Hybrid Energy Management-Based on Intelligent Controller for Smart Dc-Micro-grid

Husna[1], Arpula. Krishnaiah[2], Maisakhsi. Pavan kumar[3]

[1]Electrical and Electronics Engineering & KLR Engineering College, Palvancha, Telangana
[2]Electrical and Electronics Engineering & KLR Engineering College, Palvancha, Telangana
[3]Electrical and Electronics Engineering & KLR Engineering College, Palvancha, Telangana

Abstract

The main goal of this thesis is to develop an intelligent energy management controller of a smart DC microgrid on the basis of the Adaptive Neuro-Fuzzy Inference System (ANFIS). The suggested DC microgrid initiates photovoltaic (PV) production, wind energy (WE), and a battery bank to maintain efficient and reliable power supply. An innovative smart type of fractional-order PID (FOPID) control scheme is formulated on the source-side converters and load-side converters, which are synchronized using the proposed ANFIS-based control scheme. This will increase the solar and wind power extraction efficiency and will do a large share of power quality improvement as well. Having made wind and PV sources of renewable energy a priority, the microgrid is more economically and sustainably active. The controller proposed will ensure stable and smooth output power in different operating conditions. The usefulness of the proposed control implementation is proven by the works of MATLAB/Simulink simulation and compared to the traditional fractional-order PID and fuzzy logic controllers.

Keywords: *Renewable energy, smart university, DC-micro grid, energy management control, fuzzy logic control, fractional order control.*

1.Introduction

Production of electrical energy in the world is connected to a number of environmental pollutants. Air pollution is the primary cause of the burn of fossil fuels, which are mostly burned in coal-fired and oil-fired thermal power plants. Despite the fact that the nuclear power plants increased considerably during the oil crisis and do not directly cause air pollution, there is a problem of radioactive waste which is very difficult to process, transport and store. As a reaction to the environmentalism, the liberalization of the electricity industry market, the threat of dependence on a single source of energy, renewable energy sources, including hydro, wind, solar, and biomass, are becoming more and more important in the current power production system (1), (2).

The inability of power systems to meet the demand and supply of energy in the long run is one of the greatest challenges in the power systems. It is of the essence to keep the generation and consumption steady to facilitate grid stability. With the growing penetration of the renewable energy source, there is a need to be involved into various ancillary services backed by electrical energy storage systems (ESSs). One of the enabling factors to the mass production of renewable energy is energy storage since it reduces the fluctuations in generation and avoids load shedding in times of excess production. Additionally, ESSs offer a technical manner to achieve real-time supply and demand equilibrium to maximize the use of renewable energy by grid operators.

Localized energy storage in conjunction with distributed renewable generation has the benefit of improving the stability of energy networks through the ability to operate in islands. Placed strategically, ESSs can enhance the quality of power by permitting higher control of voltage and frequency to minimize the effects of variability in the source to delivered current, especially during peak demand hours (5), (6). Combining renewable energy sources and energy storage in standalone microgrids has thus been a research area of activity. Hybrid energy storage systems which are commonly made up of batteries and supercapacitors are usually used to enhance the storage capacity, increase the battery life, and give quick dynamic responses to transient conditions. In most real-world systems, when two or more energy sources are connected, power flow on the grid instead of directly via supercapacitors takes place (8), (9).

Microgrids may be either AC or DC or a hybrid between AC and DC. The DC microgrids have a number of benefits over AC microgrids: they are simpler in architecture, easier to integrate with renewable sources, and easier to control. Other parameters that AC microgrids need include reactive power management and frequency synchronization that make controller design difficult. Conversely, DC microgrids can be easily used both

independently and in bigger AC systems (9), (10). Recent developments in power electronics have also made DC micro grids to be more efficient and reliable.

Because of the intermittence and stochastics of renewable sources of energy, the management of energy is critical in ensuring smooth flow of processes and power supply. Techniques that have been devised to control AC microgrids cannot directly be used in DC microgrids due to the difference in their dynamics. A typical DC micro grid design will have more than one energy source and load-side converter connected to a common DC link where power is consumed and supplied. Therefore, accurate control of the DC-link voltage is an essential consideration of stable and effective operation of the DC microgrids (11), (12).

