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DC Microgrid with Energy Storage System

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***Abstract* —**
Photovoltaic (PV) generation is the technique which uses photovoltaic cell to convert solar energy to electric energy Nowadays, PV generation is developing increasingly fast as a renewable energy source. However, the disadvantage is that PV generation is intermittent for depending on weather conditions Thus, the battery energy storage is necessary to help get a stable and reliable output from PV generation system for loads and improve both steady and dynamic behaviors of the whole generation system. PV array is firstly connected to the common dc bus by a boost converter, where the battery is also connected by a bi-directional DC/DC converter, Maximum power point tracking helps PV array to generate the maximum power to the grid, and the battery energy storage can be charged and discharge to balance the power between PV generation and DC grid. Finally, different cases are simulated, and the results have verified the validity of models and control schemes. DC microgrid is an effective solution to integrate renewable energy sources which are DC power supply with DC loads. To solve the problem of power unbalance microgrid and the wide fluctuation of DC bus voltage due to unstable output of DC micro resource, Experimental results feasible through the MATLAB/SIMULINK simulation platform.
Keywords*-DC Microgrid, Incremental Conductance MPPT, Bidirectional Converter, Battery Energy storage*

I. INTRODUCTION

Nowadays, the problem of energy crisis has been increasingly tense, while low carbon energy need to be developed. distributed renewable energy has been paid more attention and developed greatly, especially wind power and photovoltaic (PV) generation, due to their abundant availability and less impact on the environment. But theory and practice have proved that these distributed renewable energy have some inherent problems, such as its intermittency, which has some negative impact on the security, reliability and power quality of utility grid [1]. On this basis, the concept of microgrid presented by Robert Lasseter and other scholars is considered to be a feasible scheme to solve the problem. The microgrid is a local energy network that includes renewable energy sources and storage systems. It can be connected to the mains grid or works isolated when there is a blackout at the main grid, and continues to supply their local loads in "islanded mode". A microgrid can be designed to support alternating current (AC) or direct current (DC).Compared with AC forms, DC microgrid can avoid the consideration of reactive power and frequency synchronization At the same time, some DC sources and DC loads, such as photovoltaic, super-capacitor, EV and LED, provide opportunities for DC microgrid. Also, DC microgrid will have the capability to increase the overall system efficiency compared to AC system.

Storage systems are usually installed to alleviate system power mismatch between generation and consumption in DC microgrid, and they can improve the stability, power quality, reliability of supply and overall performance of microgrid. Storage systems can be characterized based on power density, energy density, ramp rate, life cycle and so on, but none of the storage systems fulfill all expected features. The typical energy storage in practical engineering is lead acid batteries, which possess high energy density but low power density, low charge/discharge rates and life span of less than 1000 full cycle.

MICROGRID AC and DC

Microgrid systems can be divided into AC-bus and DC-bus systems, based on the bus that the component systems such as energy sources, loads and storages are connected to. AC bus based microgrids are advantageous because the existing AC power grid technologies can be readily applicable. However, AC grid issues including synchronization, reactive power control, and bus stability are inherited as well. DC-bus based systems can become a feasible solution because micrograms are small, localized system that the transmission loss is negligible, unlike the traditional power systems that have a long line of transmission and distribution. Moreover, it does not need to consider the AC system issues and system cost and size can be reduced compared to the typical AC-DC-AC conversion configuration because DC power is generally used in the power electronics devices as a medium.

ADVANTAGES OF DC MICROGRID

- Better Stability: In DC system there is no need of frequency synchronization.
- Storage system: In DC energy can be stored in battery, if a power mismatch between generation and consumption it can be stored.
- High efficiency: Multistage power conversion is avoided in dc so losses reduce and efficiency increases.
- Each power generation connected to the distributed system can easily be operated in coordination because it controls only dc bus voltage**.**
- It has ability to automatically disconnect or reconnect to the main grid when there is a disturbance or when the microgrid standards do not match.
- It can provide high quality uninterrupted power supply to the consumer in dc microgrid.

