

The Future of Energy: Mitigating Uncertainty with Hybrid Renewable Energy Solutions

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Abstract---The increasing global demand for sustainable energy has led to the rapid expansion of renewable energy sources such as solar photovoltaic (PV) and wind power. However, the inherent intermittency and uncertainty of these resources pose significant challenges for their effective integration into power networks. To enhance grid stability and reliability, hybrid solar PV/wind systems have emerged as a promising solution. This paper discusses methods to mitigate the uncertainty associated with renewable energy through the efficient integration of hybrid systems into existing power networks.

Keywords: Healthcare, Internet of Things, Smart hospitals, big data, Cloud Computing, Electronic health records, Smart-health, IOT-Healthcare, COVID-19, deep learning, Wearable sensors.

I. INTRODUCTION

The major purpose of the most recent evolution of self-control is energy. Agriculture, education, healthcare, accessible missions, and the required energy must all run smoothly. Without efficient energy utilization, a country cannot prosper. The economy is thought to be the main component of anation [1]. Biogas, biomass, geothermal, small hydro, PV, solar thermal, wind, and solar thermal are examples of renewable energy sources that can be used in RESs [2]. To find alternative sources of energy, it is crucial to use renewable energy (RE) [3] now to lessen the environmental impact of fossil fuels. Photovoltaic (PV) cells are one choice. The poor conversion rate of the commercial PV module (PVM), which is close to 18%, is one of its drawbacks, though [4], [5]. A PV system is a device that can convert sunlight as renewable energy into DC voltage [6]. One well-

liked RES is wind power [7]. Wind energy presents significant operational issues because of its erratic nature and volatility, especially for brittle or isolated transmission networks. Wind producing plants must meet specific requirements to follow the grid code's requirement to guarantee a controlled power output and the supply of extra ancillary services. Due to the wind's erratic behavior, scheduling becomes more difficult and the expense of maintaining the systems, necessitating a decrease in frequency [8], [9].

Wind turbines (WTs) can be combined with production to create hybrid power plants (HPPs) as a means of solving these difficulties. Utilizing a mix of conventional and RESs [10], wind solar hybrid systems (WSHS), wind hydro hybrid systems (WHHS), and wind-thermal hybrid systems (WTHS) [11] to handle energy and lessen the wind generated electricity inconsistency, the HPPs can lower their energy costs and the environmental impact of their operations [12].

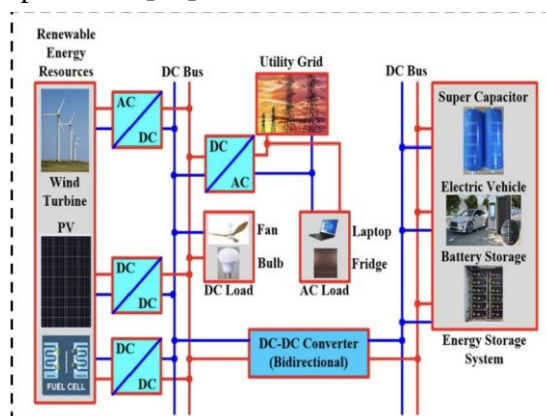


Figure 1Block Diagram

Due to their intermittent nature RESs cannot function as a standalone power generation system [13], [14]. The integration of two or more RES is thus a

potential remedy for this problem. The HRES is the integration of different renewable energy generation sources [15]. They are typically used to build an independent power generation system that boosts the effectiveness of the RES [16]. As a result, HRES systems have gained enormous popularity and are used everywhere to generate high-quality power [17]. The HRES are a more practical alternative to traditional energy sources since they enable the reliable utilization of all available resources. According to the available resources, much study has been done to present a variety of HRES options.

