Integration of Renewable Energy Sources and Smart Technologies in On-board Ships

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Abstract:

Renewable energy use is a viable approach for reducing fuel usage and greenhouse gas emissions in on-board ship. Solar power is becoming a cost-effective fuel reduction with the development of photovoltaic (PV) module technologies. Wind energy is a pollution-free, renewable source of electricity that is abundant at sea. To ensure that zero-emission oceangoing vessels are commercially available by the mid-2030s, it is required to combine hybrid renewable energy resources and vital technologies such as Artificial Intelligence in the maritime industry. This study looks into the viability of deploying renewable energy resources in the maritime industry using current technologies.

Is integration of renewable energy resources with Artificial Intelligence towards Zero-carbon fuels possible to decarbonize maritime shipping?

Is employing renewable energy resources to reduce shipping emissions in on board cost effective?

Renewable energy resources availability and its real-time forecasting is becoming increasingly important for utilities and grid balancing with large renewable energy capacity as wind and solar deployment grows. Predicting and estimating the variables such as wind speed, solar irradiance and the resulted power output, are required for various horizons of time, tend to range from a few minutes to an hour beforehand wherein for stabilizing the grid and scheduling the resources obtained to next-day for optimizing the unit to several days ahead. To generate forecasts over such a wide range of sizes, it is necessary to combine a number of methodologies, each with its own set of capabilities, into a single forecasting system. To maximize the predictive capacity of both, Physical and dynamical prediction methodologies are combined with statistical learning and artificial intelligence (AI) technology in best-practice systems. High-quality narrow projections on the order of a few minutes out to roughly six hours are crucial to aid grid operators in optimizing renewable energy.

In the case of marine solar power, the amount of fuel saved by using solar power alone on large ships is quite tiny due to the uncontrollable weather conditions. Renewable energy sources such as wind turbines and solar panels have a basic deficiency in terms of controlling the electrical generation besides expensive. As a result, if they are not adequately controlled, Grid Instability may occur due to the issues in the utility controls and in the worst scenario it may cause breakdown [Julián Ascencio-Vásquez, et.al in 2020]. Furthermore, the criteria for interfacing these systems to the utility are becoming increasingly stringent, requiring DG systems to deliver specific services, including grid frequency and voltage regulation. They are unable to provide any services due to the inconsistent and fluctuating wind speed due to which it could not give dedicated support to the system in micro grid and on board ship, where the generators will be responsible for stable active- and reactive-power requirements.

1) The discrepancy between the generated wind power and the demanded grid power is compensated or absorbed using energy storage technologies.

2) Power distribution solutions are used to regulate the flow of electricity between diverse sources and to deliver some grid services.

Distributed renewable technologies may transfer any surplus energy produced to the grid with the help of AI software, and utilities can distribute that power to where essential as it is shown in the figure 1. When the requirement is less, offshore energy storing can hold surplus power while deploying AI could be a solution for directing the energy [Branko Koovic, et.al in 2020 and Sue Ellen Haupt, et.al in 2020]. The proposed system with the deployment of AI to the Renewable energy source will provide a promising solution in onboard ships. It will lead to increased challenges in requiring synchronization, forecasting and optimization to keep the grid in balance.

Keywords: Renewable Energy resources, PV system, CO_2 Emission, MPPT, Deep Neural Network

Introduction

Extensive usage of fossil fuels for electricity generation and transportation leads to the climatic changes and the uncontrollable challenge exist in the globe is global warming. Developed countries across the globe are focusing on generating alternative solution for the power generation. Consequently, significant investment in research and development for creating the carbon free solution [M. Nurunnabi, et.al in 2019 and R. Singh, et.al in 2018]. Power generation by the solar energy and the wind energy are the renewable energy resources which plays a significant role and is eco-friendly. Integrating Renewable energy resources with the electric grid paved way for the emergence of the smart grid. Smart grid technologies include Distributive Power Network, Flexible loads, Active transmission and in other concepts [J. Ke and X. Liu in 2008, M. Xu, et.al in 2019 and A. Elgammal in 2018]. The primary purpose of making carbon free emission and cost effective solution leads to the utilization of fast growing Renewable energy resources with the enhanced Wind turbine and the Photovoltaic technologies. The size, features, and qualities of the wind turbine and photovoltaic technologies have a significant impact on strength efficacy while implementing in onboard ships.

Hybrid renewable energy technologies are becoming conventional technology for power generation since it involves the process of combining the alternating energy resources such as wind and solar because of its potential availability. Out of other renewable energy resources solar is potential one due to its cost effective nature [X. Li in 2013, U. Akram in 2017 and A. Benali in 2018]. The unpredictable nature of the renewable sources, and its uncontrolled, probabilistic, and highly fluctuating nature of the integration of the solar and wind system as hybrid system will exhibit challenges, such as operational issues and stability. Some of the other possible challenges such as Grid to load variance, voltage inconsistency, poor load following, poor power quality, frequency variation, and reliability [Z. Ullah in 2019, A. A. Z. Diab in 2019 and A. A. Z. Diab in 2019]. Due to the transient energy characteristics, the complexity of High power flow appears while integrating the wind turbine and the photovoltaic resource. Multiple nonlinearity and transformation problem will appear during the integration. A framework to characterize and address the occurrence of the High power flow during the integration of the Wind turbine and Photovoltaic technologies with the following consideration

(i) The background and the significance of the challenge
(ii) Output power estimation from the Wind turbine and the Photovoltaic is from the datasets available with the wind speed and solar radiation
(iii) Selecting objective operations
(iv) Defining technical difficulties, optimization techniques, and reliable and consistent variability
(v) Resolving High power flow challenges

Several academicians have recently addressed the OPF issue, focusing on several of the above tasks

[T. Adefarati N. T. et.al in 2017, Mbungu, et.al in 2019 and M. Venkateshkumar et.al in 2020]. Power system domain got extended due to the application of the renewable resources with the recent technological advancements.

