BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Joint Master in Electrical Engineering

Smart Grid Applications in Palestine

Submitted By

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Supervisors

Dr. Abdalkarim Awad

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August 24, 2020

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تطبيقات الشبكات الكهربائية الذكية في فلسطين

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This Thesis was submitted in partial fulfillment of the requirements for the Master’s Degree in Electrical Engineering From the Faculty of Engineering and Technology at Birzeit University, Palestine

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Dr. Mahran Quraan

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DECLARATION

I declare that this thesis entitled "Smart Grid Applications in Palestine" is the result of my own research except as cited in the references. It is being submitted to the Master's Degree in Electrical Engineering from the Faculty of Engineering and Technology at Birzeit University, Palestine. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ………………………………

Name: Islam Ahmad Al Hoor

Date: 24/08/2020

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ABSTRACT

A Smart Grid (SG) is a smart system which uses Information and Communication Technologies (ICT) in order to merge all elements of the power system such as generation, transmission, distribution, and load. The technology has many applications to achieve a power system that is safe, clean, secure, resilient, reliable, sustainable and efficient. Some of these applications may require advance technologies or high capital investment, but others may be applicable without much effort.

The potential of the several smart grid applications in Palestine will be investigated such as: Demand Side Management (DSM), Voltage and VAR Control (VVC), Integration of Renewable Energy Resources DERs, Wide Area Monitoring Control and Protection (WAMCP), Fault Detection Isolation and Restoration (FDIR), Integration of Electric Vehicle (EV), and Automatic Metering Infrastructure (AMI).

Since some wireless and satellite communication technologies are not available in Palestine at this time due to political and economic constraints; Several wireless and wired communication techniques could be used for the smart grid communication such as; Zigbee, Wireless Mesh, Cellular Network Communication, Cognitive Radio, Long Rang communication technology (LoRa), Microwave, Power Line Communication (PLC), Fiber Optics Networks, and Digital Subscriber Lines.

As a case study; some experiments related to smart grid applications were performed on Jericho MV and LV networks which are part of JDECO electrical grid. These experiments were conducted using OpenDSS simulation software.

This research provides an insight of the potential of smart grid applications in Palestine and provides an overview of the existing infrastructure and the requirements to apply smart grid applications in the Palestinian Electricity Transmission company (PETL), and Palestinian electricity distribution companies.

المستخلص

تقنية شبكات الكهربائية الذكية هي نظام ذكي يستخدم تقنيات المعلومات والاتصالات لدمج جميع عناصر النظام الكهربائي بما يشمل التوليد والنقل والتوزيع والاحمال. هذه التقنية لديها العديد من التطبيقات لتحقيق نظام كهربائي آمن ونظيف ومرن وموثوق ومستدام وفعال. قد تتطلب بعض هذه التطبيقات تقنيات متقدمة أو استثمار رأس مال مرتفع ، ولكن البعض الآخر قد يكون قابلاً للتطبيق دون بذل الكثير من الجهد.

في هذه الاطروحة ستتم دراسة إمكانية تطبيق العديد من تطبيقات الشبكات الذكية في فلسطين مثل: إدارة جانب الطلب، والتحكم في الجهد و القدرة غير الفعالة ، و تكامل موارد الطاقة المتجددة، و التحكم في مراقبة المناطق الواسعة والحماية، و عزل و كشف الأعطال واستعادة الخدمة، و دمج المركبات الكهربائية مع الشبكة ، والبنية التحتية لقراءة العدادات الكهربائية اوتوماتيكيا.

بما أن بعض تقنيات الاتصالات اللاسلكية او من خلال الاقمار الصناعية غير متوفرة في فلسطين في الوقت الحالي بسبب القيود السياسية والاقتصادية ، فانه يمكن استخدام عدد من تقنيات الاتصالات اللاسلكية والسلكية المتوفرة لغرض الاتصالات في الشبكات الذكية مثل اتصالات الشبكات الخلوية والراديو المعرفي وتكنولوجيا الاتصالات طويلة المدى والميكروويف واتصالات خطوط الطاقة وشبكات الألياف الضوئية وخطوط المشترك الرقمية.

وقد أجريت بعض التجارب المتعلقة بتطبيقات الشبكة الذكية على شبكات مدينة أريحا الكهربائية (على الجهد المتوسط والجهد المنخفض) والتي هي جزء من الشبكة الكهربائية لشركة كهرباء محافظة القدس. لقد تم تنفيذ هذه التجارب من خلال برنامج المحاكاة OpenDSS .

يقدم هذا البحث نظرة ثاقبة على إمكانات تطبيقات الشبكات الكهربائية الذكية في فلسطين ، ويقدم لمحة عامة عن البنية التحتية القائمة ومتطلبات تطبيق تطبيقات الشبكات الكهربائية الذكية في شركة نقل الكهرباء وشركات توزيع الكهرباء الفلسطينية.

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LIST of ABBREVIATIONS

Abbreviation	Full word
AC	Alternating Current
ADSL	Asymmetric Digital Subscriber Line
AMI	Automatic Metering Infrastructure
AMR	Automatic Meter Reading
AON	Active Optical Networks
BAN	Building Area Network
BPL	Broadband Power Line
CAIDI	Customer Average Interruption Duration Index
CPP	Critical Peak Pricing
CR	Cognitive Radio
DA	Distribution Automation
DAP	Data Aggregation Points
DC	Direct Current
DERs	Distributed Energy Resources
DG	Distributed Generation
DISCOs	Distribution Companies
DoE	Department of Energy
DR	Demand Response
DSM	Demand Side Management
DSDR	Distribution System Demand Response
DSS	Distribution System Simulator
DSTATCOM	Distribution Static Compensator
ECU	Embedded Control Unit
EMS	Energy Management Systems
EPON	Ethernet Passive Optical Networks
EV	Electric Vehicle
FAN	Field Area Network
FDCIR	Fault Detection Clearing Isolation and Restoration
FDIR	Fault Detection Isolation and Restoration
FiT	Feed in Tariffs
FTTH	Fiber-To-The-Home

GCC	Gulf Cooperation Council
GEDCO	Gaza Electricity Distribution Company
GPON	Gigabit Passive Optical Networks
GPP	Gaza Power Plant
G2V	Grid to Vehicle
HAN	Home Area Network
HEPCO	Hebron Electric Power Company
HVAC	Heating Ventilation and Air Conditioning
IEC	Israel Electric Corporation
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
ICT	Information and Communication Technologies
IoT	Internet of Things
IPPs	Independent Power Providers
ISM	Industrial Scientific and Medical
IT	Information Technologies
JDECO	Jerusalem District Electricity Company
KPI	Key Performance Indicators
LV	Low Voltage
LoRa	Long Rang communication technology
MAIFI	Momentary Average Interruption Frequency Index
MCC	Metering Control Center
MDMS	Meter Data Management System
MEDREG	Association of Mediterranean Energy Regulators
MFA	Modified Firefly Algorithm
MPPT	Maximum Power Point Tracking
MV	Medium Voltage
MW	Mega Watt
NAN	Neighborhood Area Network
NEDCO	Northern Electricity Distribution Company
OLTC	On Load Tap Changer
OMS	Outage Management System
ORM	Outage and Restoration Management

PA	Palestinian Authority
PCC	Point of Common Coupling
PEC	Phasor Data Concentrator
PENRA	Palestinian Energy and Natural Resources Authority
PERC	The Palestine Energy Regulation Commission
PETL	Palestinian Electricity Transmission company Ltd
PHEV	Plug-in Hybrid Electric Vehicles
PLC	Power Line Communication
PMU	Phasor Measurement Unit
PON	Passive Optical Networks
PUs	Primary Users
QoS	Quality of Service
RES	Renewable Energy Sources
RPP	Revenue Protection Program
RTP	Real Time Pricing
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SDR	Software-Defined Radio
SELCO	Southern Electric Company
SG	Smart Grid
SGCN	Smart Grid Communication Network
SGIG	Smart Grid Investment Grant
SPC	System Protection Center
SUs	Secondary Users
TDECO	Tubas District Electricity Company
ToU	Time of Use
VR	Voltage Regulator
VVC	Voltage and VAR Control
V2G	Vehicle to Grid
WAN	Wide Area Network
WAMCP	Wide Area Monitoring Control and Protection
WLANs	Wireless Local Area Networks

CHAPTER 1: INTRODUCTION

1.1 General Overview of Smart Grid

The term grid stands for power system that consists of all or some of the following operations: generation, transmission, distribution and control.

Although the smart grid does not have a unique international definition, there are several definitions used in the literature for the smart grid at international levels.

- The US Department of Energy defined Smart Grid as:

"A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources" [1].

- While, The European Technology Platform defined Smart Grid as:

"A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it: generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies" [2].

In Smart Grid, there are Intelligent equipment's that warn and inform operators when they are facing any kind of operational problem, these equipment's can be integrated with the development and widespread use of communication technology. Problems occurring on the grid can be evaluated by analyzing defects at the failure point. The important point is to find or define grid defects without any failure. Many important studies have been done in order to improve the quality of energy [3].

Since system operators have realized the need to monitor electrical network parameters such as: voltages, currents, harmonics and power outages; efforts to enhance the energy efficiency have been appeared, and the potential of smart grids has become obvious.

Smart Grid includes the whole electrical energy generation, transmission, distribution, and utilization cycle. It consists of sensors, advanced actuators, IT systems, communication infrastructure, system monitoring, control and management applications.

The key objectives of smart grid deployment are as follows [3]:

- Improving the efficiency of energy conversion, power transmission, power distribution, and storage.
- Optimizing grid utilization and averting construction of new power plant to backup peak loads.
- Enhancing security and safety in system operation by providing better power grid monitoring and control.
- Improving the power supply reliability and quality to end users.
- Enabling and promoting the integration and utilization of renewable energy sources.
- Improving resilience to disruption.
- Reducing greenhouse emission through enabling renewable energy sources.
- Enabling self-healing responses to disturbances and predictive maintenance.

1.2 Problem Statement

Palestine has a considerable potential to convert to Smart Grid system, since some of the local distribution companies already have their SCADA systems. There are several applications of Smart Grid that can be deployed in Palestine, such as:

- Automatic metering infrastructure to minimize the power losses and theft control.
- Demand side management, to reduce the power daily peak load.
- Integration of distributed generators (distributed energy resources DREs), to reduce the dependency on Israel to cover the increased power demand.
- Voltage and var control, and Fault detection isolation and restoration techniques to improve system performance.

A main key for the success of these applications is the proper selection of communication network for the system. Since, wireless and satellite communications are out of reach at this time; due to political and economic constraints. There are several practical communication systems that can be used for the special case of Palestine as:

- Microwave
- Fiber optics network
- PLC (Power Line Communication)
- Mobile communication technology, 3G through the available Palestinian mobile service providers.

Electricity distribution companies shall think seriously of smart grid applications, and they have to arrange the required assessment studies to start converting their network to be smart, in order to get the huge benefits of the smart grid applications and enhance the quality of the provided services.

1.3 Methodology

In this study several actions and steps were arranged to perform the required research. First of all, the Data collection stage was finalized; in which the required data about the electrical load, existing energy grid, renewable energy resources (Solar, wind, and Biomass), and available communication networks in Palestine were obtained. These data were gathered from the local distribution companies (NEDCO, TDECO, JDECO, HEPCO, and SELCO) and the Palestinian Electricity and Transmission Ltd (PETL).

The next stage was Data analysis stage; were the collected data in the first stage verified, analyzed, and prepared for the next stage, and also the appropriate smart grid applications suitable for Palestinian situation were deeply investigated.

Finally, Simulation arranged using Open Distribution System Simulator (OpenDSS), which is a simulation technique used to show the benefits of using smart grid applications, such as: VVC, Demand side management and peak load shifting techniques and their effect on the existing electrical grid.

1.4 Thesis Organization

This section aims to give an overview about the thesis organization for a better navigation throughout the whole report.

Chapter 2 introduces smart grid applications and technologies including: demand side management, voltage and var control approaches, integration of distributed energy resources, wide area monitoring control and protection, fault detection isolation and restoration, integration of electric vehicle to the grid, automatic metering infrastructure, and microgrids.

In chapter 3 the literature review is investigated for several smart grid applications and communication systems related works.

Chapter 4 presents the communication networks used for smart grid applications and focuses on the applicable technologies for the Palestinian situation. Also, the chapter includes the smart grid hierarchical communication networks and requirements for smart grid communications.

Chapter 5 introduces the actual situation of the electric power system in Palestine including interconnection with neighboring countries, generation, transmission, distribution, regulations, tariffs, current electricity supply and demand, future plans for generation and transmission, and renewable energy resources.

Following next, chapter 6 focuses on the simulation of different smart grid applications experiments, results of these experiments, and discussions.

Chapter 7 presents a summary about the existing smart grid applications infrastructure and recommendation to convert the conventional power grid to smart grid in generation, transmission and distribution levels.

Lastly, chapter 8 provides conclusions related to the main scope of the thesis, and suggestions for future scientific researches.

CHAPTER 2: SMART GRID APPLICATIONS

The operation of smart grid depends on a wide range of applications and technology solutions. The following application areas are considered as the most common Smart Grids applications:

2.1 Demand Side Management (DSM)

Also known as Demand Response (DR), demand side management can be viewed as an additional variable for control and management of the Smart Grid. The load can be regulated in order to provide load reduction during the peak hours in the distribution grid [4].

Demand side management is the series of operational actions initiated by the utility, the end costumers, or both to decrease the energy consumption level. A typical DR event may consist of a desired schedule, desired demand reduction level, or a list of targeted customers depending on the type of the DR program selected.

Types of demand side management

All types of customers (residential, industrial, and commercial) using different technologies can achieve demand response. However, the use of such resources varies by customer type. Demand side management resources are typically deployed in two different ways: either the utility directly dispatches the resources, or customers willingly change their consumption in response to price signals (referred to as "non-dispatchable" DR).

Customers with dispatchable resources usually enter into contracts to receive payments for demand reductions, and they may face penalties for nonperformance. Dispatchable programs are widespread in the industrial and commercial sectors. In contrast, non-dispatchable resources generally participate in price-based DR programs such as critical peak pricing, peak time rebates, real time pricing, and time-of-use tariffs. Figure 2.1, below, depicts common types of demand-side resources [5].

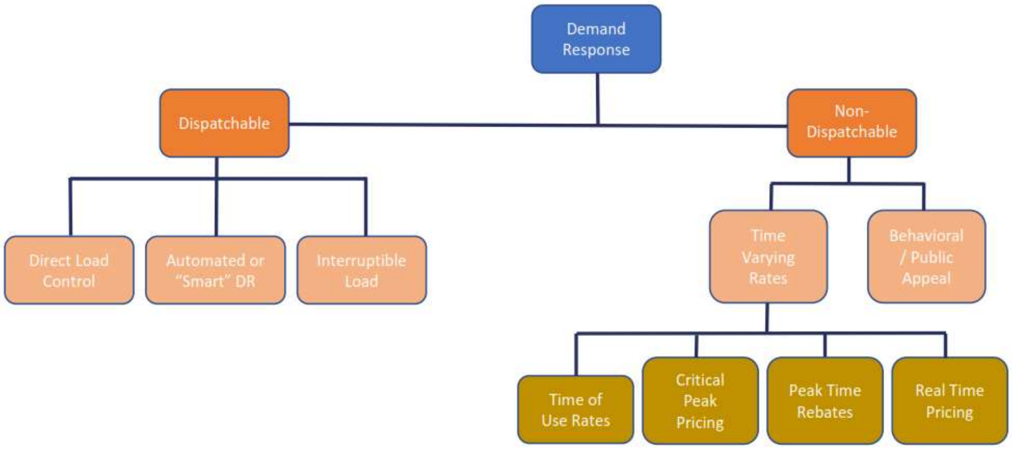

Fig. 2.1, Demand response resources [5]

2.2 Voltage and Var Control Approaches (VVC)

Distribution systems are the medium voltage networks that deliver electric power from the substations to the customer locations where the voltage is stepped down to a certain voltage suitable for end user consumption. Voltage and Var Control (VVC) refers to the control of voltage regulation devices and reactive power compensation devices for the purpose of reducing consumers demand and energy losses, and maintaining voltages at various points in the distribution network within acceptable limits.

Voltage regulation devices typically include the On-Load Tap Changer (OLTC) of the substation transformer and the tap changers on the voltage regulators on the distribution feeders. Reactive power compensation devices consist of switchable capacitor banks or DSTATCOM devices on the feeders in the substation.

2.3 Integration of Distributed Energy Resources (DERs)

Distribution energy resources, sometimes also known as distributed generation (DG), embedded generation, dispersed generation, or decentralized generation, refer to generation units within the distribution grid or on the customer side of the network.

These sources of energy often generate localized power for loads in their proximity. This would reduce the congestion on the system as well as power losses since less power needs to be transmitted to remote load points. Also, the size and the number of power lines that need to be constructed will be reduced.

This decentralized approach would fit better in the liberalized electricity market with increasing need for higher reliability and availability of service. The size of the DER can range from a few kilowatts to 100 MW or even more. These units can be owned and operated by the utility or by the customer.

DER units that run on fuels or use the previously stored energy can be dispatched for a given period of time. These units can be dispatched either remotely by the utility or locally by the individual owners. They can therefore assist in the generation dispatch of the distribution grid and at times of peak load; subject to their operational constraints. However, other units that utilize DERs such as wind and solar are normally non dispatchable, meaning they can only provide power as long as the source of energy is available (i.e., sun shining or wind blowing).These units are often set to operate in the maximum power point tracking (MPPT) mode, indicating that they are tuned to extract as much energy as available.

When operating in hybrid designs in parallel with energy storage systems such as batteries, they can be turned into dispatchable units. It should be noted that the DER units connected to the grid via DC/AC inverter circuits are capable of injecting reactive power into the grid regardless of whether or not the main source of energy is present, which makes them efficient sources for reactive power control.

Communications between the DER units and the utility can be done through the supervisory control and data acquisition (SCADA) system or other public communication links for smaller units. Typical signals exchanged are dispatch signals (in terms of active and/or reactive power set points), turn on/turn off signals, disconnection commands, measurements, and other related data.

The dependability and security requirements are high because of the potential impact that, for example, an integrity violation by an unauthorized entity or a lost communication channel can affect the overall system performance.

2.4 Wide Area Monitoring Control and Protection (WAMCP)

Power system stability can be classified as the ability of the power system to approach and operate at a stable equilibrium with acceptable grid voltage and system frequency. To ensure power system stability, a wide range of dynamic phenomena need to be considered, ranging from generator angular dynamics on a sub second time scale, via frequency dynamics on a time scale of seconds, to voltage and load dynamics on a time scale of tens of seconds to minutes. Most blackouts over the last decades have been caused by failure to preserve one or more forms of power system stability.

Classical SCADA or energy management systems (EMS) typically have a measurement update rate of several seconds or even minutes and thus need to assume that the power grid is operating in steady state, and are therefore not suitable to monitor or control such phenomena. Wide-area monitoring, control, and protection (WAMCP) extends the time resolution of classical SCADA/EMS down to the sub-second time scale, making it capable of monitoring and reacting to dynamic instabilities in the grid. Figure 2.2 below presents multilayered wide-area protection architecture.

WAMCP structure consists of the followings:

- Data acquisition, carried by Phasor Measurement Units (PMU)
- Data delivery through wide area communication system to Phasor Data Concentrator (PDC)
- Data Processing, through the System Protection Center (SPC)
- Command delivery
- Command execution

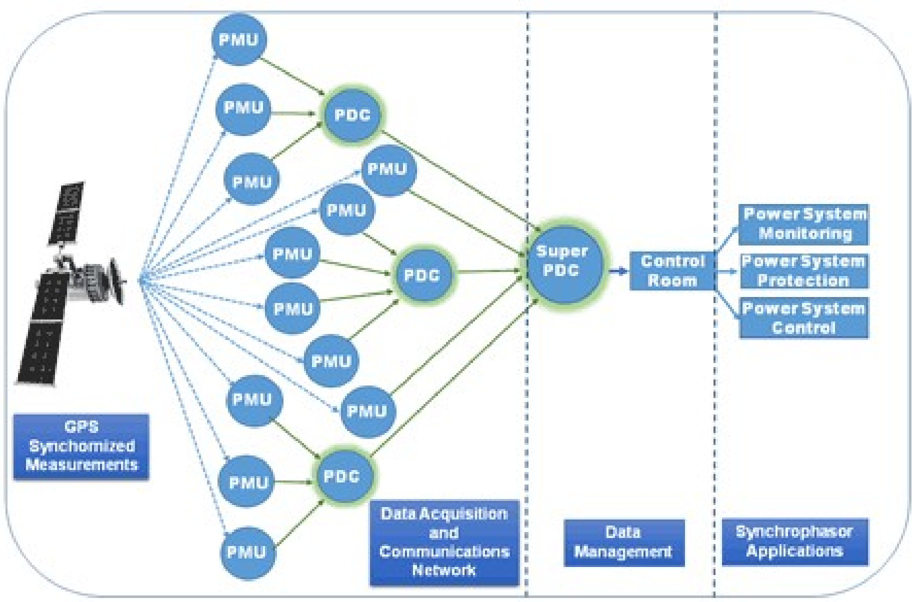

Fig. 2.2, Multilayered WAMCP architecture

2.5 Fault Detection Isolation and Restoration (FDIR)

(FDIR) is a phrase commonly used when talking about Smart Grid and communication. The automation of field switching devices, which entails the deployment of microprocessor-based intelligent electronic devices (IEDs) with long-range high-speed communication devices, paired with automated FDIR software scheme directly contributes to significant reliability and customer service enhancement.

The major driver and benefit for utilities deploying FDIR is enhanced reliability, which eventually also leads to improvement in overall system operation and efficiency. The automation of field switching devices leads to faster fault isolation and restoration of unaffected customers. Thus, customer satisfaction is a side benefit of FDIR.

Many utilities have established a target maximum restoration time to be achieved with this level of automation, such as 1 or 5 minutes. Metrics are typically used to measure reliability for utilities, and regulatory commissions typically use these metrics to force utilities into improving reliability on underperforming distribution networks.

2.6 Integration of Electric Vehicle to the Grid (V2G / G2V)

An Electric Vehicle (EV) is a vehicle that uses one or more electric motors for impulsion. Since fossil fuels generally get more expensive and diminish; fully electric vehicles or plug-in hybrid electric vehicles (PHEV) will be more popular.

There are two approaches namely Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) comes on the scene due to the wide deployment of the eclectic vehicles and as illustrated in figure 2.3 below.

In G2V approach, an external power source is used to charge the vehicle battery to store sufficient energy needed to power the electric vehicle. From the perspective of the grid, the charging operation adds a considerable new load on the existing distribution grids and this is one of the main issues in G2V approach. [7]

Optimizing EVs charging profile is one of the solutions to diminish the impact of EVs on the grid. This means, the peak power demand needed to be maintained as low as possible, taking into account the vehicle charging extra power consumption. This can be achieved by coordinating the charging process of different EVs so that they are charged at different times. Also, the grid can encourage the electric vehicle users to charge their EVs during off-peak period at cheaper rates.

In V2G approach, EVs provide a new technique to store and supply electric power. EVs can communicate with the grid to deliver power back into the grid, when they are at parking mode and connected to the grid. In the U.S. the car is driven only one hour a day on average. In other words, these cars are parked most of the time (around 95% of the day) doing nothing. [7]

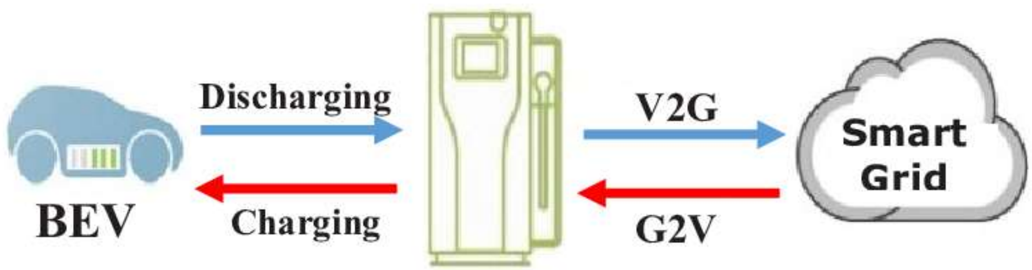

Fig. 2.3, V2G and G2V application

2.7 Automatic Metering Infrastructure (AMI)

Smart metering is one of the most essential techniques used in the SG for getting data from customers' appliances and devices, and also controlling the performance of these devices. Automatic metering infrastructure (AMI) systems are combined with automatic meter reading (AMR) systems, which are widely treated as a logical approach to understand SG. AMR is the technology of automatically collecting consumption, diagnostic, and status data from energy meters and transferring it to a central database for troubleshooting, analyzing, and billing as shown in figure 2.4; the smart meter collects the energy consumption data of the TV, refrigerator and dishwasher, also sends them control signal contains commands if needed. The data generated by the home's smart meters is sent to a data concentrator. This concentrator could be a gateway or an access point. The data can be further transferred to the utility. In AMI the real time and on demand two-way communications with the meter make it differs from conventional AMR. This provides an improved customer power demand management and system operations. [7]

A smart meter is generally an energy meter that records power consumption in intervals of time (hourly or less) and sends the data at least daily to the utility for billing and monitoring purposes. Also, a smart meter has the ability to remotely disconnect-reconnect and controls the end-user devices and appliances to manage demands and loads and within the smart homes or buildings.

From an end user's point of view, smart metering has some advantages. For example, customers can estimate their electricity bills and then reduce bills and manage their power consumptions. From a utility's point of view, they can use data from smart meters to realize pricing on real-time bases, and try to optimize power flow or to encourage users to reduce their consumption during peak load hours.

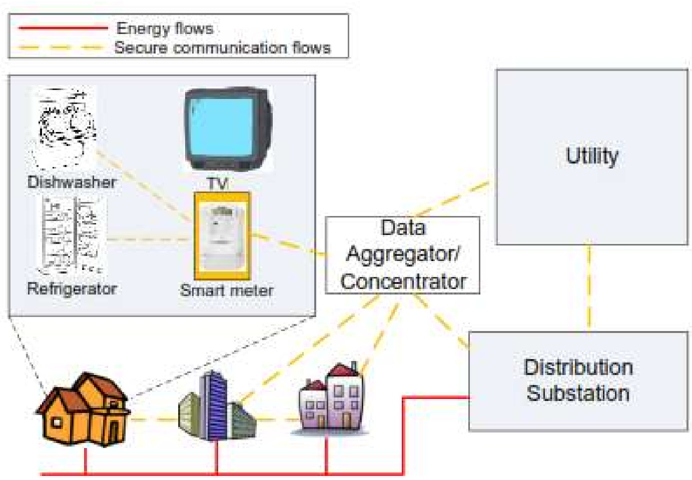

Fig. 2.4, An example of the smart metering structure [7]

2.8 Microgrids

Distributed generation encourages the development of a new grid model, called microgrid, which is considered as one of the foundations of the SG future. The plugand-play integration of microgrids is expected to play a role in the organic evolution of the SG [7].

A microgrid is a localized grouping of energy storages, loads, and electricity generations. It is connected to a traditional macro grid, in normal operation. The microgrid users can generate electricity using distributed generation, such as fuel cells, solar panels, and wind turbines.

When microgrid functioning autonomously; the point of common coupling (PCC) can be disconnected from the macro grid. This operation will lead to an islanded microgrid, in which the power delivered to the users in this microgrid from the distributed generators without getting power from the electric utility located in the macro grid. Therefore, microgrid with the ability to isolate from a macro grid during disturbances will provide electricity supply with high reliability.

During the microgrid islanding mode, although the users do not obtain power from outside, they may still exchange some information with the macro grid; this in order to decide when they should obtain electricity from the utility (reconnect with macro grid) based on macro grid status. Figure 2.5 presents an example of the microgrid application; the lower layer shows the microgrid physical structure, including buildings, PV generators, wind generators, and a wireless access point (AP). Using power lines, the buildings users and generators exchange power. Also, they exchange information via an AP-based wireless network. The middle red layer shows the power flow within this microgrid, and the top blue layer shows the information flow.

