

**ANALYSIS OF PEAK HOURS RENEWABLE ENERGY
DEMAND IN KUWAIT**

BY

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**A dissertation submitted in fulfilment of the requirement for the
degree of Master of Science - Computer and Information
Engineering**

**Kulliyyah of Engineering
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ABSTRACT

Increasing interest has been observed over the past years for analyzing renewable energy potential for meeting peak hours' energy demand. Recently published works have attributed household energy usage as one of the most significant influences of electrical energy. Peak demand has become a concern in power supply industry, where the demand goes beyond the available capacity. The peak demand has been continuing with an upward surge in strength enough to be associated with the possibility of power failures, disruption of supply, causing revenue loss. This research will demonstrate the core factors of peak energy consumption behavior. Furthermore, this research also aims to analyse the naturally available solar source of renewable energy required in residential sectors based on cost evaluation mechanism. If this study, peak hours energy demand has analyzed, and sufficient energy demand results have obtained. The aim of this research is to develop an effective solution to enhance continuous power availability and to reduce the peak load demand in Kuwait electric grid system. The peak demand is made up from solar renewable energy sources. The potential of renewable energy as power generation sources in Kuwait has been studied and solar energy potential has been analyzed. In this work, we assess the energy situation in Kuwait and its historical, current, and future conditions with a focus on the power plant sector, as it is the major consumer of energy in the country. Finally, an attempt is made to briefly describe the most realistic and efficient electricity production solutions available and to discuss other alternative resources such as nuclear, solar, and wind energy.

ملخص البحث

ولقد لوحظ اهتمام متزايد على مدى السنوات الماضية بتحليل إمكانات الطاقة المتجددة لتلبية الطلب على الطاقة في ساعات الذروة. وقد عزت الأعمال المنشورة مؤخرا استخدام الطاقة المنزلية باعتبارها واحدة من أهم التأثيرات للطاقة الكهربائية. وقد أصبح ذروة الطلب مصدر قلق في صناعة إمدادات الطاقة، حيث يتجاوز الطلب القدرة المتاحة. وما فتئ الطلب على الذروة مستمرا مع ارتفاع في القوة بما يكفي لاقترب باحتمال انقطاع التيار الكهربائي، وانقطاع الإمدادات، مما تسبب في خسارة في الإيرادات. هذا البحث سوف تظهر العوامل الأساسية للسلوك ذروة استهلاك الطاقة. وعلاوة على ذلك، يهدف هذا البحث أيضا إلى تحليل المصدر الشمسي المتاح بشكل طبيعي للطاقة المتجددة المطلوبة في القطاعات السكنية على أساس آلية تقييم التكاليف. إذا كانت هذه الدراسة، وقد حلل الطلب على الطاقة ساعات الذروة، وحصلت على نتائج كافية للطلب على الطاقة. يهدف هذا البحث إلى تطوير حل فعال لتعزيز توافر الطاقة المستمر والحد من ذروة الطلب على الحمل في نظام الشبكة الكهربائية الكويتية. يتكون ذروة الطلب من مصادر الطاقة المتجددة الشمسية. وقد تمت دراسة إمكانات الطاقة المتجددة كمصادر لتوليد الطاقة في الكويت وتحليل إمكانات الطاقة الشمسية. في هذا العمل، نقوم بتقييم حالة الطاقة في الكويت وظروفها التاريخية والحالية والمستقبلية مع التركيز على قطاع محطات الطاقة، حيث أنه المستهلك الرئيسي للطاقة في البلاد. وأخيرا، جرت محاولة لوصف أكثر حلول إنتاج الكهرباء المتاحة واقعية وكفاءة، ومناقشة الموارد البديلة الأخرى مثل الطاقة النووية والطاقة الشمسية وطاقة الرياح.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science Computer and Information Engineering.

