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AN ADVANCED INTELLIGENT NON-INTEGER CONTROL FOR SMART DCMICRO GRID UTILISING HYBRID WIND, PHOTOVOLTAIC, AND BATTERY WITH ENERGY MANAGEMENT SYSTEM

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ABSTRACT

The desire to depend increasingly on renewable energy for the production of electricity is growing due to factors such as rising energy prices, losses in the electrical system, concerns associated with nuclear power, and changes in the global environment. Nowadays, the majority of people want to live and work in smart locations, such as smart colleges and smart towns that integrate smart grid technologies. These smart grid systems rely heavily on hybrid energy sources, which makes energy management difficult. It is thus necessary to create an intelligent energy management controller. In order to create an intelligent energy management controller for a smart DC microgrid, the current research combines fuzzy logic with fractional-order proportional-integral-derivative (FO-PID) controller techniques. Three hybrid energy sources—a battery bank, wind energy, and photovoltaic (PV) energy source—are incorporated into the DC-microgrid. The novel intelligent fractional order PID approach controls the source-side converters (SSCs) in order to maximize power extraction from PV and wind energy sources and enhance the quality of power provided to the DC-microgrid. The microgrid places priority on wind and photovoltaic energy sources in order to save costs. Smooth output power and service continuity are guaranteed by the suggested controller. The given study compares the simulation results of the suggested control schema using Matlab/Simulink with the super twisting fractional-order controller.

Index Terms: fuzzy logic control, fractional order control, energy management, renewable energy, smart universities, DC-microgrid.

I. INTRODUCTION

Pollution of many kinds is produced worldwide during the manufacturing of electrical energy. The burning of fossil fuels releases emissions into the atmosphere, which are attributed to thermal power plants that use coal or oil. Conversely, nuclear power plants, whose growth accelerated in the wake of the oil crisis, have not adversely affected air quality. However, they also create radioactive waste, which poses significant challenges for processing, transportation, and storage. Renewable energies (hydraulic, wind, solar, biomass, etc.) are becoming more significant in the generation of electricity due to a number of causes, including the opening up of the electricity production market and the concern of relying only on one energy source with all of its hazards [1], [2]. Consumer energy demand is often not spread uniformly across time, which leads to issues with the phasing of energy generated against energy used.The equilibrium between production and consumption is necessary for the grid to remain stable[3]. Therefore, the pace at which renewable energies become more prevalent will depend on their involvement in these various services, which will be encouraged by the coupling of electrical energy storage systems with these clean energy sources [4].

Therefore, storage is essential to these sources' integration into the electrical grid. In addition to offering the grid operator a technological means of guaranteeing a real-time equilibrium between production and consumption, it permits the most efficient use of renewable resources by preventing load shedding in the case of excess output. Decentralized storage would also enable islanding of the resource's provided region, which would increase the resilience of the electrical grid when combined with local renewable production.

Additionally, if the electricity is provided during peak hours, a strategically positioned energy storage system (ESS) adds value to the supplied current and improves control over frequency and voltage, hence improving the quality of the power supplied and mitigating its fluctuation [5, 6].A new field of study is the combination of energy storage with renewable energy sources in stand-alone micro grids. In general, integrating several renewable energies—such as wind, solar, and tidal—is favored as it increases the energy storage system's maximum capacity. ESS is often made up of a battery and super capacitor combination, which helps prolong battery life and provides a quick system reaction to offset transients [7]. Supercapacitors are replaced by the AC grid because loads are required when all energy sources and battery storage systems (BSS) are linked [8]. Micro grids may be categorized as DC, AC, or hybrid systems. DC microgrids provide a number of advantages to AC microgrids, including easier integration, fewer controllable parameters, and a more straightforward design. However, AC type requires additional information, such as reactive power and frequency synchronization, which makes control design a difficult operation. Additionally, a DC microgrid provides the flexibility to operate in independent, integrated, or AC microgrid modes [9], [10]. The most recent advancements in power electronics allow the autonomous DC microgrid to operate at peak efficiency. However, a supplemental energy management unit is required for the energy-efficient operation and uninterrupted power transmission to the loads due to the stochastic nature of renewable energy sources. There are a lot of studies on energy management control for AC microgrids in the literature, however similar control techniques cannot be used for DC microgrids due to the significant dynamical differences between AC and DC microgrids. Actually, the load converters and the energy sources are linked in parallel in the normal DC microgrid architecture, with the DC-link serving as the conduit for either the supply or consumption of energy.

