Fully User-Compatible Microgrid Network and Its Control: A Concept

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***Abstract*—Microgrids have been an alternative to costly procedure of utility grid expansion to electrify a rather rural area. This paper proposes a model of microgrid with Distributed Generation (DG) and capability to interconnect with other microgrids, and also with the utility grid for power exchange, whenever necessary. The proposed structure consists of generation part, storage part, distribution part and control and conversion part. A new concept of Hybrid Energy Storage System (HESS) has been used for energy storage. Also, a fully functional control hub has been proposed, which could be used to connect number of generation units, both AC and DC, and could supply to both AC and DC distribution feeders. The scope of this proposed model is also discussed in this paper.**

***Index Terms*—Distributed Generation, Hybrid Energy Storage System (HESS), Microgrid**

I. Introduction

Microgrids are isolated islanded systems which generate, manage and provide electrical energy within itself. Using microgrids, limited energy can be saved by designed source holders such as batteries but their technologies must be expertly managed to control its different aspects within the limited charge window of batteries [1]. E Becquerel created the world's first PV cell in 1839 [2] and in recent years, PV cells have been extensively used as Distributed Generation units in microgrids. Similarly, the use of induction generators in microhydro power plants and wind energy stations have also grown highly [3]. As per the need of customers, the microgrids are either AC [3] or DC [4], [5], [6], [7] . Some grids exchange with the utility grid [4] or with another microgrid [6]. Such interconnections increase the reliability of the entire system. When there is low power demand on the grid (lower than generating capacity of associated generators), then it could be stored for future using HESS. Storage of generated power based on conventional storage technology using batteries only has been used previously a number of times [6], [7], [8], [9], [10], [11], [12] . But HESS has been used only a few times [5], [6], [12].

In this paper, the proposed system is such that a central controller controls multiple AC/DC grids, enables energy exchange, energy saving and power interaction with utility grid as well. Addition of a new microgrid to that system could also be enabled. This paper is divided into seven parts, part I is introduction, part II will describe the AC units, part III will describe the DC units and the subsequent parts will be about HESS, Central controller and conclusions.

II. AC Unit

The proposed system has four important parts viz. ac units, dc units, HESS and Central controller. The ac unit has general structure as in Figure 1. Based on the wind flow

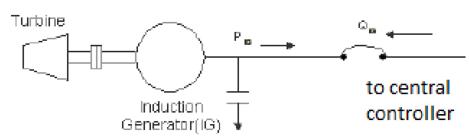

Fig. 1. General Layout of ac unit

data and equipment accessibility, wind plant could be used in various places. If there is an ample water resource then micro-hydropower generation could also be used. These stations feed the energy generated directly to the controller. All further actions will be taken care of by the controller and other parts of the system. Systems similar to this structure have been used before as well [5], [3], [13], [14].

III. DC Units

Wind flow governs the speed of wind turbine which in turn governs the output of the IG used. Similarly, water resource and its seasonal availability govern the power generated by micro-hydropower plant. AC generation is thus seasonal power generation technique because power generation capability depends on the season of year. So, AC grid alone is not always enough for a fully compatible microgrid architecture, neither is DC grid alone. In order to fulfill the off season power requirements, energy storage and DC generation is also vital. In this section, DC generation will be discussed, and energy storage will be discussed in the next section. One of the best ways of dc power generation is Photovoltaic (or PV) generation system. The following structure is proposed for DC generation. PV grid generates DC power and feeds to the central controller. As before in AC generation, further actions will be handled by the controller itself. A PV structure is shown in Figure 2.

DC microgrids are extensively in use nowadays. Many researchers have worked in this area such as in [4], [5], [6], [7], [8], [3], [15], [10], [11].

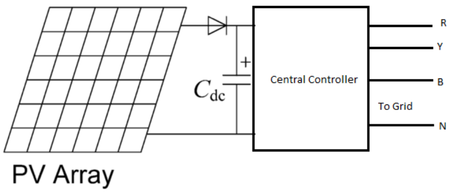

Fig. 2. General Layout of dc unit

IV. Hybrid Energy Storage System (HESS)

Storage of electrical energy is always a major concern. Conventionally, electrical energy has been stored in the form of chemical energy (batteries). But recently, a new type of storage scheme has been brought to use, which combines chemical storage and storage in electric field. This technique is known as Hybrid Energy Storage System (HESS). This system uses batteries and super capacitors as storage units. HESS has been proved to be highly efficient and effective and reliable than conventional systems of energy storage [11], [16]. State of charge (SOC) is seen as the full range of available energy that can be delivered by a battery. This range is measureable between when a battery is fully charged and when it carries no charge. Because of the limiting SOC of batteries, the problem is that the limited energy is available for a given time. Energy management deals with controlling power flow in a system by