The literature has reported different control measures towards DC-link voltage regulation. Topologies of hybrid microgrids, energy resource planning and control are examined in (13). Voltage control by fuzzy logic methods are suggested in (14) and (15) whereas dual proportionalintegral (PI) control methods are explored in (16). Despite the common use of these linear control techniques, they normally have constrained operation limits and diminished abilities when working under nonlinear and uncertain situations. In order to overcome these limitations, a number of nonlinear control methods have been investigated. In (17) adaptive droop control is introduced and in (18) optimal energy management of microgrids with a number of storage devices is investigated. Hier and H F control H/F control: H /F control is examined in (19), sliding mode control in (20), adaptive backstepping control in (21), and Lyapunov-based feedback linearization in (22). In (24) the hybrid controllers involving both backstepping and sliding mode are discussed.

In spite of these benefits, most of these nonlinear control strategies have performance shortcomings in optimum energy management and droop control systems. Such problems like chattering in sliding mode control, low stability in H infinity control of systems with multiple integrated storage units, sensitivity to uncertainty in the parameters are still major problems. Further, the majority of controllers in use today are based on the fixed gain parameters and hence are susceptible to external perturbations as well as system uncertainties.

In order to deal with these issues, the proposed study presents a new fuzzy logic-based fractional-order PID (FOPID) controller to hybrid energy management system of DC microgrids. Fractional-order controllers are more versatile in design than their integer-order counterparts and have superior damping behavior and lower oscillations and sensitivity to measurement noise. Figure 1 shows the proposed DC microgrid architecture, including a number of stochastic renewable energy sources, big DC loads and the proposed control strategy.

FIGURE 1 Hybrid system structure

The control architecture suggested uses an intelligent fractional-order PID (IFO-PID) controller as a low level control unit which works together with a high level energy management unit (EMU). EMU is constantly aware of the power generation and the load demand and produces the right reference signals to the IFO-PID controller. The main idea of such strategy is to control the converters of the source side (SSCs) in order to allow to extract the maximum power of the renewable energy, namely, wind and photovoltaic (PV) systems. Moreover, the EMU will also ensure that the DC-link voltage and reactive power are controlled to the corresponding reference values and will improve the overall power quality of the DC microgrid.

The primary contributions of the given research can be summarized as follows. The proposed study is a new fuzzy logic-based fractional-order PID (FO-PID) control scheme to a DC microgrid with large DC loads and various stochastic renewable sources. The given method includes a gain supervision mechanism based on the fuzzy logic that adaptively adjusts the FO-PID controller parameters, thus making the controller less sensitive to the external disturbances and system uncertainties. One of the benefits of the given technique is that controllers fixed gains have been set to a minimum, which diminishes the prevalence of parameters change and increases stability, global stability, and the overall resilience of the system.

2. Modeling of Case Study

2.1 Existing System

The modern system topology is a hybrid energy based smart DC micro grid which is a combination of three principal elements. The former includes the hybrid type of renewable energy sources such as solar photovoltaic (PV) and wind energy systems, battery storage system (BSS) and integrated to the common DC link via a specific power electronic converter. The second element is priority loads and the lighting systems, ventilation fans and workbenches in the laboratory can be listed among the priority loads in the case of a smart university campus. The wind and PV energy conversion systems are both run at maximum power output with the help of a maximum power point tracking (MPPT) algorithm. In order to decide the right operating modes, the energy management unit (EMU) continuously obtains the sum of the generated and consumed power. Figure 4.1 shows the generic makeup of the energy management controller.
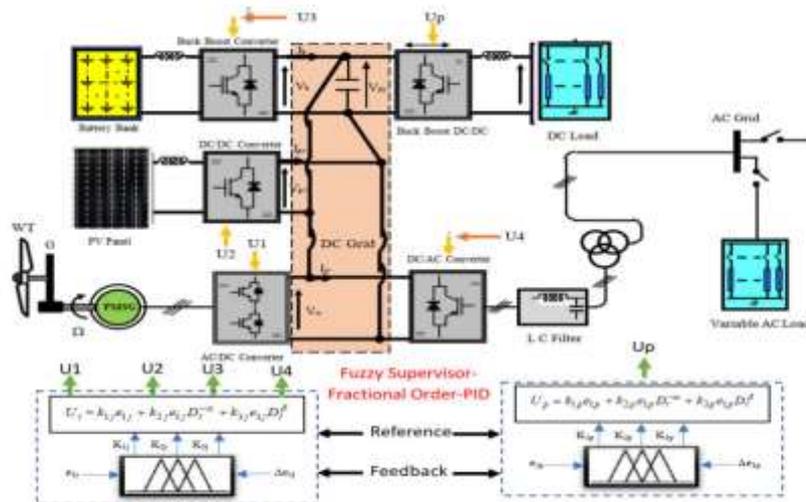
FIGURE 2 Existing systems with Fuzzy-FOPID controller

