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SUSTAINABLE SECURITY SYSTEM USING THE TURPIN SYSTEM/UTILITY GRID AT UNIVERSITY OF BUSINESS AND TECHNOLOGY, JEDDAH, SAUDI ARABA

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Abstract

The implementation of hybrid Turpin systems combined with Utility Grid (Turpin/UG) represents a significant strategy for addressing fuel resource scarcity on a global scale. Before the installation of such systems, it is crucial to meticulously evaluate the total cost involved. A recent study conducted at the University of Business and Technology in Jeddah, Kingdom of Saudi Arabia (KSA), aimed to analyze the performance of a hybrid Turpin/UG system. The primary objective was to ensure the continuous operation of the security system without incurring additional costs. The study involved calculating the average wind speed, temperature, and air density throughout the year in Jeddah. These parameters were essential for estimating the overall power generation potential of the selected wind turbines. The results of the analysis revealed that the hybrid Turpin/UG system could generate sufficient power to sustain the security system's operation without any financial burden. Specifically, the study demonstrated that the implementation of the hybrid system resulted in a monthly cost saving of 343 Saudi Riyals (SR). Over the lifetime of the system, the total accumulated savings amounted to 18,164 SR. These findings underscore the viability and economic benefits of adopting hybrid Turpin systems, especially in regions like Jeddah with favorable wind conditions. This research contributes to the growing body of evidence supporting the effectiveness of renewable energy solutions in mitigating resource scarcity and reducing operational costs. It also highlights the importance of conducting site-specific analyses to optimize the performance and economic feasibility of renewable energy systems.

Keywords: Wind Turbines, University of Business and Technology, Jeddah, KSA, Wind Speed.

1. INTRODUCTION

Renewable energy sources (RES) represent a fundamental aspect of humanity's energy landscape, offering sustainable alternatives to traditional fossil fuels and nuclear power. These sources harness natural processes that occur within relatively short timescales, ensuring their replenishment and continued availability. Throughout history, humans have relied on renewable energy in various forms, recognizing their potential to meet our energy needs while minimizing environmental impacts [1].

Solar energy stands out as one of the most promising renewable resources, capturing sunlight through photovoltaic cells or solar thermal systems to generate electricity and heat. The abundance of sunlight makes solar energy a highly accessible and widely applicable source, particularly in regions with ample sunshine. Likewise, wind energy harnesses the kinetic energy of wind through turbines, providing a clean and renewable source of electricity, often in windy coastal or open plains regions [1].

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Hydropower, derived from flowing water in rivers and waterfalls, has long been utilized to generate electricity through hydroelectric power plants. This renewable source offers a reliable and scalable energy solution, contributing significantly to global electricity generation.

Biomass energy, derived from organic materials like wood, agricultural residues, and organic waste, provides another versatile option for renewable energy production, offering potential solutions for both electricity generation and heating applications [1]. Geothermal energy taps into the Earth's heat stored beneath the surface, utilizing steam or hot water from underground reservoirs to generate electricity or provide direct heating. This resource is particularly valuable in regions with high geothermal activity, offering a constant and sustainable energy source.

Additionally, wave and tidal energy, biogas from organic waste, and ocean thermal energy conversion (OTEC) represent innovative avenues for harnessing renewable energy from the natural environment [2]. Renewable energy sources offer numerous advantages, including reduced greenhouse gas emissions, enhanced energy security, job creation, and economic development.

As technology continues to advance and economies of scale improve, the adoption of renewable energy is expected to accelerate, driving a transition towards a more sustainable and resilient energy future. By harnessing the power of renewable resources, societies can mitigate climate change, reduce dependence on finite fossil fuels, and pave the way for a cleaner, greener planet [2].

Explaining the meaning and usage of each of those different types helps to understand what the most applicable system to certain conditions is. The first type is solar energy. It is considered a main future source of clean and cheap energy because its resource is the sun, also considered the cleanest, steady, and most environmentally friendly potential resource among all renewable energy options [2].

Solar energy is defined as radiant energy transmitted by the sun and intercepted by Earth. It is transmitted through space to Earth by electromagnetic radiation with wavelengths ranging between 0.20 and 15µm. The availability of solar streams for worldly applications varies with season, time of day, location, and collecting surface orientation. [3]

Solar, wind, geothermal, hydrogen, biomass, and other renewable technologies are widely popular sources of electric energy. 85% of the world's global energy consumption is today met by fossil-based fuels such as coal, natural gas, and oils [4]. The European Wind Energy Association (EWEA) in 2005 expected Photovoltaic (PV) to be the largest renewable electricity source with a production of 25.1% of global power generation in 2040 [5].

