Control System Design for Active Rectifier in SST

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1. Introduction

Recently, Solid State Transformer (SST) is proposed to replace the conventional distribution transformers since it has potentially reduce the volume and weight. However, the active rectifier as a part of SST is a non-linear load. It cause the input current becomes distorted and it will affect the power factor of the active rectifier. For that reason, a control system needs to be designed to control the input current of the rectifier that produces the output voltage near the reference value. To achieve this target, a control system which consists of current loop control and voltage loop control are be designed. Based on that, the simulation and experiment are done to check the operation of the control system.

2. Solid State Transformer

2.1 Solid State Transformer Configuration

As shown in Figure 1, the 50/60 Hz AC voltage is transformed to a high frequency (normally in the range between several kilohertz to tens on kilohertz), then this high-frequency voltage is stepped up or down by a high frequency transformer and finally, shaped back into the desired 50/60 Hz voltage to feed the load.

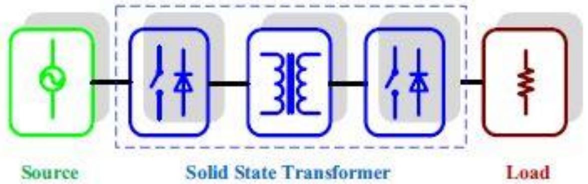

Figure 1 SST configuration

In this study, three-stages SST configuration as shown in Figure 2 is adopted. The three-stages topology consists of a rectifier, a DC-DC converter, and an inverter.

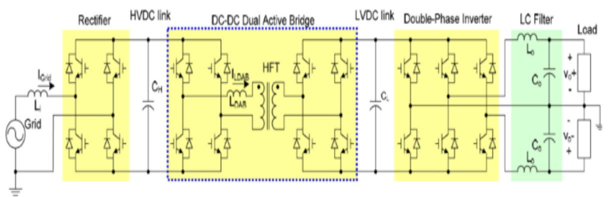

Figure 2 Three stages of SST

2.2 Active Rectifier

Active rectifiers are serve to convert AC to DC. They convert AC to DC in a number of industrial, domestic and other applications. The main constraint of this rectifier is that DC bus voltage needs to be higher than maximum line to line voltage of input generator. That is necessary in order to obtain full control over the rectifier switches.

3. PI Controller

As shown in Figure 3, PI controller is a feedback control loop that calculates an error signal by taking the difference between the output of a system and the set point (reference value). Equation (1) is the basic equation for PI controller where e is the error, k_p is the proportional gain and k_i is the integrational gain.

$$u = k_p e + k_i \int e dt \tag{1}$$

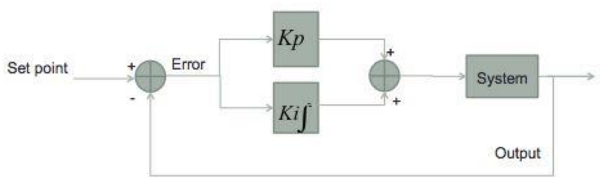

Figure 3 PI controller

4. Research Content

4.1 Research overview

Figure 4 shows the research overview for this study.

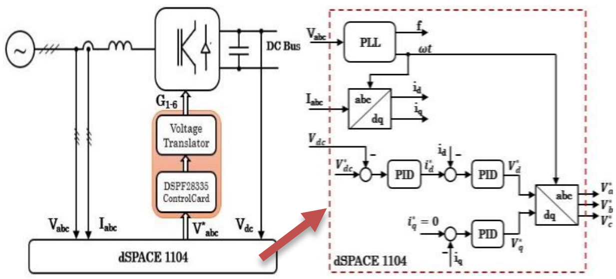

Figure 4 Research overview

To provide unity power factor, angle values are obtained from line voltages v_{abc}. This angle values are used in transformation of *abc* to *dq* frames. Line currents i_{abc} which are transformed into *dq* frame, are compared with *dq* reference currents. *d*-axis reference current i_d^* is obtained by comparing dc reference voltage v_{dc}^* and actual dc voltage v_{dc}. On the other hand, *q*-axis reference i_q^* is set to '0' in order to provide unity power factor. Then, this *dq* switching functions are transformed into *abc* frames and they are sent to PWM block to provide pulses for power switches.

4.2 Control System Design

The main purpose of this control method is to regulate v_{dc} voltage by settling i_d current and to provide unity power factor by controlling i_q current. Equation (2) and (3) show the model equations for i_d and i_q [1]. While, equation (4) is the model equation for voltage.

$$\frac{d}{dt} i_d = -\frac{R}{L} i_d + \omega i_q - \frac{1}{L} v_d \tag{2}$$

$$\frac{d}{dt} i_q = -\frac{R}{L} i_q - \omega i_d - \frac{1}{L} v_q \tag{3}$$

$$v_o = \frac{1}{C} \int i_c dt \tag{4}$$

4.3 Simulation and Result

The simulation is realized by using MATLAB Simulink. The input voltage is 20V and reference value of v_{dc} is set to 50V. The switching frequency is 10kHz, crossover frequency is 1kHz and phase margin is 75°. Parameters of controller P and I are shown in Table 1. The simulation and the result for v_{dc} are shown in Figure 5 and 6 respectively. From the result, the value for v_{dc} is 50V with settling time 5s.

