universal filtering, i.e., it operates as series-parallel active power filter, in which the series converter is composed of a single-phase full-bridge inverter (two inverter legs), while the parallel converter is composed of a three-phase three-leg inverter, totaling five inverter legs.

Proposed System

To validate experimentally the UPQC-1Ph-to-3Ph destined to feed single-and three-phase loads from the SWER power distribution systems, commonly found in rural and/or remote areas and suffer with PQ problems. By adopting the dual compensation strategy, the proposed UPQC-1Ph-to-3Ph makes possible to drain from the single-phase electrical grid a sinusoidal current in phase with the grid voltage. Furthermore, the system can also suppress harmonics from the grid voltage, as well as compensate for voltage disturbances, such as voltage sags/swell.

The topology of the UPQC-1Ph-to-3Ph is such that this one is formed by two PWM converters, being a half-bridge inverter and a split-capacitor 3-Leg inverter sharing the same dc-bus. As can be noted, a half-bridge inverter is used to compose the series converter, while in it was composed of a full-bridge inverter. Thus, besides using one leg less compared to the topology presented, the dc-bus is formed by the split-capacitor configuration, allowing access to the earthed return conductor of the load, as well to be used in SWER distribution systems. As can be noted,the four-wire of the load is connected to the dc-bus central point.

The series converter, also called SAPF, is current controlled so that the input drained current is sinusoidal and in phase with the grid voltage, resulting in a power factor (PF) very close to one. A filter inductor ( ) is placed in series with the primary winding of the single-phase series coupling transformer.

Switching Pattern of Inverter

Power losses of electric drives depend to a large extent on the switching frequency, currents, and supply voltage of the power semiconductor inverter. As these three parameters affect the motor torque and speed, they must be considered in the synthesis of the algorithms provided in the inverter adjustment. This paper presents the simulation and experimental study on a space vector modulation (SVM) inverter that supplies the alternating current (ac) electric drive with low switching losses. A new toolkit to explore different modulation techniques is described. Some methods of the load

Dependent control over ac electric drive inverters are examined through simulation and experimentation. The benefits of the new

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discontinuous SVM algorithms upon the well-known control techniques are discussed.

Nowadays, three phase alternating current (ac) electric drives are employed in different industrial areas with a wide power range starting from few watts to several megawatts. Drive industry is very benefit from the present generation of power converters and intellectual microprocessors responsible for the implementation of control functions within short cost margins. The best of the inverters for the ac electric drives would be devices that generate pure sinusoidal voltage and current of symmetrical phases. Unfortunately, a power electronic converter significantly distorts the waveforms. The distortion profile and level depend on the modulation principle of the converter switches. Any control method should perform some general demands like: a broad range of linear operation, a minimal number of switching to keep low switching losses in power components, a low content of higher harmonics in voltage and current, due to the productions of additional losses and noise in load, as well as elimination of low frequency harmonics to avoid motor torque pulsations. Power losses affect efficiency, cost, weight, size, power quality, transient responses, power consumption, and other characteristics of electric drive. Consideration on the motor parameters along with the power converter development or choice inevitably leads to the power economic design and loss decreasing. In this paper, the inverter output characteristics are related to the properties of the induction motor. Due to an influence of electromagnetic processes in the inverter□motor system, the load voltage transients have no direct relation with the reference signals. The degree of such discrepancy depends on both the motor parameters and the mode of inverter operation. Frequently, this results in additional voltage distortion and reduced usage of supply power. Therefore, the load parameters should be considered in synthesis of the switching patterns, mainly by setting the commutation law and duration of the switching intervals.

A Toolkit to Optimize Switching Patterns

The aim of the developed eModule toolkit is to search the switching patterns, including the switching law, switching frequency, and switching pulse distribution, which provide the most power effective converter performance in the scope of the required voltage and current THD indices. The package is enveloped into some modules, each performing different types of operations. For the best coherence, all the programs are joined by the common user interface thus providing a uniform layout and functionality. Using the front panel, a designer can interact with the software to choose the required mode of performance and to set up new ranges and parameter values in algorithms The toolkit aims to analyze and study threephase bridge inverters offering the solution to the following project management problems:

- Informational support throughout the selection of optimal switching patterns
- Mathematical and computer simulation along with full computation
- Test and result verification in accordance with multiple criteria
- Comparison, tuning and optimization of control systems

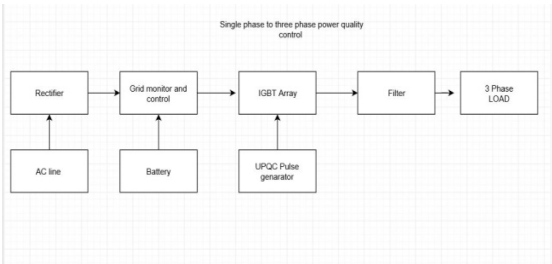
Advantages

- Good static and dynamic behavior.
- Suppress Voltage stress.

