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Energy Management System for hybrid DC–AC Microgrid

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Abstract— In this research, we introduce an energy management system that manage energy consumption in DC–AC hybrid distribution networks. It is being proposed to implement an energy management system that takes into account distributed generation, load demand, and battery-charge level. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. AC sources and loads are connected to the ac network whereas dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature, and load are also considered in system control and operation. A small hybrid grid has been modeled and simulated using the Simulink in the MATLAB. The simulation results show that the system can maintain the load demand under the proposed coordination control scheme.

Keywords— Power flow control, AC/DC hybrid microgrid, Battery storage, PV system, wind generator.

I. INTRODUCTION

In the ongoing years, distributed computing has developed The amount of power that is required all across the world is constantly increasing. Because there are a limited number of conventional sources, and because it also has negative effects on the surrounding environment, this results in a significant impaling of sources that are based on renewable energy in the power networks that are now available. A photovoltaic array system with a large capacity or a wind energy-based generator can be controlled from a centralised location by grid operators, but a photovoltaic system with a small capacity or a wind farm can be regulated by the customers. However, the majority of non-conventional sources are unpredictable by their very nature, and as a result, they have an effect on the grid. Renewable energy sources, also known as RES, are an effective alternative that may be used in place of conventional sources to reduce the amount of pollution that is released into the environment and improve the quality and efficiency of power system networks [1]. Solar photovoltaic and wind energy have the highest potential to generate power among the various RES sources; however, the output power of solar energy and PV panels is primarily dependent on environmental temperature and solar irradiance, whereas the output power of wind energy is primarily dependent upon wind speed; this results in a continuous vacillation in output power[2, 3], [4], [5]. Consequently, a source of stored energy is required to guarantee continuous power output. In [6], the author examines a droop control system for balancing the load on a PV array-storage system with power from another source. An improved version taking into account a wide variety of power sources has been introduced in [7, 8]. All of these methods work well for systems without a DC bus and loads because they efficiently control the load need and source power generation. Literature [9][10]introduces a control method for a mixed system, the focus on optimal sizing and costing analysis of the PV system and battery storage rather than power balancing. AC microgrids [11][12][13][14] are proposed here to reduce the complexity of the link of RES to existent AC systems. The AC network accommodates a wide variety of load configurations. In order to keep up with the demand, it is necessary to use both AC-DC and DC-DC converters. Integration of dispersed energy resources has been extensively discussed in [15][16][17][18]. In order to connect to the dc microgrid, however, ac power sources must first be converted to dc. Because of the need for many converters to accomplish the ac/dc conversion, the system's performance may suffer. Microgrids, both AC and DC, are connected to the central converter to guarantee reliable power flow ([19], [20]). However, the limitations of battery SOC have been disregarded in terms of feeding power into the main grid. Numerous power management strategies have been proposed in the literature for hybrid microgrids. Voltage balance, crucial for DC loads like EV charging stations, is not addressed in the surveyed literature. Voltage regulation on both the DC and AC buses, as well as a seamless handoff when switching from the AC to DC microgrid and back again. And keep the battery storage unit's minimum and maximum levels in check to lengthen the battery's cycle life. A proposed system of hybrid microgrid is depicts in fig.1.

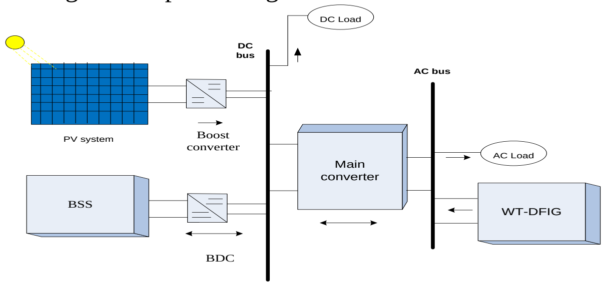

Fig. 1 Proposed hybrid microgrid system.

II. HYBRID MICROGRID MODELING

A. Modeling of PV Array System

A photovoltaic system typically includes an array of photovoltaic modules Fig.2. depicts the PV array equivalent circuit model. PV current is expressed by equation. Figure 2 depicts the PV array system's internal circuit. For obtaining the current of PV array undermentioned approach is applied.

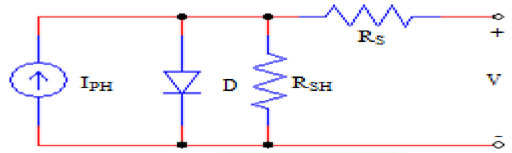

Fig.2 Equivalent circuit of PV system.

$$I_S = \left(\frac{\gamma}{\gamma_{ref}}\right) I_{Sref} + \alpha_{ISC}(T_a - T_{ref}) \qquad (1)$$

Where, γ represent irradiance level in w/m2, Ta is temperature in kelvin, α_{ISC} is coefficient of short circuit current and I_{Sref}, T_{ref} and γ_{ref} are standard value under test conditions.

