Research and Application of Shunt APF Control Technology

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Abstract. Basing on the research of the basic principle of the space vector pulse width modulation (SVPWM) control method and the DC side voltage control ,the simulation is made ,the simulation results show that the effect of the compensation current control based on SVPWM method and DC voltage control based the traditional PI regulator is ideal. In order to further stabilize the DC side voltage and enhance the compensation effect , the control strategy of the fuzzy adaptive proportional integral (PI) controller is introduced based on the voltage closed-loop control ,this significantly reduces the fluctuation of the DC side voltage overshoot and static error has been greatly improved, with good control effect. The experimental results also verify the feasibility of the design approach.

Introduction

After the APF detected the instruction current signal , on the one hand, through the appropriate PWM modulation method, functions on the converter and makes it to produce corresponding compensation current; On the other hand to make the DC side capacitor voltage to maintain in a basic fixed values, to guarantee the normal work of the active power filter [1].

This paper is mainly study the current control method based on SVPWM and the basic principle of DC side voltage control [2], and through Matlab/Simulink to establish APF control system and simulation model, then to analysis it; Based on the dc side voltage control improvement strategy is proposed and simulation validation, and finally construct platform for APF experimental system, the design is verified by the compensation current control and dc side capacitor voltage control method is effective.

DC side voltage APF control

APF control of DC side voltage is the guarantee of the important link of stable, efficient operation, and in the work of the loss or the exchange of energy will cause the fluctuations of DC side voltage, it must use the appropriate control method to make the DC side voltage to maintain constant [3]. DC side voltage control principle shown in figure 1. U_{dc} diagram for a given value of DC side voltage, DC side voltage value is U^*_{dc}, the difference of the two ΔU_{dc} into the PI regulator is obtained after the treatment of regulating signal Δi_p , the Δi_p and instantaneous active current $\overline{i_p}$ phase superposition, the fundamental active current contains a certain amount of harmonic current in operation in, so that the compensation current the converter also contain these amounts, in the realization of APF DC side and grid side energy exchange at the same time, can be adjusted to the given value of DC side voltage.

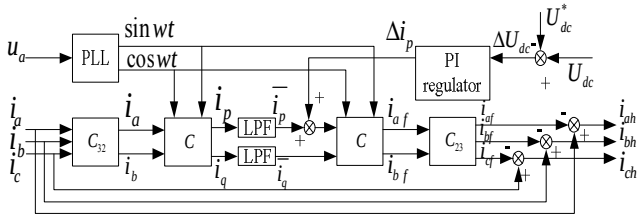


Fig.1 The principle diagram of the dc side voltage control

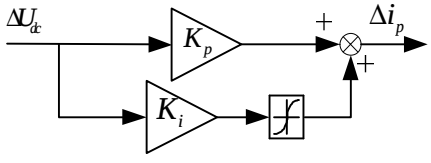


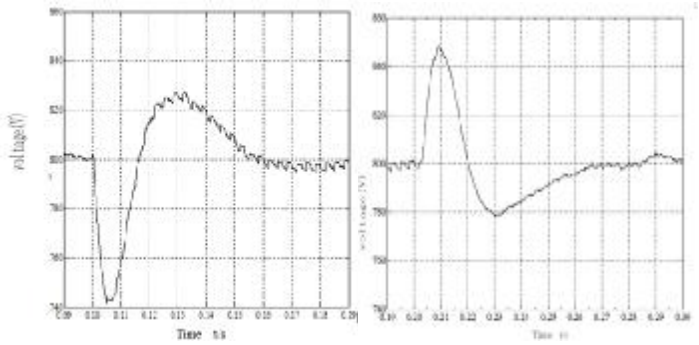
Fig. 2 PI regulator structure

PI regulator structure as shown in figure 2:

The structure satisfies : $\Delta i_p = K_p \Delta U_{dc} + K_i \int_0^t \Delta U_{dc} dt$, K_p is the proportional coefficient of PI controller, K_i is the integral time constant.

