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Resonant Converter With Universal Active Power Filter (Pwm) In Single Phase Applications

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Abstract: The performance of the universal active power filter based series resonant converter for single phase is presented. Loads attached to Power distribution systems generally draw either reactive power or harmonic currents or both from ac source in addition to main active power currents. Thus causing poor performance of supply system such as efficiency, power-factor, causing massive stresses and EMI problems for other equipments. Active filters provides an effective solution to somewhat tackle such problems. This paper presents a Universal Active Power Filter **(**UAPF**)** based much easier way to provide reactive power and harmonics compensation both for linear as well as non-linear single-phase loads. APF with a voltage source inverter with PWM current control and simple P-I (proportional-integral) dc bus voltage controller with reduced energy storage capacitor is proposed. The paper gives detailed steady state and dynamic behaviour of the UAPF.

Keywords: *PWM, Total Harmonic Distortion (THD), Series Parallel Resonant Converter.*

Introduction:

Over the last decade, high-frequency (HF) resonant converters have drawn the attention of many researchers due to high efficiency, reduced size, weight, and cost. The operating characteristics and analysis of series resonant converter (SRC), parallel resonant converter (PRC), and series-parallel resonant converter (SPRC), have been reported for both fixed- and variable-frequency operation. SPRC takes all the desirable characteristics of two element resonant topologies, namely the SRC and the PRC. Resonant converters offer a novel solution to the problems faced by the PWM hard-switched converters. Solid state power convertor have wide range of applications in controlling and converting ac power to feed large number of electrical active and passive loads. Some examples of these loads are variable speed drives, temperature controllers, electric furnaces, light controllers, solid state ac voltage regulators, SMPS and UPS. The application of solid state power conversion equipments in the power system causes a profound impact on power quality. Both high and low power nonlinear loads introduce voltage fluctuations, harmonic currents and create an imbalance in network systems.

A harmonic current in end-use electronic equipment increase power system losses (such as heating in operating systems) causes an overload on conductors and power transformers. This reduces the power factor for the electrical power system components transporting real power along with harmonic components. Several methods are proposed in the literature for improving the power factor and for reducing the line current harmonics.

These Loads attached to Power distribution systems generally draw either reactive power or harmonic currents or both from ac source in addition to main active power currents. Thus causing performance of supply system such as low efficiency, poor power-factor, causing massive stresses, poor utilization of distribution system, overheating which degrades life expectancy of other equipments, disturbance to other consumers and electromagnetic interference to communication networks.

This paper is aimed to investigate and design a [universal type single-phase active filter with a simple control scheme for reactive power and harmonic compensation of linear and non-linear loads. The proposed universal APF consists of a single-phase voltage source inverter with an energy storage capacitor at dc bus as shown in Fig. 1. This APF is connected in shunt mode with load through a filtering inductor. A simple P-I (proportional-integral) controller is employed to regulate an averaged dc bus voltage to derive the reference supply current peak value in phase with supply voltage. The carrierless hysteresis PWM current control over the supply current is used to generate the gating signals for the devices of the APF. A variety of leading lagging power-factor linear loads, uncontrolled rectifier with capacitive and solid state ac regulator non-linear loads is considered to he compensated for reactive power and harmonics by the proposed APF. The steady state and transient performance along with harmonic analysis of the APF is given and described in brief.

Operation and system design:

Fig. (1) to Fig (3) shows the operation and working principle of APF and resonant Converter. Fig.(1) shows the fundamental building block of the proposed

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parallel Universal Active Power Filter (UAPF) comprising of a standard single phase voltage source MOSFET based bridge inverter with dc bus capacitor and boost voltage for an effective current control. A PWM current control technique implementing hysteresis rule used here provides fast dynamic response. Linear loads of lagging and leading power-factors are considered for demonstrating reactive power compensation capability of the APF in response to step change.

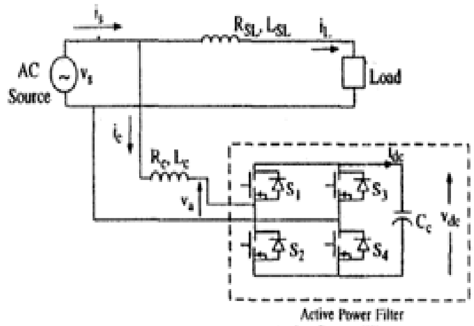

Fig: 1 Basic circuit of Active Power Filter

Fig. 3 shows Non-linear loads comprising diode rectifier with capacitive loading and inductive load in solid state ac regulator, are implied with APF system to illustrate its capability for harmonic and reactive power compensation in loads. The main application of the proposed APF is in elimination of harmonics and to facilitate reactive power requirement of the load locally so that ac source feeds only fundamental sinusoidal active component of unity power factor current. As the APF in the system is in shunt with load, which results in improved system efficiency which is because the active power delivered to the load is not processed.

