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Simulation and harmonic analysis of hybrid distributed energy generation based microgrid system using intelligent technique

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ABSTRACT

Wind and solar photovoltaic (PV) based hybrid renewable energy generation are environmentally friendly and reasonable. This study describes a hybrid distributed energy generations (DEGs)-based microgrid framework where DC-DC converter, three-stage inverter with fuzzy logics control (FLC), and LC filter channel are coupled with the PV and wind energy. In India, wind and PV energies are affordable for hybrid power frameworks since they are ecological well-disposed and broadly accessible. Generally, these sources produce a fluctuating yield voltage that prompts harm to the working grid on a steady inventory. The proposed model of the hybrid-based framework is executed utilizing MATLAB/Simulink. A boost converter being associated with PV cluster is associated with the basic DC bus also a battery is used by a two-way DC to DC converter, and connected into the utility framework by a typical DC to AC inverter. Wind cluster and PV is linked with maximum power point tracking (MPPT) to produce the higher capacity to the grid, and the charging and discharging of the battery energy can be done to adjust the energy between DEGs generation and utility network. In this paper, various cases of harmonic analysis are executed on MATLAB-simulation and feasibility of proposed grid models and FLC-based intelligent control.

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1. INTRODUCTION

To reduce ozone-depleting substances existence from the sources which produce electrical energy, the energy managers are heading towards the utilization of environmental friendly power sources or renewable energy sources [1], [2]. Recently, the electric energy area has been encountering an expansion into distributed generation-phase, and in this phase, microgrids have been accomplishing significance augmentation. Microgrids are made out of sustainable and traditional power frameworks, battery, and random demands that work under a framework control that could be processed in grid-connected or standalone mode. The number of sustainable power sources and distributed generators are increasing which require modern techniques and toolkits for the satisfactory operational activities of the power framework. In this examination, a separate microgrid containing sustainable energies or the renewable sources like wind and solar as well as battery is taken. Arrangement of microgrid comprises microgrid sources and other possibilities if these are not providing the total demand. In this study, a DC voltage hybrid framework with a primary power grid framework is being assembled with a pre-defined block set of photovoltaic model; inverter, wind model, and LC channel [3]. Diverse irradiance and changing wind speed are the criteria of inputting the information [4]. The result states that the hybrid framework has better dependability as far as yield voltage production when contrasted with the independent framework. Moreover, LC filters and three-stage universal bridge-based inverters that are introduced in the microgrid can lessen the change in yield voltage.

2. METHOD

2.1. Proposed microgrid system

Because of the random behavior of solar network and wind network, to get steady and reliable energy from the photovoltaic (PV) framework, a battery energy system is required for demand or utility grid [5], subsequently improves both the consistent and dynamic response of the entire production framework. A grid-associated PV battery generation framework is made out of PV clusters, battery, power electronic converters, filter, regulators, local burdens, and utility networks. The paper depicts about the point-by-point transient models of a lattice-associated PV battery crossover age framework. PV cluster is associated with the utility matrix by a lift converter and DC/AC inverter. Then, the battery is connected with the basic DC bus using a two-way DC to DC converter [6]. The proposed models of PV framework, battery energy storage systems (BESS) framework, and control framework are executed in MATLAB/Simulink. Three cases are simulated for the PV/battery framework, and all simulated results have confirmed the effectiveness of models and adequacy of control strategies solar system. Proposed microgrid system referred to in Figure 1.

