Control Active Power Filter for improving Power Quality in the Micro-grid

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Abstract

This paper aims at improving the power quality with controlling method shunt active power filter in Micro-grid System. A hybrid compensation system consisting of an active filter and passive filters in the Micro-grid is discussed. Passive filter is connected to a distortion source and designed to eliminate main harmonics and supply reactive power for the distortion source, while the active filter is applied to the correction of the unbalance condition a system and cancellation of the remaining harmonics. In order to examine the proposed method, simulations are carried out in the case of the distribution system with dynamic nonlinear loads and Micro turbine. Several dynamic nonlinear loads without any filters using just shunt active filter, passive filter and the proposed hybrid structure. The performance of the proposed system was analyzed and simulated via MATLAB software. The results confirm the validity of the proposed approach to eliminate undesired harmonic and distortion.

Keywords: Micro-grid, Active Filter, Passive Filter, Dispersed Generation, Harmonic, Power Quality.

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1. Introduction

The concept of Smart Grid is modernizing the electrical grid, that integrating the electrical and information technologies between any Generation point and any Consumption point [1]. These networks use power electronic devices, and related controls for efficient use of electrical energy. An electrical system often supplies consumers with various types of loads, including nonlinear loads, such as single-phase and/or three-phase thyristor converters, diode rectifiers and uninterruptible power supplies. These nonlinear loads consume reactive power, produce harmonics and make the system unbalance The situation becomes more serious with the development of the dispersed generation (DG) where power electronic converters are often used to connect the generation units, such as wind turbines, fuel cells and Micro turbine, etc. The power electronic devices generate harmonics and require reactive power. Micro turbine unit implementation is not always perfect and usually different power quality problems such as: Low power factor, reactive power consumption, voltage flicker and fluctuation and different harmonic. Therefore; develop and use effective power quality instruments to reduce the harmonic content of current, compensate reactive power and increase the power quality of the distribution systems are desired. Active and passive filters have proven their effectiveness in limiting and removing harmonics and improving power factor and THD of the system's current. But these types of filters increase the possibility of resonance in the system for dynamic loads [2]. Although, passive filters have low costs, they cannot be considered as an effective method to improve the power quality of the distribution system. On the other hand, active filter implementation is usually an expensive method in power applications. Regarding all the above, hybrid filters introduce to power systems as the best solution of power quality improvement due to their feasible cost, and high ability in removing harmonics. The topology of shunt-connected active power filter, with a self controlled DC is similar to static compensator which is used for reactive power compensation in power transmission systems. Load current harmonics can be compensated by injecting equal but in contrary direction harmonics using shunt active power filters. In fact, active filter can be considered as a current source which generates the load current harmonics phase shifted by 180°. A simple procedure of active filter implementation is shown in Figure 1.

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Moreover, fundamental voltage disturbances can be effectively improved using series filters [3].

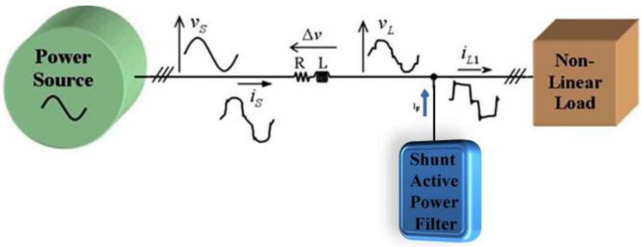

Figure 1. Filter current & generated to compensate load-current harmonics

2. Micro-Grid

The Micro grids are growing due to speedily growing distributed power generation systems. Micro grid control flexibility of the network to carry out reliability and power quality requirement. A typical micro grid is normally consists of rotating generators or Distributed Energy Resources (DER) which is connected by power electronic inverters. Generally, DERs are one of popular power system generators such as, wind, geothermal, fuel cells, solar, biomass, steam or gas turbines. The micro grid is able to optimizing DPGS via the combined heat and power (CHP) generation to increasing energy efficiency. The connected loads to micro grid system are divided into critical or non-critical load. Critical loads need a reliable power with good power quality [4]. The micro grid is connected to the utility system through a circuit breaker, which is also called Static Transfer Switch (STS) at the Point of Common Coupling (PCC). The circuit breaker ensures that the micro grid is able be disconnected from the main grid promptly during a utility interruption. Micro grids are normally operated in grid-connected mode which in addition is expected to provide generation capacity, controls, and operational strategies. These strategies are applied to supply at least some portions of the loads after disconnecting from the distribution system as a standalone (islander) system [5, 6, 7]. Simply, the inverters used in micro grids behave as current sources when they are connected to the grid and as voltage sources when they work autonomously [8]. This consisting the change of the controller when the operation mode changes from separate to grid-connected or contrariwise. Micro grids require wide-range control to ensure system security, optimal operation, emission reduction and seamless transfer from one operating mode to the other without violating system constraints and regulatory requirements. As unbalanced or nonlinear loads can demonstrate a high ratio of the total load in small-scale systems, the difficulty with power quality is a specific concern in micro grids [9].

