Analysing the Performance of Distributed Generation System Based on Renewable Energy through ANN-Tuned UPQC

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Abstract:- This article presents an advanced approach to enhancing power quality in a three-phase, low-voltage network that is integrated with a hybrid renewable energy system. This system utilizes an Artificial Neural Network (ANN)-based Unified Power Quality Conditioner (UPQC). A thorough performance analysis was carried out on this system, which harnesses energy from solar photovoltaic (PV) and wind sources and is regulated by an ANN-controlled UPQC. This novel ANN controller aims to exceed the capabilities of the conventional proportional-integral (PI) controller, and particularly the proportional-integral-derivative (PID) controller, by improving both the steady-state and dynamic performance. The system, referred to as UPQC-ANN-RE, directs energy from wind turbines and photovoltaic arrays into a 3-phase, 4-wire electrical distribution network. In its role as a UPQC, it significantly enhances key power quality metrics such as voltage and current harmonics and power factor. A detailed examination of the active-real power flow through the converters provides further insights into the operational dynamics of the system.

Keywords:- *DG System, UPQCR, ANN, Power Quality, Renewable Energy Sources.*

I. INTRODUCTION

In recent years, the construction of large power plants fueled by fossil fuels like oil, natural gas and coal, as well as nuclear and hydroelectric power plants, has led to severe socio-economic and ecological issues. This has prompted global leaders and scholars to explore alternative solutions to meet the growing energy demand. As a result, the production of electricity through alternate and hybrid-renewable energy systems (HRES) has become crucial for increasing long-term energy supply. Not only does a hybrid system improve efficiency, reliability and economics, but it also helps to mitigate the environmental impact caused by traditional energy sources. This approach allows for a wider range of energy sources to be incorporated into the current framework of electricity production.

A. Introduction to Power Quality

Power quality refers to the electrical parameters of the power supply that affect the proper functioning of electrical and electronic equipment. It encompasses various factors such as voltage level, frequency, waveform, interruptions, and harmonics. In simpler terms, it's about ensuring that the electricity supplied to devices and systems meets certain standards and doesn't cause any issues or damage.

Here's a breakdown of some key aspects of power quality. The voltage supplied should be within certain tolerances. Too high or too low voltages can damage equipment or cause it to malfunction. The frequency of the power supply (typically 50 or 60 Hertz) should remain stable. Variations in frequency can affect the performance of equipment, especially those that rely on precise timing. The shape of the voltage waveform should be sinusoidal. Distortions in the waveform, such as harmonics or transients, can cause equipment to malfunction or overheat.Power interruptions, even momentary ones, can disrupt operations and damage equipment. Uninterruptible Power Supplies (UPS) are often used to mitigate the impact of interruptions. Harmonics are frequencies that are multiples of the fundamental frequency of the power supply. They can be caused by nonlinear loads like variable speed drives or electronic equipment. Excessive harmonics can lead to overheating of equipment and inefficiencies in power distribution systems. These are short-term decreases (sags) or increases (swells) in voltage levels. They can cause equipment to malfunction or even fail, especially sensitive electronic devices.

Ensuring good power quality is essential for the reliable and efficient operation of electrical and electronic systems. It's particularly important in industries where sensitive equipment is used, such as manufacturing, healthcare, telecommunications, and data centers. Power quality monitoring and mitigation techniques, such as voltage regulation, harmonic filters, and surge protection devices, are employed to maintain high standards of power quality and minimize the risk of equipment damage or downtime.

B. Power Quality Improvement by FACTS

Power quality refers to the electrical parameters of the power supply that affect the proper functioning of electrical and electronic equipment. It encompasses various factors such as voltage level, frequency, waveform, interruptions, and harmonics. In simpler terms, it's about ensuring that the electricity supplied to devices and systems meets certain standards and doesn't cause any issues or damage.

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C. Benefits Of FACTS

FACTS devices can enhance the power transfer capability of transmission lines by controlling voltage, impedance, and phase angle. This enables more efficient utilization of existing infrastructure, reducing the need for costly investments in new transmission lines.

FACTS devices like Static Var Compensators (SVCs) and Static Synchronous Compensators (STATCOMs) can regulate voltage levels in the grid, improving voltage stability and reducing voltage fluctuations. This ensures a consistent and reliable power supply, especially during periods of high demand or grid disturbances. By providing dynamic control and flexibility, FACTS technologies help improve the reliability of electrical grids. They can mitigate voltage dips, sags, and transients, reducing the likelihood of equipment damage and power outages. This is particularly important for critical infrastructure and sensitive industrial processes. FACTS devices can mitigate power quality issues such as harmonics, flicker, and voltage variations. By improving the waveform and reducing distortions in the power supply, FACTS technologies ensure a high-quality and stable electrical supply for end-users, minimizing disruptions and equipment damage. FACTS devices enable utilities and grid operators to optimize the operation of the power system, reducing losses, improving efficiency, and maximizing the utilization of available resources. By dynamically controlling parameters such as voltage, reactive power, and power flow, FACTS technologies help maintain grid stability and balance supply and demand. FACTS devices can alleviate congestion on transmission lines by controlling power flow and rerouting electricity to less congested paths. This improves grid reliability and efficiency, reducing the risk of overloads and voltage instability in heavily loaded areas. FACTS technologies facilitate the integration of renewable energy sources such as wind and solar power into the grid. They can smooth out fluctuations in renewable generation, maintain grid stability, and support the efficient transmission of power from remote generation sites to load centers.

D. Importance of Renewable Sources

Renewable energy sources play a crucial role in addressing several pressing global challenges and are increasingly recognized for their importance in the transition to a sustainable and low-carbon future. Integrating renewable energy sources such as solar, wind, hydroelectric, and geothermal power into the electricity mix diversifies the sources of electricity generation. This reduces reliance on a single primary energy source, such as fossil fuels or nuclear power, thereby enhancing the resilience and reliability of the electricity supply. Renewable energy sources generate electricity with little to no greenhouse gas emissions during operation, unlike fossil fuels. By displacing fossil fuel-based generation, renewables contribute significantly to decarbonizing the electricity sector, which is crucial for mitigating climate change and meeting emissions reduction targets.

Renewable energy sources benefit from free fuel inputs (e.g., sunlight, wind, water), unlike fossil fuels, the prices of which can fluctuate due to geopolitical tensions, supply disruptions, or market speculation. This stability in fuel costs translates into more predictable and stable electricity prices over the long term, providing economic benefits to consumers and reducing energy price volatility.

Renewable energy sources are typically domestically available and can be harnessed in a decentralized manner, reducing dependence on imported fossil fuels and enhancing energy security. By tapping into local renewable resources, countries can bolster their energy independence, reduce vulnerability decentralized disruptions, and insulate themselves from geopolitical risks associated with fossil fuel imports.

Renewable energy sources, particularly those with inherent variability such as solar and wind power, can contribute to grid stability and resilience when integrated effectively. Advanced grid management techniques, energy

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storage systems, and demand response programs can mitigate the intermittency and variability of renewables, ensuring a reliable and resilient electricity supply.

The rapid growth and deployment of renewable energy technologies drive technological innovation and cost reductions across the entire energy sector. Advances in solar photovoltaics, wind turbines, energy storage systems, and grid integration technologies continue to improve the efficiency, reliability, and affordability of renewable energy, making it increasingly competitive with conventional fossil fuel-based generation.

The renewable energy sector provides significant opportunities for job creation, investment, and economic growth. Deployment and operation of renewable energy projects require a diverse workforce skilled in manufacturing, construction, installation, operation, and maintenance. Moreover, investments in renewable energy projects stimulate local economies, attract capital investment, and foster innovation and entrepreneurship.