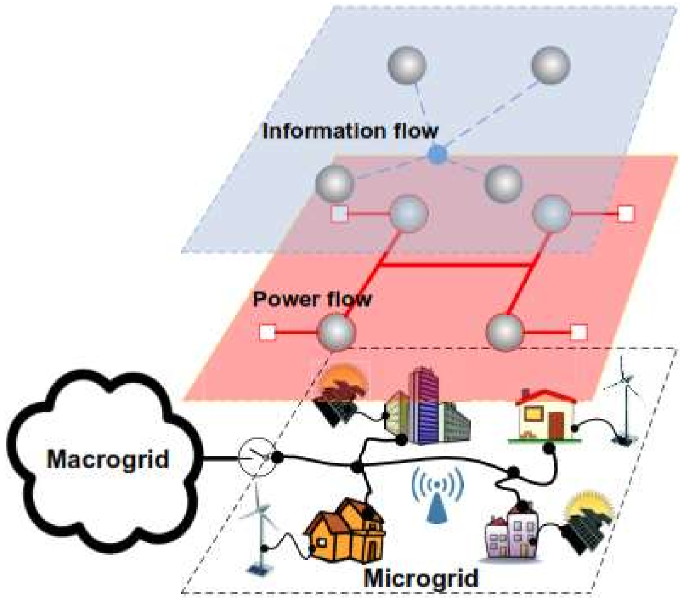

Fig. 2.5, A microgrid example [7]

The following figure 2.6, summarize the different smart grid applications mentioned in this chapter:

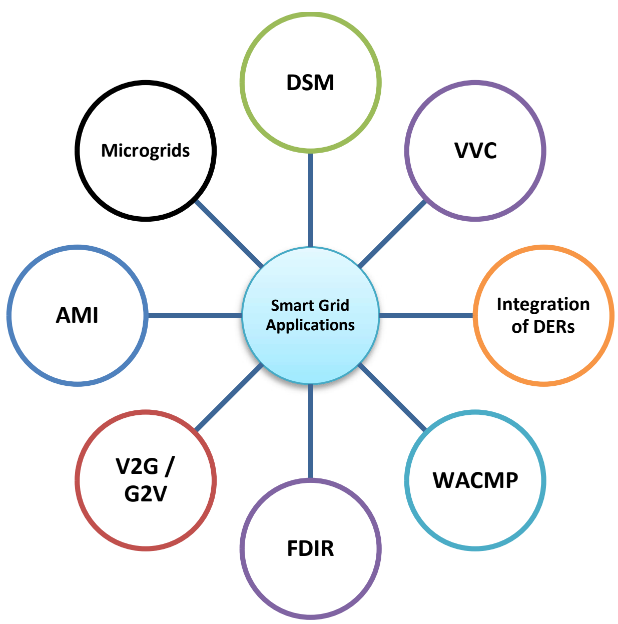

Fig. 2.6, Smart grid applications summary

CHAPTER 3: RELATED WORKS

In this chapter we review works related to smart grid applications and needed communication infrastructures including:

- First, we review similar smart grid opportunities, challenges, applications, and experiences in neighboring countries including Egypt and Jordan, also in part of the Gulf Cooperation Council (GCC) such as Oman, in addition to Turkey, Mediterranean countries, and the United State of America.
- Second, we survey researches related to communication technologies and infrastructures used for smart grid applications and their advantages and drawbacks.
- Third, we study the literature related to the effects of the smart grid applications on the power system reliability including some indices and metrics to figure out these effects.
- Finally, we review the works related to smart grid and renewable energy approaches in Palestine.

Ilhami Colak et al. [3] described Smart Grid opportunities and applications in Turkey. The feasibility, assessments, and suggestions on smart grid developments are given.

Also, they provided detailed information about the smart grid applications and the existing infrastructure of the smart grid in the electricity sector of Turkey, in addition to an overview of smart grid projects in Europe.

The paper provided a discussion about the historical development of the Turkish Electricity Distribution System Operator, the Turkish Electricity Transmission System Operator, and the Turkish Electricity Production System Operator. Also, the advantages, drawbacks and the policy of the EU toward the current smart grid projects in Europe are discussed.

Finally, the authors presented detailed overview of the smart grid opportunities, the current state of the smart grid policy, and the expected benefits if smart grid in turkey.

X. Fang et al. [7] conducted a survey of the literature till 2011 on the enabling technologies for the Smart Grid. They explored three major systems, namely the smart management system, the smart protection system, and the smart infrastructure system. Also, they proposed the possible future directions in each system.

For smart management system, they surveyed different management objectives, such as profiling demand, improving energy efficiency, controlling emission, maximizing utility, and reducing cost. While, for smart protection system, they explored the security and privacy issues in the Smart Grid, and explore various failure protection approaches which improve the reliability of the Smart Grid. Then for smart infrastructure system, they inspected the smart communication subsystem, the smart energy subsystem, and the smart information subsystem.

As results for the survey, the authors have learned the following lessons:

i) The projects and practical deployments of SG should be well-analyzed before the initiative begins.

ii) The current SG programs and projects are mainly led by related organizations or electric utilities. They probably may not have enough experience on the deployment and design of complex information and communication systems. However, SG is a complicated system of systems, resulting in complex interactions among information, communication and energy subsystems.

iii) “Smart Grid” means that the grid has the cleverness to realize functionalities and advanced management objectives. However, most of such objectives are related to supply and demand balance, emission control, utility maximization, operation cost reduction, and energy efficiency improvement.

iv) Electric utilities should investigate the behaviors of the protection system. Although SG is expected to provide advanced protection methods.

v) When utilities introduce new technologies into SG, they should also assess the possible risk introduced.

Amany El-Zonkoly [8] proposed a modified firefly based optimization algorithm (MFA) for optimal DSM of different load types in Alexandria – Egypt as a case study with optimal energy resources schedule, and other smart grid applications to cover the excessive load shedding. The objective of the proposed modified algorithm is to minimize the overall operational cost including generated energy cost, consumed energy cost, grid energy cost, energy loss cost, startup cost of thermal generating units and unserved energy cost.

The modified firefly algorithm (MFA) is applied for optimal DSM of the three loads types (industrial, residential and commercial) simultaneously and for optimal unit commitment planning. Also, the proposed energy management enables the PHEV to charge more than once a day.

The proposed algorithm (MFA) was applied effectively to the 45-bus distribution network of Alexandria, Egypt which is supported by different types of distributed generating (DGs). The test results showed an improvement in the operational conditions of the system.

Hashiesh et al. [9] proposed Broadband Power Line (BPL) communication for smart grid applications and it is implementation in a typical Egyptian network.

The suggested system is tested through the implementation on typical LV & MV networks in Egypt. A proposal for installing BPL hardware in the system is also highlighted. Effect of using noise filters is tested and offered sufficient results.

Bayram et al. [10] conducted an overview study of the current smart grid efforts in the Gulf Cooperation Council (GCC) region. A detailed overview of the current situation of the power grid was presented. The efforts divided into three main categories: energy exchange and trading within GCC interconnection, integration of RES, and shaping the demand profile through demand side management.

The power grids interconnection of GCC countries can be considered as the first major smart grid activity. The main encouraging issues of the power grid interconnection were: (i) shared spinning reserves; (ii) reduced capacity investments; (iii) cost efficiency; (iv) development of power markets; (v) and reduced carbon emissions. The energy demand growing rapidly (almost 10 % annually) and the sudden demand surges frequently threaten the supply thus requiring costly investments.

The interconnection of the grid would lead to efficient resource usage, reduce the operation cost, and improve grid stability. The implementation of DSM programs and the integration of RES such as solar resources can be very useful to replace the diesel generators at remote villages and farms.

Manar Jaradat et al. [11] discussed and provided practices and recommendations to be used in the future for Internet of Things (IoT) and Smart Grids (SG). Also, they discussed the techniques used to manage big data created by meters and sensors for application processing, and explored the different applications for smart sensors networks in the smart power grid domain along with integrating renewable energy sources to prevent climate change, and achieve sustainable energy.

Aljohani and Beshir [12] examined the effect of smart grid applications in improving the reliability of the power distribution networks. They used IEEE 34 node test feeder, to analyze the optimal placement of the automatic switching devices and quantify the devices proper installation based on distribution system performance.

The effects of two main smart grid applications have been inspected; the accommodation of distributed generation (DG), and the optimal use of the automatic sectionalizing devices, such as automatic recloser and automatic switches.

The results showed significant improvement in the system reliability indices such as SAIDI and SAIFI because of optimal installation of the automatic reclosers.

In [13] the U.S. Department of Energy (DOE), Office of Electricity Delivery and Energy Reliability (OE), was implementing the Smart Grid Investment Grant (SGIG) program under the American Recovery and Reinvestment Act of 2009. The SGIG program involves 99 projects that are deploying smart grid techniques, technologies, and tools for advanced metering, customer systems, electric distribution, and transmission.

They were expected to have enhanced capabilities for improving electric distribution reliability. The results expressed significant improvement in reducing momentary interruptions, sustained interruptions, and average system interruption duration as calculated by variations in SAIDI, MAIFI, and SAIFI respectively.

Malik et al. [14] presented a methodology and results of a study carried out in Sultanate Oman to assess the benefits of long-term load management in terms of avoided cost of distribution, transmission and generation. Also, the environmental benefits and savings in distribution and transmission losses are estimated.

The achieved benefits were then compared with estimated cost of converting the convention power grid to smarter one. The results demonstrated that the long-term load management benefits of smart grid could outweigh the cost of upgrading the grid to make it smarter. However, the study recommended that appropriate investigation of issues related to load management potential, upgrading the grid cost, the worth of increasing reliability through smart grid, and customer willingness to participate in load management activities etc. need to be assessed before moving into that direction.

Ammar Alkhalidi et al. [15] discussed the water and Energy as indicators for sustainable city site selection and design in Jordan using smart grid. The selected geographical location for the sustainable city in Aqaba gave it a unique wind energy profile. Wind energy was used to support the microclimatic techniques used in the housing sector and to generate electricity. It was shown that wind is almost unidirectional with good shape and scale factors at a more than 40% wind capacity factor. Electrical demand was covered by hybrid energy system of PV with battery storage and wind. While, Water demand was covered by desalination of sea water.

Baba [16] introduced a proposal for solving the problem of frequent power cut-off and blackouts; due to exceeding peak-limit mainly in summer in the West Bank. The idea was based on developing a smart grid that uses the wide spread ADSL Internet as a communication tool. An embedded control unit (ECU) was used for communication, data collection of power consumption, and end user loads control.

Buccella et al. [17] delivered an overview on the distribution generation (DG) and the smart grid technologies and concept. They found that ICT infrastructure could be shared among different service providers or different services (electricity, heat, gas, and water).

The authors discussed the requirements of distribution generation systems and smart grids; these DGs include Photovoltaic Generators, Wind and Mini-hydro Generators, Energy Storage Systems, Electric Vehicles and Microgrids.

Connecting RESs with the grid and managing a Microgrid or a Smart Grid may become a challenging task if the number of users and generators is very large and their power quality and/or that of the grid is not high. Accordingly, optimal operations can be achieved only by addressing reliability and stability issues.

Also, the authors studied the active management of the distribution generators, the communication systems in smart grids, real time pricing and advanced metering infrastructure, and the standards related to the smart grids.

Ilhami Colak et al. [18] presented a detailed survey of the critical challenges in smart grids in terms of sensing, measurement, information and communication technologies, power electronics, control technologies, and energy storage technologies.

Also, they pointed out smart grid projects in Europe in terms of their number, budget, stage, organization type and multinational consortia. The authors, briefly emphasized the capabilities of smart power grids with respect to the traditional power grids limitations.

As a result of all analyses conducted by authors, numerous essential problems needed to be solved and considered are uncovered for the purpose of constructing much smarter power grids in future.

Bayram et al. [19] delivered an overview of smart grid distributed energy trading concepts. They presented the enabling technologies that are required to generate, store, and communicate with the trading agencies. Then, they identified the desired outcomes and the motivation of energy trading framework.

They characterized the following enabling technologies: distributed renewable generation, electric vehicles, energy storage, and communication systems.

The authors also divided the mathematical optimization frameworks into three groups: first one included game theoretic models that are used for multi agent decision making. Second type used dingle objective maximization. Finally, the last group used simulation-based studies for energy trading mechanism.

Reddy et al. [20] provided a review and different methods of integration, control, communication, and metering of renewable energy resources based on smart grid.

Integration refers to connection of heterogeneous type of energy sources with AC or DC grid using suitable converters. Power output of the distributed renewable energy sources DREs is dependent on climatic conditions like solar irradiance and wind speed. Controls in smart grids are made intelligent to extract the maximum power from the sources, operational scheduling of energy sources and overloads, control of transients and real and reactive power.

Communication between various control nodes is necessary; for diverse smart grid effective operation. Smart metering can measure the energy parameters of the load remotely and transfer the data through the communication network to the utility operator.

In [21] MEDREG which is the Association of Mediterranean Energy Regulators, conducted an overview of the existing projects, information regarding the implication of SG activities, case studies, and the effects of SG in the Mediterranean countries.
The countries in the Mediterranean proceeded to experiment various smart grid systems, which MEDREG has collected in order to evaluate the state of play of this technology in the region, share some of these experiences, and identify to the best possible level of arrangements that need to be undertaken. In its strategy, MEDREG aims to start from an assessment of constraints and needs in particular technological and economic, to promote options that are more consistent with the specific situations in different countries.

Naveen Venkatesan et al. [22] have developed a model for residential Demand Response by developing price elasticity matrices for different types of consumers. Comprehensive price elasticity matrices have been developed for each consumer type based on their rationality assumptions. Also, the impact of Demand Response on system voltage and losses has been evaluated on a large IEEE test feeder. Results indicate that DR impacts the distribution network in 3 positive ways: (1) Voltage profile improvement (2) Losses minimization (3) Valley filling.

CHAPTER 4: COMMUNICATION NETWORKS FOR SMART GRIDS

The Palestinian telecommunication and information technology sector development is subject to the unbalanced power relationship between Palestinian Authority (PA) and Israel, similar to everything else in Palestine. This relation is established in the Annex III of Oslo Accords and the associated telecommunications and postal services agreements, which deals with telecommunication technology [23].

Although the agreement of telecommunication admitting the rights of Palestinians to construct and operate their own networks, it gives Israel full control over the telecommunication gateways internationally, the frequency spectrum, equipment import, and the access to areas labeled Area C; all under the security reasons excuse.

Until 2017 Israel's refusal to grant Palestinian access to the radio communication spectrum destroys the development of Palestinian mobile telecommunication.

Until 2017 Palestinians have no access to 3G, 4G, LTE, or future spectrum bands; because of Israel's refusal to grant Palestinian access to the radio communication; a situation that also restricts the capability of telecommunication operators in Palestine to widespread mobile access to the Internet or to deliver mobile data services.

While in beginning of 2018, Palestinians in the occupied West Bank without Gaza started receiving 3G mobile telecommunications services, after decades of struggle with the Israeli side. Jawwal and Ooredoo (The licensed Palestinian mobile service providers) began offering the service to their customers.

Worldwide 3G services were originally launched in the early 2000s, and much of the world already has 4G technology, while 5G is launched in the mid of year (2019).

4.1 Communications in Smart Grid:

The term Smart Grid generally describes the integration of elements connected to the electric grid with an information infrastructure through intelligent communication systems to offer numerous benefits for both the providers and consumers of electricity [24].

One of the major factors of a SG infrastructure is having the appropriate communication network to support its different requirements and functionalities. Communication protocols and technologies are essential for the successful implementations of SG.

One of the major aspects of the electric utility transformation to smart grid is the addition of an integrated communications network that will contact every part of the grid from generation, transmission, distribution to the end customer and will support the intelligent automated transactions that will make the grid "smart". Below figure 4.1, provides an example of communication networks in Smart Grid; a substation communicates with an electric utility over Fiber or over the power line. Communities are connected to their electric utility via free-space optical, satellite, microwave, or cellular systems. Smart meters and User devices use Power line communications, ZigBee, and WiFi. Wireless mesh networks are used for exchanges of information between users.

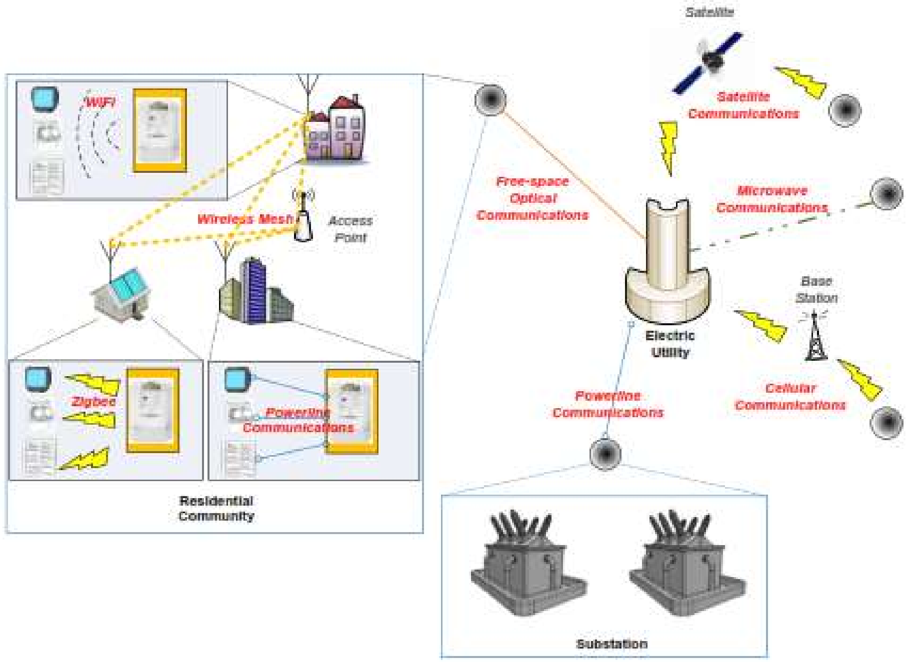

Fig. 4.1, An example of communication networks in Smart Grid [7]

4.2 Smart Grid Hierarchical Communication Networks

In smart grid technology; communication infrastructure can be categorized into WAN, NAN and HAN, based on the area coverage range and data rate. Smart grid applications are classified to Premises Network, Neighborhood Area Network (NAN), and Wide Area Network (WAN) according to their coverage range and data rate required for their optimum use [25].

4.2.1 Premises Network Applications

A premises network, which includes Home Area Network (HAN) or Building Area Network (BAN), is at end of the network architecture at the end user side. It provides communications among electric vehicles, home appliances, and other electric devices at end user premises [24].

HAN is suitable for communications between appliances and equipment in home that are able of receiving and sending messages from a smart meter, and or home and energy management systems. BAN supports industrial and commercial users with concentrate on mechanical loads such as heating ventilating and air conditioning (HVAC) loads, building automation, and other industrial applications with energy management.

A third-party electric utility or energy service provider connects the premises network to other smart grid players, via an Internet gateway or a smart meter. This permits an electric utility to achieve Neighborhood Area Network (NAN) or Field Area Network (FAN) applications in commercial, industrial and residential premises, e.g., user information messaging, load management, demand response, prepaid services, and real-time pricing and control.

4.2.2 Neighborhood Area Network Applications

A Neighborhood Area Network (NAN) provides flow of information between a Wide Area Network (WAN) and premises area network. Data collected from end users in a neighborhood and transmitted to the service provider or electric utility company. FAN/NAN connects several field devices such as intelligent electronic devices (IEDs) and provides a wide range of smart grid applications, such as, load management, smart metering, prepayment, Real Time Pricing (RTP), Time of Use (TOU) pricing, Critical Peak Pricing (CPP), distribution automation (DA), demand response (DR), restoration and outage management, electric vehicle and transportation, customer information and messaging, and service switch operation. [24]

In order to apply mentioned applications, communication technologies are needed with a coverage distance (up to 10 km) and higher data rate than those applications in a premises area network. These FAN/NAN applications are discussed below:

(1) Smart Metering enables a utility to remotely collects data from several types of meters electric/gas/water and transmit collected data to a central operation center for analysis, billing, and remote meter control. The utility is capable to perform real-time bidirectional communications with Advanced Metering Infrastructure (AMI) between meters and a centralized management site, and thus reducing operational costs and improving meter reading accuracy.

(2) Pricing applications include price information broadcasting to customer's premises devices and meters, e.g., load control devices, plug-in hybrid electric vehicles (PHEVs), and smart appliances. These are normally related with time-of-use (TOU) pricing, real-time pricing (RTP), and critical peak pricing (CPP) programs.

(3) Prepayment electric service which permits end users to buy electricity in advance.

(4) Demand side management (DSM) or demand response (DR) enables the utility operator to contact customer's devices, such as smart thermostats, smart appliances, PHEVs and load control devices, during peak demand periods. Demand response will provide load reduction in the distribution grid.

(5) Distribution automation (DA) including data communication and information management, monitor and control, automation control, and real-time operation of grid structure in the distribution system. DA achieved by enabling control of distribution-level equipment, such as DSTATCOM, capacitor bank controllers, voltage regulators (VR), re-closers, switches, and fault detectors. Main DA applications are distribution system monitoring and maintenance, Volt/VAR control, distribution system demand response (DSDR) and fault detection clearing isolation and restoration (FCIR).

(6) Outage and Restoration Management (ORM) enables the service providers to sense an outage once the power is lost through devices, such as outage detection units and

smart meters. When the electric meter loses its mains power, the electric meter will send a message to a utility's Outage Management System (OMS), and also when the meter senses that the mains power has been restored.

(7) The storage applications using storage devices installed along distribution feeder for voltage support, interruption protection, demand control, peak load shaving, and power quality. Storage applications for Distribution customer take place as a practical solution that can solve operational problems by providing fast response time, energy, and power to a distribution network allowing renewable energy sources to be integrated efficiently.

(8) Electric transportation applications include both electricity flow from vehicles to the grid (V2G, vehicle-to-grid) and electricity flow from the grid to vehicles (G2V, grid-to-vehicle). These applications permit different electric vehicle technologies to become portable distributed generation resources (based on battery, fuel cell, plug-in fuel cell, plug-in hybrid, and hybrid).

(9) Messaging and customer information applications enable end users to access to their outage information, account information and consumption data.

4.2.3 Wide Area Network Applications

Wide Area Network (WAN) supports communication links for smart grid infrastructure; and covers long distances from FAN/NAN to the grid control center. It also provides a real-time protection, control, and monitoring applications, which can help to eliminate cascading outages with real-time information associated with the state of the power grid. [24]

Wide-area monitoring, protection and control applications provide shorter response time and higher data resolution than conventional energy management (EMS) and supervisory control and data acquisition (SCADA) systems. Wide-area monitoring, protection and control applications provide high-resolution data, i.e., 60 samples per second. Compared to a measurement update of several seconds or even minutes interval in EMS/SCADA.

There are three main areas of WAN applications described below:

(1) Wide-area protection to protect power systems from transmission congestion, stressed conditions, widespread blackouts, or unexpected events via a fully automated protection system.

(2) Wide-area monitoring providing real-time system data from a set of intelligent electronic devices (IEDs) and phasor measurement units (PMUs). PMUs provide wide-area measurements through time-synchronized snapshots of electrical network including phase angles, current, and voltage. IEDs, on the other hand, send snapshots of measurement data and device status over a WAN to EMS/SCADA.

(3) Wide-area control offers a suitable platform for fast implementation of reactive power compensation switching and generator tripping for voltage support of a large power system and transient stability. It also, responds faster than manual control by a control center, and provides automatic self-healing capabilities that exceed functionalities carried by local control.

4.3 Communications Technologies Available for Smart Grids

A communications system is the key element of the smart grid infrastructure. With the integration of advanced technologies and applications for achieving a smarter electricity grid infrastructure, a huge amount of data from different applications will be generated for further control, real-time pricing methods and analysis [25].

Different communications technologies supported by two main communications media, i.e., wireless and wired, can be used for data transmission between electric utilities and smart meters. In some cases, wireless communications have some advantages over wired technologies, such as ease of connection to difficult or unreachable areas and low-cost infrastructure needed. However, the nature of the transmission path may cause the signal to attenuate. On the other hand, wired solutions do not have interference problems and their functions are not dependent on batteries, as wireless solutions often do.

In the following, some of communications technologies used for smart grid applications:

4.3.1 ZigBee

ZigBee is a technology of wireless communications that is relatively low in data rate, power usage, cost of deployment and complexity. It is an ideal technology for energy monitoring, smart lighting, automatic meter reading and home automation, etc. The communication technique is very important between smart meters and smart home appliances. Many AMI vendors choose ZigBee protocol for their smart meter's integration and communication. [25]

ZigBee has 16 channels in the 2.4 GHz band, each with 5 MHz of bandwidth. ZigBee is considered as a good option for energy management and metering and ideal for smart grid implementations along with its simplicity, mobility, robustness, low bandwidth requirements, low cost of deployment, its operation within an unlicensed spectrum, easy network implementation, and being a standardized protocol based on the IEEE 802.15.4 standard.

Practical implementations of Zigbee technology have some limitations, such as small memory size, small delay requirements, being subject to interference with other appliances sharing the same frequency and low processing capabilities.

4.3.2 Wireless Mesh

A wireless mesh network is a communication network with flexible characteristics containing of a set of nodes, where each node can work as an independent route and new nodes can join the set of nodes. The communication signals can find alternative route through the active nodes, if any node of the network should drop out; via the network self-healing feature. Wireless mesh is used in smart metering; where, every meter is supplied with a radio communication module and each of them via neighboring meters routes the metering data. Until the collected data reaches the electric utility access point; each meter works as a signal repeater. Then, these data are transmitted via a communication network to the utility [25].

Mesh networking is a self-healing with cost effective solution, high scalability services, dynamic self-organization, and self-configuration. It is with several advantages, such as balancing the load on the network, extending the network coverage range, and improving the network performance. Home energy management and advanced metering infrastructures are part of the wireless mesh technology applications.

Fading, interference, and network capacity can be considered as the main wireless mesh networking challenges. In rural areas, since the meter density cannot provide complete coverage, mesh networks have been faced with a coverage challenge.

4.3.3 Cellular Network Communication

Current cellular networks can be a suitable choice for communicating between the far nodes, smart meters and the utility. The available communications infrastructure prevents utilities from spending extra time and money for building a dedicated communications network infrastructure and less operational costs. 2G, 3G, LTE and WiMAX are the cellular communication technologies available to utilities for smart grid applications such as smart metering.

Cost-effective and widely spread advantages make cellular networks one of the important communications technologies in the market. With strong security controls, cellular networks are able to secure the data transfer. Since the cellular networks have almost a full coverage in urban or rural areas, this will encourage utilities for deployment of this technology in smart grid applications. GPRS technology has a data rate up to 170 Kb/s, while GSM data rate is up to 14.4 Kb/s, and both technologies support Premises Area Network, Demand Response and AMI applications. Authentication, user data protection, signaling protection and anonymity are the security advantages of GSM technology. Full coverage, fast installation features, lower installation cost, and lower maintenance costs, are reasons why cellular networks can be the ideal choice as a smart grid communications technology for applications, such as outage management, advanced metering infrastructures, demand response management, and HAN.

Since power grid applications with mission-critical classification need communication network with continuous availability, and as cellular networks services are shared with market customer; this may lead to decrease in network performance or cause network congestion in emergency conditions.

Cellular communication including GPRS and 3G is used as one of the communication techniques for the SCADA and smart metering systems in part of the Palestinian distribution companies (DISCOs) including JDECO, HEPCO, TDECO, and NEDCO.

4.3.4 Cognitive Radio

"A Cognitive Radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. The majority of cognitive radios will probably be SDR (Software Defined Radio) but neither having software nor being field programmable are requirements of a cognitive radio" [26].

Sine there is huge amount of data in Smart Grid Communication needs to be transmitted via the communication links. A priority for data based on its delay tolerance could be made. For example, data carrying meter reading has lower priority compared to data carrying commands and control signals with least delay and high reliability. With the data from surveillance system and multimedia monitoring, there will be terabytes of data. And to transfer this amount of data via communication channels; needs to increase the network resources and bandwidth.

Because the frequency spectrum of wireless communication is overly congested and already occupied, Cognitive Radio is a significant technology due to improved propagation characteristics, and to carry sensitive data with less delay. Because of this, CR is used for Smart Grid environment.

Cognitive radio is a Software-defined radio (SDR) platform that can reconfigure its functioning parameters according to changing requirements and circumstances, over cognition, these parameters are error coding techniques, modulation and demodulation, and compression algorithm.

Spectral efficiency improvement is the most important Cognitive Radio technology feature, which is achieved by sensing the spectrum unoccupied channels (holes) that are not occupied by Primary Users (PUs)/ licensed users, and assigning them to the Secondary Users (SUs)/ unlicensed users.

4.3.5 LoRa

LoRa is a wireless communication technology developed to provide the low-power, low-rate, but long-range communication. It uses the free ISM (Industrial, Scientific, and Medical radio) band which varies in accordance with government regulations. The communication range of LoRa can hit up to 22 kilometers [27].

