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Design and Implementation of PMUBased Two Area System for Enhanced Power System Stability

Sufia Khanam, Dr. K. Kalyan Raj, S. Prashanth Raju, V. Bhavani, R. Sai Santhosh
**(Department of Electrical and Electronics Engineering, Seshadri Rao Gudlavalleru Engineering College, Krishna.)*

Abstract:
In this paper, the investigating and comparing the performance of a Solar PV-Wind system based two area system with Phasor Measurement Unit (PMU) to that of a machine-based two area system is implemented. The Solar PV-Wind system includes solar PV and wind as renewable energy sources, while the machine-based system relies on conventional sources of energy. The PMUs are used to monitor and control the Solar PV-Wind system, providing real-time data that helps improve the stability and reliability of the system. The study compares the performance and efficiency of the two systems using simulation studies. The results of the study show that the Solar PV-Wind system with PMU outperforms the machine-based system in terms of environmental impact, efficiency, and reliability. The use of renewable energy sources like solar PV and wind contributes to reducing carbon emissions and promotes sustainability.The project provides valuable insights into the benefits of using renewable energy sources and advanced control systems in power system planning and design. The findings of the study can be used to guide future research in the development of sustainable and resilient power systems.MATLAB/Simulink 2018a Software can be employed to evaluate the system's performance.

Keywords: Boost Converter, DC-AC Converter, Solar PV, Wind Turbine, Phasor Measurement Unit.

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I. INTRODUCTION:

Effective monitoring and management of power grids can prevent significant issues such as blackouts and load shedding in the contemporary era. Utilizing Phasor Measurement Units (PMUs) for proper grid monitoring and control is one way to address this problem. Data can be transmitted across the network by measuring important parameters with PMUs, which improves fault detection and enables self-healing with state estimation. Obtaining synchronized data from the power grid is crucial to achieving an even distribution of power over a sizable area. To keep track of the condition of the electrical network, PMUs are typically installed throughout the transmission side of the grid.In order to guarantee precise and consistent measurements, these PMUs are frequently incorporated into a network known as the wide-Area Monitoring System (WAMS) and synchronized using GPS. Information such as monitoring switch status, circuit breaker status, equipment performance, traffic, outages, and demand response events are all available through the phasor parameters that PMUs provide. To support better decision-making for a reliable and high-quality power supply at reasonable prices, a variety of methods are available to determine phasor parameters [1]-[3]. The development of the Symmetrical Component Distance Relay (SCDR) in the early 1970s is where the modern phasor measurement systems got their start. Microcomputer technology at the time was not developed enough to handle the demands of a distance relay algorithm. In order to combine the six fault equations of a three-phase transmission line into a single equation using symmetrical components, the SCDR was developed. It does this by using the symmetrical components of voltages and currents.The effective techniques for measuring symmetrical components of voltages and currents used by the SCDR turned out to be useful for other applications, even though microcomputers eventually became powerful enough to handle the distance relay algorithm. In fact, positive sequence voltages and currents in a network serve as the foundation for the majority of power system analysis program, including load flow, stability, short circuit, optimum power flow, state estimation, contingency analysis, and others [4]–[6]. Precise phasor measurement in the distribution grid is made possible by the deployment of dedicated PMUs or by using the phasor measurement capability of protective relays.In order to facilitate monitoring, control, energy management, and protection strategies that are more appropriate for the current situation, this recently acquired dynamic system snapshot can be integrated into the distribution management system (DMS) [7]–[9]. Power systems have long used coherency grouping to develop reduced order models, allowing the breakdown of large models into more manageable, equivalent systems that are smaller and simpler. When dealing with many scenarios, this method simplifies the analysis of the power system and the computational effort.Studies on transient stability have used coherency analysis of generators, as well as other applications like oscillation detection, vulnerability analysis, and fault event location. In order to determine voltage stability, coherency grouping methods for reduced order models, transient stability studies, oscillation detection, and vulnerability assessment may not be useful because the series of events that cause oscillation in the power system or transient instability differ from those that cause voltage instability. The main variables in transient stability studies, oscillation detection, vulnerability assessment, and related applications [10]–[17] also involve generator speed, rotor angles, or other swing-related variables.To expedite line restoration, shorten outage times, and avoid the emergence of unstable states in power systems, power utilities must employ fault location techniques on transmission lines. The location of transmission line faults has been addressed by a number of algorithms developed in recent years. There are three primary fault location techniques, which include: (1) travelling wave methods that involve analyzing travelling waves generated by the fault; (2) intelligent computational techniques that rely on qualitative human knowledge modeling; and (3) fundamental impedance-based techniques. Although travelling-wave methods offer several benefits such as resistance to current transformer saturation and insensitivity to power system parameters and fault conditions, they also have a few significant drawbacks. These include the requirement for a high sampling rate and the inability to differentiate between a travelling wave emanating from the fault and one reflected from a remote end.Care must also be taken to take into account the mother wavelet selection and the presence of noise. However, these methods call for the installation of a large number of PMUs at different locations in the feeder, including both ends and the centre of the distribution system. This results in a rise in communication costs and infrastructure expenses associated with PMU installation. As a result, power companies may face challenges in managing their networks. Furthermore, the approach presented, fails to account for unbalanced faults and the influence of DERs. Consequently, it is imperative to develop fault location estimation methods that rely on a minimal number of PMUs and can address the challenges posed by DERs[25]-[26].Therefore, in order to overcome these issues, this paper proposes a Phasor measurement Unit based renewable energy two area system protection and stability analysis. Section-1 depicts the introduction and literature of the work, section-2 depicts system configuration, section-3 explains the proposed topology whereas section-4 depicts the results and discussion and section-5 ends with concluding the proposed work.

