A Standalone PV System with Re-Lift DC-DC Converter for Uninterrupted Power Supply

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***Abstract*— Normally the power from the solar PV is DC. It is based upon the irradiation and temperature rate of certain place. If the temperature or irradiation is very low the output power from the PV also low. So it is necessary to boost the output voltage from the solar. For boosting operation there are various converters are available. Here the converter which is called as Re lift luo converter is used for boost up the voltage. The battery is operated as the backup source A two way DC-DC converter is used for discharging operation and charging process of batteries. The MPPT technique called as the gray wolf algorithm can used for obtain the possibility of maximum power from the solar panel at any irradiation condition. Thus the applications of Re-lift converter, battery with two way DC-DC converter and gray wolf algorithm make this system as uninterrupted and also supplying the required power to load.**

***Index Terms*— solar pv, Grey wolf algorithm, Un interrupted power supply, MPPT technique**

I. Introduction

Solar Photovoltaic (PV) has become as a major source to serve as an alternative energy and is currently playing a multi role in supporting the existing conventional power generation systems. Even though the grid connected PV systems are plays a vital role today, solar system as an energy source was firstly employed for a stand-alone application purpose can used from low power electronic systems like calculators, toys and watches to high power applications like space crafts and satellites. Standalone PV systems acts as an important source today with their applications longer to remote power systems, i.e. where there is no possibility of power grids as like in rural villages and also in remote islands. The irrigation sector also achieving very much improvement because of solar PV usage. So this paper mainly concentrated in standalone PV system. The main scope of this paper is that

- To obtain maximum and uninterrupted power supply
- To design high gain DC-DC converter for getting large power from solar PV

In this paper there are three techniques used to extract the large power from solar and also providing uninterrupted power to a standalone system. Where the techniques are given by

- A high gain DC-DC converter named as Re-Lift Converter
- A Bi-Directional converter for Buck- Boost operation between battery, PV and load
- An MPPT algorithm called a gray wolf algorithm for extracting maximum power from the solar PV

The Re-lift converter is used to boost up the voltage from solar PV. Because of using this converter it is possible to boost up the voltage up to two times of the input voltage. The Two way converter is used for discharging and charging operations of the battery. The battery should be charged by low voltage to maximize the lifetime of the battery and therefore the output from the battery desires to spice up relying upon load. Where the two-way convertor doing this **each** buck and boost operation relying upon the mode of operation of batteries.

The solar output is not a constant one. It will be varied depending upon the irradiation conditions. So it is necessary to track the maximum power output from the solar at all time. For this purpose the MPPT techniques are used. Here the most modernized optimization method named as Gray Wolf algorithm for MPPT is used to track the maximum power at any radiation condition.

A. Outline of Proposed Work

The block chart for the proposed system is shown in the above figure numbered as 1.1. Here the PV panel is used as the main source. The irradiation of solar can be varied due to various conditions like time of the day, climate change of the particular area, passing cloud problems and other partial shading problems. So it is necessary to get the maximum power output from the PV at the above mentioned conditions.

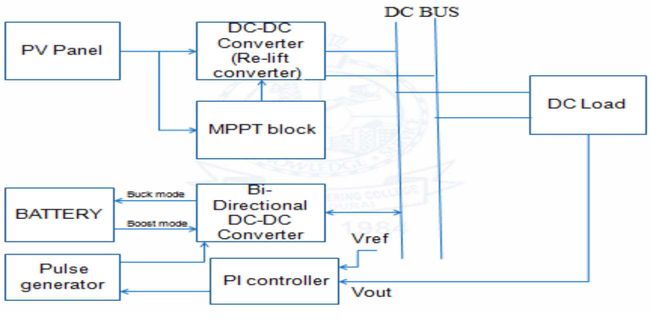

Fig. 1.1 Proposed block diagram

For tracking the maximum power the modern optimization technique named as the gray wolf algorithm is used. The re-lift converter is used to boost up the voltage from the solar PV. By using the proposed converter (re-lift Luo converter) the output voltage can boost up to three times of the input voltage, while using the battery as backup source it is compulsory to control the discharging and charging operation of batteries. Because over charging and over discharging may affect the battery life. For controlling the discharging and charging operation of battery the two way converter is used. The bi-directional converter can operate at buck mode and also in boost mode of operations. It can operate buck mode during the charging operation of battery and it can be act as a boost mode for the discharging operation of batteries.