Optimization of the hybrid power system in the smart grid system, in combination with Model Predictive Control (MPC) architecture, is another key research topic. To minimize the utilization of the utility grid and to maximize the renewable resources usages, MPC design creates a strategy. Applications adopting the combination of Renewable energy resources and grid are explicated under various scenarios [N. Mbungu, et.al in 2017, N. T. Mbungu, et.al in 2019 and 2020, D. H. Tungadio, et.al in 2018]. A technological application of microgrid context with the coordination of energy aims to develop stability in the power flow between the generation of power and consumption. Consequently balancing the power between the generated and the demand of the system will be carried out by controlling the power flow in tie lines and the frequency deviations in the microgrid using Model Predictive Control.

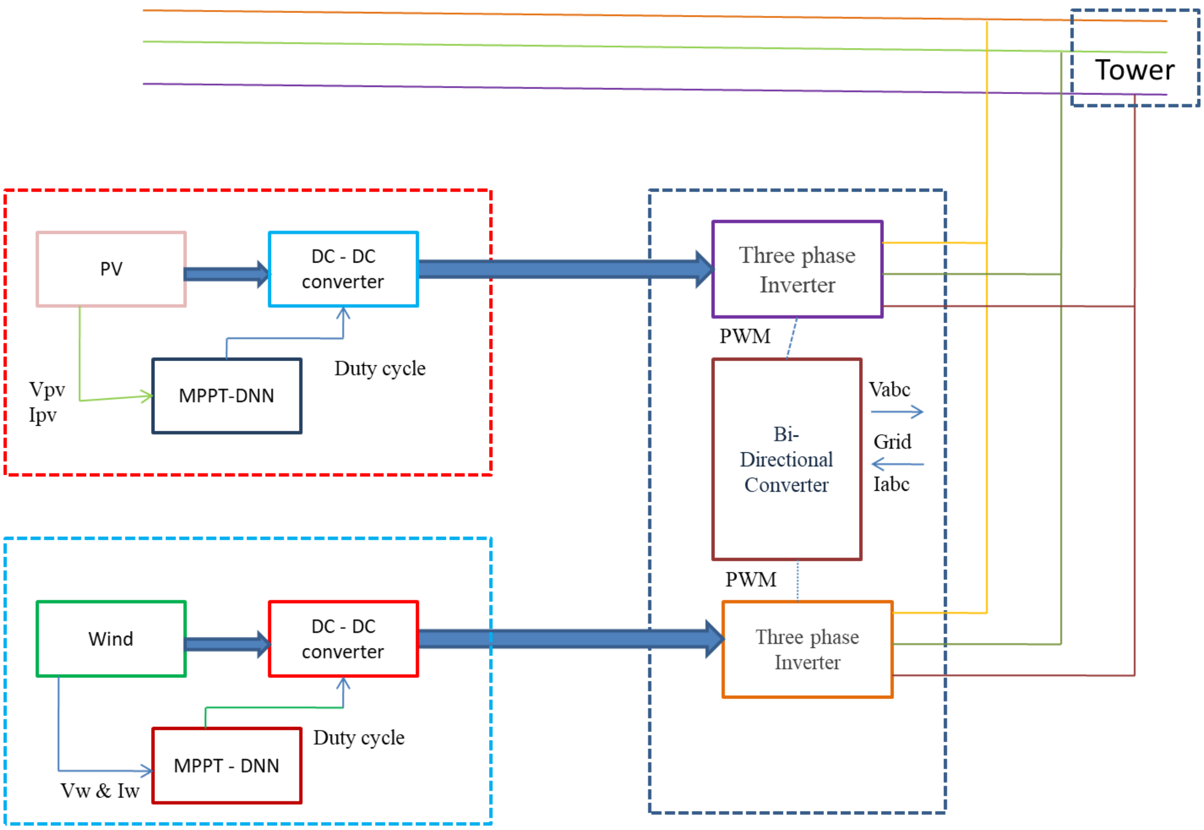


Figure 1 Block Diagram of DNN based MPPT controller for the Hybrid System

This paper concentrates on the development of novel Deep Neural Network based Maximum Power Point Tracking (MPPT) algorithm for providing solution to the challenges in integrating the Photovoltaic and Wind generators as shown in Figure 1. This article mainly contributes on the following

(i) DNN based MPPT controller design and modeling for the Photovoltaic system and analysis of performance under various weather conditions
(ii) DNN based MPPT controller design and modeling for the Wind system and analysis of performance under different wind speed and its context
(iii) DNN based MPPT controller design and modeling for the integration of grid with the Hybrid system and analysis of performance under various context

The rest of the paper is dissected as follows. Section 2 discusses about the DNN based MPPT controller design and model for PV system under various weather conditions. Section 3 discusses about the DNN based MPPT controller design and model for wind system under different wind speeds. Section 4 discusses about the DNN based MPPT controller design and model for the integration of grid with the Hybrid system. Section 5 elaborates the performance of all systems and addresses the cost effectiveness of the hybrid system. Section 6 discusses about the concluding remarks for the hybrid system and its effectiveness.

DNN based MPPT for PV system

The MPPT algorithm is to extract energy maximally under different weather contexts. Advancements have been achieved by developing new MPPT algorithm with the integration of different controllers; some of the controllers are ANFIS, ANN, Fuzzy, Perturb and Observe (P&O) and others [S. B. Santra, et.al in 2018, J. S. Ojo, et.al in 2019, S. Messalti, et.al in 2015 and R. Divyasharon, et.al in 2019]. Deep Neural Network based MPPT algorithm is developed for the Photovoltaic system by considering the dataset of different solar radiation and also observed radiation with the experimental setup at Academy of Maritime Education and Training, Deemed to be University funded by All India Council for Technical Education (AICTE), New Delhi, Government of India. The simulation is simulated with the MATLAB environment. The PV array of 1KW is considered for the proposed simulation. The proposed block diagram uses DNN based MPPT algorithm of Photovoltaic system is shown in the figure 2. The model is fed with the collected dataset from kaggle and the observed real time data at the prime location of the experiment, where it was taken. Flow model of the DNN based MPPT controller is shown in the figure 3(a) and the model representation is shown in figure 3(b). The DNN layer has two input layers such as Irradiance and the temperature from the Photovoltaic system; 500 hidden layers and an output layer. The DNN based MPPT controller is trained to predict the accurate voltage and current across the photovoltaic system.

