An Overview of Improvement of the Electrical Energy Quality using a Shunt Active Filter Supplied by a Photovoltaic Generator

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Abstract-
The issue of the quality of the electricity supplied to consumers has surfaced during the usage of the traditional electrical network for a number of years. This is because nonlinear loads are becoming more and more prevalent on the network; they are a source of harmonic pollution, which causes many disruptions and impairs the efficient operation of electrical equipment. In this work, we suggest a method for simultaneously compensating the reactive power and the harmonic currents caused by the nonlinear loads. This is achieved by using a Shunt Active Filter that is provided by a solar generator. The PWM control approach is employed in the control and regulation algorithm of the three-phase inverter that functions as a harmonics compensator. We start by identifying the reference currents, which enable us to regulate the injected currents into the network. This is made possible by a regulator that establishes the PWM control inverter's reference voltage. Finally, we were able to get extremely strong compensation performances in terms of a decrease in the harmonic distortion rate and an increase in the power factor thanks to the numerical simulation of the photovoltaic compensation system that we used in this study.

Keywords— *Quality of Electricity Supply, Disruptions and Impairs the Efficient Operation of Electrical Equipment, PWM Control.*

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INTRODUCTION

One crucial indicator of an electrical power system is Power Quality (PQ). To preserve a fully sinusoidal current wave form in phase with a purely sinusoidal voltage wave form is referred to as PQ. The producing station produces power that is exclusively sinusoidal in nature. Current and voltage harmonics caused by the widespread use of power electronics-based equipment, such as electronic power supplies, DC motor drives, adjustable-speed motor drives, battery chargers, and electronic ballasts, are primarily to blame for the declining quality of electricity. In general, these nonlinear loads use reactive power and absorb non-sinusoidal currents.

Through the point of common coupling, harmonic currents created by nonlinear loads are fed back into power distribution networks. As the harmonic currents pass through the line impedance of the system, harmonic voltages appear, causing distortion at the point of common coupling. Harmonics have a number of undesirable effects on the distribution system. They fall into two basic categories: short-term and long-term. Short-term effects are usually the most noticeable and are related to excessive voltage distortion. On the other hand, long- term effects often go undetected and are usually related to increased resistive losses or voltage stresses. In addition, the harmonic currents produced by nonlinear loads can interact adversely with a wide range of power system equipment, most notably capacitors, transformers, and motors, causing additional losses, overheating, and overloading. These harmonic currents can also cause interferences with telecommunication lines and errors in metering devices. Because of the adverse effects that harmonics have on power quality, Standard has been developed to define a reasonable framework for harmonic control. The need to generate pollution-free energy has triggered considerable effort toward renewable energy (RE) systems. Renewable energy sources such as sunlight, wind, flowing water, and biomass offer the promise of clean and abundant energy. Among the renewable energy sources, solar energy is especially an attractive option. This useful energy is supplied in the form of DC power from photovoltaic arrays (PV) bathed in sunlight and converted into more convenient AC power through an inverter system. Efforts have been made to combine the Shunt Active Filter with photovoltaic system. The photovoltaic arrays interactive shunt active power filter system can supply real power from the photovoltaic arrays to loads, and support reactive and harmonic power simultaneously to use its almost installation capacity. This technology has many excellent features: it causes little environmental burden, it is of a modular type technology that can be easily expanded, and it is applicable almost everywhere. This paper presents an analysis and simulation of a PV (supported by a MPPT controller) interactive Shunt Active Filter topology that achieves simultaneously harmonic current damping and reactive power compensation. For the Shunt Active Filter reference current computation we use the real and imaginary instantaneous powers theory, and for gating signal generation we apply the carrier-based PWM modulation. Fig. 1 shows the proposed system; a dc-dc converter can be used to adjust the value of the output voltage of PV energy source to the voltage value of the dc-side capacitor of the Shunt Active Filter, three-wire systems and nonlinear loads. In the day-time with intensive sunlight, the PV interactive Shunt Active Filter system brings all its functions into operation. At night and during no sunlight periods, the power required by the loads is received from the distribution system while the inverter system only provides reactive power compensation and filter harmonic currents.

