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Modeling and design of smart grid for optimal active power analysis using solar/wind energy

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ABSTRACT: *Due to the complexity of the power grid, the requirement of electricity has been a major role professionally. The primary source of the smart grid should be performing optimizer, system reliability, and more operational efficiency. The use of the smart grid in renewable energy resources reduces the number of the component for generation in which can be interpreted to diminish the cost of generated energy. It discusses using renewable energy power plants to feed loads in remote areas as well as in central power plants connected to electric utilities. Because solar and wind power are intermittent and unpredictable, could cause and create high technical challenges. Unfortunately, the actual energy conversion efficiency of PV and wind energy systems using traditional controllers is low. To overcome controller setback and to improve the effectiveness of the system, MPPT with intelligent control techniques is used with a closed-loop system. In this paper, the system is designed for constant wind speed and varying solar irradiation and insulation. The maximum power point tracking (MPPT) algorithm is used to extract the maximum power from the PV array. The optimization methodology proposed in this paper uses the Fuzzy (Adaptive Neuro-Fuzzy Inference System) to model the PV and wind sources. The entire proposed system has been modeled and simulated using MATLAB/Simulink software.*

KEYWORDS – *active power, ANFIS, hybrid renewable resources, optimal MPPT algorithm, voltage and current characterize.*

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I. INTRODUCTION

Because of fossil fuel conventional sources depreciation, the renewable energy sources are in great imposition remarkably. Among entire renewable sources, the photovoltaic (PV) received enormous diligence as it has environment-friendly nature, safe, clean, portable behavior, and free availability [1], [2]. However, installation and fabrication outlay is formidable presently which will depreciate bit by bit with exploration and substantial scale application. The extracted power from the PV module depends on environmental factors which observe power variations under fluctuating operating conditions. Therefore, there is an urgency to incorporate with auxiliary power supply viz. battery, diesel generator, and fuel cell. The battery and diesel generators are unable to provide all load demand and particular duration backup respectively. As PV power generation depends on solar irradiance level and has more fluctuation power with changing atmospheric conditions [3]. The fuel cell is controlled supply which delivers supplementary power requirement and meets inadequate PV-power integration with high efficiency, extensible, and fuel adjustable as major benefits [4].

The main contribution of this paper is explained as follows,

- The power converter has been performed based on the power demand of the source. It converts the power depends on the demand request.
- The parallel connection has been scaled up with better control and power management can be attaining reliable operations.
- To identify the most economic and appropriate power supply for electrification of a selected remote rural area consisting cluster of villages.

In the proposed methodology, hybrid renewable energy resources have been used in which solar and wind energy resources had been used for the proposed system. The optimal MPPT algorithm is used for the solar energy resources in which it yields maximum current and voltage. The ANFIS network is used instead of the PI controller in which it controls the voltage fluctuation. Section 1 explain the introduction part along with section 2 explain about the literature survey. The section 3 discuss the proposed methodology and section 4 explain the result and discussion part and finally the conclusion and future scope of this paper has been discussed.

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II. LITERATURE SURVEY

Calvillo, *et.al [5]* proposed the energy-related work on operation and planning models of the smart cities. The data is classified into five main types of areas such as storage, infrastructure, facilities, generation, and transport. Consolidation of more than one intervention area of more complex urban energy models is also cross-checked, marks their advantages and limitations, current challenges and trends, and also some of the applications. Along with some additional features the proposed methodology to develop an improved energy model in a smart city context.

The elaborated outline of the functional and architecture model of the smart Home Energy management system (HEMS) is proposed by Zhou, *et.al [6]*. Then the advanced function of the HEMS home appliances and smart houses are their functions are well checked and analyzed. Besides, the deployment of various long building utilities of renewable energy sources are biomass, solar power, wind, geothermal energies are also reviewed. Finally, numerous home appliances that are used to reduce the cost and improve the energy efficiency and reliability of power generation are also investigated.

Morstyn, *et.al [7]* proposed the state of the art control strategies designed for integrated energy storage (ES) systems in microgrids. Energy storage is distributed throughout the entire power system and furnishes the range of services. The preface of the distributed energy storage represents the basic change of power networks, raises the network problems, and also long time dynamics combine with the storage system of levels. With the help of a small distributed Energy system, the microgrids can be managed and it has new strategies, speed power networks, and communication network disturbances. The main focus is centralized, decentralized, and multi-control strategies to integrate micro grid ES systems.

Wu, *et.al [8]* proposed the smart home with PEV (plug-in electric vehicle) energy storage and a photovoltaic array. It used to reduce the consumers' energy charges under some tariffs satisfying the home power demand and PEV charging requirements. Firstly, using the Markov chain model the random variable models are developed. The second optimal control problem is used to manage the power flow among energy sources in the smart home. The outcomes show that electric car cost is 493.6% less than Tesla Model S with stochastic dynamic programming and it is 175.89% for Nissan leaf.

Zhou, *et.al [9]* proposed the big data energy-driven management also the model of big data-driven smart energy management is presented. Sources and the characteristic of the big energy data are studied first. Providing the systematic review of big data analytics for smart energy management the smart grid runs as a research background. It also presents the four major sources of big data namely power generation side management, microgrid, and renewable energy management, asset management and collaborative operation, and demand-side management (DSM). After all these operations industrial development of big data-driven smart energy management is analyzed.

To address the challenges about demand, renewable sources, electric vehicles, the two-level stochastic problems for energy resource scheduling are proposed by Soares, *et.al [10]*. Aims to reduce the operational and maintenance cost of energy aggregator based on stochastic programming. The outcomes show that the effectiveness and the efficiency of the stochastic model when compared with the existing models that demand response plays an important role in mitigating the uncertainty.

