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(Research Article)

Optimal charging of plug-in electric vehicles and renewable energy sources integration considering PV/WT/BT based on cost and emission reduction

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Abstract

The integration of Electric Vehicles (EVs) on the power system with Renewable Energy Sources (RESs) can have both positive and negative impacts. The positive impact could provide a comfort on the generation system and the EV, on the other hand, the negative impact increases the Greenhouse Gas (GHG) along with the cost and emission. Proper management and coordination will be needed to ensure that the integration is optimized for maximum benefit. The purpose of this article is to investigate the EV integration impact from the perspective of cost and reliability. The integration of EVs can also impact renewable energy generation. For example, if EVs are charged during periods of high renewable energy generation, it could lead to curtailment of RESs if the electricity demand from EVs is not balanced with the supply of renewable energy.

Keywords: EV; RESs; GHG; EV integration impact

1 Introduction

Solar and wind power can provide a continuous source of energy when properly designed and integrated into the power grid [1]. Energy storage systems such as batteries or pumped hydro storage, can also be used to store excess energy for later use [2]. While the availability of solar and wind power depends on weather conditions, advanced forecasting models and energy storage systems can help mitigate these challenges [3]. In terms of safety, Electric Vehicles (EVs) and other Renewable Energy Sources (RESs) are generally considered safe and reliable [4]. EVs have undergone rigorous safety testing and have numerous safety features built in [5], while solar and wind power systems do not have any moving parts that can cause accidents or injuries [6]. The integration of EVs with RESs can have cost implications for both the power system and the transportation sector [7]. The cost of EVs and the infrastructure needed to support them can be significant, and the cost of electricity from RESs can be higher than that of fossil fuels [8].

However, the cost of renewable energy has been decreasing rapidly in recent years, and the long-term benefits of reduced greenhouse gas emissions and improved air quality may outweigh the short-term costs [9]. The widespread adoption of EVs will require significant infrastructure investments in charging infrastructure, including public charging stations along with different standards and home charging stations [10], [11]. The integration of EV charging infrastructure with RESs can create opportunities for off-grid and distributed energy systems that can provide sustainable and resilient energy solutions [12].

This article contributes to the knowledge by investigating the integration impact of EV with RESs into the cost and emission as objective functions along with environmental impact. The recent of the article is organized as follows: In Section 2, the methods and materials has been discussed along with the RESs analyzed data. Section 3. Section 4.

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Eventually, the conclusion summary along followed by the list of recent cited references in the literature is closed the article.

2 Methods and materials

The integration of EVs with RESs can have cost implications for both the power system and the transportation sector [13]. The cost of EVs and the infrastructure needed to support them can be significant, and the cost of electricity from renewable energy sources can be higher than that of fossil fuels [14]. However, the cost of renewable energy has been decreasing rapidly in recent years, and the long-term benefits of reduced greenhouse gas emissions and improved air quality may outweigh the short-term costs [15]. The propped model consists of the PV/WT/BT integrated with the EV is shown in Figure 1. The comparison between fossil fuel and clean energy cost in the period of 2015-2023 is shown in Figure 2, while the global share of the RESs is presented kin Figure 3. As presented, the clean energy is having a rapidly increase in the future years due to its benefits in addressing the power, environment, cost limitations by integrating different forms of RESs.

