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MAJOR PROJECT REPORT

On

SMART GRID TECHNOLOGY SIMULATION

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ABSTRACT

The phrase "smart grid" has been in use at least since 2005, when Amin and Wallenberg's essay "Toward A Smart Grid" first used it. The phrase was used earlier, maybe as early as 1998. There are several definitions of the smart grid, some of which are technological, functional, and benefit-focused. The application of digital processing and communications to the electrical grid is a feature shared by most definitions, making data flow and information management essential components of the smart grid. The highly integrated usage of digital technology with power grids produces a variety of capabilities, and integrating the new grid information flows into utility processes and systems is one of the main challenges in the design of smart grids. Electric utilities currently find themselves undergoing three different types of transformations: business process change, infrastructure improvement (called the strong grid in China), and the addition of the digital layer, which is the core of the smart grid. The overall idea of the smart grid today incorporates a large portion of the modernization work that has been ongoing in the electric grid modernization, particularly substation and distribution automation, but new capabilities are also developing.

Power plants were carefully placed to be close to fossil fuel deposits, such as mines or wells or supply routes for rail, road, or ports. The topology of the evolving grid was significantly impacted by the placement of hydroelectric dams in mountainous regions. The location of nuclear power facilities considered the accessibility of cooling water Finally, once energy distribution networks made it practicable, fossil-fired power plants—which at first were extremely polluting—were placed as far away from population centres as possible. By the late 1960s, the vast majority of people in industrialised nations were connected to the power grid, with only remote rural regions still being "off-grid."

The goal of this project is to create and manage a hybrid system that ensures the continuation of the energy supply. In order to simultaneously accomplish three desired objectives—extract the maximum amount of power from each hybrid power system component, ensure dc bus voltage regulation at the inverter's input, and transfer the entire amount of produced power to the grid at unity power factor—a straightforward control method is applied to the suggested configuration. According to the simulation results, the fuel cell controller effectively meets the demands for deficit power while the dc-dc converters are very good at tracking the maximum power of the wind and photovoltaic sources.

DECLARATION

We declare that this written submission represents our ideas in own words, and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented of fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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This is to certify that the project report entitled "**Smart Grid Technology Simulation**" submitted by **Navneet Diwan (19117057), Tulesh Dewangan (19117093) and Umakant Sahu (19117094),** in partial fulfillment of the requirements for the award of the Bachelor of Technology in Electrical Engineering and submitted to the Department of Electrical Engineering of National Institute of Technology Raipur is an authentic record of our own work carried out during a period from July 2022 to November 2022 under the supervision of Dr. Pushkar Deo Dewangan, Associate Professor, Department of Electrical Engineering, NIT Raipur.

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Thanking you,

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TABLE OF CONTENTS

LIST OF FIGURES

Figure no. **Title** **Page no.**

CHAPTER 1

INTRODUCTION

The term "grid" has historically been used to refer to an electricity system that supports all or more of the following four functions: power generation, transmission, distribution, and control.

An improved version of the power network from the twentieth century is known as a smart grid (SG), also known as a smart electrical or power grid, intelligent grid, intelligrid, future grid, intergrid, or intragrid.

One of the primary and common uses of conventional power grids is to distribute electricity from a small number of central sources to a large number of consumers or customers. The SG, in contrast, leverages two-way flows of power and information to build a distributed advanced energy delivery network with automated control. Table 1 provides a short comparison between the SG and the current grid. The SG can adapt to a wide range of circumstances and events and supply electricity more effectively thanks to recently developed information technology. Power generation, transmission, distribution, and consumption are just a few examples of events that the SG may respond to by using the appropriate programmed methods. As an illustration, the SG may automatically change the power flow and restore the power delivery service after a medium voltage transformer failure event occurs in the distribution grid. Let's consider a different instance of demand profile shaping. In the peak period, the electric utility can activate real-time pricing to ensure some users reduce their power demands. This will allow the total demand profile full of peaks to be shaped to a delicately smoothed demand profile. Lowering peak demand and smoothing demand profile decrease the total plant and capital cost requirements. More specifically, the SG can be seen as an electric system that integrates computational intelligence, two-way, cyber-secure communication technologies, and electricity generation, transmission, substations, distribution, and consumption in order to create a system that is safe, dependable, effective, recessive, and sustainable. The complete spectrum is included in this description. An ideal SG is a vision. Under the direction of very intelligent management and control systems, it is the integration of complementary sections, subsystems, functions, and services.

Due to different concentrations and plans, different researchers may express different points of view for the SG given the broad scope of the SG research. According to the introduction, three important SG systems are covered in detail from a technical standpoint in this paper:

1.1 Smart infrastructure system:

The smart infrastructure system is the energy, information, and communication infrastructure underlying of the SG that supports:-

1. Advanced electricity generation, delivery, and utilization;

2. Advanced information metering, monitoring, and management; and

3. Advanced technologies in communication.

1.2 Smart management system:

The smart management system is the subsystem in SG that prepared advanced management and control tasks.

1.3 Smart protection system:

This section is the subsystem in SG that provides advanced grid reliability and safety analysis, failure protection, and security and privacy protection services.

A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. The smart grid was introduced with the aim of overcoming the weaknesses of conventional electrical grids by using smart net meters. Many government institutions around the world have been encouraging the use of smart grids for their potential to control and deal with global warming, emergency resilience and energy independence scenarios.

Smart grid technology is an extended form of analog technology that has also been introduced for controlling the use of appliances by employing two-way communication. However, the prevalence of Internet access in most homes has made the smart grid more practically reliable to implement. Smart grid devices transmit information in such a way that enables ordinary users, operators and automated devices to quickly respond to changes in smart grid condition systems.

Smart grid is equally advantageous for enterprises, retail stores, hospitals, universities and multinational corporations. The entire smart grid system is automated for tracking the electricity consumption at all the locations. Grid architecture is also combined with energy management software for estimating the energy consumption and its associated cost for a specific enterprise. Generally, electricity prices increase along with demand. By providing consumers with information about current consumption and energy prices, smart grid energy management services help to minimize the consumption during high-cost, peak-demand times.

A modern smart grid system has the following capabilities:

- It can repair itself.
- It encourages consumer participation in grid operations.
- It ensures a consistent and premium-quality power supply that resists power leakages.
- It allows the electricity markets to grow and make business.
- It can be operated more efficiently.

A smart grid's key features include:

• Load Handling: The sum/total of the power grid load is not stable and it varies over time. In case of heavy load, a smart grid system can advise consumers to temporarily minimize energy consumption.

• Demand Response Support: Provides users with an automated way to reduce their electricity bills by guiding them to use low-priority electronic devices when rates are lower.

• Decentralization of Power Generation: A distributed or decentralized grid system allows the individual user to generate onsite power by employing any appropriate method at his or her discretion.

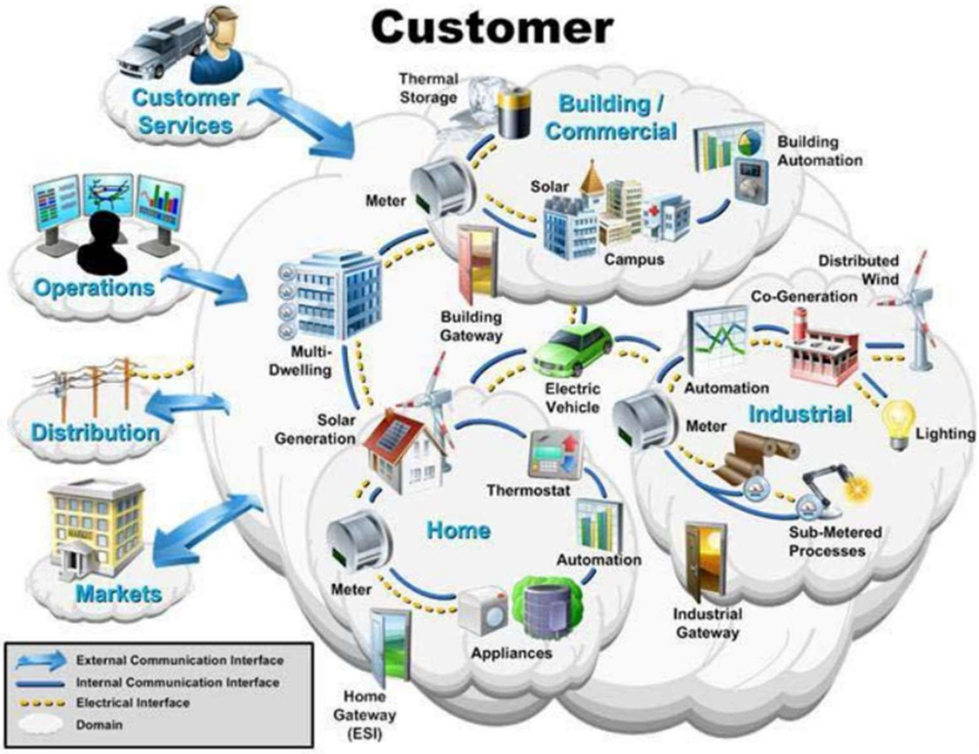

Fig1. Smart Grid Energy and Information Flow

Case Study: Asia Solar Energy Initiative Example

The Asia Solar Energy Initiative (ASEI), launched by the Asian Development Bank (ADB) in May 2010, aims to produce 3,000 MW of solar energy over the next three years throughout Asia and the Pacific (ADB2010). In order to assist the integration of large-scale solar PV and concentrated solar thermal projects, urban solar PV, and off-grid solar PV and battery projects, the initiative is pushing the development of the related transmission and distribution infrastructures with smart metres and storage batteries. Less than 500 MW of installed solar capacity existed in the area when the ASEI was launched. The final target of 3,000 MW will be reached in May 2013, three years from the initiative's commencement, once the capacity reaches 1,000 MW by the end of 2011.