II. PROPOSED METHOD

A. Solar PV

Renewable energy sources stand as paramount alternatives within the realm of non-conventional energy, consistently replenished by natural processes. Solar energy, bio-energy, and wind energy exemplify these sustainable options. A renewable energy system harnesses various sources like solar radiation, wind, water flow, waves, geothermal heat, or biomass, converting them into useful forms of heat or electricity. Among these, solar energy reigns supreme, deriving directly or indirectly from the sun and perpetually renewing itself. In contrast, the majority of the world's energy demand is currently met by non-renewable sources such as fossil fuels—coal, natural gas, and oil—which, while historically driving economic growth, exact a toll on the environment and human health through pollution. Despite their prominence, the finite nature of fossil fuel reserves necessitates a shift towards renewable alternatives, driven by their eco-friendliness, minimal pollution, and contribution to mitigating the greenhouse effect. Projections from the International Energy Agency indicate that by 2050, up to 35% of global energy production could stem from photovoltaic (PV) sources, underscoring the ascent of solar energy as the primary global energy source. Intensive research endeavors continue to enhance the accessibility and affordability of solar energy, transitioning it into a mainstream, zero-emission solution. This advancement encompasses the development of photovoltaic array models, maximum power point tracking (MPPT) technologies, and DC-DC boost converters—critical components for integrating solar power into microgrid systems.

B. Working of PV cell

The functioning of a photovoltaic (PV) cell relies on a fundamental principle known as the photovoltaic effect, wherein certain semiconductor materials possess the ability to convert light directly into electrical current. When incident radiation strikes the cell, it generates charged particles that are then separated, leading to the creation of an electrical current. Structurally, a solar cell resembles.

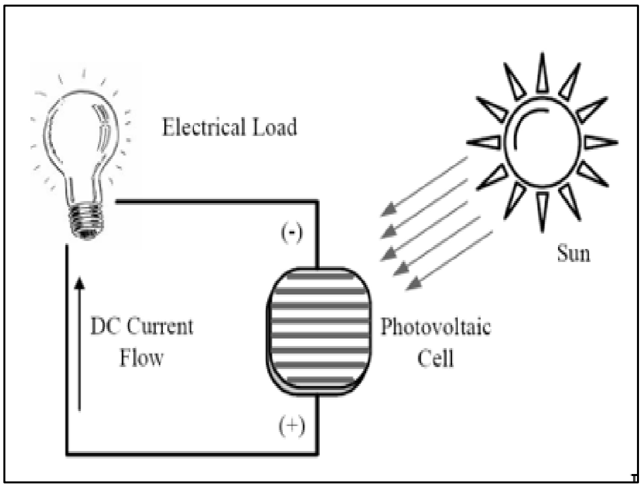

Fig 1: Working of PV Cell

A p-n junction diode, comprised of two distinct layers of silicon doped with impurity atoms—donors for the n-layer and acceptors for the p-layer. Upon connection, the charged particles either dissipate energy as heat or traverse through the cell, eventually flowing as current to neutralize potential differences.

The chemical bonding within the materials is crucial for this process, typically involving silicon layers doped with boron and phosphorus. These layers possess differing electrical charges, facilitating the generation and direction of electron flow. When combined into an array, solar cells collectively convert solar energy into usable direct current (DC) electricity. Typically, the efficiency of PV cells ranges from 15 to 25%.wafer-based cells, which utilize crystalline silicon and are subdivided into poly-silicon and mono-crystalline silicon technologies; thin-film cells, including amorphous silicon; and a third category comprising combinations of multiple thin-film technologies, still in the developmental stage and not yet widely available commercially. The basic structure of a solar PV system, consisting of PV cells, modules, and arrays, is illustrated in Fig. 2.

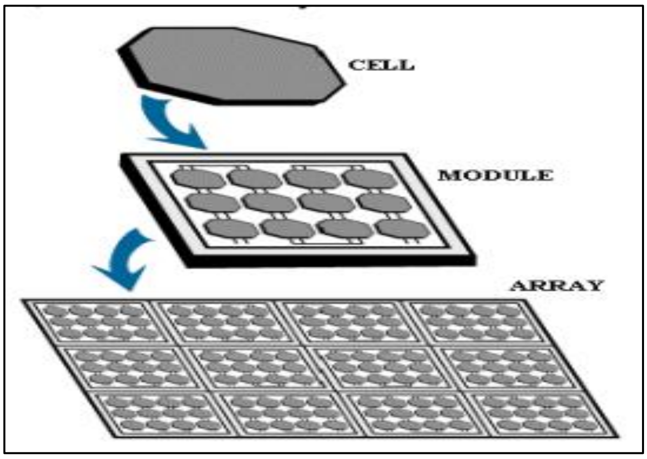

Fig 2: Photovoltaic System

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C. Wind System

Before the advent of the steam engine by James Watt in the eighteenth century, non-conventional energy sources such as wind, tidal, and solar power were considered conventional. Wind-powered ships were instrumental in exploring the new world. These sources are abundant and free, offering pollution-free and inexhaustible energy. Throughout history, humans have utilized these sources to propel ships, operate windmills for grinding corn, and pump water. However, due to limited technology and high costs, their widespread adoption was hindered. Additionally, uncertainties regarding availability and challenges in energy transportation posed obstacles to development. Fossil fuels and nuclear energy eventually supplanted non-conventional methods due to their advantages in transportation and reliability, albeit at the cost of environmental pollution. Concerns about nuclear energy's safety remain, highlighting the importance of proper control and regulation.

Fig 3: Wind Turbine

D. Characteristics of Wind Power

Wind energy is a plentiful and renewable source of energy that is also environmentally friendly. However, its availability can be uncertain, and producing enough power requires the movement of large volumes of air. Unlike conventional energy sources, wind power must be used when it is available. The formula for calculating the amount of power generated is given by multiplying the swept area in square meters and the wind velocity in kilometers per hour, and is affected by various factors. Consequently, wind energy has its limitations, but it remains a promising source of renewable energy.

Where A is the swept area in sq. metre and V the wind velocity in Km/hr. the energy developed is affected by

Power Developed =13.14x10-6AV3kW

E. UPQC

UPQC-ANN-RE mainly functions by feeding the energy generated by photovoltaic arrays and wind turbines into the electrical grid. It also improves power quality indicators such as power factor, voltage and current harmonics, thus doubling up as a UPQC. The system's converters are carefully analyzed to provide a better understanding of UPQC-ANN-RE's operation. The research then presents a simulation to evaluate the performance of the UPQC-ANN-RE system and compare it with the PI controller.

