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Solar energy roles in charging electric vehicles

Adel Ramadan Hussien Mohamed [1,*] and Abdussalam Ali Ahmed [2]

[1] *Higher Institute of Engineering Technology, Bani Walid, Libya.*
[2] *Department of Mechanical and Industrial Engineering, Bani Waleed University, Bani Waleed, Libya.*

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Abstract

Solar Energy (SE) plays a crucial role in charging Electric Vehicles (EVs), providing a sustainable and renewable source of power. This explores the significance of solar energy in charging EVs, highlighting its environmental impact, economic benefits, and technological advancements. However, solar energy could face a limitation of intermittency due to the changeable weather throughout the year and the speed of charging the EVs. The integrated technology in charging EVs represents a crucial step toward sustainable transportation. By reducing emissions, offering economic benefits, and leveraging technological advancements, solar-powered EV charging contributes to a cleaner and more energy-efficient future.

Keywords: SE; EV; Sustainable; Renewable Sources

1. Introduction

Solar energy can play a significant role in Electric Vehicle Charging Stations (EVCS) or carports by incorporating solar panels into the charging infrastructure [1]. Besides, it is possible to generate renewable energy onsite to power the charging process [2]. This reduces reliance on the grid and decreases the carbon footprint of electric vehicles [3]. Solar energy has the ability of reducing the carbon emission in transportation sector by switching into EV rather than Internal Combustion Engine Vehicle (ICEV) and exploit the Renewable Energy Sources (RESs) could combat the climate changes [4]. Additionally, EVs produce zero tailpipe emissions, meaning they don't release any Carbon Dioxide (CO_2) or other harmful pollutants while driving. Several studies have been conducted in the state-of-the-art for the utilization of solar energy and its impacts on the environment, economic, and technological advancement [5]. Based on the fact that 10 Photovoltaics (PVs) should provide roughly enough electricity to power 21 km of electric driving each year [6]. Due to the merits provided by solar energy such as Fight climate changes and provide a clean energy with low carbon, it considered as of the most of utilized renewable sources [7]. Several forms can be used for solar energy such as Concentrated Solar Power (CSP), solar panels, solar cooking, solar thermal, and solar water heating and others [8]. EVs have different form, its classification and topologies are presented in [9].

Solar energy contributes to electric vehicle charging stations in two primary ways based on the location [10]. Furthermore, off-grid charging station where grid connections are not feasible as remote areas, solar panels can provide a reliable power source for EV charging stations [11]. These standalone systems use solar energy to directly charge the vehicles, making them independent of the traditional electricity grid [12]. On contrary, the Grid-connected charging that solar panels installed at charging stations can generate electricity, which is then fed into the grid [13]. While the electricity generated may not be directly used by the charging station, it offsets the energy demand from conventional sources [14]. This helps reduce Greenhouse Gas (GHG) emissions associated with charging electric vehicles [15]. Incorporating solar energy into EV charging stations has several benefits, including reducing reliance on non-renewable energy sources, promoting sustainability, and lowering operating costs over time [16].

* Corresponding author: Adel Ramadan Hussien Mohamed

The contribution of the knowledge in this article is utilizing the solar energy in order to meet the EV charging demand and provide a green energy to improve sustainability. The reset of the article are organized as follows: Section 2 is presented the Methods and Materials along with the global data and collected data for the case study. The Modeling of the proposed system is discussed and presented in Section 3. Discussion of the obtained results are discussion in Section 4. Eventually, the conclusion including the future recommendation followed by the list of references are closing the article.

2. Material and methods

Solar energy is becoming the third most important renewable source in terms of globally installed of capacity, after hydro and wind power [17]. Globally, solar power as presented in Figure 1 can be used for various purposes such as electricity generation, water heating or even cooking [18]. Moreover, using solar power helps save the electricity bill, provide a clean energy, low carbon, fights climate change, allow power remote location, and can be used as backup power in cases of outage. The cumulative power capacity shared for the renewable (PV and WT) and natural gas for the period of 2010-2027 based on IEA is presented in Figure 2. The solar irradiance data of the case study is demonstrated in Figure 3 that utilized along with mathematical equations in order to estimate the output power for the PV.

