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Prediction of Electric Vehicle Charging Stations Distribution in Kuwait

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Abstract Kuwait has an area of 17,818 sq. km and a population of 4.3 million residents most of whom live in its urban centers, with a dry desert climate and poor agricultural cover. Demand for electric vehicles (EVs) in Kuwait is currently low. Between January and October 2021, only 88 EVs were sold in Kuwait. However, EV sales in Kuwait are expected to grow exponentially in the future. More than 50% of drivers in the country have positive attitudes toward EVs. In addition, Kuwait aims to reduce greenhouse gas (GHG) emissions and build a sustainable economy. Comparative statistical data reveals that, in 2021, Trends in oil-dependent economies related to EV adoption reflect the future of the EV market in Kuwait. The multi-criteria decision analysis approach is the method Kuwait is currently applying to optimize the infrastructure and distribution of electric vehicle charging stations (EVCS). It is an analytical hierarchy process (AHP) for establishing the sites of EVCS and enhancing their spatial distribution. Kuwait will likely integrate AHP algorithms with the geographical information system (GIS) to optimize the distribution of EV chargers, including within on-road parking spaces and off-road charging sites. Its EVCS network could include level 1-3 charging modes. Furthermore, Kuwait could leverage an EVCS management system to enhance the efficiency of EVCS operations. This research is aimed at predicting the distribution of electric vehicle charging stations in Kuwait.

Keywords Charging Stations, Electric Vehicle, Kuwait and Distribution

1. Introduction

Electric vehicles (EVs), charging optimization, and distributed generation are key paradigms addressed by sustainable transportation research [1]. Environmental concerns contribute to the growing popularity of EVs [2-4]. However, the efficiency of the current power system infrastructure in meeting the rising demand for EVs should be analyzed. Kuwait lacks infrastructural facilities designed to inspire EV adoption, such as EV-dedicated lanes, smart charging systems, and discounted or free EV parking [5]. The nation has only 31 AC cooperative or commercially sponsored EV charging facilities [5]. However, Kuwait is a promising EV market due to the urgency to minimize greenhouse gas (GHG) emissions and optimize air quality [6]. Moreover, empirical evidence indicates that over 50% of Kuwait residents have favorable attitudes toward electric vehicles [6]. An analysis of electric passenger vehicles charging stations (EVCS) infrastructure in Kuwait is vital for predicting its distribution and implications for conventional gas stations. In addition, the other type of electrical charging infrastructure for large vehicles that served a large population, Kuwait public transportation company (KPTC-government company), which can be covered in future studies.

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2. Electric Vehicle Sales in Kuwait

The demand for EVs in Kuwait and other Gulf Cooperation Council (GCC) countries is generally low [7]. Statistical data shows that only 88 EVs were sold in Kuwait between January and October 2021 [8]. Low oil prices in Kuwait contribute to the minimal demand for EVs. Nonetheless, EV sales in the country are expected to rise in the future. Notably, the Kuwait government provides residents with generous subsidies for utilities which also contributes to the low sales of EV's [8]. However, EV sales in Kuwait will increase following the implementation of government interventions for encouraging sustainable transportation. For example, the government could subsidize electricity and increase oil prices in order to promote EV adoption and alleviate adverse environmental impacts associated with the use of conventional vehicles. Markedly, Norway, another oil-producing nation, sold 800 times more

EVs and plug-in hybrid electric vehicles (PHEVs) than Kuwait in 2021 [8]. The comparative statistical data show that EV sales in Kuwait will likely match those of other oil-producing nations in the future. The optimal placement of EVCS, smart charging systems, and robust distribution network and infrastructure are solutions that would contribute to a rise in EV sales or adoption in Kuwait. Moreover, the exponential rise in Kuwait's population and industrialization correlates with increased demand for vehicles [8].