Ringler, et.*al [11]* proposed the review of techniques that are applied in the smart grid from a system perspective. For this agent-based modeling and the simulation techniques to electrical things. These two models agent-based modeling and simulation techniques only the analysis of the smart grid for the electrical systems, although it used in the limited research and used in the different applications for recent days. The simulation model and Agent-based model show how it will act in different devices and interact and produces the effect it occurs at the global level. It produces variable inputs for the delivery process that meet stakeholders and policymaking. The more advanced feature discusses the storage, role of intermediaries, local market concepts.

Rahim, *et.al [12]* proposed the design of the heuristic algorithm to evaluate the performance of home energy control management. The heuristic algorithms are Genetic algorithm (GA), Binary particle swarm optimization (BPSO), and ant colony optimization (ACO). For the growth in demand-side management, introducing the generic architecture which coordinates smart area domain with residential area domain through Wide Area Network (WAN). Besides the multiple knapsack problem algorithm is used for problem formulation. The model of time using a tariff and inclined block rates is used for energy pricing. It also proves a cost-effective solution to increase reliability and sustainability.

III. PROPOSED METHEDOLOGY

3.1 Hybrid power system

Figure 3.1 shows a typical hybrid power system structure. Each renewable source it connected to a DC/DC converter which is fed to a common DC bus. The output power of the PV and wind sources depends on the solar radiation and wind speed variations, and the battery is used to store the excess energy produced and discharge when the renewable sources are not available [15].

The converter operates at maximum power point tracking mode to extract the maximum possible energy, regardless of the variation in weather conditions. Different operating modes can be used, depending on the availability of the sources and the controller topology [16]. For example, at night when solar power is not available, wind and battery backup will be used to supply the load power. The successful operation of a hybrid system depends on the ability of the sources to supply the load with uninterrupted power. This can only be achieved if PV, wind and battery are sized accurately for any given load conditions [17].

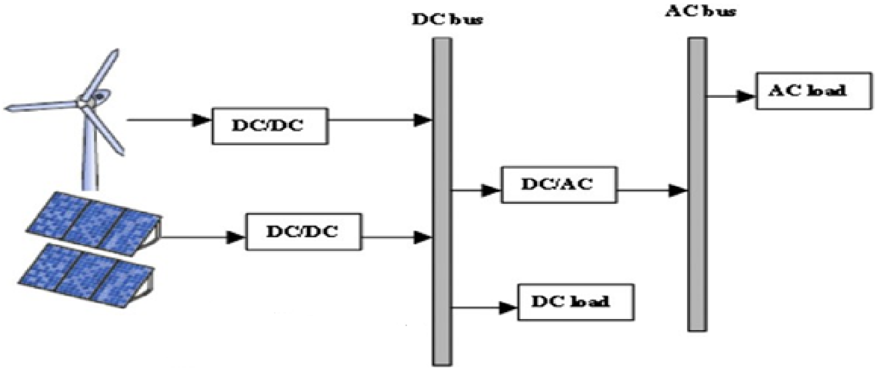

Figure 3.1: Block diagram of hybrid PV/wind/battery power system.

Hybrid power systems are predominantly deployed in remote locations, rural locations, islanded and standalone conditions where the cost of supplying power is high and the difficultly to supply power to rural locations. The daily load profile for a typical village household is shown in Figure 3.2 where the hourly load varies from 1 kW to 5 kW.

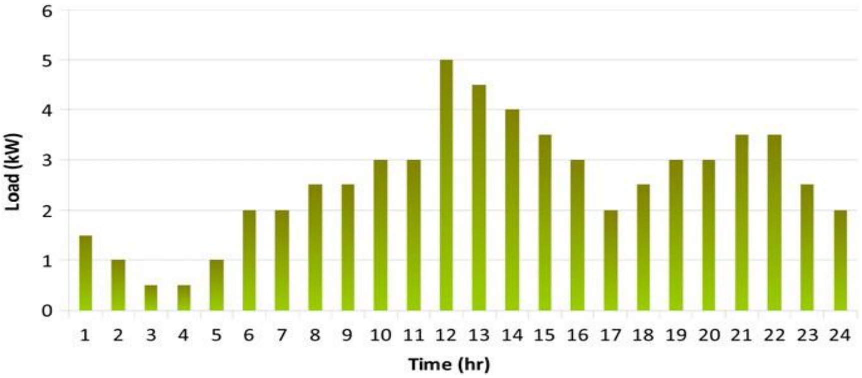

Figure 3.2: Hourly typical rural household load profile

The daily load profiles are an important part of the design of hybrid system, as it characterizes the power demand that must be met by the available renewable sources and backups. As the renewable sources vary throughout the day, the excess power is stored and battery will act as auxiliary supply to meet the load demand. DC generators can be used as backup in case of any failure to increase reliability.

3.2 Modeling using ANFIS

ANFIS (Adaptive Neuro-Fuzzy Inference System) is the fuzzy- logic based paradigm that grasps the learning abilities of ANN to enhance the intelligent system’s performance using a prior knowledge. Using a given input/output data set, ANFIS constructs a FIS (Fuzzy Inference System) whose membership function parameters are tuned using either a back-propagation algorithm alone, or in combination with a least-squares type of method. This allows the fuzzy system to learn and model from these data [18]. These techniques provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data as shown in 3.3. This learning method works similarly to that of neural networks.