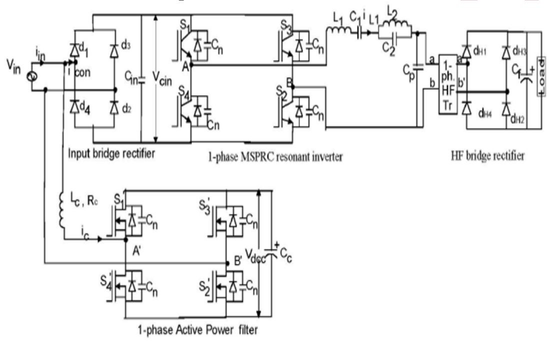

Fig:2 Single phase ac-to-dc resonant converter with ACF

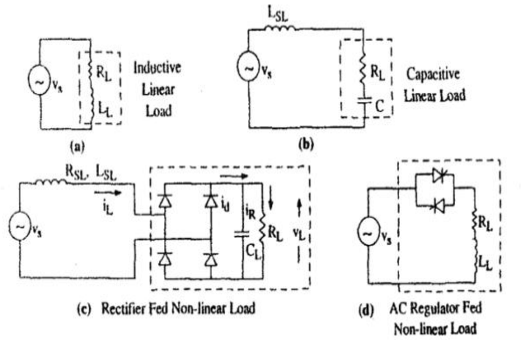

Fig: 3 Different types of loads

Control Scheme:

Fig. 3 shows the block diagram of an overall control scheme for the APF system. DC bus voltage and supply voltage and current are sensed to control the APF. AC source supplies fundamental active power component of load current and a fundamental component of a current to maintain average dc bus voltage to a constant value. The later component of source current is to supply losses in VSI such as switching loss, capacitor leakage current etc. in steady state and to recover stored energy on the dc bus capacitor during dynamic conditions such as addition or removal of the loads. The sensed dc bus voltage of the APF along with its reference value are processed in the P-I voltage controller. The truncated output of the P-I controller is taken as peak of source current. A unit vector in phase with the source voltage is derived using its sensed value. The peak source current is multiplied with the unit vector to generate a reference sinusoidal unity power factor source current. The reference source current and sensed source current are processed in hysteresis carrierless PWM current controller to derive gating signals for the MOSFETs of the APF. In response to these gating pulses, the APF impresses a PWM voltage to flow a current through filter inductor to meet the harmonic and reactive components of the load current. Since all the quantities such as dc bus voltage etc. are symmetric and periodic corresponding to the half cycle of the ac source. A corrective action is taken in each half cycle of the ac source resulting in fast dynamic response of the APF.

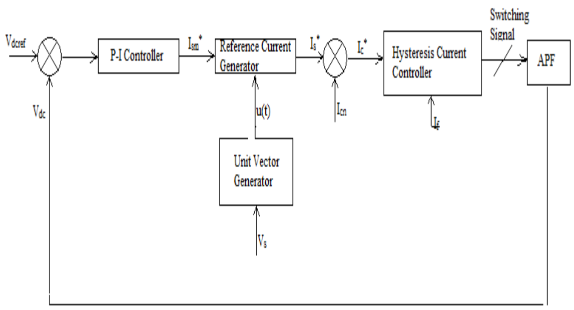

Fig: 4 Basic circuit of active power filter

Analysis and Model Equations:

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The proposed APF system is comprised of a voltage controller, a current controller, a voltage source inverter bridge with dc bus, a non-linear load with input impedance and a filter inductance at the input of the APF. All parts are modelled separately and then joined together in order to simulate the APF system.

(i) Voltage and P-I controller:

The resultant voltage error

$$e(t) = V_{dcref} - V_{dc} \quad (1)$$

$$I_{sm}^{*} = e(t) \cdot K_P + K_i/T_i \cdot \int e(t)\, dt \quad (2)$$

where, K_p and K_i are the proportionality and integral gain constants of the P-I controller.

(ii) Reference current generation:

$$I_s^{*} = u(t) \cdot I_{sm}^{*} \quad (3)$$

Where, u(t) is the unit vector for input voltage V_{in}.

(iii) Current Controller:

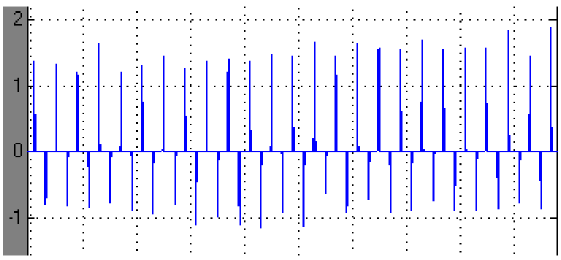
If ($I_c > I_c^{*} + h_b$) S_1 and S_2 on, S_3 and S_4 off.
If ($I_c > I_c^{*} - h_b$) S_1 and S_2 off, S_3 and S_4 on.
S_1, S_2, S_3, S_4 are the switching devices of the APF and h_b is the hysteresis bandwidth in ampere.

