Integration of Electrical Power Systems based on Renewable Energy Systems

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ABSTRACT

The increasing need for energy in the modern world cannot be met solely by conventional energy resources. One essential component of a technological revolution is electricity. Fossil fuel combustion currently provides the majority of the world's electrical needs but at the expense of damaging the environment. Nonconventional and environmentally friendly methods of producing power are taken into consideration to close the gap between supply and demand for electricity. Renewable energy systems (RESs) offer an adequate option to reduce the issues developed owing to greenhouse gasses. The main difficulties in power system dynamics, regulation, and automation brought about by the incorporation of renewable power plants are discussed in this paper. The primary areas of research going ahead will be distributed production power plant integration issues and control of electrical distribution networks. This paper addresses these subjects as well. This study examines the automation-related potential and constraints associated with incorporating a larger proportion and penetration of renewable energy as part of the grid modernization goal.

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1. INTRODUCTION

Numerous components, both controllable and non-controllable, that perform different functions make up hundreds of thousands of power systems. To maintain the power supply, this intricate operation necessitates excellent automation. Currently, available power systems have the maximum level of automation at the transmission and distribution systems, respectively, represented by the energy management system (EMS) and distribution management system (DMS) [1]. In addition to several real-time and offline power system applications, these automation systems also comprise the supervisory control and data collecting systems. The installation of renewable energy sources, such as solar and wind has grown in popularity in recent years as a result of environmental concerns and global changes in petrol and oil prices.

Depending on their generation capacity, these power plants may be incorporated into the transmission and distribution networks of the power systems. Through the transmission system, large-scale wind and solar power plants with a capacity ranging from hundreds to thousands of megawatts are interconnected. Concerns regarding the dynamics, oversight, and automation of power systems have increased due to the unstable and changeable nature of the electrical power generated by renewable power plants as well as the topological modifications they force upon the system. The primary driving force behind this study's discussion of the opportunities and difficulties in these areas that are troubling is this.

