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Stochastic Method for Electric Vehicle Integration Considering Renewability Maximization and Reliability Minimization

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Abstract:

Electric Vehicles (EV) can act as backup energy sources by storing extra energy from the power grid in their batteries during periods of low demand and resupplying that energy to the grid during periods of high demand. This calls for the vehicles to be linked to the grid which forms the Vehicle-to-Grid (V2G) technology and ready to provide energy as required. The EVs might not be accessible or readily available for this purpose in an emergency event, such as a natural disaster. To estimate the uncertain integration of EV through Stochastic method namely Stochastic Monte Carlo Simulation (SMCS). By achieving the two proposed objectives to gain a reliable and renewable system based on the aforementioned stochastic method. As a result, the reliability and renewability along with the energy comparison result are discussed.

Keywords: EV, V2G, SMCS

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Introduction

Electric vehicles (EVs) can transmit energy back to the grid through Vehicle-to-Grid (V2G) operation in addition to consuming energy from the grid that known as Grid-to-Vehicle (G2V) [1]. The aforementioned integration accepts alternative sources such as PV and WT [2], however, it faces intermittent and fluctuation due to the uncertain behavior of the integrated EV and climatology changes [3]. The aforesaid problem can be overcome with the help of stochastic algorithms. To aid in decision-making in complex situations, John von Neumann and Stanislaw Ulam developed the Monte Carlo Method during World War II. Given that chance is a key component of the modeling approach, comparable to a game of roulette, it was named after a well-known casino town called Monaco. The main objective of this study is to estimate the amount of power loss and renewability during charging period for 10 EVs.

Related work

The integration of RESs for charging EV is conducted in various studies [4]. The V2G technology is presented in the state-of-the-art considering various optimization methods for sizing system configurations such as Stochastic Monte Carlo Simulation (SMCS) and Multi-objective particle swarm optimization (MOPSO) [5]–[7]. Technical and comprehensive review articles were found in the literature studying the cases of design and optimize the system components with the present of EV and RESs integration [8]. Studying the merits of V2G technology is conducted in a study to reduce the charging peak in the charging station is reported in [9] that exploiting the Jeju Island as a case study. RESs with the present of EV integration that forms V2G sized with the help of multi-objective algorithm [10]. Many conducted researchers studying the challenges and along with technical

requirements for EV charging stations [6]. An analysis for HEV integration controlled by a supervisory control method known as Rule-based [11]. The limitation of fluctuation and intermittency of RESs can be addressed by integrating energy storge systems to stabilize the system [12], [13].
This article contributes by providing a losses and renewability estimation analysis result for EV charging based on Stochastic Monte Carlo Simulation. The rest the article is organized as follows: Section 2 represents the general definition of optimization algorithm along with brief description about the utilized stochastic method. Section 3 discusses the objective function of the study from the perspective of mathematical equations. The summery discussion of the obtained result is placed in Section 4. Eventually, the article conclusion followed by the recent list of references is closing the article.

Optimization techniques

Technology is not complete without algorithms, which allow computers and other devices to process data and reach a decision [10]. Two important types of algorithms—deterministic algorithms and stochastic algorithms—join the diverse group of algorithms. The same input always yields the same outcome in a deterministic algorithm since the rules are predetermined and not random [14]. However, a stochastic algorithm introduces unpredictability into the program's operation as it iteratively seeks an ideal outcome [15]. Another study conducted the stochastic method for managing the charging station [16]. Stochastic algorithms are a class of mathematical methods that use probability or unpredictability to solve issues or reach judgments [17]. These methods are employed in the modeling of uncertain or stochastic systems. Brownian motion, Markov chains, and Stochastic Monte Carlo simulation are a few examples of stochastic algorithms [18].

