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Article Title: An Enhanced Voltage Control Strategy with DC Microgrid for EV Stations

An Enhanced Voltage Control Strategy with DC Microgrid for EV Stations

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ABSTRACT

Growing energy demand and fossil fuel scarcity have led to significant advancements in electric vehicles (EVs) and renewable energy generation. The grid's ability to function may be severely impacted by the massive amount of electricity that electric vehicles use when grouped together at a charging station. On the charging station side, installing renewable energy is therefore thought to be a promising win-win solution. Using a photovoltaic (PV) system and a wind energy system based on distributed flexible inverter generators (DFIG), this project aims to develop a novel control mechanism for a micro grid configuration. Building a reliable and effective energy ecosystem is the main objective. Initially, the GWO-PI controller is used to optimize the power produced by photovoltaic sources. The energy that has been harvested is then mixed with the DFIG's output. However, the incorporation of renewable energy sources poses issues with power quality and harmonics in the micro grid. Initially, they offer a dependable power source to numerous electric vehicle (EV) charging stations. Variations in frequency or voltage can put stress on the parts of the charging station, which could result in wear and tear. In addition, the consistent DC power is employed to support diverse DC loads, guaranteeing effective energy management throughout the micro grid. A sophisticated PI control system is put in place to deal with these problems. Simulink and MATLAB 2021a are used to simulate and validate the proposed method.

Keywords: Electric Vehicle (EV), Photovoltaic System (PV), Maximum power point Tracking (MPPT), Fuel Cell (FC).

1 Introduction

Everywhere there is a concern for protecting the environment, there is a focus on developing technologies that will provide clean energy. Sources such as solar PV, ultra capacitors, batteries, etc. are used in place of traditional fossil fuel in vehicles such as cars, trucks, buses, ships, etc. In order to supply dependable power for "Electric Vehicles (EVs)," a "Hybrid Energy System (HES)" that integrates multiple energy sources is preferable. Power is delivered from the input sources into the loads of the EV by a power electronic converter, which is crucial to the integration of HES [1]. HES typically uses single input, single output, and parallel-connected DC-DC converters. Each parallel-connected system's dedicated reactive elements,

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semiconductor switches, and controller cause the system's size, cost, and complexity to grow. The introduction of 'Multi-Input single output DC-DC Converters (MICs)' aims to address these undesirable aspects. There are two primary categories for MICs: isolated and no isolated topologies [2]. High frequency transformers are used in isolated topologies to provide isolation, and multiple windings within the transformer's core can be used to interface multiple input sources. Two or more converter stages separate the input sources and the load in isolated topologies. It takes multiple semiconductor switches to operate these converters [3]. These switches therefore result in high costs, increased losses, and massive sizes. Because of the aforementioned disadvantages, isolated MICs become less appealing in certain applications. Over the previous 15 years, numerous non-isolated MICs have been reported [4]. It is reported that power is transferred from the input sources into the load simultaneously and independently by an improved MIC buck topology. The majority of acknowledged buck-boost converters can function in all three modes—buck/boost/buck-boost—by employing identical structures and managing their switches appropriately [5]. However, the energy is transferred from the sources to the load using two inductors and two capacitors. Despite the buck-boost converters' ability to function in boost mode, certain topologies prevent a wide range of output voltage. Additionally, a few topologies need more switches in order to carry out the boost function. Combining two single input boost converters yields the MIC boost topology [6]. Here, two input sources are integrated via the use of two inductors. A voltage accumulator consisting of a switched diode and capacitor is the foundation of a new boost MIC converter. Two inductors and five capacitors are used to combine the two input sources. The inductor cannot be charged by the second source alone, and the second input source's negative polarity contributes to increased voltage stresses on the switches [7]. A greater number of components are used in these MICs, and some of those MICs have the ability to transfer power from the connected input source simultaneously. DC-DC converters with two inputs and a high DC voltage gain. Even with that high DC voltage gain, those converters use more reactive parts. Furthermore, some converters do not allow power transfer between the input sources, V2G, V2V, etc. The power system is subject to a significant load from EVs and their charging systems, so it is important to view them as an integrated active power resource rather than just a passive load [8]. To enhance the state of the grid, EVs and RES might alter their patterns of electricity generation or consumption. Energy from EVs and RES combined with battery energy storage (BES) allows for a reduction in the reliance on fossil fuels for the production of electricity, which in turn benefits the transportation industry [9]. There are not many decades left to advance the electric generation technologies of the present and future within the power systems in order to meet the goals set forth in the Paris Agreement. Definitions of the challenges of the future power system framework and emerging changes in the current power system are necessary in order to comprehend the goals of this research project [10]. The list below demonstrates how the paper is organised: Section I gives a description of the introduction. The

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recent works are described in Section II. The proposed model and description are explained in Part III. The results are presented in Section IV. In Section V, the conclusion is presented.