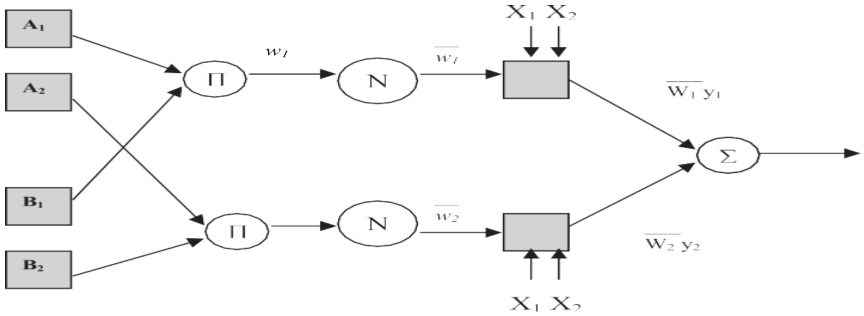

Figure3.3. ANFIS neural network structure

- Layer-1: Consists of membership functions (A_1, A_2, B_1, B_2), where the fuzzification process takes place, and every node is adaptive.
- Layer-2: The nodes in this layer are fixed. Each node output represents firing strength of a rule. Layer-2 implemented the fuzzy MIN operator. The output of the Layer-4 is comprised of a linear combination of the inputs multiplied by the normalized firing strength, w_1 and w_2.
- Layer-3: In this layer, where the normalization process per- formed acts to scale the firing strengths, the nodes are fixed. The rule's firing strength to the sum of all rule's firing strength is calculated for the corresponding node.
- Layer-4: The adaptive nodes in this layer operate as a function block whose variables are the input values and p_i, q_i, and r_i is the consequent parameter set of the node.
- Layer-5: Simple summation of the outputs of Layer-4. The adjustment of modifiable parameters is a two-step process. First, information is propagated forward in the network until Layer-4, where a least-squares estimator identifies the parameters. Then, the parameters in Layer-2 are modified using gradient descent. The only user specified information is the number of membership functions for each input and output as training information.

ANFIS uses back-propagation learning to learn the parameters related to membership functions and least mean square estimation to determine the consequent parameters. Every step in the learning procedure includes two parts. The input patterns are propagated, and the optimal consequent parameters are estimated by an iterative least mean square procedure. The premise parameters are assumed fixed for the current cycle through the training set. The pattern is propagated again, and in this epoch, back-propagation is used to modify the premise parameters, while the consequent parameters remain fixed [19].

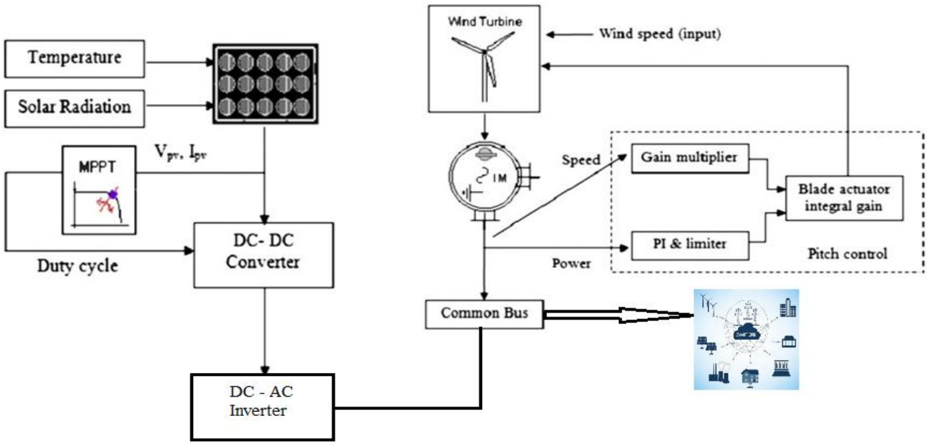

Figure 3.4: Control topologies for PV and wind generator in hybrid system.

It is important to note that HOMER and HOGA require manufacturer's data to be used for its photovoltaic, wind turbine and battery model. This type of data is not easily obtainable and its cost can vary between countries. For the simulation, user defined models were designed for wind, PV and battery. As shown, ANFIS optimization model produces appropriate sizing that result in lower excess energy due to increased battery size. HOGA produces lower battery and PV size, but with increased wind turbines size.

The result from HOMER is similar and this is expected, as ANFIS and HOMER uses COE constraints for economic optimization, but HOGA uses Net Present Cost.

IV. RESULT AND DISCUSSION

In this paper, the simulation of the smart grid using hybrid renewable source has been performed and the performance analysis of the smart grid has been explained as follows. The simulation of the smart grid is designed by MATLAB/Simulink version 2016a. The design view of the simulation is shown below.

