**An-Najah National University**

**Faculty of Graduate Studies**

# Grid and Environmental Impact Assessment of 0.5 MWp Photovoltaic Power System Connected to Salfit Governorate Electricity Distribution Network

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**This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Clean Energy and Conservation, Faculty of Graduate Studies, An-Najah National University, Nablus – Palestine.**

**2021**

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# Dedication

To my father and mother

To my brother and sister

To my wife Sondos

To my grandfather and grand mother

# Acknowledgment

I would like to thank my thesis supervisors; Dr Tamer Khatib and Prof. Dr. Amer EL-Hamouz, many thanks are also given to Clean Energy and Conservation Master program members at An-Najah National University, many thanks and appreciations also go to all the people who helped me conduct this study.

# الاقرار

أنا الموقع أدناه، مقدّم الرسالة التي تحمل العنوان:

**Grid and Environmental Impact Assessment of 0.5 MWp Photovoltaic Power System Connected to Salfit Governorate Electricity Distribution Network**

أقر بأن ما اشتملت عليه هذه الأطروحة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الاشارة إليه حيثما ورد. وأن هذه الرسالة كاملة، أو اي جزء منها لم يقدم من قبل لنيل اي درجة او لقب علمي او بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

# Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

| | |
|---|---|
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| **Date:** | **التاريخ:** ١٩ / 12 / 2021 |

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# List of Acronyms and Abbreviation

| | |
|---|---|
| **PVDG** | Photovoltaic-based distributed generations |
| **PV** | Photovoltaic |
| **THDv** | voltage total harmonic distortion |
| **DG** | distributed generations |
| **EIA** | Environment impact assessment |
| **DFIG** | Doubly Fed Induction Generator |
| **CHP** | Combined Heat and Power |
| **CSP** | Concentrated solar power |
| **GCPVS** | Grid connected PV systems |
| **UFP** | Under frequency protection |
| **OFP** | Over frequency protection |
| **UVP** | Under voltage protection |
| **OVP** | Over voltage protection |
| **US** | United states |
| **OECD** | Organization for Economic Cooperation and Development |
| **EU** | European Union |
| **UNEP** | United Nations Environmental Program |
| **EQA** | Environmental Quality Authority |
| **PEL** | Palestine environment law |
| **OP** | Operation policies |
| **EA** | Environment assessment |
| ***FI*** | Financial Intermediaries |
| **ESS** | Environment and social standard |
| **PENRA** | Palestinian Energy and Natural Recourses |
| **GHI** | Global Horizontal Irradiation |
| **DNI** | Direct Normal Irradiation |
| **IEC** | Israel electricity company |
| **PERC** | the Palestinian Electricity Regularity Council |
| **MPP** | maximum power point |
| **kWh** | Kilo watt hour |
| **IEAR** | Initial environment assessment report |
| **TOR** | terms of references |
| **ESIAR** | Environment and Social impact assessment report |

| | |
|---|---|
| **GIS** | Geographic information system |
| **ESMP** | Environment social management plan |
| **WB** | World bank |
| **NPV** | Net present value |
| **IRR** | Investment rate of return |
| **PBP** | Pay bake period |
| **PF** | Power factor |

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## Abstract

The increasing demand for electrical energy associated with finding new distribution generation elaborate the choice to go toward renewable energy. With its low maintenance and operation, it is becoming more of a trend around the world. A type of renewable energy source and the photovoltaic systems installation connected to the grid are on the increase since the past decade. This increase is elaborated with changes in voltage profiles, power factor, short circuit currents, and loading in the buses and transmission lines affecting the power quality delivered to the customers. These technical changes must be considered in line with the environmental impact associated with the project area to the flora, funa, noise, waste, water, etc. Such factors must be studied to understand the impact of these projects on each element. This thesis studies the ability to establish 0.5 MW of PV connected to Salfit municipality to decide the maximum penetration level allowed to be installed. It also studies the environment and social impacts under the umbrella of the World Bank environmental and social standard-ESS compared to the original. The first case is that of full generation and full load; the second one is a full generation and half load; the third one is a half-generation and full load; and, the last one is a half-generation and half load. Half of the study considers the electrical part while the World Bank's

ESS standards are considered in studying the environmental impacts. This thesis shows changes in the voltage profiles up to 7 Volts certain line in medium voltage level and a drop in the power factor from 0.87 to 0.82 in best scenarios; with an increase in the losses associated with an increase in short circuit levels by using ETAP software for load flow analysis. Additionally, this thesis studies the feasibility of the system installed using RET screen software by establishing a net present value study and simple payback period. This, accordingly, shows that the project is financially feasible with a three-year payback period and positive net present value with a rate of return of 32.8 % and energy production cost of 44.13 $/MWh. This thesis depicts a temporally negative environmental impacts on the project area regarding the environmental elements, such as the polluted area from the dust, the noise increases during the work, implementation, transportation issues, water problems, and waste materials problems. It also establishes an environmental impact mitigation plan and monitoring plan to control and minimize the consequences associated with the system during the pre-construction stage, construction stage, and operation and maintenance stage, on the other hand the project shows a positive impact related to the employment, $CO_2$ emission reduction by 2559.2 ton per year.

# Chapter One
# Introduction

## 1.1 Background

The growing power demand has increased electrical energy production almost to its capacity limit. However, power utilities must maintain reserve margins of existing power generation at an enough level. Currently, transmission systems are reaching their maximum capacity because of the huge amount of power to be transferred. Therefore, power utilities must invest a lot of money to expand their facilities to meet the growing power demand and to provide uninterrupted power supply to industrial and commercial customers.

The introduction of photovoltaic-based distributed generations (PVDG) in the distribution system may lead to several benefits such as voltage support, improved power quality, loss reduction, deferment of new or upgraded transmission and distribution infrastructure, and improved utility system reliability. PVDG is a grid-connected generation power unit located near consumers regardless of its power capacity or type of unit. It is an alternative way to support power demand and overcome congested transmission lines. The integration of PVDG into a distribution system will have either positive or negative impacts depending on the distribution system operating features and the PVDG characteristics. PVDG can be valuable if it meets at least the basic requirements of the system operating perspective and feeder design.

Figure (1.1) below shows a schematic diagram of a grid-connected PV system which typically consists of a PV array, a DC link capacitor, an inverter with filter, a step-up transformer, and a power grid. The DC power generated from the PV array charges the DC link capacitor. The inverter converts the DC power into AC power, which has a sinusoidal voltage and frequency like the utility grid. The diode blocks the reverse current flow through the PV array. The transformer steps up the inverter voltage to the nominal value of the grid voltage and provides electrical isolation between the PV system and the grid. The harmonic filter eliminates the harmonic components other than the fundamental electrical frequency.

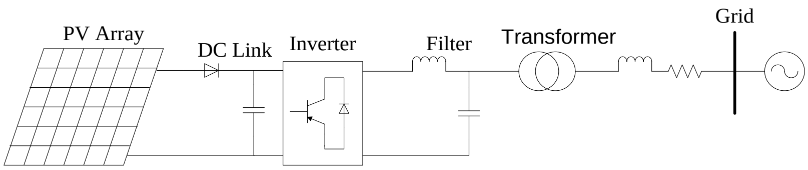



**Figure (1.1): Schematic diagram of the grid connected PV system**.

It is commonly known that PVDG needs to be installed at the distribution system level of the electric grid and located close to the load center. Studies are usually conducted to evaluate the impact of PVDG on power flow, power quality, and short-circuit analyses are very essential to assess the impact of PVDG on the grid before its installation (Khatib et. al., 2021). To reduce power losses, improve system voltage and minimize voltage total harmonic distortion (THDv), appropriate planning of power system with the presence of DG is required. Several considerations need to be considered, such as the number and the capacity of the PVDG units, the optimal PVDG location, and the type of network connection. The installation of PVDG units at non-optimal locations and with non-optimal sizes may cause higher power loss, voltage fluctuation problems, system instability, and amplification of operational cost. In terms of the environmental impact of the project, an Environmental impact assessment (EIA) will be developed. It is a tool to minimize the negative impact of human activities on the environment. The purpose of the environmental impact assessment is to first assess the impact of a proposed activity on the environment before deciding on whether to go in more details in assuming its impacts. EIA can be defined as a process of collecting information about the environmental impacts of a proposed project and consequent relevant decision-making. EIAs also consider aspects and mitigation measures which should be applied if the project can minimize or avoid its Impacts. The process of EIA comprises several different stages such as screening, scoping, reviewing, and completion. These stages of EIA may be labeled differently in different parts of the world, but their goals are similar. In the EIA process, a range of organizations may be involved, including government agencies, developers, nongovernmental, and public organizations. The level of involvement may vary significantly depending on the type of project that is assessed. The World Bank strategy for implementation EIA will be taken since it’s stricter than the Palestinian standards. Despite the variation of the EIA process in the world with respect to the funding agencies and decision makers, it’s ended with an impact assessment report, which will inform the stake holders and the decision makers whether to approve or reject the project. Figure (1.2) underneath shows a flow chart that illustrates the process of the EIA process.

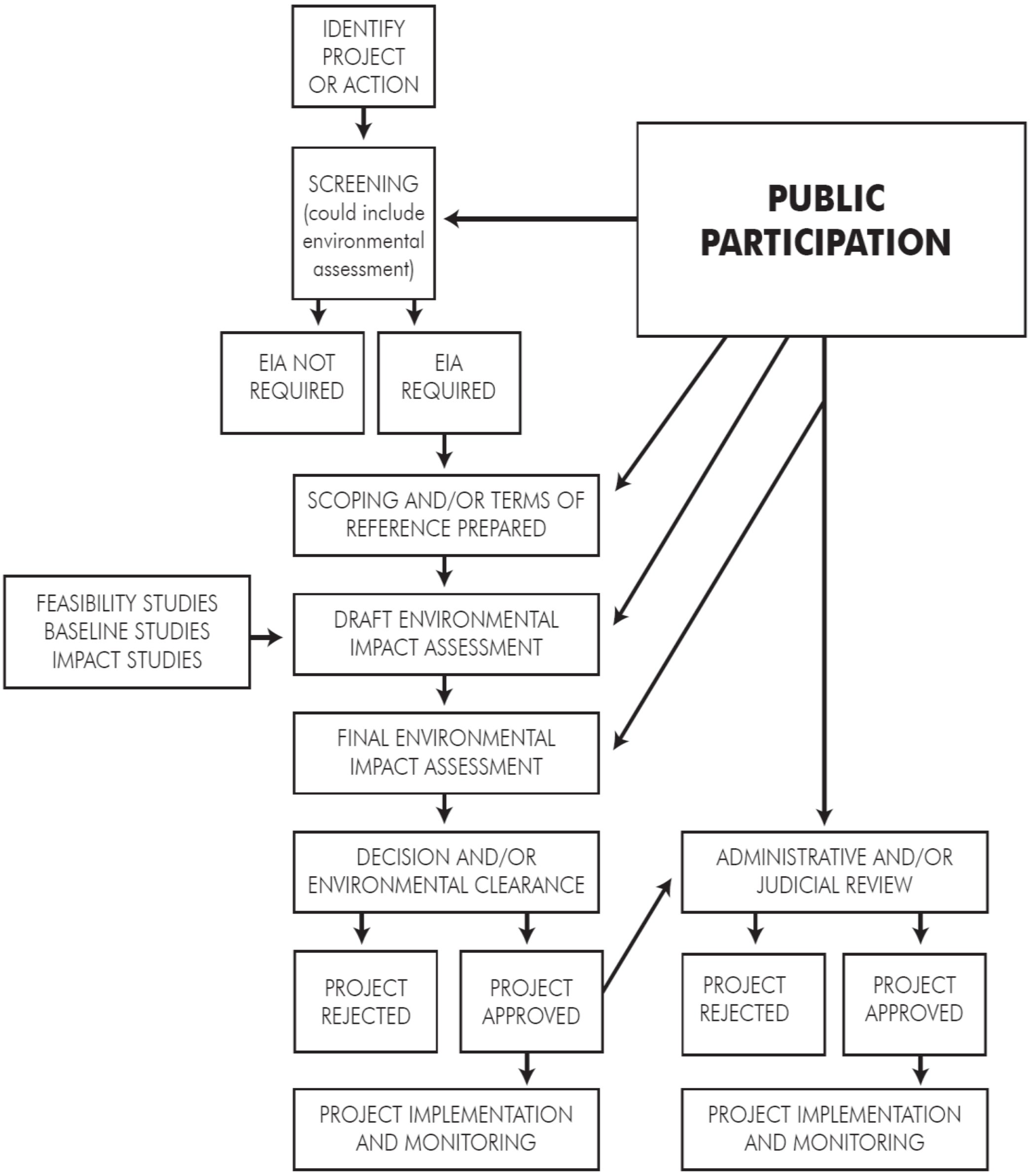



**Figure (1.2): Flow chart of the EIA process**.

## 1.2 Problem Statement

### 1. Technical impact of the proposed system.

The integration of PVDG in power systems can alleviate overloading in transmission lines, provide peak shaving, and support the general grid requirement. However, improper coordination, location, and installation of PVDG may affect the power quality of power systems. Most conventional power systems are designed and operated such that generating stations are far from the load centers and use the transmission and distribution system as pathways. The normal operation of a typical power system does not include generation in the distribution network or the customer side of the system. However, the integration of PVDG in distribution systems changes the normal operation of power systems and poses several problems which include possible bi-directional power flow, voltage variation, breaker non-coordination, alteration in the short circuit levels, and islanding operation. Therefore, studies are required to address the technical challenges caused by DG integration in distribution systems. The interconnection device between the DG and the grid must be planned and coordinated before connecting any DG.

### 2. Environment impact of the proposed system

It is important for decision-makers, funding agencies, and any stakeholder of any project to be fully aware of the environmental impact of the project. Firstly, it makes it easier to decide on this project. Thus, the second statement of the problem is described as the importance of assessing the environmental and social impact of the system considering its impact on many aspects; such as land, air quality, water, and pollution impact on plants and animals. Thus, there is a need to conduct an environmental impact study considering all the procedures illustrated in Figure (1.2) above. This must be followed by consulting the stakeholders as well as the public in Salfit governorate to draft an environmental management plan which will be the environmental and social reference for the contractor when implementing the project.

## 1.3 Research Objectives

In this thesis, five main objectives are aimed to be fulfilled as below:

1. To study the impact of a 0.5 MWp photovoltaic system on Salfit grid voltage profile and power flow.

2. To estimate the optimum penetration level of renewable energy and location to support Salfit distribution network.

3. To conduct an environmental impact assessment of the system.

4. To draft an environmental and social management plan for the project according to the World Bank procedure.

5. To conduct feasibility of the proposed system.

## 1.4 Research Methodology

### W.P 1 Data Collection

T1.1 The load on the network and the network instruments

T1.2 Define and locate the project area and start the screening process

### WP.2 Literature Review

T2.1 Literature review on grid-connected PV systems and electricity distribution network

T2.2 Literature review on power flow analysis and electricity distribution network loading and stability

T2 .3 Literature review on the environmental impact assessment procedure. Of the World Bank and current environmental policies and regulations in Palestine.

T2 .4 Data collection of solar radiation data for Palestine must be provided.

### WP.3 Modeling of Salfit Electricity Distribution Network

T3.1 Construct a one-line diagram for the electrical network.

T3 .2 Modeling the electricity network using Etab software

T3 .3 Construct power flow analysis of the network

**WP.4 Design of the Proposed Photovoltaic System and the Impact of a Proposed Photovoltaic System on the Electricity Distribution Grid**

T4.1 Studying the impact level after connecting the proposed system using: (a) 100% loading and 100% generation, (b)50% loading and 100% generation, (c) 50% loading and 50% generation, (d) 100% loading and 50 % generation

T4 .2 Studying the Distribution grid power flow analysis, grid power factor, and Distribution grid transformers loading levels

T4 .3 Estimating the maximum penetration level of renewable energy generation into the grid

**WP. 5 Environmental impact assessment of the proposed PV system.**

T5.1 Identifying and defining the project or activity

T5 .2 Screening and scoping and terms of references drafting of the project

**WP. 6 Preparation of final environment and social study**

T 6.1 Public consultation and Administrative or Judicial Review

T 6.2 Final EIA report and environmental and social management plan preparation

T6 .3 Gap analysis between Palestinian Laws and World Bank Safeguard statements.

**WP. 7 Conduct a prefeasibility of the proposed system**

T7.1 Estimating system costs including grid requirements as well as Estimating environmental management plan costs

T7 .2 Estimating the saving, including power losses and penalties

**WP 8. Results analysis**

T8 .1 Results analysis and conclusion

### 1.5 Significance of the Work

The grid impact studies of the PV systems connected to the grid are essential to understand the variation and the changes that occur in the network for future planning and expansion. This happens with the association of understanding the potential effect of the renewable energy systems on voltage levels, power losses, power quality, power factor, penalties, and the obstacles for delivering reliable power for the end-user. Not to mention that the environmental studies are essential to understand the effects and the changes that occurred on the proposed area for these projects. This takes place by defining the positive and negative impacts on the environment then identifying the mitigation measures to minimize the negative impacts to the lowest level as much as possible.

## 1.6 Thesis Organization

The thesis consists of nine chapters, as follows:

**Chapter 1: Introduction**

Includes an introduction, background, problem statement objectives, methodology, and significance of work.

**Chapter 2: Literature Review**

Review of papers of literature using open literature materials, including scientific journals, papers and articles, published reports related to grid connected PV systems, power flow analysis, review of papers related to the environment impact assessment, the procedures of the world bank, the environmental regulation on Palestine, as well as sampling the data of the solar radiation on Slafit and the instrument of the electrical network.

**Chapter 3: Modeling of Salfit Electricity Distribution Network**

Conduct Salfit electricity distribution network by constructing the one-line diagram and running the load flow by ETAP software and modeling all the electrical components and define the consumption Salfit city.

**Chapter 4: Impact of PV Distributed Generation on Grid**

Design the proposed system by starting with the first phase of installing a 0.5 MWp PV system and study the impact level after connecting the proposed system using: (a) 100% loading and 100% generation, (b) 50% loading and 100% generation, (c) 50% loading and 50% generation, (d)

100% loading and 50 % generation study the impact with different scenarios of loading and generation, and study the power flow for the grid, then deciding the maximum penetration level.

**Chapter 5: Environmental Impact Assessment of the Proposed PV System**

This chapter introduce the process of the environmental impact assessment starting with defining the project and project area, then starts with the screening process. It then defines the terms of reference based on defining the positive and negative impact of the project through the project implementation phases.

**Chapter 6: Environmental and Social study**

Prepare an EIA study according to the World Bank requirements and environmental and social framework and conduct an environmental management plan and monitoring plane considering the World Bank frame work and define the legislation frame work and the grievance mechanism.

**Chapter 7: Prefeasibility of the Proposed System**

Prepare a feasibility study to estimate the implementation cost for all the electrical component and estimate the environmental procedure cost, then define the methods used to find if the project is feasible or not.

## Chapter 8. Result and Analysis

This chapter provides an analysis of the results obtained from conducting the electrical network under the four case and defines the impact on the power factor, voltage levels, power losses, short circuit currents and bus loading, then define the feasibility of the system.

## Chapter 9: Conclusion and Future Work

This chapter represents the conclusion achieved by applying the four scenarios and introduces the future work recommendation for conducting PV station to grid.

# Chapter Two
# Literature Review

## 2.1 Introduction

The increasing demand for energy and electricity made the utilities reach almost their full capacity. However, the power utilities must have a reserve for future expansion. Therefore, power utilities must invest a lot of money to expand their facilities to meet the growing power demand, and to provide uninterrupted power supply to industrial and commercial customers (Peterson et. al., 1972). Power plants are typically located far from load centers, power losses and voltage drops are high. In this respect, installing distribution generation (DG) near load centers can contribute to solving these issues (Razavi et. al., 2019: 160).

Different types of renewable and nonrenewable DG are available including wind turbines, thermal solar, solar photovoltaic (PV), hydro power, Desil generators, fuel cells, geothermal and micro turbines (Daly & Morrison, 2001). With many concerns related to climate change, and due to the increase in load demand and power losses, this encouraged the installation of the DG on the electrical networks. However, this increase in the installation has a significant impact on the electrical networks. DG is categorized according to the active and reactive power delivered to the distribution system into the following groups (Hung & Mithulananthan, 2010: 818):

1. DG with active power injection: only this type of DG is connected to the distribution system using an appropriate power electronic interface. This includes small-scale DG units which operate at a unity power factor, such as PV, fuel cells, micro turbines, and batteries.

2. DG with reactive power injection: only DG units of this type operate at a unity power factor, supplying the required reactive power of distribution systems. Synchronous compensators fall under this category.

3. DG with active power injection and reactive power absorption: this type of DG used in wind turbines. Different types of those induction generators with improved performance exist, such as fixed-speed, variable-speed, and Doubly Fed Induction Generator (DFIG). They inject active power into the grid while absorbing reactive power.

4. DG with active and reactive power injection: this type of DG is based on synchronous machines such as gas turbines and Combined Heat and Power (CHP) units, capable of injecting both active and reactive power into the grid.

As one of the DG types; the solar photovoltaic (PV) became the most applicable choice for most of the countries around the world, regarding the amount of energy from the solar radiation the PV industry shows a decrease in the production prices for the PV systems. Growing of PV for electricity generation is one of the highest in the field for renewable energies and this tendency is expected to continue in the coming years (IEA-PVPS T1-18:2009).

## 2.2 Grid-Connected PV Systems

Solar power generation is divided into two types: photovoltaic power (PV) and concentrated solar power (CSP). The difference between the two types is that the CSP uses the heat of the sun to generate power while PV uses solar radiation. Additionally, the CSP with some certain technologies can store the heat while the PV systems can't do that on large scales. The PV system converts the solar radiation into DC then converts it to the AC connected to the grid. Grid-connected PV systems (GCPVS) are a type of DG connected to the electrical network working simultaneously with the utility distribution system with a certain percentage of penetration. The GCPVS is preferred over the conventional DG systems because of its low price, low operation cost, low maintenance cost, and it is considered environmentally clean. Parida et. al. (2011: 1627) reviewed solar photovoltaic technologies and concluded that the increased efficiency, lowering cost, and minimal pollution associated with it has led to its application in several energy projects, such as building-integrated systems, pumps, solar home systems, desalination plant, Photovoltaic, and thermal (PVT) collector technology. The energy created by the solar arrays powers the load directly with any excess being sent to the utility, resulting in net metering (WEC, 2020). Figure (2.1) below shows typical components of domestic grid-connected photovoltaic (PV) system, starting from the modules collecting the solar radiation, DC wiring, inverter, AC wiring, and then the utility connection, while Figure (2.2) illustrates typical PV plant connected to the grid.

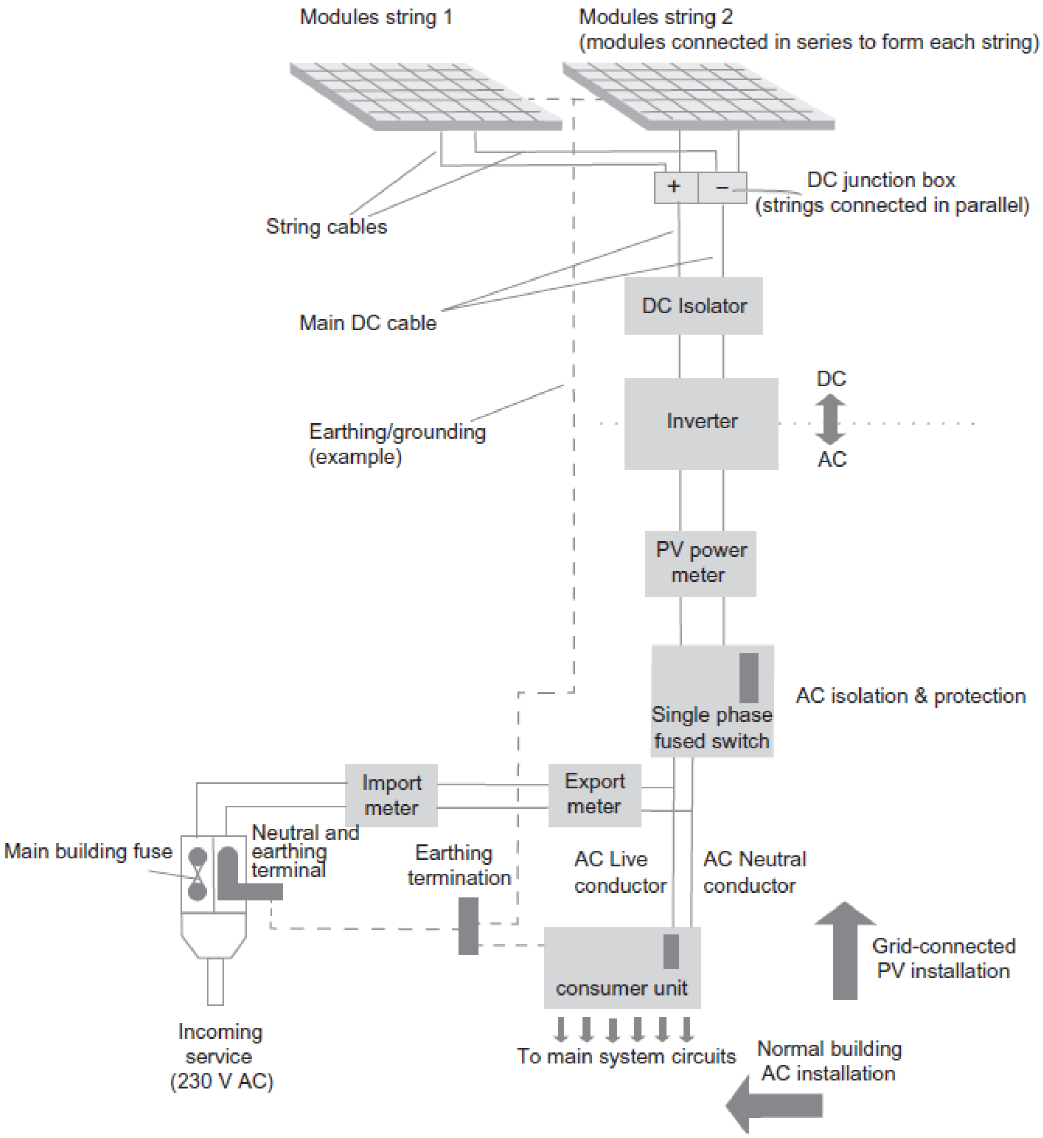



**Figure (2.1): Typical components of domestic grid-connected photovoltaic (PV) system (Jenkins, et. Al., 2018)**

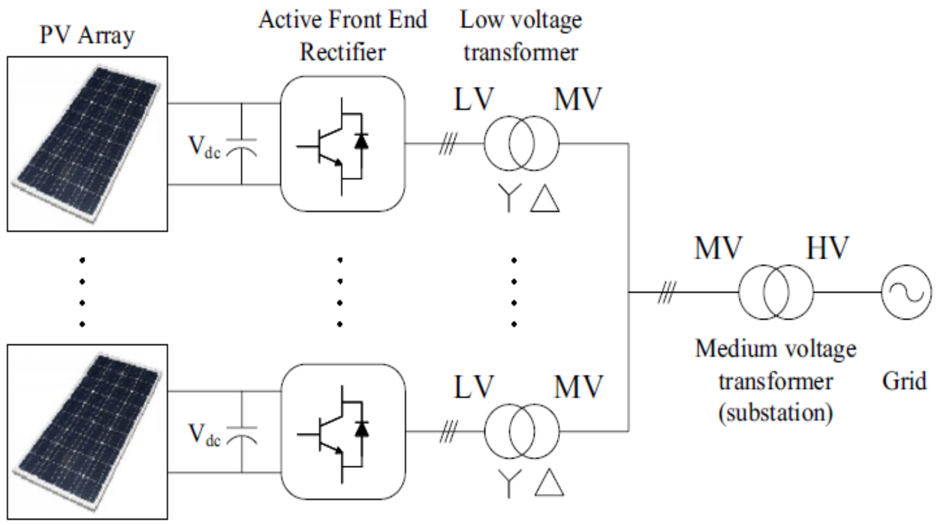



**Figure (2.2): Typical PV plant connected to the grid (Hunter et. al., 2019: 244)**

Despite all parts of the GCPVS, the inverter is the most essential one since it is required to supply constant voltage and frequency, despite the load variation conditions and the need to supply or absorb reactive power in case of reactive load (Prakash et. al., 2016). The inverters are connected to the grid supplying electricity. Due to this interaction, the inverters are required to have protection technology like islanding protection. Islanding protection means that the inverter must be turned off when the electricity from the grid is interrupted. According to IEEE 1547 in section 4, PV system power must be de-energized from the grid within two seconds of the formation of the island; this means PV plants interconnection system shall detect the island and cease to energize the grid within two seconds of the formation of the island. Not to mention that the inverter must not connect within 60 seconds of the grid reestablishing power supply after power failure (Hoke et. al., 2016). Additionally, the inverters should have over-frequency protection and under frequency protection (UFP/OFP). The inverters are required to have under-voltage protection and over-voltage protection (UVP/OVP). This means that the inverters must stop working and supplying power to the utility grid if the frequency or the amplitude of the voltage is beyond the prescribed limits.

### 2.2.1 Penetration Level and the Possible Impacts

Generally, most common conventional power systems and DG are designed and operated such that the generation stations are far away from load centers, and they use the transmission and the distribution as pathways (Abdul Kadir et. al., 2014: 7). Due to the trend of using renewable energy as a backup generation source and the concentration on using PV systems, studies aim to find the potential impact whether it is electrical or environmental. Since the solar radiation is variable making the output power unpredictable, improper design and installation of the GCPVS may cause negative impacts on the grid. In any power system, the power that is generated from the station is transmitted through transmission lines to the loads (Khatib et. al., 2021), but with the improper coordination and installation of the GCPVS, the power may flow in both directions. For distribution areas, even a small amount of PV systems may impact the system parameters if the load and the generation are not closely matched (Hoke et. al., 2016). (Willis, 2004) and (NREL, 2011) states that if the renewable sources capacity penetration is 30 %, it is considered high and requires a smart grid integration to ensure reliable grid operation. The following points represent some of the common impacts associated with the PV system installation:

1. Reverse power flow: the excess energy generated from the high penetration of DG on the grid is called reverse power. The reverse power will flow through the transmission lines and the substations. Furthermore, reverse power flow at the substation transformer level may affect voltages and loading limits for some transformers (Cipcigan & Taylor, 2007: 160).

2. Voltage regulation: the penetration level of the PVDGS on the grid will affect the voltage profiles on the network especially the areas near the PV systems causing the voltage levels to rise, making the utility plans for expansion limited. On the other hand, complaints from customers will occur. Not to mention the loads which are far away from the plants will suffer from voltage variability.

3. Unbalanced voltage and current: if the penetration of the PV systems in one phase is higher than the others, this will make the voltage, or the current deference higher causing reverse power flow or overloaded for the transmission lines.

4. Feeder loading and Power losses: the appropriate installation and sizing for the PVDGS on the grid will reduce the line currents on the transmission lines. Additionally, the power losses will decrease. On the other hand, if the penetration level increases, the amount of the currents flowing in the line will also increase, causing overloading for the lines. Then, the power losses will increase, and a reverse power will occur as

well. This thing will happen on the transmission line several times during the day.

## 2.3 Electricity Distribution Network

Appropriate installation and designing of the electrical network are the main reasons for a good service to the end-user. Power provision to individual customer's premises can be enhanced through an efficient and proper electrical power and distribution system. A typical distribution network consists of a substation of substations, primary feeders, transformers, distributers, and service main (Taher & Afsari, 2012). With the increasing demand and renewable energy trending in the world, appropriate design and technologies for the electrical networks are required. The most commonly used network architectures are radial network, ring network, and mesh network. The definition, advantages, and disadvantages are discussed below.

1. Radial network: the most commonly used type of electrical network in distribution systems, the architecture of the network can be represented with a tree with no closed loop in it. The topology of the network is made from the main connection bus then transmission lines to the other buss. Figure (2.3) below illustrates the architecture of the radial network. This type of electrical network is characterized by its simplicity of installation and expansion and it's also easy to determine the system requirements for protection and cable sizing. This type of electrical network is preferred when the station is located at the center

of the loads as it brings simplicity to analyze and operate the system. However, with this type of electrical network, interruption or faults happens that risk the system shutdown. Not to mention the system flexibility for more load addition is low since it may require a replacement for all the electrical components.

