AN ADVANCED FUZZY LOGIC CONTROL BASED ACTIVE POWER FILTER WITH RESONANT CONTROLLER

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ABSTRACT

Here in this paper a new simple indirect control strategy for an active power filter (APF) application are recommended here. The approaches are exemplarily presented to maintain modified APF structure. The main advantage over other control techniques is the achieved excellent simplicity to performance ratio. The recommended control techniques are based on the concept of virtual impedance computation to provide high power and the fuzzy logic control strategy has been proposed. To validate the operating principle, a single phase low power model has been developed and experimentally tested. This model operates at a extremely low operating switching frequency of 5 kHz is digitally controlled by a digital signal processor.

Keywords: Active Power Filters (APF), Dc-Ac Converters, Implicit Control, and Sensor Less Control Techniques.

I. INTRODUCTION

Non-linear loads integrated to electric energy distribution networks produce harmonic pollution. Such nonlinear loads drain currents with fluctuating degree of harmonic contents. The harmonic current components do not represent useful active power due to the frequency mismatch with the grid voltage. Even though the circulation of harmonic currents through feeders and careful network element produces joule losses and electromagnetic emissions that might interfere with other devices integrated to the distribution system. This affects the electrical performance of control and communication systems involved with the careful elements. Several other adverse effects are observed as discussed in this paper. A remedy to the harmonic current injection problem is to connect passive, active or hybrid filters in parallel with the loads. These are named shunt active power filters (APFs). APFs are circuits depend on switched power semiconductors (generally operating voltage source inverters) that inject opposed phase harmonic currents at the point of common coupling (PCC). This result in the total nonlinear load plus APF system emulating nearly resistive load characteristics at the PCC terminals. Power transmission in the network is thus enhanced and all nonlinear load low frequency harmonic electromagnetic compatibility problems are reduced. Two responsibilities are important to an APF to perform well its function, namely the generation of suitable current references and the ability to rapidly follow the reference current signals. Thus typical shunt APFs are utilized the error signal produced by the comparison of computed currents with the references. The main control objective is to *mitigate* such error. Finally the integrated controllers produce the modulation signals to the inverter power section. Basically error mitigation is achieved through two different types of methods, the direct control techniques or the indirect ones. In the direct control strategies the desired compensation inverter current reference is the one produced with in the control algorithm. Moreover the indirect control approaches generate the APF current reference indirectly, i.e. by causing that the APF plus nonlinear load currents follow sinusoidal reference current signal in phase with the PCC voltages. Here in this paper a traditional APF system design where the L_F is series integrated to the voltage source inverter. The compensation opposite phase load harmonic currents transfer through the inductor, generating the according harmonic voltages across the inductor in this design. Assuming a purely sinusoidal supply voltage Vs results in that the voltage drop across the inductor is produced by the inverter output voltage. Hence the bandwidth of the modulation signal must be compatible with the voltage harmonics that are to be produced since the modulation signal is directly proportional to such voltage. In general considering that around 50th order harmonic component must be compensated in specifications i.e., 2.5 kHz in a 50 Hz network leads to the need to employ high switching frequency c . Carrier frequencies above $fc > 25$ kHz would be required, and the local averaging approach would provide accurate results to model the system.

II. EXISTED SYSTEM

An alternate solution to this challenge is to consider the APF system design illustrated in the above fig. The smoothing inductor LF is now placed in series with the interconnected network and not with the inverter as usual.

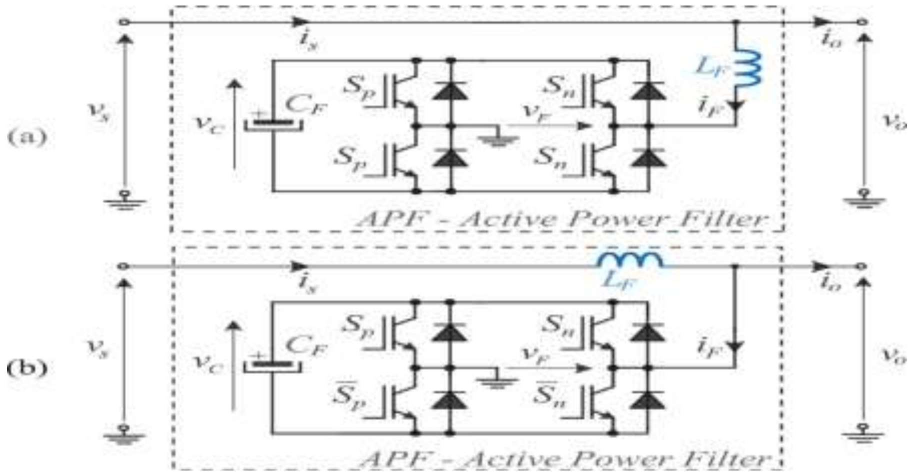

Fig.1 (A) Typical Single-Phase APF System Architecture

(b) APF architecture used in this work.

