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Design and control of Hybrid PV Battery system using fuzzy based MMC

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Abstract: This paper describes about an innovative topology of cascaded H Bridge or modular multilevel Converter (MMC) is incorporated to integrate PV system with grid. However, the system scheduling necessity is much difficult in PV MMC for renewable sources. For mitigation of this limitation, in this paper a two-layer hierarchical method is proposed. Moreover, one layer that lower layer is take the importance for reducing the PQ and distribution among each H Bridge as well as the upper layer monitor the power dispatching at each H Bridge. In this study, the fuzzy logic control technique is proposed for the system in lower layer. With the proposed approach, a hybrid PV and battery system can be coordinated controlled with only a single power conversion stage. The system performance has analyzed on MATLAB/SIMULINK software environment. The proposed method can give better performance than conventional PV battery integration system.

Keywords: cascaded H bridge, PV system, grid, fuzzy control, battery system.

Introduction

With the growing penetration of multiple renewable energy sources, more structures have arisen to help interface the grid. A CHB structure with PV arrays has been proposed in [1][2], where PV arrays are directly connected to the DC link of each H-bridge (HB) which reduces the cost of additional DC/DC converters to integrate the system into high voltage grid with enhanced efficiency and reduced cost. However, for the internal intermittent characteristic of PV arrays, stable power flow cannot always be guaranteed. It certainly cannot meet with the power control requirement from power system operators.

At the same time, with the distributed energy sources incorporate into the grid, various energy storage elements like batteries and super capacitors are implemented to offer energy snubber functions and coordination of supply and demands [3]. When PV and batteries are used together, a controllable PQ injection method can be realized, such as in [4-7]. However, this two-level power conversion topology reduces the power density and cost more power loss.

Cascaded inverters consist of several converters connected in series; thus, the high power and/or high voltage from the combination of the multiple modules would favor this topology in medium and large grid-connected PV systems [8]–[10]. There are two types of cascaded inverters. Fig. 1(e) shows a cascaded dc/dc converter connection of PV modules [11], [12]. Each PV module has its own dc/dc converter, and the modules with their associated converters are still connected in series to create a high dc voltage, which is provided to a simplified dc/ac inverter. This approach combines aspects of string inverters and ac-module inverters and offers the advantages of individual module maximum power point (MPP) tracking (MPPT), but it is less costly and more efficient than ac-module inverters. However, there are two power conversion stages in this configuration. Another cascaded inverter is shown in Fig. 1(f), where each PV panel is connected to its own dc/ac inverter, and those inverters are then placed in series to reach a high-voltage level [13]–[16]. This cascaded inverter would maintain the benefits of "one converter per panel," such as better utilization per PV module, capability of mixing different sources, and redundancy of the system. In addition, this dc/ac cascaded inverter removes the need for the per-string dc bus.

Using a single stage power conversion, such as CHB, is definitely an attractive solution. However, due to the characteristic differences between PV panels and batteries, simultaneous operation of them may cause a few problems such as conflicts between MPPT and SOC control, and increased switching ripples. This is because conventional CHB only integrate the same type of distributed power sources into grid.

In order to overcome this limitation, a CHB topology with PVs and energy storage elements directly connected to separate DC rails are proposed in this paper. A hierarchical two-layer control scheme is developed, PVs and battery are coordinated controlled to offer sustained energy according to the dispatching instructions from the grid. Power supply instability due to the uncertainty of PVs is alleviated. Simulation results are provided to validate the effectiveness of the proposed method. In this paper, fuzzy control approach is suggested in lower layer for mitigating the various difficulties at different circumstances.

