Fuzzy Based Control Approach for Three-Phase Single-Stage Grid-Connected Boost Inverter

Electrical and Computer Engineering
ECE

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Arman Sargolzaei, PhD; Eric Chan, BSc; Muhammad H. Rashid, PhD;
Florida Polytechnic University, Lakeland, FL, USA

Abstract

A novel control method based on fuzzy logic is developed to control the active and reactive power of a three-phase current source boost inverter. The proposed procedure utilizes the SVPWM switching pattern with advantages of simple implementation and decent DC-bus utilization. Additionally, it is capable of boosting the low DC voltage to a higher level in just one stage. In previous studies, the controller could not respond efficiently and accurately due to simultaneous active and reactive power step changes.

Using the proposed technique, both active and reactive power can be changed at the same time which will have a better system response under fault conditions. The simulation analysis of the proposed control technique is conducted using MATLAB and shows that the proposed controller is able to track the active and reactive power accurately while they change simultaneously. As a result, the system is more robust under fault conditions compared with traditional control approaches..

Background

To incorporate the DC voltage output of photovoltaics (solar panels) into the power grid, the DC voltage needs to be inverted into balanced three phase AC voltages. This can be done by a current source inverter (CSI) which has six switches (MOSFETs or IGBTs) that need to be controlled to generate the three phase AC output.

The switching pattern used for a CSI is called space vector pulse width modulation (SVPWM), which denotes a specific time period when each switch is on. This time period is going to be controlled by the proposed controller, as it affects the output active and reactive power of the system. Previously, other controllers have had individual reference tracking for active or reactive power, but they did not do well when both simultaneously change—this controller seeks to solve those issues.

Objectives

- Invert a DC voltage into robust three phase AC voltage for the power grid.
- Reduce overshoot and reduce the transient response time of the system compared to a previous control method.
- Track simultaneous active and reactive power reference changes efficiently.

Procedure

- We can control the active and reactive power output by controlling the switching time period of the CSI switches. A PID controller was first tuned to accomplish this.
- Then, the PID controller was converted into a Fuzzy controller using the following equations, where G_E set a constant gain of the error. (See Figure 2 for implementation details) Figure 3 shows the Fuzzy membership functions used.

$$G_{CU} = \frac{K_i}{G_E} \quad (1)$$

$$G_{CE} = G_E\left(K_p - \frac{\sqrt{K_p{}^2 - 4K_iK_d}}{2K_i}\right) \quad (2)$$

$$G_U = \frac{K_d}{G_{CE}} \quad (3)$$

- Then, a robust sign of the error (RISE) controller was tuned and used along with the Fuzzy controller. The output for the RISE controller is based on the parameters K_F and β,

$$\dot{\mu}(t) = K_F e + \beta sign(e)$$

- The outputs of all of these systems are then summed to produce the overall switching time for the six control switches.