The dc-link capacitor Cf requirements are nearly the similar as in the standard APF configuration. The disadvantages of this design are that the inductor carries full load current, except the harmonics, the PCC voltage vo is now activated (it desired a low pass filter prior to the load), and the load voltage can be distorted due to load current harmonic components. Another condition is that the presence of LF controls the rate of change of the load current. Even though this APF design implies an advantage from the APF control technique viewpoint. The inductor current becomes independent from the harmonic currents of the load.

The recommended control approach is much easy to implement than traditional strategies, such as the ones listed in following. Probably the most comprehensive method is the average current mode control, which presents an outer voltage control loop and an internal current control closed loop. Large control boundaries are generally desired with this control strategy. Hysteresis current control is also employed and demands a single outer voltage control loop to produce the current references. This control strategy leads to very quick dynamics but brings all disadvantages inherent to fluctuating frequency. Examples of digital control techniques utilizing intern model principles are the adaptive and dead beat control. One of the main control challenges faced in all these approaches is the production of current references. Among the theories to calculate the compensation reference current are the $p-q$ theory, the synchronic reference frame, the discrete Fourier transform, adaptive neutral networks and Lyapunov function based control. These control approaches while having an acceptable performance for accomplishing unity power factor relatively difficult to implement. A novel APF control indirect techniques are recommended here as alternative to the cited techniques. These new indirect methods are depends on the concept of virtual impedance emulation through inverters to obtain unity power factor at input side. A major feature is that either mains side current or voltage sensor is utilized, leading to senseless approaches. The APF implicit current reference does not contain higher order harmonic components to ensure unity power factor at the mains side, and hence the control technique is highly reduced, leading to the control methods classified in this paper.

III. APF INDIRECT CONTROL STRATEGY CONCEPTS

3.1 Current Senseless Control Strategy

Applying Kirchhoff's second law to the diagram in Fig.1 describes the following expression.

$$v_s - L_F.\frac{di_s}{dt} - (S_p - S_n).v_c = 0 \quad (1)$$

Where $S_p\,and\;S_n$ are the switching functions for switches $S_p\;and\;S_n$, respectively. These are indicated as +1 if a switch is closed and 0 for when it is off. The resulting switching operation for the filter comprehends both of these into $S_F = S_p - S_n$. The switching pulses are produced by a accurate modulation control scheme. For the case at hand, phase shifted pulse width modulation (PWM) is accepted. The high frequency harmonics are generally mitigated with filters, and the following analysis considers only the low frequency characteristics of the circuit. This is accomplished with the definition of the local average value of the quantities within a switching period T_s. Applying this definition to the APF switching operation leads to

$$S_F = \frac{1}{T_S}\int_{t-T_S}^{t} S_F\,dt = d_F \quad (2)$$

Where d_F is the resulting APF duty cycle. This is to be produced by the control technique.

The produced control block diagram control technique is simple and does not desired complex calculations for the production of references. The phase shifted PWM leads to the inverter producing a voltage with twice the carrier frequency and with mitigated current ripple. The procedure to calculate the duty cycle explained earlier is input current sensor less and has the advantage of only computing the input and the dc link voltages to produce the control pulse.

3.2Voltage Sensor less Control Strategy

The voltage sensor less control technique is developed with the schematic diagram as illustrated in Fig.2. The control approach is straight forward and similar from the practical implementation aspects to the current senseless one is that over current measurement. Even though the semiconductor currents are not directly measured in neither approach. Convenient current protection for insulated gate bipolar transistors can be developed through high performance gate drivers, low precision current sensors, and the measurement of the dc side current.

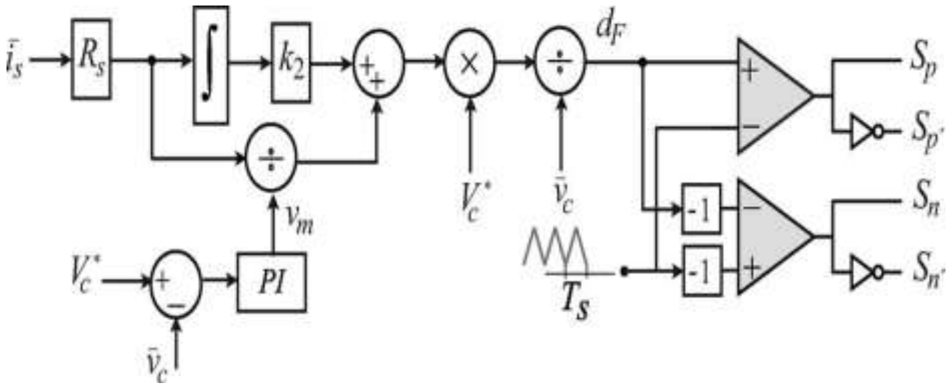

Fig.2. Block Diagram for the Voltage Senseless Control Strategy

IV. PROPOSED SYSTEM

Here in this paper presents theoretical analysis regarding the equivalent circuit observed from the mains and a control approach that uses traditional feedback control theory with a resonant controller to achieve close to unity power factor.