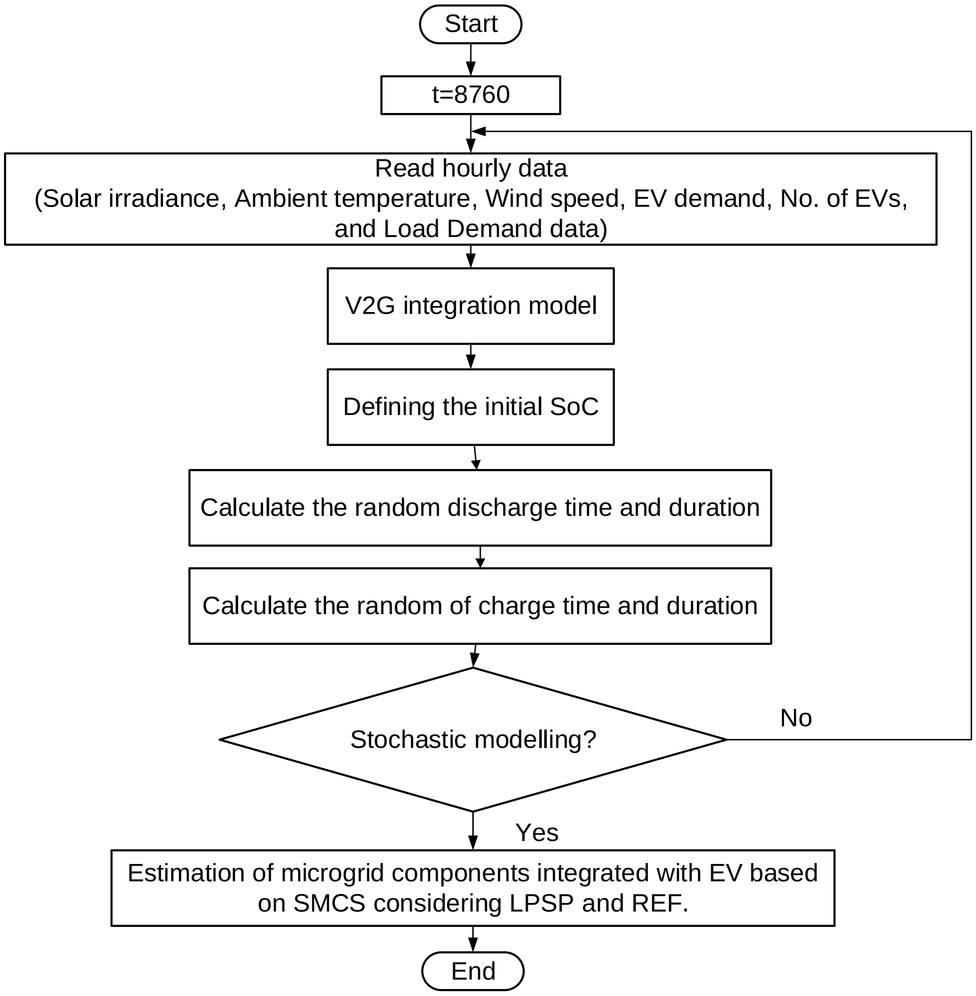

Figure 1. Flowchart of Stochastic Monte Carlo simulation.

Objective Function

The objective function can be defined as the trad-off of the connected parameters in the system in order to gain a reliable and renewable system [19].

Loss Power Supply Probability

The probability of a power supply system experiencing a power loss or interruption is referred to as Losses Power Supply Probability (LPSP) as mathematically counted in Eq. (1) that ranges between 0 and 1 [20]. Furthermore, the 0 refers to meeting the demand without losses, while 1 refers to unmet the demand. A more reliable system with fewer power supply losses is indicated by lower percentages or decimal figures, whereas a less reliable system with more frequent power outages is indicated by greater percentages or decimal values.