CHAPTER 2

LITERATURE REVIEW

The creation and application of smart grids involves the creation of new and enhanced energy technologies, the introduction of information management systems, the monitoring and management of energy consumption, and is closely associated with alternative energy and the decarbonization of the economy. Because they seek to address issues in each of these fields, the themes of scientific study on smart grids vary greatly. Therefore, the purpose of this study is to provide a bibliometric overview to describe the current level of scientific production in the "Smart Grid" field. The Scopus database's 1359 publications from the years 2008 to 2020 were examined. The Scopus database's "Title, Abstract, and Keywords" search area was used. Utilizing the VOSviewer programme to map the data graphically, the results were visualized. Keyword cooccurrence and co-authorship (country) analyses were utilised in the study. The most successful writers and periodicals were identified as a consequence. The studies with the greatest citations were identified. Both term (co-occurrence) clusters and country clusters were detected. The analysis's findings and visual representations are pertinent, and they serve as the cornerstone for a better comprehension of the idea behind the smart grid.

Attacks and calamities won't be able to take the Smart Grid down. Not only will the Smart Grid be resistant to physical attacks, but also to cyberattacks. The main driver of economic growth in the United States is a complex system called the electrical power grid. The electrical power grid is therefore a crucial asset, and damage to it could have catastrophic effects on the welfare of our society. [3] draws comparisons between the Roman aqueduct network and the current power grid. The Roman aqueducts experienced design modifications throughout time. The perception of threat decreased as the Roman Empire expanded. This resulted in design modifications that gave priority to form and functionality rather than security. Then, when the Roman Empire drew to an end, the architectural modifications made these aqueducts simple military targets for advancing troops. Roman aqueducts had grown to be a vital infrastructure on which the Romans relied, hence attacks on them had significant societal repercussions. We rely heavily on the electrical power supply, which must be resistant to all types of assault.

Electricity quality will improve thanks to the Smart Grid. The power system must provide electricity at all times, and that electricity must keep a steady voltage. Variations in voltage can have a significant impact on some manufacturing processes. On some industrial operations, a voltage drop lasting less than 100 ms might have the same impact as a power outage lasting several minutes or more. In commercial facilities, these voltage swings are thought to result in productivity losses that can cost hundreds to millions of dollars each time. By 2011, 16% of the electrical demand is anticipated to require digital grade electricity. All generation and storage options are supported by the Smart Grid.

There are a number of challenges in integrating renewable energy into the electrical system. Currently, electricity can only travel in one direction, from a single generation source to numerous users, thanks to the broadcast architecture of the electric power system. Traditional power sources and renewable energy sources are frequently geographically apart, and when they are included into the electrical grid, it is as dispersed power sources. This presents challenges since the electrical power system was created to handle a single power source, not a number of scattered power sources. Germany has had difficulties because to faults with their electrical power infrastructure. Customers that use solar panels run the risk of overloading the electrical grid when those panels experience power spikes [4].

Since fossil fuels cannot be used indefinitely, new alternative energy sources will be investigated. Along with the conventional power sources, the Smart Grid will be able to accommodate these new energy sources.

Electrical marketplaces will be possible with the Smart Grid. The Smart Grid's electrical marketplaces will promote competition among power providers. This competition will encourage energy providers to create less expensive and more effective ways to generate electricity. Customers will pay less for electricity as suppliers compete for their business as a result. Distributed power sources will be supported by the Smart Grid as well. This makes it possible for new suppliers of electrical power and electrical services to enter the market. A supply-demand model-based electrical market will announce current electricity prices. When there is an excess of power, it will be less expensive and the cost of electricity will decrease.

The Smart Grid will work effectively and utilise its resources. Asset management may make advantage of the same principles that will enable self-healing in the Smart Grid. The Smart Grid will be able to control equipment setup and automatically evaluate equipment condition. Compared to human management, this management automation may be done at significantly reduced costs. Since the deterioration of equipment can be monitored, automation of equipment management will also lower the likelihood of equipment failure. New technologies that will lessen energy loss during electrical transit will also be incorporated into the Smart Grid. By reducing energy waste, this reduction in energy loss will improve the effectiveness of the electrical power system.

CHAPTER 3

CONFIGURATION OF HYBRID SYSTEM

A cascaded H-bridge inverter, three independent control units, and the three primary subsystems of PV, WEC, and FC are integrated into the suggested structure for the combined hybrid energy system in Figure. The FC stack is employed as a backup energy source, while the PV and WEC systems are used as the main energy sources. Three different non-isolated dc-dc boost converters are used to link each of the three energy systems in parallel to a single dc bus line. In order to supply the appropriate power to the grid and grid-connected loads even when just one source is available and the others are decreased, the outputs from the three distinct power sources are integrated on the dc side and merged in parallel using a cascaded single-phase H-bridge inverter. The MPPT of PV and WEC systems uses two dc-dc boost converters. The FC for load or grid power fluctuation compensator is controlled by a second dc-dc boost converter.

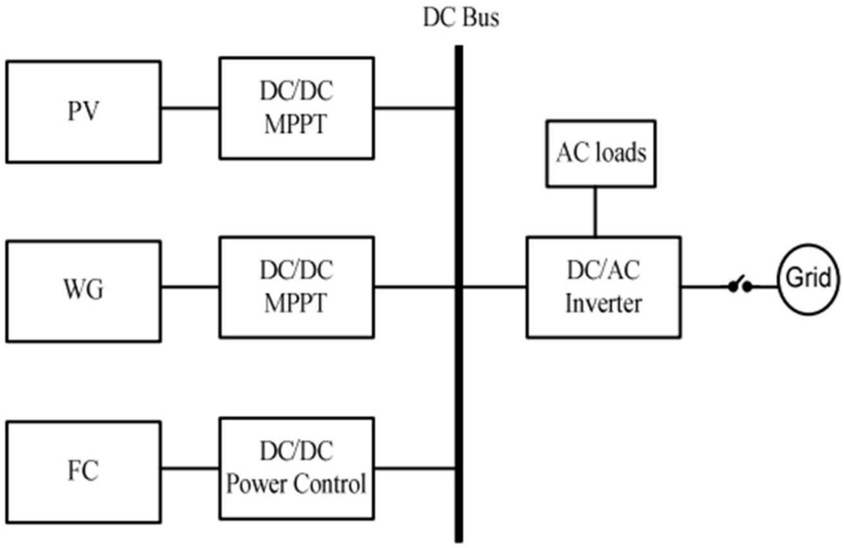

Fig2. Grid connected hybrid WEC/PV/FC system.

Due to the daily and monthly fluctuations in the climatic variables, including solar irradiance, wind speed, temperature, and other factors, the integration of such renewable energy sources to create a hybrid system is a fantastic choice for distributed energy production. A non-polluting, dependable energy source is created by combining PV and wind energy sources with FCs as a storage device in place of typical, enormous batteries or super storage capacitors.

This also lowers overall maintenance costs. The FC generating system is superior to existing generation systems in several ways, including minimal emissions, great efficiency, a variety of fuel options, and onsite installation. Such hybrid systems made up of WEC, PV, and FC have been covered in literature in great detail.

For maximum power point tracking (MPPT) and dc output voltage control for each subsystem of WEC and PV, two dc-dc buck boost converters are used.
Additionally, four sophisticated fuzzy logic controllers are created to modify the two buck boost converters' duty cycles in order to provide MPPT and output voltage management for wind and solar power systems. For standalone applications, this research aims to integrate WEC, PV, and FC producing systems to optimise output energy and minimise output power fluctuations. The proposed hybrid WEC-PV-FC system is connected to the grid as a distributed generation system using a PWM inverter in order to reduce the grid's energy demand stress and serve as an uninterruptible power supply in the event that the grid is cut off.

