New PQ Controller for Interconnected Microgrids

Shahram Ramezani[1] and Mohammad Ali Azimi[2]
[1]Student, Department of Electrical Engineering, Sarvestan University, Fars, IRAN
[2]Student, Department of Electrical Engineering, Sarvestan University, Fars, IRAN

[1]Corresponding Author: ShahramRamezani23@gmail.com

ABSTRACT

Distributed Generation Sources are becoming an inseparable part of modern electrical grids. Finding the control strategies which can help them to be as much as possibly beneficial for the grid has been a big concern among the researchers. In this work, a PQ controller for connecting A DC source simulates the effect of a Distributed Generation to the grid based on the decoupling of Active and Reactive powers has been proposed. The Simulation results which have been in the MATLAB/Simulink environment show the effectiveness of this control technique for injecting the defined value of active and reactive power to the grid.

Keywords— Distributed Generation, PQ Controller, Interconnected Mode, Microgrids, DG

I. INTRODUCTION

A microgrid is an integration of Distributed Generation Resources (DGR) and a Load which works in a centralized condition. In other definition, it can be expressed as a power grid in distribution level that can be activated autonomously or interconnected to the utility grid. To run microgrids to work properly, a switch should be able to disconnect microgrid with the upstream grid. In this case, the microgrid will work in islanding mode. In the islanding situation, loads will be fed by DGR. The voltage and frequency should be maintained in the acceptable range in this condition.

Distributed Energy Resources which are being used in microgrids nowadays are:
1. Combined heat and power (CHP) systems
2. Wind energy conversion systems (WECS)
3. Solar photovoltaic (PV) systems
4. Small-scale hydroelectric generation
5. Fuel cell
6. Biomass
7. Other Distributed Generation Resources [1-2].

Among all mentioned resources PV farms play a significant role in microgrids and future electrical grids. It is one of the most important DC sources for providing power to the load and grid. Microgrids, by having the ability to move smoothly from interconnected to islanding mode, a vice versa can provide enough power for loads. In islanding mode, microgrid needs coordination between produced power by DGs and loads with proper voltage and frequency. While in interconnected mode, a microgrid can update itself by the main grid to match voltage and frequency with the main grid. These issues can be addressed by controlling power electronics interfaces. In this part, control strategies for islanding microgrids have been categorized [3-4].
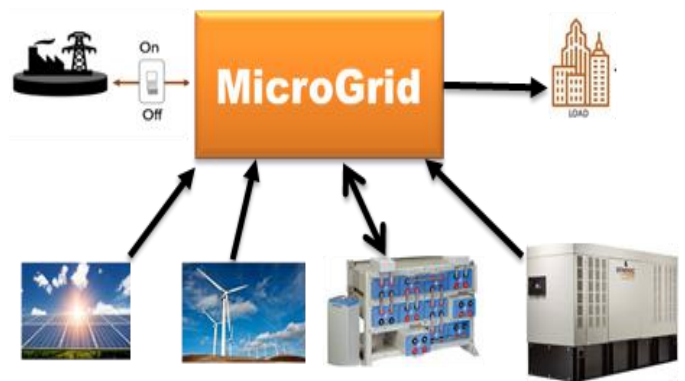

Figure 1: Existing Mechanisms for your paper

Figure (1) shows a microgrid integrated with resources and load. Researchers are working to improve the capabilities of microgrids in many aspects like hybrid-microgrids [5], power quality issues [6], prices [7] and possibility and optimization [8] and connecting electric vehicles [9] to the grids. In recent years, a lot of researchers in the field have focused on designing new controllers to reach out to the defined goals for the microgrid's projects. In this paper, a PQ controller for regulating the output power of the inverter of a DC source has been designed. This controller compares the reference active and reactive power with the inverter output and injects control signals to the PWM. For verifying the effectiveness of the designed controller, the simulation results in MATLAB/Simulink environment have been presented.

II. PQ CONTROLLER

Distributed energy resources as a prominent part of the electrical grid. These resources such as photovoltaic, wind turbines, and fuel cells produce DC power and for connecting them to load or AC grid the generated power

should be connected to the power system with pre-defined waveform, frequency, magnitude, and phase angle. The power electronic interfaces are responsible for this connection. Fig (2) illustrates an electrical circuit of this process. A DC source is used as a source with constant voltage to be connected to the inverter. The Total Harmonic Distortion (THD) has been almost cleared by low pass filters. The output of the inverter is connected in parallel with the grid and the load.
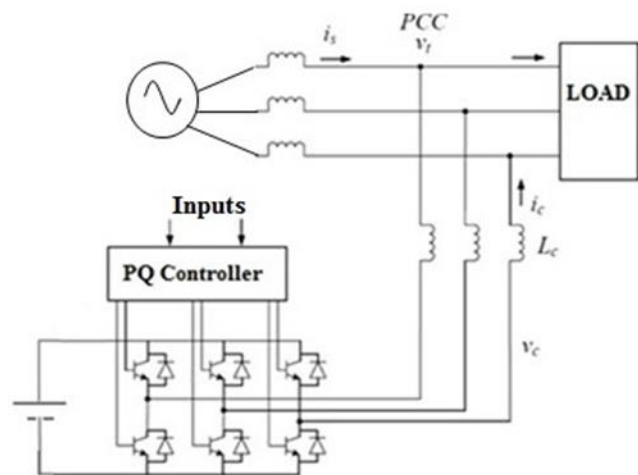

