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Sustainable and Environmentally Friendly Wind Energy Contribution for Charging Electric Vehicles

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Abstract:
Wind Energy (WE) as a kinetic energy has the ability to power residential and commercial loads through wind turbines to charge Electric Vehicles (EVs) and run home appliances. Charging Electric Vehicles (CEVs) using WE is a sustainable and environmentally friendly solution to reduce carbon emissions in the transportation sector. However, WE face with intermittency, grid Integration, and Land and Resource Constraints. The aforementioned limitations can be addressed by integrating energy storage. By harnessing the power of Wind Turbines (WTs), Renewable Energy (RE) can be generated and utilized to charge electric vehicles. The process involves installing WTs either onshore or offshore to capture the kinetic energy of the wind and convert it into electricity. This electricity can then be fed into the grid or stored in batteries for later use. To CEV, specialized charging stations equipped with charging infrastructure are set up. These stations are connected to the renewable energy grid, allowing EVs to access clean and green energy for charging purposes. By utilizing WE to CEV, we can significantly reduce the reliance on fossil fuels and lower greenhouse gas emissions. It supports the transition towards a more sustainable transportation system, ultimately contributing to a greener future.

Keywords: Wind Energy, CEVs, Electric Vehicles, Wind Turbine.

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مساهمة مستدامة وصديقة للبيئة في استخدام طاقة الرياح لشحن المركبات الكهربائية

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الملخص
طاقة الرياح (WE) كطاقة حركية لديها القدرة على تشغيل الأحمال السكنية والتجارية من خلال توربينات الرياح لشحن المركبات الكهربائية (EVs) وتشغيل الأجهزة المنزلية. يعد شحن المركبات الكهربائية (CEVs) باستخدام WE حلاً مستدامًا وصديقًا للبيئة لتقليل انبعاثات الكربون في قطاع النقل. ومع ذلك، فإننا نواجه التقطع، وتكامل الشبكة، وقيود الأرض والموارد. يمكن معالجة القيود المذكورة أعلاه من خلال دمج تخزين الطاقة. من خلال تسخير طاقة توربينات الرياح (WTs)، يمكن توليد الطاقة المتجددة (RE) واستخدامها لشحن المركبات الكهربائية. تتضمن العملية تركيب WTs إما

على الشاطئ أو في الخارج لالتقاط الطاقة الحركية للرياح وتحويلها إلى كهرباء. يمكن بعد ذلك إدخال هذه الكهرباء في الشبكة أو تخزينها في بطاريات لاستخدامها لاحقًا. بالنسبة لـ CEV، تم إنشاء محطات شحن متخصصة مجهزة ببنية تحتية للشحن. ترتبط هذه المحطات بشبكة الطاقة المتجددة، مما يسمح للمركبات الكهربائية بالوصول إلى الطاقة النظيفة والخضراء لأغراض الشحن. من خلال استخدام WE في CEV، يمكننا تقليل الاعتماد بشكل كبير على الوقود الأحفوري وتقليل انبعاثات غازات الاحتباس الحراري. وهو يدعم الانتقال نحو نظام نقل أكثر استدامة، مما يساهم في نهاية المطاف في مستقبل أكثر اخضرارًا.

الكلمات المفتاحية: طاقة الرياح، شحن المركبات الكهربائية، السيارات الكهربائية، توربينات الرياح.

1. Introduction

Wind energy refers to the power generated from the conversion of wind into electrical or mechanical energy [1]. It is considered a Renewable Source of Energy (RSE) as it relies on the natural occurrence of wind. Wind turbines are commonly used to harness this energy by converting the kinetic energy of the wind into mechanical power, which is then transformed into electricity [2]. Wind energy is considered clean and sustainable, as it does not produce greenhouse gas emissions or air pollutants during operation [3]. It plays a crucial role in global efforts to reduce reliance on fossil fuels and mitigate climate change. In the literature, various scholars presented different studies in [4]. Energy Management Strategy for controlling the flown power in the system is conducted in [5]. Due to the necessity of providing clean and green energy by replacing the EV rather than the ICEV (ICEV), in [6], studying the feasibility of grid-connected system along with the integration of RESs in order to charge EV.