Some of the advantages of renewable energy are that the operating and maintenance costs of renewable energy facilities are low compared with traditional fossil fuel plants. Also, their low harmful emissions, high operating efficiency, sustainable energy supply, and low

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maintenance and operating requirements are considered important reasons to substitute them with other types of energy [6].

Windmills to mill wheat or pump water have been powered by using the wind for centuries as a renewable energy source. Large wind turbines were designed to generate electricity. This source of energy is nonpolluting and freely available in many areas. Wind turbines are becoming more efficient. The cost of the electricity they generate is falling [7].

Using one source of renewable energy such as photovoltaic (PV) or wind turbines (WT), will demand a high investment cost and less sustainability because of the limitation of the sources [8]. However, mixing various renewable resources, namely, hybrid renewable energy systems (HRES) can help overcome the previous issues. One of the great worth of HRES is to operate in a grid-connected or autonomous mode.

The net cost of HRES plays a major obstacle to creating electricity from renewable resources due to the high initial payment and maintenance cost of energy storage. In the autonomous mode of the microgrid, energy storage is required to achieve load energy demand which contributes to increasing the total cost [9]. Wind energy is also subject to limitations due to wind speed fluctuation. When the wind speed is lower than the cut-in speed of the assigned wind turbine, there is no energy output because of insufficient torque exerted by the wind on the turbine blades.

On the other hand, when the wind speed exceeds the rated cut-out speed, the control system will activate the braking system of wind turbines to protect the rotor of the wind generator. Generally, a storage system plays an important role in operating renewable energy systems to achieve sustainability and reliability [9]. In 2015, Dr. El-Sayed et al. experimented with a hybrid renewable energy model in the engineering building of the same university, promising to develop and consider the new Cornish campus. The proposed work model generates energy depending on the hybrid PV/battery bank/ utility grid system (PV/BB/UG).

This system proved a significant saving in the consumption of energy used in the building. The net cost of the generated power saves 343 SAR/month and the total saving for the system's lifetime is 18,164 SAR [10]. A few years later in 2017 Dr. El-Sayed et al. introduced a fully automated power management control system for hybrid PV/Battery Sank/ Utility Grid (PV/B S/UG) system and he and his colleagues tested their modified system again at the university. There are four different modes of operation such as feeding the utility, feeding the battery banks, feeding both utility and battery banks, and getting power from the utility grid [11].

The study conducted by Dr. Tazay et al. in 2020 at Albaha University aimed to address the issue of high energy consumption in university buildings by implementing renewable energy solutions. The renewable energy system comprises photovoltaic (PV) modules, wind turbines, battery banks, and fuel cells.

One of the key findings of the study was that the initial cost of the solar PV system, as well as the cost of fuel cells, had the most significant impact on the total net present cost and the cost of energy of the system. This suggests that the upfront investment required for installing the

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solar PV system and fuel cells plays a crucial role in determining the overall economic feasibility and efficiency of the renewable energy system implemented in Albaha University buildings. The study likely provided valuable insights into the economic aspects of integrating renewable energy sources into building energy systems, highlighting the importance of considering initial costs and identifying potential areas for cost optimization to make renewable energy solutions more viable and sustainable in the long term [12].

Saudi Arabia is exploring the implementation of a sustainable security system utilizing the innovative Turpin System/Utility Grid. This initiative aims to enhance security measures on campus while promoting sustainability practices. By integrating renewable energy sources and advanced security technologies, the university seeks to create a robust and eco-friendly security infrastructure.

This approach not only strengthens security protocols but also aligns with the university's commitment to environmental stewardship and energy efficiency. In this context, the integration of the Turpin System/Utility Grid presents a promising opportunity to elevate security standards while reducing the institution's carbon footprint.

This introduction sets the stage for a comprehensive examination of how sustainable practices and cutting-edge security solutions can converge to safeguard the University of Business and Technology in Jeddah. In this study, we designed a hybrid PV/battery bank/ Turpin system/ Utility Grid (PV/BB/Turpin/UG) to reduce the consumption of the electricity bill in a chosen campus in Jeddah, Saudi Arabia. University of Business and Technology (UBT) has the great advantage of having a campus near the Red Sea, this location allows the university to take advantage of the sunny and windy weather as this area is recognized with most of the years [13].

