NEURAL NETWORK CONTROLLER BASED INTERLINKING CONVERTERFOR POWER QUALITY IMPROVEMENT IN MICROGRID SYSTEMS

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Abstract

- The project aims to improve power quality using a neural network-based interlinking converter. The proposed control system is designed to reduce harmonics and improve dynamic response compared to conventional notch-filter techniques. The system is also developed for a three-phase power system application and can compensate for both balanced and unbalanced harmonics with higher accuracy. The use of a neural network allows for more precise control of the converter, resulting in a more efficient and effective system. The system's ability to reduce harmonics and improve dynamic response is crucial in improving power quality, as it minimizes the risk of equipment damage and improves the overall reliability of the power system. The proposed control scheme is an improvement over conventional notch-filter techniques because it provides more accurate compensation for harmonics. The system is also able to handle both balanced and unbalanced harmonics, which is critical in real-world power systems. Overall, the implementation of the NN-based interlinking converter has the potential to significantly improve power quality, leading to a more reliable and efficient power system.

Keywords: Grid-connected microgrid, harmonics reduction, notch filter, power management, Neural Networks Controller.

I. INTRODUCTION

Harmonics in power systems can cause a range of issues, including increased losses, reduced efficiency, equipment overheating, and interference with communication systems. In microgrids, the problem of harmonics is even more critical, as the presence of distributed energy resources (DERs) such as renewable energy sources and energy storage systems can exacerbate the harmonic distortion. To reduce the harmonic distortion in microgrids, filters such as LC or LCL filters can be used to mitigate the effects of power electronic devices. These filters are designed to suppress the high-frequency harmonics generated by the converters. Non-linear loads, on the other hand, require a different approach. These loads draw non-sinusoidal currents that can distort the voltage waveform. This, in turn, can increase the THD of the grid voltage and current. To mitigate this problem, it is important to ensure that the THD level is kept within an acceptable range based on the grid standards. The IEEE standard 1547 and Australian standard 4777 both specify that the total current distortion should be less than 5%. This means that the sum of all the harmonic currents should not exceed 5% of the fundamental current. Meeting these standards requires careful design and control of microgrids, including proper selection and placement of filters and other mitigation measures.

II. LITERATURE REVIEW

The proposed autonomous power management scheme for interlinked AC-DC microgrids addresses the operational drawbacks of existing control schemes by considering the specific loading conditions of the DC microgrid before importing power from the interlinked

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AC microgrid. This strategy enables efficient voltage regulation in the DC microgrid and reduces the number of converters in operation. The proposed scheme is fully autonomous, allowing for plug-n-play features for generators and tie-converters. The performance of the proposed control scheme has been validated under different operating scenarios, demonstrating its effectiveness in managing power deficits in the DC microgrid efficiently and autonomously while maintaining better voltage regulation. Overall, this proposed power management scheme has the potential to improve the operational efficiency of interlinked AC-DC microgrids, providing more reliable and stable power to end-users.

The proposed multifunctional control strategy and associated control algorithms for distributed wind turbine (WT) based nano-grids connected to a distorted utility-grid are designed to address several key challenges associated with the integration of renewable energy sources to the grid. The novelty of the proposed control design lies in its ability to simultaneously maximize the generated power from the WT, maintain power quality in both AC- and DC-sides under critical conditions of the power grid, and improve power quality against distortion from local nonlinear loads under a reduced switching frequency. The control strategy is based on a unique control design that coordinates multiple converters for multitasking operation of the nano-grids. The proposed control algorithms use a robust fast-dynamic predictive control method to fulfill the multifunctional requirements of the current controllers. The fast-dynamic predictive control method is designed to optimize the current reference and reduce the current tracking error in real- time.

One of the key advantages of the proposed control strategy is its ability to maintain power quality in both AC and DC - sides under critical conditions of the power grid. This is achieved through the use of advanced control algorithms that are capable of detecting and mitigating grid voltage variations and harmonic distortions. The control algorithms can also balance the power flow between the AC and DC sides of the nano-grid to ensure a stable power supply. Another significant advantage of the proposed control strategy is its ability to improve power quality against distortion from local nonlinear loads under a reduced switching frequency. This is achieved through the use of advanced filtering techniques that can effectively remove harmonic distortions and other power quality issues.

