PI and Fuzzy Controller Utilizing PV-HESS Based Zeta Converter for BLDC Motor Drive

B. Rajani, G. Seshadri, T. Anil Kumar, V. Chandra Jagan Mohan

Abstract: Due to speedy enfeeblement of finite resources in the early modern period of development, non conventional resources of energy, are being focused in various countries to reach the growing demand of electrical energy. Increased importance of non conventional energy in the auto mobile industry needs the use of brushless DC (BLDC) motor drives to fuel solar photo voltaic (PV). To overcome the disadvantages in the conservative DC-DC converters, Zeta converters are enterprising to optimize power processing. By regulating the duty cycle of the Zeta converter through particle swam optimization (PSO) we obtain the maximum power from PV array. To mitigate changes in output of PV, the Hybrid Energy Storage System (HESS) is implemented into the PV system to maintain a continuous voltage at the BLDC motor input. The robust power management algorithm controls the PV-HESS system .By keeping the power management of maximum power point tracking the Zeta converter can meet the trouble free performance of the system. The interpretation of the BLDC motor with zeta converter relic verified using proportional integral(pi) and fuzzy logic(FL) controller. Design method and parametric analysis is carried out in MATLAB simulation and results are validated.

Keywords: Brushless DC motor (BLDC), Fuzzy logic(FL), Hybrid energy storage system(HESS), maximum power point (MPP), Proportional integral (PI),Solar Photo voltaic (SPV).

I. INTRODUCTION

Electrical vitality acts as mainstay in a present day modernized life . The spread of world's power demand grabs interest in exploration of valuable usage of non-conventional energy sources. Solar power is promising out of all non-conventional energy sources, as it is environmental friendly & clean. Solar energy is inexhaustible and available from the sun with free of cost. The transformation of sunlight into electricity is solar power. Electricity plays a vital role in our day to day life.

Solar power is created from sunlight and it is abundant, so the heat acquired by the receiver is utilized as electricity for the functioning of various activities. As the solar energy is occurring at irregular intervals, MPPT of PV module changes with the deviations of solar irradiance, in order to enhance the effectiveness of the solar power system it needs the MPP tracking point.

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Therefore, MPP tracking is an required part of PV system to make sure that the power converters operate at the MPP of the solar array.

Persistent work is continuing in the development of MPPT innovations [2] to conquer disadvantages of previous algorithms. PSO algorithm for MPPT calculation is a proficient MPPT methods[3] for finest grabing of largest power from PV array. This method can track global MPP instead of having multiple peaks.

To order to keep steady supply sunlight based PV array needs backup like energy storage system, one of its kind is HESS which is a combination of super capacitor and battery. The battery provides backup in steady-state whereas super capacitor acts as a tailback for transient situations .

The HESS can be discharged or charged via a two-way buck-boost type converter to increase the voltage of a PV array. Based on power management algorithm, switching pulses for the bidirectional converter will be obtained. The zeta converter regard to a buck-boost converter group serving as a non-inverting buck-boost converter which is close to solar PV array to clip upmost solar power.

II. SCHEMATIC DIAGRAM

SPV-HESS fed BLDC motor with PSO-based MPP tracking algorithm using Zeta converter is displayed in Figure 1. SPV systems are the primary basis for BLDC motor drives and HESS will be used as a backup to accord with periodic circumstances due to changes in environmental conditions. The change of Zeta converter is arranged with pulses generated by the PSO based MPP tracking controller. The system's power management will be performed by the battery and super capacitor under different environmental conditions.

