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Design and Development of Control Strategies for Micro grid of 7.5KW Hybrid RES

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Abstract- To meet the ever-increasing energy demand, microgrids connected to distributed energy-based grids will soon become the most reliable way to upgrade the electricity system. The introduction of microgrid systems brings great benefits to electricity providers and end users. Microgrid is usually connected to the main grid, that is, it operates in grid-connected mode and if the main grid does not provide electricity to users, the microgrid operates in island mode and provides independent power from the main grid. This paper presents a control strategy for a 7.5 KW hybrid microgrid with 1.5 kW wind and 6 kW solar installed at Maharashtra State College of Engineering. PQ control strategies and control strategies related to microgrid operation methods are focussed. This paper also discusses microgrids issues such as islanding mode, stability and voltage imbalance to ensure effective power quality. The P-Q control strategy, which balances real and reactive power with voltage control and current control, is a promising strategy for real power control in power systems without internal communication. A microgrid can provide stable and efficient performance by providing voltage and frequency support, improving power quality. Following this strategy, the PQ control simulation is completed and the promising results are obtained for the 415V and 18A system. Mathematical modeling of P-Q control and droop control is also established and compared with the simulation results. The comparative validation is also found to be successful.

Keywords— Active Reactive Power (PQ), Renewable energy system (RES), micro grid, Droop

I. INTRODUCTION

Small electrical systems, known as microgrids, connect users to a source of electricity. In a microgrid, you can find multiple connected and distributed power generation sources, such as solar cells, wind turbines, or fuel-burning generators. Large batteries, electric vehicles, hardware and software are needed to manage and distribute electricity. End users like homes, businesses and buildings use it. Microgrids are capable of storing electricity during outages and can operate independently or be connected to a larger grid. In addition, microgrids often need to include control mechanisms to determine the allocation of resources over long periods and to quickly maintain the balance of real and reactive power when the system is isolated. In addition, the control system must understand how and when to connect to the network. A microgrid power system is a mobile power distribution system designed to provide electricity to small cities. In the past decade, microgrid technology has gained popularity in research and development. An important advantage of microgrids is their ability to operate independently during power outages or blackouts. There are two operating modes for micropores: island mode and connected hole mode. When operating in island mode, the microgrid is disconnected from the main grid and manages outages independently, providing a high level of service without compromising the integrity of the transmission system. A micro grid is connected to a larger grid in grid mode.Thus it provides two-way power flow.

Fig. 1. Solar-wind 7.5KW RES microgrid

There are two types of microgrids

1. AC Microgrid
2. DC Micro grid

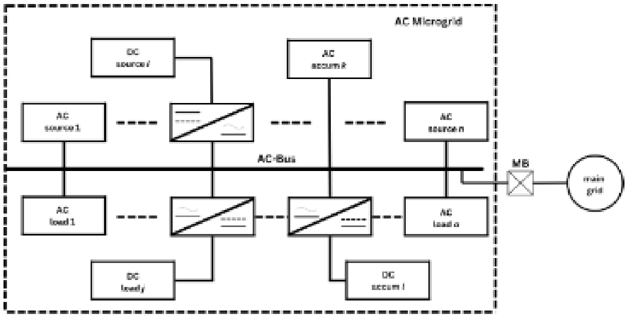


Fig. 2. AC Micro grid

From Fig. 2 it shows a typical alternating current microgrid (AC-MG). It contains an AC power source and an inverter. If necessary, connect the alternating current load to the MG through a power converter. By adding additional power electronics, it is possible to connect not only an AC source but also a DC supply and a DC load to the AC-MG through the interface, but this may result in an increase in the power loss. The operation of the AC-mode MG is determined by the position of the main circuit breaker which connects the AC-MG to the AC bus and the main network. Consequently, the AC-MG can run in either grid-connected (disabled Main Breaker) or island mode (Main Breaker enabled) from the main grid. In grid-connected mode, the AC-MG power supply does not need to manage voltage magnitude or frequency because the electrical grid controls these factors. In stand-alone mode, on the other hand, the MG's DG must regulate the magnitude of voltage and frequency, for both steady-state and transient operation.