LoRa is a WAN fully convergent technology based on open standards, low cost, and was designed from the beginning to build urban platforms for smart grids applications and IoT (Internet of Things).

As frequency range of operation is also located on non-licensed 900 MHz spectrum, covered area tends to be very similar to RF Mesh. Advanced modulation techniques and access (CDMA) are also used to make the network virtually immune to interference and increased sensitivity of LoRAWAN embedded interfaces on endpoint devices [28].

4.3.6 Microwave

Microwave technology is commonly used for line of sight (point to point) communications, because of their small wavelength; directional antennas appropriately sized can be used to get high bandwidths and secure data transfer. More than half of the mobile networks base stations worldwide are connected using line of sight (point to point) microwave technologies. [7]

Therefore, an important application of this communications technology is to create SG communication networks. This communication technology is important mainly in remote and rural areas, where using other wired or wireless communication technologies is difficult or costly. However, Microwave communication is depending on line of sight. Therefore, the communication quality is greatly affected by environmental constraints (such as rain fade) and obstacles (such as hills or buildings). In Palestine this technology is used as part of the communication network of PETL (Palestinian Electricity Transmission Ltd) SCADA system which is used to control and monitor the company power stations, at the initial stage it is used for communication between Al Jalamah substation in Jenin in the Northern of Palestine and PETL headquarter in Ramallah.

4.3.7 Power Line Communication

Power line communication (PLC) is a technique that uses the existing power lines to transmit high-speed (2–3 Mb/s) data signals from one device to the other [7]. In urban areas where other communication methods struggle to meet the requirements of utilities, PLC has been considered optimum selection for successful implementations of AMI and communication with the electricity meter; due to the direct interface with the smart meter. In a PLC communication network, meters are connected to the data aggregator through overhead power lines or underground cables (usually up to the distribution transformer) and then data is transmitted to the data center of utility operator via cellular network or fiber optics technologies.

PLC can be considered as a promising communication technology for smart grid applications, because the existing infrastructure (Power Lines) reduces the communication network installation cost.

Because of broadcast nature of Data transmissions in PLC communication; there are serious security aspects. User intervention and integrity, authentication, and confidentiality, are part of the smart grid communications critical issues.

Due to the power line networks nature; there are some technical challenges. The power line transmission environment is a noisy and harsh medium that makes the channel modeling difficult. Also, the type and number of the connected equipment or devices to the power lines, the network topology, the distance of lines and wires between devices' transmitter and concentrators' receiver, all adversely affect the data signals' quality.

The dependency on the quality of signal and sensitivity of PLC to noises and disturbances are the drawbacks that make this communication technology is not appropriate for data transmission in some smart grid applications. However, some technologies, i.e., GSM/GPRS/3G are combined with PLC technology to create hybrid solutions in which, full-connectivity is provided.

In Palestine TDECO is planning to install around 2000 smart meters using PLC communication in Far'a refugees camp (17 km northeast of Nablus), the project aims to achieve remote meters reading, improve the efficiency of power system, and reduce the losses.

4.3.8 Digital Subscriber Lines

Digital Subscriber Lines (DSLs) is a technology uses the wires of the voice telephone network for high-speed digital data transmission. Via an ADSL enabled telephone line it is common to see frequencies greater than 1 MHz [26]. Similar to PLC technology the available existing infrastructure of DSL network minimize the installation cost. Because of that, many electrical utilities chose this DSL communication technology for their smart grid applications projects. The DSL communication connection throughput is related to how far away the serving telephone exchange from the subscriber and this makes the performance of DSL technology characterization difficult.

The high data transmissions bandwidth, low-cost, and widespread availability are the main reasons and advantages for considering this communication technology as one of the best communications networks choices for implementing the smart grid concept including smart metering and other smart grid applications in electrical utilities.

For mission critical applications and due to the potential down time and reliability; DSL technology may not be suitable. Additional problems may cause by Lack of standardization and distance dependence.

4.3.9 Optical Communications

Optical communication is extensively used as the backbone of the communication network in electric grid environment to connect electric utility control centers with substations, because of many crucial advantages such as; immune to interference from electro-magnetic sources and other wireless networks, high data transmission rate up 10s of Gb/s up to hundred kilometers, and low latency [26].

Optical networks are two types, Passive and Active: Passive Optical Networks (PON) consists of several passive splitters, couplers, and devices. This shared PON network has max supported distance of 10–20 km for serving about 32 customers. On the other hand, Active Optical Network (AON) is a shared network that consists of electrically powered active manageable devices to provide fiber aggregation access. Depending upon the type of switches and devices used, it can provide supported distance up to 80 km max.

The main advantage of PON network is, active equipment are only used at the receiving ends and source; therefore, Fiber-to-the-home (FTTH) the most common optical communication uses PON technology. Three types of PON network are available: Gigabit PON (GPON), Ethernet PON (EPON), and Broadband PON (BPON).

Because of its low latency and higher bandwidth, optical communications are considered as one of the major wired communication technologies in Smart Grid Communication Network (SGCN). Although there are problems of high installation cost; recent researches and studies are now suggesting expanding the optical fibers utilization to give SG benefits until end users.

Optical Fiber network is used as one of the communication techniques for the SCADA system in part of DISCOs in Palestine, including JDECO, HEPCO, and NEDCO. For example, JDECO SCADA system contains dark fiber network connected between the substations and the SCADA control center in Jerusalem. Also, the Palestinian Electricity and Transmission Ltd (PETL) company uses optical fiber communication as part of the communication network for the existing SCADA system which controls and monitors Al JAlameh 161/33 KV substation in the north as initial stage.

4.4 Smart Grid Communications Requirements

In smart grid networks the communication infrastructure between the grid main components; power generation, transmission, distribution, and end users load need to be two-way communications with sufficient bandwidth, end-to-end security, reliable, and low-latencies. Also, the system should be immune and secure enough to prevent cyber-attacks and achieve system reliability and stability with advanced controls [25].

The following are main requirements for smart grid communication:

4.4.1 Security

Secure information transmission and storage are extremely essential for power grids and utilities, especially for grid control and billing applications. To prevent hacking and cyber-attacks, standardization efforts related to the security of the grid should be prepared, and efficient security procedures should be adopted.

4.4.2 Scalability

The smart grid should be capable to be scalable enough to simplify the power grid operation. Many smart meters, sensor nodes, smart data collectors, and renewable energy resources are sharing the communications network. Therefore, SG should manage the scalability with the integration of advanced functionalities, such as security aspects and self-configuration, with advanced web services and reliable protocols.

4.4.3 Quality-of-Service (QoS)

The communication between the end user and electrical utility is a major issue in SG applications. Performance degradation like outage or delay could reduce system stability; thus, a Quality of Service procedure shall be made to assure that communications system requirements such as QoS, high-speed routing, and suitable routing protocol are achieved.

4.4.4 System Reliability, Robustness and Availability

Achieving the system reliability is a major priority for electrical utilities. Increasing energy consumption, peak demand and aging power infrastructure are some of the reasons that create unreliable power grid. Utilizing the communication and information technologies, more robust and faster control devices, secure and modern communication protocols, intelligent electronic devices (IEDs) for the entire grid (from substation to end user), will considerably reinforce the system robustness and reliability.

The availability of the smart grid communication network is related to the chosen communication technique. Wired communication technologies with increased, security and reliability can be costly. While, Wireless communication technologies, with reduced installation costs and constrained security level and bandwidth can be an optimum solution for large-scale SG projects.

To conclude; wired communication technologies such as PLC, Optical Fiber, and DSL, are costly for deployments in wide areas but they have the capability to improve the communications system reliability, security, and capacity. On the other hand, wireless communication technologies such as ZigBee, Wireless Mesh, Cellular Networks, Cognitive Radio and LoRa are with reduced installation costs, but they have constrained security and bandwidth issues.

A mixed communication technology with a hybrid combination between wireless and wired techniques can be used with appropriate installation costs, to provide improved availability, reliability, and robustness of the communication system at the same time.

CHAPTER 5: ELECTRICAL POWER SYSTEM IN PALESTINE

The Palestinian Energy and Natural Resources Authority (PENRA), was established in 1995 and its mandate was solidified based on the guidelines highlighted in the 1997 "Letter of Sector Policy" whose core elements included [30]:

- Rehabilitation of the network and extension to unserved areas,
- Separation of policy and regulatory entities from commercial activities,
- Establishment of a public transmission company,
- Creation of autonomous commercial distribution companies,
- Development of a tariff that allowed full cost recovery, and more.

As a result, six distribution companies (DISCOs) have been established, with five in the West Bank and one in Gaza. Outside of the six DISCOs, around 150 individual village councils and municipalities in the West Bank act as electricity service providers and represent approximately 25% of the total electricity consumption in the West Bank. Jerusalem District Electricity Company (JDECO) is the oldest energy institution in West Bank & Gaza and was established in 1914. In 1998, the Gaza Electricity Distribution Company (GEDCO) was established and it is the sole electricity distribution company (DISCO) in the Gaza Strip. In 2002, the Southern Electric Company (SELCO) was established, followed by Tubas District Electricity Company (TDECO) in 2003, Hebron Electric Power Company (HEPCO) in 2006, and the Northern Electricity Distribution Company (NEDCO) in 2008.

5.1 Interconnection with Neighboring Countries

A small-scale supply interconnection project has been completed by PENRA, one between Jericho and Jordan with capacity of 26 MW, and the other between Rafah and Egypt with capacity of 28 MW.

PENRA became a full member of the 7 countries interconnection project in October 2008, and become the country number eight; the countries are Egypt, Jordan, Lebanon, Syria, Turkey, Iraq, Libya, and Palestine. This membership will allow Palestine to be connected to these countries electric grid at a large scale, specially connecting West Bank to Jordan and Gaza to Egypt.

It is expected to provide an initial capacity of 150 MW for Gaza, covering a large part of the existing deficit and funding for the project by the Islamic Development Bank. The project will expand to 300 MW later. But unfortunately, the project is stopped for political reasons.

5.2 Generation

Palestine imports about 88 percent of its electricity from Israel, while around 4 percent of total supply imported from Jordan and Egypt. Around 7.3 percent of Palestine's electricity produced by Gaza Power Plant (GPP) which is equal to 23.5 percent of Gaza electricity consumption [31].

- GPP is the only significant generation source in Palestine with 140 MW installed capacity. Under a long-term power purchase agreement power is delivered from GPP to Gaza strip. GPP is the only major power facility privately developed, operated, and financed.
- Between 1967 and 2002, Gaza was only reliant on electricity supplied by Egypt and Israel. Gaza's power plant became in operation in 2002, but it remains the only

power generation plant for about two million Palestinians. When the plant built, its production capacity was 140 MW. In 2006, the plant reached production of 90 MW. In the same year, Israel bombed the plant, to destroy its fuel reservoir and six of its transformers. The power plant today is capable of generating around 110 megawatts maximum after repairs, but the lack of fuel, whether for political or funding arguments have restricted the plant production capacity to around 60 MW only. The power plant generation process depends on the fuel supply which is purchased from Israel [32].

- PENRA will encourage the construction of new generating capacity within Palestine, in order to reduce supply dependency on Israel and increase system capacity. Two Power plants will be created in West Bank; one in the North and the other in the South.

5.3 Transmission

Palestinian Electricity Transmission Company Limited (PETL) was established in the beginning of 2014 according to the Palestinian Electricity Law. This public company is planned to reduce the PA electricity debts, provide additional sources of supply, regulate, and develop the Palestinian electricity sector. The major functions of the company importing and exporting electricity, in addition to involve the transmission of electricity between consumers, distribution companies, and the source. PETL maintains, holds, and develops the Palestinian National Transmission Network, and it is aimed to replace the already existing 230 transformers and substations in West Bank's with only around 10 connection substations, as presented in the below figure 5.1 [31].

PETL has now three power substation 161/33KV connected with IEC, these substations distributed as the following:

Jenin - Al Jalamah Substation:

The station is located in the village of Al Jalamah, north of the city of Jenin, on an area of 10,000 m2. The station transforms the electrical power from high voltage (161 kV) to medium voltage (33 kV) with a capacity of 135 MW which can be increased in the future to 180 MW. The substation will supply power to the city of Jenin and surrounding areas as well as the industrial zone in the future.

Nablus - Sarra Substation:

The station is located in the village of Sarra to the south-west of the city of Nablus on an area of 10,000 m2. The station transforms the electrical power from high voltage (161 kV) to medium voltage (33) kV, with a capacity of 90 MW. The substation will supply power to the city of Nablus and the surrounding areas.

Hebron - Beit Ula Substation:

The station is located in the village of Beit Ula, north of Hebron, with an area of 10,000 m2. It transforms the electrical energy from high voltage (161 kV) to medium voltage (33 kV) with a capacity of 90 MW, which can be increased in the future to 180 MW. The substation is expected to feed the surrounding areas.

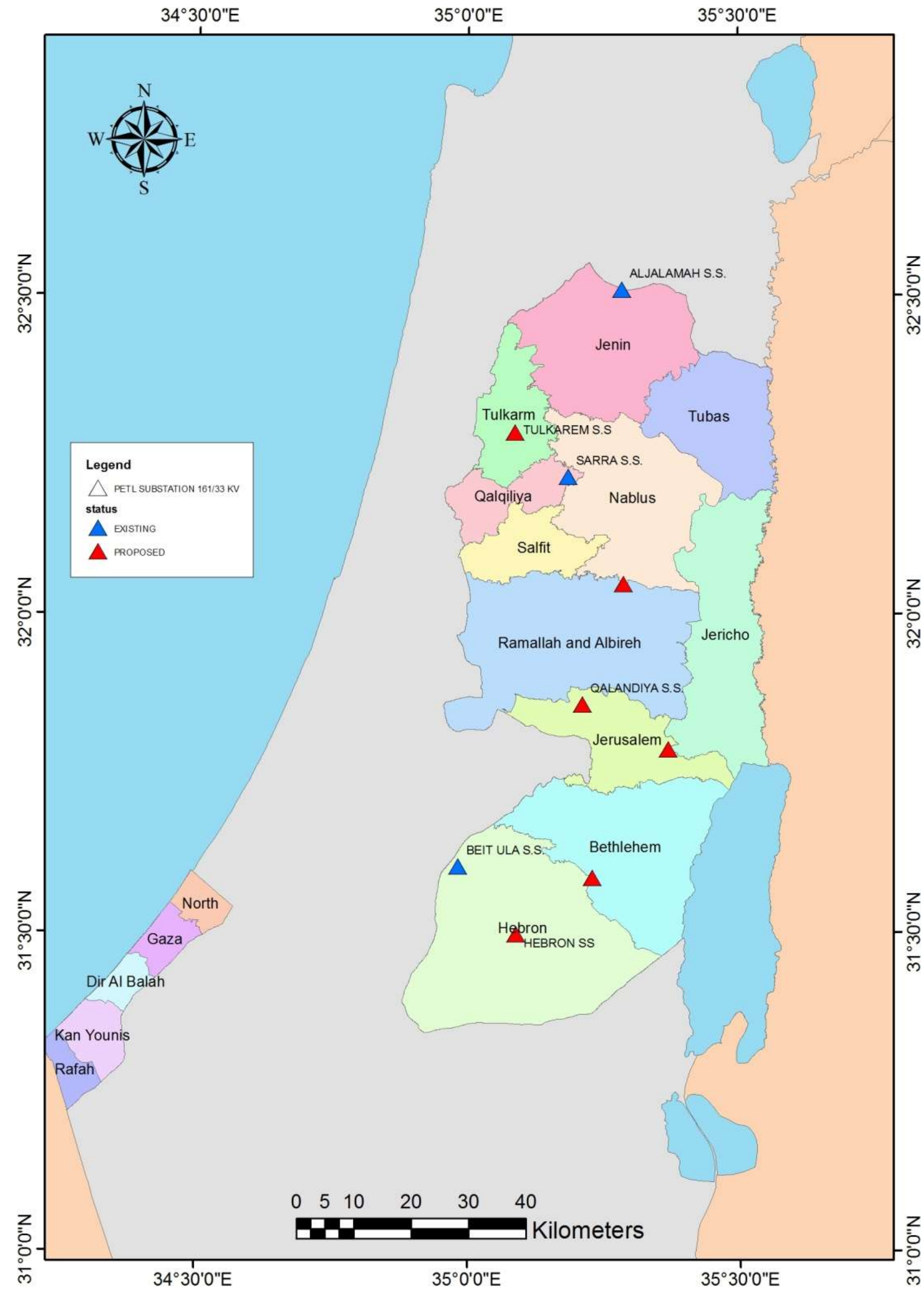

Fig. 5.1, A map for PETL existing and future plans for the construction of power stations in the West Bank and Gaza Strip

5.4 Distribution

Palestinian communities receive electrical services from 6 DISCOS (1 in Gaza and 5 in the West Bank), in addition to individual village councils and municipalities not affiliated with any distribution company. Four of these distribution companies (JDECO, GEDCO, TDECO, and NEDCO) have the legal form of joint stock private companies, while the remaining two (SELCO, and HEPCO) still work without proper registration at competent departments informally [31].

According to The Palestine Energy Regulation Commission (PERC) 2018 and 2019 Key Performance Indicators (KPI) reports, the performance of these distribution companies in West Bank is as the following:

5.4.1 Customers Number:

According to the reports the following table 5.1 shows the classification of the customers and their number in each distribution company:

TABLE 5.1, Customers numbers in distribution companies

Customers Class.	**JDECO**	**NEDCO**	**TDECO**	**HEPCO**	**SELCO**	**Total**
Residential	247,923	89,612	17,216	39,993	29,628	**424,372**
Commercial	45,237	23,070	1,928	13,064	3,838	**87,137**
Industrial	1,528	902	87	1,576	145	**4,238**
Others	9,693	3,981	671	2,241	1,216	**17,802**
Customer # 2019	**304,381**	**117,565**	**19,902**	**56,874**	**34,827**	**533,549**
Customer # 2018	**291,313**	**113,784**	**19,282**	**53,409**	**33,219**	**511,007**
Customer # 2017	**280,078**	**100,850**	**18,558**	**50,409**	**31,643**	**481,538**

5.4.2 Energy Purchased Energy Sold and Annual Growth

Table 5.2 displays the energy purchased, energy sold, and annual growth in each distribution company according to the report:

TABLE 5.2, Energy purchased sold and annual growth

Description	**JDECO**	**NEDCO**	**TDECO**	**HEPCO**	**SELCO**	**Total**
Energy Sold (GWH) 2019	1,950	569	129	394	164	**3,206**
Energy Sold (GWH) 2018	1,776	532	113	369	148	**2,938**
Annual Growth	10%	7%	14%	7%	11%	**9%**
Energy Purchased (GWH) 2019	2,545	703	158	492	208	4,106
Energy Purchased (GWH) 2018	2,334	650	137	466	188	**3,775**
Annual Growth	9%	8%	15%	6%	11%	9%

5.4.3 The Average Frequency and Duration of Sustained Outages

Reliability indices are commonly used to assess outages and evaluate the performance of electric systems. The indices used for the analysis include:

- System Average Interruption Duration Index (SAIDI)
- System Average Interruption Frequency Index (SAIFI)
- Customer Average Interruption Duration Index (CAIDI)

According to the report table 5.3 represents the reliability indices for each distribution company:

TABLE 5.3, Reliability indices SAIDI SAIFI and CAIDI for each distribution company

Indices	Year	JDECO	NEDCO	TDECO	HEPCO	SELCO
SAIDI (Minutes)	2019	435	773	576	258	1,516
	2018	272	654	685	126	1,048
	2017	271	860	778	474	844
	2016	435	795	1,026	561	1,112
SAIFI (Numbers)	2019	7	13	21	6	19
	2018	6	13	9	3	11
	2017	5	11	29	9	8
	2016	7	9	20	9	6
CAIDI (Minutes)	2019	62	57	27	42	80
	2018	48	52	72	36	97
	2017	53	76	27	56	103
	2016	61	84	51	61	172

5.4.4 Losses and Financial Cost

Table 5.4 demonstrates the energy losses and the financial cost for these losses in each distribution company:

TABLE 5.4, Losses percentage and losses cost in each distribution company

Indices	Year	JDECO	NEDCO	TDECO	HEPCO	SELCO	Total
Losses %	2019	23 %	19 %	18 %	20 %	21 %	**22 %**
	2018	23 %	18 %	18 %	21 %	21 %	**21 %**
	2017	23 %	19 %	21 %	23 %	31 %	**23 %**
Losses Cost (ILS Million)	2019	222	51	11	37	17	**338**
	2018	204	45	9	37	16	**311**
	2017	198	46	11	41	23	**319**

5.4.5 Renewable Energy Resources

The following table 5.5, and figure 5.2, shows the installed renewable energy resources in each distribution company:

TABLE 5.5, Installed renewable energy resources in each distribution company

Indices	Year	JDECO	NEDCO	TDECO	HEPCO	SELCO	Total (kW)
Renewable Energy Projects (kW)	2019	22,116	3,162	5,493	3,860	1,194	**35,825**
	2018	8,780	2,232	4,914	2,410	797	**19,133**
	2017	6,291	337	3,485	1,110	620	**11,843**
	2016	3,489	100	1,272	650	504	**6,015**
Annual Growth (2018 - 2019)		152 %	42 %	12 %	60 %	50 %	**87 %**

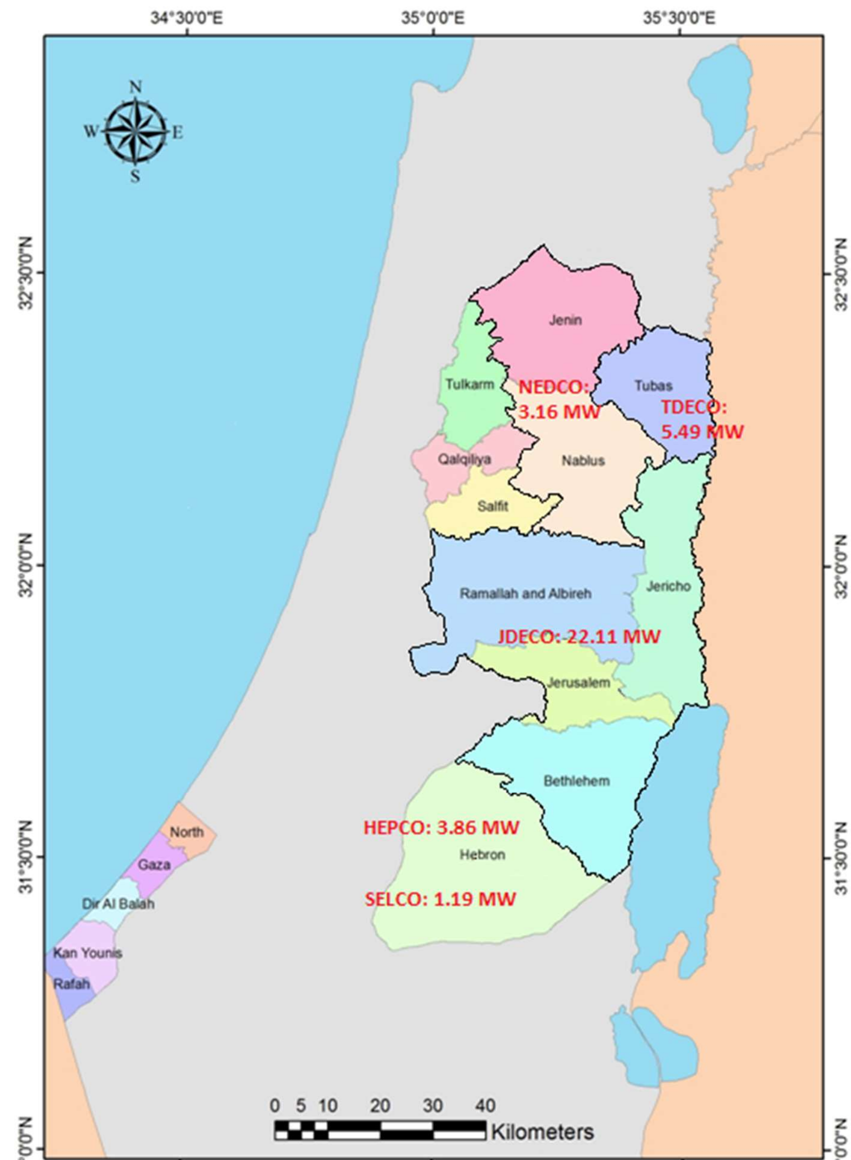

Fig. 5.2, A map for DISCOs installed renewable energy projects until end of 2019

5.4.6 Maximum Demand

The following table 5.6 displays the maximum demand in each distribution company:

TABLE 5.6, Maximum demand in each distribution company

Indices	Year	JDECO	NEDCO	TDECO	HEPCO	SELCO
Maximum Demand (MW)	2019	544	140	39	117	57
	2018	506	129	31	116	52
	2017	493	125	28	110	50
	2016	492	114	22	105	47
Month	2019	February	July	June	March	December
	2018	December	July	July	January	December
	2017	December	July	July	December	December
	2016	December	December	March	December	December

5.4.7 Electricity Meters

The Palestinian Energy and Natural Resources Authority (PENRA) cooperated with the World Bank begun the ambitious project aims to improve the operational performance of Palestinian Electricity Distribution Companies (DISCOs) through the implementation of a Revenue Protection Program (RPP). The RPP will install smart meters to a segment of commercial and industrial consumers, which represent the largest electricity consumption and sales of the selected DISCOs. Thus, the RPP is expected to improve billing and collection from this "high-value" segment of customers.

The RPP will also include Advance Metering Infrastructure (AMI), comprising communication devices, software, i.e. Meter Data Management System (MDMS), and a Metering Control Center (MCC). The functionalities of the AMI and MCC include revenue protection (detection of theft and frauds), automatic meter reading, remote disconnection/reconnection, and load control and outage detection. The available budget for the RPP was US$ 3.4 million.

A pilot smart meters project financed and managed by the Jerusalem District Electricity Company (JDECO) has been reported 91,144 smart meters (45% of total JDECO's meters) were recorded as installed at the end of 2018, thus, has encouraged other

DISCOs to follow suit to increase their revenues and improve the quality of service. The project planned to install additional 13,200 smart meters and related Advanced Metering Infrastructure (e.g. MDM, MCC) in five years in the selected DISCOs. In this project the meters collect the data and send it using PLC up to the concentrator/aggregator, and then the concentrators are connected to the company Data center using GPRS or Fiber Optics networks.

Table 5.7 illustrates the number and type of meters in each distribution company.

TABLE 5.7, Meters types and numbers in each distribution company

Indices	**Type**	**JDECO**	**NEDCO**	**TDECO**	**HEPCO**	**SELCO**
Meters Numbers	Billing Meter	109,403	28,463	343	12,087	4,200
	Prepaid Meter	88,840	89,102	18,977	42,380	30,300
	Smart Meter	106,138	0	166	701	170

5.4.8 SCADA System

Five distribution companies (JDECO, GEDCO, NEDCO, TDECO, and HEPCO) have SCADA systems. Table 5.8, summarizes the existing situation of the SCADA system in the distribution companies:

TABLE 5.8, DISCOs SCADA system and features of the system

Type	**JDECO**	**NEDCO**	**TDECO**	**HEPCO**	**SELCO**
SCADA available?	Yes	Yes	Yes	Yes	No
Communication Type	Fiber / GPRS	GPRS/3G Fiber soon	GPRS	Fiber	-
Equipment connected to SCADA system	Substation Breakers, meters, and Sensors	Substation Breakers, meters, and Sensors	Substation Breakers, and meters	Substation Breakers, meters, and Sensors	-
OLTC Controlled by SCADA	Capable (but not connected)	Capable (but not connected)	Capable (but not connected)	Capable (but not connected)	-

5.4.9 Self-Generation

a) Net-Metering

A net-metering scheme is in place in Palestine since 2015. Based on Council of Minister's decision number 04/77/17 of the year 2015, Palestinian electricity regulatory council PERC and Palestinian energy and natural resources authority PENRA in collaboration with the distribution companies (DISCOs) prepared the net metering regulations for RE systems (max capacity of 1000 KWp).

Net metering is done on a kWh basis. Imported and exported electricity are netted at the end of the month. If a surplus gets generated by the end of the month, 75% of the surplus kilowatt hours get remunerated as credit for customer at the end of the project's production year (1 April-31 March) so that the energy balance exported to the prosumer is rotated within only one year of production.