3. Power Quality Problems of DG Unit

Dispersed generation systems are necessary regarding the future demand of power markets. Several technical aspects like low power quality of micro-grid systems and necessitates the usage of power quality improvement facilities in parallel with micro turbine systems is reported as drawback [10-11]. Voltage fluctuations are remarkable in the case of micro turbine unit installation especially at connection points which is usually due to the micro turbine unit switching.
Consequently, in order to prevent the power instruments and costumers from damage, and in order to limit the voltage fluctuation in the desired range, load flow analysis system is considered. Technically, the existence of high contents of harmonics and inter harmonics in the current waveform of the system is seen as the most important power quality problem of dispersed generation system. There are several solutions to limit the harmonic's level of generating power less than their standard values such as limiting the maximum output power of micro turbine units in the system or use effective power quality improvement or harmonic removal facilities in the power system. An effective solution for the improvement of power quality aspects of micro turbine unit is proposed and studied in this paper [12].

4. Filter System

Eliminating harmonics by hybrid filters require knowledge on passive and active filter. Although passive filters are cheaper than active filters, but the efficiency of active filter in damping harmonics is more suited than a passive one. Therefore, in this research the combination of these two filters is used to overcome aforementioned drawbacks.

4.1 passive filters

Passive filters are often designed to provide a harmonic sink in their frequency transfer function, a low impedance path at certain frequencies to eliminate specific current harmonics. A six pulse thyristor converter load need a passive filter tune at 5th and 7th harmonic frequencies and higher. Figure 3 portrays a shunt filter which is included the single tuned filters for 5th and 7th harmonics and higher. The passive filter has lower impedance than the system impedance at the tuned frequencies (5th and 7th frequencies). Therefore, harmonic filtering improves power quality by decreasing the harmonic impedance of the passive filter. In addition, passive filter bank generates reactive power in presence of fundamental voltage,

4.2 Active filters

Modern applications of power electronics are used in active power compensators for the generation of various current or voltage harmonics. These appliances compensate the system current and voltage harmonics by generating a harmonic current or voltage in opposite phase to the harmonic current or voltage to be corrected. Parallel compensation and series compensation are the main two basic configurations of active filters. In a parallel compensation, the compensator is normally connected to the circuit in parallel and injects a compensation current at the connection point. On the other hand, a series compensator is connected into the circuit in series, usually through a transformer, to insert a compensation voltage into the circuit. Normally, the thyristor converter discussed in the paper is considered as a harmonic current source, while the parallel compensation system is the choice.

4.3 Hybrid filters

Active power filter and passive filters are combined with hybrid filters which have both active and passive advantages and lower costs. As well as, these filters decrease the probability of resonance and non dynamic responses and also high costs of active filters [13-14].

5. Control of the Active Filter

The configuration of the control system is shown in Fig. 3 [15]. It is based on duplication of controller to reach to zero steady-state error; when the reference current has a high harmonic content. The harmonic compensation achieves good performance in terms of harmonics mitigation by modelling the current control (in this case, a PI control). The Discrete Fourier Transform (DFT) provides selective compensation with unity gain for harmonic compensation.

The discrete transfer function of DFT is given by:

$$F_{DFT}(z) = \frac{2}{N}\sum_{i=0}^{N-1}\left(\sum_{k\in N_h}\cos\left(\frac{2\pi}{N}h(i+N_a)\right)\right)z^{-i} \quad (1)$$

Where N is the number of the modulus, N_h is the set of selected harmonic frequencies and N_a is the number of leading steps necessary to maintain the system stability. In addition, the parameter k_R determines the response speed of the controller (Block diagram of Fig.2) [15]. In addition, the complexity of the repetitive control does not change by increasing the number of the compensated harmonics. A different essential appearance concerning the repetitive control is the smaller number of parameters when compared to other frequency techniques, while employing multiple rotating integrators or multiple resonant controllers.