II. SYSTEM DESCRIPTION:

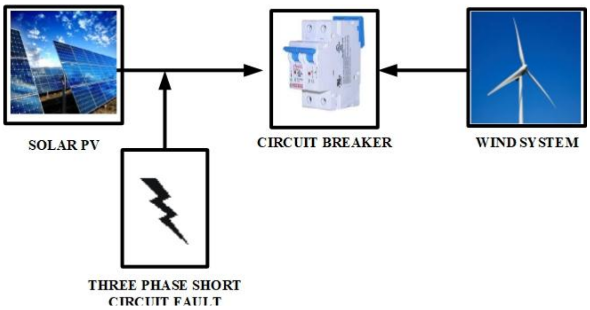

Figure 1: Block Diagram of the proposed system

The above figure will depict about the block diagram of the proposed system. It mainly consists of 2-areas. The generated power is supplied to the respected areas through the transmission lines. Two sources namely Solar PV and WIND are considered. The voltage and currents of respected parameters are measured by using Phasor Measurement Unit. This related description is explained below.

1. SOLAR PV SYSTEM

In this system, solar panels convert sunlight into electrical energy, which is then sent to the load for immediate use. The solar PV system consists of solar panels, a boost converter, and an inverter. T The inverter converts the DC power generated by the solar panels into AC power that can be used by the load. When the solar panels generate more power than the load needs, the excess energy is not stored and is typically lost. On the other hand, if the load requires more power than the solar panels can provide, the system will draw power from other sources such as the grid or a backup generator.

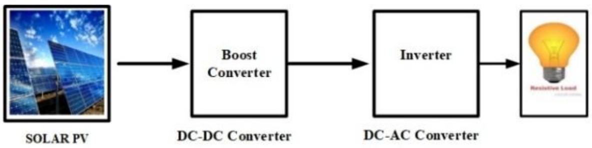

Figure 2: Schematic representation of Solar PV System

This system is frequently utilized in distant regions where grid access is unavailable or in circumstances where the expense of linking to the grid is prohibitively expensive. It is also suitable for applications where power demand is low and can be met by the solar panels' output. The below figure-2 depicts the schematic representation of solar PV system.

2. WIND POWER GENERATION

An apparatus that harnesses wind power and utilizes a doubly fed induction generator (DFIG) system transforms the mechanical energy of wind into electrical energy. The DFIG system features a power converter that links the three-phase windings on the stator with the three-phase winding on the rotor.The power converter allows the rotor winding to be connected to the grid through a variable frequency drive, which enables control of the generator speed and reactive power.The DFIG system has several advantages over other types of wind turbine systems, including better control of the output power, improved efficiency, and lower maintenance costs. It also allows the wind turbine to operate at variable speeds, which can help to optimize energy production in different wind conditions.However, the DFIG system also has some disadvantages, including the need for additional control equipment, such as the power converter, which can increase the overall cost of the system. Additionally, the DFIG system can be less reliable than other types of wind turbine systems, particularly in harsh weather conditions.Overall, wind turbines with DFIG systems are a popular choice for wind power generation due to their flexibility and efficiency, but they also require careful design and maintenance to ensure reliable and cost-effective operation.

