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Enhancing Efficiency and Stability in Rooftop PV-IWPT Systems for LVDC Grids Using Fuzzy Logic Control and MPPT Techniques

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***Abstract*— A rooftop photovoltaic (PV) system is a significant solution for building-integrated centralized generation in low-voltage (LV) DC grids. The drilling-free rooftop PV-inductive wireless power transfer (PV-IWPT) system can reduce installation and post-maintenance costs by eliminating physical cable connections, thereby preventing thermal bridge disruption and rain penetration. Additionally, the PV-IWPT system offers inherent isolation properties between the input and output terminals. However, achieving maximum efficiency point tracking (MEPT) for both the PV panels and the system under diverse irradiance conditions is challenging. This paper proposes a novel approach to improve system performance by replacing the traditional Proportional-Integral (PI) controller with a Fuzzy Logic Controller (FLC) and utilizing Maximum Power Point Tracking (MPPT) instead of MEPT. Furthermore, Pulse Width Modulation (PWM) techniques are employed to ensure stable output. The proposed method enhances efficiency, stability, and adaptability of the PV-IWPT system, making it a robust solution for LVDC grid integration.**

Keywords*— *Rooftop Photovoltaic (PV) System, Inductive Wireless Power Transfer (IWPT), Low-Voltage DC Grid (LVDC), Fuzzy Logic Controller (FLC), Maximum Power Point Tracking (MPPT) etc.

I. INTRODUCTION

Building infrastructure that incorporates renewable energy sources is essential to the development of sustainable and energy-efficient metropolitan areas. Rooftop photovoltaic (PV) systems have become a prominent option for building-integrated centralized generation in low-voltage (LV) DC grids among a variety of renewable energy sources. By capturing solar energy and turning it into electrical power that can be utilized inside the building or fed into the grid, these systems lessen the need for fossil fuels and cut greenhouse gas emissions.

Using inductive wireless power transmission is one cutting-edge development in rooftop PV systems (IWPT). Physical cable connections are not required with the drilling-free rooftop PV-IWPT system, which drastically lowers installation and maintenance expenses. It also avoids problems with thermal bridges failing and rain seeping through the roof and into the building. By separating the input and output terminals, the IWPT system's intrinsic isolation qualities offer a safety benefit.

Nonetheless, the mix of PV-IWPT frameworks represents specific difficulties, especially in accomplishing most extreme effectiveness and power yield under changing irradiance conditions. Conventional frameworks frequently utilize Corresponding Essential (PI) regulators and Greatest Productivity Point Following (MEPT) to control the power move and enhance proficiency. While powerful, these strategies may not satisfactorily address the dynamic and non-straight nature of PV frameworks, particularly under fluctuating ecological circumstances.

In this paper, we propose a strategy to improve the exhibition of PV-IWPT frameworks by supplanting the PI regulator with a Fluffy Rationale Regulator (FLC) and using Greatest Power Point Following (MPPT) rather than MEPT. The FLC offers unrivaled flexibility and power in taking care of the non-direct qualities of PV frameworks, prompting further developed execution under different irradiance conditions. Moreover, the execution of Heartbeat Width Adjustment (PWM) strategies guarantees steady and productive power move to the LVDC network.

The proposed framework plans to give a more solid and productive answer for incorporating housetop PV frameworks with IWPT innovation. By utilizing progressed control calculations and power adjustment strategies, this approach tends to the restrictions of existing techniques and upgrades the general viability of the PV-IWPT framework. This paper frames the plan, execution, and advantages of the proposed technique, showing its capability to add to the economical improvement of energy frameworks in metropolitan conditions.

Figure 1 presents an example of local energy exchange within a low-voltage direct current (LVDC) grid, illustrating the interconnected nature of generation, energy storage, and load consumption. This configuration exemplifies a decentralized approach where local renewable energy sources (RES) such as rooftop photovoltaic (PV) systems directly supply power to nearby loads and energy storage units.

Components of Local Energy Exchange

1. **Interconnected Generation**:

Renewable Energy Sources (RES): Solar panels, wind turbines, and other RES are primary generation units. They convert natural energy into electrical power, contributing to the grid's sustainability.

