3 Simulation Results and Discussion

To verify the effectiveness of proposed ANFIS controllers, the simulink model of study system is implemented in MATLAB/Simulink environment. The simulink model consists of a Microgrid with two different sources, a nonlinear PV source and a battery source. Time domain responses of the system are obtained under load variation with classical PI controller and also with proposed controllers. System parameters and classical PI controller values are taken from [15]. The responses of the system with classical controllers and ANFIS controllers are presented in (Figs.11 & 12) and (Figs.13 & 14) respectively. It is considered that the PV system works at its rated power (2300W) level and load is varied from 1500W to 2900W and back to 1500W, as shown in Fig.11 (a) and Fig.13(a). The DC/DC converter of battery tries to maintain constant voltage across common DC-bus (300V) irrespective of load variation and also control the battery charge or discharge currents at its maximum limit.

During 0-0.4 sec and 0.8-1 sec: The load power is considered 1500W, as shown in Fig.11(a) and Fig.13(a). As the total load demand power is less than the nominal power of PV generation system, excessive power is fed to the battery unit via bi-directional DC/DC converter and hence, battery gets charge (-ve power flow) as shown in Fig.11(a) and Fig.13(a). Battery charging voltage and current are shown in Fig.12 (a,b) and Fig.14 (a,d) for Classical and ANFIS controllers respectively.

During 0.4-0.8 sec: The load power is increased to 2900W from 1500W during this time interval, as shown in Fig.11(a) and Fig.13(a). As the total load demand power is more than the nominal generating power of PV generation system, the battery gets discharge during this interval (+ve power flow) and therefore, the battery feeds power to the load for fulfilling the load/consumer demand, as shown in Fig.11(a) and Fig.13(a). Battery voltage and current are shown in Fig.12 (a,b) and Fig.14 (a,b), during discharging conditions, with classical and ANFIS Controllers.

- It is observed, from Fig.11(b) and Fig.13(b), that the dc-link voltage across common DC-link capacitor is maintained constant irrespective of the load variation.
- It can be notice, from Fig.12(b) and Fig.14(b), that the battery current gets negative during charging condition i.e. battery current flows from common DC-link to battery to store energy. During discharging condition, battery current becomes positive i.e. battery current flows from battery side to common DC-Bus for releasing the power.
- Three-phase inverter voltage is shown in Fig.12 (c,d) and Fig.14(c,d) without and with ANFIS controller respectively.
- From Fig.11(d) and Fig.13(d), it is observed that the both control schemes are enough capable to maintain islanding load voltage to its rated value.