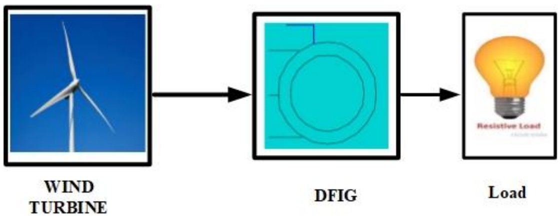

Figure 3: Schematic representation of Wind System

The above figure-3 describes the schematic representation of the proposed system of wind system.

3. Phasor Measurement Unit

A Phasor Measurement Unit (PMU) is a tool employed in the realm of monitoring and regulating power systems.It is used to measure the electrical parameters of an alternating current (AC) power system, such as voltage, current, frequency, and phase angle, at a specific point in the system. PMUs are commonly used in power systems to monitor the state of the system in real-time and provide accurate and synchronized data to the control center.PMUs measure the phasor or the complex sinusoidal representation of the AC signal, which consists of the amplitude and phase angle. The PMU converts the measured analog signal into a digital signal, which is then transmitted to the control center through a communication network. The data from multiple PMUs can be synchronized using a common time reference, which allows for accurate measurement of the power system's dynamic behavior, including power flow, oscillations, and transient events.PMUs are an essential component of modern power system control and protection systems. They are used for applications such as wide-area monitoring, system stability analysis, fault detection and location, and control of power system equipment. PMUs are also employed in renewable energy systems, where they can enhance the management and sizing of the power grid's incorporation of renewable energy sources.

4. ASYMMETRICAL FAULTS

A three-phase asymmetrical fault is a type of fault in an electrical power system that involves an unequal or unbalanced distribution of fault current among the three phases of the system. Three-phase asymmetrical faults can occur due to various reasons, such as insulation failure, lightning strikes, or accidental damage to power lines.

In a three-phase asymmetrical fault, the fault current in each phase of the power system is different, which can cause voltage imbalances, phase shifts, and other disturbances in the system. The severity and duration of the fault depend on factors such as the fault location, fault impedance, and the protective devices installed in the system.

Three-phase asymmetrical faults can take many different forms, including:

1. Line-to-Line fault: When two power system phases are short-circuited together, a fault of this type develops. Line-to-line faults can result in significant voltage and phase shifts within the system, as well as high fault currents.

2. Line-to-Ground fault: When one phase of the power system is shorted to ground, a fault of this type occurs. In addition to seriously harming the system, line-to-ground faults can cause voltage drops and power supply flickering.
3. Double Line-to-Ground fault: When two power system phases are shorted to ground, this kind of fault happens. Voltage imbalances and phase shifts can result from double Line-to-Ground faults, which can also seriously harm the system.To protect the power system from three-phase asymmetrical faults, protective devices such as circuit breakers, fuses, and relays are installed in the system.

In this work, three phase asymmetrical LLLG fault is injected into the system to evaluate the performance of the respected areas with getting affected of the grid systems.

III. PROPOSED SYSTEM:

The combination of solar PV and wind energy systems has become increasingly popular in recent years, as it provides a more reliable and efficient energy source compared to relying on just one type of renewable energy. In this context, implementing a PMU based two area system can help enhance the stability of the overall power system. The system can be modeled as two interconnected areas, with each area consisting of solar PV and wind power sources, along with other components such as inverters, transformers, and transmission lines. The system can incorporate Phasor Measurement Units (PMUs) to measure the voltage and current phasors at various locations throughout the power network. The PMU data can be used to monitor the system in real-time and find any potential faults or disturbances.A control system can be designed to manage the operation of the solar PV-wind system. The control system can include various components such as power converters, inverters, and energy storage systems. The control system can also use the PMU data to adjust the operation of the system to maintain stability.

IV. SIMULATION BASED RESULTS:

This section shows the system's suggested simulation-based results. A two-area generator-based existing system is compared to the performance of the two renewable energy-based systems in the proposed method. These outcomes are evaluated using MATLAB/Simulink 2018a software.