2. NUMERICAL MODEL AND DATA COLLECTION

To calculate the total cost of installing and running the proposed renewable energy system using wind turbines (Turpin) at the new UBT campus in Cornish, you will need to follow these general steps:

- Determine Energy Consumption: Calculate the total energy consumption of the campus by considering various factors such as buildings, lighting, heating, cooling, equipment, and other energy-consuming activities. This could involve historical data if available, or estimations based on similar campuses.
- Evaluate Wind Potential: Assess the wind potential at the campus location near the Red Sea. Consider factors such as average wind speed, wind direction, and the feasibility of installing wind turbines.
- Select Turbine Type and Number: Choose the appropriate type and number of wind turbines (Turpin) based on the assessed wind potential and the energy consumption of the campus.

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- Calculate Installation Costs: Estimate the installation costs of the wind turbines, including the cost of purchasing and installing the turbines, as well as any necessary infrastructure such as towers, foundations, and electrical connections.
- Estimate Maintenance Costs: Determine the ongoing maintenance costs associated with operating the wind turbines, including regular inspections, repairs, and replacement of components.
- Calculate Savings from Renewable Energy: Estimate the savings achieved by substituting the energy from the utility grid with the energy generated by the wind turbines. Consider factors such as the cost of electricity from the grid, any applicable incentives or rebates for renewable energy, and the expected lifespan of the wind turbines.
- Consider Changes in Campus Area: Account for any changes in the total area of the campus that may affect energy consumption or the feasibility of installing wind turbines.
- Perform Financial Analysis: Calculate the net present value (NPV), internal rate of return (IRR), payback period, and other financial metrics to evaluate the economic viability of the proposed renewable energy system over its expected lifespan.
- Consider Environmental Benefits: Factor in the environmental benefits of using renewable energy, such as reduced greenhouse gas emissions and dependence on fossil fuels.
- Optimize the System: Fine-tune the design and operation of the renewable energy system to maximize efficiency and cost-effectiveness, considering any technological advancements or changes in energy consumption patterns.

Numerical Model Development:

Define the parameters: Determine the key variables such as turbine capacity, installation costs, maintenance expenses, energy output, and system lifespan.

Data collection: Gather data on wind patterns, turbine efficiency, equipment costs, installation expenses, maintenance costs, and expected energy production.

Cost assessment: Develop a numerical model to estimate the total cost of installing and operating the wind turbines over their lifespan.

Data Collection:

Wind data: Collect historical wind speed data for the installation location to assess the potential energy generation.

Turbine specifications: Gather information on the selected wind turbines (e.g., capacity, efficiency, cost).

Installation costs: Obtain quotes or estimates for turbine installation, including site preparation and infrastructure requirements.

Maintenance expenses: Research ongoing maintenance costs for the turbines, including repairs and servicing.

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Energy output: Estimate the energy output of the turbines based on the collected wind data and turbine efficiency.

Cost Calculation:

Initial investment: Calculate the total cost of purchasing and installing the wind turbines.

Operating costs: Estimate the annual maintenance and operational expenses.

Energy production: Determine the expected energy output and revenue generated from selling this energy.

Lifetime costs: Compute the total cost of ownership over the projected lifespan of the wind turbines, factoring in maintenance, repairs, and energy production. By following these steps, you can calculate the total cost of installing and running the proposed renewable energy system using wind turbines at the new UBT campus in Cornish and assess its economic and environmental impact.

Numerical model for wind turbine equations

Wind Power depends on the amount of air (volume), the speed of air (velocity), and the mass of air (density), flowing through the area of interest [14]

Generated power equation [15-16]

The generated power from a wind turbine can be calculated using Equation (1).

$$P_m = Apv^3c_p \quad (1)$$

Where A is the swept area ($A = \pi R^2$) and R is the rotor radius (m), ρ is the air density (kg/m^3), v is the wind speed (m/s), and c_p is the rotor power coefficient [17]. The air density can be calculated using Equation (2).

$$\rho = \frac{P}{R_{specific}T} \quad (2)$$

Where P is the average air pressure (Pa).

Specific gas constant for dry air of 28.964917 g/mol. The specific gas constant of a gas or a mixture of gases ($S_{pecific}$) is given by the molar gas constant divided by the molar mass (M) of the gas or mixture. [18] The average temperature during the year in Jeddah is mostly warm with the highest temperature is 305.5 K during the summer months from July to August. While the lowest temperature is 297 K during January through February.