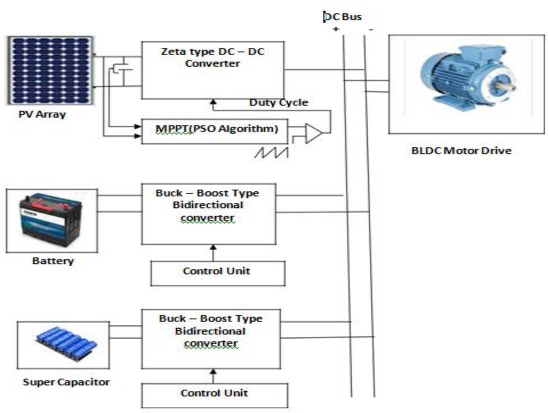


Fig.1: SPV-HESS fed BLDC motor drive

$P_M=P_{PV}+P_{SC}+P_B$. (1)

The explicit goal is to provide constant voltage on the BLDC motor even under different environmental conditions, as accomplish by allotting power management algorithms. The power balancing equation is shown in equation 1,the power generated using solar energy is P_{PV} ,P_M is a demand power by BLDC motor driver; P_B & P_{SC} are the instantaneous power of battery & super capacitors respectively.

A. Zeta converter design and operation

The Zeta converter produce non-inverted output voltage which removes negative voltage sensors and it can raise or drop the output voltage by making the appropriate switch like a buck-boost converter . Figure 2 displays the line diagram of the zeta converter.

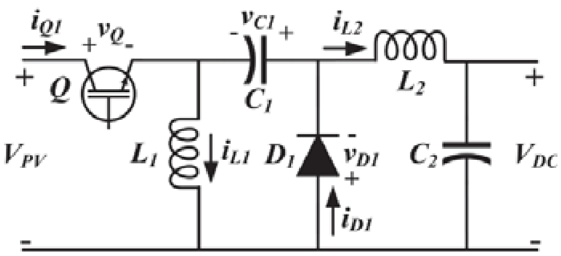


Fig.2: line diagram of a zeta converter.

The zeta converter is a combination of IGBT switching transistor Q, diode D_1, capacitor C_1,two inductors L_1, L_2 and output capacitor C_2. Table. 1 consists of specifications of zeta converter. When switch Q is on, the inductors L_1 & L_2 are charged and stores energy. When switch is off L_1 & L_2 are in discharged state and stores the energy into coupling capacitor C1 and L2 transforms energy to the output section. Based on the speed of the motor DC Link Capacitor C_2 has been chosen , and the best value must be within C_{2min} and C_{2rated} .

Table-I: specifications of zeta converter

Various Parameter	Equation	Set value
Duty cycle :D	$` D = \frac{V_{DC}}{V_{DC}+V_{VV}}$ (2)	0.76
Inductors:L_1=L_2	$L_1 = L_2 = \frac{DV_{PV}}{\int_{SW} \Delta I_L}$ (3)	6MH
Capacitor:C_1	$C_1 = \frac{DI_{DC}}{\int_{SW} \Delta V_{C1}}$ (4)	$20\mu F$
Dc link capacitor:C_2	$C_{2\min} = \frac{I_{DC}}{6\times W_{\min} \times \Delta V_{DC}}$ (5) $C_{2rated} = \frac{I_{DC}}{6\times W_{rated} \times \Delta V_{DC}}$ (6)	$850\mu F$

III. CONTROL STRATEGIES

B. PSO based MPP tracking applications

PSO has a wide range of applications in power system problem optimization, engineering application, power converter harmonic reduction and so on. Similar biological evolutionary algorithms, such as genetic algorithms and colonial optimization, require more parameter calculations. However, PSO is potential and takes minimum time than other evolution algorithms. The outstanding PSO-based MPPT technique is used to calculate optimum duty cycle through which the power is maximized, using sensors and computers the controller measures *Vpv* , *Ipv* and the output power.

Particles in the PSO move in the problem space to find the best solution and store it in memory. The best adaptability in the overall and throughout the iteration is called the best value for individuals and the best value for the world. Each particle moves at certain speed to the personal and global best value, and accordingly adjust after every iteration. The speed and position of the first particle are updated until the criteria are met . Otherwise, add the iteration counter and re-evaluate the fit value. When any changes in shadow mode are noticed, the particles in the group are reinitialized. During the unification and partial darkening of the photovoltaic array, the MPP tracking controller fully tracks the global maximum power.