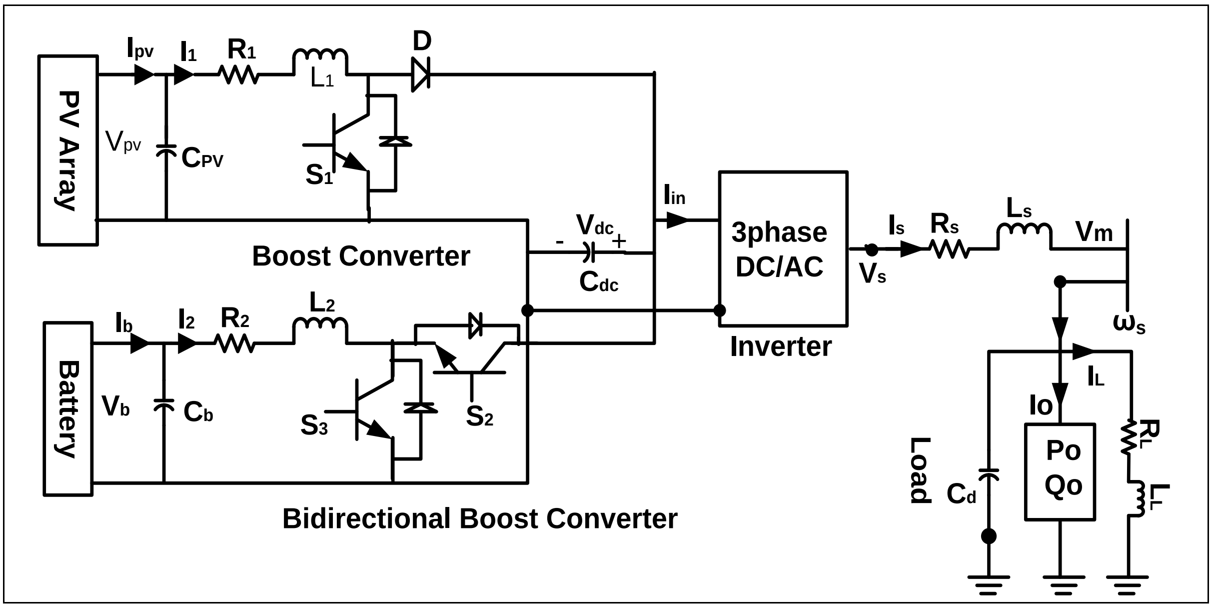


Fig. 1. Block diagram of a Stand-alone System with PV and Battery Units [15].

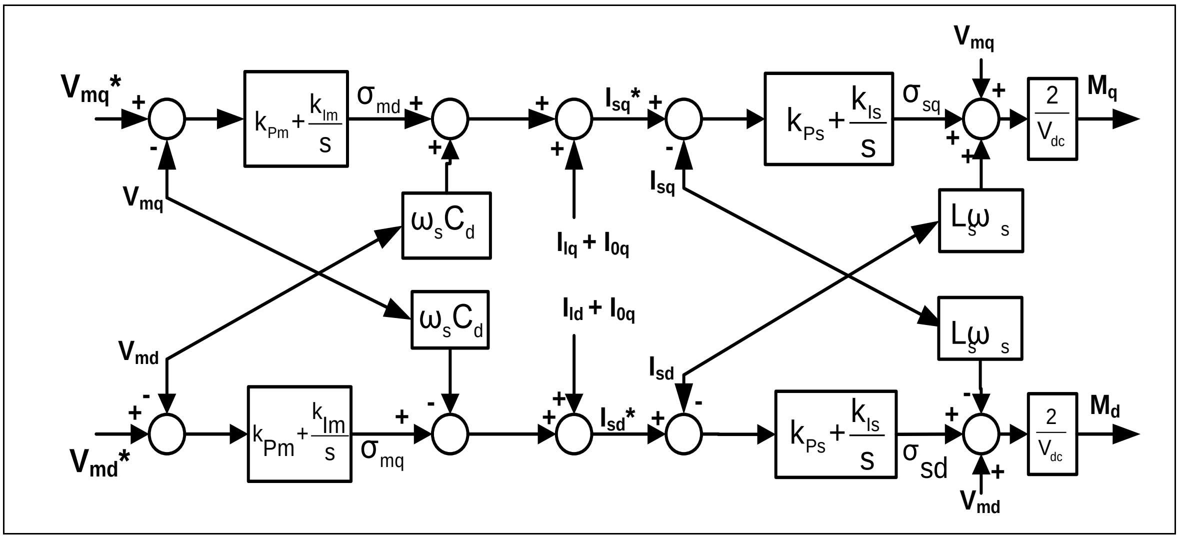


Fig. 2. Block Diagram of Control Scheme for DC-AC 3-phase Converter [15].

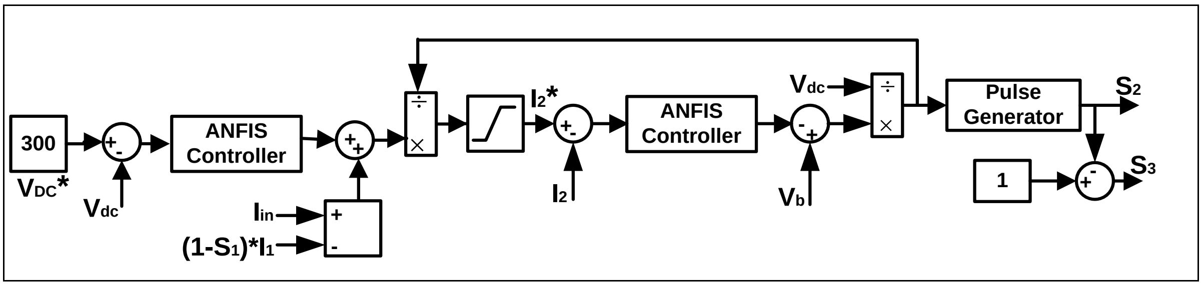


Fig. 3. ANFIS based Control Scheme for DC/DC Bi-directional Boost Converter of Battery Unit.