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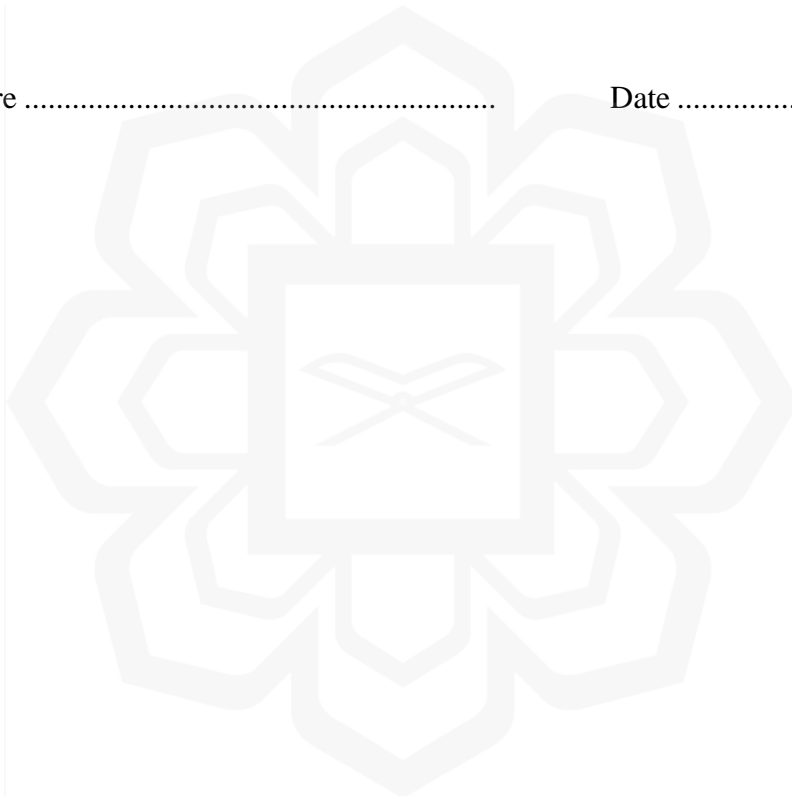
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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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I would like to dedicate this dissertation to my beloved parents for bringing me up and for laying the foundation of what I turned out to be in life, Thank you!



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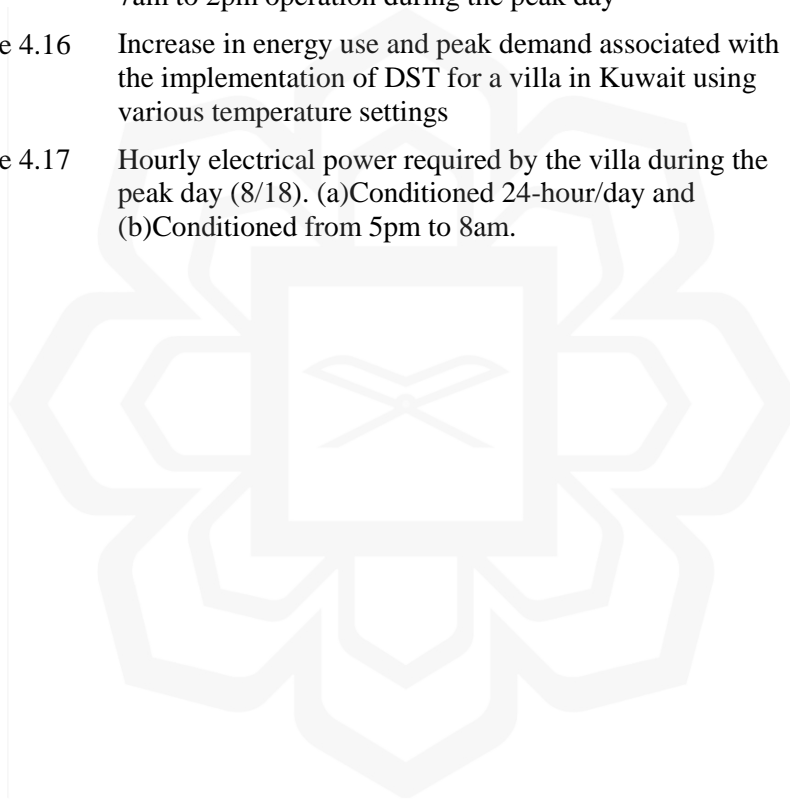
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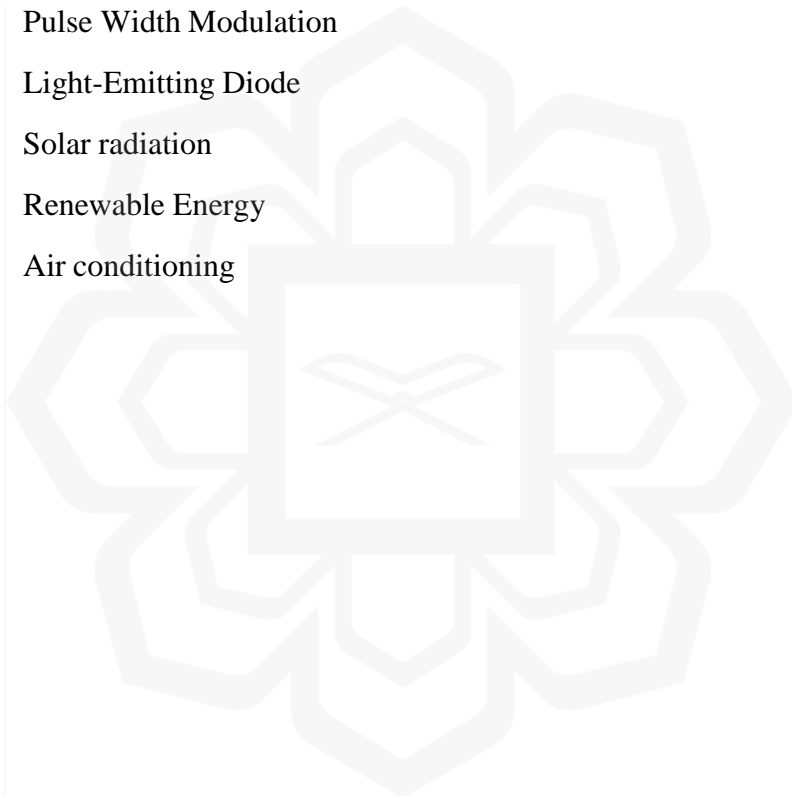
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LIST OF ABBREVIATIONS