- **Inverter Interfaces**: These components convert the DC power generated by RES into a form suitable for local loads or further transmission.

2. **Energy Storage**:

- **Battery Systems**: Essential for storing excess energy generated during peak production times. These batteries release stored energy during periods of low generation or high demand, ensuring a stable power supply.
- **Energy Management Systems (EMS)**: These systems monitor and control the charge-discharge cycles of batteries to optimize energy usage and prolong battery life.

3. **Load Consumption**:

- **Residential and Commercial Loads**: Various electrical appliances, lighting, heating, and cooling systems in homes and businesses that consume the energy supplied by the local generation and storage units.
- **Load Management Systems**: Devices or software applications that manage and prioritize power distribution to different loads, ensuring efficient energy use.

Centralized RES Generation in LVDC Grids

While local energy exchange systems are crucial for providing immediate and localized energy solutions, centralized renewable energy generation plays a significant role in enhancing the overall efficiency and sustainability of LVDC grids. Centralized RES systems aggregate power from multiple sources and distribute it across a wider network, offering several benefits:

1. **Enhanced Stability**: Centralized generation can stabilize the grid by balancing fluctuations in local energy production and consumption.

2. **Improved Efficiency**: Large-scale RES installations can achieve higher efficiency through economies of scale and advanced technologies.

3. **Sustainable Development**: Centralized generation supports the sustainable growth of LVDC grids by integrating large amounts of clean energy, reducing reliance on fossil fuels, and lowering greenhouse gas emissions.

Sustainable Improvement of LVDC Grids

The combination of local energy exchange systems and centralized RES generation paves the way for the sustainable improvement of LVDC grids. Key advantages include:

- **Reliability**: Enhanced grid reliability through diverse and redundant energy sources.
- **Flexibility**: Increased grid flexibility to accommodate varying demand and generation profiles.
- **Scalability**: Easier scalability to integrate additional renewable sources and expand the grid.

By leveraging both local and centralized approaches, LVDC grids can achieve a robust, efficient, and sustainable energy network that meets the demands of modern urban environments.

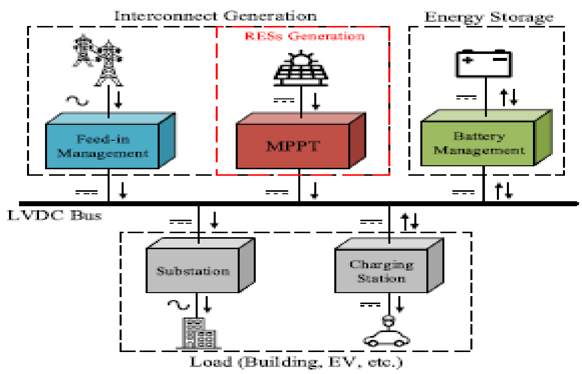

Fig. 1. Schematic overview of a typical low-voltage DC grid

This study's organizational framework separates the research into several areas. Section 2 presents the Literature Survey. Section 3 covered the suggested system techniques. Additionally, results are addressed and illustrated in section 4. Section 5 concludes with a presentation of future work and conclusions.

II. Literature Survey

Many facets of the integration of renewable energy sources into power systems, including control techniques, energy storage, inverter interfaces, and power management, have been the subject of substantial research. In order to better understand the development of reliable and stable rooftop solar (PV) systems coupled with inductive wireless power transfer (IWPT) for low-voltage direct current (LVDC) grids, this literature review examines significant contributions made in these fields.

Jia et al. (2019) investigated how directional relay operations were affected by renewable energy generators that were interfaced with inverters and suggested a better plan to deal with the related issues. This study emphasizes the complexity that inverter-based sources bring to power networks and the necessity of sophisticated control techniques to guarantee dependable protective mechanisms.

Dong et al.'s (2022) study looked into integrated energy stations' low-carbon optimal planning, combining gas-fired and combined power-to-gas units with carbon capture systems. Their research emphasizes how critical it is to reduce carbon footprints through comprehensive planning and optimization, as this is essential for sustainable energy systems.

