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The Future Impact of Plug-in Electric Vehicles on Kuwait's Grid Compared to Hybrid Cars: A Study Based on Empirical Parameters

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ABSTRACT

The growing adoption of electric vehicles (EVs) worldwide is reshaping energy consumption patterns, presenting both opportunities and challenges for national power grids. In Kuwait, a country characterized by high electricity demand per capita and a power infrastructure heavily reliant on fossil fuels, the introduction of EVs poses unique implications. This study investigates the potential impact of EV charging on Kuwait's electrical grid by analyzing consumption trends, charging behaviors, and infrastructure readiness. Key findings suggest that unregulated charging during peak demand hours could significantly strain residential distribution networks, particularly during the hot summer months. However, the integration of smart charging systems, renewable energy sources, and vehicle-to-grid (V2G) technologies presents viable solutions to mitigate these effects. This research highlights the importance of proactive energy policies and infrastructure planning to ensure a sustainable and resilient energy transition in Kuwait.

This paper examines the potential impact of plug-in electric vehicles (PEVs) on Kuwait's grid compared to hybrid cars, utilizing empirical parameters to assess their energy consumption, charging behavior, and implications for grid stability. Through a combination of real-world data analysis and modeling, the study provides insights into the challenges and opportunities associated with the widespread adoption of PEVs in Kuwait, offering recommendations for policymakers and stakeholders to manage the transition to electric mobility.

Keywords: Electric Vehicles, Plug-in Electric Vehicle, Kuwait Power Grid, Hybrid Electric Vehicle

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I. INTRODUCTION

Electric vehicles are set to have a significant impact on the shift towards a low-carbon transportation system. As we monitor and predict this transformation, learning rates provide a means to measure the historical speed and progress of emerging transportation alternatives. They also allow us to understand the interplay between technology-specific advancements and broader changes within the transportation system, as well as the economic implications of various policy choices. The deployment of electric vehicles has seen a rapid increase worldwide in the last ten years. Sustained growth in the next decade is essential to reach the ambitious goal of decarburizing the transportation industry.

Almost 14 million new electric cars1 were registered globally in 2023, bringing their total number on the roads to 40 million, closely tracking the sales forecast from the 2023 edition of the Global EV Outlook (GEVO-2023). Electric car sales in 2023 were 3.5 million higher than in 2022, a 35% year-on-year increase.

; Whereas locally a number of 10,000 PEV approximately will encompass the roads in Kuwait, that will incur the power grid of about 0.5 GW.

In terms of charging methods we predict that the residential home-wall sockets will be the main source of PEV charging in Kuwait, and a smaller number of commercial purposes vehicles will use a fast charge centralized sources.

The main effects of connecting electric vehicles to the power grid are outlined in this paper. These effects encompass an increase in short-circuit currents, a potential deviation from the standard voltage limits, a higher power demand, and an impact on the lifespan of the equipment. The analysis of the impact on voltage level, power demand, and active power losses for various penetration levels and power demand scenarios of electric vehicles is examined in the case study.

II) Analyzing the Pattern of Electrical Energy in Kuwait

This study aims to evaluate the potential impacts of Electric vehicle charging on The Kuwait's electricity network from a scientific perspective, taking into account climatic conditions, consumption pattern, and current energy infrastructure, Therefore we shall review all related data as a proportional reference to aid our analysis and evaluation in this paper.

2.1 Electrical Energy Expansion in Kuwait:

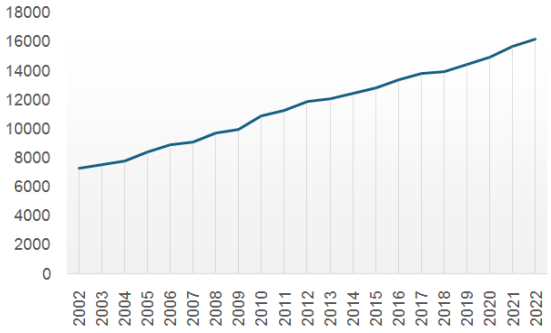

Fig.1. Expansion of Kuwait's Electrical Energy Demand in the last 2 decades

The robust urban in Kuwait and expand of the industrial Areas which was the normal need for the expansion of residential Areas, All of that led to high demand in power. The demand was increased rabidly (Table.1), we can see that the demand was doubled in 20 years from 6450 MW in 2000 to 13910 MW in 2019.The peak demand season in Kuwait is the summer season from May to October and the least month is from November to February.

Table.1: Max. Consumption Load (MWh) of Electrical Energy in Kuwait During 2004-2022

Period	Max. Consumption (MWh)
2002	7250
2003	7480
2004	7750
2005	8400
2006	8900
2007	9070
2008	9710
2009	9960
2010	10890
2011	11220
2012	11850
2013	12060
2014	12410
2015	12810
2016	13390
2017	13800
2018	13910
2019	14420
2020	14960
2021	15670
2022	16180
2023	16940

2.2 Monthly Power Consumption Guide Values:

Kuwait location in the Arabian Peninsula keeps the weather conditions hot in summer season with high Temperature, as an average the temperature reaches 45 C° in summer and 6 C° in winter so, the demand on Energy in summer season will be High specially in August, but in February it's less demand.