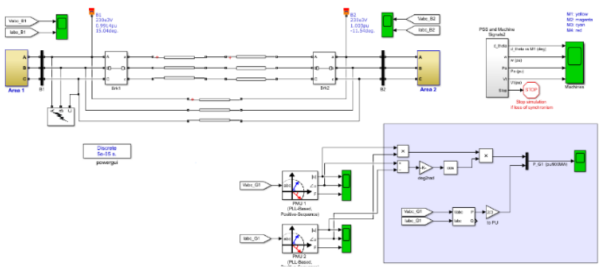

Figure 4: Simulink Model of Proposed System

The above figure depicts the Simulink model of the machine based two area system. The simulation aims to evaluate the effectiveness of the proposed PMU-based two area system in enhancing power system stability. The simulation assumes a two-area power system, where each area is modeled as a generator with a governor, excitation system, and automatic voltage regulator (AVR). The simulation also considers the presence of disturbances, such as load changes and fault events.

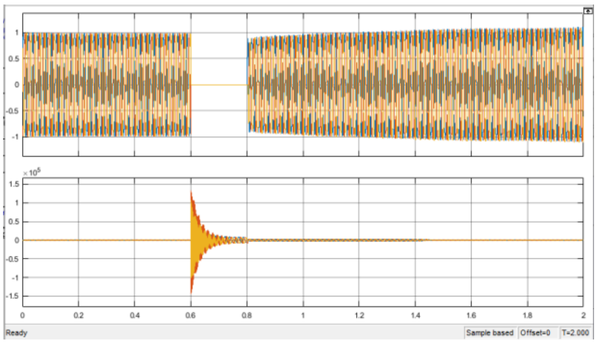

Figure 5: AREA-1 related Voltage and Current

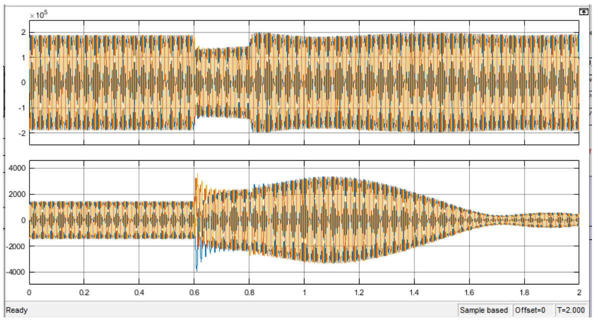

Figure 6: AREA-2 related Voltage and Current

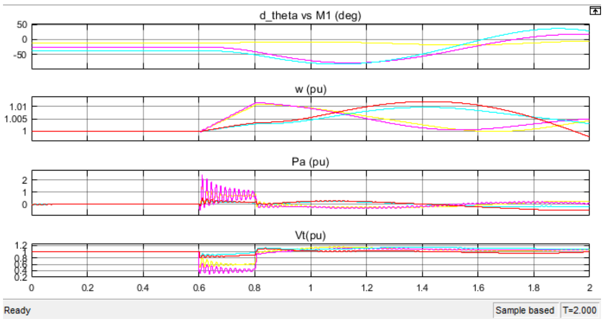

Figure 7: PSS and MachineSignals2

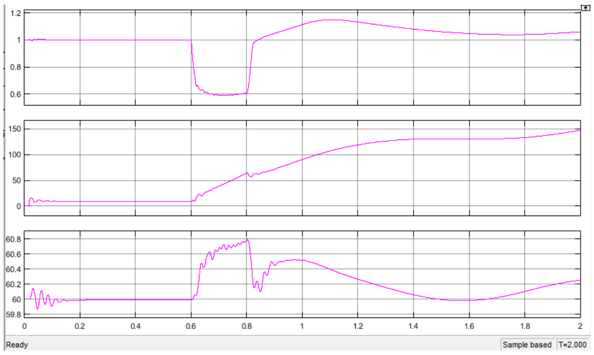

Figure 8: (PLL-Based,Positive-Sequence) of Vabc

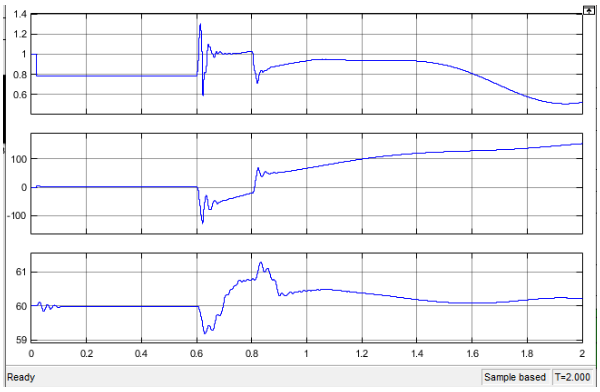

Figure 9: (PLL-Based,Positive-Sequence) of Iabc
a)