Therefore, for the DC microgrid to operate effectively and steadily, the DC-link voltage must be controlled [11], [12]. The literature has published a number of control solutions to deal with DC-link voltage problems. A summary of the most current advancements and trends in hybrid micro grid topology with energy resource planning and control is provided in [13]. To manage the DC voltage, a fuzzy controller and voltage control are integrated in [14]. A fuzzy logic control technique with fewer rules is examined in [15]. A dual proportional-integral controller is used in [16]. The aforementioned control methods, however, are linear and have a short operating time for DC-link regulation. Therefore, nonlinear controllers have been studied in order to get around this constraint.

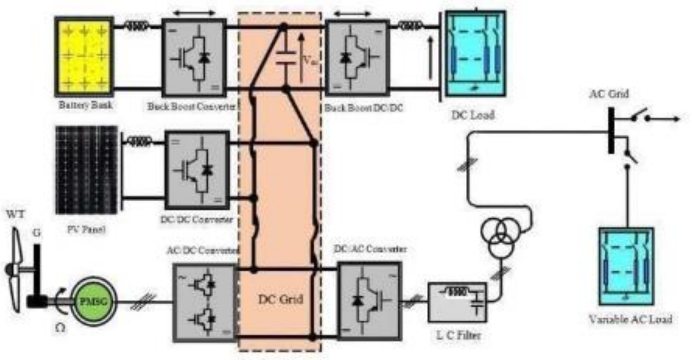


FIGURE 1. Studied hybrid system structure.

the works of literature. An approach for an adaptive droop controller is shown in [17]. In [18], various energy storage systems in a microgrid are examined using energy management based optimum control. A strong H∞ control approach is created in [19]. In [20], a robust sliding mode technique is suggested. A mechanism for adaptive backstepping control is proposed in [21]. In [22], a Lyapunov-based approach is provided. [23] discusses feedback linearization control. In [24], a hybrid controller that combines sliding mode and backstepping is examined. Unfortunately, the previously suggested nonlinear controls exhibit poor stability for the H∞ approach, chattering concerns with the sliding mode, and limits in performances in the case of the droop control strategy and optimum energy management. Additionally, a significant portion of these controls rely heavily on fixed gains, which are particularly susceptible to outside disturbances and uncertainty in the parameters.

The energy management unit is represented by the last section. To solve the issues with traditional integer controllers in hybrid energy management, a novel fractional order PID controller is developed in this study together with a fuzzy logic approach. Compared to integer order controls, fractional-order controllers provide more benefits, such as a large degree of freedom, robust behavior against oscillations, and measurement noise. The energy management unit is combined with the proposed new controller for a DC microgrid that is integrated with many stochastic sources and necessary DC demands, as shown in Figure 1. The energy management unit will work as the high-level controller, creating the proper references for the IFO-PID and keeping track of the power that is produced and consumed, while the suggested intelligent Fractional-Order PID (IFO-PID) controls will be used as a low-level controller. The two primary goals of this study are to manage the source-side converters (SSCs) in order to maximize power extraction from renewable energy sources (photovoltaics and wind) by using the suggested IFO-PID. The second objective is to use the energy management unit (EMU) to regulate the reactive power and the DC-link voltage to their references in order to enhance the power quality delivered to the DC-microgrid. The following is a summary of the current work's uniqueness and contribution:

- A fuzzy logic approach and the novel fractional order PID (FO-PID) controller are designed for a DC-micro grid integrated with many stochastic sources and necessary DC loads.

- The key feature of this approach is the extremely low number of fixed gains used by the proposed strategy which avoids its sensitivity to parameter uncertainties, which highly improves the robustness property and global stability of the system. • The global stability of the system is ensured and further validated by extensive simulation results. • The fuzzy logic method is chosen as a fuzzy gain supervisor to adaptively adjust gains of the FO-PID which greatly enhances the robustness of the proposed approach against various uncertainties external disturbances.