2.0 Suggested CHB architecture

The topology proposed in this paper is shown in Fig. 1, where PV arrays and a battery are directly connected to the DC link of each HB. A two-layer controller architecture is implemented. The lower layer synthesizes a controllable voltage phasor to manage power distribution between HBs. The upper layer works as a power dispatcher and offers power

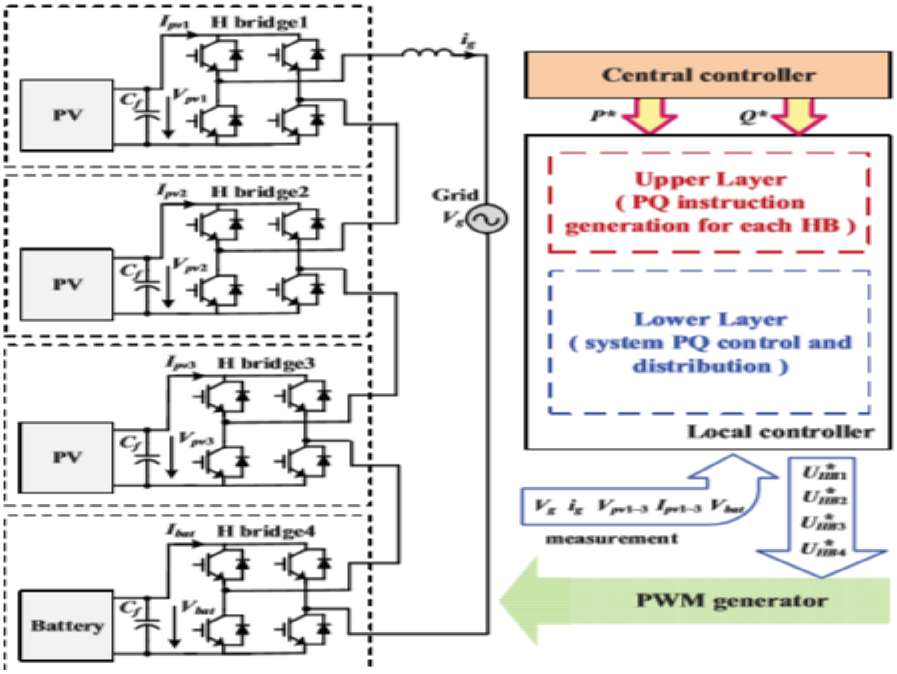

Fig.1 CHB architecture with energy storage system.