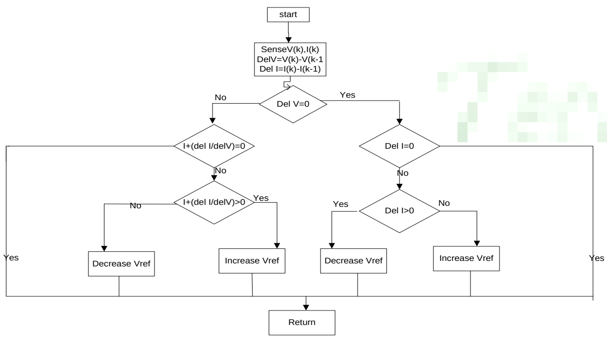

Fig.3. Incremental conductance MPPT algorithm flowchart

Due to the irradiance in PV array, there is variation in the generated power and maximum power point tracking (MPPT). To trace the MPPT, incremental conductance (INC) MPPT method as shown in Fig.3. is performed with an adjustable variable step size. This algorithm itself change the step size to observe the maximum power point (MPP) with step size adaptation coefficient, and a user predefine fix value is not important for the junction of this MPPT method, thus clarify the design of the PV system

B. Modeling of Battery Storage

A battery is an origin of electric power made up of one or more electrochemical cells. SB unit are attuned to diminish the output of solar slow power fluctuation. The state of charge (SOC) of the battery is resolved using the method of current integration, where Q(t0) is the initial charge to the battery at time to, α is the discharge/charge efficiency and I is the current

$$V_B = V_{OC} + R_B.I_B - K\frac{Q}{Q+\int I_B dt} + A.\exp(B\int I_B dt \qquad (2)$$

Modeling of Wind

The output expression of a WT in terms of ambient wind speed can be obtained by a piecewise function.

$$P(v) = \begin{cases} \frac{P_r(v-v_{ci})}{(v_r-v_{ci})} & v_{ci} \le v \le v_r \\ P_r & v_r \le v \le v_{co} \\ 0 & v < v_{ci} \text{ or } v > v_{co} \end{cases} \qquad (3)$$

Where $P_W(v)$ is wind turbine generator output with ambient wind speed v, P_r is power of wind turbine at rated speed and v_{ci} is cut in wind speed , v_{co} is the cut-out wind speed and vr is rated wind speed.

III. ENERGY MANAGEMENT SYSTEM (EMS)

Figure 4 illustrates the control algorithm of a customized hybrid microgrid network using the proposed EMS. In this proposed EMS design, the PV system is linked to the DC bus by a boost converter, and the battery storage unit is linked via a bidirectional converter to handle the charging /discharging process. A main converter is used to connect the DC and AC buses and exchange the power flow smoothly. The mode of operation of the hybrid micro grid is determined by the availability of PV system output power, wind turbine output power, battery power and SOC, as well as the demand for DC and AC loads. As a result, power flow in the hybrid micro grid is always steady. The EMS works based on following equations:

Grid mode:

$$P_{PV} + P_W \mp P_B = P_{DC}^{Load} + P_{AC}^{Load} \qquad (4)$$

Here in the equations P_{PV} stands for the output of the PV system, here P_W is the output power of wind turbine generator, term P_B is the battery power (-ve sign here represents charging of battery and +ve sign represents discharging). P_{DC}^{Load} , P_{AC}^{Load} represent the AC and DC load respectively.

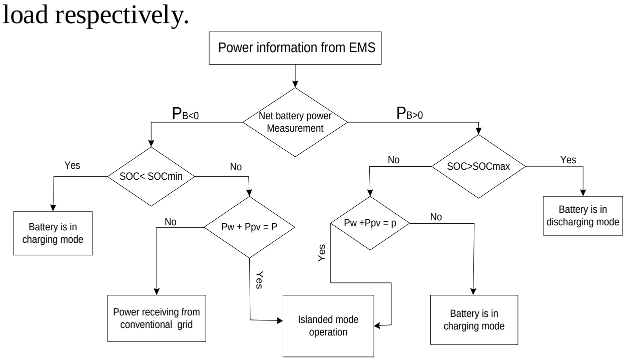

Fig. 4 Energy management system for hybrid DC-AC microgrid.