Strategies for Maximum Power Point Tracking (MPPT) For PV systems, Yang et al. (2012) presented a very effective analog MPPT (AMPPT) technique. The study exhibited the efficacy of analog control in attaining accurate and prompt tracking of the maximum power point, a crucial aspect in optimizing the energy obtained from photovoltaic panels.

A study of solar PV and wind-powered residential DC nanogrids with dual energy storage systems under various operating modes was carried out by Keerthana et al. in 2022. Their results demonstrate the advantages of using a variety of energy storage options to improve the dependability and adaptability of renewable energy systems.

A high-density two-stage topology for grid-interface bidirectional converters in residential DC distribution systems was presented by Dong et al. (2013). The design of effective power conversion systems that can easily interface with household loads and the grid is relevant to this effort.

An autonomous power management strategy for LVDC microgrids based on a superimposed frequency droop mechanism was presented by Peyghami et al. (2018). Their approach provides a decentralized way to keep microgrids stable and power balanced, which is important for systems that use a lot of renewable energy.

of their 2017 review, Mohammadi and Mehraeen examined the difficulties of integrating PV in low-voltage secondary networks. They highlighted the necessity of sophisticated control and management techniques by identifying problems with voltage regulation, protection coordination, and grid stability.

Peyghami et al. (2019) explored decentralized droop control in DC microgrids using a frequency injection approach . Their research demonstrated the feasibility and effectiveness of decentralized control in enhancing the stability and scalability of microgrids.

A decentralized control architecture for DC nanogrid clusters was presented by Nasir et al. (2019) with the goal of electrifying rural areas in developing nations. This study demonstrated how decentralized methods can offer scalable and dependable energy solutions in places with inadequate infrastructure.

The idea and design concerns of a PV DC-building-module-based BIPV system were covered by Liu et al. (2011). Their research shed light on how PV systems can be integrated into building structures while highlighting the advantages of these systems' design and operation.

III. Existing System

The suggested Photovoltaic-Inductive Wireless Power Transfer (PV-IWPT) system is shown in Figure 2. This system uses a Synchronous Active Rectifier (SAR) for direct efficiency optimization at the receiver side and combines a PV array with a Series-Series Inductive Wireless Power Transfer (SS-IWPT) configuration. Here, we dissect the essential parts of the PV-IWPT system and explain how they work.

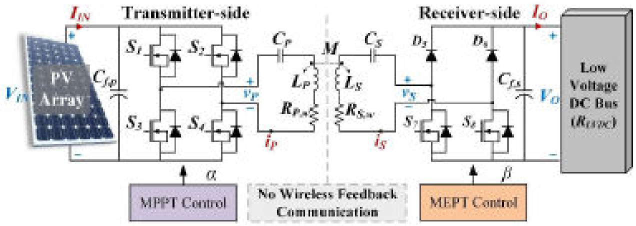

Fig. 2. Circuit Cnfiguration of existing method

A. *Transmitter-Side Components*

1. PV array: Serves as the main power source by transforming solar energy into DC current and voltage (VIN and IIN). A full-bridge inverter is used to modulate the DC output of the PV array into an AC voltage (vP) at a constant angular frequency.

2. Full-Bridge Inverter: Consists of four MOSFET switches (S1–S4) made of silicon carbide (SiC). transforms the PV array's DC input into an AC voltage to power the resonant circuit.

3. Resonant Circuit: Made composed of a magnetic coupler with mutual inductance (M) and self-inductances (LP and LS). At both the transmitter and receiver ends, series compensation capacitors (CS and CP) are utilized to attain resonance at angular frequencies ωP=LPCP1 and ωS=LSCS1.The formula for the coupling coefficient (kk) is k=LPLSM. Resistances (R,w and RP,w) represent coil losses.

Input Capacitor: To reduce current pulsations in the PV panels and provide steady DC output, a high-capacitance input capacitor (Cf,p) is utilized.

B. Receiver-Side Components

1. AC Voltage and Current: The transmitter-side resonant circuit provides the AC voltage (Vb) and current (iS), which are then fed into the SAR.
2. Synchronous Active Rectifier (SAR): This device has two MOSFET switches (S7 and S8) on the lower legs and two diodes (D5 and D6) on the upper legs. effectively transforms the AC electricity received back into DC.
3. Output Capacitor: To even out the DC output voltage (VO) and current (IO), a sizable output capacitor (Cf,s) is linked in parallel.