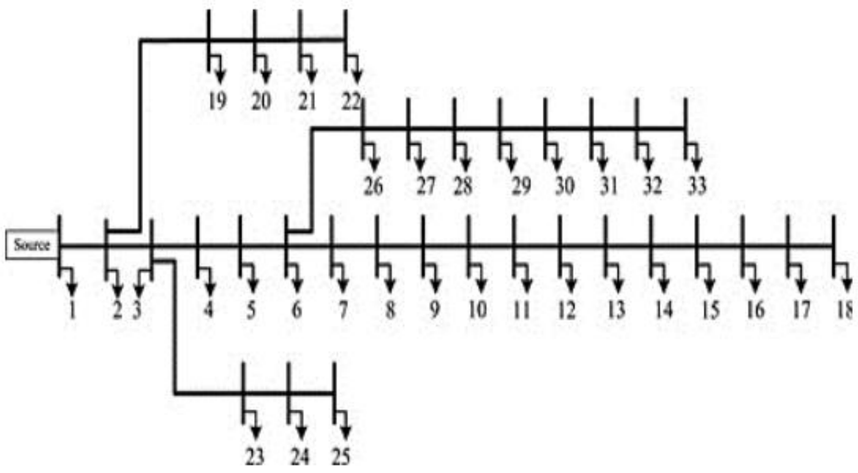



**Figure (2.3): IEEE 69 bus system**

2. A ring network: the architecture of the network can be represented with a closed-loop starting from one source feeding the loads from different routes. In other words, all the nodes in the ring network are connected in such a way that they make a close loop structure making runs through or around an area, serving one or more distribution transformers or load center, and returns to the same substation (Reprint Edn et. al., 2006). In this type of network, the power can be transferred in more than one way making the system more reliable with a good performance. Thus, any interruption that occurs does not affect the system. On the other hand, it is more complex to detect the location of the fault. Additionally, the lines connected to the load should be able to cover all the demand in any

case. In terms of complexity, a loop feeder system is only slightly more complicated than a radial system and has a major drawback of catering to the capacity and cost of the loop system (WEC, 2020). The below Figure (2.4) illustrates the architecture of the ring network.

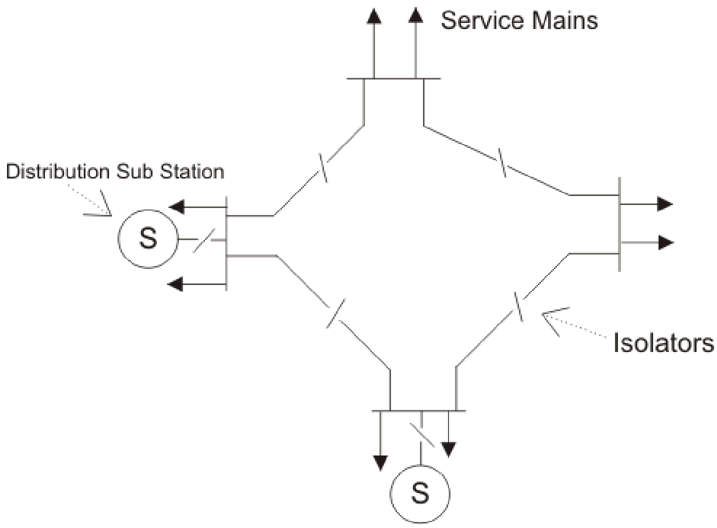



**Figure (2.4): Ring distribution network (Parida et. al., 2011: 1627)**

3. Mesh network: A mesh network structure follows the radial structure but includes redundant lines in addition to the main lines. These are organized as backups to reroute power in the event of failures to the main line (Electrical Grid, 2020). Figure (2.5) shows the structure of the mesh network. The mesh network is more complicated and more complex from the radial and the ring network due to the connectivity options with the load, making the control configuration more difficult. It is still more reliable than the other networks. The advantages of the meshed network are the relatively balanced voltage profile and high reliability through redundancy (Ahmad & Dakyo, 2013). Table (2.1)

below shows a comparison between the three types of networks (Prakash et. al., 2016).

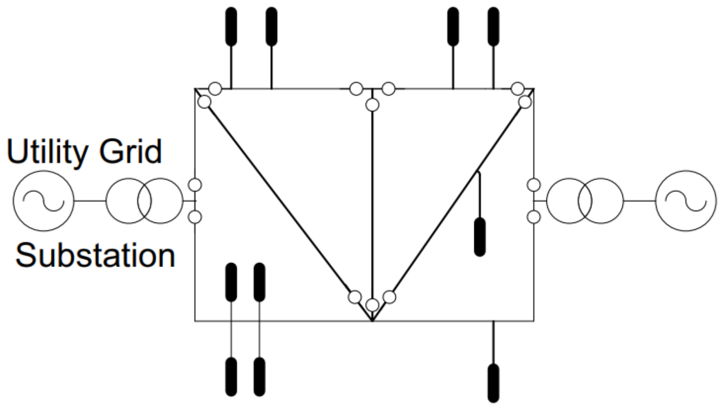



**Figure (2.5): Mesh network architecture (Parida et. al., 2011: 1627)**

**Table (2.1): Comparison between the three types of the networks**

| Network | Source | Stability | reliability | Capital cost | maintenance | Voltage level | protection | Penetration |
|---|---|---|---|---|---|---|---|---|
| Radial | Single | Low | Low | Low | High | Low | Medium | Problematic |
| Ring | Multiple | High | Medium | High | Low | Low | High | Accepted |
| Mesh | Multiple | High | High | Low | High | Medium | Higher | Moderate |

## 2.4 Power Flow Analysis

The continuous increase in the demand associated with different types of loads and penetration levels of the DG on the utility grids requires an expansion of the power system. This expansion requires a comprehensive study of the power system. Overall, the result courses from this expansion. For the past years, a lot of methods were written and implemented to solve the power system problems associated with voltage profile variability under transient and steady-state stability occurring from the load expansion with different types and requirements, since the loads themselves are categorized under residential, commercial, and industrial.

Load flow is the procedure used for obtaining the steady-state voltage for an electric power system at fundamental frequency (Herraiz et. al. ,2003). The voltage stability for a power system is to have a constant voltage for all the busses on the network. The load flow study for the power system gives us the voltage levels on each bus, real and reactive power, phase angle, power factor, transmission lines loading, transformer loading, and the results which occur from the expected future expansion.

Various types of methods were obtained to solve a nonlinear equation like the Gauss Seidel method, Newton Raphson, and Fast Decoupled but still, all these methods suffer from drawbacks. Peterson et. al. (1972) presented a fast-approximated method for solving the AC power flow problem for line and generator outages, which is applicable for system future planning and fast installation criteria.

There is a suggested method for the analysis of load flow in radially operated 3-phase distribution networks. This method does not fix the famous conventional load flow equations. Such a method applies to distribution systems with unbalanced loads. It is important to note that the size of the used matrix is noticeably small in comparison with the conventional methods. The used memory is little, whereas the speed is considerably high. Subsequently, the relative speed of calculation increases per the system's size (Golkar, 2007: 334).

There is an algorithm for a fast continuation load flow to determine the critical load for a bus. This is by its voltage collapse limit of the inter-connected multi-bus power system. It uses the criterion of the singularity of load flow of the Jacobian Matrix. This method has been tested on IEEE 30 and IEEE 118 bus systems for validity. (Chakavorty & Gupta, 2012: 18)

To solve unbalanced radial distribution systems, there has been a suggested simple and efficient algorithm. This algorithm has the property of a good convergence for any practical distribution network with a practical R\X ratio. Such a method is perceived to be very efficient (Cipcigan & Taylor, 2007: 160).

There has also been a suggested methodology to solve the radial flow of analyzing the optimal capacitor sizing problem. Every network branch in this method is written in terms of the branch power flow and bus voltage. Subsequently, there has been a decrease in the number of equations by using terminal conditions connected to the main feeder and its laterals. The

Newton-Raphson method is applied to this reduced set. Not to mention that the computational efficiency is thus improved by simplifications made to the Jacobian method (Baran & Wu, 1989).

Three various algorithms have been also suggested to solve radial distribution networks per the proposed method of Baran and Wu by Chiang (Chiang, 1991: 135). They had proposed decoupled, fast decoupled, and very fast decoupled distribution load-flow algorithms. The first two which were proposed by (Chiang, 1991:135), were akin to Baran and Wu's (Baran & Wu, 1989). there has also been a proposed direct method for solving radial and meshed distribution networks by Goswami and Basu (Goswami & Basu, 1991: 80) Their method, however, has the limitation of having no node in the network which functions as the junction of more than three branches; i.e. one incoming and two outgoing branches.

Additionally, to fix radial distribution networks, (Das et. al., 1994: 292) also propose a load-flow technique that calculates the wholly real and reactive power which are fed through any node. This method functions by applying the power convergence with the assistance of the coding at the lateral and sub-lateral nodes of large systems; all of which heightens the complexity of the computation. However, such a method was only applicable to sequential branch and node numbering schemes. Forward sweep has been used to calculate the voltage of each receiving end node. They first attempted to solve radial distribution networks using zero initial power loss. It turned out that it can solve simple algebraic recursive expressions of voltage magnitude. As such, all the data is easily stored in vector form. Hence, a huge amount of computer memory is saved.

Another efficient method to solve both radial and meshed networks by using more than one feeding node has been suggested by Haque (Haque, 1996). Haque's method first converts the multiple-source mesh network into an equivalent single-source network. This is conducted by adding dummy nodes. This could be subsequently followed by the traditional ladder network method which applies to radial systems. Different from the previously introduced methods, this method incorporates the effect of shunt and load admittances; since it could be applied to solve special transmission networks. It is important to note that this method has an excellent convergence for the radial network.

To fix the power flow problem in radial distribution systems, Eminoglu and Hocaoglu (Eminoglu & Hocaoglu, 2005) suggested a simple method that is based on the voltage dependency of static loads as well as line charging capacities. This method is built on the forward and backward voltage updating by making use of the polynomial voltage equation and backward ladder equation for every branch. The suggested algorithm has a solid convergence capacity in comparison with the improved module of the classical forward-backward ladder method.

For a load-flow solution of radial distribution networks, Ghosh and Sherpa (Chosh & Sherpa, 2008: 2097) proposed a method with less data preparation. This method applies the simple equation to calculate the voltage magnitude. This method also can manage composite load modeling. However, for this algorithm to be implemented, huge programming efforts must be made.

Gurpreet Kauur (Kauur, 2012), on the other hand, suggests a new algorithm to solve the radial distribution networks by applying a method of load-flow and a sequential numbering scheme. His method, which aspires to decrease the data preparation, suggests a way to identify the nodes beyond each branch with minimal computational effort.

## 2.5 EIA Historical Background

at the beginning, it was introduced in the United States (US) then it was followed by several countries and institutions. It was considered a severe procedure for the implementation of some projects. The first country that developed an EIA system was the US. The social awareness for the environmental impacts and the mitigation procedures reached a high proportion by the med of 1960. With this increase, the National Environmental Policy Act (1969), and for the first time, EIA requiring environmental consideration in large-scale projects were enforced as legislation. Following the US initiative, many countries started to provide EIA systems like Australia (1974), France (1976), Pakistan (1983), and many other countries.

From the cooperation of several international countries like the Organization for Economic Cooperation and Development (OECD) and the European Union (EU), the EIA took its first steps around the world in the 1980s.

In 1982, United Nations Environmental Program (UNEP) began with the adoption of the world laws of nature. The law stated that EIA should be implemented to ensure the minimization of the impact of any suggested project on the environment. Then, UNEP 1987 established a committee for EIA discussion and implementation and established standards and regulatory models. On the other hand, the organization for economic cooperation and development (OECD) declared the environmental policy in 1974 which was to protect the environment. Article 9 stated the following to prevent future environmental deterioration, prior assessment of the environmental consequences of significant public and private activities should be an essential element of policies applied at the national, regional and local levels (OECD).

In 1985, the European Union (EU) instruction towards the EIA was adopted. These instructions require a defined EIA to be implemented before the approvals for any project with potential environmental impact, so all the countries in the EU should perform an EIA by the end of 1988 (European Commission, 2021).

World Bank (WB), a multi-faced institution that gives loans and finance to the developed countries and their developed projects, adopted the environmental policy in 1984. In 1989, it stated the operational directive related to EIA, and in 1998, the final draft of the operational policies was completed (International Finance Cooperation, 1998).

## 2.6 Environmental Policies and Regulations in Palestine

### 2.6.1 Palestine environment law

In Palestine, Enviroment Quality Authority (EQA) regulates and sets policies for the environmental sector. EQA was established in 1996 with the ambition to maintain and protect the environment in Palestine. It has two headquarters, one is in the city of Ramallah and one in Gaza. It also has offices distributed in major cities.

Measures have been taken by the Palestinian Environmental Legal and Administrative Framework for the protection of environmental resources and organizing their management. PEL, an abbreviation for the Palestinian Environmental Law, comprehensively covers major issues of the environment, its protection, and the enforcement of the law. Some of its goals are as follows:

1. Trying to reduce pollution to protect the environment.
2. Maintaining social and public health.
3. Placing protection of environmental resources in future social and economic plans.

4. Focusing on the protection of significant ecological areas and the rehabilitation of ruined areas.

5. Placing regulations and various protective standards in many environmental areas.

6. Promoting environmental awareness through training.

Additionally, PEL highlights diverse issues of the environment, such as:

1. It highlights the issues of land, air, water, and other natural and historical resources.

2. It conducts an Environmental Impact Assessment for environmental projects.

3. It sets penalties and punishments to whoever violates the law or its items.

The legislation also addresses issues of environmental emergencies and the incorporation of the public in environmental research and training.

In 1999, PEL has declared that "Ministry, in coordination with the competent agencies, shall set standards to determine which projects and fields shall be subject to the environmental impact assessment studies. It shall also prepare lists of these projects and set the rules and procedures of the environmental impact assessment".

### 2.6.2 Palestine EIA Procedure

Under the umbrella of the Palestinian National Authority, the Environmental Quality Authority (EQA) is the legislative institution for the environment acting laws, which is responsible for environmental quality and applying the environmental law and the EIA procedures written in the Palestinian law.

The implementation of the EIA procedure aims to provide a sustainable economic and social in Palestine by achieving the following (EQA, 1997):

1. Setting a standard for an appropriate life that does not marginalize the basic needs of the people as well as their social values through any developmental activity.

2. Maintaining the capability of the environment to self-sustainment.

3. Protecting the biodiversity of the landscapes.

4. Minimizing and avoiding environmental damage from environmental projects.

The Palestinian EIA procedure starts with applying for environmental approval containing a description for the proposed project with a screening for the proposed area. The screening criteria and output determine whether the project needs an EIA and determine whether the project is likely to (EQA, 1999):

1. Diversely use of a natural resource to promote other uses of the same resource.
2. Cause the displacement of people.
3. Take place near areas of high sensitivity, i.e. reserves, historical site, etc.
4. Cause high environmental impacts.
5. Be a source of public concern.
6. Need more developmental activities which subsequently will lead to further impacts on the environment.

Then it must be provided with an initial environmental evaluation and then an environmental impact assessment report if the project contains significant effects on the environment. Figure (2.6) illustrate the EIA procedure according to the PEL.

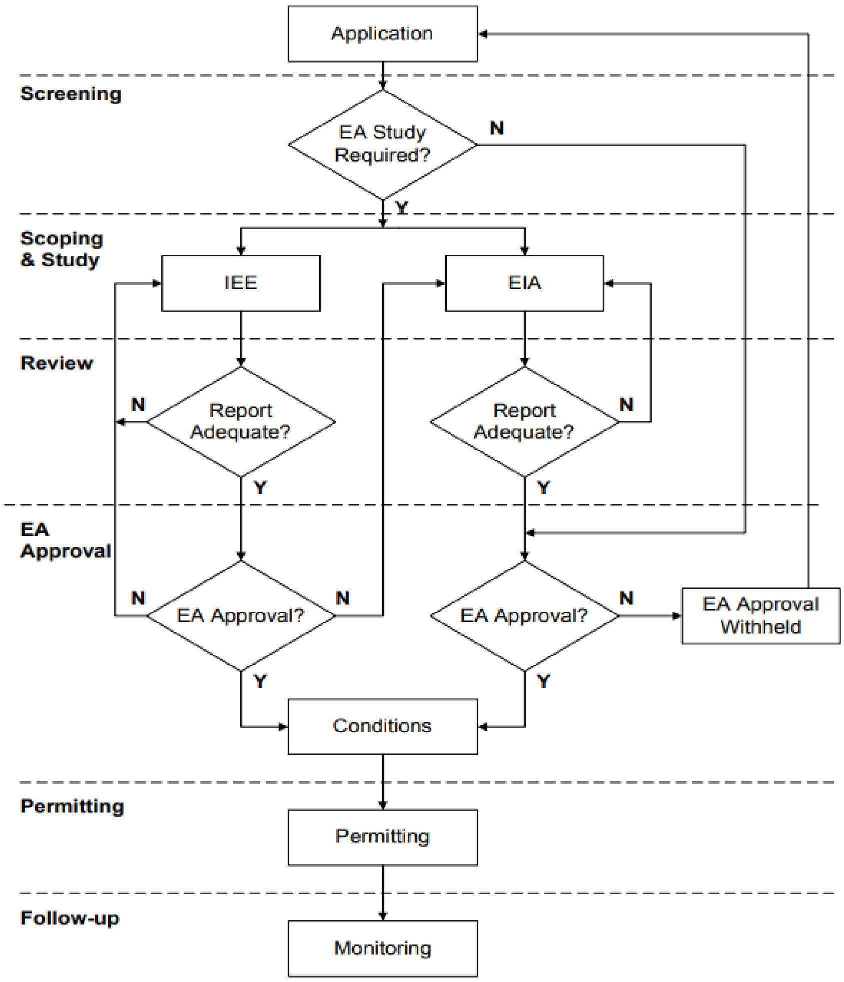



**Figure (2.6): Flow chart for Palestine EIA procedure (EQA, 1999)**

## 2.7 World Bank EIA Procedures

International finance corporation OP/BP 4.01 operational policies, 1998, an Environmental Assessment (EA) of environmental projects is required by the World Bank to follow certain criteria based on certain data. Such EA is supposed to provide a clear spectrum of the environmental outputs and impacts of any environmental project. EA, thus, is supposed to provide an assessment of potential risks, other proposed alternatives, the siting, the implementation strategy, the positive impacts, and ways to improve the project (International Finance Cooperation, 1998).

Therefore, EA must keep into consideration the natural resources of air, water, soil, and plants. Not to mention the safety aspects of human life, the physical cultural resources, and the life of the indigenous people. (International Finance Cooperation, 1998).

Accordingly, the Bank assigns the Borrower country to be responsible for carrying out the EA. It is part of the Borrower's responsibility to retain highly professional experts to conduct the EA. Sometimes, if a project is risky or of high significance, then the Borrower may also employ an advisory panel of environmental specialists (International Finance Cooperation, 1998).

Henceforth, the Bank advises the borrower based on the outputs retained by the EA on what further recommendations or/and measures to be undertaken (International Finance Cooperation, 1998).

For the Bank to determine the highlights of EA, then an environmental screening of any environmental project must be conducted. A project is thus classified into one of the following categories (based on type, siting, the significance of the project, impacts, etc.) (International Finance Cooperation, 1998):

1. Category (A): This includes the projects of high environmental sensitivity and impacts.

2. Category (B): This includes projects whose environmental risks and impacts are of less significance than the Category (A) projects.

3. Category (C): This refers to projects of minimal environmental impacts.

4. Category *FI*: This refers to the projects that are funded by the bank through an intermediary.

In the case of *FI*, the Bank requires to have a screen of the subprojects and appropriate EA. The Bank, additionally, investigates the compatibility of a country's environmental requirements with a certain project. (International Finance Cooperation, 1998).

The Bank also suggests certain policies for projects of urgent need of assistance based on the institutional capacity, public consultation, disclosure, and implementation. For institutional capacity, the Bank requires that the project includes components that strengthen the borrower's capacity should it have a certain inadequate capacity. A consultation is also required to be conducted by the borrower by which it consults other affiliated groups and NGOs. Their perspectives on the project and its environmental impacts must be taken into consideration. Before the consultation, the borrower must disclose an appropriate and intelligible summary of the project, its aspects, and its prospected impacts. As for the implementation, the Bank requires a report from the borrower about the project, how it meets the measures stipulated by the Bank, and the mitigation measures (International Finance Cooperation, 1998).

A Category (A) environmental assessment report should highlight the environmental issues of the project. Accordingly, it should include the following stipulated aspects: an executive summary that includes the findings and recommendations, a description of the project based on geographical, ecological, and social levels, a baseline data which assesses the scope of the project and its dimensions, a prediction of the prospected environmental impacts, an assessment of the alternatives, an environmental management plan which looks into mitigation measures and monitoring, and a list of appendices. The new world bank environmental and social framework replaced all the Policy (OP) and Bank Procedures (BP), OP/BP4.00, Piloting the Use of Borrower Systems to address Environmental and Social Safeguard Issues in Bank Supported Projects, OP/BP4.01, Environmental Assessment, OP/BP4.04, Natural Habitats; OP4.09, Pest Management; OP/BP4.10, Indigenous Peoples; OP/BP4.11, Physical Cultural Resources; OP/BP4.12, Involuntary Resettlement; OP/BP4.36, Forests; and OP/BP4.37, Safety of Dams. This Framework does not replace OP/BP4.03, Performance Standards for Private Sector Activities; OP/BP7.50, Projects on International Waterways; and OP/BP7.60, Projects in Disputed (The World Bank, 2017). Also, the new world bank frame work classifies the project upon the risk associated with the project implementation:

1. High risk.

2. Substantial risk.

3. Moderate risk.

4. Low risk.

## 2.8 Solar Radiation Data Collection for Palestine

The rate of deployment of solar PV systems is greatly influenced by the perception of the general public and utilities, national policies, as well as the availability of suitable standards and codes to govern it. According to the major drop in PV systems cost, the PV systems have become a very feasible source of energy with the addition of the decrease in its component, installation, and maintenance also with the availability of the source (the Sun). The geographical area and the climate for Palestine keep the generation level of the PV system at its maximum efficiency. Palestine is in the geographical region between the Mediterranean Sea and the Jordan River. At latitudes of 31 and 33 degrees and longitudes of 34 and 36 degrees. Its elevation ranges from 350 m below sea level in the Jordan Valley, to sea level along Gaza Strip shore, and exceeding 1,000 m above sea level in the hilly areas of the West Bank.

According to the Atlas of Solar Resources for Palestine issued by PENRA in 2014, Palestine has high solar radiation potential; on an annual average, the Global Horizontal Irradiation (GHI) is higher than 1900 $kWh/m^2$ and the Direct Normal Irradiation (DNI) is higher than 2000 $kWh/m^2$ and the average solar radiation of 5.4 $kWh/m^2/day$. According to the Atlas, the average energy production from a 1 kW PV system is between 1700 and 1775 kWh/kWp and it will reach 1800 kWh/kWp in Gaza (Atlas of Solar, 2014). The below Figure (2.7) illustrates the average hourly profile for 0.5 MWp system and, Figure (2.8) shows the monthly average output power for 0.5 MWp system.

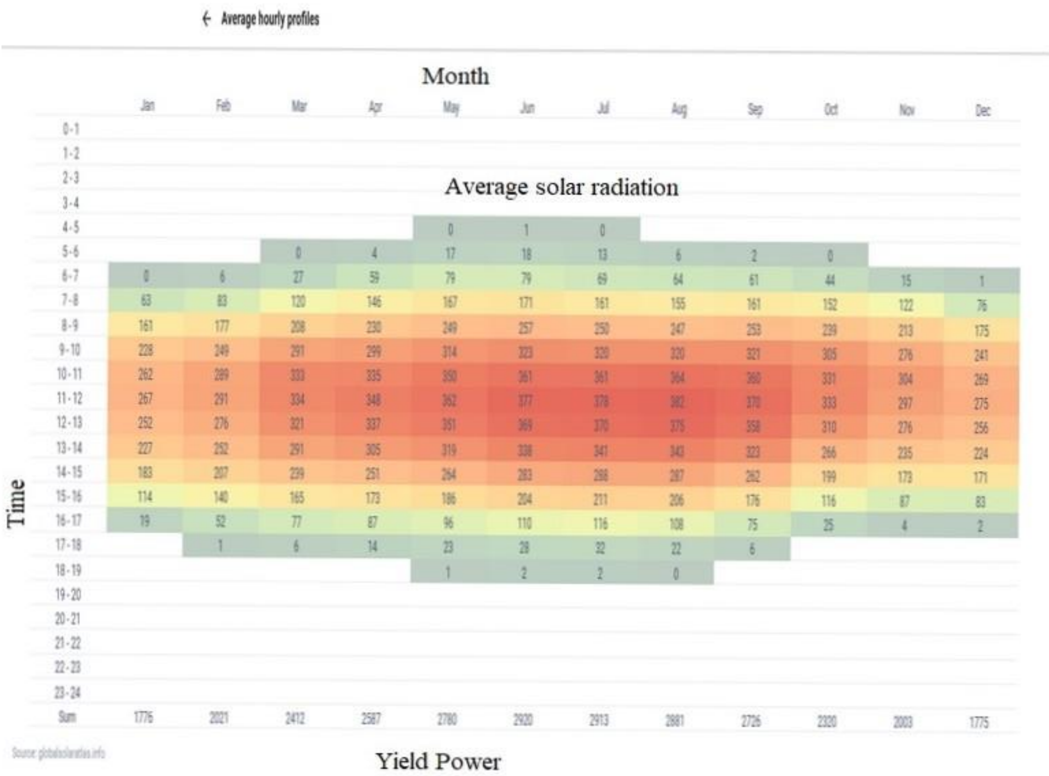



**Figure (2.7): Average hourly profile for 0.5 MWp system (Global Solar Atlas, 2008**

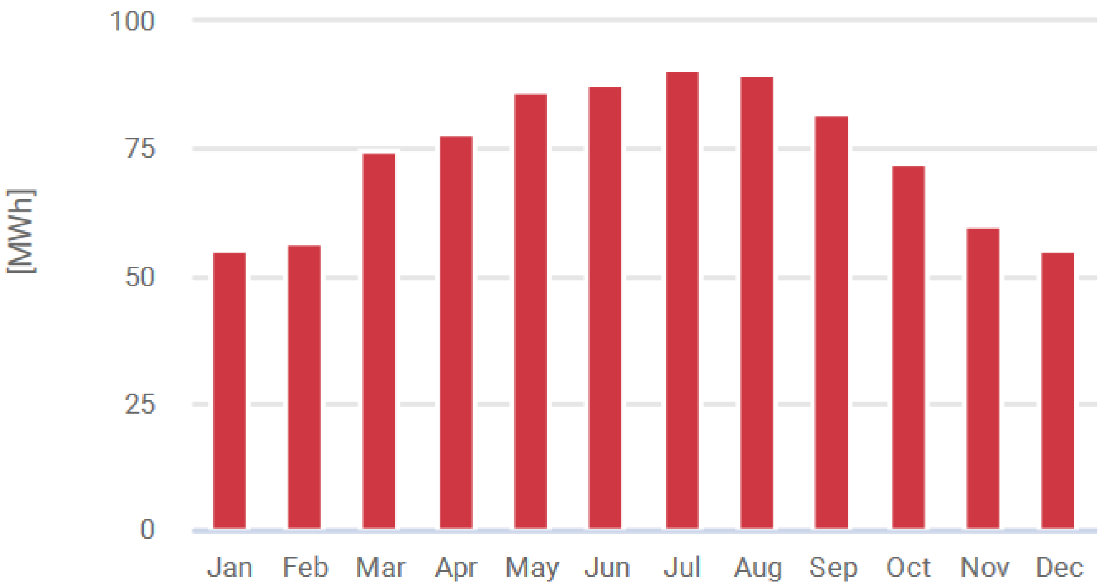



**Figure (2.8): Monthly average output power for 0.5 MWp (Global Solar Atlas, 2008)**

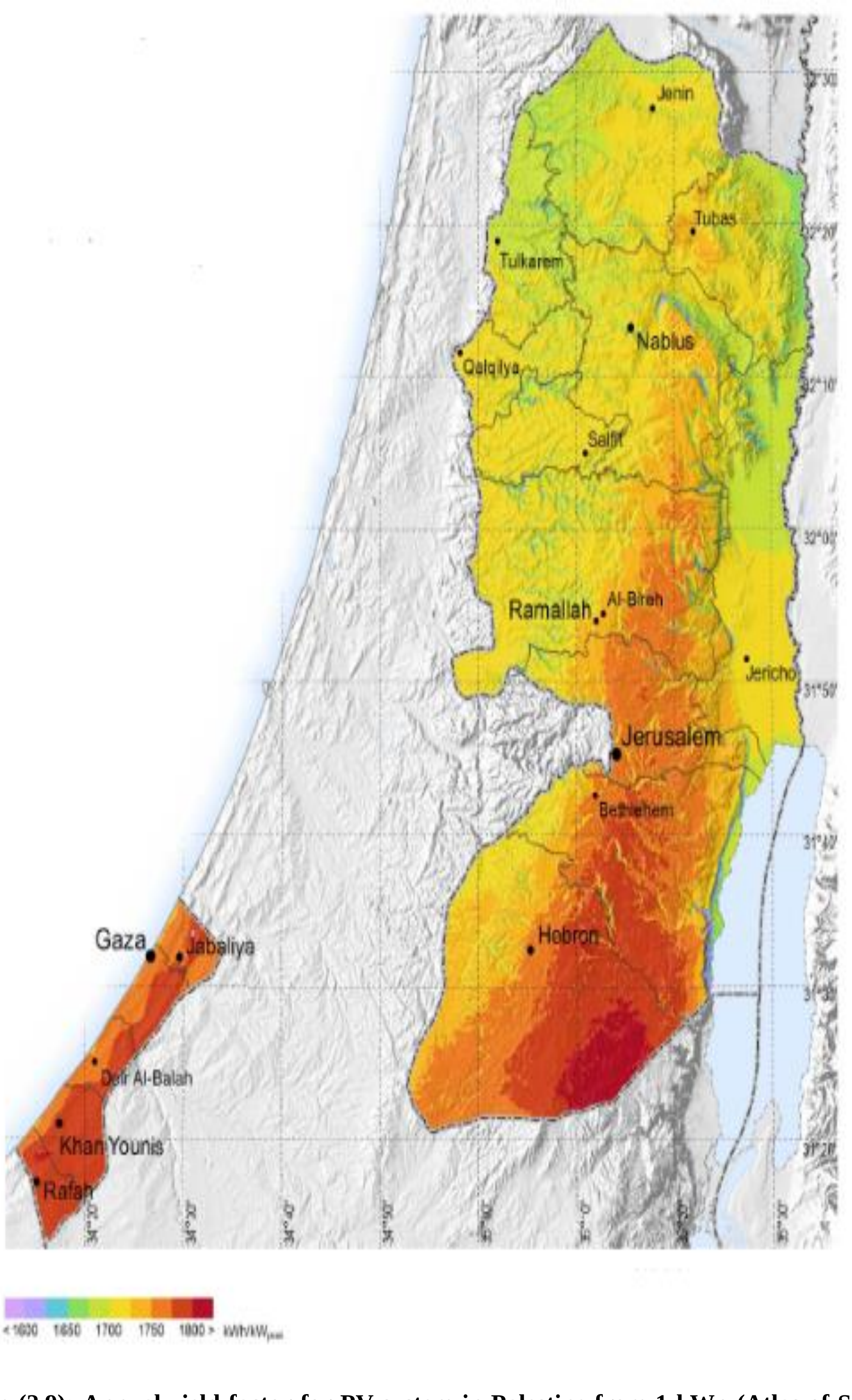



**Figure (2.9): Annual yield factor for PV system in Palestine from 1 kWp (Atlas of Solar, 2014)**

# Chapter Three
# Modeling of Salfit Electricity Distribution Network

## 3.1 Introduction

Salfit governorate is in the northwest of Palestine resting on a group of mountains 520m above sea level. Salfit city has a population of 11602 people according to the Palestinian Bureau of Central Statics, with a total area of 23117 Dunm for the governorate. Despite the surrounding settlements, Salfit consists of an area of 5694 Dunm. Table (3.1) below represents general information for Salfit city and, Figure (3.1) represents Salfit master plan. Salfit area is divided into four main categories, residential area with 3527 Dunm, industrial area with 715.8 Dunm, commercial area with 230 Dunm, agricultural area with 77.7 Dunm, and 1374.3 Dunm located in area C and some of them are located outside the master plan.