6. System Configuration

The configuration of the studied system is illustrated in Figure 3. It is consist of distribution system with several nonlinear loads as well as various types of micro turbine unit like micro turbine.

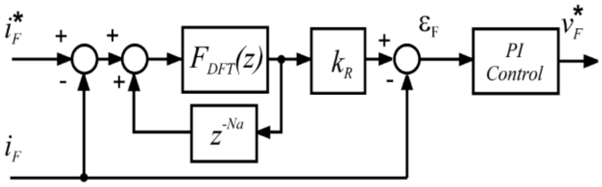

Figure 2. Current Control Scheme for the active filter.

In this research, power quality of dispersed generation systems is discussed. Moreover, the benefits of using hybrid filters instead of only active or passive filters have been investigated. The proposed hybrid filter is made of a shunt active filter and distributed passive filters which are connected in parallel with a Micro turbine. Regarding to parameters of passive filters, and control system of active filter, different power quality for this topology are studied.

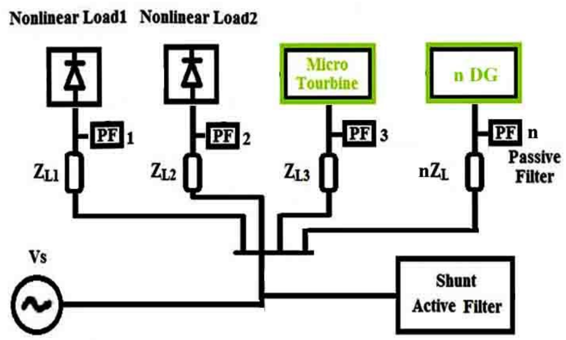

Figure 3. Schematic of the simulated study case.

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7. System Impedance characteristics

Connecting of multiple passive filters to system will change the impedance matrix. Consequently the efficiency of filtering system and resonance harmonics is changed. Therefore, it is necessary to study the system impedance characteristics to avoid such undesirable phenomenon.

Generally there are two main harmonic sources namely voltage harmonic sources and current harmonic sources. Parallel filters are more useful in elimination of current harmonics. However, passive filters are tuned voltage harmonics within the frequency range.

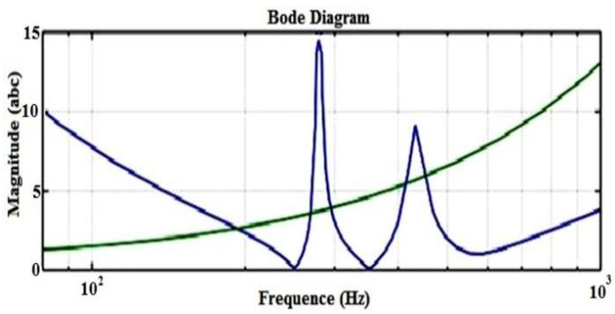

Figure 4. Shunt Passive filter characteristics.

In Figure 3, the topology of distribution network is formed by micro turbine unit and two loads. load1, load2 and micro turbine are considered as current sources which are injected current harmonics to the system. A linear relation between the inductance and frequency is assumed. To illustrate the effects of line length on the impedance characteristics, another set of line parameters for shorter electrical distance (1/5 of Z_{L1}, Z_{L2} and Z_{L3}) is explained. Table I illustrates desire system characteristics.

TABLE I. LOAD DG PARAMETERS AND CONDITION FOR THE SYSTEM STUDIED

Identifier	Component of Load/DG	Associated Passive filter	Current (THD)
Load1	Three unbalanced single phase diode rectifier	PF2	14,14.23 ,14.34
Load2	Three phase diode rectifier	PF3	14
DG1	Micro turbine	PF1	28

8. Simulation studies

A comprehensive simulation study is performed on MATLAB software package on the system illustrated in Fig. 3. To have better simulation a sinusoidal voltage for the network is assumed. The uncompensated loads current waveform is shown in Fig. 5. Full load current of DG units is illustrated in Fig. 6. By comparing the waveforms in Figs. 5 and 6, is addressed the efficiency of passive filter.