CHAPTER 4

SYSTEM DESCRIPTION AND MODELING

4.1 Wind Energy Conversion System

The proposed WEC system, as seen in Fig. 2, is made up of a dc-dc boost converter, a three-phase diode bridge, a permanent magnet generator, and a variable speed wind turbine. Torque is produced by the wind turbine using wind energy. The turbine/generator shaft transmits the torque to the generator's rotor. The mechanical system either accelerates, decelerates, or maintains a constant speed depending on the ratio between the electrical torque produced by the generator and the mechanical torque generated by the wind turbine. The generator is coupled to a three-phase diode bridge converter, which supplies the wind system's dc-dc boost converter with rectified three-phase power from the generator.

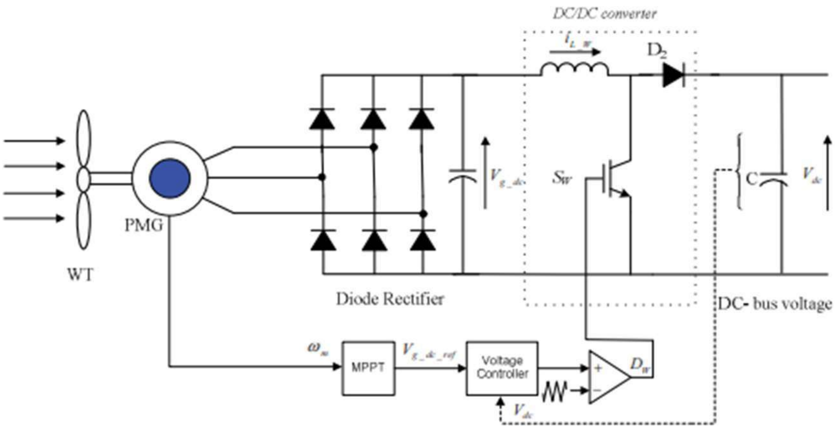

Figure 3. WEC system with dc-dc boost converter connected to dc bus line.

The rectified dc voltage of the generator is controlled in accordance with the following principles to control the dc-dc converter and extract MPPT from the WEC.

The basic equation for the mechanical power generated by wind turbine rotor blades and used to power the electrical generator is as follows:

$P = \rho A C p V^3$

where V is the wind speed (m/s), is the air density (kg/m3), A is the area swept by the turbine blades (m2), and Cp is the power coefficient of the wind turbine.

The output power of the wind turbine will thus depend on the power coefficient if the air density, swept area, and wind speed are considered to be constants. The tip-speed ratio, or TSR, which is how a wind turbine is typically described, is calculated as follows:

$TSR = \omega_m V/R$

R and m in (2) stand for the mechanical angular speed and the turbine radius, respectively. The power coefficient reaches its greatest value at the tip-speed ratio TSR opt's ideal value, resulting in the wind turbine's highest possible efficiency and wind power absorption.

As can be seen from (2), different rotor speeds produce the highest power for various wind speeds. As a result, the turbine speed should be managed to adhere to the ideal tip-speed ratio. To accomplish this, a speed control is incorporated into the system design that allows the rotor to run at high speed in strong winds and at low speed in weak winds.

By adjusting the voltage at the output of a diode bridge rectifier connected to the PM generator, the MPPT of the WEC system is accomplished. The generator terminal voltage may be changed by adjusting the voltage on the dc rectifier, which will also alter the generator's output current. Since current and torque are inversely related, the dc-dc converter will be able to regulate the turbine's speed. By using a preset relationship between rotor speed and diode rectifier voltage, the dc-dc converter may be controlled.

4.2. Photovoltaic System

Solar photovoltaic production systems are gaining importance as a renewable energy source due to its many benefits, which include not requiring any fuel, producing no pollution, needing no maintenance, and making no noise. The solar cell, which is essentially a p-n semiconductor junction, is the foundation of PV arrays. The solar photovoltaic's current-voltage (V-I) characteristic is given by

$$V_{PV}= n_s(AkT/q)\ln\{(n_pI_{sc}-I_{pv}+n_pI_o)/ n_pI_o\}- n_s/n_p\ I_{pv}R_s$$

where VPV and PV I stand for the solar cell's output voltage and current, respectively; q is the electron charge, sc I is the light-generated current, and o I is the reverse saturation current. Rs is the cell's series resistance. A is the dimensionless junction material factor, k is the temperature (1.38e-23 J/K), and T is the Boltzmann constant. The number of parallel and series connections is denoted by the letters n p and s n, respectively.

The setting in which the research of the PV system is explored is the topological circuit of Fig. 4. The PV system primarily consists of a typical PV array with a dc-dc converter and MPPT controller. The DC-DC boost converter that supplies a stepped-up voltage to the DC-bus link is linked to the PV panel. To increase the average power output of the array, the boost converter is switched on and off appropriately to modify the PV voltage. The operating voltage of the PV array fluctuates at a specific irradiation situation, and as a result, so does the power flow from the PV. The objective of the PV MPPT controller is to immediately compel the boost converter to follow the maximum PV power, regardless of variations in solar irradiation or other factors.

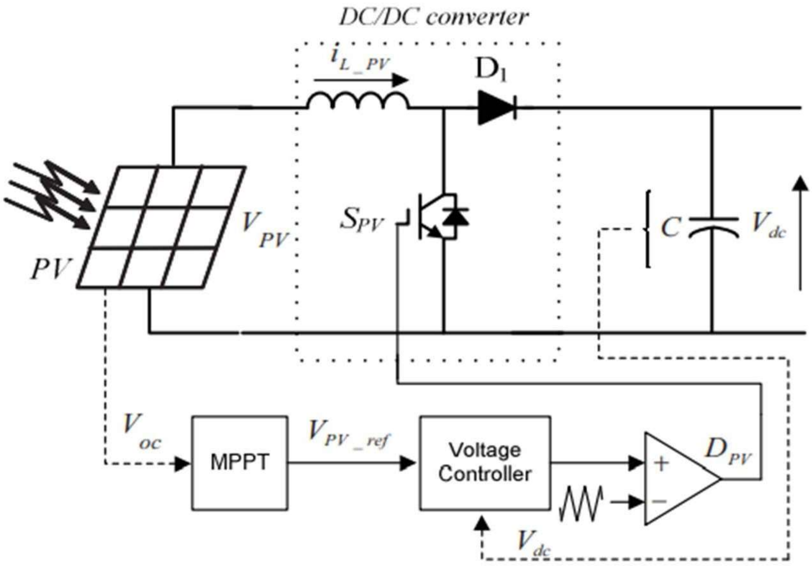

Fig4. PV array connected to dc-bus line through dc-dc converter.

4.3 Fuel Cell System

A static device called the FC transforms fuel's chemical energy straight into electric energy. If the fuel is pure hydrogen, the only byproducts are heat and water. An electrolyte and two electrodes with catalyst coatings make up a standard FC.

On either side of the electrolytic layer, a porous cathode and anode serve as the electrodes. Continuously supplied oxygen from the air is fed to the cathode while gaseous fuel, often hydrogen, is given to the anode. It is feasible to divide hydrogen into protons and electrons by passing it through an anode and a catalyst. While the protons go through the electrolyte, the electrons will move via an external circuit as a current.

When the electrons return from the external circuit, they react with oxygen and protons to create water and heat. It might be claimed that oxygen and hydrogen fuel are mixed to create electricity.

Proton exchange membrane (PEM) FCs are the most promising for small-scale applications despite the fact that there are many different types of FCs. The suggested system uses air as the oxidant, hydrogen from a tank of hydrogen as the fuel, and atmospheric pressure for the cell pressure. Due to their superior benefits and ability to be installed at any site in the distribution system, without regard to location, PEM FCs are becoming more and more important in many applications as distribution systems.

You may get a thorough overview of polarisation properties and PEM FC modelling. The following general equation for the electrical terminal voltage may be used to get the current for the entire stack, assuming that each cell has an equivalent output voltage.

$$V_{FC} = N_{cell}\left[E - \ln\left(\frac{I_{FC} + A_{cell}\, i_n}{A_{cell}\, i_o}\right) - r\left(\frac{I_{FC}}{A_{cell}}\right) - m\exp\left(n\frac{I_{FC}}{A_{cell}}\right)\right]$$

where m and n are constants of the concentration or mass transfer loss parameters, E is the open circuit voltage, cell N is the number of cells connected in series, cell A is the electrode area of each cell, r is the area-specific resistance in 2 k.cm, ni is the internal and crossover current density in 2 mA / m, and cell A is the electrode area.