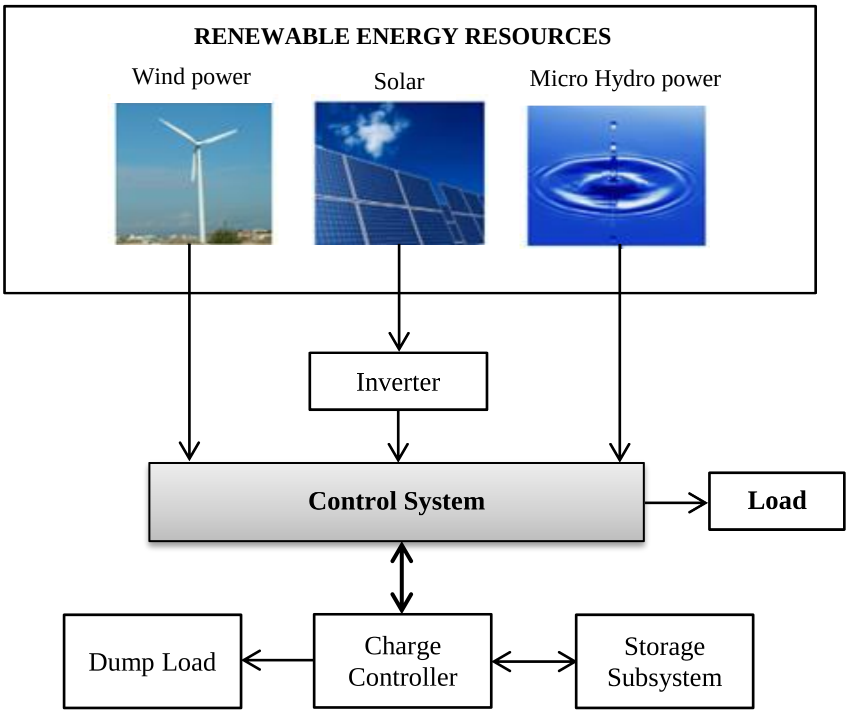

Figure 1.1. Diagram of the Integrated Wind, Solar, and MHP Combination

When renewable energy sources are combined, IRES can combine benefits like energy conservation and efficiency. When diverse renewable energy sources are used in concert, the need for energy storage is reduced and power supply reliability and quality are raised. To control the stochastic behavior of renewable energy resources like solar and wind, these systems are invariably integrated with storage devices for independent uses. A wind-solar-MHPH integrated system is depicted in Figure 1.1. In 2012, the final energy consumption in the world came from renewable sources to the tune of 16%. Traditional biomass, mostly used for heating, accounted for 10% of the total, while hydroelectricity contributed 3.4%. Small hydro, contemporary biomass, solar, geothermal, wind power, and biofuels are among the new renewable sources that contributed 2.8% and are expanding at a very quick pace. About 19% of electricity is generated by renewable sources [2], with hydroelectricity accounting for 16% of global electricity production and new renewables for 3%. However, the vast majority of nations worldwide do not have RESs as a significant component of their energy mix. As a result, governments have begun offering incentives to businesses interested in putting money into RES electricity generation, which typically uses solar and wind energy.

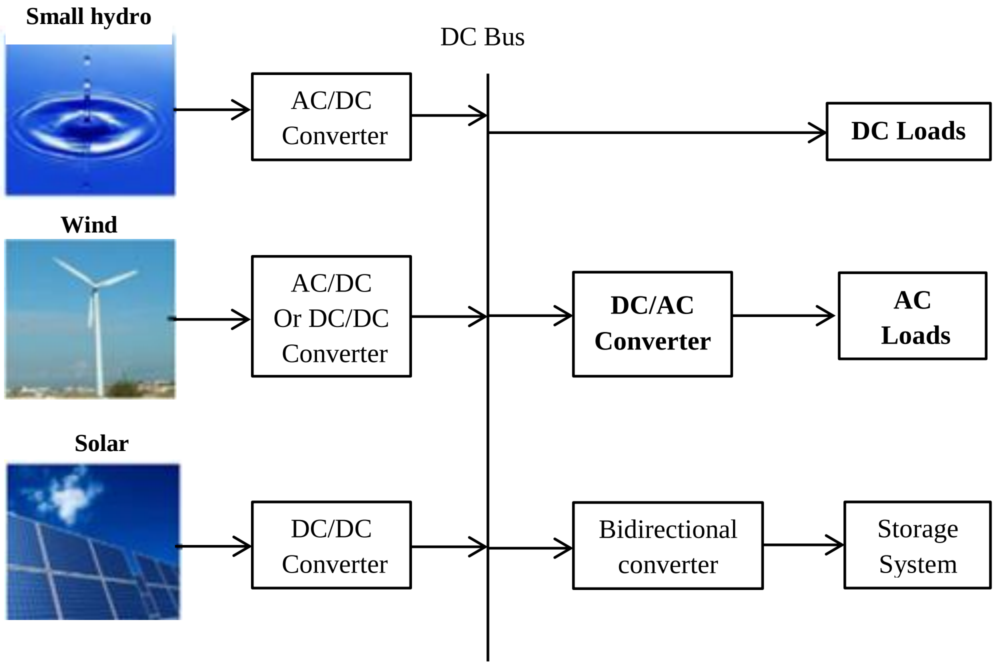

Figure 1.2 DC Linked Design of a Tiny Integrated Hydro-Wind-Solar Combination

All renewable energy sources are linked to the single DC bus in this setup via appropriate power electronics interface circuits. Direct connections to DC buses are made by energy sources that generate DC electricity. To keep the user's DC voltage level consistent, DC/DC converters service DC loads from the DC bus. By using an inverter, this setup can also provide power to AC loads. Since synchronization is not necessary to combine several energy sources [3], DC-linked schemes are straightforward. Under this plan, the entire system will not be able to supply electricity to the AC load if the inverter fails. Several modest rating synchronized inverters connected in tandem to provide AC power could solve this issue. Figure 1.2 shows a modest hydro-wind-solar integrated structure with a DC-connected arrangement.

