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The Study of Solar and Wind Power Systems under Different Weather Conditions

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Abstract. The Hybrid power system integrates a PV station and wind park via an AC-bus to optimize overall attainment. Employing Maximum power point Tracking (MPPT) technology, both in PV systems and wind farms, ensures efficient operation of the hybrid system amid changing environmental conditions. Simulation using Simulink software allows for thorough assessment of the MPPT technology and control strategies in various environmental scenarios, encompassing solar effulgence and wind speed variations. The conceal after effect underscore the persuasiveness of the MPPT knack in maximizing power extirpation from hybrid power systems across diverse environmental conditions. Attaining unity power factor, the hybrid system synchronously injects current into the grid, maintaining phase alignment with the voltage. This control approach ensures grid voltage stability irrespective of external factors or injected electricity from the hybrid system. The solar and wind power system demonstrates commendable performance, leveraging renewable energy sources to produce electricity. While solar panels harness sunlight for electricity generation and wind turbines utilizes wind power, their environmental advantages include miniaturized carbon emissions and receded credence on fossil fuels. Nonetheless, remonstrance arise due to the intermittent nature of these energy sources, heavily reliant on weather conditions. To mitigate such challenges, advanced technologies like energy storage systems play a pivotal role. Continuous monitoring of system efficiency, coupled with advancements in weather forecasting and technical enhancements, is imperative for bolstering reliability and augmenting the contributions of PV and wind power to maintainable energy systems.

1 Introduction

The integration of renewable energy geneses, such as solar systems and wind power, has become a critical priority in the search of sustainable and better energy solutions. This transformation is being pushed by an urgent need to decrease carbon emissions and minimize the effects of aroma difference. In this context, photovoltaic and wind power system performance and analysis are critical to determining their viability, efficiency, and contribution to the overall energy landscape [1]. Photovoltaic systems, also called solar power systems, use sunshine to generate electricity. Solar irradiation, temperature, and system design all have an impact on how these systems work. Solar panels made of transistors turn daylight into direct current (DC) electricity [2].

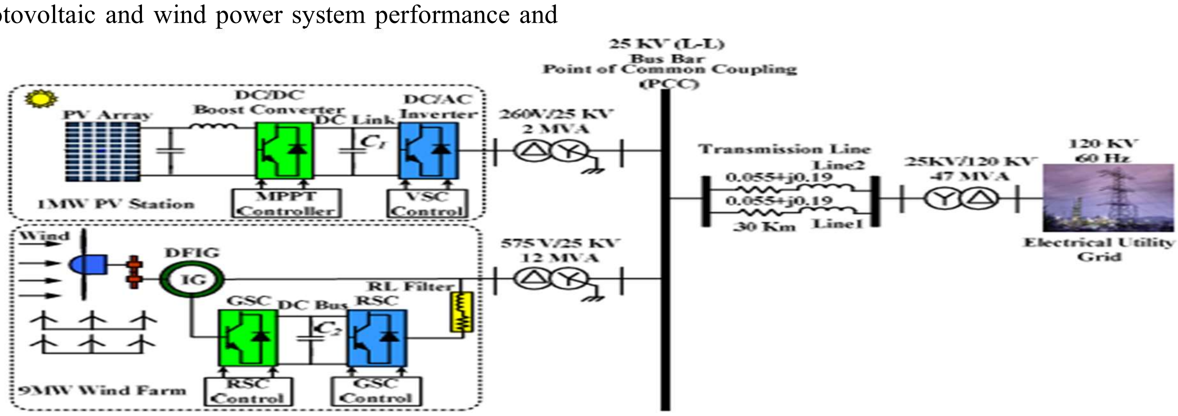

Fig. 1.Solar System and Wind System Model

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Wind power systems on the other hand, employ wind turbines to convert the wind locomotive energy into electrical energy. Wind speed, turbine design, and site selection all have an impact on wind energy system performance. Modern wind turbines are accessible in a variety of sizes and outlines, ranging from modest residential units to massive utility-scale installations. Aerodynamics, materials, and control system advancements have all contributed to improved efficiency and lower maintenance costs for wind power plants .The analysis of the parameters like current voltage power are observed by comparing the both power systems .The algorithms and problems are solved through the results of the system. [3]

