Harmonic Distorted Load Control in a Microgrid

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ABSTRACT
In this paper the response of a microgrid to the interfaced harmonic distorted load is analyzed. A new control algorithm to mitigate harmonic distortion is considered for distributed generators (DGs) and the effect of this control scheme is shown in the currents of DGs and other loads.

The proposed control algorithm is compared with the conventional control strategy for harmonic distorted loads that is sinusoidal source current strategy based on the instantaneous reactive power (IRP) theory. PSCAD simulation results for IRP theory control show high total harmonic distortion (THD) and 3rd harmonic percent. In comparison inner voltage and current controllers of the proposed control scheme with their disturbance rejection capability, mitigate THD and 3rd harmonic percent. For this control system MATLAB simulation results are shown.

By demonstrating the traditional sinusoidal source current control strategy based on IRP theory, it is concluded that ignoring the distortion power (D) in compensating process and also sub-harmonics of $P\alpha\beta$ crossing from the controller interior high pass filter cause the presence of some harmonic components and high THD.

Keywords: distributed generation, instantaneous reactive power theory, harmonic distortion, microgrid.

1. Introduction

Power electronic devices have been widely used with different operations in power system. As the aspect of loads these nonlinear structures provide high efficiency and controllability, while decreasing overall power quality by distorting source voltages and/or currents. This causes pollution in power system that is harmful for sensitive loads, such as computers and processor controlled based devices.

In 1976, Gyugyi presented active filters and the concept of harmonic distortion mitigation, consisting of PWM inverters using active power switches [1].

In the past, the performance of active filters was considered with the battery as a dc source [2] but recently using distributed generator as an active filter is considered. Many literatures have already proposed new techniques to alleviate the harmonics produced by nonlinear loads [3] and many researches have been done on this control scheme. In [4] the use of automatic gain control in the shunt active power filter for harmonic reduction in a distorted power system is presented. In [5] digital-controlled active filter, based on voltage recognition to decrease harmonic distortion is proposed. The application of neural networks as a smart control scheme for a shunt active filter has been described. Other intelligent control algorithms such as artificial intelligence and genetic as controllers for active filters can also be used [6].

The instantaneous reactive power (IRP) theory (p–q theory) that is presented by Akagi and developed by others, provides mathematical methods for the control of PWM inverter based switching active power filters [7-9]. Although there is still no exact information with respect to the definition of power concept in power system with non-sinusoidal and unbalanced conditions, the p–q theory seems to be well established in power system compensation [10-12].

Since the p–q theory was proposed, many control methods based on instantaneous reactive power theory have been presented for the harmonic compensation strategies of the active filters and power quality enhancement [13-17]; “constant source power” and “sinusoidal source current” are effective control schemes used in different applications. Development of IRP theory in recent studies is also remarkable [18-21].

Recently the growing integration of renewable energy resources into power networks has had a significant impact on power system [22]. Distributed generation and microgrid are new concepts in power system studies and inverter interfaced DGs can play an important role in harmonic distortion mitigation [23].

In this paper, in order to evaluate the effectiveness of IRP theory control strategy, an experimental microgrid is studied and simulated in PSCAD based on sinusoidal source current strategy. DG operates as a shunt active filter. Different harmonic distortions are applied to the aforementioned load; Source and load currents THD and third harmonic percent before and after the DG location are observed. In order to reduce THD in the source and other load sides, a new control strategy for DGs in a microgrid is presented and the results are compared with the IRP control theory.

2. P-Q Control Strategy

Conventional control strategy for active power filters is based on p-q theory which is called IRP (instantaneous reactive power) theory. This control scheme is used to detect and compensate undesirable powers. To achieve this goal active and reactive powers are calculated in time domain and presented in a coordinate frame in which power components are obvious. Clarke Transform of voltages and currents specified in phase a, b and c coordinates, as shown in figure 1, into quantities in orthogonal α , β and 0 coordinates can help us to achieve this goal.

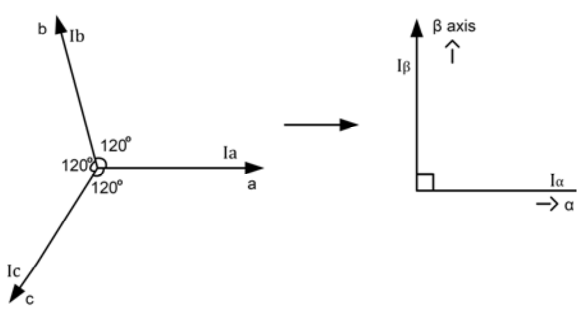

Figure 1. coordinate frame transform.

Clarke Transformation of three-phase voltages and currents has the form below.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad (2)$$

and consequently, instantaneous active and reactive power of such a system are equal to:

$$\begin{bmatrix} p_0 \\ p_{\alpha\beta} \\ q \end{bmatrix} = \begin{bmatrix} v_0 & 0 & 0 \\ 0 & v_\alpha & v_\beta \\ 0 & -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} \qquad (3)$$

Active power is presented in two separate zero and summation of positive and negative consequence modes. If the voltage and current of such a load has the form (4) and (5) respectively:

$$v(t) = \sum_{n=1}^{\infty} \sqrt{2} v_n \sin(n\omega t + \phi_n) \qquad (4)$$

$$i(t) = \sum_{n=1}^{\infty} \sqrt{2} i_n \sin(n\omega t + \delta_n) \qquad (5)$$

According to the previous equations we can represent the active and reactive powers as:

$$p_{\alpha\beta} = \overline{p}_{\alpha\beta} + \widetilde{p}_{\alpha\beta} \qquad (6)$$

$$\overline{p}_{\alpha\beta} = \sum_{n=1} 3v_{+n} i_{+n} \cos(\phi_{+n} - \delta_{+n}) + \sum_{n=1}^{\infty} 3v_{-n} i_{-n} \cos(\phi_{-n} - \delta_{-n}) \qquad (7)$$

$$\widetilde{p}_{\alpha\beta} = \sum_{\substack{m \neq n \\ m=1}}^{\infty} \sum_{n=1}^{\infty} 3v_{+m} i_{+n} \cos((m-n)\omega t + \phi_{+m} - \delta_{+n})$$

$$+ \sum_{\substack{m \neq n \\ m=1}}^{\infty} \sum_{n=1}^{\infty} 3v_{-m} i_{-n} \cos((m-n)\omega t + \phi_{-m} - \delta_{-n})$$

$$- \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} 3v_{-m} i_{+n} \cos((n+m)\omega t + \phi_{-m} + \delta_{+n}) \qquad (8)$$

$$p_0 = \overline{p}_0 + \widetilde{p}_0 \qquad (9)$$