To meet the demand for power in numerous regions around the world, academics have assessed various groups of HRES. Like control system, selection criteria, sizing, energy management, and configurations, the author presented all the parameters required when building and executing the hybrid energy system (HES) [18]. Because wind generation systems have a moment of inertia, wind-based HRES can support the utility grid dynamically, and the availability of multiple energy sources boosts the reliability of the power supply [19]. To convert low to high voltage for greater exploitation of RESs, effective DC-DC converters are needed. The converter needs to be affordable, lightweight, have low voltage switching tension (LVST), and have a high power density (HPD) [7], [20], [21]. To improve power conversion efficiency, research has recently focused on AC-DC/DC DC conversion approaches [21]. The use of various power electronic converters (PECs) in RES applications

II. CHALLENGES FOR WIND/PV INTEGRATION

A. WIND AND PV INTEGRATION CHALLENGES Wind and PV are important contributors to modern power systems since they provide clean and environmentally friendly electricity. The PV and Wind system features, such as intermittent and protection difficulties, present additional obstacles to successful and cost-effective grid integration [47], [48], [49], [50], [51].

1) REACTIVE POWER (RP) An induction generator is commonly used to generate electricity from WE it also consumes RP, and it cannot provide RP to the grid as synchronous machines do [52]. In [53] wind turbines' ability to offer RP to grid.

Whereas, direct current is achieved using power from PV, it lacks the benefit of RP, which is a feature of AC sources [54]. As a result, the significance of novel expertise for supplying RP capability is growing. According to a paper on the reactive power capabilities of a North American grid, variable generating facilities like solar and wind could add to the network's RP capability [55].

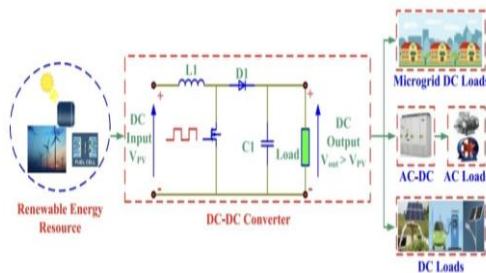


Figure 2 Wind and PV Integration

B. POWER QUALITY ISSUES

Power quality difficulties may arise as a result of large scale RES integration [56], [57]. As a result, rules and regulations have been implemented in

several nations to ensure the quality of power generated by RESs. The voltage transients, voltage unbalance, flickers, and harmonics, are the primary power quality challenges associated with RES integration [58]. Power electronic converters (EPC) are used to incorporate PV into grids, create harmonics that can damage network-connected equipment and impair its efficiency and longevity. The features of harmonics generated from the integration of numerous PV systems into the grid were investigated [59], [60], [61].

The WTs, like other conventional generator, must produce electricity of sufficient quality. The harmonics will be introduced at different network levels as a result of WT integration into grid [62].

3) FREQUENCY EFFECT The addition of a backup controller to the WT central control unit in [63] can regulate make point of torque to create it flexible to deviations in frequency of grid by utilizing the WT mass during a disturbance. Using the same concept in [64] suggested controller for grid frequency to maintain output power of PMSG. When PV system is integrated into grid raises the generation and demand imbalance due to it having intermittent nature. It may also cause frequency fluctuation in the networks, resulting in total loss or partial of electrical supply [51]. During the solar eclipse, the output influence of PV power plants on frequency constancy for the synchronous zone in Europe was investigated [65]. Combining PV and wind generators in a hybrid system can help to improve energy production and efficiency. For example, wind turbines can produce energy during the night or

on cloudy days when PV panels are less effective, while PV panels can produce energy during the day when wind speeds are typically lower [66].

III. DIFFERENT INTERMITTENCE MITIGATE TECHNIQUES

A variety of control techniques have been used to build load frequency controllers [67]. The speed-governor system uses the proportional and integral (PI) control approach [68], [69] extensively when operating in normal mode [68]. However, in real-world power systems, there are a lot of uncertainties, including modeling errors, random load disturbance, fluctuation from renewable sources, and parameter uncertainties. For this reason, PI load frequency control (LFC) may be built in conjunction with sophisticated control approaches to enhance controller performance. In recent years, the LFC has been designed using a variety of control techniques, including robust control [70], adaptive control, intelligent control [71], optimal control, SMC [72], [73], and adaptive control [71].

The hybrid power system LFC issue is also resolved by the energy storage devices. However, one obstacle to application is the expense and upkeep of batteries [74]. The wind speed's erratic behavior causes external disturbances and model uncertainty to affect the WEGS. The main goals of the suggested work are to address the unknown disruptions that are brought about by the erratic wind speed and to lessen the system's chattering issue, which is the

main drawback of traditional SMC [75].