$$LPSP = \frac{\sum_{i=1}^{N}\left[P_L(t) - \left(P_{WT}(\mathrm{t}) + P_{PV}(t) + SoC_{BT}(\mathrm{t}) + SoC_{EV}(\mathrm{t})\right)\right]}{\sum_{i=1}^{N} P_L(\mathrm{t})} \quad (1)$$

where the LPSP refers to the losses power supply probability in (%), $P_L(t)$ is the load demand of the considered case study in time of (t) that measured by (kW), and $P_{PV}(t)$ is the output power generated from the PV in (kW). Additionally, the $P_{WT}(t)$ represents the generated output power from the WT in time (t) that scaled in (kW), the $SoC_{BT}(\mathrm{t})$ and $SoC_{EV}(\mathrm{t})$ are the state of charge of the deep cycle battery and EV battery, respectively.

Renewable Energy Fraction

The Renewable Energy Fraction (REF) is a measurement of the percentage of an area's or nation's energy that comes from renewable resources as presented in Eq. (2). This is computed by dividing the total energy produced from renewable sources—such as solar, wind, hydro, geothermal, and bioenergy—by the total energy produced from all sources (renewable and non-renewable), and then expressing the result as a percentage [21].

$$REF = \frac{\sum_{1}^{8760}(P_{PV} + P_{WT}) * \Delta t}{\sum_{1}^{8760}\left(P_{PV} + P_{WT} + P_{grid_{purchased}}\right) * \Delta t} \quad (2)$$

The REF calculated the percentage output power from the exploited RESs (PV and WT) and $P_{grid_{purchased}}$ is the amount of purchased energy from the grid to charge the EVs and other electric appliances.

Simulation results and discussion

Therefore, the comparison of load demand with and without the integration of EV is presented in Figure 2. The shown impact of electric vehicles on the grid is during charging period. As a crucial tool for reducing the consequences of climate change is the EV, the number of EV that proposed to be charged during first 24 h is presented in Figure 3. Figure 4 presented the LPSP analysis results that show the values that range between 0 and 1, which show close to the value of 0 that refers to meeting the demand with lower losses.

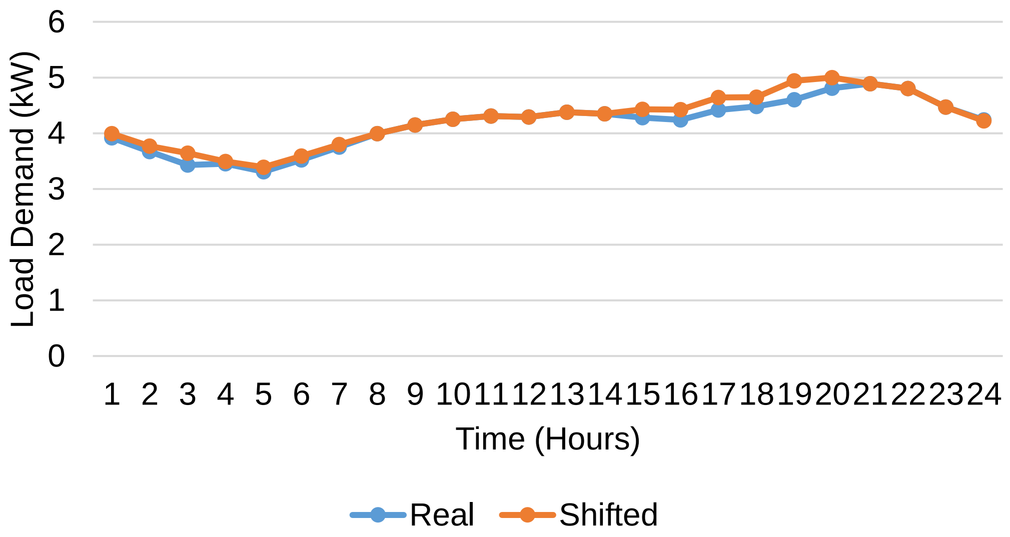

Figure 2. Original and shifted load demand.