There are several reasons why wind energy may not be as widely used as other renewable energy sources of energy [7]. Initial costs, intermittency, visual and noise impact, environmental considerations, and infrastructure challenges are considered as the limitation of the wind energy [8]. Despite these challenges, the use of wind energy has been growing steadily in recent years as technology improves and costs continue to decrease [9]. There are several key points to consider when evaluating the use of wind energy for charging purposes which are environmental benefits, availability and scalability, cost-effectiveness, integration challenges, and infrastructure development [10]. Besides, wind energy holds great promise for CEV, offering a clean, abundant, and cost-effective options [11]. With continued advancements and integration strategies, wind power can play a significant role in reducing the carbon footprint associated with transportation [1].

The contribution of this study. The remining section of the paper is classified into four sections as follows: Section 2 consists of the methods and materials along with comparison collected data. Section 3 discusses components modeling and system architecture. Section 4 is presenting and discussing the acquired result along with the analysis of the obtained output power to show its sustainable achievement. The conclusion and list of recent references are closing the article.

2. Methods and materials

Various energy web pages involve general and specific database of energy and climate data such as International Energy Agency (IEA) , International Renewable Energy Agency (IRENA), National Aeronautics and Space Administration (NASA) [12]. The growth expectation of RESs (PV and WT) in the next years by 5% as shown in Figure 1, the PV more installed in comparison with WT based on IEA collected data. Additionally, based on the collected data from International Renewable Energy Agency (IRENA), Figure 2 is presented the percentage utilization for each source.

Wind energy can play a significant role in meeting the electric vehicle (EV) demand [13]. As the demand for EVs increases, so does the need for clean and sustainable sources of energy to power them. Wind energy is one of the most promising RESs that can be harnessed to charge electric vehicles [14]. The wind energy electrification support of transportation operation is demonstrated in Figure 3.

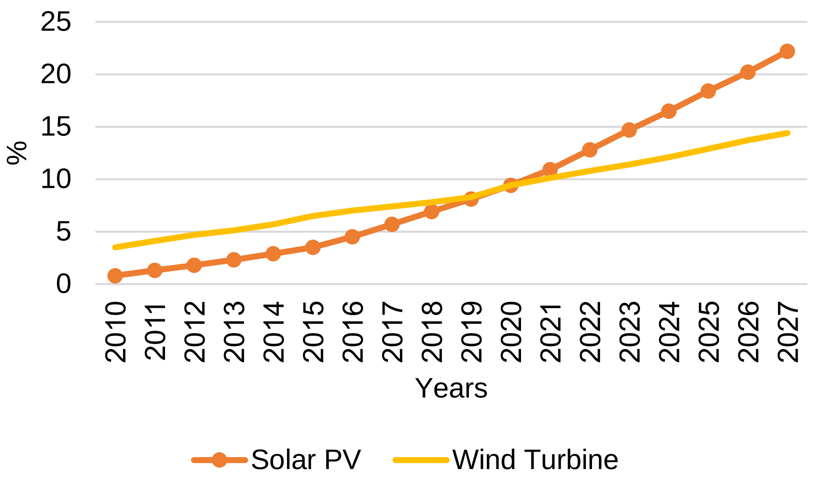

Figure 1. Share of cumulative power capacity by technology, 2010-2027 based on IEA.