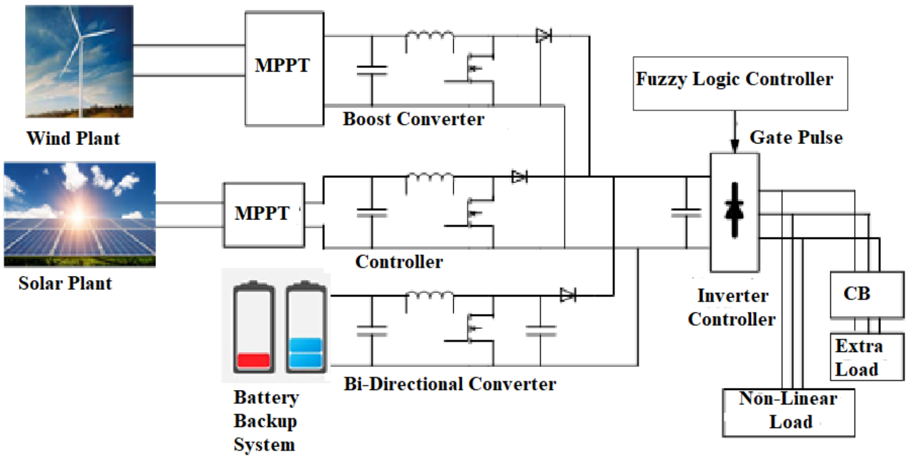

Figure 1. Framework of proposed solar-wind-battery based grid system

The hybrid solar wind-based-energy framework is connected with DC bus using a bi-lateral DC to DC converter. Fuzzy logic controller is being coupled into the utility grid-based inverter with LC-filters where a battery support has been provided. Isolated gate bipolar transistor (IGBT)-based boost converter is being connected to solar oriented PV array having perturbation and observation (P&O) method based maximum power point tracking (MPPT) strategy for maximum PV-power. The whole association of hybrid power frameworks is accumulated through a typical DC interface then a pulse-width modulation (PWM) IGBT based inverter utilized for DC to AC transformation which is control by the fuzzy logics control (FLC) and afterward further coupled through LC-filter. P&O strategy can change the perturbation as the real-time activity point changes; thus, both of the following speed and calculation exactness are fulfilled. At the point when solar-oriented irradiance or temperature varies, PV production will change this. A battery can be charged or release to keep up the energy balance between PV production and the requests, and subsequently improve the stability of the whole framework [7].

2.2. Solar system

Figure 2 calibrate and track the maximum solar DC output voltage is shown here which is being measured by a solar PV subsystem where solar PV cell output DC terminal is being connected with maximum MPPT algorithm block according to irradiation available at atmospheric condition [8]. Table 1 shows the solar data which has been considered in this study. MPPT strategy is used to find maximum output from the PV panel in Figure 3. There are several MPPT methods are available in the literature [9]. Figure 3 displays the simulated outcomes of the PV framework, as DC reference voltage computed by MPPT regulator, PV array yield voltage, yields current and yield power [10]-[12]. As we know that whenever the solar irradiance varies, the V-I characteristics of the PV array vary, and the MPPT is also modified. With various solar irradiances, the MPPT regulator can chase the MPP fast and always generate maximum power output from the PV array. In this study P&O is employed. Figure 3 shows the MPPT regulator with PV array [13], [14]. During 5-6 sec instant PV generation is zero because at that instant solar irradiance value is zero referred to in Table 1.