The charge range (SOC) of the battery can be controlled by the PI controller. It is very much helpful for controlling the overcharging and over discharging of battery which is very much useful to increase the battery life.

II. Re-Lift Converter

2.1 Introduction

Voltage Lift (VL) technique [2] and [3] is a method which is widely used in the design of electronic circuits. It has been widely used in DC to DC converter applications in the recent years and providing a way to designing the high voltage gain converters. The high step series like four step Luo Converters are the main examples of voltage lift converters and also an implementation process of voltage lift technique.

2.2 Re-Lift Luo Converter

Re-lift converters are the DC-DC converters which three times than the input voltage and reduces the voltage ripples also. By means of using the re-lift converter the voltage gain of the system is improved and the output voltage has fewer ripples. The various operational modes of re- lift Luo converter are given below.

2.3 Operation of Re-Lift Converter

The circuit diagram of Positive Output Re-Lift Converter (PORLC) is shown in fig 2.1. It consists of two power electronics switches like MOSFET namely S1 and S2, three inductors L1, L2, and L3 four capacitors C1, C2, C3, and C4 and also the diodes D1, D2, and D3. The positive output re-lift Luo converter circuit has two voltage lift circuits. Comparing with the PORLC converter, an extra VLC, which consists of a capacitor C2 and a diode D2, is added to with the circuit. Another switch S2 is implemented. The main operational circuit of re-lift converter is shown in the Fig 2.1. The output voltage equation of re-lift converter is given by

$$V_O = (2 * V_S)/(1 - k) \text{ (volts)} \qquad (2.1)$$

The re-lift converter operates in two modes given as

- ON state operation
- OFF state operation

The modes of operation of re- lift converter are given below

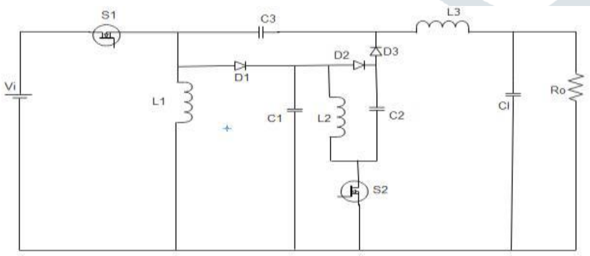

Fig 2.1 Circuit diagram of re-lift converter

2.3.1 ON State Operation

The circuit diagram for the ON state operation of re-lift converter is given in the Fig 2.1.1 are operating based on voltage lifting technique.[4],and[5] It can be given the output voltage which is equal to three times of input voltage. The output voltage of re-lift luo converter is

When switches $S_{1,}$ S_2 are ON the source current is equal to

$$I_{in} = I_{L1} + I_{L2} + I_{L3} + I_{C1} + I_C \quad \text{(amps)} \qquad (2.2)$$

Inductor L1 and L2 and capacitor C2 absorb energy from the source. Simultaneously inductor L3 absorbs energy from source and capacitor C. Both currents that IL1 and IL2 increase during the converter-ON period. The addition of input voltage and the capacitor voltage Vc that is stored in it during converter-OFF period supply the load current.

2.3.2 OFF State Operation

The circuit diagram for the OFF state operation of re-lift converter is shown in Fig 2.1.2.

The stored energy in the inductors L1 and L2 and the capacitor C2 discharges and charge the capacitor C1 with the direction as shown in the Fig 4.3. Simultaneously current IL1 flows through the load, which is sustained by the inductor L1. Both currents IL2 and IL3 decreases during the OFF period.