4.4 System Control

The boost converter is regarded as the most favourable dc-dc converter topology in this application due to its ease of use, low cost, and great efficiency. The system voltage is split into two levels by the dc-dc boost converter: variable voltage at the energy source's output terminal and fixed dc voltage at the dc bus. The output voltage from each source is separately regulated, and the dc bus line output voltage from all converters is configured to be fixed.

The dc bus voltage and the voltage of the MPPT controller are used to manage the terminal voltage in solar and wind power systems, respectively. The operational voltage of the power producing array is then set to the reference value, which corresponds to maximum power, if an unloaded cell is mounted on the array, kept in the same environment as the power producing cells, and its open circuit voltage is frequently recorded. In order to get MPPT of a PV system under any operating circumstances, the MPPT approach suggested in this study uses a preset relationship between the maximum voltage and the open circuit voltage [16]. The reference rectified voltage of the PMG for the WEC system is established dependent on the rotor speed. A voltage controller receives the values of the reference rectified voltage and the dc bus voltage to regulate the duty cycle of the WEC system converter.

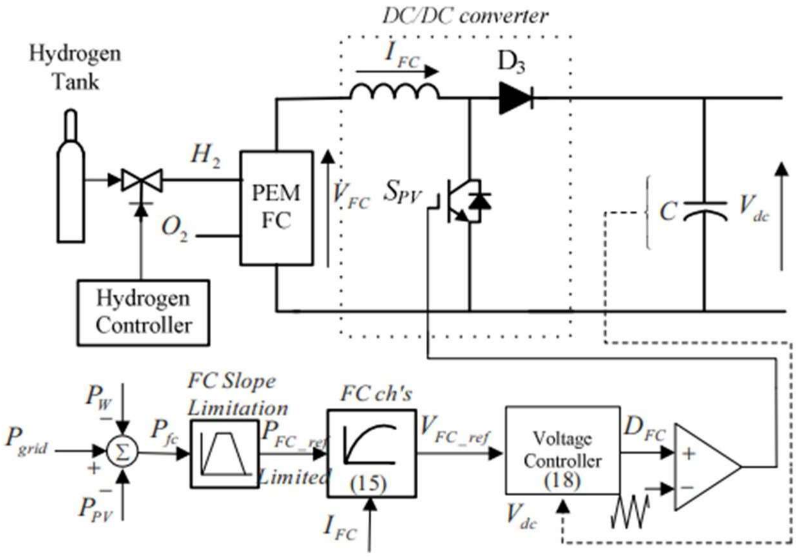

Figure 5. FC system connected to the dc bus line with dc-dc boost converter.

Since the output power of PV and wind systems fluctuates with irradiance and wind speed, the total hybrid system generated power must be managed in order to satisfy the needed grid and grid-connected load demand. The shortfall power, which is the load power (demand value) less the total power produced by the PV and wind, is used to adjust the FC's output power. Figures display the control topology setup for each of the three dc-dc converters used for wind, photovoltaics, and fuel cells, respectively. Numerous producing units can be connected due to the arrangement of the dc boost converter, which prevents reverse power flow in this system.

The utility grid and the grid-connected load are linked to the hybrid system's dc bus voltage through an inductor and a capacitor by a PWM inverter. The inverter regulates the grid current at unity power factor and offers power conversion from the dc bus to the grid. Additionally, it controls the dc bus voltage at the inverter's input. After filtering, sinusoidal current produced by the current regulated inverter is supplied to the utility line to provide the required amount of electricity. It also regulates the voltage of the DC connection. The inverter's output power grows as the dc bus voltage rises. On the other side, the inverter reduces output power when the dc bus voltage rises. The suggested control approach generates appropriate pulses for driving the controllable switches of the inverter using suitable PI controllers and the pulse width modulation (PWM) method.

Figure displays the proposed utility-interactive inverter system's condensed control block diagram.

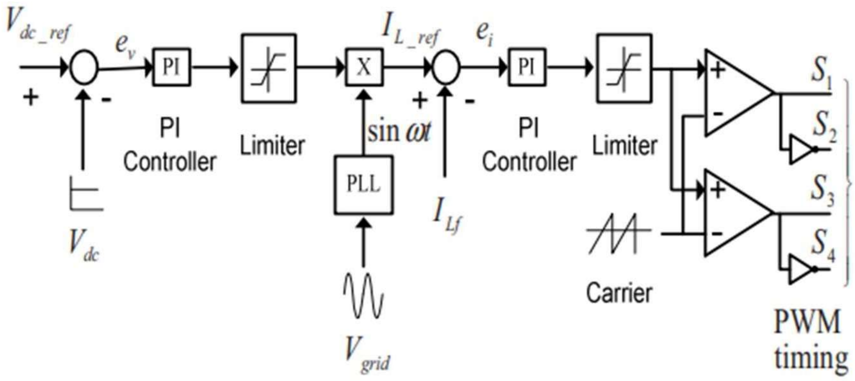

Figure 6. Block diagram of the proposed inverter controller.

The grid current should be adjusted in phase with the grid voltage and have a power factor of unity. In order to perform this function, the amount of the reference grid current generated by the dc bus voltage controller is multiplied by the phase angle of the grid voltage as determined by a phase locked loop (PLL). In order to regulate the unity power factor, an inner current controller is employed, and another PI current controller establishes the current reference of the grid current.

CHAPTER 5

MATLAB SIMULINK MODEL

5.1 Conventional grid with Hybrid Wind, PV and Fuel Cell

The development of renewable energy sources is advancing and staying concentrated due to the critical state of industrial fuels like oil, gas, and others. Renewable energy sources have only grown in significance and demand because of this. Other factors include benefits like being readily available in nature, eco-friendly, and recyclable. There are several renewable energy sources, including sun, wind, hydro, and tidal. Due to technological advancement, solar and wind energy are among the renewable energy sources with the greatest rate of growth. Through wind and photovoltaic cells, energy is converted without the release of any pollutants.

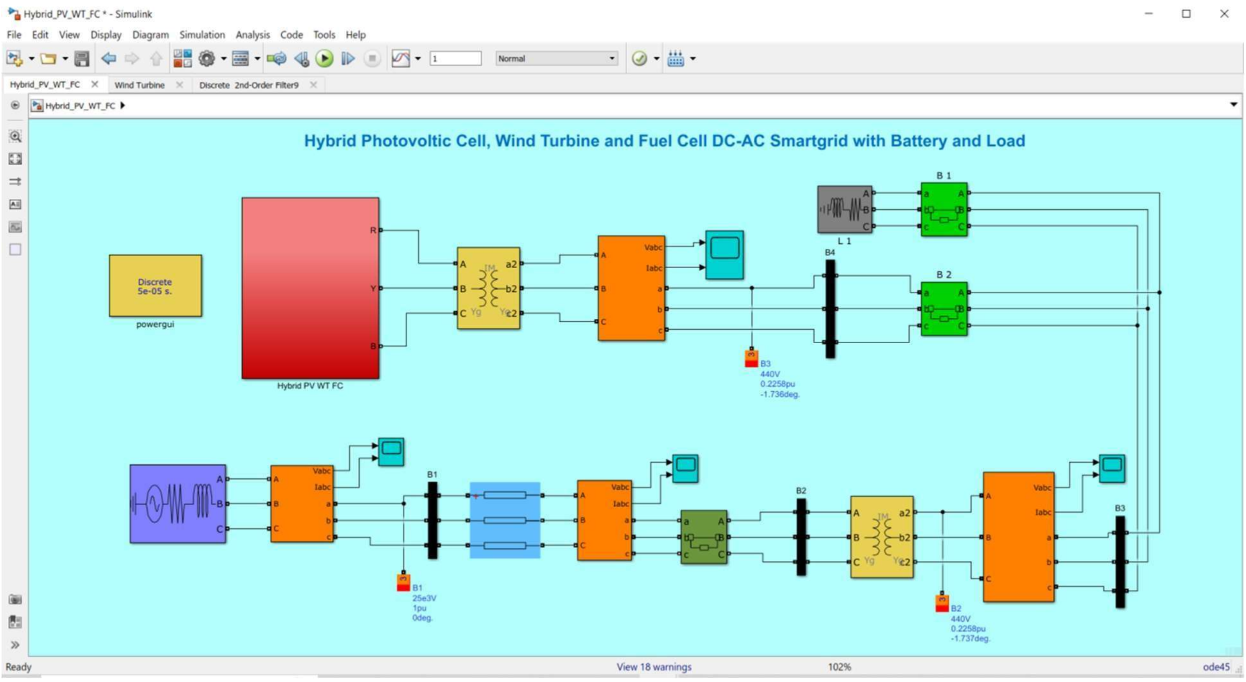

Fig7. Represent Conventional grid with Hybrid Wind, PV and Fuel Cell

Due to the growing population, the need for power is steadily rising each day.

