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Reactive Power Control of PV Grid system With Fuzzy Controller

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Abstract:

Historically, electric power system operators have seen photovoltaic (PV) power systems as potential sources of problems due to intermittency and lack of controllability. However, the flexibility of power electronic inverters allows PV to provide grid-friendly features including volt-VAR control, ramp-rate control, high-frequency power curtailment, and event ride-through. Commercially available smart PV inverters can further provide frequency down-regulation by curtailing power, but they are unable to provide true frequency regulation through active power control (APC) because they are unable to increase power on command. This paper proposes a coordinated DC-link voltage control and deloading control for two-stage PV system to offer frequency support in an islanded microgrid without energy storage system (ESS).

Introduction:

Power supply and power quality have been critical issues in power system recently. The grid-connected photovoltaic (PV) generator has nowadays become more popular because of its reliable performance and its ability to generate power from clean energy resources. The dc output voltage of PV arrays is connected to a dc/dc boost converter using a maximum power point tracking (MPPT) controller to maximize their produced energy. Then, that converter is linked to a dc/ac voltage source converter (VSC) to let the PV system push electric power to the ac utility. The local load of the PV system can specially be a non- linear load, such as computers, compact fluorescent lamps, and many other home appliances, that requires distorted currents. Development of a means to compensate the distribution system harmonics is equally urgent. In this case, PV generators should provide the utility with distorted compensation capability, which makes currents injected/absorbed by the utility to be sinusoidal. Therefore, the harmonic compensation function can be realized through flexible control of dc/ac VSC. Instantaneous power theory has successfully completed active power filter (APF) designing with good performance. However, the PV-APF combination has just been gradually developed for several years. This combination is capable of simultaneously compensating power factor, current imbalance, and current harmonics, and also of injecting the energy generated by PV with low total harmonic distortion (THD).

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Even when there is no energy available from PV, the combination can still operate to enhance the power quality of the utility. To the best of our knowledge, this idea was initiated in 1996 by Kim *et al.*. In this study, the PV system needs energy storage elements, which negatively increase the entire cost. Besides, the mathematical demonstration was not sufficiently provided. After that, the control techniques have been improved in some later efforts to develop PV inverters with real power injection and APF features. However, their research did not show consistent results obtained by their proposed theories, and they are applicable for a single-phase PV only.

PROPOSED SYSTEM:

The configuration of the three-phase grid-connected inverter for the grid-connected and islanding operations is shown in Fig. 1. The power circuit contains a microsource such as photovoltaic panels and fuel cells represented by the dc source, a three-phase pulse width modulation (PWM) inverter, a three phase sensitive load connected to the output of the LCL filter, a static transfer switch (STS) for grid-on or grid-off control, and an LCL filter with a damping resistor. An LCL filter is used instead of an L filter, as it can provide higher high-frequency harmonic attenuation with the same inductance value. However, a system with an LCL filter has an inherent high-resonant peak at the resonant frequency of the LCL filter, which would make the current control system unstable. To avoid this stability problem, various active damping approaches for PI-based current control of a grid-connected inverter with an LCL filter are proposed by using additional feedback or by adjusting the ratio of the control frequency and resonance frequency of the LCL filter.