2 Recent Works

Ankit Kumar Singh *et al* [2020] [11] have created a dual power source power electronic converter (PEC) that can be used for both grid and solar photovoltaic (PV) charging of plug-in electric vehicles (PEVs). All vehicle modes (charging, propulsion (PP), and regenerative braking (RB)) were achieved by the developed configuration. When the car is at rest, the grid either charges the battery or the grid and solar PV system both charge the battery at the same time. RB operation can also be used to charge the battery while the vehicle is in running mode by harnessing the kinetic energy of the wheels. When charging solar PV, the suggested converter functions as a non-isolated SEPIC, but when charging plug-in (PIC) mode, it functions as an isolated SEPIC. Additionally, the suggested PEC operates as a conventional boost converter and conventional buck converter in the PP and RB modes, respectively.

Matthieu Amyotte *et al* [2020] [12] have proposed the distribution of energy resources, resulting in systems that are more intricate and require more power converters. For the purpose of assessing reliability and finances, large and microgrids alike require accurate converter loss prediction. Current system-level analysis assumes fixed efficiency of converter losses, oversimplifying them in the process and concentrating on distribution losses. Converter losses, however, vary greatly depending on the operating environment. Furthermore, multidomain simulation tools that are sold commercially are too slow to be used for system-level analysis. The rapid loss estimation (RLE) equation is proposed to provide computationally simple loss prediction under all operating conditions. First, the converter's actual operating conditions for the intended application are ascertained. Subsequently, precise loss data is obtained from intricate converter behavior in multidomain simulations.

Alireza ramyar *et al* [2021] [13] have presented a reversible linear emulator for photovoltaic modules set up for differential diffusion charge redistribution that includes an analogy controller. It is demonstrated that cell mismatch and partial shading are equivalent, and that two distinct continuous-time circuits coupled by feedback and constraints can represent the averaged behavior of these switched-capacitor solar photovoltaic modules. This emulator design is then demonstrated through a hardware prototype. With just one module-level converter, differential diffusion charge redistribution is a switched-capacitor architecture that uses differential power processing to achieve maximum power point tracking with cell-level granularity. Preventing damage to the integrated circuits embedded in the modules for the corner cases during fault and failure testing of connected hardware components, such as power converters, is one of the prohibitive challenges.

Hamid Reza Baghaee *et al* [2019] [14] have introduced a new anti-islanding protection scheme for LV VSC-based microgrids that takes advantage of SVMs' powerful classification capability. The sensor monitors seven inputs measured at the PCC, including the RMS value

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of voltage and current (RMSV, RMSI), THD of voltage and current (T HDV, T HDI), frequency (f), and active and reactive powers (P, Q). Since this approach is based on passive monitoring, it does not affect the PQ. To cover as many scenarios as possible, minimize false tripping, and remain selective, training and detection procedures are simply introduced. Based on the presented sampling method and input model, the proposed method is tested under various scenarios, including PHEV rapid charging, adding it.

Rohini Sharma *et al* [2020] [15] have proposed an algorithm for adaptive control to optimize the distributed generations (DGs) in an islanded micro grid. Compared to traditional LMS control, the approximate multiplier least mean square (AMLMS) control scheme performs better by extracting the fundamental load component with a lower steady state error and faster convergence. This control adds multipliers to the finite impulse response (FIR) filter and updates the coefficients with the goal of reducing the complexity of the LMS. When feeding nonlinear load into an islanded micro grid system, the AMLMS control algorithm for a voltage source converter (VSC) is also effective at compensating harmonics for an improvement in power quality (PQ).

3 Proposed Work Explanation

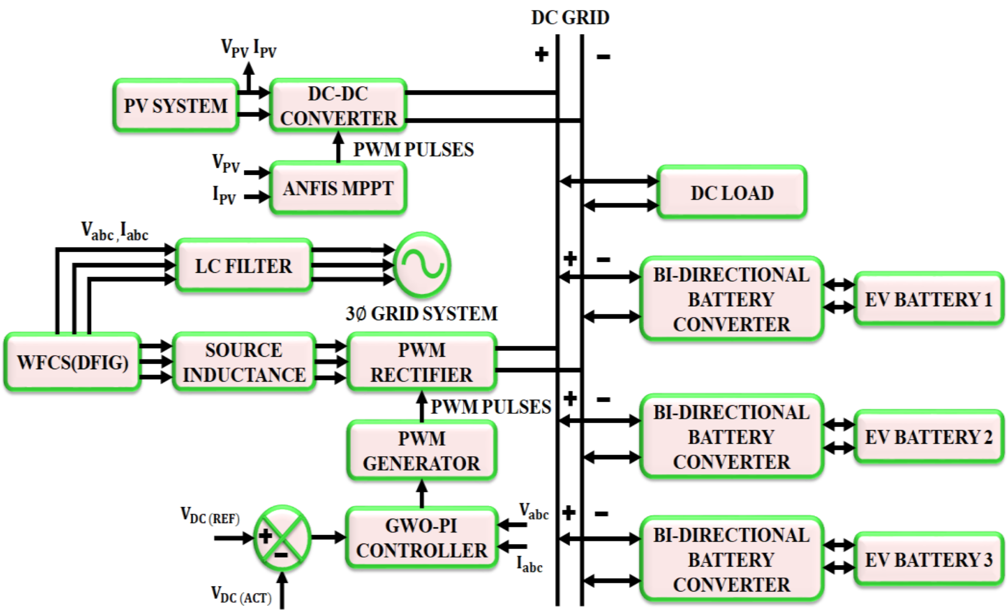

Figure 1: *Proposed Block diagram*

A number of energy sources, including photovoltaic (PV) panels, energy storage systems, and DFIG, are used in this proposed micro grid-based EV charging system. The GWO-PI controller is used in the first phase to optimize the power produced by photovoltaic sources. Subsequently, the energy harvested is mixed with the DFIG output. However, the micro grid's harmonics and power quality are put to the test when renewable energy sources are integrated.

