PALESTINE POLYTECHNIC UNIVERSITY

AL-QUDS UNIVERSITY

Master Program of Renewable Energy and Sustainability

Consumer Load Management Using Forecasting Algorithms

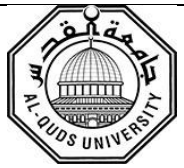
By

Rafat K. N. Aljuneidi

Supervisor

Dr. Radwan Tahboub

August, 2019



JAMILA

TEMPUS

Joint mAster of Mediterranean Initiatives on renewabLe and sustainAble energy

Palestine Polytechnic University

Deanship of Graduate Studies and Scientific Research

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Thesis submitted in partial fulfillment of the requirements of the degree

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Dedication

I dedicate this work to my family.

Acknowledgement

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Abstract

With the high-growing demands of modern life and industry on electricity, and with the very rapid growth of renewable energy generation and distribution technologies rise a need of an integrated platform to manage electricity services in more efficient, reliable and intelligent way. Smart Grid Network (SGN) is one of the creative technologies that controls efficient and intelligent traditional and non-traditional resources of energy with respect to electric power generation, consumption, transmission and distribution. The stability of the distribution grid with fail-over techniques and consumer bill reduction are among the main goals of SGN. However, electricity consumers may input the extra stored electricity that they do not consume into the smart grid for sale to reduce peak-time electricity usage. Time-varying pricing schemes have become a main part of smart grids, by managing both sides from the electricity sold to consumers and the electricity pushed from the consumer. Such SGN's can gather information, such as weather forecasts, storage level and the peak-time. Thus, by using this data, future levels of electricity generation (e.g., the energy from Photovoltaics (PV), which is mainly affected by the weather status) can be predicted with high accuracy.

SGN needs to exchange the information between the consumers and the power supply companies. Smart meters are considered as SGN consumer device and will be suggested to be an Internet of Things (IoT) device to be used to record consumption of electric energy in intervals of an hour or less and send that information back to the company in a timely fashion for monitoring, controlling or billing purposes. Through this thesis, a load forecasting model will be presented, in which more than one source of energy is combined with a local grid control system. This model aims to estimate the electrical load of the consumers based on their previous readings. To achieve this prediction, A time series model and stochastic model were applied with a live sample of load profile data. This data was not used previously by any researcher.

Different case studies has been run in order to ensure that the proposed model give the expected results, and investigating the results in different months during the year. To perform such a study, the analysis of the collected data transferred will be experimented and presented so as to minimize the load at the peak time by comparing the expected load level using the Markov Decision Process (MDP) algorithm and the Auto-Regressive Moving Average (ARMA) algorithm. Conclusions show that using the ARMA algorithm give an error percent of 3.7% for one day ahead forecasting. While for one day ahead forecasting, the MDP algorithm gives a range of readings according to the load consumption group.

إدارة الحمل للمستهلك باستخدام خوارزميات التنبؤ

اعداد: رأفت كريم الجنيدي

الملخص:

مع زيادة الطلب على الكهرباء، ومع النمو السريع في قطاع توليد الطاقة المتجددة وتقنيات توزيعها، تبرز الحاجة إلى نظام متكامل لإدارة خدمات الكهرباء بطريقة أكثر كفاءة وموثوقية وذكاء. الشبكة الذكية Smart Grid Network (SGN) هي واحدة من التقنيات الإبداعية التي تتحكم في موارد الطاقة التقليدية وغير التقليدية بفعالية، حيث انها تقوم بمتابعه عمليات توليد الطاقة الكهربائية واستهلاكها ونقلها وتوزيعها. من بين الأهداف الرئيسية للشبكة الذكية هو الحفاظ على استمراريه الخدمة مع ضمان خفض فاتورة المستهلك. يتم ذلك بالسماح للمستهلكين إدخال الكهرباء الإضافية المخزنة او المولدة من قبلهم في الشبكة الذكية للبيع وذلك لتقليل استخدام الكهرباء في وقت الذروة. وبالتالي أصبحت التسعير المتغيرة مع الوقت للاستهلاك جزءًا رئيسيًا من الشبكات الذكية، من خلال إدارة كلا الجانبين من الكهرباء المباعة للمستهلكين والكهرباء المضخوخة للشبكة من المستهلك. يمكن للشبكة الذكية جمع المعلومات، مثل توقعات الطقس ومستوى التخزين ووقت الذروة. حيث يتم استخدام هذه البيانات التنبؤ بمستويات الاستهلاك او الانتاج في المستقبل (مثل الطاقة الكهروضوئية، والتي تتأثر بشكل رئيسي بحالة الطقس) بدقة عالية. تعتبر تقنية انترنت الاشياء Internet of Things "IoT" الجديدة والتي تجعل الأشياء قابلة للبرمجة والتحكم فيها بواسطة شبكات الحاسب والتي يمكن استخدامها لجمع البيانات من الشبكة ومعالجتها وأداء المهام وفقًا للنتائج.