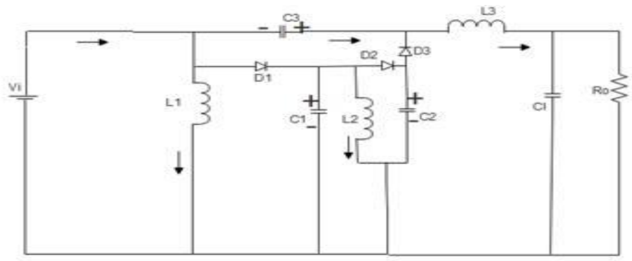

Fig 2.1.1 ON state operation of re-lift converter

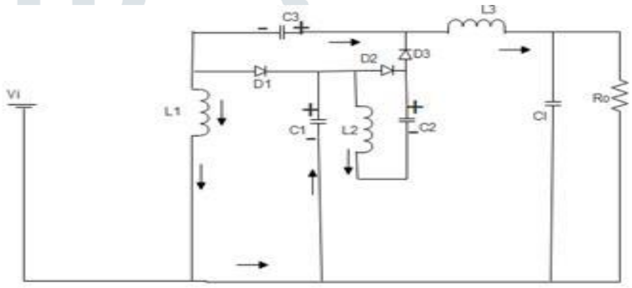

Fig 2.1.2 OFF state operation of re-lifts Converter

III. Bi-Directional DC-DC Converter

3.1 Introduction

In a DC power supply system, DC power between 400 and 500V is supplied with high voltage applications like traction, apartment building, factory and also domestic places through a DC bus, and power generated by solar PV operation or is supplied to the DC bus. Surplus power is sent to the energy storing devices using metal ion batteries or different sorts of batteries. The two way DC-DC convertor is a power convertor unit that may transport, power between the DC bus and energy storage systems depending on conditions.

3.2 Bi-Directional DC-DC Converter

The proposed two way DC–DC converter [6],[7] and[8], which has the merits of simple topology and control strategy. The voltage-conversion range of this converter is wider, than the conventional two way buck and boost convertor. The proposed two way DC-DC converter is shown in the Fig 3.1.

The operating principles and steady-state analyses in the boost up/down modes are described here. Some conditions are assumed as:

- The ON-state resistance of the switches and the capacitors are ignored.
- The capacitors CH1, CH2, and CL are large enough, and the voltages across the capacitors can be treated as constant.
- The capacitance of the capacitors CH1 and CH2 are equal. Thus, VH1 = VH2 = VH/2.

3.3 Operation of Two Way Converter

The proposed system consists four numbers of semiconductor switches named as S1, S2, S3 and S4. Where it can be operated in two operating modes such are

- Buck mode
- Boost mode

And each mode consists of three stages of operations. Such are Stage 1, 2 and 3 operations.

3.4 Controlling of Charging and Discharging Battery

The battery life may be affected by various reasons such are over charging and over discharging, over heat, temperature conditions, etc. Whenever the battery used as back up source in standalone system it should necessary to control discharging and charging of the battery.

3.4.1 Conditions for discharging and charging of battery

There are many conditions for operating the PV panel for a standalone system by using the battery as the backup source. The conditions are given by

If output power from the solar is maximum than the demand and also the SOC of battery is minimum than the SOC the battery will charge and at the same time the power is supplied to the utilities also

Ppv > Pload and SOC < SOCmax then battery charging + load added

If output power from the solar is more than the demand and the SOC of battery have reached its maximum value, then the battery is disconnected supply and the maximum utilities can be added to the supply.

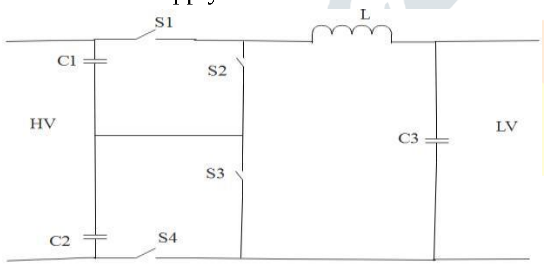

Fig 3.1Circuit diagram of bi directional converter

Ppv > Pload and SOC < SOCmax

Then Disconnect battery from supply and add more enough load to supply.