II. DC MICROGRID

The figure1 represents the DC microgrid structure. DC microgrid consists of photovoltaic source as main source of energy due abundant availability and less impact on environment and storage system include battery and is used so electricity shortage occur at time storage energy can be used and is interfaced with power electronic converter. DC load is connected to DC grid directly, The PV panel is connected to dc bus through an buck boost unidirectional converter, which can extract maximum power from PV panel using maximum power point tracking algorithm. Battery is connected to DC bus through bidirectional DC/DC converter.

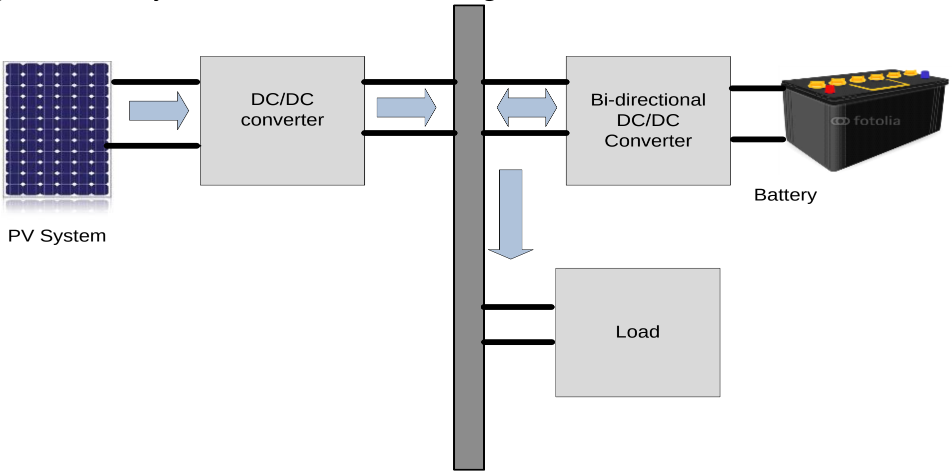


Fig 1:DC microgrid with storage system

A. PV module

PV Module is nonlinear source of energy. Its maximum power generation capacity is highly dependent on irradiation and temperature, while it's instantaneous power generation directly dependent on its output impedance. PV Module can be represented by single diode equivalent circuit.

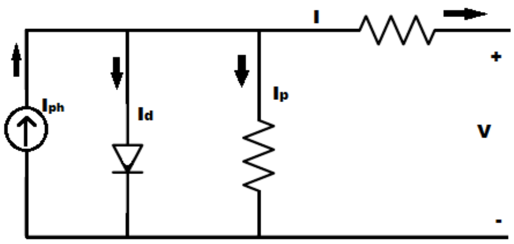


Fig: 2 equivalent circuit of PV cell

PV Cell current can be given by

$$i_{pv} = i_{ph} - i_0[\mathrm{q}(V_{pv} + i_{pv} * R_S)/nkt - 1]$$

$$-V_{pv} + i_{pv} * \frac{R_S}{R_{sh}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

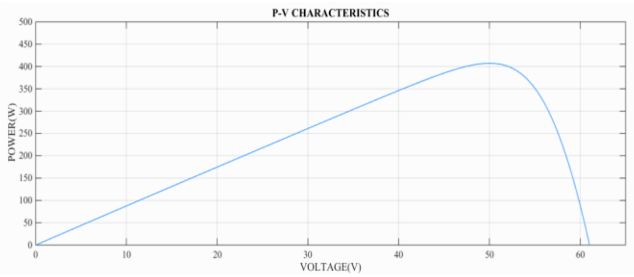
Photo current which is depend on Irradiance and temperature is given by

$$\mathrm{I}_{\mathrm{Ph}=\frac{\mathrm{G}}{\mathrm{G_{ref}}}}(\mathrm{I_{phref}} + \mu_{\mathrm{sc}} * \ \mathrm{deltaT}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

I_0 can be given by:

$$I_0 = I_{0ref} * \left(\frac{T_C}{T_{Cref}}\right)^3 * \exp\left[\left(\frac{qE_g}{AK}\right)\left(\frac{1}{T_{cref}} - \frac{1}{T_c}\right)\right] \ldots (3)$$