The control strategy for a system that includes renewable energy sources, such as solar and wind, and a battery unit. The renewable energy sources generate power that is used to provide a continuous power supply. Since the output of these sources is in the form of DC, the batteries are used to store this DC current. Batteries are chemical devices that store electrical energy in the form of chemicals. Through electrochemical reactions, they convert the stored chemical energy into direct current (DC) electric energy. This DC electric energy can be used to power various devices or can be converted into AC electric energy using an inverter to power AC devices.

III. SYSTEM CONFIGURATION

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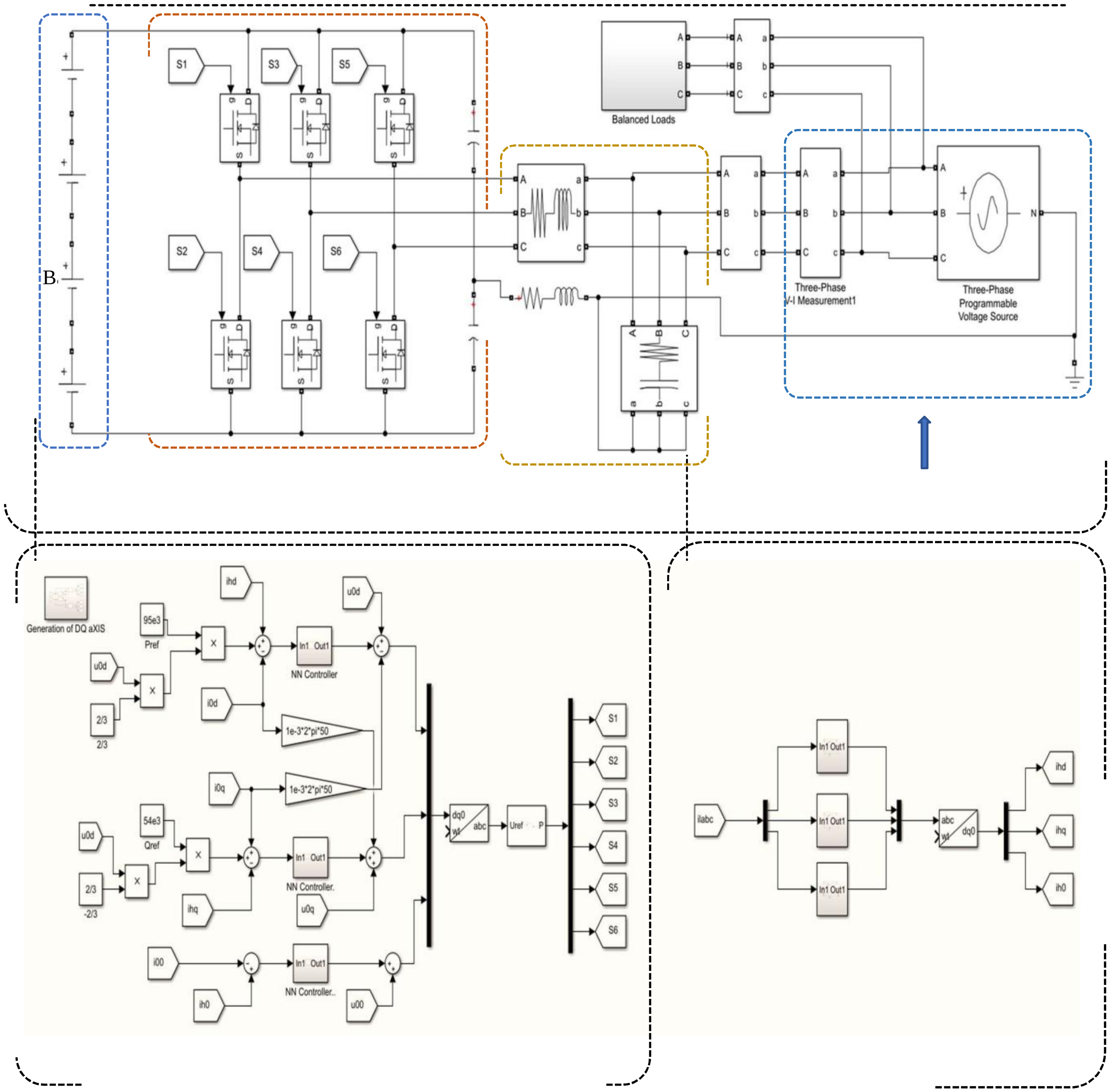
Four-leg converter   Three-phase Loads



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By using LC filter to minimize ripples that occur during the conversion process. The goal of the project is to improve power quality in the microgrid system, which is made up of distributed energy sources such as solar and wind power. To control harmonics in the system, a neural network controller is being implemented. This controller uses artificial intelligence techniques to learn and adapt to the behavior of the microgrid system and help reduce harmonic distortion. Overall, the project aims to deliver power to loads and consumers in a more efficient and reliable manner, without causing damage to any equipment.