The prosumer's current electricity meter should be replaced with a Bidirectional Meter to measure the electricity consumption and the exported electricity to the distributor network. The prosumer will pay for the replacement. If the meter mentioned above is not available for any reason, another meter should be added to measure the exported electricity to the distributor network; in this case, the prosumer will have two meters and will have to pay for the extra meter. In case that the prosumer has a pre-paid meter; the distributor should replace it with a normal post-paid meter to be able to make the financial calculations.

b) Wheeling

Different location of the project and place of consumption with no contradiction to the terms of instructions, any prosumer within the Distributor's area of operation shall be entitled to set up a project for the production of renewable energy (max capacity of

1000 KWp) and connect it to the distributor's network. The place of consumption of electricity produced from this project could be in a different location than the place of production provided that both places are in the same distributor's area of operation.

In this case and based on Palestinian Council of Minister's decision number 04/77/17 of the year 2015. The distributor will deduct 10% of the produced electricity as transmission fees.

The beneficiaries of this system have to comply with all other rules and instructions that regulate renewable energy projects that connected to the electricity network with Net – Metering system.

Table 5.9, represents the net metering installed capacity and annual production in Palestine until end of 2018.

TABLE 5.9, Net metering installed capacity and annual production in Palestine

Description	Unit	2015	2016	2017	2018
Net Metering Installed Capacity	KWp	0	2,919	5,483	11,893
Net Metering Production	KWh	0	3,164,435	6,715,199	13,532,938

5.4.10 Distributed Generation

a) Feed-in Tariffs (FiT)

FiT scheme provides a long-term purchase guarantee of electricity from renewable energy sources at a pre-determined price. In 2012, a photovoltaic (PV) FiT scheme was introduced through the Palestinian Solar Initiative (PSI). This category concerns investment by households and small commercial businesses with eligible systems up to 5 kW connected with DISCO's networks and the scope is to install up to 5 MWp at the end of 2020.

The tariff was set for three stages, the first one at 1.07 ILS/kWh, so higher than the electricity purchased from IEC which was at 0.4 ILS/kWh at that time; the Ministry of Finance MoF to cover the cost difference. Then the second FiT stage was reduced to

0.8 ILS/kWh. In 2015, the FiT scheme was re-introduced with a third stage tariff of 0.54 ILS/kWh. By 2018, about 400 out of 1000 envisaged systems with a total of 1124 kW were installed and connected to the grid.

b) Medium Capacities Projects

A Mid capacities scheme is in place since 2018. Based on PENRA's chairman decision number (1) of the year 2018, PERC in collaboration with the DISCOs prepared the Mid capacities regulations and guidelines for RE mid capacities system (max capacity of 999 KWp).

This category concerns those who wish to invest in medium scale PV plant, the system which is called "RE Station" could start from 5 KWp till the max of 999 KWp, this generation station should be owned by a private and independent company to sell DISCOs electricity in affordable prices.

5.5 Regulation

In 2009, the Palestinian Electricity Regulatory Council (PERC) was established with the mandate of regulating and monitoring the energy sector in Palestine. PERC proposed the existing unified tariff for all DISCOs in the West Bank and is responsible for its revisions. Moreover, PERC provides licenses to DISCOs and monitors their financial, technical, and operational performance parameters, including losses and collection rates. The PA has shown its commitment to strengthen the role of PERC.

5.6 Tariffs

According to PERC, and based on Palestinian Council of Minister's decision number 05/54/18 of the year 2020, the following tariffs structures are adopted in Palestine:

5.6.1 Residential Customer's Tariffs:

a) The following split tariffs are applicable in all areas except Jericho area, for home and residential customers within residential projects or separate residential houses, mosques and churches, charities, educational and government facilities, and elevators used by the said participants for services of the one and three phases and prepaid meters:

TABLE 5.10, Residential customer's split tariffs in Palestine expect Jericho

Tariffs Cost (ILS/kWh)	Range / Monthly
0.4443	1-160 kWh
0.4790	161-250 kWh
0.5524	251-400 kWh
0.5906	401-600 kWh
0.6530	>600 kWh

b) The above split tariffs applied to all residential customers, including those with prepaid meters, and if the technical possibility does not allow this, the following flat tariff will be applied:

TABLE 5.11, Residential customer's flat tariff for customers with pre-paid meters in Palestine expect Jericho

Tariff Cost (ILS/kWh)	Tariff Type (Meter Type)
0.4834	Flat Tariff (Pre-paid meters)

c) For home and residential customers within residential projects or separate residential houses, mosques and churches, charities, educational and government facilities, and elevators used by the said participants for services of the one and three phases and prepaid meters in Jericho area the following split tariffs are applicable in Jericho:

TABLE 5.12, Residential customer's split tariffs in Jericho

Tariffs Cost (ILS/kWh)	Range / Monthly
0.4156	1-700 kWh
0.4592	>700 kWh

d) The previous split tariffs applied to all residential customers, including those with prepaid meters, and if the technical possibility does not allow this, the following flat tariff will be applied in Jericho:

TABLE 5.13, Residential customer's flat tariff for customers with pre-paid meters in Jericho

Tariff Cost (ILS/kWh)	Tariff Type (Meter Type)
0.4403	Flat Tariff (Pre-paid meters)

5.6.2 Commercial Customer's Tariffs:

a) The following flat tariff is applicable to hotels, public buildings, hospitals, sports social and cultural clubs, shops, private and public companies, banks, restaurants, amusement parks, cinemas, bakeries, confectionery shops, photography studios, doctors' clinics, pharmacies, radiology laboratories, laboratories, sewing shops, shoe shops, electric elevators in commercial buildings, Shops that purify water and package it for the purposes of trading, private water pumps for the sale and trade of water, refrigerators for the preservation of vegetable and animal freezers for trading and whose owners are paid for the preservation of freezers and not owned by farmers, car shops including laundries, electricity and car mechanics, refrigerator repair shops, offices, engineering and service companies, private educational facilities, and civil society and international institutions, for single phase and three phases services and non-prepaid meters:

TABLE 5.14, Commercial customer's flat tariff

Tariff Cost (ILS/kWh)	Tariff Type
0.6090	Flat Tariff

b) While, the following table 5.15 represents the flat tariff applicable for commercial customers with pre-paid meters:

TABLE 5.15, Commercial customer's flat tariff for customers with pre-paid meters

Tariff Cost (ILS/kWh)	Tariff Type (Meter Type)
0.5813	Flat Tariff (Pre-paid meters)

5.6.3 Industrial Customer's Tariffs:

a) For industrial customers connected to LV network and their annual consumption is less than 60,000 kWh; the following flat tariff is applicable:

TABLE 5.16, Industrial LV customer's flat tariff

Tariff Cost (ILS/kWh)	**Tariff Type**
0.4960	Flat Tariff

b) For industrial customers connected to MV networks (6.6, 11, and 33 kV) and there is no technical capability to apply time of use tariff; the following flat tariff is applicable:

TABLE 5.17, Industrial MV customer's flat tariff

Tariff Cost (ILS/kWh)	**Tariff Type**
0.4230	Flat Tariff

c) For stone and marble factories connected to LV network and regardless the amount of their consumption; the following flat tariff is applicable:

TABLE 5.18, Stone and marble LV factories' flat tariff

Tariff Cost (ILS/kWh)	**Tariff Type**
0.5264	Flat Tariff

5.6.4 Pumping Stations Tariff:

The following flat tariff is applied to water pumping stations for drinking purposes, purification stations of the Water Authority, municipalities and local councils:

TABLE 5.19, Pumping stations flat tariff

Tariff Cost (ILS/kWh)	**Tariff Type**
0.4703	Flat Tariff

5.6.5 Agriculture Customer's Tariff:

The following flat tariff is applied to farms of all types, farms of livestock, poultry and birds, as well as storage refrigerators for fresh agricultural product between seasons owned by farmers, and seed storage refrigerators for single and three phases services, and water pumps for irrigation and licensed for agricultural use by the Ministry of Agriculture and the Water Authority:

TABLE 5.20, Agriculture customer's flat tariff

Tariff Cost (ILS/kWh)	Tariff Type
0.4500	Flat Tariff

5.6.6 Streets Lighting Tariff:

The following flat tariff is applied to street lighting, squares and public squares lighting in cities, villages and residential communities:

TABLE 5.21, Street lighting flat tariff

Tariff Cost (ILS/kWh)	Tariff Type
0.4602	Flat Tariff

5.6.7 Temporary Customer's Tariff:

The following flat tariff is applied to customers with temporary services including temporary customers with pre-paid meters:

TABLE 5.22, Temporary customer's flat tariff

Tariff Cost (ILS/kWh)	Tariff Type
0.7710	Flat Tariff

5.6.8 Time of Use Tariff:

a) For industrial customers connected to LV network and their annual consumption is greater than 60,000 kWh and there is technical capability to apply time of use tariff; the following time of use tariff is applicable:

TABLE 5.23, Time of use tariff for LV industrial customers

Tariff Cost (ILS/kWh)	Tariff Type	Season
0.3619	LV Tariff A	Summer
0.5261	LV Tariff B	
1.1570	LV Tariff C	
0.3500	LV Tariff A	Spring and Autumn
0.4241	LV Tariff B	
0.5118	LV Tariff C	
0.3909	LV Tariff A	Winter
0.6333	LV Tariff B	
1.0487	LV Tariff C	

b) For industrial customers connected to MV networks (6.6, 11, and 33 kV) and there is technical capability to apply time of use tariff; the following time of use tariff is applicable:

TABLE 5.24, Time of use tariff for MV industrial customers

Tariff Cost (ILS/kWh)	Tariff Type	Season
0.2779	MV Tariff A	Summer
0.4236	MV Tariff B	
1.0047	MV Tariff C	
0.2720	MV Tariff A	Spring and Autumn
0.3377	MV Tariff B	
0.4197	MV Tariff C	
0.3092	MV Tariff A	Winter
0.5411	MV Tariff B	
0.9215	MV Tariff C	

5.7 Current Electricity Supply and Demand

The pattern of electricity supply and characteristics of electricity consumption in the Gaza region are different from those in the West Bank. The following table 5.25, summarizes the electricity situation in Gaza and West Bank based on the World Bank Electricity Sector Performance Improvement Project June 30, 2017 [33]:

TABLE 5.25, Key features of the electricity sector in the West Bank and Gaza

West Bank	Gaza Strip
Population (number): 2,930,000 **Electricity demand (GWh):** 4,380 **Electricity supply (GWh):** 4,150 **Sources of supply:** Jordan and Israel **Domestic generation:** 15 MW of distributed solar **Transmission:** None (4 HV substations, one energized, three yet to be energized) **Distribution:** 5 DISCOs (JDECO, NEDCO, SELCO, HEPCO, and TDECO) and several municipalities and villages councils **Regulation:** PERC except East Jerusalem which is regulated by Israel Public Utility Authority (PUA)	**Population (number):** 1,880,000 **Electricity demand (GWh):** 2,461 **Electricity supply (GWh):** 1,890 **Sources of supply:** Israel, Egypt, and Gaza Power Plant (GPP) **Domestic generation:** 60 MW GPP (140 MW rated capacity) **Transmission:** None (161 kV line from Israel in planning stage) **Distribution:** 1 DISCO (GEDCO) **Regulation:** PERC, but mandate not effective in Gaza

5.8 Future Plans for Generation & Transmission

PENRA will encourage the construction of new generation plants in Palestine. Two Generation Power plants will be constructed in West Bank (One in the North and the other in the South). By doing this, PENRA will encourage independent power providers (IPPs) for maximum participation as private sector. The following figure 5.3, presenting a map for the future plans for the construction of new transmission lines between the main substations in the West Bank and Gaza. These transmission lines will play a vital role in applying smart grid applications between different areas in Palestine.

Fig. 5.3, A map for future plans for the construction of transmission lines in the West Bank and Gaza Strip.

5.9 Renewable Energy Resources in Palestine

There are many advantages for using wind and solar "renewable energies" instead of fossil fuels. The use of these renewable resources all over the world is associated with effective approaches to sustainable development; as they have high potential to be, reliable, cost-efficient, environment friendly, and designed properly for local conditions.

Due to economic, political, geographic, environmental, infrastructural and social conditions in Palestine, the benefits of "RE" compared to traditional fossil fuels are greater than it is in other cases. All renewable energy projects can meet the growing energy demand in many areas in Palestine where traditional energy systems do not reach at suitable prices or do not reach reliably because of the Israeli occupation. The unreliable and small energy system is one of the main reasons of reducing the Palestinian economic and community development.

On the contrary to the low traditional energy sources on Palestine, there are many supplies of "RE" resources, such as wind, solar and biomass energies, for the production of renewable nontraditional energy. The development of renewable energy sources would be the first step in order to achieve independency to Palestinian energy; including small and large-scale energy production farms and stand-alone projects.

5.9.1 Solar Energy

The West Bank mostly imports around 75% of the power to its three million people need from Israel, and less amount from Jordan.

In the Gaza Strip, power generation is very minimal, even with imports from Egypt and Israel, it gets just one-third of what it needs; so, the two million people suffer with a just four hours of electricity a day on average.

According to NASA, parts of the West Bank, in the Jordan Valley, receive high radiation levels: 5.40–5.98 kWh/m^2 per day annually. These are optimum conditions for solar energy production for both stand-alone and large-scale applications. [34]
The area of the Jordan Valley and Jericho is about 10% of Palestinian land (593 km^2 out of 6020 km^2). A PV plant (polycrystalline silicon with an efficiency of 11%) with an area of 8 km^2 can produce 500 MW of electricity. This could cover 1.34% of the land in the Jordan Valley and could produce around 600 GWh per year (based on 5 sun hours, 300 days and a performance ratio of 0.8). Such a project could account for 11% of current Palestinian electricity demand.

Similar PV or solar thermal power plants could be installed in the West Bank northern regions as well, such as in Nablus and Jenin where the solar radiation ratio average per day varies from 5.4 to 5.9 kW/m^2.
Rooftop PV installations can play a small role in producing electricity to the grid as well. The number of Rooftop panels has increased four times in four years and they are now spread on most balconies and rooftops on homes, hospitals, shops, banks, schools and mosques in a place where there are around 300 sun shining days a year.

5.9.2 Biomass Energy

Biomass energy is the source of fuel, can be found anywhere, and it helps in protect environment. So, it could be considered as strategic energy resource. Biomass is of essential importance for both developing and developed countries.
Biomass energy can be used for both; cooking and heating (traditional uses) and electricity producing (modern uses). Now, biomass energy contributes 9–13% of the global energy supply and about 8% of Palestinian energy supply [34].

Palestine is famous for its farming and trading. Farming is still the main economic activity. So, Palestine has a big chance for biomass energy.

Al-Jebrini Dairy industry's idea started in Hebron five years ago in order to get rid of the enormous amount of waste produced by hundreds of cows in their "Cattle Farm" in Al-Thahriya south of Hebron.

The projects' idea is based on turning cows' dung into electricity that is sufficient for the farm consumption within the so called" Bio-mass energy", providing electricity to Al-Thahriya town that benefited from part of the project's surplus and contributes to environmental preservation.

The project present capacity is 340 KW electricity generated from Bio-methane and expected to reach 990 KW in the second stage.

5.9.3 Wind Energy

The wind energy technology use has spread and growing rapidly in the last years. Knowing that wind power is a local resource, environmentally friendly, and clean; it is essential to arrange the required economic and technical studies in order to check the feasibility of using this energy.

The knowledge of the wind characteristics and its location needed to be known in order to use wind energy efficiently. To design wind farms and generates power; the wind speeds and distribution must be known.

For both northern and southern West Bank, the average annual wind speeds are more than 4 m/s. The wind speed value of 4–6 m/s is of specific importance because it is typically only at wind speeds greater than this threshold that turbines work efficiently. Nevertheless, this wind speed range can be employed for smaller wind turbines' electricity production.

For a modern wind turbine, the cut-in wind speed needed for a turbine to begin electricity generation is normally between 3 and 5 m/s and depending on the turbine size. For 100 m height turbines, the required wind speed will be between 5.7 and 6 m/s.

Using a 100-m wind turbine with blade of 52 m length and 0.4 power coefficient, the expected annual power generation is 3.3 and 3.8 GWh for the northern and southern West Bank, respectively. Using a 50 turbines wind farm, each would produce 355 GWh annually, which could account for 6.6% of the electricity demand in Palestine.

The highly crowded buildings and the lack of empty and open areas in Gaza Strip reduce the possibility of creating wind farms there. But offshore wind farms could be installed in the sea, were it not for present due to the obstacles of Israeli occupation.

The first large-scale wind turbine in Palestine was at the Al-Ahli Hospital in Hebron. One of the main objectives of project was to reduce the Energy consumption of al Ahli hospital by (30-40) % by using a Wind Turbine with an approximate power of 750 KW. Due to site restrictions; only 330 KW Wind Turbine was installed and leads to a saving of only 20% of the electricity consumption of the Hospital [35]. But, in the last few years this wind turbine was replaced with roof top PV station.

In 2019, the official announcement of the implementation of the water and energy link project in the Tubas and Jenin governorates, which depends on wind power generation financed by the French government and the European Union with a financial value of 18 million Euros. The project consists of two wind turbines each with 850 kW; total capacity of 1700 kW.

If the available renewable energy sources, such as wind, biomass, and solar are used; it could replace more than 25% of the Palestinian energy need. On the other hand, any Palestinian activity in the energy sector, traditional or renewable would face a number of difficulties, including: political obstacles to developing the institutions, building the physical infrastructure, implementing the policies, and controlling the borders.

CHAPTER 6: SIMULATION, RESULTS AND DISCUSSION

In this chapter we will explore some smart grid applications and show the benefits of applying these applications in Jericho network as a case study.

OpenDSS will be used as a simulation tool in this study. OpenDSS is an electric power Distribution System Simulator (DSS) developed by Electric Power Research Institute (EPRI), and designed to support grid modernization, grid integration, and distributed energy resource (DER). OpenDSS allows technical engineers to conduct complex analyses using a customizable, easy to use, and flexible platform intended specifically to provides a foundation for understanding and integrating new technologies and resources, and meet current and future challenges of distribution system.

The simulation will be performed on Jericho MV (33 KV) network as part of JDECO network, and as shown in figure 6.1; the single line diagram of Jericho 33 KV network. Jericho electrical network is supplied from two main sources; IEC network (161/33 kV) and Jordan (132/33 kV). As indicated in figure 6.1, the connection with IEC is at bus 1 and the connection with Jordan is at bus 4. Also, there are two existing PV farms connected to Jericho network until the end of 2017. The first one is the Dead Sea plant with a capacity of 720 kVA and located at bus 3 (PV1). The second one is the Industrial Area plant with a capacity of 300 kVA and located at bus 5 (PV2) [36]. The overhead power lines, underground cables, transformers, PV stations, and loads data are based on the data received from JDECO.

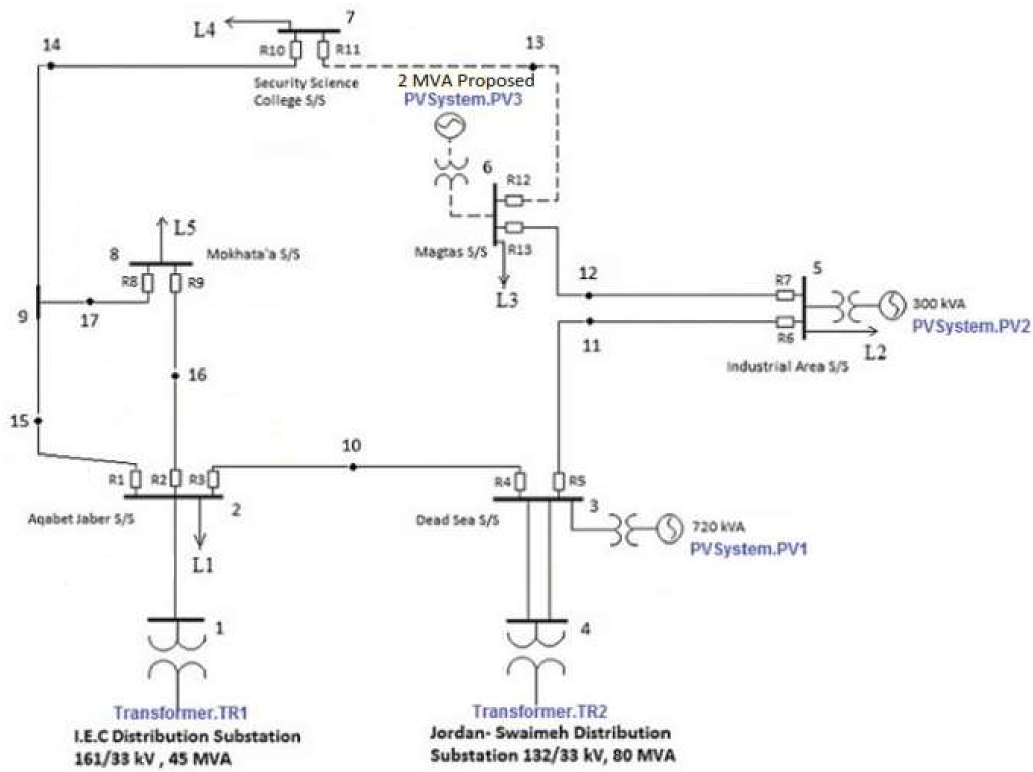

Fig. 6.1, Jericho MV (33 kV) network single line diagram [36]

The loads data are based on JDECO's SCADA system data in 2017. The following figure 6.2, illustrate the Source annual apparent power curve, from which it is observed that the end of July has the maximum peak day of around 35 MVA.

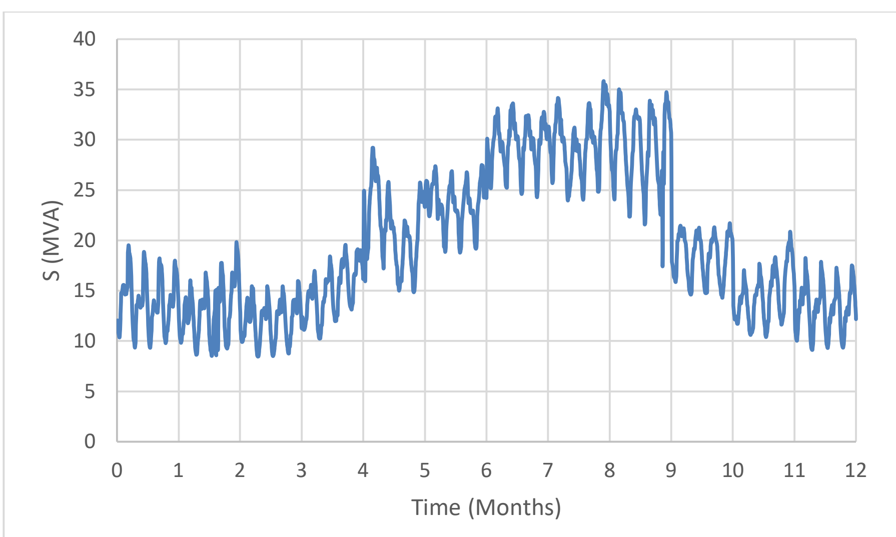

Fig. 6.2, Source annual apparent power curve in Jericho

Since the day of the maximum peak was determined in the previous curve; the following experiments were conducted on this day to examine several smart grid applications and their impact on the grid performance:

6.1 Peak Shave Experiment

The aim of the experiment is to avoid the power peak by using peak shave technique; in which battery storage system used to inject the stored energy during the peak hours. The storage system will be charged during lower load periods or during time with lowest energy price, if there is Time of Use Tarif. The daily load profile before the experiment was as presented in below figure 6.3:

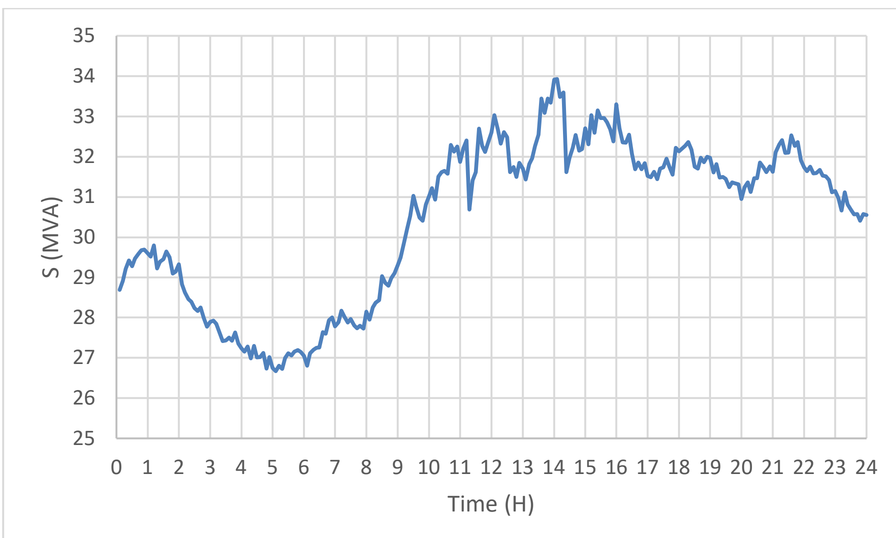

Fig. 6.3, Source daily power load curve without peak shave

As shown, the power peak is at 14:06 with total apparent power of 33,927 kVA (11,309 KVA on each phase). A storage system was added to Substation 3 (Magtas S/S) with 2MW (6 MWH) capacity. The storage system is controlled using storage controller by sensing the power delivered from the source; if it reaches the target peak then the storage starts to discharge the stored energy. Also, the controller will charge the storage system during the lowest load period.

Figure 6.4, is the block diagram for the storage system, and figure 6.5, is the Storage System Charging and Discharging Curve.

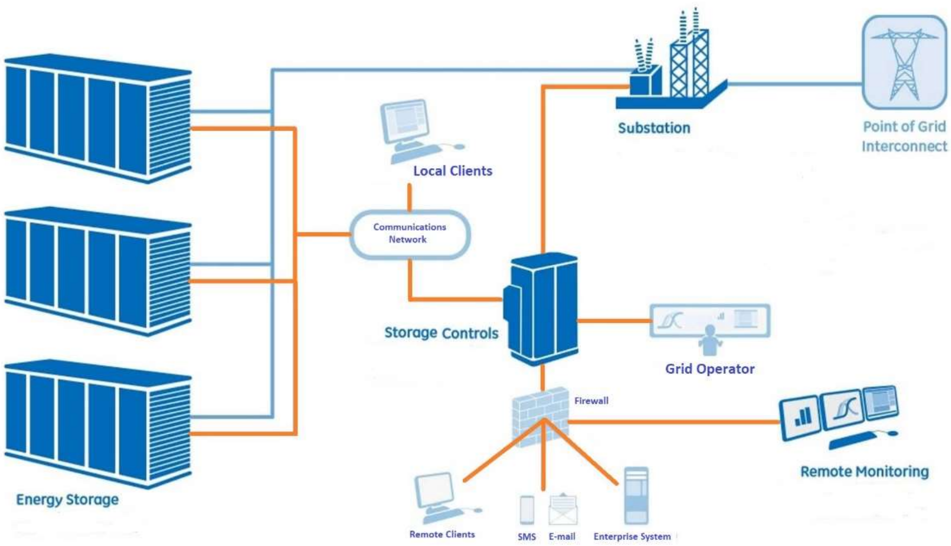

Fig. 6.4, Storage system block diagram

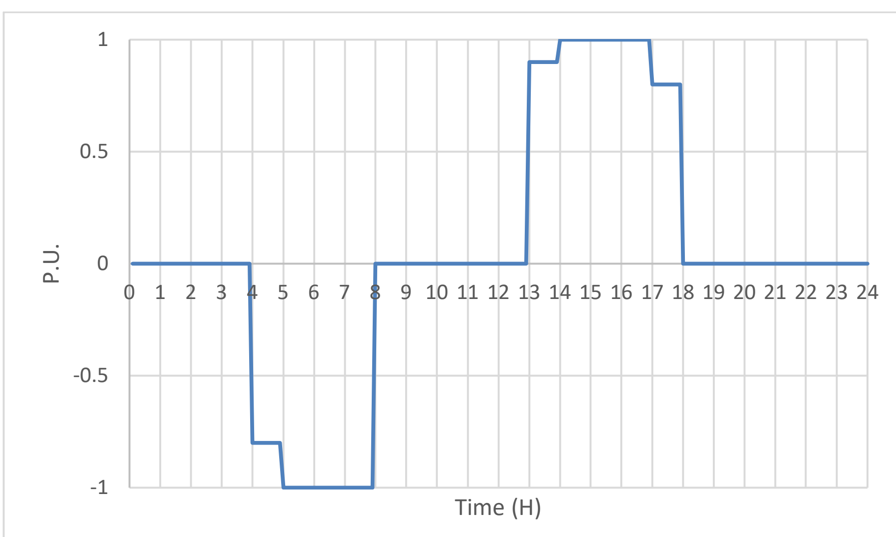

Fig. 6.5, Storage system charging and discharging curve, discharging at period (13:00-18:00)

The daily load profile after the experiment is as shown in the below figure 6.6:

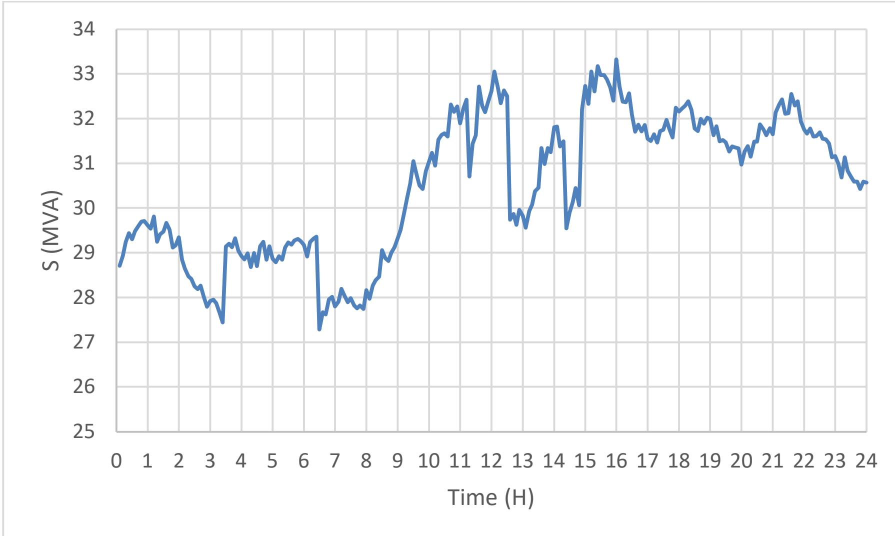

Fig. 6.6, Source daily power load curve with peak shave

As shown, the power demand at 14:18 is with total apparent power of 31,494.9 kVA (10,498.3 KVA on each phase); this means 7.168% peak reduction is achieved. The new peak shifted to be at 16:00 is with total apparent power of 33,322.5 kVA; this means an overall peak reduction of 1.782% is achieved. Also, from the figure 6.6 the storage system will be charged during the low demand period (4:00-7:00).