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Initially, a GWO-PI control system is put into place to supply multiple electric vehicle (EV) charging stations with a dependable power source. Variations in voltage can put stress on the parts of the charging station, which could result in wear and tear.

The project uses GWO optimized PI controller settings to lower harmonics and preserve power quality in order to address harmonic issues within the micro grid. In addition, the consistent DC power is employed to support diverse DC loads, guaranteeing effective energy management throughout the micro grid. In addition to extracting the sine wave signal from the square wave, the LC filter eliminates noise from the system. A simulation model developed using MATLAB and a laboratory prototype are examined to determine how well the proposed layout functions in terms of efficiency and dynamic compensation. The outcomes of the simulation aid in assessing a proposed system's effectiveness and pinpointing its shortcomings.

3.1 PV system

The PV uses the heat or light energy it receives from the sun to convert daylight into DC power. Photons, which are particles of light, fall upon the solar panel. Through the photovoltaic effect, light is converted into electricity by the solar panel. The process that causes a photovoltaic cell to produce voltage or current when it is exposed to sunlight is known as photovoltaic effects. Solar cells with semiconductor qualities make up a solar panel. The PV cluster is made up of several solar cells that are linked in parallel and series to achieve the required voltage and current. Numerous atmospheric factors, including cloud cover, temperature, resistance, and solar intensity, have a significant impact on the PV array's output.

3.2 ANFIS MPPT Controller

The development of the highly intelligent and versatile hybrid system known as ANFIS is the outcome of the flawless cooperation between Adaptive Neural Networks (ANN) and Fuzzy Inference System (FIS). The fuzzy rule sets that the FIS derives from the ANN's learning capacity help with parameter optimization. When the ANFIS technique is used for MPPT operations, the FIS-based MPPT is driven by the ANN, which has been trained to assess the ideal MPP.

There is little chance of getting the best performance because the modelling of the traditional FLC is trial and error based. Consequently, learning with ANFIS can yield membership functions and fuzzy rules. First, the trained data should be gathered. The following steps must be taken in order to obtain the trained data:

- Conventional MPPT algorithms were utilized to simulate the system under varying solar radiation and temperature conditions.
- A MATLAB code specifically designed for this purpose was used to gather and manipulate the data in order to obtain the desired results.
- After that, the altered data were shuffled. After another filtering, only the unique rows from the data collection are retained in the results data.

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3.3 PWM rectifier

A PWM rectifier's main job is to change the alternating current (AC) that the wind turbine generator produces into direct current (DC). Variable-frequency AC power produced by wind turbines can be converted to DC for improved control and grid compatibility. PWM rectifiers provide accurate control, which is necessary to keep the DC voltage level constant even in the event of wind speed variations, making the power source more dependable. PWM rectifiers are known for their quick and dynamic response times. They can quickly adjust the output voltage and current to match variations in wind power.