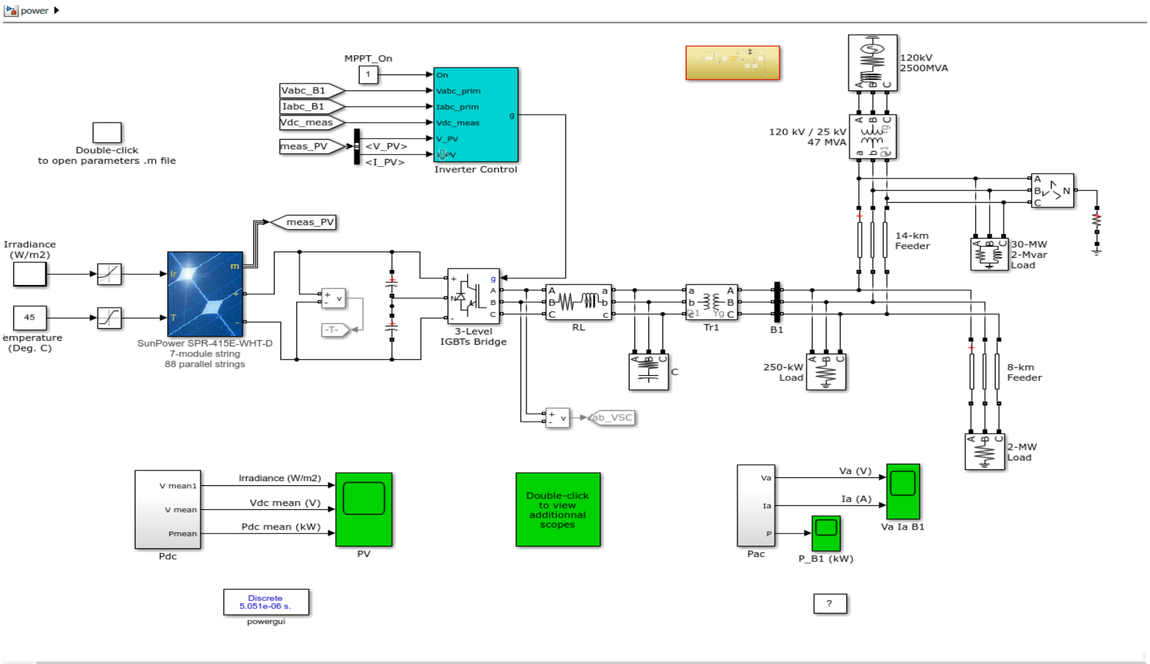

Figure 4.1: Hybrid Solar/Wind Smart gris system

Figure 4.1 had demonstrated the overall smart grid system in which it contain solar energy resources and wind energy resources. These two system is inconnected with the load and transmission using grid. This is grid tied design in which all the subsystem has been connected by utizing bus system.

