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Energy Management of Microgrid: Review of State of the Art

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Abstract
This paper is an overview of the amalgamation of research carried out in the last five years in the field of energy management of microgrid. The growing demand for renewable distributed generation for safe and reliable power consumption is unceasing. This mission can only be accomplished with an economical overview of the applicable cost factors including resource cost, generation cost, distribution cost and consumption cost. To maintain its stability and power quality, the right monitoring and control of the EMS are highly essential. It begins with effective planning and controlled operation. Microgrids are capable of managing the power sources more efficiently. Also with the advent of microgrids, the ones who were consumer can now become sellers due to extra energy generated from newly deployed renewable energy sources.

Keywords: *EMS, BESS, supercapacitor, renewable*

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INTRODUCTION

Energy demand is one of prime indicators of how developed a country is, and without it, our giant energy hungry world would come to a standstill. Most of the world's demand of energy is met by oil, coal and other non-renewable sources. The problem with such sources of energy is: first of all they pollute the environment; and secondly, they are limited and have been put to enormous stress in recent years. Also they are not going to last forever and there extinction can give nightmares to every citizen on this planet.

To solve these problems related to non-renewable sources, we are now switching to renewable resources like solar energy, wind energy, etc. But the problem with non-renewable resources is their intermittent nature and paper deals with such problems and how can we apply them to increase the efficiency of our microgrid, or in other words, manage energy generated by microgrid. Microgrid is an independent generation system which generates energy by sunlight or wind energy to serve electrical loads and it operates in grid connected or island mode. These systems are directly connected to distribution stations. Despite exorbitant initial cost of setting up PV systems, they are being used on a large scale to supply electricity to small power consuming units [1].

One of the excellent features of microgrid is the smartness of the grid to separate itself from distribution system during blackouts or brownouts, also called the island mode. Some problems related to microgrid are: high frequency or high power transient which may last for some seconds or for couple of minutes in high unstable weather conditions, these sudden spikes in load are inimical to safe operation of microgrid. Repeated increase in the output current would increase the operating temperature of battery and decrease its life [2].

To resolve these issues, supercapacitors are employed because they are high power density devices and can handle rapid charging and discharging over larger period of time and it compensates for surge in output current. Another problem with the microgrid is the battery used to store energy; the chemical compounds used in battery degrade overtime, also, batteries cannot withstand many charge and discharge cycles. Contrary to batteries, supercapacitors use a completely different mechanism to store energy. Today, microgrids are used extensively in rural areas where it is impossible to send electricity through transmission wires. These grids have made many districts in India energy independent, which says all about this fantastic technology. Dharnai in Bihar district is a live example of success of microgrids as this district had no electricity since the last 30 years. This technology has immense potential to be exploited even in urban areas; and from consumers of electricity, they can become producers of electricity and contribute to reducing global carbon footprint of their country.

Our contribution to paper is that we have studied the various storage technologies used in grids. The paper has four parts: In the next part, the materials and methods available for EMS, then the results and discussion involving a comparative study of the merits and demerits of the methodologies reviewed with the current state-of-art and finally the conclusion is presented.

MATERIAL AND METHODS

Microgrid is an integration of many sources. So, there is a need for managing the whole system to promise a smooth supply to the connected load. Different types of management are there, for e.g. management on supply side, management on demand side and also, power management. But the most important amongst these is EMS. The reason for it is that there are a number of sources in a microgrid which need to be managed in accordance to the demand. We need to manage how many sources are ON at a particular time so that it is sufficient for the demand. Along with this, storage system is very important because it is a support for the whole system during unexpected times. EMS is a combination of hardware and software part which does the monitoring of micro-grid along with its control [3].

It is a secondary control system which handles operation of microgrid in such a way that it is reliable and efficient. Also, it provides guidelines to controllers which are a part of device. There are various EMS methods which can be used for different types of microgrids [4].

Methodologies

Energy storage solves many purposes like peak demand response, frequency regulation and also nullifies the effect of intermittent non-conventional energy sources. It is important to note that every usage has a different battery associated with it. Most of the batteries used today in microgrids are lithium ion batteries because of high energy density, good charging and discharging efficiency. The major disadvantages of lithium ion battery are its inability to handle deep discharge cycle and much deep discharge cycle can reduce its energy storage ability. Lithium ion batteries are used in frequency regulation and maintaining power quality. In lithium ion batteries, lithium ions move from anode to cathode to release energy which is used to our purpose. And during discharge, reverse of this process is done. Figure 1 shows the simulink model of microgrid. Some of the other batteries used for storage purposes are sodium nickel batteries, also by the name of Zebra batteries; the major advantage of these batteries is their ability to handle deep discharge [5]. Another class of battery used is the lead acid battery, it is the oldest type of battery and it has evolved a lot. The major advantages of these batteries are that they are inexpensive and handle peak demand response.