4 Result and Discussion

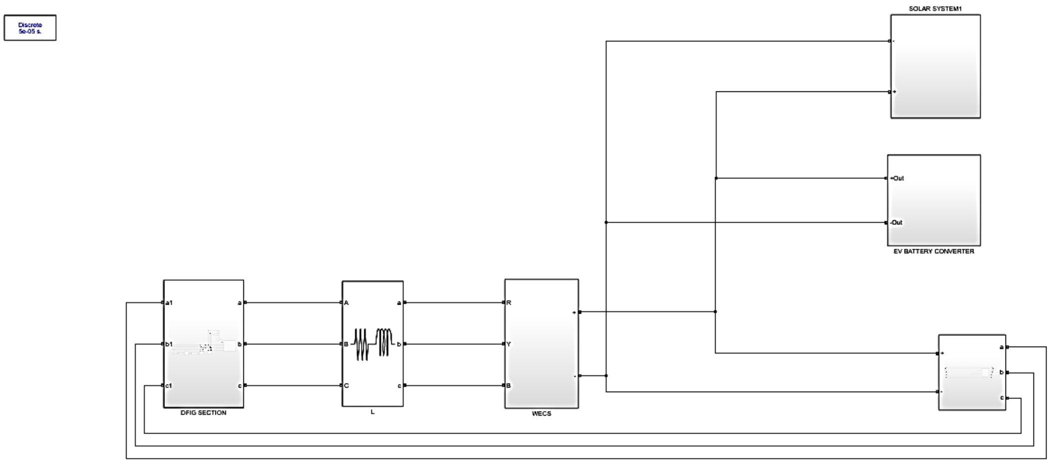

Figure 2: *Over All Matlab Simulink View*

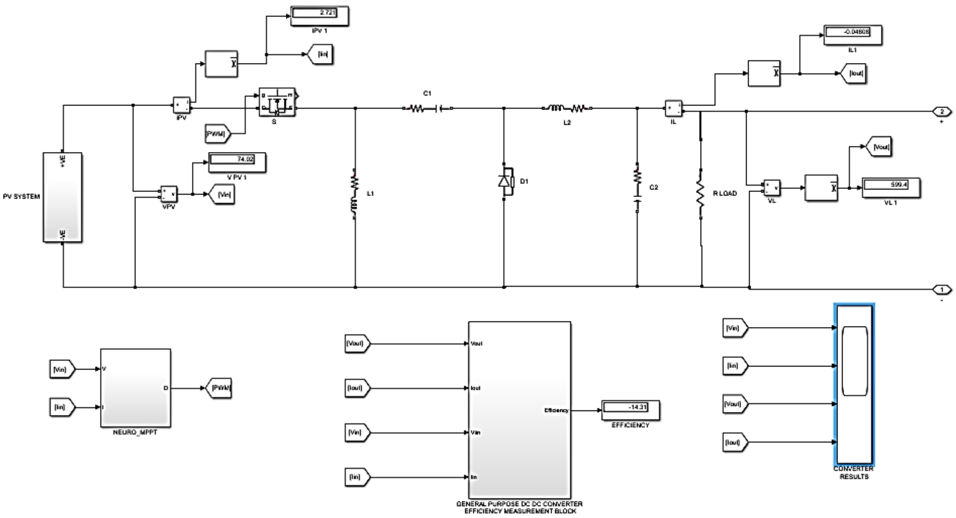

Figure 3: *Solar with Luo Converter*

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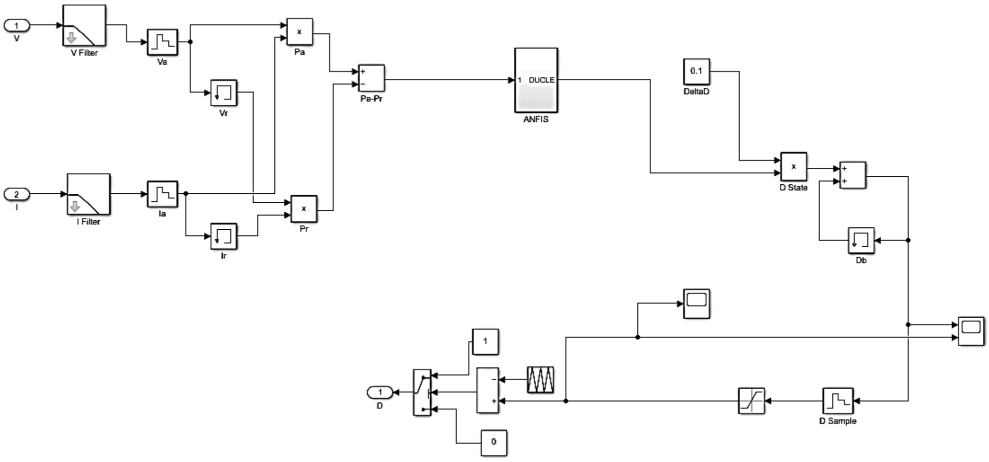