having a limited amount of energy, or to work with it in a "saving manner." To extend the time of use from a limited source, load monitoring and control are required [17]. Hence, by analyzing the SOC of battery used and improving the capacitor, we can improve the HESS and its SOC. Since Lithium-Iron-Phosphate batteries (Lipo batteries) have been proven to have longer life cycles and higher safety in comparison to other Li-ion chemistry [18], its use in HESS could make the storage system more effective. The general possible schemes of HESS structure is shown in the figure below:

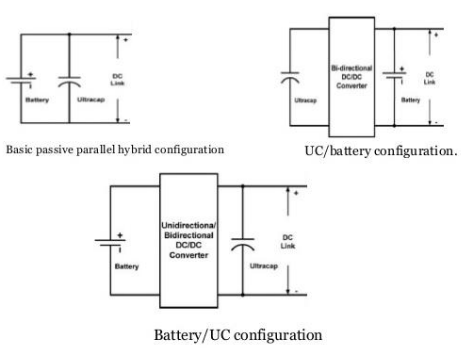

Fig. 3. General Layout of HESS

V. Central Control Unit

This unit is the heart as well as the brain of the proposed system. In brief, the major work of this unit is summarized below:

(i) To convert the voltage of a dc generating unit to desired level and either (a) store the power in HESS if the demand is low or (b) invert it to AC of the provided reference voltage for AC distribution.

(ii) To rectify the AC from AC sources to desired level of DC and perform action (a) if the demand is low or (c) distribute AC to the consumers if the demand is high.

(iii) If the HESS is fully energized, and still the load demand is low, this unit feds the energy to the main grid.

(iv) If there is energy deficiency in the microgrid, it extracts energy from main grid to charge the HESS or to distribute to the consumers or do both.

(v) If there is any fault or contingencies in the main grid or in one or more of the associated microgrids, central unit senses this fault and immediately isolates the faulty part unless the fault or anomalies has been cleared. The sensing could be done by wavelet transform methods [14].

Some of the concept of this intelligent energy management system has been used in [8] and some references have been taken from the same.

VI. Simulation and Results

A preliminary model of the proposed system was developed in MATLABTM/Simulink 2016 and analyzed. The overview of the model is shown in Figure 4.

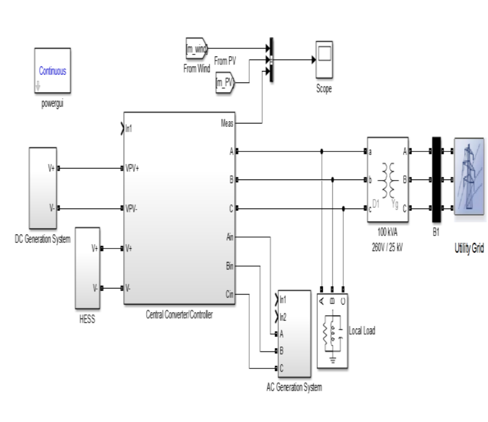

Fig. 4. Outer layout of the proposed system in Simulink

The main four parts of the system in the above picture, namely the AC generating units, the DC generation units, the hybrid energy storage system and finally, the central part, the central controller could be clearly seen in Figure 4. Taking a look at the simulated hypothetical AC generating system of the simulation by entering the AC subsystem, we see as below (Figure 5).

Similarly, the DC generating unit, which is supposed to generate DC power from PV panels, used in this simulation is shown in Figure 6.

The HESS subsystem in Figure 4 when seen in detail looks like as in Figure 7.

Finally, the most important part of the proposed system and the simulation, the central controller which controls all other parts and manages ang governs the energy storage and flow is shown in Figure 8.