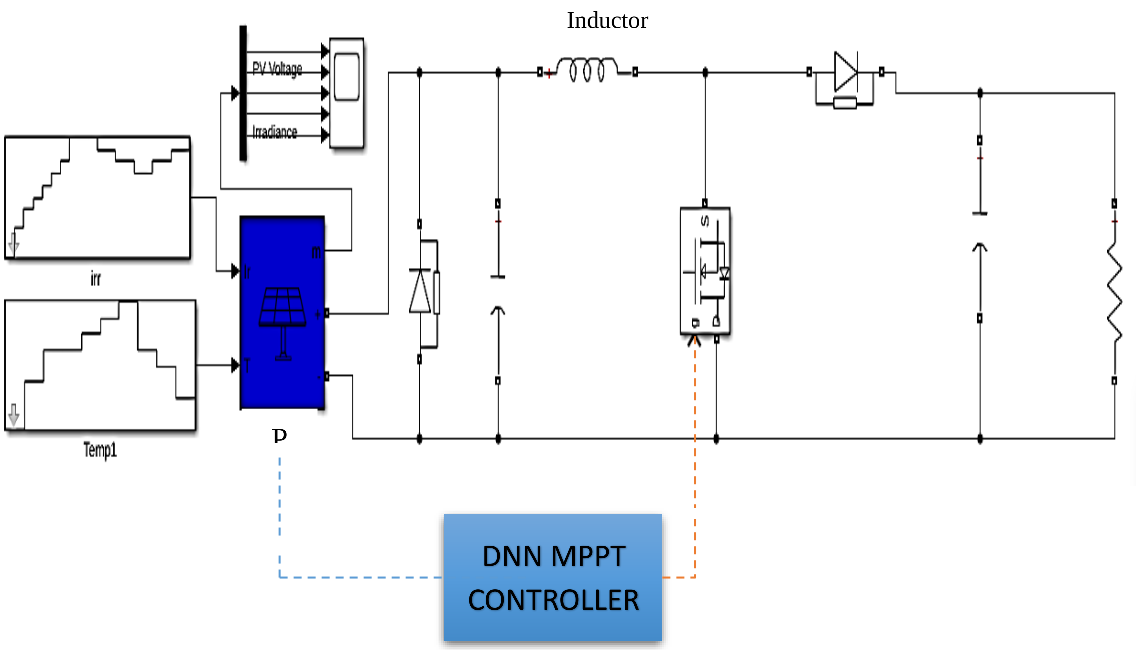
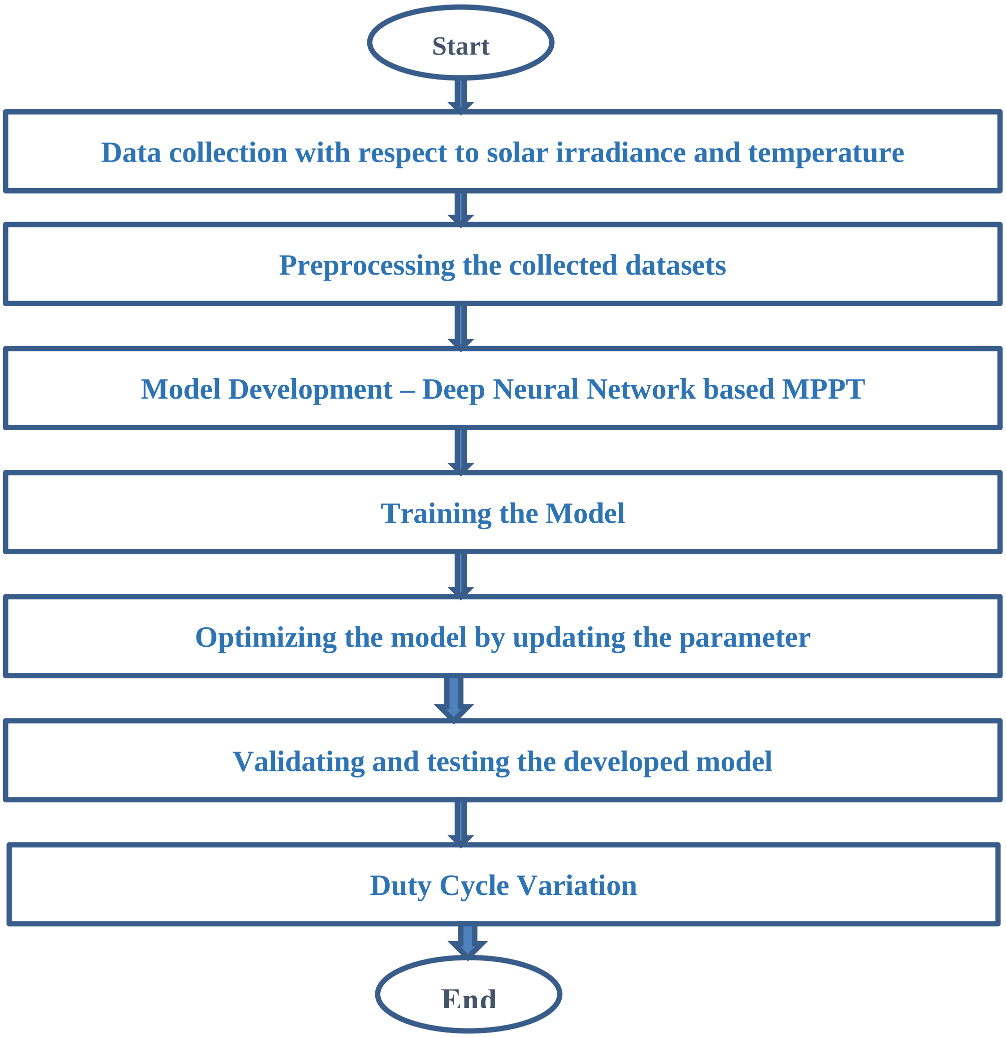
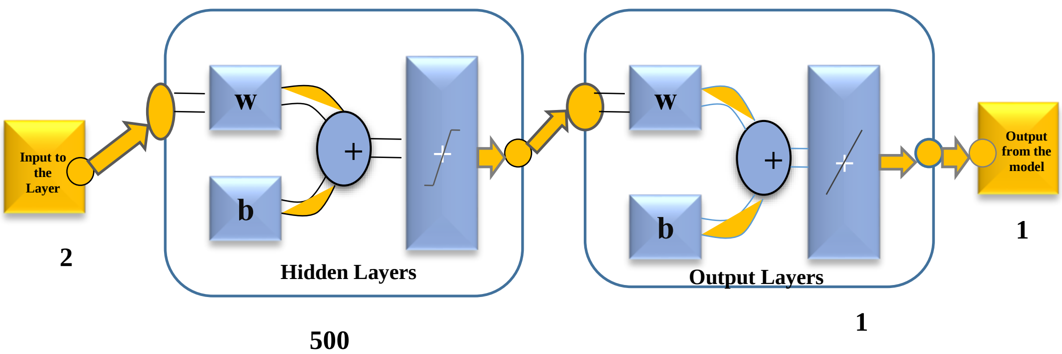