**Table (3.1): Salfit city general information**

| General Information | Description |
|---|---|
| Governorate | Salfit |
| City | Salfit |
| Population | 11602 |
| Coordination | 32°06'11", 35°07'09 |

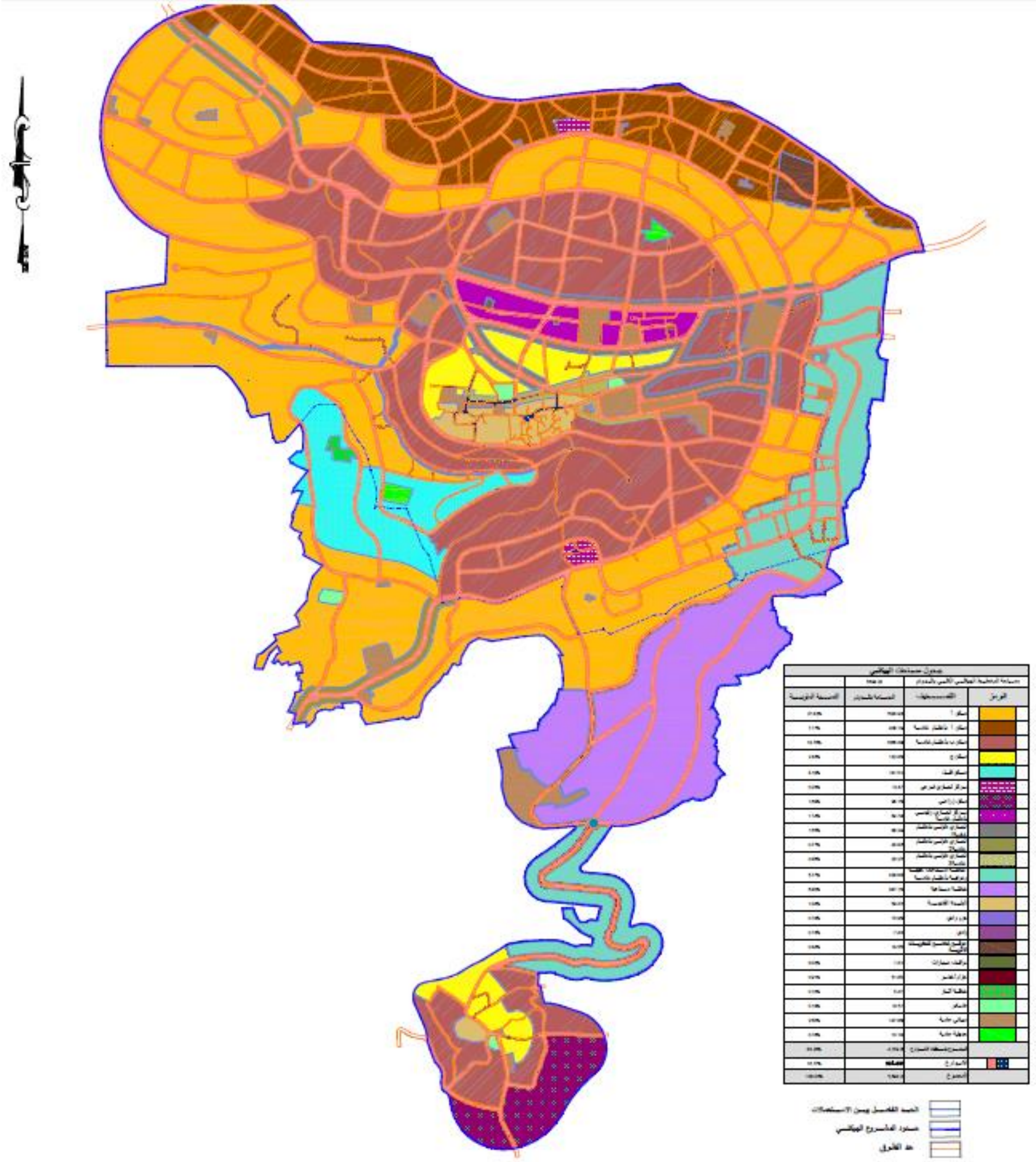


**Figure (3.1): Salfit master plan (Shtayeh, 2021)**

## 3.2 Salfit Electrical Network

Salfit purchases electricity from Israel Electrical Company (IEC). While Salfit municipality manages the distribution of electricity between the city of Salfit and three other villages (Farkha, Skaka, Amorya), the electrical department at the municipality, which contains two electrical engineers and four electricians, is responsible for the maintenance and the operation of the electrical network.

Salfit electrical network is connected to the Israeli side from a one connection point with a total capacity of 120 Amp at a medium voltage rated at 33 kV. With a total medium voltage network of 21000 m and 120 km low voltage, Salfit's electrical network provides electricity for 5252 customers who are divided into four main categories: residential with a total number of 4289, industrial with a total of 192, governmental 117 and commercial with a total number of 654 and street lighting of 19. Beneath, Figure (3.2) shows the percentage for each type.

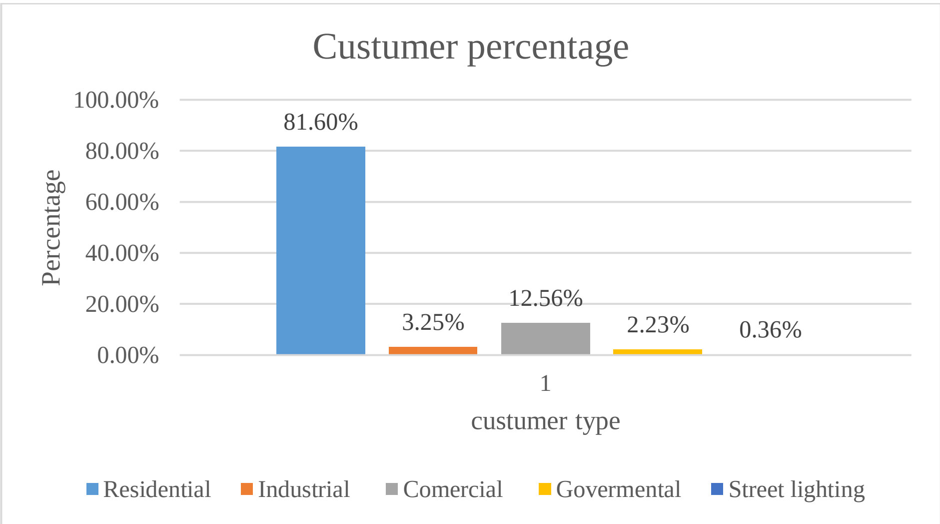



**Figure (3.2): Customers types and percentage in Salfit city**

Slafit Municipality approved connecting the photovoltaic systems on the grid in 2017 by taking into consideration the framework determined by the Palestinian Electricity Regularity Council (PERC) following the net metering for the connection. Since 2017 and until February 2020, the total number of customers is 66 with a total capacity of 601 kW in Salfit only.

However, in Farkha village, the total number of customers is 27 with a total capacity of 127 kW. Additionally, Farkha is connected to a PV station with a total capacity of 270 kW that is connected to the medium-voltage lines. Skaka and Amorya, on the other hand, still underway to get approvals from their council to permit the installation of the PV systems.

The transmission lines in the electrical grid are mostly of overhead aluminum ACSR with a total number of transformers of 36 that convert the voltage from 33 KV to 0.4 KV in Salfit and the three other villages with 1,273 Km of underground cable. Additionally, the network has an ABC aluminum cable with a total length of 130km distribution network that consists of the following components:

- ACSR overhead cables
- Medium voltage Underground cable
- 38 transformers represented as [630 kVA (14 units), 400 kVA (12 units), 250

kVA (7units), 150 kVA (1 unit), 160 kVA (2 units)]

- PV project systems
- ABC aluminum cable
- (6x25) mm
- (4x50 +2x25) mm

- (4x95+2x50) mm
- Wooden poles
- Steel poles
- Steel M.V. towers
- Steel ladders

## 3.3 Modeling of the electrical grid

To understand the behavior of the electrical network and its elements, we need to understand its equivalent circuit and mathematical description. In other words, it's called the molding of power system elements. These models will give us a good description of how these elements work in all conditions starting from the generator, to the transmission line, to the transformer, and ending with the loads.

### 3.3.1 Generator

A generator is an electrical machine that converts mechanical energy into electrical energy. The type of generator that we are interested in is the synchronous generator. The synchronous generator is made from two main parts; a stationary part which is called a stator and a rotating part called a rotor. The rotor rotates inside the stator producing what is called field winding; which is supplied by DC that produces magnetic force from its rotation. This force produces a flux between the air gap between the stator and the rotor and makes the current go throw the slots attached into the stator. The speed of rotation of the generator depends on the number of the pole that's made off (Stevenson, 1975: 565) according to the following equation:

$$f = \frac{P}{2} * \frac{N}{60} \tag{3.1}$$

Where f is the frequency in hertz, P is the number of poles, N is number of rotations.

To represent the equivalent circuit for the generator, Figure (3.3) represent a phasor diagram for the flux and the electromagnetic force were the:

$\O_f$ : the rotor flux

$E_{a0}$ : no load voltage which equals $E_f$

$\O_f$ : total flux from $\O_f + \O_{ar}$ and that gives us $\O_r$

$E_{ar}$ : the result of the armature current= $-jI_a * X_{ar}$

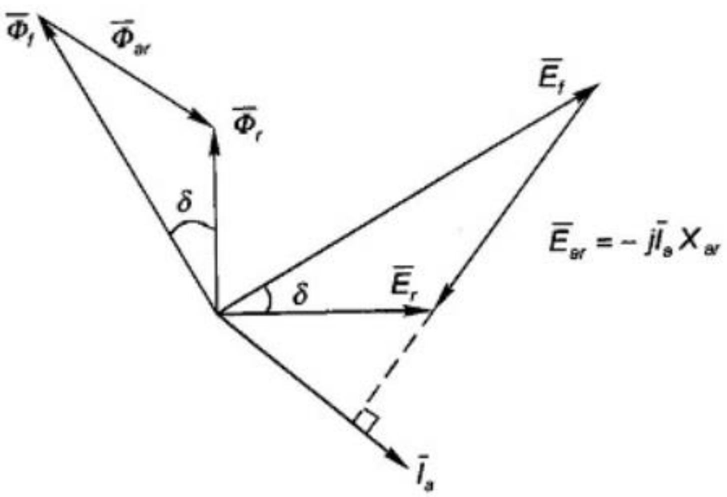



**Figure (3.3): Phasor diagram for the generator (Stevenson, 1975: 565)**

From the phasor diagram

$$E_r = E_f + E_{ar} = E_f - j\, I_a * X_{ar} \tag{3.2}$$

Due the armature leakage reactance ($X_l$) and armature current the output voltage, Figure (3.4) represents the equivalent circuit for the generator.

$$V_t = E_r - j\, I_a * X_l \tag{3.3}$$

$$V_t = E_f - I_a( R_a + jX_s ), X_s = X_{ar} - X_l \tag{3.4}$$

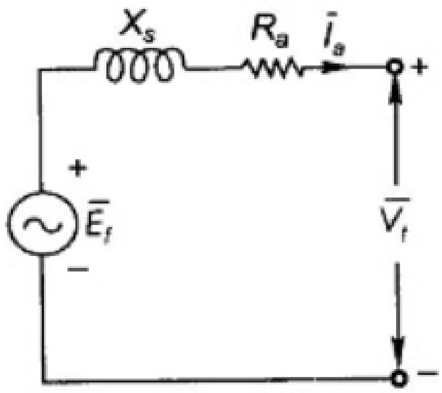



**Figure (3.4): Equivalent circuit for the generator (Stevenson, 1975: 565)**

### 3.3.2 Transformer

A transformer is an electrical device that converts voltages from high voltage to lower voltage or vice versa. For us to understand the circuit model and mathematical formulas for our practical transformer, we will take the ideal transformer as a simple approach. The most important aspects of the ideal transformer are that the permeability of the core is finite and the resistance of the transformer is zero (Stevenson, 1975: 565). The following Figure (3.5) represents the ideal transformer equivalent circuit:

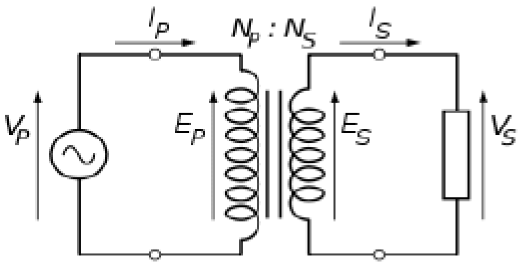



**Figure (3.5): Ideal transformer equivalent circuit**

From Figure (3.5) “the voltage induced in each winding by the charging flux is also the terminal voltage since the winding resistance is zero” (Stevenson, 1975: 565). By applying Faraday law:

$$V_1 = N_1(d\ ø/d\ t) \tag{3.5}$$

$$V_2 = N_2(d\ ø/d\ t) \tag{3.6}$$

Where:

d ø : for constant flux.

N : number of turns.

And, if we assumed that the applied flux is sinusoidal:

$$V_2/V_1 = N_1/N_2 \tag{3.7}$$

To find the relation between the two winding currents, we apply Amperes law which relates the current to the field intensity around a closed bath:

$$\int H.ds = i \tag{3.8}$$

Where (i) is the current enclosed by the line integral and H represents the field intensity, and, for the currents in two windings, we obtain:

$$\int H.ds = N_1 i_1 - N_2 i_2 \tag{3.9}$$

and, as we know, the integration over a closed-loop equals zero:

$$N_1 i_1 = N_2 i_2 \tag{3.10}$$

$$i_2/i_1 = N_1/N_2 \tag{3.11}$$

Where:

N: number of turns.

i: the current in the primary and the secondary sides of the transformer

As for the practical transformer, which has a few differences from the ideal like permeability, it is not finite. Winding resistance is present, and it has iron core losses. Not to mention that the practical transformer has two types of losses: first, eddy current losses due to the current induced in the iron = $I^2$*R. Second, the hysteresis current and is dissipated as heat. Figure (3.6) shows the equivalent circuit of the practical transformer after neglecting the magnetization current since it is too small compared to the load current (Stevenson, 1975: 565).

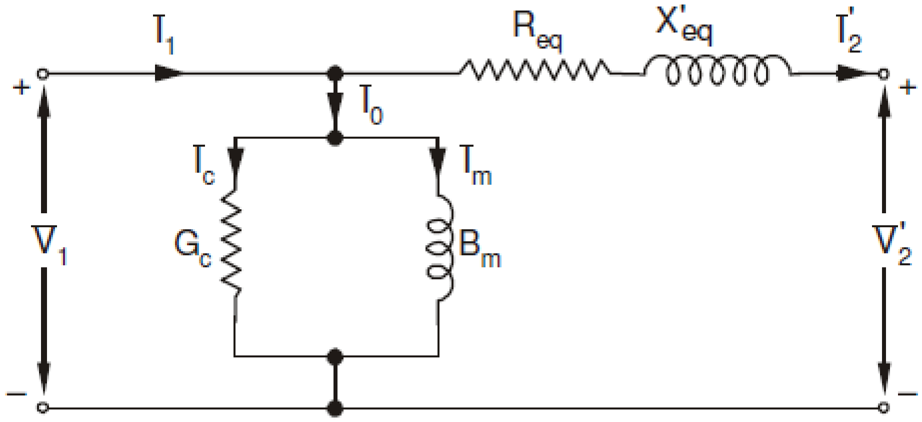



**Figure (3.6): Practical transformer equivalent circuit**

### 3.3.3 Transmission line

Whether it's a head or an underground cable, the main purpose of the transmission line is the connection between the elements of the power system starting from the generator and ending with the load. The transmission lines are classified into three main categories: first, less than 80 km is short; second, between 80 km to 240 km long; third, over 240 km needs an additional calculation (Stevenson, 1975: 565). Figures (3.7, 3.8, 3.9) represent the equivalent circuit for all types of transmission line (Manuel Reta-Hernavndez, 2006).

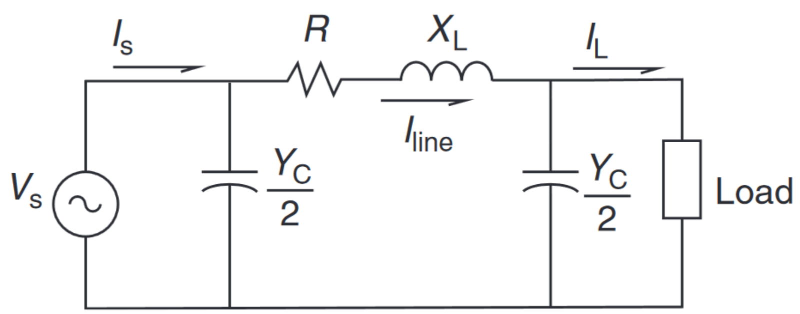



**Figure (3.7): Equivalent circuit of medium length transmission line**

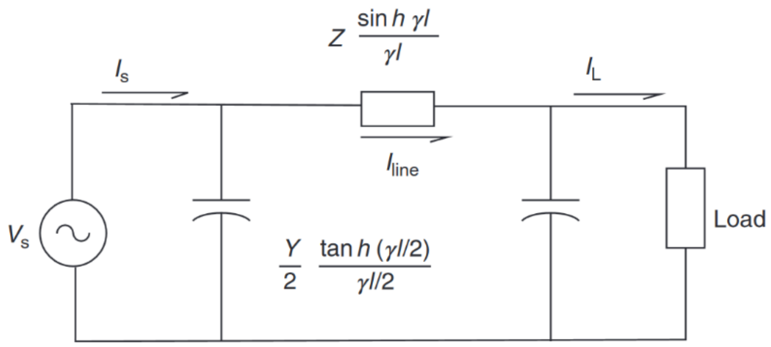



**Figure (3.8): Equivalent circuit of long transmission line**

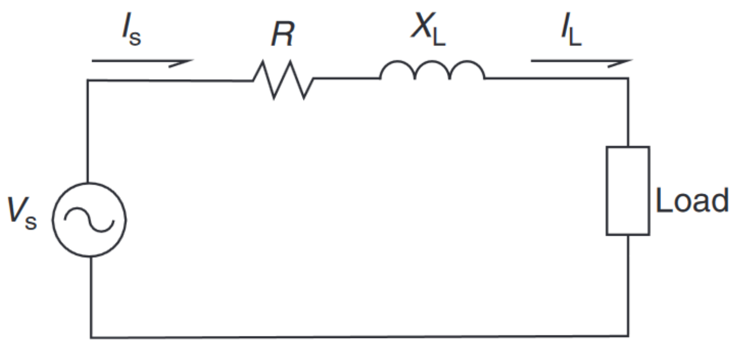



**Figure (3.9): Equivalent circuit of short transmission line**

The resistance of the transmission line can be expressed by the following equation (Stevenson, 1975: 565):

$$R = \frac{\rho L}{A} \tag{3.12}$$

Where

$\rho$ : the resistivity of the material

L : the length

A : the cross-sectional area

While the inductance of the transmission line depends on the distance between the line and the length of the line, it can be expressed by the following equation:

$$L = 2 * 10^{-7} Ln \frac{GMD}{GMR} \quad (3.13)$$

Where GMR is the geometric mean radius and equals to ($e^{-1/4}$ r =0.778 r) and the GMD represents the distance between three conductors, and it is expressed by this formula:

$$GMD = \sqrt[3]{D1D2D3} \quad (3.14)$$

Where D1, D2 and D3 represents the distance between the three conductors. And as for the short model of the transmission line that we are mainly interested in, the following equation represents the resistance and the reactance of the model:

$$R = rd \quad (3.15)$$

$$Xl = Xd \quad (3.16)$$

Where rd is the series resistance and $Xd$ is the series reactance.

### 3.3.4 PV systems

The PV (photovoltaic) systems mainly consist of a PV module that absorbs sunlight to produce electricity (dc), then connect it to the inverter to convert the dc power into ac power and then connect it to the grid. The PV system took its place in the electrical power system since the number of the systems and its rated power is increasing significantly. This increase made the PV studies for the grid impact essential. Modeling the PV systems is used for power flow calculation, short circuit calculation, voltage stability studies, and harmonic interaction studies. The PV systems circuit can be modeled using a single diode model which is illustrated in Figure (3.10) (Cuk et al, 2011). Using the single diode model as it's shown in the following Figure, the current and the voltage characteristic can be represented by the following equation (Cuk et al, 2011):

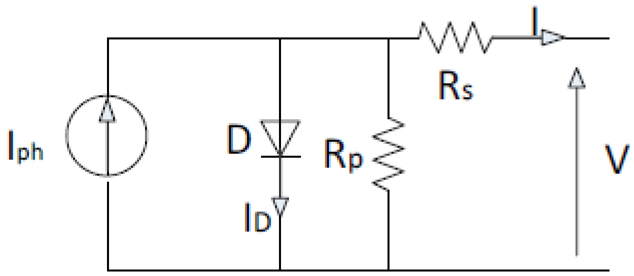



**Figure (3.10): Single diode model for solar cell (Masters, 2004)**.

$$V_{oc}(T) = V_{ocstc} + Kv(T - T_{ref}) \quad (3.17)$$

Where $V_{ocstc}$ is the open circuit voltage in STC and $Kv$ is the open-circuit voltage temperature coefficient (V/°K).

$$I(G,T) = I_{scstc}\frac{G}{G_{stc}}[1 + k_i(T - T_{ref})] \quad (3.18)$$

Where G is irradiation and $G_{STC}$ is irradiation in STC(1000W/m2), $I_{sc,stc}$ is the short circuit current at STC, $T_{ref}$ is the reference temperature at STC (298°K) and $k_i$ is the short-circuit current temperature coefficient. The photovoltaic cell is combined with other cells to perform a group of modules that represents a PV array. The output current of the PV array can be represented as follows:

$$I = I_{sc} - I_o((exp(38.9\, V_d)) - 1) - V_d/R_P \qquad (3.19)$$

And the output voltage of the cell:

$$V = n(V_d - IR_s) \qquad (3.20)$$

Then, from the output voltage and current, we can find the power produced from the module Where:

$V_d$ : voltage junction

$R_s$ : series resistance

$R_p$ : parallel resistance

The output power of the module depends on the parallel resistance and the series resistance to improve the output power the $R_p$ should be high and $R_s$ should be zero. Figure (3.11) below represents the I-V curve of the PV module and the effect of the parallel resistance and series:

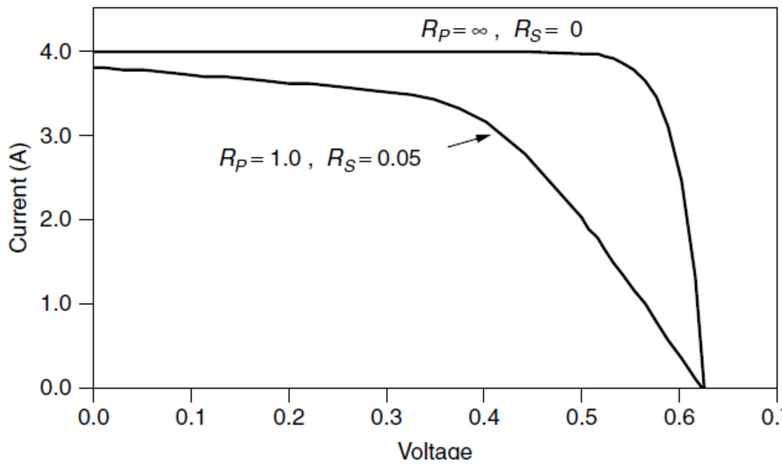



**Figure (3.11): I-V curve of a PV module and the effect of Rs and Rp (Masters, 2004).**

The inverter in the PV system works to produce the highest power of the PV. This is represented with the largest rectangle that can be drawn under the I-V curve. Also, to draw this rectangle, we need the MPP (maximum power point) to represent the highest voltage and the highest current. This can be done with a device called the tracker. Figure (3.12) shows the amount of the output power with different points in the IV curve:

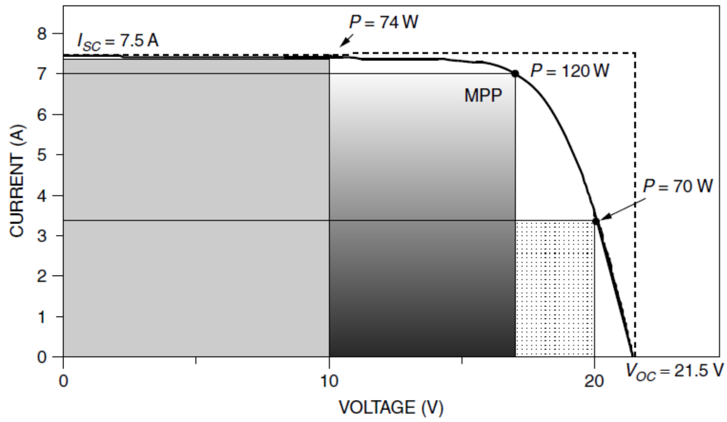



**Figure (3.12): The maximum power point (MPP) corresponds to the biggest rectangle that can fit beneath the I –V curve (Masters, 2004).**

Since the current produced is a function of temperature and radiation, the following figure shows their effect on the output power. The increasing temperature will reduce the output power as it's illustrated in Figure (3.13) the ambient tempreture higly influence the performance of PVS ((Aziz et. al., 2019). However, the increase in the radiation will increase the output power as it's illustrated Figure (3.14):

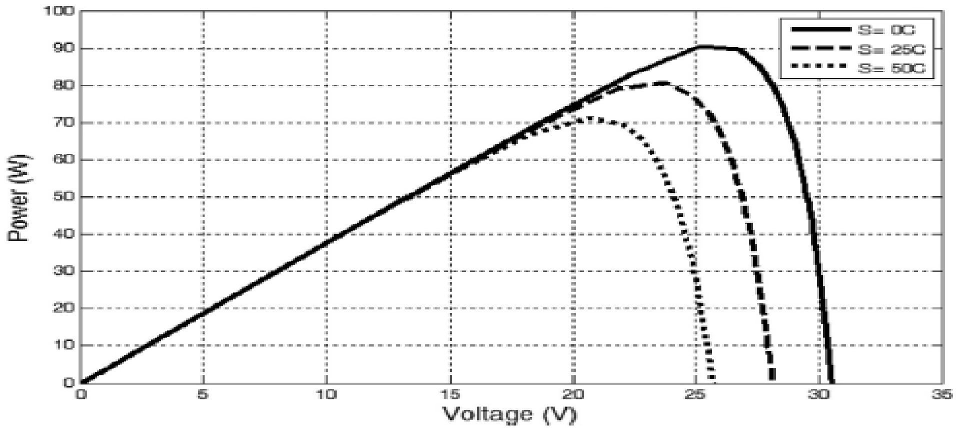



**Figure (3.13): Relation between temperature and power output (AlNozahy & Salama, 2013)**

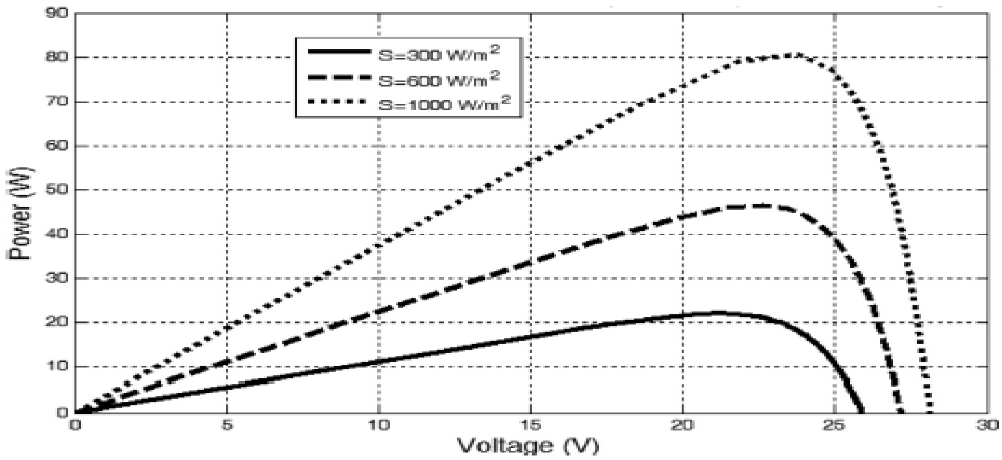



**Figure (3.14): Relation between solar radiation and power output (AlNozahy et.al, 2013:032702)**

### 3.3.5 One-line diagram

The One-line Diagram is a combination of all power system elements used in the grid which gives us consistent information about the electrical grid. The elements in the one-line Diagram are represented by simple symbols and not with their equivalent circuit. The amount of the elements represented in the diagram depends on the amount of information needed which is mainly used for the load flow analysis. The below Figure (3.15) represents the one-line diagram for Salfit electrical network.

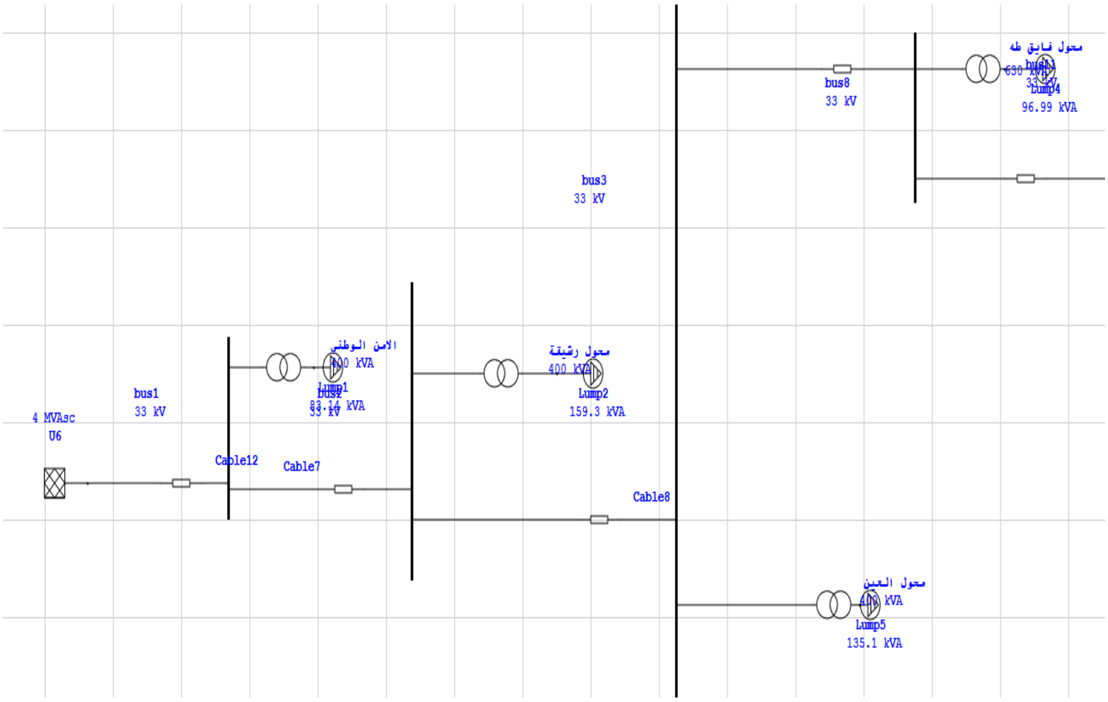



**Figure (3.15): Part of the one-line diagram for Salfit electrical network.**

### 3.3.6 Load flow analysis

To study the performance of the electrical grid and its component, it is essential to do the power flow analysis; in other words, load flow analysis. The load flow analysis gives us a full indication of how the electrical grid works, which is also necessary for future planning for expansion and control. It is additionally needed to understand the effects that might happen in the grid for the utility. The principle information obtained from load flow is the magnitude and the phase angle of the voltage at each bus and the real and reactive load flowing in each line (Ghiasi, 2018: 157). The following equation represents the formulation for the load flow starting with the following equation:

$$I = Ybus * V \tag{3.21}$$

Where Ybus represents the matrix of the admittance of the power system. The nodal formula can be expressed as:

$$I = \sum_{j=1}^{n} Y_{ij} * V_j \tag{3.22}$$

And the complex power can be expressed as:

$$P_i + jQ_i = V_i \, I^* \tag{3.23}$$

Where P is the real power and Q is the reactive power on each bus, referring to I,

$$\frac{P_i - jQ_i}{V^*} = \left(V_i \sum_{j=1}^{n} Y_{ij}\right) - \left(\sum_{j=1}^{n} Y_{ij} * V_j\right) \tag{3.24}$$

And according to Karim et. al. (2013), the complex injection power can be represented as:

$$S_i = S_{gi} - S_{di} =$$
$$generation - load \tag{3.25}$$

Where $Sgi$ is the complex generation power and $Sdi$ is the load complex power, and the current injection can be represented as:

$$I_i = I_{gi} - I_{di} = c \tag{3.26}$$

$$S_i = V_i I_i^* = V_i \sum_k^n (Y_{ik} * V_{ik}) \tag{3.27}$$

$$S_i = \sum_k^n V_i * V_k \, e^{j\delta k} (G_{ik} - jB_{ik}) \tag{3.28}$$

Where $G_{kj}$ and $B_{kj}$ as the real and imaginary parts of the admittance matrix element Ykj, respectively, so that $Y_{kj}=G_{kj}+jB_{kj}$, where $Y_{ik}$ is the admittance matrix then we can find the real and reactive power:

$$P_i = \sum_k^n |V_i| * |V_k| [G_{ik} cos(\delta_{ik}) + B_{ik} \sin(\delta_{ik}) \tag{3.29}$$

$$Q_i = \sum_k^n |Vi| * |V_k| [G_{ik} cos(\delta_{ik}) - B_{ik} [\sin(\delta_{ik})] \tag{3.30}$$

Where: δ is the phase angle, P is real power, Q is reactive power, and $|V_i|$ is voltage magnitude.