3.1. Control Strategy

This control strategy uses the dq transformation to transform the three-phase current signals into two orthogonal components: the d-component, which represents the current in the direction of the grid voltage, and the q-component, which represents the current in the direction of the magnetic field. The dq current controller then regulates the d-component current to control the active power flow and the q-component current to control the reactive power flow.

$$P + P_l = 3/2(u_{od}i_{od} + u_{oq}i_{oq} + u_{od}i_{hd} + u_{oq}i_{hq})$$

$$Q + Q_l = 3/2(u_{oq}i_{od} - u_{od}i_{oq} + u_{oq}i_{hd} - u_{od}i_{hq})$$

Where, P_m and Q_m are the expected output active and reactive powers, respectively. P_h and Q_h are the active and reactive power loss caused by harmonics from the load side. Since the reference frame is synchronised with the utility network, u_{oq} becomes zero. As a result, (1) can be rewritten as:

$$P + P_l = 3u_{od}i_{od}/2 + 3u_{od}i_{hd}/2$$

$$Q + Q_l = -3u_{od}i_{oq}/2 - 3u_{od}i_{hq}/2$$

In addition to the dq current controller, a voltage controller is also used to regulate the voltage level in the microgrid. This controller adjusts the output voltage of the inverters to maintain a constant voltage level in the microgrid.

$$P_{ref} = 3u_{od}i_{od}/2 + 3u_{od}i_{hd}/2$$

$$Q_{ref} = -3u_{od}i_{oq}/2 - 3u_{od}i_{hq}/2$$

By using above reference powers, can't determine the harmonics in a three-phase system. So, taking a reference current to determine the harmonics in a three-phase system;

to a computational model that is inspired by the structure and function of biological neural networks. These networks are composed of artificial neurons or nodes, which are interconnected through weighted connections. These weights are adjusted through a process called training, during which the network learns to perform a specific task, such as image recognition or language translation. Once trained, the network can be used to make predictions on new data by passing it through the network and producing an output. Biological neural networks, also known as neural circuits or neuronal networks, are composed of a group of neurons that are chemically connected or functionally associated.

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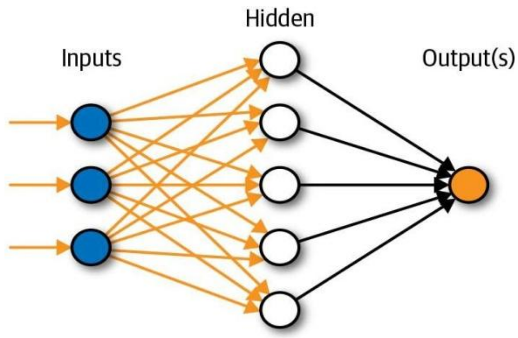


Fig. 2. Neural Network

A single neuron can receive input and send output to many other neurons, forming complex networks of interconnected neurons. These networks can be found throughout the nervous systems of animals, including humans. The total number of neurons and connections in a neural network can vary widely, from small networks of just a few neurons to large networks with billions of neurons and trillions of connections. The connections between neurons, also known as synapses, allow for the transmission of electrical and chemical signals between neurons, enabling neural circuits to process information and generate behavior. Neural networks are essential for many functions of the nervous system, including sensory processing, motor control, learning, and memory.

$i^* = i^* + i_{hd} = 2P_{ref}/3u_{od} + i_{hd}$

Fig. 3. Neural Network Block Diagram

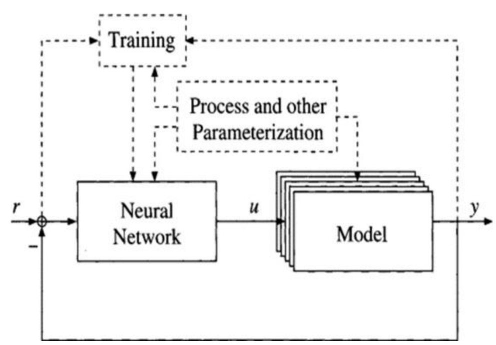
d od

$i^*_q = i^*_{oq} + i_{hq}$

$= -2Q_{ref}$

$/3u$

od $+ i_{hq}$



The working of a neural network controller is correct. The input layer receives sensory inputs, the

IV. System Configuration using Neural Networks

In artificial intelligence, a neural network refers

hidden layers process the inputs and extract relevant features, and the output layer produces the control signal based on the processed inputs. The neural network controller is trained on a dataset of input-output pairs, and

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the weights and biases of the neurons in the network are adjusted to minimize the error between the predicted output and the actual output. Once trained, the neural network controller can make accurate predictions and produce appropriate control signals in real-time based on the current inputs.