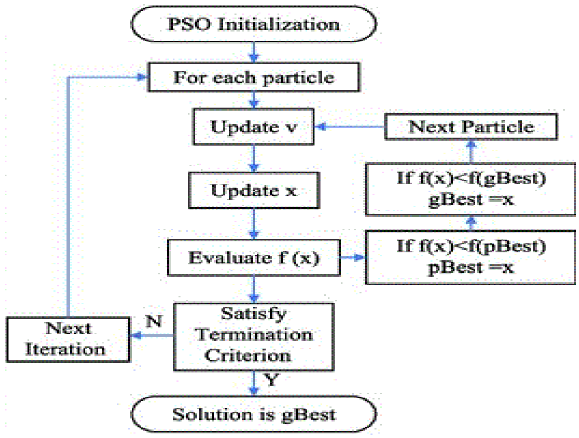


Fig.3: Flowchart of PSO-MPPT algorithm

C. Power management control strategy

Regulating two-way DC-DC converter provides stable DC voltage of the BLDC drive even under distinct environmental conditions. The power management algorithm abide of two loops to create the reference current (I_{ref}) which recommended to provide stable DC voltage. To achieve I_{ref} for the HESS system proportional integration (PI) controller is used . In addition, it is split of super capacitors and Battery, individual control I_{ref} is sown in equation 7.

$$I_{ref} = (k_p + {}^{k_I}/_{s})*V_{error} \quad (7)$$

k_p, k_I is proportional gain and integral gain. The value of k_p, k_I can be evaluated by Ziegler-Nicholas method.

PI is a feedback controller that uses the weighted sum of error & its integral value to shoot the control operation.

The input to the PI controller is the difference between the voltage reference value and error value voltage , by comparing both the reference and error values of voltage, linear PI edits its k_p and k_I for lowering the steady state error to zero. Due to its simple control structure it is commonly used. But the PI controller has a disadvantage of having fixed gains i.e. for varying parameter conditions of the system it cannot accommodate .

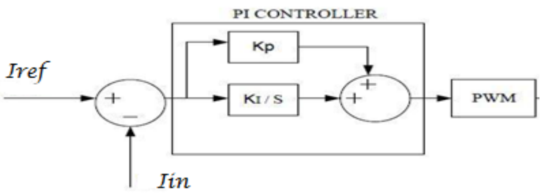


Fig.4: Basic PI control

IV. PROPOSED FL CONTROLLER

The disadvantages of the PI controller have been eliminated with ambiguity by using FL controller ,which is useful because it frees the system from precise and tedious mathematical modeling and calculations. Fuzzy logic controller has established better performance to improve transient and stable state. The fuzzy logic controller consists of four main functional modules, knowledge base, fuzzification, Inference mechanics and defuzzification are which are shown in Fig. 5.

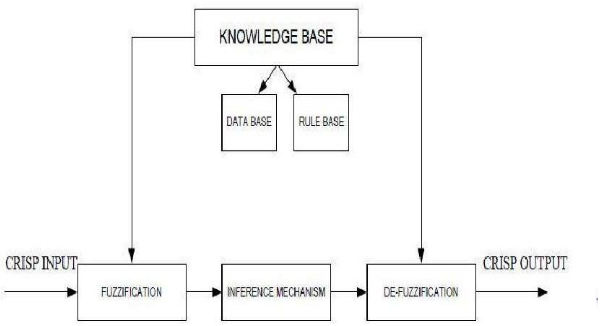


Fig.5: Schematic diagram for fuzzy controller

The FL controller utilizes the Mamdani inference type. It vaguely transforms clear input and output variables into fuzzy variables ladder-formation functions, while the anti-de resolution fuzzing process is based on the centeroid method. The core of the controller is the fuzzy rule. This comes mainly from intuition and experience,the fuzzy rules are shown in below table.

