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Review on Ideal Microgrid for Indian Farmers

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Abstract - *The government of India, looking at a middle class farmer being unable to cultivate his land due to unavailability of water, has introduced a scheme called KUSUM to give him another source of income by generating electricity from solar microgrid not just to satisfy his own need of electricity by reducing his dependency on distribution system but also by selling the excessive energy to grid and generating revenue through it.*

In this paper, an ideal model of solar microgrid for the farmers has been introduced, which includes PV panels, MPPT, 3phase inverter and battery storage. A brief study of each part of system is done comparing techniques of implementation such as different algorithms of MPPT, various control schemes of Thee Phase Inverter and Battery energy storage system. The advantages and drawbacks are mentioned along with superiority of techniques.

Key Words: **Battery, Inverter, MPPT, PV panel, Solar Microgrid**

1. INTRODUCTION

The rise in temperature of earth due to global warming and pollution indicates it is high time we change our electricity burden from conventional power plants to renewable power plants (energy sources). In developing countries like India, where primary profession is farming, almost 17% of total generated electricity is used for irrigation purpose. Therefore the Gov of India, along with Ministry of New and Renewable Energy (MNRE) has put forward a scheme named PM KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan) under which, the farmers of India are encouraged to set up their own Solar Microgrid to fulfill their own energy requirement.

Along with the large scale solar power generation plants with capacity of 500 MW and above, it is planned to develop decentralized solar and other renewable energy plants upto capacity of 2 MW, and connecting them to existing substation of distribution companies. This will save requirement of transmission system along with T&D losses.

Due to unavailability of water, the farmers face the issue of barren and uncultivated land which can be used for placing solar panels. In this way the farmers will get an opportunity to increase their income and the uncultivated land will also be utilized. Also slits of the cultivated land can be utilized.

There are approximately 30 million agricultural pumps installed in India, out of which, nearly 10 million are powered by diesel, and the Distribution company is unable to power them due to less generation capacity than required. Feeding these with solar power can bring a lot more production through farming. Also, solarisation of the other 20 million grid connected agricultural pumps will reduce a major burden from our current power system at the same time making the farmers independent of conventional sources of energy and provide them with another source of income by feeding the excess of generated energy to the grid.

Proposed block diagram of microgid for farmers

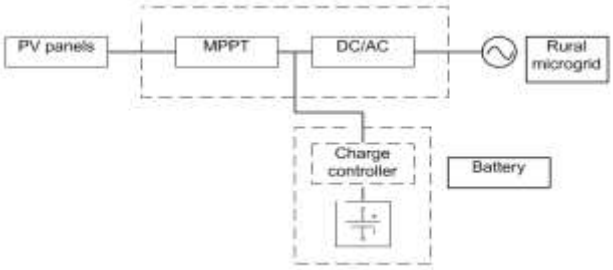

Fig -1: Block diagram of Solar System

Fig 1 is a general block diagram of a solar based power generation unit. It consist of PV panels, inverter and battery storage.

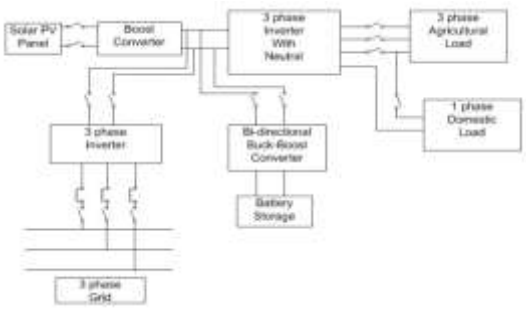

Fig 21: Block diagram of proposed scheme

Fig 2 is the proposed scheme block diagram which has similar blocks to fig 1 with a few modifications. We will discuss each block in detail below.

2. PV PANELS

PV panels are a large number of solar cells connected in series and parallel to get required amount of voltage and current. A solar cell is made up of sandwich of silicon material doped with p and n type impurities. When solar radiation falls on the surface of solar cell, the energy gets converted to electrical energy by photovoltaic effect.

There are numerous developments done in the field of Solar panels depending on the material and new technologies which is not covered in this paper.

The open circuit voltage and short circuit current of a solar cell is approximately 0.6 volts and 3.5 mA respectively.

Solar Panel details [1]

Brand name: Domghui

Voc = 43.6V, Isc = 11.7A

Working voltage = 36V max

Operating current = 9.7A

Dimensions = 1950*992*40 mm3

Weight = 22 kg

No. of cells = 72

Price = $90

Specifications vary with brands. These panels are connected in series and parallel as per requirement of power.

3. MAXIMUM POWER POINT TRACKING

The solar radiations are varying with time hence selecting a constant operating point is uneconomical in case of working with solar panels. Thus, there are two techniques available to increase the efficiency of solar system

- Electromechanical sun tracking
- Electrical operating position tracking

As the name suggest, in the first technique, the sunrays are tracked by using complicated mechanical system to capture maximum solar energy. This system requires tedious calculations and the orientation changes with time of the day and season [2].

The second technique is comparatively easier and gives better efficiency. The maximum power a PV can deliver changes with cell temperature and solar irradiance. Impedence mismatch between the source and load also reduce output power [3]. Thus the operating point has to be shifted time to time according to the changes in external conditions. MPPT principle generally applies to variable power source.