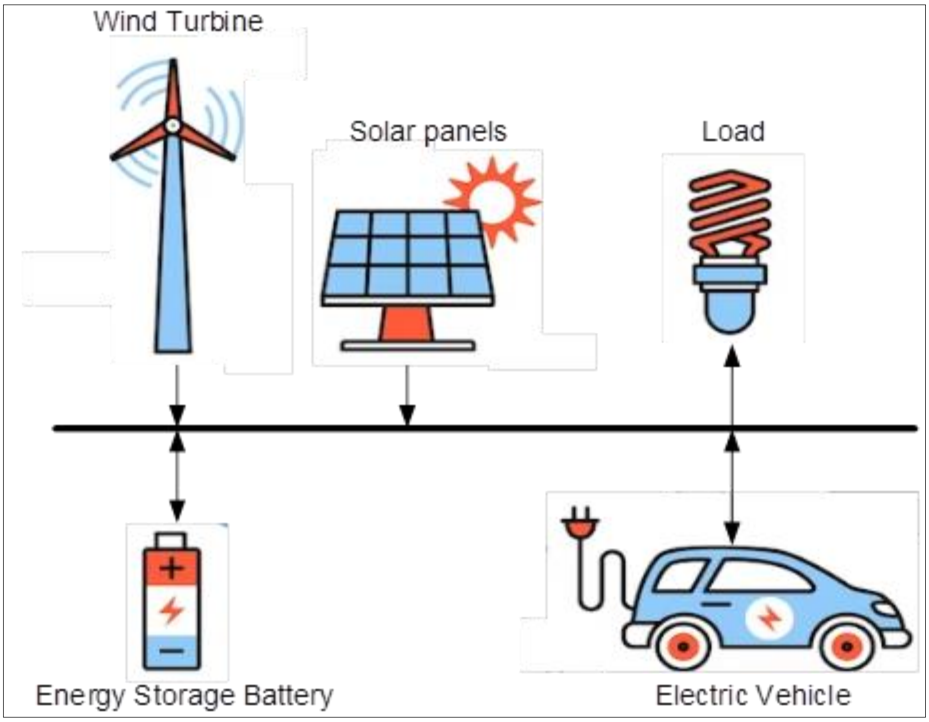

Figure 1 The proposed diagram

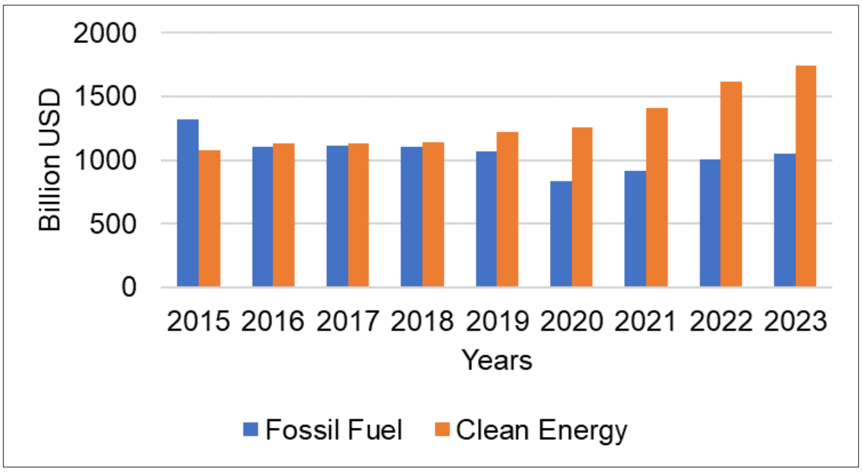

Figure 2 Comparison between fossil fuel and clean energy cost in 2015-2023.

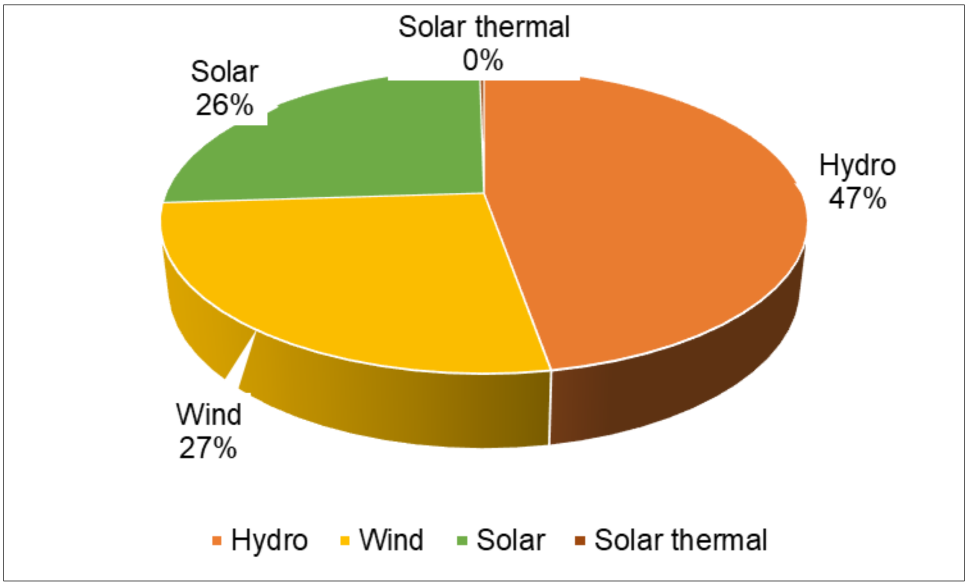

Figure 3 Global shared of renewable energy sources.