Table-II: Fuzzy rule table

e/Δe	NB	NM	NS	Z	PS	PM	PS
NB	NB	NB	NB	NB	NM	Z	Z
NM	NB	NB	NB	NM	PS	PS	Z
NS	NB	NB	NM	NM	Z	PM	PM
Z	NM	NM	Z	Z	Z	PM	PB
PS	NM	NB	PB	PM	PB	PB	PB
PM	NB	PB	PB	PM	PB	PB	PB
PB	Z	PB	PM	PB	PB	PB	PB

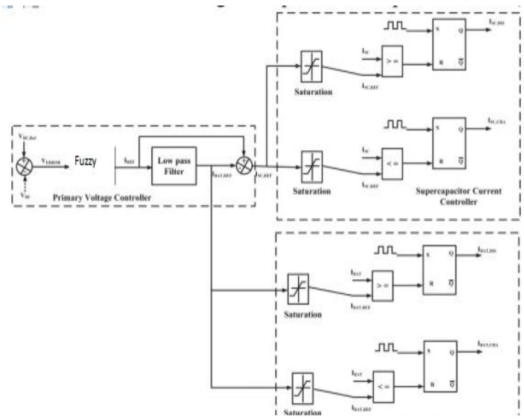


Fig.6: Power management control strategy

The I_{ref} which is obtained by the separation of low-pass filters provides to batteries and super capacitors. By comparing the error obtained by the I_{ref} and the actual current, the reset pin of the SR trigger is given. Battery and super capacitor will switch to discharged mode when the actual current is more than the I_{ref} , and they will switch to charging mode when the actual current is less than the reference value. Fig.6.gives a detailed sketch of the power management control strategy.

V. SIMULATION RESULTS AND DISCUSSIONS

The basic simulation diagram of the hybrid PV-ESS fed BLDC motor drive in matlab/simulink is presentedinFigure7.