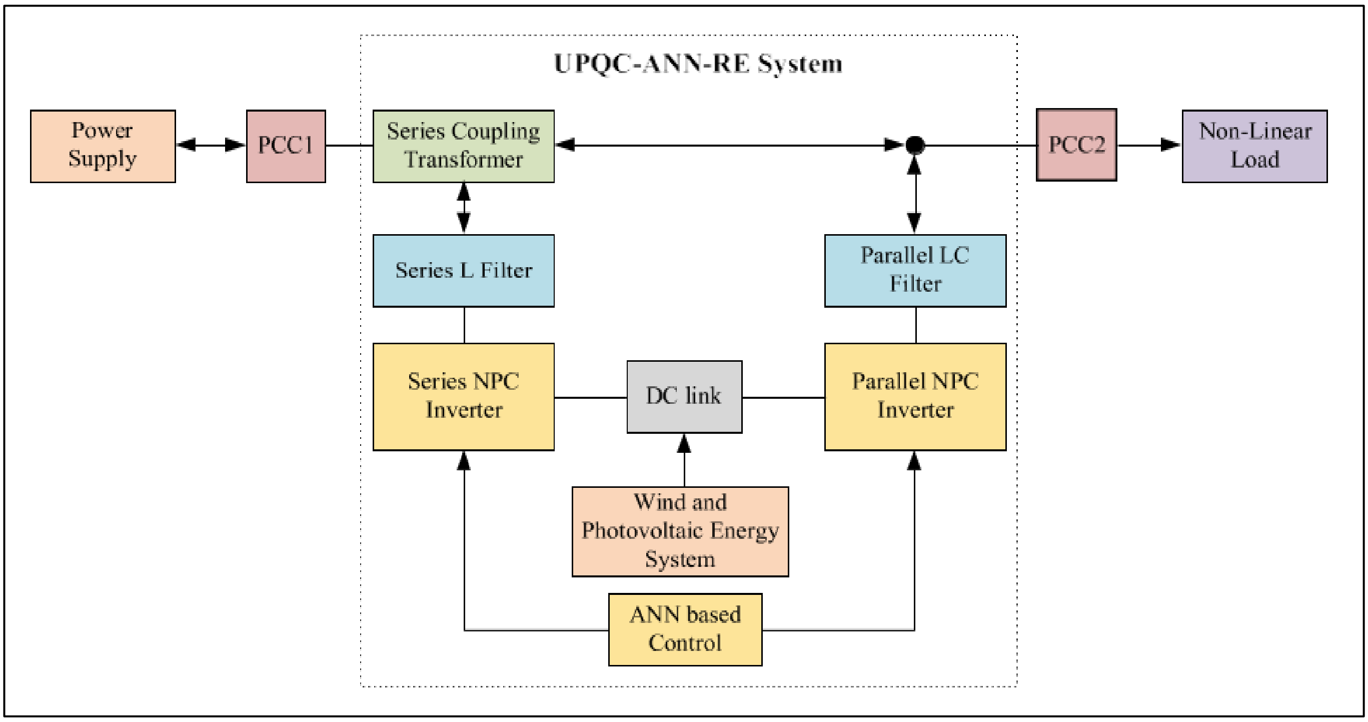

Fig 4: Block Diagram of UPQC

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F. UPQC Operation

To improve power quality in power systems, the Unified Power Quality Controller (UPQC) is used. It addresses problems such as voltage sag, voltage swell, voltage flicker, and harmonics by combining two voltage source inverters. One inverter is connected in parallel, and the other in series with the transmission line.

The series inverter works to regulate voltage by injecting an opposite polarity voltage to existing voltage, thus reducing sags and swells. The parallel inverter helps keep a balanced power factor by injecting an opposite phase and amplitude current to reactive power and harmonics.

The UPQC's advanced control algorithm diligently monitors power quality parameters and adjusts its output to match the requirements. This makes it an indispensable tool across various sectors, including data centers, renewable energy generation, and industrial operations. By ensuring consistent power delivery and minimizing harmonic distortion, the UPQC enhances the efficiency and reliability of power systems.

It effectively accomplishes important enhancements, such as voltage stability, elimination of harmonics, augmentation of current, and an overall increase in power quality. The UPQC system couples shunt and series active power filters over a shared DC connection. We use shunt filters to offset reactive power and minimize harmonics in the load current. On the other hand,Conversely, series filters address issues like voltage sags, swells, and flickers on the source side. ower filter (APF) may adjust the voltage at the DC connection. UPQC devices have the ability to simultaneously execute the tasks of both parallel-active power filter (P-APF) and series-active power filter (S-APF).

Solar modules power the UPQC system, which further enhances its performance with a boost converter, MPPT P&O algorithm, and PI controller. This model effectively addresses the issue of reactive power compensation and minimizes the occurrence of load voltage and source current harmonics. However, it is not as effective in minimizing voltage sags and disturbances that result from the integration of photovoltaic systems. Furthermore, a method to enhance power quality (PQ) was employed by utilizing a Unified Power Quality Conditioner (UPQC) with Battery Energy Storage (BES) in a micro-grid that is powered by a combination of photovoltaic (PV) and wind energy sources. The results of this study show that both fuzzy logic controllers (FLC) and PI controllers have the ability to enhance power quality and minimize distortions in output power. Additionally, we employed a Unified Power Quality Conditioner (UPQC) system, coupling it to a wind turbine and integrating it with the UPQC DC-link circuit. In this setup, the use of a PI controller effectively mitigated issues related to high voltages, voltage level fluctuations, and reactive power fluctuations, regardless of the system's connection to the power grid.