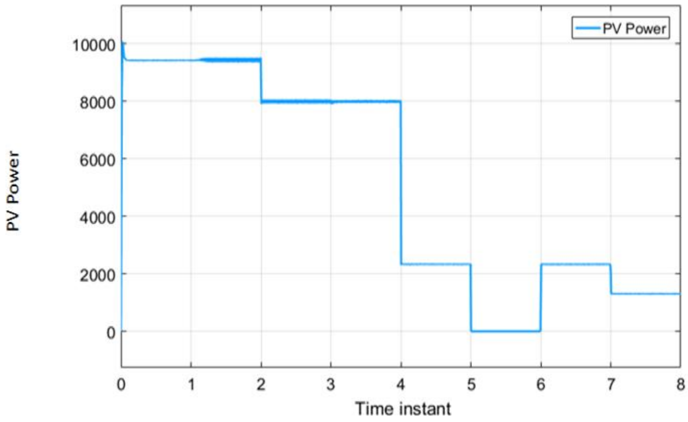

Figure 2. PV power generation

Table 1. Solar irradiance data concerning time instants

S. No.	Time instant	Solar irradiance(w/m^2)
1.	0	900
2.	2	850
3.	4	300
4.	5	0
5.	6	300
6.	7	200

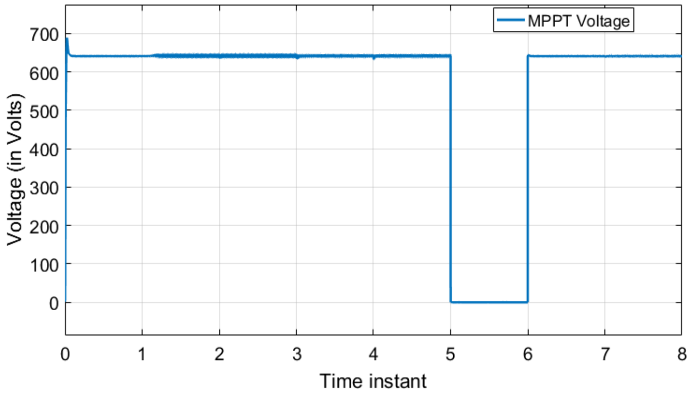

Figure 3. Characteristics of V_{MPPT}

2.3. Wind energy system

Table 2 showing the wind speed data for time [15]. Likewise, wind turbine comprises of three-stage AC alternator which creates the AC power additionally control by regulator circuit. This research represents the P&O-based MPPT for a stand-alone wind power conversion unit. This approach is requiring the wind turbine characteristics also associated with mechanical sensors [16]. The procedure of self-control is utilized to distributed operating points of the related system by adjusting the duty cycle of the coupled converter to monitor the variation on DC side power [17], [18]. The proposed system identifies the highest power and the shift of wind energy via the correlation between DC side power as well as the associated duty cycle of the buck converter. The ideal turbine yield power versus turbine speed graph showing that the best way to catch the greatest power from the variety of wind speed alluded in Figure 4 and Figure 5 also shows the wind MPPT regulator strategy [19] which is implemented in MATLAB.

Figure 6 shows the controlling strategy for the wind energy framework which controls the wind speed, mechanical force, mechanical inputting, and speed of the turbine [20]. The main objective of $P_{Turbine}$ analysis is to create flexible as well as fixed pitch angle and wind turbine simulator [21]. The analytic subsystem has been developed demonstrating the nominal power, to illustrate the model calculations using a MATLAB/Simulink [22], [23]. The subsystem is modeled to validate the efficiency of the static-pitch angle at a specific rotator speed [24]. In Figure 6, maximum wind speed of 12 m/s achieved at 1.1 sec instant.