Figure 2: DE system with a power electronics interface [14]

Improvements in the electrical system and new technologies have turned in the recent years, several works for finding an optimal controller for connecting a DG have been conducted by the researcher in the field. In this work, a new control PQ strategy for connecting a DG to the electrical grid has been presented. This method controls the Active and Reactive power of the DG and delivers defined power to the grid. Figure () shows the whole process from sensing the data to producing the signal for feeding Pulsed Width Modulation (PWM).

An important characteristic of this control method is that both active and reactive powers will be controlled independently. The active power mode is responsible for controlling active power while the output active power is controlled at a reference level. This can be happened by controlling the output current at a reference level. By controlling the powers, the power factor can be controlled at the desired value. Like what has been explained for active power, Th reactive power mode is responsible for controlling reactive power while the output reactive power is controlled at a reference level. This can be happened by controlling the output current at a reference level. By controlling the powers, the power factor can be controlled at the desired value. After controlling the process, and sending the controlling signal to the PWM, the output will be the signal switching which should be given to the gates

drive of the inverter to turn the power electronics switches on or off [6-8]. In this paper, instead of using Active power (P) and Reactive Power (Q) in the equations (1-2), Active power (P) and Reactive Power (Q) have been taken after low pass filter to calculate the power and comparing to the reference values [14].

$$P(t) \approx \frac{v_t \, v_c}{\omega \, L_c} \tag{1}$$

$$Q(t) = \frac{v_t}{\omega \, L_c} \, (Vt - Vc) \tag{2}$$

A phase-locked loop or phase lock loop (PLL) is a control system that takes the voltage of the grid and based on that produces an output signal whose phase of the input signal. Fig (3) shows a PLL that takes V_{abc} and provides frequency and V_{rms} for the control system. Fig (4) illustrates the designed control strategy in this research. Based on equations (1-2), P will be responsible for finding phase reference while the Q is used to define the value of voltage.

$$\Delta\omega = k_{p1} \, (p^* - p) + k_{I1} \int_0^t (p^* - p) dt \tag{3}$$

$$\alpha^* = k_{I1} \int_0^t (\Delta\omega - \omega) dt \tag{4}$$

Based on the equations (3-4) and fig (3), the pre-defined value for active power is compared to the output active power P of the inverter. The output of this stage has been given to the first PI controller based on Eq (3). The output of the PI controller is $\Delta\omega$. KP_1 and KI_1 are the gains related to proportional and integral parts of the PI_1. This $\Delta\omega$ is added to the previous ω and they shape the new phase angle α which should be given to equation for finding control signal. The new value of the phase angle is α* Eq (4).

Based on the equations (5-6) and fig (3), the pre-defined value for reactive power is compared to the output reactive power Q of the inverter. The output of this stage has been given to the second PI controller based on Eq (5). KP_2 and KI2 KI_2 are the proportional gain and integral gain of the PI_2. The output of PI controller is ΔE This ΔE Is added to the previous E and they shape the new phase angle E which should be given to equation for finding control signal.
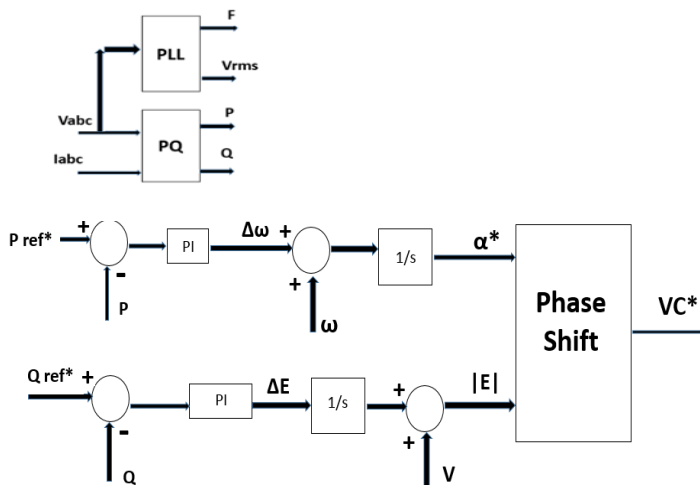
Figure 3: PQ control strategy

