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Study of Operational Modes of a Grid Connected Solar Power Generation With Storage Battery

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Abstract: This paper proposes operation modes of a typical solar power generation system. It is having solar as renewable energy source, storage battery and load, is connected to AC grid. This system uses converters and switches, and by controlling them it can be operated in different modes. In this paper, the behaviour of system for every transition of mode is explained, by controlling the switching devices, which is tested in Simulink package and results assure that power is supplied to load, and balanced forevery mode of operation.

Keywords: Operational Modes, Solar Power Generation, Storage Battery, AC grid.

I. INTRODUCTION

Renewable energy sources are good remedy for todays energy and environment issues. Solar power generation is upper most prioritized energy conversion now. We take a small solar power generation system to supply a residential load and study operation modes. Solar panel is attached with boost converter, which is boosting up the generated voltage, through this we can connect and disconnect the solar panel to circuit. Battery is connected parallel to panel through charger, which can change the status of battery, and farther inverter is connected since, we require to supply AC load, and to connect AC circuit, finally grid is connected through a operational circuit breaker, as shown in fig.(1). Usually these type of circuits can be operated in two different operational states as islanded and grid connected. For grid connected operation C.B is kept ON, for Islanded operation It is kept OFF.OFF-grid or Islanded system is mainly used for road lamp, highway monitors and communication systems. The large scale systems that supply residential loads are still needed to develop [1]. The controlling of switching devices gives the operational states of system for particular load demand, those different modes and mode transactions are briefed here in it. One flow chart is drawn, which gives the information of modes, mainly works on power balance equation i.e, power generation is equal to power demand. So the controlling of switching devices is using this power balance condition.

II. OPERATIONAL MODES OF THE SYSTEM

Fig(1).shows a typical block diagram of PV-based grid connected system. There are 3 separate sources to feed an AC load. PV panel, battery is DC voltage sources connected through boost converter and charger respectively. The mod- elling of sources to design particular model is cited [2],[3]. Those sources are connected in parallel to each other and then total circuit is connected to grid in series through a converter, which is well known as bi-directional converter here, since it converters AC to DC, DC to AC. A C.B (circuit breaker) is arranged between converter and grid, to switch the grid to circuit. Preferably, we use AC source, so it is connected at AC part of the circuit.

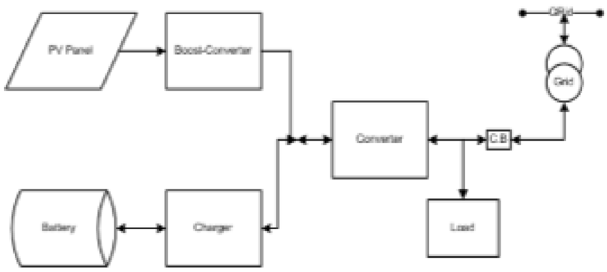

Fig. 1. block diagram of the system

PV works on radiation effect, boost converter is to boost up the voltage. Panel is operated at MPP to give possible maximum power for particular operating point. For this many techniques are invented ,in which here used is open circuit voltage and short circuit current techniques [4],[5]. These are very simple MPP methods, but not efficient. We just multiply approximated fraction to open circuit voltage and short circuit currents, to get an operated point that gives maximum possible power from PV panel. Battery also works on SOC percentage. Battery is connected through charger works on charger status, which is having constant current, constant voltage modes for charging and discharging the battery respectively. Converter works as rectifier and inverter depends on power flow in circuit. Circuit breaker is just to pass the current through it in either directions. Our circuit can be operated in 8 modes, from their status of operations of switching devices. Those modes are derived by binary operations. PV system can't be worked without a battery, since its voltage needs to be stabilized every time of changing radiation, so 4th, 5th states don't mean anything [6] as shown in Table (1). The remaining states are divided as on mode, off mode, and emergency mode, grid mode and all on mode depends on the sources connected to the network. so here is the mode names and sources' operating status'.