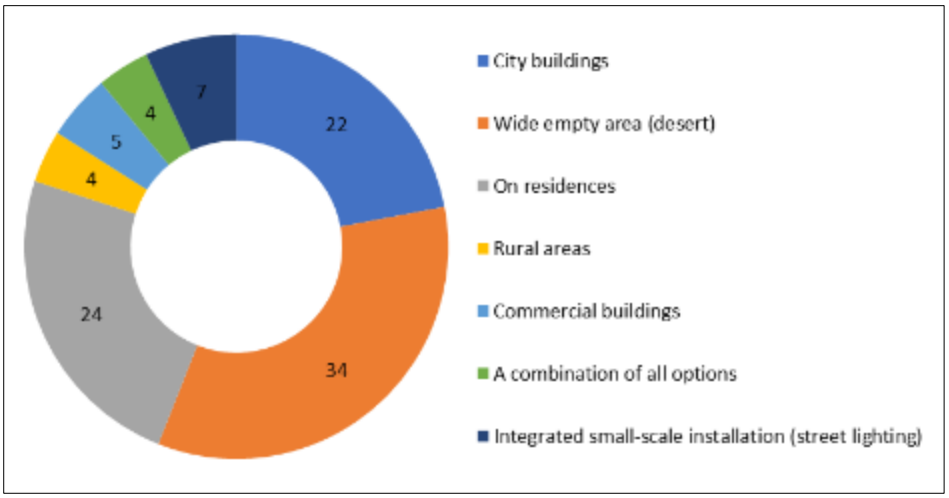

Figure 1 Global PV contribution

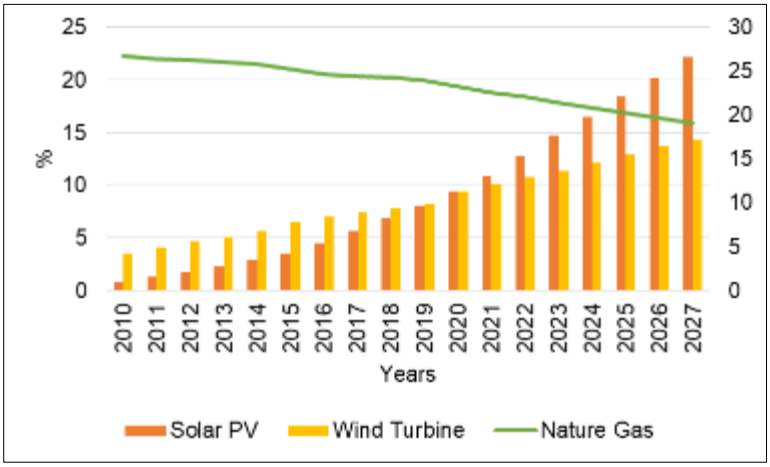

Figure 2 Share of cumulative power capacity by technology, 2010-2027 based on IEA

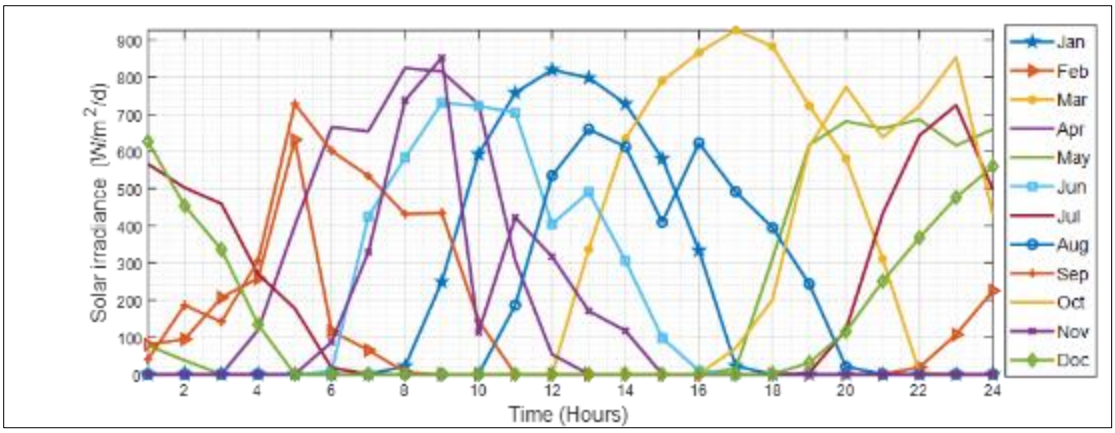

Figure 3 Solar irradiance of the case study area

Solar energy harnessing energy from the sun, solar panels can generate electricity that is used to charge EVs [19]. Some of the roles of PV in charging station can be presented in Figure 4. While solar energy can contribute to charging stations, it's important to note that incorporating energy storage solutions such as batteries may be necessary to ensure round-the-clock availability of charging services, especially during periods of low sunlight or high demand.