2.2 Proposed System

The proposed system is a smart DC microgrid that is based on a hybrid energy system, which consists of renewable energy sources and a storage facility. One can distinguish three main elements hybrid renewable energy sources (solar PV and wind generation), a battery storage system (BSS) attached to the DC link with its converter, and the load subsystem. A fractional-order PID (FOPID) control strategy is used to control the power extraction in the renewable sources by controlling the source-side converters. The proposed Adaptive Neuro-Fuzzy Inference System (ANFIS)-based control mechanism controls the load-side AC/DC converters to guarantee stable and high quality power output.

Priority loads are represented by the load subsystem that in a smart campus application is comprised of lighting, ventilation, and laboratory equipment. The wind, as well as the PV energy conversion systems, are compelled to work at their maximum power points with the help of MPPT algorithms. The energy management unit measures the generated and consumed power in real time and chooses the best control modes. The general structure of the suggested system is depicted in Figure 1.
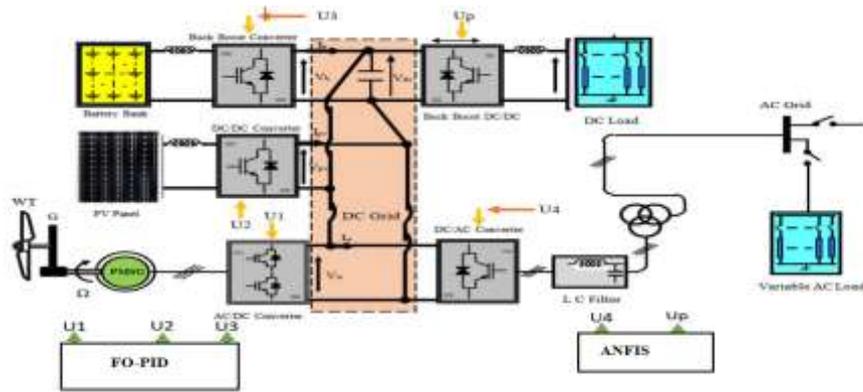
FIGURE 3 Proposed systems with ANFIS controller Structure
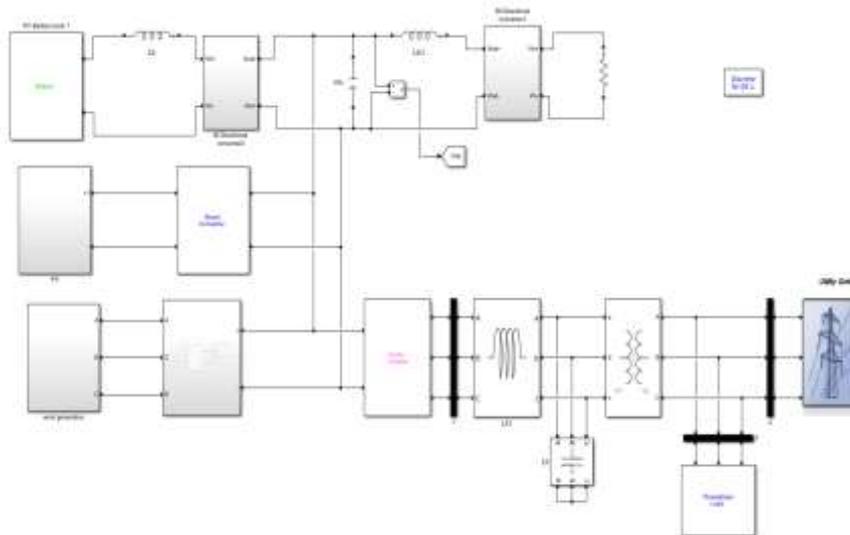
3.Simulation Results