Table 2. Wind speed data for time instants

S. No.	Time instant	Wind speed (m/s)
1.	0	6
2.	1	12
3.	3	9
4.	5	0
5.	6	5
6.	7	6

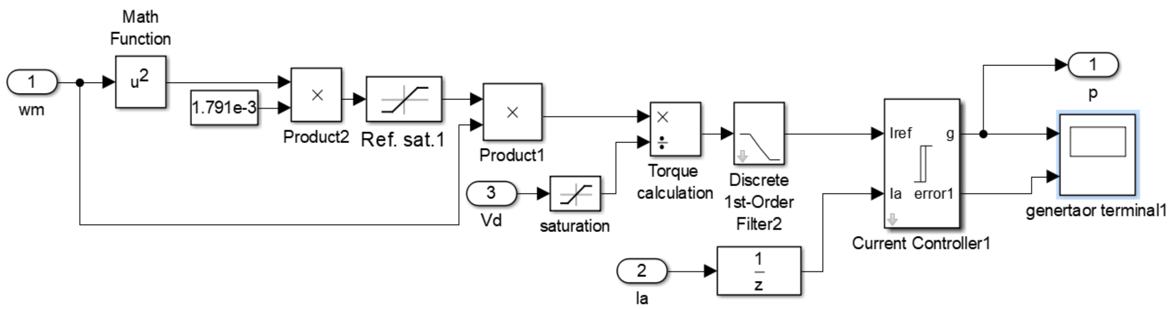

Figure 4. Internal circuit of P&O based MPPT for wind energy subsystem

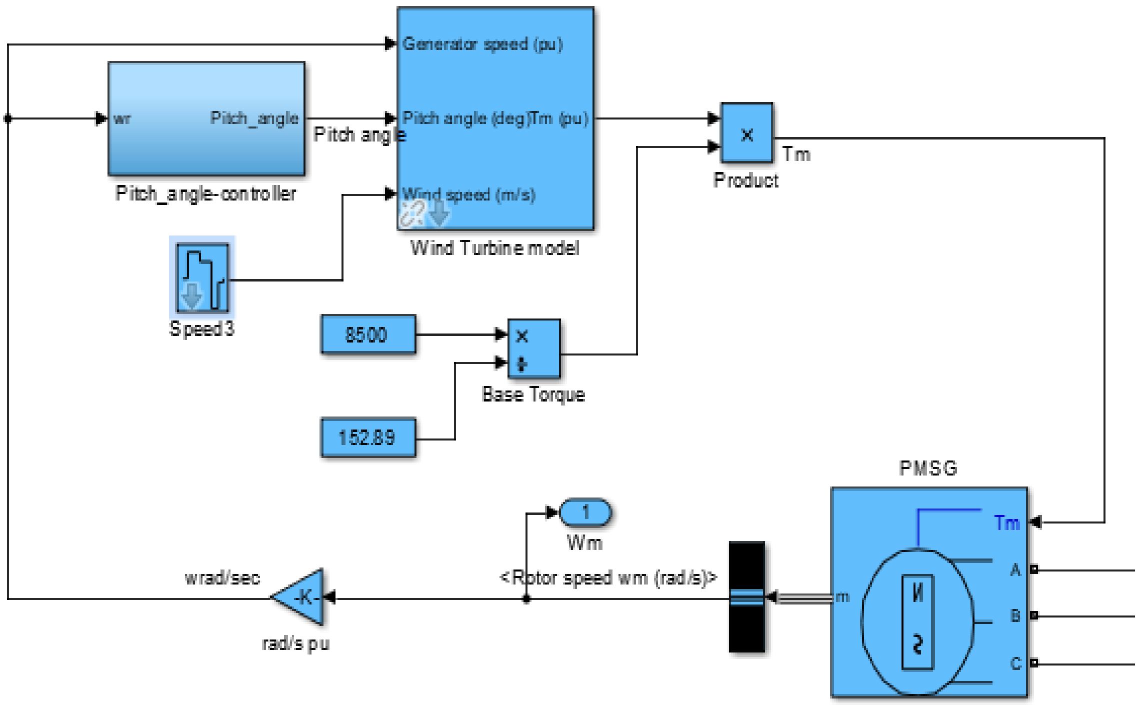

Figure 5. Mathematical modeling of wind subsystem model in MATLAB

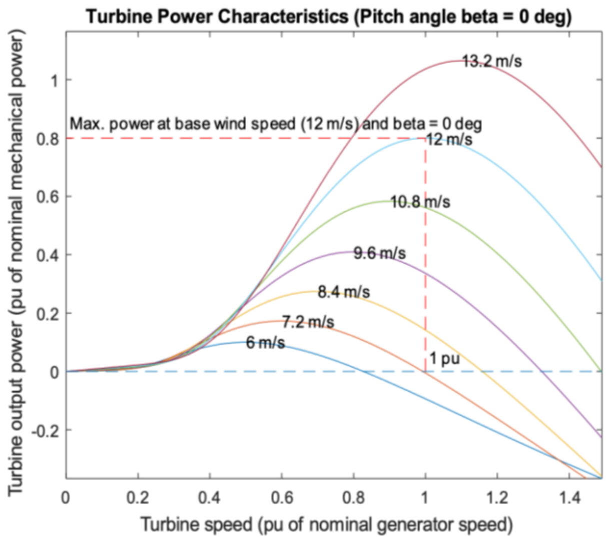

Figure 6. Characteristics of $P_{Turbine}$ with β=0 degree

2.4. Battery backup system

In Figure 7, the battery is charging and discharging based on the required generation to maintain the load level. The state of charge (SOC) is high during 3-4 sec, due to the battery supplying the power to load and start decaying after that. Figure 8 shows the battery subsystem MATLAB model, which is combined with a fundamental energy framework utilizing a three-stage inverter circuit. That battery