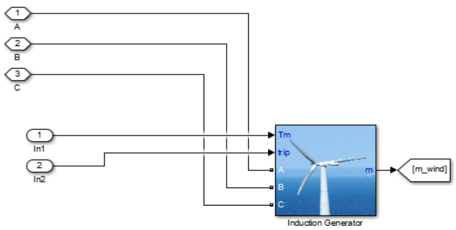

Fig. 5. AC generation layouts in Simulink (Wind Energy Farm)

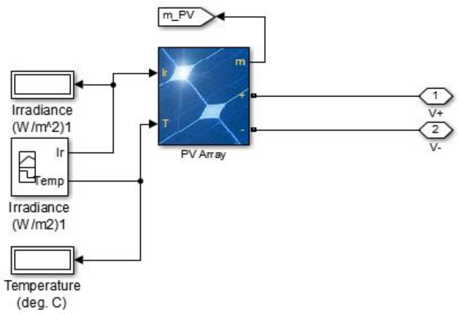

Fig. 6. DC generation layouts in Simulink(PV Solar Panels)

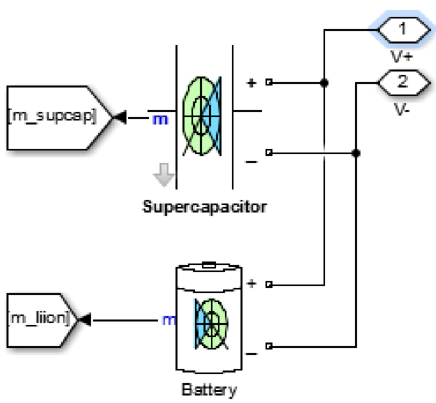

Fig. 7. HESS layouts in Simulink(Battery and Supercapacittor)

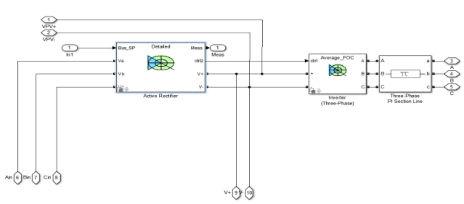

Fig. 8. Scheme of the central controller in Simulink

Finally, the result obtained, the voltage profile of the grid and the DC generation units are shown in Figure 9 and 10 respectively.

Remaining part of the system is under development in MATLABTM/Simulink and the improvement of central controller and AC generation system is being conducted.

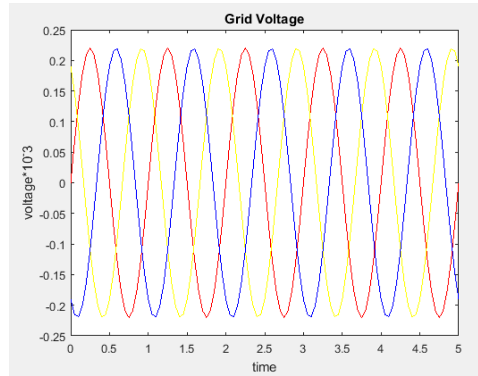

Fig. 9. Utility Grid Voltage Profile

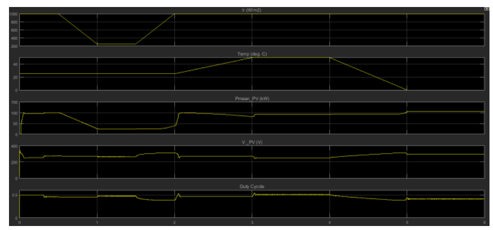

Fig. 10. DC generation voltage, power and temperature and irradiance profile

VII. Future Works

The future works for the development of this system is listed below:

- Improvement of the central control unit so that it could be monitored and controlled by a computerized system.
- The AC generation system used in present simulation is a very rough and preliminary work. It needs to be upgraded and more variables should be considered to get better results.
- Similarly, the variables used in DC generation are enough, but could be upgraded and new data could be used.
- MPPT has not been included in any of the systems. If MPPT could be added, then the system could be more advanced and automatic.
- Islanding and fault detection using HF injection is proposed to be included in the next upgrade of the system.

VIII. Conclusion

Compared to traditional microgrids, this new scheme involves better control of power flow, better control over the generating units and the storage units and provides a unique bidirectional power flow facility from microgrid to utility grid. Energy conversion and storage is managed by a single unit and interconnection with utility grid is also monitored by the same. The generated AC power is first rectified to DC and then further sent either to rectification for distribution or utility grid or to HESS for storage. Apart from other advantages, AC involves multiple rectification and inversion which seems to be a rather lossy process. Steps are being taken to reduce the aforementioned losses in the future versions of this scheme. The results presented by the developed parts of the system, *i.e.*

the utility grid and the DC generation unit look quite promising and hence show potential for future success and development.

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