If output power from the solar is less than the demand and DOD of battery is maximum than DOD minimum then the battery is discharged and supply the power to utilities. Where the battery and solar PV supplies power to the load.

Ppv < Pload and DOD> DODmin

then Ppv+ Pbatt= Pload

If the output power from the solar is less than the demand and DOD of battery is minimum than DOD minimum then the battery is disconnected from the line and switch off the extra loads

Ppv < Pload and DOD< DODmin

Then disconnects battery from line and switch off extra loads.

By the above conditions the discharging and charging states of battery can be controlled.

These conditions are helpful to designing the PI controller for the proposed mode. The flow chart representation of the above mentioned conditions are given in the Fig 3.4.

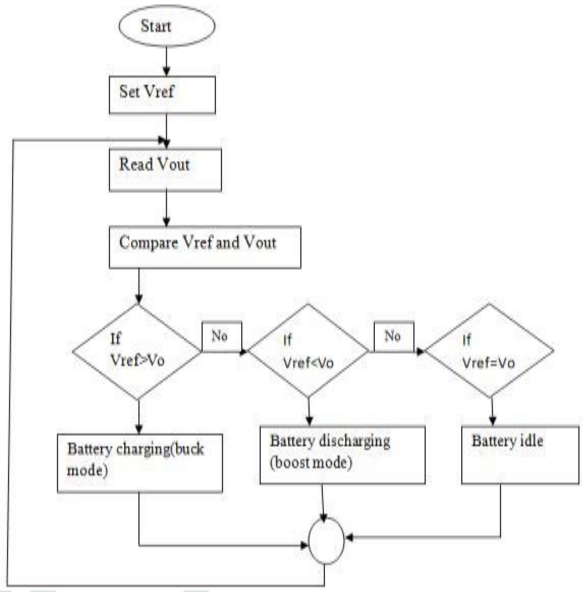

Fig 3.4 Flow chart for controlling discharging and charging of the battery

IV. Design of Grey Wolf Algorithm

4.1 Introduction

The GWO is a modern optimization [9] and [10] method which overcomes the limitations as lower tracking problems which affect efficiency, steady-state oscillations conditions, and transient problems as provide in perturb and observe (P&O) and improved PSO techniques. The problem presently in tracking in the global peak of a PV system during the partial shading conditions is the major reasons for employing the GWO MPPT technique. The proposed algorithm is studied for a PV system under partial shading Conditions which exhibits multiple peaks and its tracking efficiency. It normally has three steps of operations, such are

- Tracking, chasing, and watching the prey
- Following, encircling, and harassing the prey until it stops running.
- Attacking towards the prey

Based on the above techniques this optimization method is generated.

4.2 Mathematical Model

The hunting techniques and the social ladder of gray wolves can be mathematically designed in order to create GW Optimization.

4.2.1 Social Hierarchy

The social ladder of the Grey wolfs are in four categories. Such are given by alpha (α), beta (β), delta (δ) and omega (ω). In case of modeling the social ladder of wolves when designing the GW Optimization, it should be necessary to consider the fittest solution as alpha (α). Then, the second and third best solutions are considered to be beta (β) and delta (δ) respectively. The final or least solutions are named as omega (ω). In the GWO algorithm the hunting (optimization) is guided by alpha, beta, and delta. The ω wolves follow these three wolves.

4.2.2 Encircling prey

As depends upon the social ladder, a grey wolf encircles the prey [11] and [12] during the hunting process. In order to mathematically model the encircling behavior the following equations can be proposed

$$D = \left|C * X_P(t) - X_P(t)\right| \quad (4.1)$$

$$X(t+1) = X_P(t) - A * D \quad (4.2)$$

- t denotes the current iteration,
- D, A and C denote coefficient vectors,
- X_p is the position vector of the prey,
- X indicates the position vector of the gray wolf.