PV	Battery	Grid	Mode
off	off	off	off mode
off	off	on	grid mode
off	on	off	emergency-discharging
off	on	on	grid-charging
on	off	off	–
on	off	on	–
on	on	off	PV on mode
on	on	on	All on mode

Table.1

As listed in table, in OFF mode no source works. For grid mode, the power demand is met by the power supplied by the grid, so only C.B is kept open. For emergency mode, battery works, it discharges until SOC reaches to 20, still if any source is not connected, then system goes to OFF state. But this state is no longer operated, converter acts as inverter. As well, if grid is connected, obviously battery charges and load demand is met, for this converter acts as rectifier and charger acts as constant current source, and this mode is grid and charging mode. For PV ON mode, if the irradiation is sufficient, the output power is enough to support the total load. That mode can be called as export mode, since the grid is taking power from PV system. As well, When irradiation is not sufficient, the loads are supplied by Grid as discussed earlier. That mode can be called as export mode. ALL sources ON mode the battery either charges or discharges according SOC level. If SOC is below 20 percentage, it charges until SOC gets 80 percentage. Once it reaches, it checks for load demand and if load demand is still meeting by grid it charges farther other wise starts discharging. So converter state is in either rectifier or inverter mode and C.B should be on

mode	boost-converter	charger	converter	circuit breaker	status
off mode	–	–	–	–	no power flow
grid mode	off	off	off	on	grid to load
emergency mode	off	CV	DC to AC	off	discharging of battery
grid-battery charging	off	CC	AC to DC	on	grid to load,battery
PV on mode	boosting up	CV	DC to AC	off	PV,battery to load
PV on mode	boosting up	CC	DC to AC	off	PV to battery,load
all on mode	boosting up	CV	DC to AC	on	power to load from all sources
all on mode	boosting up	CC	DC to AC	on	power to load and battery

Table.2

III. COORDINATION OF MODES

To change the modes, power balance equation is used here. Pp, Pb, Pg are the power delivered by PV, battery, Grid and Pd is power demanded by load. By balancing these power parameters, which are demanding, which are supplying is checked, that condition changes the status of controlled variables C.B, converter, Boost converter, charger and so the modes are set. For emergency mode, the PV, grid status are needed to be checked. Unless they are OFF, the battery doesnt need to supply the power to load. If the grid is connected in circuit, PV, battery are no longer needed, since, grid can take care of any load. PV panel supports to supply load, battery, grid, if it generates more power than they demand.
Power flow equation at load for grid connected operation.

$$pp + pb + pg = pd \quad (1)$$

Here, all sources are supplying power to load Pd. In case, if battery reaches 20 of its SOC, it will charge. So,

$$pp + pg = pd = pb \quad (2)$$

For isolated grid mode, means C.B is off,only PV, and Battery will supply load, until battery reaches 20 of its SOC

$$pp = pb = pd \quad (3)$$

If source PV is able to supply load alone, then battery will be disconnected (if battery SOC Is 100), and extra power can be exported to Grid. So, in that case,

$$pp + pd = pg \quad (4)$$

If only battery is connected to circuit, PV is giving insufficient and grid is not connected then battery supplies power to load. It is emergency mode and it stays no longer.

$$pb = pd \quad (5)$$

where,
pp = power generated by PV panel pb = power handling by battery pg = power imported or exported by grid pd = power demanded through load These all balanced equations are fixed in below flow chart model.In every mode of operation the DC bus voltage is maintained constant. To achieve that, a capacitor is connected to that circuit. This capacitor maintains a constant voltage, which equals to output voltage or MPP voltage of PV panel. That voltage obviously is applied to terminals of battery

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charger, so' it needs to be maintained constant voltage. So, it is connected between booster converter and main converter. In matlab simulink model it is modelled[7]. Once it charged, it maintains constant voltage, until that point, transients may occur in overall system. Farther it starts maintaining constant voltage. So for charging mode the charger acts as constant current mode, since battery charging and foe discharging mode the charger acts as constant voltage mode, since the out put voltage of battery needs to be constant.