Comparative statistical data depicting an increase in EV sales in the Gulf region indicates the expected market landscape of EVs in Kuwait. The region's nations aim to achieve 30% vehicle electrification by 2030 [9]. The fossil fuel reduction targets in GCC countries inspire programs for enhancing road transport electrification. Fossil fuel-driven economies like Kuwait should establish and implement comprehensive policy frameworks and programs aimed at advancing their sustainability goals. Improving EV penetration in Kuwait is a precondition for diversifying its economy and lessening its dependence on oil. The country should pursue Intended Nationally Determined Contributions (INDCs) goals to limit the environmental impact of its oil-dependent economy. In addition, Kuwait should subsidize EVs and their accessories to encourage adoption and increase their sales. Moreover, it should enhance standards for EV chargers to promote shorter charging time. another study can cover Kuwait public transportation buses (government company) which could be contributed to encourage people for using EV.

3. New Outcomes and Optimal Placement of EVCS

The multi-criteria decision-making (MCDM) methodology is applied to optimize the siting of EVCS in Kuwait [10]. It is an analytical hierarchy process (AHP) useful for establishing the locations of EVCS [11,12]. The MCDM algorithms would enable Kuwait to address challenges related to the spatial siting of on-road EVCS. In addition, the country would integrate EV chargers into on-road parking spaces with smart chargers to optimize the distribution of EV charging infrastructure. More importantly, off-road charging sites designed to power multiple vehicles concurrently should be part of the nation's EV charging solutions. The implementation of the AHP technique encompasses four spatial siting methodologies: criteria determination, criteria weighing, EVCS availability score, and site ranking [13].

The combination of AHP and the geographical information system (GIS) provides a robust approach to optimizing EVCS spatial siting [13,14]. It stipulates the mapping of EVCS based on location-specific data like geography, road infrastructure, and demographics. Markedly, Kuwait is generally densely populated, with a population of 4.3 million, most of which live in metropolitan areas [15]. Demographic and geographical data should be utilized in planning and optimizing Kuwait's EVCS infrastructure. Figure 1 depicts Kuwait's main urban locations. The program for enhancing Kuwait's EVCS network should initially focus on its main urban areas because of its dense population and potential for an increase in EV adoption. In addition, the AHP-GIS model applies to assessing and addressing constraints that affect EVCS siting. They include road type, slope, access, on-road parking, EV charging points, and car parks [16].

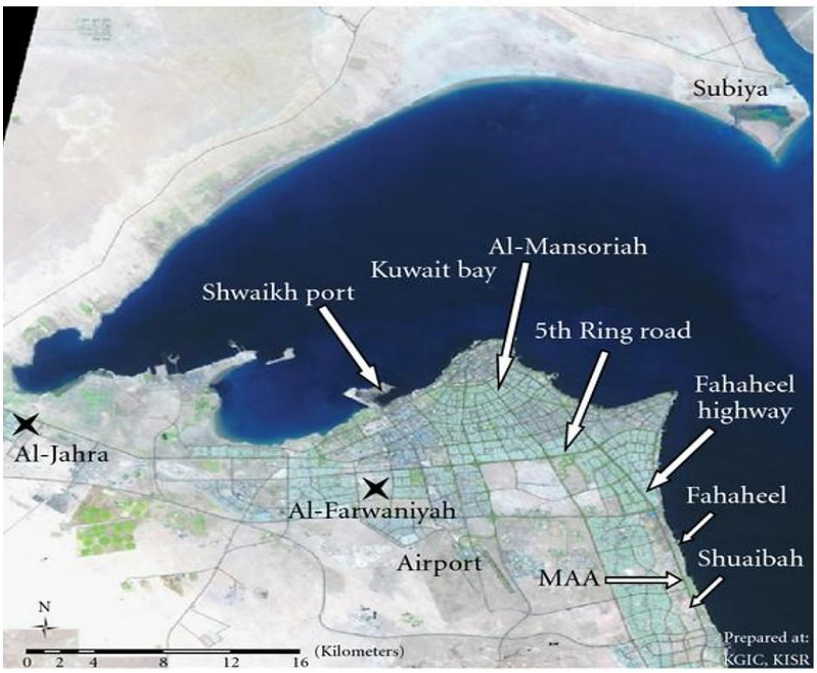

Figure 1. Main locations in urban Kuwait [17]

More importantly, the AHP-GIS model would allow Kuwait to optimize its EV charging infrastructure based on suitability criteria such as petrol stations, EV ownership, off-road parking, population distribution, and a low-voltage electric network.