The vectors A and C are calculated by

$$A = 2a * r_1 - a \quad (4.3)$$

$$C = 2 * r_2 \quad (4.4)$$

4.2 Working of Grey Wolf Algorithm

During partial shading condition, the Power-Voltage curve is separated by multiple peaks having various local peaks and one Global peak. It should be noted that when the wolf finds the MPP that correlated coefficient vector becomes nearly equal to zero. In this method, the attempt has been made to combine GW Optimization with direct duty-cycle control, at the MPP, the duty cycle is remains at a constant value which in turn reduces the steady-state oscillation i.e. that exist in conventional MPPT techniques, the power loss due to oscillation is reduced resulting by higher system efficiency. To implement the GW Optimization based MPPT, duty cycle *D* is defined by a grey wolf. Where equation (4.3), can be modified as follows

$$D_i(k+1) = D_i(k) - A * D \quad (4.5)$$

Thus, the fines function of the GW optimization algorithm is formulated by

$$P(dki) > P(dk - 1i) \quad (4.6)$$

Where *P* represents power, *d* is duty cycle, *I* is the number of current gray wolves, and *k* is the number of iterations.

Thus the gray wolf algorithm is used for tracking the maximum power during variation of solar irradiation. The working flow representation of a gray wolf algorithm is explained in the Fig 4.1.

IV. Modelling of Proposed System

5.1 Introduction

The simulation for this proposed model is done by using MATLAB/Simulink software version 2009.

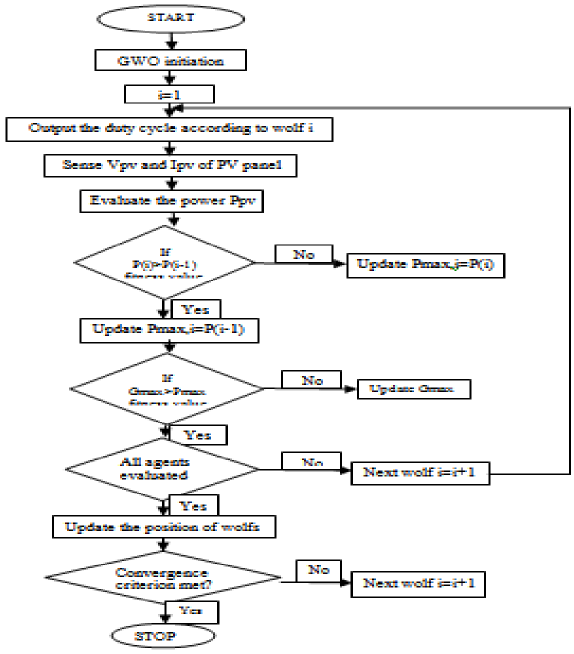

Fig 4.1 Flow chart for Grey wolf optimization

5.2 Simulation Model of Proposed System

Here the re-lift converter is used to boost up the output voltage from the solar PV and the two way converter is used to discharge and charging the battery. The controller loop is used to set the conditions about discharging and charging of the battery. The solar PV panel is used as the main source for this model. The converters i.e. Re-lift converter and two way DC-DC converters for the proposed system are modeled by using the Simulink software. This system is worked on close loop operation because of using the PI controller. The simulation model of the proposed system is shown in the fig 5.1.

The output from the solar PV is dc. The relift DC-DC converter is used to boosting up the voltage from PV.

During the night time and cloudy conditions the battery is employed as the backup supply. To buck the charging voltage of the battery and to boosting the output voltage of the battery a DC-DC convertor named as two way converter is used for this system.

5.3 Output Performance by Using Grey Wolf MPPT

The solar panel output depends upon the irradiation. The output from the solar may be reduced due to poor radiation. During this poor radiation conditions to track the maximum power output from the solar the gray wolf optimization technique is used. The output of solar PV depending upon various irradiation conditions are listed below.