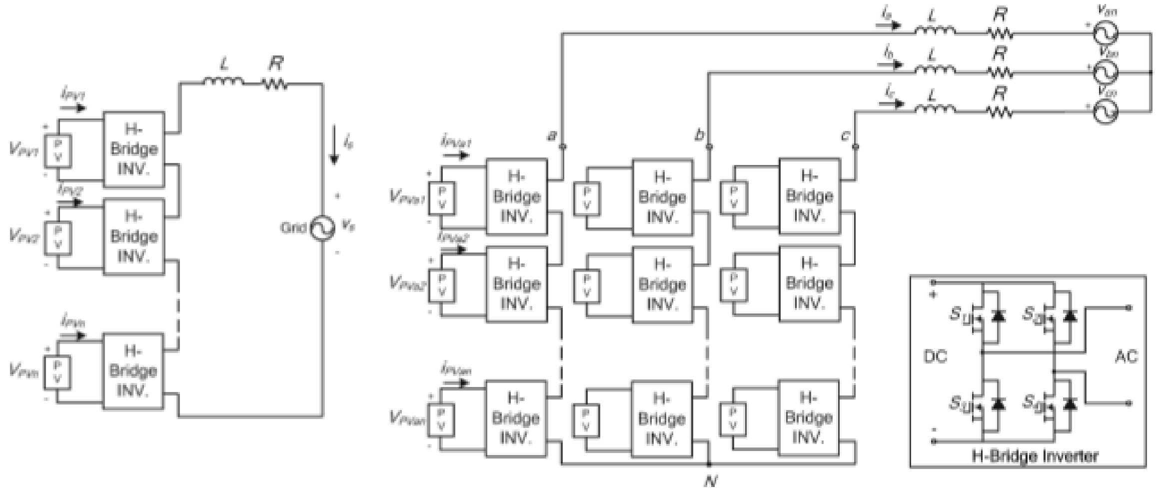

Fig. 2. Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

As mentioned earlier, a PV mismatch may cause more problems to a three-phase modular cascaded H-bridge multilevel PV inverter. With the individual MPPT control in each H-bridge module, the input solar power of each phase would be different, which introduces unbalanced current to the grid. To solve the issue, a zero-sequence voltage can be imposed upon the phase legs in order to affect the current flowing into each phase. If the updated inverter output phase voltage is proportional to the unbalanced power, the current will be balanced. Thus, the modulation compensation block, as shown in Fig. 2, is added to the control system of three-phase modular cascaded multilevel PV inverters. The key is how to update the modulation index of each phase without increasing thecomplexity of the control system. First, the unbalanced power is weighted by ratio rj, which is calculated as,

$$r_j = \frac{P_{\text{inav}}}{P_{\text{inj}}}$$

where Pm,j istheinputpowerofphase j (j = a,b,c),and Pmax is the average input power. Then, the injected zero sequence modulation index can be generated as,

$$d_0 = \frac{1}{2}\left[\min(r_a \cdot d_a, r_b \cdot d_b, r_c \cdot d_c) + \max(r_a \cdot d_a, r_b \cdot d_b, r_c \cdot d_c)\right]$$

In this system, the fuzzy logic control approach was penetrated into the lower layer of the suggested system.In this study, the fuzzy control technique is proposed to endorse the system in lower layer. With the proposed approach, a hybrid PV and battery system can be coordinated controlled with only a single power conversion stage. The suggested method in hybrid PV and battery integrated to grid is shown the better performance as compared to other existing methods.

3.0 Designing of Fuzzy

The term fuzzy refers to things which are not clear or are vague. In the real world many times we encounter a situation when we can’t determine whether the state is true or false, their fuzzy logic provides a very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.

In boolean system truth value, 1.0 represents absolute truth value and 0.0 represents absolute false value. But in the fuzzy system, there is no logic for absolute truth and absolute false value. But in fuzzy logic, there is intermediate value too present which is partially true and partially false.

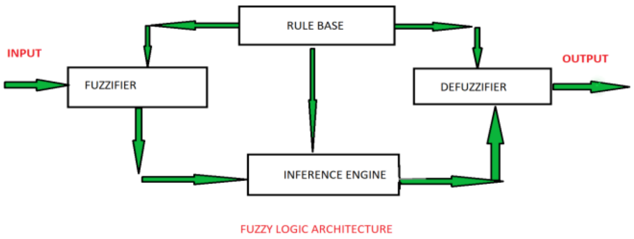

Fig.3 Fuzzy logic controller

Membership function is a graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set (u), which contain all the possible elements of concern in each particular application.

- There are largely three types of fuzzifiers:
- singleton fuzzifier,
- Gaussian fuzzifier, and
- trapezoidal or triangular fuzzifier

There are three principal elements to a fuzzy logic controller:

1. Fuzzification module (Fuzzifer)
2. Rule base and Inference engine
3. Defuzzification module (DE fuzzifier)

Fuzzy control is based on a logical system called fuzzy logic. It is much close in spirit to human Thinking than classical logical systems. The LFC has been reported in several papers is to maintain Balance between production and consumption of electrical power. Due to the complexity and Multi-variable nature of power systems, a conventional control method has not provided satisfactory solutions. The fuzzy logic control has tried to handle the robustness, reliability and nonlinearities associated with power system controls. Therefore, a fuzzy logic controller (FLC) becomes nonlinear and adaptive in nature having a robust performance under parameter variations with the ability to get desired control actions for complex uncertain, and nonlinear systems without their mathematical models and parameter estimation [9]. This work proposes a fuzzy controller with up to 49 rules with 7 membership function as negative big (NB), negative medium (NM), negative small (NS),zero (ZE) , positive small (PS) , positive medium (PM) , positive big (PB) .