Figure 2 Block diagram of the DNN based MPPT controller



(a)



(b)

Figure 3 Deep Neural Network Model of PV system (a) Flow Model (b) Model representation

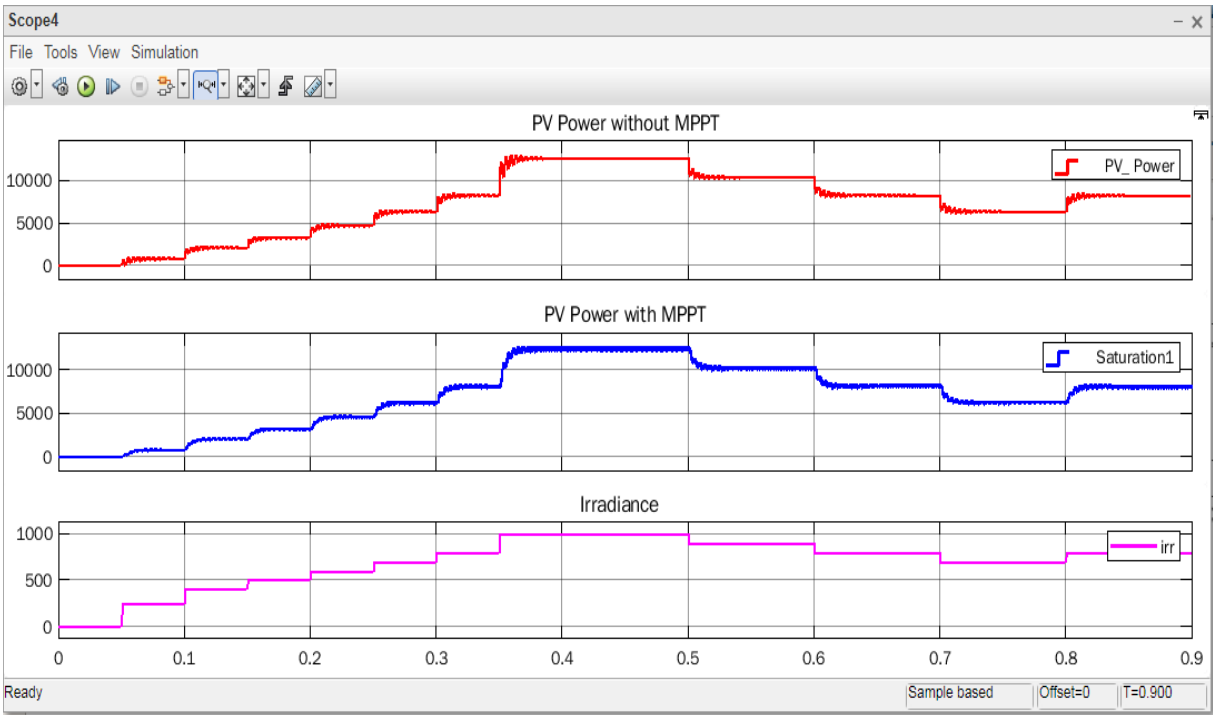


Figure 4 DNN based MPPT controller output for PV system with respect to radiance and temperature