The advantages of neural network controllers over traditional controllers, which include non-linearity, adaptability, fault tolerance, and generalization. Neural network controllers can handle non-linear systems, adapt to changing conditions and environments, tolerate faults and failures, and generalize well to new situations. These advantages make neural network controllers a powerful tool for controlling complex systems.

V. Future Scope for neural networks

Artificial intelligence: One of the major limitations of neural network controllers is their lack of transparency and interpretability. Explainable AI is a field that aims to address this issue by providing insights into the reasoning behind the decisions made by these systems. In the future, neural network controllers may be developed to provide more explainable and transparent decision-making processes.

Reinforcement learning: Neural network controllers can be trained using reinforcement learning, which involves learning from trial and error. The future of neural network controllers may involve using advanced reinforcement learning techniques to improve their decision-making capabilities.

Transfer learning: Transfer learning involves transferring knowledge learned from one task to another, and it can be applied to neural network controllers. This approach can help improve the efficiency of training and the accuracy of predictions.

Integration with other technologies: Neural network controllers can be integrated with other technologies, such as robotics and autonomous vehicles, to improve their capabilities. In the future, we may see more advanced integration with these technologies, leading to even more sophisticated and capable neural network controllers.

Hybrid architectures: Hybrid architectures combine different types of neural networks, such as convolutional and recurrent neural networks, to create more powerful systems. Future development of neural network controllers may involve the creation of even more advanced hybrid architectures that can handle complex tasks.

Edge computing: Edge computing involves performing computation and data processing closer to the source of the data, rather than sending it to a centralized location. The future of neural network controllers may involve developing models that can run on edge devices, enabling faster decision-making and more efficient use of resources. Overall, the future of neural network controllers looks promising, with ongoing research and development aimed at addressing their limitations and
expanding their capabilities. We can expect to see more advanced and capable systems in the years to come.

VI. Simulation Results

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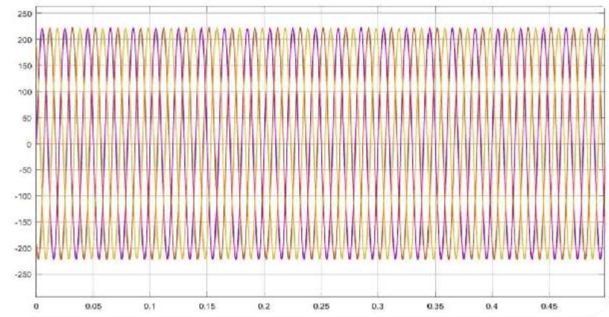