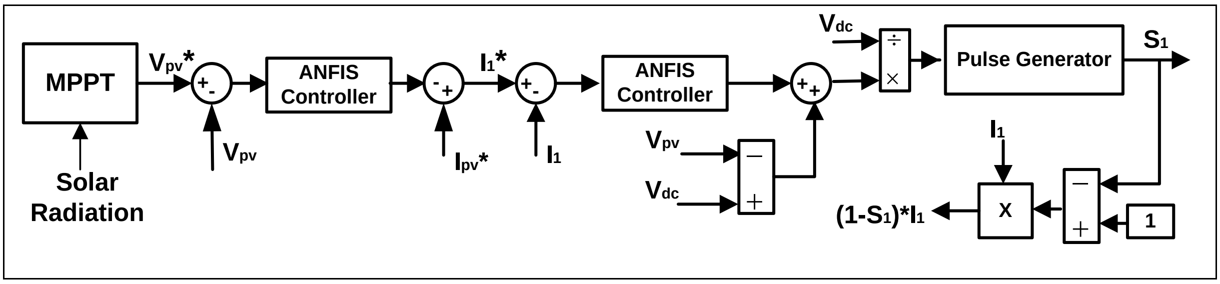


Fig. 4. ANFIS based Control Scheme for DC/DC Boost Converter of PV Unit.

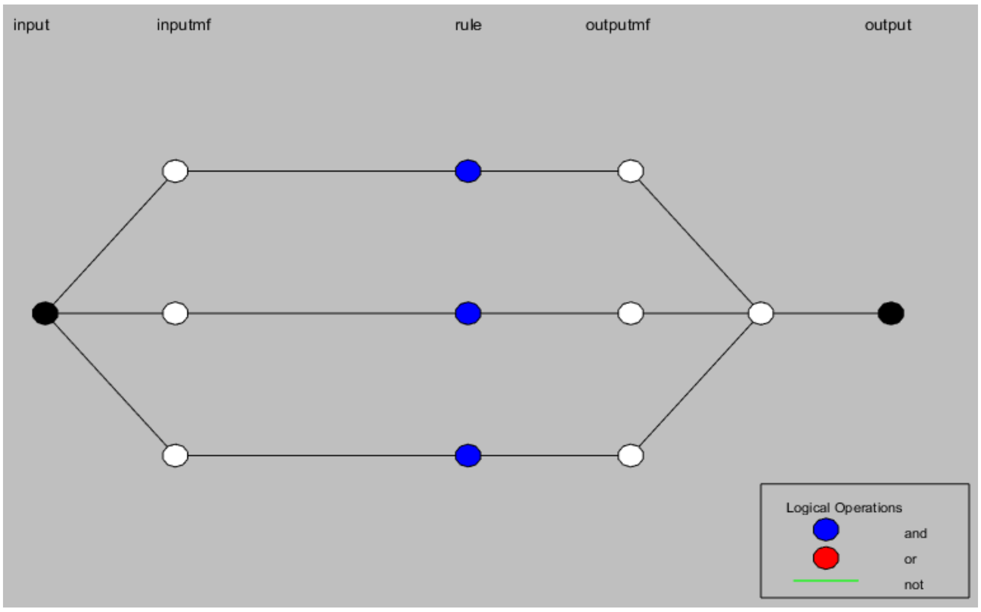


Fig. 5. Structure for Adaptive Network.