EV could make an effect on the power system with the integration of RESs [16]. The penetration of EVs on the power system can have both positive and negative impacts on the integration of RESs is demonstrated in Figure 4. As more EVs are adopted, there will be an increase in the demand for electricity. This can have a positive impact on the integration of RES as it can create a greater market for renewable energy. However, if the electricity demand from EVs is not balanced with the supply of renewable energy, it could lead to an increase in the use of fossil fuels [17].

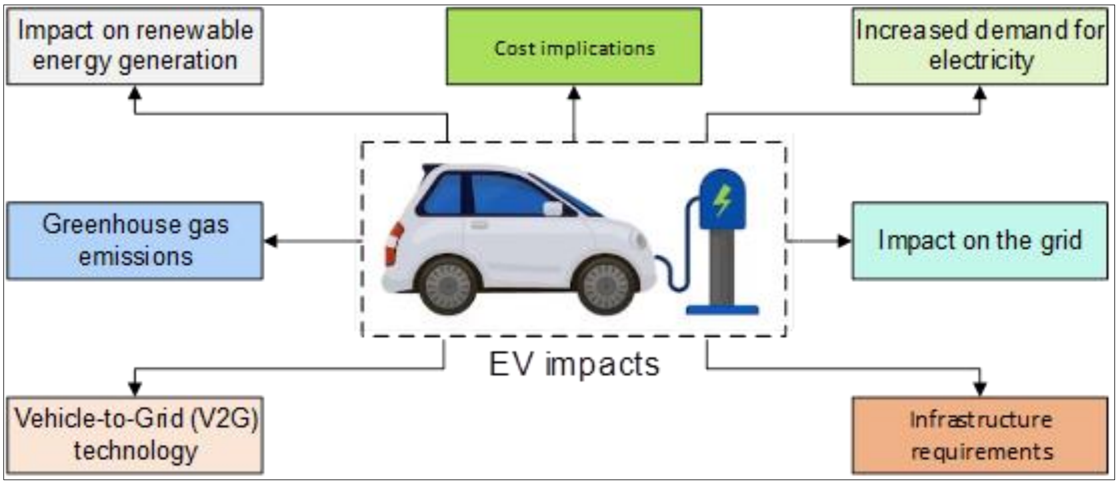

Figure 4 Electric Vehicle impacts.

3 Objective function

The objective function refers to the approach of optimizing the objective or goal [18]–[20]. The main objective function in this study are to minimize the cost and emission by integration EV and RESs in order not meet the required demand as will be in detailed in the sub section [21].

3.1 Cost

The Cost Of Electricity (COE) is the total amount of money that a consumer pays for the electricity they use [22]. This cost is made up of several components, including the cost of the electricity itself, the cost of transmission and distribution, and any taxes or fees associated with the electricity. The value of COE can be mathematically estimated as expressed in Eq. (1) with the help of Capital Recovery Factor (CRF) that presented in Eq. (2) that calculated based on the interest rate that mathematically presented in Eq. (3).

$$COE\left(\frac{\$}{kWh}\right) = \frac{Total\ Net\ Present\ Cost(\$)}{\sum_{h=1}^{h=8760} P_{load}(h)(kWh)} * CRF \quad (1)$$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (2)$$

where i is the interest rate that calculated by Eq. (3) with the help of the inflation rate (f), n is the lifetime of the project [23].

$$i = \frac{i' - f}{1 + f'} \quad (3)$$

3.2 Emission

The emission can be mathematically expressed as in Eq. (4) which measured in kg/h.

$$P_i = \sum_{i=2}^{N} (d_i + e_i p_i + f_i P_i^2)\ kg/h \quad (4)$$

where the d_i, f_i, e_i are the emission coefficient of i^{th} unit generating, p_i is the active power of each generator, N refers to the number of generators.

4 Results and Discussion

Due to the significant impact that EV make on the grid, environment, and RESs integration, the model system is required further investigation and provide several solutions. According to the system modeled in Figure 1 using MATLAB R2021a and Microsoft Office Excel that is running on an Intel (R) Core (TM) i5-8250U CPU @1.60 GHz. The obtained result is presented in Figure 5 for the output power from the utilized RESs (PV & WT). Figure 6 in terms of cost and emission in the case study. The utilized data that Implemented with the help of mathematical equation are analyzed and tabulated in Table 1.