Fig. 4. Balanced three-phase grid currents

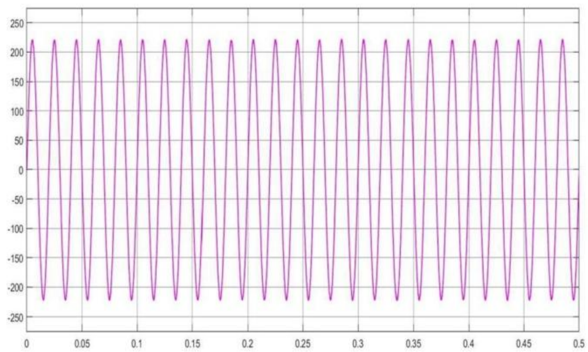

Fig. 5. Balanced grid current in phase-a

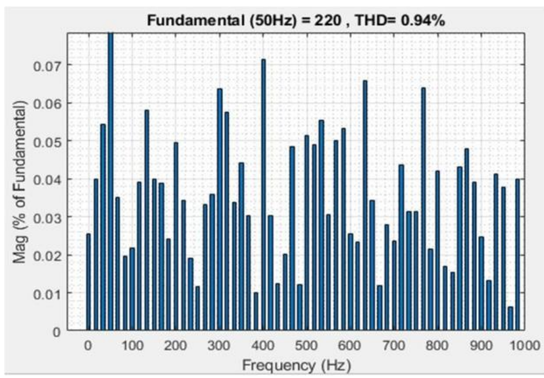

Fig. 6. THD of balanced grid current in phase-a

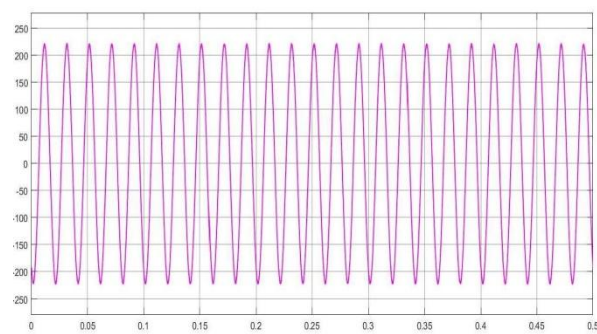

Fig. 7. Balanced grid current in phase-b

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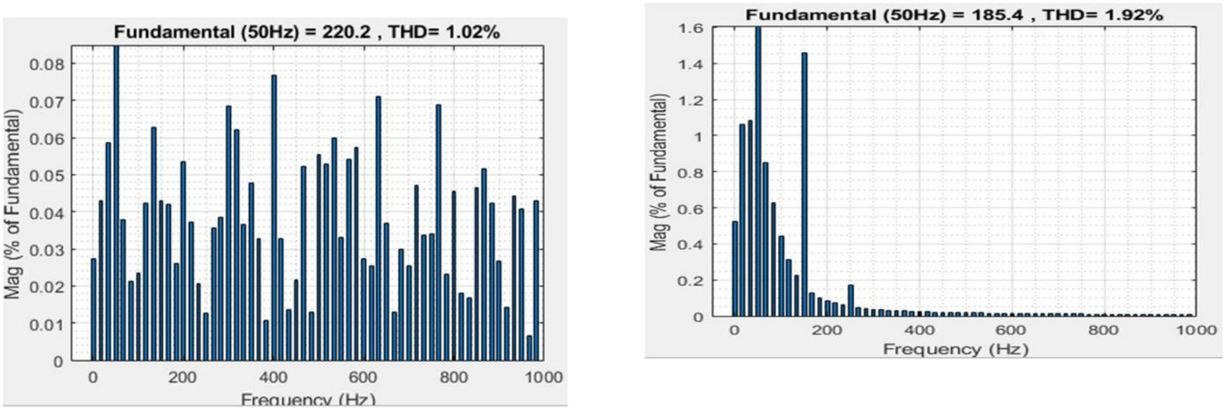

Fig. 8. THD of balanced grid current in phase-b

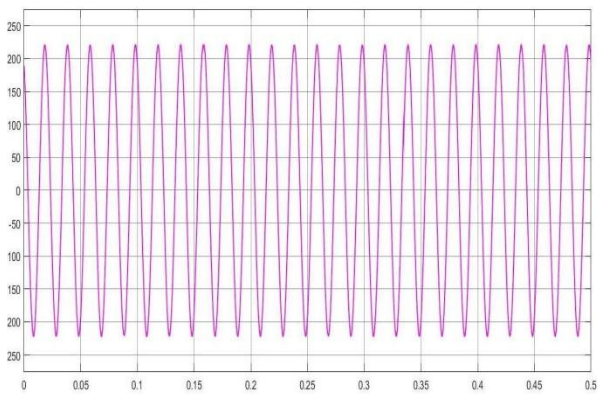

Fig. 9. Balanced grid current in phase-c

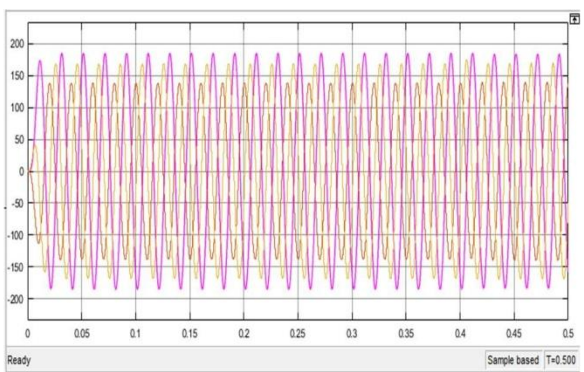

Fig. 10. Unbalanced three-phase grid currents

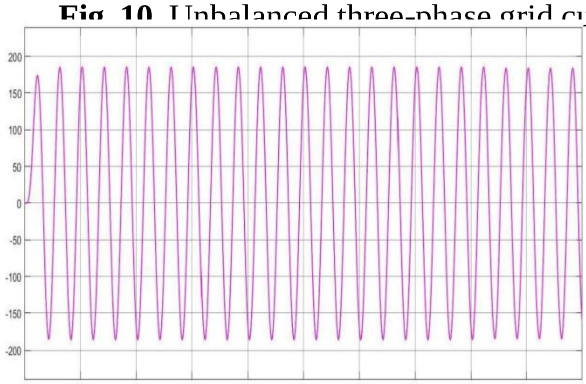

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Fig. 11. Unbalanced grid current in phase-a