4. LVDC Bus Connection: The PV-IWPT system's DC output is linked to the LVDC bus. To guarantee smooth integration, the output voltage (VO) must coincide with the voltage of the LVDC bus.

A full-bridge inverter is used in the PV-IWPT system's operation to convert the DC output of the PV array into AC power. The magnetic coupler enables wireless power transfer to the receiver side while the AC power powers the resonant circuit at the transmitter side. Subsequently, the incoming AC is transformed by the SAR back into regulated DC and linked to the LVDC bus. Through direct efficiency optimization at the receiver side, performance is maximized and losses are minimized, ensuring efficient and consistent power transfer from the PV array to the LVDC grid. Resonant circuits and high-capacitance capacitors are used to keep the system stable and effective as a whole.

IV. PROPOSED METHOD

By integrating MPPT controllers at both the transmitter and receiver ends along with a fuzzy logic controller, the suggested solution greatly improves the stability and efficiency of the PV-IWPT system. By using this technique, the PV array's maximum power extraction, effective wireless power transfer, and steady LVDC grid functioning are all guaranteed. Consequently, it maximizes the functionality of renewable energy systems integrated into buildings, increasing their dependability and efficiency.

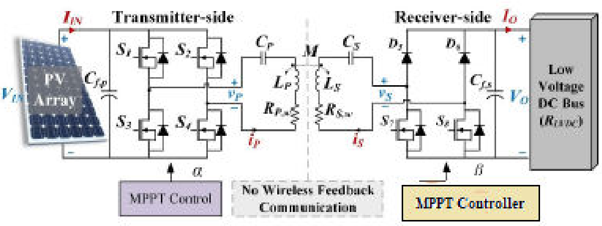

Fig. 3. Circuit Cnfiguration of Proposed method

Using a Fuzzy Logic Controller (FLC) for optimal control and Maximum Power Point Tracking (MPPT) controllers at the transmitter and receiver sides, we improve the stability and efficiency of the PV-IWPT system in the suggested approach.

A photovoltaic (PV) array powers a Series-Series Inductive Wireless Power Transfer (SS-IWPT) configuration in the PV-IWPT system. The receiver side of the system can directly optimize efficiency through the use of Synchronous Active Rectification (SAR). The inverter, magnetic coupler, compensating capacitors, and control mechanisms are important parts.

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A. Transmitter-Side Components

1. PV Array: Provides DC current (IIN) and voltage (VIN). converted using a full-bridge inverter running at a steady angular frequency into AC voltage (vP).
2. MPPT Controller: This device maximizes the power produced from the solar panels by ensuring that the PV array works at its maximum power point. responds to variations in temperature and irradiance by adjusting the operating point.

3. Full-Bridge Inverter: Made up of four MOSFET switches made of silicon carbide (SiC) (S1 through S4). drives the resonant circuit by converting DC input to AC.

4. Resonant Circuit: Consists of a magnetic coupler with mutual inductance (MM) and self-inductances ($\boldsymbol{XP}$ and LS). Resonance is reached via series compensation capacitors (L and W) at angular frequencies ωP=LPCP1 and ωS=LSCS1. Equation for the coupling coefficient (k) is k=LPLSM.

1. Input Capacitor:
   High-capacitance input capacitor (Cf,p) minimizes current pulsation in the PV panels.

B. Receiver-Side Components

1. SAR with MPPT:
   Receives AC voltage (vS) and current (iS). Consists of diodes (D5 and D6) and MOSFET switches (S7 and S8). Converts AC back to DC, optimizing efficiency through MPPT.

2. Fuzzy Logic Controller (FLC):
   Enhances system adaptability and performance by handling the non-linear characteristics of the PV system. Provides robust control under varying environmental conditions, ensuring stable and efficient power transfer.

3. Output Capacitor
   Large output capacitor (Cf,s) smooths out DC output voltage (VO) and current (IO).

4. LVDC Bus Connection:
   Ensures VO matches the LVDC bus voltage for seamless integration.

C. Operation and Control Strategy

The proposed system operates by converting the PV array's DC output to AC using a full-bridge inverter. This AC power drives the resonant circuit at the transmitter side, with efficient wireless power transfer to the receiver side facilitated by the magnetic coupler. At the receiver, the SAR converts AC back to DC, with both transmitter and receiver sides employing MPPT controllers to maximize power efficiency.

