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PERFORMANCE ANALYSIS OF SOLAR PV-BATTERY GRID CONNECTED SINGLE PHASE TRANSFORMERLESS INVERTER

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***Abstract*— Solar power efficiency is reduced by location and weather. To overcome this drawback, different renewable sources and converters are needed to be integrated with each other. In this paper, a grid tied solar PV system with energy storage is proposed. The aim is to provide continuous power supply for consumer by consuming the solar energy effectively. For this purpose, two components such as collector and a storage unit are required due to the nature of solar energy. BEMS helps to manage the situation by absorb it when excess energy is produced from PV panels and release it when the productivity drops by using Bidirectional converter. MPPT is used to obtain a maximum power tracking point. By Synchronous reference frame theory, the output from a transformerless inverter is connected to the grid. Simulation results are obtained from MATLAB/SIMULINK.**

Keywords— **Solar energy, battery storage system, MPPT, transformerless inverter, tied to grid.**

I. INTRODUCTION

In today's climate of growing energy needs and increasing environmental concern, alternatives to use of non renewable and polluting fossil fuels have to be investigated [1,2]. One such alternative is solar energy. It is one of the important sources due to its characteristic such as renewable, clean, eco-friendly during electricity production. Much of the world's required energy can be supplied directly by solar power. Integrating of renewable energy resources in existing system is going wild. The existing topology [3] is shown in fig 1. In this, dc power obtained from the PV array is stepped up by using converter [4]. Huusari *et al.* (2012) suggested that to meet the requirements for high-power applications, the converters are connected in series or in parallel [5]. Then inverter converts DC into AC to make it suitable for grid connection. A single-stage [6-8] or double-stage topology [9,10] is used. Barnes *et al.* (2012) have suggested that the efficiency of two-stage topology is higher than single-stage [11]. But expected efficiency is not obtained yet.

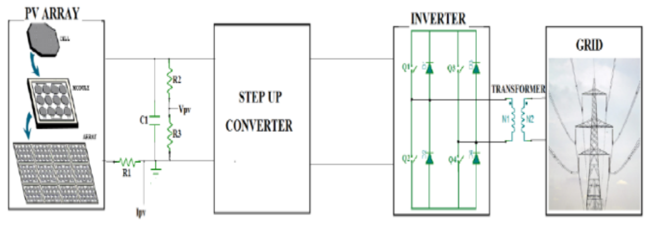


Fig.1.The equivalent circuit of a single-phase full bridge inverter with connected to grid.

Carrasco *et al*. (2006) stated the issue that solar energy output during the course of the day and year is not predictable. Reasons are clouds that pass over affect the solar power plants limit generation for short time, change in weather conditions and during night time [12,13]. This affects the efficiency of the solar power. To overcome this battery storage is included to have uninterrupted power supply.

II. PROPOSED SYSTEM

A. Description of a proposed system –

In this paper detailed modeling, control and simulation of a PV energy system that supply the load with battery backup are developed. Between battery storage and dc- link, a control algorithm is developed using bidirectional converter. LC filter is connected after the inverter to eliminate the high frequency harmonics.

A single phase transformerless inverter with vector control scheme is used to control the load side voltage in names of amplitude and frequency. The overall block diagram of the proposed system is shown in fig.2.

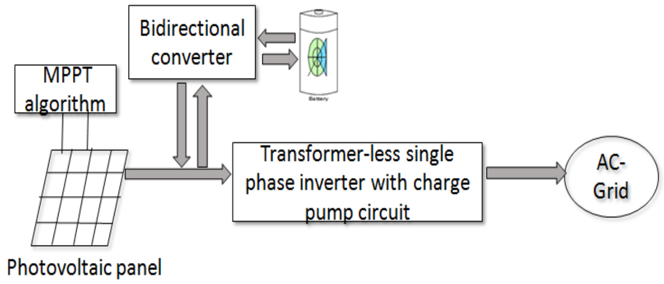
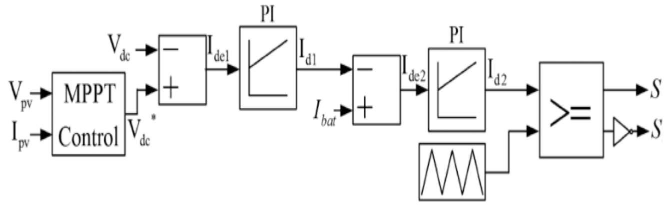
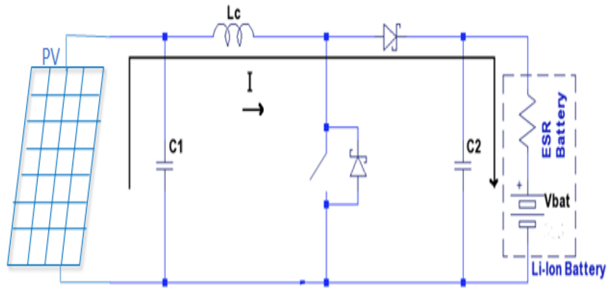