Figure 4: *ANFIS MPPT*

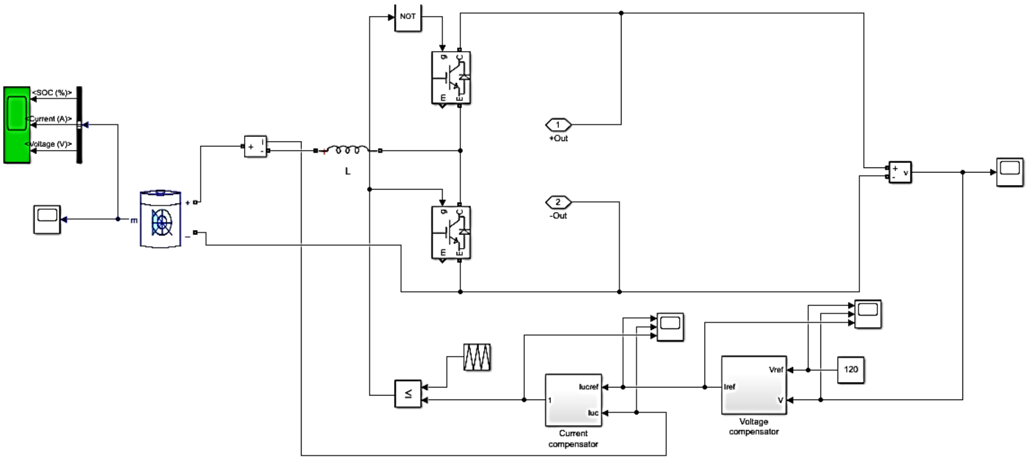

Figure 5: *Battery with Bi-directional Converter*

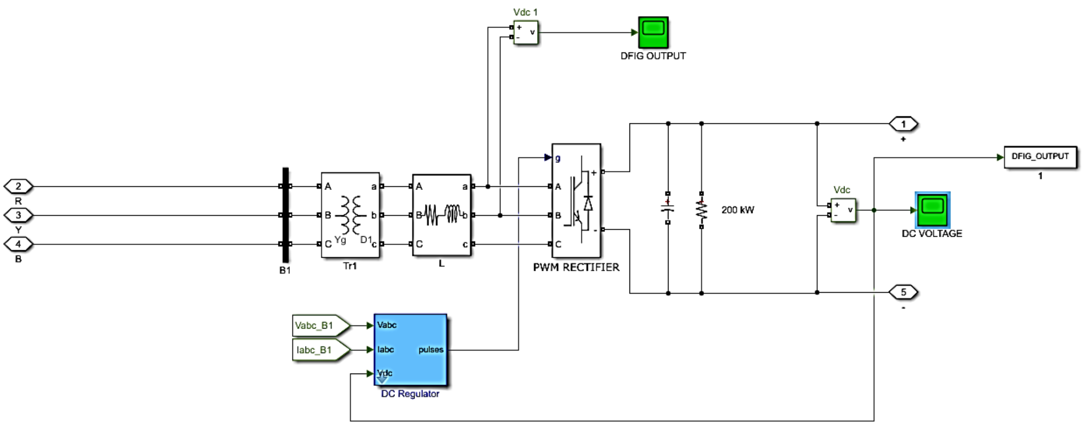

Figure 6: *WECS with PWM Rectifier*

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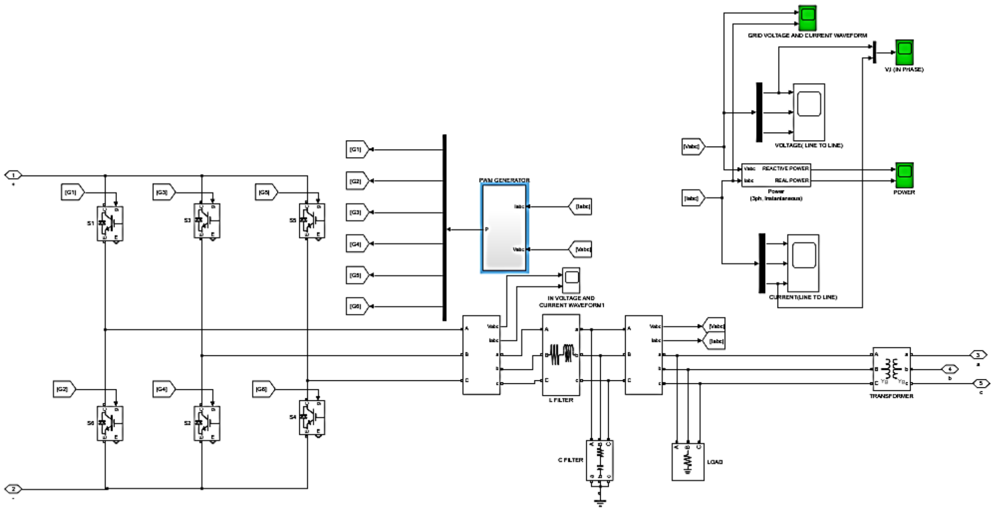

Figure 7: *Three Phase Grid System*

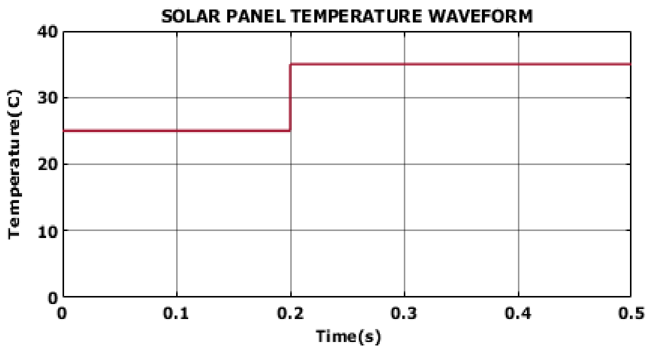

Figure 7 (a): *PV Temperature waveform*

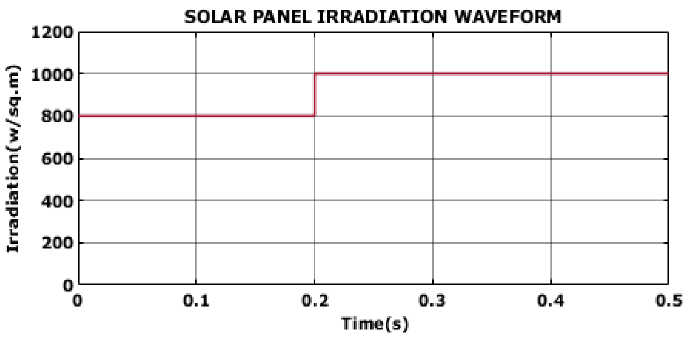

Figure 7 (b): *PV Irradiation Waveform*

The PV temperature waveform is shown in Figure 7a, and it shows the temperature variation of a PV panel from 25 to 35 degrees Celsius. The variation of the PV panel irradiance waveform from 800 w/sq.m. To 1000 w/sq.m. is shown in Figure 7b.