In which $I_{0,f}$ can be given as:



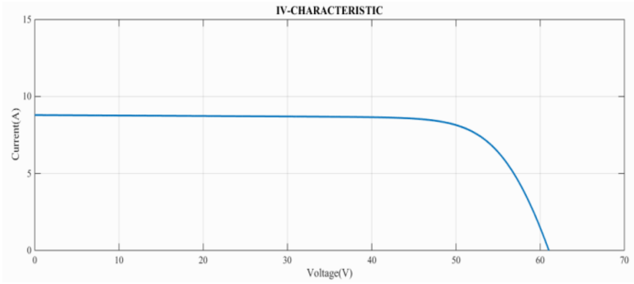


Fig 3: PV-Curve solar module ***Fig 4: IV-Curve solar module***

From PV and IV curve of PV Module it can be seen that generated photo current of PV Panel is proportional to irradiation level and maximum power at maximum power point voltage is limited by number of series cell in panel due to parallel diode of PV Cell.

B. MAXIMUM POWER POINT TRACKING

The power produced by a PV array is dependent on the Irradiance and temperature. There is a maximum power point (MPP) which should be tracked in the power-voltage (P-V) Curve. It can be accomplished through DC/DC converter linking the PV array to the DC bus as shown in fig.2. Typical MPPT control strategies include open-circuit voltage method, Short-current circuit current method, perturb and observe Method (P&Q) and incremental conductance method (INC).In general, P&Q method and INC method are the widely used Approaches for MPPT control. However, those conventional MPPT algorithms have disadvantages such as instability, poor Adaptability to external environment. Sometimes they may fail to track the MPP when the atmospheric conditions change rapidly. To solve the tradeoff between the accuracy of the dynamic and steady state, a variable-step size INC method is Utilized to realize MPPT of PV panel in this paper.

C. Incremental Conductance method

The incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. In incremental conductance method the array terminal voltage is always adjusted according to the maximum power point voltage it is based on the incremental and instantaneous conductance of the PV module. Below P-V array power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand side of the MPP. The basic equations of this method are as follows

$dV/dI = -I/V$ at MPP

$dV/dI > -I/V$ Left of MPP

$dV/dI < -I/V$ Right of MPP

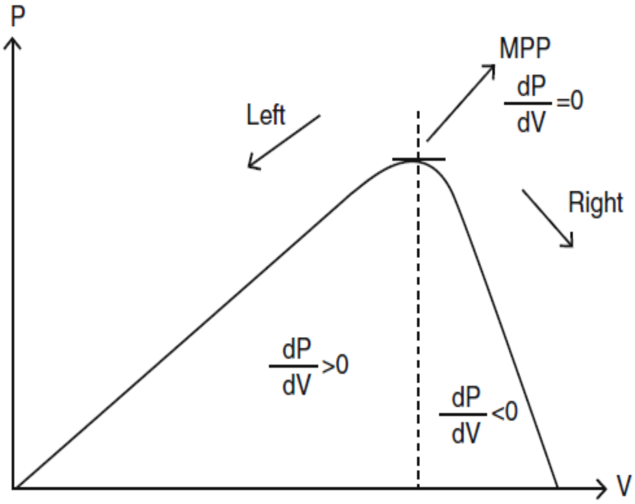


Fig: 5 P-V curve of incremental conductance method on a solar plane.