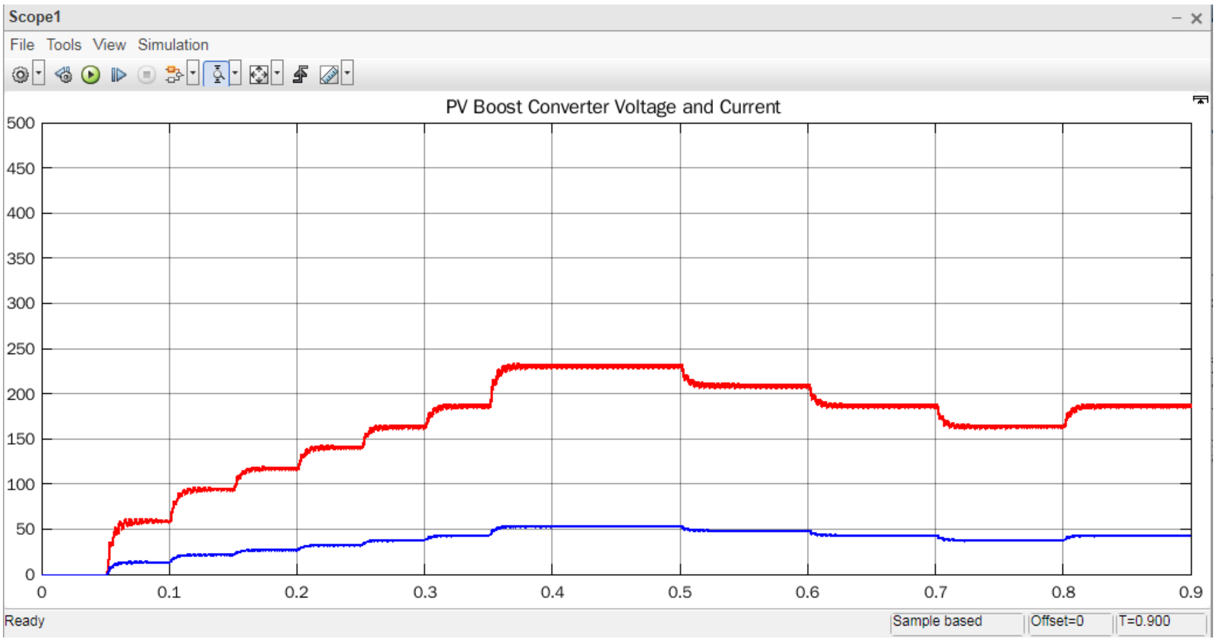


Figure 5 Photovoltaic Boost converter voltage and current

The simulated output for the DNN based MPPT controller output for PV system with respect to radiance and temperature is shown in figure 4. The proposed DNN based MPPT controller is developed in the MATLAB environment with the applied voltage of 1KW for the Photovoltaic system and observed the results under various solar radiations. Consequently, Buck-Boost converter is used in the experimental setup to boost the voltage from the solar radiation and the simulated results are shown in the figure 5.

DNN based MPPT for Wind system

Deep Neural Network based MPPT algorithm is developed for the experimental setup available in

AMET University, by considering the dataset of different wind speed [S. Yushu, et.al in 2019 and T. Adefarati, et.al in 2019]. The simulation is simulated with the MATLAB environment. The 1KW wind energy system is considered for the proposed simulation. Figure 6 shows the proposed block diagram of DNN based MPPT algorithm. The model is fed with the collected dataset from kaggle and the observed real time data at the prime location of the experiment, where it was taken. Flow model of the DNN based MPPT controller is shown in the figure 7(a) and the model representation is shown in figure 7(b). The DNN layer has two input layers such as wind speed and otheres from the wind system; 500 hidden layers and an output layer. The DNN based MPPT controller is trained to predict the accurate voltage and current across the wind energy system.

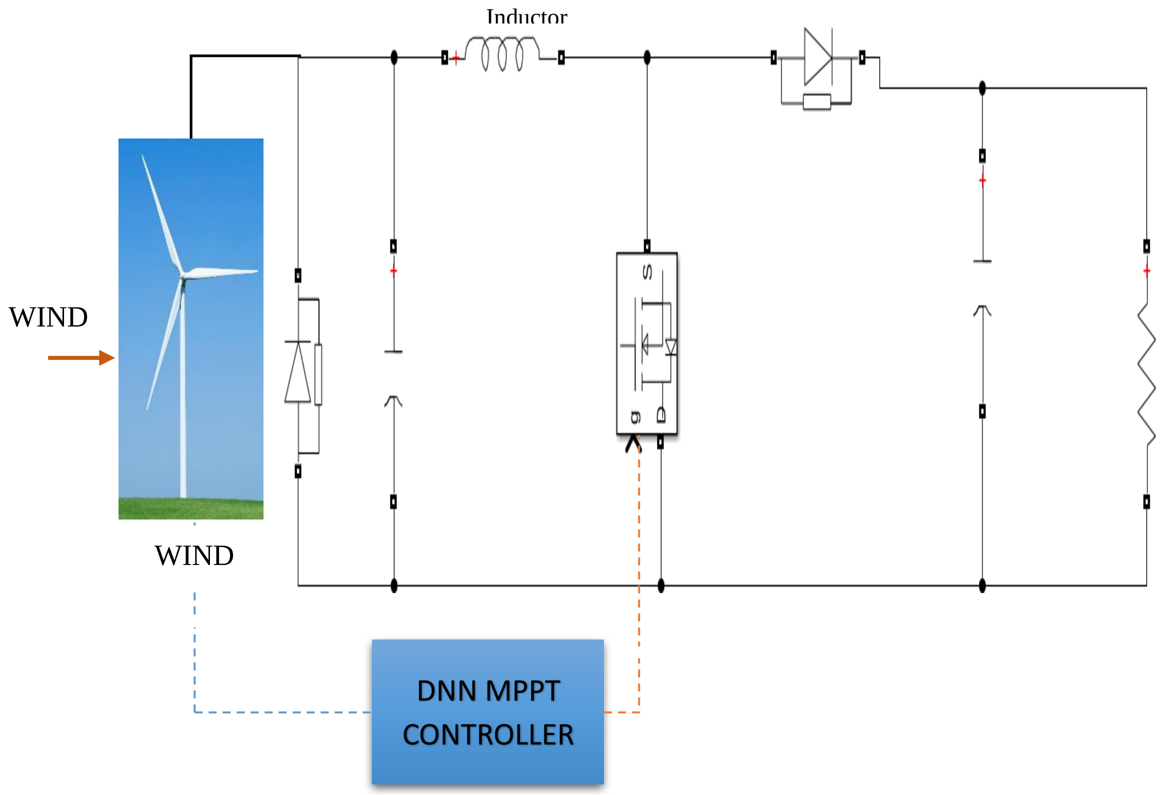
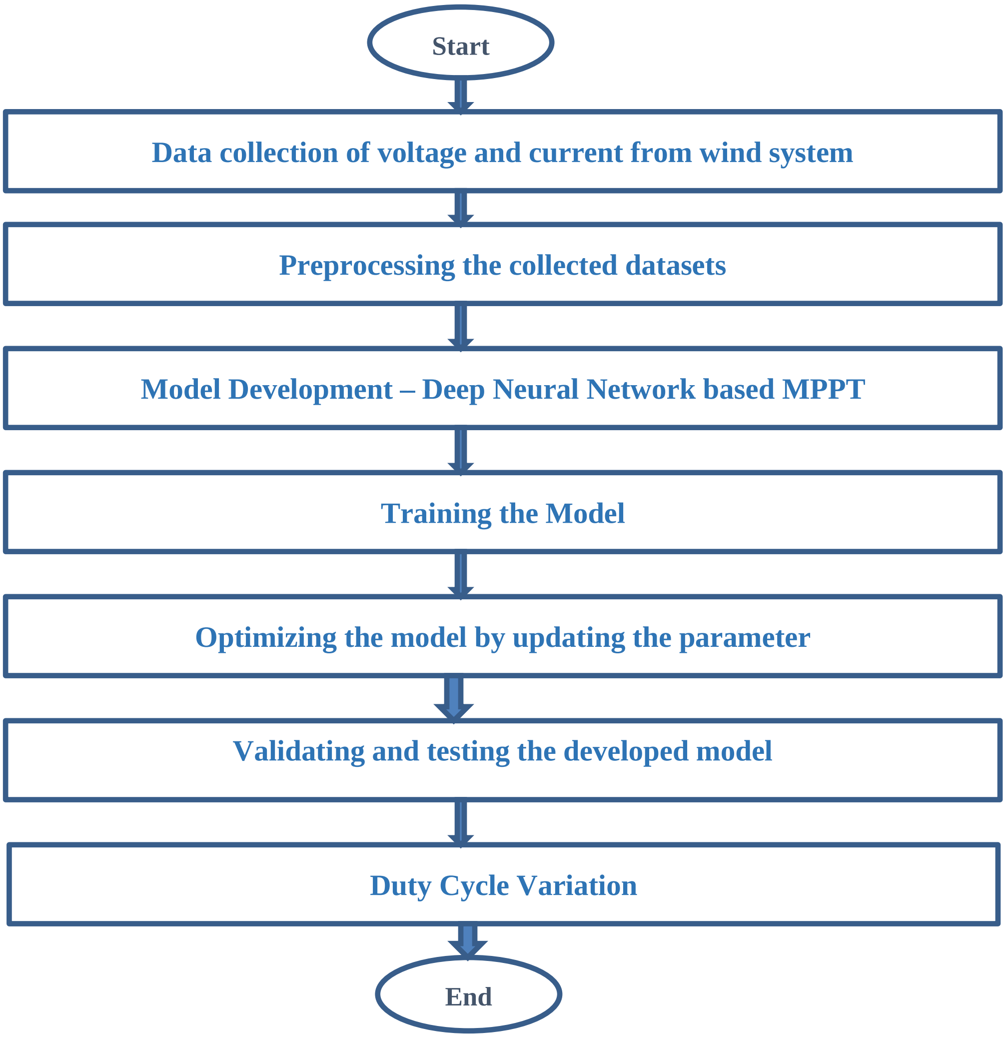
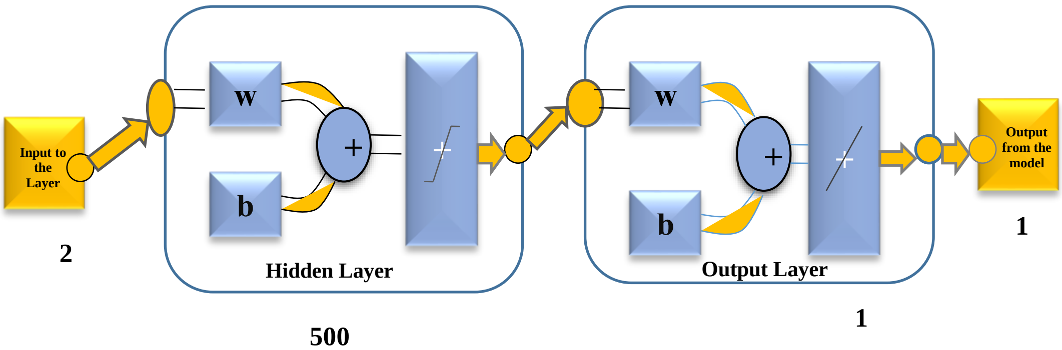