From the waveforms in the Fig 5.2 it can be able to calculate the power output from the solar PV during 800 W/m^2 irradiation condition. The panel gives about 120 watts power output for the above irradiation condition. But the output without using MPPT technique is given in the Fig 5.3. From the wave form the panel output power went to peak at $200W/m^2$ but it will reduces suddenly due to the poor radiation conditions due to climatic changes or shading conditions. So by using the gray wolf algorithm the maximum power output from the solar PV can be tracked.

The Fig 5.4 shows the output of solar PV during 500 W/m^2 irradiation without using the MPPT technique. Similarly the solar output for 250W $/m^2$ irradiation condition will be given below

At 300 W /m^2 irradiation condition the output of solar PV also reduced during this condition the output power is about 25 to 30 watts. During this condition the maximum output can be tracked by using the grey wolf algorithm.

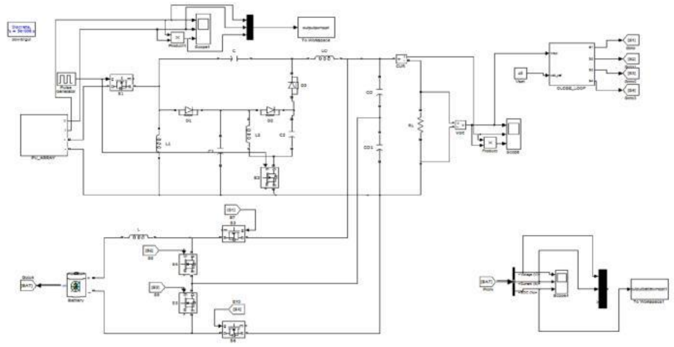

Fig 5.1 MATLAB/Simulink diagram for the proposed model

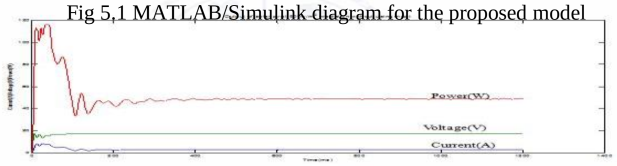

Fig 5.2 Output of solar PV at 800 W /m^2 irradiation by without using MPPT

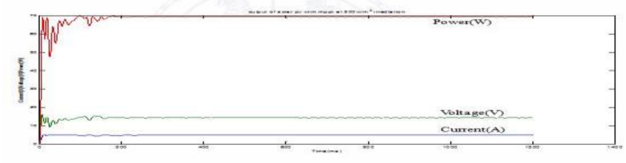

Fig 5.3 Output of solar PV at 800 W /m^2 irradiation by with using MPPT

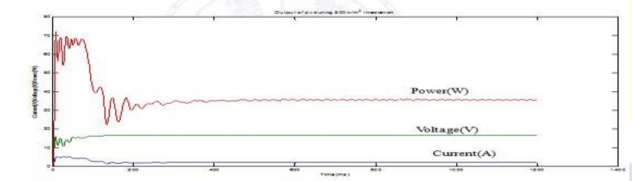

Fig 5.4 Output of solar PV at 500 W /m^2 irradiation by without using MPPT

At 300 W /m^2 irradiation condition the solar PV output without MPPT is given in the Fig 5.5 and Fig 5.6. During this condition the panel output will be very low compared to the output obtain by using MPPT.

5.4 *Output of Proposed Model*

The output performance of the proposed model are given by the figures (5.7-5.10)

During the 800 W/m^2 irradiation condition the output of solar PV is more than the load. So the power can be supplied to the load as well as the battery will charging. At this condition the two way convertor acts as Buck mode to charging the battery.

During the various climatic conditions or the sun rise or sun set time the irradiation from solar is very low so the output power also very less. At this time the power generated by solar PV also very less which is not sufficient to meet the load demand.

