Frequency Control and Energy Management of Microgrid with Distributed Energy Storage

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Abstract. The purpose of the Energy Management System (EMS) is to ensure a high degree of efficiency, stability, and dependability. And the electrical system should have the ability to adjust to the majority of changes such as renewable energy integration. In some situations, the power generated by distributed power sources is greater than the local demand. This has an effect on the microgrid's stability and frequency. Smart energy management in a microgrid is proposed in this research., consisting of a wind power generator, photovoltaic and storage energy system for frequency regulation, and system balance. The above paper's main contribution is a system for managing energy. based on a clever strategy using MATLAB/Simulink. The results of the simulation and analyses demonstrate that the suggested microgrid energy management system is efficient at balancing energy.

1 Introduction

A small-scale power network, energy system storage, renewable energy resources, and loads connected to AC or DC bus is a Microgrid (MG) [1,2]. MGs are run both in the grid-connected type anywhere power is transferred with the main grid or in an islanded mode where the microgrid operates to supply the loads connected to its bus. A microgrid is a smart small power grid based on local renewable energy production to supply the building(s) with high power quality. A microgrid not only transmits energy, but also data on consumption, production, or storage where appropriate.

The electrical architecture of microgrid is mainly based on the application, infrastructure, and user requirements. The microgrid may could be classified has three categories: AC Microgrid, DC Microgrid, and hybrid Microgrid. Microgrids provide a number of advantages In light of Request Response programs [3,] there is also a high ability to hasten the actively participating of the final user's consumers. A microgrid central controller (MGCC) can make use of a variety of technologies resource plans to reduce overall costs while simultaneously ensuring high levels of dependability and security [4].

The electricity system requires to respect the supply/demand balance. Indeed, electricity store very little or no and it must be available in real time, in any season, and at any time of the day for consumers. In this case, the power production must therefore be equal to consumption each instant. Indeed, the example, if the consumption is greater than the production then the means of production disconnect from the power grid automatically to avoid the blackout [5].

A microgrid command center necessity regulates the power balance, voltage and frequency when in a grid-connected or islanded mode is specified limits of power quality and reliability. Microgrid control is divide into two centralized and decentralized methods.

One of most important parameters are voltage and frequency in the sake of safety, stability, and operation concerning to the electrical power system. Indeed, from the consumer point of view, rotating machines or other appliances are sized to operate with fixed voltage and frequency values. From the manager's (MGCC) point of view fixed voltage and frequency ensure good quality and better continuity of service [6].

The renewable production integration to the power grid executes it also challenging to control power stability and can appear in high-frequency variations on a microgrid. Ancillary assistance presents the additional power sources needed to manage the instantaneous balance between sources and load and to guarantee the frequency limits.

In this context, A frequency control technique for energy management. This study proposes using an isolated microgrid. Consisting of wind power, PV, and battery energy storage to assure AC load demand. For this technique, the power generation systems (wind and PV) operate under their maximum power using a Control of maximum power point tracking (MPPT).

The remainder of the paper is arranged as follows. 2nd Section describes the proposed microgrid system. Section 3 illustrates the proposed technique for energy management. And the Section 4 shows the findings and discussions, while Section 5 brings the study to a close.

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2 Modeling of microgrid

The electrical framework of a hybrid microgrid is depicted in the first picture, which is made up of two Distributed Energy Resources (DER) (photovoltaic, wind turbine) and an energy storage system based on a battery system. These versions are wired together in such a way that they have a constant power supply of AC load is ensured. A hybrid power system comprised Pv system (PV), wind turbine (WT), and energy storage system with battery (BES) could be an economic answer to balance energy in the microgrid based on frequency control.

2.1 Modeling of PV

The equivalent electric circuit can be used to simulate a photovoltaic cell. To take the cellular level, The latter is made up of a current generator and a parallel diode with a series resistor Rs (shunt). [7].

The diode current can be expressed as follows:

$$I_d = I_0 \left(exp^{\frac{V_{pv} + R_S I}{V_T}} - 1 \right) \quad (1)$$

And the output current of the Pv system of the Ns series of cells can be expressed as

$$I_{PV} = I_{ph} - I_0 \left(exp^{\frac{V_{pv} + R_S I}{V_T}} - 1 \right) - \frac{V_{pv} + R_S I}{R_{sh}} \quad (2)$$

$$V_T = \frac{N_s\, n\, k\, T}{q}$$

V_T: The thermal voltage;
n: The diode ideality constant;
N_s cells connected in series;
T is the temperature of the p-n junction;
q: is the electron charge;
k: is the Boltzmann constant;
I_0: Reverse saturation currents of the diode.
I_{ph}: The photo-current;

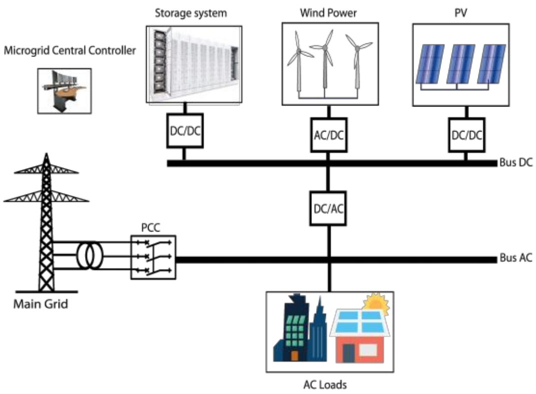

Fig. 1. Structure of microgrid.