PV	Photovoltaic
DC	Direct Current
CO ₂	Carbon Dioxide
cm	Centimeter
Wp	Peak Watts
AC	Alternating Current
PWM	Pulse Width Modulation
LED	Light-Emitting Diode
SR	Solar radiation
RE	Renewable Energy
A/C	Air conditioning



LIST OF SYMBOLS

V	Voltage
η	Efficiency
V	Voltage
I	Current
P	Power



CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

The economy of Gulf countries has shown to be highly dependent on the fossil fuel industry over the last few decades. Though, the current progress of the Gulf countries has shown an increasing interest in renewable energy sources for their electrical power generation. The fundamental concept and understanding of renewable energy is that it is electrical energy generated from sources that can restore themselves without fading or getting depleted over a short span of time. The traditional fossil based energy generation has been of environmental concerns by many, and the tendency towards renewable energy generation has been generating interest because such a source would reduce this concern greatly. Mostly in the developed countries, the electric power systems provide electricity on demand to places such as residential areas, commercial, agricultural and industrial areas.

In this dissertation, the focus is set to analyze electrical power supply from solar energy, since the Gulf States fall in the vicinity of high-solar intensity radiation. The Gulf States including Kuwait, Qatar, Bahrain, Saudi Arabia, Oman and the United Arab Emirates (UAE), are located in geographical regions having a major source of income on exporting to the world oil and related products. Oil as a non-renewable energy remains the main source of energy for electric power generation now. Since 2015, a significant drop in oil prices has been reported (Vohra, 2017). Also, these countries are faced with the challenge to make up their electrical power generation from sources other than fossil fuel. Furthermore, the fossil fuel-based energy generation provides a huge drawback of

polluting the environment by increasing the carbon dioxide (CO₂) emission, consequently, promoting global warming related issues and concerns (Buonocore et al., 2016).

As per the International Energy Agency (IEA) statistical report, Gulf countries have seen experiencing rising economic growth of lifestyle, industrial sector growth and have become over the year's major energy consumers throughout the four seasons of the regions due to rising living standards and continued industrialization. It has been noted that regional electricity use has been growing at almost 8% a year, making demand of generating 100 GW of additional power every passing decade. This has necessitated the generation of renewable generation from the fuel-less sources of renewable energy more than ever before, freeing oil related products for export. In further note by the IEA report, approximately 81.1% and 80.1% of the total world primary energy is generated from fossil-fuels means of power generation in 2014 and 2015 respectively (IEA, 2018). Consequently, the release of global greenhouse gas has been rising intensely (Hossain et al., 2018). It is noted that the emission of carbon dioxide generated world-wide in 2010 has been estimated to be 54 billion tons and it is expected to reach 70 billion tons by 2050 (WEO, 2018). Hence, several countries are turning to generating power from renewable and environmentally friendly and responsive energy resources.