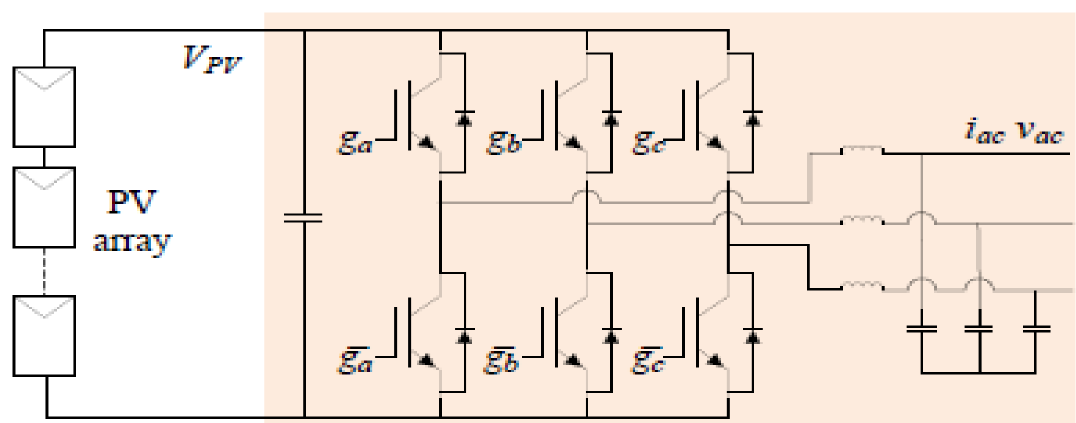

Figure 1: Proposed PV System using APC

The V_{PV} voltage controller regulates the PV voltage by sending the d-axis current command, *id*, as in [4]. The inverter's output current is controlled in the DC-AC controller block using sinusoidal pulse-width modulation (PWM) with independent proportional-integral (PI) control on the d-axis and q-axis

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currents in the rotating synchronous (dq) reference frame, as in [4]. Reactive power output can be controlled separately by regulating the q-axis current command *iq* in the voltage regulation block, but that is not the focus here.

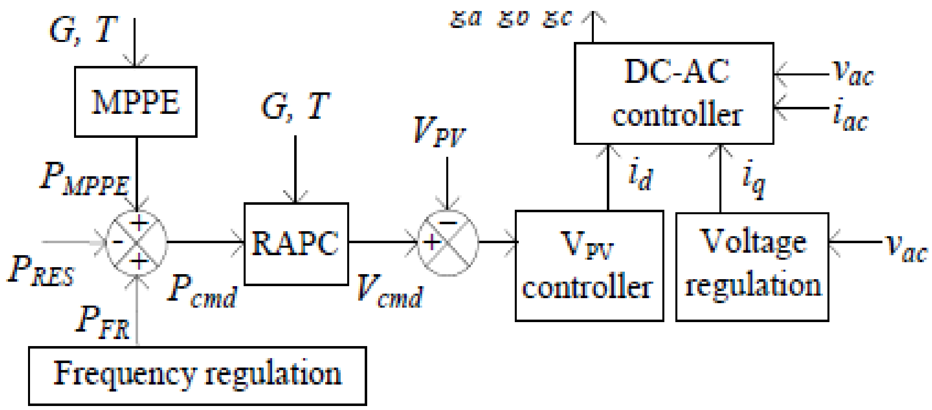

Figure 2: Control Structure for PV Inverter

FUZZY LOGIC CONTROLLER:

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy logic controller (FLC) shown in figure 7. Generally, the FLC is one of the most important software based technique in adaptive methods [7].

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

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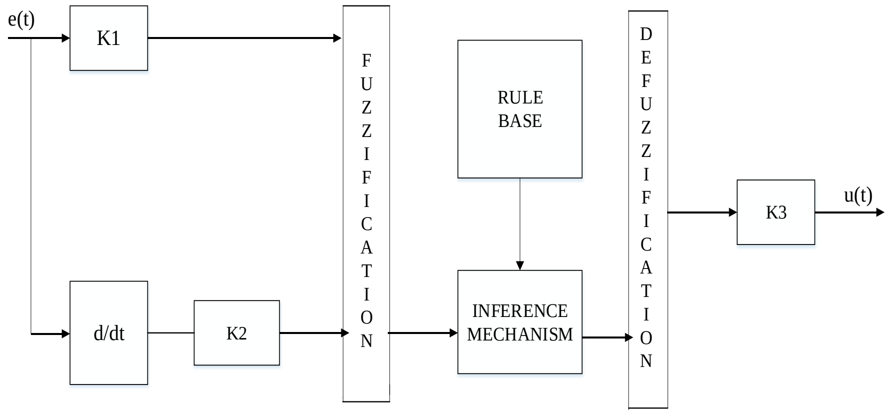

Figure 3: Basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered.

SIMULATION DIAGRAM & RESULT:

For demonstration purposes, the MPPE method was implemented in a three-phase, single-stage prototype inverter using a simple three-phase bridge power stage and an L-C output filter in MATLAB/Simulink Environment, as shown in Figure 4.