Fig.2. A proposed solar power system connected to the grid



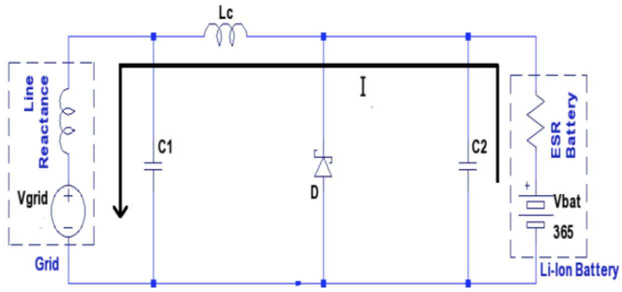
(b)

Fig.3. (a) bidiectional converter (b) control algorithm to maintain reference DC-link voltage



(a)

Fig.4. (a) Operation of Bidirectional converter in Boost mode



(b)

Fig.4. (b) Operation of Bidirectional converter in Buck mode

B. Mppt algorithm –

To maximize the power from the panels, MPPT is used by controlling the voltage and current optimal point. This power extraction control is required due to changes with solar radiation incident and panel temperature. The MPPT communicates with bidirectional converter for knowing whether the battery is charging or discharging. Its function is to control the output voltage by regulate the PWM duty cycle. There are different types of MPPT algorithm. Among these P&O algorithm is chose for its simple and efficient.

C. Bidirectional converter –

A charging to discharging and discharging to charging process is required in battery storage system. For this process to be take place bidirectional converter is used. This buck-boost is suitable for this operation because this topology requires minimal storage elements and two switching devices. This means less space ultimately less cost.

The bidirectional converter acts as boost converter, when V_{out} is higher than battery voltage or acts as a buck converter, when V_{out} is lower than battery voltage. If less power obtained from the solar panel means battery is discharged and if solar radiation is high means battery is charging by the control algorithm of bidirectional converter as shown in the fig.3. The two different operation modes are shown in fig.4 (a),(b). It achieves the best efficiency by using lower voltage power devices and operating current.

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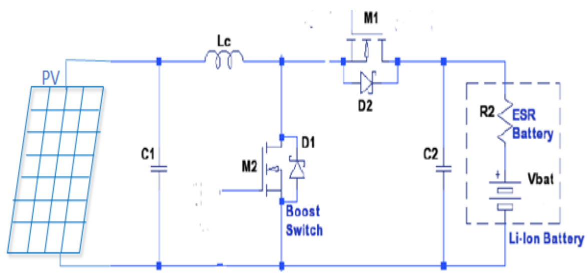

(a)

Table -2 Modes of bidirectional converter

MODES	S1	S2	DESCRIPTION
Boost	On	Off	Battery is charged.
Buck	Off	On	Battery is discharged by supply its energy.

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D. Transformerless inverter –

An inverter is necessary for any PV system involving a conversion between DC and AC power. The inverter selection, as with any other in the system, must be chosen carefully. Single phase transformerless inverter is used here. It consists of 4 MOSFET switches and 2 diodes as shown in fig. 6. This topology is chosen because it eliminates the leakage current by connecting the neutral of the grid to the negative terminal of the charge pump circuit. Diodes D1, D2 and capacitors C1, C2 connected across switches S3 and S4 to form charge pump circuit. Hence, the injection of dc into the grid is eliminated. This topology is also simple and easy to design.

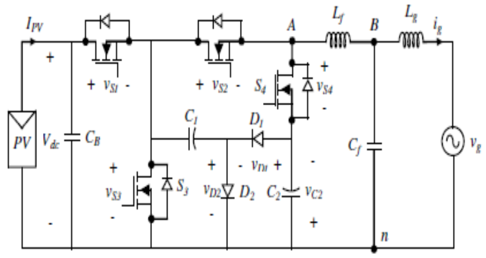

Fig.5. Single phase transformerless inverter

This topology is modulated by unipolar PWM. Four mode of operation that generate voltage state of $+V_{dc}$, 0, $-V_{dc}$ is shown in table 2. Mode 1 conduction generates $+V_{dc}$. Likewise, Mode 3 during negative cycle generates $–V_{dc}$ and Mode 2, Mode 4 for zero state.