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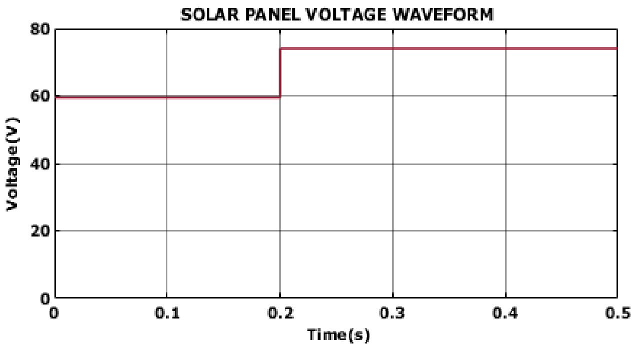


Figure 8 (a): *PV Panel Voltage Waveform*

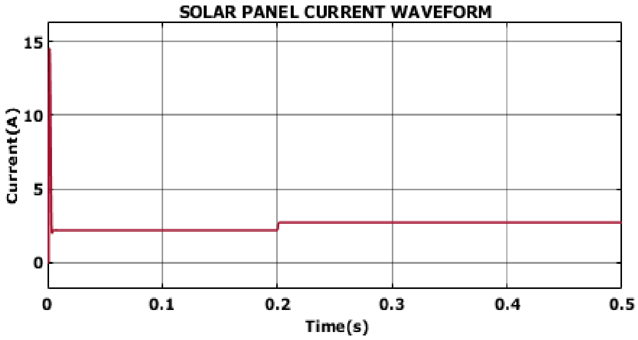
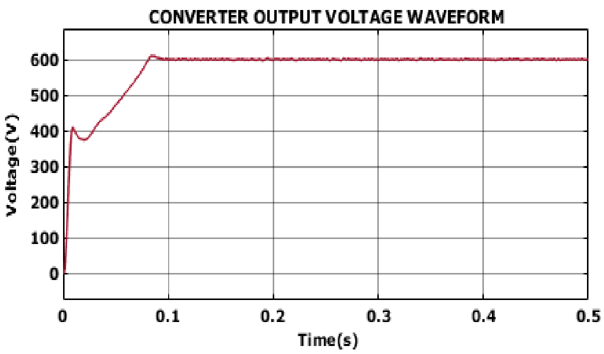
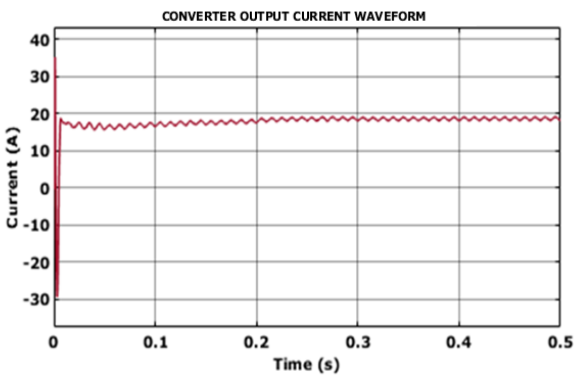


Figure 8 (b): *PV panel Current Waveform*

The PV panel voltage waveform, which represents DC voltage, is shown in Figure 8A. In general, it doesn't change when there is enough sunlight present. That is 75V. The PV panel current waveform, is shown in Figure 8b.



(a)



(b)

Figure 9: *LUO Converter Output Voltage and Output Current*

Order as shown in Figure 9, the Luo converter yields a continuous output voltage of 600V and a current of 18.66A.

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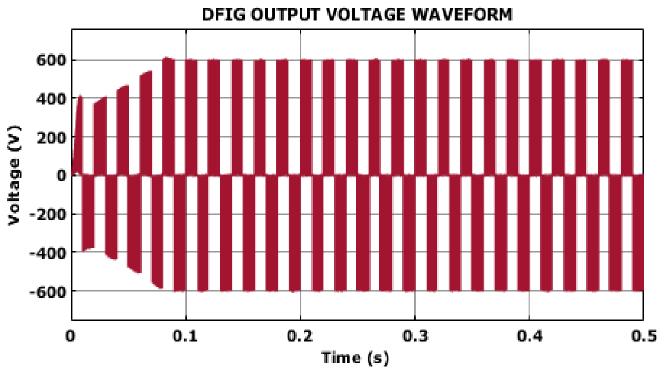


Figure 10: *Voltage Waveform for DFIG Output*

The output voltage of the proposed WECS system, based on DFIG, is displayed in Figure 10. The voltage value is 600 (V).