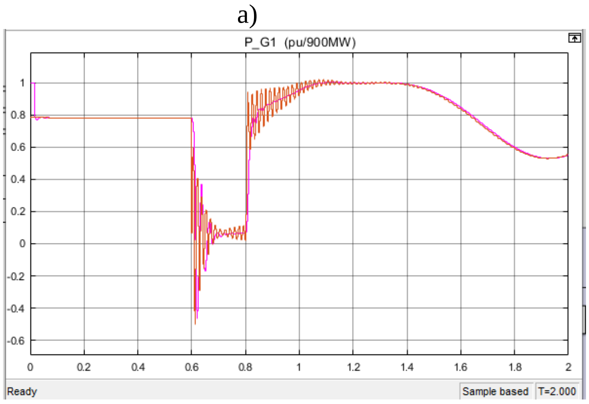

Figure 10: P_G1 (pu/900MW)

The above figure depicts the simulation results obtained by employing machines-basedgrid system. At 0.6s to 0.8s, the fault has been injected. Initially the circuit breaker is in closed position whenever the fault is occurred, then circuit breaker will gets opened, so that the effect of fault will not fall on the respected area systems. The voltages, current and active power of the area system is depicted above. PMU is used to measure the positive, negative sequence of the frequency in the area-1. The effect of fault will also falls on the grid system. So, that their respective signals will also changes the amplitudes of the specified parameters. The values obtained is mentioned in the below comparison table-1.

CASE-2 WITH PMU BASED SOLAR PV-WIND SYSTEM:

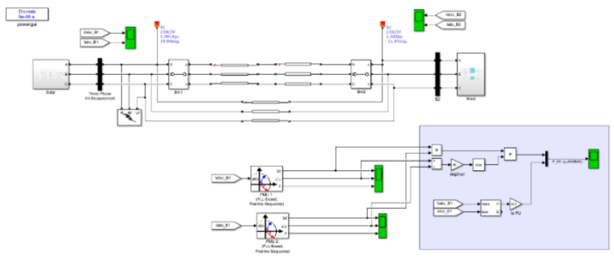

Figure 11: Simulink Model of RES based 2-Area System

Incorporating solar and wind energy will boost the system's overall power generation capacity, assisting in meeting the rising demand for electricity. The system may have energy storage components, such as batteries or pumped hydro storage, to store extra energy produced by the solar and wind sources during periods of peak output.The accumulated energy can subsequently be utilized to fulfill the demand when renewable energy production is low. The incorporation of renewable energy sources may result in voltage fluctuations that can trigger instability within the system. However, the PMUs can monitor and control the voltage levels in real-time, ensuring that the system remains stable. The integration of renewable energy sources can also cause fluctuations in the frequency of the system. PMUs can monitor and control the frequency levels in real-time, ensuring that the system remains stable.PMUs can also monitor the power flow within the system and adjust it in real-time to maintain a balance between the power generation and demand.