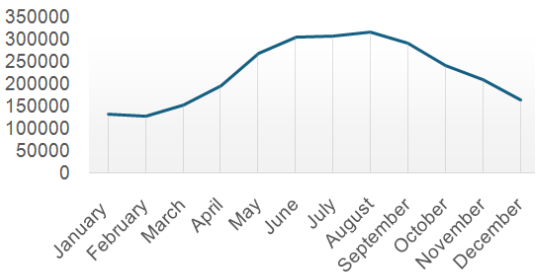

Fig.2. Monthly Max. Consumption (MWh) of Electrical Energy in Kuwait 2022

When we proceed to our research subject our main aim is to analyze the electrical impact of PEV on Kuwait's grid, therefore we shall review the primary figures and data of Kuwait's Electrical power consumption on monthly bases (Ttable.2). Reference to the consumption chart (Fig. 2) that elaborates the power demand monthly, we can signify the peak demand times in Kuwait in order to utilize it so that we can predict the future impact of PEV on local Grid.

Table.2: Monthly Max. Consumption (MWh) of Electrical Energy in Kuwait 2022

Month	Max. Consumption (MWh)
Jan	132893
Feb	127777
Mar	152912
Apr	196776
May	268840
Jun	304554
Jul	308316
Aug	316942
Sep	292749
Oct	242133
Nov	208754
Dec	164367

III) Impact of Electric Vehicle on Kuwait's Grid:

To evaluate the impact of Electric Vehicles we should first classify A PEV is a Plug-in Electric Vehicle that is equipped with a larger motor and battery pack than what's offered in a PHEV. The key difference between PEV vs. PHEV is that a PEV runs on electricity alone and produces zero emissions, Hereunder a brief elaboration.

3.1) Types of EV :

a) Hybrid EV: Where the drive train consist of dual motive forces, The main prime mover is the internal combustion engine (ICE) assisted by electrical motor, The battery bank is confined Integrally, and re-charged itself internally by regenerative braking system and a driven generator by ICE.

b) Plug-in Electric Vehicle (PEV): which depends on the electric motor is as a main motive force (prime mover) without any mechanical assist and the battery bank has to be re-charged from external power source through home adapter or by dedicated public (ancillary) power unit, where the re-charging duration depends on the power rating which varies according to the adapter/unit capability such as Phase-number for residential charger and for DC type according to the rectifier's power rating (Table.3).

Table.3: PEV chargers classification

Type	Description
DC Fast Charging Ports	Available as public stations with a power range from 40 - 350 kW-hr
Residential Chargers	Available as Home-wall chargers. with a power range from 1.8 - 19 kW-hr

3.2) PEV Re-charging calculations :

The impact on power grid will be caused primarily by residential charging of PEV, which is dictated by several factors such as the adaptor power rating, PEV battery capacity and time of charging during the day.

We assume a simple equation (1) to compute an estimate time and power required to fully charge an average PEV in the market

$$t = \frac{kwh}{kw} \qquad (1)$$

Where,

t = is the durating required to fully recharge (hrs)

kWh = PEV battery power

kW = Charger's power rating

, So if we assume fully recharging a PEV with a battery capacity of 45 kWh by using a 3 kWh

residential charger, and reference to equation (1) the required time can calculated as follow:

$$t = \frac{kwh}{kw}$$

$$t = 45\ kWh / 3\ kW$$

$$= 15\ hrs$$

, Therefore the power grid will be incurred by additional 3 kW for 15 hours times the number of PEV needs to which be re-charged simultaneously, and most likely the anticipated re-charging period will be over-night (9PM to 6AM).

With a number of a future PEV in Kuwait estimated by 10000 unite at 2035 the demand can reach 30MWh and this value is subjected to increase according the charger's power rating.

Table.3 : Hourly power consumption during average day in March

Time	Peak Load (MW)
00:00	14060
00:30	13750
01:00	13750
01:30	13750
02:00	13750
02:30	13150
03:00	13150
03:30	12925
04:00	12925
04:30	12535
05:00	12535
05:30	12245
06:00	12245
06:30	12730
07:00	12730
07:30	13290
08:00	13290
08:30	13760
09:00	13760
09:30	14480
10:00	14480
10:30	14970
11:00	14970
11:30	15410
12:00	15410
12:30	15900
13:00	15900
13:30	16150
14:00	16150
14:30	16180
15:00	16140
15:30	16090
16:00	16090
16:30	15995
17:00	15995
17:30	15720
18:00	15720
18:30	15525
19:00	15525
19:30	15245
20:00	15245
20:30	15060
21:00	15060
21:30	14980
22:30	14980
23:00	14320
23:00	14320
00:00	13740

And in order to define the time of the day at which Kuwait's power grid will sustain the burden, we could refer to the Table.3 and its illustrated values represented in graph Fig.3

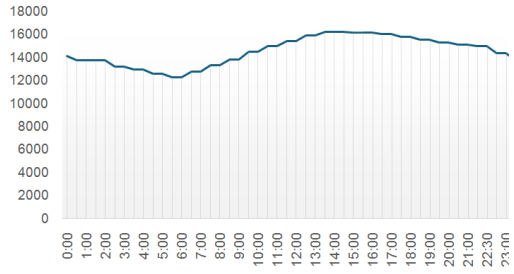

Fig.3 : Hourly power demand during average day in March

IV) Results & Discussions

Based on all above data and results, the for the future presumed 10000 number of PEV in Kuwait, it is obvious that the impact on the grid will not be much significant , as long as the residential chargers are single phase system with a maximum current of 13 Amp.

Nevertheless, the government should take a tangible procedures to imply an inclusive policy and strategies to manage the integration of PEVs into Kuwait's energy system effectively recommendations for incentivizing sustainable mobility, promoting renewable energy integration, and enhancing grid infrastructure.

V) Conclusion:

Summary of key findings and insights from the empirical study on the impact of PEVs on Kuwait's grid compared to hybrid cars, meanwhile implications for the future of electric mobility in Kuwait and the broader transition towards sustainable transportation. and that's deems a research and collaboration to address remaining challenges and uncertainties.

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