Table -2 Modes of operation

Modes	S1	S2	S3	S4	Output voltage
1	1	1	0	0	$+V_d$
2	0	1	1	0	0
3	1	0	0	1	$-V_d$
4	0	1	1	0	0

E. Inverter control –

The main aim is to generate sinusoidal reference grid currents, in order to operate the grid at unity power factor. Therefore, the inverter is controlled by using SRF theory, in order to generate reference grid currents. In the Synchronous reference frame, it converts grid voltage and grid current into frame that rotates synchronously with grid voltage vector by park transformation.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos wt & \sin wt \\ -\sin wt & \cos wt \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

To obtain this, phase angle of grid voltage is detect by phase-locked loop. Now, steady state error is reduced by pi controller. Next d and q axes reference current are converted into α, β using the below expression.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos wt & -\sin wt \\ \sin wt & \cos wt \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix}$$

It needs a phase locked loop to generate synchronized sine and cosine signals, for α, β to d-q reference frame transformation and for vice-versa.

III. EXPERIMENT AND RESULT

MATLAB 14a software platform is use to perform the experiment is shown in fig.6. The parameters are listed in table 3. The proposed scheme is simulated. From the simulation of the experiment results shown in fig.7(a),(b), we can draw to the conclusion that changes in solar panel power due to irradiance and temperature does not affect the inverter output due to the help of battery energy management.

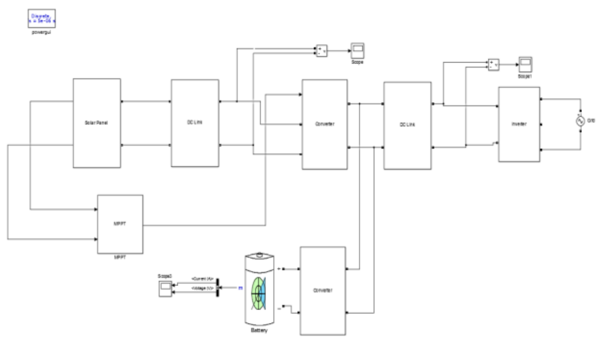

Fig.6. SIMULINK diagram of a proposed system

Table -3 Parameters of a proposed system

PARAMETRERS	RATING
Input voltage	312V
Grid voltage	220(rms)
Grid frequency	50Hz
Rated power	5Kw
AC output current	16A
Switching frequency	20kHz
Lf	6mH
Cf	13μF
Lg	3mH
Battery voltage	440V
Battery Ah	200Ah
SOC	40%

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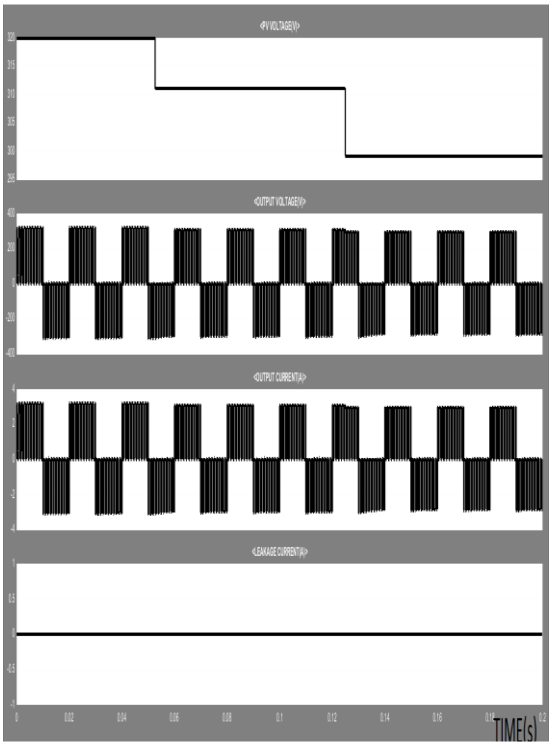
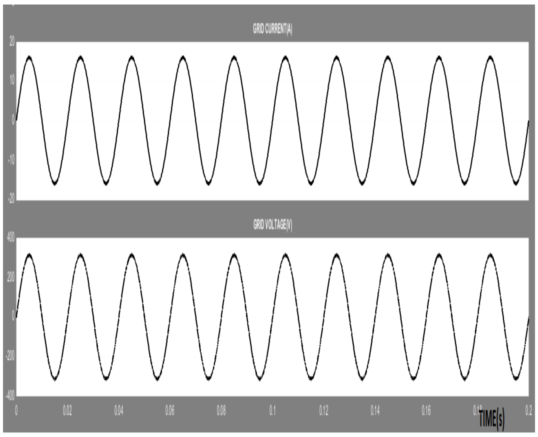