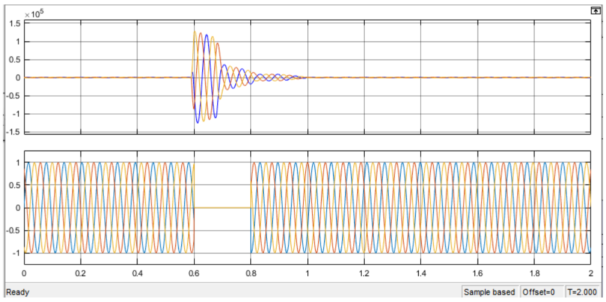

Figure 12: Solar Area related Voltage and Current

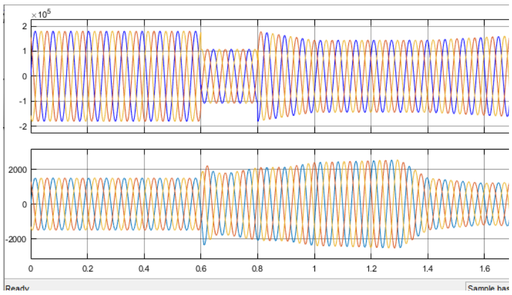

Figure 13: Wind Area related Voltage and Current

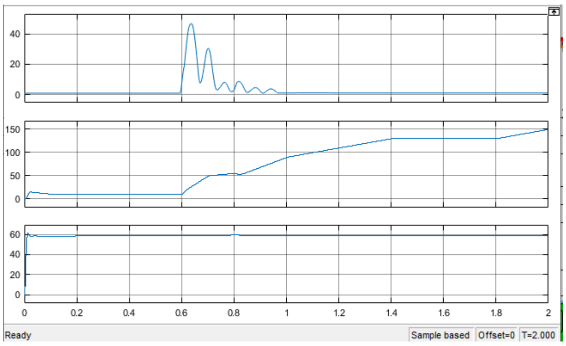

Figure 14: (PLL-Based,Positive-Sequence) atVabc_B1

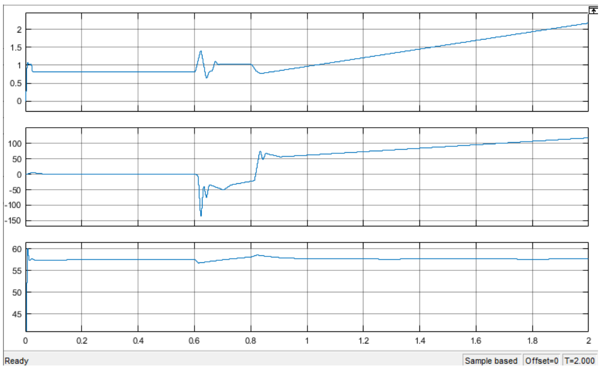

Figure 15: (PLL-Based,Positive-Sequence) at Iabc_B1

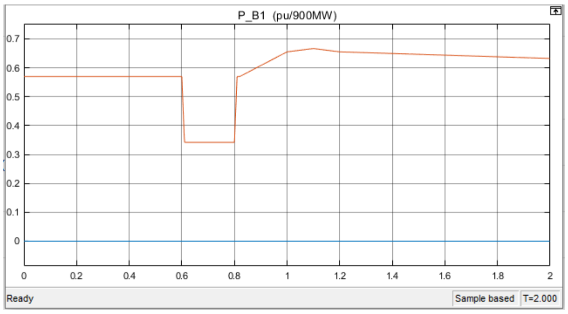

Figure 16: Active and Reactive power of the system

The above figure depicts the simulation results obtained by employing the renewable energy based two area system. At 0.6s to 0.8s, the fault has been injected. Initially the circuit breaker is in closed position whenever the fault is occurred, then circuit breaker will gets opened, so that the effect of fault will not fall on the solar PV and wind system. The voltages, current and active power of the area system is depicted above. PMU is used to measure the positive, negative sequence of the frequency in the solar area. The valuesobtained is mentioned in the below comparison table-1

TABLE 1: Comparison Table of Conventional and proposed method

Parameter	Grid Connected System		Renewable energy-based System	
	AREA-1	AREA-2	SOLAR	WIND
Input Voltage	20000V	20000V	100V, Vdc=1500V	250V
Current	1A	1.8e5A	1A	1.8e5A
Output Voltage	1500V	1490V	1500V	1490V
Reactive power	900MW		900MW	

The above table describes the comparison of the conventional and proposed system. The discontinuity in the supply of the system will leads to the less power transmission. In order to overcome these issues, the area-1 and area-2 is replaced with renewable energy systems like solar and wind. The same values are evaluated but the only difference here is continuous power generation is possible.

V. CONCLUSION:

In this work, the Solar PV-Wind system based two area system with Phasor Measurement Unit (PMU) is a more advanced and efficient system compared to the machine based two area system. The former system takes a step towards sustainability and the reduction of carbon emissions by using renewable energy sources like solar PV and wind. The use of PMUs for system monitoring and control also provides real-time data and contributes to the system's increased stability and dependability.In contrast, the machine-based two area system relies solely on conventional power sources and does not incorporate modern technologies like PMUs, which limits its performance and efficiency. While machine-based systems may still have a place in the current energy landscape, it is clear that a transition towards renewable energy and advanced control systems is necessary to ensure a sustainable and resilient energy future.Overall, the Solar PV-Wind system based two area system with PMU is a promising approach for future power system planning and design, as it offers significant advantages over conventional systems in terms of environmental impact, efficiency, and reliability.

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