D. MPPT Controllers

1. Transmitter-Side MPPT:

Continuously adjusts the inverter's operating point to extract maximum power from the PV array, considering changes in irradiance and temperature.

2. Receiver-Side MPPT:

Ensures efficient rectification and power transfer, maintaining optimal load conditions.

E. Fuzzy Logic Controller (FLC)

The FLC enhances system adaptability and performance by managing the non-linear characteristics of the PV system. It provides robust control under varying environmental conditions, ensuring stable and efficient power transfer. The FLC dynamically adjusts control parameters to maintain optimal performance.

The PV-IWPT system operates by converting the PV array's DC output to AC using the full-bridge inverter. This AC power drives the resonant circuit at the transmitter side, and the magnetic coupler facilitates wireless power transfer to the receiver side. At the receiver, the SAR converts AC back to DC, with the output optimized by the receiver-side MPPT controller. The FLC ensures overall system stability and efficiency by dynamically adjusting control parameters to respond to environmental changes.

V. RESULTS AND DISCUSSION

A. Existing Method

The existing method is modeled in Simulink to simulate the performance of the PV-IWPT system. The block diagram illustrates the overall system configuration, including the PV array, power electronics components, and control strategies.

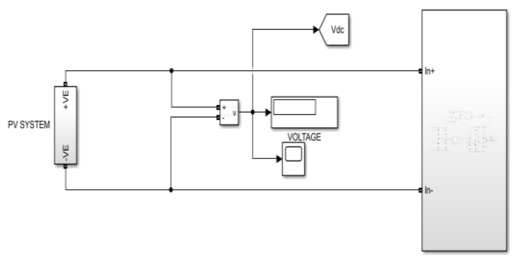

Fig. 4. Existing simulink block diagram

1. PV System

This figure shows the voltage and current generated by the PV system under varying irradiance conditions. It demonstrates how the PV array responds to changes in solar irradiance, affecting the voltage (*Vpv*) and current (*Ipv*) outputs.

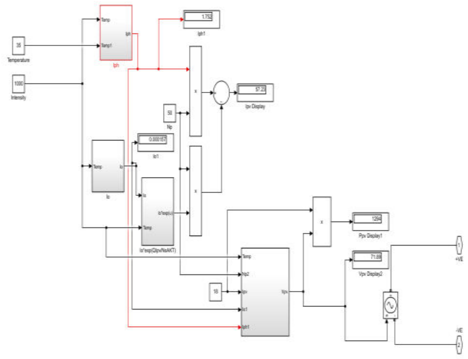

Fig. 5. PV System Simulink Model

2. SubSystem:

- **Input Voltage (*Vin*)**: This represents the DC voltage input from the PV array.
- **Output Voltage (*Vout*)**: This is the DC output voltage after processing through the inverter and other power electronics components.
- **Inverter Voltage**: Shows the AC voltage produced by the full-bridge inverter before it is transferred through the inductive wireless power transfer (IWPT) system.

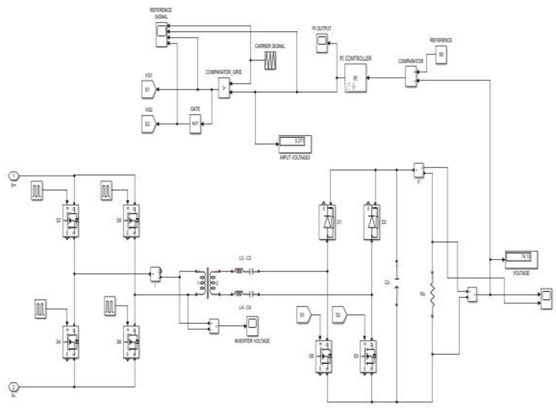

Fig. 6. Subsystem simulink model

3. Wave Forms(Grid Parameter):

- PWM Rectifier DC Output Voltage Waveform: Displays the DC voltage waveform at the output of the PWM rectifier, highlighting any fluctuations or instabilities in the voltage.
- PWM Rectifier DC Output Current Waveform: Illustrates the DC current waveform at the output of the PWM rectifier, indicating how the current varies with the load and input conditions.