2. NONCONVENTIONAL ENERGY SOURCES

2.1 INTRODUCTION

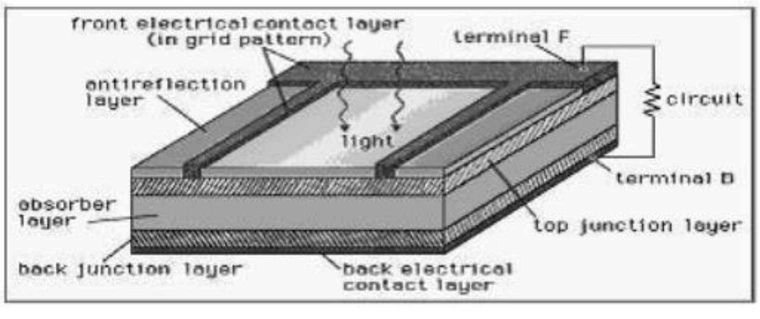
This chapter provides a short discussion of the project's non-conventional energy sources, including the wind, hydro, photovoltaic, and battery systems. with the essential terminology and background knowledge about them.

2.3 SOLAR PHOTOVOLTAICS

2.3.1 Introduction

Becquerel was the first to notice the photovoltaic effect, which converts solar energy. It is usually understood to mean that when light is shone on a solid or liquid system, an electric voltage appears between two electrodes linked to the system. Solar cells are energy conversion devices that employ the photovoltaic effect to transform sunlight into electrical current. A solar cell, or more broadly a photovoltaic cell, is a single converter cell. A solar array, or solar module, is a group of these cells intended to maximize the generation of electric power; this is how the term "photovoltaic arrays" originates.

2.3.2 Basics of Solar Cells



The overwhelming majority of solar cells are fabricated from silicon with increasing efficiency and lowering cost as the materials range from amorphous (noncrystalline) to polycrystalline to crystalline (single crystal) silicon forms.

3.BATTERY

3.1 Energy Storage

Power is a more versatile use of energy than other forms since it can be efficiently converted into other forms because to its remarkable organization. For example, it can switch between a 100% yield for hotness and a 100% yield for mechanical structure. However, since nuclear power is an arbitrary kind of energy measured in iotas, it cannot be converted into energy with great competence. Accordingly, a typical fossil nuclear power plant's overall warmth to electrical transformation competence is significantly less than half. Power's drawback is that it can only be stored for a vast scope with great effort. These days, almost all electricity used is handled at the point of production. In conventional power plants, where fuel consumption varies with heap, it is everything from a problem. Due to their unpredictable power sources, air and photovoltaics (PV) are unable to continuously provide the need for weight, 24 hours a day, 365 days a year. The following main classifications apply to current and future power storing innovations for backup wind or solar power structures:

- Batteries with electrochemistry

Air packed with a flywheel and a superconducting coil

3.1Types of Battery

There are at least six major rechargeable electro-chemistries available today. They are as follows:

- Lead-acid (Pb-acid) 27
- Nickel-cadmium (NiCd)
- Nickel-metal hydride (NiMH)
- Lithium-ion (Li-ion)
- Lithium-polymer (Li-poly)
- Zinc-air

4.MATHEMATICAL DESCRIPTION OF THE HYBRID ENERGY SYSTEM

Three main components of the hybrid energy system integrated smart DC-microgrid are depicted in Figure 1: the hybrid energy sources, which are made up of solar, wind, and battery storage systems connected to the DC-link via their respective converters. In the instance of a smart university, these loads may include laboratory experimental benches, fans, and lighting. The second section shows the loads that are thought to be a priority. Both the solar and wind power conversion systems utilize a maximum power point tracking algorithm to compel them to run at maximum power. To choose the appropriate control modes, the energy management unit computes the total energy generated and consumed.