Supercapacitor stores energy electrostatically and there are no chemical reactions involved in it. In earlier times, supercapacitors were used as a subordinate component to supply power in case of transients which arise due to intermittent nature of renewable energy sources. But with proper blend of various technologies, supercapacitor can be used as independent source of energy. One way to improve energy storage system by supercapacitor is to use voltage mode controller then using the traditional current mode controller. One major problem with this method is the separation of distributed generator reference and supercapacitor reference by use of high pass filter, and due to this, there is leakage current which decrease efficiency of the system. Supercapacitor banks are designed on the basis of voltage and current requirement. Finally, supercapacitor banks are connected to various converters [2].

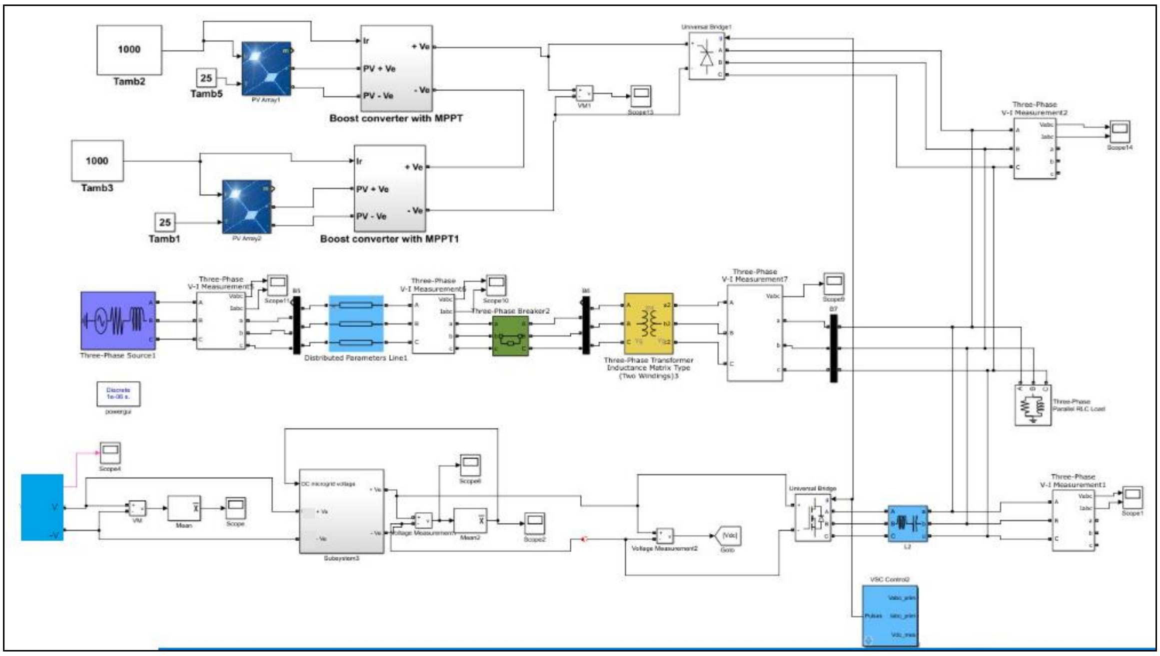

***Fig. 1**: Simulink Model of Microgrid.*

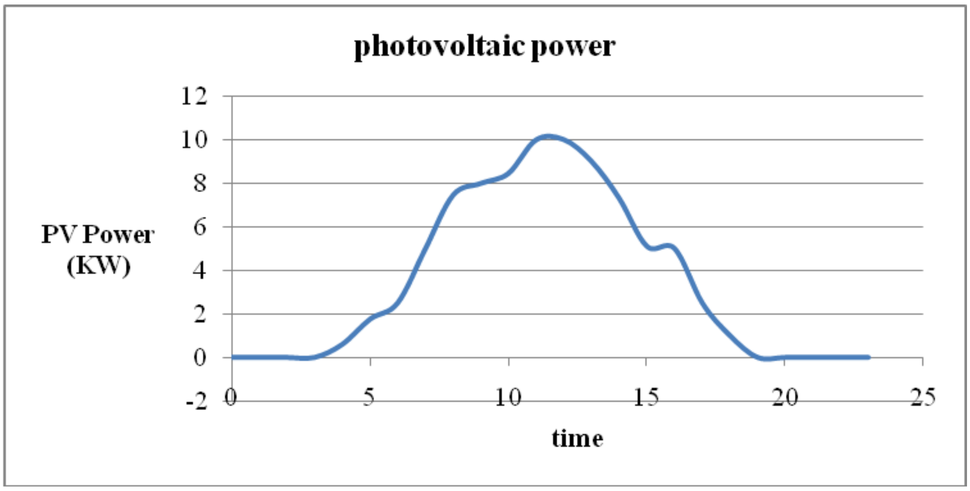

***Fig. 2**: Plot between Photovoltaic Power and Time.*

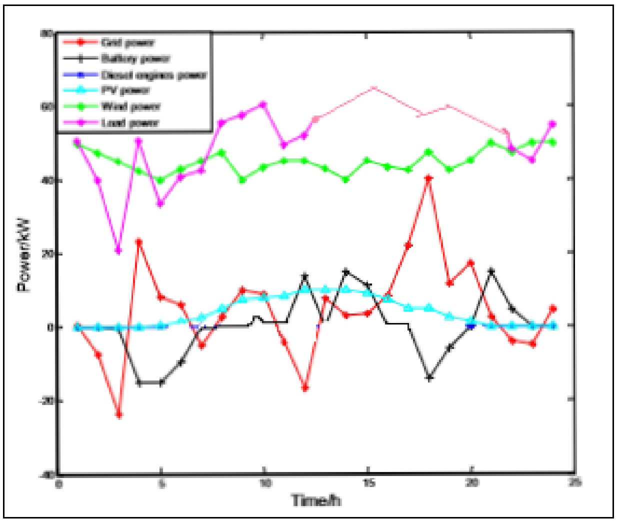

***Fig. 3**: Comparison between Different Sources of Microgrid.*

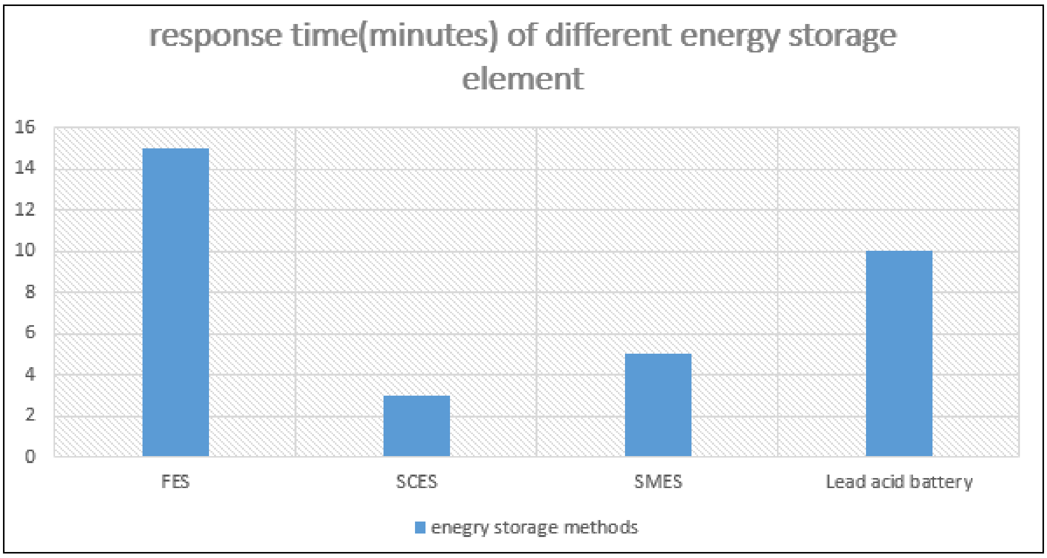

Fig. 4: *Response Time of Different Energy Storage Methods.*

Till now we have discussed two methodologies pertaining to energy storage in microgrid. One is the use of lithium ion battery and other one is use of supercapacitor. In earlier times, it was believed that these two technologies are competing technologies and only one is going to go long in the future. But now, both these technologies are going to complement each other. Also the fusion of these two technologies has given birth to a more robust battery called the ultra-battery. Another important energy storage method is the use of superconducting energy storage system [6]. It consist of a superconducting coil, a cryogenic system just like Large Hadron Collider and energy conditioning system which is used to improve power level. Superconducting coil is the main part of SMES system and this coil is charged and discharged using a two quadrant chopper which consists of high power device. The main feature of SMES is that it does not require any in between energy conversion; so it is highly efficient [6–11]. A SMES system has the ability to absorb/inject reactive power and so it is very useful in AC transmission because reactive may increase or decrease in case of faults, which would completely disrupt the transmission. So we see that SMES systems are versatile which can be used in DC as well in AC transmission.