Vs(rms) = 325V, f = 50Hz, Rc = 0.01 ohm, Lc= 10.12 mH, Cc = 8000 µF, Kp = 1, Ki = 1.

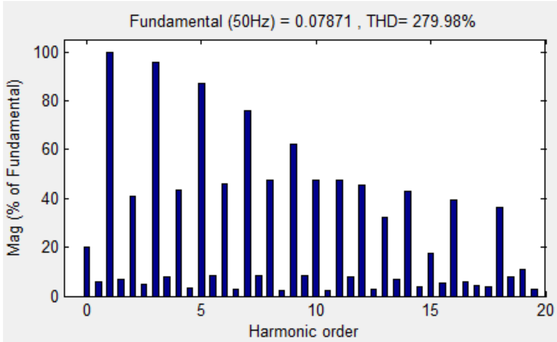
Results:

Results from the APF system are demonstrated through Fig 5 – Fig 7.

Fig. 5(a) shows the waveforms of input current (i_s) without active power filter for an AC to DC rectifier load. Fig. 5(b) Supply current is 10A with a huge THD with different frequency spectrums specially having 3rd, 5th... harmonics.



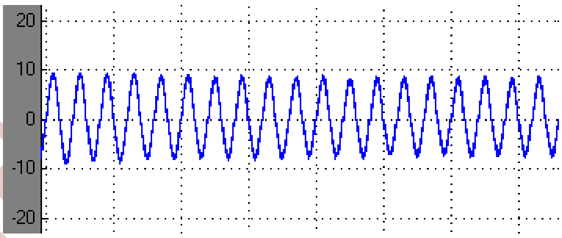
(a)



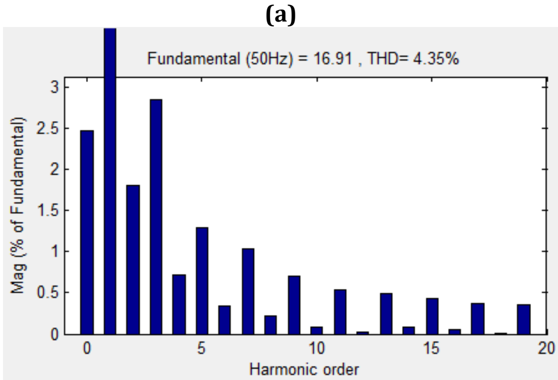
(b)

Fig: 5 Without APF (a) Input current (b) THD analysis

From fig. 6(a) and Fig. 6(b) it may observed that harmonics are eliminated from the supply current. Therefore, APF is quite effective to reduce the THD of supply current well below the permitted value of 5 % by IEEE-519 standard.

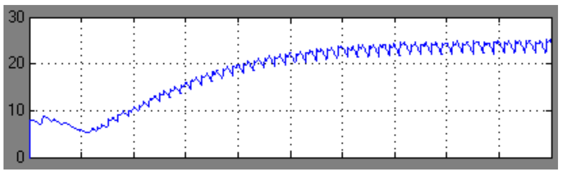


(a)

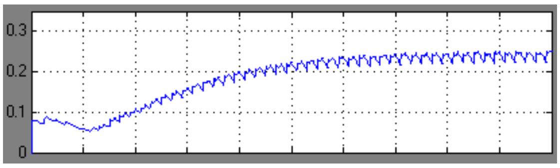


(b)

Fig: 6 With APF (a) Input current (b) THD analysis



(a)



(b)

Fig: 7 With Series-Parallel resonant Converter (a) DC Load Voltage (b) DC Load Current

Fig 7 (a) and (b) shows the output DC voltage and current for load resistance 100 ohm. Fig 7 shows the performance of Series Parallel resonant converter. The THD of supply current is not much affected by dc bus capacitor values. From these results it may be concluded that for the proper selection of ratings of dc bus capacitor, controller parameters and device specifications, the proposed modelling is essential at design stage the APF system.

Conclusion:

The proper selection of dc bus capacitor, controller parameters and device specifications, at design stage of the APF system can be used quite effectively to reduce the THD of supply current well below the permitted value of 5 % (IEEE standard). And is much easier way to provide reactive power and harmonics compensation both for linear as well as non-linear single-phase loads. The APF eliminates frequency harmonic components effectively and is able to compensate the reactive power required by the ac-to-dc converter. Hysteresis current controller is used to obtain the gate signals for switching devices of APF.

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