This paper provides a thorough analysis of several topics about IRES in stand-alone mode, including integration configurations, storage choices, sizing techniques, and IRES system control. Section 2 provides a variety of integration setups for incorporating renewable energy sources. The storage technology possibilities for integrated systems are covered in Section 3. Section 4 provides a mathematical model for converting renewable energy sources into usable energy. Section 5 presents the discussions and results of the IRES review effort.

2. LITERATURE REVIEW

Shahid, A. et.al [4] Using traditional transmission lines, the primary grid, which is a sizable generator equipped with an excitation system and a secondary control, functions as the major utility providing power. Conversely, electric power converters link dispersed generators (RESs) to the grid via interfaces that can be static or dynamically coupled. This hybrid and distributed power source design, in combination, is a highly efficient way to control several dynamic electrical characteristics. The system can be configured to solely employ the most cost-effective power sources, or it can combine efficiency and dependability in ways that are specific to the load demand, dumping extra power into the storage units.

Egeland-Eriksen, T., et.al [5] By 2040, the IEA predicts that about one-third of the world's electricity will come from sporadic renewable energy sources like solar and wind. This will necessitate finding ways to store electricity on a massive scale for an extended period. One potential technology is hydrogen generation and storage. Hydrogen can be stored in a variety of ways for later use. Thus far, compressed gas has been the most often used approach. Storing it as a liquid at extremely low temperatures is an additional technique. Other methods for storing hydrogen include chemisorption with metal hydrides or physical adhesion on a solid material's surface, known as physisorption.

Holjevac, N., et.al [6] In addition to modeling the production of power, it is crucial to identify specifics related to electricity consumption. The majority of Croatia's electricity-intensive industries are found close to the country's sizable thermal power facilities in the country's north. In contrast, Croatia's coastal region is less industrialized, with tourism serving as the primary driver of development. Due to the seasonal nature of tourism, which results in exceptionally high summer electricity demand and relatively low winter electricity consumption, this hurts the Croatian power system. Peak demand during summertime is many times greater than that during the winter. Each season's distinctive power flow direction is impacted by this seasonality.

Akhtar, I., et.al [7] The inclusion of renewable energy sources gives the load distributor more operational flexibility. It is possible to modify the bidirectional flow of power in a hybrid energy system that is connected to the grid and the variable generation of renewable electricity by exploiting the flexible properties of renewable energy sources. There are fewer network problems when a grid-connected hybrid energy system is operating. Renewable energy sources are a source of supply that the utility grid can give and take. The opposite direction power, or power from both the external grid and renewable energy resources, can be used to power various loads in this operating mode.

Paiva, J. E., et.al [8] A controlled electrical consumption in a generation system with stochastic sources is the primary goal of the current setup. The system must be able to supply a predetermined constant power with fluctuating wind and sun power and use a storage unit to balance out any excess or deficiency in power from renewable sources. A DC bus serves as the link between these three components. DCeDC converters are responsible for power control. In addition to providing control references for the various converters' operations, a central supervisor gathers the voltage and current required to evaluate the various elements' operational states. Individual control algorithm developers work with the supervisor to define the converters' control signals.

Kumar, S., et.al [9] The erratic properties of renewable energy sources must be taken into account in EPSs. Why analysis of uncertainty parameters is necessary is also mentioned. Possibilistic and probabilistic handling techniques are necessary for "uncertainty," which causes the system to become unreliable. Fuzzy arithmetic is utilized in the Possibilistic Approach to solve problems with unknown parameters represented by fuzzy membership functions. The modeling of uncertain characteristics in a probabilistic approach is carried out using probability density functions (PDFs), which are further evaluated using the MCS and point estimation techniques.

Panda, A., et.al [10] Despite the widespread acceptance of the benefits of EES installations for power system operations, there are still some significant obstacles associated with their deployment. These include the following: (1) choosing the best type of storage facility for a power system network (small, medium, large, or hybrid); (2) analyzing the techno-economic operational aspects of preservation integration; (3) comparing the achievement of various storage-integrated hybrid power networks; and (4) providing a state-of-the-art survey that takes into account the use of small to large scale EES on various power structure applications.