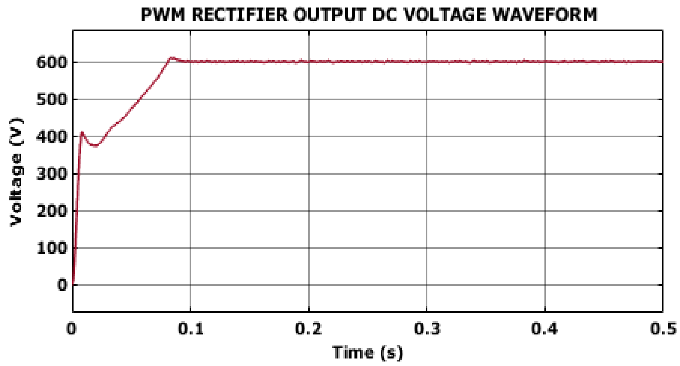
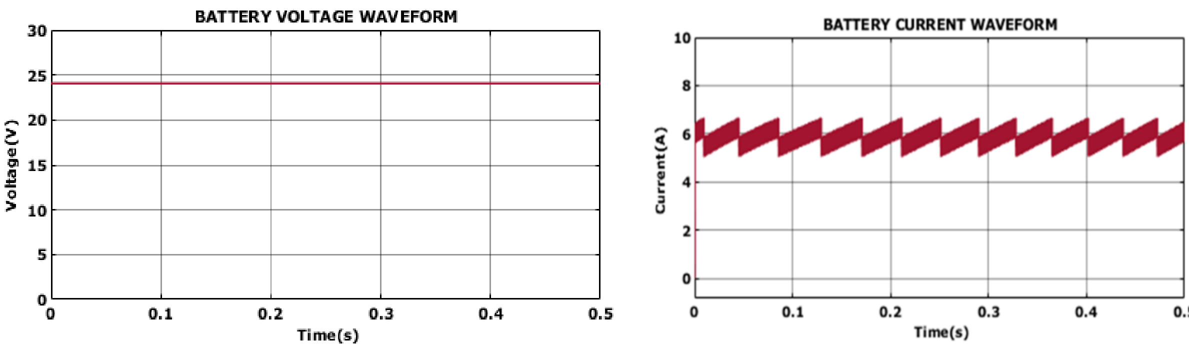


Figure 11: *PWM Rectifier Voltage Waveform*

Figure 11 illustrates how the PWM rectifier's output voltage is maintained at roughly 600 volts.



(a) (b)

Figure 12: *Battery Waveforms for Current and Voltage*

Figure 12 displays the waveforms that indicate the battery's voltage and current levels. The voltage and current of the battery are 24V and 6A, respectively. Batteries are used to store excess power produced by solar and wind power. The battery serves as a backup power source

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by discharging and transferring energy to the load and grid system when the primary power source is unavailable.

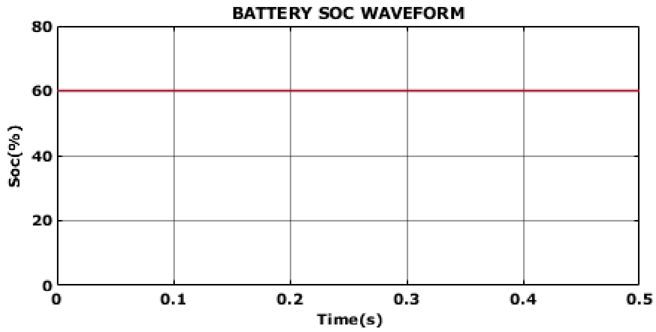

Figure 13: *SOC of Battery*

The waveforms for the battery's state of charge (SOC), which is 94% as shown in Figure 13

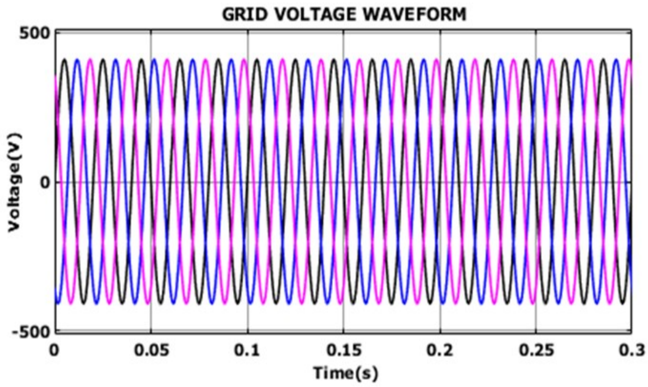

Figure 14: *Grid Voltage Waveform*

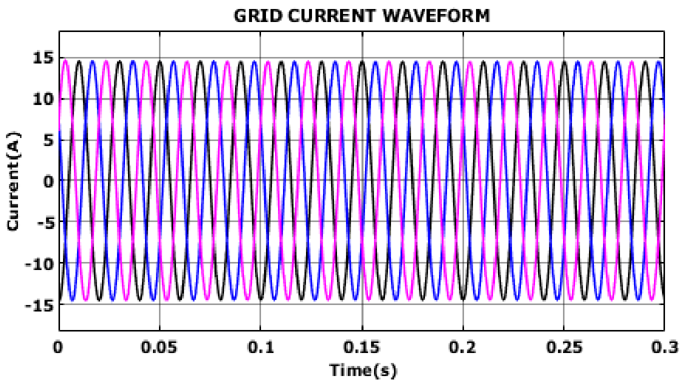

Figure 15: *Grid Current Waveform*

Figures 15 and 16 show the grid voltage and current waveforms, respectively.
There are no fluctuations affecting the grid voltage or current; they are both constant and stable. 415 volts and 13 amps of voltage and current are noted.