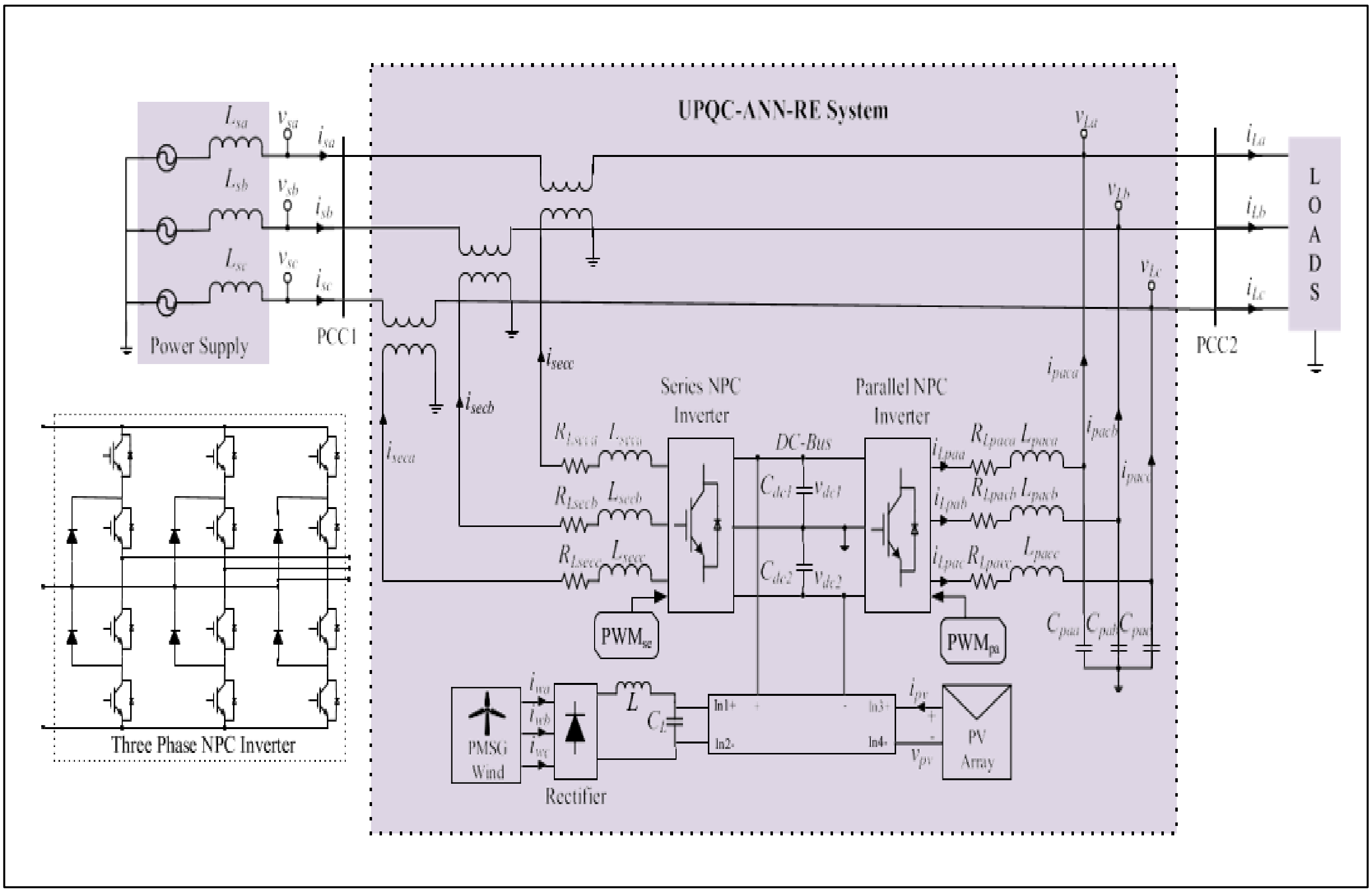

Fig 5: Schemetic Diagram UPQC

III. RESULTS

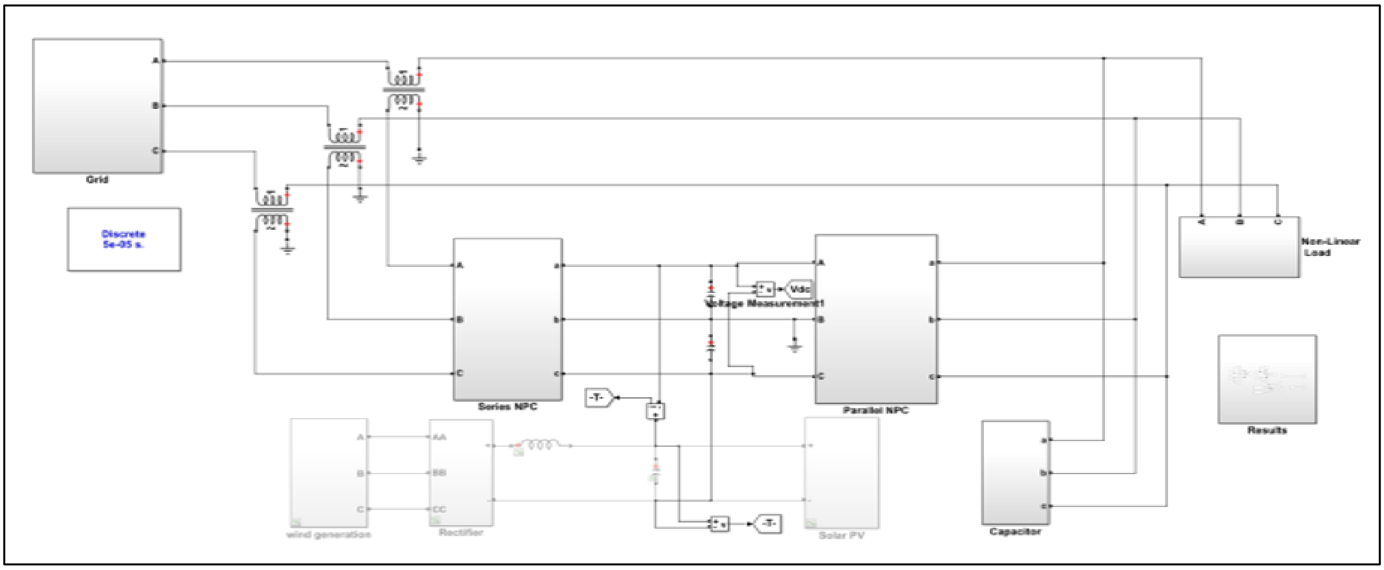

Fig 6: Simulink Model at OPC

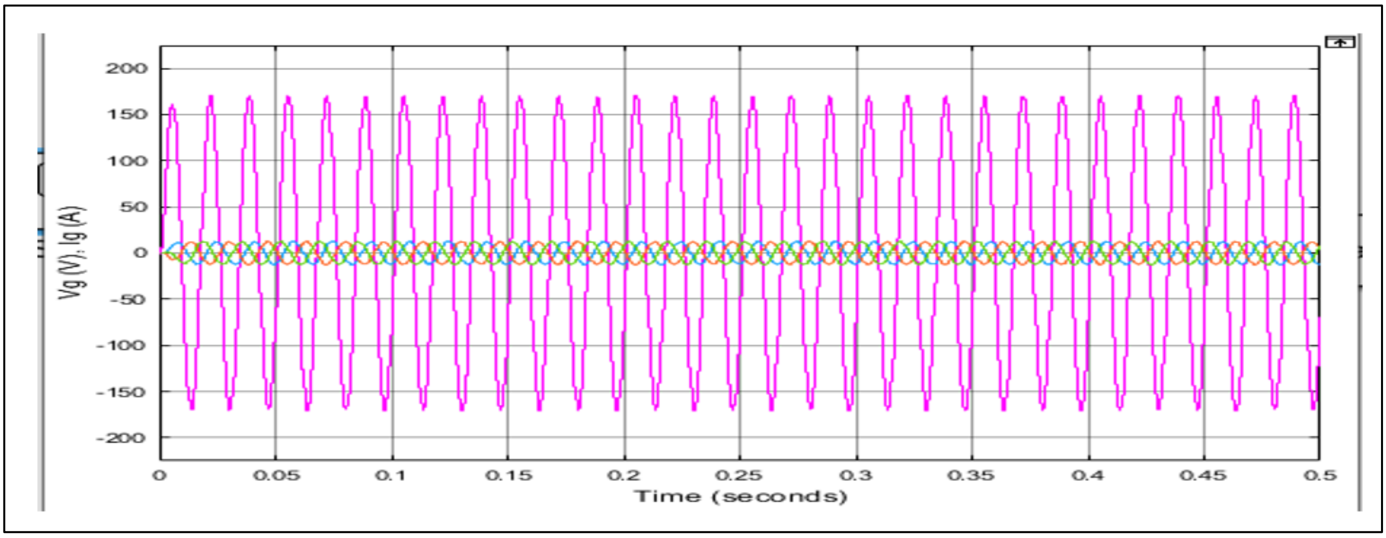

Fig 7: Grid Voltage and Grid Current