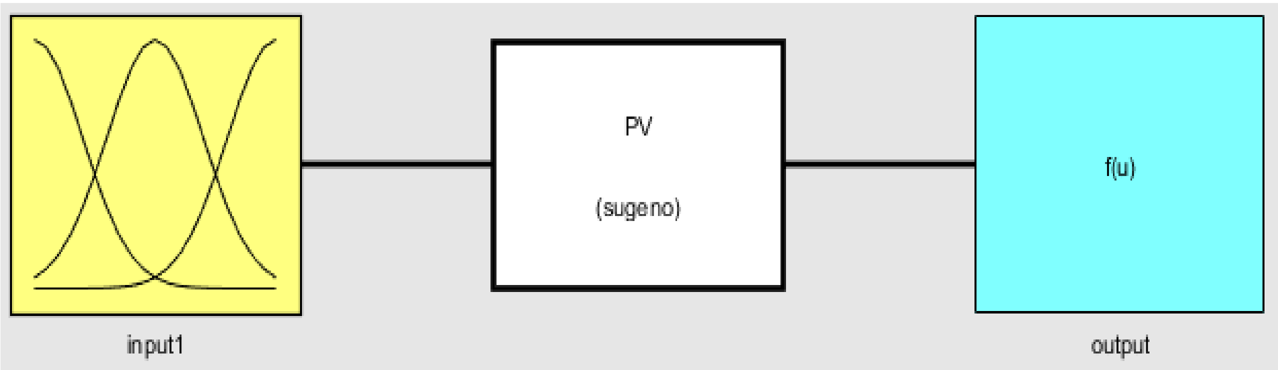
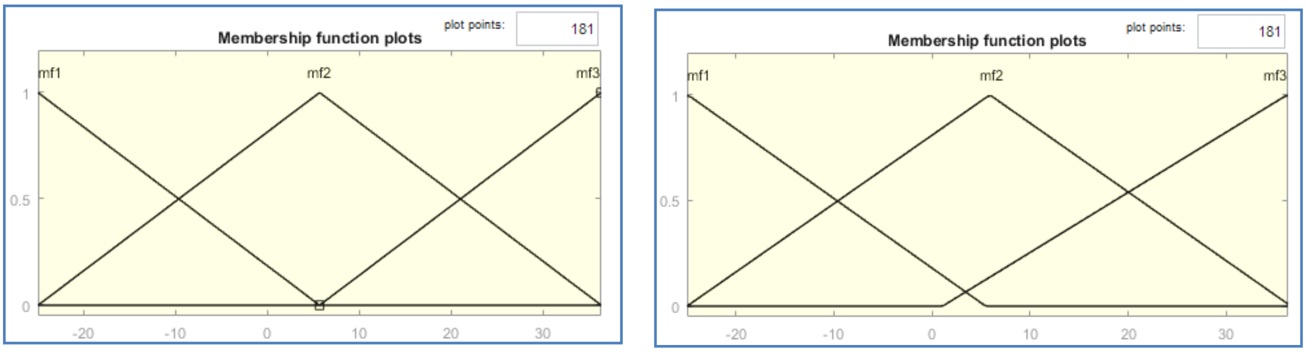
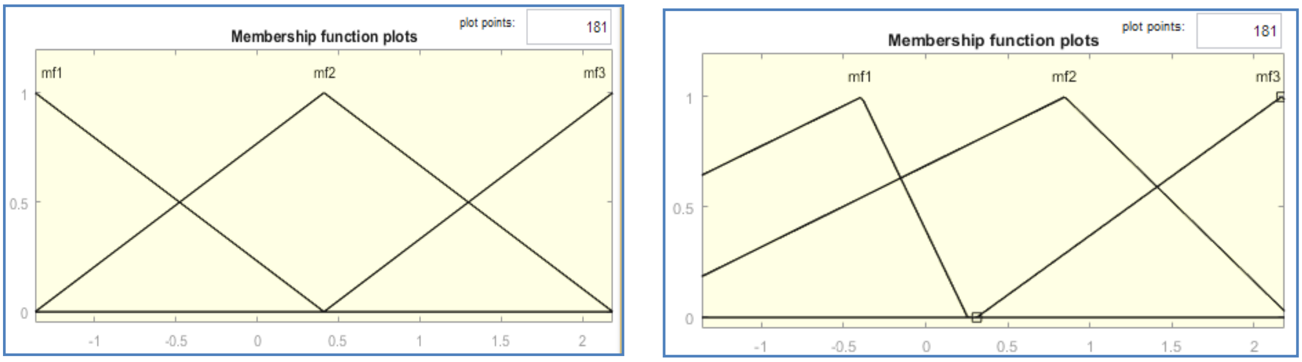