4.1 Equivalent Circuit Based Analysis

Consider the low frequency behavior of the recommended APF configuration and a constant dc link voltage $v_c = V_c^* = V_c$ leads to

$$v_s = L_F.\frac{di_s}{dt} + s_F\, v_c \cong L_F.\frac{di_s}{dt} + d_F V_c \qquad (2)$$

The ability of bidirectional inverters to emulate virtual negative inductances has been proved in other applications. Hence another implementation possibility for the recommended APF control is to replace the virtual capacitance with a virtual negative inductance. This derived from the idea given by the mains side equivalent circuit analysis generating a series capacitance.

4.2 Equivalent Feedback Control Based Analysis

The recommended control methods do not present an explicit current loop control. The current control is generally implicit in the control laws that calculate the APF duty cycle. This is understood in the following. The derivation of the following shows the equivalent between the recommended control approaches and a traditional feedback control loop assuming that both are in steady state with a constant dc link voltage. Finally the large signal models are liberalized around an operating point. Low power single power laboratory prototype of the recommended APF has been developed in order to validate the theoretical analysis of the indirect control. The experimental design employs the similar configuration and parameters as the system utilized in the circuit simulations. The implementation of the modulation algorithm is performed in fixed point DSP. The power stage configuration utilized in the simulation based analysis of the suggested APF system. An exceptional low AOF switching frequency of fc = 5kHz is utilized to highlight the performance of the recommended approach. Other experimental parameters are also specified in this paper. Here step up transformers were selected to approach the experimental set up also explained. The non-linear load is single phase diode bridge rectifier was utilized.

V. PROPOSED CONTROL STRATEGY

The simulation result is carried out for the voltage senseless control technique. Here in this paper the voltage senseless by adding with Fuzzy Logic Controller was used. The non linear load currents at the PCC and after the HF filter. The currents are same except from the HF harmonics provides a high total harmonic distortion even considering the only first 50 harmonic components.

The APF capacitor voltage vc the APF output voltage vo and the mains supply voltage vs are explained in this paper. Hence it proves the ability of new APF approach to emulate a resistive behavior when observed from the mains.

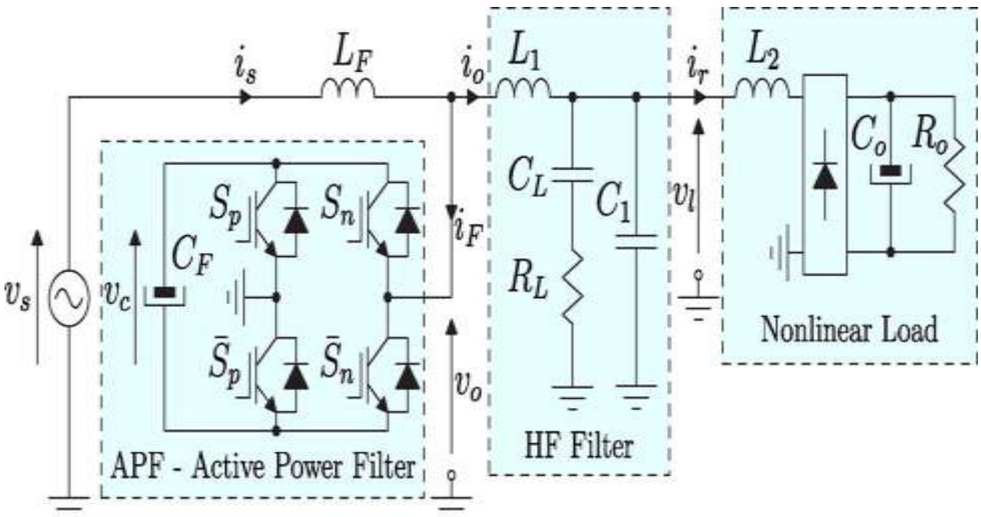

Fig.3.APF Power Stage Setup Used both In the Simulations and In the Experimental Results

The similar results are found for the current senseless control technique as observed in suggested system. It can be evident that the harmonic distortion appears as the load current causes a distorted voltage across inductor L1, which is partially filtered with the parallel branch. This effect should be analyzed on a case based control technique in order to evaluate the load voltage. Reducing inductor L1, increasing capacitance CL, and including capacitance C1 reduces the load voltage distortion as presented in the filter design guidelines also provided in this paper.

VI. CONCLUSION

A new control approaches for a modified shunt APF architecture have been recommended in this paper. The suggested control techniques were able to guarantee close to unity power factor. Both current and voltage senseless versions have been analyzed in detail about its operating performance, equivalent circuit and stability.

The important features of the techniques are their extreme simplicity since no complex current reference calculations are desired. The implicit control loop is another inventive characteristic. In this sense it was proven that the recommended control approaches are equivalent to exploit current control strategies employing a resonant type controller. This explains the excellent sinusoidal tracking performance.

In addition to the resistive behavior, the APF emulates virtual capacitance and negative inductance. Hence zero mains side current phase displacement is accomplished. These characteristics were verified through circuit simulation and in an experimental setup including a nonlinear rectifier load, with the APF being triggered at 5 kHz. This is a very low switching and highlights the achievable performance. The concept can be easily extended to the control of PFC rectifiers and three phase system

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