2.2 Modelling of wind power

The wind of speed v, which is placed at the wind turbine blades and serves to rotate the turbine and create mechanical power on the turbine shaft, turns the turbine and generates mechanical power on the turbine bar, as described by P_{wind} [8]:

$$P_{wind}(\vartheta) = \frac{1}{2}\, \rho A C_p(\lambda, \beta) \vartheta_{wind}^3 \quad (3)$$

Cp is called the performance parameter which depends on the point ratio of speed and also based on the pitch angle (deg). The size of the turbine blades (m2), the peak speed ratio, and the pitch angle are all given by A. (deg), and ρ which is indeed density of the air (kg / m^3).

2.3 Modelling of BES

The modulation of the dynamic batteries is represented as [9]:

$$\mathrm{SOC_{batt}} = 100 \left[1 - \left(\frac{1}{Q_{bat}} . \int_0^t i_{bat}(t)\, dt \right) \right] \quad (4)$$

Where SOC_{batt} denotes the battery's state of charge (percentage), and i_{bat} denotes the battery's current (A). The maximum battery capacity is Q_{bat} (Ah)

3 Proposed Control Scheme

In the beginning, for the standalone microgrid, the battery is charged according to the algorithm. in the event of excess energy and at each moment the control system by checking the battery state of charge (SOC). Then, if there is excess energy, the PCC supplies it to the primary grid.

If renewable energy generation is insufficient (P_{DER}=P_{PV}+P_{wind}), the storage tank system fills in the blanks, and the control method proceeds to check the SOC to balance the production and consumption ($P_{DER} = P_{load}$) and frequency control.

The most crucial element for the security and stability of the electric system is frequency. As a result, the frequency of microgrids must be kept within very precise limitations. Frequency border: The system's frequency must be within the permissible borders. [10].

$$Fmin \le F = 50\ Hz \le Fmax \quad (5)$$

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4 Results and discussions

This single-phase hybrid system is simulated using MATLAB/Simulink. To extract as much power as possible from each source in this scenario. Each source of electricity is linked to a boost converter. Therefore, the P&O MPPT technique apply in order to track of the PV's maximum power panel and wind turbine. Table 1 presents the characteristics of each source.

Tab 1. Microgrid component specification

SYMBOL	Specification
DC_BUS	$V = 11KVV;\ P = 0\ KW$
Battery	$V = 500V;\ Q_{batt} = 2000Ah$
PV PANEL	$P_{PV} = 2.3MW$
Wind turbine	$P_W = 1.4MW$
Load	$P_{LAC} = 3MW$

The simulation is applied for 10 seconds with 1e-5 sampling times, to display the AC_Bus power with different solar irradiance values, we have a multiple irradiance scenario, in order to show the robustness of our management strategy against to a sudden change in meteorological parameters, as seen in Fig.2 and we put the speed of the wind at 14m/s.

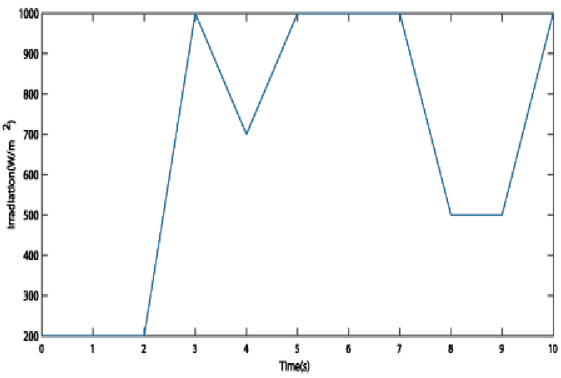

Fig. 2. Solar Irradiation (W/m²).

The Fig.3 and Fig.4 shown the power produced using Solar panel and wind turbine.

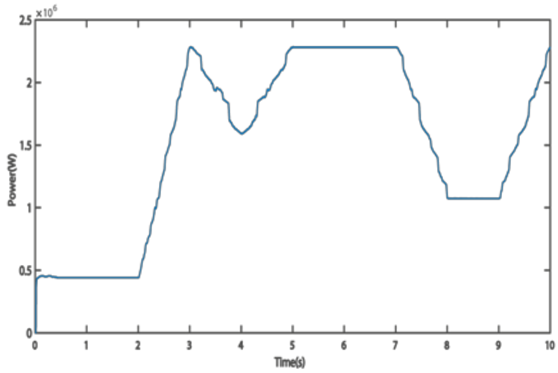

Fig. 3. Solar Power (W).

