A Method for Power Conditioning with Harmonic Reduction in Micro grids

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***Abstract.* This paper presents a control method of Renewable Energy Sources (RES) to reduce the harmonic content of the distribution system to which are connected, such as a Microgrid. By this method the RES is acting as a Power Conditioner and its supplying system consists of a buck-boost converter connected back-to-back to a polarity swapping inverter. A RES or a Distributed Generator (DG) such as a micro turbine is synchronized to the distribution system, which is assumed to be distorted by a high-order voltage harmonic. Utilizing the proposed method, the RES not only exports its output power to the grid, but also reduces the existing harmonic distortion, improving voltage quality at the Point of Common Coupling (PCC). Simulations in Matlab/Simulink platform have been performed in order to verify the effectiveness of the suggested approach to reduce harmonic content.**

Key words:**Power Conditioner, Harmonic Reduction, Microgrid, Power Quality, Buck Boost Converter.**

I. Introduction

Nowadays there is a significant trend for distributed and renewable generation. These types of generation have many advantages compared with conventional generation, such as low fuel cost, small or no environmental footprint and higher efficiency. The volatility of those power resources together with some technical difficulties interfacing them to the distribution system, created a worldwide scientific interest in the formation of a new type of grid, the microgrid [1]. In its final form, the microgrid will be able to accommodate RES without disturbing system operation. Microgrids are supposed to interconnect with the already existing grids, maintaining at the same time the capability to isolate themselves from the grid (i.e. islanding) whenever a fault jeopardizes their security or the security of the grid to which they are connected. A lot of power conditioners and active filters have been proposed worldwide in order to alleviate the distribution system from the problem of high order harmonic distortion and improve power quality. Harmonic distortion occurs due to a number of reasons, such as loads' behavior, their converter's switching operation and the switching operation of the RES' inverters connected to the grid. The use of inverters may have a lot of advantages, such as fast voltage and frequency regulation, but also displays an important drawback. They export high order harmonics to the grid due to the switching operation of the semiconductors included in them. Similarly, harmonic distortion occurs due to loads supplied by converters as well to their inductive behavior. Harmonic distortion leads to poor power quality to the end user. Many power conditioners and active filters configurations have been implemented, but few of them deal with grid's power quality improvement. Instead, they focus in harmonic cancellation and power quality improvement of critical loads against grid's distortions. In reference [2], a harmonic compensation method, based on closed-loop synchronous frame control of line currents as well as a selective open-loop approach based on load current sensing are presented, concluding that the proposed method is robust enough for compensating distortions provoked by non-linear loads, but it operates only when the distorting loads have slowly varying high-order harmonics. In [3], a signal processing system for harmonic and current components calculation is introduced. This system is adopted as a part of a single-phase active power filter and results in a satisfying compensation, although it may lack implementation ease. Moreover, in [4] an interesting approach has been made, proposing a multifunctional series power quality conditioner. This conditioner consists of one series and one shunt part and is based on an asymmetry cascade multilevel inverter, which has low switching losses and implementation difficulty. This conditioner can efficiently compensate load harmonic current and improve power quality of the end user, but it does not take into consideration a potential inductive source, such as a wind turbine. Reference [5] suggests an active filter based on a space vector modulation (SVM) controlled converter for harmonic compensation and power factor correction, but it exhibits robust behavior only with balanced dc side voltages. A robust adaptive control strategy of active filters for harmonic compensation, power factor correction and balancing of nonlinear loads is implemented in [6]. It shows satisfying performance and has fewer sensors, but a bulky capacitor bank is used. Moreover, an alternative implementation of active filters in High-Voltage Direct Current (HVDC) application in dc transmission systems has been made, showing widely developed applicability of such devices and making clear the importance of harmonic compensation and power quality improvement[7]. Besides active filters, a large number of power conditioners has been proposed worldwide in order to improve power quality and reduce harmonic content of critical loads against utility system distortions or DG unbalance. The aim of these conditioners is to protect certain loads from poor power quality, but none of them deals with the alleviation of grid's high-order harmonic distortion. Reference [16] suggests a method that uses residential PV panels in order to compensate harmonic distortion in distribution system which is produced by nonlinear loads and/or capacitor banks installation. Virtual harmonic resistance control scheme is implemented to achieve harmonic compensation. A virtual harmonic impedance control scheme which would be suitable for microgrid implementation is also mentioned. Moreover, authors present and compare two different harmonic compensation schemes, in order to determine which method will be suitable for usage in any case, although system's load must been known so that the decision can be made. These methods are distributed compensation configuration, the operation of all the parts of the proposed power conditioner as well as the synchronization procedure. Section 3 presents the simulation results in the MATLAB/SIMULINK platform. Simulations results verify the proposed method. Conclusions are drawn in section 4.