Additionally, Kuwait could leverage pervasive mobility data to enhance the deployment and distribution of its EV charging network and infrastructure. A data-driven optimization framework is useful for the efficacious siting of EVCS within urban centers [18]. The datasets used with data-driven optimization approaches include EV taxi-trajectory and mobile phone data. Notably, the optimization framework begins with demand modeling, which encompasses designing energy demand models congruent with EV trip trajectories [18]. Then it proceeds to optimization model formulation, which includes framing the location optimization challenge. Data analysis in the data-driven optimization framework deployment entails estimating EV energy demand in line with EV adoption rates [18]. It also concludes with the stipulation of optimization methods to establish the optimal locations for EVCS [18].

Kuwait should optimize its EVCS infrastructure by including various charging modes and techniques to meet the needs of different EV car consumers. Notably, there are three charging levels for EVs that can be incorporated into Kuwait's EVCS network. Level 1 charging encompasses universally compatible charge cables plugged into 120V outlets [19]. Level 2 charging includes stations within residential and public locations which requires a 240V single-phase power supply [19]. Level 3 charging is the fastest method commonly used in commercial and public areas [19]. It is an optimal method for charging EVs in shopping centers, gas stations, ministries, and entertainment districts. For example, Kuwait could include a level 3 charging infrastructure at supermarkets to enable consumers to charge their EVs expediently during shopping. Figure 2 shows different EV charging levels.

The charging techniques that could be integrated into an optimized EVCS in Kuwait include inductive charging, conductive charging, and battery swapping. The aspects of inductive charging include wireless charging and trickle charging [19]. Nonetheless, inductive charging is associated with costly infrastructure, high power losses, and low efficiency. Conductive charging encompasses AC public charging, speedy DC public charging, wired charging, an onboard charging system, and off-board charging capability [19]. It is associated with minimal power loss and is highly efficient. Batteries swapping entails off-board charging and quick changeover [19]. This charging technique would be the most beneficial because it has minimal management costs, less power loss, and is highly efficient. However, including all the charging techniques in Kuwait's EVCS infrastructure is necessary for providing consumers with the desired conveniences and efficiencies.