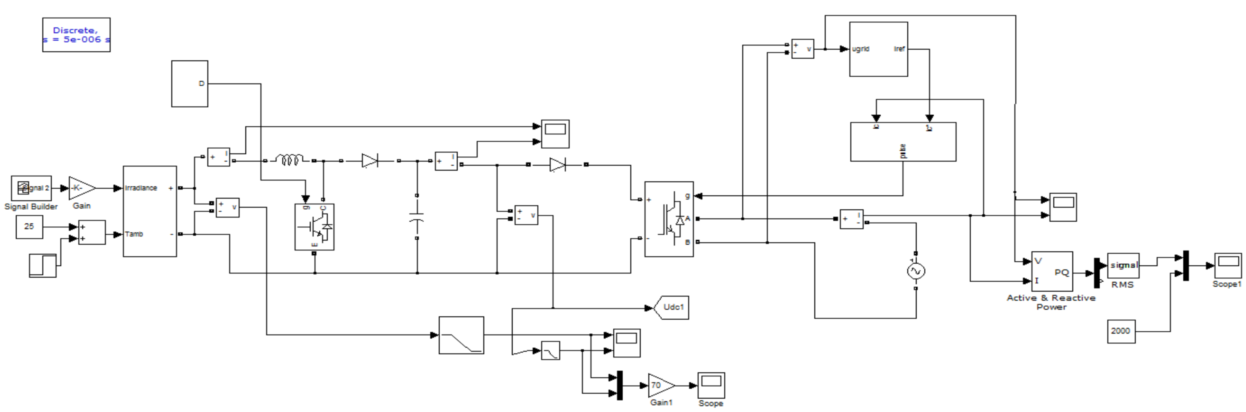

Figure 4: Simulation Diagram for PV-Grid System

Case 1: Implementation of Proposed system with Conventional Controller.