- Grid Independence
- Cost Savings
- On-Site Generation
- Renewable and Clean
- Scalability and Expansion

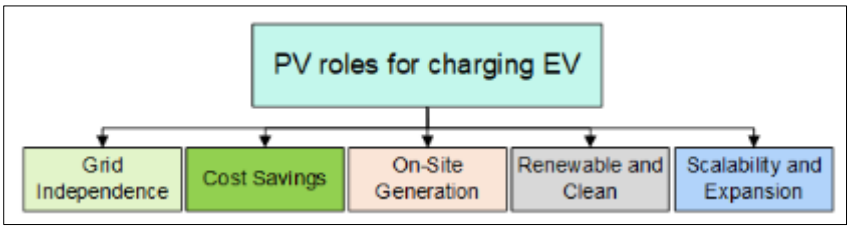

Figure 4 Solar energy Roles for electric vehicle charge station

Solar energy highlighted as hot topic among research's as shown in Figure 5 that offers a sustainable and renewable source of power for charging EVs, reducing dependency on traditional electricity grids [20]. It is providing an eco-friendly power source for charging electric vehicles [21]. These kinds of stations use the electricity generated from sunlight to charge EV batteries directly which is beneficial in remote areas or during power outages [22]. Moreover, it is environmentally beneficial that reduce carbon emissions from fossil fuel combustion, promoting a greener transportation sector [23].