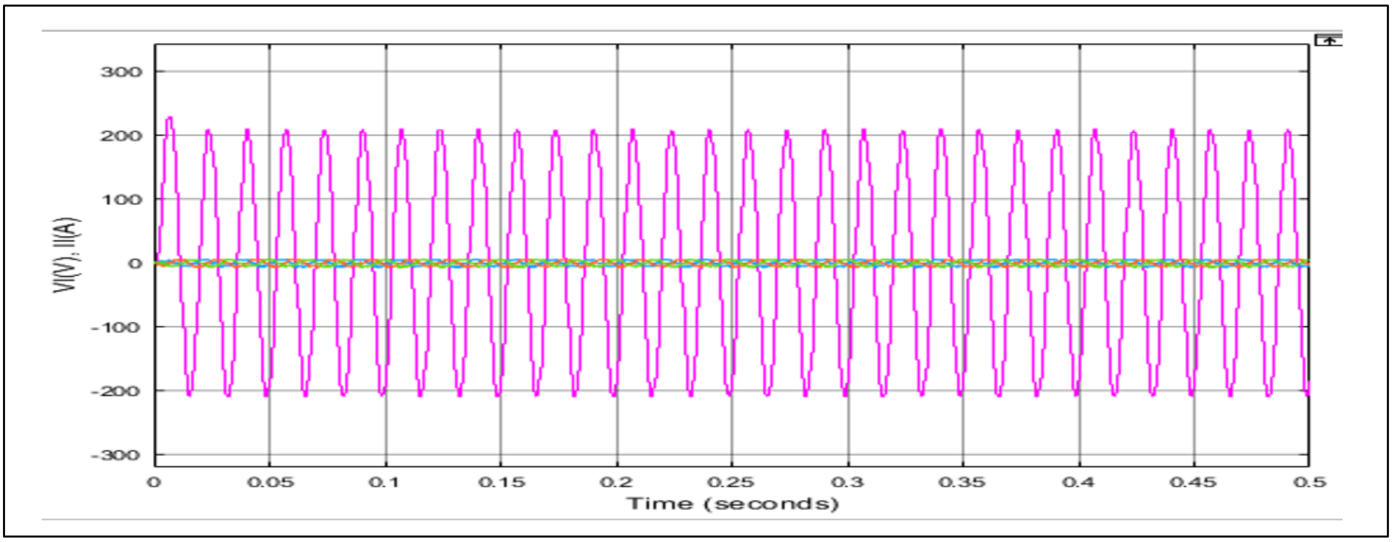

Fig 8: Load Voltage and Load Current

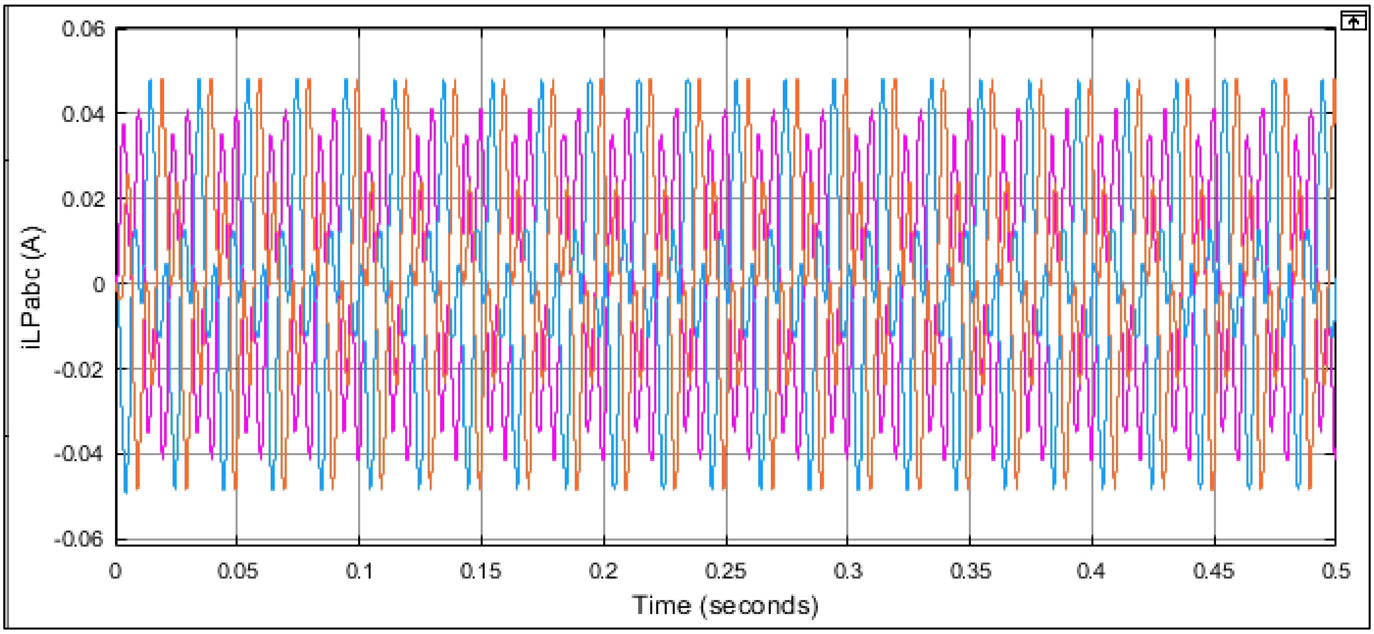

Fig 9: Current at Parallel Inverter

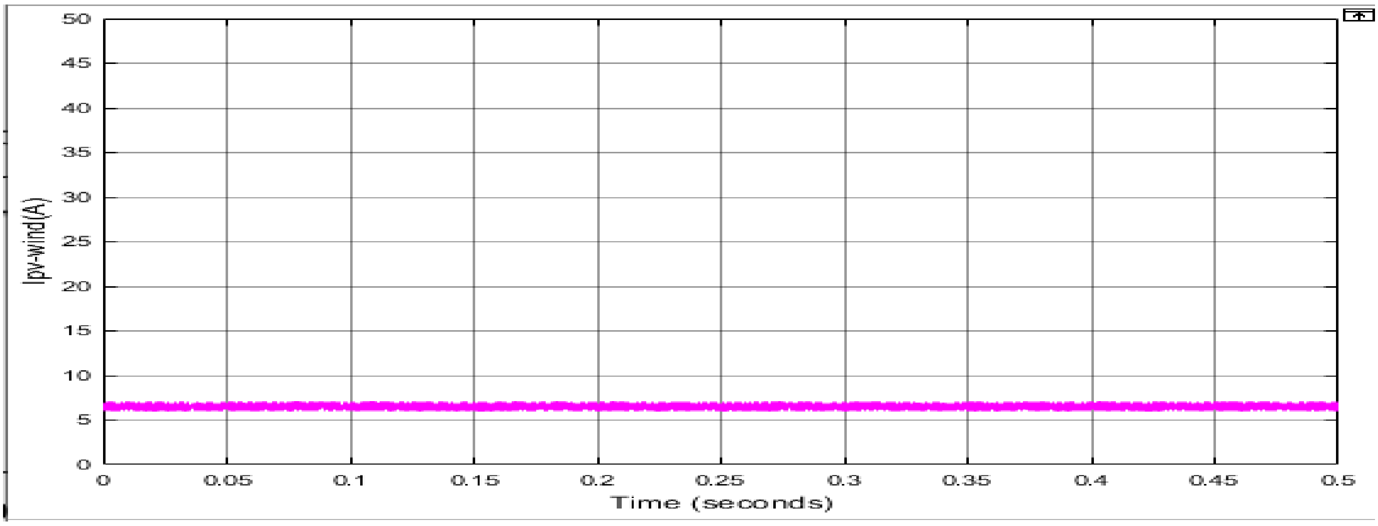

Fig 10: PV array and Wind Turbine Current