A. WIND SYSTEM MODEL

The mathematical model of the wind power that can be transformed by the turbine is given by [25]:

$$
\begin{aligned}
P_m &= \frac{1}{2}\rho C_p(\beta,\lambda)Av^3\\
T_m &= \frac{P_m}{\omega_t}\\
C_p(\beta,\lambda) &= \frac{1}{2}\left(\frac{116}{\lambda_i}-0.4\beta-5\right)e^{-\left(\frac{21}{\lambda_i}\right)}\\
\lambda_i^{-1} &= (\lambda+0.08\beta)^{-1}-0.035\left(1+\beta^3\right)^{-1}\\
\lambda &= \frac{\omega_t R}{v},
\end{aligned}
$$

B. SOLAR POWER SYSTEM MODEL

The PV panel coupled to the DClink via a DC-DC boost converter makes up the solar conversion system (SCS). The following is the mathematical model for SCS:

$$\frac{dV_{pv}}{dt}=\frac{I_{pv}}{C_{pv}}-\frac{I_{Lpv}}{C_{pv}}$$

C. AC GRID MODEL

Buckto-buck converters, which are similar to wind and AC grid converters, are used (see Figure 7). Subsequently, the AC grid converter system's mathematical modeling may be described as follows:

$$\frac{dV_g}{dt} = \frac{I_g}{C_g} - \frac{I_{Lg}}{C_g}$$
$$\frac{V_g}{L_g} = \frac{dI_g}{dt} + (1 - U_4)\frac{V_{dc}}{L_g} - D_7$$

$$\frac{dV_{dc}}{dt} = (1 - U_4)\frac{I_{Lg}}{C_{dc}} - \frac{I_{Og}}{C_{dc}} + D_8$$

5. SIMULINK MODEL AND RESULTS

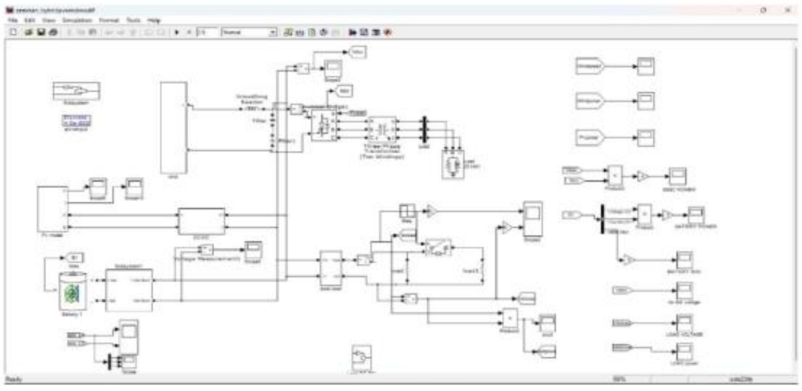


Fig-5.1 simulation circuit

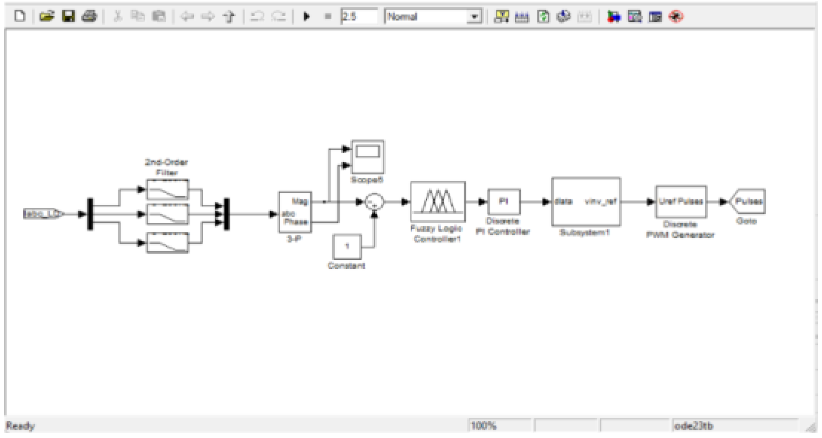


Fig-5.1.1 The above figure Simulink Model shows the combination of Fuzzy controller and Fractional-Order PID Controller.