Fig. 6. Structure for ANFIS.



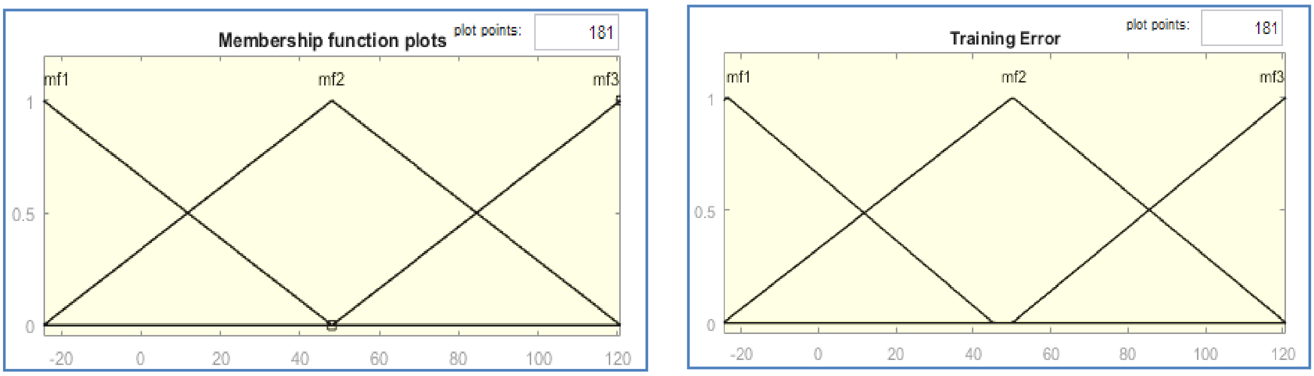
Before Training (b) After Training

Fig. 7. Membership Function for Inner Control Loop of battery Control Scheme.



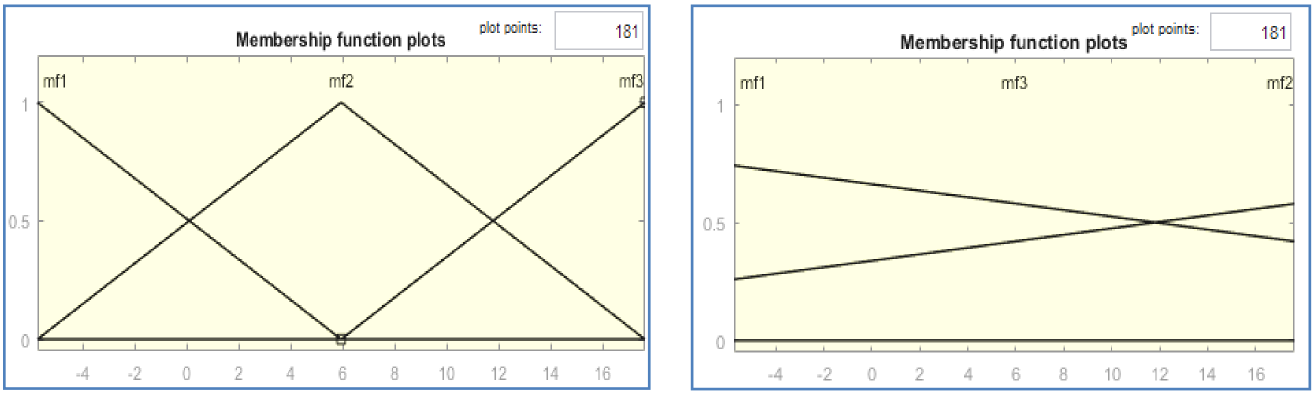
(a) Before Training (b) After Training

Fig. 8. Membership Function for Outer Control Loop of battery Control Scheme.