Solar PV system has many configurations considering inverter systems, battery, and electrical loads. MPPT focus on increasing the efficiency of power transferred from solar cell to load, because it depends on solar irradiance and electrical characteristics of load [1]. As the amount of sunlight varies, characteristics giving max efficiency of power transferred changes, thus to optimize the system efficiency load characteristics has to be changed. This point is called maximum power point and MPPT is the technique to find this point and keep the load characteristics there.

The output efficiency of solar cell is non linear due to complex relation between temperature and total resistance [1], and can be analyzed based on current-voltage curve. MPPT system samples the output of PV and applies the suitable resistance (load) to obtain maximum power for each moment of time with varying amount of sunlight.

There are various algorithms available for implementation of MPPT as follows

a. Perturb and observe
b. Incremental conduction
c. Fractional open circuit voltage

There are few more artificial intelligence based techniques available considering the conditions of partial shading [3] which are not studied in this paper.

a. P and O is most widely used considering and less sensor requirement [3]. it is the simplest among all algorithms, but diverges from MPP during rapid changing of irradiance [2].
b. Incremental conduction is based on mathematical fact that derivative of PV power at MPP is zero, at left of MPP negative and at right of MPP positive [2]. It overcomes limitations of P and O as it does

not involve perturbation [4]. This method can track rapid changes in atmospheric conditions [1]. Also, this technique can determine the MPP to be achieved whereas P and O oscillates around same point [4][5].

c. Fractional open circuit voltage method is based on non linear relation between voltage at MPP and open circuit voltage [1]. The value of Vmpp/Voc is between 0.71 to 0.78 [5]. Wastage of power during disconnection of converter is the major disadvantage of this algorithm[1].
d. Table summarizing comparison of MPPT techniques

Table -1: Summary of comparison of MPPT

Parameters	Techniques		
	P & O	INC	FVoc
Steady Tracking	Reasonable	High	Medium
Algorithm Complexity	Low	High	Low
Hardware Complexity	Low	Low	Medium
Sensors	V & I	V & I	V
Dynamic Tracking	Reasonable	High	High

4. THREE PHASE INVERTER

The basic function of an inverter is to convert generated DC power to AC [6] but it is not as simple as that. The microgrid can either be connected to the grid (on grid) or can be standalone (off grid).

Many PV systems are run in off grid mode due to high cost of its grid connection [6]. Depending upon whether the grid is connected or not, the requirement of inverter changes. Grid connected inverter should be able to detect islanding situation and take measures to protect the equipments [7]. Also, IEC [8] and IEEE [9] put limit on max DC current that can be injected to grid [10]. This is to avoid saturation of distribution transformer [7]. Total harmonic distortion (THD) should be limited to 5% [11].

In this paper we are discussing different topologies for connecting PV panels to three phase Grid.

Inverters can be categorized by

- Number of power processing stages
- Use of decoupling capacitors
- Use or no use of transformers

Some three phase topologies can be compared / presented based on type of control. We are discussing classification based on number of power processing stages in detail.

a. Single stage inverters / Centralized inverters – single centralized inverter is connected to PV panels. It handles MPPT, grid current control and voltage amplification [6]. This has many disadvantages as the inverter is bulky, heavy and difficult to install with low PF and high harmonic content [11]. Main disadvantage id absence of individual MPPT which results in affected performance due to partial shading or clouding [11]
b. Dual stage / Multistring inverters – DC/DC inverters are added along with inverters. The controlling of current is done by PWM or Bang-Bang operation. Number of panels connected in series to form string and MPPT is attached to each string. It also suffers from shading problem.
c. Microinverters – Each module is connected to individual DC-DC converter with MPPT [11]. This topology overcomes drawbacks of string and central inverter topology. Major advantage of microinverter is it eliminates the clouding and shading effect. It also eliminated use of DC cables [11]. The disadvantages are high cost and complex design. [12]

5. BATTERY STORAGE SYSTEM

Considering the uncertainty of solar power generation, it is suggested to have battery energy storage system (BESS) with effective control. PV and battery size are important parameters for the evaluation of performance of microgrid [13]. A bidirectional Buck-Boost DC-DC converter can be used to maintain the bus voltage at peak load conditions by providing energy through BESS. One three phase bidirectional inverter enables multiple and parallel energy flows between PV, battery, and ac grid [13]. LC filter can be used to reduce the ripple at converter output [14].

Nickel Metal Hydrite Battery has advantages like simple storage and transportation and environment friendly [15]. When the load requirement is less than produced energy by solar, battery starts charging. In case of any imbalance during peak load the battery

supply the power. Charging of battery depends on State of Charge and direction of current flow [15].

The basics of BESS planning depend on strategies used for charging / discharging control of battery [16]. Control strategies sets upper and lower limit for charging and discharging to keep SOC within the limit [17][18]. SOC slope indicates the rate of charge / discharge of battery [19] battery charging and discharging is used to ensure the generated power is kept equal to load demand. A detailed study of Solar PV with load and battery is discussed in [16] along with simulation waveforms of load power, PV power and battery SOC at different conditions.

CONCLUSION

After detailed study of each block of the system and with above discussion, we can conclude that the proposed system can be implemented in real. The system will be first implemented in MATLAB to study the waveforms and problems that will be occurring in real life implementation. For this purpose, from various available technologies, we can select the suitable one considering the simplicity of operation and cost effectiveness. MPPT by Incremental conductance gives better results with simple operation. System can be implemented with grid connected inverter in two stage control with PWM method to control the power flows and battery storage system necessary to maintain the bus voltages.

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