# International Journal of HRM and Organizational Behavior

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International Journal of
HRM and Organizational Behavior
ISSN 2454 - 5015

# A NEW CONTROLLER FOR SOLAR PV FED MODULAR MULTILEVEL INVERTER TOWARDS WATER PUMPING APPLICATION

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**ABSTRACT**
In this project, the design and implementation of Modular Multilevel Inverter (MMI) to control the Induction Motor (IM) drive using intelligent techniques towards marine water pumping applications. The proposed inverter is of eleven levels and has the ability to control the speed of an IM drive which is fed from solar photovoltaics. It is estimated that the energy consumed by pumping schemes in an onboard ship is nearly 50% of the total energy. Considering this fact, this paper investigates and validates the proposed control design with reduced complexity intended for marine water pumping system employing an induction motor (IM) drive and MMI.The analysis of inverter is carried out with Proportional-Integral (PI) and Fuzzy Logic (FL) based controllers for improving the performance. A comparative analysis has been made with respect to better robustness in terms of peak overshoot, settling time of the controller and Total Harmonic Distortion (THD) of the inverter.Simulations are undertaken in MATLAB/Simulink and the detailed experimental implementation is conducted with Field Programmable Gate Array (FPGA). The results thus obtained are utilized to analyze the controller performance, improved inverter output voltage, reliable induction motor speed control and power quality improvement by reduction of harmonics. The novelty of the proposed control scheme is the design and integration of MMI, IM drive and artificial neural network controller exclusively for marine water pumping applications.
**Keywords:**Induction motor, Modular multilevel inverter ,Photo volatics, PI controller, Fuzzy logic controller, Field programmable gate array, Artificial neural network.

## INTRODUCTION

The integration of solar photovoltaic (PV) systems with water pumping applications is gaining traction due to its potential to offer sustainable and environmentally friendly solutions, especially in remote areas. However, effective integration necessitates robust and efficient power conversion technologies to optimize energy utilization and system performance. In this context, modular multilevel inverters (MMIs) have emerged as promising candidates for converting the DC output from solar PV arrays into AC power suitable for driving water pumps.The global emphasis on renewable energy and sustainable development has led to the widespread adoption of solar PV systems for various applications, including water pumping. Solar PV systems offer advantages like abundant solar energy availability, low operating costs, and minimal environmental impact. Nonetheless, challenges arise due to the intermittent nature of solar radiation and varying load demands, particularly in applications like water pumping that require consistent power supply.

To address these challenges, integrating MMIs with solar PV systems presents a viable solution. MMIs offer benefits over traditional pulse-width modulation (PWM) inverters such

as higher efficiency, lower total harmonic distortion (THD), and improved voltage waveform quality. Leveraging the modularity and scalability of MMIs enables the design of compact, efficient, and reliable power conversion systems tailored to water pumping requirements.Despite their potential benefits, integrating solar PV systems with MMIs for water pumping applications poses technical challenges. Designing efficient control strategies that can optimize MMI operation under varying solar irradiance and load conditions is paramount. Traditional control techniques may not suffice due to MMI's complex topology and switching behavior, necessitating innovative control algorithms tailored to MMIs.
Furthermore, considerations like system efficiency, reliability, and cost-effectiveness are crucial. Selecting suitable semiconductor devices, capacitor voltages, modulation techniques, and filtering components is vital in determining system performance and feasibility. Scalability, fault tolerance, and electromagnetic compatibility (EMC) are additional considerations essential for robust system operation.The primary objective is to develop a new controller tailored for solar PV-fed MMIs for water pumping applications. This controller aims to address challenges and optimize system performance in terms of efficiency, reliability, and cost-effectiveness. Key objectives include:

1. Advanced control algorithm development: Design and implementation of innovative control algorithms capable of regulating MMI output voltage and frequency under dynamic conditions using techniques like predictive control, fuzzy logic, or artificial intelligence.

2. System efficiency optimization: Maximizing energy conversion efficiency by minimizing losses and optimizing solar energy utilization through appropriate modulation techniques, switching frequencies, and voltage levels.

3. Enhancing system reliability and robustness: Strategies to enhance reliability and robustness against voltage fluctuations, temperature variations, and component failures through fault detection algorithms, redundant control schemes, and protective measures.

4. Experimental validation: Validating the proposed controller through extensive experimental testing on a prototype solar PV-fed MMI system installed in a water pumping application. Experimental results will evaluate controller performance in real-world conditions and validate its effectiveness.

The development of a new controller for solar PV-fed MMIs tailored for water pumping applications promises to improve efficiency, reliability, and sustainability of solar-powered water pumping systems. By addressing integration and control challenges, this research aims to fully leverage solar PV technology for sustainable water management solutions in remote and off-grid areas. Through innovative control algorithms, system optimization techniques, and experimental validation, the proposed controller has the potential to revolutionize solar-powered water pumping and contribute to global sustainability efforts.