4.0 Simulation results:

Volatge ,current of CHB : Steady state performance. When P* = 2.5kW, Q* = 0, sinusoidal current waveform and nine-level voltage waveforms is shown in Figure below

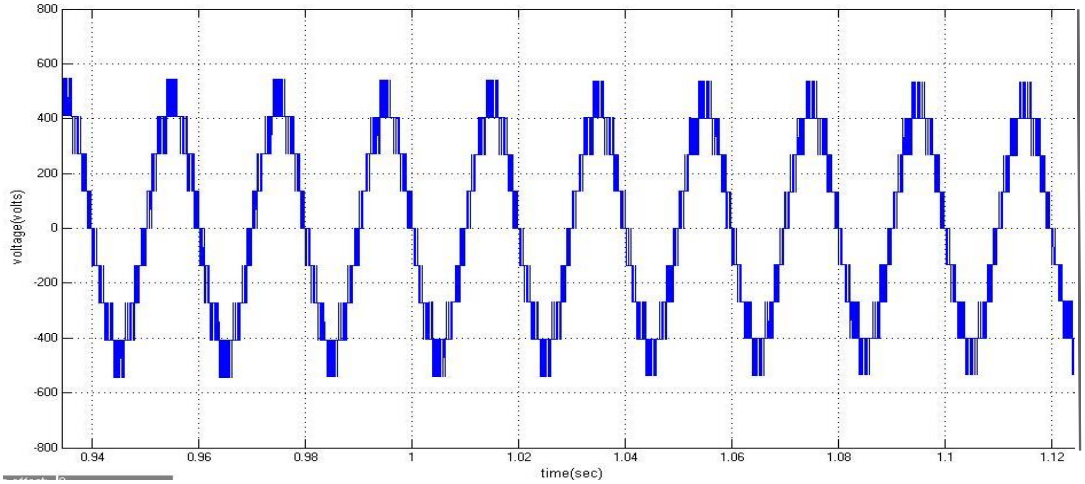

Fig 4 output voltage of cascaded h bridge converter

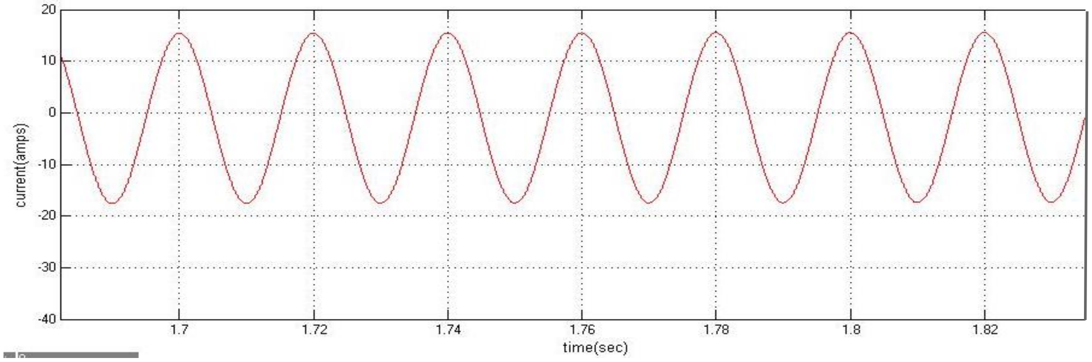

Fig 5 output current of cascaded h bridge converter

Active power variation : Transient performance at unity power factor. P* jumps from 2.5kW to 3.2kW at 1.0s. Current step response is stable, and 3 PVs keep on tracking their MPPs at 105.3V as shown in Figure below. The additionally required 700W active power is supplied by the battery.