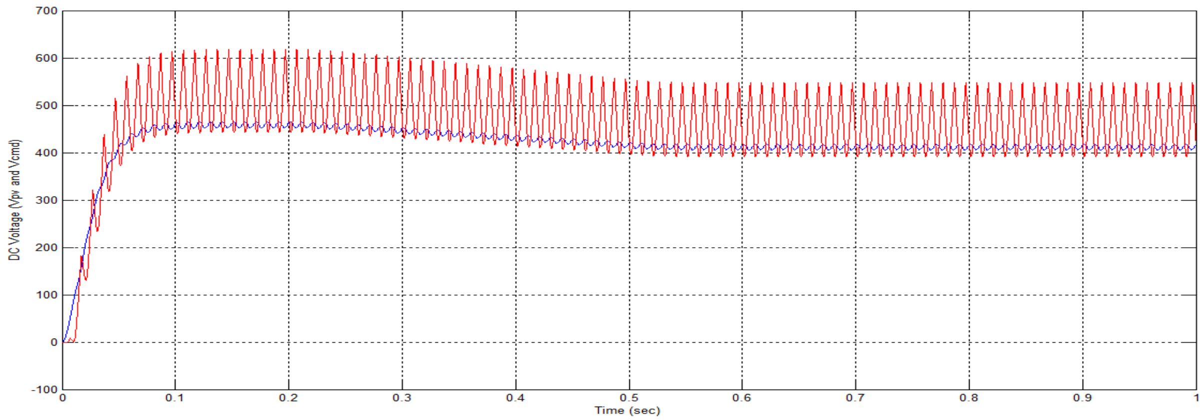

Figure 5: Simulation Result for DC Voltage for PV and CMD

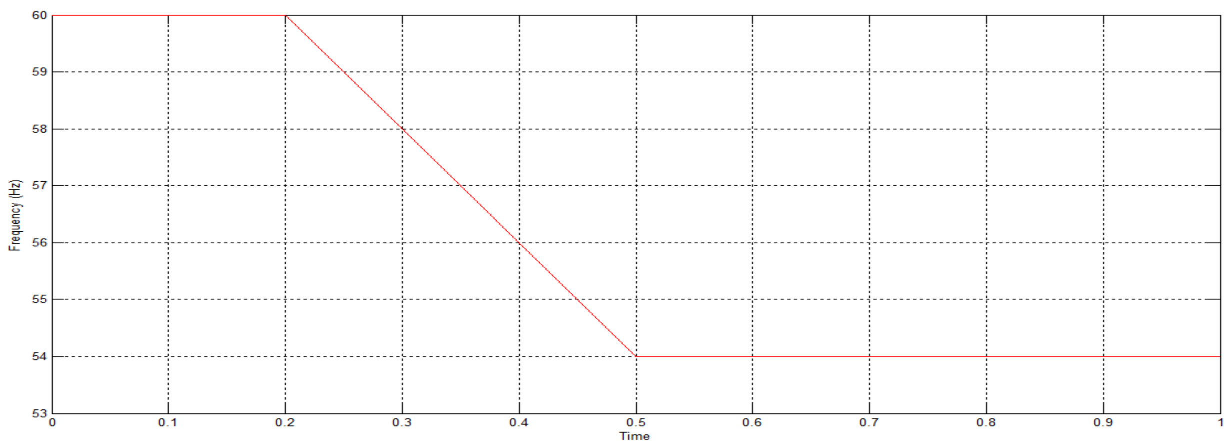

Figure 6: Simulation Result for Frequency

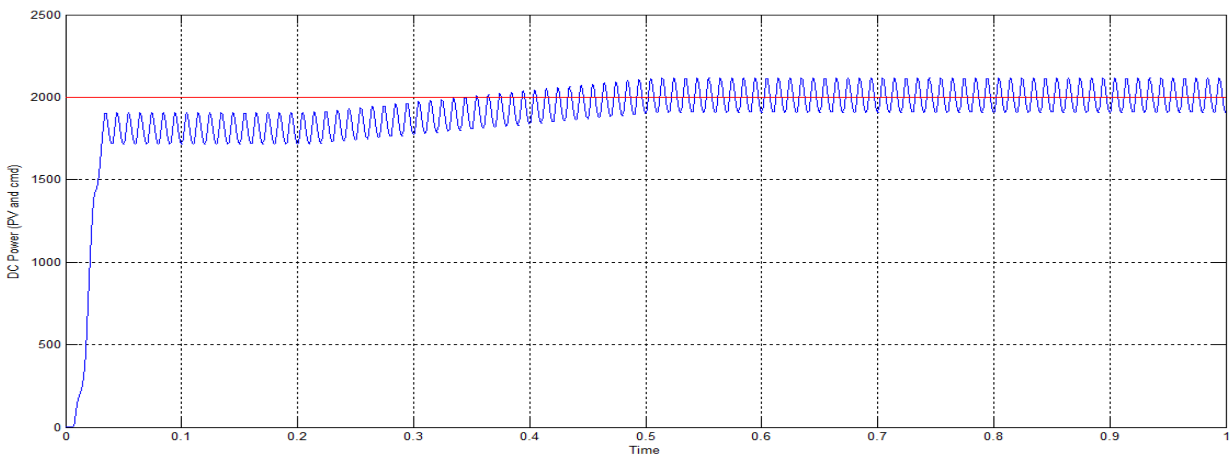

Figure 7: Simulation Result for DC Powers of PV and cmd

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The frequency regulation block in Fig. 5 was programmed with a 5% droop slope. This means that a frequency change equal to 5% of the nominal frequency, or 3 Hz, will result in a change of 100% of the inverter's nominal power, so $PFR = P0\cdot(f - f0)/(f0\cdot 0.05)$, where $P0$ is the rated inverter power, f is the measured grid frequency from the PLL, and $f0$ = 60 Hz. A 5% droop slope is a common value used in synchronous machines, though machine droop response is orders of magnitude slower than the inverter responses shown below.

Case 2: Implementation of Proposed system with Fuzzy Logic Controller.