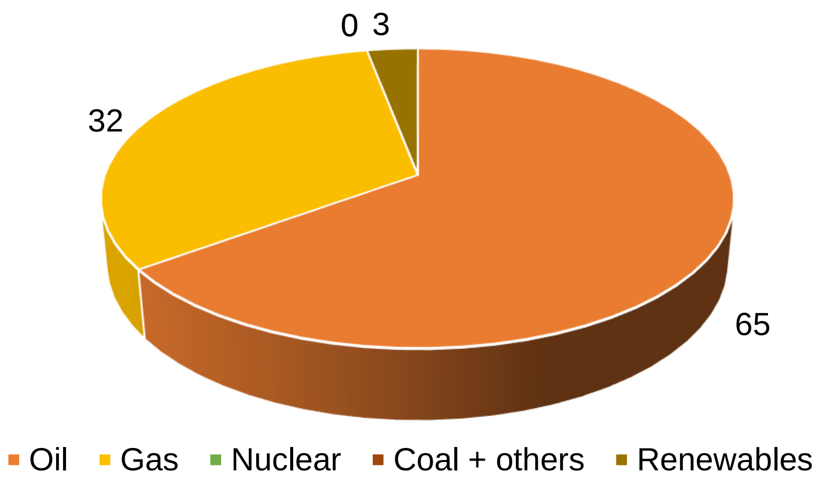

Figure 2. Total Energy Supply based on IRENA.

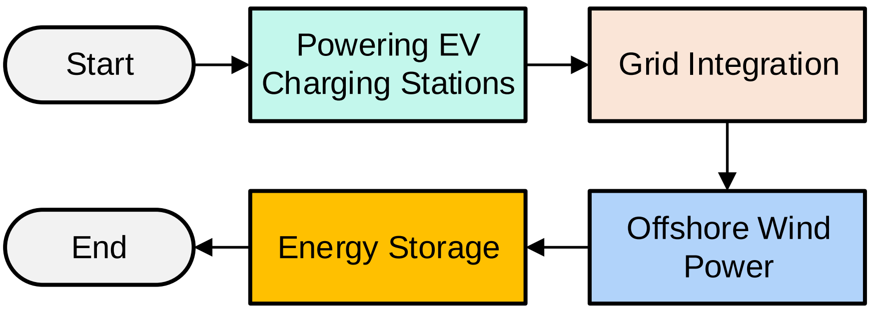

Figure 3. Wind energy electrification support process.

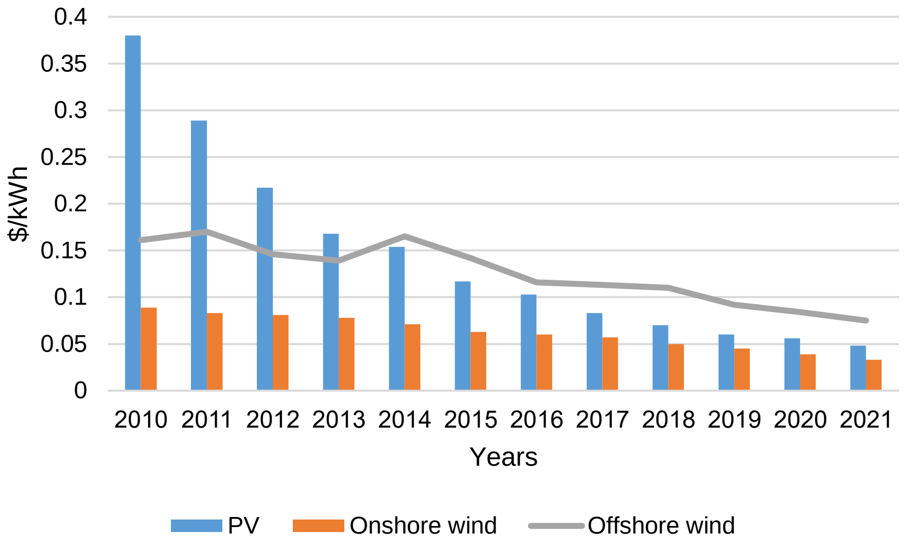

Figure 4. Comparison between PV and WT systems based on IEA.

3. Components Model and system architecture

Wind energy is a renewable resource that harnesses the power of wind to generate electricity [15]. Unlike fossil fuels such as gasoline or diesel, wind energy does not deplete over time, making it a sustainable option for charging EVs [16]. The benefits can be acquired from WT are RES, zero emissions at point of use, energy independence, environmental benefits, synergy with grid integration, and technological advancements [17]. This section involves the mathematical models for the exploited system components as demonstrated in Figure 5, while the further mathematical equation for each component of the system is mathematically expressed in the subsections.