توضح هذه الأطروحة كيف يمكن للمستهلكين الاستفادة من المعلومات المتوفر لأحمالهم السابقة في التنبؤ بالحمل لمده معينه وذلك باستخدام خوارزميات مقترحة من أجل الحصول على أقصى قدر من الفائدة، من خلال النظر في الأسعار المتغيرة للسوق بالإضافة الى سلوك المستهلك واستخدامها في التنبؤ للأحمال المستقبلية القريبة. لإجراء مثل هذه الدراسة سيتم تجربة تحليل البيانات التي تم جمعها وتقديمها من أجل تقليل الاستهلاك خلال وقت الذروة من خلال مقارنة مستوى الحمل المتوقع باستخدام خوارزمية MDP وخوارزمية ARMA. تُظهر الاستنتاجات أن استخدام خوارزمية ARMA يعطي خطأ بنسبة3.7٪ للتنبؤ قبل يوم واحد. بينما على المدى القصير، ستقدم خوارزمية MDP تقديرا للحمل وفقًا لمجموعة استهلاك الحمل.

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Abbreviations

ACF	**A**uto-**C**orrelation **F**unction
ACC	**A**uto-**C**orrelation **C**oefficient
ANN	**A**rtificial **N**eural **N**etworks
ARMA	**A**uto-**R**egressive **M**oving **A**verage
ARIMA	**A**uto-**R**egressive **I**ntegrated **M**oving **A**verage
ARMAX	**A**uto-**R**egressive **I**ntegrated **M**oving **A**verage with e**X**ogenous inputs
BDAP	**B**ig **D**ata **A**nalytic **P**latform
BIC	**B**ayesian **I**nformation **C**riterion
CoEC	**C**ost **o**f **E**nergy **C**onsumption
DMS	**D**emand-**S**ide **M**anagement
EMS	**E**nergy **M**anagement **S**ystem
GPS	**G**lobal **P**ositioning **S**atellite systems
HEMS	**H**ome **E**nergy **M**anagement **S**ystem
HMM	**H**idden **M**arkov **M**odel
ICT	**I**nformation and **C**ommunications **T**echnology
IoT	**I**nternet **o**f **T**hings
IRENA	**I**nternational **R**enewable **E**nergy **A**gency
MDP	**M**arkov **D**ecision **P**rocess
PACC	**P**artial **A**uto-**C**orrelation **C**oefficient
PV	**P**hoto**V**oltaics
PACF	**P**artial **A**uto-**C**orrelation **F**unction
PENRA	**P**alestinian **E**nergy and **N**atural **R**esources **A**uthority
PMUs	**P**hasor **M**easurement **U**nits
RTP	**R**eal **T**ime **P**ricing
RTU	**R**emote **T**erminal **U**nits
SCADA	**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition
SG	**S**mart **G**rid
SGN	**S**mart **G**rid **N**etwok
TW	**T**era**W**att
WAMS	**W**ide **A**rea **M**onitoring **S**ystem

Chapter 1

Introduction

Nowadays, with the high demand of energy consumption rises new visions of energy management and demand response. Smart grid (SG) is a highly automated and integrated power system, Real-Time information flow through network, thus customers can forecast their load consumption and then schedule their behaviors, according to the change of electricity price depending on the history of the load consumption and price profile. Some tools are needed to achieve this forecasting to collect information and analyze it such as Internet of Things (IoT)[8].

IoT is a new technology that takes part in different fields of smart technologies such as Smart Homes, Smart City and Smart Grid Networks (SGN) [9, 10]. These programmable network based devices are used to monitor and control things to perform certain tasks. As SGN and smart city features, IoT devices are used in converting the traditional grid into a smart grid [11]. Monitoring and managing grids in an automated way are the main goals of IoT devices in smart grids. Secure data transmission is needed in this grid; however, hacking the data across the network will affect the work and may cause damage in the grid. The power grid moves the generated electricity from power plants to consumers. Such grids are connected for commercial purposes and more reliable networks that enhance the management and planning of electricity demand and supply. Depending on the International Renewable Energy Agency (IRENA) report[12], renewable energy generation is rapidly growing worldwide [12]. from 2012 to 2017, Palestine generated about 1, 1, 3, 12, 14, 18 MW respectively from renewable energy resources, mainly from solar energy [12]. This growth is inconsistent with the international growth, where generated power increased from 2012 to 2017 from 1.5 TW to 2.2 TW [12].

The smart grid network is the network that connects to the electricity grid, in order to get information about the power generation, transmission and distribution across all grid operations, using a variety of components [8] including the Smart meter. This can be