(a) Before Training (b) After Training

Fig. 9. Membership Function for Outer Control Loop of PV Control Scheme.



(a) Before Training (b) After Training

Fig. 10. Membership Function for Inner Control Loop of PV Control Scheme.

4 Comparison of System Responses Obtained with Proposed and Classical PI based Control Schemes

Time responses of the system with classical PI controller as well as those with ANFIS controller have been presented in section-3. The results obtained in section-3, using the two types of controllers, are listed in Table-I along with comments on the responses for comparison.

Table-1: Comparison of System Responses with Classical PI & Proposed ANFIS controllers

Variables	Figure No		Comments on system responses at varying loads and constant irradiations.
	With Classical PI Controller	With ANFIS Controller	
Power	Fig.11(a)	Fig.13(a)	It can be noted that both the controllers are capable of managing the power flow of a solar-battery based stand-alone system for satisfying the load end demands. When compared, it can be seen that response of battery power during discharging interval are oscillated with classical PI controller. But, there is no oscillation observed with ANFIS controllers.
DC-link voltage	Fig.11(b)	Fig.13(b)	Both the controllers have perfectly tracked the reference values of V_{dc} and kept it fixed to its rated level. But, the dc-link voltage obtained with ANFIS controller is smoother than that of obtained with classical PI controllers.
Battery voltage and Current	Fig.12(a) and Fig.12(b)	Fig.14(a) and Fig.14(b)	It is observed that the battery voltage and current, obtained with classical PI controller, are more oscillatory in nature than that of using ANFIS controller. Therefore, it can be concluded that ANFIS controller based control schemes give better responses as compare to classical controller based control schemes.

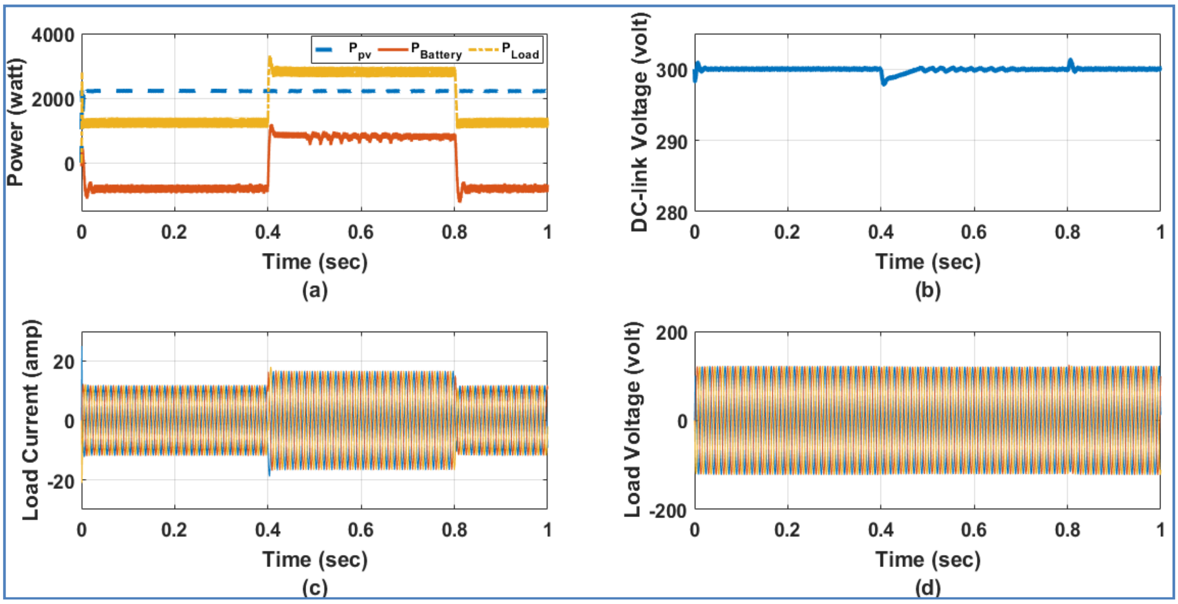


Fig. 11. (a) Power (watt), (b) DC-link Voltage (volt) (c) Load current (amp) and (d) Load voltage (volt) (With Classical PI Controller)