B. BATTERY ENERGY STORAGE SYSTEM (BESS)

Providing electricity to rural places using renewable energy sources like solar and wind power is the major problem. There must be ways to store this energy because it cannot be produced continuously because the energy supply from renewable sources is sporadic [76], [77].

The power quality of hybrid power production systems that use RES can be enhanced by the BESS adaptable energy management options. To improve power quality or smooth out fluctuations in wind power, a number of control strategies and configurations for hybrid energy storage systems have been proposed. These include a fuel cell/electrolyzer hybrid system [78], [79], [80], a BESS [81], [82], a superconducting magnetic energy system (SMES) [83], a flywheel energy system (FES) [84], an energy capacitor system (ECS) [85], and a fuel cell/electrolyzer hybrid system [79]. The topic of how to even out power variations in solar and wind power generation is one that is receiving a lot of attention and interest these days. While one issue is being resolved, another one has emerged regarding the use of an energy storage device like a BESS.

Battery effort and smoothness level are trade-offs when utilizing BESS to manage PV and wind power variations. That is, some effort can be saved on the batteries provided one is ready to put up with a less smooth output. Although several efficient BESS-based techniques for reducing power fluctuations in renewable energy systems have been put

forth thus far, smoothing targets for grid-connected wind and photovoltaic farms have not typically been developed [81], [86], [87]. For such systems, smoothing control through power fluctuation rate restrictions has hardly ever been addressed. The control algorithms presented in [81], [82], [88], [89], [90], and [91] were primarily developed for small scale BESS-based smoothing; as a result, power distribution across several BESS was not taken into account.

Therefore, a suitable and efficient control method for large-scale BESS is still desperately needed. The size, technology, and particular use of the battery storage system, in addition to regional laws and market circumstances, can all affect the benefits and drawbacks of BESS. When assessing the advantages and restrictions of BESS, it is crucial to carefully take into account the unique conditions and requirements shown in Table 1 [92].

IV. PROPOSED METHODOLOGY

The suggested processes for the hybrid integrated system are shown in Figure 3. The suggested system initially begins reading the hourly necessary load data (LD) to meet its power demand, as well as the average data for solar radiation and wind speed at each time to determine the best design for the hybrid system model. The electricity from wind and sun is then calculated using a simulation model. Simulation based computation of power from both wind and PV has been analyzed. After that if power from wind is obtained then system connect with DC power and total

power can be achieved by adding with power of PV. If $P_1 > P_2$ is obtained system it means that system power depends on one minimum combined power of wind and PV, if it does not happen then system can obtain values using sensors.