2 The Studied Wind/Solar Hybrid Power System

The hybrid power system analyzed here includes of a 1.5 MW solar power plant and a 9 MW wind farm strategically placed in different locations. The coalescence of the PV plant and the wind park through the base bus facilitates the power supply and meliorate the overall system consummation. To achieve the required power, a solar power plant is equipped with many solar modules are electrically connected in parallel. In addition, it has a combined DC/AC inverter to convert DC to AC and a DC-DC boost converter to boost the result voltage of the group [4]. The system uses an MPPT approach with incremental conductivity to optimize energy consumption from fluctuations in solar radiation. The wind farm is expected to operate an equivalent doubly fed induction generator (DFIG) coupled to a significant conjoint cycle wind turbine. To maximize the wind farm's electrical energy harvesting, the wind farm's grid side converter (GSC) maintains a constant DC bus voltage. In addition, a detailed MPPT technology predicated on electrical energy analysis is used to apprehend paramount power during wind speed fluctuations. The transformer facilitates the acquaintance between the wind park and the external grid. Through this transformer and a 30 kilometre long transmission line, the mixed energy system transfers the increased mobile power to the power grid. In particular, the network manages to operate at a uniform power factor. [5].

Table 1. Specialized characteristics of the data acquisition system

Parameters	Voltage Range	Current Range	Power Range
Voltage	0-25V	--	--
Current	--	0-10A	--
Power	--	--	1500W

Table 2. Ratings of the Power system

Parameters	Voltage Range
Solar Power system	1000wm^2
Wind Power System	1500W

Hybrid power systems use several kinds of energy sources to combine affordability and dependability. Reliability is increased by combining traditional sources, like diesel generators, with viable energy sources, like PV and wind, to provide backup power during periods of intermittent renewable energy availability [6]. By minimizing credence on a unique source, this diversification lowers the peril of outages and ensures a steady supply of power. In addition, the reduction in fuel consumption and maintenance needs offsets the original investment expenditures in the long run. All things considered, hybrid systems provide an environmentally friendly way to power a variety of applications, from industrial sites to isolated villages, while balancing price and dependability[7].

Table 3. Reliability and Cost

Specifications	Solar Power System	Wind Power System	Hybrid Power System
Performance	High	High	Low
Cost	High	High	Low
Maintenance	Low	High	Moderate
Flexible	Low	Moderate	High
Land	Less	Less	More

3 Outcomes and Discussions

The study of hybrid power systems that combine wind and solar energy has shown encouraging findings. By utilizing the complementarily of renewable resources, these systems improve the stability and dependability of energy generation. Studies show that integrating solar and wind energy reduces sporadic problems and increases total production and efficiency. The grid's integration of renewable energy is advanced by hybrid setups, which frequently outperform standalone installations in terms of capacity factors. The importance of hybrid solar-wind systems in promoting robust and sustainable energy infrastructures is highlighted by this study.
Hybrid solar-wind systems, which systematically combine two enhancing renewable resources, have shown improved dependability and stability in the generation of power. While wind energy is more reliable

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and can provide energy day or night, solar energy production usually peaks during the day. By combining these two energy sources, the intermittent problems that stand alone solar or wind installations frequently cause are reduced and a more steady and balanced energy supply is produced. Research has demonstrated that the combined output of hybrid systems can produce more reliable and consistent results, which can enhance grid stability and energy management [8].

Optimizing performance and maximizing efficiency has also been made possible by technology developments in hybrid system design, such as enhanced prediction models, hybrid controller algorithms, and integrated batteries. Advanced control techniques. Batteries and pumped hydro storage are instances of energy storage technologies that make it simpler to keep extra energy during high-generation times and release it subsequently during low-generation times, assuring a reliable and consistent power supply.

In terms of economic growth, hybrid solar-wind systems are highly favoured over standalone installations, especially when it comes to affordability and cost-effectiveness. Research has demonstrated that hybrid systems, as opposed to standalone solar or wind farms, can yield lower levelized costs of electricity (LCOE) [9]. This is mainly because of economies of scale, minimized equipment duplication, and optimal use of existing facilities