FIGURE 4 MATLAB/SIMULINK circuit diagram of the system

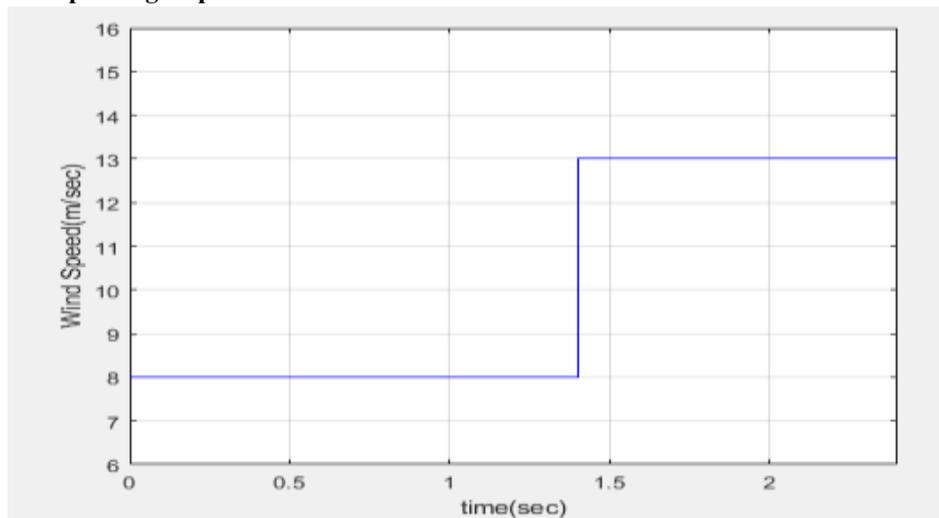**3.1 Existing Results**

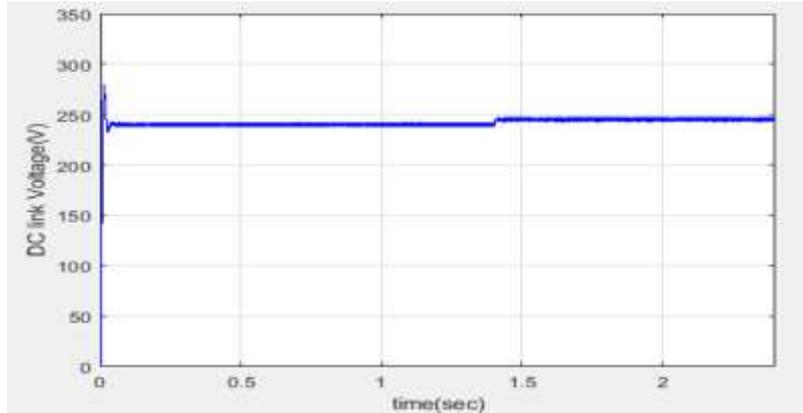**Case1: Under step changes speed**

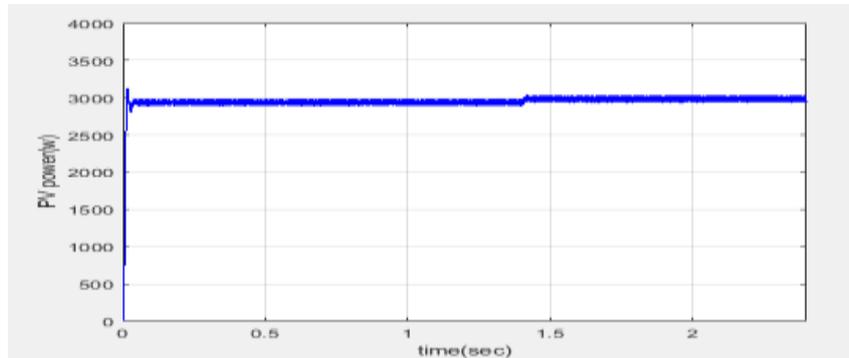**FIGURE 5** Wind speed

FIGURE 6 Wind power

FIGURE 7 Solar power
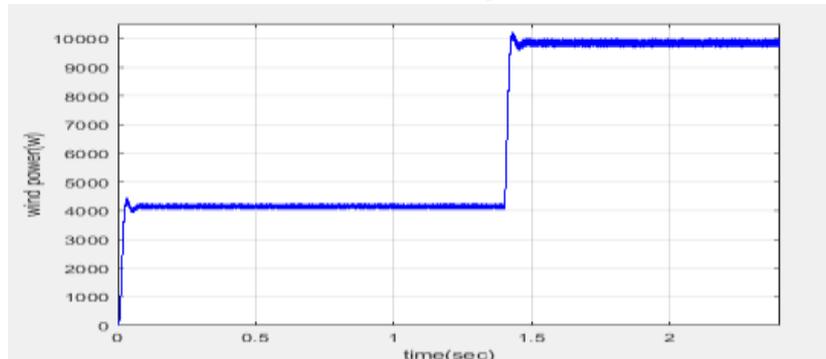
FIGURE 8 Wind power
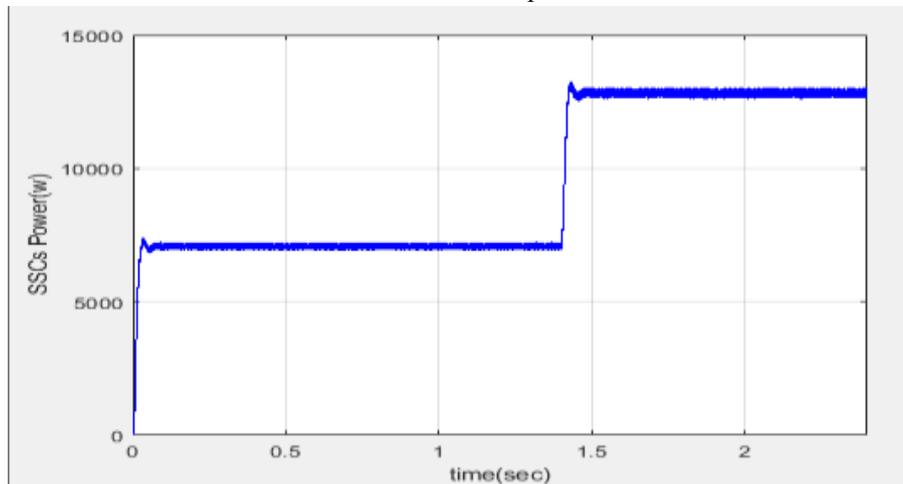
FIGURE 9 SSCs power