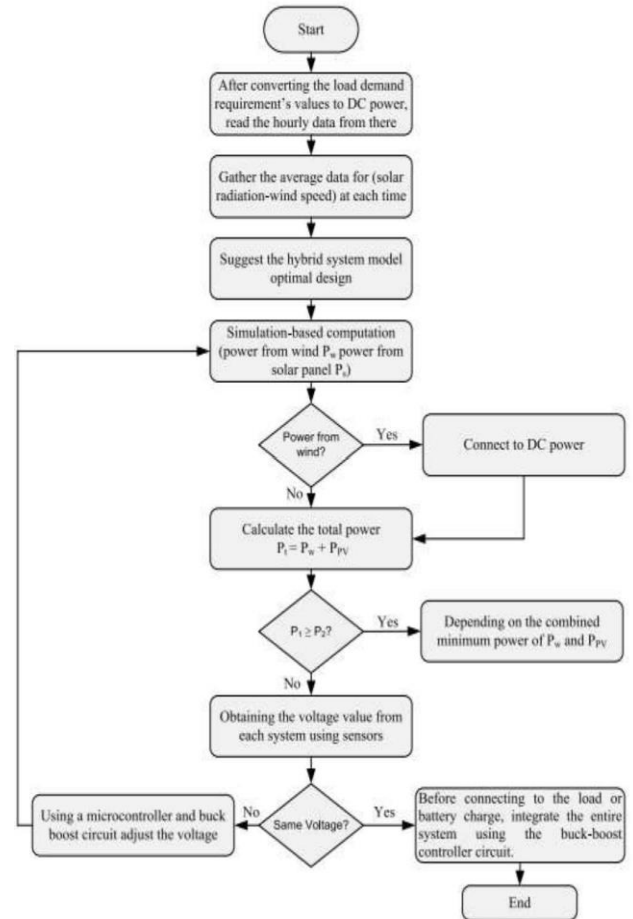


Figure 3 Process

The meticulous examination of simulation based power computation from both wind and photovoltaic (PV) sources stands as a pivotal aspect of this scholarly investigation. In scenarios where wind power alone fails to meet predetermined thresholds, the system seamlessly integrates with DC power, compensating for the shortfall by supplementing with power generated by PV arrays. The critical determinant of system operation is contingent upon

whether the combined power output (P1) surpasses the specified power requirement (P2). This pivotal criterion delineates the system's operational paradigm, mandating the maintenance of a minimum combined power output from both wind and PV sources to ensure seamless functionality. In instances where this requisite condition remains unfulfilled, the system resorts to sensor-based analyses for recalibration, exemplifying its adaptive capacity and robustness in navigating dynamic environmental conditions.

The elucidation of Figure 3 presents a comprehensive visual narrative encapsulating the methodological rigor underlying the assessment of the proposed approach's efficacy. This methodological framework unfolds across several meticulously orchestrated steps, commencing with the system's initiation (Step 1), followed by the judicious evaluation of PV and wind data to align with the exigencies of the load requirements (Step 2). Subsequent stages encompass the design and refinement of a hybrid PV and wind model (Step 3), underpinned by simulation based power computations (Step 4). Should the requisite power threshold from PV and wind be attained, seamless dispatch to the load ensues; however, in cases of non-compliance, iterative computational analyses are conducted to recalibrate the system (Step 5). Upon achieving the requisite power threshold, the system seamlessly integrates with a battery through the comprehensive amalgamation of the entire system, facilitated by a meticulously engineered buck-boost converter (Step 6).

Failure to achieve the specified power threshold instigates a recursive loopback to simulation-based computations for further analysis and refinement, underscoring the iterative nature of system optimization (Step 7). This intricate procedural framework epitomizes the methodological rigor and analytical depth requisite for advancing our understanding of sustainable energy systems and underscores the imperative of integrating cutting-edge technological solutions to address contemporary energy challenges

V. RESULTS AND DISCUSSIONS

The suggested controller's effectiveness was evaluated using MATLAB simulations in which the controller is applied to a Wind and PV system. To validate the performance of the suggested system, it was implemented over the same model as the conventional controller.

A. MODEL OF SOLAR INTEGRATION

On MATLAB SIMULINK a solar model has been created to combine with a wind model to create a hybrid system that is integrated into both units to collect the most energy possible. To explore the PV radiation effect and to adjust in voltage caused by altering the radiation model has been modified to analysis the radiation of PV. Figure 4 and 5 illustrates that the comparative analysis is presented between conventional and proposed methods to validate which method is best to mitigate disturbances in the PV

system.

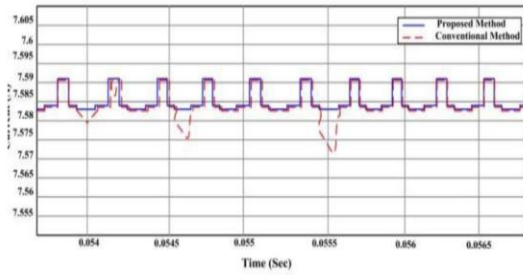


Figure 4 Analysis

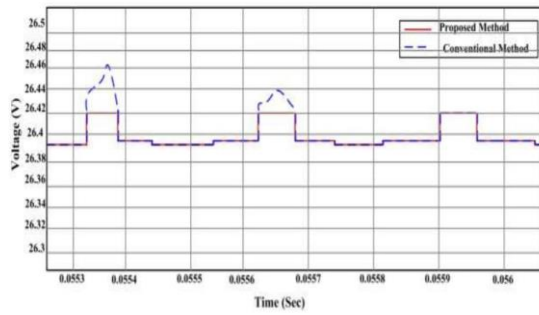


Figure 5 Output Waveform

The disturbance happens in PV due to the solar intensity not being constant and varied from time to another, temperature variations climate changes.