(a)

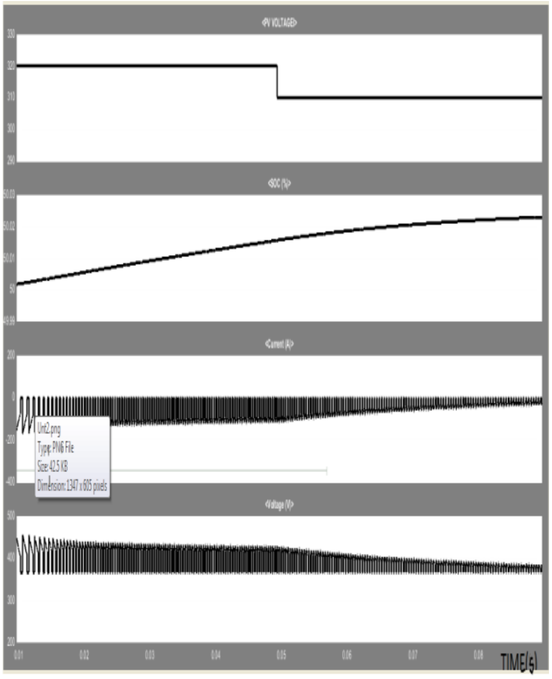
Fig.7. (a) PV voltage , output voltage of inverter without LC filter, output current without LC filter, leakage current.



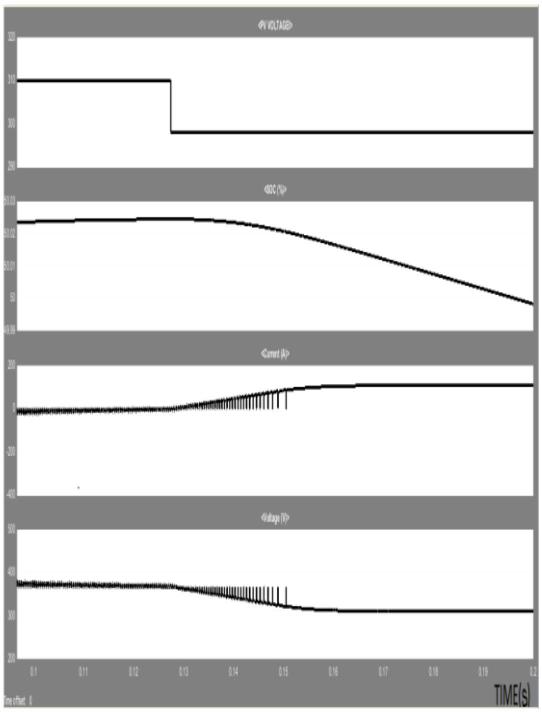
(b)

Fig.7. (b) Grid current, Grid voltage

When the solar power is less than DC-link voltage, battery discharge and as well as charge if solar power is excess to maintain the required DC-link voltage is shown in fig. 8(a),(b).



(a)



(b)

Fig.8. (a) show PV voltage, SOC, battery current, battery voltage while battery is charging. (b) show PV voltage, SOC, battery current, battery voltage while battery is discharging.

IV. CONCLUSION

The varying nature of the solar power output decreases the efficiency of the system. This is over came by a storage unit called battery. At the same time, solar energy is utilized effectively.

Therefore, charging function of battery absorbs excess PV power and during reduced PV power discharging function provides continuous power supply to the grid by the bidirectional DC-DC converter. The leakage current is eliminated by charge pump circuit of transformerless inverter. By synchronous frame theory, the output from solar power generation is injected into the grid

A proposed design of single phase grid connected transformerless PV inverter system with energy storage is analyzed and simulated by using MATLAB/SIMULINK. This proves that continuous power supply to the grid irrespective of solar PV output.

Thus, this proposed configuration can greatly reduces the existing power demand by utilizing maximum of its energy, limits the use of conventional power generation techniques along with benefit of cost reduction from utility and also it is the only means to tackle the future power requirement.

V. ACKNOWLEDGEMENT

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