Figure 6 Block diagram of DNN based MPPT controller for Wind system

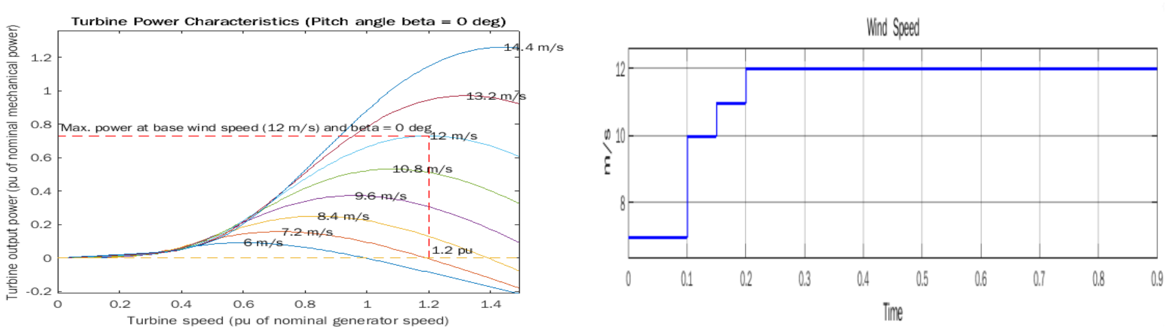


(a)



(b)

Figure 7 Deep Neural Network Model of Wind system (a) Flow Model (b) Model representation



(a) (b)