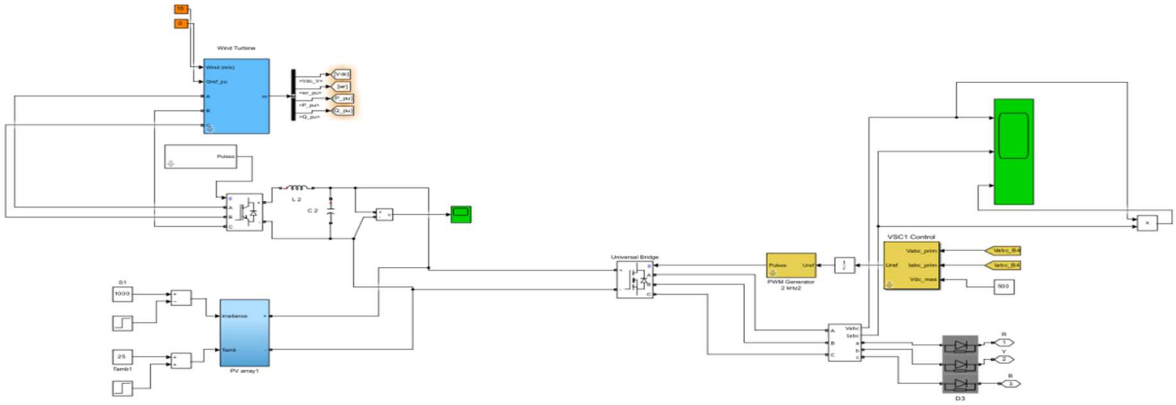

Fig. 2.Simulation Model

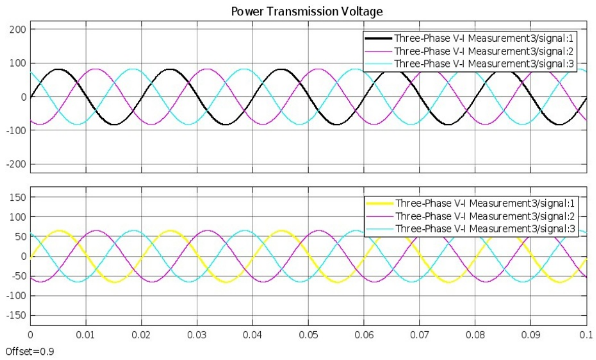

Figure (1): Three Phase v-I measurements of hybrid power system.

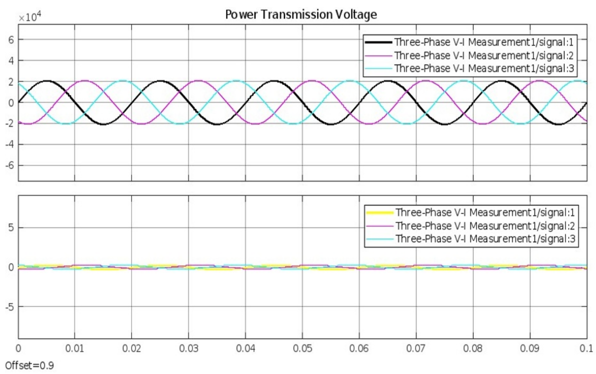

Figure (2): Transmission Voltage.

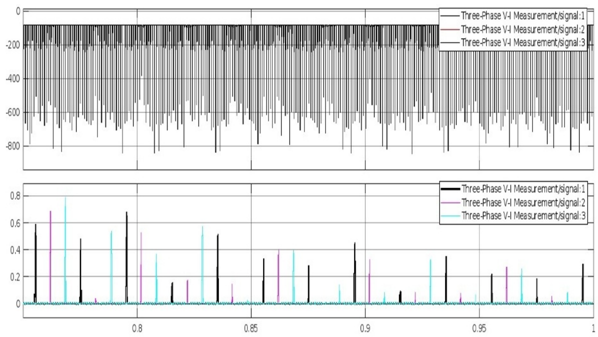

Figure (3): Solar Power.

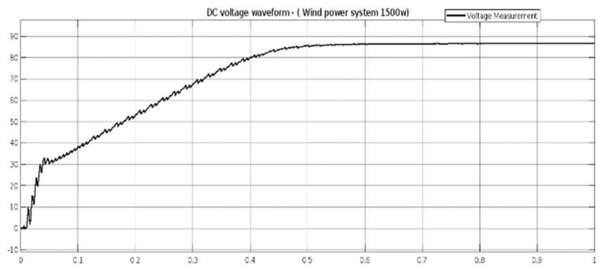

Figure (4): DC voltage wave form at 1500w wind power.

Figure 1 presents the output voltage and current measurement from the hybrid power system and the analysis of this figure we can calculate the some of the problems related to the solar and wind power system figure2 represents the transmission voltage and the figure 3 indicates that the solar power output and figure 4 indicates the dc voltage wave form at 1500w of wind power.

(a). Dynamic Performance of PV station during variation of the solar irradiance.[10]