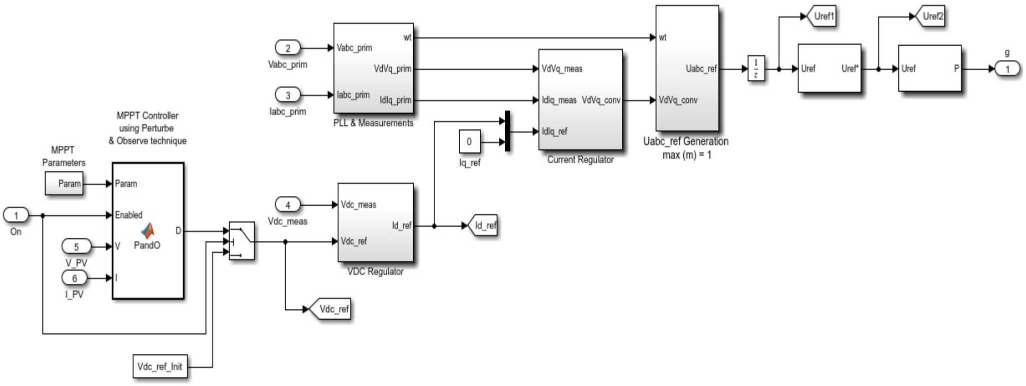

Figure 4.2: Solar Power generation system

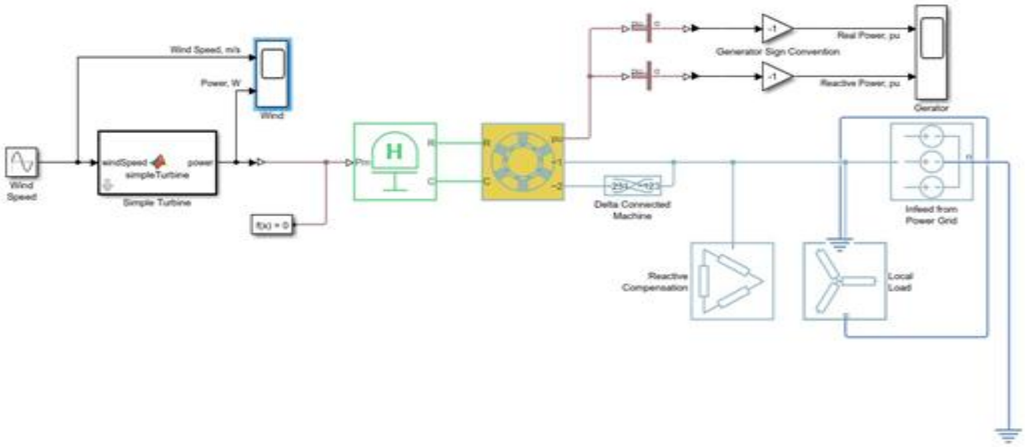

Figure 4.3: wind power generation system

SIMULATION RESULT

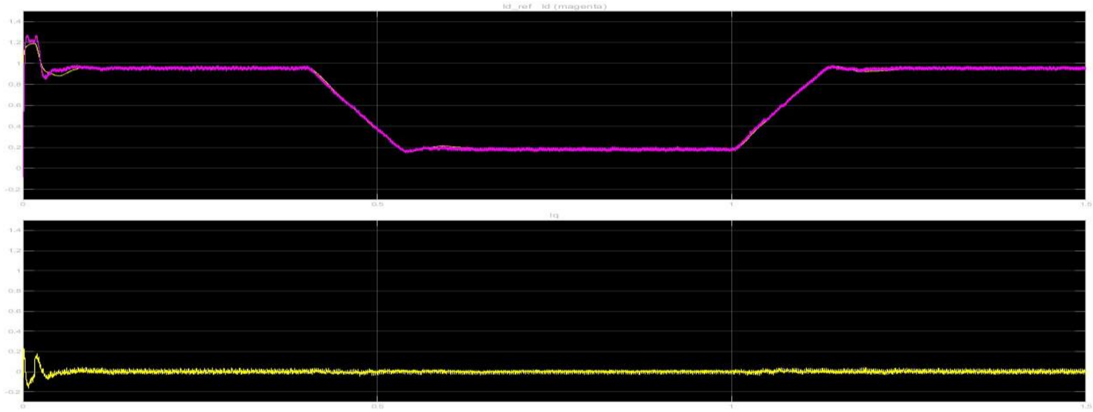

Figure 4.4: Time Vs Id & Iq Plot

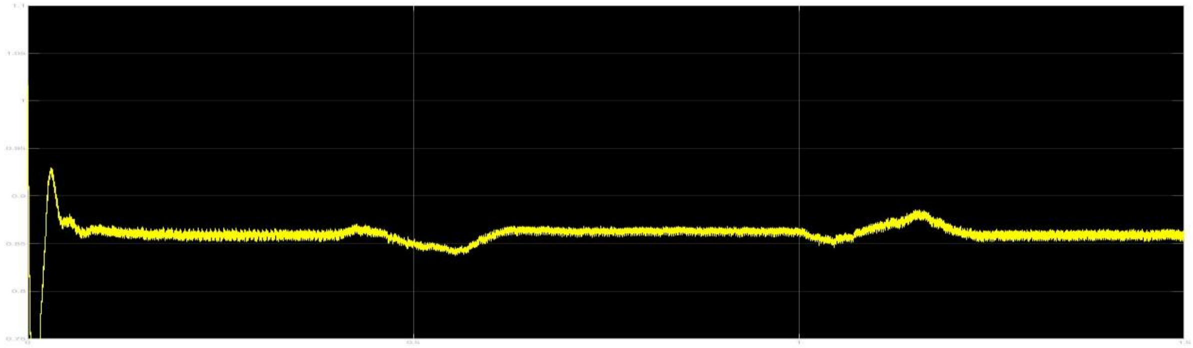