Figure 8 Wind Characteristics (a) Wind Generator Turbine Speed (b) Wind speed

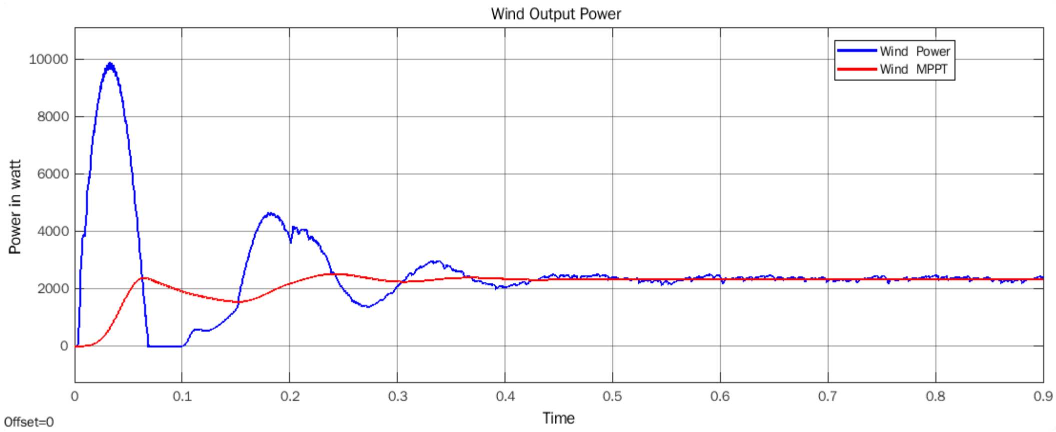


Figure 9 DNN - Wind Power with and without MPPT

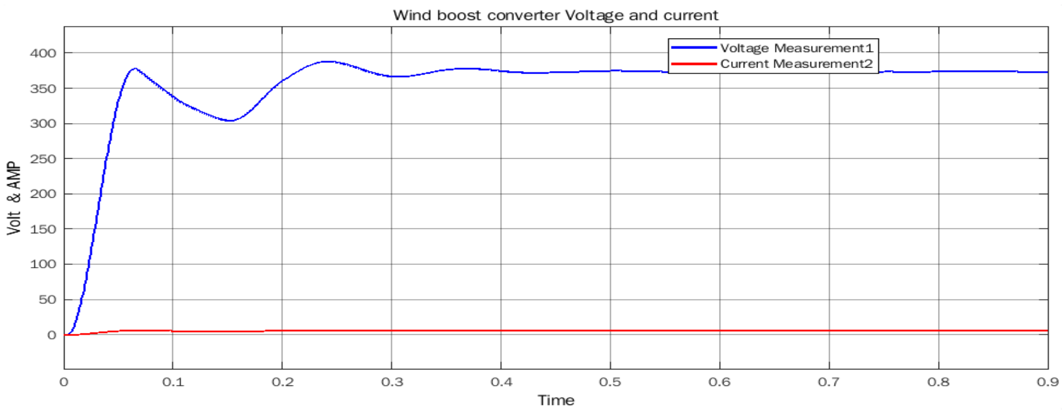


Figure 10 Wind boost converter Voltage and Current

The wind's turbine generated speed and the wind speed is shown in the figure 8. The simulated output for the DNN based MPPT controller output for Wind system with and without MPPT wind power is shown in figure 9. The proposed DNN based MPPT controller is developed in the MATLAB environment with the applied voltage of 1KW for the wind system and observed the results under different wind speeds. Consequently, Buck-Boost converter is used in the experimental setup to boost the voltage from the wind energy system and the simulated results are shown in the figure 10.

DNN based MPPT for Hybrid system

Deep Neural Network based MPPT algorithm is developed for an experimental setup at Academy of

Maritime Education and Training, Deemed to be University funded by All India Council for Technical Education (AICTE), New Delhi, Government of India. The Hybrid system is developed by considering the dataset of both solar and wind under different weather conditions. The simulation results are developed using MATLAB environment. Both the 1KW Photovoltaic energy system and wind energy system is considered. The model representation is shown in figure 11. 1000 hidden layers are considered in the Hybrid system. The DNN based MPPT controller is trained to predict the accurate voltage and current across the hybrid system using the input voltage and current.

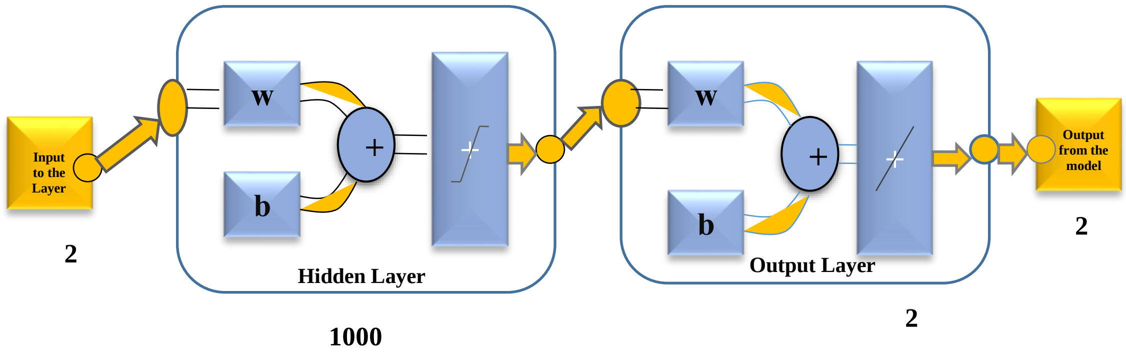


Figure 11 Deep Neural Network Model of Hybrid system

Figure 12 and 13 shows the Load real power and reactive power consumed by the load in terms of kilo watts. The simulated output of the total power generated by the Hybrid system is shown in figure 14.

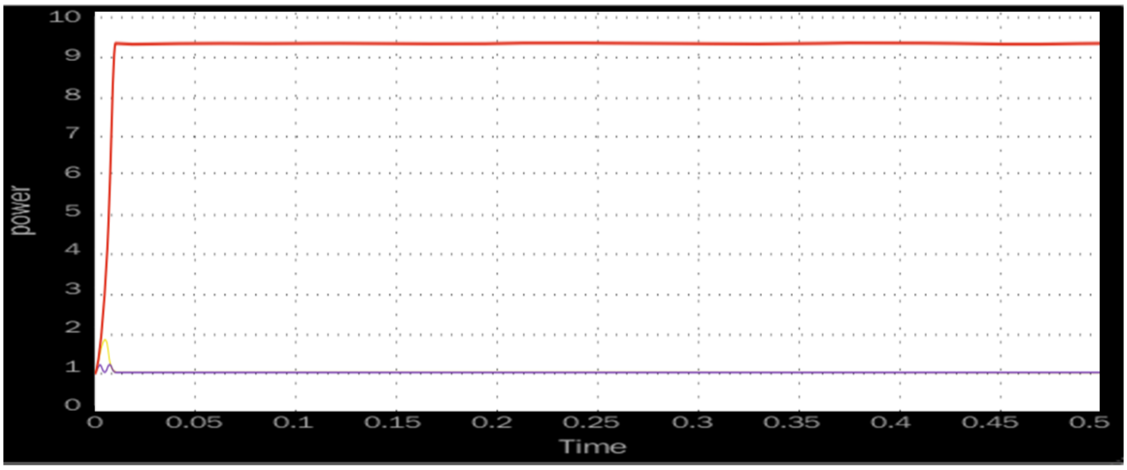


Figure 12 Real power consumed (KW)