framework accumulation the energy during normal force framework activity [25]-[27] and use this collected energy during unusual atmospheric condition at which wind or irradiance-based PV framework not accessible.

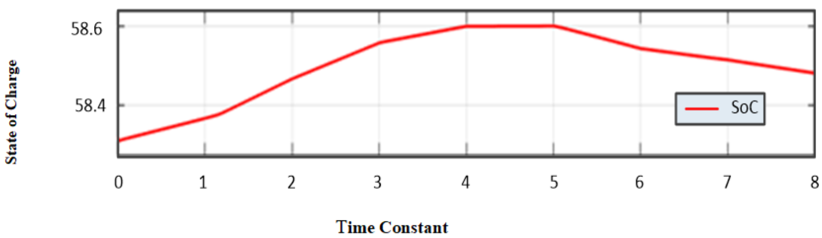

Figure 7. SOC of battery backup source

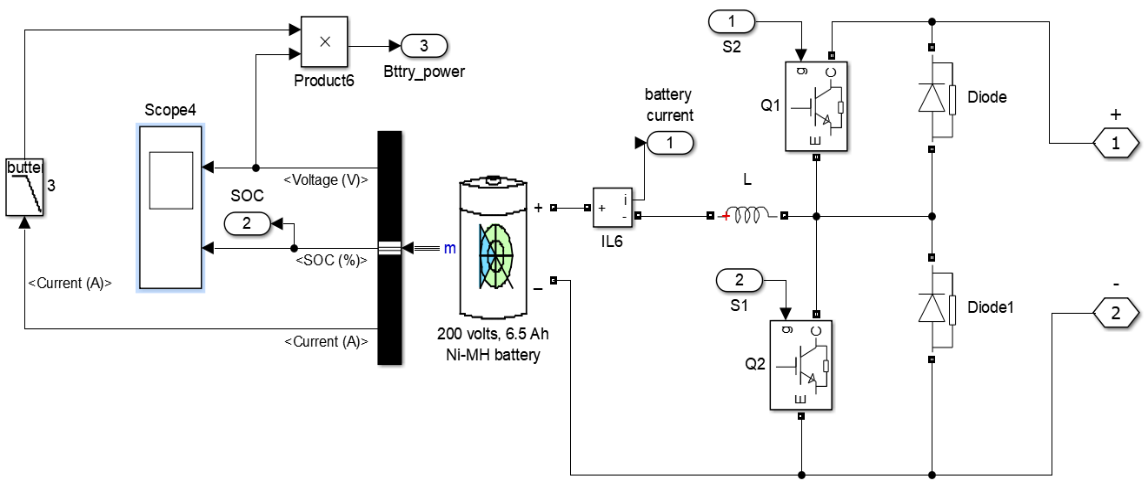

Figure 8. Simulation of battery backup system

3. RESULT AND DISCUSSION
3.1. Fuzzy logic based PWM inverter control

Fuzzy logic control is a control technique dependent on the fuzzy rationale, where it includes four phases which comprise of knowledge base [28], interference mechanisms, and defuzzification. The fundamental motivation behind this task is to perform concentrated on fuzzy rationale control for a three-stage LC filter to lessen whole harmonic distortion. Here Mamdani inference method and centroid defuzzification are employed.

