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Active Power Filter based Power Factor Correction using Embedded System

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Abstract-According to last few years, the power quality of the AC system has become a great concern due to the rapidly increased numbers of inductive loads, electronic equipment, power electronics and high voltage power system. In order to reduce line losses and improve the transmission efficiency, power factor correction research became a hot topic. Many control methods for the Power Factor Correction (PFC) were proposed. This paper describes the design and development of a single-phase power factor correction using PIC (Programmable Interface Circuit) micro-controlling chip. This paper presents a technique for single phase power factor correction of non-linear loads employing an active power filter. The current control strategy is the same used in the boost pre-regulator, which is the average current mode technique. It will focus on the design methodology and the analysis of the control strategy which allows the compensation of harmonics and phase displacement of the input current, for single and multiple non-linear and linear loads.

Keywords- Micro-Controller, Control Strategy, Harmonic Reduction, Power Factor, Active Power Filter.

1. INTRODUCTION

The main ac supply convert in to dc consisting of a line frequency diode bridge rectifier with a large output filter capacitor is cheap and robust, but demands a harmonic rich ac line current. Using rectification circuit, the input power factor is poor [1]. Different power factor correction (PFC) techniques are employed to overcome these types of power quality problems [2] out of which the boost converter topology has been extensively used in various ac/dc and dc/dc applications for power factor correction. In fact, today's ac/dc power supplies with power-factor correction (PFC) is almost exclusively implemented with boost converter [3], [4], [5]. The low power factor and high pulsating current from the AC mains are the main disadvantages of the diode rectifier. Power factor is the ratio of true power or watts to apparent power or volt amps. They are identical only when current and voltage are in phase then the power factor is 1.0. The most usual single phase non-linear load is the frontend rectifier followed by a bulk capacitor, which draws current from the input during its charging.

The boost pre-regulator is used to reduce the harmonic contents and improves the power factor. The current control loop consists in the average current mode technique. The boost pre-regulator has some disadvantage because it cannot be used in equipment already in service, and it is applied only to one kind of non-linear load which is the front end rectifier followed by a bulk capacitor.

A very interesting solution is the use of a single-phase active power filter, which is connected in parallel with then on-linear loads. The active power filters concept uses in power electronics to produce harmonic components which cancel the harmonic components from the non-linear loads. It can limit harmonics to acceptable levels and can adapt itself in case of harmonic component alteration or even changes in then on-linear loads types. Usually the technique used to control the single-phase active filter senses the non-linear load current and calculates its harmonics. This paper will focus on the design and the control strategy for a shunt single-phase active power filter. The active filters are able to compensate the displacement of the input current in relation to the AC mains voltage and the harmonics components of single and multiple non-linear loads, through the sensing of the input current.

2. POWER FACTOR

The power factor of electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit and dimensionless number between 0 and 1. Real power is the capacity of performing work in circuit in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. A load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred in an electric power system. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Electrical utilities will usually charge a higher cost to industrial or commercial customers because of the costs of larger equipment and wasted energy, where there is a low power factor. The low power factor (such as induction motors) of linear loads can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, drawn from the system, distort the current. Generally, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The power factor correction devices may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

3. PLATFORM DESIGN

The diagrammatic representation of power factor of nonlinear load using active power filter as shown in fig.1 in this fig the active filter is connected in parallel to AC mains. The converter which is used as the active filter is a full bridge voltage source inverter due to current reversibility characteristics. The boost pre-regulator is used to reduce the harmonics and improves the power factor. And the active filter is cancelling the harmonics components from nonlinear load. A current transformer (CT) is used for measurement of alternating electric currents. Potential transformers (PT) (also called voltage transformers (VT)) are a parallel connected type of instrument transformer. Isolation amplifiers are a form of differential amplifier that allows measurement of small signals in the presence of a high common mode voltage by providing electrical isolation and an electrical safety barrier. In this paper we use PIC controller. The full-bridge voltage source inverter controlled through the sensor of the AC load current is used as the active filter. Sine multiplication theory is implemented using microcontroller. Theoretical analysis and experimental results of the active filter compensating for a group of loads validates the analysis. Harmonics generated by nonlinear loads are one of the major causes of a poor power quality. So, harmonic elimination, in the source or with active filtering, is needed to achieve a better power quality. Results obtained with a three phase active filter prototype show its effectiveness both in static and dynamic operation, namely with a high nonlinear load. The main characteristics of the presented active filter are: the employed control technique is very simple and easy to implement, the AHF is able to compensate for the fundamental load current phase displacement and the load current harmonic distortion, a high power factor is achieved. Thought the proposed control technique has a drawback of slow initial response time.