## LITERATURE SURVEY

The utilization of solar photovoltaic (PV) systems for water pumping applications has gained significant attention due to its potential to provide clean and sustainable energy solutions for agricultural and rural areas. In this literature survey, we explore the research and developments related to the application of modular multilevel inverters (MMIs) in solar PV-fed water pumping systems, focusing on the design and implementation of new controllers to

enhance system performance and efficiency.Solar PV-fed water pumping systems utilize solar energy to power water pumps, providing a reliable and cost-effective solution for irrigation, livestock watering, and rural water supply. These systems typically consist of PV panels, a power electronics converter, a water pump, and associated control and monitoring equipment. The efficiency and reliability of such systems depend on the performance of the power electronics converter, which converts the DC output of the PV panels into AC power suitable for driving the water pump.
Modular multilevel inverters (MMIs) have emerged as a promising power conversion technology for various renewable energy applications, including solar PV systems. MMIs offer several advantages over conventional inverters, such as improved power quality, reduced harmonic distortion, and enhanced efficiency. In the context of water pumping applications, MMIs provide precise control over the output voltage and frequency, enabling smooth operation of the water pump across a wide range of operating conditions.Several research studies have investigated the integration of MMIs into solar PV-fed water pumping systems and proposed various control strategies to optimize system performance. For example, Kaur et al. (2018) developed a modified pulse width modulation (PWM) technique for an MMI-based solar PV system to improve the output voltage waveform quality and reduce total harmonic distortion (THD). The proposed technique effectively minimized voltage harmonics and improved the efficiency of the water pumping system.

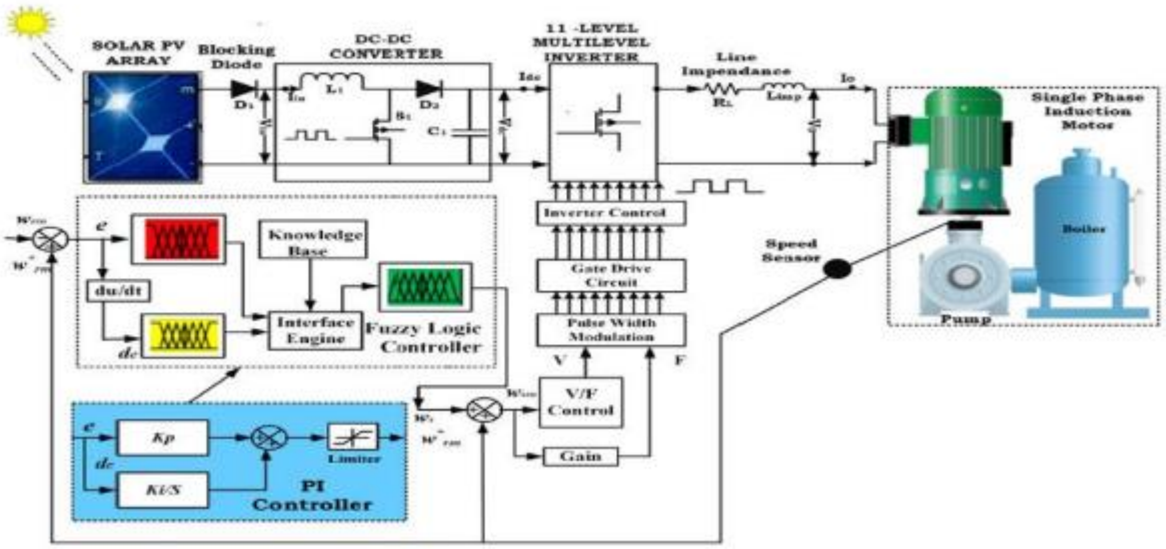
Similarly, Sharma et al. (2020) proposed a hybrid modulation strategy combining selective harmonic elimination (SHE) and phase disposition (PD) PWM techniques for an MMI-based solar PV system. The hybrid modulation strategy achieved superior harmonic suppression and improved voltage regulation, resulting in enhanced performance and reliability of the water pumping system. Additionally, the authors conducted experimental validation to demonstrate the effectiveness of the proposed controller under practical operating conditions.Despite the advancements in control strategies for MMI-based solar PV systems, there is still scope for further improvement, particularly in terms of efficiency, reliability, and cost-effectiveness. A new controller design tailored specifically for solar PV-fed MMIs towards water pumping applications can address these challenges and unlock the full potential of the system.