An FLC is employed the IF and THEN rule base that are associates with a situation further termed as linguistic-based variables [29]. These variables are set to a gate pulse output for the PWM inverter. If a part is primarily utilized to gain expertise by utilizing the flexible environments, and the THEN component can be used to provide the estimation in the proposed linguistic variable form [30], [31]. Thus IF-THEN rule is commonly applied by the FIS to calculate the error of input variables to desired output variables based on the appropriate rule-based. Figure 9 indicates simulated FLC model Toolbox in the MATLAB simulation. That has 2 inputs (error and change in error). Figure 10 shows the proposed FLC system with desired output for PWM inverter gate pulse [screen preview of MATLAB r2016a].

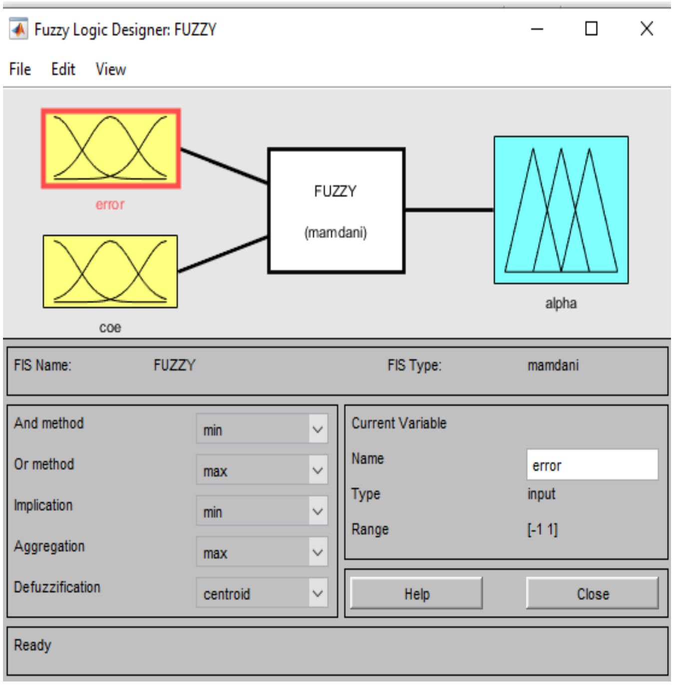

Figure 9. Indicates simulated FLC model toolbox in the MATLAB simulation. That has 2 inputs (error and change in error)

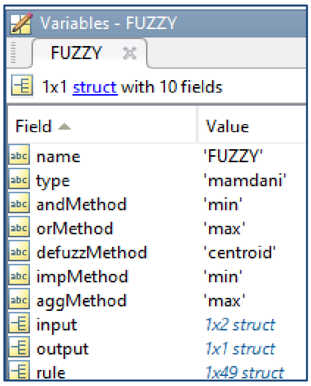

Figure 10. Shows the proposed FLC system with desired output for PWM inverter gate pulse

3.2. Simulation result

The simulation model of the proposed model system is referred in Figure 11. At the time duration of instant (0-1 sec), solar power is being supplied to the load while wind generation is zero. And battery source is in a charging state. During 1-2 sec, both solar and wind power are supplying to maintain the load. Thus, the battery backup source is again in the charging mode.

In Figure 12, during 2-3 sec, again both solar and wind generations supplying the power to load. In the duration of 3-4 sec, sudden load level increase, both solar and wind generation is sufficient to supply the power, while battery source is in charging state. Now, in 4-5 sec, solar generation is zero, at that instant wind source is capable to maintain the load level, also the battery backup source delivering the power to load (battery in discharging stage). At 5 sec and 6 sec instant, both solar and wind are tending to zero, so that only battery backup source delivering the power to continue to maintain the associated load. In 6 sec, solar power is increasing but still wind generation is zero, so that battery backup and solar supplying the power to maintain the load level. In the last duration (7-8 sec), solar generation is increasing, and the wind plant is also generating the power at that moment battery again in charging state. In Table 3, The power responses and charging/disharging state of battery backup system has been shown. In Table 4, total harmonic distortion (THD) values lying in specified limit in every instant, which is less than 5% value, fulfil the IEEE standards. In instant 1-2, THD is higher than another instant due to switching of sudden high load and drastically changes charging states.