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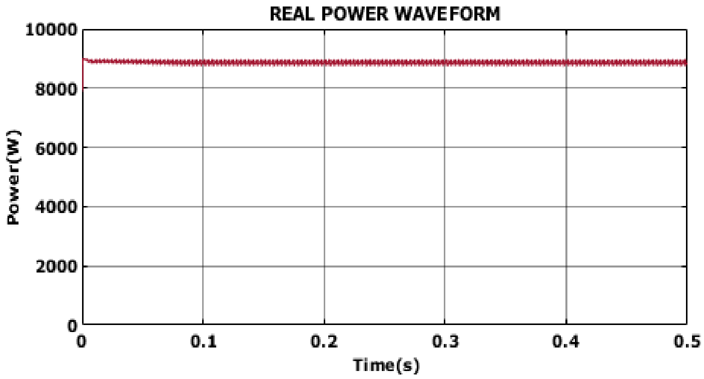

Figure 16: *Real Power waveform*

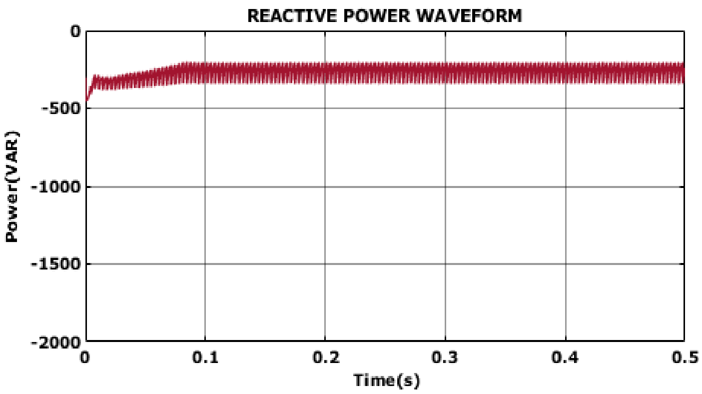

Figure 17: *Reactive Power Waveform*

The real power reached 9000(W), and Figure 16, 17 displays the reactive and real power waveform of this work.

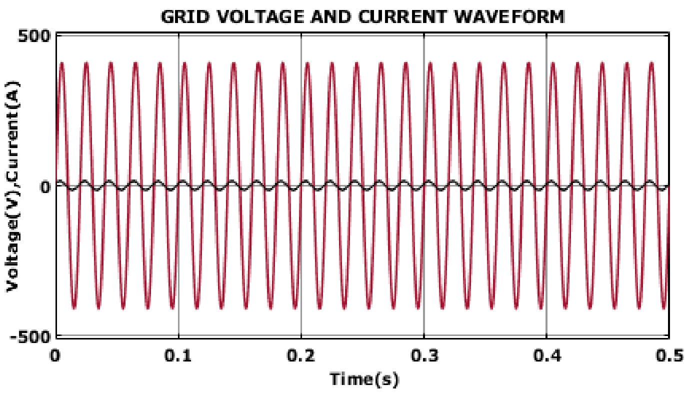

Figure 18: *Grid Voltage and Grid Current Waveform*

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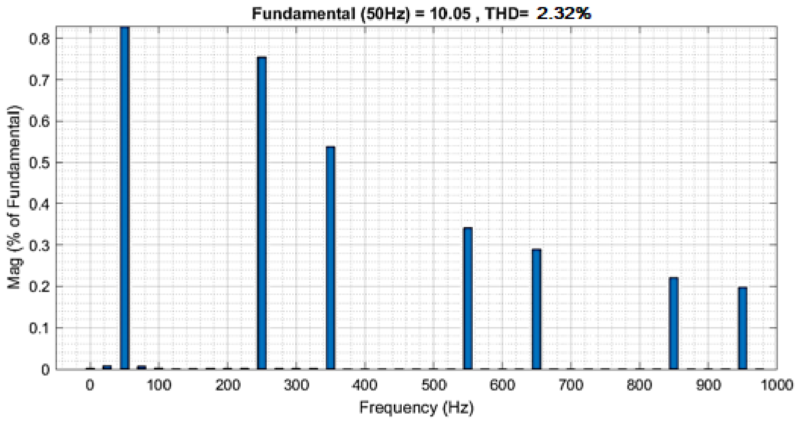

Figure 19: *THD*

The THD value in figure 19 is approximately 2.32%, which amply demonstrates how applying the dq theory transformation significantly reduces harmonics and minimizes losses as well.

5 Conclusion

The objective of this project is to integrate photovoltaic (PV) sources with a System (ANFIS) for (MPPT) and a (DFIG) into a DC micro grid in order to create an energy ecosystem that is both efficient and sustainable. A greener environment is made possible by the DC micro grid's integration of PV and DFIG sources, which allow for the use of sustainable and clean energy sources. By guaranteeing the effective use of solar energy, the ANFIS-based MPPT maximizes power generation from photovoltaic sources. This system uses Grey Wolf Optimization (GWO) proportional-integral (PI) control to detect harmonic problems and reduce them. This guarantees that the DC micro grid's power quality is kept at a respectable level. Through the reduction of fluctuations and improvement of reliability, the GWO PI control aids in maintaining a constant output voltage in the DC micro grid.

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