3. METHODS AND MATERIALS

3.1 Problems and fixes for integrating VRE

High degrees of VRE integration into electric power systems provide several difficulties. A variety of potential solutions will be reviewed along with a discussion of some of those difficulties with an emphasis on operational issues in this part. The answers are always location- and system-specific, and they might or might not work in particular circumstances.

The variability of the supply and how to compensate for it across several periods are the primary VRE attributes that need to be addressed. There are several technical options to build more adaptable grids that can support higher amounts of VRE because VRE is not dispatchable. It explains several integration choices and how they might increase power systems' VRE.

3.1.1 Variable resource variety in geography

Comprehending the advantages of spatial diversity in changeable resources is crucial. The system-wide variability decreases noticeably as you extend the VRE over a region. Several researchers have looked into how to lower the overall variability of the system for both solar and wind power [11]. Only as the scale of the interconnected system grows is this feasible, even some tiny institutions might not have the resources to increase the geographic diversity within their network. The fact that wind and sun energy are frequently complementary to one another depending on location is another intriguing aspect of diversity. These might be seasonal as well as daily additions.

3.1.2 Forecasting of Renewable Energy

Operating ultra-high renewable systems requires the ability to estimate the VRE output, unless large reserve margins are built in to accommodate for the possibility of not being able to foresee future VRE output predicting can have a variety of effects and values at various predicting horizons, from one day ahead to several minutes ahead. Forecasting of renewable resources functions similarly to dispatchable generation scheduling. Predicting VRE output accurately can guarantee the most economical systems and drastically lower reserve margins. New forecasting methodologies have proven increased value above and beyond enduring prediction, and the usefulness of sustainable prediction has been investigated to include higher VRE penetrations.

3.1.3 Generator adaptability

The flexibility of a generator encompasses the capacity to function at low output levels and gradually increase and decrease power. When attempting to combine load and available generation, the scaling power of the current generation is a crucial factor. Ramping capabilities must be available because high levels of VRE can result in significant changes to the net loads observed by other generators. Another important consideration is the current generator's lowest demand, as this often indicates the maximum amount of VRE that may be operated at any one time.

3.1.4 Energy conservation

In systems where VRE levels are exceptionally high, energy storage is essential. Energy storage can serve various functions, including regulation, load afterwards, and energy transference to either contribute or absorb electricity from the electrical grid, in scenarios where there is an excess or shortage of renewable energy. An extensive overview of the many energy storage options that can be included in electric power systems can be found. Even though it is substantial, the quantity of energy storage needed in large-scale power systems to achieve ultra-high levels of VRE may only represent a small portion of the system's total size. The research named Renewable Electricity Futures (REF) was carried out by the National Renewable Energy Laboratory.

3.1.5 Load management

Using load control to change demand is another way to raise the amount of VRE. Systems can be built to consume energy when VRE power is available, as an alternative to constructing grids to deliver electricity when loads want it. In this case, the generation will not follow loads. Instead, the load starts to lag behind its generation. In addition to being able to adjust power and energy consumption during the day, controlled loads can also serve as storage by precooling or warming the heated air of structures.

According to references, one of the most underutilized resources for reliability is the use of responsive loads, which can balance over a wide range of periods, from seconds to seasons.

3.2 Different Small Power System Types

Rural and isolated locations are primarily served by small power systems. Mini-grid installations have increased in tandem with declining costs for inverter, solar, and wind technologies. Small power sources can be divided into many groups based on how they are connected to the main network: grid-tied and off-grid generators are the two broad types.

3.2.1 Disconnected Systems

Off-grid power systems make up the majority of small power installations that are specifically engineered and optimized to satisfy the power demands of remote locations. There is no connection between an off-grid system and the main electrical grid. The size and uses of standalone systems range greatly, from timepieces and calculators to remote buildings and spacecraft.

3.2.2 Grid-Connected Systems

A system that is grid-connected transfers energy directly into a larger independent grid, usually the public electricity grid. To feed power into the grid, a synchronizing grid-tie inverter—also known as a grid-interactive inverter—must convert DC to AC.