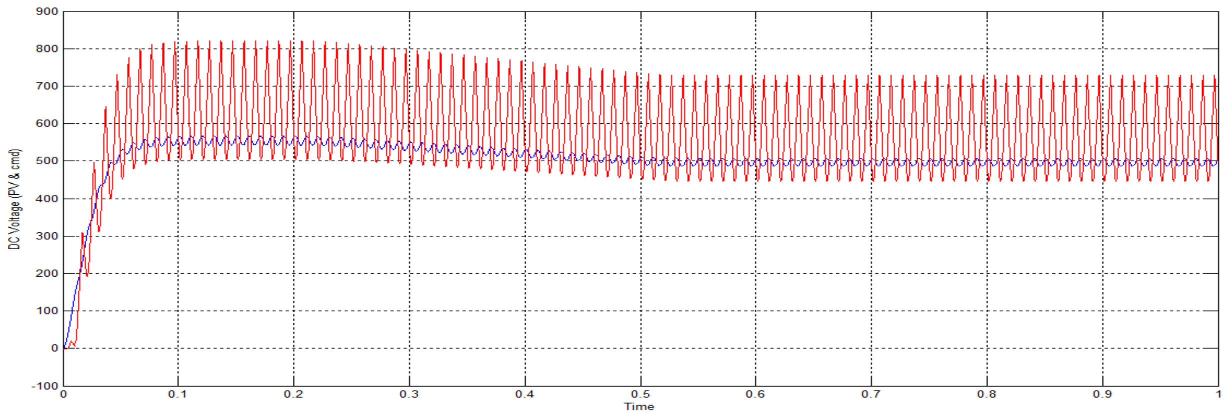

Figure 8: Simulation Result for DC Voltage for PV and CMD

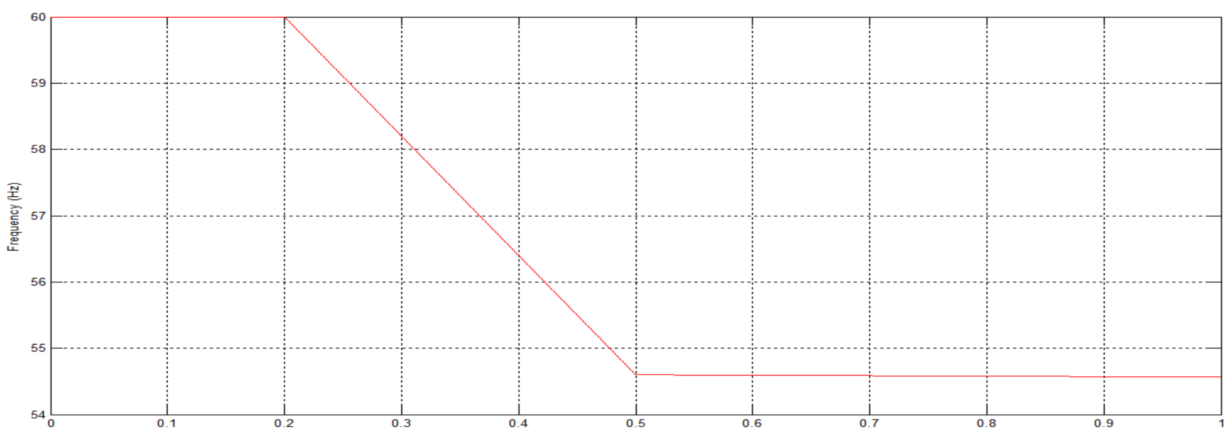

Figure 9: Simulation Result for Frequency

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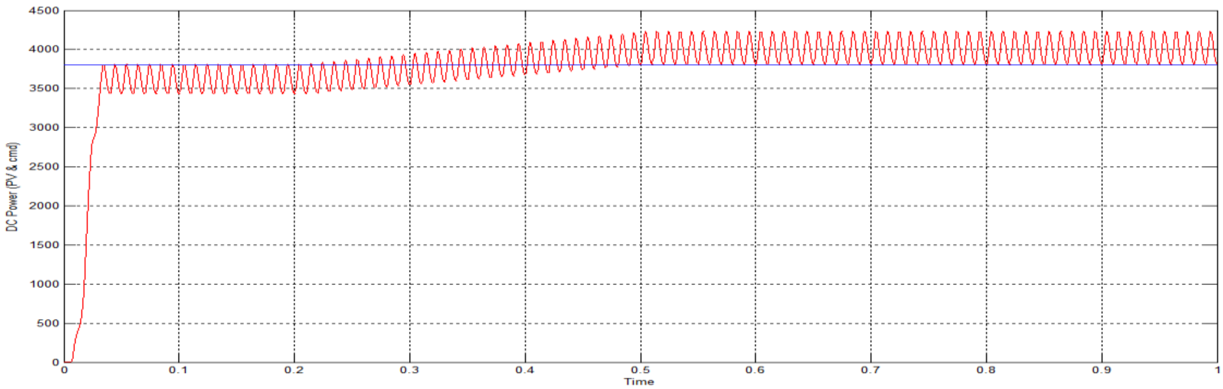

Figure 10: Simulation Result for DC Powers of PV and cmd

Conclusion:

The rapid active power control method introduced here has been experimentally shown to provide very fast and accurate response to a demanding range of grid frequency events and tested in Matlab/Simulink using conventional and Fuzzy logic conrollerss. The experimental validation used two real PV arrays to demonstrate that the method is robust to realistic changes in weather conditions. Used in conjunction with a PV maximum power point estimation method experimentally validated here, the RAPC method enables a suite of fast-responding PV inverter active power control methods, including but not limited to the fast power-frequency droop response demonstrated here. There has been little incentive in the past for grid-interactive PV inverters to have particularly high-bandwidth PLLs or DC voltage controllers.

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