II. The Suggested Power Conditioner and the Studied Microgrid

In this section the topology and operation of the parts of the proposed power conditioner, as well as its grid synchronization procedure are described.

A. Topology and Operation of the Power Conditioner

The suggested power conditioner is connected to the PCC. The aim is to alleviate the already existing high order harmonics in order to cope with Distribution and Utilization standards (IEEE519-92) [21]. These standards dictate that the percentage of the Total Harmonic Distortion (THD) in every node of the system and for every device which is connected to it should be less than 5%. Fig. 1 shows the configuration of the studied system.The studied system consists of the power conditioner supplied by a RES and it is connected through an impedance to a weak and harmonically distorted microgrid. RL emulates the load at the PCC.

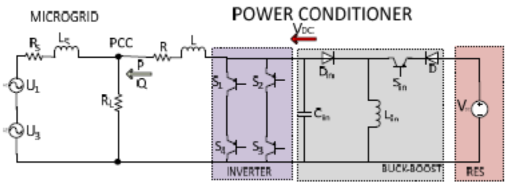
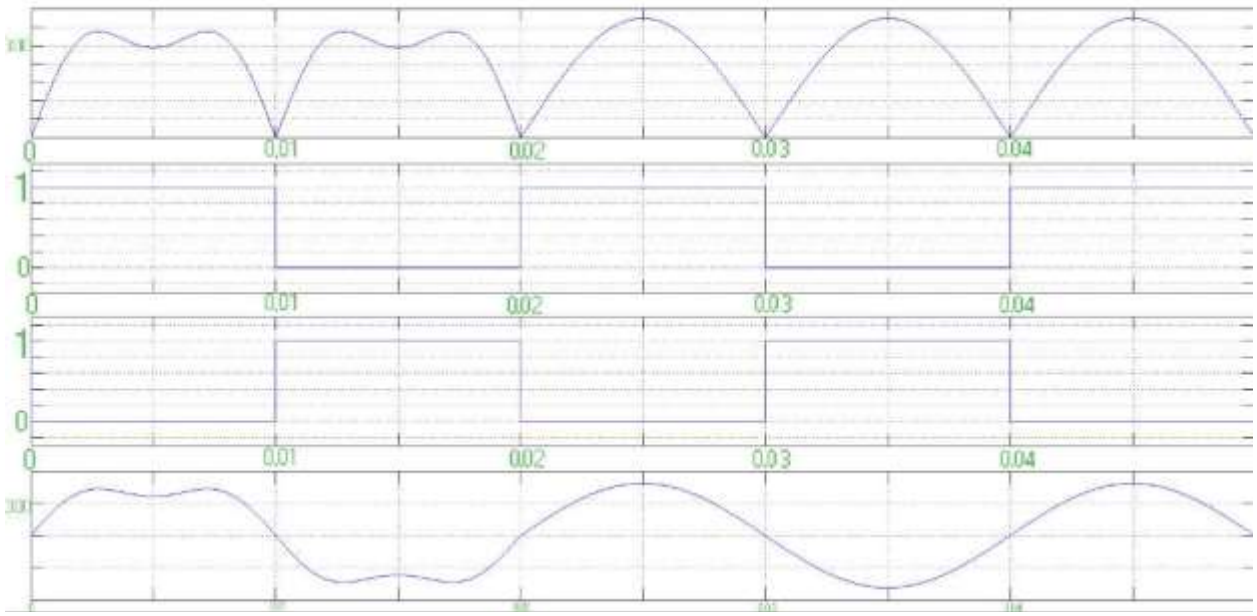


Fig. 1. Configuration of the studied system.