The new value of the phase angle is $| E |$ Eq (6). This output voltage is in phase with the V_{abc} [10-12].

$$\Delta E = k_{p2} (Q^{\cdot} - Q) + k_{I2} \int_0^t (Q^{\cdot} - Q)dt \quad (5)$$

$$|E| = k_{I2} \int_0^t (Q^{\cdot} - Q)dt + V_{rms} \quad (6)$$

Generating three-phase reference voltage is taken place with $| E |$ and α* with the below equations. BY considering $|E|$ as E_{ref} and α* as δ_{ref} and finally, three-phase reference voltages will be transferred to gate signals by PWM.

$$V_a = E_{ref} \sin (\omega t + \delta_{ref}) \quad (7)$$

$$V_b = E_{ref} \sin (\omega t + \delta_{ref} - 120°) \quad (8)$$

$$V_c = E_{ref} \sin (\omega t + \delta_{ref} - 120^O) \quad (9)$$

III.   SIMULATION RESULTS

The circuit in Fig (2), and the controller have been designed and simulated in MATLAB/Simulink environment. The grid voltage in this research is 380 V while the frequency defines as 50 Hz. In this work, the DC source has 800V and should deliver active and reactive power as $P = 10\ KW$ and $Q = 0.$ As figure (5) shows that PQ controller has been applied to the DC source has a good performance. The goal is to provide 10 kW for load from the inverter and 40 kw from the grid have been provided to the load. The top figures show the output voltage and current of the inverter. This voltage is sinusoidal and with low THD. Based on figure (5), the injected power from the grid to load are: $P = 40\ KW$ and $P = 10\ KVAR.$ These values from grid and inverter provide the required active and reactive power for the load.

IV.   CONCLUSION

In this paper, a PQ controller applied to the inverter with a DC source to deliver a specific active and reactive power to the load. The controller performance evaluated in MATLAB/Simulink environment. The simulation results verify the effectiveness of this control strategy. This control strategy can be used in the interconnected microgrid to deliver defined power to the load or the grid.
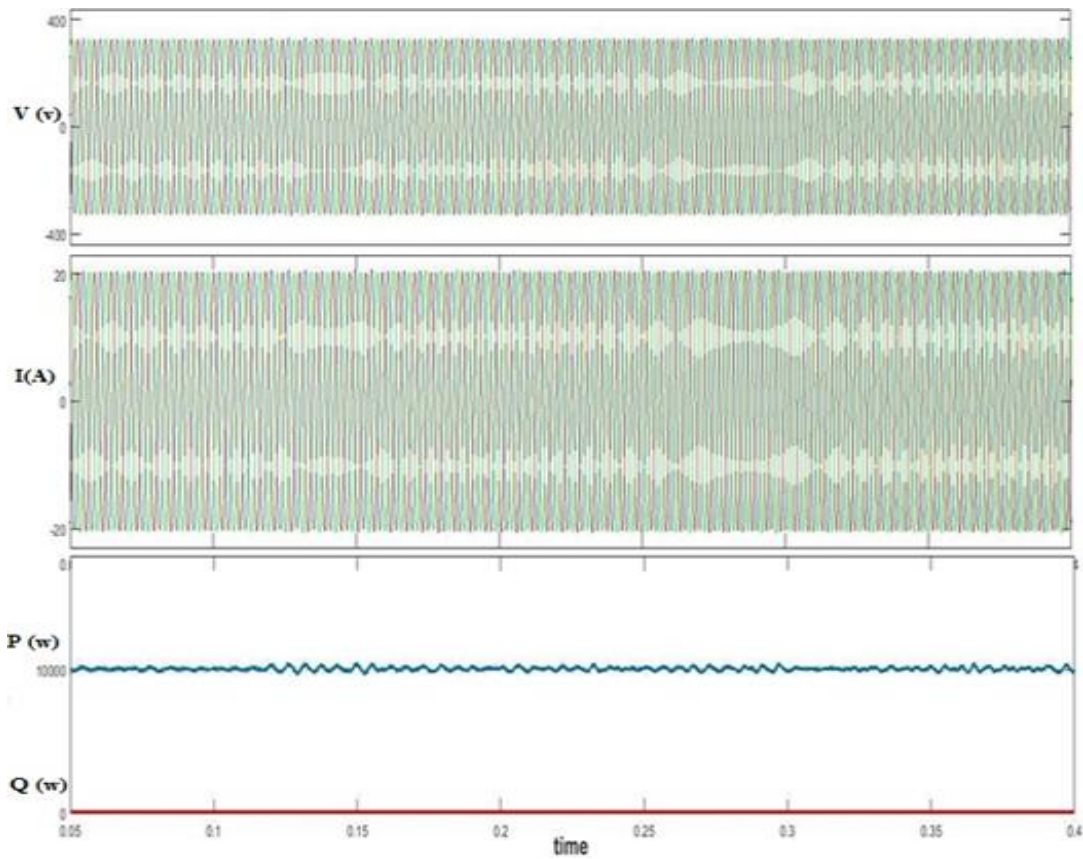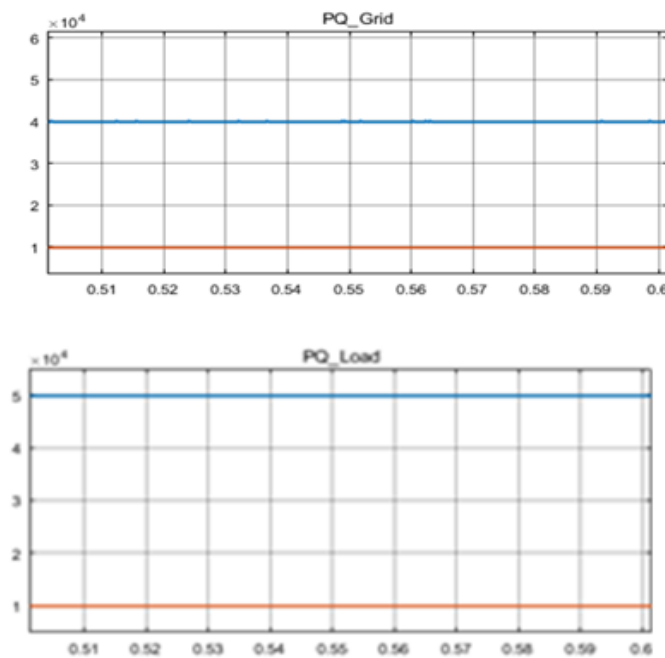
Figure 4: Simulation Results