The Proposed Control System

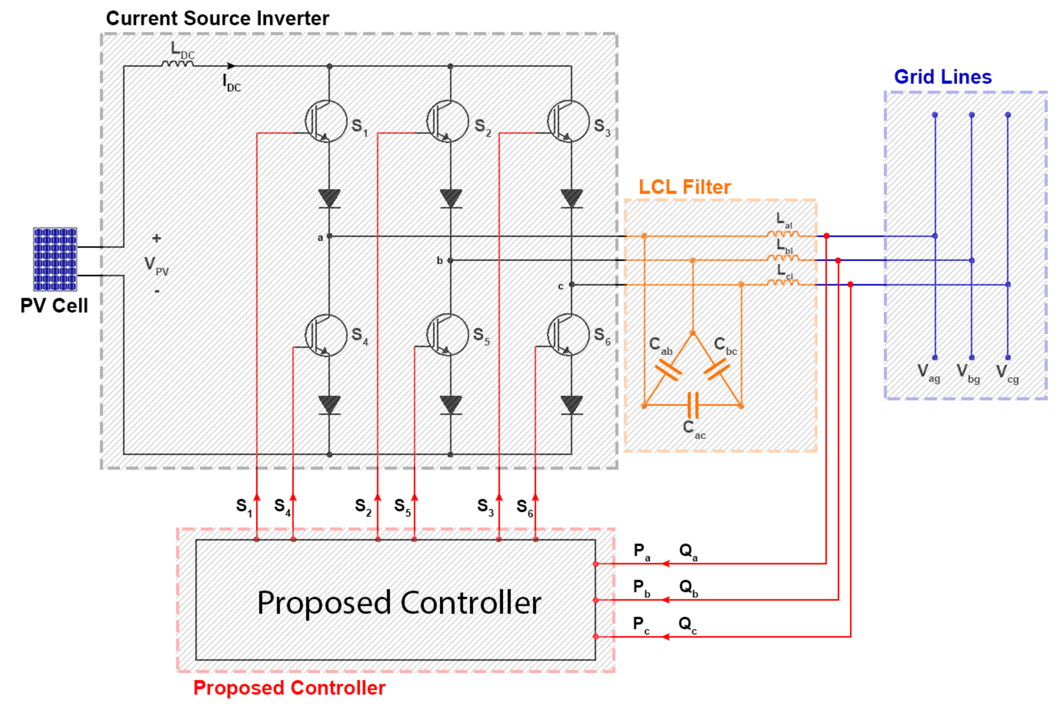

Figure 1 Incorporating the PV cells into the power grid system

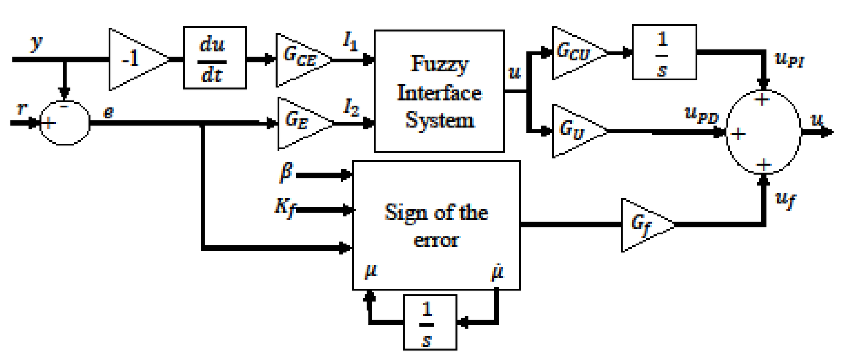

Figure 2 Proposed Controller Schematic

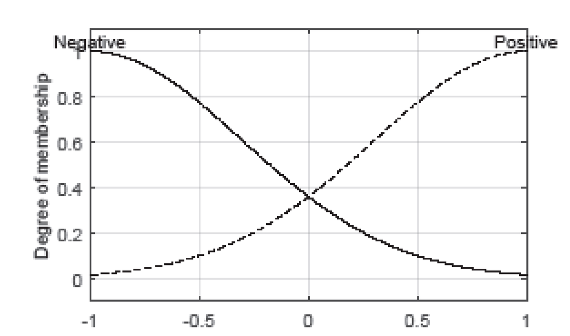

Figure 3 Fuzzy Membership functions of the fuzzy controller

Results

The system was tested by setting up the system shown in Figure 1 in MATLAB with the following parameters: $L_f = 2mH$, $C_f = 15\mu F$, $R_f = 2\Omega$, $L_{dc} = 6mH$, $R_{dc} = 0.2\Omega$. In this case, L_f and C_f refer to the filtering inductor and capacitors. The active and reactive outputs are shown in Figures 4 and 5 comparing only a fuzzy controller for reference tracking with the fuzzy and RISE controller.

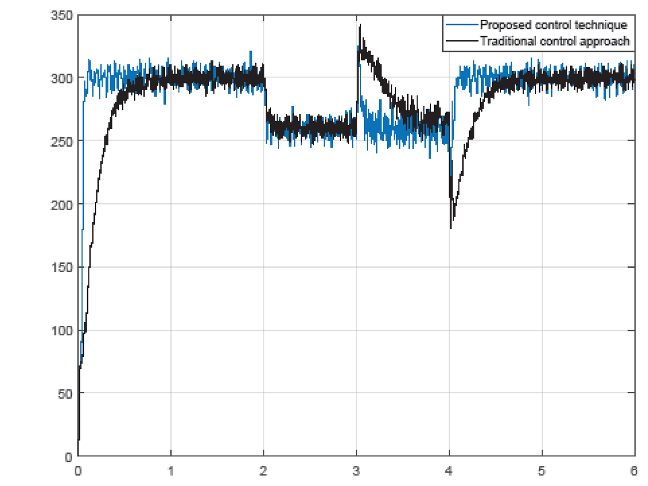

Figure 4 The active power tracking comparison of the two systems

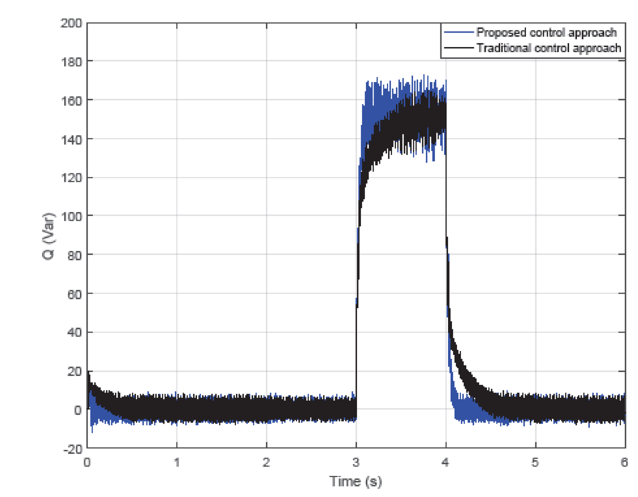

Figure 5 The reactive power tracking comparison of two systems

Table 1 Comparison of the two control approaches

Performance Measure	Proposed Approach	Traditional Approach
Active power mean-squared error	193.59	1447.2
Reactive power MSE	25.15	67.49
Active power rise time	0.06 s	0.37 s
Reactive power rise time	0.064 s	0.21 s

Conclusions

Compared to the traditional approach of using a Fuzzy PID controller, the proposed controller using the RISE control method shows that the system could respond efficiently and accurately to track a reference active and reactive power. Additionally, it is better at adjusting to simultaneous active and reactive power changes, which results in a more robust system that performs well under fault conditions of the grid. This controller for a current source inverter shows to be an effective way to incorporate photovoltaic cells to the grid.