Improved Control Scheme for Shunt-type H-bridge Active Power Filters

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Abstract. This paper attempts to improve the dynamic performance of H-bridge APF. The method of adaline harmonic detection is proposed to calculate harmonic current more accurately in less time while the supply voltage is distorted. H-bridge APF based on CPS-SPWM can reach the more satisfying performance in lower on-off frequency, and the structure of cascaded H-bridge module is easy to maintain. To demonstrate the effectiveness of the method proposed in this paper, the simulation is conducted in Matlab/Simulink.

Introduction

Nowadays, lots of nonlinear loads are connected into the power grid. Conventionally, passive LC filters were applied to handle the harmonics problem. However, there are some weaknesses such as possible resonance with other system components, fixed compensation and aging effect in the passive filter[1-4].The static synchronous compensator(STATCOM) is widely used to eliminate the harmonic current. APF which is one of the STATCOM is considered to be one of the most effective applications of eliminating harmonics [5].

H-bridge inverters hold the advantages of convenience of modular design and maintenance. In H-bridge APF, several H-bridge converters are cascaded to construct one leg of bridge of APF. [6] used repetitive predictor theory to improve the system performance, but the harmonic current detection is easily affected by voltage distortion. This paper proposes the adaline harmonic current detection replacing the method of instantaneous reactive power theory. In this application, one capacitor is used to store energy in one H-bridge module instead of DC power supply. The outer-loop voltage PI controller and the inner-loop average voltage proportion controller are proposed to maintain the stabilization of the capacitors' voltage.

Shunt-type H-bridge Active Power Filters Topology

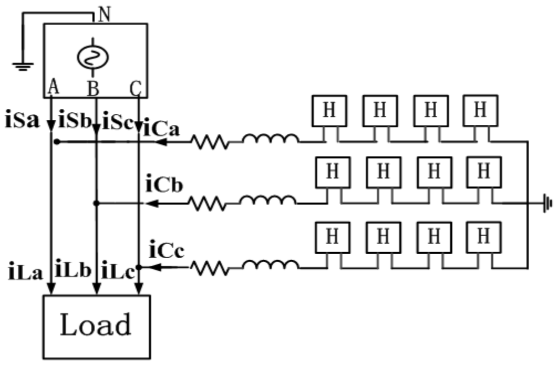


Fig.1 Shunt-Type H-Bridge Active Power Filter

Fig.1 shows the topology of the shunt-type H-bridge APF composed of three legs of bridge consisting of several H-bridge units. Each leg of bridge is interfaced into the power grid via series connected resistance(R) and inductor(L).The three phase voltages of the power supply are represented as u_{sa}, u_{sb}, u_{sc} while the three output voltages of APF are represented as U_a, U_b, U_c .

Adaline Algorithm of Harmonics Detection

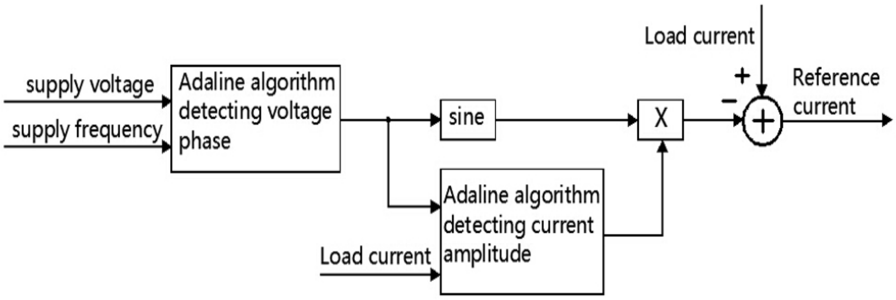
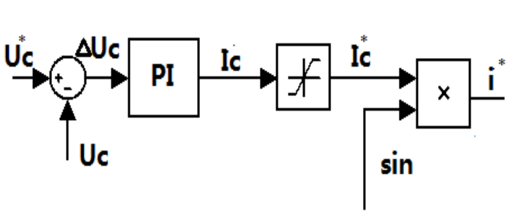


Fig.2 Adaline Algorithm of Harmonics Detection

The procedure of adaline algorithm of harmonics detection is shown in Fig.2.In power grid, the fundamental voltage frequency(f_0) is almost constant which is strictly limited within a small range. In Fig.2, adaline algorithm is used to calculate the fundamental voltage according to the supply voltage and the constant frequency, and the amplitude of the active fundamental current is calculated by adaline algorithm under the condition of the fundamental voltage phase. Through the phase, the unit fundamental current could be calculated by using sine function. And then, the fundamental current could be calculated by multiplying the unit fundamental current and the active fundamental current amplitude. The reference compensation current is gained by the total load current minus fundamental current.

The Control Algorithm and Strategy of H-bridge APF

In order to compensate the energy loss of APF capacitor, this paper proposes the outer-loop voltage PI controller (shown in Fig.3)and the inner-loop average voltage proportion controller(shown in Fig.4).