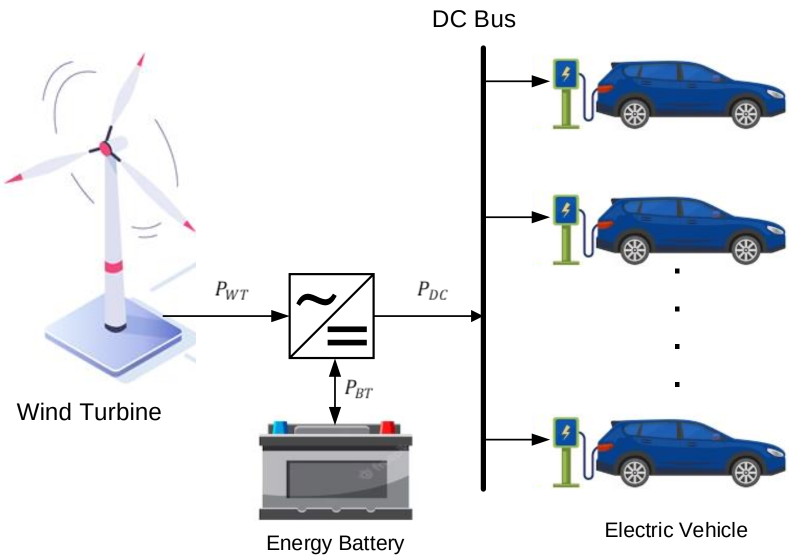

Figure 5. Proposed system architecture.

3.1 Wind Turbine

Charging electric vehicles (EVs) using wind energy is considered a sustainable and environmentally friendly solution. It aligns with the global goals of reducing carbon emissions, combating climate change, and transitioning to a greener energy future. The output power generated from WT (P_{WT}) can be mathematically expressed in Eq. (1) [18]. The used WT is 100-kW XANT M-21 due to its good performance and certain economic advantages [19].

$$P_{WT} = \begin{cases} 0 & v(t) \leq v_{cut-in} \\ P_r \dfrac{v(t) - v_{cut-in}}{v_r - v_{cut-out}} & v_{cut-in} < v_r \\ P_r & v_r < v(t) < v_{cut-out} \end{cases} \quad (1)$$

where v represents the wind speed of the case study, v_{cut-in} and $v_{cut-out}$ the cut in and cut out, P_r is the rated power of the WT, and v_r is the rated speed of the WT.

3.2 Converter

Converts the power in the system from AC to DC. The exchanged power from the converter can be presented using Eq. (2).

$$C_{Con/Inv} = P_{Con/Inv} \times \left(1 + \frac{1}{(1+i)^{10}}\right) \quad (2)$$

The present worth of the converter/inverter ($C_{Con/Inv}$) is presented in Eq. (2), $P_{Con/Inv}$ is the converter/inverter price, the 10 refers to the lifetime of the converter/inverter, and i is the interest rate.

3.3 Electric Vehicle Charging Station

The EVCS is formulating the EV to be charged as the main load [4].

$$P_{consumption} = \int_{t_0}^{t_o+T} P(t)dt = (1 - SoC_{inl}) \times Q_r \quad (3)$$

where the $P_{consumption}$ is the power consumption for time (t_o), T charging duration, $P(t)$ charging power at time t_0, SoC_{inl} the initial State-of-Charge, and Q_r is the rated capacity of EV battery.

3.4 Battery

Energy storage battery is exploited as back up device in case of unwind days. The generated output power from the battery (P_{BT}) to complement with the WT at time (t) in order to meet the demand can be mathematically expressed in Eq. (4) [20]. Due to the high storage efficiency and light weight, exploited deep cycle battery is L16P (lead-acid) with 6 V, 360 Ah, and 2.16 kWh [21].

$$P_{BT}(t) = E_{BT}(t-1).(1-\sigma) + \left((P_{WT}(t)).\eta_{inv} - \frac{P_I(t)}{\eta_{inv}}\right).\eta_{BT} \quad (4)$$

where E_{BT} is the battery energy, σ is the self-discharge of the battery which equals 0.007% /hours [22], η_{inv} is the efficiency of the inverter, P_I represents the load demand, η_{BT} is the battery the efficiency.

