

Single-Phase to Three-Phase UPQC for Quality Improvement in Domestic Distribution System

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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 disturbances, 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.

KEYWORDS: Dual compensation strategy, rural and remote areas, single-wire earth return (SWER), unified power quality conditioner (UPQC).

I.INTRODUCTION

Remote regions in Brazil, as well as in some areas of countries such as Australia and New Zealand, for instance, 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 [1]–[5], since lower installation and maintenance costs are achieved [4], [6]. 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. 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 [6]. The demand for electrical energy in single-phase rural distribution grids has considerably increased in the last decades, both in agriculture and in livestock, mainly due to the increasing evolution and modernization of the technologies used, as well as the increase in the mechanization of production processes. It is possible to mention, for example, the automation of irrigation, as well as the postharvest agricultural processing involving seed selection and milling, ventilation and refrigeration, washing and packaging lines, among others. The voltage regulation is characterized as one of the main problems of PQ found in the rural single-phase grids [4], [5], because when subjected to large loads, these grids have significant voltage drops, whereas at times of low consumption the voltage tends to rise [1]. Nevertheless, a solution not so efficient due to constant load variations can be

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adopted by adjusting the taps of the transformer of the SWER network. Another solution, more efficient in this case, is the use of single-phase voltage regulators [5]. Some ways to bypass large capital investments to meet the growing demand of rural properties have been adopted [3]. In [3], the impacts caused between distributed generation systems implemented through photovoltaic systems and the SWER distribution systems are presented. On the other hand, in [8], the use of energy storage systems by means of batteries and their use at peak demand is discussed. 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. Currently, most of them could be driven by three-phase induction motors instead of single-phase motors, for they have a higher starting torque [7]. Furthermore, the use of medium- and high-power three-phase voltage inverters involved in modern automated systems also justifies the need for three-phase grids in rural areas.

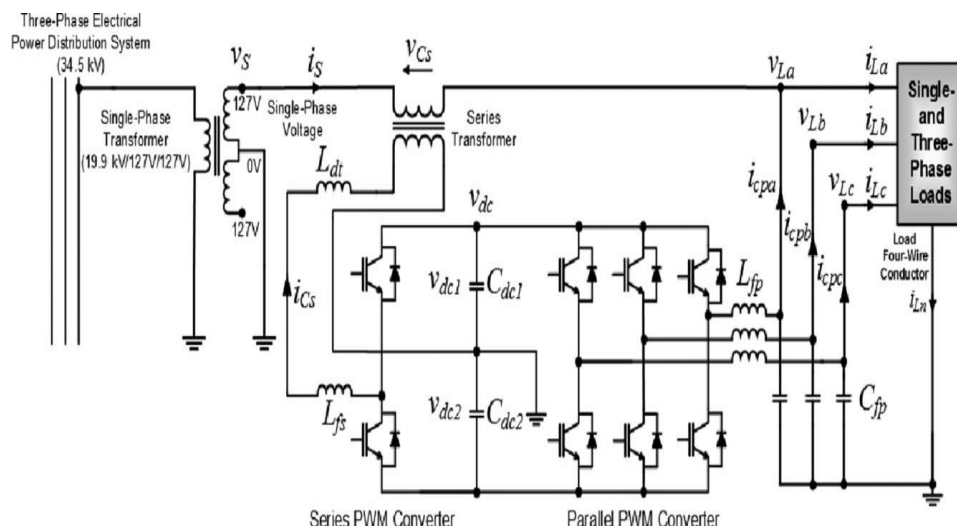


Fig. 1. Topology of the UPQC-1Ph-to-3Ph.

For this purpose, several solutions and/or configurations of single-phase-to-three-phase (1Ph-to-3Ph) converters have been addressed in the literature [6], [7], C.Nagarajan et al [6]–[8]. These include 1Ph-to-3Ph four-wire converters, which are able of supplying three-phase and single-phase loads [6], [7], [9], or 1Ph-to-3Ph three-wire converters intended to supply only three-phase loads. 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 in 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. In integrating the functionality of a UPQC, a 1Ph-to-3Ph converter was dedicated for creating a local three-phase four-wire (3P4W) EPDS from a single-phase distribution system. The series converter is composed of a half-bridge inverter (one inverter leg), while the parallel converter is composed of a three-leg split-capacitor inverter, totaling four inverter legs. Thus, it was allowed feed single- and three-phase loads. On the other hand, limited results have only been presented by means of simulations. In addition, no detail regarding to the dimensioning and control of the converters were suitably treated. In this paper, the 1Ph-to-3Ph converter presented in is experimentally validated. It is called UPQC-1Ph-to-3Ph and its power circuit configuration is shown in Fig. 1. This system is indicated for applications in rural or remote areas where, for economic reasons, only single-phase EPDS, such as SWER system, is accessible to the consumer. Once the proposed system deployed in this paper was conceived based on the UPQC functionalities, some discussions related to the UPQC should be performed. Since they simultaneously perform the functions of series active power filter (SAPF) and parallel active power filter (PAPF), the UPQCs have been commonly employed to mitigate PQ.

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The main contribution presented in this paper is 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.

III. RESULT AND DISCUSSION

The voltage regulation is characterized as one of the main problems of PQ found in the rural single-phase grids [4], [5], because when subjected to large loads, these grids have significant voltage drops, whereas at times of low consumption the voltage tends to rise [1]. Nevertheless, a solution not so efficient due to constant load variations can be adopted by adjusting the taps of the transformer of the SWER network. Another solution, more efficient in this case, is the use of single-phase voltage regulators [5].

Some ways to bypass large capital investments to meet the growing demand of rural properties have been adopted [3], [8]. In [3], the impacts caused between distributed generation systems implemented through photovoltaic systems and the SWER distribution systems are presented. On the other hand, in [8], the use of energy storage systems by means of batteries and their use at peak demand is discussed.

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. Currently, most of them could be driven by three-phase induction motors instead of single-phase motors, for they have a higher starting torque [7]. Furthermore, the use of medium- and high-power three-phase voltage inverters involved in modern 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

IV. CONCLUSION

The voltage regulation is characterized as one of the main problems of PQ found in the rural single-phase grids, because when subjected to large loads, these grids have significant voltage drops, whereas at times of low consumption the voltage tends to rise. Nevertheless, a solution not so efficient due to constant load variations can be adopted by adjusting the taps of the transformer of the SWER network. Another solution, more efficient in this case, is the use of single-phase voltage regulators. Some ways to bypass large capital investments to meet the growing demand of rural properties have been adopted. the impacts caused between distributed generation systems implemented through photovoltaic systems and the SWER distribution systems are presented. On the other hand, the use of energy storage systems by means of batteries and their use at peak demand is discussed. 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. Currently, most of them could be driven by three-phase induction motors instead of single-phase motors, for they have a higher starting torque. Furthermore, the use of medium- and high-power three-phase voltage inverters involved in modern automated systems also justifies the need for batteries and their use at peak demand is discussed

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