Figure 4.5: Modulation Index Plot

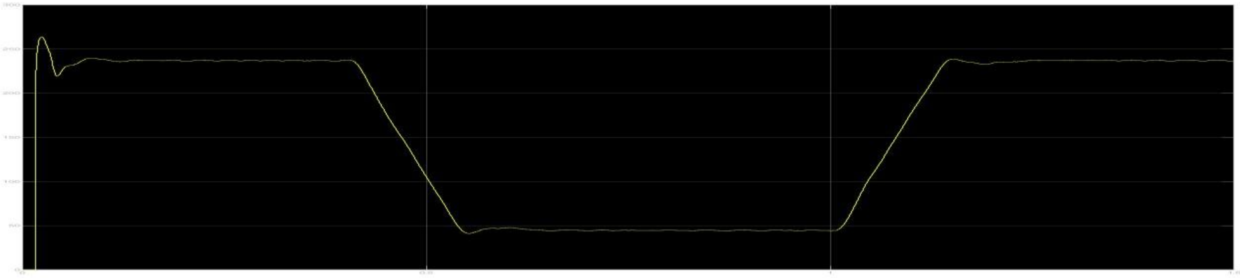

Figure 4.6: Power Characteristic Plot

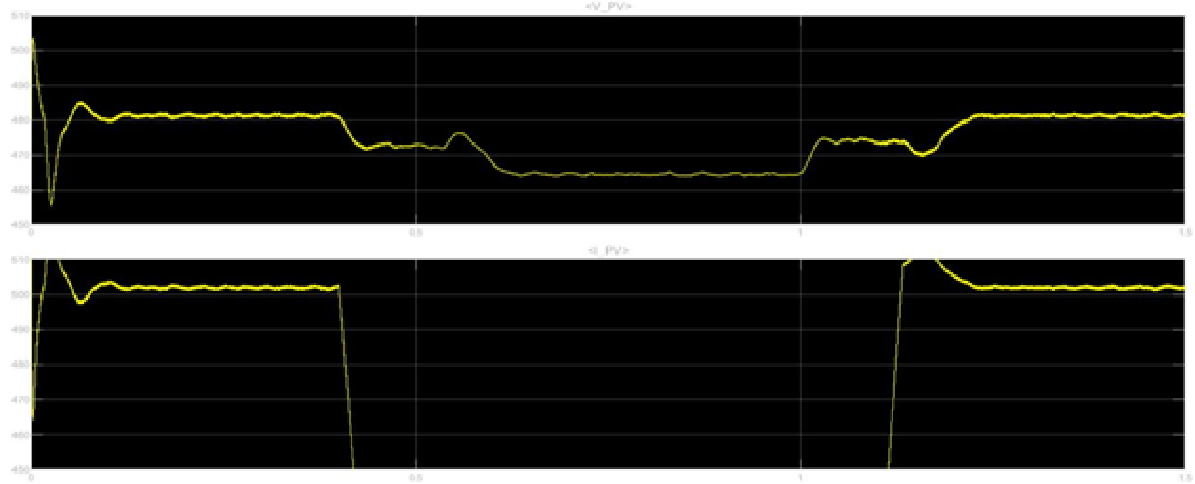

Figure 4.7: Voltage and Current characteristic

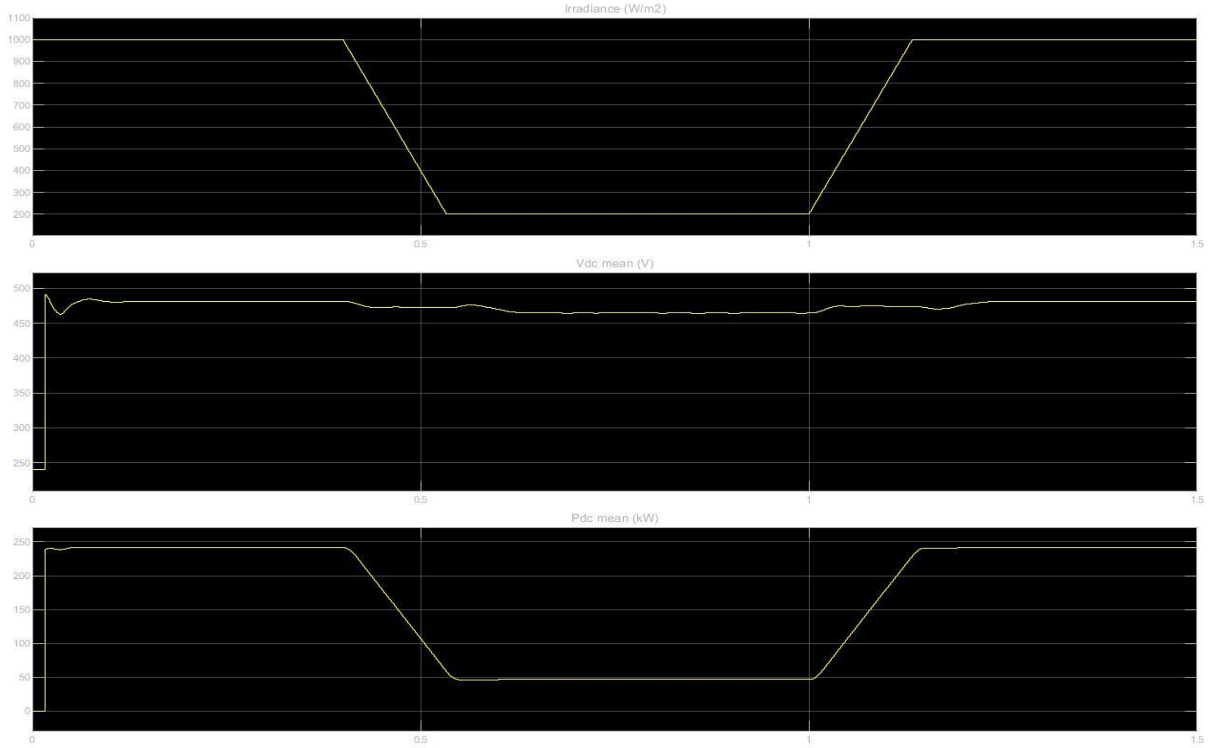

Figure 4.8: Irradiance, Voltage and Current characteristic for the solar system