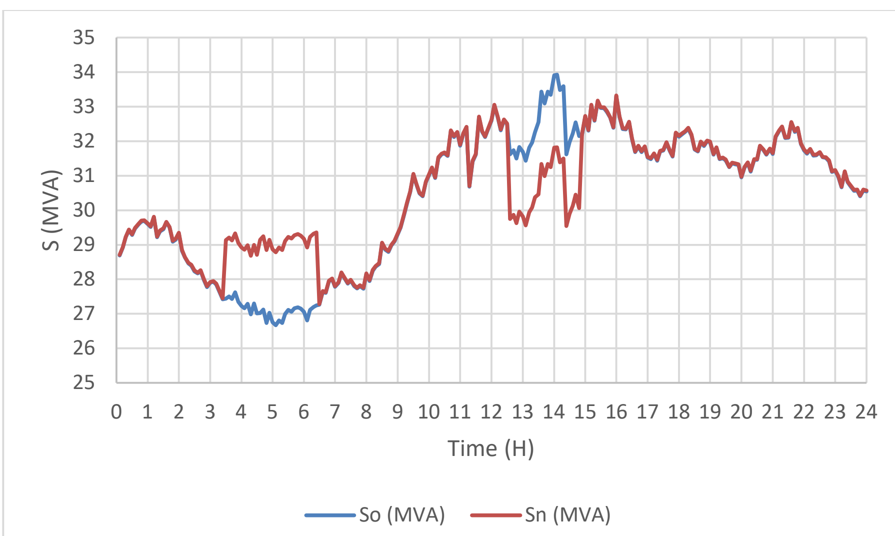

Fig. 6.7, Source daily power load curve without and with peak shave

TABLE 6.1, Experiment 6.1 summary

Approach	Peak Time	Peak Value (KVA)	Reduction
Without Peak Shave	14:06	33,927.0	-
With Peak Shave	14:18	31,494.9	7.168 %
With Peak Shave	16:00	33,322.5	1.782 %

Table 6.1 summarize experiment 6.1, from this experiment it is noticed that using peak shave technique through Battery Storage System will achieve the target and avoid requesting more capacity from IEC or Jordan. Other storage systems could be used instead of batteries such as pumped hydroelectric energy storage (PHES) which will be suitable for Jericho case since it is surrounded by mountains.

6.2 Integration of Renewable Energy Sources Experiment

This experiment aims to demonstrate the effects of adding new RES to the grid. 2 MW PV farm (which is a planned future project according to JDECO) was added to substation 3 (Magtas S/S).

The daily load profile before the experiment is as displayed in the below figure 6.8 (Red color curve So). The power peak is at 14:06 with total apparent power of 33,927 kVA (11,309 KVA on each phase).

After installing the new 2MW PV farm at SS3 (Magtas S/S) the daily load profile will be as presented below in figure 6.8 (Blue color curve Sn):

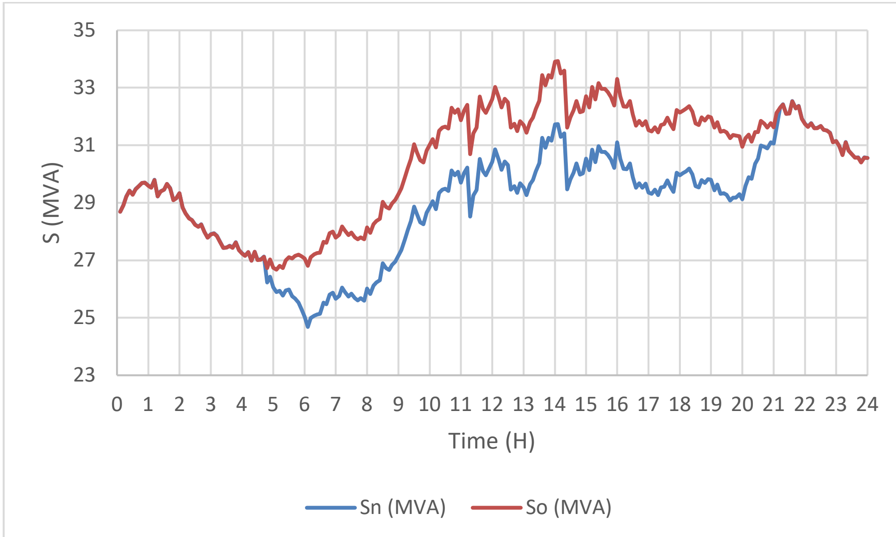

Fig. 6.8, Source daily power load curve without and with adding 2 MW PV farm

Table 6.2 provides a summary for experiment 6.2, as shown the new power peak is at 21:36 with total apparent power of 32,538.9 kVA (10,846.3 KVA on each phase). This means 4.09 % an overall peak reduction is achieved. The peak at 14:06 (previous peak time) is 31,735.2 KVA (10,578.4KVA on each phase); which is a 6.46 % peak reduction.

TABLE 6.2, Experiment 6.2 summary

Approach	**Peak Time**	**Peak Value (KVA)**	**Reduction**
Without New PV Farm	14:06	33,927.0	-
With 2MW PV Farm	21:36	32,538.9	4.09 %
With 2MW PV Farm	14:06	31,735.2	6.46 %

By combining experiment 6.1 and experiment 6.2 together; adding 2MW (6MWH) Battery Storage System and 2 MW PV farm to substation 3 (Magtas S/S) at the same time, the result will be as illustrated in figure 6.9.

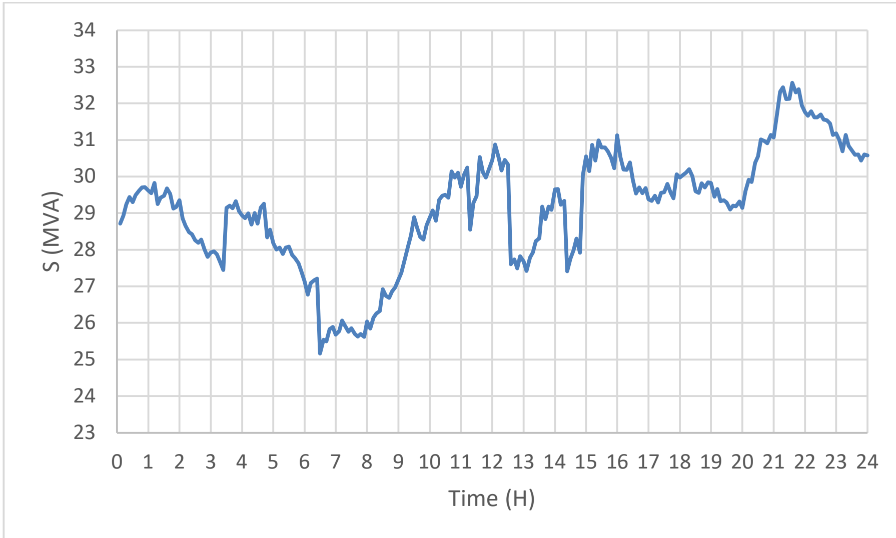

Fig. 6.9, Source daily power load curve with adding 2 MW PV farm and 2MW (6MWH) battery storage system to substation 3 storage system discharging at period (13:00-18:00)

From the figure it is clear that adding the storage system and PV farm will lead to further reduction of the peak at 14:00. The new peak is at 21:36 with total apparent power of 32,560.5 kVA (10,853.5 KVA on each phase). By changing the discharging period to shave the new peak at 21:36 as shown in figure 6.10; the result will be as presented in figure 6.11.

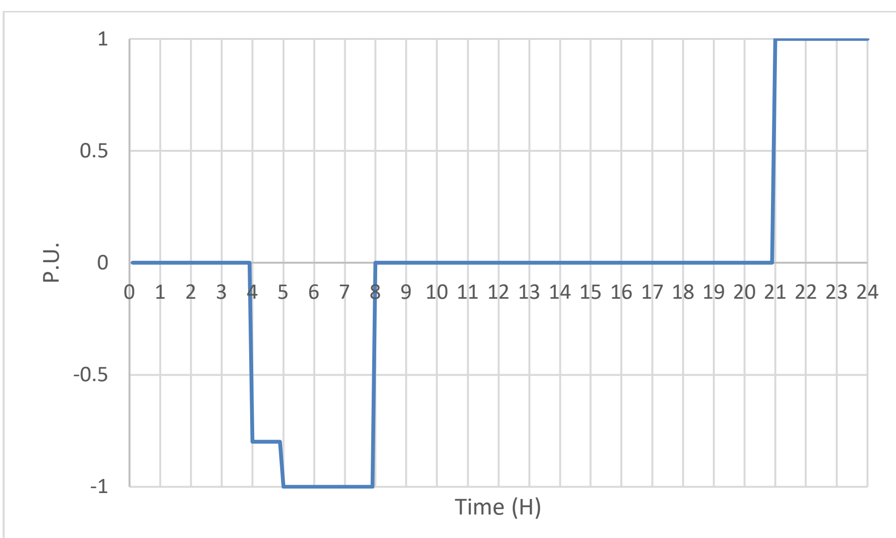

Fig. 6.10, Storage system charging and discharging curve, discharging at period (21:00-00:00)

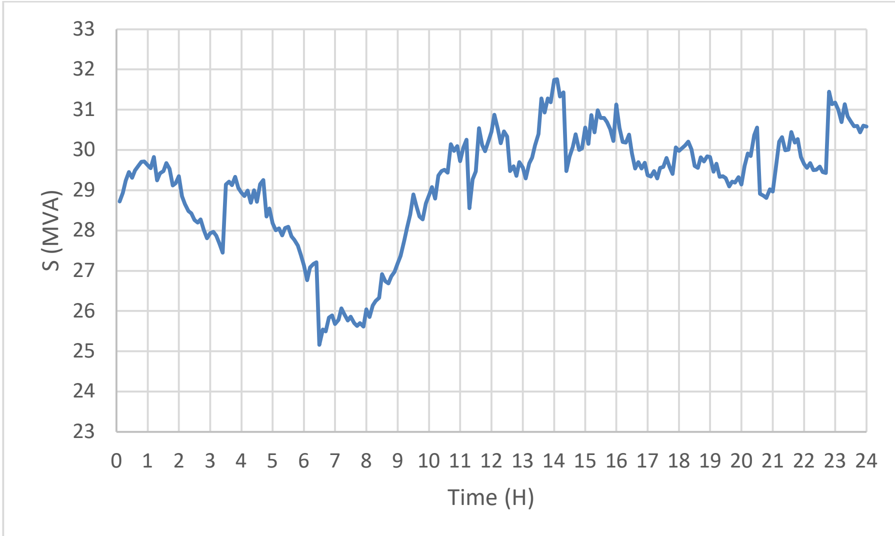

Fig. 6.11, Source daily power load curve with adding 2 MW PV farm and 2MW (6MWH) battery storage system to substation 3 storage system discharging at period (21:00-00:00)

As shown, the power peak is at 14:06 (previous peak time) is 31,735.2 KVA (10,578.4KVA on each phase); which is a 6.46 % peak reduction as indicated in table 6.3, and the load curve as represented in figure 6.11 and figure 6.12 is flatter than the previous one.

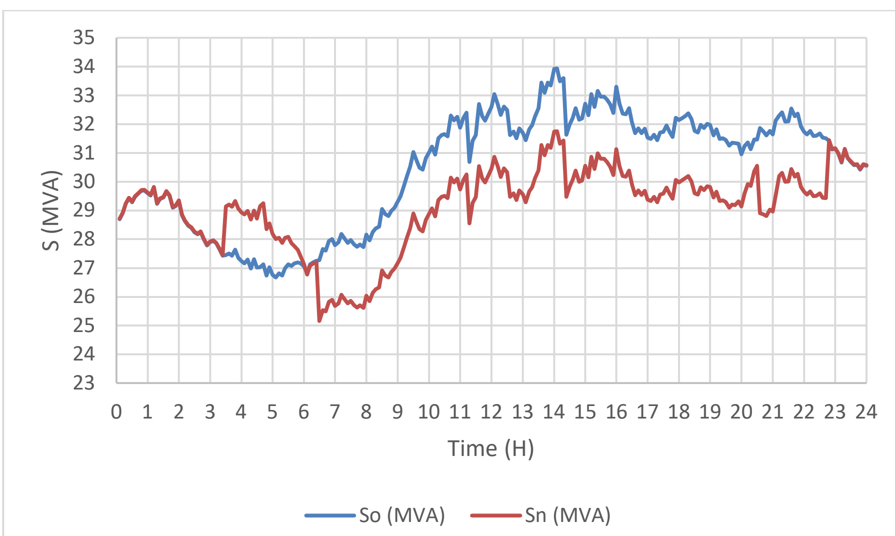

Fig. 6.12, Source daily power load curve without and with adding 2 MW PV farm and 2MW battery storage system to substation 3 storage system discharging at period (21:00-00:00)

TABLE 6.3, Combination of experiment 6.1 and experiment 6.2 summary

Approach	Peak Time	Peak Value (KVA)	Reduction
Without New PV Farm and 2MW (6MWH) Storage	14:06	33,927.0	-
With 2MW PV Farm and 2MW (6MWH) Storage	14:06	31,735.2	6.46 %

6.3 VVC and RES Integration Experiment

This experiment goal is to study the effects Volt Var Control (VVC) and Renewable Energy Sources (RES) integration on LV feeders. The following LV feeders were connected to transformer T400517 as demonstrated in figure 6.13 below:

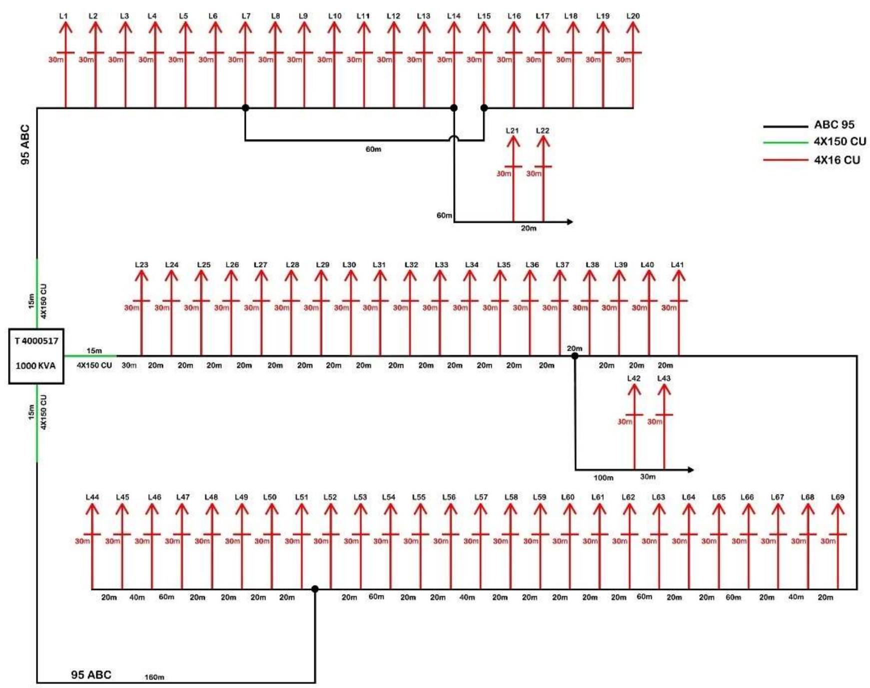

Fig. 6.13, LV feeders with 69 houses connected to transformer T400517

6.3.1 Simulation Without Any RES Connected to the Houses:

By running the simulation without any RES connected to the houses and with disabling the transformer OLTC, it is observed that house 66 has the lowest line to neutral voltage level of 190.3 V at 14:00, and as displayed in the below figure 6.14.

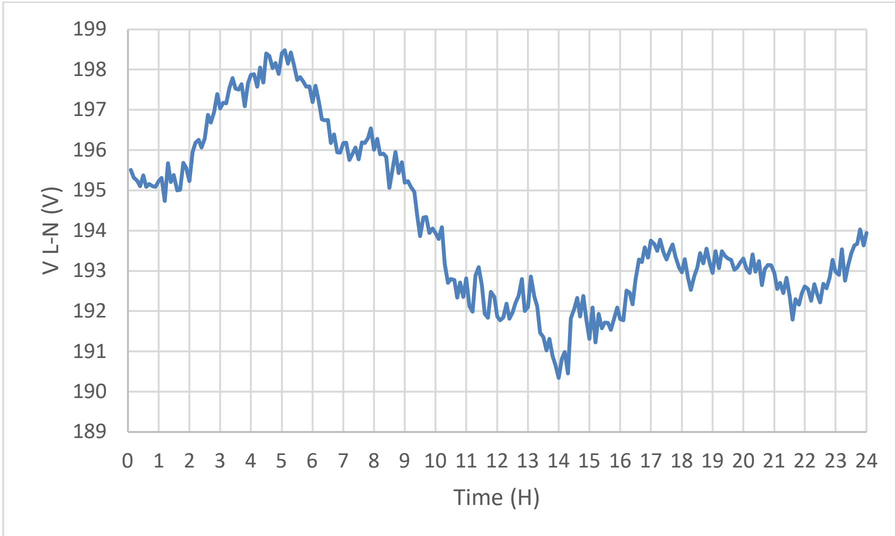

Fig. 6.14, House 66 voltage profile without OLTC connected to transformer T400517

Also, the transformer (T400517) peak is 301.74 kVA at 14:18 and as illustrated in the below figure 6.15.

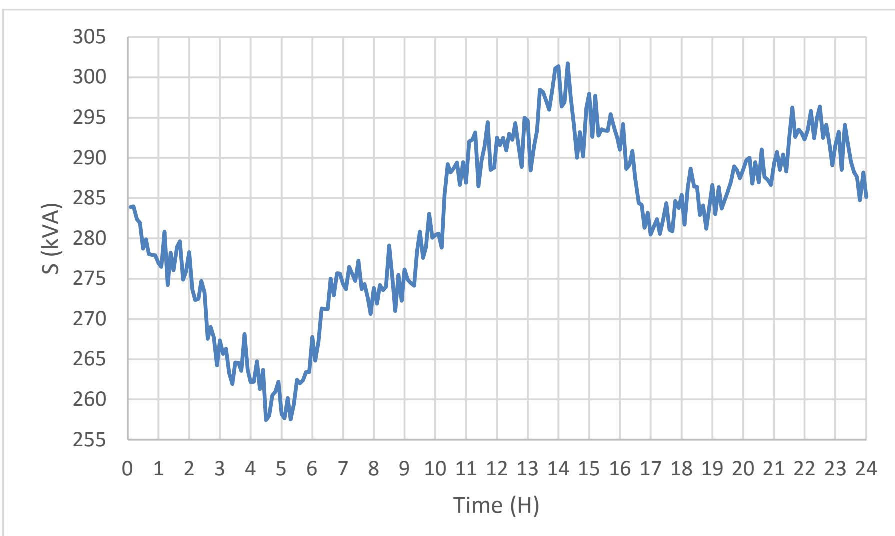

Fig. 6.15, Transformer T400517 daily load curve without OLTC

Now by running the simulation without any RES connected to the houses, but there is OLTC connected to the transformer T400517, the OLTC aims to control the voltage of the feeders with Vreg (L-N) = 250 V. It is observed that house 66 has the lowest line to neutral voltage level of 208.54 V at 14:00 as presented in the following figure 6.16.

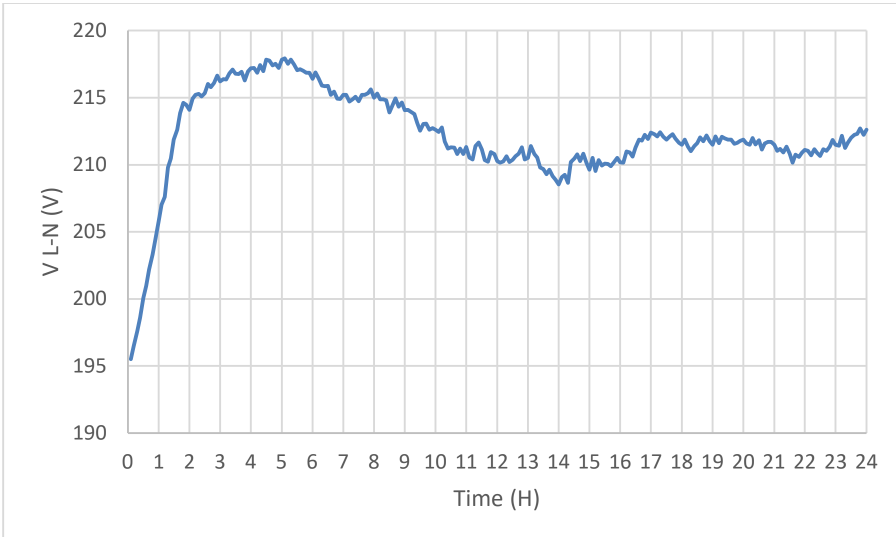

Fig. 6.16, House 66 voltage profile with OLTC connected to transformer T400517

Also, the transformer (T400517) peak is 365.22 kVA at 14:18 and as shown in the below figure 6.17. Table 6.4 summarizes the results of experiment 6.3.1.

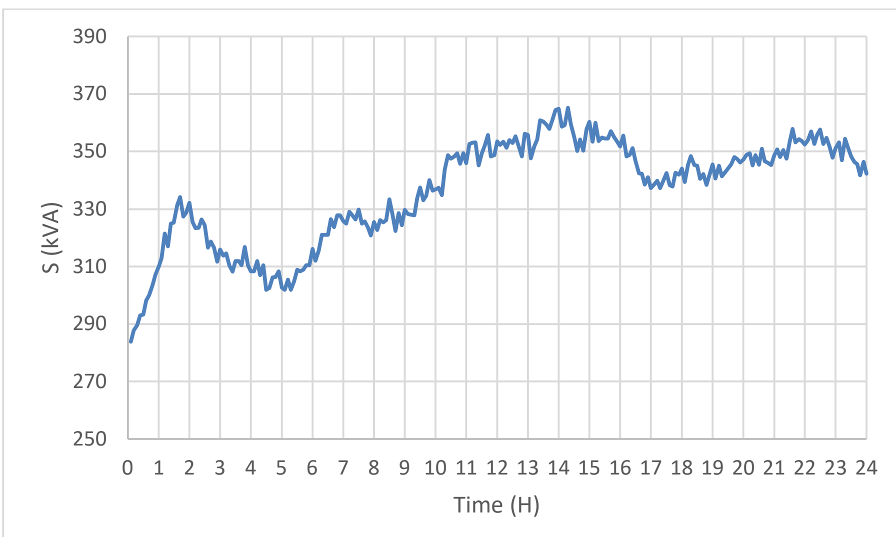

Fig. 6.17, Transformer T400517 daily load curve with OLTC

TABLE 6.4, Experiment 6.3.1 summary (transformer peak and min voltage)

Approach	**Time**	**Min L-N Voltage (V)**	**Increment**
Without OLTC	14:00	190.3	-
With OLTC	14:00	208.54	9.58 %
Approach	**Peak Time**	**Peak Value (KVA)**	**Increment**
Without OLTC	14:18	301.74	-
With OLTC	14:18	365.22	21.04 %

Since the voltage near to house 66 is 190.3 V and as the OLTC will raise the voltage to be within the accepted standard limits; the power delivered from the transformer will increase as the loads type is constant impedance loads.

6.3.2 30% of Houses with PV Stations Each with 5 kWp:

By providing 30% of houses (23 houses) with PV stations each with 5 kWp capacity, the daily load curve of the transformer is as displayed in the below figure 6.18.