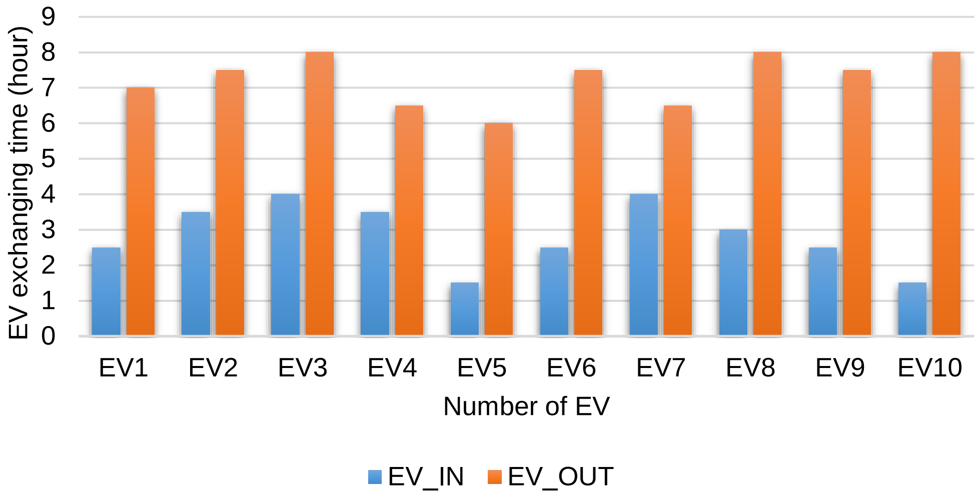

Figure 3. EV arrival and departure.

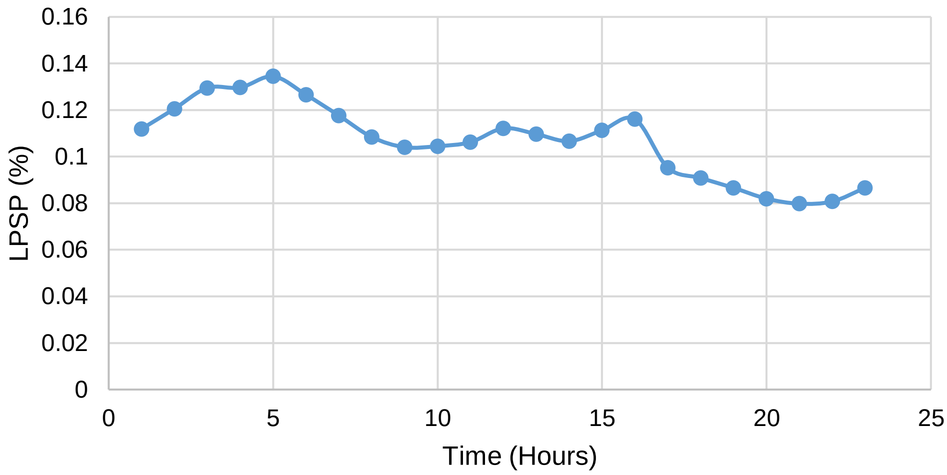

Figure 4. Losses Power Supply Probability analysis results.

The acquired analysis result of the renewability is presented in Figure 5. As presented, the values are varying from time to time, while the drop at 18 pm refers to the sunset time which is not having a sufficient radiation to generate enough energy from the RESs.