Figure 5: active and reactive power for grid and load

REFERENCES

[1] https://building-microgrid.lbl.gov/about-microgrids.

[2] S. Chowdhury, S. P. Chowdhury,, & P. Crossley. (2009). *Microgrids and active distribution networks*. Available at: http://uni-site.ir/khuelec/wp-content/uploads/Microgrids-and-Active-Distribution-Networks.pdf.

[3] H. Han et al. (2016). Review of power sharing control strategies for islanding operation of ac microgrids. *IEEE Transactions on Smart Grid, 7*(1), 200-215.

[4] N. Pogaku, M. Prodanovic, & T. C. Green. (2007). Modeling, analysis and testing of autonomous operation of an inverter-based microgrid. *IEEE Transactions on Power Electronics, 22*(2), 613–625.

[5] S. Daneshvar Dehnavi & E. Shayani. (2015). Compensation of voltage disturbances in hybrid AC/DC microgrids using series converter. *Journal of Ciencia & Natura, 37*(2), 349-356.

[6] S. Daneshvar Dehnavi, M. shahparasti, M. Simab, & S.M.B. Mortezavi. (2015). Employing interface compensators to enhance the power quality in hybrid AC/DC microgrids. *Journal of Ciencia & Natura, 37*(2), 357-363.

[7] Shirvani, A. & D. Volchenkov. (2019). A regulated market under sanctions: On tail dependence between oil, gold, and tehran stock exchange index. *Journal of Vibration Testing and System Dynamics, 3*(3), 297–311.

[8] J. Aghaei & M.I. Alizadeh. (2013). Multi-objective self-scheduling of CHP (combined heat and power)-based microgrids considering demand response programs and ESSs (energy storage systems). *Energy, 55*, 1044-1054.

[9] Amir Ghaedi, Saeed Daneshvar Dehnavi, & Hadi Fotoohabadi. (2016). Probabilistic scheduling of smart electric grids considering plug-in hybrid electric vehicles. *Journal of Intelligent & Fuzzy Systems*, 1-12.

[10] Y. Xu, L. M. Tolbert, J. N. Chiasson, F. Z. Peng, & J. B. Campbell. (2007). Generalized instantaneous nonactive power theory for STATCOM. *IET Electric Power Applications, 1*(6), 853-861.

[11] N. Mohan, T. M. Undeland, & W. P. Robbins. (1995). *Power electronics: Converters, applications, and design*. (2nd ed.). John Wiley and Sons.

[12] D. Garrad & U. Hassan. (1998). What is power quality?. *In Proceedings of the 10th British Wind Energy Association Conference*, pp. 22–24.

[13] S. Adhikari et al. (2011). Utility-side voltage and PQ control with inverter-based photovoltaic systems. *In Proc. 18th World Congress, Milan, Italy*, pp. 611.