3.3 AES power system reasons and requirements for control

The Integrated Power System is the foundation for modern AES configurations. IPS, as illustrated in Figure 3.1, is a concept in which the electric drive propeller system and the ship service electrical infrastructure are powered by a single electric bus [12]. Power production, transmission, power electronics converters, and electrical loads, such as propulsion and service, are all components of a conventional IPS. The IPS has benefits over the typical ship mechanical propelling system, including less noise, more survivability, fewer primary movers, lower energy usage, and easier general layout.

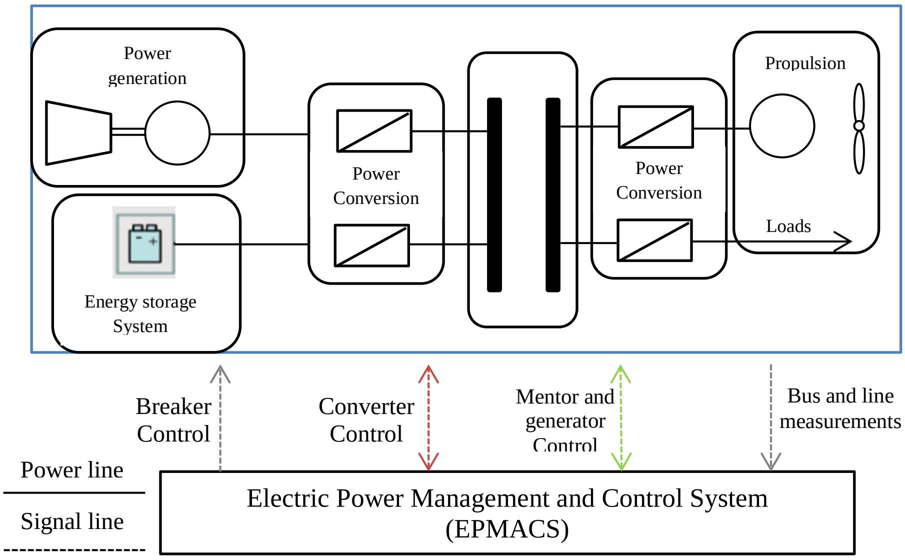

Figure 3.1 Schematic of the Integrated Power System

For electrical propulsion, modern ship loads need a significant quantity of electricity, while at the same time particularly about the EPMACS, several configurations are under consideration; however, the most prevalent concept has not yet emerged. This is because, while the AES electrical system structure is still developing, moving from more conventional AC network arrangements to multi-zonal moderate voltage DC arrangements, there is still a dearth of experimental data to warrant the results of simulations. But in both cases, because of the great variety of AES electrical systems and the interconnection of various power modules, there is an increasing interest in hierarchy and decentralized designs.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

Table 1 displays the particular relevant variables of the comparable load in each of the scenarios. The statistics presented in Table 1 demonstrate how the installation of the CSP plant greatly lessens the highs and lows, whereas the greatest peak-valley differential of the corresponding load remains relatively constant in the solar power generating system without the CSP plant. The load fluctuation can be represented as comparable load variance. The comparable load variation is increased by the renewable energy generating system without CSP because of its unpredictable production.

By adding the CSP plant, the detrimental effects of clean energy sources on conventional thermal power generation are effectively mitigated. Peak shaving costs are passed on to the sustainable energy generation structure [13], thereby lowering the cost of producing thermal power units as their load decreases. When the thermal power unit carries the whole load, it is referred to as the initial scenario in Table 2. The influence of the green energy system's uncertainty on the heating units' dispatch is reflected in the start-up cost. The specific wind power usage and abandoned data are displayed in Table 3.