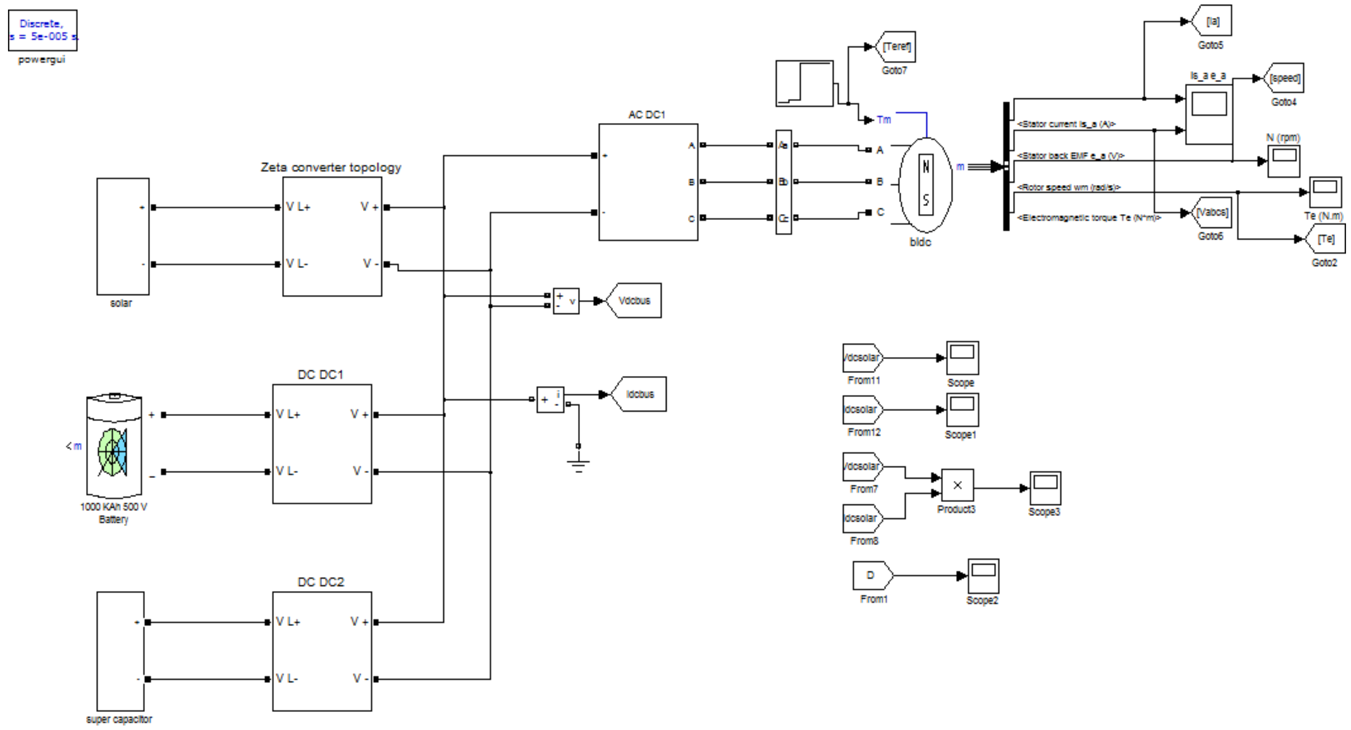


Fig.7: PV- HESS fed simulink diagram of the BLDC motor drive

The Simulation diagram abide of various components i.e. , Photo Voltaic array, Hybrid –ESS is a combo of Battery & Super Capacitor, Zeta Converter, BLDC Motor, Buck – Boost Converter, PI and FL controller.

The PV may not grab full power at every time because of irradiance and temperature abrupt variations due to climatic conditions. To have constant voltage at the load backup system is required, that will be provided by HESS. The Power can be controlled in the ESS by using Pi & fuzzy control techniques in Buck – Boost converter. Using FL Controller we get system stable quickly by reducing the errors. When sudden changes of load occur and switching of the load can cause system unstable.

With the PI Controller the errors may not reduce quickly due to fixed gains and this controller does not operate according to the system condition. PI linear controller which does not make the system stable accurately this drawbacks can be eliminated by using the FL controller.

This is non linear controller which is operating according to the system conditions in which we give the set of rules. These rules help us to reduce the errors by comparing the errors and change in error and we get required output to make the system stable quickly and accurately.