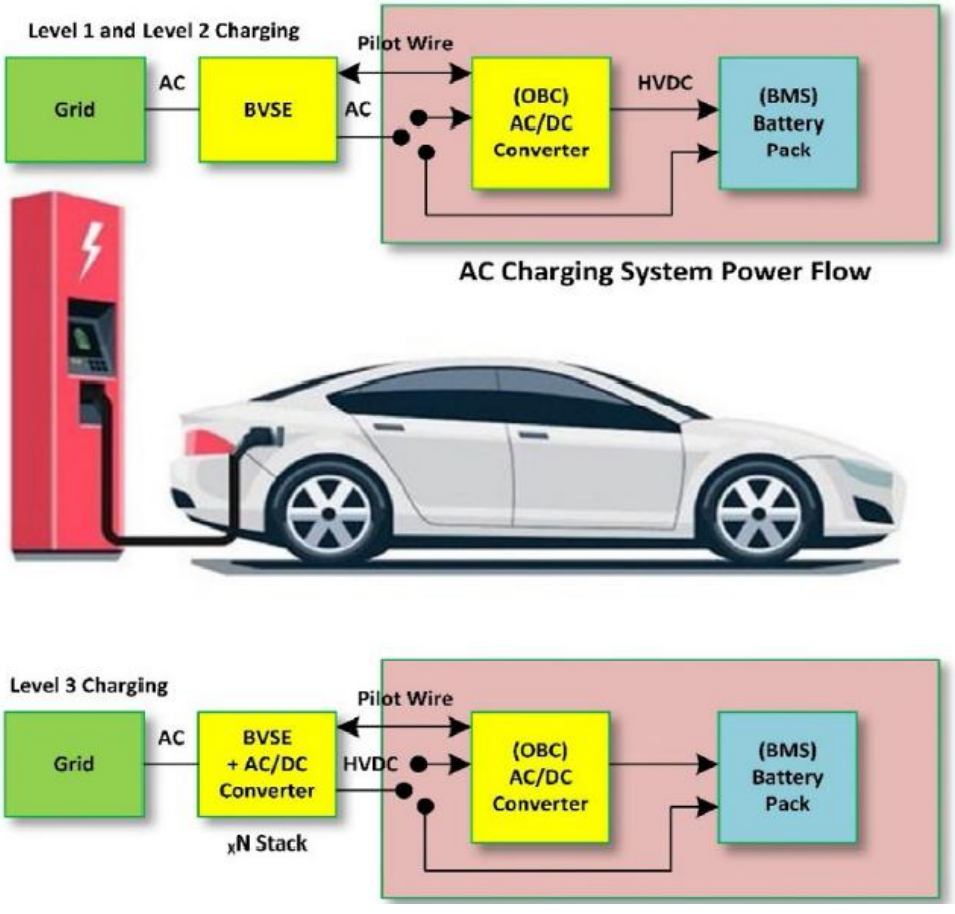

Figure 2. EV charging levels [19]

Moreover, Kuwait could benefit from the EV user approach to optimizing its EVCS infrastructure. The methodology entails placing EVCS with the intention of influencing the charging behaviors of EV users [20]. In deploying the EV user approach, the objective functions are traveling cost, access cost, and wait time cost. The team responsible for implementing the program for optimizing Kuwait's EVCS network should understand that using various methods and real-world data is a prerequisite to realizing desired outcomes. In addition, further development of the existing EVs infrastructure is crucial for meeting the demands of the growing EV fleets [21]. Furthermore, comprehensive sensitivity analyses of data pertaining to EV charging capacity, driving range, road traffic load, and EVs share of the automotive market are vital for sustaining optimal EVCS networks [21].

Kuwait should develop and deploy an EVCS management system to promote the on-demand electric power delivery required for optimal EV charging. Advanced EVCS management systems include capabilities such as Internet connectivity, open charge point protocol (OCPP), and EVCS firmware [22]. Internet connectivity is crucial for remote EV charging management while EVCS firmware is useful for enabling low-level control over EVCS hardware [22,23]. The EVCS management system is a specialized software package with algorithms that enable users to efficiently manage EVCS operations like scheduling, authentication, and record keeping [22]. Human-machine interfaces (HMIs) are also useful for managing EVCS operations.

An adequate EVCS infrastructure is essential for inspiring consumers in Kuwait to adopt EVs. The nation should endeavor to establish and sustain expedient and reliable technology across its EVCS network. It should deploy renewable energy on a large scale to promote its sustainability and economic growth objectives. Kuwait should implement a coordinated renewable energy growth (REG) program to ensure its EVCS infrastructure is optimized to meet the rising demand for EVs. Notably, a complete EVCS network encompasses power infrastructure, communication and control capabilities, connectors, charging ports, and mechanisms for meeting relevant industry standards [24]. Dynamic and static charging infrastructure should also be included in Kuwait's EVCS network to ensure that EV mobility considerations are addressed. In addition, the EVCS management system should provide coordinated charging controls. It should be designed to eliminate delays in EV charging time. Control structure considerations in EVCS infrastructure deployment are vital for ascertaining that EVCS are distributed spatially across a robust distribution grid [19]. In addition, Kuwait should consider including mechanisms for centralized control of the EVCS framework. There should be master control for centralizing operations such as charging rates and schedules.

4. Conclusions

An analysis of Kuwait's EVCS infrastructure indicates that it is not adequately elaborate. The nation should focus on shifting its dependence on oil to renewable energy solutions. It needs to implement a comprehensive REG program, which includes the design, development, and deployment of an advanced EVCS infrastructure and distribution network. Kuwait should also implement policy frameworks for promoting EV adoption, including subsidies and regulation of oil consumption and GHG emissions. it should also gain insights from other oil-rich nations which have achieved significant progress in EV adoption and the reduction of GHGs. Collaboration between stakeholders within Kuwait's private and public sectors is crucial for realizing sustainability goals. The nation's REG program should apply evidence-based methodologies to enhance its success in establishing and sustaining an efficacious EVCS network.

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