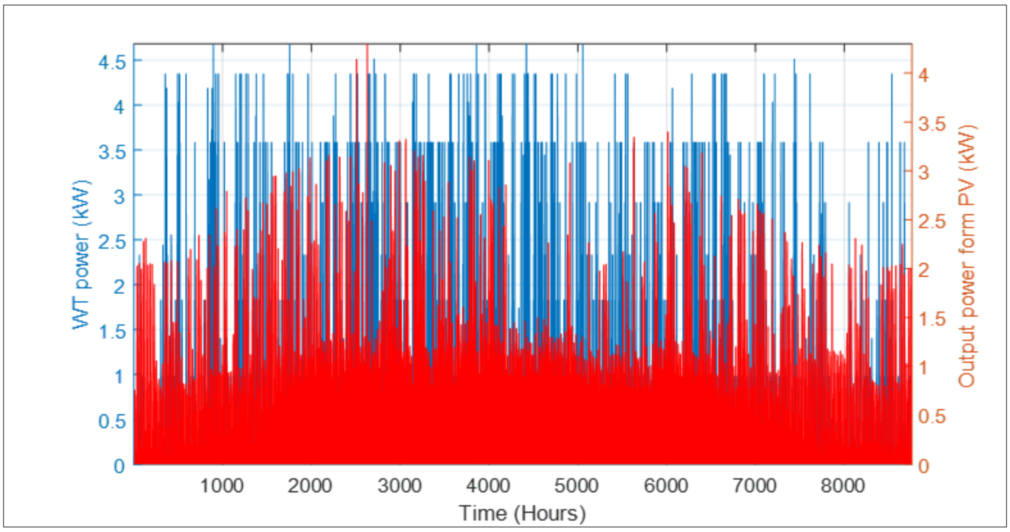

Figure 5 Outpower generated from PV and WT

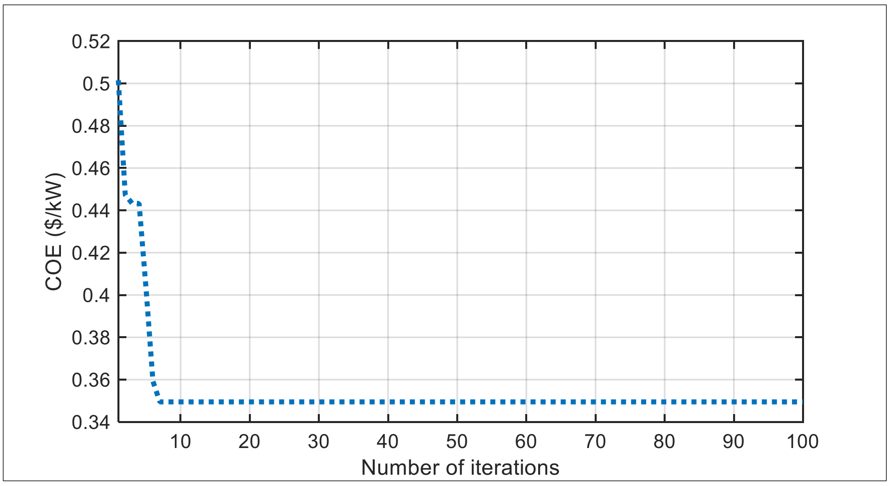

Figure 6 Cost and emission results

Table 1 Hourly solar radiation, ambient temperature, wind speed, load demand

Time (h)	Solar radiation (W/m²)	Wind speed (m/s)	Ambient temperature (°C)	Load demand (kW)
1	0	3.7	10	306.9
2	0	3.4	9.8	296.34
3	0	4.3	9.5	281.16
4	0	3.5	9.2	273.9
5	0	2.8	8.9	270.27
6	0	3.3	8.6	260.7
7	0	2.9	7.8	233.4
8	0	2.6	7	233.4
9	23	2.9	9.1	233.4
10	100	3.3	11.2	233.4
11	100	3.6	13.3	233.4
12	85	3.1	15.1	233.4
13	92	2.6	17	266.64
14	92	1	18.4	268.29
15	96	1.5	20	259.82
16	85	1.5	20	258.28
17	76	1.5	19	260.59
18	42	2.1	17	264.22
19	1	0	15	315.37
20	0	2.6	14.5	349.36
21	0	3.1	13	341.88
22	0	0	11	322.63
23	0	0	11	295.68
24	0	0	11	272.58

5 Conclusion

In conclusion, the integration of EVs with renewable energy sources can provide opportunities for decarbonization and increased energy efficiency. However, careful planning and management will be needed to address the challenges and maximize the benefits of this integration. Governments, utilities, and other stakeholders will need to work together to develop policies, regulations, and incentives that encourage the adoption of EVs and the integration of renewable energy sources into the power system.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no competing interests.

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