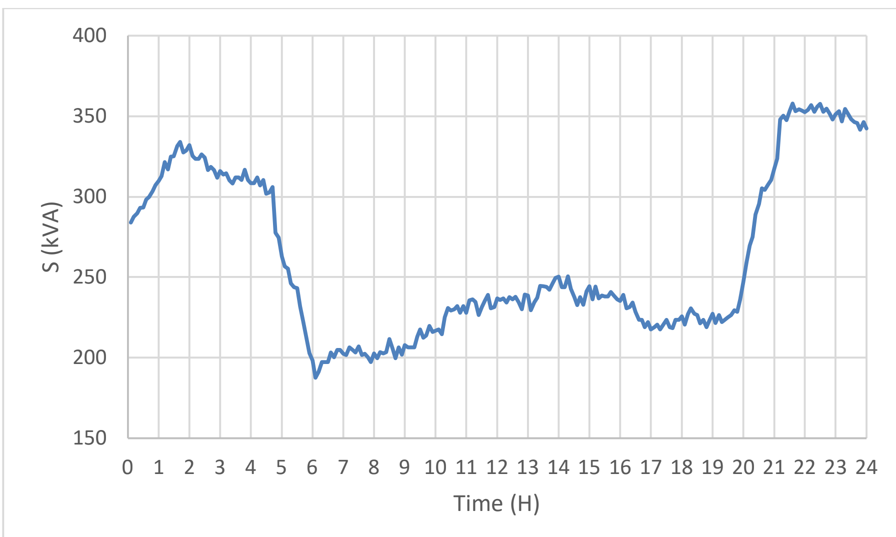

Fig. 6.18, Transformer T400517 daily load curve with 30% PV penetration

The voltage profiles of the first feeder beginning and end are as presented in the following figure 6.19 (near to house # 1) and figure 6.20 (near to house # 20)

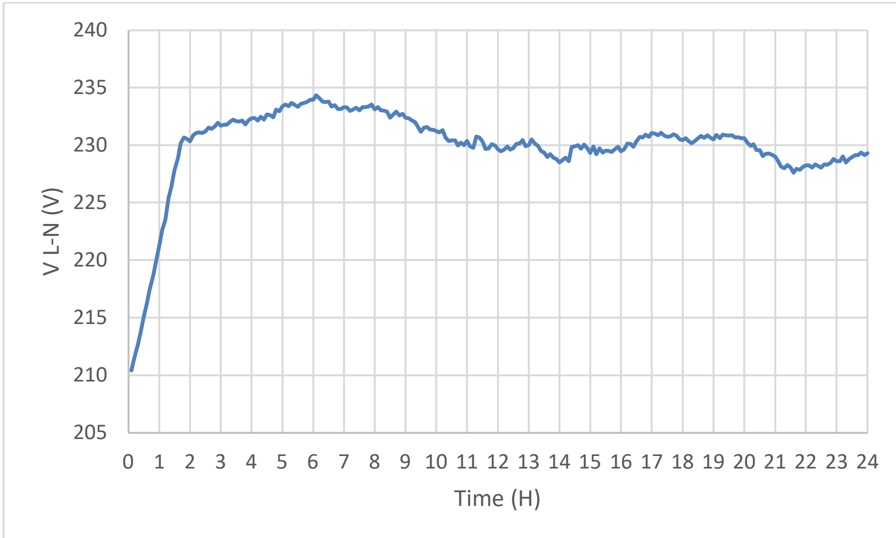

Fig. 6.19, First feeder beginning voltage profile with 30% PV penetration

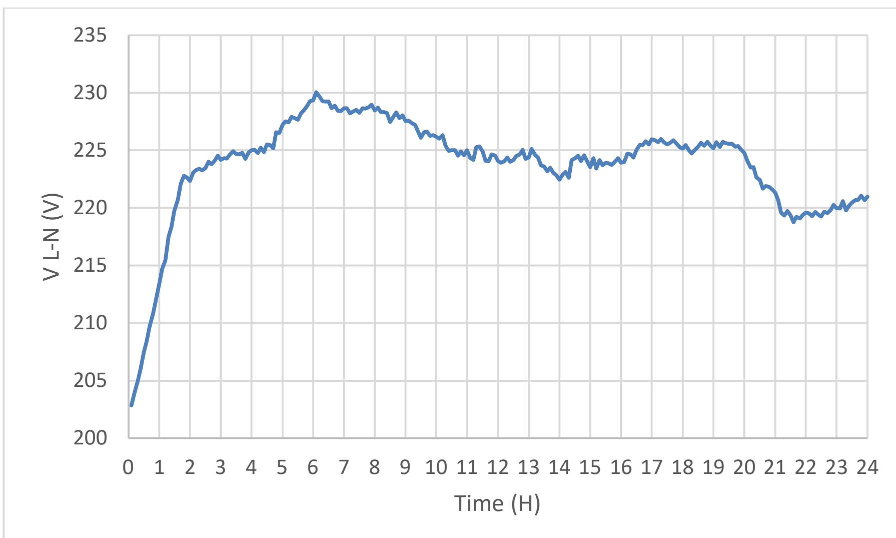

Fig. 6.20, First feeder end voltage profile with 30% PV penetration

Then, the voltage profiles of the second feeder beginning and end are as demonstrated in the following figure 6.21 (near to house # 23) and figure 6.22 (near to house # 41)

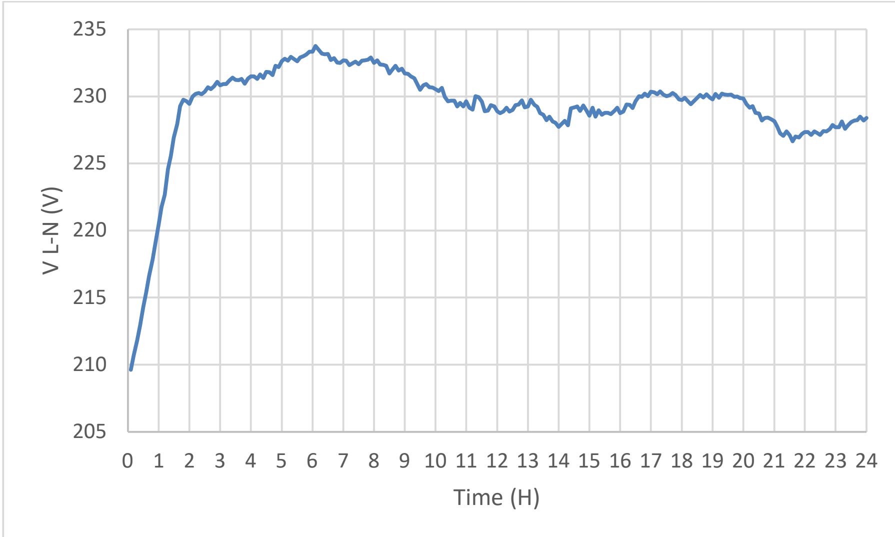

Fig. 6.21, Second feeder beginning voltage profile with 30% PV penetration

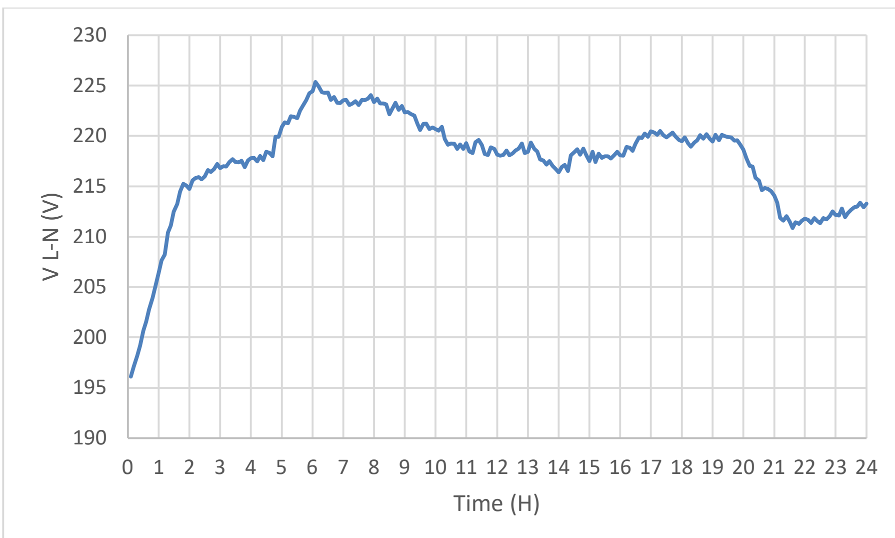

Fig. 6.22, Second feeder end voltage profile with 30% PV penetration

Finally, the voltage profiles of the third feeder beginning and end are as illustrated in the following figure 6.23 (near to house # 52) and figure 6.24 (near to house # 66)

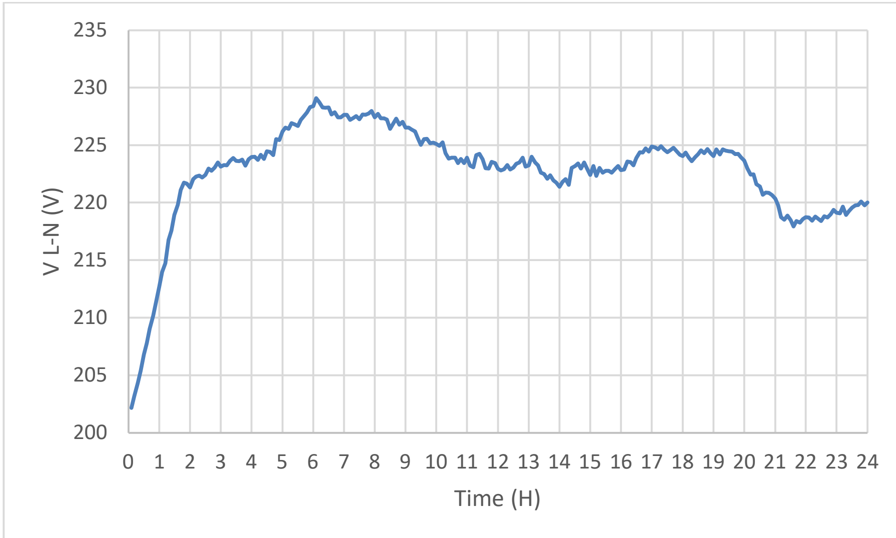

Fig. 6.23, Third feeder beginning voltage profile with 30% PV penetration

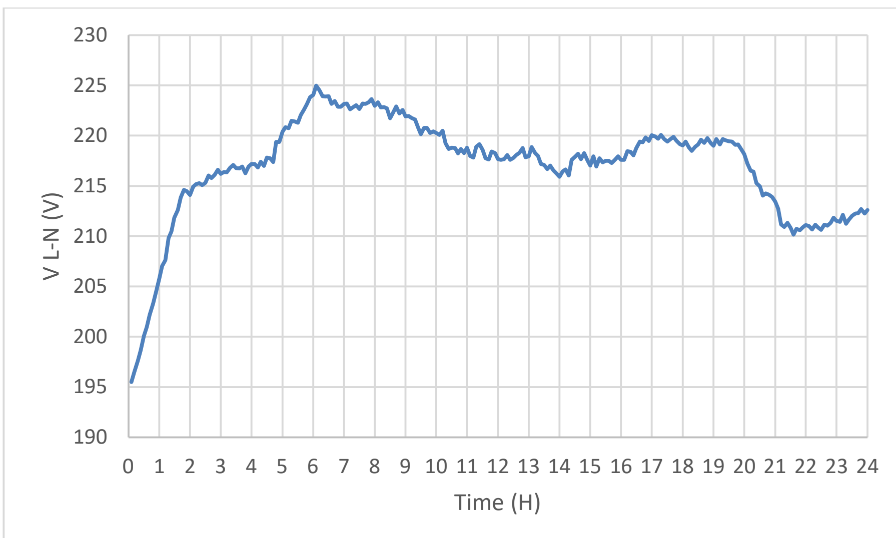

Fig. 6.24, Third feeder end voltage profile with 30% PV penetration

6.3.3 50% of Houses with PV Stations Each with 5 kWp:

By providing 50% of houses (35 houses) with PV stations each with 5 kWp capacity, the daily load curve of the transformer is as displayed in the below figure 6.25

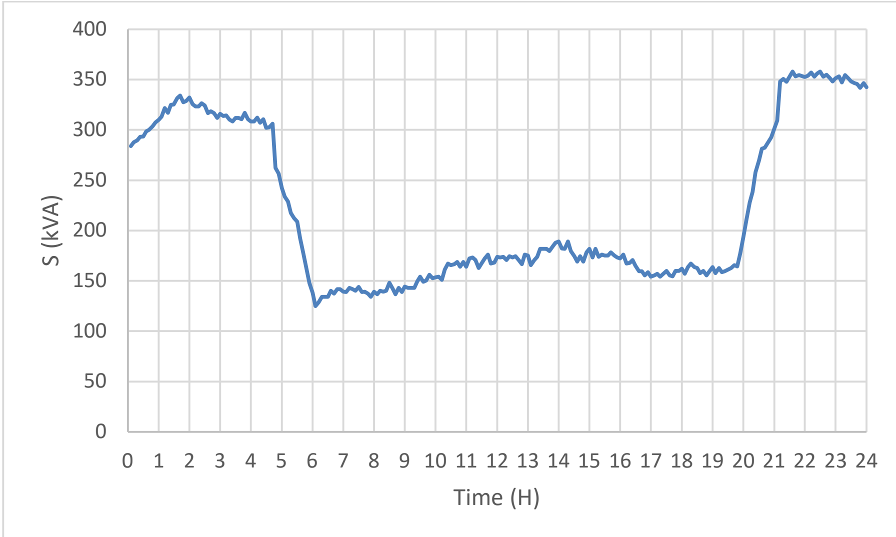

Fig. 6.25, Transformer T400517 daily load curve with 50% PV penetration

The voltage profiles of the first feeder beginning and end are as presented in the following figure 6.26 (near to house # 1) and figure 6.27 (near to house # 20)

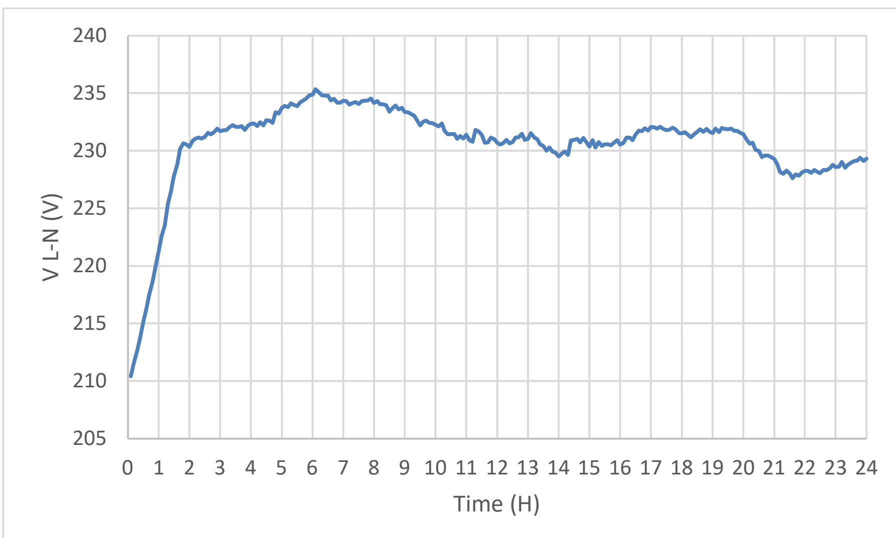

Fig. 6.26, First feeder beginning voltage profile with 50% PV penetration

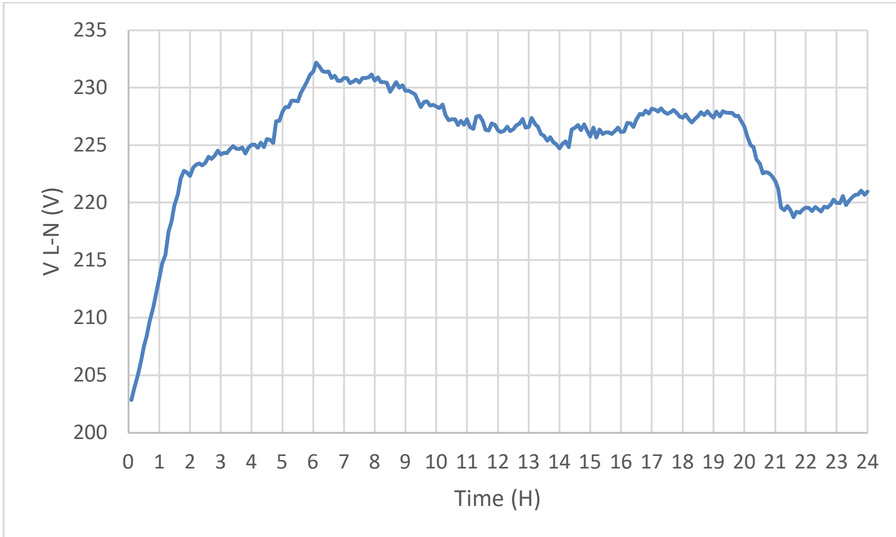

Fig. 6.27, First feeder end voltage profile with 50% PV penetration

Then, the voltage profiles of the second feeder beginning and end are as demonstrated in the following figure 6.28 (near to house # 23) and figure 6.29 (near to house # 41).

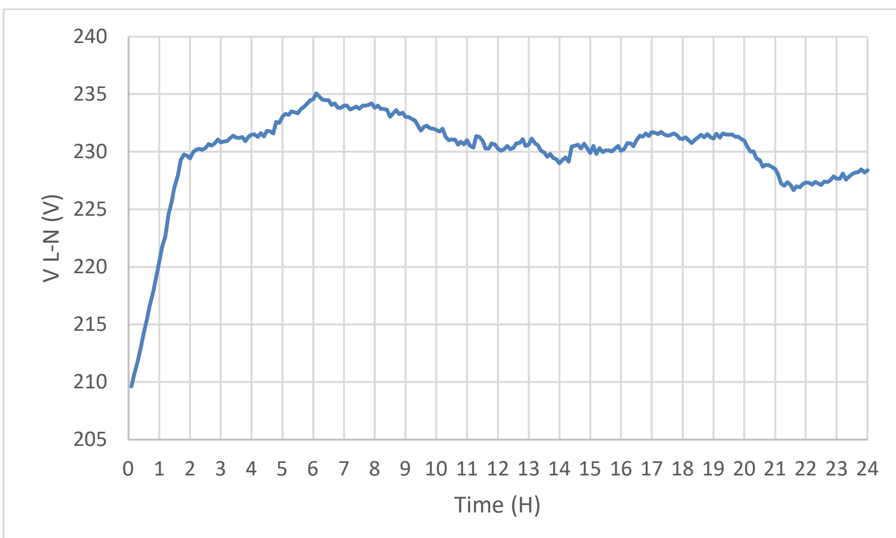

Fig. 6.28, Second feeder beginning voltage profile with 50% PV penetration

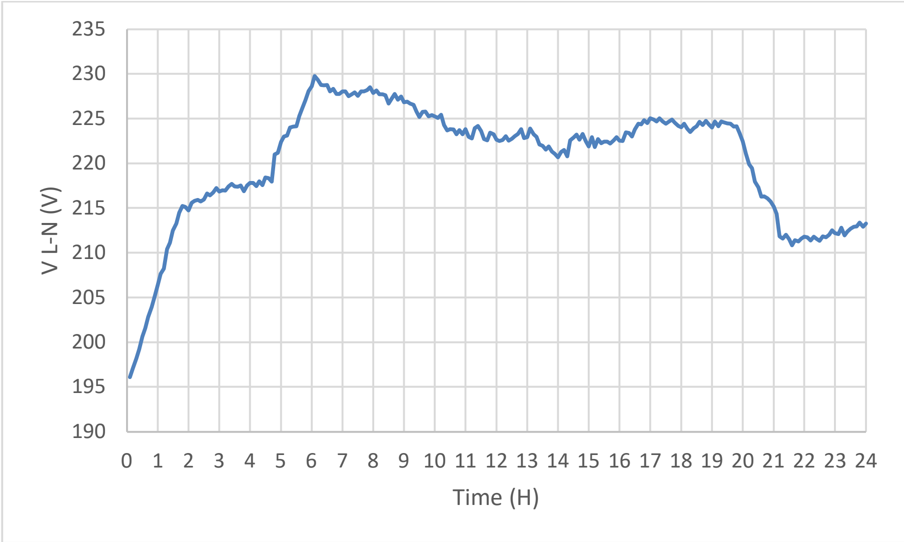

Fig. 6.29, Second feeder end voltage profile with 50% PV penetration

Finally, the voltage profiles of the third feeder beginning and end are as illustrated in the following figure 6.30 (near to house # 52) and figure 6.31 (near to house # 66)

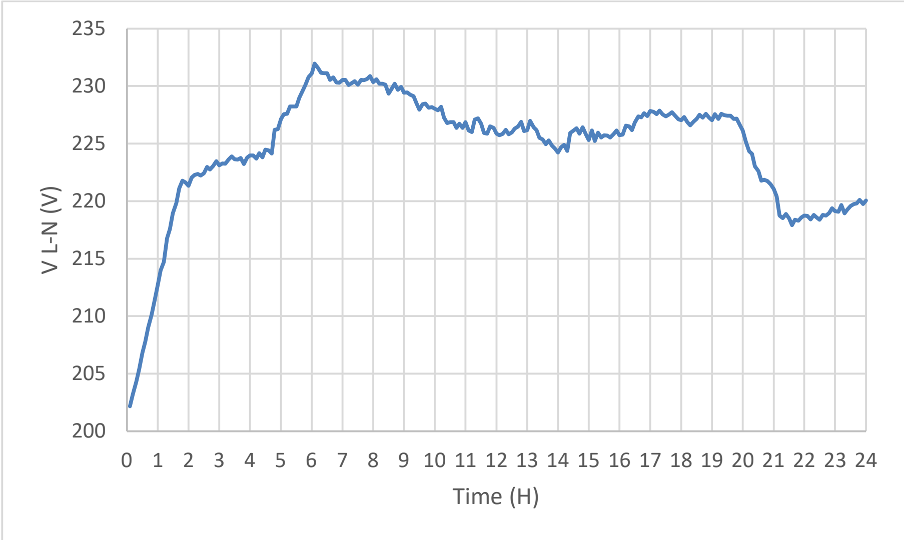

Fig. 6.30, Third feeder beginning voltage profile with 50% PV penetration

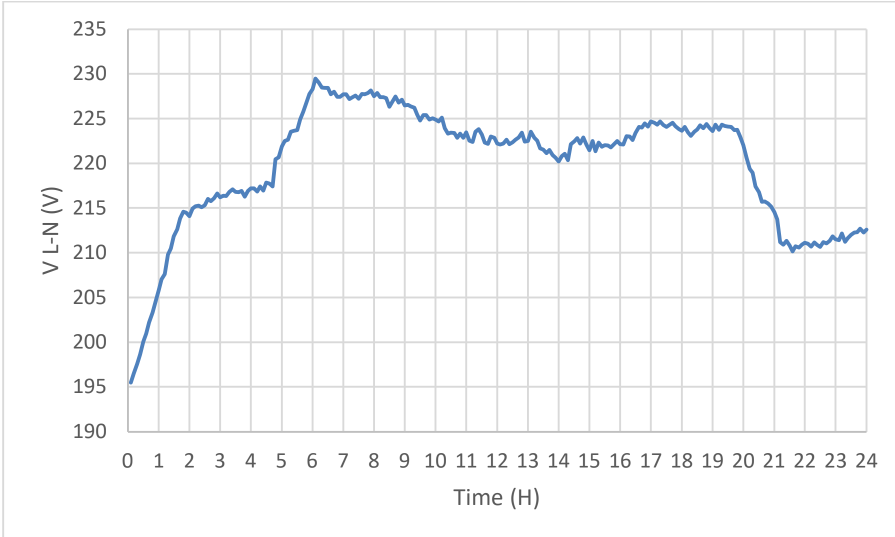

Fig. 6.31, Third feeder end voltage profile with 50% PV penetration

6.3.4 75% of Houses with PV Stations Each with 5 kWp:

By providing 75% of houses (52 houses) with PV stations each with 5 kWp capacity, the daily load curve of the transformer is as displayed in the below figure 6.32:

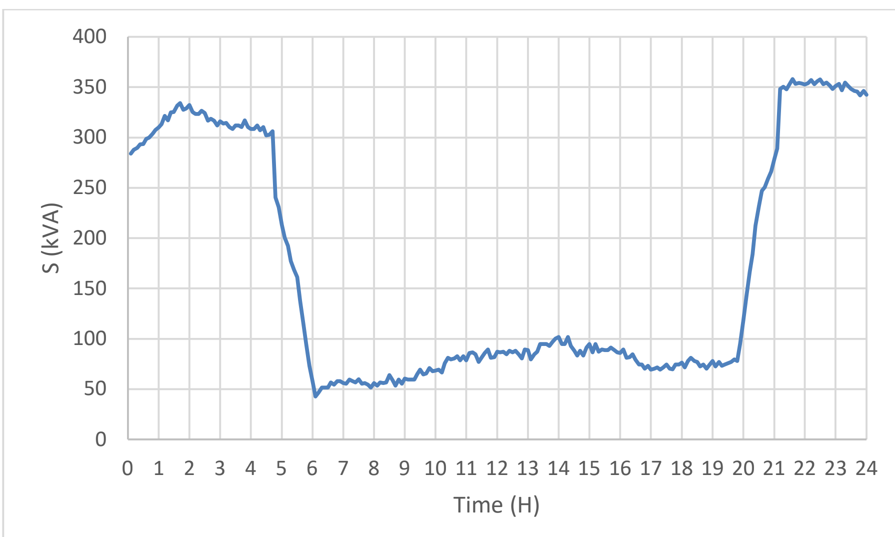

Fig. 6.32, Transformer T400517 daily load curve with 75% PV penetration

The voltage profiles of the first feeder beginning and end are as presented in the following figure 6.33 (near to house # 1) and figure 6.34 (near to house # 20)

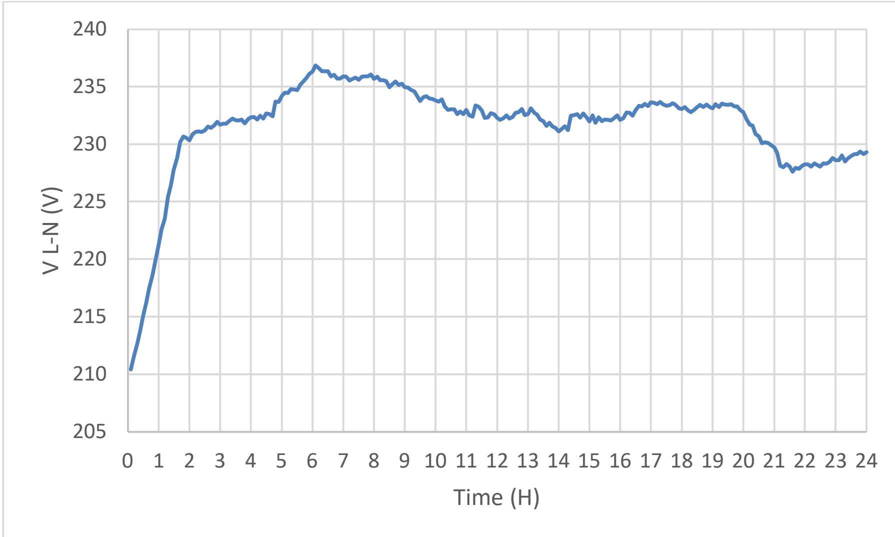

Fig. 6.33, First feeder beginning voltage profile with 75% PV penetration

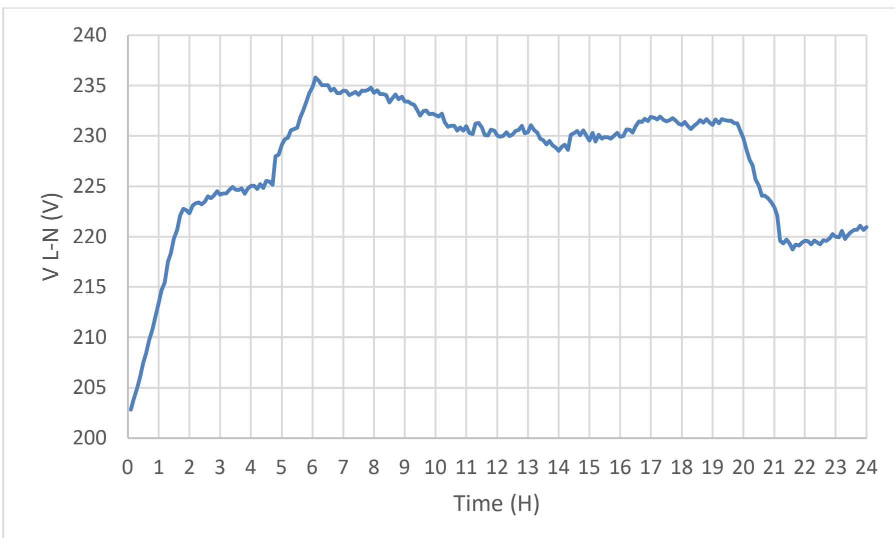

Fig. 6.34, First feeder end voltage profile with 75% PV penetration

Then, the voltage profiles of the second feeder beginning and end are as demonstrated in the following figure 6.35 (near to house # 23) and figure 6.36 (near to house # 41)