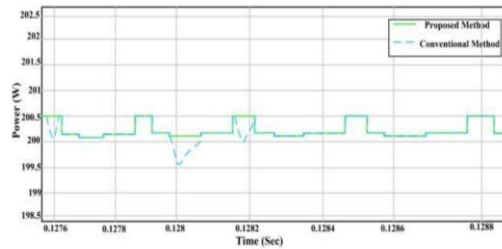


Figure 6 Comparative Analysis

It can be seen that the starting current is fine at 7.58 to 7.584 A after that in conventional method some amount of current falls at different three steps at different time: at step 1, from 7.58 to 7.573 A for 0.053 to 0.056 sec, at step 2, 7.581 to 7.576 A for 0.0546 to 0.0548 sec, and step 3, from 7.58 to 7.56 for the time of 0.0553 to 0.0556 sec, whereas, proposed there is no any such disturbance observed, the estimated method has high

closeness to the actual current form. Figure 6 illustrates that the comparative analysis is presented between proposed and conventional methods to validate which method is best to mitigate disturbances in the PV system.

The disturbance of voltage occurred in PV system due to voltage increasing from 26.42 to 26.46V for the time from 0.05536 to 0.05539 sec at step 1 at step 2 voltages fluctuated from 26.42 to 26.45V from 0.055602 to 0.055605 sec respectively.

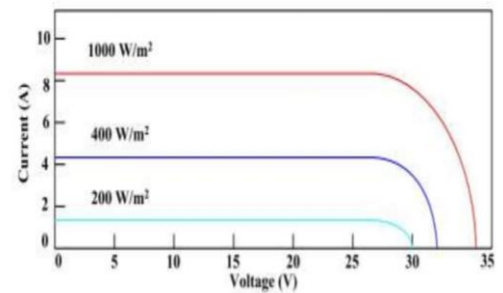


Figure 7 VI Characteristic

Whereas, in the proposed method there are not any fluctuations in voltage, which means that the estimated method has high closeness to the actual voltage. The proposed design has lower deviation indices compared to the conventional design.

The wind power system modeling comprises 500 W, so to replicate the wind power system it must compute the wind turbine performance coefficient $C_p(\lambda\beta)$. The turbine's output power is given in Eq. (3), where $P_m = 500W$; is the air density $1225(kg/m^2)$; A is the area swept (m^2); β is the blade pitch angle, λ is the tip speed ratio, and V_w is the wind speed (m/s). Furthermore a 500 W wind turbine model in MATLAB to

analyze the different wind speed condition wind turbine from 6 m/s to 14.4 m/s.

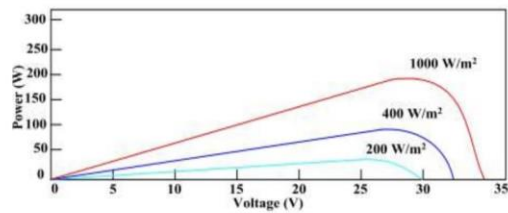


FIGURE 10. VI and PV characteristics of PV at distinct irradiance.

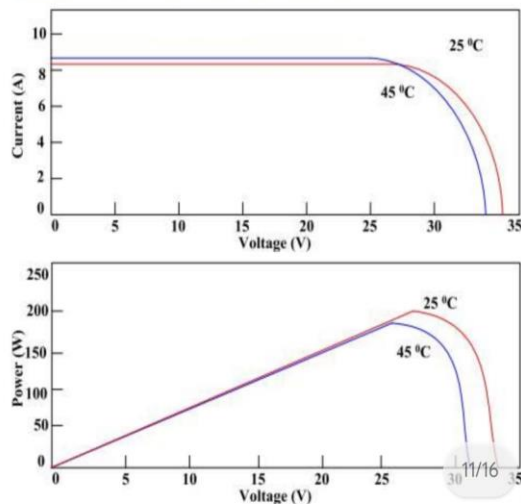


Figure 8 Output Waveforms

The maximum power at wind speed is 12 m/s and beta 00 . At axis shows output power of wind whereas, axis shows the speed of turbine is shown in Figure 8. The simulation wind model in Figure 9 is intended to examine various variables that may have an impact on the wind power (WP) in the suggested integration model. The simulation model's characteristics are the PA is kept steady at 600; the output voltage ripple is reduced using a capacitor; and the output power is obtained data for the proposed turbine's load current and output voltage.