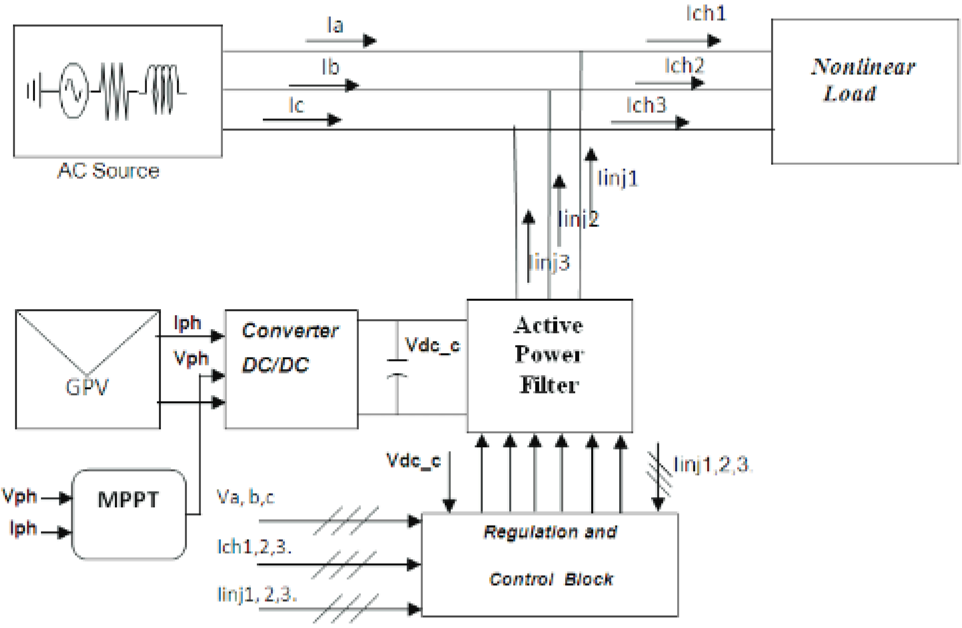

Figure 1- Configurations of photovoltaic interactive Shunt Active Filter system

DC-LINK SYSTEM FOR VOLTAGE REGULATION

Two voltage control loops one for the DC/DC converter and one for the inverter voltage loop are included in the suggested approach for managing the DC link in this system. Two voltage loops are necessary so that a controller will be left to maintain the DC link voltage in the event that the DC/DC converter shuts down and no longer has energy from the PV array. The inverter DC voltage control loop bandwidth was designed to be at least ten times smaller than the bandwidth of the DC/DC converter voltage loop in order to prevent interference between the two controllers. The DC/DC converter voltage loop dominates the inverter voltage loop while the PV array is operational and when the DC/DC converter shuts down the inverter voltage loop takes over control of the DC link voltage. Simulations of the loop gain for the DC/DC voltage loop and the inverter voltage loop show that when the DC/DC converter is in operation, the inverter voltage loop gain is never greater that unity and when the DC/DC converter shuts down the inverter voltage loop gain rises back up to its designed bandwidth. The principle of DPC has been proposed in and developed later in many applications. The objective is to eliminate the modulation block and internal loops by replacing them with a switchboard whose inputs are the errors between the reference values and the measurements. With the DPC there is no current control loop or PWM modulation element, because the switching states of the inverter, for each sampling period, are selected from a switching table, based on the instantaneous error between reference values and those measured or estimated active and reactive powers, and the angular position of the

source voltage vector. Generally, with this control strategy, the DC bus voltage is regulated for active power control and operation with a factor of unit power is obtained by imposing the reactive power at a zero value.