In the long term of electrical energy production interest, the solar energy source is said to have the potential of an infinite supply of renewable energy resources within the Gulf countries (Masud et al., 2018). The most common solar technologies are the solar photovoltaic (PV) system and the solar thermal system (Ismail et al., 2015).

Since solar PV is more commonly used around the world to produce electricity, this

work will focus on solar PV systems because the cost of renewable energy has been dropping continuously and dramatically. Also, generating energy from solar in the GCC countries fits very well with energy demand patterns where air conditioning dominates the electricity demand curve. Studies have shown that the annual average solar radiation in Kuwait is expected to be between 2100 and 2200 kW/m² (Alnaser et al., 2019). The average daily sunshine in one year for Kuwait ranges from 6 to 9 hours as shown in Figure 1.1 (International Energy Agency, 2019). Moreover, according to daily global forecasts (webpage: Weather Report, 2019), the maximum solar radiation and peak electricity demand in the country occur at approximately the same hours of the day and the same months of the year, making solar power generation the most useful renewable energy source for the country. Kuwait enjoys hot and long summer periods of seven months, extending from April to October every year with temperatures rising, on some days, to more than 50°C.

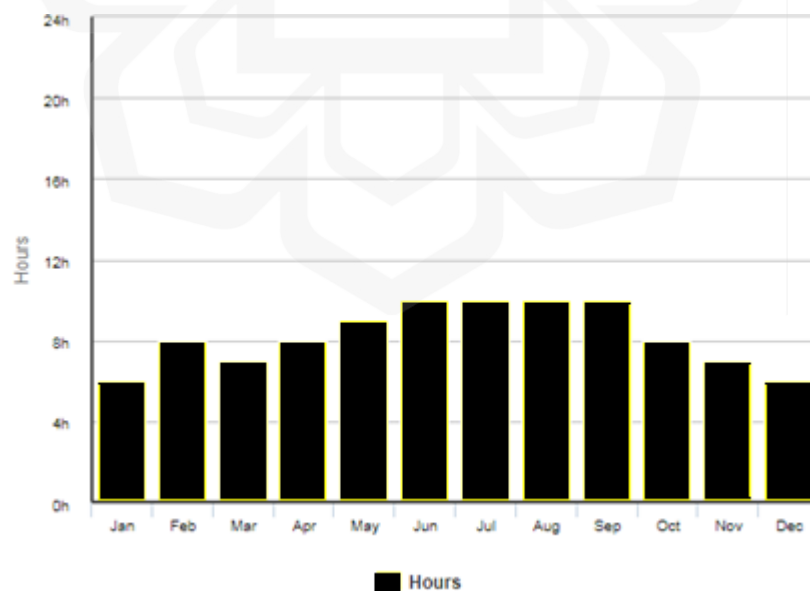


Figure 1.1 Average daily sunshine hours (International Energy Agency, 2019)

This work will analyze the energy potential of Kuwait to determine the peak hours' energy demand as shown in Figure 1.2 for commercial, industrial, residential, agriculture

and other sectors of consumers. It can be noted that the residential sector consumes 43% of total electrical energy, which is the highest when compared to other energy consumption sectors. This shows that the residential sectors are consuming the highest energy.

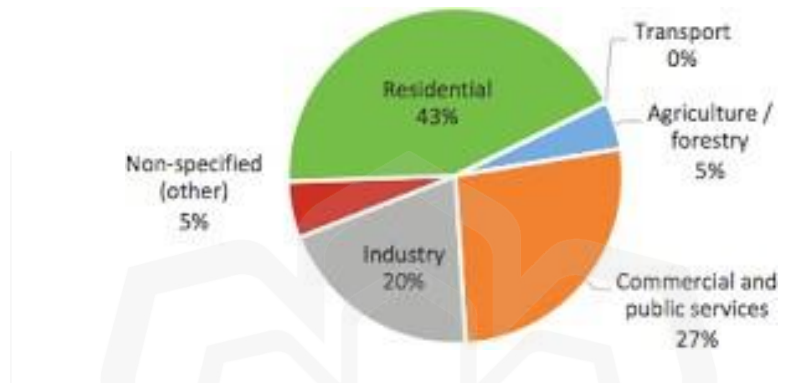


Figure 1.2 Kuwait's electrical energy consumption by sectors (Sabouni, 2017).