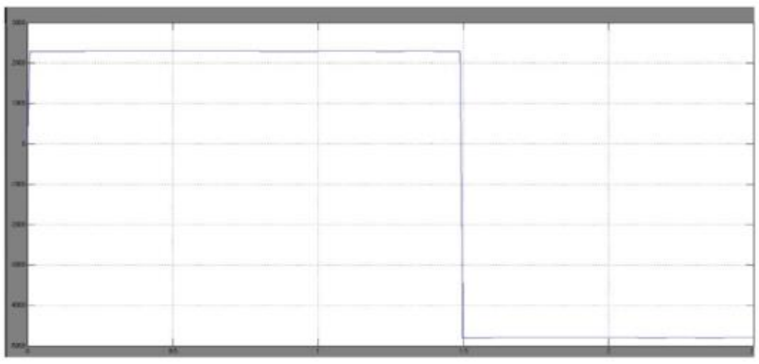


FIG5.2 -BATTERY POWER

The figure shows BSS power under random variations which is varying Between 5000 and -5000w. The battery supplies the microgrid with about 2300 watt in time intervals [0-1.4]s , The BSS works perfectly in this charge/discharge mode.

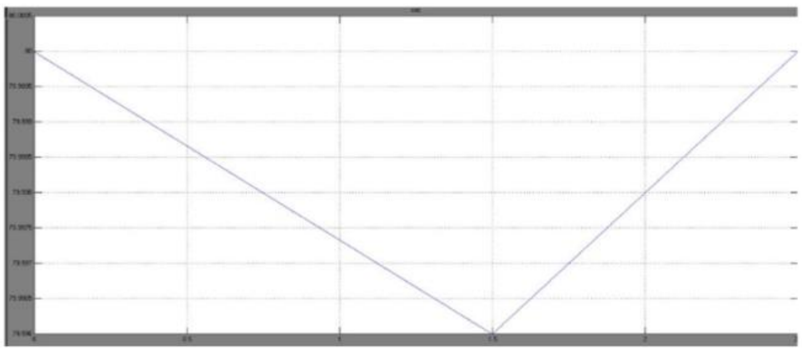
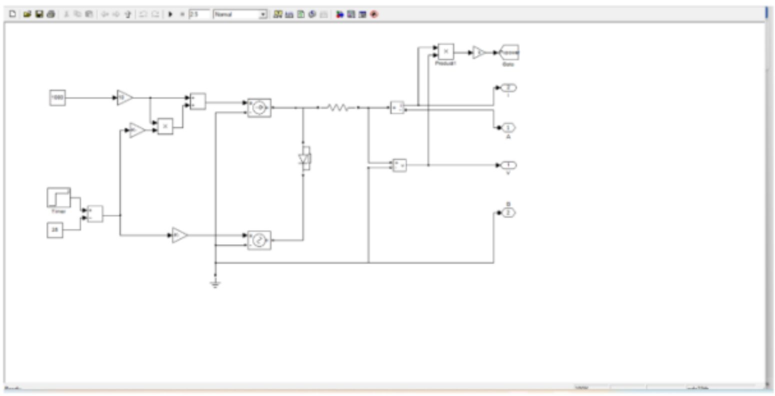


FIG 5.3-Battery SOC

The above figure shows battery supplies the microgrid with about 2300 watt in time intervals [0-1.4]s when SOC>20% While in time interval [1.4-2.3]s

SIMULINK MODEL OF PV PANEL:



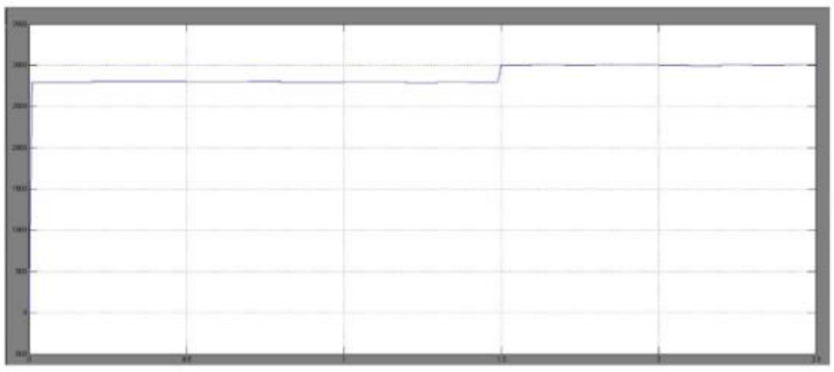
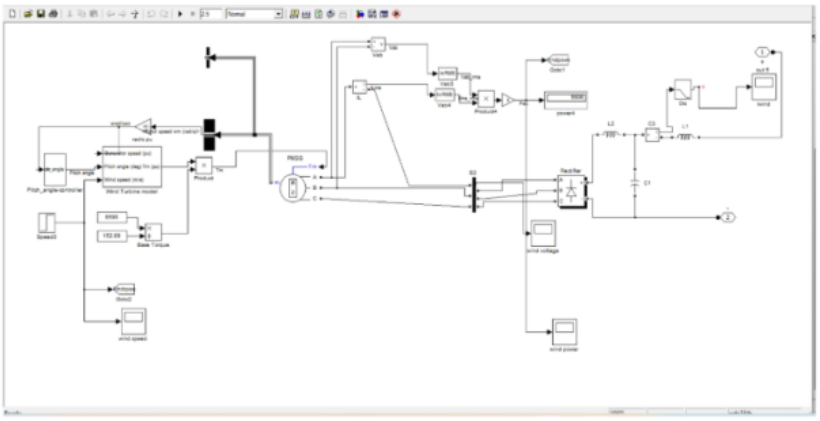


FIG 5.4 - PV POWER

The above figure demonstrates how MPPT control forces the PV panel tomaximum power regardless solar power variation.

SIMULINK MODEL OF WIND:



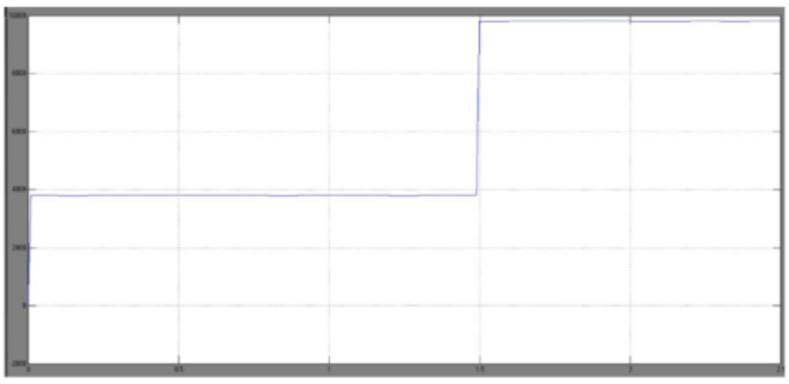


FIG 5.5 :WIND POWER

The above figure shows generated wind power varying between 4000 and 10000Watts according to wind speed

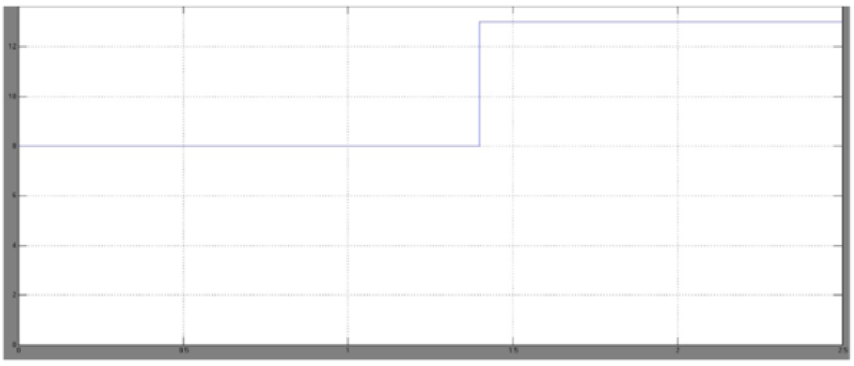


FIG 5.6: WIND SPEED

The above figure shows wind profile between 8-13m/s

6.CONCLUSION

In order to manage the energy of hybrid energy sources connected to a smart grid via a DClink voltage, a unique intelligent fractional order