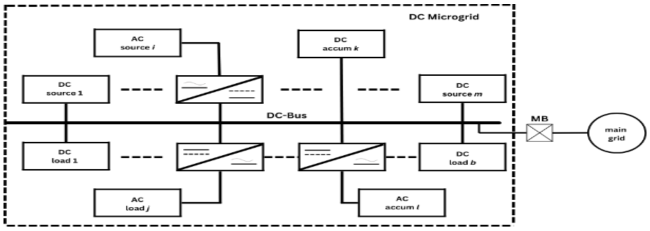


Fig. 3. DC Microgrid

Fig. 3 shows a typical direct current microgrid system (DC-MG). In this example, the DC load and generator units are connected to the MG via power cables. If necessary, use a converter. Due to the decreasing cost of solar panels, DC-MG is becoming more and more popular. Additionally, an additional power electronics interface in the DC-MG can be used to connect AC loads and AC sources. Hybrid MGs are composed of DC and AC sub-MGs, as well as network interfaces that link or disconnect the utility from the rest of the system. For bidirectional power exchange between AC-DC microgrids, one or more interconnected converters (ICC) are employed.

II. CONTROL STRATEGIES AND ITS ANALYSIS

A microgrid should also include a control strategy to maintain the balance of active and reactive power even if the system is isolated, and to determine the distribution of resources in a longer period of time. The control system must also know when and how to connect/disconnect from the network and follow different control strategies.

A) PQ management strategy.

B) Droop Management Strategy.

C) V/F management strategy.

D) Current management strategy.

This paper presents a PQ control strategy and a droop control strategy.

A. *Active Reactive (PQ) Control Strategy*

The PQ method is a standard control used in microgrid systems. PQ calculates active and reactive power to adjust the inverter output voltage. PQ control prevents the microgrid controller from changing the microgrid output parameters in response to voltage or frequency changes in the terminal, which depends on the reference frequency signal.

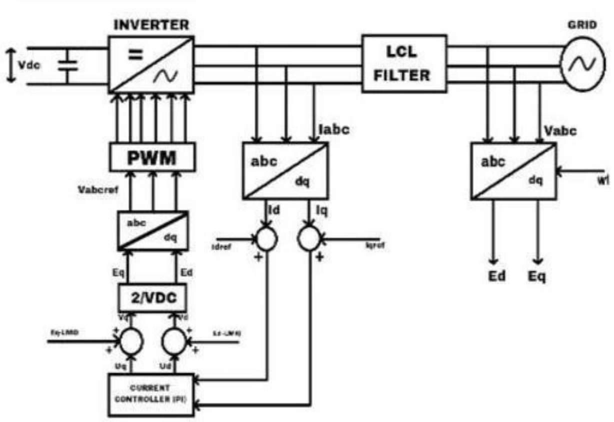
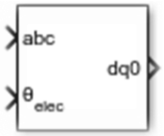


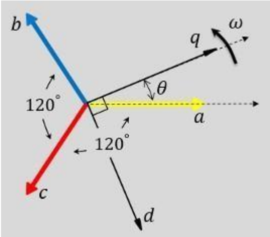
Fig.4. Active reactive (PQ) control strategy Block representation



The Park transform block transforms the time domain components of the three-phase system from the ABC reference frame to the forward, quadrature, and null components of the rotating reference frame. Block forces can be active and reactive using system forces in the ABC repository by implementing an inverse version of Park's transformation. Zero is equivalent to zero when you have a balanced system. The block can be adjusted to align axis a from a three-phase system at time t=0 with axis d or q from a rotary reference frame. The direction data abc of the magnetic axis of the stator winding and the rotating reference frame dq0 are shown in the image.

Where:

- At first, the axis a and q are lined up.



In the above two situations, angle $\theta = \omega t$, where as:
For alignment of axis q, it is the angle between axes a and q and for alignment of axis d, it is the angle between axes a and d.The rotational speed of the d-q reference frame is given by ω Start with initial alignment Time t is in seconds. Transformation for alignment between axis A and axis Q is an implementation using the Park transform block

$$\begin{bmatrix} d \\ q \\ 0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(\theta) & \sin(\theta-\frac{2\pi}{3}) & \sin(\theta+\frac{2\pi}{3}) \\ \cos(\theta) & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} a \\ b \\ c \end{bmatrix},$$

Where:

1. In the abc reference frame, the three phases system is represented as a, b, and c.
2. The Dual-axis system with the rotating the terms of reference frame includes d and q.
3. Within the stationary reference frame, the zero element of the two-axis system is equal to 0.