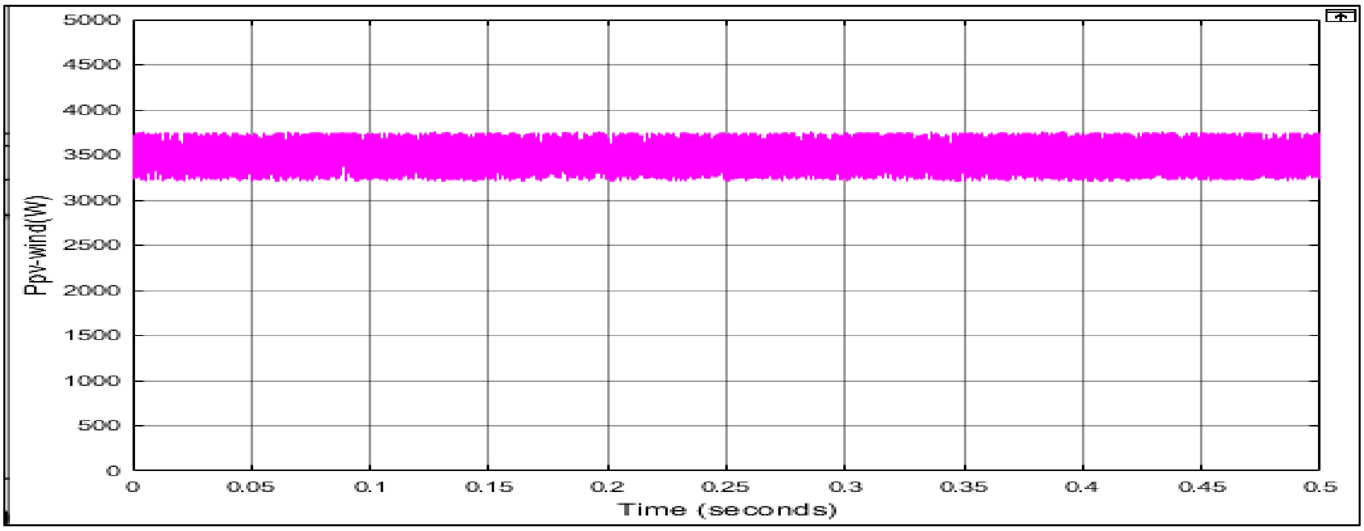

Fig 11: Power of PV Array and Wind Turbine

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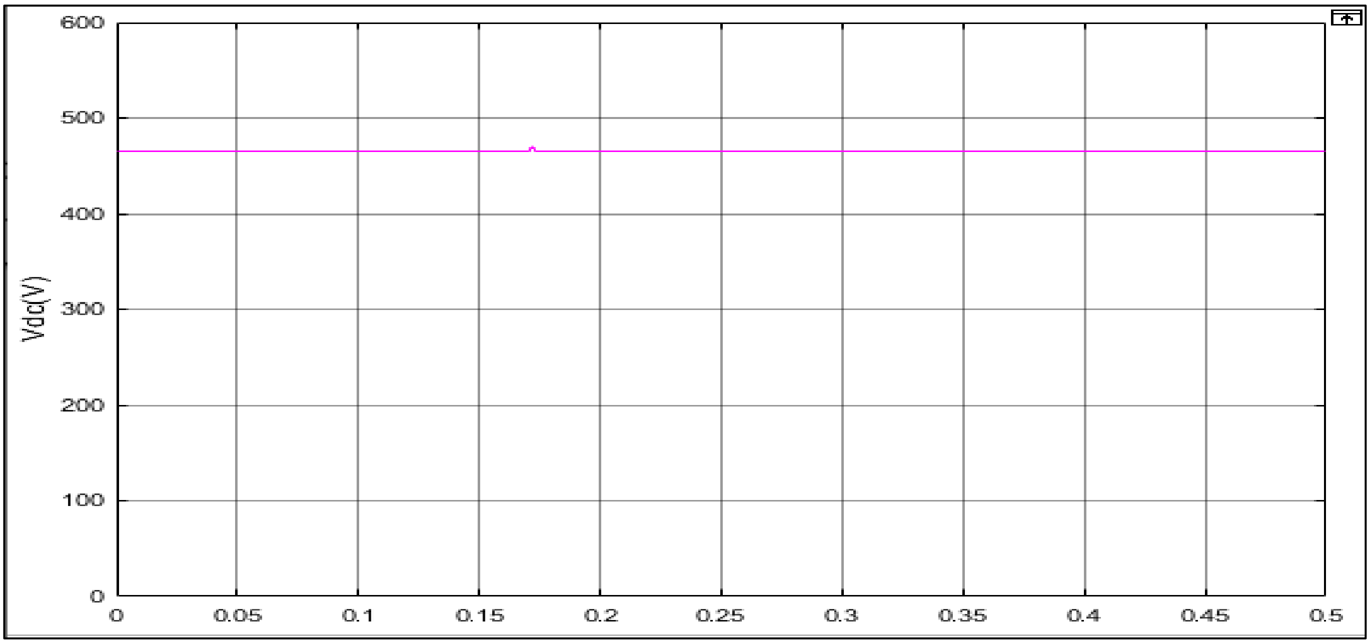

Fig 12: DC Link Voltage VDC (V)