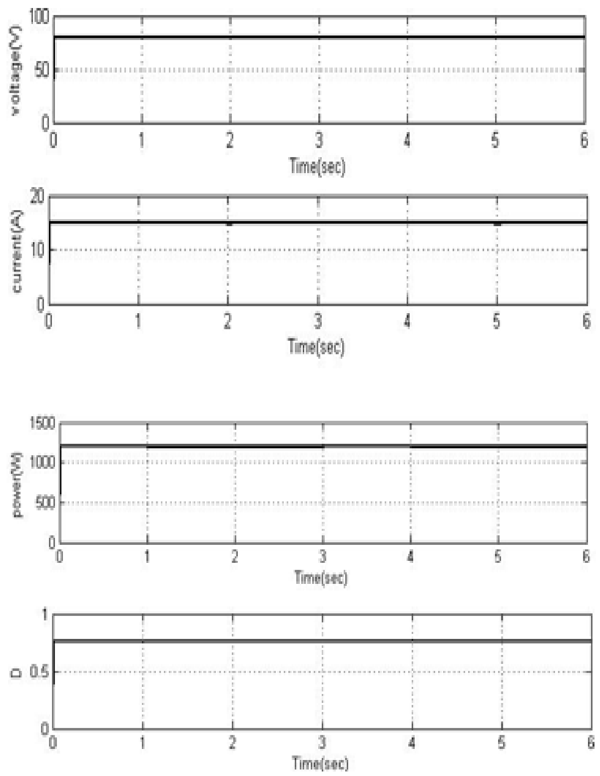


Fig.8: Partial shading tracking curves

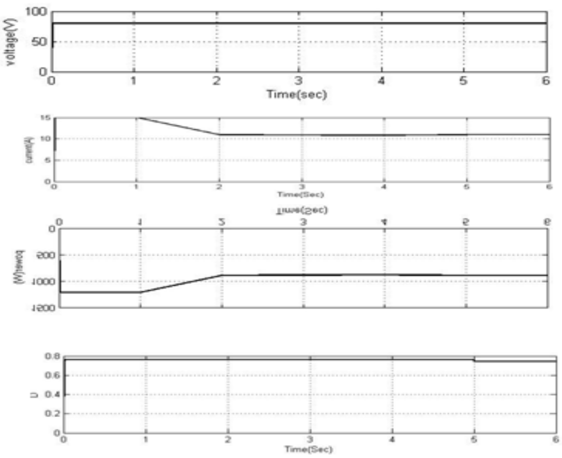


Fig.9: Uniform shading tracking curves

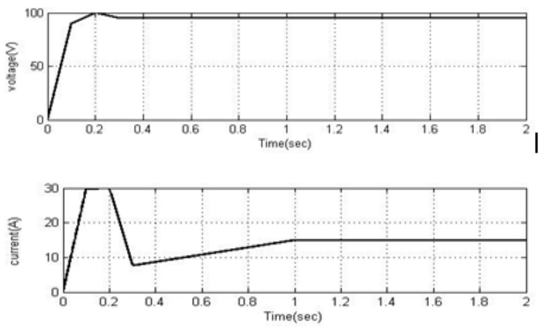


Fig.10:PV array parameters (a) voltage (b) current

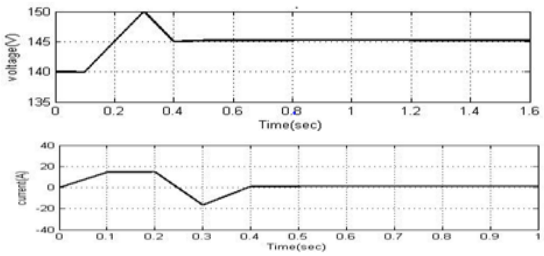


Fig.11: Battery parameters (a) voltage, (b) current

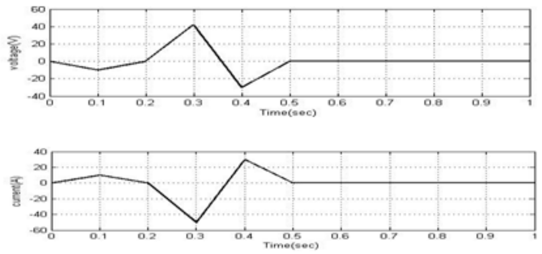


Fig.12: Super capacitor parameters voltage, current

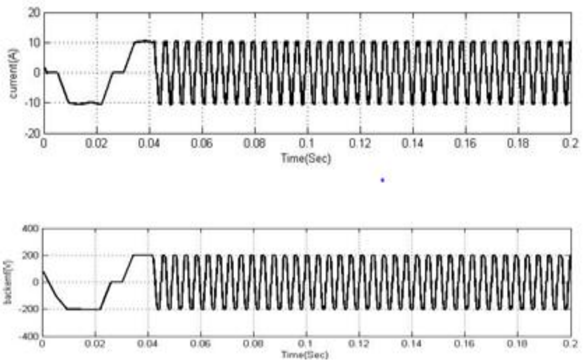
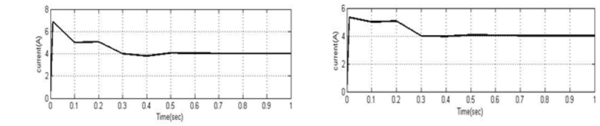


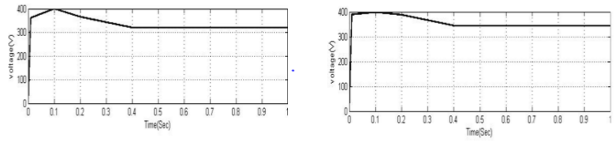
Fig.13: Stator current and back emf of BLDC motor

The fuzzy controller is applied to the DC-DC converter and the dynamics of the system have been improved by using fuzzy and the results are displayed in below figures. The settling time for Pi and fuzzy are compared and displayed in table. 3.We can identify clearly that fuzzy settling time is fast when compared to PI.