The table shows that the temperature in Jeddah is always warm according to weather.com. Figure 1 observes the relation between the changes in the temperature during the months of the year where the temperature is low during the winter season (December and January February) and starts to increase during the spring season (March and April) to reach the beak in August then decreasing again during September. [18-19]

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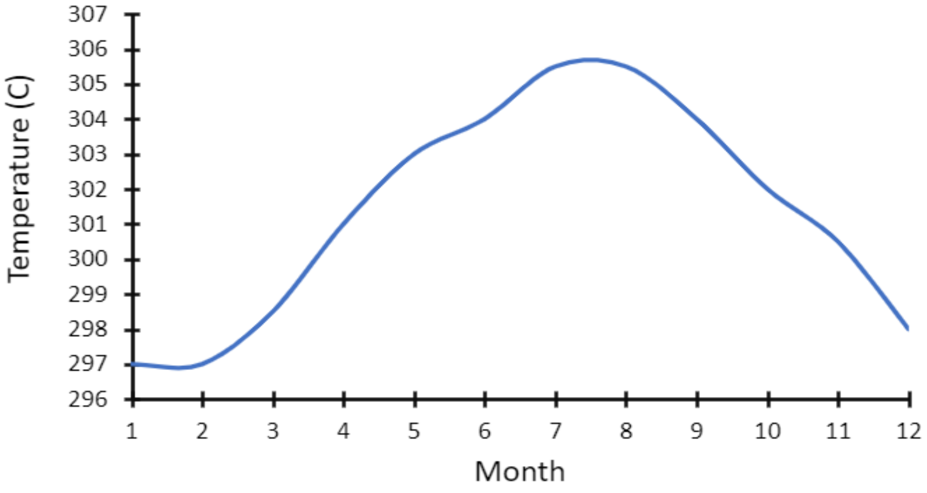

Figure 1: Average Temperature in Jeddah Saudi Arabia [20]

Air density is a measure of how much mass (or weight) of air is present in each volume. It is influenced by several factors, including temperature, pressure, and humidity.

Temperature: Air density decreases as temperature increases. This is because warmer air molecules have more energy and spread out, resulting in lower density. Conversely, colder air is denser because the molecules are closer together.

Pressure: Air density is also affected by atmospheric pressure. Higher pressure compresses air molecules closer together, increasing density, while lower pressure allows air molecules to spread out more, decreasing density.

Humidity: Water vapor, or humidity, in the air affects its density. Moist air (high humidity) is less dense than dry air (low humidity) because water vapor molecules are lighter than nitrogen and oxygen molecules, which are the primary components of dry air.

Altitude: Air density decreases with altitude. As you go higher in the atmosphere, the air becomes less dense because there is less atmospheric pressure pushing down on it. This means that air at higher altitudes contains fewer air molecules per unit volume compared to air at lower altitudes.

Figure 2 illustrates how air density changes over a year, indicating peaks and troughs corresponding to different seasons and weather patterns. For example, air density might be higher in colder months due to lower temperatures and higher pressure, while it might be lower in warmer months due to higher temperatures and lower pressure.

Understanding the variation in air density is important in various fields such as aviation, meteorology, and climate science, as it affects the behavior of gases in the atmosphere and has implications for weather patterns, air quality, and aircraft performance, among other factors.

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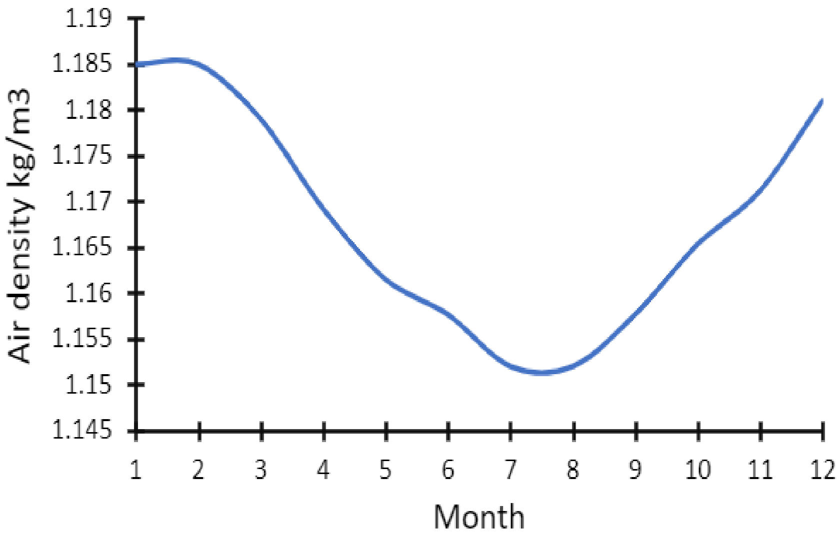