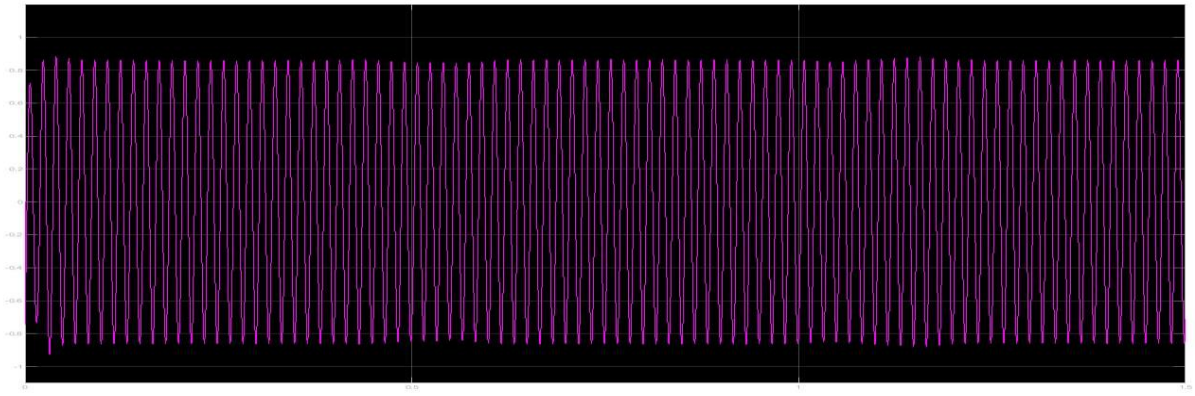

Figure 4.9: Phase lock loop Umeasure and Ureference plot

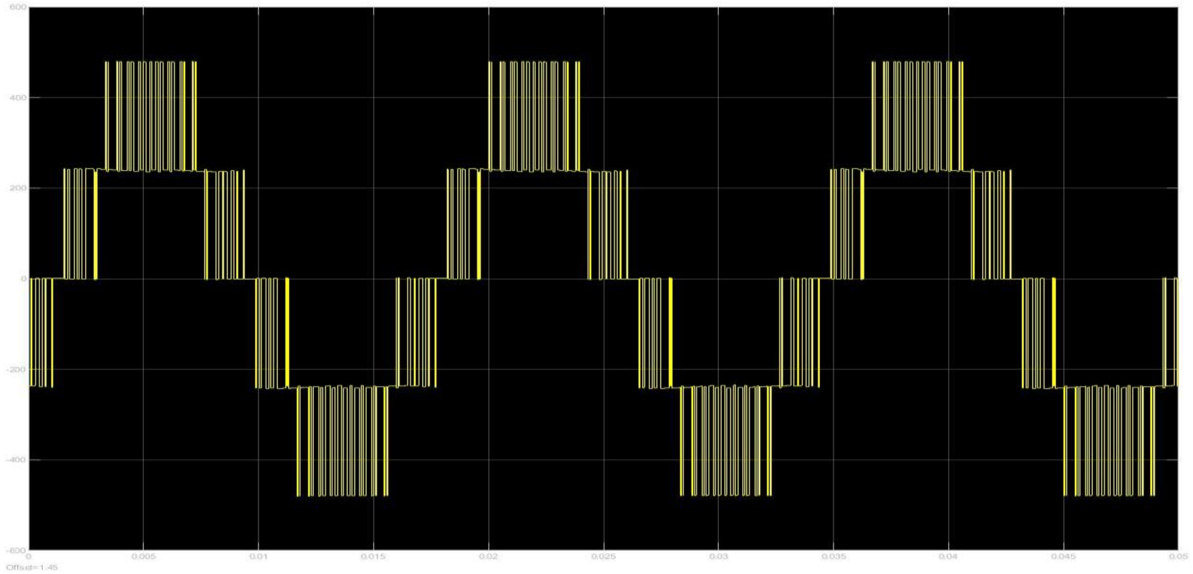

Figure 4.10:Voltage Characteristic of Inverter

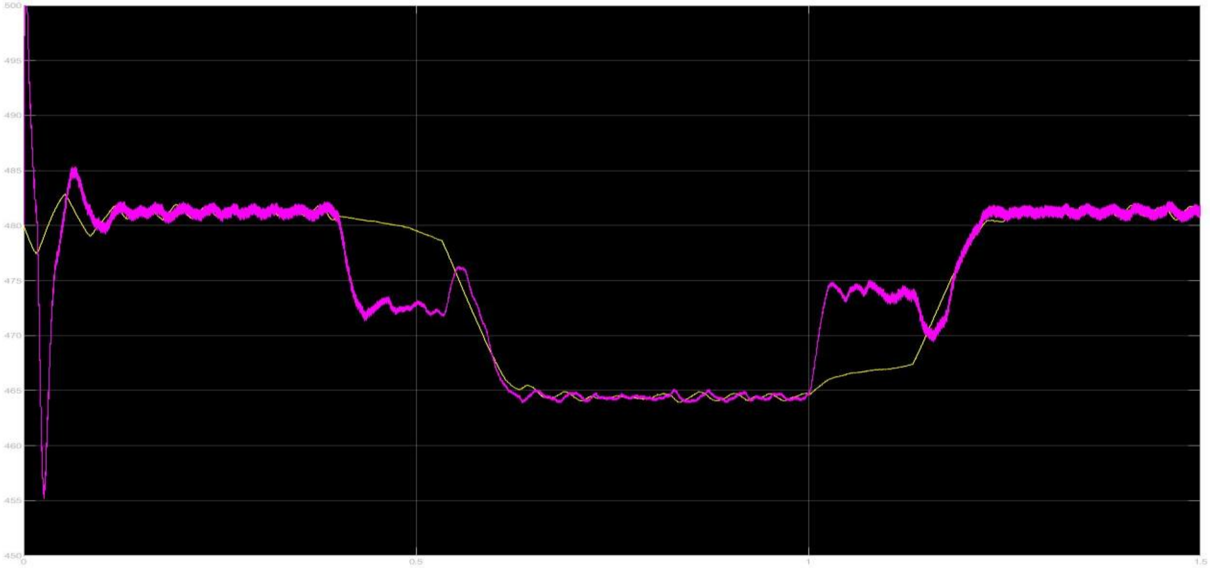

Figure 4.11: DC Voltage(Vdc)