Table 1. The particular Relevant Variables of The Comparable Load in Various Scenarios

Case	**Thermal power cost**	**PV Cost (S)**	**Wind power ($)**	**CSP Cost ($)**	**Total Cost ($)**
1	335409.66	23461	27976	_	366846.66
2	338732.22	23461	30184	_	382377.22
3	335824.41	23461	30352	_	369637.41
4	29645	23461	35400	35536	36089

	7.16				4.15

Table 2. The cost Criteria For Producing Heat Power in Various Scenarios

Case	**Peak**	**Valley**	**Maximum peak-valley difference**	**Equivalent load mean square error**
Unique load	690	410	370	6547.526
PBDR load	690	445	345	5279.9427
2	665	410	355	5865
2	642	440	302	5830
4	635	440	295	5651
5	567	360	307	5422

Table 3. Utilization of Wind Energy And Disengagement in Various Scenarios

Circumstance	**Working Cost($)**	**Start-up cost ($)**	**Total cost ($)**	**Total power group**	**Unit power group cost ($)**
Original	380841.45	4380	384221.45	20725	36.51
2	331109.66	5300	335409.66	10335	35.23
3	334772.22	4960	338732.22	10435	35.31
4	331984.41	4840	335824.41	10406	35.08
5	292917.16	4540	296457.16	9141	34.13

Wind energy production and the CSP plant's effect, Wind power generating is the form of clean energy technology that is most vulnerable to unpredictability. The comparison of the four scenarios' abandoning power and wind power usage is displayed in Figure 4.1. The specific wind power usage and the abandonment data are displayed in Table 1.

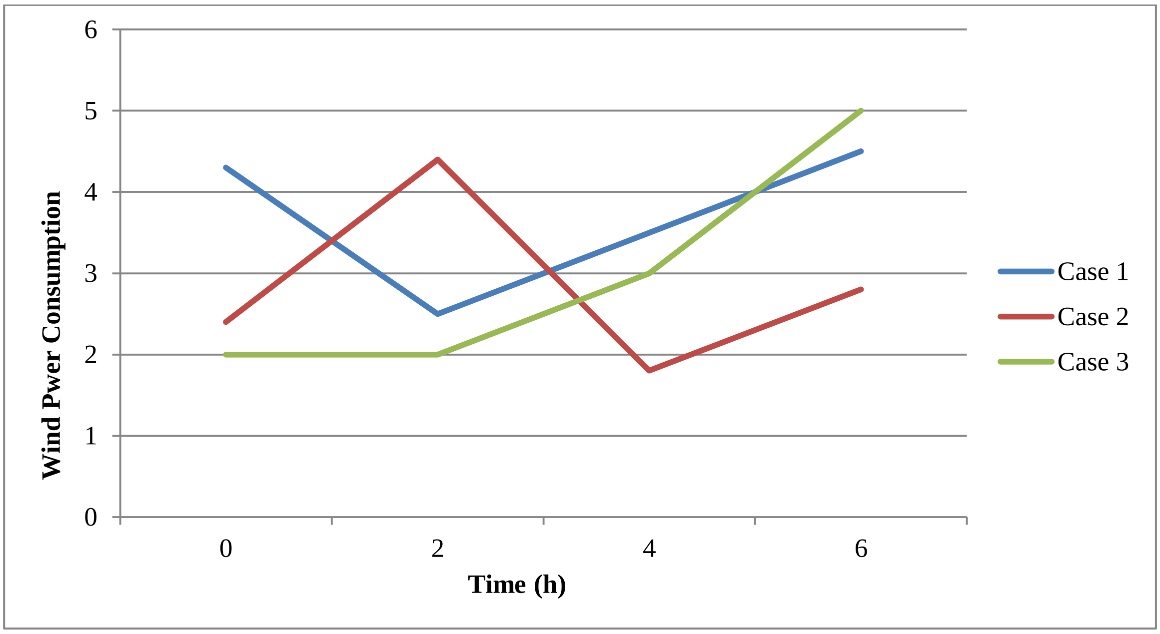

Figure 4.1. Wind power generation under various scenarios

Compared to the previous cases, Case 4's wind electrical consumption rate is much higher. It is clear from the curve that Case 4's wind electrical consumption rate is larger than that of the other examples almost the entire day, especially during the 9–13 the evening interval. Figure 4.1 illustrates that Case 4 only experiences a partial windy desertion event throughout the early stages.