The active filter is switched on at 0.1 seconds. Fig .7 portrays the current waveforms in line branches of active filter and passive filter. Fig. 8 presents the injected current waveforms by the active filter when micro turbine units, loads and filters are in operation. Before the active filter is switched on, the system current is unbalanced and contains harmonics.

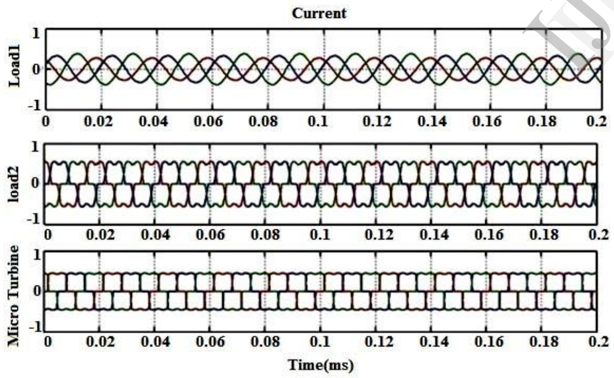

Figure 5. Current waveforms of DG unit and loads any compensators

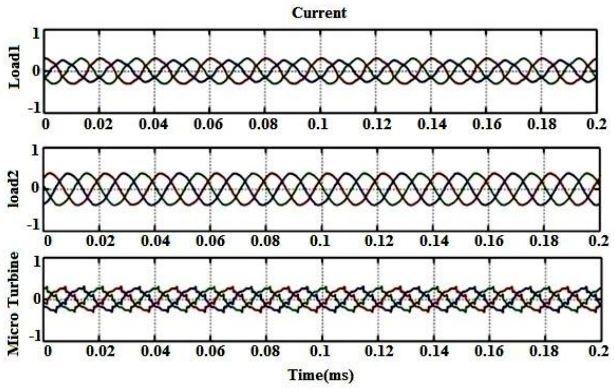

Figure 6. Current waveforms in line branches after passive filters

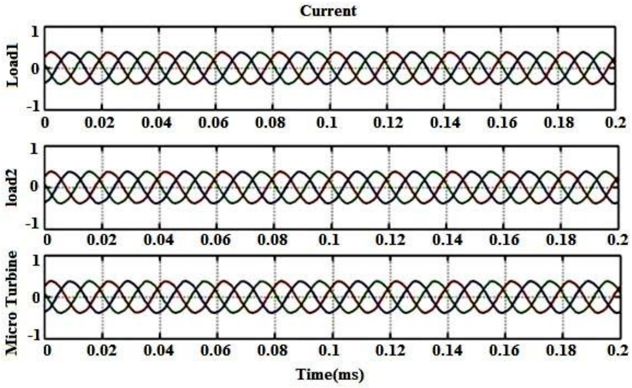

Figure 7. Current waveforms in line branches after Active filter and passive filters

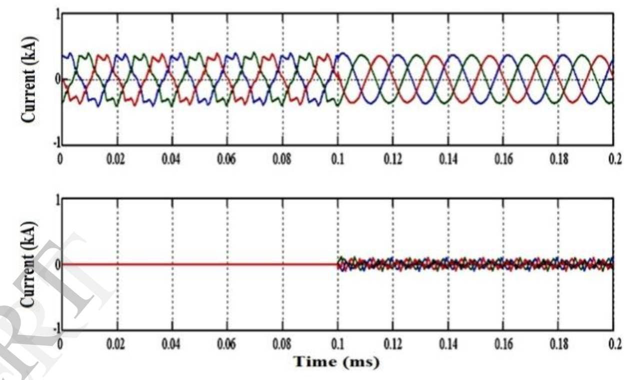

Figure 8. System and active filter current waveforms

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9. Conclusion

Investigating of proposed control strategy for the generation system presented in Fig. 2 and power quality compensation of the distribution system is done in MATLAB software. Passive filters are used to eliminate harmonics and reactive power compensation for each distorting load/DG. The active filter is connected in parallel with the distributed passive filters and loads/DGs to correct the system unbalance and eliminate the remaining harmonic components. Simulation results show that by using passive and active filters, high harmonic contents of nonlinear loads and micro turbine unit are removed. When the passive filters are in operation, the harmonic and unbalance waveforms have been corrected. The active filter is controlled harmonic compensation and unbalance waveform, but it is not compensating the reactive power. The effectiveness of the proposed hybrid filter in removing current harmonics and decreasing its THD was compared in different cases.

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