https://joetsr.com/

3.2 Extension Results
Case1: Under step changes speed
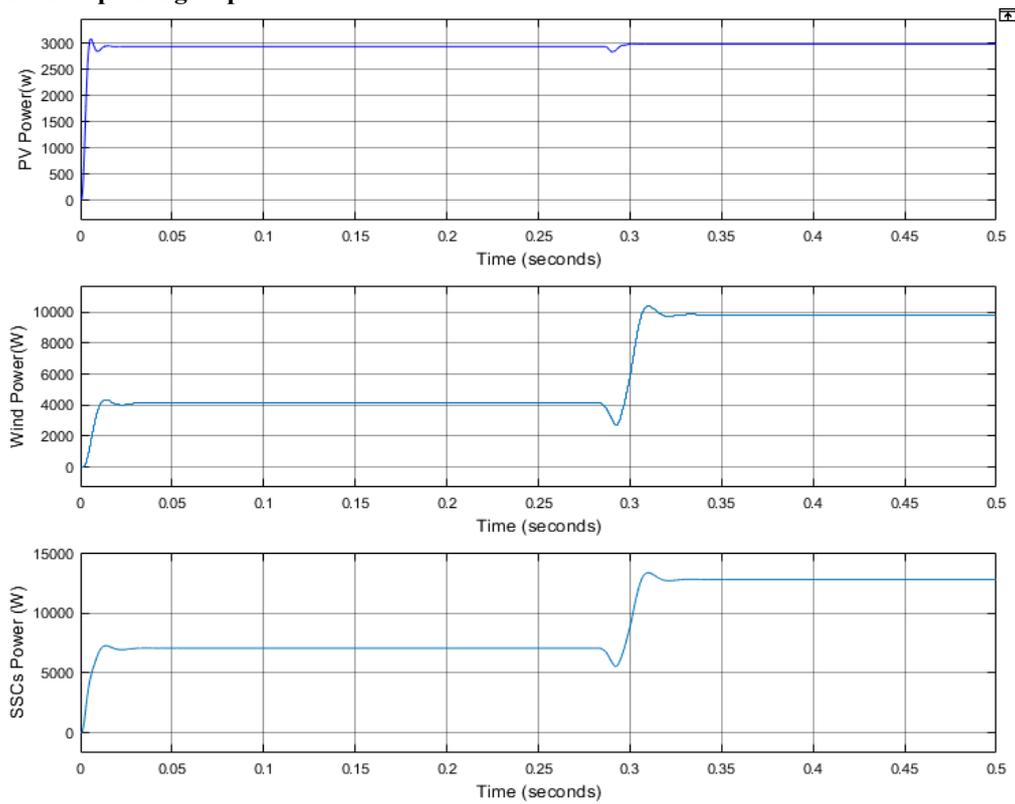
FIGURE 10 PV, Wind and SSCs power