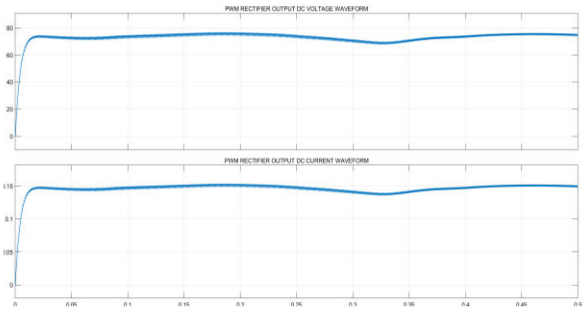

Fig. 7. Grid Waveforms

B. Proposed System

The proposed system improves upon the existing method by integrating MPPT controllers and Fuzzy Logic Controllers (FLC) to enhance stability and efficiency. The proposed system's Simulink model is similar to the existing one but includes additional control elements for improved performance.

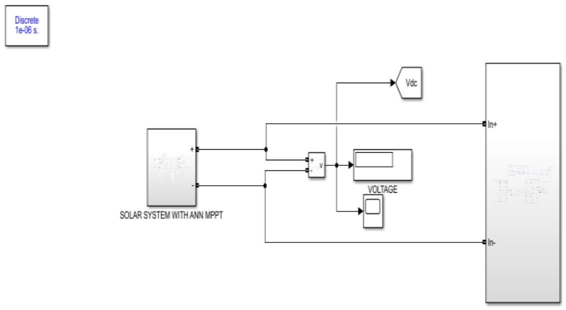

Fig. 8. Proposed simulink model

1. Solar system with MPPT

MPPT Implementation: This model shows the PV system integrated with an MPPT controller. The MPPT algorithm ensures the PV array operates at its maximum power point, adjusting the operating voltage and current to maximize energy extraction. Voltage and Current Outputs: The voltage (Vpv) and current (Ipv) outputs are optimized for maximum power delivery under varying irradiance and temperature conditions.

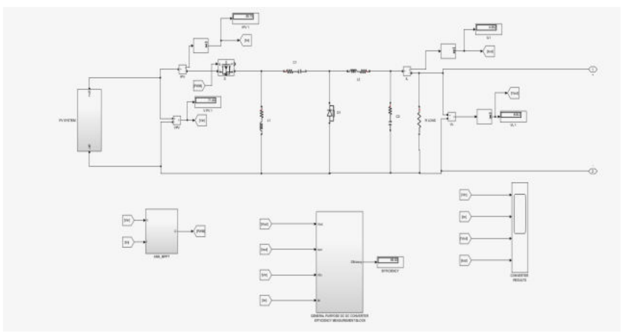

Fig. 9. Solar system with MPPT Controller

2. Subsystem:

- **Input Voltage** (Vin): The DC voltage input from the PV array, optimized by the MPPT controller.
- **Output Voltage** ($Vout$): The DC output voltage, which is more stable due to the MPPT and FLC implementation.
- **Inverter Voltage**: The AC voltage produced by the full-bridge inverter, with improved waveform quality and reduced harmonics due to enhanced control strategies.

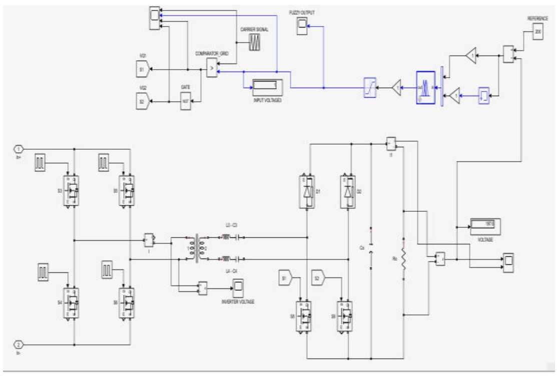

Fig. 10. Subsystem simulonk model

3. Waveforms

- **PWM Rectifier DC Output Voltage Waveform**: Displays the DC voltage at the output of the PWM rectifier, showing increased stability and reduced fluctuations compared to the existing method.
- **PWM Rectifier DC Output Current Waveform**: Illustrates the DC current at the output of the PWM rectifier, indicating smoother and more consistent current delivery due to improved control.