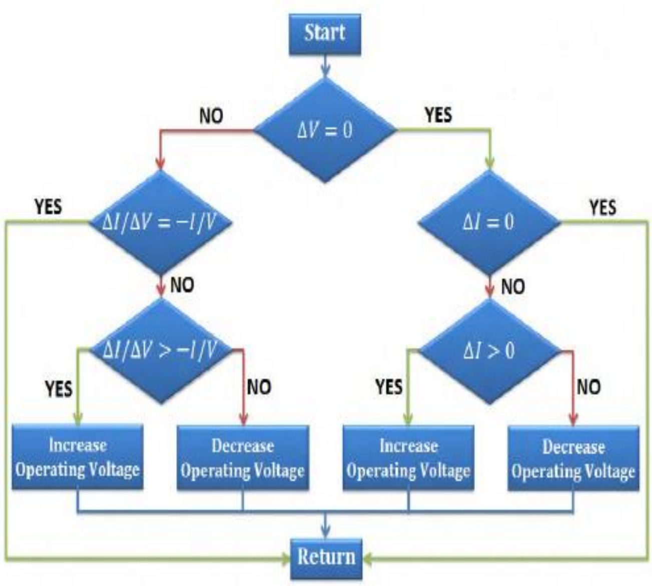


Fig: 6 Flow chart of incremental conductance

D. BATTERY CONTROL STARTEGY

Battery has high energy density whereas it has relatively slow charging and discharging speed the battery as a long-term energy storage device is applied to meet the energy demand. The battery is modelled using a simple controlled voltage source in series with a constant resistance. The bi-directional buck/boost converter is used in the paper to link battery with the DC bus. The structure of the two converters is a parallel connection boost converter during storage unit discharge mode and a buck converter during charge mode. The control method is a conventional double loop, including an inner current loop and an outer voltage loop

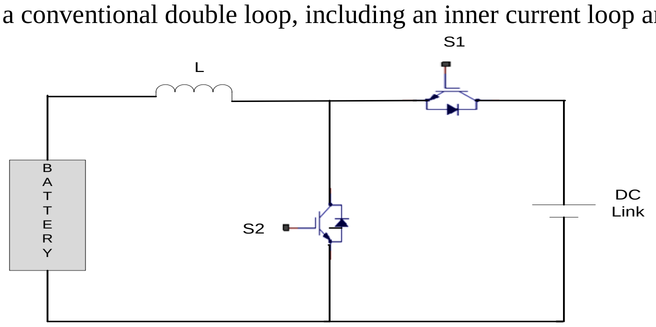


fig:7 Battery with bidirectional Converter

In charging mode switch S1 is in on state and S2 is off during which the bidirectional converter is used to buck the DC bus voltage to a suitable low level 120V battery voltage. Because grid voltage is higher than battery voltage so it is step-down. Inductor current increase in buck mode the control diagram of the bidirectional DC/DC converter at charging status. There are two control loops, an inner current control loop and an outer voltage control loop. A current limiter was insert in the current loop to limit the charging current.

In discharging switch S2 is in on state and switch S1 is in off the power will transfer from battery to dc grid and its will work in boost mode as battery voltage is less then grid voltage so it is step up and feeded to grid. The difference of Voltage is sent to the voltage PI regulator and the output is sent to the PWM generator to drive

III SIMULATION AND RESULT

A. PV MODULE AND MAXIMUM POWER POINT TRACKING

Here, 5 modules in series and 1modules in parallel used to form PV Array for total power of 2037Watt. For, Maximum power point tracking buck-boost converter with incremental conductance is used which is shown in below figure.

Table:1 Parameter of PV System

PARAMETER	VALUE
Maximum power [P_{mpp}]	410.108 Watt
Current at maximum power point [I_{mpp}]	8.15 Amp
Voltage at maximum power point [V_{mpp}]	50.32 Volt
Short-circuit current [I_{sc}]	8.77 Amp
Open-circuit voltage [V_{oc}]	61.06 Volt
Ideality Factor [A]	2.564
Number of cell in one module [N_s]	96
Temperature Coefficient At short circuit	0.004 $\frac{A}{^0C}$
At open circuit	-0.225 $\frac{V}{^0C}$
Series resistance [R_s]	0.322 Ω
Parallel resistance [R_{sh}]	330.13 Ω