The block accomplishes the transition by utilizing the following equation for the alignment of the axis of phases a to q with constant power:

$$\begin{bmatrix} d \\ q \\ 0 \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \sin(\theta) & \sin(\theta-\frac{2\pi}{3}) & \sin(\theta+\frac{2\pi}{3}) \\ \cos(\theta) & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} \end{bmatrix}\begin{bmatrix} a \\ b \\ c \end{bmatrix}.$$

The block implements the transition by utilizing the following equation for the alignment of the axis of phases a to d:

$$\begin{bmatrix} d \\ q \\ 0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ -\sin(\theta) & -\sin(\theta-\frac{2\pi}{3}) & -\sin(\theta+\frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} a \\ b \\ c \end{bmatrix}.$$

The block implements the transition with Constant power the alignment of the axis of phase a to d is

$$\begin{bmatrix} d \\ q \\ 0 \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \cos(\theta) & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ -\sin(\theta) & -\sin(\theta-\frac{2\pi}{3}) & -\sin(\theta+\frac{2\pi}{3}) \\ \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} \end{bmatrix}\begin{bmatrix} a \\ b \\ c \end{bmatrix}.$$

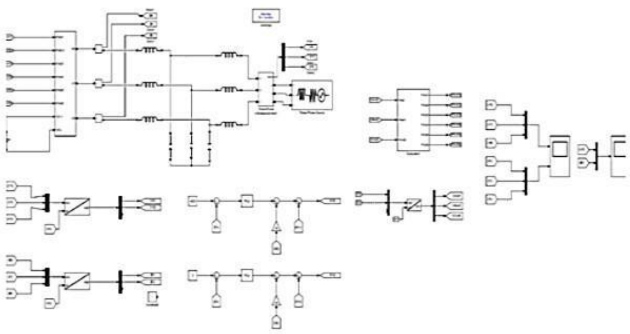


Fig. 5. Simulation of PQ control strategy

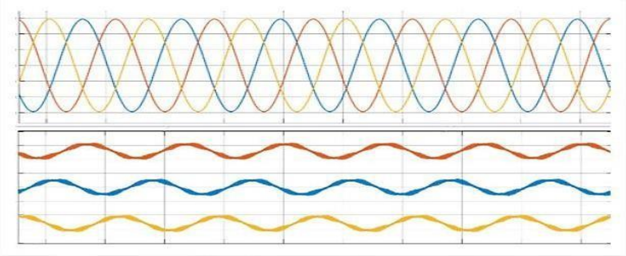


Fig. 6. Voltage and current response (3 Phase)

The above result of the simulation shows the graph between 3 phase Voltage w.r.t. time. And the result on the lower part shows the graph between 3 phase current w.r.t. Time.

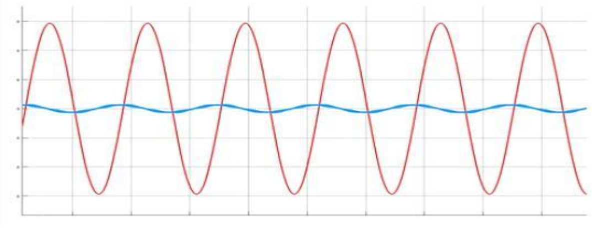


Fig. 7. Voltage and current response (1 Phase)

Where, the graph shows Current and Voltage response versus time. Voltage is represented by red colored waveform and current by sky blue waveform.

After performing the simulation and mathematical modelling accurate results have been observed.

B. *Droop Control*

The DG output voltage's consistent amplitude and frequency are assured by the v/f control. The fundamental idea behind v/f control is to lateralize the slope curve itself. In this control, the frequency remains constant where the voltage varies.

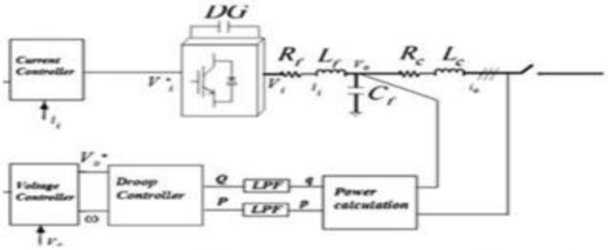


Fig. 8. Block diagram of Droop control

Mathematical Modelling for Droop Control: Frequency droop and voltage magnitude v droop d are determined in grid-connected droop control using filtered active power pLPF and reactive power qLPF, as illustrated in the following formula:

$$\omega_{droop} = \omega_0 + m_\omega(p_{LPF} - p_0)$$

$$v_{droop,d} = v_0 + m_v(q_{LPF} - q_0)$$

Normally, ω0 and v0 are set to 1pu, which is their nominal values. Degrees of freedom are provided by p0 and q0, which are both zeroed out in this work. The slope coefficients are mω and mv. Angle θ (abc to dq) of the park transformation is calculated by integrating ωdroop.