The subgroup focuses into the solar station's active performance when solar irradiance alters. The surface heat of the photovoltaic array is thought to remain same at 25°C for the entirety of the result. The sunny irradiance variation can be seen. This variation, for example, shows how solar irradiation changes during the day and how a cloud's shadow looks. Proper to excerpt the maximal power from the PV array during deviation in solar irradiation, depicts how the output voltage from the PV array precisely paths the voltage at maximum power. The array output voltage (VPV) is lowered by the MPPT controller from 273.5 V to 254.8 V when the solar irradiation drops from 1000 W/m2 to 250 W/m2The PV array's output current represents the same scenario for variations in solar irradiation. When the solar irradiation distress from 1000 W/m2 to 250 W/m2, the PV array's output current drops from 367.7 A to 87.2 A. The power derivative with regard to voltage is nearly zero (dPpv/dVpv=0), as seen in Fig. 12(d). As a result, when the sun's irradiance varies, the PV array continues to function effectively at its Maximum Power Point (MPP) [11]. Variations in sunlight have an immediate effect on PV station production. The PV modules receive fewer rays of sunlight and produce less power as solar irradiance levels drop because of things like passing clouds or shadowing. On the other hand, as irradiance levels rise, more sunshine reaches the PV modules, and increasing power output. Comprehending these fluctuations is essential for forecasting PV system efficacy and maximizing energy generation. Effective energy management requires an understanding of the dynamic performance of PV stations during variations in solar irradiation. With the use of this data, utilities, companies, and consumers can optimize energy use, put energy storage systems into place, and put demand-side management techniques into practice. To enhance grid stability and reliability, grid operators might include PV system data into their energy scheduling and dispatch methods to sum upwards, the dynamic performance of photovoltaic stations under changes in solar irradiation is a complex subject with consequences for energy management, grid integration, and renewable energy systems

(b) Dynamic Performance of Wind Farm during variation of the Wind Speed [12]

This subsection investigates the active performance of a wind park based on wind speed variations illustrated by a ramp. Specifically, the wind speed increases out of 15 m/s to 9 m/s between t=10 and t=13 seconds. Consequently, the mechanical output of the wind turbine replicates that change, reflecting the change in wind speed. MPPT Controller The cleverly follows the set point when the wind speed decreases from 16 m/s to 8 m/s, resulting in a decrease in mechanical torque of 0.79 p.u. 0.37 p.u, which optimizes the extraction of electricity from the wind turbine. At the eventually, the GSC controller effectively relevance the DC bus voltage at a constant level of 1150 V, as shown in Figure 1.14(c), ensuring stable operation of the wind park during wind speed fluctuations. In particular mobile power supplied by the wind farm changes depending on the change in wind speed. If the wind speed is a maximum of 18 m/s, the supplied kinetic power corresponds to its nominal value. Similarly, the MPPT controller closely follows the reference and adjusts the committed power of the wind farm accordingly when the wind speed decreases. In addition, the wind farm operates efficiently at unity power factor, as evidenced by the maintenance of zero inserted reactive power [13].

With its substantial contribution to the world's electricity output, wind energy has become an essential part of the mix of renewable energy sources. To maximize the efficiency and dependability of wind farms, it is essential to comprehend their dynamic performance, especially in reaction to changes in wind speed. This article examines the dynamic behaviour of wind farms during variations in wind speed and how those variations affect the farms' overall performance. Wind turbines create more electricity as wind speed increases, and at greater wind speeds, they reach their rated capacity [14]. In contrast, turbines generate less power or can even cease to function completely during low wind conditions. It is crucial to correctly forecast and control wind speed variations because of the nonlinear consanguinity between wind speed and power output [15].

4 Conclusions

The challenges of intermittency and variability inherent in renewable energy sources can be successfully solved by hybrid power systems that combine solar and wind energy technology [16]. By integrating wind turbines and solar photovoltaic (PV) in a beneficial way, these systems make use of how complementary solar and wind resources are, which improves overall performance, stability, and dependability. Because of their adaptability, hybrid power systems are suited to a wide range of applications, from utility-scale projects to isolated off-grid sites connected to the grid. Hybrid power systems help reduce greenhouse gas emissions, mitigate climate change, and advance sustainable development goals by utilizing the plentiful and freely available energy from the sun and wind. The capacity of hybrid power systems to provide a more steady and reliable power supply in contrast to autonomous solar or wind installations is one of its main advantages. Hybrid systems are able to reduce oscillations in energy generation and enhance overall system stability by combining two renewable energy sources with unique temporal and spatial properties. Wind turbines can continue to produce electricity during times of low solar irradiation, and vice versa, safeguarding a more steady supply of electricity [17]. Applications that need constant electricity, such distant communities, telecom infrastructure, and vital facilities like hospitals and data centres, will benefit most from this increased reliability. Hybrid power systems are more cost-effective and produce more energy, which is beneficial to the economy. These systems may exceed standalone solar or wind installations in terms of capacity factors and energy yields by diversifying the renewable energy mix.

By combining solar and wind energy, projects can make better use of the land and infrastructure that is already available, saving money overall. Furthermore, the levelized cost of electricity (also known as for hybrid projects is decreasing due to developments in control algorithms, energy management technologies, and hybrid system design, making hybrid power plants more competitive with traditional fossil fuel-based generation. The results of the simulations demonstrate the success of the MPPT addresses to excerpt the highest power from the hybrid power system when the surroundings Moreover, because the reactive power supplied from the hybrid power system equals zero, the hybrid power system runs prosperous at unity power factor.

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