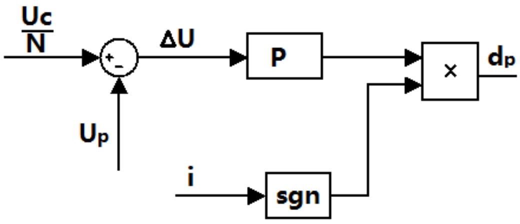


Fig.3 Outer loop voltage PI controller Fig.4 Inner loop average voltage proportion controller

In Fig.3, U_c is the actual voltage over each leg of bridge and U^*_c is the reference voltage. When the current flowing into the leg of bridge is in the same phase with the supply voltage, the leg of bridge gets energy to raise its voltage. So the current (i^*)for voltage maintaining could be gained by multiplying I^*_c with unit synchronization signal of the supply voltage .The inner-loop average voltage proportion controller as is shown in Fig.4 is used to make every capacitor voltage be the same where $\frac{U_c}{N}$ is the average capacitor voltage, U_p is the actual capacitor voltage, P is proportion controller, *sgn* represents the sine function and d_p is the modulation wave signal.

Deadbeat control for following reference current

In order to precisely and fast follow the reference current, the deadbeat control strategy is given in this paper. The equivalent circuit of a-phase is given as follows:

$$u_{sa} + i_{ca}R + L\frac{di_{ca}}{dt} = U_a \tag{1}$$

Discretize the Eq.1:

$$u_{sa} + i_{ca}R + L\frac{i_{ca}^{\ *} - i_{ca}}{T_s} = U_a \tag{2}$$

Where $i_{ca}^{\ *}$ is the reference current, i_{ca} is the present actual current, and T_s is the sample period time. The modulation wave signal *d* could be expressed as:

$$d_a = \frac{u_{sa} + i_{ca}R + L\dfrac{i_{ca}^{\ *} - i_{ca}}{T_s}}{u_{ca}} \tag{3}$$

Carrier phase-shifted sinusoidal pulse width modulation technique

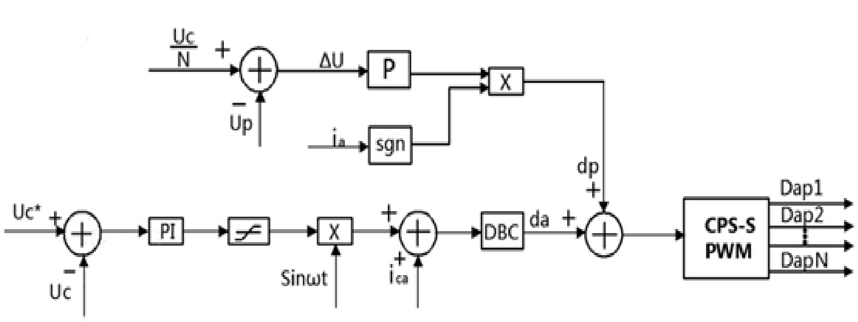
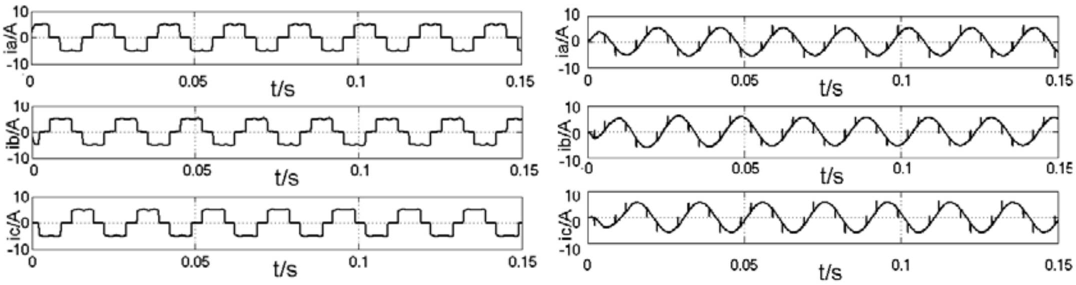


Fig.5 Carrier phase-shifted sinusoidal pulse width modulation technique

As is shown in Fig.5, the pulse width modulation signal (D_{ap1}) for each H-bridge module in a-phase leg of bridge is generated. The combination of the modulation wave signal(d_a) from deadbeat controller and the modulation wave signal (d_p)from inner loop average voltage proportion controller forms the modulation wave signal of the first a-phase leg of bridge, which compares with the triangle carriers whose phases are staggered. And the phase of the *L-th* H-bridge inverter module is $\varphi_L = \varphi + 2\pi L / N$.

Simulation validation

The validation of the proposed method for shunt-type H-bridge APF is simulated in Matlab/Simulink. In simulation, each leg of bridge of APF is formed of four H-bridge inverter modules. The supply *rms* voltage of each phase was set by 110V, and some harmonic voltage was added into the supply at 0.5s.



(a) (b)

Fig.6 Performance of the APF (a) Three supply currents before compensation
(b) Three supply currents after compensation

By comparison of two graphs in Fig.6, APF based on the proposed method can efficiently eliminate the harmonic current whether the supply voltage is distorted or not.

Summary

The adaline harmonics detecting algorithm and other control methods proposed in this paper for controlling the shunt-type H-bridge APF have been implemented in compensating harmonic current in a three-phase distribution system. The simulation result has proved that the adaline harmonics detecting algorithm can detect the harmonic current quickly and accurately. It also proves the effectiveness of proposed the outer-loop voltage PI controller and the inner-loop average voltage proportion controller.

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