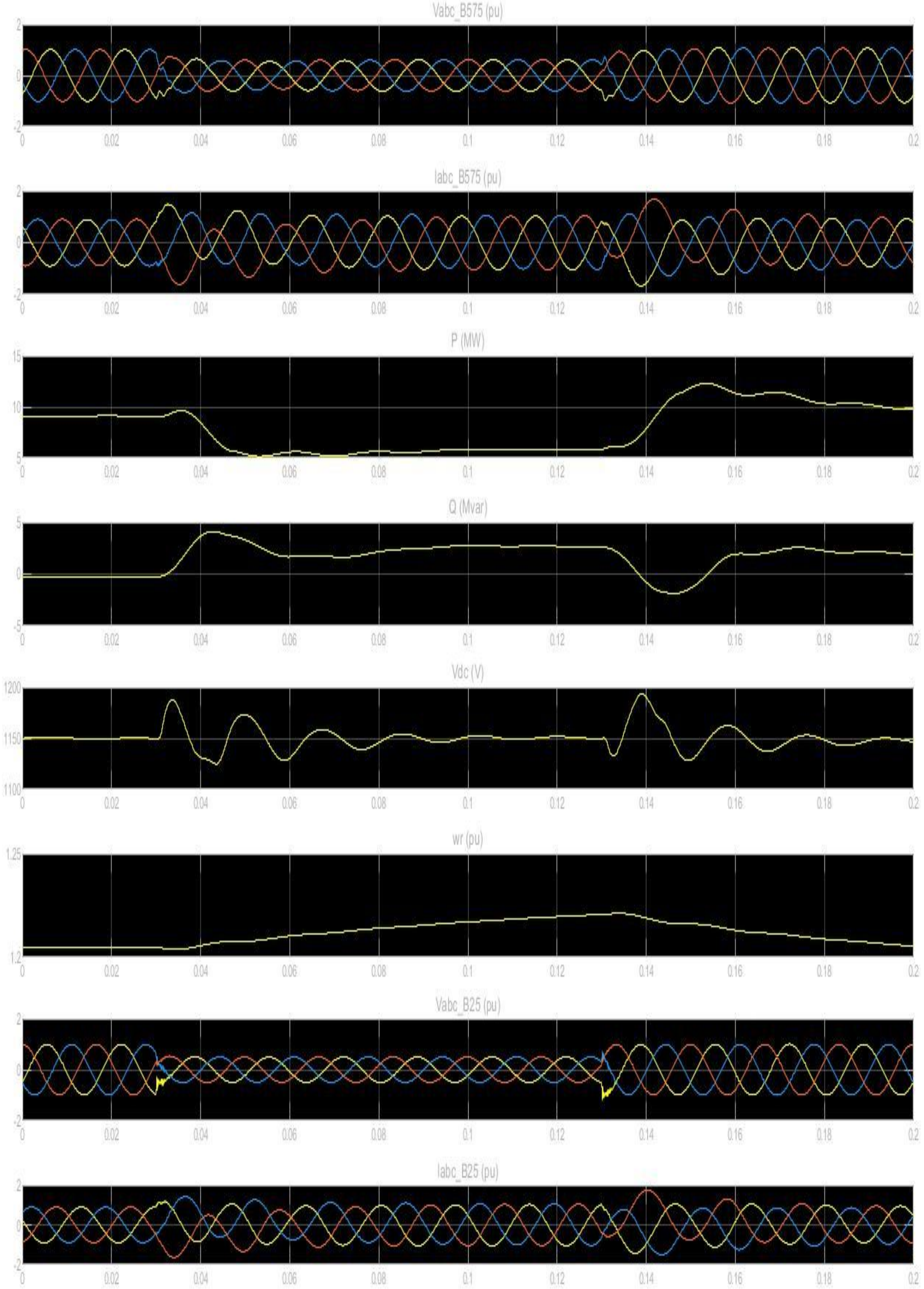

Figure 4.12: Voltage, P, Q, Vabc, Iabc and wind speed for the wind turbine characteristics

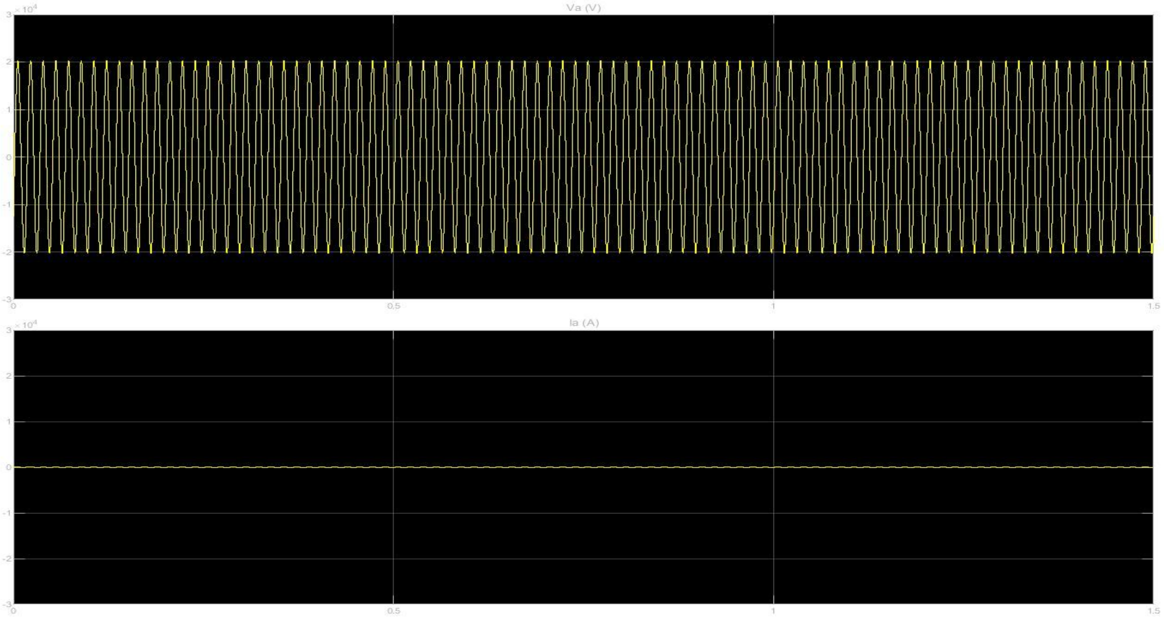

Figure 4.13: Voltage and Current Characteristic of the hybrid power plant

V. CONCLUSION

This paper presents a Neuro-Fuzzy approach to model and optimize the sizing of a hybrid standalone power system. The Neuro-Fuzzy model was developed using real meteorological data from various location. The Fuzzy based optimization algorithm developed incorporates autonomy and efficiency sizing with minimum cost function. The optimization model presented in this paper is independent of any specific manufacturer's model and hence gives a greater option for component selection. The results show that the fuzzy model produces an accurate power output, and the optimization algorithm produces configuration with the lowest cost and excess energy for the desired LPSP. The fuzzy model developed is validated using PSCAD simulation and the results show that the optimized configuration produces high efficiency for LPSP of 0.01.

VI. FUTURE SCOPE

With reduced costs and improved technologies, the solar energy ensures the reduced electricity bills, increases countries' energy security through reliance on an indigenous, inexhaustible resources, enhanced sustainability, reduced pollution, lower the costs of mitigating global warming, and keeps fossil fuel prices lower than otherwise. It is environment friendly and any one can use it. The advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared.

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