Fuel cell is an energy storage device which stores excess electricity produced. In this process, the surplus energy is supplied to cell which consist of water and this water is split into its constituents, hydrogen and oxygen. This hydrogen is used as in time when demand increases the supply. A brief working of the fuel cell is: First hydrogen atom enters anode where they are converted into hydrogen ions and then oxygen enters fuel cell which then combines with hydrogen ion to from water which is the byproduct of the reaction (Figures 1–5). The important part of the fuel cell is its electrolyte which must only permit selected ions through it otherwise fuel cell won't work properly. Fuel cells find a wide application in plethora of field. For example, fuel cell is being used in cars which is a cross between internal combustion engine and battery power. One problem with fuel cell is the storage of hydrogen which is produced in the process because it is difficult to store hydrogen as it is highly inflammable [12–17].

RESULTS AND DISCUSSION

Comparative Study (Table 1) [6–15]

$$U_C = \frac{Q}{C}$$

Where, Q is the charge stored in supercapacitor, C is the capacitance of the supercapacitor and energy stored in supercapacitor is given by the electromagnetic energy and L is the inductance.

$$E = \frac{1}{2} C U_C^2$$

$$E_{SMES} = 0.5 L I^2$$

Table 1: *Comparative Study of the Methodology Adopted.*

Methodology Adopted	**Merits**	**Demerits**
Supercapacitor (SC)	• Long working life. • High current capacity. • High efficiency. • Temperature range is wide. • Can be used at any voltage.	• Low cell voltage. • Additional converter is needed to make terminal voltage leveled.
SMES	• Current density of SMES coil is 100 times more than common coil. • Coil works at a temperature which has virtually no losses due to resistance. • Improves power system stability along with the quality of power. • Fast reaction. • High energy storage efficiency. • Fast charging and discharging.	• Not been practically used as compared to other methods.
BESS	• Completely indemnify for the power fluctuations. • Increases system reliability. • Successful for providing an unceasing power supply. • Can cut down on the electricity bills. • Full charging and discharging process can add to its efficient storage. • Act as charging stations for electric vehicles. • Smoothening of power generation from wind, PVs is achievable using BESS.	• Extravagant battery cost for its installation. • High temperature hinders the efficiency. • Being a fixed volume system there is no scope for extension of its capacity.
Fuel Cell	• Low emission rates. • Compact footprint. • Successful in achieving High reliability for grid operations.	• Highly sensitive to any kind of minute voltage fluctuation. • Since hydrogen is rarely found unalloyed, it is difficult to produce constant power as the • Supply is affected. • Not much of research has been carried out on its development.

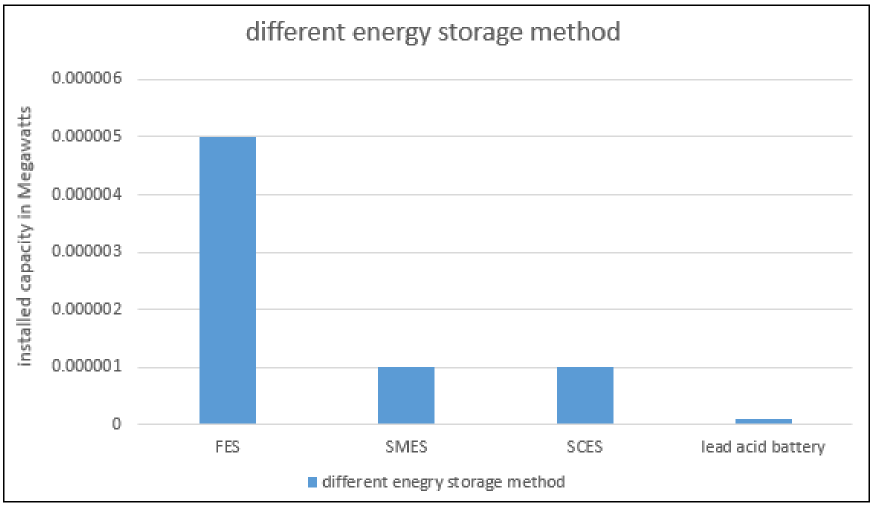

Fig. 5: *Different Energy Storage Methods.*

CONCLUSION

These days, Li ion batteries are extensively used in microgrid due to above mentioned benefits combined with intelligent power control and proper energy management system. And standalone ability of the fully automated battery system will reduce the dependence on fossil fuels and our generation would head to sustainable development. Nowadays everything is evolving to become smarter and microgrids have also followed the suit, interfacing these storage equipment with intelligent software AC battery managing system (ACBM), battery power plant management (BPPM), and SCADA integrated energy management system. These softwares serve plethora of purposes like, enable the battery to switch on or off according to requirement, it keeps a check on battery that it is capable of providing required energy and the last and important one is that it keeps the batteries in their comfort zone which optimizes their life. Another very important use of microgrids is their ability to handle frequency response which thermal power plants cannot handle effectively.

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