The bus is the connection point between the transformer and the transmission line or the load. It is classified into three main categories: slack bus, generator bus, and load bus. In the past, the load flow analysis used to be done mathematically by three main methods; which are:

- **Newton Raphson Method:**

This method solves the following equation using the Jacobean matrix

$$\begin{pmatrix} \triangle P \\ \triangle Q \end{pmatrix} = \begin{pmatrix} J1 & J2 \\ J3 & J4 \end{pmatrix} \begin{pmatrix} \triangle I \\ \triangle V \end{pmatrix} \tag{3.31}$$

Where (J1to J4) represent the Jacobean matrix.

- **Fast-Decoupled Method:**

This method is derived from the newton Raphson method. It uses less iteration since its main principle is: any small change in the voltage will not affect the magnitude of the real power nor the complex power. The following equation represents the method:

$$|\triangle P| = |J1||\triangle I| \quad (3.32)$$

$$|\triangle Q| = |J3||\triangle V| \quad (3.33)$$

- **Accelerated Gauss-Seidel method:**

This method uses the nodal voltage method to solve the following formula iteratively and it's the simplest iterative way to solve the power flow

$$|P + JQ| = |V^T|\left|Y^*{}_{,bus} * V^*\right| \quad (3.34)$$

Where in the equation P and Q are the specified bus real and reactive power , V is the bus voltage vector; $Y_{bus}$ is the system admittance matrix. $Y^*{}_{,bus}$and $V^*$ are the conjugates of $Y_{bus}$ and V, respectively; $V^T$ is defined as the transpose of V.

## 3.4 Electrical Grid Analysis and Consumptions

As an engineer working in Salfit Municipality, I was able to access all the data needed for the analysis of the electrical network. To be able to fulfill this study, the analysis of the performance of the network started by drawing the grid using AutoCAD software and the EATP software to fully understand the performance of the network, its applicability by adding the PV systems, and its impact on the grid.

By referring to the financial department in the municipality, the average annual consumption of electricity for Salfit and the three other villages during 2016 to 2019 is 20008050 kWh (842739.7 NIS); with an annual increase in the demand of 1.2% as is depicted in the following Table (3.2):

**Table (3.2): Yearly consumption of Salfit city since 2016**

| Year | Total bill (kWh) | NIS |
|---|---|---|
| 2016 | 18845000 | 7937514 |
| 2017 | 18721000 | 7885285 |
| 2018 | 19693000 | 8294692 |
| 2019 | 22773200 | 9592072 |

By returning to the monthly bills from IEC, the highest consumption of electricity is in summer. Hence, the stakeholders in Salfit Municipality decided to add and give permission for the installation of PV systems. Figure (3.16) below shows the one-line diagram of the grid without the PV systems per the customers from 2017 until the beginning of 2020. As we mentioned earlier, the total number of customers in Salfit is only 66 customers and 40 applications are pending for their confirmation to start installing their projects.

**Table (3.3): ETAP software general results for the electrical network without PV systems**

| Source | MW | MVAr | MVA | P.F |
|---|---|---|---|---|
| Source (swing) | 3.897 | 1.629 | 4.224 | 92.27 |
| Source (non-swing) | 0 | 0 | 0 | 0 |
| Apparent loses | 0.063 | 0.053 | | |

**Table (3.4): Monthly consumption for Salfit city for the past 4 years**

| Month | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| 1 | 1600000 | 1900000 | 1850000 | 2220000 |
| 2 | 1500000 | 1550000 | 1520000 | 1830000 |
| 3 | 1450000 | 1500000 | 1350000 | 1650000 |
| 4 | 1400000 | 1200000 | 1250000 | 1778000 |
| 5 | 2020000 | 1290000 | 1575000 | 1530000 |
| 6 | 1000000 | 1576000 | 1590000 | 1752000 |
| 7 | 1740000 | 1970000 | 1950000 | 2340000 |
| 8 | 1800000 | 1850000 | 1880000 | 2250000 |
| 9 | 1500000 | 1575000 | 1778000 | 1980000 |
| 10 | 1600000 | 1430000 | 1500000 | 1753200 |
| 11 | 1620000 | 1230000 | 1450000 | 1650000 |
| 12 | 1615000 | 1650000 | 2000000 | 2040000 |
| sum | 18845000 | 18721000 | 19693000 | 22773200 |

From the above table, there is a slight increase in electrical consumption from the year 2017 to 2018. However, it increases in 2019 because of climate change which increases demand. Figure (3.16) shows the ETAP software analysis for the electrical grid with the PV systems.

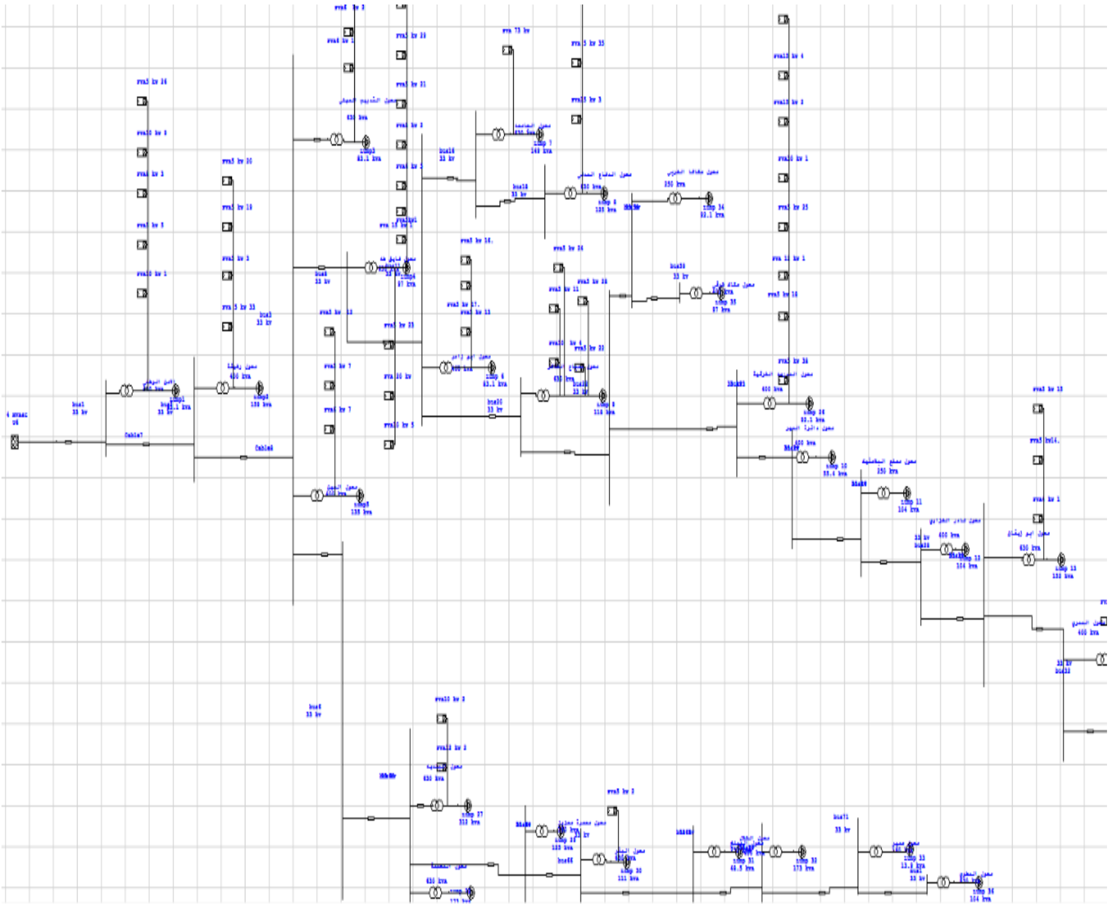


**Figure (3.16): ETAP one-line diagram of the network with PV systems.**

and after running the load flow analysis for the network, we get the following results:

**Table (3.5): ETAP software general results for the electrical network with PV systems**

| Source | MW | MVAr | MVA | P.F |
|---|---|---|---|---|
| Source (swing) | 2.970 | 1.647 | 3.396 | 0.8745 |
| Source (non swing) | 0.917 | 0 | .917 | 1 |
| Apparent loses | 0.045 | -0.037 | | |

As depicted above, the power factor percentage is lower than the one specified from IEC which is 92%. By returning to the financial department, in 2019, there is a difference between the purchasing value and selling value of kWh due to the losses, which might be electrical losses or mechanical losses.

# Chapter Four
# Impact of PV Distributed Generation on Grid

## 4.1 Introduction

Distribution generation refers to any element in the power grid that produces electricity starting from the generators, wind turbine, PV stations, and municipal waste. The increasing energy demand made the utilities search for solutions to cover their peak demands. The distribution generation can be defined as small-scale, dispersed, decentralized, and on-site electric energy systems (Begovic, 2001).

PV distribution generation (PVDS) was chosen to be implemented in Palestine since it is the only allowable generation source and because of the good irradiation in this country. With a variety of capacities ranging from kilowatts to megawatts, the installation of power plants is still going. The PVDG can be classified into four main categories: micro-scale, small-scale, medium-scale, and utility-scale. The PVDG integration in the electrical network may lead to severe consequences and might interfere with the system's capability to maintain the operation and the control of the system. The impact severity is a function of the penetration level (Begovic et. al., 2012).The impact of PVDG varies because of the instability of the out power of the PV plants since it depends on the weather (solar radiation and temperature). Therefore, the variety of the out power of the PV is quite wide due to shading issues and clouds. With the low capacity of the PV systems, the impact of the PVDG is low. However, with a higher penetration level, the impact increases.

## 4.2 Design of the Proposed Photovoltaic System

The commonly used PV model for each PV system consists of multiple steps, including finding solar irradiance in the sky projecting solar irradiance to the panel, determining the dc output from the panel, and converting the power output computable to the grid (Enslin, 2011). The inverter is used to convert the dc into ac and using the step-up transformer to make the voltage computable with the voltage grid as shown in figure (4.1)

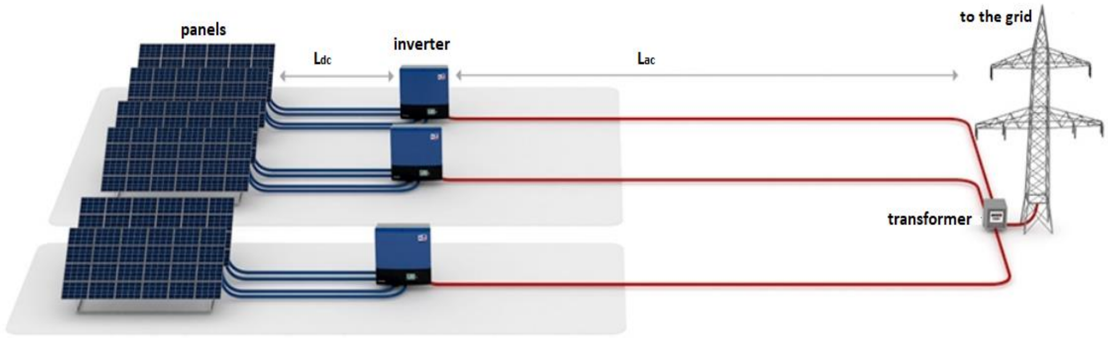



**Figure (4.1): Scheme diagram for PV station**

Salfit municipality, which represents the electrical company for providing the electricity and maintenance for the electrical grid, is responsible for the network and any future planning. Nowadays, the municipality is following the trend by installing the PVDG on the electrical network aiming to achieve 5MW of PV connected starting from 0.5 MW as the first phase of the project.

### 4.2.1 Solar Radiation

Salfit is one of Palestine's governorates that is characterized by the solar radiation to which it is exposed during the year. Figure (4.2) and table (4.1) show average monthly output power for the 0.5 MWp station

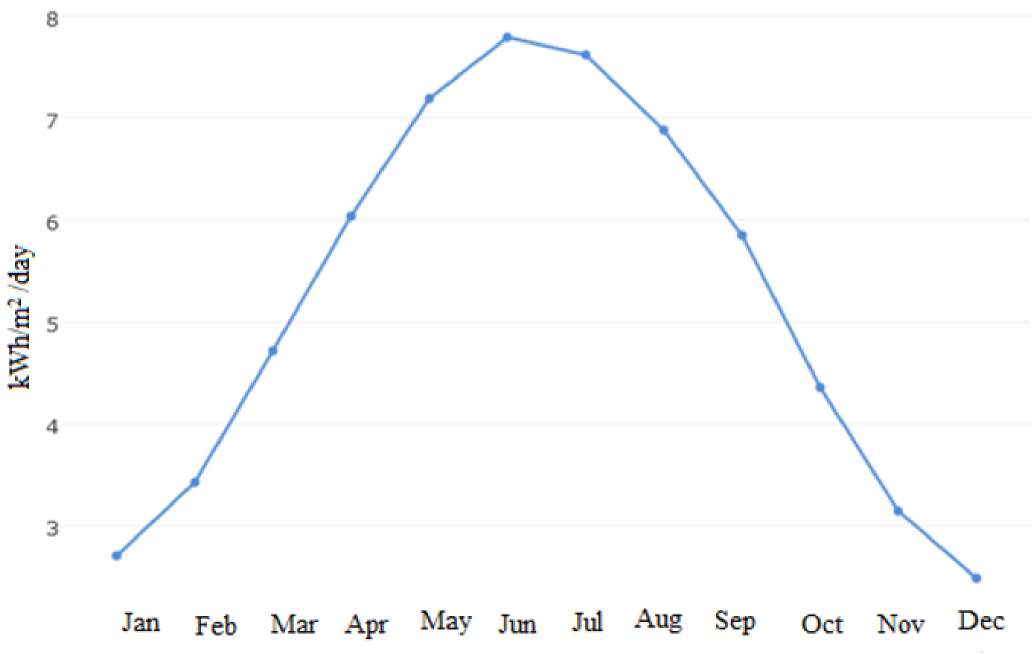



**Figure (4.2): Solar energy for one year of 0.5 MWp (Global Solar Atlas, 2008).**

**Table (4.1): The avrage monthly energy output for 0.5 MWp**

| Month | Output energy yield from 1kWp | Output energy yield from 0.5 MWp |
|---|---|---|
| Month | kWh/kWp | kWh |
| Jan | 110.5 | 55250.3 |
| Feb | 112.3 | 56146.9 |
| Mar | 148.1 | 74046.4 |
| Apr | 155.9 | 77957.8 |
| May | 174 | 86990 |
| Jun | 176.1 | 88032.6 |
| Jul | 181.7 | 90848.3 |
| Aug | 179.7 | 89848.1 |
| Sep | 164.7 | 82339.1 |
| Oct | 145.5 | 72771 |
| Nov | 120.7 | 60328 |
| Dec | 111.3 | 55668.3 |
| Yearly | 1780.5 | 890226.7 |

From figure (4.2) , it’s clear that the output power of the station varies with the amount of solar radiation during the month with its highest values between May and September.

### 4.2.2 Location of the Proposed System

With an optimum tilt angle of 28 degrees facing the south as it is illustrated in the figure (4.3) with 130 m away from the nearest connection point, while the longitude and the latitude for the proposed location is (35.18131, 32.07461) (Global Solar Atlas, 2008), while the physical location is between Salfit city and Amorya village and it’s going to be connected to the bus (46) as it is shown in figure (4.4).

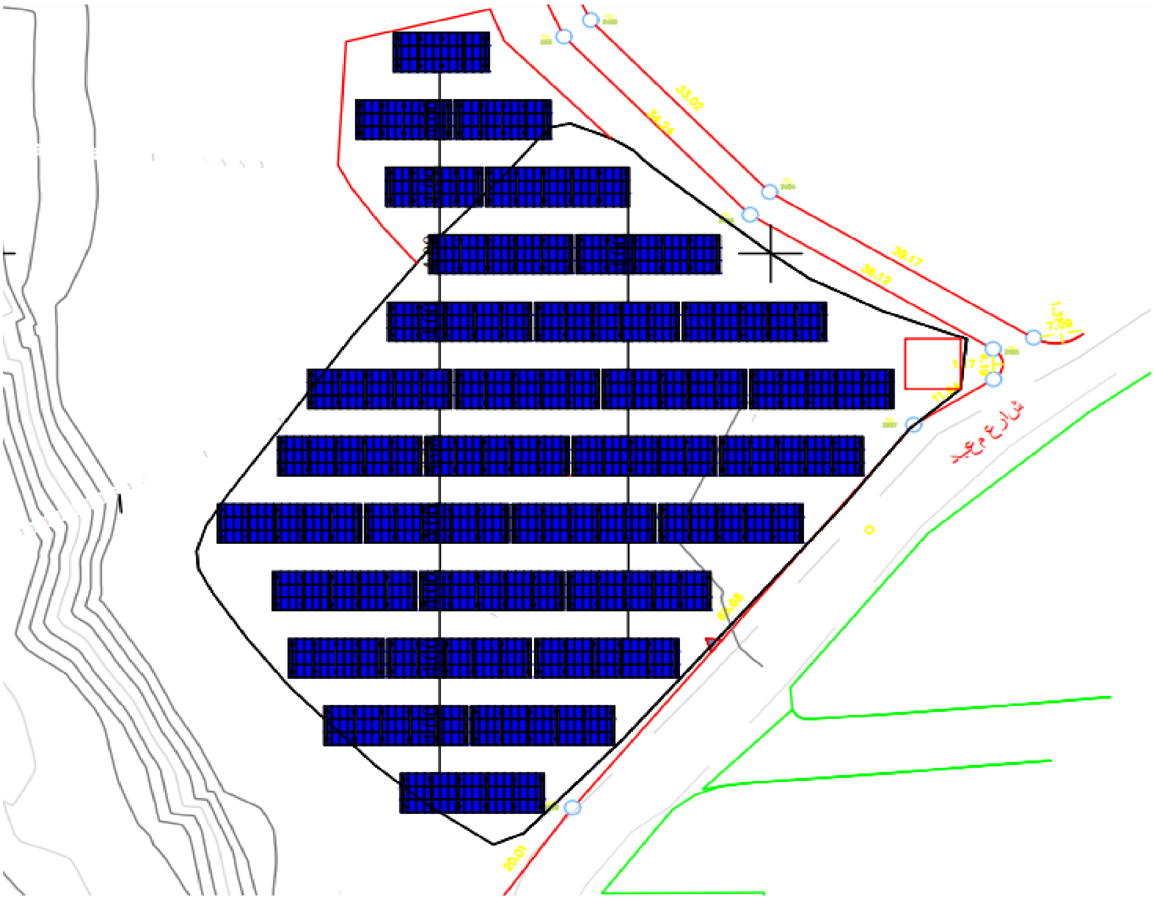


**Figure (4.3): PV layout for 0.5 MWp system**

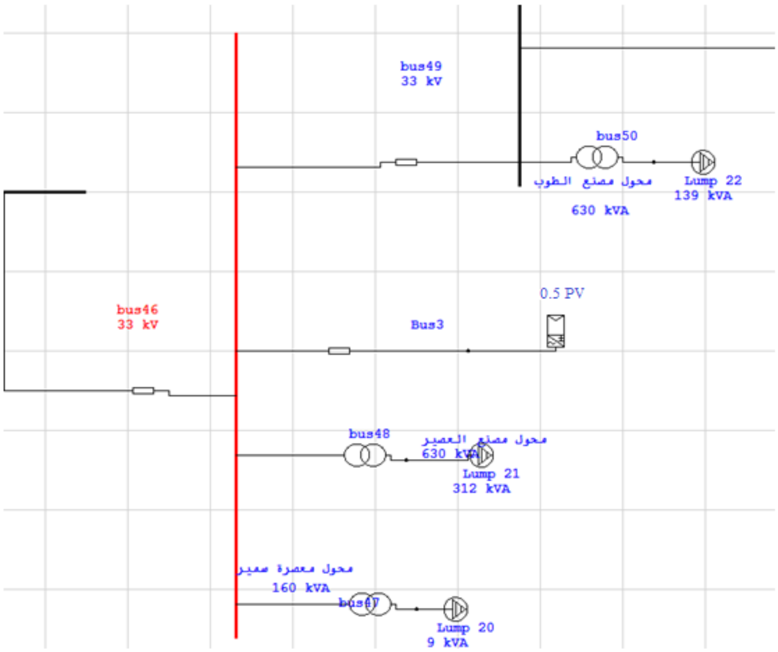



**Figure (4.4): PV station connection to the grid**

## 4.3 Grid Impact and Consequences for Grid Connected PV Systems

The DG of conventional sources has a predicted impact on the grid since its output and input are controllable. However, the intermittent DG (e.g., photovoltaics, wind) poses specific challenges given the volatile and uncontrollable nature of its primary source (Begovic et. al., 2012). Regarding the increase in the percentage of power systems connected to the network, the impact of these DG may lead to severe consequences related to the voltage regulation, power factor, and power losses real and reactive power, reverse power flow; which may affect the system stability.

### 4.3.1 Voltage Regulation

It can be defined as the difference between the actual voltage and the line voltage. The distribution networks are traditionally designed based on the downstream flow of power from the transmission network to the distribution network(Kharrazi et. al., 2020). Voltage regulation caused by the high penetration of the PVDG. The PVDG is connected to the electrical network since the output power of the PV depends on the climate. The out power which varies during the day causes the voltage change on the bus to which it is connected. However, the effects are particularly pronounced when a large amount of solar PV is installed near the less loaded feeders (Kumar & Selvan, 2017). This means that if the PVDG is at high levels, this will cause the voltage feeder to rise and may cause a reverse power. Figure (4.5) beneath shows the impact on voltage with and without PVDG with nominal load and light load:

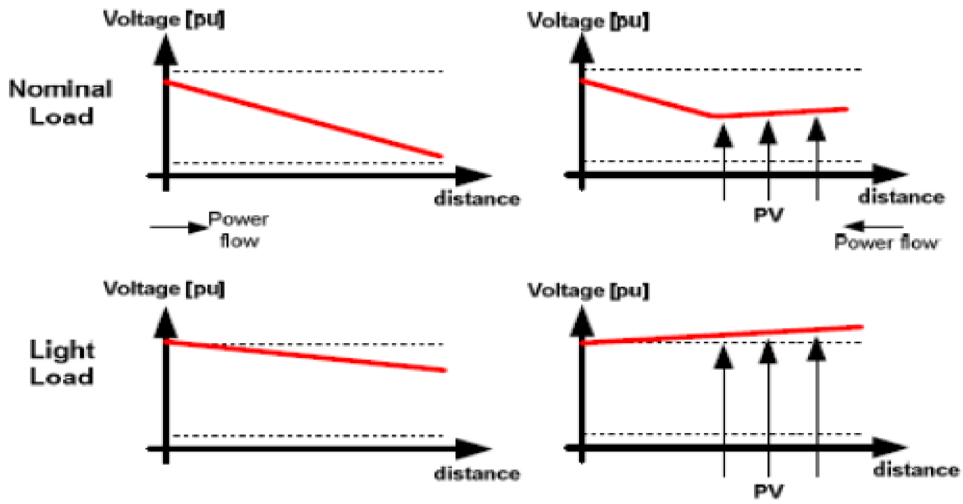



**Figure (4.5): Medium voltage with and without PV (Demirok et. al., 2009).**

### 4.3.2 Real and Reactive power

The most important aspect of the PVGD for utilities is that it reduces the peak demand and lowers the cost for the infrastructure. The PVDG provides the utility with real power injected into the network which causes the reduction of the demand and reduces the losses of the real power if the station is near the center of loads. However, the reactive power losses will increase as the real power is reduced from the connection point while the reactive power is kept the same. Reactive power is not less important than real power since reactive power makes it possible to transfer real power through transmission and distribution lines to customers (Borges & Falcao, 2006: 415).

### 4.3.3 Power losses

Reducing power losses is one of the advantages related to the PVDG. With low penetration of PVDG, the total current consumed by the feeder will reduce and cause a reduction in the power needed to be connected to the bus or through the lines. However, the large penetration level of PVDG may cause a reverse power flow and increase the magnitude of the line distribution current, line losses, and equipment loading (Begovic et. al., 2012).

### 4.3.4 Power Factor

As we know, the power factor can be represented as a function of the real power and reactive power represented by the following equation:

$$P.F = cos\ (invers\ tan(Q/P)) \qquad (4.2)$$

Where:

Q: reactive power.

P: real power.

Increasing the real power injected into the network will reduce the amount of power consumed from the connection point. As a result, the power factor will reduce and thus cause penalties to the utilities. This impact can be reduced by making the inverter of the PV not working in unity power factor. But, by allowing them to produce reactive power to compensate for the reduction in the power factor.

### 4.3.5 Power system stability

An IEEE/CIGRE Joint Task Force on Stability Terms and Definitions has defined the power system stability as the ability of an electric power system for a given initial operating condition to regain a state of operating equilibrium after being subjected to a physical disturbance with most system variables bounded so that practically the entire system remains intact (Kundur, 1994). However, since the power system is considered with the wide variability of the components and the faults and the condition that might occur on the power system or its components, a simple approach is considered to describe the system's stability. The following graph illustrates a summary for the classification of power system stability based on the dynamism of the phenomenon.

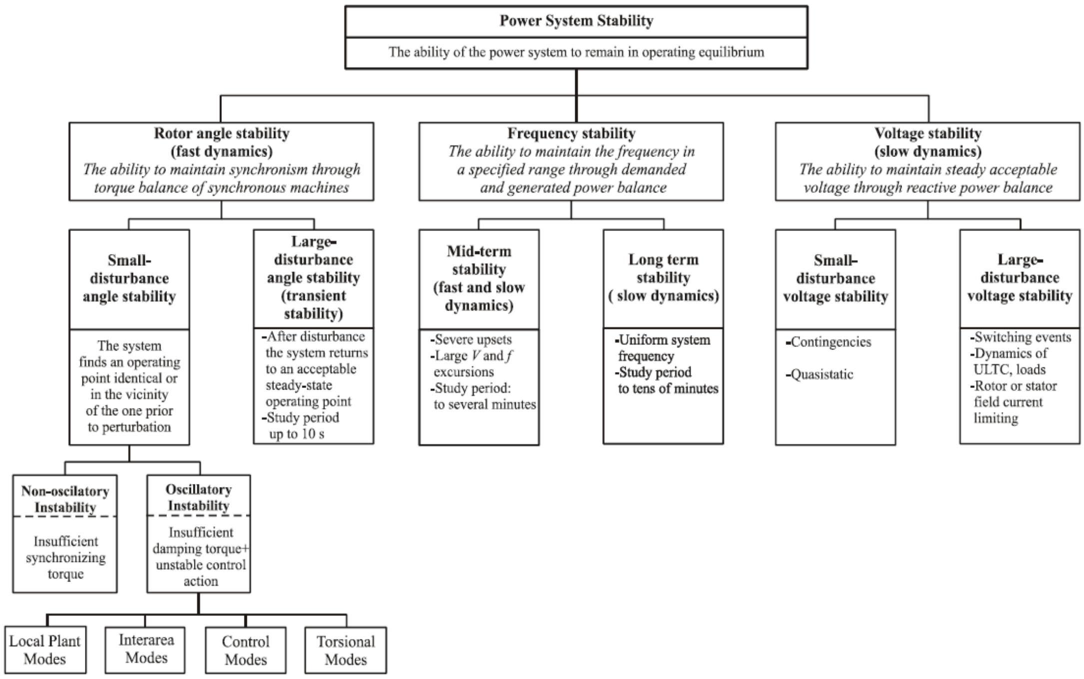



**Figure (4.6): Classification of power system stability based on the dynamics of the phenomenon (Kundur, 1994).**

For more understanding of the power system stability study and analysis, the fault can be represented with switching (on and off). Then, the behavior of the system depends on the type of fault that occurred whether it's a small or large fault. Afterward, a few points need to be checked to see if the system is stable or not, as well as the router angle, voltage stability, and frequency stability.

Rotor angle: its ability of the synchronous machine is to stay in synchronism after a fault or disturbance happens. Staying in synchronism means that the electromagnetic torque stays in synchronous rhythm with the output mechanical power of the prime mover. This rhythm might be broken with a large disturbance or a small one, such as; a low load disconnection of turning off a generator or it might be a large load. For more understanding of the rotor angle and the behavior of the synchronous machine, the swing equation will represent that as follows:

$$\theta = W_s T + \delta \tag{4.3}$$

Where:

$\delta$: angle between rotor field and reference angle (angular position of the rotor at any instant.

$T$ : Angular displacement.

$W_s$ : synchronous speed.

Differentiate both sides of the equation two times:

$$\frac{d\theta}{dt} = Ws + \frac{d\delta}{dt} \tag{4.4}$$

$$\frac{d^2\theta}{dt^2} = \frac{d^2\delta}{dt^2} \tag{4.5}$$

The result represents the angular acceleration

$$\alpha=\frac{d^2\,\theta}{dt^2}=\frac{d^2\,\delta}{dt^2}\text{ elec.rad/s}^2 \qquad (4.6)$$

The accelerating torque in a synchronous generator equals the difference between the mechanical input shaft and the electromagnetic output torque

$$T_a = T_s - T_e \qquad (4.7)$$

Where:

Ta: accelerating torque

Ts: shaft torque

Te: electromagnetic torque

While the angular momentum of the rotor is expressed by the following equation:

$$M = Jw \qquad (4.8)$$

Where:

M: angular momentum

J: moment of inertia

w: synchronous speed of the rotor

And we know that:

$$wT_a = wT_s - wT_e \tag{4.9}$$

Can be expressed as the following:

$$P_a = P_s - P_e \tag{4.10}$$

Where:

Pa: accelerating power input

Ps: mechanical power output

Pe : electrical power

But,

$$J\frac{d^2\,\delta}{dt^2} = T_a \tag{4.11}$$

$$J\frac{d^2\,\theta}{dt^2} = T_a \tag{4.12}$$

$$wJ\frac{d^2\,\theta}{dt^2} = wT_a \tag{4.13}$$

$$M\frac{d^2\,\delta}{dt^2} = P_a = P_s - P_e \tag{4.14}$$

Equation (4.14) gives the relation between the accelerating power and the angular acceleration.

# Chapter Five

# Environmental Impact Assessment of the Proposed PV System

## 5.1 Introduction

In Palestine, Environment Quality Authority (EQA) represents the main institution for enacting laws of the environment, and it works to ensure sustainability in Palestine. The EQA aims to improve the environment quality, maintains its diversity, and encourages economic and social improvements in ways that do not affect the environment (EQA, 1999). According to EQA, the following projects are listed as the ones which need a full environmental impact assessment:

- Power generation plants
- Quarries and mines
- Water treatment plants
- Cement factories
- Solid waste dumps
- Facilities that store dangerous materials
- Airport and runways
- Ports and harbors

- Oil refineries
- Industrial cities
- Reservoirs and dams
- Main roads
- Iron and steel

Since our project is considered as part of the power generation plants, there is a need to have a "no objection" for the project from EQA. Hence, the following steps represent the executive procedures for the environmental assessment for any proposed project:

- Environmental approval request (ERA).
- Initial environment assessment report (IEAR)
- Environment and social impact assessment report if needed.
- Environmental approval request (EAR):

The (EAR) is a document prepared by the proponent related to the project to ask related authorities, i.e., EQA, the Municipality, Palestinian Energy and Natural Recourses Authority (PENRA), etc., for no environmental objection. The EAR should contain a description of the project and a list of its activities and impacts on the environment. In our case, the municipality is the responsible authority to be contacted first.

- **Initial environment assessment report (IEAR):**

If the project is found to have a non-severe environmental impact, then EQA will ask the proponent to prepare an (IEAR). The IEAR includes a full description of the project with its environmental impacts. Hence, the EQA officer will make a site visit to the project site and fill a checklist, this step is called screening. This will be followed by the preparation of terms of references (TOR) by the EQA officer. The TOR is sent to the proponent to prepare a scoping report as part of a full environmental and social impact assessment report if needed. In this report, general prospective results of the project mainly depend on the amount of available information. The main purpose is to identify the potential environmental impacts, estimate how dangerous they are, and propose mitigation actions and environmental and social management plan.

- **Environment and Social impact assessment report (ESIAR):**

Based on terms of references provided by EQA, the EIAR document includes results out of the scoping process with detailed impacts of the projects' activities on the environment. Therefore, this report outlines all potential negative and positive impacts with proper mitigation procedures and plans. At the end of ESIAR, monitoring and environmental management plans will be prepared.

## 5.2 Project Description

### 5.2.1 General Description

Salfit municipally is planning to install PVDG with a capacity of 5 MW. The project is divided into four phases, starting with 0.5 MW PVDG in the first phase. The installation consists of several components which include solar panels of 1528 panels divided into seven groups connected to 7 inverters of 75 kW, with the solar panels having a capacity not less than 310 w connected to the inverters. Each inverter is connected to surge arrestors and then connected to a step-up transformer with a capacity of 630 kVA. The average expected working hours is 5.1 (1871 kWh/kWp) per day during the year. According to the municipality, the tender is still not finished yet due to components specification. However, the PV panels which the main component is expected to be from the top ten tiers in the world. The project will be oriented to the south with the appropriate angles; on the northern side of Salfit at the road connecting Salfit to Ramallah.