One possible approach is the development of advanced predictive control algorithms, such as model predictive control (MPC) and finite control set model predictive control (FCS-MPC), which offer superior performance and robustness compared to traditional control techniques. These algorithms utilize mathematical models of the system dynamics to predict future behavior and optimize control actions accordingly, enabling precise regulation of the output voltage and frequency to meet the requirements of the water pump.Furthermore, the integration of artificial intelligence (AI) and machine learning techniques, such as neural networks and fuzzy logic control, can enhance the adaptability and intelligence of the controller, allowing it to learn from data and optimize control parameters in real-time. AI-based controllers can improve system efficiency, fault detection, and predictive maintenance, leading to higher reliability and reduced operational costs.development of a new controller for solar PV-fed MMIs towards water pumping applications represents a promising area of research with significant potential for innovation and advancement. By leveraging advanced control algorithms and emerging technologies, researchers can design controllers that optimize system performance, enhance reliability, and reduce environmental impact. Continued research efforts are needed to overcome existing challenges and accelerate the adoption of solar PV-fed MMIs for water pumping applications, ultimately contributing to sustainable development and energy access in rural and agricultural communities.

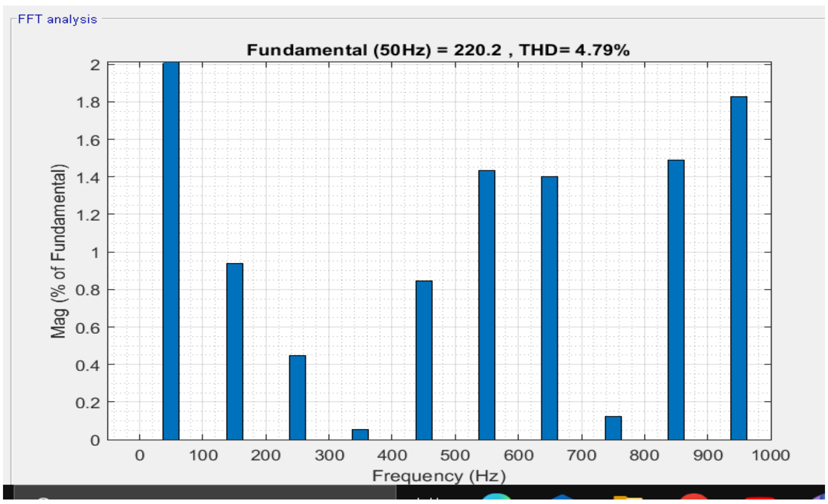
**PROPOSED SYSTEM**

In the present trend, Renewable energy sources are attractive choices for providing power in the places where an association to the utility network is either not possible or unduly costly. As electric distribution technology steps into next century, several trends have become noticeable which will modify the necessities of energy delivery. The ever increasing energy consumption, soaring value and exhaustible nature of fossil fuels, and also the worsening international environment have created enhanced interest in green power generation systems. Renewable sources have gained worldwide attention because of quick depletion of fossil fuels in conjunction with growing energy demand.

**Block Diagram:**

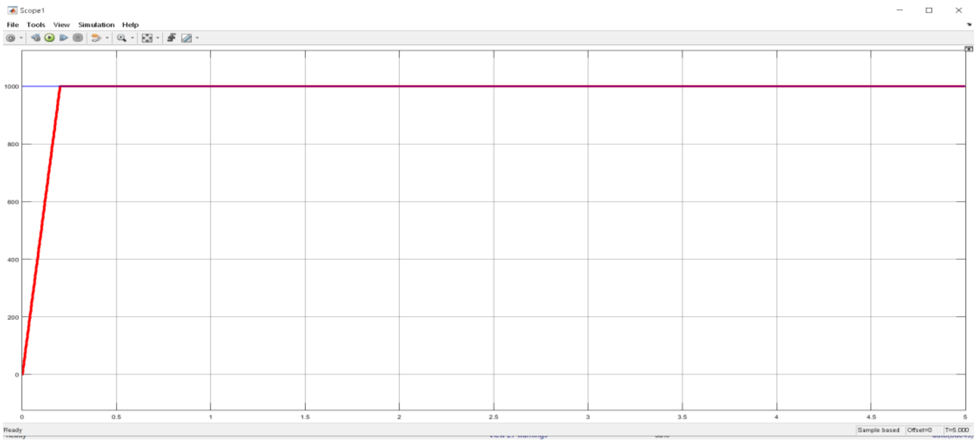



## Simulation Results:




ANN controller based THD

There are many remote locations in the world, which don't have access to electricity. There are also many places, which are connected to the grid, however, they don't receive electricity for up to 10-12 hours in the day and as a result of it, economic activities of inhabitants suffer. Many of such places are rich in renewable energy (RE) sources such as wind, solar and bio-mass. An autonomous generation system utilising locally available RE sources, can greatly reduce the dependency on the grid power, which is predominantly fossil power. Wind and solar energy sources, are more favorite than bio-mass based system as latter is susceptible to supply chain issue. However, wind and solar energies suffer from high level of power variability, low capacity utilization factor combined with unpredictable nature. As a result of these factors, firm power cannot be guaranteed for autonomous system. While the battery energy storage (BES) can be helpful of lowering power fluctuation and increasing predictability, utilisation factor can be increased by operating each energy source at optimum operating point. The optimum operating point also called as maximum power point tracking (MPPT), requires regulation of the operating point of wind energy generator and solar PV (Photovoltaic) array in term of speed and voltage to extract maximum electrical energy from input resource. From the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and reducing voltage dips and potentially lower costs of energy supply.