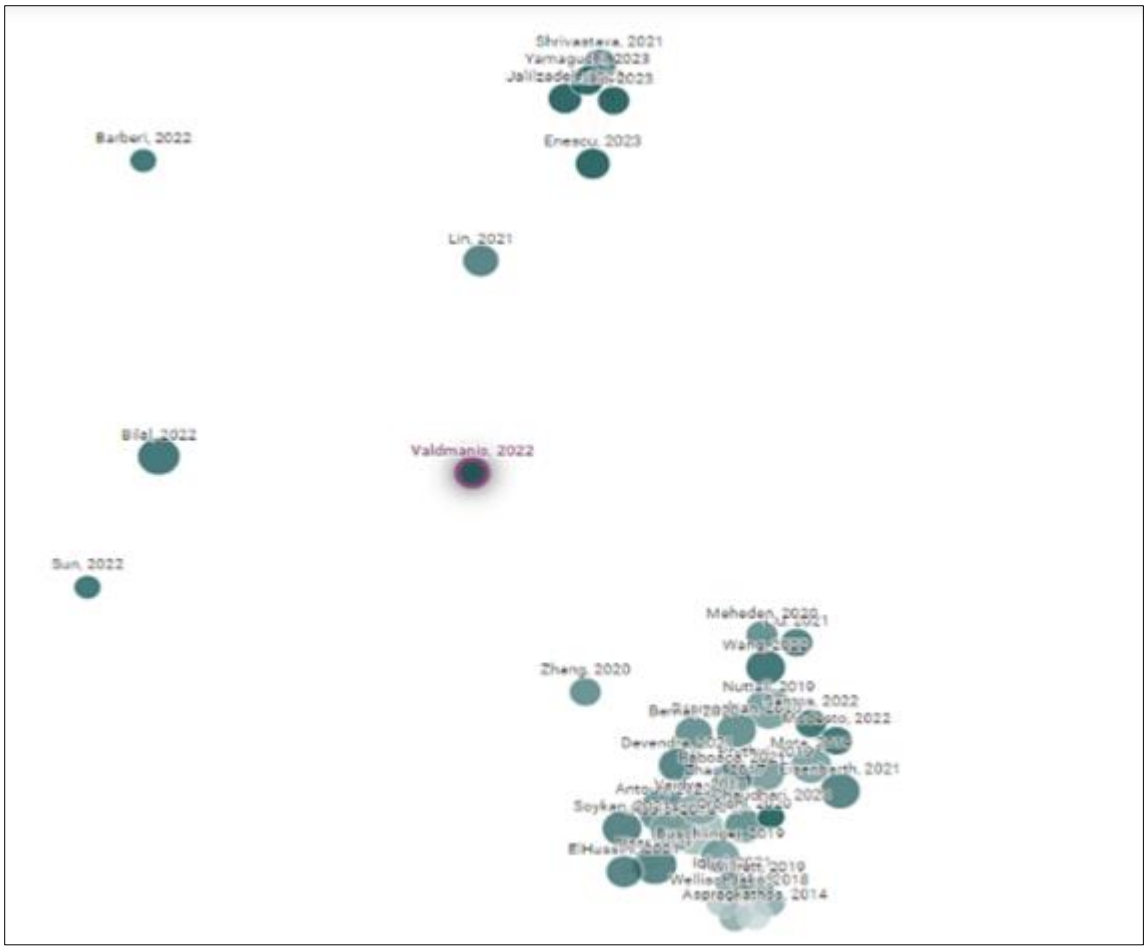

Figure 5 VOS viewer co-occurrence map visualization of solar energy for electric vehicle charging station

2.1. Modeling of the proposed system

Impacts and mathematical equations [24]. Integrating solar panels with EV charging stations creates a sustainable charging infrastructure as shown in Figure 6. This allows EV owners to charge their vehicles with clean energy, further minimizing their carbon footprint [25].

Figure 6 The proposed diagram for charging EV using PV

The mathematical equation that utilized to generate the power from the PV is expressed in Eq. (1) [24].

$$P_{PV}(t) = P_{(PV_{rated})} \times \frac{G_{(t)}}{1000} \times \left[1 + \alpha_t \left(\begin{matrix} T_{amb} + (G_{(t)} \times \\ \left(\frac{NOCT-20}{800}\right) - T_{C_{STC}} \end{matrix} \right)\right] \ldots\ldots\ldots \quad (1)$$

where the $P_{PV}(t)$ denoted be the obtained output power from the PV (Watt) at a time (t), $P_{(PV_{rated})}$ is the PV-rated power in (Watt), $G_{(t)}$ represents the solar irradiance throughout the year (W/m2), 1000 (W/m2) is the rated radiation at the earth's surface, the irradiance on the cell surface (800 W/m2), α_t is the ambient temperature coefficient, which equals (-3.7×10^{-3}), T_{amb} refers to the ambient temperature (°C), $T_{C_{STC}}$ is the cell temparuture at Standard Test Condition (STC) [26]. Additionally, 20 refers to the air temperature in (°C) while the considered value of Nominal Operation Cell Temperature (NOCT) which is 45 (°C) is taken in consideration in this study (depending on the PV module given by the manufacturer).

3. Results and discussion

Reducing carbon emission in the transportation sector can be acquired by integrating solar panels in the Electric Vehicle Charging stations. Nevertheless, exploiting public transportation to ensure sustainable and promote a cleaner future, and avoid the fossil fuel. renewable energy source, sustainable charging Infrastructure, off-grid charging, energy Independence, cost savings, and grid integration and Energy storage. The monthly maximum of the generated power from the PV is tabulated in Table 1. Further explanation, the output power of PV to meet the EV demand is figured in Figure 7.

Table 1 Monthly max of generated power from PV

Months	PV output (kW)	Months	PV output (kW)
Jan	4.349	Jul	4.682
Feb	4.683	Aug	4.349
Mar	4.683	Sep	4.349
Apr	4.513	Oct	4.349
May	4.349	Nov	4.513
Jun	4.682	Dec	4.349