### 5.2.2 Expected Yield Energy and Technology

The total system is expected to produce 982,275 kWh per year. The electricity produced will be used to cover part of the city’s electricity consumption.

The total electrical generation over the 25 years is illustrated in Table (5.1) below. Five of the seven inverters will be connected to 1170 solar panels. The two remaining inverters will be connected to 216 and 198 respectively.

The modules will be installed on a galvanized steel structure with azimuth angle = 0 and tilt angle 25. Then, the inverters will be connected to the step-up transformer; after which they will be connected to the grid with a 50 $mm^2$ overhead aluminum transmission line with a total length of 130 m. Table (5.1) represents the expected output power for 25 years:

**Table (5.1): Expected yield energy for 25 years from 0.5 MWp**

| Year | Energy | Year | Energy |
|---|---|---|---|
| 1 | 982275 | 14 | 382394.31 |
| 2 | 913515.75 | 15 | 355626.71 |
| 3 | 849569.65 | 16 | 330732.84 |
| 4 | 790099.77 | 17 | 307581.54 |
| 5 | 734792.79 | 18 | 286050.83 |
| 6 | 683357.29 | 19 | 266027.27 |
| 7 | 635522.28 | 20 | 247405.37 |
| 8 | 591035.72 | 21 | 230086.99 |
| 9 | 549663.22 | 22 | 213980.9 |
| 10 | 511186.8 | 23 | 199002.24 |
| 11 | 475403.72 | 24 | 185072.08 |
| 12 | 442125.46 | 25 | 172117.04 |
| 13 | 411176.68 | | |

### 5.2.3 Project Work Intervals

For the aim of constructing and operating the project, all work involved consists of the construction and installation of the solar panels with all auxiliary units followed by the operation of the project.

- **Construction**

This stage included land preparation and leveling the ground so that the steel structure can be installed. Sources for water supply and electricity services for this stage must be provided. According to the tendering instruction, the contractor must establish offices for the engineers and the workers. It is also required to install a fence around the station then start installing the panels as planned. The contractor will build a room to install the electrical equipment in (inverters, electrical panels, transformer, and switchgear).

- **Commencing the project**

This starts by connecting the panels, then connecting them with the inverters. This will be followed by connecting the panels to the step-up transformer and then the transformer to the grid throws the switchgear.

## 5.3 Screening and Scoping and Terms of Reference Drafting of the Project

### 5.3.1 Screening

As mentioned before, screening often results in the categorization of the project, and, from this, a decision is made on whether a full EIA is to be carried out (Dougherty & Hall, 1995)

- **Land background and climate conditions:**

The project land, with a total area of 6.5 Dunum is in the southern direction of Salfit in the west bank as illustrated in figure (5.1). The land used to be an agricultural area. It is now used to build a PV plant to produce electricity with the first phase of 0.5 MW. Firstly, the land does have water and electricity services since it is located on the road from Salfit to a few villages nearby as is shown in the geographic information system, GIS for

Salfit city with the project location which is illustrated in Figure (5.2) underneath. Salfit Municipality reserves 20 dunums in the same area to establish PV plants. The municipality decided to make the area an industrial area in the master plan. Its climate is just like the Mediterranean with an average amount of rain of 750 mm and an average temperature of 28 $c^0$. However, it suffers from dust pollutants from a few factories nearby. It is located on the road between Salfit and other villages. The land can be considered as mountainous, and rich with olive trees, loaf, wild thyme, wild fennel, and Zaror, according to the Environment and Health Department in Salfit Municipality. Figure (5.2) below shows the nature of the land in that area. Take into consideration that the land does not contain any plants that are subjected to extinction. The area does not contain any people living near it. The work in the PV plant is going to be done by a contractor who respectively will provide workers, engineers, blacksmiths, and technicians. Fortunately, the land does not contain any cultural or heritage areas nearby that could be affected by the project. As for the underground water, it is completely safe since it’s on a mountain and the nearest underground water to the surface is 300 m away from the ground


**Figure (5.1): GIS picture for Salfit city (Shtayeh, 2021)**


**Figure (5.2): GIS picture for the project area (Shtayeh, 2021)**

The following table is used for screening purposes to summarize the characteristics of the proposed project and its potential impacts on the surrounding areas.

## Table (5.2): Properties of the proposed project

| Survey question | Potential effects |
|---|---|
| Environmental Sensitivity of project concerning existing and approved land use. | The project is sensitive for the environment since it uses a large area of the agricultural land |
| Availability, quality, and regenerative capacity of natural resources (including soil, land, water, and biodiversity) in the area and are underground. | N/A. But, after the end of the project, that might happen. |
| Potential of work to impact directly or indirectly on sites designated for nature conservation. | No specific place is used for nature conservation, but the project will affect the agricultural area and its surroundings. The land is considered industrial land. |
| Potential for impacts directly or indirectly on Habitats or Species | Project excavation will affect the habitats and the breeding places for the animals directly. |
| Potential for impacts on breeding places of any species protected under the Wildlife Act? | |
| Potential to impact directly or indirectly the Council Development Plan? | For the project implementation purposes the municipality considered the area as an industrial area relating to an approval requests from the vendor |
| Potential to impact directly or indirectly any protected structure or recorded monuments and places of Archaeological Interest | N/A |
| Potential to impact directly or indirectly | N/A |
| Listed or scenic views or protected landscape in the County Development Plan? | |
| Potential to impact areas in which there has already been a failure to meet the environmental quality standards and relevance of the project, or in which it is considered that there is such a failure. | N/A |
| Potential to impact on densely populated areas. | N/A |

- **Potential Impacts**

According to EQA template, and after the site survey, the main environmental elements that could be affected by the project are checked as “X” in Table (5.3) below:

**Table (5.3): List of the potentially affected elements**

| Type | | Environment element |
|---|---|---|
| Biophysical elements and their use | X | Climate and air quality |
| | X | surface water and quality |
| | X | Underground water and quality |
| | | Natural hazardous and terrain |
| | X | Soil and plants |
| | X | Wildlife |
| | X | Water resources |
| | | Tourism resources |
| | | Forest resources |
| | X | Agricultural resources |
| | | Mineral resources |
| Economical elements | X | Direct employment |
| | X | Indirect employment |
| | X | Labor market condition |
| | X | Sources of supply and resources |
| | X | Transportation requirements |
| | | Infrastructure development |
| | X | Governmental revenues and expenses |
| | X | Direct opportunities for economic development |
| Cultural and heritage elements | | Archeological places |
| | | Places for heritage use |
| | | Historical sites |
| Social elements | | Social and demographic |
| | | Population |
| | | Shelter |
| | X | Land use and water |
| | X | Transportation |
| | X | Goods delivery |
| | X | Local government revenues |
| | | Social support service |
| | | Community stability |
| | | Gender equality |
| Health elements | X | Health services and facilities |
| | | Water delivery for people |
| | X | Waste treatment and disposal |
| | X | Air and water quality around the project |
| | X | Public health-hazardous |
| | X | Protective worker health |
| | X | Noise |
| | X | Community health |

The main objective of this project is to maintain the continuity of electricity in Salfit and to reduce the IEC bill. However, this project still has its impact, whether on the technical side or on the environmental since we are talking about 6.5 Dunms to be used for this project. This type of project is associated with positive impacts or/and negative impacts. The positive ones or the advantages are the continuity of the electricity, employment opportunities, encouragement of clean energy implementation. On the other hand, the negative impacts and their mitigation measures are illustrated in Table (5.4) underneath:

**Table (5.4): The possible impacts and the mitigation measures**

| Impact | Mitigation measures |
|---|---|
| Solid waste generation and disposal | 1. Cleaning the site from the waste and sending it to special places. |
| | 2. Managing the waste to be used in other places or other projects or for this project during the construction phase. |
| Air pollution | 1. Minimizing the dust generation as much as possible. |
| | 2. Using sprinklers on the soil to reduce the dust. |
| Noise pollution | 1. Equipment delivery for the site will be during the daytime. |
| | 2. Working on the site will be during the day and not during the holidays.<br>3. using low noise machines if its applicable |
| Sourcing of raw materials | 1. The raw material must be compliant with Salfit Municipality. |
| | 2. The contractor will use the needed quantity for the project. |
| | 3. The contractor will use as much as possible from the solid waste obtained during the construction as base layer for the project |
| Occupational Health and Safety of Workers | 1. The contractor will employ well-qualified health safety officer |
| | 2. The contractor will provide a first aid kit on site. |
| | 3. The contractor will provide all workers and visitors in the field with all safety equipment. |
| | 4. Fence installation around the site. |
| Fire hazard | 1. Fire extinguisher/sand buckets/ water in the facility |
| Ground and surface water | 1. Waste will be removed from the site Special drains for the surface water will be used |

The considered renewable energy sources are clean and sustainable. Among renewable energy resources, solar energy offers a clean source for electrical power generation with zero emissions of greenhouse gases (GHG) to the atmosphere (Tawalbeh et. al., 2021). It is important to note that the $CO_2$ emissions for PV plants, with an average irradiance of 1700 $kWh/m^2$, are (60 g/kWh) (Alsema, 2000: 18). On the other hand, the $CO_2$

emissions for a conventional coal plant are (915.8 g/kWh) (Tahara et. al., 1997). In our case, for installing a 0.5 MW PV plant, the $CO_2$ reduction can be calculated as follow:

- $CO_2$ emission per year $= \frac{\text{energy produced} * \text{CO2 emission factor}}{\text{life time}}$ (5.1)
- The total energy expected from the 0.5 MW =7475549.29 kWh
- Life time expected for the project =25 years.
- The average $CO_2$ emission produced from the PV plant = 17.941 ton per year

The average $CO_2$ emission produced from the coal power plant for the same amount of energy =273.8 ton per year.

- $CO_2$ reduction =255.9 ton $CO_2$ per year.

### 5.3.2 Environmental and Social Risk Assessment

Here, a description of the potential impacts on the biophysical and socioeconomic environments are described, which may occur due to the project's proposed activities. Impacts are identified and predicted based on the analysis of the information collected from the following:

- Project description information.
- Site visits and meeting project's stakeholders

According to the WB, all projects (including projects involving Financial Intermediaries (FIs)) are classified into one of four classifications: High Risk, Substantial Risk, Moderate Risk, or Low Risk. In determining the appropriate risk classification, the WB considers relevant issues, such as the type, location, sensitivity, and scale of the project; the nature and magnitude of the potential environmental and social risks and impacts; and the capacity and commitment of the Borrower (including any other entity responsible for the implementation of the project) to manage the environmental and social risks and impacts in a manner consistent with the ESSs. To assess the significance of the potential environmental and social impacts, the criteria shown in Table (5.5) below is used implicitly for each impact, while Table (5.6) shows the risk assessment for each impact.

**Table (5.5): Risk assessment criteria**

| Parameter | Evaluation Description | Rating |
|---|---|---|
| Special Influence | Low: Within the project site | 1 |
| | Medium: Widespread impact beyond site boundary; Local | 2 |
| | High: Impact widespread far beyond site boundary; Regional/national | 3 |
| Duration | Low: Quickly reversible, less than project life, short term (0-5 years) | 1 |
| | Medium: Reversible over time; medium-term to the life of the project (5-15 years) | 2 |
| | High: Beyond closure; permanent; irreplaceable or irretrievable commitment of resources | 3 |
| Intensity | Low: Minor deterioration, nuisance or irritation, minor change in species/habitat/diversity or resource or very little quality deterioration; very little improvement | 1 |
| | Medium: moderate deterioration, discomfort. Partial loss of habitat biodiversity/resource or slight or alternation, moderate improvement. | 2 |
| | high: habitat/diversity or resource, severe alteration or disturbance i mportant processes; severe improvement | 3 |
| Probability | Low: Unlikely likelihood; No known risk or vulnerabilityto natural or induced hazards. Unlikely; low likelih ood; Seldom No known risk vulnerability to natural or induced hazards. | 1 |
| | Medium: Possible, distinct possibility, frequent Low to medium risk or vulnerability to natural or induced hazards. | 2 |
| | High:Definite (regardless of prevention measures),highlylikely, continuous high risk or vulnerability to natural or induced hazards. | 3 |
| Significance Risk | Deduced from the summation of the ratings with the range d efined as follows: 1- 4 as low, 5-7 moderate; 8-10 Medium and 11-12 High | |

## Table (5.6): Risk assessment for each element

| No | Parameter | Risk | Descriptive Adjective | | Significance Risk |
|---|---|---|---|---|---|
| 1 | Air quality | The impact on the air quality will be concentrated around the project area but it will be irreversible quickly after the implementation of the project in a short time, while the intensity of the impact will be concentrated during the construction stage the impact on air quality will maintain during the three stages of the project. | Probability | 2 | Medium |
| | | | Intensity | 2 | |
| | | | Special Influence | 2 | |
| | | | Duration | 2 | |
| 2 | Earth | The impact will be concentrated in the project area caused by the excavation happens. The earth itself will be restrained after the end life of the project. The intensity of this impact will be on the first stage and getting lower in the other stages. | Probability | 3 | Medium |
| | | | Special Influence | 2 | |
| | | | Intensity | 3 | |
| | | | Duration | 1 | |
| 3 | Topsoil | The impact on the soil is low since there are no chemical materials within the project equipment, the impact on the soil will be concentrated within the project area, the intensity of the impact will be during the first stage, but it will be irreversible within the project life. | Probability | 2 | Moderate |
| | | | Special Influence | 1 | |
| | | | Intensity | 2 | |
| | | | Duration | 2 | |
| 4 | Water resources and wastewaters | The resources might get affected even outside the project area from the excavation and the accident which might occur to the main pipelines near the project, this impact is possible to happen | Probability | 1 | Moderate |
| | | | Special Influence | 1 | |
| | | | Intensity | 1 | |
| | | | Duration | 2 | |
| 5 | Noise | The noise impact will be concentrated during the first stage of the project and with being irreversible but still, it will spread outside the project area but still for a very short time . | Probability | 3 | Medium |
| | | | Special Influence | 2 | |
| | | | Intensity | 2 | |
| | | | Duration | 1 | |
| 6 | Natural habitat | The impact on the natural habitat is only on the project area and the surrounding of the project but still low since no Haigh intensity of this impact related to the low number of animals in the area, and it’s irreversible during the lifetime of the project. | Probability | 1 | Low |
| | | | Special Influence | 1 | |
| | | | Intensity | 1 | |
| | | | Duration | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Flora and fauna | The plants and the wildlife will be affected by this project even in the areas surrounding the project area, the excavation and the noise including dust and waste material are reasons for this impact, and it is irreversible after the end life of the project. The intensity of this impact could be considered moderate and it is definite to be happen. | Probability | 2 | Medium |
| | | | Special Influence | 2 | |
| | | | Intensity | 2 | |
| | | | Duration | 3 | |
| 8 | aesthetic and landscape | This impact is likely to last to the end of the project life and after that, since changing the shape and the nature of the land also the view will be affected, this impact is definite to happen, with high intensity and its effect could be seen outside the project area. | Probability | 2 | Medium |
| | | | Special Influence | 2 | |
| | | | Intensity | 2 | |
| | | | Duration | 2 | |
| 9 | Agriculture | The impact on the land and the soil is medium, the agricultural effect will be concentrated only on the project area and it will happen for the project lifetime with low intensity. | Probability | 2 | Medium |
| | | | Special Influence | 1 | |
| | | | Intensity | 2 | |
| | | | Duration | 3 | |
| 10 | Livestock | The life stoke in the project is low and might be neglected | Probability | 1 | Low |
| | | | Special Influence | 1 | |
| | | | Intensity | 1 | |
| | | | Duration | 1 | |
| 11 | Health and safety of residents and worker | Most of this effect will be concentrated during the first stage of the project implementation and it will be concentrated on the project area only, this effect is a medium risk to happen, but it still might be happening with low possibilities during the life project | Probability | 1 | Moderate |
| | | | Special Influence | 2 | |
| | | | Intensity | 2 | |
| | | | Duration | 3 | |
| 12 | Areas of historical and cultural value | N/A | Probability | - | N/A |
| | | | Special Influence | - | |
| | | | Intensity | - | |
| | | | Duration | - | |
| 13 | Resettlement and Land acquisition | N/A. | Probability | - | N/A |
| | | | Special Influence | - | |
| | | | Intensity | - | |
| | | | Duration | - | |

The assessment for the affected elements shows that the risk in this project is significant. It will need an environmental and social management plan associated with the monitoring plan to reduce and mitigate the impacts of these elements

### 5.3.3 Scoping and Terms of Reference

Scoping is the process of determining which the most critical issues to study are and the impact of this project on the environment (Eminoglu & Hocaoglu, 2005). Following the above screening step, the terms of reference that will be received from EQA. The specific requirements for the initial environmental assessment, according to the EQA, should discuss the environmental impact and the related issues to the environmental elements listed in the above table. Based on the screening phase, the following environmental parameters are further elaborated for their impact resulting from the project's activities.

- Air quality
- Surface water
- Soil and plants
- Water resources and their use
- Wildlife
- Transportation
- Infrastructure

- Landscape features
- Worker service
- Public health
- Wastewater
- Noise
- Solid residue
- **Environmental impact assessment using Leopold matrix**

Leopold matrix is used for project analysis regarding the probable impacts on the environment associated with all the work activities of the project. The advantage of using Leopold Matrix that it is 'as a checklist or reminder' where the large scope of actions and impacts on the environment can be related to the proposed actions (Josipovic et. al., 2014). The Leopold matrix consists of three main elements: the effects on the environment, the magnitude of the effects, and the importance of each effect taking into consideration the work activities related to each stage. Stages start with pre-construction, construction, and operation. The work activities for our project are listed below:

**1. The construction phase:**

- Ground leveling.
- Spread the base layer.
- Fence installing.
- Bases preparation (drilling).
- Ground leveling.
- Build control room.
- Panel's installation.
- Inverters and electrical panels.
- Cable and electrical component installation.

**2. Operation phase**:

The environmental elements will be the terms of the reference in the previous section, while the impact estimation for each element will be divided into magnitude in the upper corner of the rectangle with a range from (1-14). This means how much the relationship between the selected environmental element and the project activities is. In other words, the element with the higher number is the most affected. The importance in the lower corner of the rectangle with a range of (1-14) describes the importance of the element during the work activity. The higher the value, the higher the importance; the lower the value, the lower the importance.

Assignment of a numerical value for importance is based on the subjective judgement. A simple matrix will be used with the activities in the horizontal part and the TOR in the vertical part to find if there is any interaction between them as it is illustrated in Table (5.7), while Table (5.8) represents the Leopold matrix for our project.

**Table (5.7): Environmental Elements Simple Matrix Table**

| Environmental Impact Factors | Ground Leveling | Spread the Base Layer | Fence Installing | Bases Preparation (Drilling) | Steel Structure Installation | Build Control Room | Panels Installation | Inverters and Electrical Panels | Cable and Electrical Component Installation | System Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|
| Air Quality | X | X | | X | | X | | | | |
| Surface Water | X | | | | | X | | | X | |
| Soil | X | X | | X | | X | | | X | |
| Noise | X | X | X | X | X | X | X | X | X | X |
| Water Resources | X | | | X | | X | | | | |
| Infrastructure | | | X | X | X | X | X | X | X | |
| Flora | X | X | | | | | | | | |
| Fauna | X | X | | | | | | | | |
| Landscape | X | X | | | X | X | X | | | |
| Transportation | X | X | X | X | X | | X | X | X | X |
| Public Health | X | X | | | | X | | | X | |
| Worker Service | X | X | X | X | X | X | X | X | X | X |
| Wastewater | | | X | | | X | X | X | X | X |
| Solid Residue | X | X | X | X | | X | | | | |

| | | envirimenta impact factors | ground leveling | spread the base layer | fence installing | bases preparation (drilling) | steel structure installation | build control room | panels installtion | inverters and electrical panels | cable and electrical component install | system maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | project activities | pre construction | | | construction | | | | | | operation |
| physical components | | air quality | 13/14 | 11/2 | 3/2 | 11/8 | 1/1 | 9/5 | 1/1 | 1/1 | 1/1 | 1/1 |
| | | surface water | 12/7 | 13/3 | 3/1 | 3/1 | 1/1 | 8/4 | 1/1 | 1/1 | 2/1 | 1/1 |
| | | soil | 14/14 | 15/10 | 4/2 | 7/2 | 1/1 | 12/7 | 1/1 | 1/1 | 6/2 | 1/1 |
| | | noise | 10/4 | 11/9 | 5/2 | 9/2 | 5/7 | 6/2 | 4/2 | 2/1 | 3/1 | 3/1 |
| | | water recsources | 6/5 | 6/1 | 2/2 | 4/1 | 4/1 | 7/2 | 3/1 | 1/1 | 2/1 | 1/1 |
| | | infrastucure | 2/12 | 2/1 | 3/1 | 2/1 | 2/1 | 6/3 | 1/1 | 1/1 | 3/1 | 1/1 |
| biological components | wild life | flora | 11/12 | 8/4 | 1/1 | 1/1 | 1/1 | 2/1 | 1/1 | 1/1 | 1/1 | 1/1 |
| | | fauna | 11/12 | 8/3 | 1/1 | 1/1 | 1/1 | 2/1 | 1/1 | 1/1 | 1/1 | 1/1 |
| socio-cultural component | | landscape | 9/11 | 10/2 | 5/2 | 4/2 | 7/6 | 7/1 | 9/4 | 1/1 | 3/1 | 1/1 |
| | | transportation | 10/6 | 14/8 | 11/3 | 5/2 | 8/2 | 6/3 | 6/3 | 3/1 | 3/1 | 3/1 |
| | | publice health | 1/8 | 10/5 | 1/4 | 5/1 | 5/1 | 4/1 | 2/1 | 2/1 | 5/1 | 2/1 |
| | | employment | 14/5 | 12/5 | 3/2 | 4/5 | 6/3 | 8/5 | 7/5 | 5/3 | 6/6 | 5/3 |
| chimecal component | | waste water | 6/1 | 12/1 | 1/2 | 2/1 | 2/1 | 5/2 | 2/1 | 3/1 | 2/2 | 1/1 |
| | | solid resdue | 10/8 | 11/1 | 4/2 | 8/4 | 2/1 | 5/2 | 2/1 | 1/1 | 1/1 | 1/1 |

**Figure (5.3): Leopoled Matrix**

After evaluating the impacts using the Leopold matrix, the following summarizes the impact of the project's activities on each element starting from the construction phase and ending with the operation phase.

## 1. Construction phase

**Air quality**: there will be a potential impact on the air quality for the surrounding areas associated with excavation and construction, due to the dust generation from construction and the wind which will increase the dust. Also, transportation and traffic in the area will affect the air quality due to the increasing emissions from any vehicle or construction machines like bulldozers. Additionally, the dusty area and roads will also increase the odds for dusty air, from the Leopold matrix and during the construction phase the importance and the magnitude for this element is high since the majority of the dust and the pollutants will be during the construction and pre-construction, that is why it's assigned with 13 for the magnitude and 14 for the importance.

**Surface Water:** surface water will be affected by the construction and demolition of the area, the oil spill from the trucks and construction machines. Additionally, some contaminants from the construction and solid waste will affect the surface water, the importance and the magnitude represented in the Leopold matrix is much more affected during the construction phase than the operation one, because of the excavation during this period, that’s why it is assigned with 12 for the magnitude and 7 for the importance during the preconstruction phase.

**Soil and plants**: mixing, losses, compaction, pollution; these things will happen to the soil from the construction demolition and excavation. Not to mention the association of solid waste and trucks and transportation with pollution. On the other hand, the plants will suffer from the removals with no certain type threatened by extinction. Referring to the Leopold matrixes, the magnitude assigned with 14 and the importance with 14 will be directly connected with this element. However, the magnitude and importance will get lower during the next phases.

**Water resources and their use:** the potential risk might happen for the water resources and underground water from leakage of contaminants through construction and creating new pollution pathways. Not to mention the risk from the leakage from the sewage water to the main water, from the site location, and the establishment for the water drains and main water pipes the risk is much lower so this element is assigned with 6 for the magnitude and 5 for the importance during the pre-construction phase, the dependence of the assigned numbers of this element on the location of the water pipes.

**Wildlife:** the project area is not classified as legal or illegal for its nature and for the certain type of wildlife that it contains. The potential ecological impacts for the project are the losses for the habitat of some nesting birds due to clearance and excavation of the area. Not to mention the removal of some olive trees and plants which also might be a habitat for certain types of animals**.** Due to the large impact of the project on the project area, specialty the flora and the fauna, the magnitude and the importance assigned are of high value; the magnitude 11 and the importance 12.

**Transportation:** temporary delay in transportation in the area, a contaminant from the trucks and its cargo, blocked roads, the increase in heave vehicle in the roads which carry goods, public transportation capacity and impact on the facilities and factories**,** during the construction and preconstruction phase of the project the transportation will increase significantly. Accordingly, it is assigned 10 for the magnitude and 6 for importance.

**Infrastructure:** the effect on the infrastructure for the area is somewhat low. The project will cause a little increase in water consumption, electricity consumption, in the number of vehicles on the roads, and it will increase more with certain circumstances like breaking the main water pipeline or damage of the electrical near network, the effect as its mention is low, for this reason, the magnitude and the importance for this element are assigned with 2 and 12 respectively.

**Landscape features:** the area of the project will suffer from excavation demolition and construction changing the nature of the land. Not to mention the leveling of the land and view starting with the panel installation to the new electricity towers and cable. The landscape characteristic for the near land should be considered on-site and off-site; the project impact should be as low as possible for them. Changing the topology of the land will be high during the construction and preconstruction phase since it's changed from an agricultural area into a PV plant site (project area) so it's assigned with 9 and 11 for the magnitude and the importance respectively.

**Worker service (employment):** per the project implementation, the project will provide opportunities for the local workers to work and train if needed, and it will provide long-term employment for certain jobs. The impact will increase to reach the existing business in the area, and it will be a good material for learning and training for the trainees for this it's assigned 14 for the magnitude and 5 for the importance as it's considered a positive effect.

**Public health:** the impact of the project will reach the near areas and facilities from the ongoing construction and air pollution. Additionally, they will be affected by the noise and the solid waste generated. They will also be affected by the wastewater generated in the site associated with the offices of the workers and engineers. There might also be the occurrence of accidents that might happen from the trucks and heavy vehicles carrying goods for this during the construction and pre-construction. It is assigned 1 for the magnitude and 8 for the importance. During the spreading of the base layer, the impact is much higher with 10 for magnitude and 5 for importance.

**Wastewater (solid or liquid):** the surface water will be affected by the wastewater generated in the site. Additionally, the underground water will be affected if unsuitable ways are used to deal with the wastewater; like using pits to cover it. Not to mention it will affect the health of the near occupants and the workers on the site, its impact depends on the working phase and the location of the wastewater disposal area. Thus, it is assigned 6 for the magnitude and 1 for importance. However, during the spreading of the base, it is assigned 12 and 1 for magnitude and importance respectively

**Noise:** the impact of the noise will appear during all phases of implementation of the project; starting from the construction machines to the inverters working and through the goods transportation by trucks and the movement of the construction vehicles, affecting the nearby occupants and affecting the wildlife (animals) nearby. Accordingly, it is assigned 10 and 4 for magnitude and importance. However, the criteria for magnitude and importance ratings depend on the near area and the occupants in it.

**Solid residue:** the creation of the solid waste will be during the construction phase only. Dust, stones, and iron structures will be produced. Unsuitable disposal of them will affect the near area, occupants, nature, and wildlife. During the construction and preconstruction phases, the residue will be high; hence it is assigned 10 for magnitude and 8 for importance**.**

**2. Operation phase**

**Air quality**: during the operation phase, the impact will be lower, and it will be affected by transportation, especially for maintenance and site visits. Thus, the impact is high in the construction phase compare to operation  as it is reflected through the assigned values for magnitudes and importance; 11 and 8 respectively.

**Surface water**: impact on the surface water will be affected by the oil spills that might happen from the vehicle that visits the site; whether it’s for maintenance or monitoring. Hence, the magnitude is assigned 1 and importance 1.

**Soil and plants:** during the operation phase the impact is much lower. The soil will only suffer from the mixing and pollution with the contaminates existed in the materials used to clean the panels. During the operation phase, the impact is low. Thus, the magnitude and importance are assigned 1 and 1 respectively.

**Water resources and their use:** the surface water or the underground water will not be affected by the operation phase, since there is no construction or excavation in the area. Therefore, the magnitude is assigned 1 and importance 1.

**Wildlife:** the impact on plants and trees will be lower than the impact on animals since the habitat for some animals will be affected during the operation phase. It is important to note that the major impact happens during the construction and preconstruction phases. Thus, the magnitude and importance are assigned 1 and 1 respectively.

**Transportation**: the number of vehicles that visit the site will be lower. The purpose of the visits will be for monitoring or maintenance. During these situations, the impact might appear on the air, infrastructure, and water resources. Accordingly, the impact during the operation will be lower; hence assigning the magnitude 3 and importance 1.

**Infrastructure:** the impact on the operation phase will be lower than the construction phase. However, during the operation phase, the number of materials used will be higher since there are some used to clean the panels regularly. Also, electricity usage is going to increase for maintenance purposes. Not to mention that the road usage and traffic generation will be much less than in the construction phase. Hence, during the operation phase, the magnitude is assigned 1 and importance 1.

**Landscape**: landscape features impact will be much less or might be neglected during the operation phase since the major change is going to happen during the construction phase. Accordingly, the magnitude is assigned 1 and importance 1.

**Worker service:** during the operation phase, the impact on employment opportunities will be less than that at the construction phase. It will focus on monitoring and cleaning the panels with full-time job opportunities for one or two persons. Accordingly, it is considered a positive impact and assigned 3 for importance and 5 for the magnitude**.**

**Noise:** the noise levels during the operation will be at their minimum; since the loud instruments, such as the inverters, will be installed inside a special room. Therefore, the noise might be neglected. Since the noise could be neglected as an impact during the operation, the magnitude is assigned 3 and importance 1.

**Solid residue**: the amount of solid waste and residue during the operation phase is negligible. Thus, the impact can be neglected. Accordingly, the magnitude and importance are assigned 1 and 1 respectively.

**Wastewater**: the amount of wastewater produced during the operation is higher than the construction because of the cleaning for the panels. The produced water contains contaminants that might affect the surface water. However, it has a lower impact during the operation. Therefore, the magnitude is assigned 1 and importance with 1.

**Public health**: the near occupants around the project area will suffer less in this phase; mainly from the noise caused by the cleaning machines or from the vehicle. Due to the lower impact on public health during the operation phase, the magnitude and importance are assigned 2 and 1.

The estimated values for the magnitude and importance for each element during each phase depends on the project area, the topology of the land, the infrastructure used, the population in that area, road usage from the nearby occupants, the activities of the project, and the responsibilities associated with all the stakeholders for the project. All these factors draw the frame of evaluation for each element.

# Chapter Six
# Environmental and Social Study

## 6.1 Introduction

Salfit municipality is considering using international financing for the implementation of the PV plant project. It is also aiming toward World Bank funding, as the renewable solar energy projects are under the umbrella of funding of the World Bank. An environmental impact assessment was carried out to meet the environmental and social requirements for the World Bank funding process. The EIA contains:

- Project discerption (described previously)
- Legislation framework
- Stakeholder engagement
- Communication and grievance mechanism
- An environmental and social management plan
- Monitoring plan

## 6.2 Legislation framework

According to the environmental law in 1999, it assures that all the projects implanted in Palestine should consider the environmental issues. This project falls under the enacting laws from the environment quality authority (EQA). Environmental assessment provides effective means that integrate environmental factors into the planning and decision-making process; in a way that enhances the sustainable development process (Dougherty & Hall., 1995). Also, the Palestinian Energy and Natural Recourses (PENRA) authority, referring to the electrical law in 1997, states that every electrical facility issues the requirements to implement the environmental conditions that must be met in electrical installations. On the other hand, the local ministry of the local government asked the municipalities to be committed to the laws issued from the related fields. Using the World Bank framework for EIA will be under the legislative laws of Palestine related to the environmental concerns, taking in account the World Bank ESS

## 6.3 Gap Analysis between Palestinian Laws and World Bank Safeguard Statements

The World Bank's environmental and social framework shows the Bank's commitment throughout the policies that shape the procedures of the World Bank. To reduce the poverty and decrease the richness of the people, this framework comprises (The World Bank, 2017):

1. Vision for Sustainable Development.
2. The World Bank Environmental and Social Policy for investment and financing.
3. Environmental and Social Standards.

This environmental and social framework provides standards that the project must go through its life cycle and referred to them as ESS and they are:

- ESS1: Assessment and Management of Environmental and Social Risks and Impacts.
- ESS2: Labor and Working Conditions.
- ESS3: Resource Efficiency and Pollution Prevention and Management.
- ESS4: Community Health and Safety.
- ESS5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement.
- ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources.
- ESS7: Indigenous Peoples/Sub-Saharan African Historically Underserved Traditional Local Communities.
- ESS8: Cultural Heritage.
- ESS9: Financial Intermediaries.
- ESS10: Stakeholder Engagement and Information Disclosure.