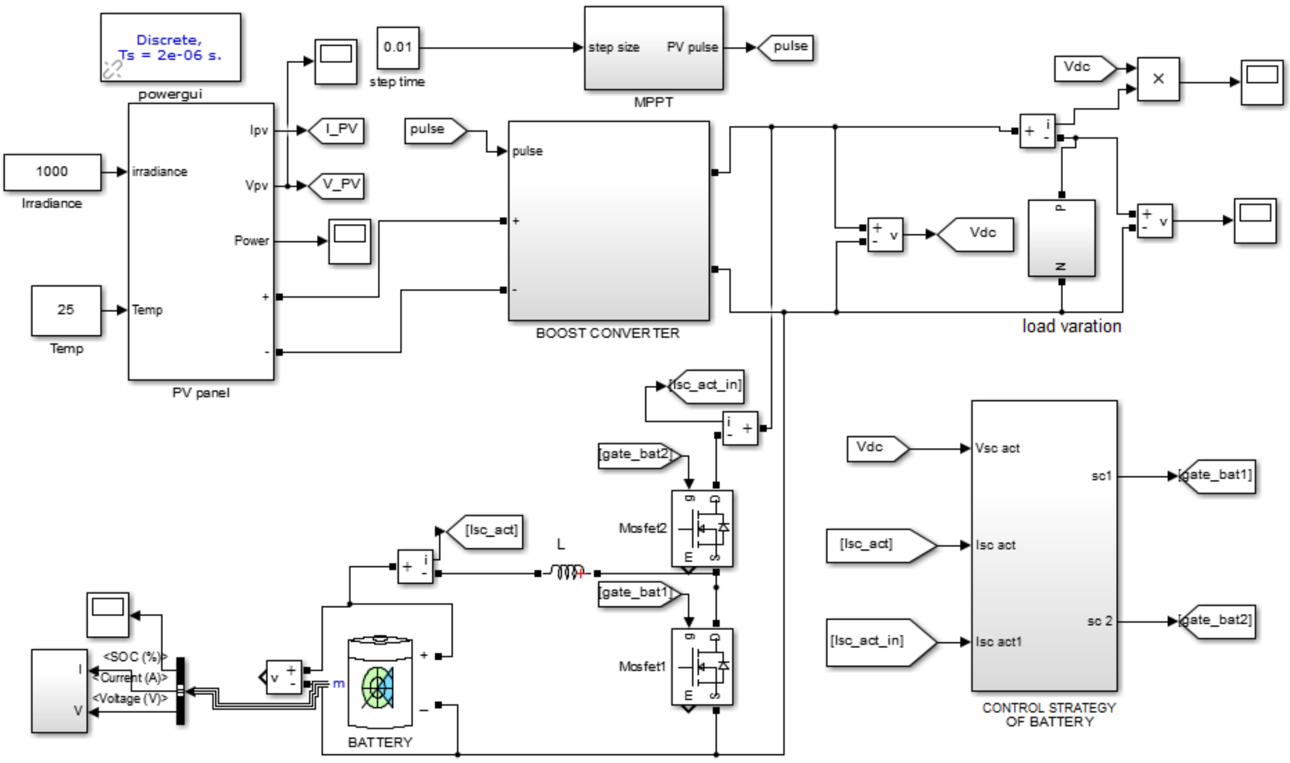


Fig:8 Simulation block of PV system with Battery

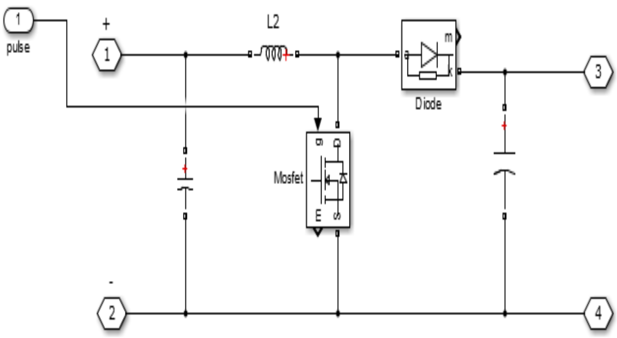


Fig:9 Boost Converter Subsystem

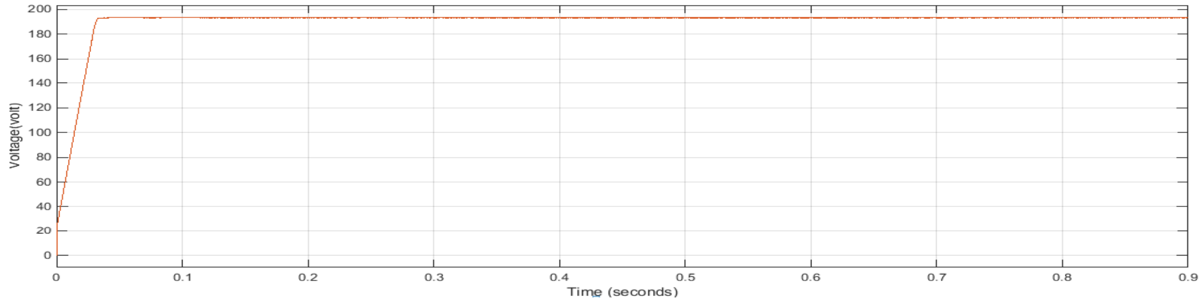


Fig:10 Input Voltage of PV

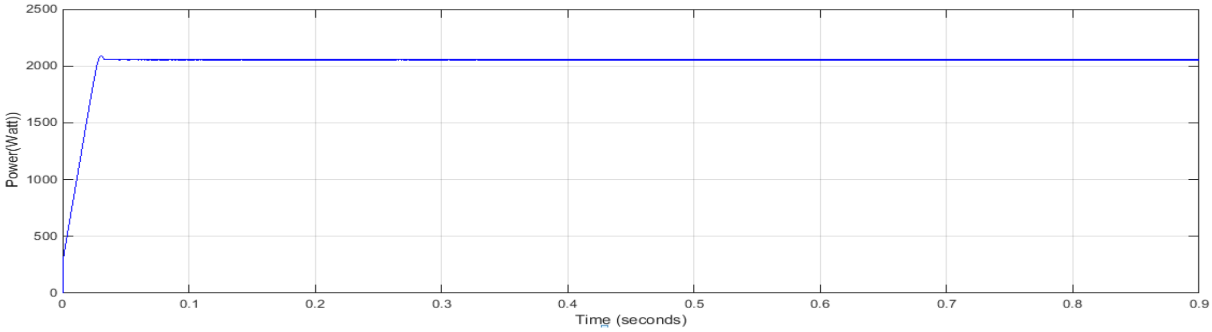


Fig:11 Input Power of PV

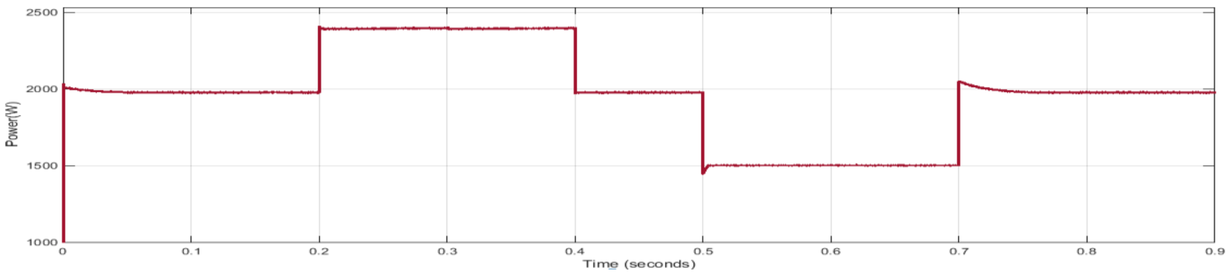


Fig:12 Load Power of DC/DC Converter

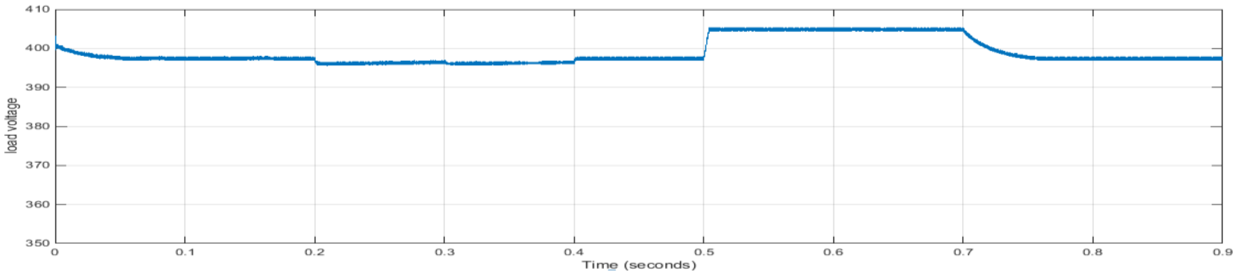


Fig:13 Load Voltage of DC/DC Converter