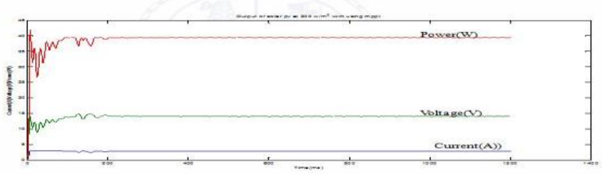

Fig 5.5 Output of solar PV at 300 W /m^2

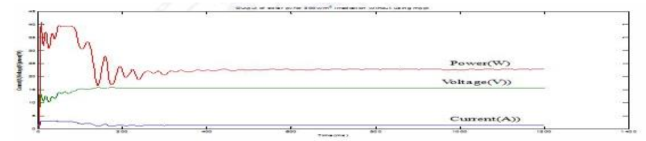

Fig 5.6 Output of solar PV at 300 W /m^2 irradiation by without using MPPT

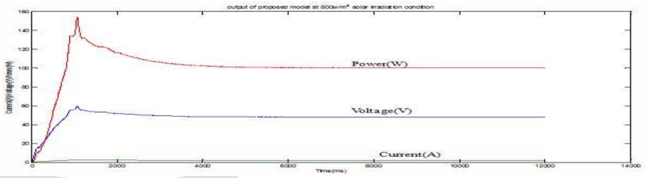

Fig 5.7 Output of the proposed model at 800 W /m^2 irradiation

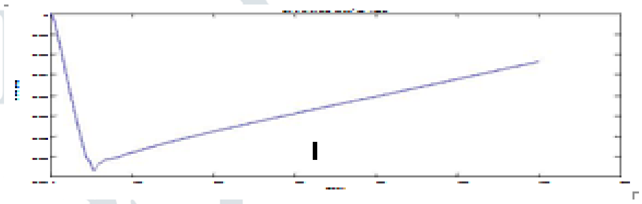

Fig 5.8 Charging of battery during 800 W /m2 irradiation from solar

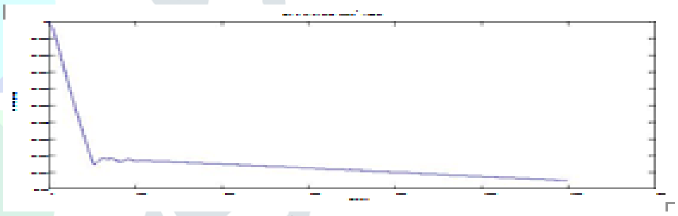

Fig 5.9 Discharging of battery during 300W/m2 irradiation from solar

During 300W/m^2 irradiation the battery will discharge to meet the load demand. At this time the two way converter works in as boost mode to increasing battery output power.

When the output power from the solar is not satisfying the load, the battery will be discharging to support the solar panel for satisfying the load demand. During the discharging process the two way converter will act as boost mode of operation. Where the output from the battery is boosted up and then it will be provided to the load.

When the power from solar is more than the battery will charge by the excess power. During this condition the two way converter will act in the buck mode for charging the battery.

V. CONCLUSION

This proposed system helps to extract the maximum power output from the solar PV. By providing the optimization algorithm called grey wolf algorithm the output power can be tracked as maximum during different irradiation conditions. This ensures that the maximum power output from the solar at any irradiation condition.

The designed converter i.e. relift Luo converter lifting the output voltage as four to five times of the input voltage. This is very much helpful to boosting up the output voltage from the solar depending upon the load demand. Whatever may be the output voltage level of the solar this converter can be boost up the voltage up to three times of the input. This is considerably helpful to avoid a fast potential fall within the system. Thus the maximum power output can be obtained from the solar by means of using this high gain converter along with the optimization technique. The proposed two way converter helps in discharging and charging operation of batteries. The battery output can be boosted up by using this two way converter. Thus the uninterruptable power supply can be obtained by using the backup battery source combining with the proposed two way converter.

Thus the uninterrupted power supply can be obtained by this proposed method. In future this converter can be improved to connecting with AC grid after inverting the DC output into AC.

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