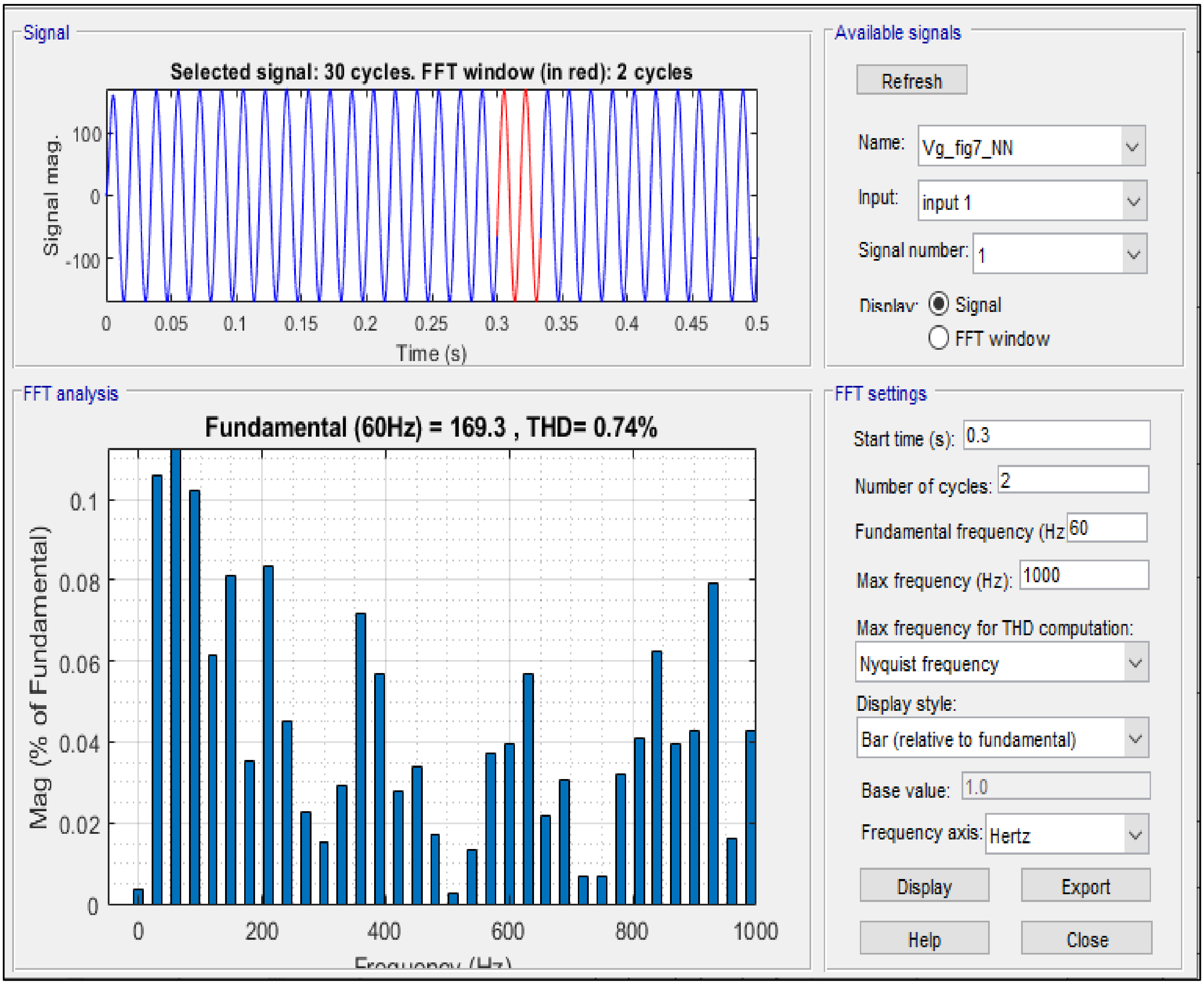

Fig 13: THD of Grid Voltage

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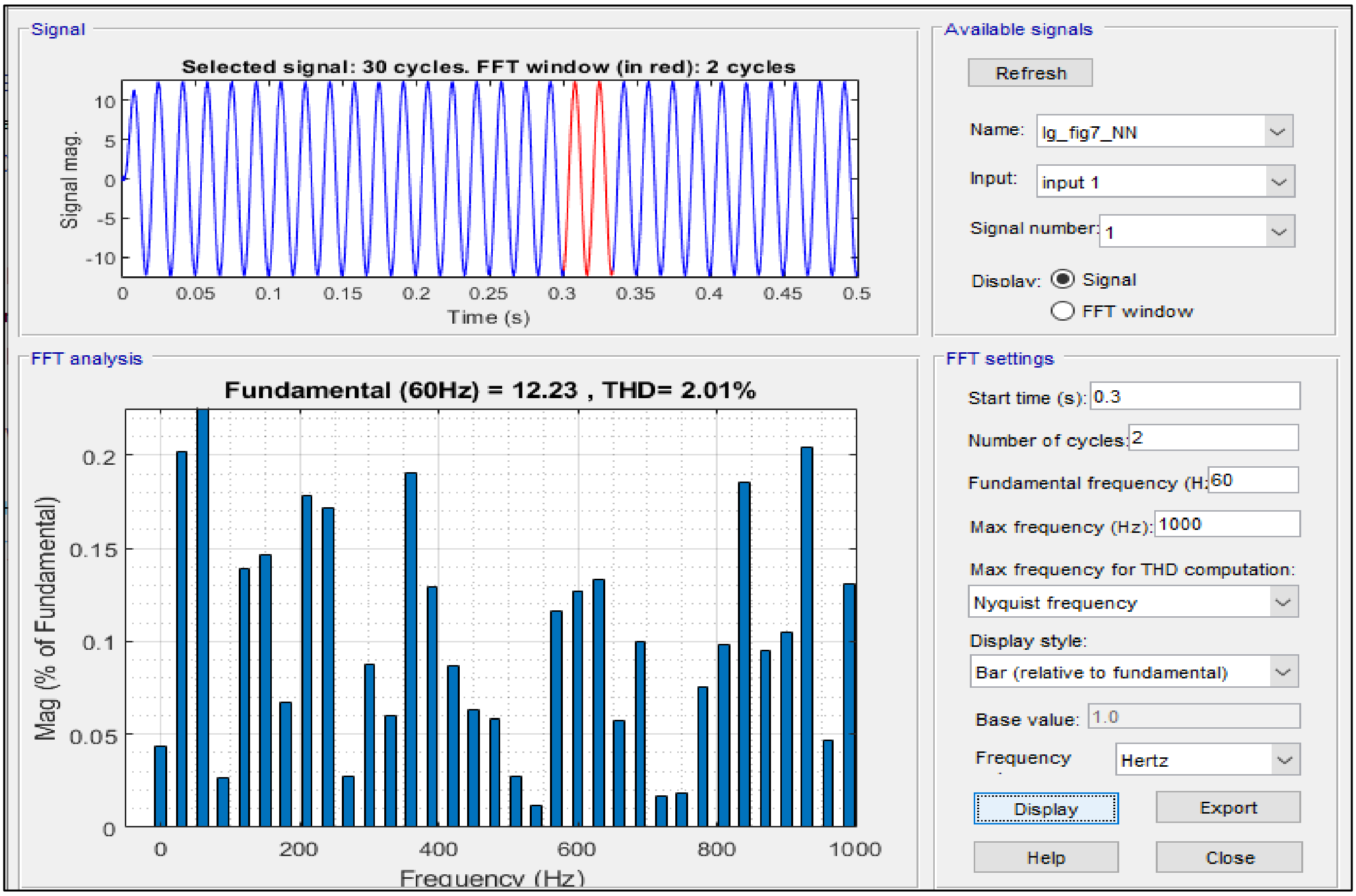