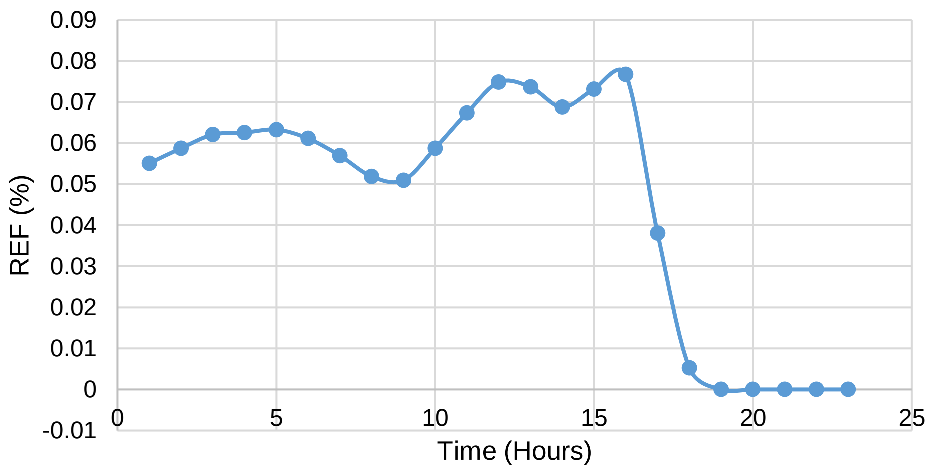

Figure 5. Renewable Energy Fraction analysis results.

Based on the stochastic method result, Figure 6 is demonstrating the seasonal output of the energy under four scenarios and four seasons. Furthermore, the obtained values in terms of kWh of consumed energy from grid, energy consumed from driver, RESs energy, and the exported energy from EV, respectively. The higher amount present from the driver when charging the EV from the grid, RESs energy is positioned as second energy, and the lowest energy is the exported energy from the EV, respectively. The previous statement represents the V2G technology is a reliable, renewable, and economic technology.

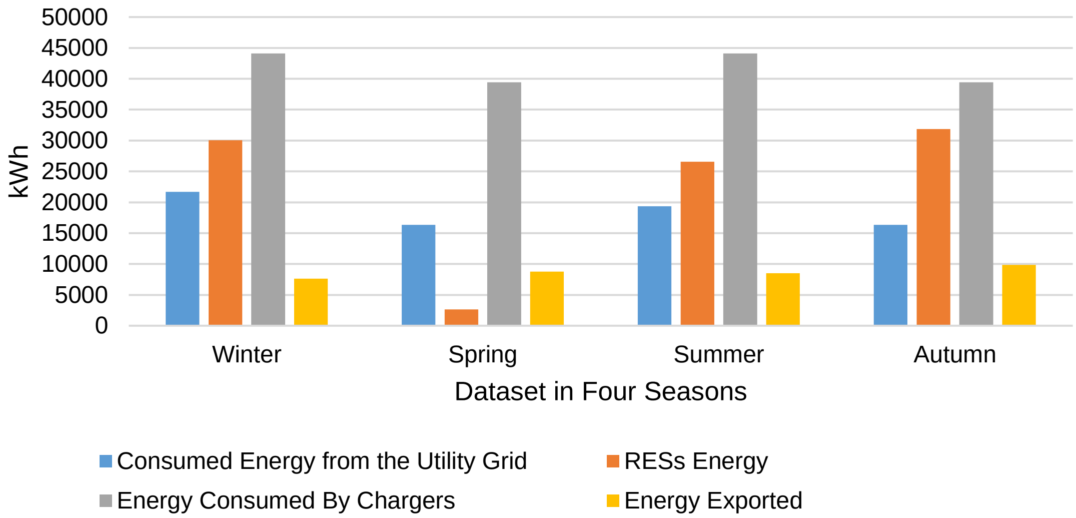

Figure 6. Comparison results of the system operation.

Conclusion

In the nutshell, EV integration with renewable energy sources can present chances for decarbonization and improved energy efficiency. To deal with the difficulties and optimize the advantages of this integration, though, careful planning and management will be required. The development of laws, rules, and incentives to promote the use of EVs and the incorporation of renewable energy sources into the power grid would require cooperation between governments, utilities, and other stakeholders. The utilized objective has been achieved for the case study. Further studies may explore another random method such as Brownian motion or Markov chains in order to estimate the uncertain behavior of the integrated EVs.

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