However, the available base load plants cannot meet the demand for power. Therefore, at peak loads, these energy sources can be employed to close the gap between supply and demand.

In isolated locations where traditional power generation is impossible, this sort of small-scale standalone power producing equipment can also be utilised.

5.2 Inside Hybrid PV WT FC Block

The entire system is simulated in order to verify the performance of the suggested hybrid system with each of its constituent controllers. All three energy sources can be regulated precisely and successfully. The hybrid system is designed to run an ac home power application or a standard 2 kW/200V dc communications load continuously throughout the year in outlying areas or isolated islands.

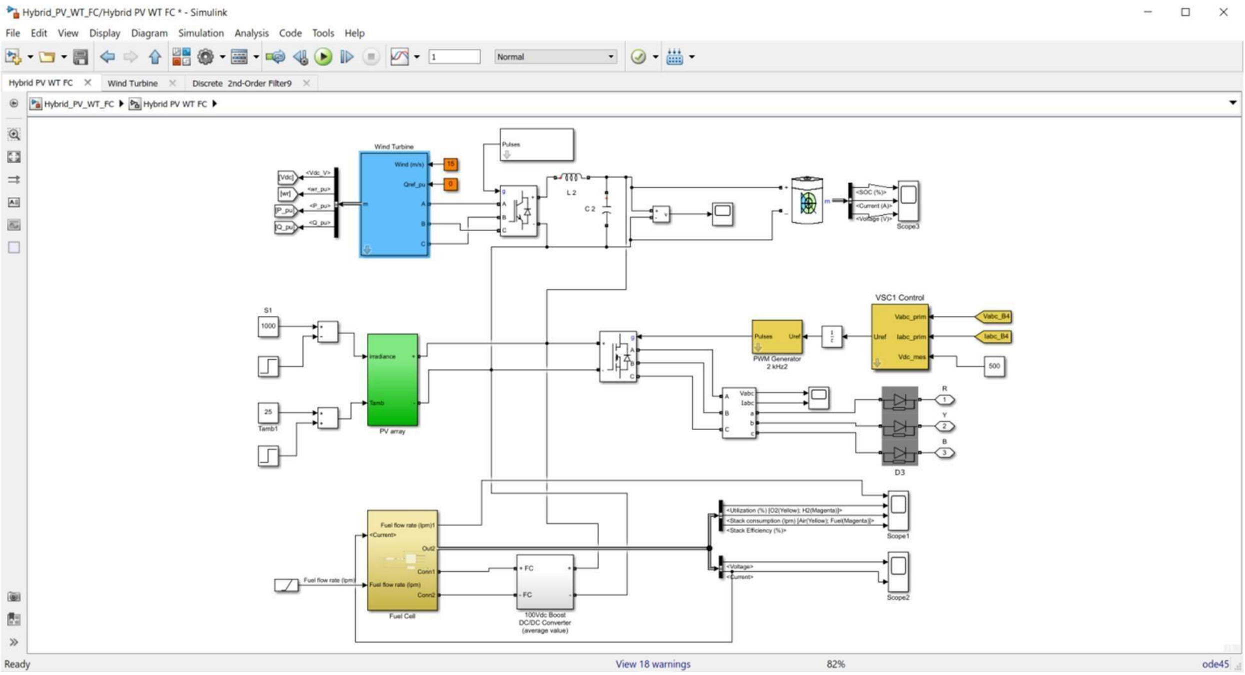

Fig8. Represent Hybrid PV WT FC Block

5.3 Wind Turbine Simulation

Torque is produced by the wind turbine using wind energy. The turbine/generator shaft transmits the torque to the generator's rotor. The mechanical system either accelerates, decelerates, or maintains a constant speed depending on the ratio between the electrical torque produced by the generator and the mechanical torque generated by the wind turbine. The generator is connected to a three-phase diode bridge converter, which supplies the wind system's dc-dc boost converter with rectified three-phase power from the generator.

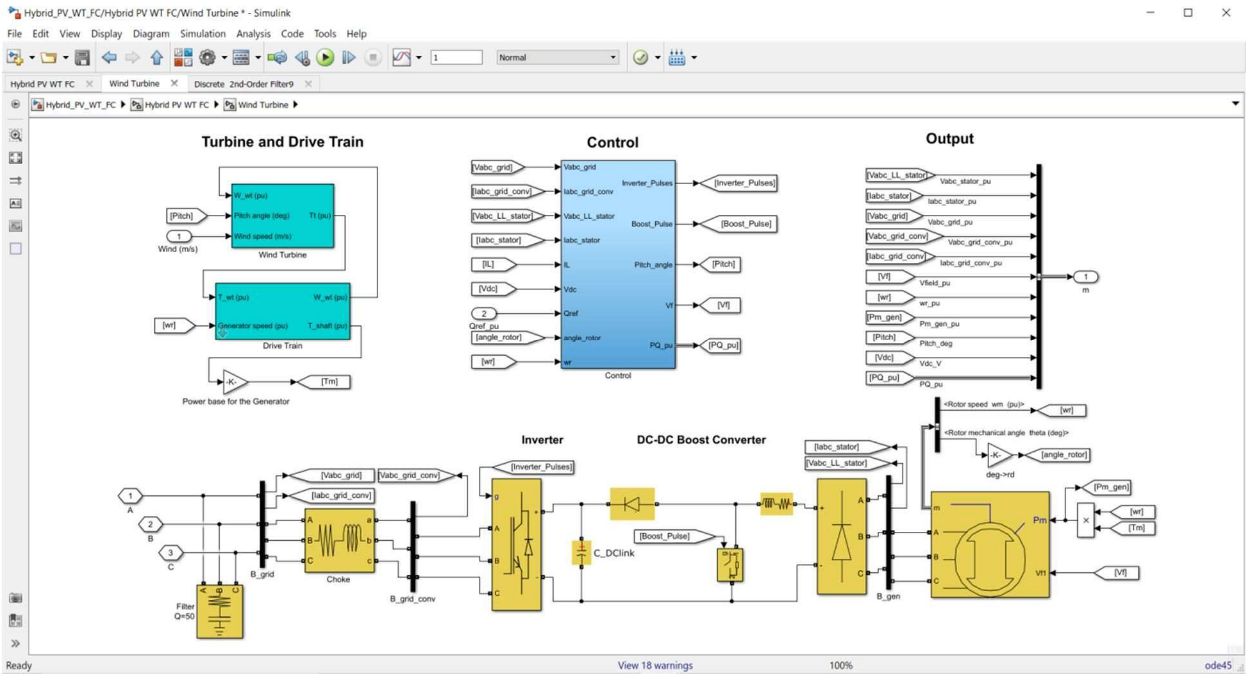

Fig9. Represent Wind Turbine Simulation

5.4 Photovoltaic Array Simulation

Solar photovoltaic production systems are gaining importance as a renewable energy source due to its many benefits, which include not requiring any fuel, producing no pollution, needing no maintenance, and making no noise. The solar cell, which is essentially a p-n semiconductor junction, is the foundation of PV arrays.