Fig 14: THD of Grid Current

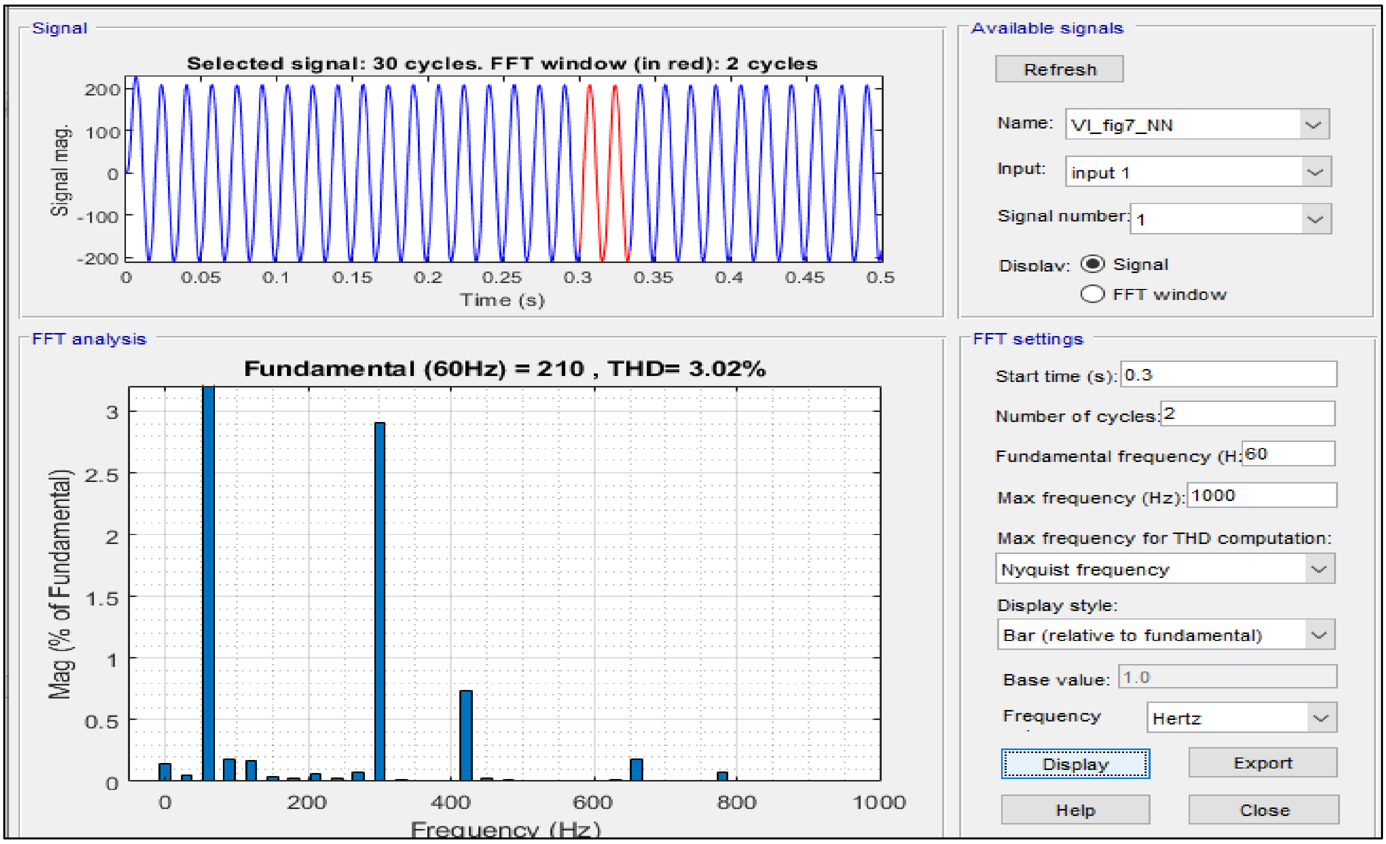

Fig 15: THD of Load Voltage

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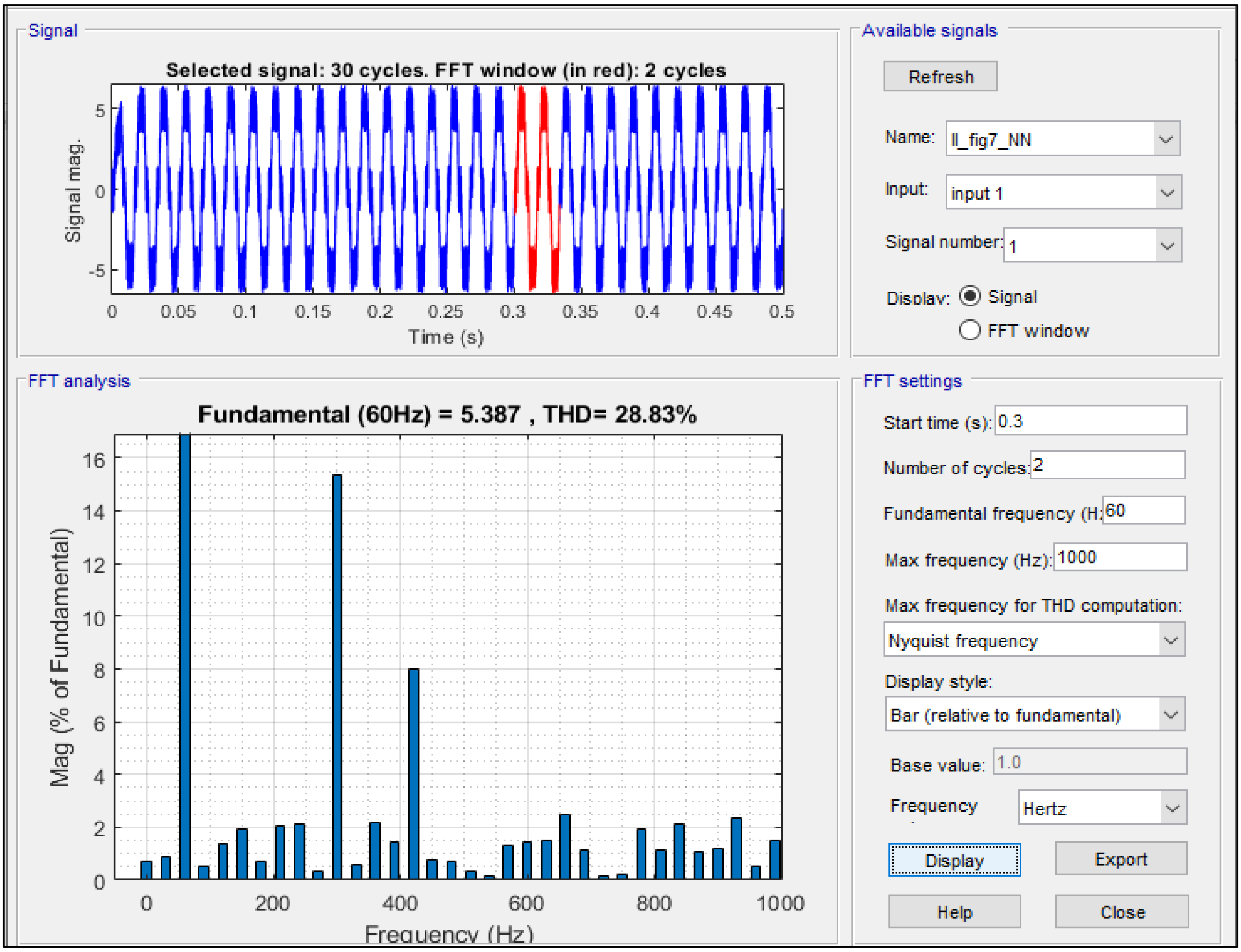

Fig 16: THD of Load Current

IV. CONCLUSION

In order to assess the static performance, the analysis used four operational scenarios: grid voltages, load characteristics, and energy outputs from both solar and wind turbine sources (OPC 1-4). We evaluated the system's dynamic response by subjecting it to sudden changes in solar irradiation, wind speed, and load dynamics. The results of the simulation show that the UPQC-ANN-RE system effectively lowers harmonics that are caused by nonlinear loads and achieves a total harmonic distortion (THD) for both load-side voltages and currents that is slightly better than the PI controller's performance. Both systems conform to the threshold standards set by IEEE 519.

REFERENCES

[1]. Namburi Nireekshana; M. Anil Goud; R. Bhavani Shankar; G. Nitin Sai chandra. (Volume. 8 Issue. 5, May - 2023) "Solar Powered Multipurpose Agriculture Robot." , International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 299–306. https://doi.org/10.5281/zenodo.7940166.

[2]. Namburi Nireekshana; Tanvi H Nerlekar; Palle Nitish Kumar; Mohammed Mohsin Bajaber. (Volume. 8 Issue. 4, April - 2023) "An Innovative Solar Based Robotic Floor Cleaner." , International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 1880-1885. https://doi.org/10.5281/zenodo.7918621.

[3]. Namburi Nireekshana; Onteru Divya; Mohammed Abdul Saquib Adil; Rathod Rahul; Mohammed Shoaib Mohiuddin. (Volume. 9 Issue. 1, January - 2024) "An Innovative SSSC Device for Power Quality Enhancement." International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 23212326.https://doi.org/10.5281/zenodo.1067052

[4]. Namburi Nireekshana; K.Pulla Reddy; Reyya Bose Babu; Bonda Sunder; G.Sumanth Kumar; P.Vivekananda Raj. (Volume. 9 Issue. 2, February - 2024) "Static Var Compensator for Reactive Power Control." International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 27-30.https://doi.org/10.5281/zenodo.10638477.

[5]. Namburi Nireekshana; A. Archana; Setla Manvitha; Mohammed Saad Ahmed; Nisar Ahmed Khan; Akellu George Muller. (Volume. 9 Issue. 2, February - 2024) "Unique Facts Device for Power Quality Mitigation." International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 145-148.https://doi.org/10.5281/zenodo.10652911.

[6]. Namburi Nireekshana; Manmarry Vaibhav Murali; Makka Harinath; Ch.Vishal; Ankam Sandeep Kumar. (Volume. 9 Issue. 2, February - 2024) "Power Quality Improvement by Thyristor Controlled Series Capacitor." International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165 , PP :- 423-427.https://doi.org/10.5281/zenodo.10669448.

[7]. Namburi Nireekshana, R. Ramachandran and G. V. Narayana (2023), A Novel Swarm Approach for Regulating Load Frequency in Two-Area Energy Systems. IJEER 11(2), 371-377. DOI: 10.37391/IJEER.110218.

[8]. Namburi Nireekshana, R. Ramachandran and G. V. Narayana (2023), A New Soft Computing Fuzzy Logic Frequency Regulation Scheme for Two Area Hybrid Power Systems. IJEER 11(3), 705-710. DOI: 10.37391/ijeer.110310.

[9]. N Nireekshana, R Ramachandran, GV Narayana -An innovative fuzzy logic frequency regulation strategy for two-area power systemsInternational Journal of Power Electronics and Drive …, 2024

[10]. N. Nireekshana, R. Ramachandran, and G. V. Narayana, "Novel Intelligence ANFIS Technique for Two-Area Hybrid Power System's Load Frequency Regulation," *E3S Web Conf.*, vol. 472, p. 02005, 2024, doi: 10.1051/e3sconf/202447202005.

[11]. N. Namburi Nireekshana and K. R. Kumar, "A Modern Distribution Power Flow Controller With A PID-Fuzzy Approach: Improves The Power Quality", Accessed: Apr. 25, 2024. [Online]. Available: https://ijeer.forexjournal.co.in/papers-pdf/ijeer-120124.pdf.

[12]. N. Nireekshana, R. Ramachandran, and G. V. Narayana, "A New Soft Computing Fuzzy Logic Frequency Regulation Scheme for Two Area Hybrid Power Systems," Int. J. Electr. Electron. Res., vol. 11, no. 3, pp. 705–710, Aug. 2023, doi: 10.37391/IJEER.110310.

[13]. N. Nireekshana, R. Ramachandran, and G. V. Narayana, "An innovative fuzzy logic frequency regulation strategy for two-area power systems," Int. J. Power Electron. Drive Syst. IJPEDS, vol. 15, no. 1, Art. no. 1, Mar. 2024, doi: 10.11591/ijpeds.v15.i1.pp603-610.

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