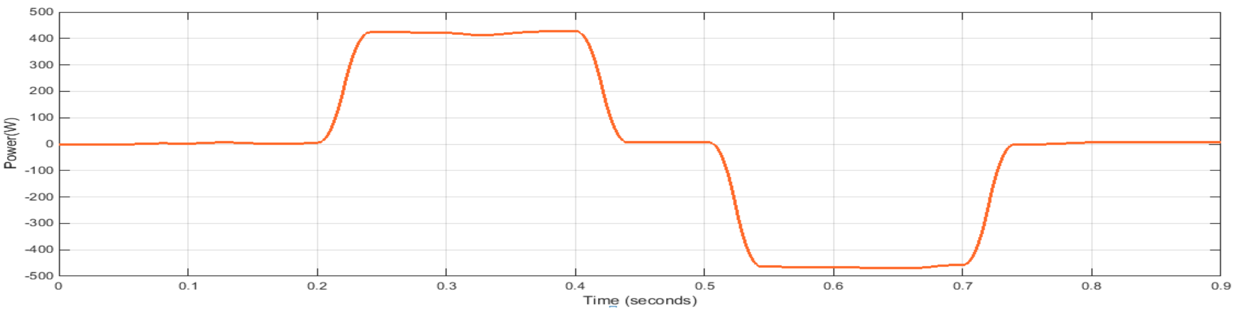


Fig:14 O/P Power of Battery with variation of load

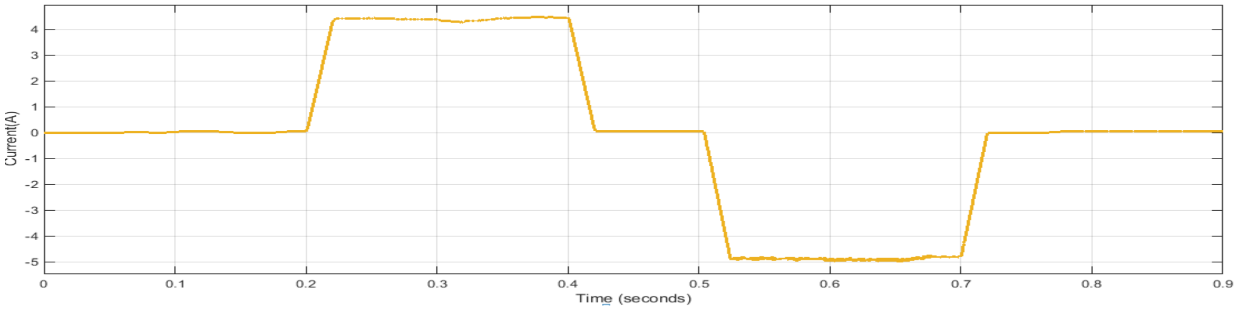


Fig:15 O/P Current of Battery with variation of load

Table2:Battery simulation result

Time(second)	Condition	Action
0 to 0.2 0.4 to 0.5 0.7 to 0.9	PV Power=Load	PV supplies to load no battery charging
0.2 to 0.4	PV Power>Load	PV supplies load and battery discharging
0.5 to 0.7	PV Power<Load	Battery supplies to the load Battery is charge

Conclusion:

From the simulation of PV system and boost converter conclusion can be made that at constant Irradiance, constant power is available from PV source, incremental conductance MPPT algorithm is able to improve dynamic and steady state performance of PV system under change in atmospheric condition .From the simulation of storage system can be used with bidirectional converter can be used to maintain power balance between PV source and load.

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