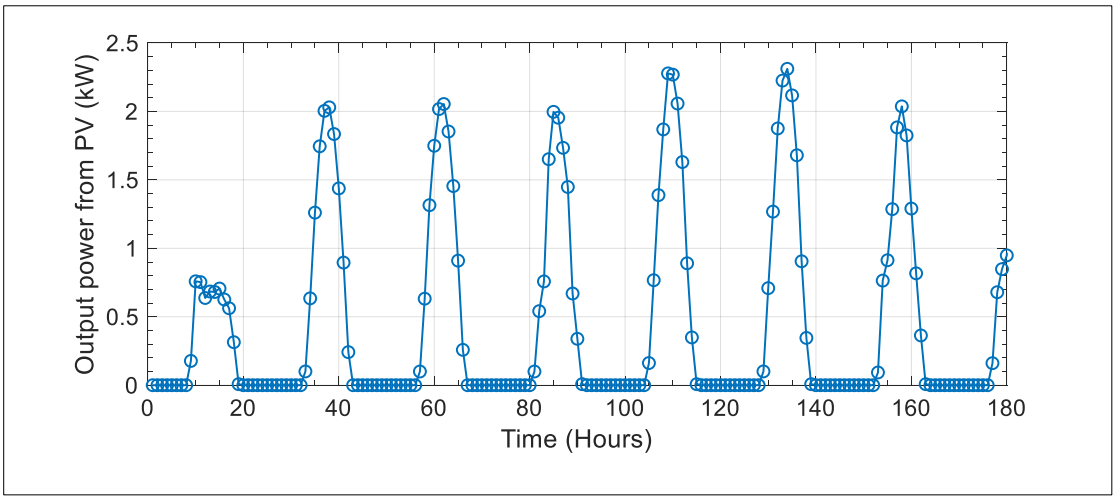

Figure 7 Generated output power of PV to charge the electric vehicle

While the EV demand that has been met by the PV is illustrated in Figure 8 (a) and Figure 8 (b), respectively. Furthermore, the presented demand is based on the State-of-Charge of EV, this is the reason the demand is presented with randomly changes.

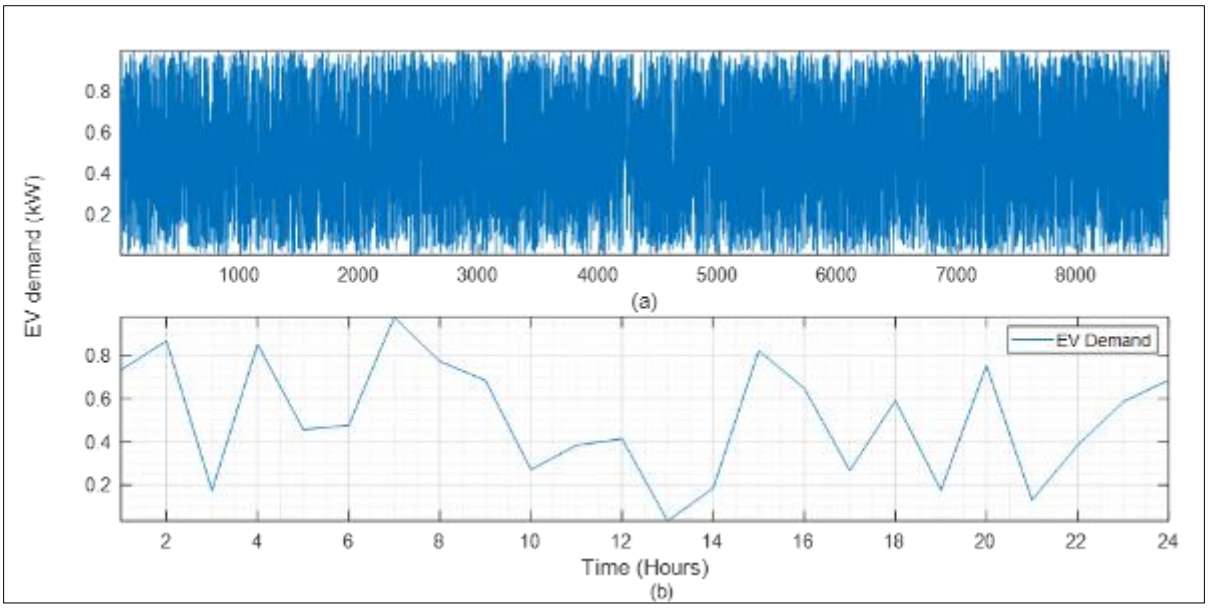

Figure 8 EV demand

4. Conclusion

In conclusion, solar energy plays a vital role in charging EVs, offering environmental benefits, energy independence, cost savings, grid stabilization, and scalability. Incorporating solar power into the EV charging ecosystem helps promote sustainable transportation and a cleaner future. While solar energy is a promising solution for EV charging, certain challenges remain, such as limited charging speed and the need for additional infrastructure. However, ongoing advancements in solar panel efficiency and battery technology are steadily addressing these obstacles, making solar energy an increasingly viable and sustainable option for powering electric vehicles.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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