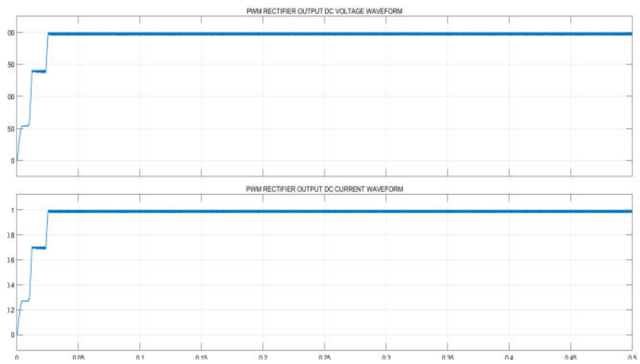

Fig. 11. Grid waveforms for proposed method

Improvements

- **Stability**: The proposed system shows increased stability in both voltage and current waveforms due to the integration of MPPT and FLC. The MPPT controller optimizes the power extraction from the PV array, while the FLC provides robust control under varying conditions.

- **Efficiency**: The efficiency of the system is enhanced as the MPPT controller ensures the PV array operates at its maximum power point, and the FLC reduces losses and improves the overall system performance.
- **Waveform Quality**: The voltage and current waveforms at the PWM rectifier output are smoother and exhibit fewer fluctuations, indicating better power quality and reduced harmonic distortion.
- Overall, the proposed method demonstrates significant improvements in stability and efficiency, providing a more reliable and effective solution for integrating PV-IWPT systems with LVDC grids.

VI. Conclusion

The proposed enhancement of the rooftop photovoltaic-inductive wireless power transfer (PV-IWPT) system, through the integration of Maximum Power Point Tracking (MPPT) controllers and a Fuzzy Logic Controller (FLC), demonstrates significant improvements in both stability and efficiency. The MPPT controllers ensure that the PV array consistently operates at its maximum power point, optimizing energy extraction even under varying environmental conditions. Meanwhile, the FLC provides robust and adaptive control, addressing the non-linear and dynamic characteristics of the system.

The simulation results indicate that the proposed method achieves more stable voltage and current outputs compared to the existing method. This stability is crucial for maintaining reliable operation within the low-voltage direct current (LVDC) grid. Additionally, the enhanced control strategies reduce power losses and improve overall system performance, making the PV-IWPT system a more viable and efficient solution for building-integrated renewable energy generation.

Future Scope

In future the proposed method can be extended with Exploring more advanced control strategies, such as machine learning-based predictive control, can further optimize system performance by anticipating and responding to changes in environmental conditions more effectively.