The Palestinian environmental legislations are not as serious and comprehensive as the way by which the World Bank works. The World Bank depends, in applying the social and environmental standards comparing applicable regulations are within the borrower country. If such regulations are stricter, then they are applicable; if not, then the standards of the World Bank are applied. What follows is a comparison between the World Bank's ESSs (The World Bank, 2017) and what is applied in the Palestinian National Regulations (EQA, 1999). The first Environmental Social Standard (ESS1) calls for the assessment and management of environmental and social risks and impacts. One of the first objectives of ESS1 is to be able to evaluate, assess and regulate the environmental and social risks or impacts. In 1999, the environmental Act No. 7 stipulated that its aim for the protection of the environment the various kinds of pollutants. Not to mention that it also calls for the installment of environmental protection bases in future economic and social planning. Act No. 7 additionally calls in other sections for the identification of environmental projects, the setting out of the standards of the environmental projects as well as the observation of such environmental projects. Hence, Act No. 7 depicts compatibility with Standard 1 regarding the identification and assessment of risks and impacts on the environment.

ESS1 also calls for the adoption of a mitigation hierarchy that can predict and avoiding risks, mitigating the risks should they be unavoidable, and compensating when there are residual impacts that remain. Act No. 7 of 1999 also goes hand in hand with the previously stated aims; as it calls for the protection, mitigation, and compensation of environmentally sensitive areas.

ESS1 additionally calls for the adoption of taking various measures to make sure that the impacts do not fall all at once over a disadvantaged or vulnerable area. In the Palestinian National Laws, however, there is a discrepancy in that it does not provide any provisions for the adoption of different measures.

Furthermore, ESS1 stresses the significance of utilizing national environmental and social institutions, systems, or laws in the assessment and implementation of projects. In Palestine, there exist various institutions and laws, such as the EQA, the Palestinian Environmental Friends Association, and the Environment Act No. 7, all of which assist in the assessment and implementation of environmental projects. ESS1 also calls for the promotion of improved environmental performance. The Palestinian National Regulations, as well, supports the improvement of environmental performance as it did through “the Project to strengthen the capacity of the Ministry of Environmental Affairs in the field of supervision and inspection 2013”.

Another standard that has been stipulated by the World Bank is ESS2 which focuses on labor and working conditions. It stresses the vitality of promoting safety and welfare at work. Article 34 of Section 5, Chapter 1 of the Public Health Act No 20, 2004, stipulates the health conditions which must be met in work. There are other Articles of other regulations which also emphasize the necessity of laying out the working hours per week, the resting period during work, and the necessity of providing all needs of protection during work. ESS2 also focuses on promoting a fair environment of labor with equal opportunities with no source of discrimination. In Palestine, the Employment Act No 7, 2000; Article 2, also stresses the fact that work is a right for every person who is fit to work. It also prohibits gender discrimination between men and women. Additionally, when ESS2 focuses on protecting the rights of vulnerable workers, workers with disabilities, and women, the previous Article also emphasizes the previous idea that work is a right for every citizen with the necessity to employ disabled workers who have the appropriate qualifications to work, to employ women and treat them equally as men, to prohibit the employment of children, and other aspects which go hand in hand with the objectives of ESS2. ESS2 has other objectives to be met which are compatible with the Palestinian National Regulations. However, a gap could be depicted in the objective of providing workers with accessible means to raise their concerns in their workplace. In Palestine, there are no such direct regulations nor labor courts. Thus, it is necessary to work on this point and develop a grievance mechanism for workers to express their work concerns.

Another standard of the World Bank is the one that focuses on the efficient management and prevention of pollution (ESS3). ESS3 focuses on the aspects of promoting the usage of sustainable resources, minimizing or avoid, if possible, the impacts on humans and the environment, minimizing or avoid the emissions of the projects and other climate pollutants, and managing the production of hazardous waste. The Palestinian Environment Act No. 7, 1999, as well, calls for the protection of the environment from pollutants. Such protection includes all kinds of nature, including air, water, soil, and others. However, the national laws do not address all the requirements of the ESS3, hence creating a small discrepancy between the national laws and ESS3. As for the other previously stipulated objectives, the national laws do not depict any significant gap as they also focus on the protection of the environment of all pollutants, the analysis of the environmental projects and their prospected impacts on the humans and environment, the mitigation of impacts or avoiding them if possible, and the compensation for damaged areas. They also stress the necessity of decreasing or avoiding pollutants using the appropriate equipment and measures. All these aspects are illustrated profusely in the Environment Act No. 7, 1999 in various chapters which discuss each point separately and comprehensively.

The World Bank has also stipulated another standard that focuses on the health and safety of a community (ESS4). ESS4 revolves around the objectives of stressing the importance of anticipating and avoiding impacts on health and safety. It also seeks to minimize the community’s exposure to traffic and road risks or diseases, to maintain safety measures in cases of emergency, and to make sure that the community does not face and risks by any environmental object-related impacts. Unfortunately, there is an evident gap in the Palestinian National Regulations. There is yet to be a plan that ensures the safety and health of a community from any impact that may occur. As for the avoidance of diseases and road risks, there are several provisions, such as Traffic Act No 5 of 2000, and Articles (7, 11, 12, 13), which address the fact that all conditions of road safety, waste management plans, the restriction of using dangerous materials and other things that may risk the health of a community must be met. However, a gap persists between these provisions and the ESS4 in that these provisions only offer guidelines with no detailed instruction of what must be done. The very same gap persists with the other objectives of ESS4.

The World Bank also pays heeds to the protocols of land acquisition and places restrictions on land use (ESS5). It classifies, accordingly, the people who are eligible for land acquisition or with legal rights or a claim to land and assets. Fortunately, the civil regulation in Palestine goes hand in hand with this objective of avoiding involuntary resettlement. Hence, we have the Palestinian Civil Act No 4 of 2012, the Palestinian Constitution Article 21, and other acts, all of which stress the illegality of forcefully depriving anyone of their rightful property. ESS5 also has the objectives of avoiding forced evictions, assisting any displaced people in retaining their livelihoods, improving the living conditions of the poor, and other objectives which protect the rights of the people. Fortunately, the Palestinian law states various procedures to be followed for the acquisition of land or property in a way that does not negatively impact the people. It also suggests certain cases of evictions with a necessity to provide compensations for the people, such as the Land Expropriation Act No 2, 1953, Article 5, Article 6, Article 7, and others.

The World Bank additionally addresses the idea of conserving biodiversity and managing natural resources (ESS6). For the protection of habitats and biodiversity, the Environment Act No 7 of 1999 includes many Articles which sets grounds for the protection of natural habitats (Article 40), the prevention of hunting wild animals (Article 41), and the protection of biodiversity (Article 42). The only discrepancy that exists between the Palestinian National Regulations and the ESS6 is that the Palestinian regulations do not include any actual measures to protect biodiversity and natural habitats. ESS6 also necessitates the inclusion of mitigation measures in the case of projects which may influence biodiversity. In Palestine, luckily, we have the Environment Act No 7 of 1999 which aspires for the protection of the wildlife of all kinds of pollutants that may emit from the projects. On the other hand, other Palestinian Acts add to Ac No. 7 in what ways to mitigate, protect, or assist in maintaining the wildlife or natural resources.

A discrepancy, however, emerges between the ESS6 objective promoting a sustainable management of resources; the natural resources to be more specific. Even though the previously mention Act 7 does include various chapters which focus on the protection of all-natural resources, ESS6 includes a provision for the necessity of certification for industrial production and the welfare of the wildlife, on the other hand ESS7 is not applicable on our project since there are no indigoes communities in the area.

Aside from the protection of wildlife and biodiversity, there is another standard that addresses the cultural aspect as well (ESS8). ESS8 includes the objectives of maintaining cultural heritage from the risks of projects. It views the cultural heritage as an important aspect to be regarded during consultations with the stakeholders, and the necessity of equitable shares in the benefits that come back should they make use of the cultural heritage. Regarding these objectives, two major gaps appear between the standard and the Palestinian national regulations. Act No 7 does mention the protection of cultural heritage, it does not, however, include the same identification of tangible and intangible cultural heritage. Another transparent gap appears in the fact that Palestinian regulations do not include anything that addresses the equitable sharing of cultural benefits and relating to our project area the land does not contain any cultural heritage areas. On the other hand, ESS9 is not applicable since there is no actions related to the financial intermediates.

Just like the World Bank addresses the cultural heritage and land acquisition, it also addresses the engagement of stakeholders and the necessity of sharing information (ESS10). ESS10 calls for the establishment of a systematic approach to engage stakeholders in a way that helps the borrower country to build a constructive rapport with them. In Palestine, even though the Environment Act No. 7 does refer to the inclusion of stakeholders within plans, it still does not have a systematic approach in how to do so; thus, creating a slight gap. Another apparent gap appears in the objective of providing means to effectively include stakeholders throughout all phases of the project. In the Palestinian regulations, there are no direct statements that refer to the necessity of informing and engaging all parties of the project with the project. As for the other objectives of providing the stakeholders with ways to raise their concerns regarding the project or other issues and the up-to-date disclosure of information regarding the project, there are no discrepancies between the Palestinian National Regulations and ESS10. The Palestinian bylaws and the Environmental Impact Assessment Policy of 1999 ensure the coordination of delivering up-to-date information as well as the ability to raise concerns.

## 6.4 Public Participation and Site Visits and Stakeholder's Engagement

Stakeholders' engagement represents any related or affected parties to the project to give their opinion on the project, be it positive or negative. Their engagement in the project process will help us by indicating how this project will affect the environment and daily life. On the other hand, site visits should be organized during the whole process of implementation of the project, and, after that, the community (as school student) is also welcomed to visit for educational purposes; especially students. The following table represents the stakeholders' parties, the interested ones, and their engagement plan. Additionally, stakeholders' engagement gives a provision for the effectiveness of the mitigation measures associated with ESMP and gives a good indication about the project areas. The engagement of the stakeholders should cover the following objectives:

- Define the directly or indirectly stakeholders engaged in the project.
- Define the stakeholder activates.
- Determine the frequency of stakeholder engagement.

The following represents the stakeholders engaged in the project:

- Government institution: PENRA, EQA
- Local institution: Salfit municipality, local government directorate, local agricultural directorate.
- Interested groups: universities, directorate of education, industrial schools
- Settlements around the project: Khrbit Qais

Table (6.1) below represents the public stakeholder and the interested ones associated with the project implantation. Also, it shows the mechanism for their consultation and how to discuss their status.

**Table (6.1): Stakeholders engagement procedures**

| Stakeholders | Consultation Mechanism | Status of consultation |
|---|---|---|
| Public Stakeholders | | |
| Affected People | Meetings with interested and impacted people | Discussion and interviews about the potential impact of the PV plant will be held |
| Wider Community | Informative procedures to be conducted to inform the wider community of the project plans and the impacts | Using radios related media station in the city and interviews with the local community will be held |
| Community Leaders | Interviews of directly affected communities; meetings with community leaders | Workshops; interviews conducted in communities where new reservoirs and treatment facilities will be located; meetings held with community leaders |

| Interested Stakeholders | | |
|---|---|---|
| Non-Governmental Organisations | Round Table meeting and Scoping Workshop | Round Table meeting and Scoping Workshop will be held |
| Municipalities and Village Councils | Technical meetings, Consultation, Workshops | Consultation and planning workshops held |
| Academics and Researchers | Round Table meeting, Scoping Workshop | Meeting and Scoping Workshop held |
| Government Ministries/Agencies | Consultation and Planning Workshops and Round Table Meeting | Consultation and Planning Workshops; Round Table Meeting |
| Private sector | Meetings with representatives of relevant sectors/companies | Meetings with representatives of relevant sectors/companies held |
| International Organisations/ Donors | Consultation and Round Table meeting | Consultation and Round Table Meeting held |

## 6.5 Grievance mechanism

EIA requires, out of many, to employ an effective strategy for it to record all the complains and grievances. There are primary principles to achieve effective communication; which are:

- All the acquired information must be accurate and protected during the execution of the EA.
- The stakeholders must be informed about the progress of the project and how it is monitored. The acquired information must be evaluated to prepare periodic reports.
- There must be an assigned public relations officers on the head of public relations, complaints, recording oral complaints, and making the necessary reports.
- Information regarding the Grievance Mechanism must be shared with the impacted communities.

The Information Acquisition Act works as a guarantee for the project's grievance mechanism, the rights of the impacted categories to be informed about the said project, and their right to express their complaints. The Municipality of Salfit will make sure to create a local grievance mechanism that deals with the complaints effectively.

The system of Salfit Municipality allows the stakeholders to directly communicate with it via a local electronic grievance mechanism. Such a system is based within the body of the Municipality of Salfit. Not to mention that such a system is implemented and monitored by Salfit's Council. All of this will be accessible to the stakeholders and eases the way for them to issue their complaints.

The Municipality will be responsible for the recording and monitoring of the grievance mechanism in addition to the environmental issues. There will be a staff responsible for managing the grievance mechanism on-site and in the municipality headquarter. The specialist of social public relations is responsible as well for managing the grievance and the contractor's social personnel. The Municipality of Salfit shall organize the agreements with the contractor so that it ensures the presence of a consultant in charge for recording and following up the grievance on site. The Grievance Redress Mechanism shall be followed by the personnel to record and work out the complaints of the stakeholders. They will also suggest follow-up procedures to solve the complaints. The Municipality shall also provide contact information through public and consultation meetings, as well as brochures regarding the project to maintain both awareness and the transparency of the project. There will be various methods for stakeholders to voice their complaints, such as:

- They could do it face to face.
- They can fill up complaint forms that contain their grievances.
- Via telephone.
- Via email.
- Or, by filling an online application.

## 6.6 Environmental and Social Management Plan

A project's environmental and social management plan (EMSP) consists of the set of mitigation and monitoring measures to be taken during implementation and operation and pre-construction to eliminate adverse environmental and social impacts, offset them, or reduce them to acceptable levels. The plan also includes the actions needed to implement these measures, Management plans are essential elements of EA reports for Category A projects; for many Category B projects, the EA may result in a management plan relating to all environment elements and relating it the land topology as it mentioned before in the TOR and land back ground, table (6.2) represent the environment and social management plan.

# Table (6.2): Environment and social management plan

| Ecological Social or Environmental Component | Potential Impacts | Impact Mitigation Measures | Monitoring Actions | Responsibility | Monitoring |
|---|---|---|---|---|---|
| **stage** | **Construction stage** | | | | |
| **Air quality** | Dust associated with construction and help to spread by wind | • Dust prevention by watering and other means.<br>• Use covered trucks to transport dusty materials from and out of the site.<br>• Avoid transporting the dusty materials on windy days<br>• Avoid setting the fire near the construction site.<br>• Move the dusty material to a fair place, not near the construction site.<br>• The speed of the vehicle should be as low as possible near the construction.<br>• The site engineer should maintain enough use of the construction machines. | • Site visits from the supervisor engineer; whether it's from the municipality side or the contractor side.in regular basses<br>• The contractor is obliged to perform the mitigation measures | Contractor | Municipality |

| | | | | | |
|---|---|---|---|---|---|
| **Earth** | • Waste pollution, especially waste caused by construction and domestic activities;<br>• Material storage, civil work, and other impacts;<br>• Landfill of wastes and other materials;<br>• Impacts of excavation work;<br>• Possibility of erosion;<br>• Wastewater. | • Protection of the surroundings of the construction site.<br>• Limited work in the vulnerable zones;<br>• Identify adequate areas to store residue materials, and transportation of all construction-related effluent materials into the predetermined site;<br>• Control of erosion process;<br>• Provide earth stabilization/green cover over vertical points and slopes to minimize landslide risks;<br>• Prevent the discharge of excavated material to the river beds or lakes;<br>• Avoid unwanted traffic blockage, collect excavated spoil material, | Site visits from the municipality daily The agricultural department making sure laws are implemented carefully | Contractor | Municipality and Agricultural department |

| | | | | | |
|---|---|---|---|---|---|
| | | and discharge somewhere close to the construction site;<br>• Discharge wastewater flows to the closest sewage line, installation of toilets, and septic tanks. | | | |
| **Topsoil** | • The damages that will occur on the soil from the excavation and the landfill causing pollution for the soil<br>• also, the losses that might happen for the soil from removing and drilling the land for the construction.<br>• Besides that, the mixing that will happen with the soil from other pollutants like trucks oil | • Proper design and implementation<br>• Trucks changing oil monitoring<br>• Using landfill in the proper site<br>• Reuse as much as possible of the drilled soil<br>• Qualified drilling and excavation will minimize the impact on the soil<br>• The contractor must oblige to these terms | • Daily visits for the site from the supervisor engineer<br>• Visits from the department of agricultural | Contractor | Municipality and department of agricultural |
| **Water resources and wastewaters** | • Pollution from Sloid and liquid pollutants from wastewater materials<br>• Break | • The drilling will be according to the approved design and under the supervision of the | • Daily site visits to implement the mitigation measures<br>• Checking | Contractor and Municipality | Contractor and Municipality |

| | | | | | |
|---|---|---|---|---|---|
| | pipeline of wastewater near the site<br>• Land pollution from the wastewater leakages<br>• Underground pollution from wastewater leakage<br>• Excavation near the main source of water<br>• Constriction and excavation affecting the rainwater | engineers<br>• Construct a well-isolated septic tank to collect the unnecessary and polluted waters<br>• Avoid the construction near the main pipeline of water<br>• Avoid the construction near the mainline of wastewater near the area<br>• Build water drains for the rain waters<br>• The depth of the construction will be as minimum as possible<br>• Landfill for the waste material must be far away from the water resources<br>• Avoid oil change for the trucks near the site.<br>• Use well-qualified engineers and technicians | the septic tank for any leakage daily<br>• Making sure the landfills are far from the water sources | | |
| **Noise** | • Noise from the construction work<br>• Noise from | • Materials transportation will be a minimum to not | • Make sure the safety tools are used through site | Contractor | Labor department and |

| | | | | | |
|---|---|---|---|---|---|
| | the transportation and traffic<br>• Noise from the workers | cause traffic<br>• Working will be during the day and the working hours.<br>• Using appropriate machines<br>• Not working during holidays.<br>• Using ear protection for site workers and site visitors. | visits<br>• The commitment from the contractor to work during working hours<br>• Site visits from the labor department and the labor association | | Municipality and Labor association |
| **Natural habitat** | • The damage that happens to the earth and the land because of the construction causing noises and dust and with no seasonal time-related. | • Lowering the dust produced and the noise connected to construction activities as possible so it may not affect the near areas. | Site surveys for the location to count the related animals and site visits to make sure the measures are fully applied | Contractor | Municipality and Contractor and Agricultural department |
| **Flora and fauna** | • Plant removal<br>• Animal removal<br>• Cutting trees<br>• birds losing their nests.<br>• Affecting the animals that are living near the location site | • Paying attention while displacing soil for the existence of the animals and plants<br>• Explaining to the workers the importance of biodiversity<br>• Transfer animals and plants if its applicable to another location | Site visits from the municipality and the agricultural department regularly | Contractor | Municipality and Agricultural department |

| | | | | | |
|---|---|---|---|---|---|
| | | • The contractor must be obliged to these measures | | | |
| **Aesthetics and landscape** | The impact of construction and excavation of the land causing a decrease in green areas and replace it with construction site | • Carful implantation of the design<br>• Manage to transfer trees to another place as it is possible<br>• Explaining the importance of the green areas to the workers | • Site visits monthly<br>• Careful implementation | Contractor | Municipality and Agricultural department |
| **Agriculture** | Same as the land and the soil the agricultural sector will be the most affected part since it used to be considered agricultural since its rich in olive trees | • Transport the trees to another place<br>• Keep the agricultural law under consideration<br>• Avoid cutting unnecessary ones<br>• Grievance mechanism should be implemented to the near locations | The municipality and the agricultural department should give site visits to the location to make sure the measure is fully implanted in monthly basses | Contractor | Municipality and Agricultural department |
| **Livestock** | The impact is quite low since the live stoke itself is not big | • Inform the farmers and the beneficiaries from this about the project<br>• Find them a good place for their livestock | Site surveys for the near citizen to find the ones who use the land and inform them of the decision | Municipality | Municipality and Agricultural department |

| | | | | | |
|---|---|---|---|---|---|
| **Health and safety of residents and workers** | • Health risks from solid waste from the construction<br>• Risks from the dust produced and carried from the wind<br>• Workers' risks during work<br>• Wastewater pollution for the project water source<br>• Citizens' risk from material transportation and moving trucks.<br>• Risks to the workers from the construction machines | • Fence installation<br>• Signs installation<br>• Notify the near citizens about the work construction.<br>• measures dealing with security and environmental protection issues.<br>• Qualified workers and technicians<br>• Sun broads if applicable<br>• Work during the day<br>• Noise level as low as possible<br>• Management of materials per the relevant ecological and sanitary hygiene norms. | Site visits and daily check-ups from the municipality side and the labor department, labor association, and the contractor should be obliged to these measures | Contractor | Municipality and Labor department and Labor association |
| **Areas of historical and cultural value** | NA | There are no areas of historic/cultural value to be affected by the project. But if it is found during the construction, relevant measures need to be taken | NA | Contractor | Municipality and contractor |

| | | | | | |
|---|---|---|---|---|---|
| **Resettlement**<br>**Land acquisition** | • NA since the land belongs to the municipality<br>• continue avoiding the damaging of the near ones | • Take to the neighbors of land and give updates about the land situation and the decision made to implement PV plant near them and the consequences related to this project<br>• Building fence around the project land to prevent any damages that might happen to the near areas | Site visits, the site serves for the project land and the near areas from the municipality and the agricultural department | Municipality and Contractor | Municipality and agricultural department |
| **stage** | **Operations stage** | | | | |
| **Noise** | • Noise pollution from the sound of the inverters<br>• Noise from the workers in the offices and some machines | • Use isolated rooms and offices especially for indoor transformer<br>• Construct the room in the far end of the land away from the nearest people and connection point with the surrounding areas. | Municipality engineer to make sure the mitigation measures are implemented correctly and done according to the proposed design regularly | Contractor Municipality | Contractor municipality |
| **Air quality** | Affected the air from transportation and maintenance and the vehicles from the visitors; caused the dust and dirt to be carried through the | • . Maintain the transportation to the project area at low speed as possible<br>• Watering the land of the project<br>• Avoid any | Municipality daily visits<br>To maintain the order | Municipality | Municipality |

| | | | | | |
|---|---|---|---|---|---|
| | wind | maintenance during windy days | | | |
| **Community health and safety** | • Air pollution from the maintenance<br>• Water sources contamination<br>• Noise pollution<br>• Accidents | • Avoid air pollution and water sources<br>• Fence installation to ensure the safety of workers and the near community<br>• Dumping unwanted waste or unwanted material in inhabitant region<br>• Use sub roads to ensure the safety of the citizen<br>• Reduce noise level<br>• Using warning signs on the site and the near road to inform the people about the work and plant trees | • Daily check from the site workers<br>• The contractor obliged to the mitigation measures<br>• Labor department check on the site regularly | Contractor and Municipality and Labor department | Contractor and Municipality and Labor department |
| **Solid waste and wastewater** | • Pollution from the septic tank installed<br>• Soil impact from the landfill<br>• Maintenance of waste pollution<br>• Surface water pollution | • Use proposed landfill places approved by the municipality<br>• Use the proposed septic tank for waste materials<br>• Careful usage of materials and machines in maintenance on the | • Daily check for the septic tank<br>• Daily checks for soil pollution and landfills | Municipality and contractor | Municipality and contractor |

| | | | | | |
|---|---|---|---|---|---|
| | | site<br>• Use a well-qualified technician<br>• Use water drains and clean them continuously | | | |
| **Workers health** | • Daily Hazards on the workers<br>• Injured visitors<br>• Health problems for the near citizens<br>• May cause car accidents from the reflection of the sun | • Training of staff on safety and human security issues and how to deal with visitors<br>• Using signs for introduction and informative issues<br>• Using qualified workers on the site<br>• Using safety tools for the workers and the visitors | • Municipality check for measures implementation<br>• Labor department check And association labor in regular basses | Municipality | Labor department and Municipality and Association labor |

## 6.7 Monitoring Plan

The overall objective of environmental and social monitoring is to qualitatively and quantitatively measure the effectiveness of mitigation measures, develop appropriate responses to incompatibility with Project standards, and emerging environmental and social issues. A framework for monitoring activities and thresholds is provided in this chapter. Monitoring will be carried out to ensure that all Project activities and mitigation measures comply with the national legislation and the World Bank. Salfit municipality meets their commitments and requirements of this ESMP in terms of periodical audits and reporting. The main objectives of developing a monitoring program and defining parameters are to:

1. Control that all mitigation measures are in place,
2. Measure effectiveness of the mitigation measures,
3. Provide mechanisms for taking timely action when unexpected environmental and social incidents are encountered and identify all levels of organizational structure.

Roles and responsibilities, monitoring parameters, monitoring frequencies, and Project's monitoring requirements are required to be identified in the implementation of the Monitoring Plan. To determine whether monitoring outcomes comply with the Project standards, implementation of mitigation measures will be observed and measured. Table (6.3) below represents the monitoring plan:

## Table (6.3): EIA monitoring plan

| Element | Responsibility | Location | Frequency | Monitoring Method | Relevant Legislation Standard | Reporting |
|---|---|---|---|---|---|---|
| Prepare an action plan for the project | Salfit municipality | Main office | Pre-construction phase | Document saving | ESS5:Land Acquisition, Restrictions on Land Use and Involuntary Resettlement<br>ESS10: Stakeholder Engagement and Information Disclosure | Monthly |
| Permission to use the project land | Salfit municipality | Main office | Pre-construction phase | Document saving | Palestine environment law 1999 | Monthly |
| Determine the project area and the roads and excavation burring area | Salfit municipality | Main office | Pre-construction phase | Document saving | ESS1: Assessment and Management of Environmental and Social Risks and Impacts<br>ESS3: Resource Efficiency and Pollution Prevention and Management<br>ESS5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement<br>ESS10: Stakeholder Engagement and Information Disclosure<br>Salfit municipality law for land use under their permission | Monthly |
| Ensuring underground water Safety | Salfit municipality & water Authority | Main office | Pre-construction phase | Document saving | Water law 2002<br>ESS1: Assessment and Management of Environmental and Social | Monthly |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | Risks and Impacts<br>ESS3: Resource Efficiency and Pollution Prevention and Management | |
| Environmental Management (Waste Contracts, additional environment& social studies, Preparation of Site-specific management plans and procedures, | Salfit municipality | Main office | Pre-construction phase | Document saving | Palestine environment law 1999<br>ESS1: Assessment and Management of Environmental and Social Risks and Impacts<br>ESS3: Resource Efficiency and Pollution Prevention and Management<br>ESS10: Stakeholder Engagement and Information Disclosure<br>Salfit municipality law for land use under their permission | Monthly |
| Air Quality | Contractor | Project working area | Every two months or if there is a complains | Site visits | ESS3: Resource Efficiency and Pollution Prevention and Management | Monthly |
| Noise | Contractor | Project working area during excavation and construction | At the beginning of the construction or if there are any complaints | Using instruments to measure the noise level | ESS 4: Community Health and Safety.<br>Palestine environment law 1991 | Quarterly |
| Water quality | Contractor | Project working area during excavation and construction | At regular basis every month or if there is any complains | Taking samples and analysis | Palestine environment law<br>ESS 3: Resource Efficiency and Pollution Prevention and Management<br>ESS 4: Community Health and Safety | Monthly |

| | | | | | | |
|---|---|---|---|---|---|---|
| Topsoil | Contractor | Project working area during excavation and construction | Continuously on regular basis during the execution phase | Check and analyze the soil and taking samples | Palestine environment law 1999<br>ESS 3: Resource Efficiency and Pollution Prevention and Management | Quarterly |
| Waste | Contractor | Project working area during excavation and construction | Daily | Site visit and observation | Palestine environment law 1999<br>ESS 3: Resource Efficiency and Pollution Prevention and Management | monthly |
| Ecology | Contractor | Project working area during excavation and construction | At the beginning of the project and the end | Site visit and taking samples | ESS 5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement<br>Palestine environment law 1999 | Quarterly |
| Occupational Health and Safety | Contractor | Project working area during excavation and construction | Daily | Site visit and observation | ESS 4: Community Health and Safety | Weekly |
| Water resources and wastewaters | Contractor | Project working area during excavation and construction | Daily | Site visit and observation<br>Ant taking samples | ESS 3: Resource Efficiency and Pollution Prevention and Management Palestine water law 2002<br>ESS 7: Natural Resources. | Monthly |
| Natural habitat | Contractor | Project working area during excavation and construction | At the beginning of the project and the end | Site visit and observation | Palestine environment law 1999<br>ESS 6: Biodiversity Conservation and Sustainable Management of Living | Quarterly |
| Flora and fauna | Contractor | Project working area during | At the beginning of the project and the end | Site visit and observation | ESS 6: Biodiversity Conservation and Sustainable Management of Living | Quarterly |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | excavation and construction | | | Palestine environment law 1999 | |
| Aesthetics and landscape | Contractor | Project working area during excavation and construction | At the beginning of the project and the end | Site visit and observation | ESS 5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement. | Quarterly |
| Agriculture | Contractor | Project working area during excavation and construction | At the beginning of the project and the end | Site visit and observation | ESS 7: Natural Resources Palestine environment law 1999 | Quarterly |
| Livestock | Contractor | Project working area during excavation and construction | At the beginning of the project and the end | Site visit and observation | ESS 3: Resource Efficiency and Pollution Prevention and Management. | Quarterly |
| Health and safety of residents and workers | Contractor | Project working area during excavation and construction | Daily | Site visit and observation | ESS 2: Labor and Working Conditions. | Weekly |
| Areas of historical and cultural value | Contractor | Project working area during excavation and construction | Pre-construction | Site visit and observation | ESS 9: Cultural Heritage. | Quarterly |
| Resettlement Land acquisition | Contractor | Project working area during excavation and construction | Regular bases during the project execution | Site visit and observation | ESS 5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement. | Quarterly |

| | | | | | | |
|---|---|---|---|---|---|---|
| Noise | Salfit municipality | Project working area | Regular bases during the operation phase or if there are any complaints | Site visit and observation and using a measuring instrument | Municipality equation Palestine environment law | Monthly |
| Air quality | Salfit municipality | Project working area | Regular bases during the operation phase or if there are any complaints | Site visit and observation | Municipality equation Palestine environment law | Monthly |
| Community health and safety | Salfit municipality | Project working area | Regular bases during the operation phase or if there are any complaints | Site visit and observation | Municipality equation Palestine environment law 1999 | Weekly |
| Solid waste and wastewater | Salfit municipality | Project working area | Regular bases during the operation phase or if there are any complaints | Site visit and observation also taking samples and analyze them | Municipality Palestine environment law 1999 | Quarterly |
| Workers health | Salfit municipality | Project working area | Regular bases during the operation phase or if there are any complaints | Site visit and observation | Palestine environment law 1999 ,municipality | Weekly |

# Chapter Seven
# Prefeasibility of the Proposed System

## 7.1 Introduction

Solar PV systems are unlike conventional systems with their high installation value at the first stage. It comes with low operation and maintenance costs. The economic evaluation of the system is essential to find the lowest price with the highest outcome from the proposed system. Similarly, the environmental planning and assessment are essential for proposal approval from the donors' side, such as the World Bank, which must be added to the cost of the project implementation.

To analyze the profitability of our system, a few methods are commonly used, i.e. the net present value (NPV), internal rate of return (IRR), and the payback period (PBP). The NPV represents the difference between the income and the outcome of the project, if it is positive, visible, negative, or not. While the PBP represents the required time for the project to recover the installation cost, the IRR can be used to measure and compare the profitability of investments (Reniers, 2016) . The first step for the analysis is to define the project budget with all parameters and define the expected yield energy from the system. The financial study for the project is done by RETSCREEN software.

## 7.2 System Cost

Table (7.1) below represents the system budget to install 0.5 MWp of PV including the electrical part. It is important to note we assumed that the minimum capacity allowed for the PV panel is 310 watt and the minimum capacity for the inverters is 50 kVA. The following system budget is as follows. By calculating the cost from the electrical part and the environment part, the total estimated cost for the installation of 0.5 MWp is 537710$.