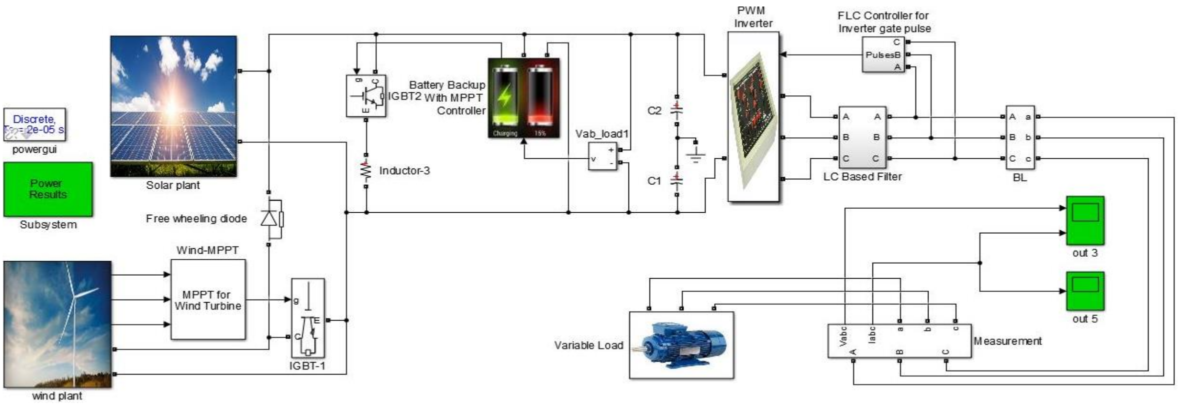

Figure 11. Proposed hybrid DEGs based microgrid system using FLC in MATLAB simulation

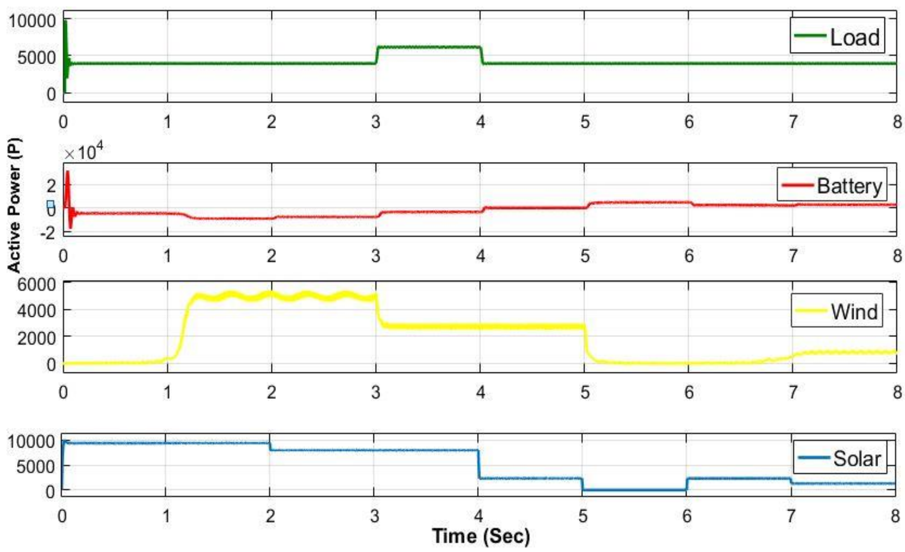

Figure 12. Characteristics of generating power (solar and wind) and battery backup power vs. load power

Table 3. Instant 1, 2, 3, 7, 8 (charging state) and instant 4, 5 and 6 (discharging state) & the load value is maintained at each instant by hybrid distribution and battery backup storage as referred to in Figure 11