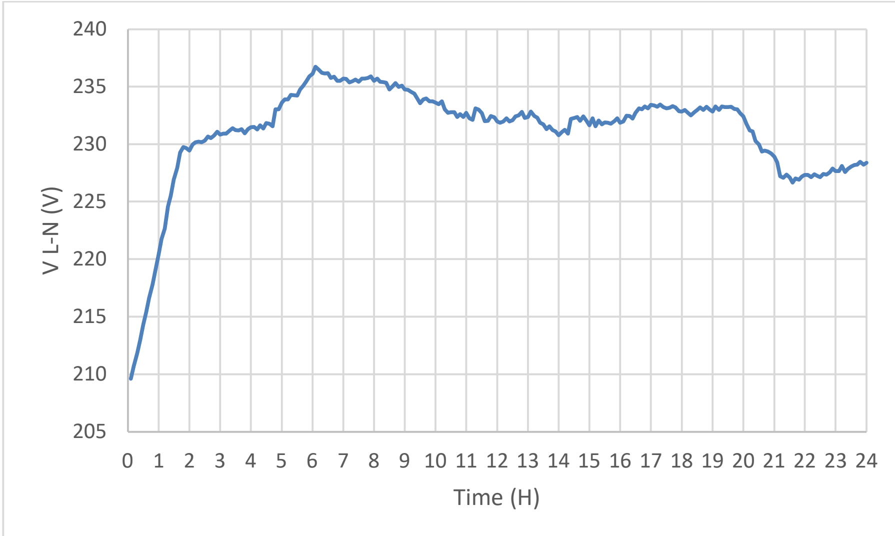

Fig. 6.35, Second feeder beginning voltage profile with 75% PV penetration

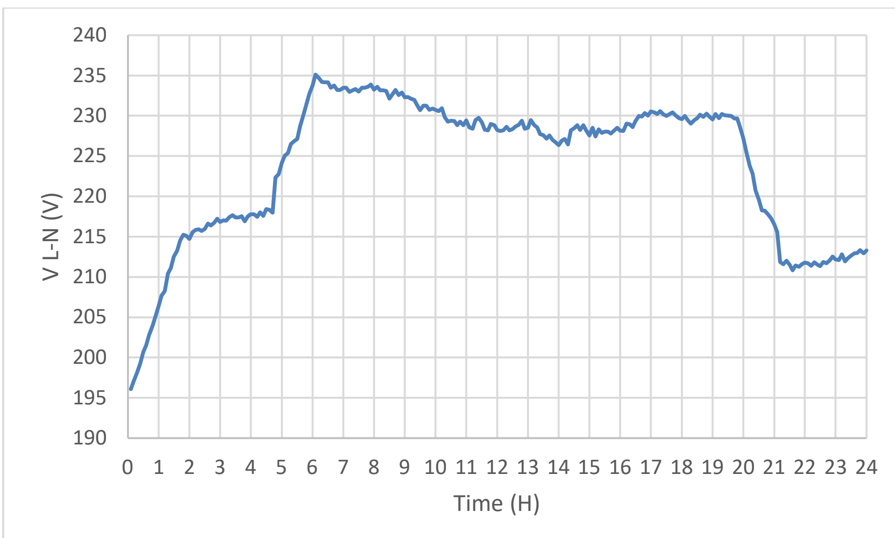

Fig. 6.36, Second feeder end voltage profile with 75% PV penetration

Finally, the voltage profiles of the third feeder beginning and end are as illustrated in the following figure 6.37 (near to house # 52) and figure 6.38 (near to house # 66)

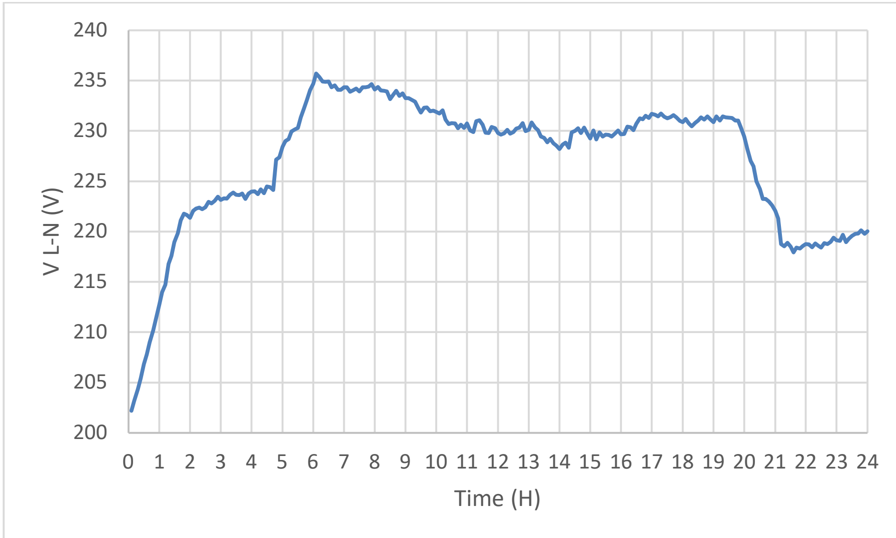

Fig. 6.37, Third feeder beginning voltage profile with 75% PV penetration

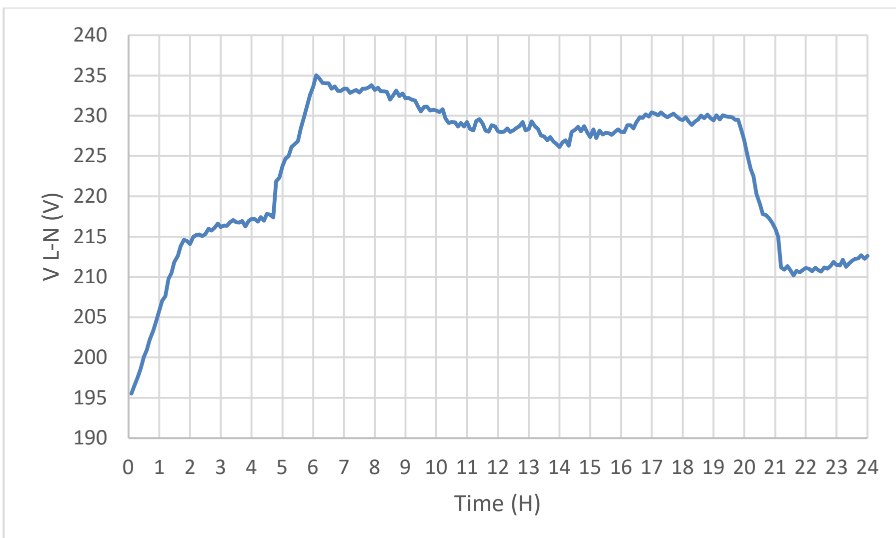

Fig. 6.38, Third feeder end voltage profile with 75% PV penetration

6.3.5 100% of Houses with PV Station Each with 5 kWp:

By providing 100% of houses (69 houses) with PV stations each with 5 kWp capacity, the daily load curve of the transformer is as displayed in the below figure 6.39:

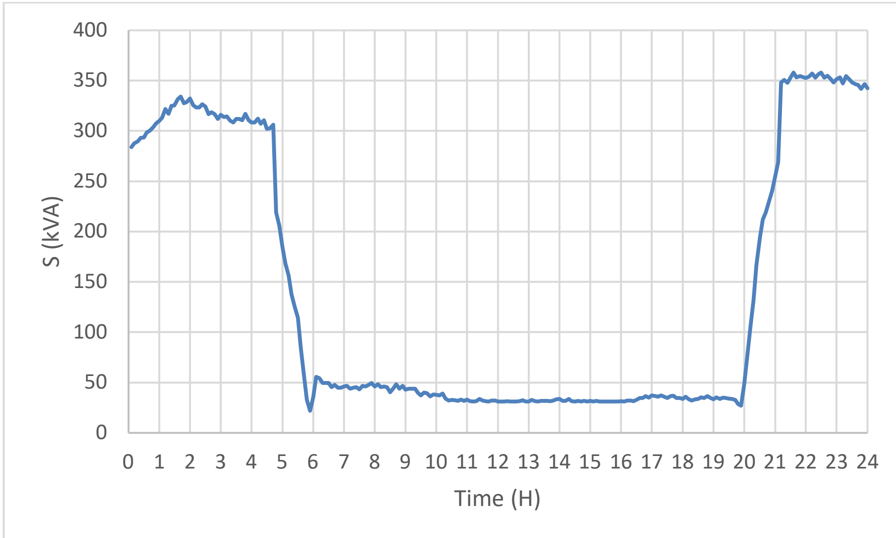

Fig. 6.39, Transformer T400517 daily load curve with 100% PV penetration

The voltage profiles of the first feeder beginning and end are as presented in the following figure 6.40 (near to house # 1) and figure 6.41 (near to house # 20)

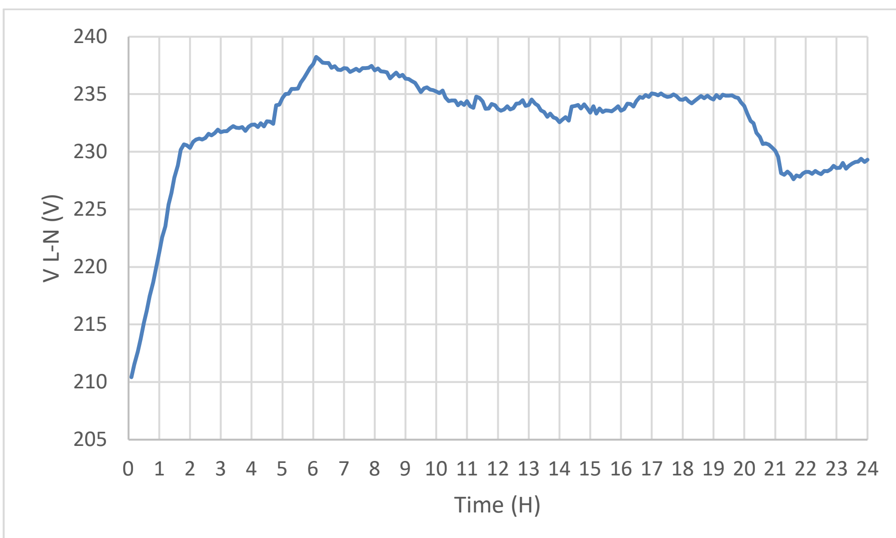

Fig. 6.40, First feeder beginning voltage profile with 100% PV penetration

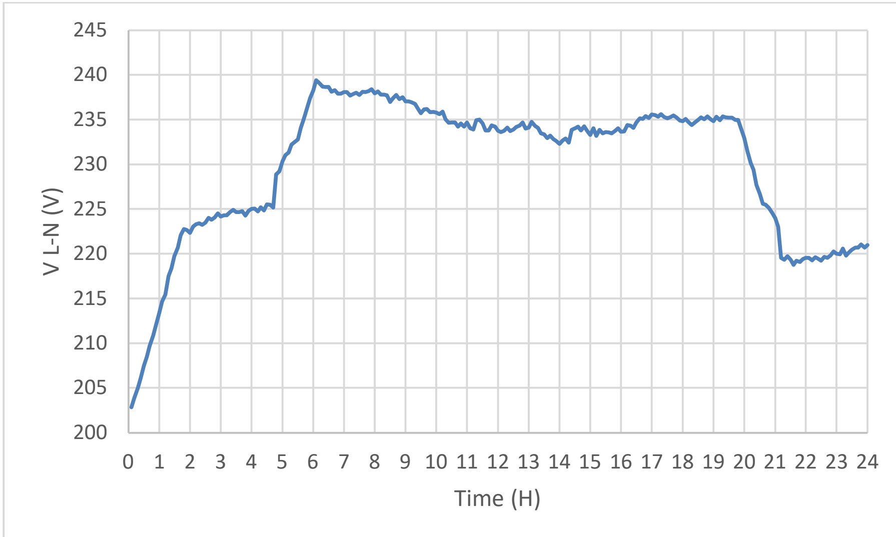

Fig. 6.41, First feeder end voltage profile with 100% PV penetration

Then, the voltage profiles of the second feeder beginning and end are as demonstrated in the following figure 6.42 (near to house # 23) and figure 6.43 (near to house # 41)

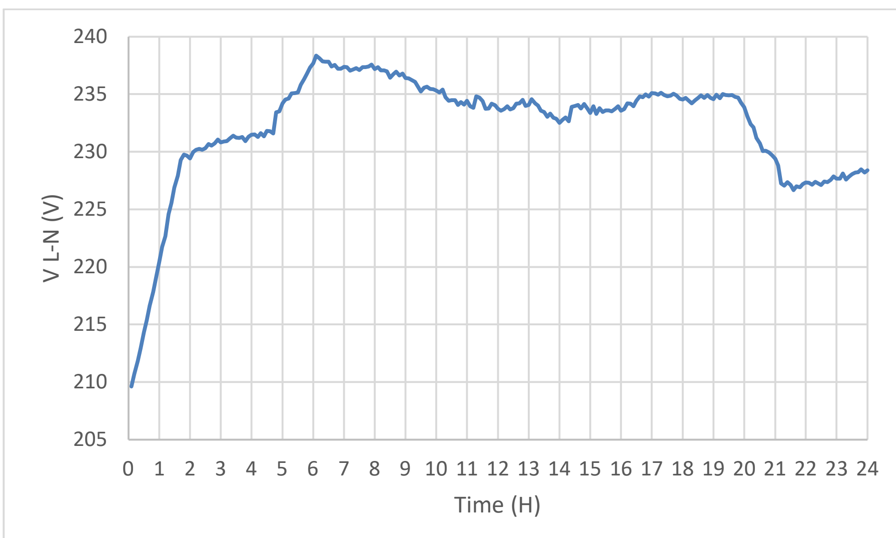

Fig. 6.42, Second feeder beginning voltage profile with 100% PV penetration

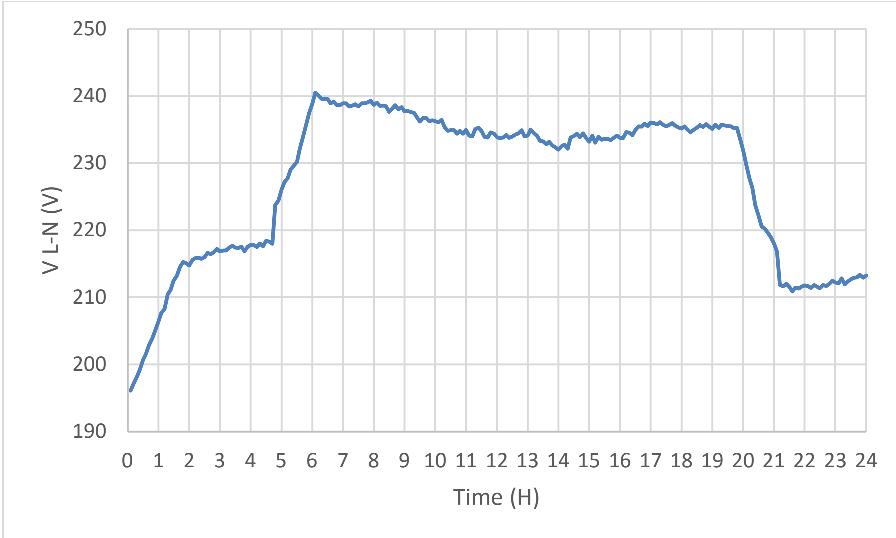

Fig. 6.43, Second feeder end voltage profile with 100% PV penetration

Finally, the voltage profiles of the third feeder beginning and end are as illustrated in the following figure 6.44 (near to house # 52) and figure 6.45 (near to house # 66)

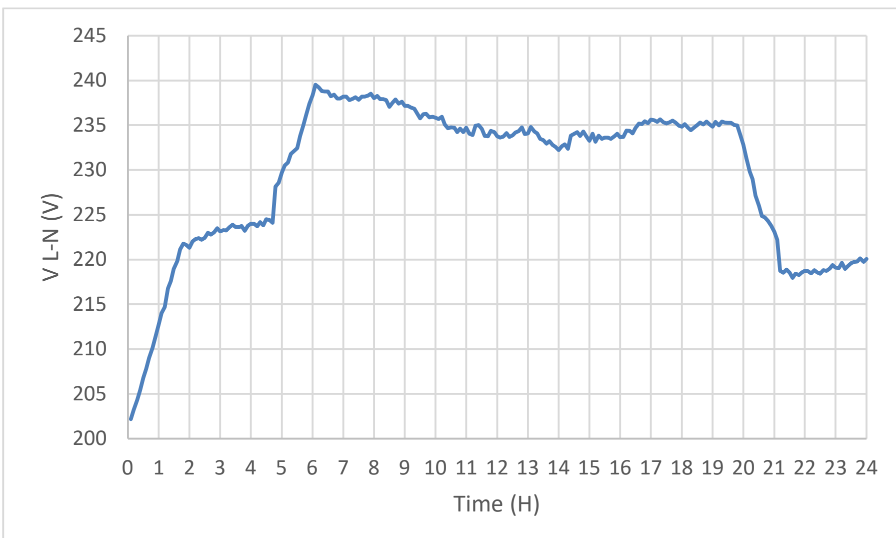

Fig. 6.44, Third feeder beginning voltage profile with 100% PV penetration

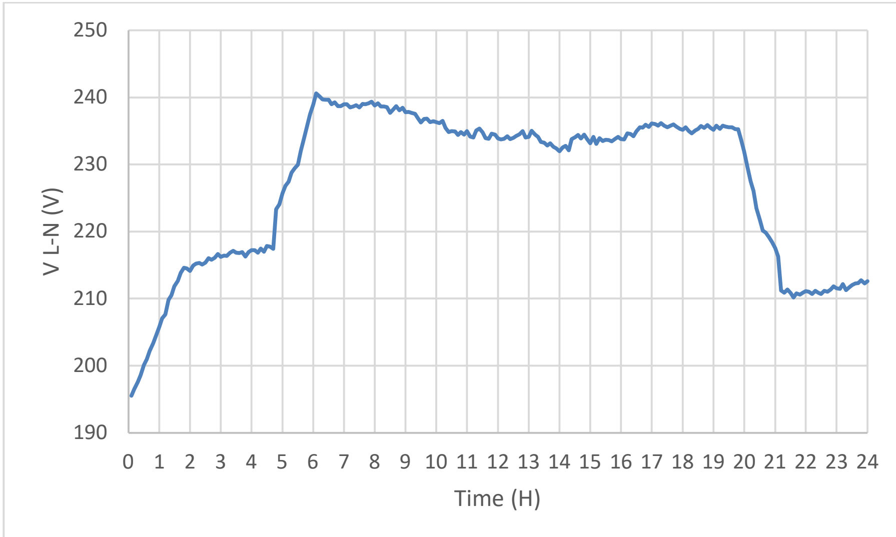

Fig. 6.45, Third feeder end voltage profile with 100% PV penetration

TABLE 6.5, Experiment 6.3 summary table

PV Penetration Level	Transformer power during peak time (kVA)	Min Voltage 1st Feeder End (V)	Min Voltage 2nd Feeder End (V)	Min Voltage 3rd Feeder End (V)
0%	365.2	217.4	209.4	208.7
30%	250.5	222.5	216.4	215.9
50%	189.3	224.7	220.7	220.2
75%	101.7	228.5	226.3	226.1
100%	33.5	232.3	232	232

6.4EV Integration Experiment

In this experiment, the effect of Electric Vehicle (EV) integration on LV feeders will be studied. The experiment is executed on the same LV feeder of experiment 6.3 (LV feeders connected to transformer T400517).

The EV charging characteristics are assumed based on PEUGEOT battery electric vehicle on board charger; 11kW (three phase) and with 5 hours full charging time.

6.4.1 20% of Houses with 11 kW EV– Worst Case:

The transformer (T400517) peak without any EV is 365.22 kVA at 14:18. The voltage profile at the end of second and third feeders will be as shown in the following figure 6.46 (near to house # 41) and figure 6.47 (near to house # 66).

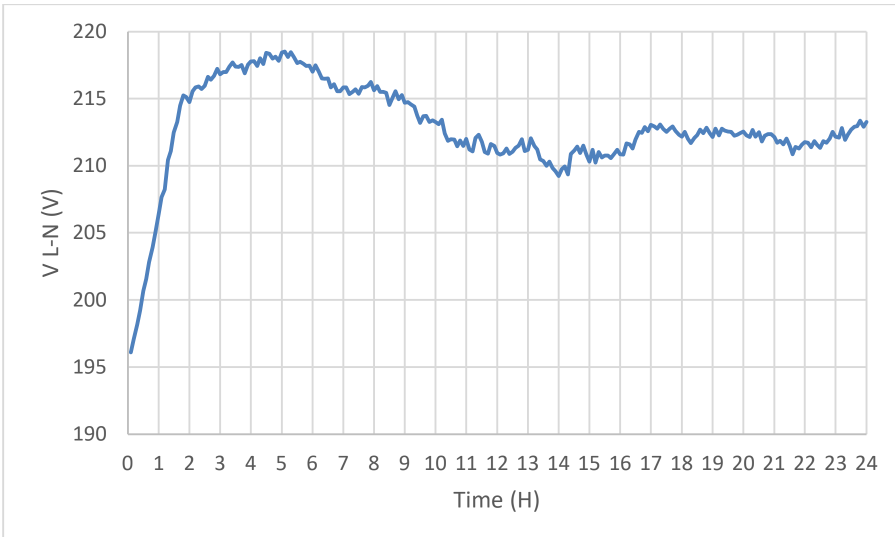

Fig. 6.46, Second feeder end voltage profile without EV

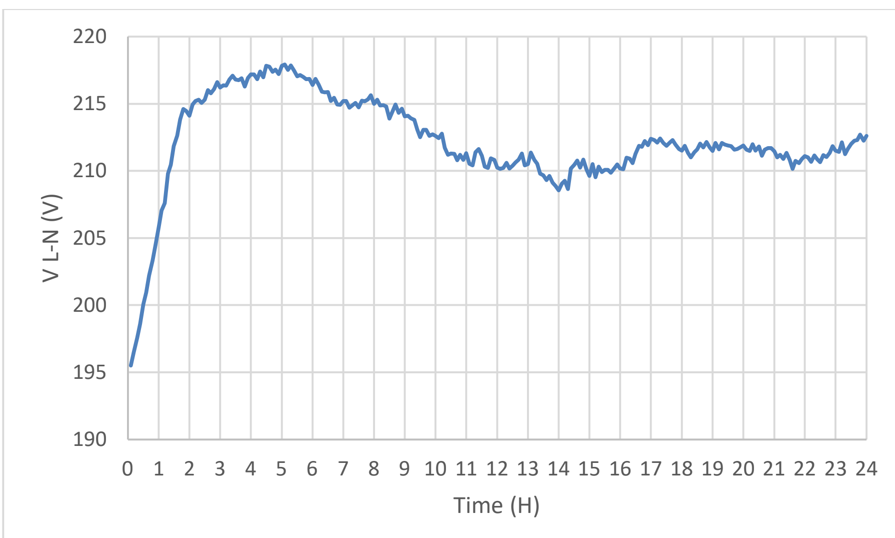

Fig. 6.47, Third feeder end voltage profile without EV

Form the voltage profile figures at the second and third feeder's end it is observed that the lowest L-N voltage value will be 208.54 V at 14:00 near to house 66; which is greater than the lowest accepted voltage limit (207 V).

Now assuming 20% of houses (14 houses) are with EV each 11 kW rated. Also, assuming the worst-case scenario in which all customers will start to charge the electric vehicles at the same time when they return back from work; at 18:00 and for 5 hours (charging period).

The transformer load curve will be as demonstrated in the following figure 6.48, and new peak resulted of 501.74 kVA at 22:30.

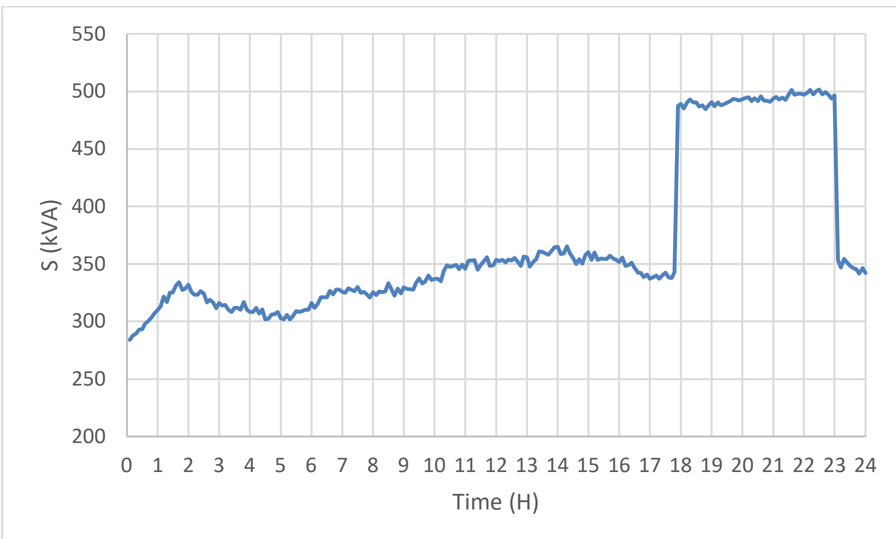

Fig. 6.48, Transformer T400517 daily load curve with 20% of houses with EV charging on 18:00-23:00

The voltage profile at the end of second and third feeders will be as displayed in the following figure 6.49 (near to house # 41) and figure 6.50 (near to house # 66).

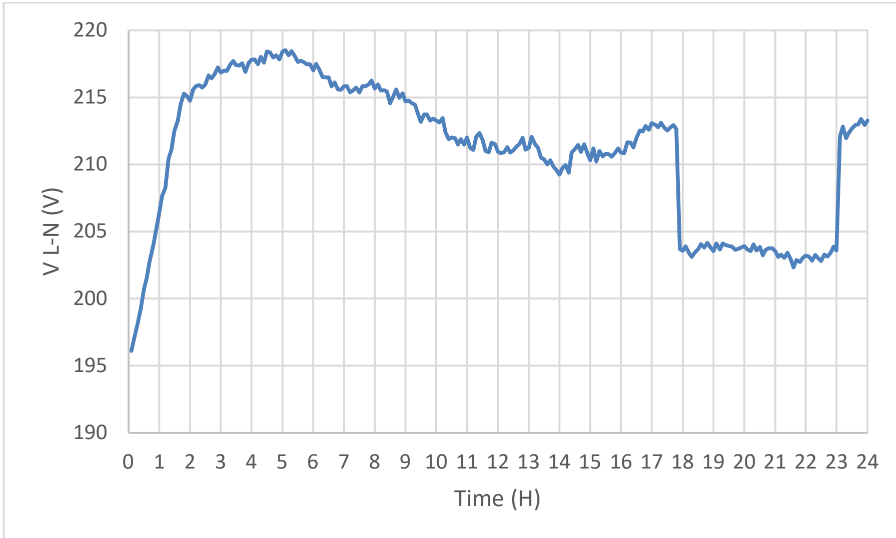

Fig. 6.49, Second feeder end voltage profile with 20% of houses with EV charging on 18:00-23:00

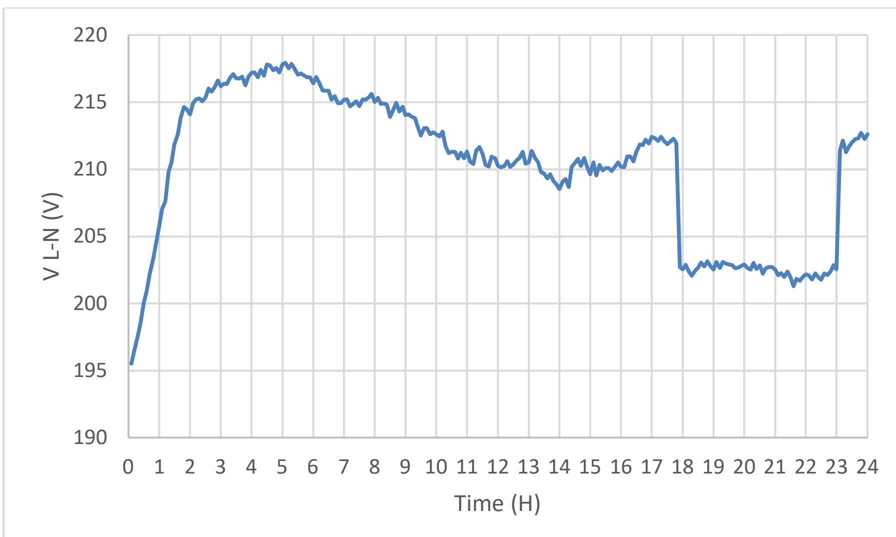

Fig. 6.50, Third feeder end voltage profile with 20% of houses with EV charging on 18:00-23:00

From these figures it is clear that the voltage at the second and third feeders end is lower than 205 V (lower than accepted voltage limits 207 V) during the EV charging period.

6.4.2 20% of Houses with 11 kW EV– Optimized Case:

In this case 20% of houses (14 houses) are assumed with EV each 11 kW rated. All customers will start to charge the electric vehicles at the same time; at the lowest demand period, at 02:00 and for 5 hours (charging period).

This will be guaranteed by time of use tariffs, and day ahead prices messages received by the customers from the electric utility.

The transformer load curve will be as illustrated in the following figure 6.51, and new peak resulted of 481.26 kVA at 07:12.