Figure 2: The density of air (kg/m) in Jeddah during the year [21]

The relatively stable wind speed pattern observed in Jeddah, Saudi Arabia, throughout the year, can have several implications and provide insights into the local climate and environmental conditions:

- Stable Weather Conditions: The consistent wind speeds throughout the year suggest that Jeddah experiences relatively stable weather conditions. This stability can be advantageous for various outdoor activities, construction projects, and transportation planning as it reduces the uncertainty associated with weather-related disruptions.
- Impact on Energy Generation: Consistent wind speeds can also be beneficial for wind energy generation projects. Wind turbines typically require consistent and moderate wind speeds to operate optimally. In Jeddah, the relatively steady wind speeds may provide a reliable source of renewable energy, contributing to the region's energy sustainability goals.
- Aviation and Maritime Considerations: The predictable wind patterns are crucial for aviation and maritime industries. Pilots and ship captains rely on wind forecasts to plan routes, takeoffs, and landings effectively. The stable wind conditions in Jeddah may simplify flight and navigation planning, reducing the risk of weather-related disruptions.
- Environmental Impact: Understanding the wind patterns in Jeddah is essential for assessing air quality and dispersion of pollutants. Consistent wind speeds can help disperse pollutants and improve air quality by preventing the buildup of pollutants in specific areas.
- Outdoor Activities and Tourism: The stable wind conditions can also benefit outdoor recreational activities and tourism in Jeddah. Predictable weather patterns make it easier for tourists to plan outdoor excursions, such as beach outings, desert safaris, and water sports, without significant concerns about unexpected weather changes.

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- Urban Planning and Infrastructure: Knowledge of local wind patterns is crucial for urban planning and infrastructure development. Designing buildings, roads, and other structures to withstand prevailing wind conditions ensures the safety and longevity of infrastructure projects in the region.

Overall, the relatively stable wind speed pattern observed in Jeddah reflects the region's climate characteristics and provides valuable insights for various sectors, including energy, transportation, tourism, and urban planning. Understanding and harnessing these wind patterns effectively can contribute to sustainable development and resilience in the region.

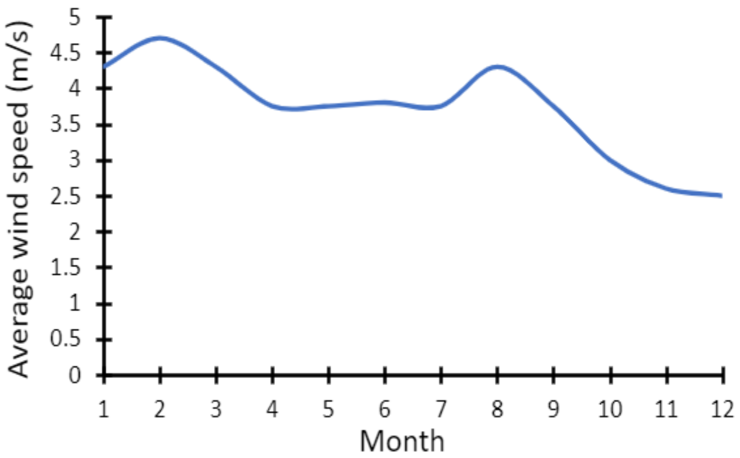

Figure 3: the average wind speed (m/s) during the months of the year [22]

Equipment parameters

The wind energy factsheet for wind from the Center for Sustainability System for the University of Michigan shows that most turbines extract ~50% of the energy from the wind that passes through the rotor area. [23] The name of the wind turbine the researcher chose is 1000W Peak 12V / 24V Wind Turbine. It has a 5 Blade Wind Generator Turbine and is a Wind Turbine with a Controller – 12V. The rated power is 500W where the maximum power is 1000W. Also, the rated wind speed is 11.5 m/s, the start-up wind speed is 2.0 m/s, and the survival wind speed should not exceed 55 m/s. Table 1. Specify all the wind Turbine features as follows:

- Name: The name of the wind turbine model is 1000W Peak 12V / 24V Wind Turbine. This nomenclature likely indicates its peak power output and the voltage systems it is compatible with.
- Blade Type: The wind turbine features a 5-blade design for its rotor. The number of blades can impact the turbine's efficiency and performance in different wind conditions.
- Controller: This wind turbine comes with a controller specifically designed for 12V systems. The controller regulates the electrical output from the turbine, ensuring safe and efficient operation of the system.