The dc voltage produced by the RES is being fed to a dc/dc buck -boost converter. The topology of the buckboost converter is shown in fig. 1. This converter operates at a high switching frequency (e. g. 20 KHz). The duty cycle D is being continuously calculated under the above mentioned frequency using Pulse Width Modulation (PWM) technique [20], and it is given by:

This constant calculation takes place in order to create a rectified voltage. This voltage is being fed to the polarity swapping inverter that operates at a low switching frequency (50 Hz) and inverts the dc voltage to ac. Furtermore, an on-line Fast Fourier Analysis (FFT) of the harmonic content at the PCC takes place, so that information of the exact amplitude and angle of PCC's. harmonics is obtained. The power conditioner injects the exact amount of high order harmonic, so that the THD is reduced. In order to eliminate the existing distortion the injected harmonic component will have the same amplitude but a 180° phase shift in relation with the one existing in the grid. This sine wave is being fed into the 20 KHz PWM duty cycle calculation, so that proper pulses are created in order to shape converter's output sine voltage. The inverter is only responsible for swapping the output voltage of the buck-boost converter so that a suitable ac voltage is generated. Therefore, the switching frequency is 50 Hz as grid's frequency. Inverter's low frequency is one of the major advantages of this power conditioner, as it combines harmonic reduction along with low switching losses. A single phase full-bridge topology was selected. This topology consists of four semiconductors which are triggered in pair (S1-S4, S2-S3). The inverter is synchronized with the chopper in order to change output voltage polarity. Every time buck boost's voltage becomes zero (or at least reaches its minimum value), inverter's conducting pair changes. The topology of the used inverter is shown in fig. 1. In fig. 2 an example of inverter's operation is illustrated, showing: (a) buck boost's output voltage, (b)S1 S4 semiconductors pulses, (c) S2 S3 semiconductors pulses (d) inverter's outputvoltage.



B. Harmonic Cancellation Method

The generation of the required harmonic component is feasible via proper pulse modulation of the buck-boost conditioner. The key idea is that proper trigger pulse generation will lead the converter to create a voltage containing the suitable for the occasion mirror harmonic content, resulting in harmonic compensation. Buckboost's trigger pulses are being initially created by the comparison of the rectified PCC's voltage signal and the 20 KHz reference triangle, taking into consideration the duty cycle D of buck-boost, given by (1). After synchronization an FFT analysis of PCC's voltage takes place. A sine wave, the mirror harmonic of grid's high order harmonic component that has the same frequency and amplitude but a 180° phase shift from it, is added to the 50 Hz sine signal during the pulse generation modulation. Afterwards, FFT is carried out again so that information about the alternation of the harmonic content is obtained.

III. Conclusion

A novel system of a RES connected with an electronic converter was proposed to act as a power conditioner, through a pulse technique of high harmonic injection to a microgrid. Main advantages of the proposed topology are its robustness, its converter's low switching losses and the simplicity of its harmonic control. Its performance was verified by a series of simulations. The simulation results proved robustness and efficient operation of the proposed power conditioner under different and difficult conditions, such as a severally distorted grid. Simulation results show that the power conditioner achieves harmonic compensation that leads to a Total Harmonic Distortion (THD) less than 5%, as dictated by standards. Implementation of this configuration to future microgrids would alleviate the problem of high order harmonics. Power conditioner's operation in transients as well as its economical and technical evaluation should be examined in future research. Therefore, a RES (or generally a DG) which will be connected to a microgrid via this power conditioner will be able not only to export its generated power to the grid, but also improve power quality of the grid.

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