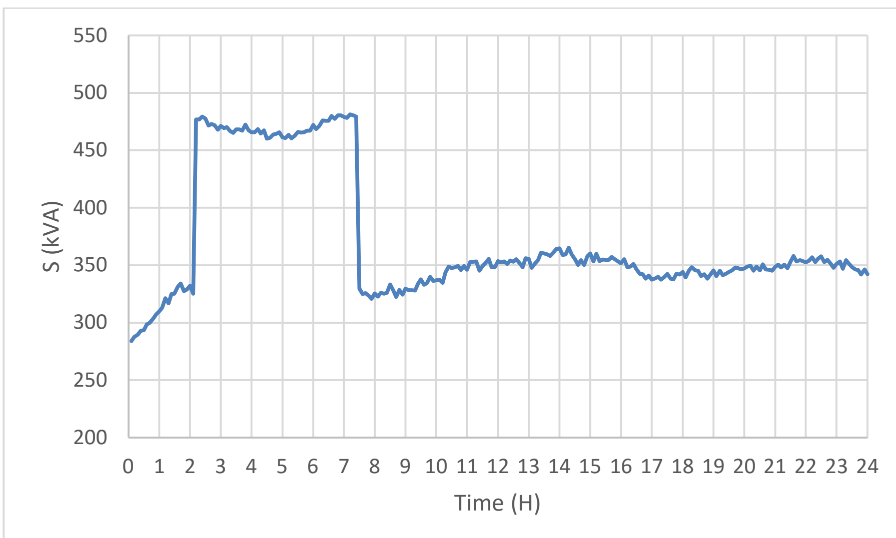

Fig. 6.51, Transformer T400517 daily load curve with 20% of houses with EV charging on 02:00-07:00

The voltage profile at the end of second and third feeders will be as displayed in the following figure 6.52 (near to house # 41) and figure 6.53 (near to house # 66).

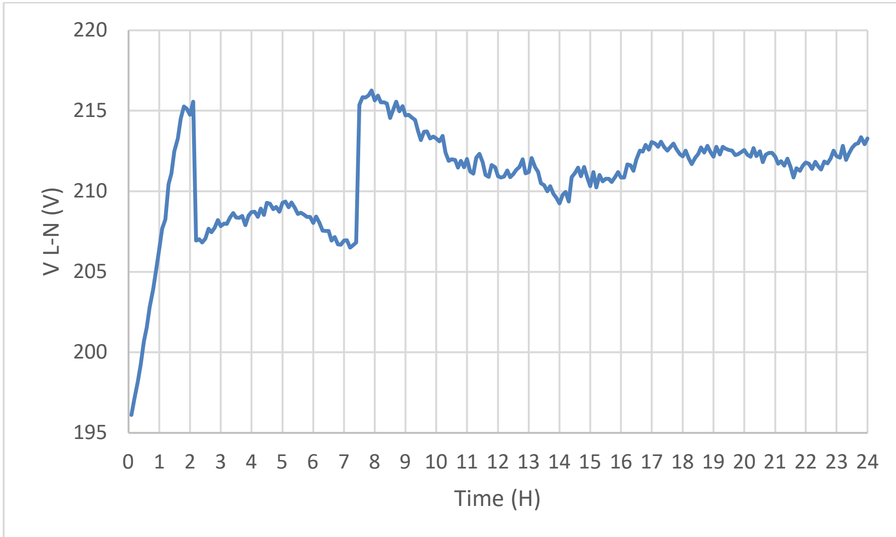

Fig. 6.52, Second feeder end voltage profile with 20% of houses with EV charging on 02:00-07:00

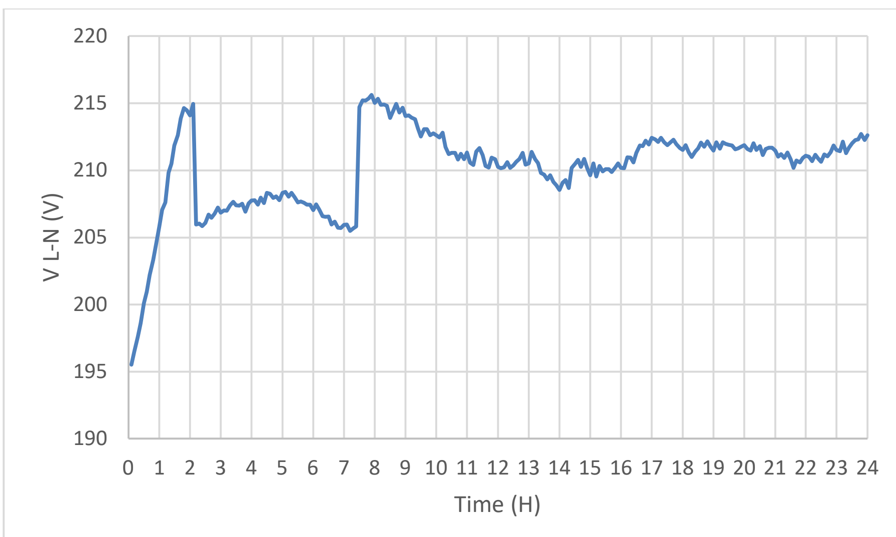

Fig. 6.53, Third feeder end voltage profile with 20% of houses with EV charging on 02:00-07:00

Form the voltage profile figures at the second and third feeder's end; it is observed that the lowest L-N voltage value will be 205.49 V at 07:12 near to house 66; which is lower than the lowest accepted voltage limit (207 V).

6.4.3 20% of Houses with 11 kW EV– Optimum Case:

In this case it is assumed that 20% of houses (14 houses) are with EV each 11 kW rated. 70% of those customers (10 houses) will start to charge the electric vehicles at the lowest demand period; at 02:00 and for 5 hours (charging period).

The other 30% of customers (4 houses) will start to charge the electric vehicles when they return back from work; at 18:00 and for 5 hours (charging period).

Again, this will be guaranteed by Time of use tariffs, and day ahead prices messages received by the customers from the electric utility.

The transformer load curve will be as presented in the following figure 6.54, and new peak resulted of 439.17 kVA at 07:12.

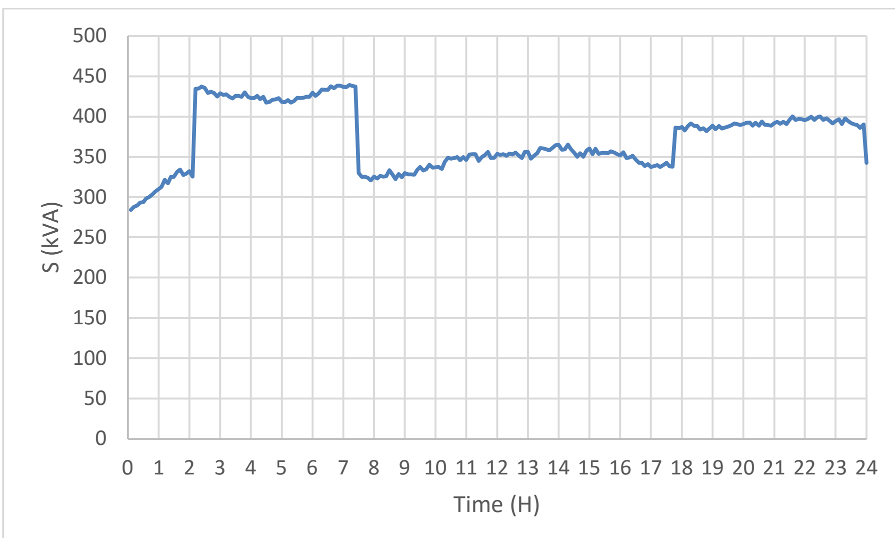

Fig. 6.54, Transformer T400517 daily load curve with 20% of houses (14 houses) with EV, 10 houses charging on 02:00-07:00 and 4 houses charging on 18:00-23:00

The voltage profile at the end of second and third feeders will be as demonstrated in the following figure 6.55 (near to house # 41) and figure 6.56 (near to house # 66).

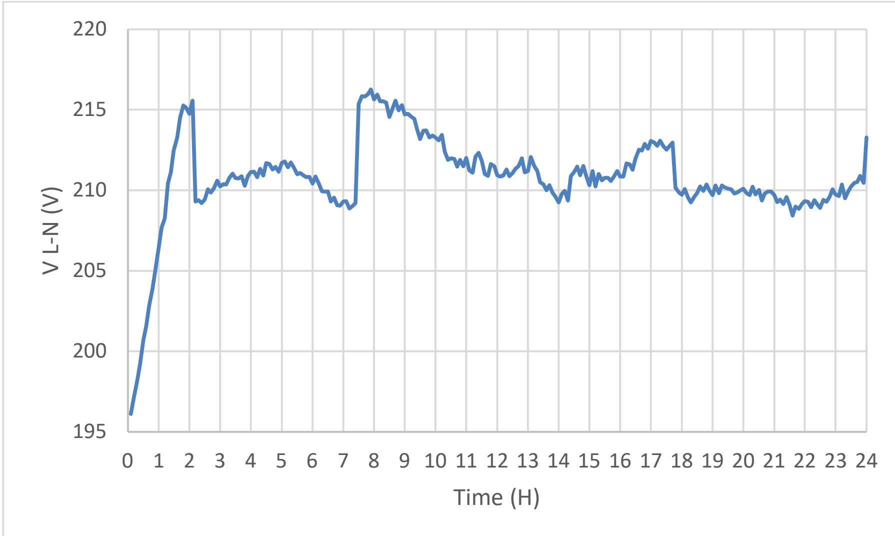

Fig. 6.55, Second feeder end voltage profile with 20% of houses (14 houses) with EV, 10 houses charging on 02:00-07:00 and 4 houses charging on 18:00-23:00

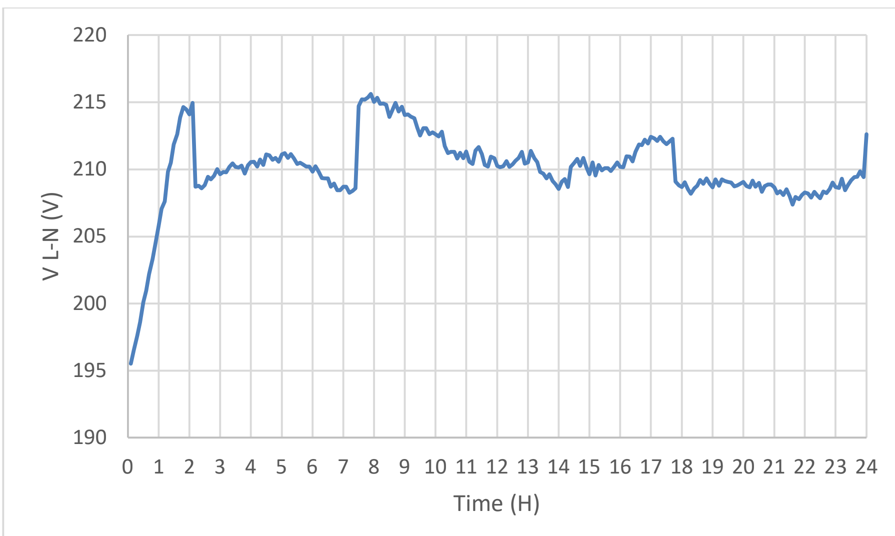

Fig. 6.56, Third feeder end voltage profile with 20% of houses (14 houses) with EV, 10 houses charging on 02:00-07:00 and 4 houses charging on 18:00-23:00

Form the voltage profile figures at the second and third feeder's end; it is observed that the lowest L-N voltage value will be 207.36 V at 21:36 near to house 66; which is greater than the lowest accepted voltage limit (207 V).

6.5 Results and Discussion

- In first experiment, and by using peak shave technique through Battery Storage System which is one of smart grid applications, the target to avoid requesting more capacity from IEC or Jordan is achieved. This means injecting the stored energy in the storage system during peak hours to the grid. Other storage systems could be used instead of batteries such as pumped hydroelectric energy storage (PHES) which will be suitable for Jericho case since it is surrounded by mountains.
- The integration of renewable energy sources was tested in the second experiment. As the peak period in Jericho is between 13:00 and 15:00 which is same period of the PV systems peak production; this means that adding additional PV farms as distributed generation will participate in reducing the peak demand from the source. Around 6.5% peak reduction resulted from adding 2 MWp PV farm near to Substation 3 (Magtas S/S).
- Further load peak reduction achieved when combining the peak shave technique using batteries storage system and integration of renewable energy sources, but a new peak resulted during the evening period. Therefore, the optimum combination of the PV system and storage system obtained when changing the storage system discharging period to shave the new peak (at the evening period), and a flatter load curve resulted.
- In the third experiment, Volt Var Control and RES integration were conducted on LV feeders of residential compound. The OLTC on the distribution transformer with closed loop control contribute on maintaining the voltage at the farest feeder's end withing the accepted standard limits. Also, the effect of PV penetration level on the transformer load curve, and the voltage profiles at the feeder's beginning and

end were studied. Higher penetration levels lead to better feeder's voltage profile, and lower transformer demand from the source.

- Finally, the electric vehicle (EV) integration with the grid was examined in the last experiment. The worst-case scenario, in which all customers with EVs (20% proposed) will start to charge their vehicle when they return to home from work; this will create a new peak period on the transformer, and may cause transformer's overload. Also, the voltage profiles at the second and third feeders ends become lower than 205V which are less than the accepted voltage level (207 V) according to the standards.
- The second scenario was proposed; in which all customers with EVs will start charging at the early morning (lower demand period). But, due to this group charging at the same period, a new peak resulted and the voltage profile at the third feeder's end is lower than the accepted voltage limit.
- The optimized scenario achieved by managing the charging process; 70% of EVs will be charged during the lower demand period (early morning), while the remaining 30% of EVs will be charged when customers return to home (at evening). This may be guaranteed by time of use tariffs and day ahead prices messages. The results of this scenario are flatter load curve and feeder's voltage profiles within the accepted standard limits.

CHAPTER 7: EXISTING INFRASTRUCTURE AND RECOMMENDATIONS

The Existing infrastructures, recommendations and the requirements to apply smart grid applications in the Palestinian Electricity transmission company (PETL), and Palestinian Electricity Distribution companies (NEDCO, TDECO, JDECO, HEPCO, SELCO, and GEDCO) are mentioned below:

7.1 Recommendations at Transmission and Generation Levels

7.1.1 PENRA and PETEL:

1. PENRA and PETEL shall emphasis on the interconnection with neighboring countries Jordan and Egypt with improving the existing transmission lines capacity and or building new lines to eliminate the imported energy from the Israeli side.
2. Also, PENRA and PETEL shall Implement generation plants in west bank and encourage donors and investors to support such step which will be a key factor in the independency of the Palestinian electricity sector despite the difficulties imposed by the Israeli occupation.
3. PNERA shall conduct the required negotiation and communication with international community to force Israel to permit the restoration and expansion of Gaza power plant to solve the drastic energy shortage situation in Gaza strip.
4. Also, PENERA shall aid Gaza power plant to convert the generator’s fuel from diesel to natural gas, this will lead to a huge reduction in the operation cost (around 30% according to the world bank reports) and thus reducing the electricity prices.
5. PENRA shall also encourage investment in large scale RES project including PV, Wind, Biogas, and CSP (Concentrated Solar Power).
6. PENRA shall support pilot energy storage projects and combine them with RES projects and search for the related donation from the international firms.

7. PETEL has to proceed in implementing the planned transmission line between the new constructed and future 161/33 KV substations, and obtain the required licenses from the Israeli side which will be the major bottle neck of this project. These transmission lines will play a vital role in applying smart grid applications between different areas in Palestine.
8. PETEL shall expand the existing SCADA system which monitor and control Jalamah substation in Jenin to include all other constructed substations, future substation, RES projects and future generation sites; to provide a centralized reliable control and monitoring of the transmission and generation systems.
9. The existing SCADA system provides data in 5 minutes interval, which is not suitable to detect many power quality issues, which usually happened in second or sub-seconds duration. PETEL should start use more time sensitive equipment such as Phasor Measurement Unit (PMU) which provides data in sub-second intervals.
10. PNERA and PERC shall adopt Time of use tariff for all customers' categories (Industrial, commercial, residential and agricultural) not for part of industrial customers only; since time off use tariff will aid to apply demand response applications. PERC shall assign the required studies to arrange this time of use tariffs and propose different types of demand response programs to encourage end user to participate in this approach.
11. PNERA shall release the required laws and regulations for the RES projects in all distribution companies, also the regulations shall be compatible with international standards.
12. Also, PNERA and PERC shall prepare the required regulations for Storage system projects in order enhance the use of storage system as an additional source of grid.

Storage system is one of the promising smart grid applications specially when combined with renewable energy sources projects or microgrids.

13. Since Palestine has around 104 Electric Vehicles at the beginning of 2020; PERC and PNERA shall cooperate in preparing the required regulations related to the EV, in order to manage the relation between EV and the grid and vice versa.
14. PERC shall assign the required regulations and monitoring to ensure that distribution and transmission companies are delivering power with the required quality and according to the international standards. Power quality issues are causing many drawbacks to the end users; 30 - 40 % of all business downtime is related to PQ Problems.
15. PERC shall obligate distribution and transmission companies to improve power system reliability and to provide the required monitoring to ensure that.
16. PNERA shall assign the required regulations to encourage distribution companies to convert conventional protection system to be smart through converting the protection equipment to smart or enabling the smart features; in order to enhance the power system performance and reliability.
17. PNERA must develop clear long-term and short-term plans for progressive implementation of smart grid applications in order to convert the existing electrical grid to smart grid. Short-term plan will be for applications that could be implemented directly (such as smart metering and RES integration), and long-term plan will be to involve more applications to obtain the smart grid applications advantages which are internationally proven.

Applicable Smart Grid Applications in PTEL:

1. Voltage and VAR Control; by controlling the transformer's OLTC through SCADA, and controllable Capacitor banks or DSTATCOM.
2. Demand Response
3. Automatic Metering Infrastructure / Smart Metering
4. Wide Area Monitoring Control and Protection; through SCADA system
5. Fault Detection Isolation and Restoration; through SCADA system
6. Integration of Renewable Energy Sources

7.2 Recommendations at Distribution Level

7.2.1 NEDCO:

1. Since the existing communication of the SCADA system is GSM/3G and Ethernet; NEDCO shall complete the fiber optics network to be as second path of its SCADA system communication network, to improve the system reliability and achieve communication network redundancy.
2. The distribution transformers are with automatic OLTC but remote control is not activated. NEDCO shall control the OLTC through SCADA system instead of local manual control.
3. As NEDCO didn't start using smart metering yet. NEDCO shall start adopting smart metering system to obtain the benefits of this type of metering technology. NEDCO can start with installing these smart meters for customers with large loads (for example costumers with loads greater than 100 Amps).
4. NEDCO shall support self-generation by encouraging customers and investors to implement more renewable energy projects to reduce the dependency on the IEC generation.

5. NEDCO shall upgrade the protection system to be smarter by converting the protection equipment to smart ones; this will lead to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
6. The existing SCADA system provides data in 5 minutes interval, which is not suitable to detect many power quality issues, which usually happened in second or sub-seconds duration. NEDCO should start use more time sensitive equipment such as Phasor Measurement Unit (PMU) which provides data in sub-second intervals.
7. NDECO should develop smart phone application to enable customers to follow up all data related to their accounts such as meter reading, bills paying, day ahead prices, faults reporting, and other services. This mobile application will play a vital rule when using demand response programs.

Applicable Smart Grid Applications in NEDCO:

1. Voltage and VAR Control; by controlling the transformer's OLTC through SCADA, and controllable Capacitor banks or DSTATCOM.
2. Demand Response
3. Automatic Metering Infrastructure / Smart Metering
4. Wide Area Monitoring Control and Protection; through SCADA system
5. Fault Detection Isolation and Restoration; through SCADA system
6. Integration of Renewable Energy Sources
7. Microgrids

7.2.2 TDECO:

1. TDECO shall improve the existing GPRS communication used in the SCADA system to more reliable systems such as Fiber optics and microwave or combination between them and converting the existing GPRS system to 3G and keep it as a backup communication.

2. TDECO shall upgrade the protection system to be smarter by converting the protection equipment to smart ones; this will lead to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
3. TDECO shall focus on smart metering since there is only around 100 smart meters for large customers. Approximately 2,000 Smart Meters out of 95,000 (2 percent) consumers will be installed in in Far'a refugee's camp, these meters will aid to reduce the amount of untechnical losses such as theft, and provide important data about customers and statues of the network.
4. Since TDECO has the highest RES penetration level among the distribution companies in Palestine; evaluation studies shall be conducted to evaluate the feasibility and impact of any new renewable energy projects.
5. TDECO shall arrange the feasibility study for Storage Projects, due to the high PV penetration level; storage system may be a good smart grid application for TDECO to store the excess energy during the peak production and using it during night or days with less PV generation.
6. TDECO should develop smart phone application to enable customers to follow up all data related to their accounts such as meter reading, bills paying, day ahead prices, faults reporting, and other services. This mobile application will play a vital rule when using demand response programs.

Applicable Smart Grid Applications in NEDCO:

1. Voltage and VAR Control; by controlling the transformer's OLTC through SCADA, and controllable Capacitor banks or DSTATCOM.
2. Demand Response
3. Automatic Metering Infrastructure / Smart Metering

4. Wide Area Monitoring Control and Protection; through SCADA system
5. Fault Detection Isolation and Restoration; through SCADA system
6. Integration of Renewable Energy Sources
7. Microgrids

7.2.3 JDECO:

1. Since JDECO has around 250 SCADA locations controlling and monitoring around 700 points of the MV network; JDECO can expand the SCADA system to include LV network; in order to achieve more advanced control and monitoring of the entire electrical network.
2. The distribution transformers are with automatic OLTC but remote control is not activated. JDECO shall control the OLTC through SCADA system instead of local manual control.
3. JDECO shall upgrade the protection system to be smarter by converting the protection equipment to smart ones; this will lead to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
4. 33 substation using Fiber technology for SCADA system communication, and there are 10 substations with GSM/GPRS communication; JDECO shall complete the transfer of the communication in these 10 substations to fiber.
5. JDECO PV projects are concentrated in Jericho, it is recommended to encourage these projects in other locations such as Jerusalem, Ramallah and Bethlehem.
6. JDECO is the leader distribution company with largest number of smart meters among distribution companies; JDECO shall continue in this approach in order to transfer all meters to smart.
7. JDECO shall arrange the feasibility study for Storage Projects, due to the high penetration level of PV projects in Jericho; storage system may be a good smart

grid application to store the excess energy during the peak production and using it during night or days with less PV generation. Pumped hydroelectric energy storage (PHES) and or Battery Storage systems could be feasible storage systems for Jericho case.

8. The existing SCADA system provides data in 5 minutes interval, which is not suitable to detect many power quality issues, which usually happened in second or sub-seconds duration. JDECO should start use more time sensitive equipment such as Phasor Measurement Unit (PMU) which provides data in sub-second intervals.

Applicable Smart Grid Applications in JEDCO:

1. Voltage and VAR Control; by controlling the transformer's OLTC through SCADA, and controllable Capacitor banks or DSTATCOM.
2. Demand Response
3. Automatic Metering Infrastructure / Smart Metering
4. Wide Area Monitoring Control and Protection; through SCADA system
5. Fault Detection Isolation and Restoration; through SCADA system
6. Integration of Renewable Energy Sources
7. Microgrids

7.2.4 HEPCO:

1. The distribution transformers are with automatic OLTC but remote control is not activated. HEPCO shall control the OLTC through SCADA system instead of local manual control.
2. HEPCO shall focus on smart metering since there is only around 700 smart meters (for customers with large loads). These meters will aid to reduce the amount of untechnical losses such as theft, and provide important data about customers and statues of the network.

3. HEPCO shall support self-generation by encouraging customers and investors to implement more renewable energy projects to reduce the dependency on the IEC generation.
4. HEPCO shall upgrade the protection system to be smarter by converting the protection equipment to smart ones; this will lead to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
5. The existing SCADA system provides data in 5 minutes interval, which is not suitable to detect many power quality issues, which usually happened in second or sub-seconds duration. HEPCO should start use more time sensitive equipment such as Phasor Measurement Unit (PMU) which provides data in sub-second intervals.

Applicable Smart Grid Applications in HEPCO:

1. Voltage and VAR control; by controlling the transformer's OLTC through SCADA, and controllable Capacitor banks or DSTATCOM.
2. Demand Response
3. Automatic Metering Infrastructure / Smart Metering
4. Wide Area Monitoring Control and Protection; through SCADA system
5. Fault Detection Isolation and Restoration; through SCADA system
6. Integration of Renewable Energy Sources
7. Microgrids

7.2.5 SELCO:

1. SELCO is the only distribution company in Palestine without SCADA system, SELCO shall start with the SCADA system urgently; in order to improve the network and the performance.
2. Since SELCO has the lowest RES penetration level among distribution companies; SELCO shall support self-generation by encouraging customers and investors to

implement more renewable energy projects to reduce the dependency on the IEC generation.

3. SELCO shall focus on smart metering since there is only around 150 smart meters. These meters will aid to reduce the amount of untechnical losses such as theft, and provide important data about customers and statues of the network.
4. SELCO shall upgrade the protection system to be smarter by converting the protection equipment to smart ones; this will lead to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
5. SELCO should develop smart phone application to enable customers to follow up all data related to their accounts such as meter reading, bills paying, day ahead prices, faults reporting, and other services. This mobile application will play a vital rule when using demand response programs.

Applicable Smart Grid Applications in SELCO:

1. Demand Response
2. Automatic Metering Infrastructure / Smart Metering
3. Integration of Renewable Energy Sources
4. Microgrids

The following table 7.1 summarizes the applicable smart grid applications in each electrical distribution and transmission company with the rank of the capability; (+) low capability, (++) moderate capability, (+++) high capability, (++++) full capability, and (N/A) not applicable.

TABLE 7.1, Smart Grid applications applicable in transmission and distribution companies

	Transmission Company	Distribution Companies					
Application	**PTEL**	**NEDCO**	**TDECO**	**JDECO**	**HEPCO**	**SELCO**	**GEDCO**
VVC	+	+	+	+	+	N/A	+
DR/DSM	+	+	+	+	+	N/A	+
AMI/AMR	+		+	+++	+	+	+
WAMCP	++	+	+	++	++	N/A	+
FDIR	++	+	+	++	++	N/A	+
RES Integration	+	+	++	++	+	+	++
V2G / G2V	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Storage	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Microgrids	N/A	+	+	+	+	+	++

CHAPTER 8: CONCLUSIONS AND FUTRE WORKS

8.1 Conclusions

As result of this research study the following conclusions are related to the actual situation of the smart grid applications in the Palestinian electricity sector:

- Palestine has a great potential for smart grid applications specially demand response DR, voltage and VAR control, integration of distributed energy resources, fault detection isolation and restoration, wide area monitoring control and protection WAMCP, automatic metering infrastructure, and Microgrids.
- JDECO, HEPCO, and NEDCO are moving faster to smart grid as they have existing SCADA systems. While, TDECO shall enhance the performance of its SCADA system, and SELCO shall start implementing their SCADA system shortly and assign the required budgets for this project.
- Other smart grid applications such as storage system and integration of electric vehicle with grid will take more time to be appropriate to the Palestinian situation. This is because the lower number of electric vehicles in Palestine and high implementation cost of storage systems.
- For smart grid communications, a hybrid communication technology mixed with wired and wireless solutions can be used with acceptable installation costs to provide improved availability, reliability, and robustness of the communication system at the same time.
- PNERA should take several important legislations and put satisfactory encouraging regulations for the investors to move forward to smart grid projects.
- PNERA and PERC shall adopt different demand response programs including: time of use tariff (for all type of customers: residential, commercial and industrial),

critical peak pricing, and other programs for non-dispatchable loads. For dispatchable loads, direct load control and interruptible loads programs may be employed.

- Also, PNERA shall encourage interconnection with neighboring countries (Jordan and Egypt) and enlarge the existing connection capacities to reduce dependency on the IEC grid.
- Electrical distribution companies shall upgrade their protection system to be smarter by converting the protection equipment to be smart; in order to improve power system reliability and enhance the capability to use advanced smart grid applications such as WAMCP and FDIR.
- Palestinian transmission and distribution companies shall focus on increasing their generation capabilities specially from renewable energy projects. Concentrated Solar Power may be proposed for large scale renewable energy production, in addition to the available PV systems.

8.2 Future Works

Since experiments with actual data are typically time consuming, many different experiments, scenarios, tests, and adaptations have been left for the future; due to the lack of time. Future works may include the following arrangements:

- Studying the financial impact and the feasibility of converting the conventional grid to smart grid in the different distribution companies. Also, arrange the required feasibility studies for implementing each application of smart grid technologies.

- Conducting more investigation about the electrical system in Gaza Strip including the problems in generation, transmission, and distribution levels. And propose the suitable solutions to cover these difficulties.
- Studying a proposal of microgrids in Gaza strip; by combining different renewable energy projects such as PV and offshore Wind farms with electrical storage system; in order to solve the power outage issues and reduce the dependency on external power sources.
- Arranging the required researches about the suitable energy storage system for the electrical distribution companies including Battery Storage, PHES, and other storage technologies. Also, studying their feasibility, optimum placement and sizing.
- Proposing a study for a large scale Concentrated Solar Power plant in the south of Hebron since there is the suitable land, including the needed grid assessment and the financial and technical studies.

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