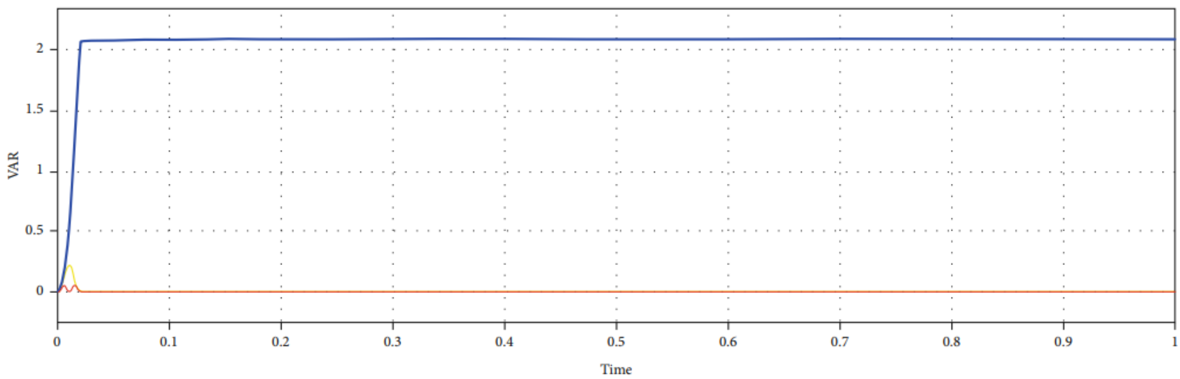


Figure 13 Reactive Power consumed (KW)

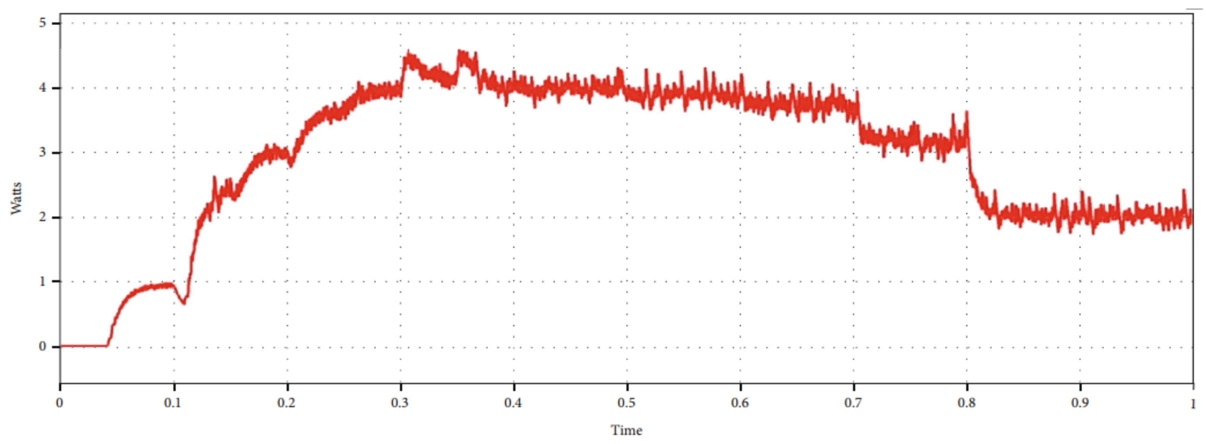


Figure 14 Total Power generated by the Hybrid System (Photovoltaic and Wind System)

Results and Discussion

The Simulation results of the Photovoltaic, Wind, and the Hybrid system under various weather influences are discussed in the paper. The simulations are carried out in the MATLAB environment. The performance of the Photovoltaic, Wind and the Hybrid system for the Total Harmonic Distortion with the proposed DNN-MPPT controller and the PI controller in terms of voltage and current values is tabulated in the table 1. It clearly depicts the effectiveness of the system which will be used for carbon free environment.

Table 1 Total Harmonic Distortion

System	DNN-MPPT Controller		PI Controller	
	Voltage (V)	Current (A)	Voltage (V)	Current (A)
Hybrid	0.11	0.10	0.16	3.60
PV	0.11	0.015	0.16	0.33
Wind	0.11	2.25	0.16	29.5

From the Proposed system, the hybrid power is about 2KW, which is a combination of Photovoltaic and wind system. The Photovoltaic array could be mounted on the deck areas of the vessel or on the sails or on both areas. The installation area should be subjected to the weather influences and the marine environmental conditions such as humidity, corrosion and other limitations in the area. The wind system can also be mounted on the deck area of the vessel subjected to the wind characteristics. The Hybrid system with the grid in onboard ships will provide considerable cost effective solution.

Conclusion

The proposed research dealt with the viability of implementing the renewable energy resources such as Solar and Wind in on-board ships; Integration of the Hybrid system and the Smart Technology have the possibility of reducing ship's emission and to progress towards zero carbon emission. The technological, environmental, and economic implications of a hybrid energy system are highlighted in this research by incorporating hybrid energy systems into On-board ships. Integration of renewable energy resources into existing fleets or into the new shipbuilding and design, with a limited number of new ships aiming for 100 percent zero-emissions technology implementation in on-board ships as a cost-effective solution in the long run. The research work analyzes the Deep Neural Network integration with the Maximum Power Point Tracker controller and is employed with the Photovoltaic system, Wind System and the Hybrid system. The level of challenges encountered depends on the appropriate energy availability in the sea route, and the primary cost in implementation. This research work also concentrates on the generation of renewable energy resources and the challenges in maintaining the stability of the system. The Deep Neural Network based MPPT controller would be a viable solution to maintain the grid stability. It concludes that the Smart technology integrated renewable energy resources utilization as a Hybrid system in on-board ships will be a promising solution for upgrading the Maritime Industry towards Industry 4.0.

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