Fig. 12. THD of balanced grid current in phase-a

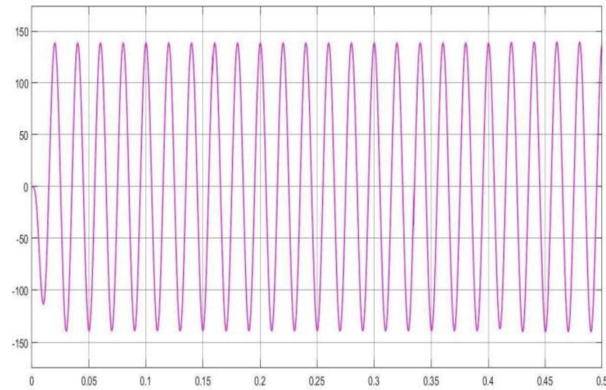

Fig. 13. Unbalanced grid current in phase-b

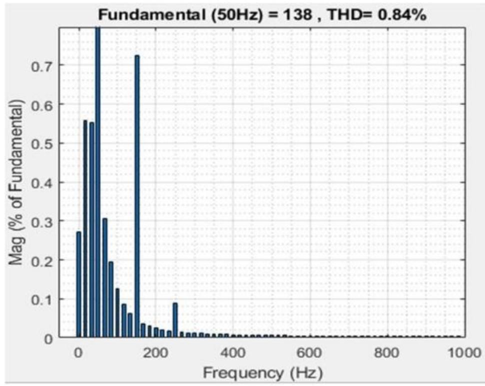

Fig. 14. THD of balanced grid current in phase-b

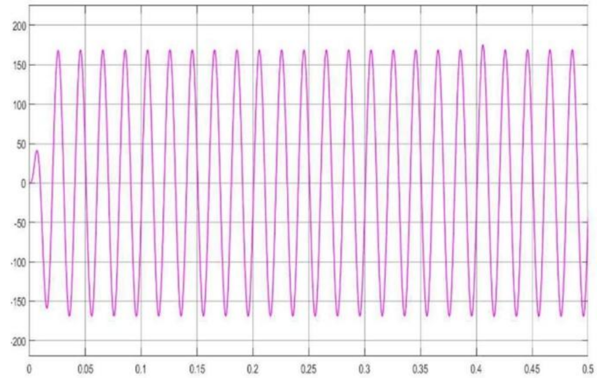

Fig. 15. Unbalanced grid current in phase-c

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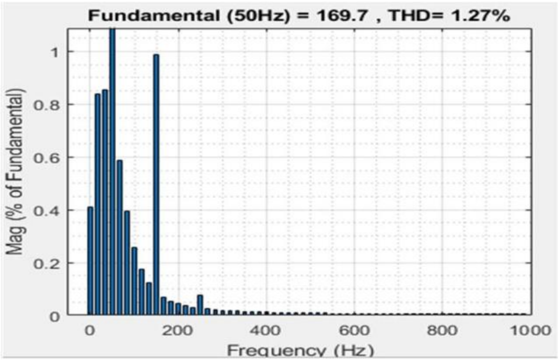

Fig. 16. THD of balanced grid current in phase-c

VII. CONCLUSION

Power quality issues, such as harmonics, are becoming more prevalent due to the increasing use of power electronic devices. Therefore, developing effective methods to eliminate harmonics is essential for improving power quality. I agree that traditional methods, such as notch filters, may not always provide reliable and satisfactory results. The use of neural networks in power system control is becoming more prevalent due to their ability to learn from data and provide accurate control. Therefore, I think that using a neural network-based interlinking converter for improving power quality is a promising approach. Replacing the PI controller with a neural network controller can improve the dynamic response and reduce harmonics. However, it is important to ensure that the neural network is properly trained and validated to achieve optimal performance. Additionally, it is essential to consider the robustness and stability of the system when using neural networks in control. It is great to hear that you have verified the effectiveness of the proposed method through simulation. I suggest considering further testing and validation, such as hardware-in-the-loop testing, to ensure the proposed method's reliability and robustness in real-world conditions.

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