IV. RESULTS AND DISCUSSION

With the help of simulation results, the regulations of the hybrid microgrid are validated when subjected to a variety of load circumstances, as well as alternating and direct current sources of energy.

The photovoltaic array system, the wind turbine generator, and the battery storage system are the only ones that contribute to the generation of electricity while the hybrid microgrid system is operating in autonomous mode. the state of charge of the battery will eventually reach a point where it will surpass its maximum possible state of charge. This will result in the battery sending excess power to the conventional grid, as shown in figure 5. (a). As can be seen in figure 5, the BSS (b) helps to smooth out the fluctuations in output power that are caused by the PV array system. As shown in figure 4, the output power of the WT generator is reduced to 20 kilowatts when the ambient wind speed reduces from 12 metres per second to 9 metres per second at time t equal to 10 seconds. (c). As a consequence of this, and in order to control the amount of power consumed by the AC load, the EMS cuts off the power supply to the Battery, as shown in figures 5(a) and 5(c). As can be seen in figures 6(a) and 6(b) (b), the DC bus voltage is maintained at a constant level by the duty cycle of the battery converter. The dc load current (c) and dc load power (d) are depicted in figures 6(c) and 6(d), respectively. In the Islanded mode of operation, the battery state of charge (SOC) is more than the upper limit (SOC>70%). This can be seen in figure 7. (d). The battery is shown in figures 6(b) and 7(c) operating in the discharging mode. The voltage measured at the battery terminals is depicted in Figure 7(a). SOC of battery lower than the SOC minimum limit (SOC< 30%) as shown in the fig.7(d). BSS needs to be in charging state. At t= 0 sec to t=10 sec grid supply is very less to hybrid microgrid as shown in fig. 7

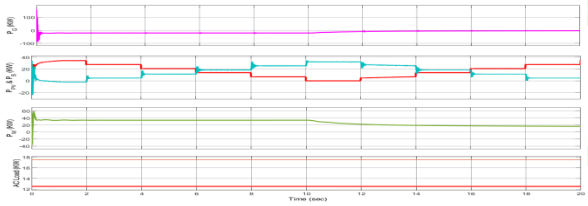

Fig. 5 (a) grid power from hybrid MG. (b) PV system output power and battery power (c) Wind generator output power (d) AC load

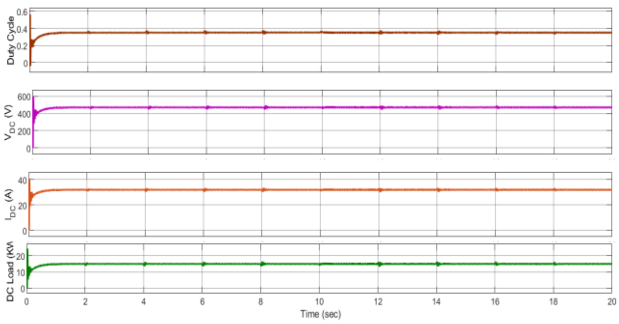

Fig. 6 Islanded mode of hybrid microgrid (a) duty cycle (b) dc bus voltage (c) dc load current (d) DC load.

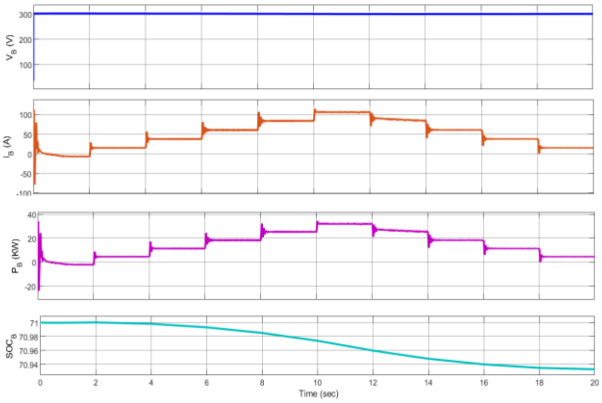

Fig. 7 Islanded mode of hybrid microgrid (a) battery terminal voltage (b) battery current (c) battery power (d) battery SOC.

V. CONCLUSION

The paper here proposes a novel approach of active power control and management system for a hybrid micro grid that includes both AC and DC loads. The future EMS regulates the flow of power either in hybrid microgrids or conventional ones. Therefore, the described EMS also maintains the dependability of the power supply to all of the units, even when the amount of electricity produced by the solar panels and wind turbines varies due to changes in the amount of irradiance and the speed of the wind. Simulation and verification of the power management technique are carried out in the MATLAB environment. When switching between modes of operation, there is no disruption to the flow of power. In the future, it will be possible to adapt this work to match to changeable load.

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