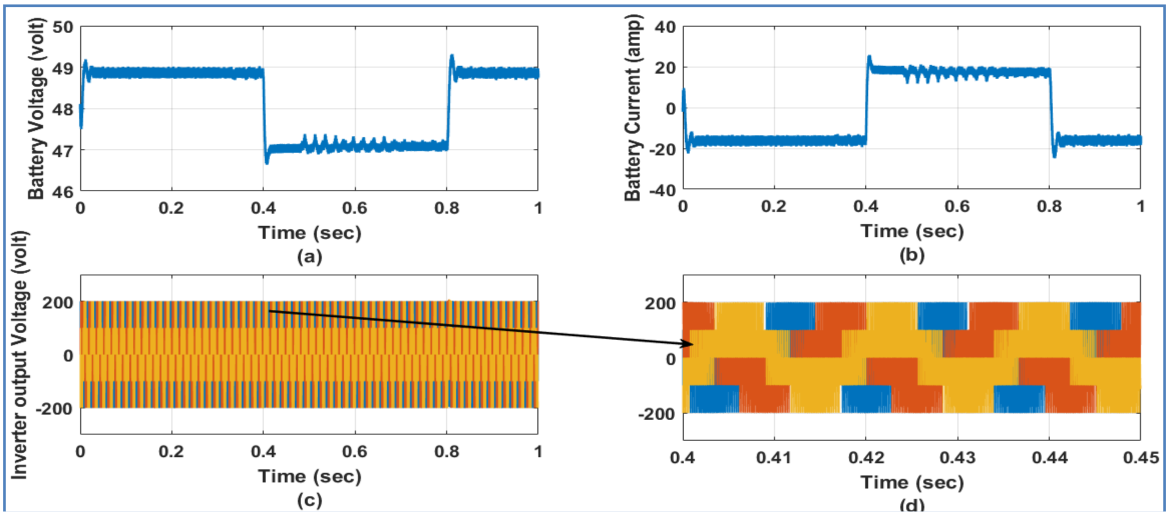


Fig. 12.(a) Voltage of Battery (volt), (b) Current of Battery (amp) (c) Output Voltage of 3-phase Inverter (volt), and (b) Zoom viewed of Inverter Output Voltage(volt) (With Classical PI Controller).