I.e. one cycle for start of compensation but it is very efficient, cost effective and simple to implement for small distributed networks. The controller is used for control strategy a regulated power supply is an embedded circuit; it converts unregulated AC into a constant DC. With the help of a rectifier it converts AC supply into DC. On LCD we can see the result.

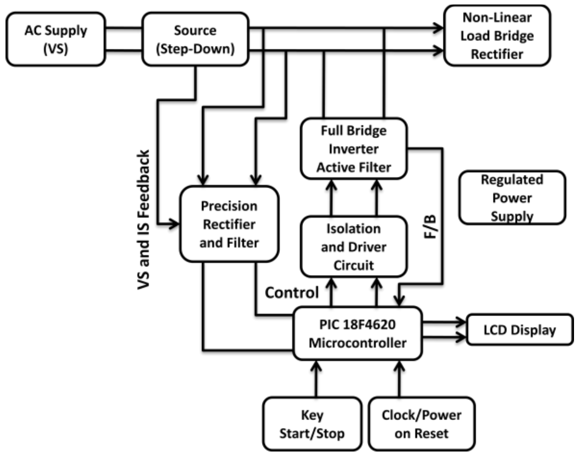

Fig.1. Block Diagram of System

An excellent performance of a system has been observed as a universal power-factor controller and an ideal reactive power compensator. APF is able to reduce the harmonics well below 5 % in all the cases of extremely reactive and harmonic polluted loads. APF has maintained sinusoidal supply current in phase with the supply voltage resulting in unity power-factor of the supply both in steady state and transient conditions. It is concluded that the proper selection of value of dc bus capacitor and P-1 controller parameters results in satisfactory performance of the system.

4. SYSTEM ANALYSIS

There are two methods which can be useful to do the analysis of system. We will check it one by one and its topology according to system validation.

4.1 ***Active Power Filters Topology***

The converter, which is used as the active filter, is a full bridge voltage source inverter, due to its current reversibility characteristics.

The full-bridge inverter is connected in parallel with the AC mains through a filter inductance Lf, and the DC side of the inverter is connected to a filter capacitor Cf, as shown in Fig 2.Thanks to the appropriate control of the full bridge switches, the current If cancels the harmonics components of the non-linear loads, resulting in a sinusoidal input current in phase with the AC mains voltage. The switching frequency is constant and the SI and S2 gate signals are complementary to S3 and S4 ones. If the output voltage of the active filter (VF) is kept constant, then the active power flowing in the active filter is zero. Thus, in the active filter flows a reactive power that cancels the reactive power generated by the non-linear loads, emulating a resistive load for the AC mains. The outer voltage loop consists in the comparison AF the voltage VF with a reference voltage. The resulting error is injected in an appropriate voltage controller. The output of the voltage controller is then multiplied by a sinusoidal signal proportional and in phase with the input voltage. The result of this multiplication is a reference current I ref. The inner current loop consists of the comparison of the reference current with the input current. The resulting error is injected in an appropriate current controller that in this case uses the average current mode technique.