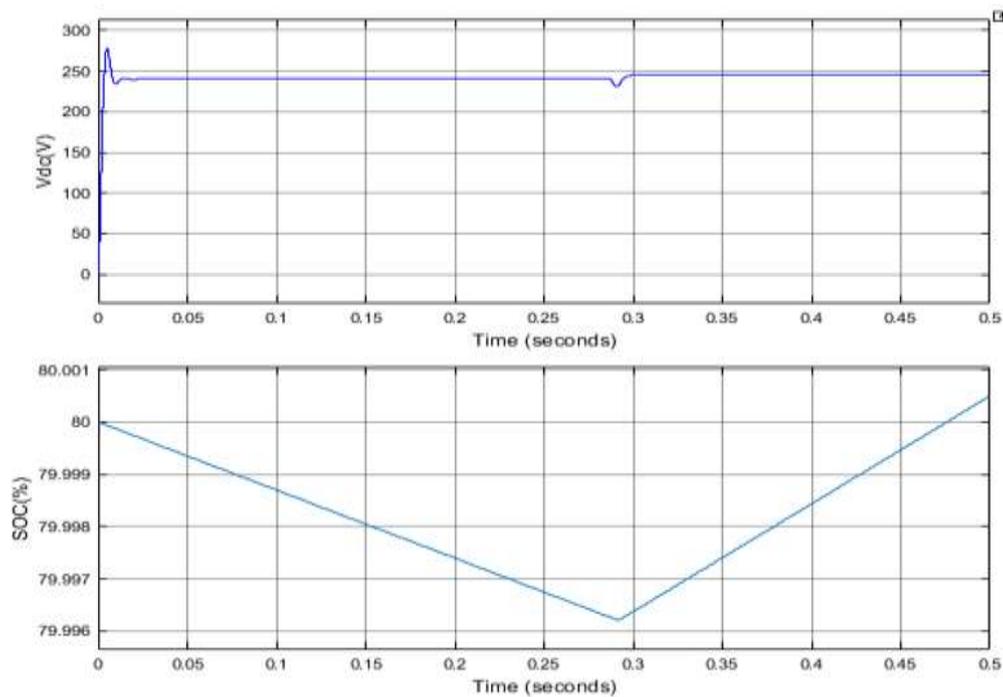
FIGURE 11 DC link voltage and SOC%
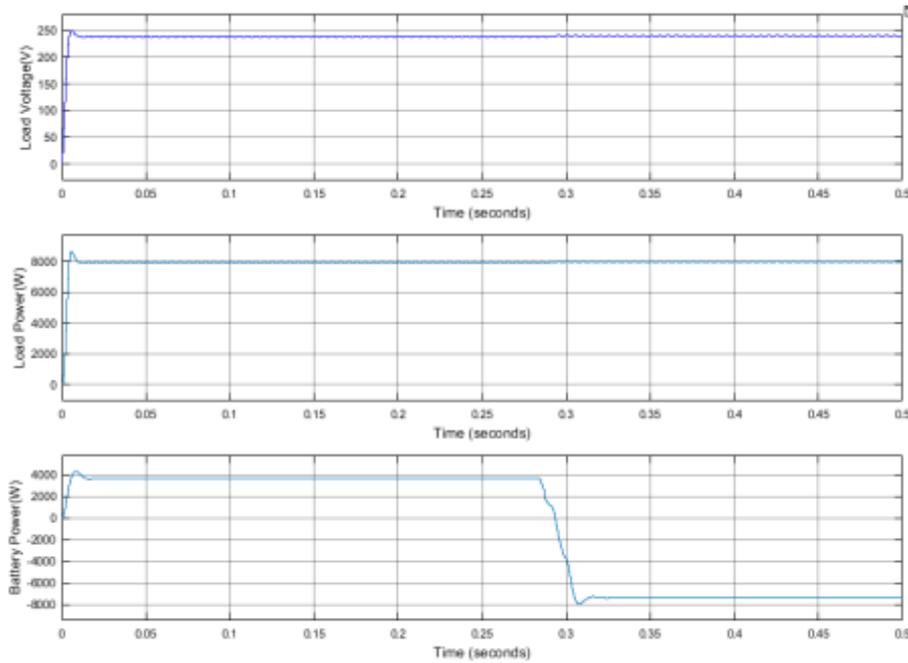
FIGURE 12 Load voltage, Load power and Battery power