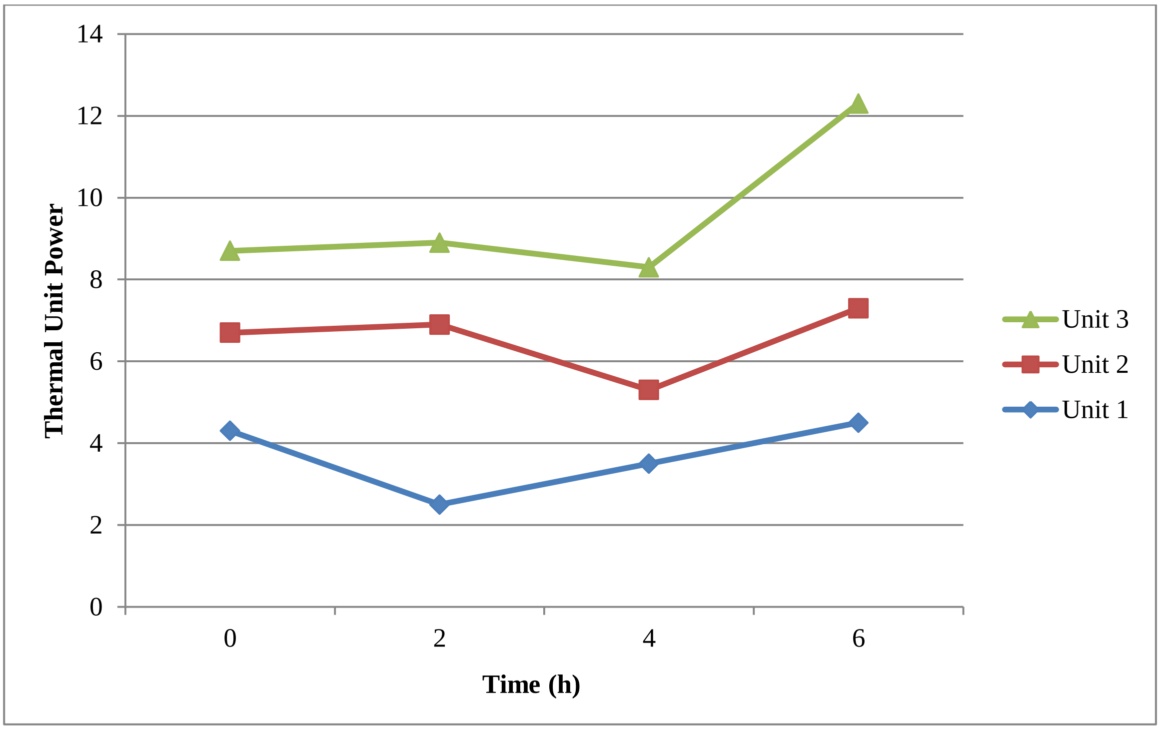

Figure 4.2. Case 3's e Thermal Unit Output in Terms of Total Wind Electrical Consumption

Moreover, Table 2's data demonstrate that the CSP plant's addition lowers the wind power curtailment rate to 7.34%. Compared to the other measures, there is a discernible improvement in wind power absorption with the CSP plant included. After all energy produced by natural sources has been used, Figure 4.2 shows the final output of the heating and cooling units in Case 3, facilitating a closer look at the CSP plant's operation and the reasons behind the abandonment. It is evident from the comparison of Figure 4.2 that unit 3's production is primarily impacted when wind power is absorbed. Figure 4.3 shows the heat power unit 3's cost operation, which is connected with the unit's production and the number of unit start-ups.