**Table (7.1) :Bill of Quntity**

| Item | Description of Goods | Quantity | Unit | Unit price$ | Total Price$ |
|---|---|---|---|---|---|
| 1 | PV panels | 1520 | Unit | 138 | 209760 |
| 2 | Inverters | 10 | Unit | 7450 | 74500 |
| 3 | 400 kVA Step up transformer | 1 | Unit | 10500 | 10500 |
| 4 | AC and DC cable | Sum | Sum | 20200 | 20200 |
| 5 | Conduits | 1600 | M | 2.65 | 4250 |
| 6 | Steel structure | 1 | Sum | 65000 | 65000 |
| 7 | Electrical Panels | 10 | Unit | 800 | 8000 |
| 8 | Junction box | 10 | Unit | 750 | 7500 |
| 9 | Earth system | 1 | Unit | 3900 | 3900 |
| 10 | Lightning protection system | 1 | Unit | 1350 | 1350 |
| 11 | Fence around the system | 320 | M | 25 | 8000 |
| 12 | Land preparation | 5500 | M | 5.5 | 30250 |
| 13 | Medium voltage equipment’s | LS | LS | 6850 | 6850 |
| | | | | Total | 450060$ |

Table (7.2) below represents the budget required for training, consultation, and employment for this project. While the mitigation measures discussed in the mitigation plan and the monitoring are estimated to be 30000$. The following table represents an example of the measures which will be applied during the project:

- Dust removal and waste removal procedure.
- Clean the site from solid waste and unwanted materials.
- An engagement process for the stakeholders and grievance mechanism.

**Table (7.2): Environmental assessment estimated cost**

| Item | Activities | Quantity | Unit Rate $ | Total $ |
|---|---|---|---|---|
| 1 | Health Insurance | 2 | 800 | 1600 |
| 2 | Site visits | 1-2 visits /week | 50 | 2400 |
| 3 | Consultation sessions | 50 | 50 | 50 |
| 4 | Training sessions for contractors | 3 | 1000 | 3000 |
| 5 | Information disclosure (including media) | 8 | 1,000 | 8000 |
| 6 | Internal Training | 2 | 500 | 1000 |
| 7 | Monitoring Site visits | 2 visits /months | 50 | 600 |
| 8 | Environmental orientation Seminars | 4 | 6,000 | 24000 |
| 9 | Environmental and social management cost under Local Technical Consultant contract | 1 | 3,000 | 3000 |
| 10 | Legal consultant | 1 | 3,000 | 3000 |
| 11 | Dispute resolution budget | 1 | 5000 | 5000 |
| 12 | Miscellaneous | 1 | 6,000 | 6000 |
| | | | Total | 57650 $ |

## 7.3 Energy Yield

The amount of electricity produced from the system depends on the angle, direction, irradiation, temperature, the efficiency of the panels, and the weather. The annual measured energy yield in Palestine is found to be 1684 kWh/kWp and the performance ratio is 84% which describes the relationship between the real and the estimated energy output; taking into consideration the degradation percent for the output power =2.1% (Ibrik, 2020). Table (7.3) underneath represents the expected output power from the system for 20 years lifetime(yearly cash flow) and the value of the produced energy for 0.166$/kWh.

**Table (7.3): Estimated energy produced for 20 years lifetime from 0.5 MWp**

| Year | Energy produced kWh | Cumulative $ |
|---|---|---|
| 1 | 854356 | -483,550 |
| 2 | 836414.5 | -323,390 |
| 3 | 818849.8 | -163,600 |
| 4 | 801654 | -4,192 |
| 5 | 784819.2 | 154,822 |
| 6 | 768338 | 313,431 |
| 7 | 752202.9 | 471,623 |
| 8 | 736406.7 | 629,385 |
| 9 | 720942.1 | 786,704 |
| 10 | 705802.3 | 943,567 |
| 11 | 690980.5 | 1,099,960 |
| 12 | 676469.9 | 1,255,870 |
| 13 | 662264 | 1,411,281 |
| 14 | 648356.5 | 1,566,179 |
| 15 | 634741 | 1,720,549 |
| 16 | 621411.4 | 1,874,373 |
| 17 | 608361.8 | 2,027,637 |
| 18 | 595586.2 | 2,180,324 |
| 19 | 583078.9 | 2,332,415 |
| 20 | 570834.2 | 2,483,893 |

# Chapter Eight
# Result and Analysis

## 8.1 Grid impact analysis

It is necessary to understand the impact of the penetration levels of the PVDG on Salfit's electrical network in terms of the voltage levels, power losses, power factor, and stability, since the system with high penetration renewable energy may also cause the system to carry high line loading and introduce more losses .So, the author built the network using ETAP software, at first, without the PV plant. Then, he added the PV with 0.5 MW connected to the medium voltage as a first step and to see if we can increase the capacity of the plant according to its impact. This study is done with four different scenarios: 100% generation with 100% load, 100%generation with 50 % load, 50% generation with 100 percent load, and 50% generation with 50% load all the previous cases are represented in Table (8.1), while Figure (8.1) represents the one-line diagram for Salfit electrical network without connecting the PV station.

**Table (8.1): Cases classification**

| Case | Description |
|---|---|
| Case 1 | 100 % generation ,100% load |
| Case 2 | 100 % generation ,50% load |
| Case 3 | 50 % generation ,100% load |
| Case 4 | 50%generation ,50 % load |

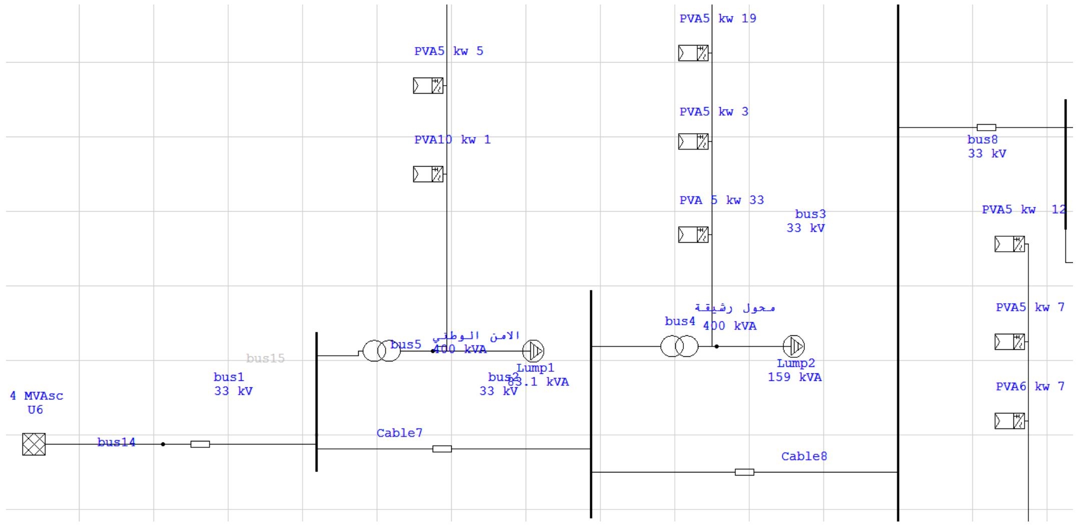



**Figure (8.1): One-line diagram for part of the electrical network.**

In general, after running the load flow analysis the electrical network consumes 2,964 MW and 1.645 MVAr with a total loss of 0.04 MW and -0.039 MVAr, a total PV capacity from the customers' side of .998 MW, a power factor of 0.8744, with a total ampere consumption of 59.31 Amp. The connected PVDG is going to be connected to bus 46 and the bus itself is connected directly to three other busses bus 49 and bus 78. These two main busses, since they are directly connected to the PVDG, will suffer the most from the penetration level. Table (8.2) represents the connected buses and their voltage level, loadings, and power factor. After running the load flow analysis using ETAP for our network, Figure (8.2) illustrates the power factor for each bus in the network before connecting the plant, while the real and the reactive power losses are illustrated in Figure (8.3) and Figure (8.4) respectively.

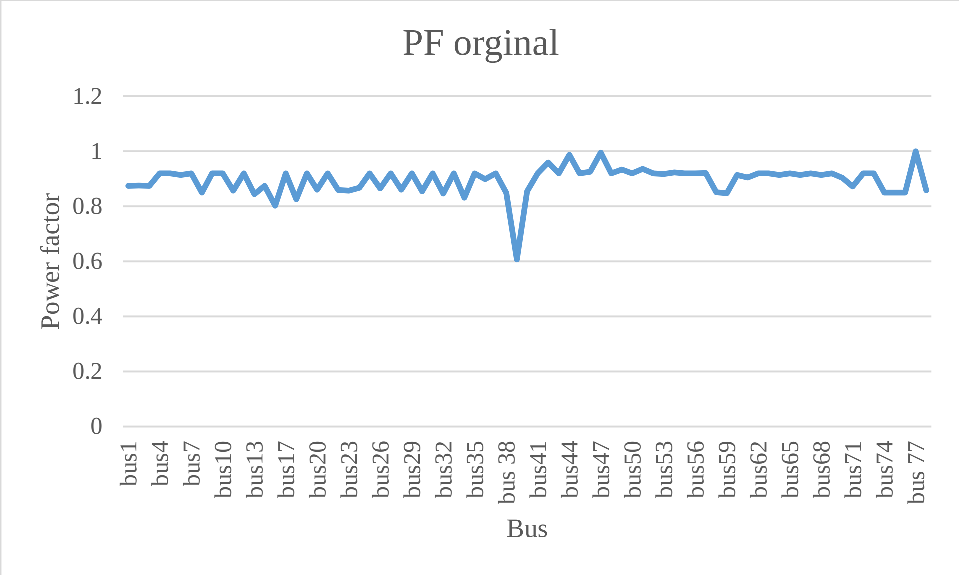



**Figure (8.2): Power factor level for each bus before connecting the station.**

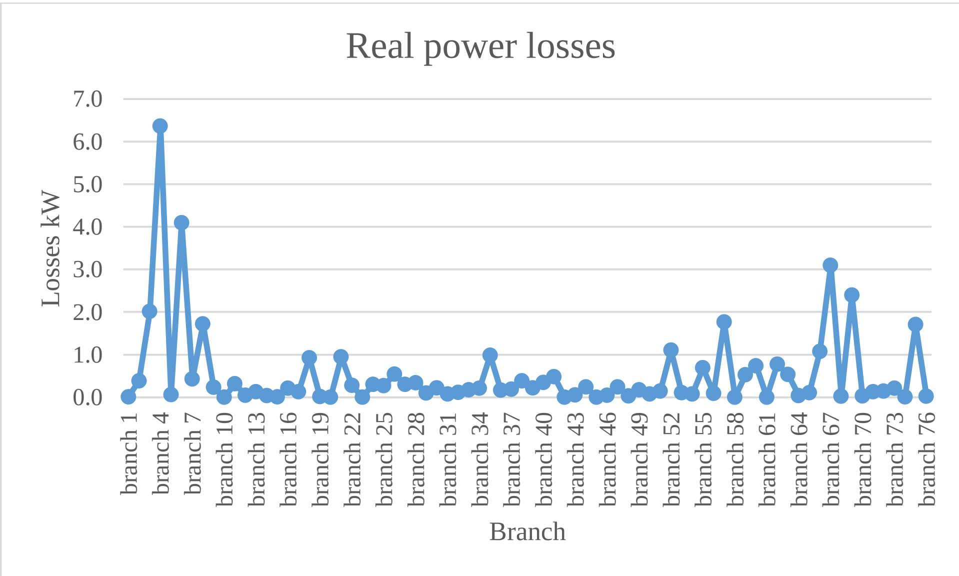



**Figure (8.3): Real power losses in each branch before connecting the station.**

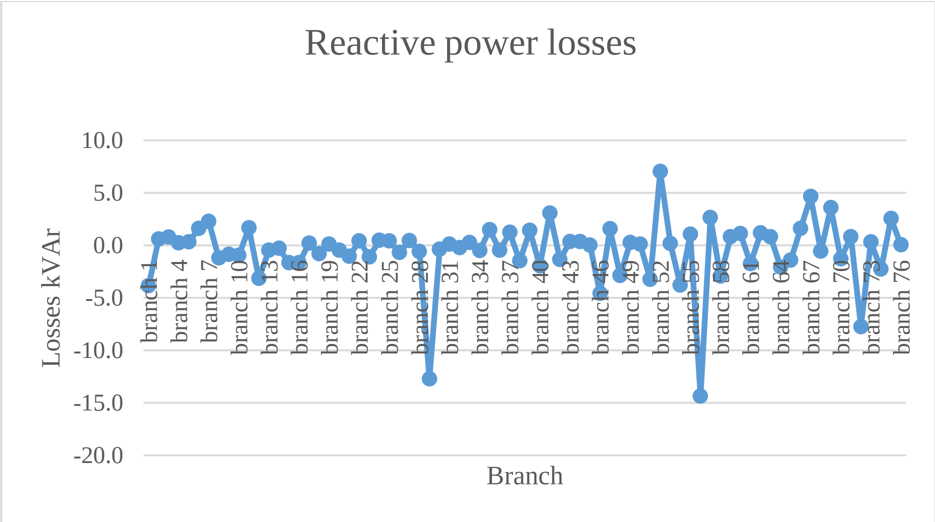



**Figure (8.4): Reactive power losses in each branch before connecting the station.**

**Table (8.2): Voltage, power factor, loading for bus 46,49and bus 78.**

| Bus | Voltage | P.F | Loading | Amp |
|---|---|---|---|---|
| 46 | 99.15 | 91.4 | 0.694 | 18.2 |
| 49 | 99.11 | 93.4 | 0.408 | 7.7 |
| 78 | 99.18 | 85.8 | 0.667 | 13.7 |

### 8.1.1 Voltage regulation

The values for the voltage reading depend on the penetration levels which depend on the capacity of the installed PV and the peak consumption. The three main buses connected to the PVDG show an increase in the voltage levels compared to the original case, but they are still within the acceptable ranges, as is depicted in Table (8.3) and Figure (8.5). On the other hand, the voltage for most of the buses increased; mainly when we decreased the load to half in case 2 and case 4, the voltage stability needs to be preserved to maintain the voltage in safety range to operate . Figure (8.6) to Figure (8.9) represent the voltage levels in each case. The case with the full load capacity shows a slight improvement in the voltage levels for all buses. However, it is still an improvement for all of them. Whereas the cases with low load demand depict a major improvement. The bus near the PVDG shows a major enhancement in the voltage levels

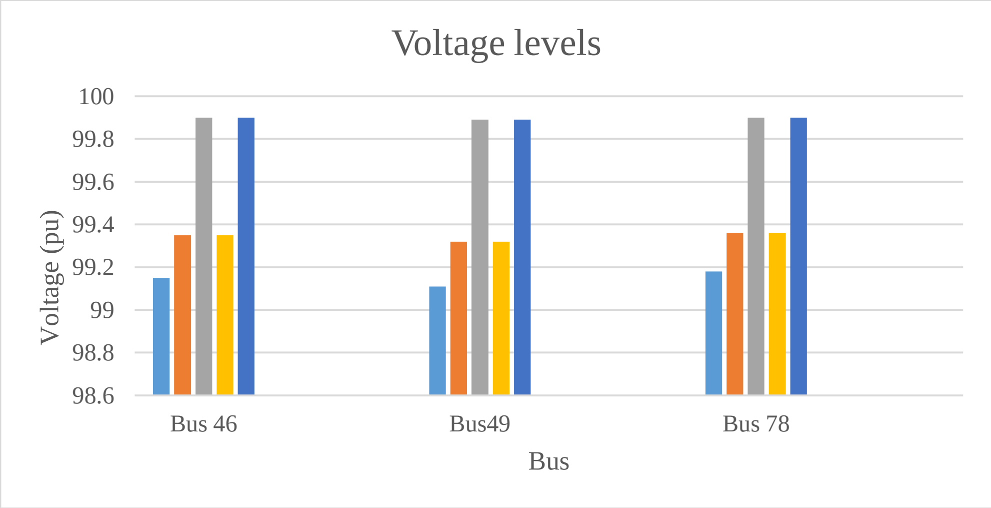



**Figure (8.5): Voltage level for bus 46 ,49 and bus 78 in each case compared to the original**

**Table (8.3): Voltage level for buss 46,49and 78 in each case compared to the original**.

| bus | Without PV station | 100 %gen ,100 % load | 100 %gen ,50 % load | 50 %gen ,100 % load | 50 %gen ,50 % load |
|---|---|---|---|---|---|
| 46 | 99.15 | 99.35 | 99.9 | 99.35 | 99.9 |
| 49 | 99.11 | 99.32 | 99.89 | 99.32 | 99.89 |
| 78 | 99.18 | 99.36 | 99.9 | 99.36 | 99.9 |

The following figures represent the improvement occurred to the voltage levels through different penetration levels. The penetration level is calculated as the percentage of the installed PV capacity to the total load connected. The improvement associated with case 1 is represented in Figure (8.6). With penetration level of 50 % the improvement reached all the busses, bus 62 before the PV connection was 97.1 due the voltage drops and after connection the PV station it reached 98.2. As case 2 represented in figure (8.7) with penetration level of 75 the voltage levels for each bus improved. Bus 62 before connecting the PV station was 97.1 and after connecting it reached 99.2 due the load reduction and increasing the PV penetration

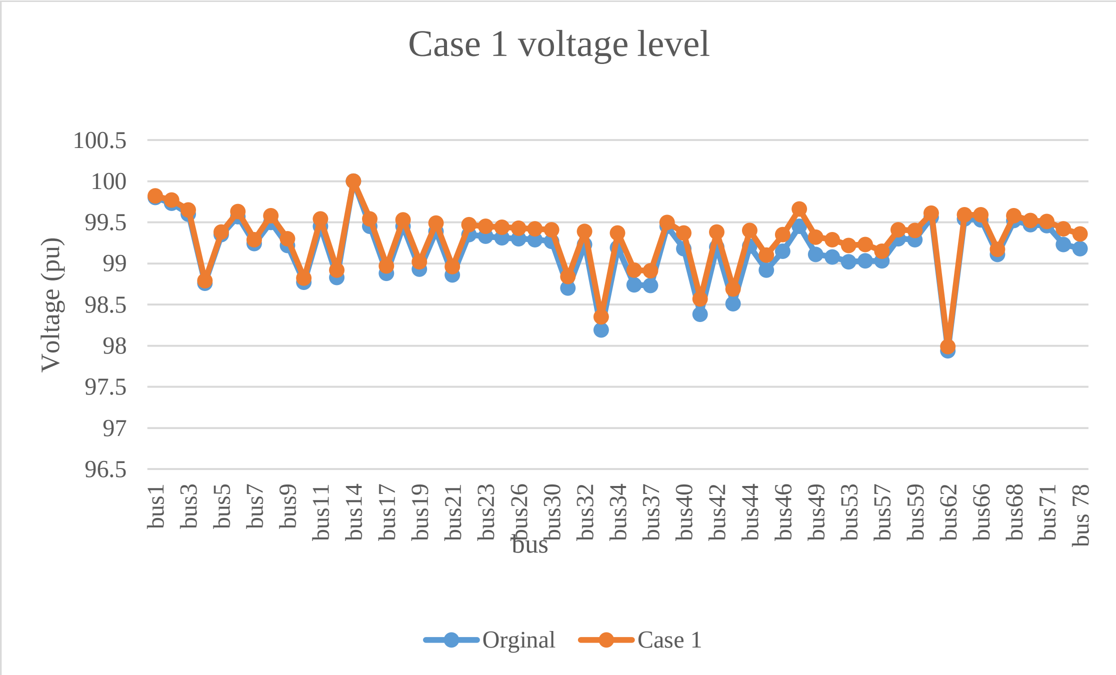



**Figure (8.6): Case1 voltage level compared to the original case.**

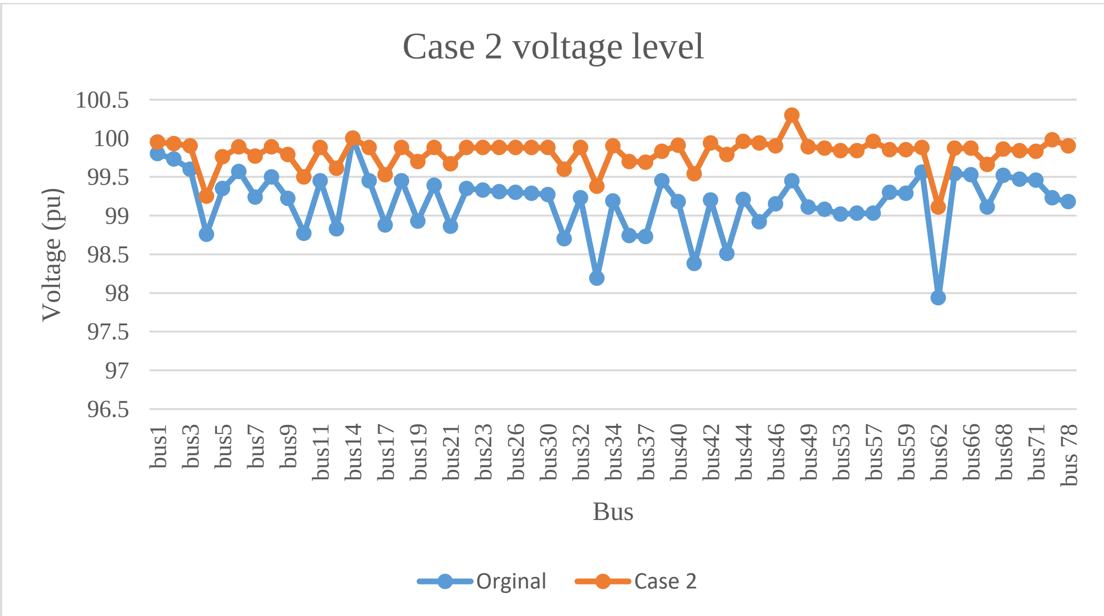



**Figure (8.7): Case 2 voltage level compared to the original case.**

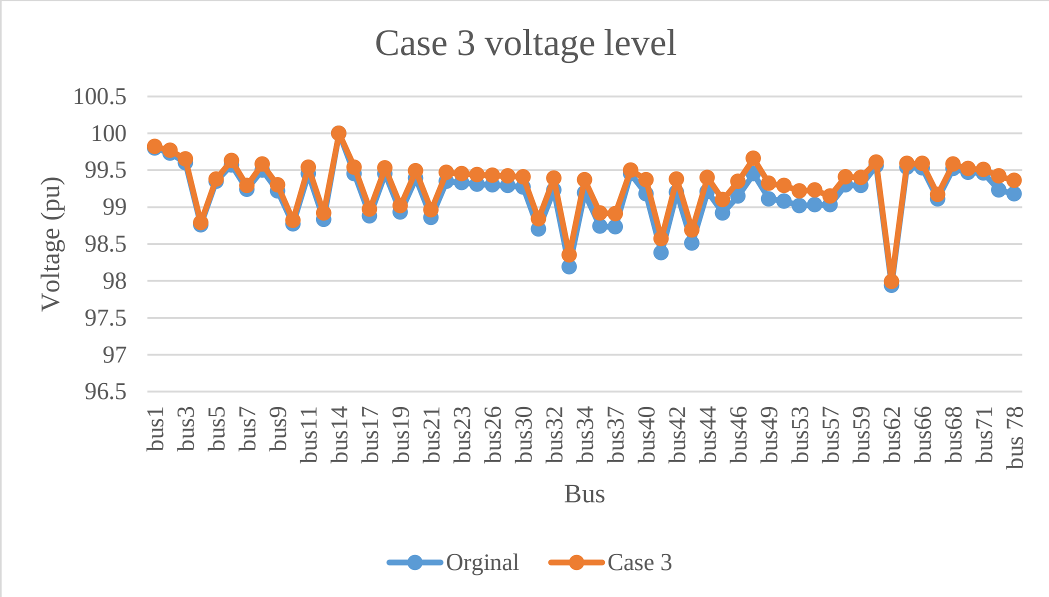



**Figure (8.8): Case 3 voltage level compared to the original case.**

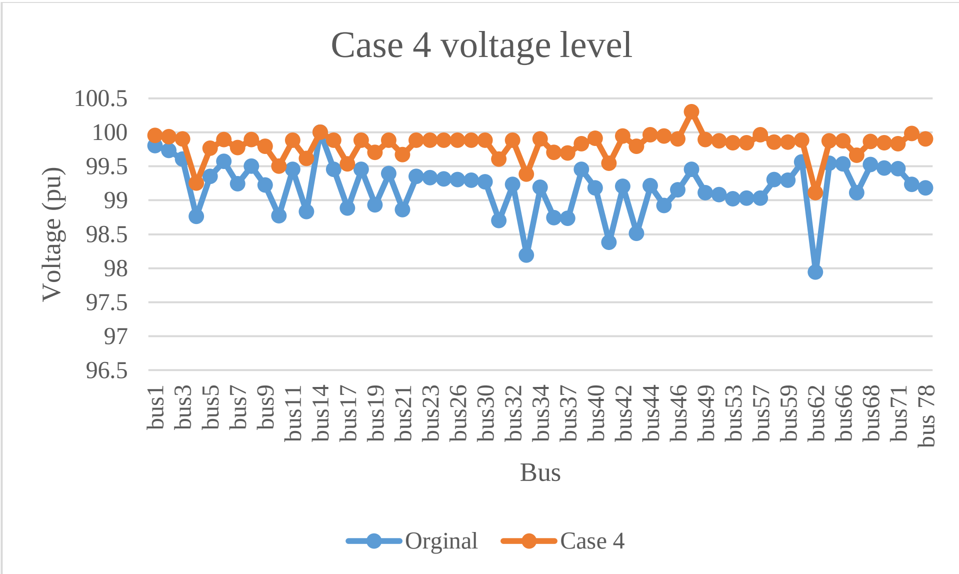



**Figure (8.9): Case 4 voltage level compared to the original case.**

As shown from the previous figures, the voltage levels are proportional to the PV capacities connected to the grid. While mainly the improvement will happen during the working hours of the PV station, but the increase in penetration will rise the voltage levels.

### 8.1.2 Power Factor and Bus Loading

The power factor reading changed due to the penetration level of PVDG. The power factor is a function of the real power and reactive. The increase of the generated real power causes a decrease in the amount of the real power consumed. Hence, the power factor drops in the connection point with the utility. On the other hand, the total bus loading varies also due to the penetration level. The following figures represent the power factor levels and the bus loadings before the PVDG and after in the four cases. As for the main three buses which are connected directly to PVDG, Table (8.4) illustrates the values for the power factor and Table (8.5) represents the values of bus loading. The figures from Figure (8.10) to Figure (8.13) show that the improvement of the power factor levels is negligible. On the other hand, most of the buses show a decrease in power factor levels, especially from bus 1 to bus 36 which are the buses that are far from the PVDG due the injection of the real power while the reactive power consumption stays the same . As for the near ones they have a good power factor level. In case 1, there is a small decrease in power factor level while, in cases 2 and 4, the level of decrease is much higher. Since the load levels are low as compared to the other cases, this impact can be clarified with the total amount of bus loading as it is represented in Figure (8.14). In case 2 and case 4, when the bus loading is minimum, the power factor decreased the most since it’s a function of the real power as mentioned before. Additionally speaking, the levels of the bus loading are affected the most when the load levels are the lowest

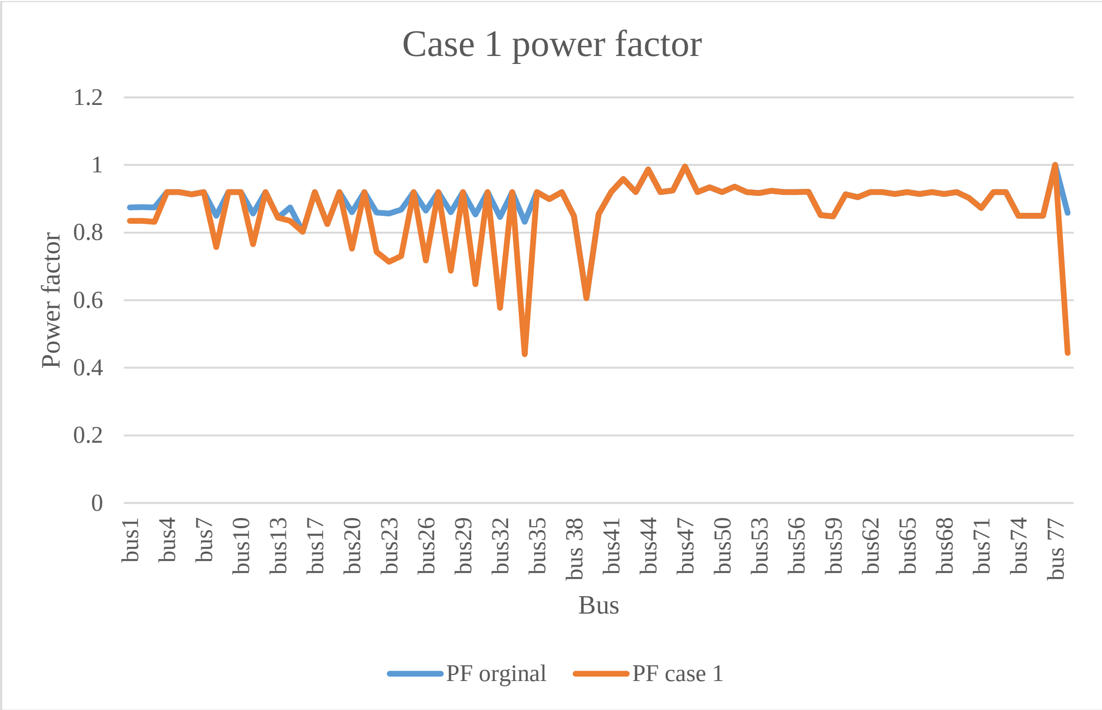
**Table (8.4): Bus 46,49 and bus 78 power factor levels compeared to the original case**

| PF / bus | Without PV | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| 46 | 0.925 | 0.925 | 0.969 | 0.925 | 0.969 |
| 49 | 0.934 | 0.934 | 0.951 | 0.934 | 0.951 |
| 78 | 0.855 | 0.443 | 0.911 | 0.443 | 0.911 |

**Table (8.5): Bus 46,49 and bus 78 loading levels compared to the original case in MW**

| load / bus | Without PV | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| 46 | 0.694 | 0.695 | 0.502 | 0.695 | 0.502 |
| 49 | 0.408 | 0.409 | 0.204 | 0.409 | 0.204 |
| 78 | 0.667 | 0.197 | 0.39 | 0.197 | 0.39 |

The power factor in each case shows a decrease in their levels, due the distance from the PV station in all penetration levels specially from bus 1 to bus 36 as mentioned earlier, while the reaming busses shows a slight improvement in their levels due the injection of the real power. However, the far end buss in the electrical network maintains at low levels of real power causing the decrease in power factor.