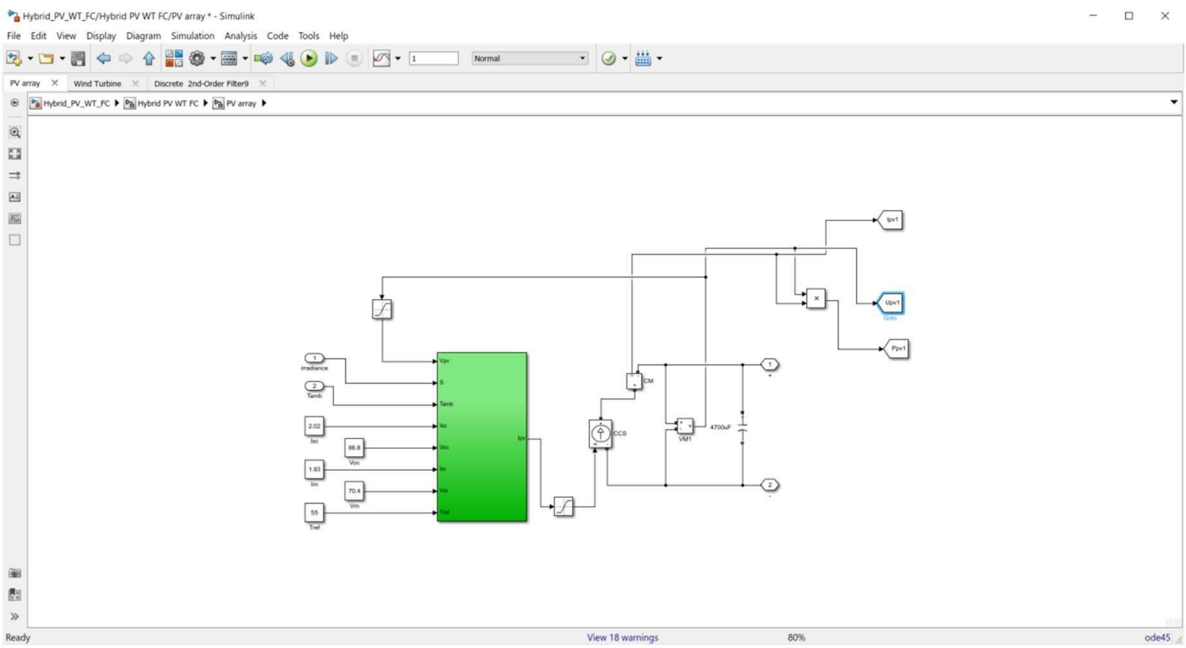

Fig10. Photovoltaic Array Simulation

5.5 Fuel Cell Simulation

A static device called the FC transforms fuel's chemical energy straight into electric energy. If the fuel is pure hydrogen, the only byproducts are heat and water. An electrolyte and two electrodes with catalyst coatings make up a standard FC.

On either side of the electrolytic layer, a porous cathode and anode serve as the electrodes. Continuously supplied oxygen from the air is fed to the cathode while gaseous fuel, often hydrogen, is given to the anode. It is feasible to divide hydrogen into protons and electrons by passing it through an anode and a catalyst. While the protons go through the electrolyte, the electrons will move via an external circuit as a current. When the electrons return from the external circuit, they react with oxygen and protons to create water and heat. It might be claimed that oxygen and hydrogen fuel are mixed to create electricity.

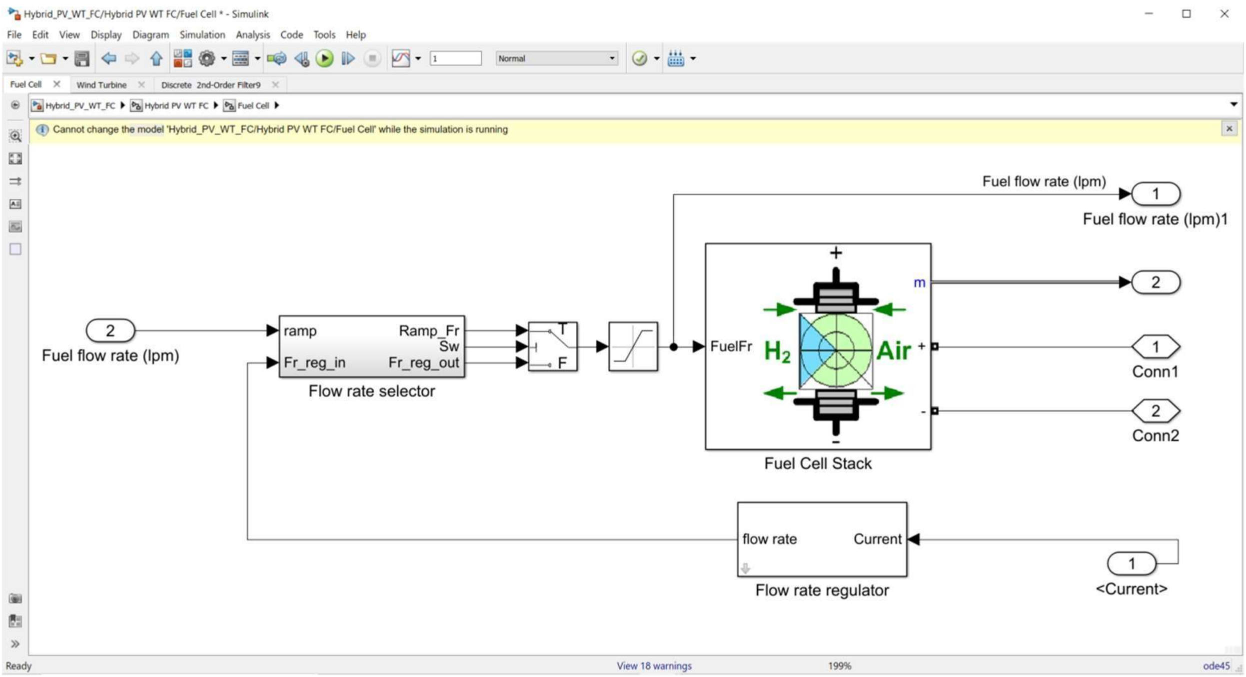

Fig11. Fuel Cell Simulation

CHAPTER 6

SIMULATION RESULTS

1. Simulation Result of Grid Voltage and Current

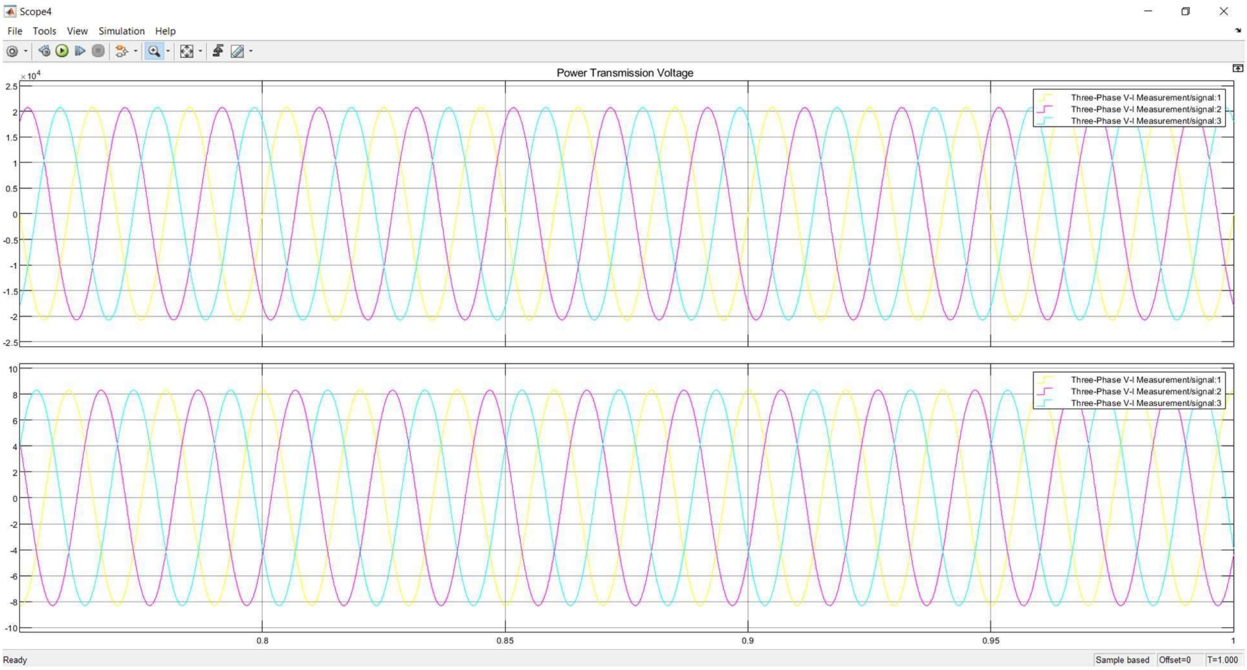

Fig12. Voltage and Current of Conventional grid supply

2. Simulation Result of Grid Voltage and Current after distributed line

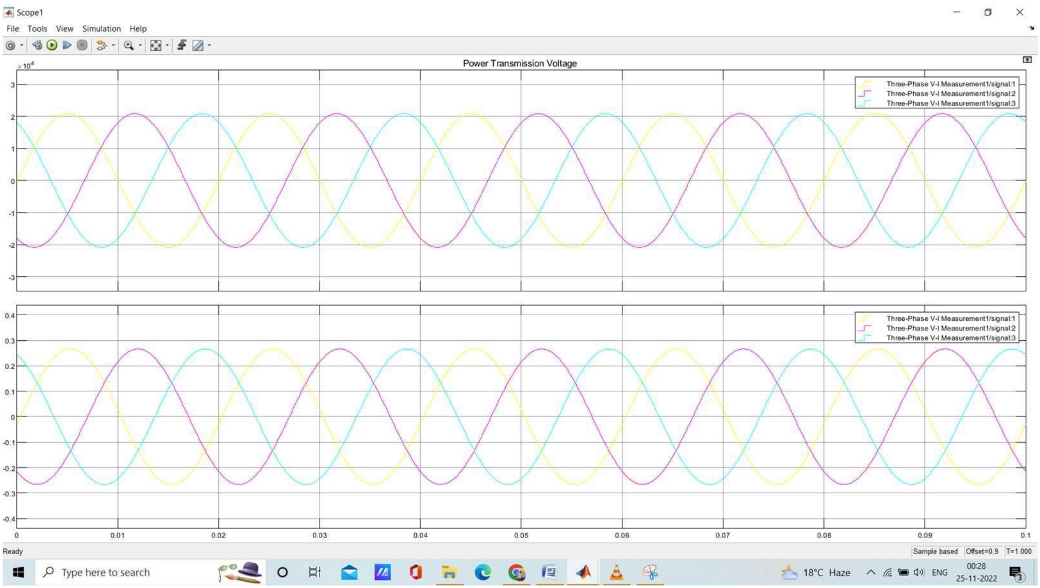

Fig13. Supply side Voltage and Current after distributed line

In this figure 13, we can observe decrease in three phase current due to transmission losses.