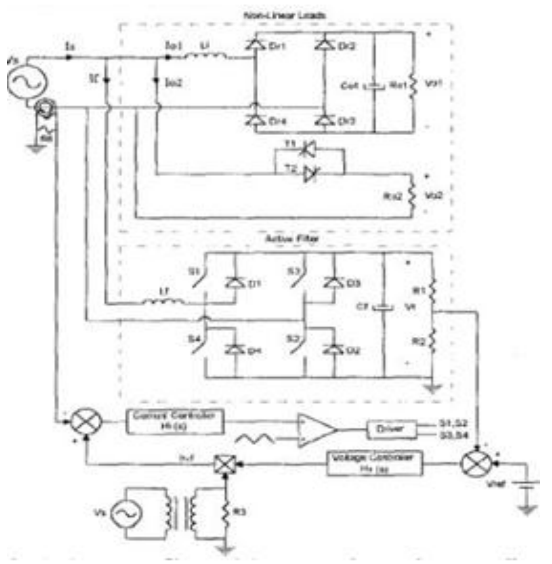

Fig.2. Active Power Filter and its Control Strategy

The output of the current controller is then compared with a triangular signal, generating the drive signals to the switches. The control strategy of the active filter allows the compensation of harmonics and phase displacement of the input current for any non-liner load and nonlinear load.

4.2 ***Relevant Analysis Results***

The relevant equations used to design the active filter; its outer voltage control loop and the inner current loop are presented below. The active filter capacitor Cf is calculated using equation (1). The voltage ripple is defined about 10% VF, Po is the active power of the non-linear load and fline is the frequency of the AC mains. The active filter inductance Lf is calculated using equation (2).AI is the maximum current ripple and f is the switching frequency. The smaller inductance Lf, better ability to track desired input current. However, the maximum ripple increases. The choice of the maximum current ripple depends on the harmonics components of the non-linear loads. The bigger the harmonic distortion of the load, the bigger should be the tolerated ripple; otherwise the inductor will not track properly the input current. The DC voltage-to-inductor current transfer function is presented in equation (3). The controller is a one pole one zero configuration. The zero must be located at a small frequency (around 1 Hz), and the pole must be located at about two decades above the zero. The voltage controller transfer function is presented in equation (4).

$$C_f \geq \frac{P_0}{2.f_{line}.\left(V_{f\,max}^{\;2} - V_{f\,min}^{\;2}\right)} \tag{1}$$

$$L_f = \frac{0{,}5.V_f}{\Delta I_{max}.f_s} \tag{2}$$

$$G_v(s) = \frac{\Delta V_f(s)}{\Delta I_f(s)} = \frac{V_{s_{rms}}}{V_f}.\frac{1}{C_f.s^2} \tag{3}$$

$$H_v(s) = k_v.\frac{\left(1 + s/w_{zv}\right)}{\left(1 + s/w_{pv}\right)} \tag{4}$$

The inductor current-to-duty- cycle (D) transfer function is presented in equation (5). As can be noticed the difference between this transfer function and the one obtained in the boost pre regulator is the gain. Thus the controller is the same used for the boost pre-regulator, which is a one, zero two poles configuration. However, due to the different gain, the position of the poles and zero are different. The zero must be located about two decades above the switching frequency, one pole is located at 0 Hz. While another other pole must be located around the switching frequency.

The current controller transfer function is presented in equation (6). The transfer function of the ac line current sampling effect is shown in equation (7) and must be taken in consideration in the current controller design.

$$G_i(s) = \frac{\Delta I_f(s)}{\Delta D(s)} = \frac{-2.V_f}{L_f} \cdot \frac{1}{s} \quad (5)$$

$$H_i(s) = k_i \cdot \frac{-(1 + s/w_{zi})}{s.(1 + s/w_{pi})} \quad (6)$$

$$H_e(s) = 1 - \frac{s}{2.f_s} + \left(\frac{s}{\pi.f_s}\right)^2 \quad (7)$$

5. CONCLUSION

In this paper would be presented a design methodology of an active filter and its new control loops strategy. The Experimental results of an active filter compensating an uncontrolled rectifier with RC filter would be used for validating the theoretical analysis. In despite of a simple control strategy, a high power factor is obtained. The active power filter combined with the control strategy is a very attractive solution, because a high power factor can be achieved to any type of non-linear load, including equipment already in service.

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