MAXIMUM POWER POINT TRACKER (MPPT)

The maximum power point of a solar array is the point along the I-V curve that corresponds to the maximum output power possible for the array. This value can be determined by finding the maximum area under the I-V curve. Fig. 2 Typically, the MPPT is achieved by interposing a DC-DC converter between the PV generator and the load, thus, from the voltage and/or current measurements, the MPPT algorithm calculates the optimal duty cycle (D) in order to maximize the power flow. Obviously, as the radiation and temperature are dynamic variables, the MPPT algorithm must work practically in real time, updating D constantly and keeping the accuracy and speed of tracking. Perturb and Observe (P&O) is one of the most used MPPT algorithms in PV tracking systems. The main advantage of this technique is that the search for the MPP will be done independently on the environmental conditions, however its implementation require a voltage and a current sensor. When in operation, the P&O algorithm calculates the PV output power P(n-1)=I(n-1)*V(n-1) and causes a perturbation on the duty cycle D . If after the perturbation the power P(n)=I(n)*V(n) increase P(n)>P(n-1), the perturbation is kept at the same direction. On the other hand, if after the perturbation the power P(n)=I(n)*V(n) decreases, P(n)<P(n-1), the direction of the duty cycle is inverted.

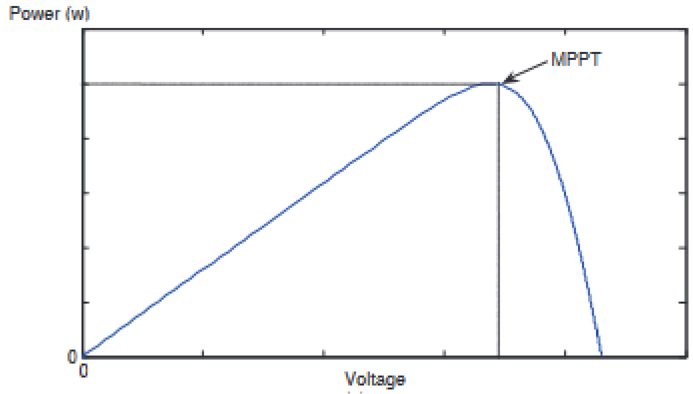

Figure 2-Example PV array V-I curve

CONTROLLER AND MODEL FOR SHUNT ACTIVE FILTER

The Shunt Active Filter power stage is a six switch current bi-directional converter that consists of a switching network and the filter components. The output of the inverter is connected to the utility grid, which is represented as an ideal, balanced, delta, three phase voltage source. This simplification of the utility grid model is based on a simplifying assumption that the utility voltage is stiff and therefore is unaffected by the converter output currents. Each of the switches in the switching network are IGBTs with anti-parallel diodes to allow current flow in both directions. The Real and Imaginary Instantaneous Powers Theory was developed by Akagi, with the objective of applying it to the control of active power filters.

(i) Real and Imaginary Instantaneous Powers Theory- This theory is based on time-domain, what makes it valid for operation in steady-state or transitory regime, as well as for generic voltage and current power system waveforms, allowing to control the active power filters in real-time. Another important characteristic of this theory is the simplicity of the calculations, which involves only algebraic calculation (exception done to the need of separating the mean and alternated values of the calculated power components).

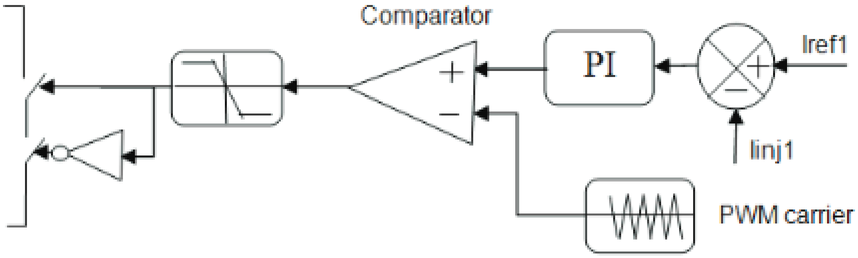

Figure 3- PWM carrier control for Shunt Active Filter

(ii) Current Control by PWM Carrier Strategy- The Shunt Active Filter is controlled by a PWM (pulse width modulated) carrier strategy. Reference currents Iref1, Iref2 and Iref3 and injected currents Iinj1, Iinj2 and Iinj3 are used in a PI (proportional integral) loop control. Control signal is limited and then compared to a triangular PWM carrier signal in order to command VSI (voltage source inverters) switches. Fig. 3 illustrates PWM control for Active Shunt Filter.