3. Simulation Result of Grid Stepped Down Voltage and Current using Three Phase Transformer

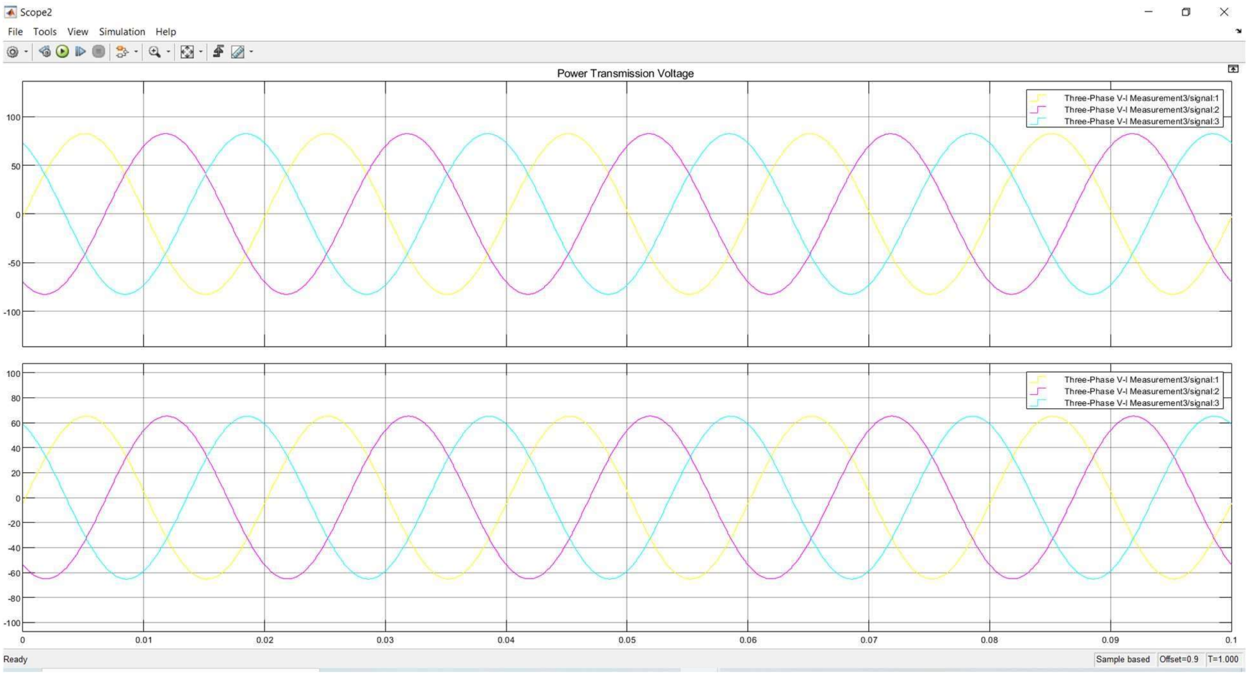

Fig14. Grid Stepped Down Voltage and Current using Three Phase Transformer

We can observe voltage is stepped down to 254.03V from primary voltage of 63510.4V. At the same time, current enhanced such that power should remain before and after the transformation. Now, it is supplied to RL load using AC bus.

4. Hybrid Photovoltaic, Wind Turbine and Fuel Cell Output supply Simulation

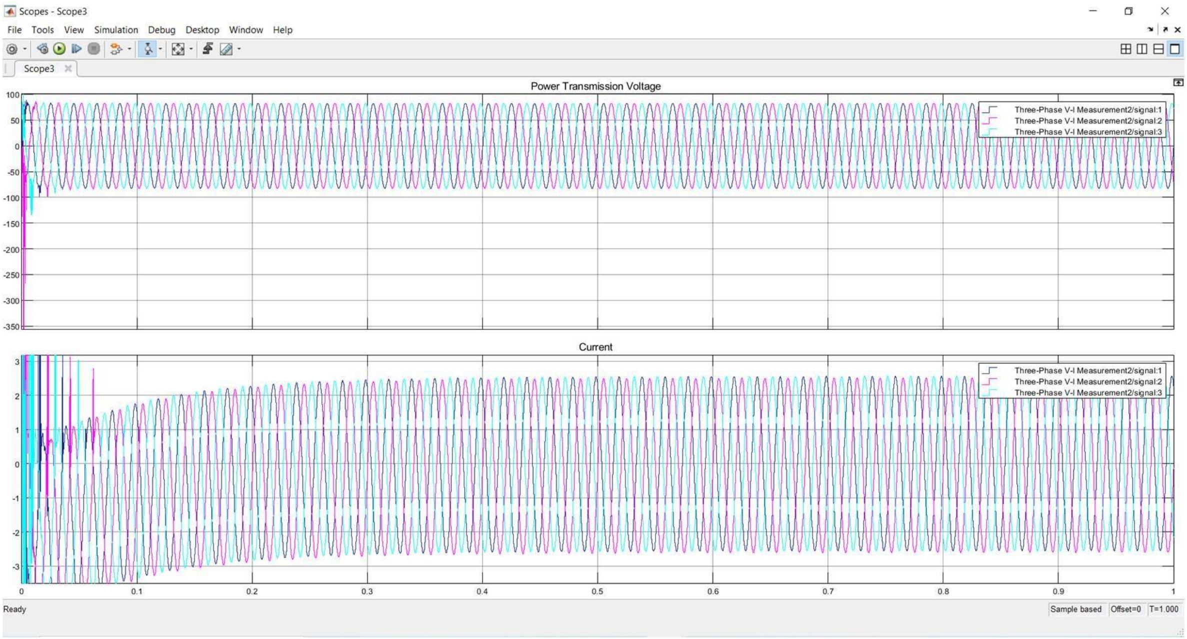

Fig15. Hybrid Photovoltaic, Wind Turbine and Fuel Cell Output supply Simulation

5. Fuel Cell Simulation Results

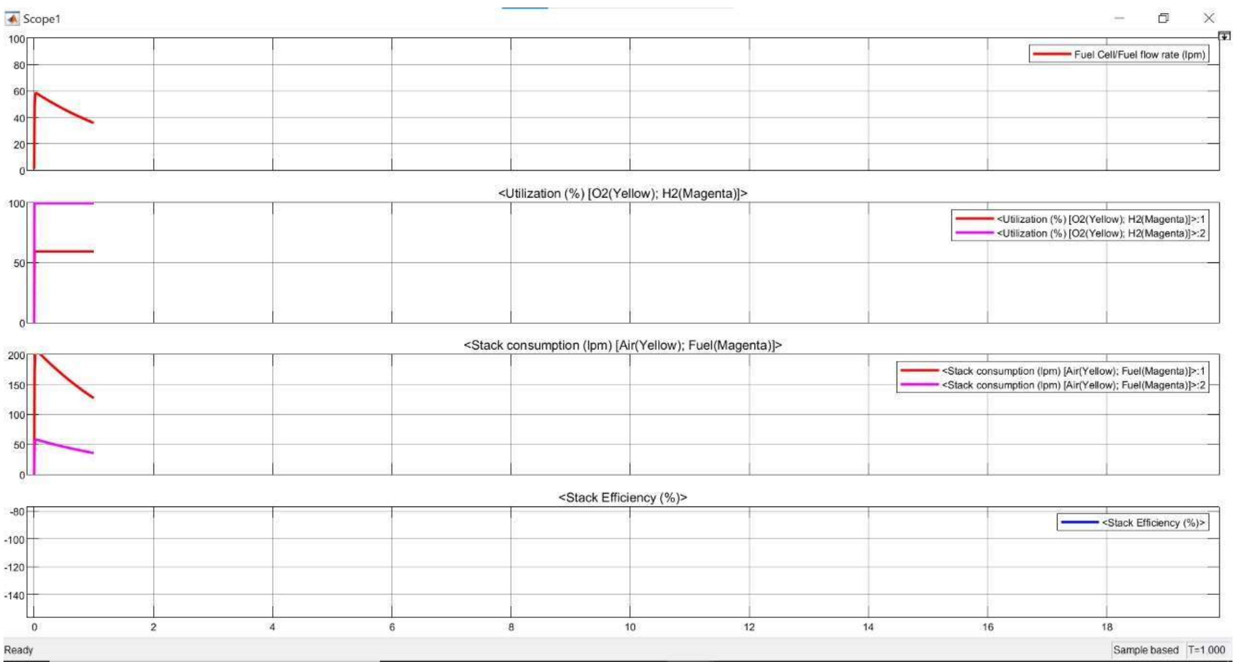

Fig. 16 Utilization of O_2 and H_2, Stack Consumption and Stack Efficiency of Fuel Cell

The suggested system uses air as the oxidant, hydrogen from a tank of hydrogen as the fuel, and atmospheric pressure for the cell pressure. Due to their superior benefits and ability to be installed at any site in the distribution system, without regard to location, PEM FCs are becoming more and more important in many applications as distribution systems.