Sub System	at Instant 1	at Instant 2	at Instant 3	at Instant 4	at Instant 5	at Instant 6	at Instant 7	at Instant 8
P_L	4.896x10^3	4.869x10^3	5.89x10^3	5.80 x10^3	4.78 x10^3	4.99 x10^3	4.78 x10^3	4.56 x10^3
P_B	-0.84 x10^3 (Charging)	-1.06 x10^3 (Charging)	-0.70^{3}x10^3 (Charging)	0.44 x10^3 (Discharging)	0.67 x10^3 (Discharging)	1.34 x10^3 (Discharging)	-0.87 x10^3 (Charging)	-0.33^{3}x10^3 (Charging)
P_W	0..55 x10^3	7.28 x10^3	6.28 x10^3	3.52 x10^3	3.67x10^3	0.44 x10^3	0.36 x10^3	1.23 x10^3
P_S	8.46 x10^3	8.14 x10^3	6.34 x10^3	6.25 x10^3	2.34 x10^3	0.35 x10^3	3.34 x10^3	2.45 x10^3

Table 4. Overall power quality analysis of proposed grid system using FFT

THD of load	THD value (in %) at each duration							
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
V_L	3.35%	4.88%	2.34%	3.44%	3.34%	2.10%	3.20%	2.44%
I_L	3.67%	4.50%	2.90%	3.10%	3.35%	2.95%	3.50%	2.80%

The harmonics exist and pass through the power line, but these limits must be within the definite range, these values are directly affecting the overall power quality in such a manner that reactive power and real power must be preceded. These quantities further relate with the THD using fast fourier transformation (FFT) analysis. In Figure 13, THD is noted "3 sec to 5 sec", which is 3.60% (within the limit of IEEE standards) with the help of FFT analysis in the MATLAB simulation tool. For future work, proposed system can be implement another controller such as fractional fuzzy logic [32], fractional PID, and integral tilt derivative controller [33]. Thus, proposed simulation successfully validated the results that are accessible to support the proposed FLC based control of optimal utilization of hybrid renewable energy (HRE) system strategy under intermittent nature of energy resources.

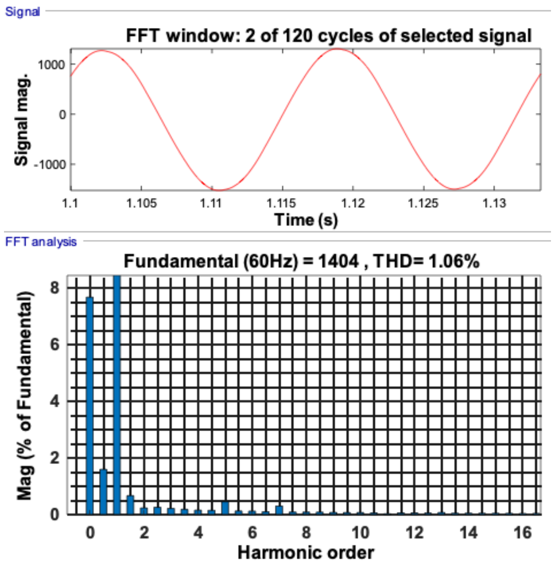

Figure 13. Simulation of THD of load voltage (V_L)

4. CONCLUSION

In this study, the Simulink-based study and test has been conducted which verifies the operational activity of PV-wind framework. It employs an independent inverter which works as a microgrid generating network in all the modes that may be grid-connected mode or independent (standalone) mode. A sustainable power framework is presented here which ultimately is co-related to photovoltaic and wind. The microgrid power framework exclusively relies upon the random sustainable power sources produces a fluctuating yield voltage that is detrimental and damaging the machines that work on a steady stock. The arrangement of the microgrid network with PWM converter, LC channel and three-stage inverter are fabricated with the help of MATLAB Simulink. The task simulation has an input of variegated irradiance of solar energy and varying wind speed. There is likely to be more steady and stable outcomes in the microgrid framework as far as yield voltage generation is concerned. Moreover, diode clamped multi-level inverter and LC-filter that is introduced in the microgrid can lessen the disturbance output voltage.

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