Simulation Based Grid Integration Model of Wind And PV

The hybrid PV-wind energy system is

illustrated in Figure 10 was modeled in MATLAB/Simulink and its responses are illustrated in Figures 11 and 12. The hybrid model is created by combining solar energy and wind energy as two renewable inputs. When there is a power outage, the grid serves as a source of backup power for renewable energy. When renewable energy systems produce too much electricity, the grid also functions as a storage mechanism.

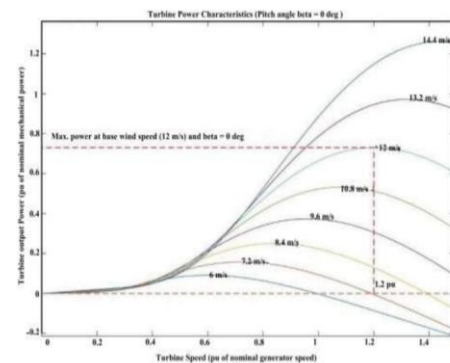


FIGURE 12. Simulation of Wind Turbine at distinct Wind speed.

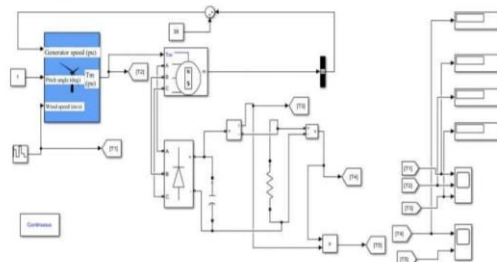
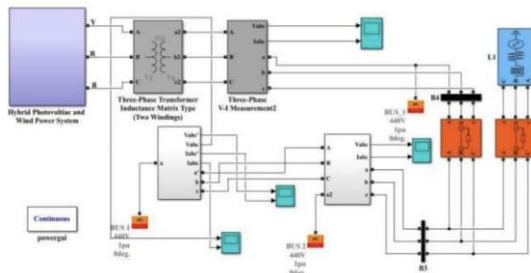


Figure 9 Matlab Model

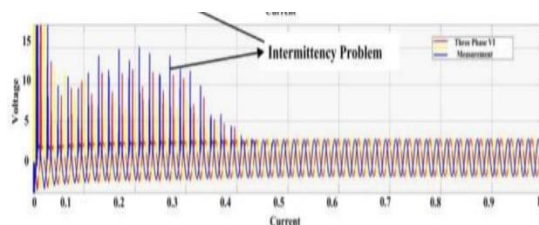
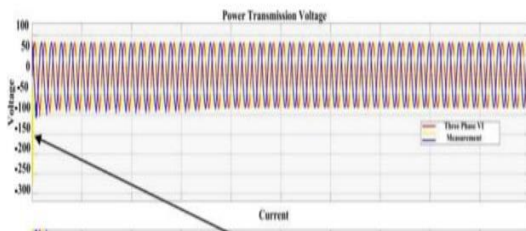
If solar or wind energy is scarce or wind energy or if these sources are unable to supply enough electricity to meet load demands, the grid will automatically meet all the demand. The hybrid source outputs 87.5 W of power, 0–25 V of voltage, and 0–3.5 A of current. By altering cells in series and parallel connections for the necessary energy sources in simulations, these values can be changed. Figure 10 display the 3Ø AC voltages produced by PV and wind. The graphs show the output of the hybrid

15, that when there are some disturbances occur from 0 to 15 at time from 0 to 0.4 it is due to in PV, the solar intensity is not constant and varies from time to another, temperature variations climate changes and in wind, wind speed and the climate changes also may be the sources of intermittency problem. In this condition the conventional controller is not performed satisfactorily. After the application of the proposed method, it can be seen in Figure 16 that intermittency problem is mitigated and smooth response is obtained, there is no further intermittency problem present.



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