Fundamentally, electricity is produced through the movement of positive and negatively charged atoms. Electricity is the main energy source without which any electrical and electronic device is to function at all. Hence, the electric power system is basically comprising of a supply side and a demand side. The supply side consists of generation, transmission, distribution and demand as four major segments as shown in Figure 1.3 (Oluwole, 2018). The demand sector stems from consumption to support the commercial and residential activities. The supply side and the demand side must always balance. For this reason, peak demand, which is the maximum demand for electricity over a specified period has been the focus of the electric utility.

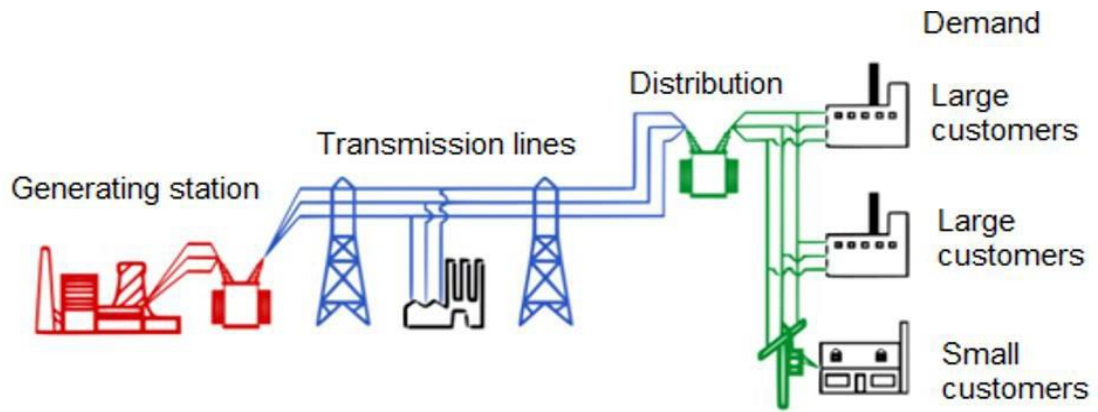


Figure 1.3 Typical Representation of Electric Network (Canova et al., 2009)

Peak demand which can be annual, seasonal or daily, is defined as the highest energy consumption that occurs over a specific time period on a system (Gonen 2008). It states and gives an estimate of the electricity usage by the consumers. Also, it has been noted that peak demand can worsen the system stability due to insufficient generation (or transmission) of electricity to consumers.

1.2 PROBLEM STATEMENT

This study proposes to analyze the potential of renewable energy to meet peak energy demand. There are many challenges that hinder the sustainability of renewable energy sources towards energy supply. These challenges include choosing the most appropriate power supply technology due to the existence of many renewable energy technologies, the lack of data available for analysis, and the lack of study conducted to generate the power needed to meet the increasing demand during peak hours. Hence, the study of energy generation methods is of paramount importance to justify the use of renewable energy. Factors that drive solar energy, along with pro-environmental attitudes and preferences, include findings that suggest significant financial returns for price and insulation is critically important. Other factors include policy variables, consumer discounts, the

renewable solar credit price, and sales tax credits. This indicates that commercial installations are mostly driven by their promise of financial returns, and continued growth in this market segment is likely to depend on lower installation costs and the availability of incentives. Thus, the research focuses on analyzing the potential of solar energy generation in Kuwait to understand the possibility of meeting the peak energy demand completely or partially from renewable energy source.

1.3 OBJECTIVES

The objectives identified for this study are as follows:

- 1- To make a critical review the status of PV potential in the Middle East with a focus on Kuwait.
- 2
2- To conduct a comprehensive review of renewable sources using the projected solar energy potential.
- 3- To calculate and analyze the peak hour demand to be met by solar energy.

1.4 RESEARCH METHODOLOGY

The flow of the research is shown below. Phase-1:

- Derive an analytical modelling representative in terms of the annual demand for electricity consumption.
- Show with diagrams the amount of energy consumption that has been trending over the years for consumers in the residential, agriculture, industrial sectors.
- To regulate the energy demand in the form, which makes it possible to meet it from renewable energy sources.

Phase-2:

- Test whether the presented energy consumption model is good enough to partially or fully compensate for solar renewable energy.

Phase-3:

- Study to see how much of the energy demand can be comfortably met from the renewable energy source of solar
- Test a case study scenario model for energy demand consisting of target consumers.

The above methodology clearly addresses these Research Questions:

1. How to bring the energy demand closer to the solar energy generation of Kuwait?
2. How can the proposed analytical modeling be made to meet the energy demand in Kuwait with 100% of solar energy?

The flow of the above stated research methodology is as shown below.