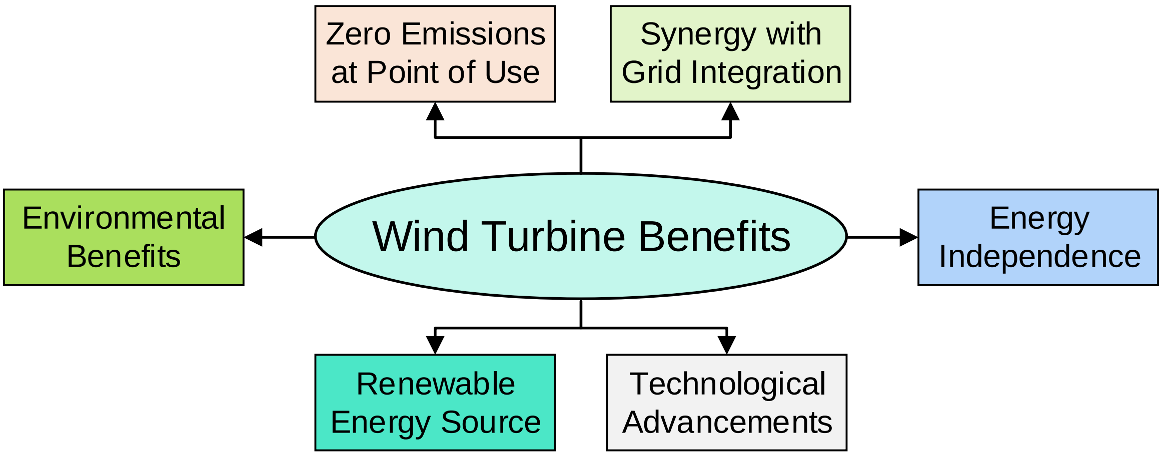

Figure 6. Wind turbine benefits.

4. Results and discussion

The operation of charging EV is an important operation to be considered due to its necessity of meeting the demand and avoid the limitation of RESs such as intermittency. Based on the proposed model in Figure 5, the acquired output from the exploited WT in this study is plotted in Figure 7 with maximum 4.5 kW as presented for the first 1000 hours. The aforementioned hours are representing the two seasons: winter and spring. The lower values represent the hours with low generated wind speed that leads to generate lower output. Additionally, the monthly analyzed output energy for the WT is tabulated in Table 1, while the maximum output is shown in winter, spring, and summer with 4.68 kW, respectively. The monthly analyzed wind speed data for the case study is demonstrated in Figure 8.

Table 1. WT maximum monthly contribution to charge EV.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum output	4.34	4.68	4.68	4.51	4.34	4.68	4.68	4.34	4.34	4.34	4.51	4.34

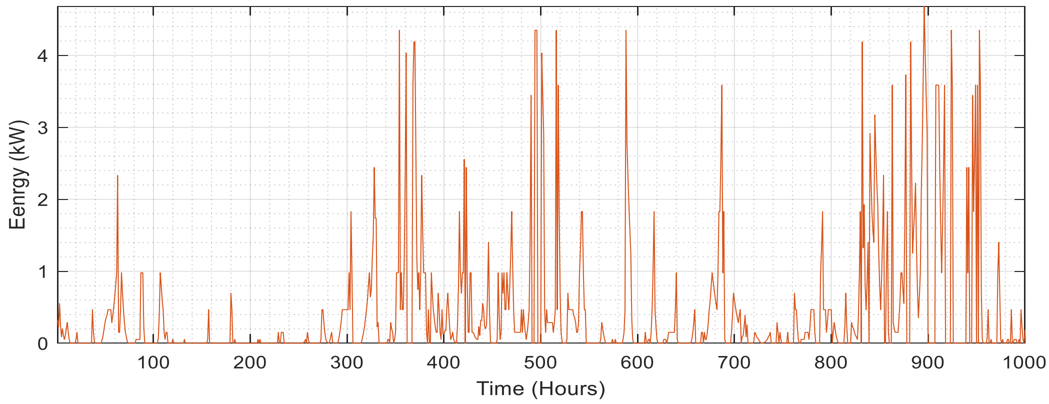

Figure 7. Output power from the WT.