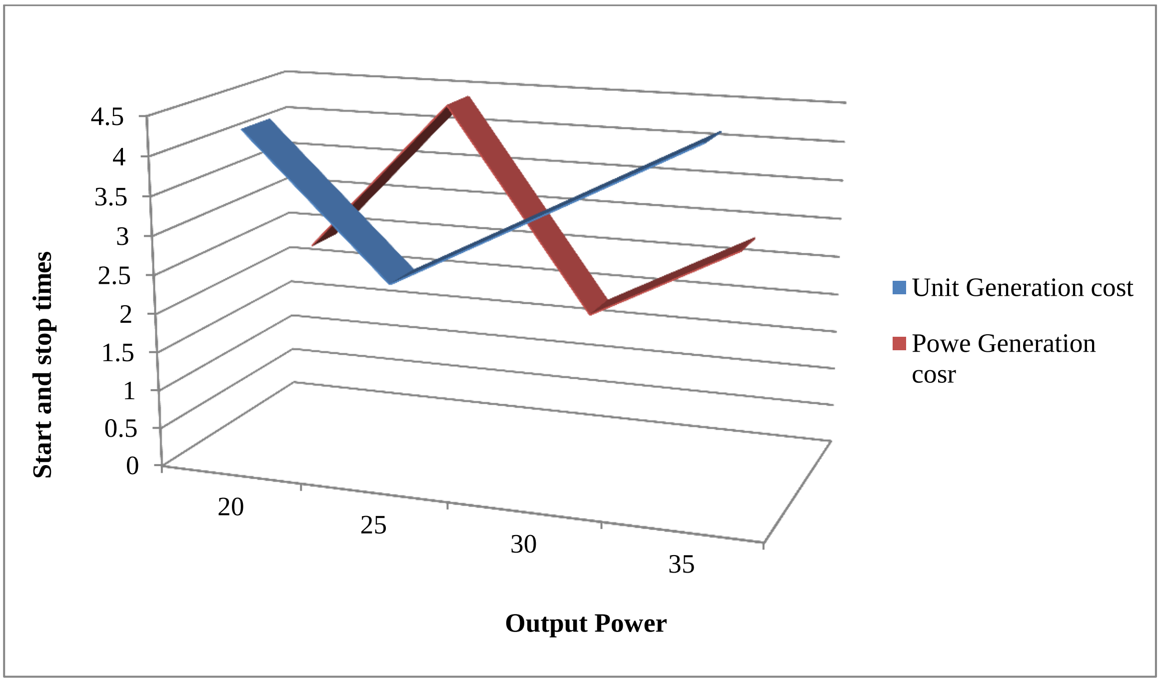

Figure 4.3. The thermal power units 1 and 3's cost occupation

Figure 4.3 illustrates that, in the case of full load operation, the quantity of starts has no discernible effect on unit 3's power-generating cost. However, the unit's cost is more directly impacted by its output, it increases the power generation cost of the unit when the output is erratic. Thus, [14], Case 3 has a high number of wind abandonment scenarios; the CSP plant's inclusion guarantees the thermal power units' steady operation even at high wind utilization rates.

It transfers the peak shaving requirement to the CSP unit, so guaranteeing the rate of wind power consumption and reducing the thermal power generation cost. Additionally, the graphic demonstrates that the unit power generating cost is devoid of the quantity of units. decreases as output power increases. Additionally, unit 1's large capacity unit energy production cost is higher than unit 3's low output electricity unit generation cost.

5. CONCLUSION

Power system operators have historically used dispatchable centralized power facilities to match the load. However, when wind and solar energy facilities are present, this becomes more problematic due to their unpredictability and fluctuation. Determining the system's security and instability margins gets more difficult in steady-state analysis. Furthermore, because renewable power plants frequently have power electronics interfaces that isolate them from the system, their contributions to system dynamics are complex, unpredictable, and reliant on the controller that is utilized in their interface

Unit 1's cost is less than Unit 3's minimal power-generating cost when it is operating at full load. The power generating cost function and pertinent statistics for thermal power units show that large-capacity units have high start-up costs and low full-load operating costs. Small capacity units, on the other hand, have minimal start-up costs but comparatively high operational costs. As a result, the base load is frequently handled by the large-capacity units, and the peak shaving is handled by the small-capacity machines. It is also possible to lower the generation of thermal power and comprehensive power. Future research will aim to further improve the system's model while also investigating the possibility of solar thermal power plants and accounting for both the power generation model and the system's profitability.

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