5. Conclusion and Future work

In this paper, a novel Adaptive Neuro-Fuzzy Inference System (ANFIS)–based controller is proposed for the energy management of hybrid renewable energy sources connected to a smart grid through a DC-link voltage. The hybrid energy system integrated into the DC microgrid consists of a battery bank, wind energy generation, and photovoltaic (PV) sources. The source-side converters (SSCs) are regulated using an intelligent fractional-order PID (FO-PID) control strategy to maximize power extraction from renewable energy sources and enhance the power quality delivered to the DC microgrid. To improve the economic operation of the microgrid, wind and PV sources are prioritized over energy storage. The load-side converters are controlled using the proposed ANFIS-based control technique, which ensures smooth output power and uninterrupted service continuity. Simulation results obtained using MATLAB/Simulink validate the effectiveness of the proposed control scheme and demonstrate its superiority compared with existing nonlinear control approaches. Future work will focus on experimental validation of the proposed control strategy using a real-time test bench.

Conflicts of interest

The authors have no conflicts of interest to declare

References

1. Dinh HT, Yun J, Kim DM, Lee K, Kim D. A home energy management system with renewable energy and energy storage utilizing main grid and electricity selling. IEEE Access. 2020;8(1):49436–49450.
2. Byers C, Botterud A. Additional capacity value from synergy of variable renewable energy and energy storage. IEEE Transactions on Sustainable Energy. 2020;11(2):1106–1109.
3. Rizwan M, Hong L, Muhammad W, Azeem SW, Li Y. Hybrid Harris Hawks optimizer for integration of renewable energy sources considering stochastic behavior of energy sources. International Transactions on Electrical Energy Systems. 2021;31(2):e12694.
4. Sun Y, Zhao Z, Yang M, Jia D, Pei W, Xu B. Overview of energy storage in renewable energy power fluctuation mitigation. CSEE Journal of Power and Energy Systems. 2020;6(1):160–173.
5. Salameh T, Abdelkareem MA, Olabi AG, Sayed ET, Al-Chaderchi M, Rezk H. Integrated standalone hybrid solar PV, fuel cell and diesel generator power system for battery or supercapacitor storage systems in Khorfakkan, United Arab Emirates. International Journal of Hydrogen Energy. 2021;46(8):6014–6027.
6. Çolak M, Kaya Ä. Multi-criteria evaluation of energy storage technologies based on hesitant fuzzy information: A case study for Turkey. Journal of Energy Storage. 2020;28(1):101211.

7. Hannan MA, Hoque MM, Mohamed A, Ayob A. Review of energy storage systems for electric vehicle applications: Issues and challenges. Renewable and Sustainable Energy Reviews. 2017;69(1):771–789.

8. Amirante R, Cassone E, Distaso E, Tamburrano P. Overview on recent developments in energy storage: Mechanical, electrochemical and hydrogen technologies. Energy Conversion and Management. 2017;132(1):372–387.

9. Ma T, Yang H, Lu L. Development of hybrid battery–supercapacitor energy storage for remote area renewable energy systems. Applied Energy. 2015;153(1):56–62.

10. Wang X, Yu D, Le Blond S, Zhao Z, Wilson P. A novel controller of a battery–supercapacitor hybrid energy storage system for domestic applications. Energy and Buildings. 2017;141(1):167–174.