Applications

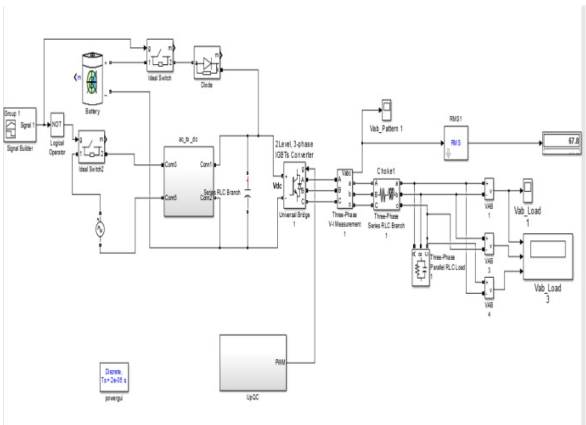
- Grid applications.
- Power distribution applications.

III. BLOCK DIAGRAM



IV. SIMULATION RESULT

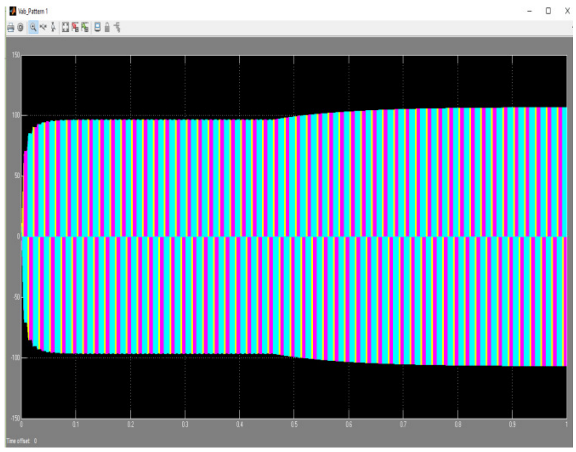
Simulink Diagram



Simulink diagram

A Simulink diagram consists of blocks that represent different parts of a system and signal lines that define the relationship between the blocks. These diagrams are widely used by engineers for controls, signal processing, communications, and mechatronics. Provide a high-level graphical representation. Analyze dynamic system behavior in time and frequency domains.

Current Waveform



Current Waveform

The input analysis is a technique that allows the accurate recording of current waveforms and generation of the corresponding central waveform.

One-phase Output

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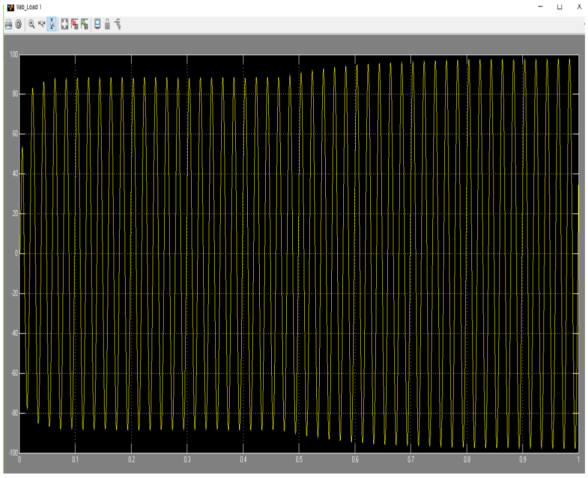
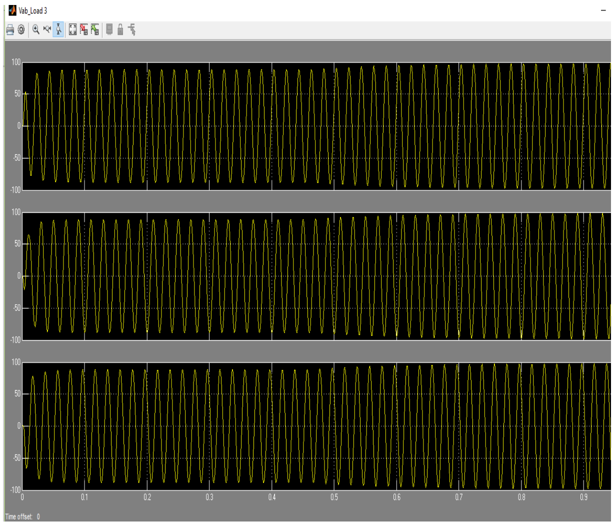


One-phase Output

In this, the one phase waveform Generator produces a variety of different waveforms at a desired frequency.

Three-phase Output



Three-phase Output

In this, the three phase waveform Generator produces a variety of different waveforms at a desired frequency.

V. CONCLUSION

Since, the demand for electrical energy in single-phase rural distribution grids has considerably increased in the last decades, it is possible to notice an increasing need to use three-phase distribution grids to meet the demand for electrical energy in rural areas Currently, most of them could be driven by three-phase induction motors instead of single-phase motors, for they have a higher starting torque. Thus the proposed system has three-phase four-wire electrical power distribution system, using a single- to three-phase unified power quality conditioner topology, called UPQC-1Ph-to-3Ph. This topology is indicated for applications in rural or remote areas in which, for economic reasons, only EPDS with single wire earth return are accessible to the consumer. Since the use of three-phase loads is increasing in these areas, access to a three-phase distribution system becomes preponderant.

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