A REPETITIVE-BASED CONTROL FOR A SINGLE-PHASE SHUNT ACTIVE POWER FILTER FOR HARMONIC VOLTAGE COMPENSATION

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Abstract— In this paper a repetitive based control is used in shunt active filter in order to remove the harmonic distortion. Active filter is mainly to remove the harmonic distortion during the point of installation. The active filter used is a single phase voltage source inverter in order to generate voltage in phase with respect to the detected signal during installation. Proposed method that is the repetitive based control regulates the fundamental frequencies power so as to maintain the dc voltage of the capacitor. It is placed on the dc side of the filter which is close to the reference. Because of this the self-charging functionality problem arises. Simulation results are provided to show the effectiveness and feasibility of the proposed system.

Keywords- APF, Shunt Active Filter, Point of Common Connection, PI controller.

I. INTRODUCTION

Shunt Active Filters are mainly used to eliminate the harmonic distortion in electric powered transmission and distribution systems. A voltage source inverter is used to inject harmonic currents into the ac system in order to compensate the current harmonics produced by the distortion load. Shunt active filters are widely available in markets for their continuous requirements.

Facts about the Shunt Active Filters while compensating the harmonic voltage at the point of coupling in the transmission/distribution feeder is explained as follows. In 1983 Kawa hira, et al. [1], different harmonic methods are explained in detail. In the Voltage detection Method, the compensating current in the time domain for an AF is given as follows:

\[ i_{AF} = k_v \times v_n \]  \hspace{1cm} (1)

Where \( k_v \) is the real number values, \( v_n \) is the harmonic voltage. From above equation it is clear that active filter acts a current source and behaves as a pure resistance. In 1997 Akagi [2] proposed a strategy to control shunt AF which behaves as resistor. In time domain the voltage detection is the most suitable among the harmonic detection methods. The conclusion is that Voltage detection installed at the end of the feeder line is more prone to harmonic propagation. In 2014, Menniti. et al. [9] effectively used some methods to damp the harmonic resonance along a power distribution line by avoiding the line characteristics impedance.

\[ V_{AF} = k_v \times v_n \]  \hspace{1cm} (2)

In Fig.1, the basic block diagram of SAPF is shown above. From ref [6-9] the focus is mainly on the Shunt AFs based on the detection of the voltage at PCC, from equation 2it is clear that the compensation of the harmonic voltages is obtained from the detected voltage. In this paper a repetitive based control for the shunt Active Filter is done, the same control regulates the power at the fundamental frequency in order to maintain the voltage across capacitance placed at the dc side, simulation results are shown inorder to prove the efficiency and feasibility.
Compensation of the harmonic voltages in the electrical power distribution system is done by the proposed method i.e the repetitive control method which is given in fig 1. The control signal is the sum of two output signals $V_{\text{fund, ctrl}}$ and $V_{\text{harm, ctrl}}$ where the first block is power regulation at the fundamental frequency represented as $\text{fund}_{\text{ctrl}}$, second block is the power regulation at the non-fundamental frequencies represented as $\text{harm}_{\text{ctrl}}$. It is designed in a way such that when the power source is absent the control is activated by the self charging functionality. In this the fundamental power is equal to the sum of non-fundamental power inorder to compensate the harmonic distortion. In order to operate without the presence of power source, it should be placed parallel to the capacitance C.
In case if the power source is present, depends upon the amount of power value, the fundamental power is regulated by the control methodology for the compensation of harmonics. The fundamental power is the pure active power because the fundamental current of the active filter is in phase with fundamental voltage at the PCC, In Fig.1. Repetitive control method for Shunt active filters is designed in a way such that the two blocks fund_ctrl and harm_ctrl are involved in the harmonic voltage compensation is also used in control of a conventional or small photovoltaic inverter [7, 15]. A microcontroller implementation of those blocks with proper difference is developed for the proposed control to employ in already existing distributed generation solutions.

A) FUNDAMENTAL FREQUENCY CONTROL

The fundamental frequency control block fund_ctrl regulates the fundamental power, the power is calculated inorder to maintain the voltage $V_{dc}$ across the capacitance which is close to the $V_{dc_{ref}}$. it is close to the DC side of the VSI. Hence the $V_{dc}$ across the capacitance should be less than the $V_{dc_{ref}}$. The input of the $G_c$ block is given as follows

$$G_c(s) = \frac{K_1}{\pi}$$

The above equation returns the amplitude of the filter current at the fundamental frequency and this value is multiplied by sine term in order to obtain a reference current value in phase with respect to the voltage at the PCC and also at the fundamental frequency. The input of the $G_{2\pi f}$ block is given as follows

$$G_{2\pi f}(s) = \frac{2 \times K_2 \times \omega_p \times s}{s^2 + 2 \omega_p \times s + (\omega)^2}$$

The above equation 6 returns the control signal of the single phase inverter at the fundamental frequency, the value of the sine term is obtained by filtering the voltage using a second order generalized integrator.

B) NON-FUNDAMENTAL FREQUENCY CONTROL

The non-fundamental frequency power is regulated by the harm_ctrl block, this block also eliminates the non-fundamental voltage at the PCC. The non-fundamental voltage is given as

$$v^h_{pcc} = v^{1 \, pcc_{\, ref}} - v^{1 \, pcc}$$

$v^{1 \, pcc}$ is the PCC voltage at the fundamental frequency. The difference between the non-fundamental and the reference value is the input of the PI repetitive controller which returns the control signal of the single phase inverter.

III. SIMULATION RESULTS

To verify the feasibility of the proposed strategy, simulations are carried out.

Fig.4. Proposed system Simulink diagram
Fig. 5. Input voltage and current waveform

Fig. 6. Input voltage and current waveform at PCC

Fig. 7. Inverter output voltage waveform
IV. CONCLUSIONS

At the point of common coupling, a repetitive-based control is proposed in this paper for a single-phase shunt active power in order to compensate for the harmonic voltages. The voltage detection method (the voltage at the point of common coupling is detected) and voltage-controlled method (the voltage source inverter representing the active filter acts as a voltage source instead of a current source) are implemented by the proposed control. The repetitive-based control also regulates power at the fundamental frequency; the self-charging functionality is also implemented by the control when the active filter is not a distributed generation solution. The effectiveness and the feasibility of the proposed control in compensating for the harmonic voltages at the point of common coupling is demonstrated by numerical experiments concerning a real test case. A numerical result for the proposed control with the active filter compensated for the harmonic voltages at the PCC clearly demonstrates, reduced THD from 3.2% to about 0.6%.

REFERENCES

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