DC side voltage APF simulation

Through Matlab simulation, to establish the simulation model of DC side voltage control method based on PI adjustment[4]. The related parameters of the simulation model is set as follows: three-phase voltage is 380V/50Hz, the DC side capacitor 1.65mF, master switch pipe is made of IGBT pipe anti parallel diode, APF output inductance is 4.5mH; rectifier load resistance is 15Ω, the inductance value is 1mH. The detection part of the harmonic APF system using ip-iq method based on instantaneous reactive power theory, the compensation current part adopts SVPWM based current control, given the DC side voltage value is set to 800V. Figure 3 is a APF suddenly loading and unloading load fluctuation of DC voltage waveform.



(a) load dc side voltage (b) processes during the dc side voltage

Fig. 3 PI regulating of dc side voltage fluctuation simulation waveform

Strategies to improve the DC side voltage control

As the harmonic in the power grid is nonlinear and real-time change, and conventional PI regulator is not online setting, the function, which makes the system can't under different deviation of PI parameters self-tuning, which could further improve the control effect.In order to achieve the purpose of further improve the control precision and effect, here to replace PI controller with fuzzy adaptive PI controller.On the basis of the conventional PI control, parameter adaptive fuzzy PI control using the theory of fuzzy logic reasoning based PI parameters, and the deviation between the absolute value and the deviation rate of binary function relationships: $\Delta K_p = f_1(e, ec)$, $\Delta K_i = f_2(e, ec)$, and according to the different e 、 ec , and to adjust parameters,. K_p 、 K_i Set of fuzzy language values of input variable and output variable sets are {NB (negative), NM (negative) and NS (negative), ZO (zero), PS (small), PM (middle), PB (board)}.On the theory of domain coverage and accuracy, NB Z membership function of fuzzy language variables, PB in s-shaped nationalities degree function, the rest of the triangular membership functions[5]. The structure of the fuzzy adaptive PI controller is shown in figure 4, the diagram for deviation of quantitative factors, for the deviation rate of quantitative factors.Under the parameter self-adjusting fuzzy PI control, the controller output variable K_p 、 K_i , the value of the said as $K_p = K_p^* + \Delta K_P$, $K_i = K_i^* + \Delta K_i$, and among them, K_p^* 、 K_i^* are the PI controller`s initial value of parameters K_p 、 K_p , respectively, ΔK_p 、 ΔK_i are the output value of the two-dimensional fuzzy controller respectively. U_{dcr} is a given value of voltage in dc side, U_{dcs} is the actual value of voltage in DC Side[6].

Figure 5 for fuzzy adaptive PI control simulation modeling. For the modeling and Simulation of fuzzy adaptive PI control[7]. Two-dimensional fuzzy controller is provided by Matlab Fuzzy Logic Toolbox

simulation toolbox, take offset quantization factor a_e=0.075, deviation change rate quantization factor a_{ec}=0.075, the ratio of output were 0.06 and 0.3, select the Mamdani reasoning algorithm of fuzzy inference, defuzzification method selection and weighted average method. Figure 6 is a APF in the fuzzy adaptive PI regulator control suddenly loading and unloading load fluctuation of DC voltage waveform.

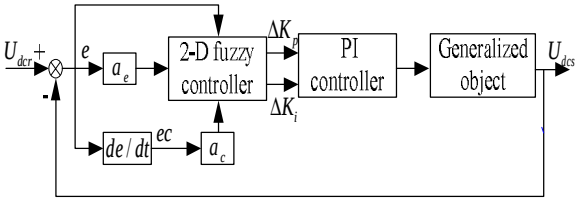


Fig. 4 The structure of the fuzzy adaptive PI controlle

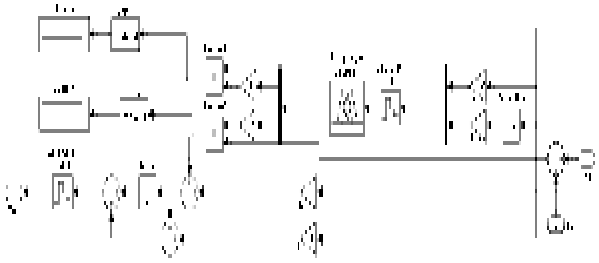
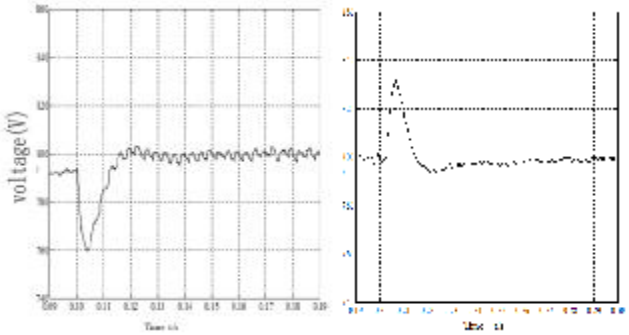