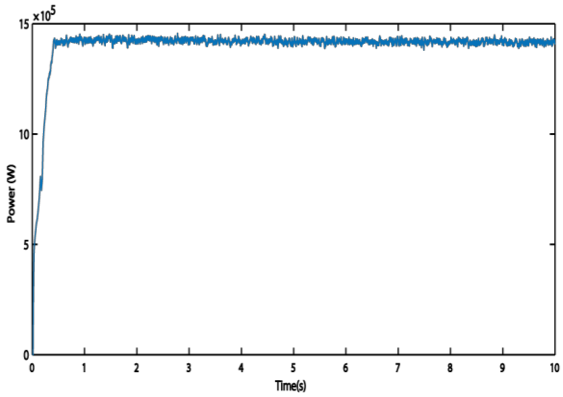

Fig. 4. Wind Power (W).

As we can see from the Fig.3 and Fig.4 the power produced is not stable. Therefore, the balance at AC_Bus will be covered using the battery as we describe in the control strategy. In order to compensate the load demanded and regulate the frequency at the AC_BUS.

The Fig 5 indicates the volatility in the state of charge of the battery over the simulation. The battery stores the energy surplus, and provide the needed energy, which maintains the power stability in the Bus_AC and frequency in its limited zones as shown in Fig.6 and Fig.7.

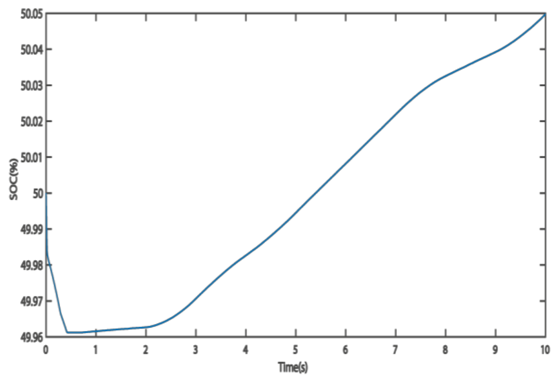

Fig. 5. Battery state of charge (%).

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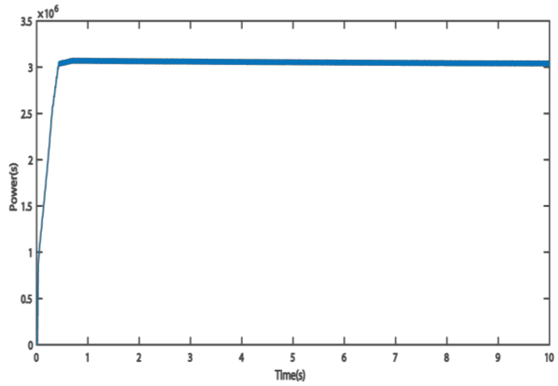

Fig. 6. Power at AC_Bus (W).

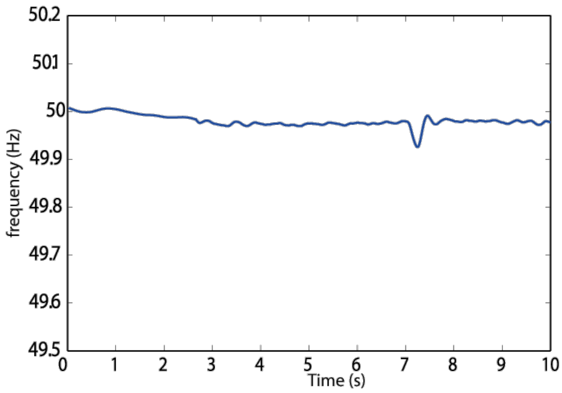

Fig. 7. Frequency at AC_Bus (Hz).

From Fig.6 and Fig.7 we can see that despite the surpluses and the energy requirements in the microgrid AC bus, the power is still stable at 3MW and the frequency stable at 50 Hz.The achieved findings demonstrate the proposed method's efficacy and robustness of energy management strategy against all the sudden changes in weather conditions.

4 Conclusion

Renewable technologies are viewed as clean sources of energy, and their best utilization reduces environmental consequences and produces the least amount of secondary and sustainable waste. Provide a tremendous potential to reduce greenhouse gas emissions and global warming and Reduce Transmission and Distribution Losses. This paper presented a strategy of managing energy built based on renewable energy sources. This work's primary focus was the balancing of power produced and load demand at the AC BUS. In this contribution, we implemented a control strategy for energy management. The control approach is based on the maximization of energy produced from each renewables source, the control of the battery for charging or discharging in order to stabilize the power of AC_Bus, then the protection of the battery by maintaining its state of charge between 20% and 80%.

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