Table 1 Parameters of controller

	P	I
Current Controller	0.1	48
Voltage Controller	0.6	0.6

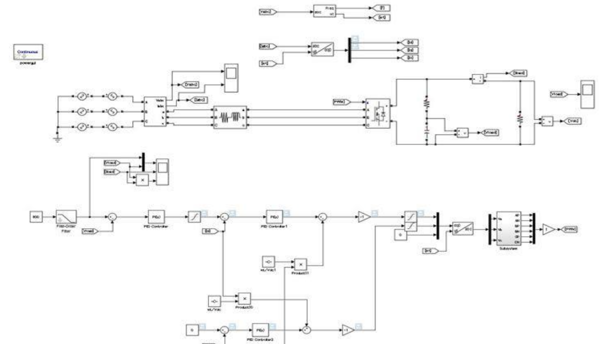

Figure 5 Simulation

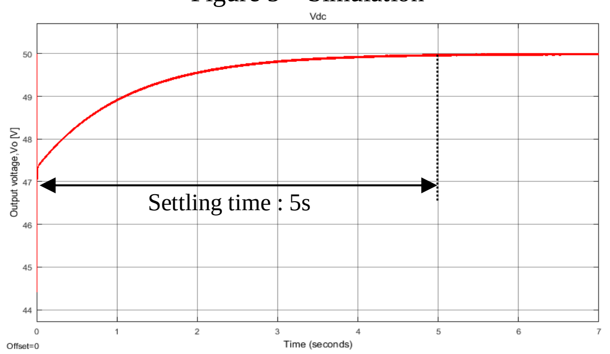

Figure 6 Result for v_{dc}

4.4 Experiment and Result

The workspace of experiment is shown in Figure 7. The input voltage is regulated by using slider before it connected to the current sensor and voltage sensor. The three phase input current i_{abc} and input voltage v_{abc} are detected and be flown to DSPACE 1104 to control the output three phase voltage reference v^*_{abc}. By using, RTI model connected to the DSPACE 1104, v^*_{abc} can be regulated then it will be flown to DSP board and voltage translator board for PWM configuration of MyWay Inverter which acts as active rectifier. The result of the experiment is expressed by using ControlDesk as shown in Figure 8. v^*_{dc} is set to 50V and v_{dc} is 50.19V.

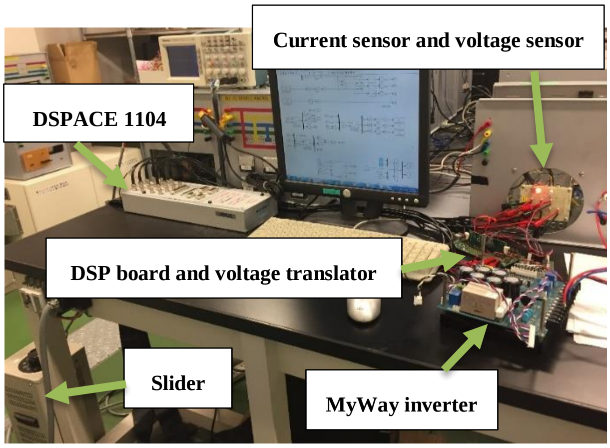

Figure 7 Workspace of experiment

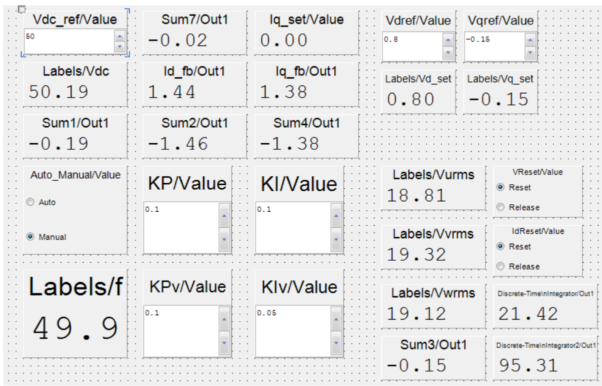

Figure 8 Experiment result

5. Conclusion and Future Works

This new control algorithm gave the new controlled input currents better signals to form PWM configuration. Therefore, it regulated the output voltage around the reference value. Hence, the amount of steady state error can be reduced. For the future works, this active rectifier, dc-dc converter and inverter will be connected together in order to form SST.

References

[1] Marco Liserre, Antonio Dell'Aquila, Frede Blaabjerg: *"Design and Control of a Three-phase Active Rectifier Under Non-ideal Operating Conditions"*.