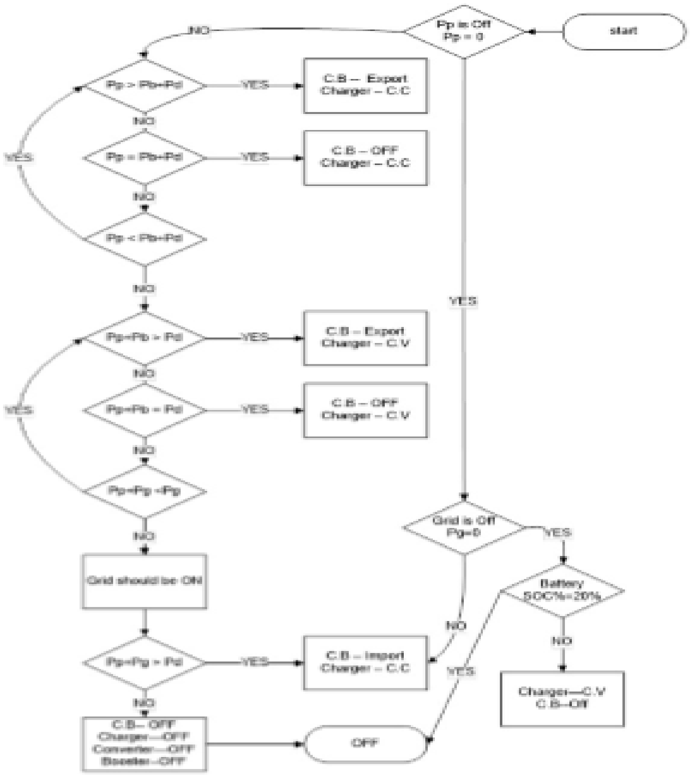

Fig. 2. flow chart for coordination control

IV. SIMULINK RESULTS MATLAB

Simulink package was used to simulate this circuit. The booster converter had been designed with inductor, a switching device and a capacitor. Charger was designed with two switching devices and a high valued inductor to smooth the current flowing in it. Those two switching devices are fro charging and discharging modes [8]. Converter was designed to act as rectifier and inverter. The grid is modelled as a 3-ph source with a transformer. Load was just taken from simulink block. here given are the simulation results of the circuit. But the switches are manually operated for time being.

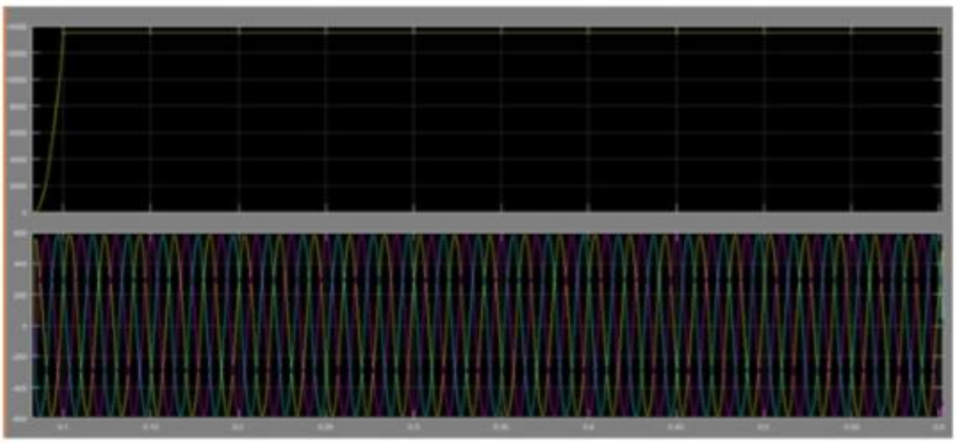

Fig. 3. Power and Voltage from grid, when grid is operated alone

This profile is for grid connected mode (when no other source is operated). The voltage supplied to load is balanced 3-ph voltage, and power is supplied constantly from 0.1 sec and maintains though out this mode. see figure 3.

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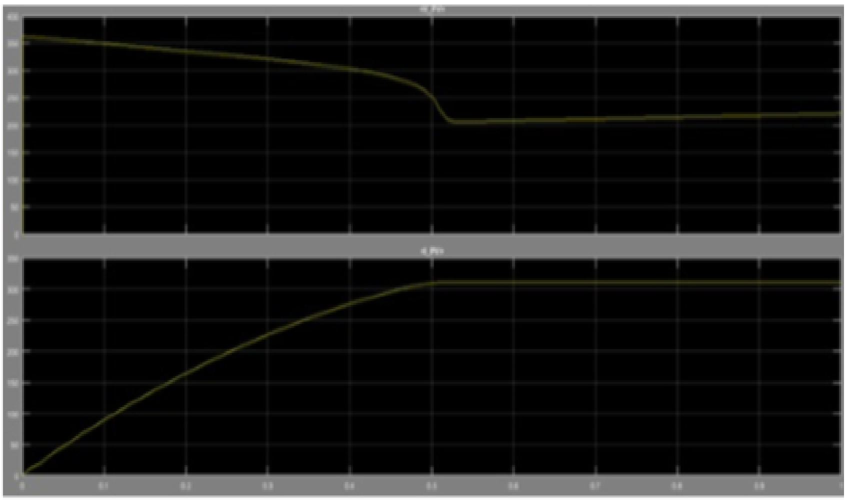