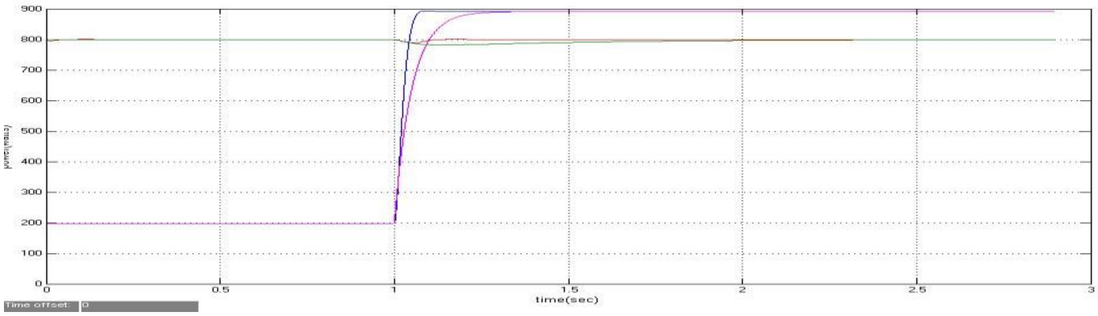

Fig 6 wave forms of pv system,battery with PI and fuzzy controllers

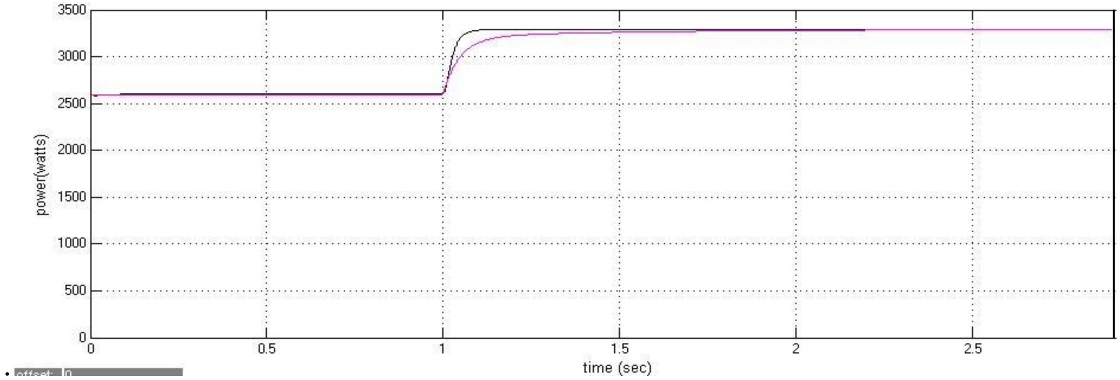

Fig 7 total power delivered by source with PI and fuzzy controllers

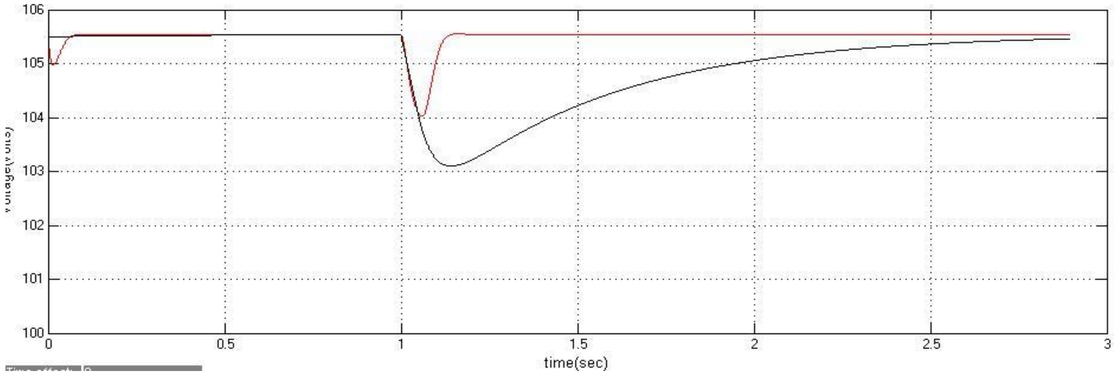

Fig 7 MPPT voltages with PI and fuzzy logic

Irradiance variation : Internal disturbance attenuation at unity power factor. In Fig.7, PV1 irradiance falls to 500W/m2 at 1.0s. P* = 2.5kW, Q* = 0. PV1 keeps on tracking its new MPP at 106.1V and 393.6W, while the lost power due to irradiance change turns to the battery to offer. The total power injected to the grid is not affected by internal disturbances.