References

1. K. Jia, Z. Yang, Y. Fang, T. Bi, and M. Sumner, ‘‘Influence of inverter-interfaced renewable energy generators on directional relay and an improved scheme,’’ *IEEE Trans. Power Electron.*, vol. 34, no. 12, pp. 11843–11855, Dec. 2019.
2. W. Dong, Z. Lu, L. He, L. Geng, X. Guo, and J. Zhang, ‘‘Low-carbon ptimal planning of an integrated energy station considering combined power-to-gas and gas-fired units equipped with carbon capture systems,’’ *Int. J. Electr. Power Energy Syst.*, vol. 138, Jun. 2022, Art. no. 107966.
3. C.-Y. Yang, C.-Y. Hsieh, F.-K. Feng, and K.-H. Chen, ‘‘Highly efficient analog maximum power point tracking (AMPPT) in a photovoltaic system,’’ *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 59, no. 7, pp. 1546–1556, Jul. 2012.
4. M. S. Keerthana, G. Uma, and U. Sowmmiya, ‘‘A study of a solar PV and wind-based residential DC NanoGrid with dual energy storage system under islanded/interconnected/grid-tied modes,’’ *Int. J. Electr. Power Energy Syst.*, vol. 143, Dec. 2022, Art. no. 108473.
5. D. Dong, I. Cvetkovic, D. Boroyevich, W. Zhang, R. Wang, and P. Mattavelli, ‘‘Grid-interface bidirectional converter for residential DC distribution systems—Part one: High-density two-stage topology,’’ *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1655–1666, Apr. 2013.
6. S. Peyghami, H. Mokhtari, and F. Blaabjerg, ‘‘Autonomous power management in LVDC microgrids based on a superimposed frequency droop,’’ *IEEE Trans. Power Electron.*, vol. 33, no. 6, pp. 5341–5350, Jun. 2018.
7. P. Mohammadi and S. Mehraeen, ‘‘Challenges of PV integration in lowvoltage secondary networks,’’ *IEEE Trans. Power Del.*, vol. 32, no. 1,pp. 525–535, Feb. 2017.
8. S. Peyghami, P. Davari, H. Mokhtari, and F. Blaabjerg, ‘‘Decentralizeddroop control in DC microgrids based on a frequency injection approach,’’*IEEE Trans. Smart Grid*, vol. 10, no. 6, pp. 6782–6791, Nov. 2019.
9. M. Nasir, Z. Jin, H. A. Khan, N. A. Zaffar, J. C. Vasquez, andJ. M. Guerrero, ‘‘A decentralized control architecture applied to DCnanogrid clusters for rural electrification in developing regions,’’ *IEEETrans. Power Electron.*, vol. 34, no. 2, pp. 1773–1785, Feb. 2019.
10. B. Liu, S. Duan, and T. Cai, ‘‘Photovoltaic DC-building-module-based BIPV system—Concept and design considerations,’’ *IEEE Trans. Power Electron.*, vol. 26, no. 5, pp. 1418–1429, May 2011.
11. M. Sechilariu, B.Wang, and F. Locment, ‘‘Building integrated photovoltaic system with energy storage and smart grid communication,’’ *IEEE Trans.Ind. Electron.*, vol. 60, no. 4, pp. 1607–1618, Apr. 2013.
12. M. Rentschler and I. Bhattacharya, ‘‘Decoupled control of wireless power transfer: Eliminating the interdependence of load resistance and coupling to achieve a simple control framework with fast response times,’’ *Int J. Electr. Power Energy Syst.*, vol. 99, pp. 1–10, Jul. 2018.
13. A. Kuperman, ‘‘Additional two-capacitor basic compensation topologies for resonant inductive WPT links,’’ *IEEE Trans. Power Del.*, vol. 35, no. 5, pp. 2568–2570, Oct. 2020.
14. T. Tan, K. Chen, Q. Lin, Y. Jiang, L. Yuan, and Z. Zhao, ‘‘Impedance shaping control strategy for wireless power transfer system based on dynamic small-signal analysis,’’ *IEEE Trans. Circuits Syst. I, Reg. Papers* vol. 68, no. 3, pp. 1354–1365, Mar. 2021.
15. E. Holton, A. Halbe, A. Garney, J. Whitbeck, K. Sharpe, D. Metacarpa, and P. Haldar, ‘‘Cost and market analysis of integrative lightweight PV systems for low-slope commercial rooftops,’’ in *Proc. IEEE 40th Photovolt. Spec Conf. (PVSC)*, Jun. 2014, pp. 2740–2742.
16. R. J. Yang, ‘‘Overcoming technical barriers and risks in the application of building integrated photovoltaics (BIPV): Hardware and software strategies,’’ *Autom. Construct.*, vol. 51, pp. 92–102, Mar. 2015.
17. B. Minnaert, S. Ravyts, J. Driesen, and N. Stevens, ‘‘Challenges for wireless power transfer in building-integrated photovoltaics,’’ in *Proc. IEEE PELSWorkshop Emerg. Technol.,Wireless Power Transf.*, Jun. 2018, pp. 1–5.
18. H. Gholami, H. Nils Røstvik, and K. Steemers, ‘‘The contribution of building-integrated photovoltaics (BIPV) to the concept of nearly zeroenergy cities in Europe: Potential and challenges ahead,’’ *Energies*, vol. 14, no. 19, p. 6015, Sep. 2021..

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