Fig. 4. Voltage and current profiles for PV-battery combined operation

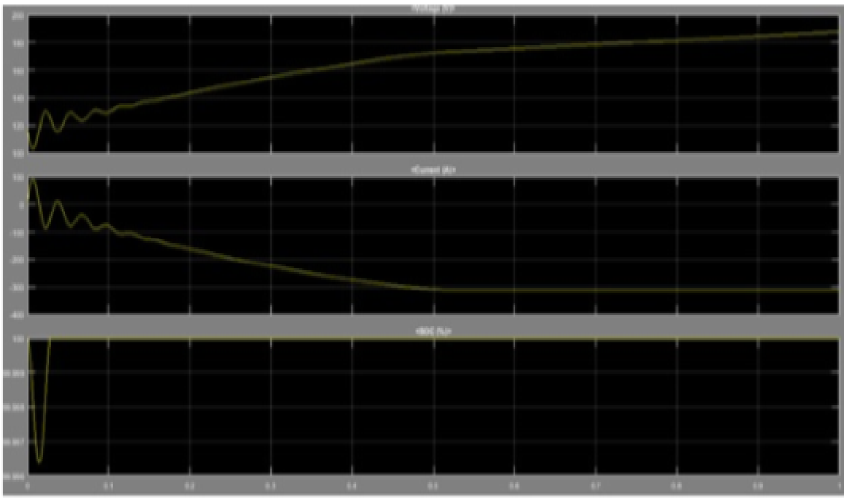

Fig. 5. V,I,SOC profiles of battery for PV-battery combined operation

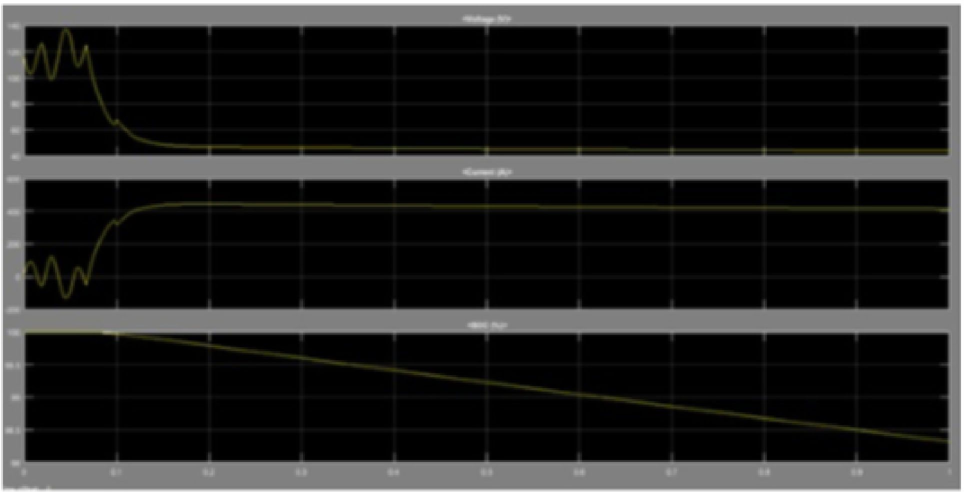

Fig. 6. Battery V,I,SOC profiles for emergency mode

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When PV and battery are operated combining with is- landed operation, the load is supplied by PV and the battery is charging. These profiles show that, till 0.5 sec the transient period is occurring and from then, the power is supplied by PV and the same time time the battery is charging with constant current and increasing voltage. see figures 4,5. This profile is for emergency mode. When PV and Grid are disconnected and battery is alone operated, The battery discharges total power in it with constant voltage and decreas- ing current. That SOC curve assures the battery discharging. see figure 6.
Here only 3 modes profiles are given, they assure the load demand meeting with supplying power.

V. CONCLUSION

As for we have seen the behaviour of solar power genera- tion system. The power demand of load is met for every mode, and results are showing steady values. Here, for time being just manual operated system is being considered. But flow chart is given based on power balanced equation, that Flow chart helps to programme a controller. For future research work it will be programmed and worked. Farther we can add any number of renewable sources such as wind, fuel cells and get it worked based on this power balancing equation.

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