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- Rated Power: The rated power of the wind turbine is 500W. This is the power output that the turbine is designed to consistently produce under optimal wind conditions.
- Maximum Power: The maximum power output of the turbine is 1000W. This indicates the maximum amount of electrical power that the turbine can generate under peak wind conditions.
- Rated Wind Speed: The rated wind speed of 11.5 m/s signifies the wind speed at which the turbine is designed to achieve its rated power output. This is the ideal wind speed for optimal performance.
- Start-up Wind Speed: The start-up wind speed of 2.0 m/s is the minimum wind speed required for the turbine to begin generating electricity. Below this speed, the turbine may not be able to produce usable power efficiently.
- Survival Wind Speed: The survival wind speed of 55 m/s indicates the maximum wind speed that the turbine can withstand without sustaining damage. This is an important safety parameter to ensure the durability and longevity of the turbine in extreme weather conditions.

These specifications collectively provide a comprehensive overview of the wind turbine's design, performance capabilities, and operational characteristics, enabling users to assess its suitability for specific applications and environmental conditions.

Table 1: Specification for the wind Turbine 1000W Peak 12V / 24V Wind Turbine 5 Blade Wind Generator Turbine Wind Turbine with Controller – 12V

Brand	NE
Rated power	500W
Maximum power	1000W
Rated voltage	12V/24V
Start-up wind speed	2.0m/s
Rated wind speed	11.5m/s
Survival wind speed	55m/s
Top net weight	6.2kg
Wheel diameter	1.3m
Blades number	3/5
Blades material	Nylon fiber
Generator	Three-phase permanent magnet AC generator
Magnetic steel	NdFeB
Generator case	Die-casting aluminum
Control system	Electromagnet
Speed regulation	Automatically adjust windward
Working temperature	-40℃～80℃
Included	Mounting accessories
Not included	Mounting post

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(a) (b)

Figure 4: (a), (b) winds Turpin [23]

The specification of the wind Turpin is shown in Figures 4 a and b where the controlling system is Electromagnet, and the Blades material is Nylon fiber.

3. RESULTS AND DISCUSSION

In the University of Business and Technology's new building they continue to consider the environmental economy design and the experiment they have in the Dahban model (PV/ UG) of Hybrid Renewable Energy in engineering building was promising to develop and take into consideration for the new Cornish campus. The developed model generating energy depending on a hybrid Turpin system/ Utility Grid (Turpin/UG) proved a significant saving in the consumption of energy. The result shows the energy that has been produced using the mentioned system and where we can see the difference in each month. The average power generated during the beginning of the year in January is 22 w where it increases to reach the beak during mid of March to reach 26 w. then because the reduction in the wind speed starting from April continues until starts to increase slightly by May shows some fluctuation during the summer months June when it reaches 20 w then in July becomes 18 w then a sudden drop to reach the lowest in September to be 8 w then start increasing again after that to reach 16 w by December.

The hybrid renewable energy system at the University of Business and Technology's Dahban model shows fluctuations in energy generation throughout the year:

- Energy peaks in mid-March at 26 W and drops to its lowest in September at 8 W.
- Factors like wind speed and solar irradiance influence these fluctuations.
- Summer months experience lower energy generation, while winter months see a gradual increase.

Understanding these patterns helps optimize system performance and informs decisions for the new Cornish campus, such as integrating energy storage and smart management systems for reliable and efficient power generation.