PROPOSED SYSTEM STRUCTURE

The proposed system in this work composed of a photo- voltaic solar generator connected to the DC bus of a three-phase inverter. It is also coupled in parallel to the grid via an inductor.

$$I = Isc \cdot \left[1 - \left(\exp\left[\frac{V - Voc \cdot \mathrm{NS} + 1Rs \cdot \mathrm{NS}}{Vth}\right]\right)\right] \qquad (1)$$

Open Circuit Voltage (Voc) and Short Circuit Current (Isc) are obtained by Eqs. (2) and (3) respectively:

$$Voc = Voc(\mathrm{STC}) + C_3 \cdot \left(Tc - Tc(\mathrm{STC}) + Vth \ln\left[\frac{Ga}{Ga(\mathrm{STC})}\right]\right) \qquad (2)$$

$$Isc = C_1 \cdot Ga\left[1 + \left(Tc - Tc(\mathrm{STC})\right) \cdot 5 \cdot 10^{-4}\right] \qquad (3)$$

with

$$C_1 = \left(Isc(\mathrm{STC})\right) / Ga(\mathrm{STC}).$$

This grid supplies a nonlinear load consisting of a series load PD3 rectifier with an inductance (Fig. 4). The BP MSX-150 photovoltaic module is adopted for modeling and simulation. This module is composed of (72) multi-crystalline silicon solar cells and provides a maximum power rating of 150W. The coefficient C_3 represents the voltage correction factor of the open circuit as a function of the temperature. The typical value of this factor is $-2.3\ 10^{-3}$ V/°C. Cells temperature (Tc) depends on the solar irradiation Ga and the ambient temperature Ta.

Tc: Absolute temperature of the junction operation (K°), and

Vth: the thermal stress.

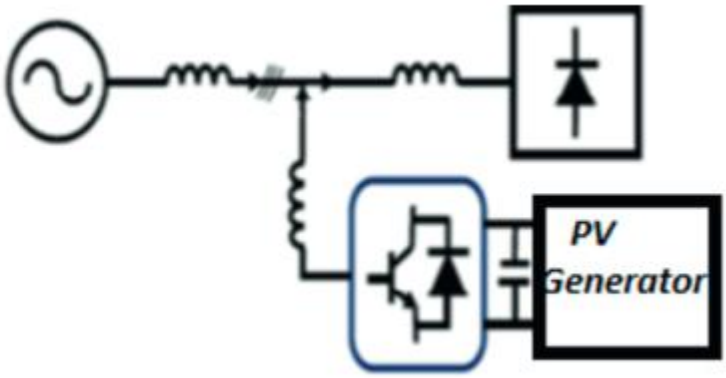

Figure 4- Proposed system, which based on grid-connected PV and three-phase voltage inverter

CONCLUSION

In this study, we analyze and simulate a PV interactive Shunt Active Filter that is backed by an MPPT controller. By using this technology, reactive power correction and nonlinear load harmonics are removed. We selected the parallel active filter due to its benefits, including its ability to adjust to changes in the load dynamically. In order to detect the reactive power and harmonic currents, either independently or concurrently, to guarantee their compensation, we chose the identification of instantaneous power approach. To evaluate the outcomes and ascertain the power active filter efficiency, spectral studies are performed both before and after filtering harmonic. This article presents a research on the modeling and control of a solar system that is linked to the grid and supplies a nonlinear load. The goal of the suggested control algorithms is to enable the chain to operate as optimally as possible in two steps: To minimize the effect of nonlinear load on the electrical network, current harmonics should be eliminated. Additionally, solar power should be maximized as a backup source to meet load demands. Two voltage inverter control strategies the DPC Control and the Hysteresis Control have been put forth to accomplish the first goal.

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