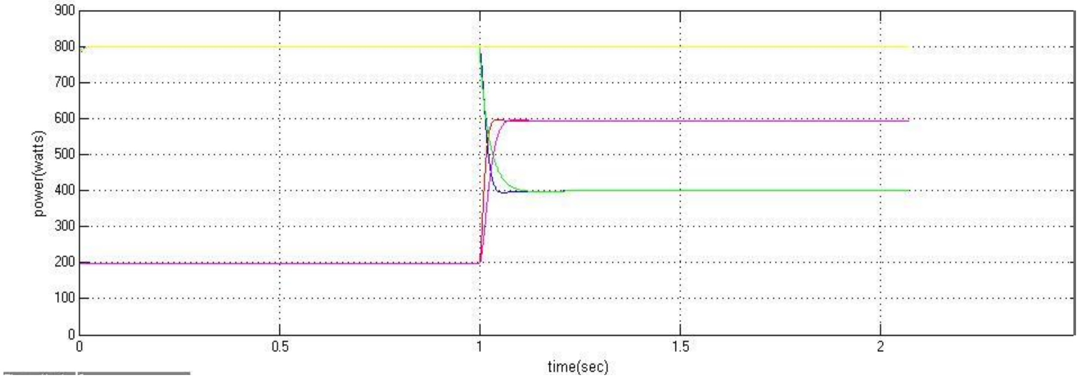

Fig 8 power of pv pannels,battery with PI and fuzzy controller

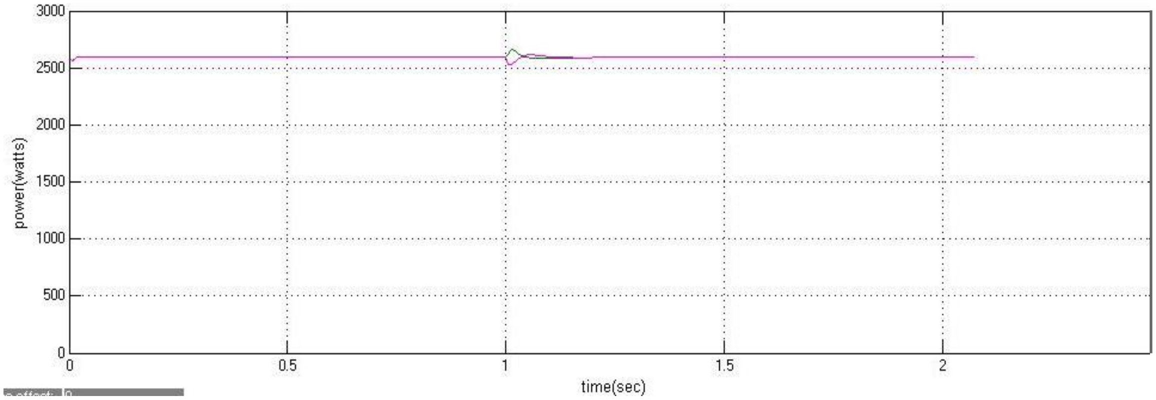

Fig 9 total power delivered by system with PI and fuzzy controller

Reactive power variation: Reactive power step response. As shown in figure below, when Q* jumps from 0 to -2.4kvar at 1.0s, P*=2.5kW. Reactive power is distributed among each HBs according to their surplus power capacity. Due to MPPT of each PV, the HB with the battery only contribute a small proportion of the total active power, and mainly concentrate on generating reactive power. Current transient waveform is shown in Fig. 8, where current tracking result is satisfying