PID controller is suggested in this study. Three energy sources make up the hybrid energy sources incorporated into the DC-microgrid: photovoltaic (PV), wind, and battery bank. In order to maximize power extraction from renewable energy sources (wind and photovoltaics) and enhance the quality of power provided to the DC-microgrid, the source side converters (SCCs) are controlled by the novel intelligent fractional order PID approach. The microgrid places priority on wind and photovoltaic energy sources in order to save costs. Smooth output power and service continuity are guaranteed by the suggested controller. The suggested control schema's simulation results using Matlab/Simulink are shown and contrasted with those of the other nonlinear controllers. Table 3 presents a thorough comparison study using super twisting fractional order control, FO-PID, and PID. It is clear from this research that the suggested method outperforms the other suggested control systems in terms of power generation and performance. According to the current comparison investigation, as compared to the PID control, the suggested controller generates +3.15% wind power, +50% PV power, +2.5% load power over the super twisting fractional-order, and more. The experimental validation of the suggested control on an actual test bench will be the main focus of future efforts.

7.REFERENCES

[1] Received June 24, 2021, accepted July 6, 2021, date of publication July 9, 2021, date of current version July 19, 2021. Digital Object Identifier 10.1109/ACCESS.2021.3095973Hybrid Wind/PV/Battery Energy Management-Based Intelligent Non-Integer Control for Smart DC-Microgrid of Smart University

[2] H. T. Dinh, J. Yun, D. M. Kim, K. Lee, and D. Kim, ‘‘A home energy management system with renewable energy and energy storage utilizing main grid and electricity selling,’’ IEEE Access, vol. 8, pp. 49436–49450, 2020.

[3] C. Byers and A. Botterud, ‘‘Additional capacity value from synergy of variable renewable energy and energy storage,’’ IEEE Trans. Sustain. Energy, vol. 11, no. 2, pp. 1106–1109, Apr. 2020.

[4] M. Rizwan, L. Hong, W. Muhammad, S. W. Azeem, and Y. Li, ‘‘Hybrid Harris Hawks optimizer for integration of renewable energy sources considering stochastic behavior of energy sources,’’ Int. Trans. Elect. Energy Syst., vol. 31, no. 2, 2021, Art. no. e12694, doi: 10.1002/2050- 7038.12694.

[5] Y. Sun, Z. Zhao, M. Yang, D. Jia, W. Pei, and B. Xu, ‘‘Overview of energy storage in renewable energy power fluctuation mitigation,’’ CSEE J. Power Energy Syst., vol. 6, no. 1, pp. 160–173, 2020.

[6] T. Salameh, M. A. Abdelkareem, A. G. Olabi, E. T. Sayed, M. Al-Chaderchi, and H. Rezk, ‘‘Integrated standalone hybrid solar PV, fuel cell and diesel generator power system for battery or supercapacitor storage systems in khorfakkan, united arab emirates,’’ Int. J. Hydrogen Energy, vol. 46, no. 8, pp. 6014–6027, Jan. 2021

[7] M. Çolak and Ä. Kaya, ‘‘Multi-criteria evaluation of energy storage technologies based on hesitant fuzzy information: A case study for turkey,’’ J. Energy Storage, vol. 28, Apr. 2020, Art. no. 101211.

[8] M. A. Hannan, M. M. Hoque, A. Mohamed, and A. Ayob, ‘‘Review of energy storage systems for electric vehicle applications: Issues and challenges,’’ Renew. Sustain. Energy Rev., vol. 69, pp. 771–789, Mar. 2017.

[9] R. Amirante, E. Cassone, E. Distaso, and P. Tamburrano, ‘‘Overview on recentdevelopments in energy storage: Mechanical, electrochemical and hydrogen technologies,’’ Energy Convers. Manage., vol. 132, pp. 372–387, Jan. 2017.

[10] T. Ma, H. Yang, and L. Lu, ‘‘Development of hybrid battery–supercapacitor energy storage for remote area renewable energy systems,’’ Appl. Energy, vol. 153, pp. 56–62, Sep. 2015.

[11] X. Wang, D. Yu, S. Le Blond, Z. Zhao, and P. Wilson, ‘‘A novel controller ofa batterysupercapacitor hybrid energy storage system for domestic applications,’’ Energy Buildings, vol. 141, pp. 167–174, Apr. 2017.