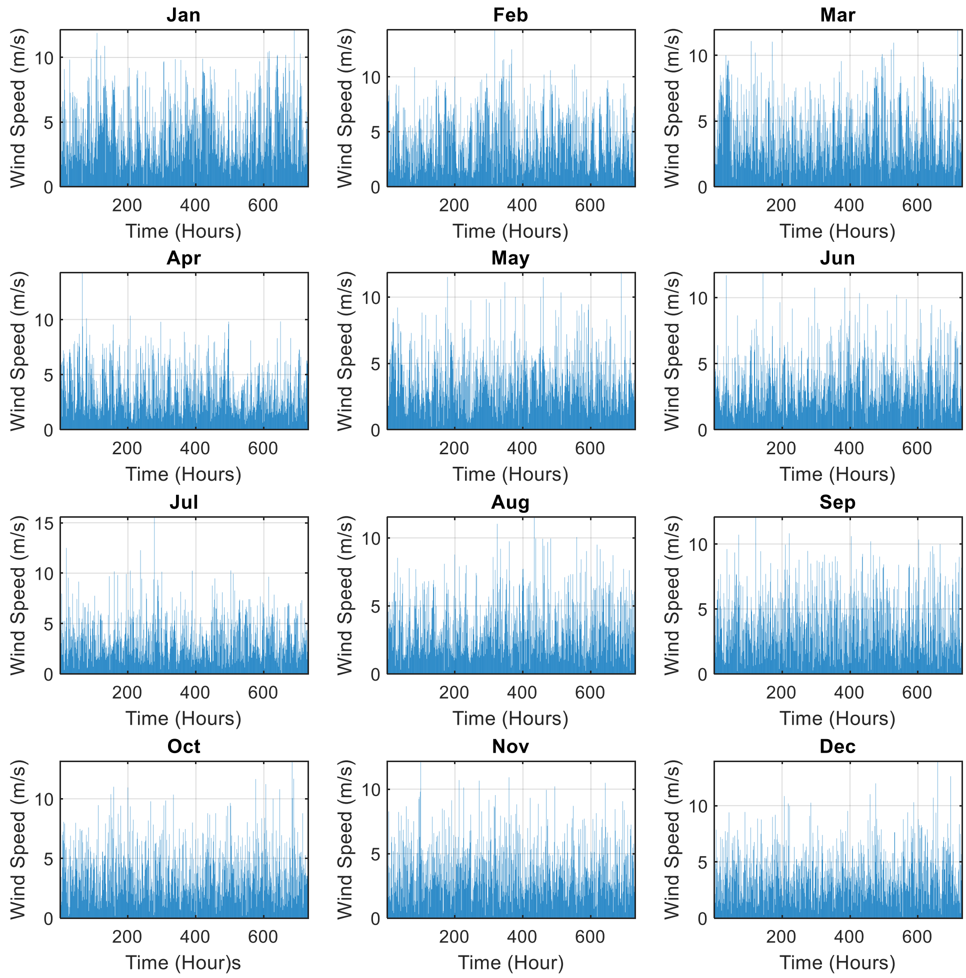

Figure 8. Monthly analysis of the wind speed data of the considered site.

Conclusion

In conclusion, Wind energy is a sustainable and renewable source of power that shows great potential for charging electric vehicles. Charging electric vehicles using wind energy is an environmentally friendly and sustainable solution. It involves harnessing the power of wind turbines to generate electricity, which is then used to charge electric vehicle batteries. This method helps reduce greenhouse gas emissions and dependence on fossil fuels. By utilizing wind energy, we can promote a cleaner transportation sector and contribute to combating climate change. For future studies, the Net Present Cost (NPC) and the payback period of the wind system should be considered in future studies along with the integrating other renewable energy sources.

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