Fig. 5 The fuzzy adaptive PI regulator simulation modeling



(a) load dc side voltage (b) processes during the dc side voltage

Fig.6 Fuzzy adaptive PI control dc side voltage fluctuation simulation waveform

Can be seen from the simulation results, compared with the conventional PI controller, fuzzy PI regulator due to the adoption of PI parameters self adjustment, so that the voltage in the method of small overshoot, quick response, especially to meet the requirements of DC side voltage control on the load mutation occurs, the effect is obviously superior to the traditional PI control method.

The results

According to the control method of active power filter, the main control chip for the TMS320F28335 type DSP, to complete the detection and compensation control function. An experimental system model, the experimental parameters were: the line voltage 380V, frequency 50Hz AC power grid, the output inductor 2mH, the DC side capacitor 4700 F, the capacitor voltage 800V. The main circuit of power switch device using IPM module (PM75RL1A120 Mitsubishi). Using bridge rectifier load with resistance load. Current was detected by i_p-i_q assay; current control with voltage space vector control; DC side voltage control based on fuzzy adaptive PI control. The load current harmonic distortion rate of harmonic THD=21.6%, mainly concentrated in the 6n±1 characteristic harmonic. The load current spectrum as shown in Figure 7, Figure 8, 9 for the experiment of active filter of each experimental waveform.

In Figure 8, wave 1 for compensation after the grid side current waveform, waveform 2 load current waveform; Figure 9 for DC voltage fluctuation in the process of APF soft start system side capacitor waveform. From the above measured waveform can be seen, the active power filter can accurately isolate the harmonic component, which can meet the requirements of DC side voltage control on the load mutation, and be able to real-time control the compensation current output, general compensation effect is very good.

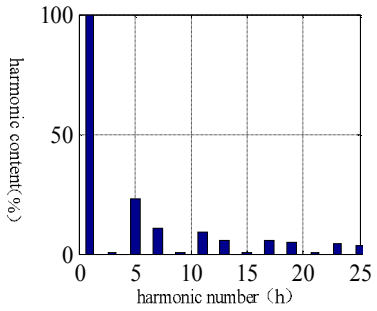


Fig. 7 Load current spectrum analysis diagram

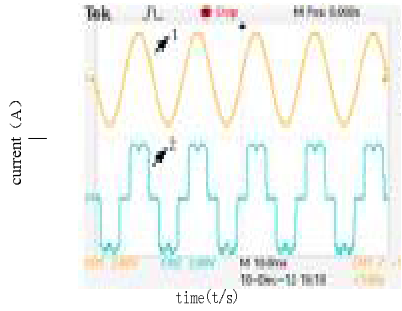


Fig. 8 Compensation after the source side and load side current waveform figure

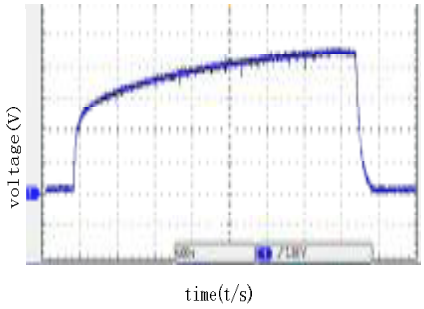


Fig. 9 Soft start in the process of dc side capacitor voltage fluctuation waveform

Conclusions

In this paper, the voltage space vector pulse width modulation current control method and based on the DC side voltage control strategy of PI regulating method based on in the analysis, modeling and simulation result reflects the fuzzy adaptive PI adjusting voltage control has obvious advantages in the DC side. The simulation and experimental results demonstrate the effectiveness of the design method of compensation current control and DC voltage control strategy. In addition, according to the application of fuzzy adaptive PI controller of fuzzy control in active power filter rule table and system testing and implementation of full digital control is the direction of future efforts.

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