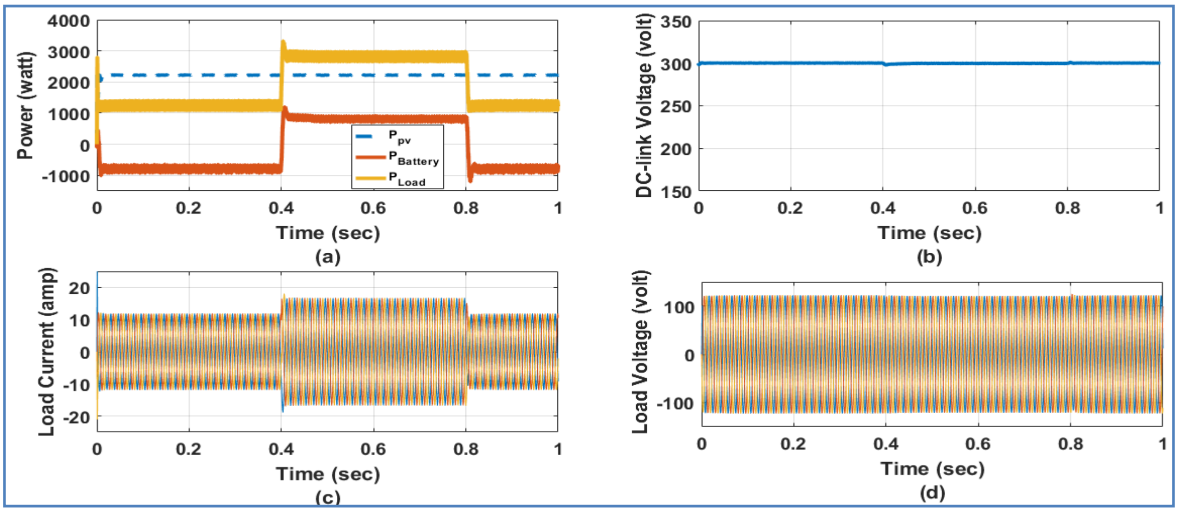


Fig. 13. (a) Power (watt), (b) DC-link Voltage (volt) (c) Load current (amp) and (d) Load voltage (volt) (With ANFIS Controller).

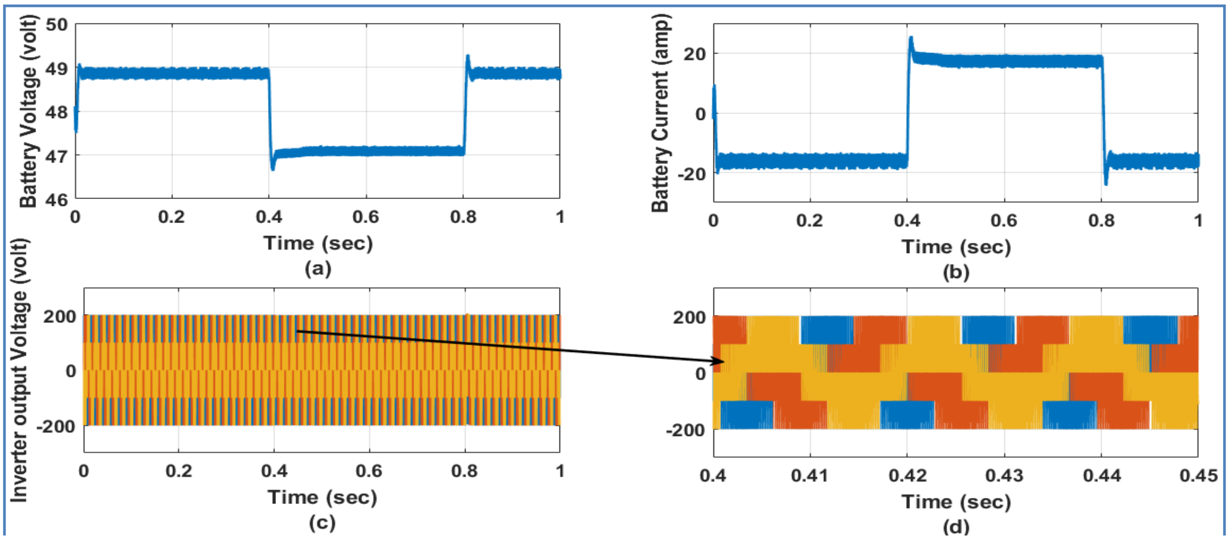


Fig. 14.(a) Voltage of Battery (volt), (b) Current of Battery (amp) (c) Output Voltage of 3-phase Inverter (volt), and (b) Zoom viewed of Inverter Output Voltage(volt) (with ANFIS Controller).

5 Conclusion

In this paper, a simulink model for solar-PV and battery based stand-alone power system is implemented in MATLAB/simulink environment. The performances of the system are studied by varying loads and at constant (rated) solar irradiation (1pu). ANFIS based control schemes are designed for PV and battery units of the study system for balancing the power flow between source and load with lower oscillation during both transient and steady state conditions. Simulink results obtained with ANFIS controller are compared with that of classical PI controllers. From simulink results, it can be observed that ANFIS based control schemes give better responses as compare to classical control schemes.

The advantages of using ANFIS are that they provide better alternative as compared to classical conventional system; they exhibit a faster converging speed, good performance, less oscillation under steady-state conditions.

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