6. Battery storage simulation

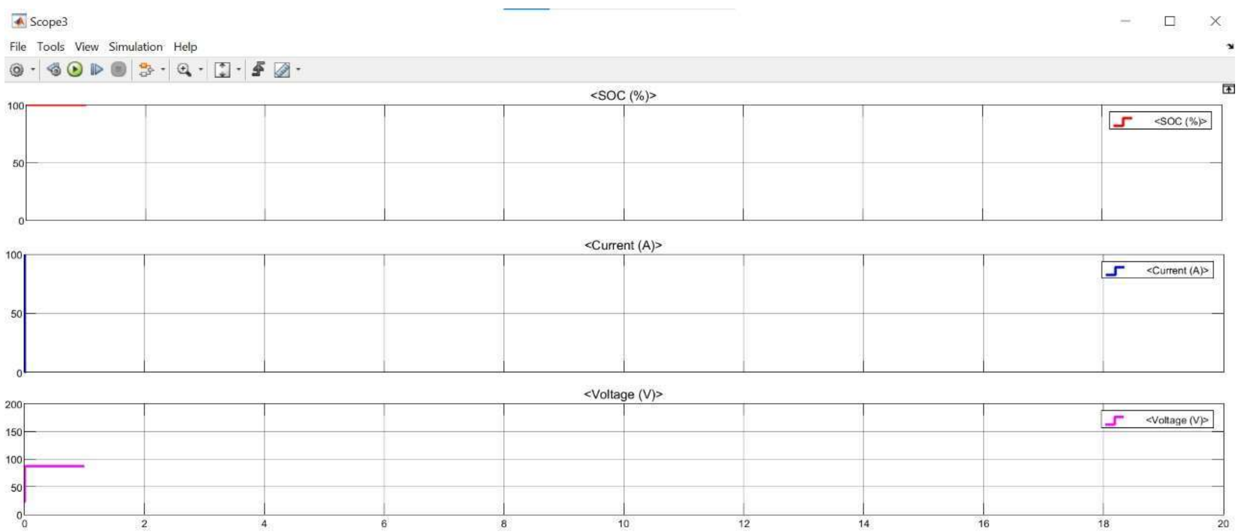

Fig17. SOC, Current and Voltage of Battery System

7. Battery storage simulation

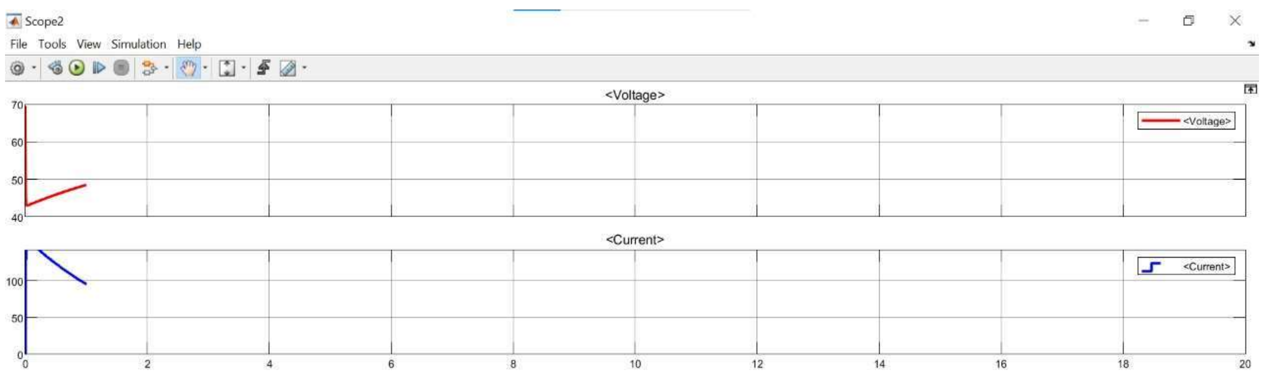

Fig18. Current and Voltage of Fuel Cell

CHAPTER 7

CONCLUSION

A utility interactive hybrid WEC/PV/FC power system with MPPT and dc bus voltage management is shown in the study. The suggested hybrid system has a higher level of dependability and can practically continuously supply electricity. The MPPT control feature is available on the wind and PV controllers, while the load power fluctuation compensation feature is available on the FC controller. Without monitoring the wind speed or solar irradiance, a straightforward control approach that follows the MPP of the wind and PV is provided. This method is especially helpful for actual small-size wind turbines and PV systems. Thus, when the primary combined PV and wind energy sources are unable to satisfy the net grid or load power requirement, the FC is managed to supply the deficit power. The hybrid system has been fully described, along with its intricate control strategy and simulation results that confirm its viability. When compared to each separate system, the hybrid system's power fluctuation has been lessened, and the FC system has totally eliminated it.

CHAPTER 8

FUTHER IMPROVEMENT

On the overall system design and experimental implementation , further work can be done. Further we can add smart substation and smart meter in the simulation that will make this grid more smarter. We can add digital electronic protection equipments to ensure self healing action of the smart grid.

CHAPTER 9
REFERENCES

[1] Demetrios P. Papadopoulos, John Ch. Dermentzoglou, “Economic Viability Analysis of Planned WEC System Installations for Electrical Power Production", Renewable Energy, vol. 25, no. 2, 2002, pp. 199- 217.

[2] Carlo Rubbia, “Today the World of Tomorrow—The Energy Challenge”, Energy Conversion and Management, vol. 47, no. 17, Oct. 2006, pp. 2695-2697.

[3] Y. H. Kim and S. S. Kim, “An Electrical Modeling and Fuzzy Logic Control of a Fuel Cell Generation System,” IEEE Trans. on Energy Conversion, vol. 14, no. 2, Jun. 1999, pp. 239–244.

[4] Tao Zhou, B. Francois, M. E. Lebbal, S. Lecoeuche, "Real-Time Emulation of a Hydrogen-Production Process for Assessment of an Active Wind-Energy Conversion System", IEEE Trans. on Ind. Electr., vol. 56, no. 3, March 2009, pp. 737-746.

[5] Mohamed B. A. Zahran, ”Photovoltaic Hybrid Systems Reliability and Availability”, Int. Journal of Power Electr., vol. 3, no. 3, July 2003, pp. 145-150 .

[6] Hongxing Yang, Lin Lu and Wei Zhou, “A Novel Optimization Sizing Model for Hybrid Solar-Wind Power Generation System”, Journal of Solar Energy, vol. 81, no 1, January 2007, pp. 76–84.

[7] Thomas E. Hoff, Richard Perez, Robert M. Margolis, “Maximizing the Value of Customer-Sited PV Systems Using Storage and Controls”, Journal of Solar Energy, vol. 81, no. 7, 2007, pp. 940–945.

[8] Kaushik Rajashekara, “Hybrid Fuel-Cell Strategies for Clean Power Generation”, IEEE Trans. on Industry Applications, vol. 41, no. 3, May/June 2005, pp. 682-689.

[9] Ke Jin, Xinbo Ruan, Mengxiong Yang, Min Xu, "A Hybrid Fuel Cell Power System", IEEE Trans. on Ind. Electr., vol. 56, no. 4, April 2009, pp. 1212–1222.

[10] Saiful Islam and Ronnie Belmans, “Grid Independent Photovoltaic FuelCell Hybrid System: Design and Control Strategy”, KIEE International Transactions on Electrical Machinery and Energy Conversion Systems, vol. 5-B, no. 4, 2005, pp. 399-404.