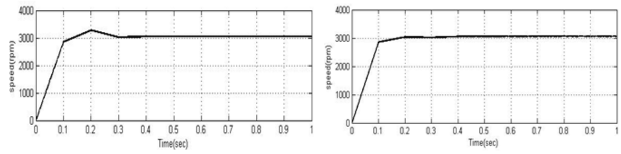
Using PI Controller Using FUZZY Controller

Fig.14: Comparison of load current using PI & FUZZY



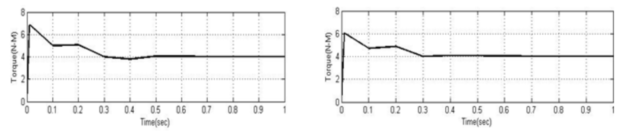
Using PI Controller Using FUZZY Controller

Fig.15:Comparision of Load voltage using PI & FUZZY



Using PI Controller Using FUZZY Controller

Fig.16: Comparison of Rotor speed using PI & FUZZY



Using PI Controller Using FUZZY Controller

Fig.17: Comparison of Torque using PI & FUZZY

The power management among the PV source, HESS and BLDC motor for a abrupt change in irradiation level from 1000 W/m^2 to 0 W/m^2 is displayed in the Fig.18. The power which is demanded by the BLDC will be produced by the source SPV over a time of 0-2s the SPV will produce 1200W of power and HESS will be in the charging mode. The HESS will fulfill the load demand in the case of sudden change of irradiation, during 2-3 s the irradiation was suddenly falls to 0 W/m^2. The effect of change in irradiation on voltage and current can be observed from the Fig.8. &Fig.9

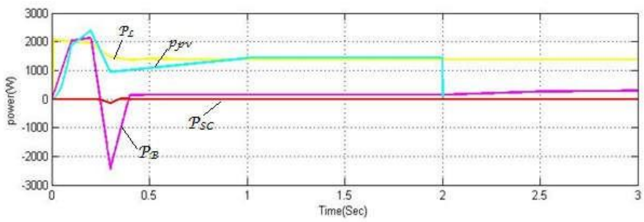


Fig.18:Power management curve for a step change of 1000W/m^2 to 0W/m^2 at time 2 seconds.

Table- III:Comparison of PI-FL Controllers for Various Parameters of PV-HESS based ZETA Converter

Parameters	PI Settling time(sec)	FUZZY Settling time(sec)
Load current	0.5	0.3
Load voltage	0.4	0.4
Speed	0.3	0.1
Torque	0.5	0.3

VI. CONCLUSION

The execution of PV fed BLDC motor drives, using various control techniques, have been observed in this paper. These controllers have their own advantages and use different methods to control load parameters. Exiting PI controller does not stabilize the system quickly and steadily. But recommended FL controller in this paper use to stabilize the system too fast. It can be concluded that the PV fed BLDC motor driver using the HESS-assisted Zeta converter has been proven as an effective alternative to conventional energy use.

The Zeta converter is well performed in term of MPPT and the motor drive runs smoothly. In addition, the power management algorithm for HESS systems maintains a constant voltage of the BLDC motor. Various expected performance, such as PSO-based MPPT in different climatic conditions, zeta converter operation, dynamic execution of the overall structure has been verified using MATLAB/Simulink flatform. The outcome of this study endorse the efficiency of the control algorithm.

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