In grid-connected hang-up control, the output active power

*p and reactive power *q are determined by the filtered frequency and voltage, respectively. As a result, active and reactive powers are isolated rather than frequency or voltage, as in the preceding equation for the grid-forming droplet equation:

$$p^* = p_0 + \frac{1}{m_\omega}(\omega_{LPF} - \omega_0),$$

$$q^* = q_0 + \frac{1}{m_v}(v_{LPF} - v_0),$$

Generally, ω0 and v0 specify the nominal frequency and voltage values respectively and offer a certain amount of freedom, where ωLPF and vLPF are frequency and amplitude of the measured and low-pass filtered voltage.

The secondary controller of the microgrid central controller establishes p0 and q0.

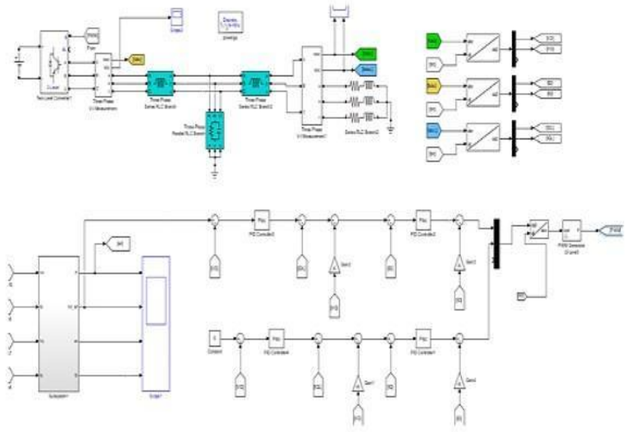


Fig. 9. Droop control strategy Simulation model

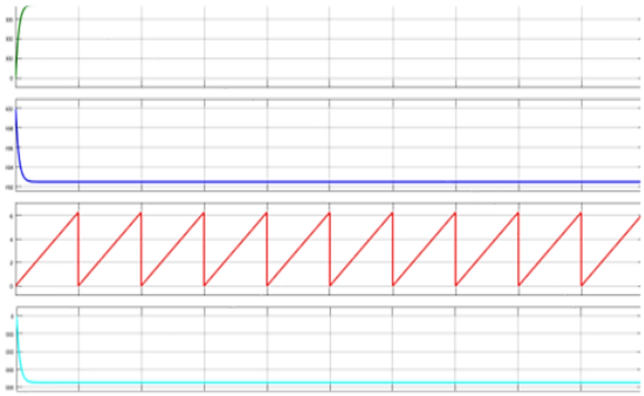


Fig. 10. Droop control strategy resulting waveforms

- The 1st block of simulation result, represented by the green colored waveform shows graph between Power (in watts) w.r.t. Active power.
- The 2nd block shows the result that is represented by the blue colored waveform showing graph of Voltage (in volts) w.r.t. reference voltage.
- The red colored waveform shows graph between Phase angle w.r.t. Amplitude (Radians).
- The last block shows the simulation result, represented by the sky blue colored waveform showing graph between Power (in watts w.r.t. the Reactive power.

III. CONCLUSION

The distributed energy sources becomes popular with the increased interest in pollution free environment and development of sustainable energy solutions. In this regard, the idea of a microgrid is initiated in this paper to enable the incorporation of micro generators, energy storage and charging systems. Research shows that most of the initial research work focuses on AC micro grids. However, considering the improved efficiency brought by the elimination of the power electronics conversion step, DC micro grids and hybrid micro grids have attracted so much attention and research from the scientific community. This paper has examined in detail the distributed cooperative control system currently used in these micro grid topologies. Micro grid control is essential to maintain efficient micro grid performance and consumer satisfaction. Different control strategies can be used to control the micro grid. This article introduces the P, Q control strategy and the drawdown control strategy in detail. The objective of the P-Q control technique is to balance the active and reactive power and to control the voltage on the transmitter side. The simulation results of this strategy are observed to be accurate compared to the theoretical values. When regulating the voltage drop and frequency changes and by performing simulations it can be observed that the power quality is maintained.

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