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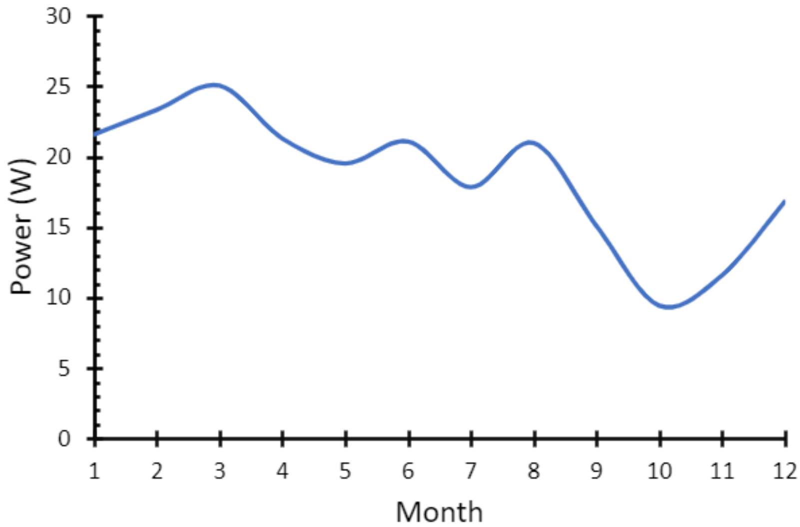

Figure 5: The average power during the months of the year

January: With an average power generation of 22 W, January marks the beginning of the year. This could be a time when various environmental factors, such as wind speed and solar radiation, contribute to energy production. It sets a baseline for energy generation at the start of the year.

March: Power generation peaks in mid-March, reaching 26 W. This increase could be attributed to favorable weather conditions, including higher wind speeds and increased sunlight exposure. March could be considered a favorable month for energy production in the system.

April-May: From April onwards, there is a reduction in wind speed, leading to a decrease in power generation. However, by May, there is a slight uptick in power generation as wind speeds begin to increase slightly. This period marks a transition from higher to lower energy production as environmental conditions change.

June-July: During the summer months, particularly in June and July, power generation sees a decline. This decrease could be due to various factors such as changes in wind patterns, temperature, and possibly solar radiation. The system's performance might be impacted by these fluctuations in weather conditions.

September: September experiences the lowest power generation, dropping to 8 W. This significant decrease could be attributed to specific environmental factors or seasonal variations that adversely affect energy production. It might be a time of low wind speeds or reduced solar radiation, impacting the overall efficiency of the hybrid renewable energy system.

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December: Power generation begins to increase again, reaching 16 W by December. As the year progresses towards winter, there might be changes in environmental conditions that favor energy production, leading to the observed increase in power generation.

Overall, the energy generation pattern reflects the system's response to varying environmental conditions throughout the year. The fluctuations can help engineers and designers optimize the hybrid renewable energy system, potentially through adjustments in system components, operational strategies, or the incorporation of additional renewable energy sources to enhance overall efficiency and reliability.

The net cost of the generated power saves 343 SR per month and the total saving for the lifetime of the system is 18,164 SR.

4. CONCLUSIONS

The University of Business and Technology in Jeddah, Saudi Arabia, faces the challenge of ensuring an uninterrupted power supply for its security system while also managing costs effectively. To address this challenge, the university has implemented a hybrid Battery Bank/Turpin system/Utility Grid (BB/Turpin/UG) solution. This hybrid system integrates multiple sources of power generation and storage to optimize energy efficiency and reliability.

The Battery Bank serves as a storage mechanism for surplus energy generated, while the Turpin system harnesses wind energy to supplement the grid power supply. The Utility Grid acts as a backup source of power when renewable sources are insufficient. The decision to utilize a wind turbine for power generation is based on various environmental factors specific to Jeddah, such as average temperature, wind speed, and air density. These factors influence the overall output of the wind turbine and its contribution to the hybrid system's power generation capacity.

The study's findings highlight the economic benefits of implementing the BB/Turpin/UG system. By utilizing renewable energy sources and optimizing energy storage, the university can save 343 Saudi Riyals (SR) per month compared to traditional power supply methods. Over the system's lifetime, this amounts to significant cost savings totaling 18,164 SR. Moreover, the paper provides a comprehensive examination of the hybrid system's performance. It evaluates key metrics such as energy generation capacity, cost-effectiveness, system reliability, and environmental impact.

Through detailed analysis and data-driven insights, the study aims to demonstrate the feasibility and effectiveness of the hybrid BB/Turpin/UG system for powering the university's security infrastructure. Overall, the implementation of the hybrid renewable energy system underscores the university's commitment to sustainability, cost efficiency, and uninterrupted operation of critical facilities. It serves as a model for integrating renewable energy technologies into institutional infrastructure, contributing to both financial savings and environmental stewardship.

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Conflicts of Interest Statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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