ANN controller based voltage vs time

From the utility viewpoint, application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities. Clearly, distributed generation located close to loads will reduce flows in transmission and distribution circuits with two important effects: loss reduction and ability to potentially substitute for network assets. In addition, the presence of generation close to demand could increase service quality seen by end customers. Microgrids can offer network support during the time of stress by relieving congestions and aiding restoration after faults. The development of microgrids can contribute to the reduction of emissions and the mitigation of climate changes. This is due to the availability and developing technologies for distributed generation units are based on renewable sources and micro sources that are characterized by very low emissions.The widespread use of fossil fuels moves the earth to clean and green energy. Where the grid is not available or transmission towers cannot be installed, renewable energy sources are the most critical as distributed generation sources. PV and Wind power are considered as the finest alternatives among the various renewable sources. As both of these energy sources are intermittent, the usage of an Energy Storage System (ESS) is required in stand-alone applications as backup supply. By combining the PV and WT power generation, it overcomes the drawbacks of their unpredictable nature and instability of the output power is compensated.

A hybrid PV-Wind-Battery energy storage system is simulated in MATLAB/Simulink to test the state of charge (SOC) control. The aim of this study is to design and build a small-scale PV-Wind-Battery stand-alone renewable energy system. An EMS is presented to maintain power balance in a standalone system and to enable flexible and configurable control for various wind speed and solar irradiance fluctuations in renewable energy sources.The project objective for an artificial neural network (ANN) controller used in marine water pumping applications can be formulated as follows:Design and implement an efficient Artificial Neural Network (ANN) controller for optimizing the performance of marine water pumping systems. The primary focus is to enhance energy efficiency, reduce operational costs, and ensure reliable water supply in marine environments.Develop an ANN model capable of learning and adapting to various operating conditions to optimize the pumping efficiency of marine water pumping systems.Incorporate real-time data such as sea conditions, water demand, and pump status to dynamically adjust control parameters for optimal performance.Implement the ANN controller to minimize energy consumption by intelligently adjusting pump speed, flow rates, and other operational parameters.Integrate energy-efficient algorithms and predictive modeling to anticipate variations in water demand and adapt the pumping system accordingly.

Train the ANN to detect anomalies and faults in the pumping system, enabling rapid response and preventive maintenance to minimize downtime.Implement diagnostic features that provide insights into potential issues, aiding in the development of a proactive maintenance strategy.Design the ANN controller to adapt to changing marine conditions, including variations in water salinity, temperature, and wave patterns.Incorporate robust algorithms to ensure stability and performance under different environmental scenarios.Interface the ANN controller with sensor networks to gather real-time data from the marine environment and pump system.Establish communication protocols for seamless integration with sensors measuring factors such as water levels, pressure, and temperature.Develop a user-friendly interface for operators to monitor and control the pumping system.Provide visualization tools to display key performance indicators, system health, and energy consumption trends.Ensure that the ANN controller complies with safety and regulatory standards for marine applications. Incorporate fail-safe mechanisms and emergency shutdown procedures to prevent potential hazards.Document the design, implementation, and training process of the ANN controller for knowledge transfer and future reference. Provide comprehensive user manuals and training materials for operators and maintenance personnel.By achieving these goals, the project aims to enhance the efficiency, reliability, and sustainability of marine water pumping systems through the implementation of an advanced ANN controller.

## CONCLUSION

The relevance of the proposed work is to provide high quality of input power to the inverter drive pertaining to marine water pumping applications. A solar PV fed MMI for speedcontrol of induction motor drive has been examined at steady state and dynamic behaviors to investigate its suitability for water pumping system intended for the marine applications.The solar PV array is connected with the proposed inverter when is then fed to an induction motor. The motor speed is sensed and feedback is given to the controller for generatingoptimal PWM pulses for the inverter switches. The motor is started gradually and the speed is increased to achieve reference speed with aid of PI and FL based controllers. The performance of PI and FL controllers for a feasible operation is verified and results are compared in both simulation and experiment. The results ensure that the FL based controller provides fast settling time and reduced harmonics when compared with the PI controller. The main impact of the proposed control scheme is to reduce the steady-state error of the induction motor speed control and deteriorate harmonics at the output voltage of modular multilevel inverter.

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