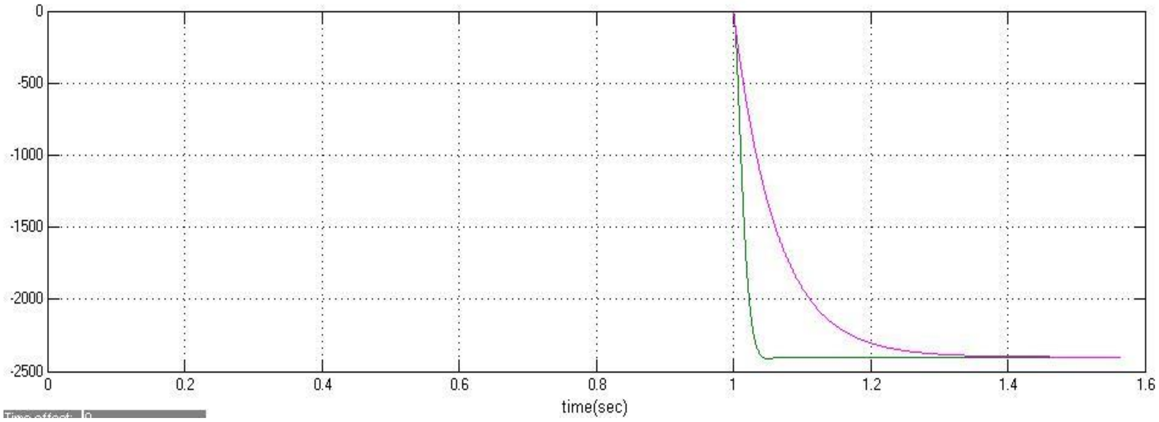

Fig 10 reactive power supplied with PI and fuzzy controllers.

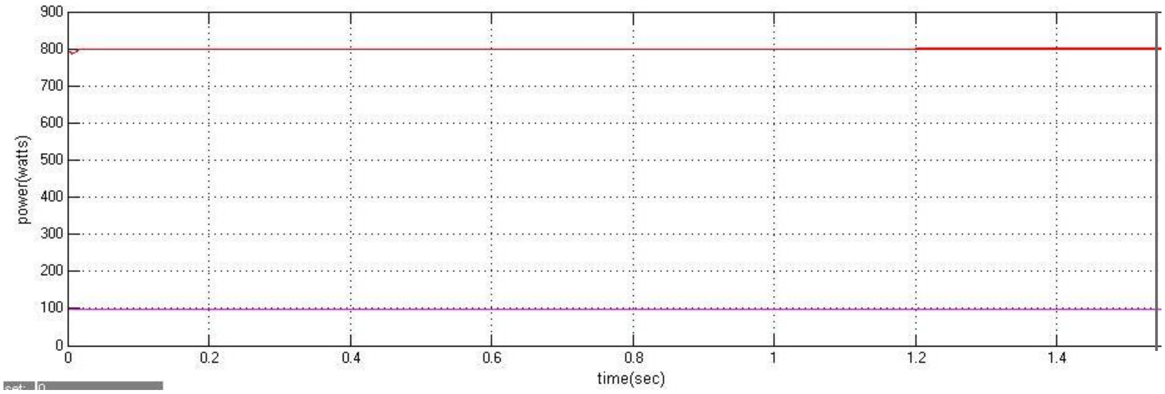

Fig 11 active power delivered by pv pannels ,battery .

Conclusion:

In this work, hybrid PV and battery system has designed with one CHB converter. In this regard, the battery and PV system are directly connected to the DC rails. For mitigating the difficulties while connecting the PV and battery system, two-layer power regulated method was suggested. Moreover, one layer that lower layer is take the importance for reducing the PQ and distribution among each H bridge as well as the upper layer monitor the power dispatching at each H bridge. In this study, the fuzzy control technique is proposed to endorse the system in lower layer. With the proposed approach, a hybrid PV and battery system can be coordinated controlled with only a single power conversion stage. The suggested method in hybrid PV and battery integrated to grid is shown the better performance as compared to other existing methods.

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