**Figure(8.10): Power factor level for case 1 compared to the original.**

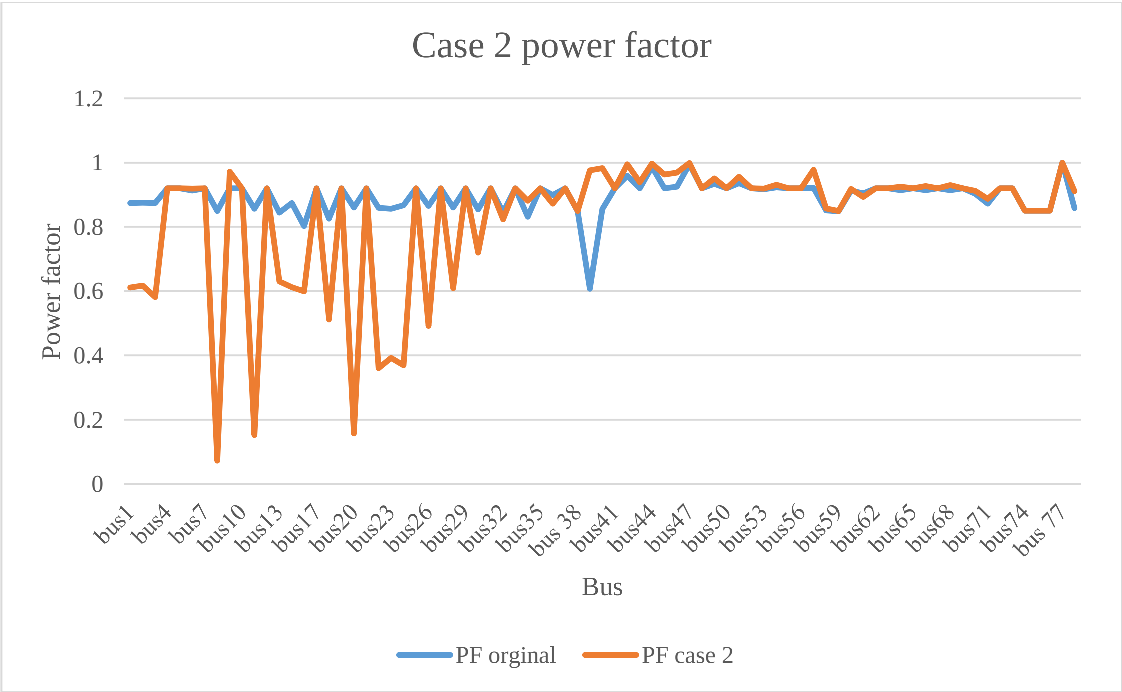



**Figure (8.11): Power factor level for case 2 compared to the original.**

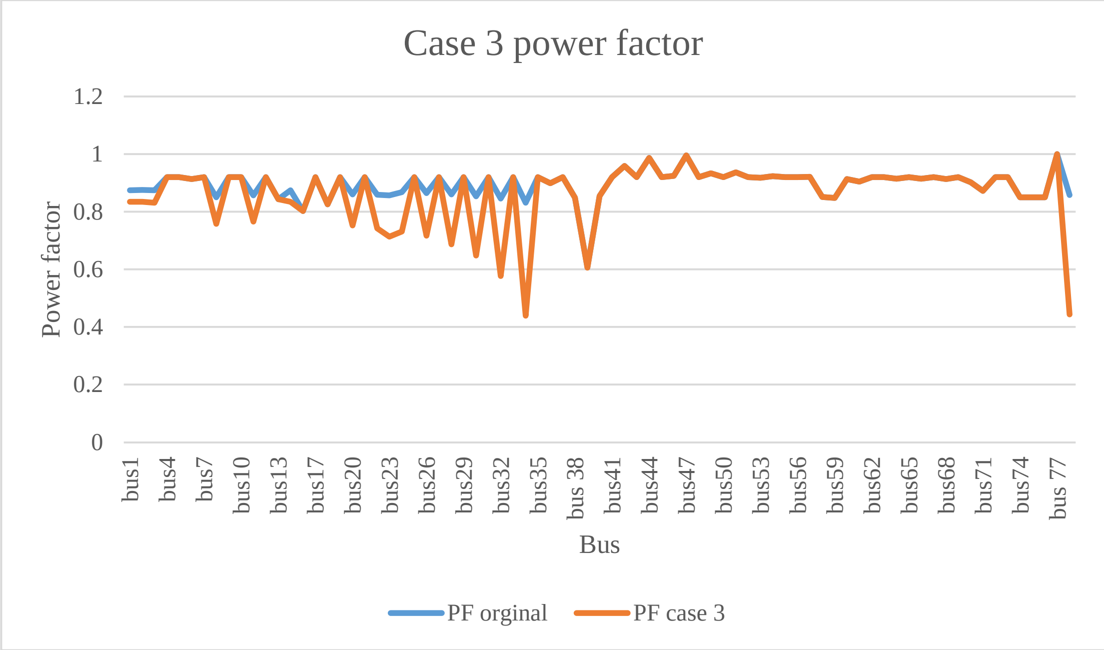



**Figure (8.12): Power factor level for case 3 compared to the original.**

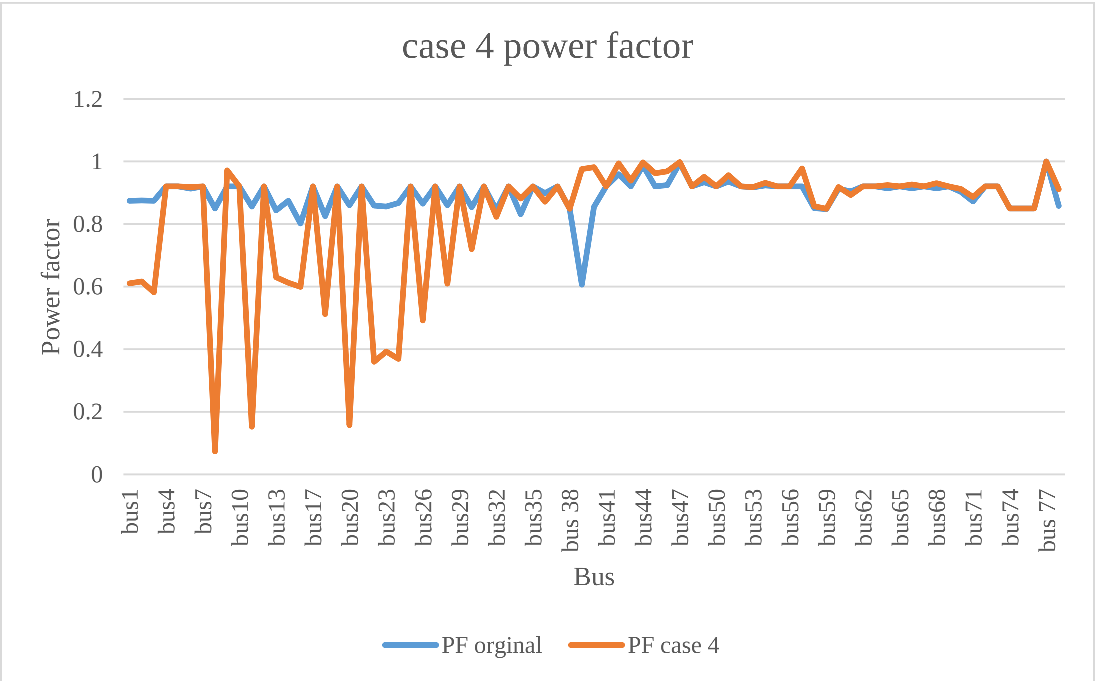



**Figure (8.13): Power factor level for case 4 compared to the original.**

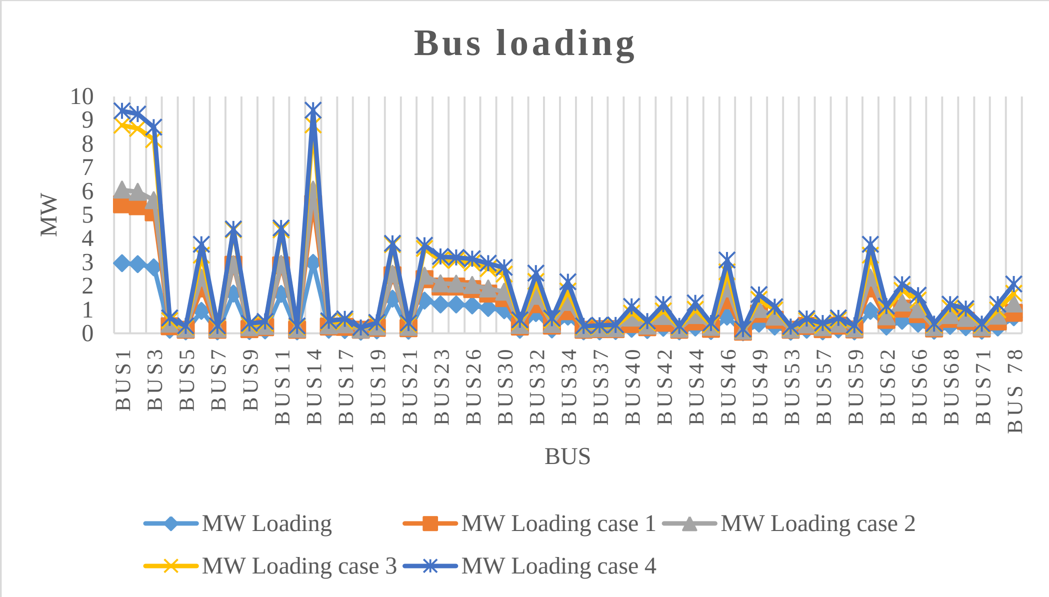



**Figure (8.14): Bus loading in MW for all cases compared to the original case**

As it's shown in Figure (8.14), the loading for each bus decreases following the increase in the real power generated. Not to mention that the power factor decreased. Table (8.6) represents the total consumption and the power factor in the connection point with IEC. As it is illustrated, case 3 represents the highest power factor among them.

**Table (8.6): Total consumption and power factor**

| Power | Without PV | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| Pf | 0.8744 | 0.8347 | 0.6123 | 0.8565 | 0.7311 |
| Power MW | 2.964 | 2.49 | 0.612 | 2.727 | 0.847 |

### 8.1.3 Branch Loading and Branch Losses

With the different levels of penetrations of PVDG connected to the grid, the loading on each branch and the losses vary according to these levels. In Table (8.7) and Figure (8.15), they represent the total real power and reactive power losses in each case.

**Table (8.7): Real power and reactive power losses**

| Power | Original | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|---|
| kW | 40.2 | 34.7 | 7.1 | 37.2 | 7.4 |
| kVAr | -39.1 | -42.2 | -82.1 | -40.9 | -81.8 |

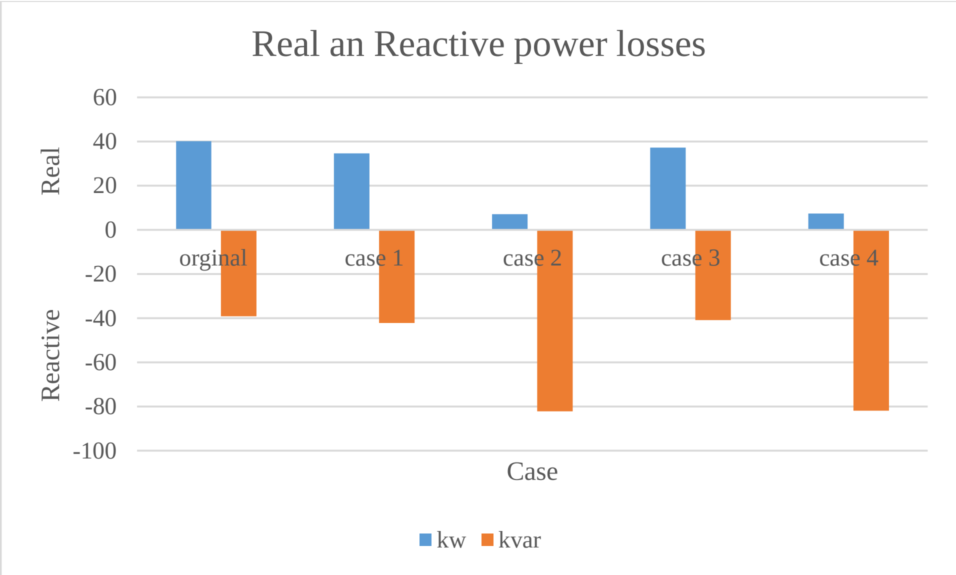



**Figure (8.15): Real and reactive power losses for all cases compared to the original**

From Table (8.7), it can be shown that the real power losses decrease in each case of the four cases. This is due to the amount of load in each branch. From Figure (8.16) which represent the branch loading in each case compared to the original on, we found that the branch loading decreases due the injection of the real power associated with load decrease. However, as the real power losses decrease, the reactive power losses increase. In case 1, the real power decreased by 13.6 %, and the reactive power losses increased by 7.9%. In case 2, however, the penetration level is (75). The real power losses show a decrease of 82.3% while the reactive power losses show an increase of 109.9%. However, the reduction of the power losses is proportional to the amount of the bus near the PV station the same goes for the power factor, but it should be far from the connection point, so it does not affect the main power supply.

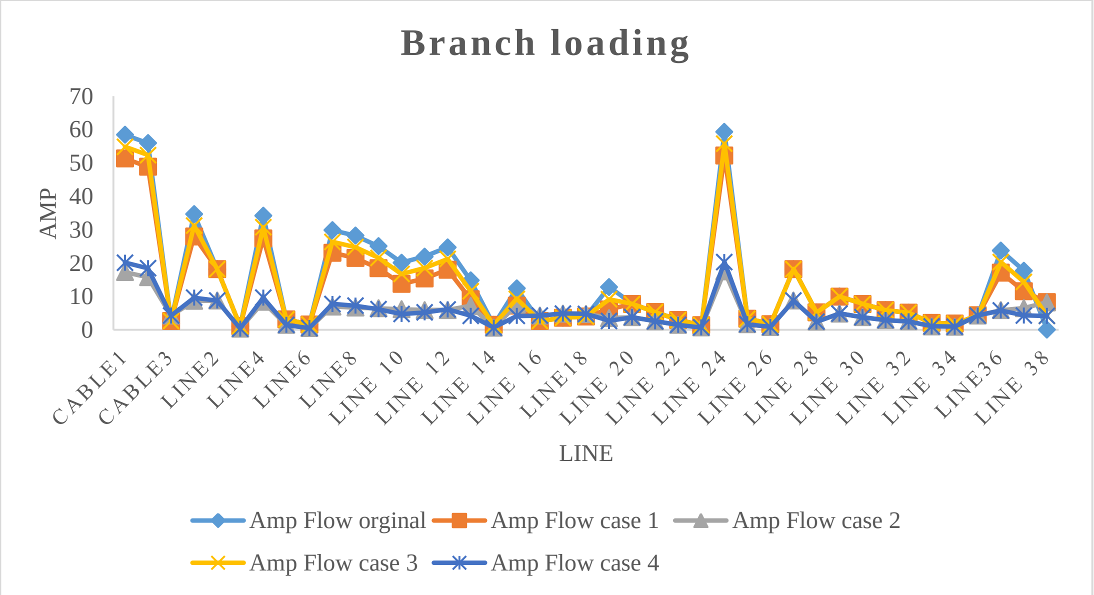



**Figure (8.16): The branch loading in each case compared to the original case**

Also, while the PVDG is connected to bus 46, some buses suffer from reverse power as the generation is higher than the load demand; especially in case 2 where the generation is 100 % and the load is 50 percent. At this point, and according to the load flow, the reverse power almost reaches the connection point with the utility. In case 1, which is with 100 % load and 100% generation no reversible power. The following figures show the reverse power that occurred in each case, taking into consideration the main connected buss to the PVDG. The first figure shows no reverse power while case two shows a reverse power on bus 46 affecting the power factor. This reverse power reaches bus 20 with .398 kVA and 6.6 Amp with no overloading for the transmission line as shown in the below in Figure (8.21).

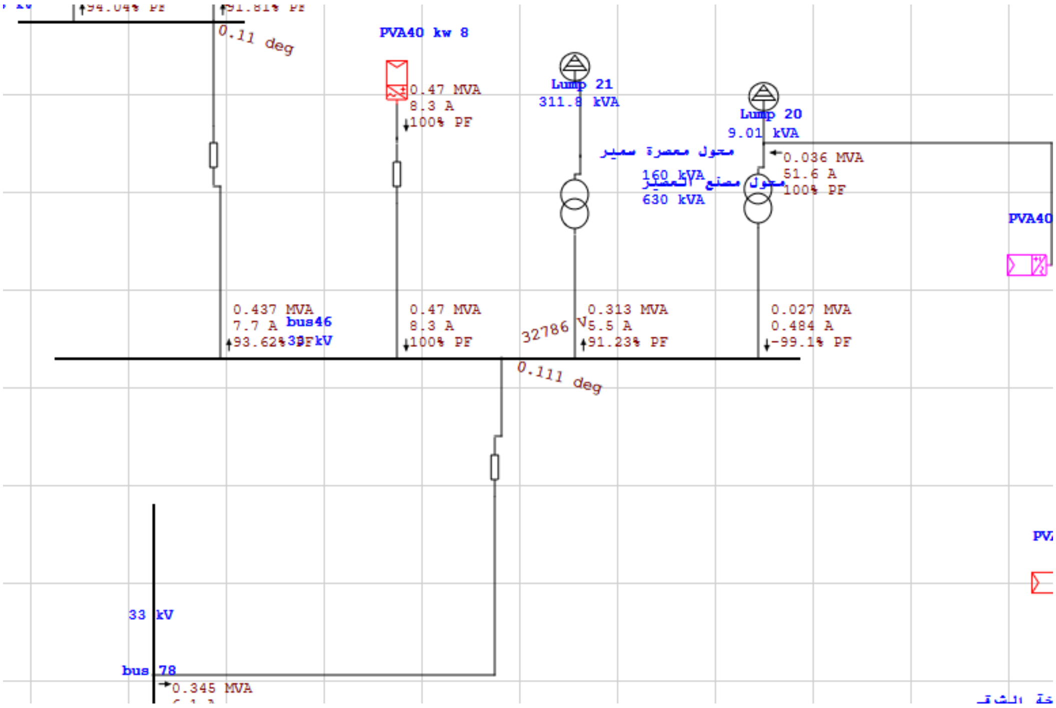


Figure (8.17): Case 1 reverse power in near buss to the connection point to the grid

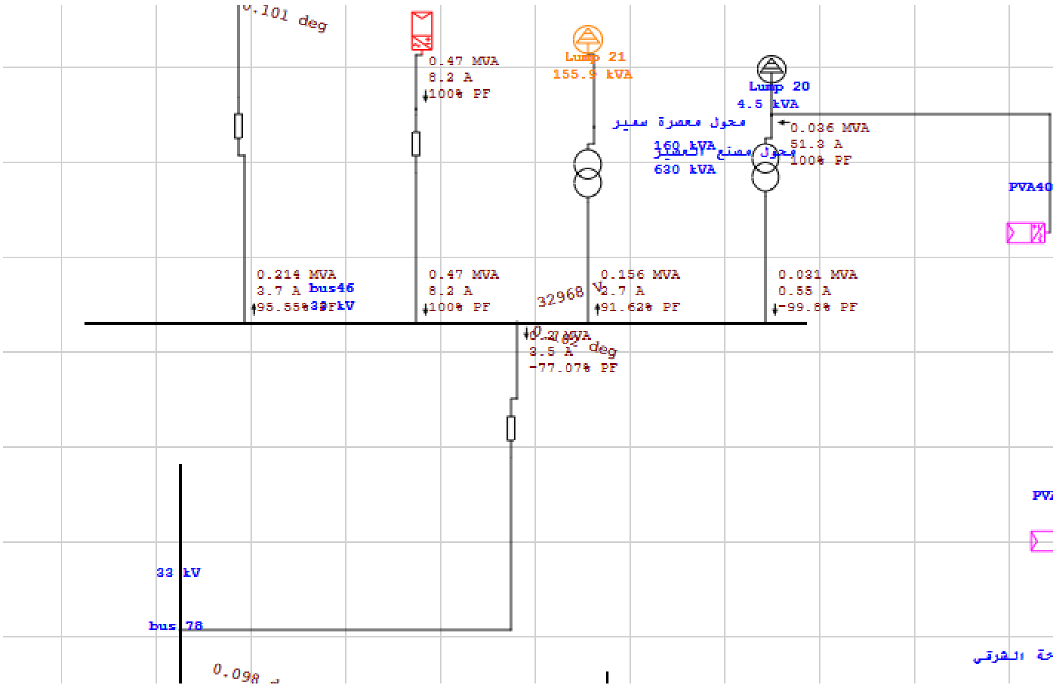


Figure (8.18): Case 2 reverse power in near buss to the connection point to the grid

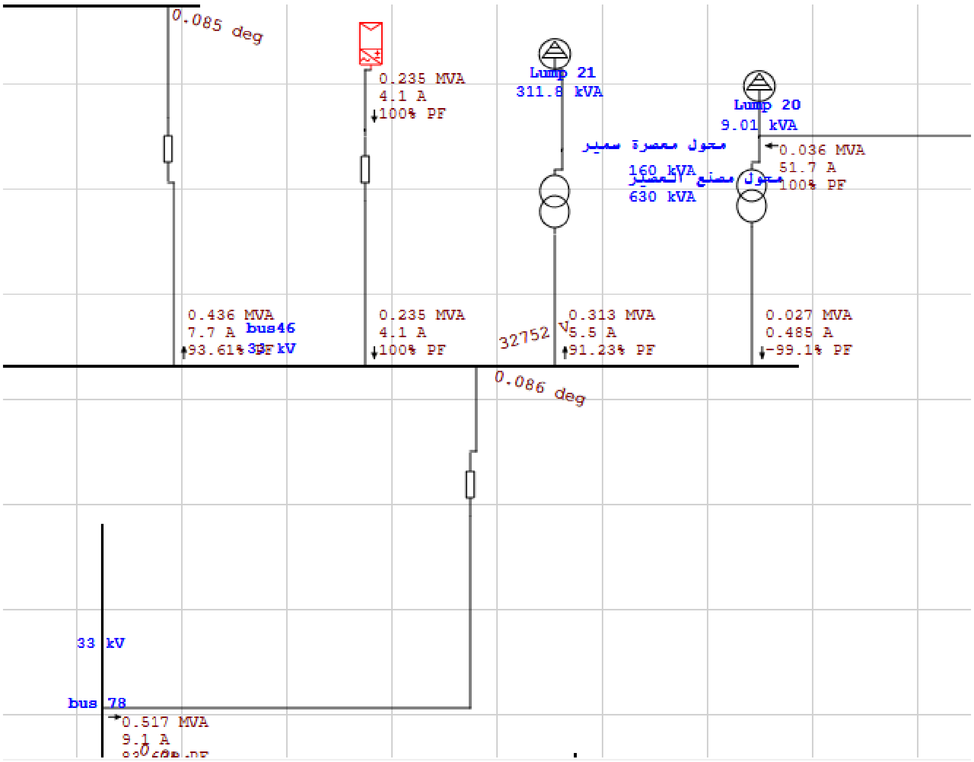



Figure (8.19): Case 3 reverse power in near buss to the connection point to the grid

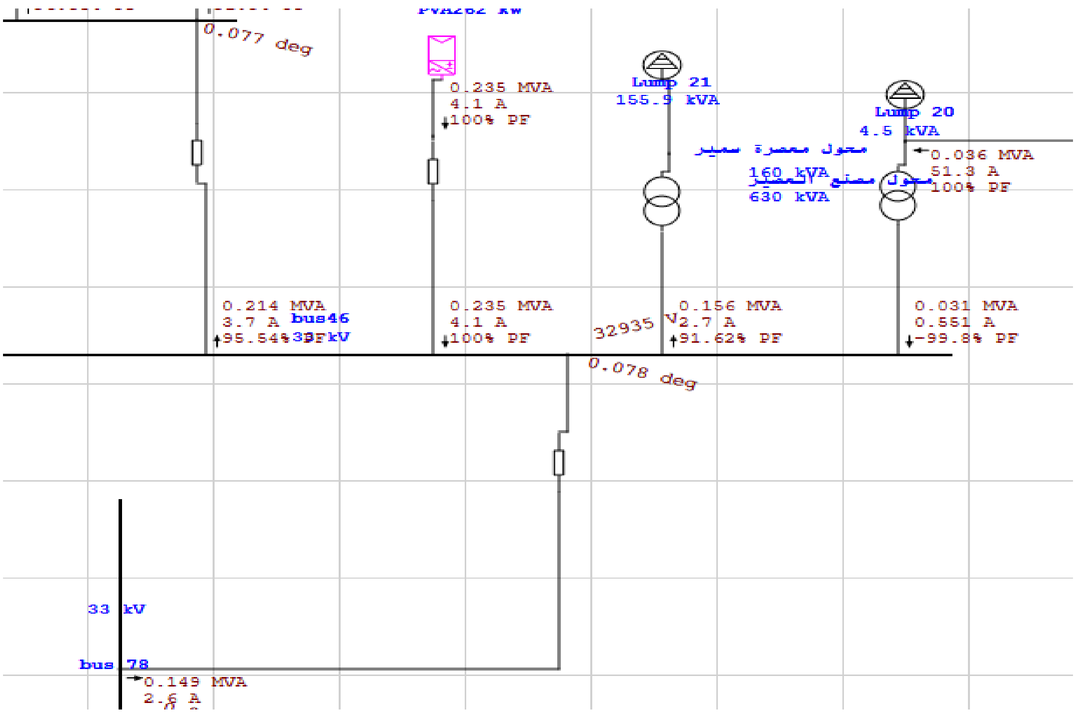



Figure (8.20): Case 4 reverse power in near buss to the connection point to the grid

The excess energy will be at maximum during the working hours of the PV and with low consumption load, for this the PV station location is optimum since the reverse power in any case of the four cases did not reach the utility point, otherwise there will be a compensation with the ampere from the utility.

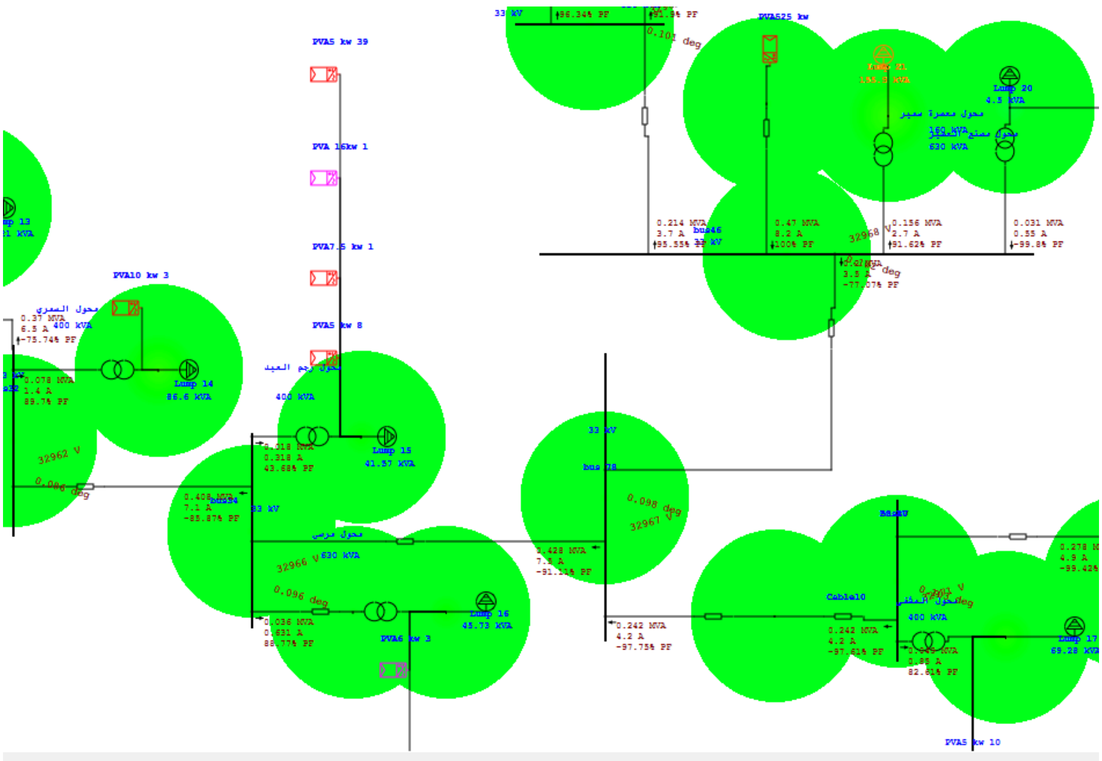


**Figure (8.21): Case 2 thermal figure for bus loading**

### 8.1.4 Short Circuit Analysis

To study the impact of the PVDG in the network, a three-phase fault test is done on bus 1, starting from the original case to the four cases. Table (8.8) shows an increase in IP (first peak of the fault current), in addition to an increase in voltage levels in the buses as illustrated in the following graph; which represents the thermal representation for the voltages. The values for the short circuit current can be used to determine the required protective devices.

IP : Maximum current (first peak of the fault current).

Ik : Steady-state short-circuit current.

Ik" : Initial symmetrical short-circuit current.

**Table (8.8): Short circuit current**

| case | short circuit current in kA | | |
|---|---|---|---|
| | Ik" | Ip | Ik |
| Original | 0.436 | 0.834 | 0.077 |
| Case 1 | 0.44 | 0.837 | 0.083 |
| Case 2 | 0.274 | 0.538 | 0.083 |
| Case 3 | 0.438 | 0.835 | 0.08 |
| Case 4 | 0.272 | 0.536 | 0.08 |

From the above table which is obtained from sort circuit analysis on ETAP, the peak value for the fault current reaches its maximum value at (0.837 kA). This occurred in case 1 and the current starts converting to a steady state at 0.083 kA since the load is at its maximum level. However, when the load demand decreased in case 2 and case 4, the peak value decreased but with little higher ratings when the generation is at 100 % as in case 3, short circuit fault causes an over loading for the instrument and cable. Figure (8.22) represents the thermal map for part of the electrical network after applying the fault in case 1.

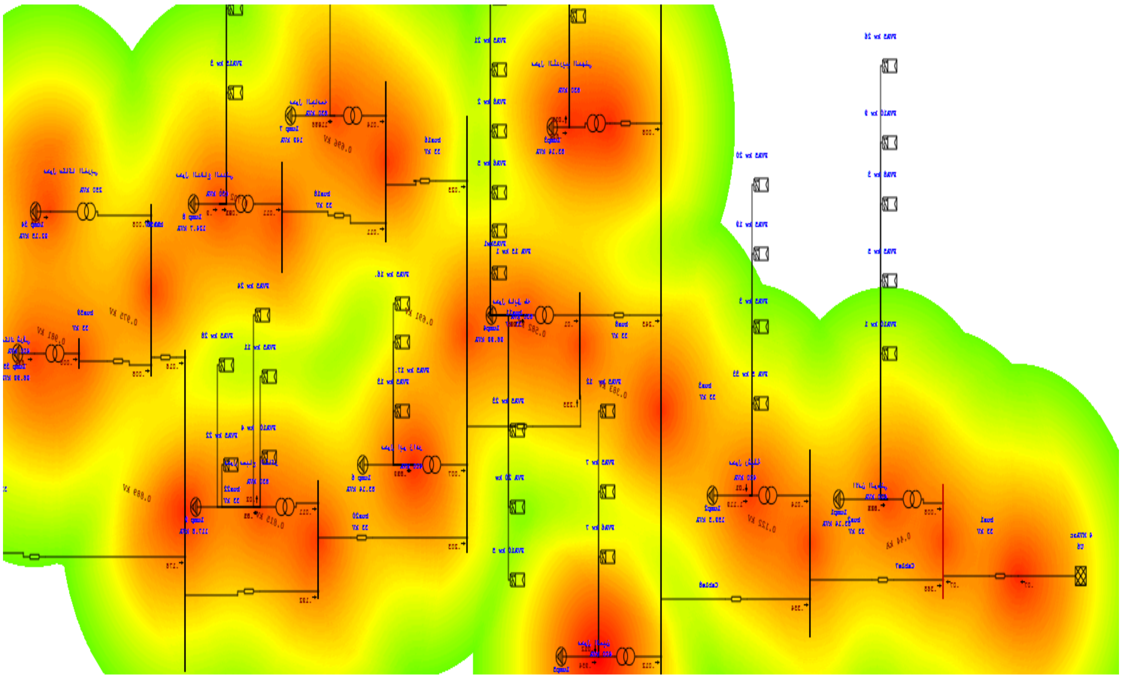


**Figure (8.22): Thermal representation for the short circuit analysis**

The above results are a glimpse of the different studied scenarios. The effect of the PV systems connected to the grid depends on the size of the connected ones .The first one is large PV systems that might affect the grid with severe changes, such as severe power frequency and voltage fluctuation, an increase in the service requirements, and stability problems. The other part is small to medium PV systems up to 0.5 MWp which might affect the grid with reverse power flow, over-voltage, an increase in the difficulty of voltage control, an increase in the power losses, phase unbalance, power quality problems, an increase in reactive power requirements, and difficulty of islanding detection. Looking into case 1 as a full load and full generation, the penetration level equals 50% which is high, and it will get higher with the decrease in load demand; especially on weekends. The following represents the changes that will take place:

- Reverse power flow: in this case, the reverse power flow from the 0.5 MW plant did not occur. However, the increasing installation of PV systems from the customer side reaching its limits caused reverse power flow for some transformers, Table (8.9) represents the revers power for two busses (bus 23 and bus 40):

**Table (8.9): Revers power on bus 23 and bus 40**

| Bus | Revers power |
|---|---|
| Bus 23 | 0.036 MVA |
| Bus 40 | 0.147 MVA |

It still did not reach the power source. However, if the load decreased or the penetration level even increased more, the reverse power will increase in different branches

- Increase the difficulty of voltage control, phase balance, and service requirement

The existence of the 0.5 MW plant decreased the voltage in the transmission lines. Table (8.10) represents the changes that happened on some lines.

**Table (8.10): Voltage drop in line 20, 19, and line 13**

| line | Before connecting 0.5 MW | After connecting 0.5 MW |
|---|---|---|
| Line 20 | 11.9 V | 11.8 V |
| Line 19 | 10.5 V | 4.2 V |
| Line 13 | 14.4 V | 6.8 V |

But still, this decrease in voltage drop, faced with phase unbalance on distribution feeders, caused some phases to be higher, which will need extra service.

- Increase in power losses: before installing the system, the total power losses were 0.04 MW and -0.039 MVAr. After adding the system, the losses decreased to 0.035 MW and 0.042 MVAr, and, by increasing the penetration, the losses will increase too.

- Reactive power and power factor: after installing the system, the P.F dropped from 87 to 83 due to the generation of the real power. The reactive power, however, maintained almost the same requirements for power factor. The improvement will increase with the penetration's increase.

**8.2 System feasibility**

The feasibility of the system is conducted by using the NPV method and defining the PBP using the RETscreen software the total cost equals to 483550 contain the environmental procedure as an extra cost, the payback period for our project is calculated to be 3 years and the NPV  2,071,096 $, with a production energy cost of 44.13 $/MWh. Figure (8.23) represents the cash flow the project .Table (8.11) shows a summary of the financial viability obtained from RETscreen software. Accordingly, with respect to the output results, the project is financially feasible.

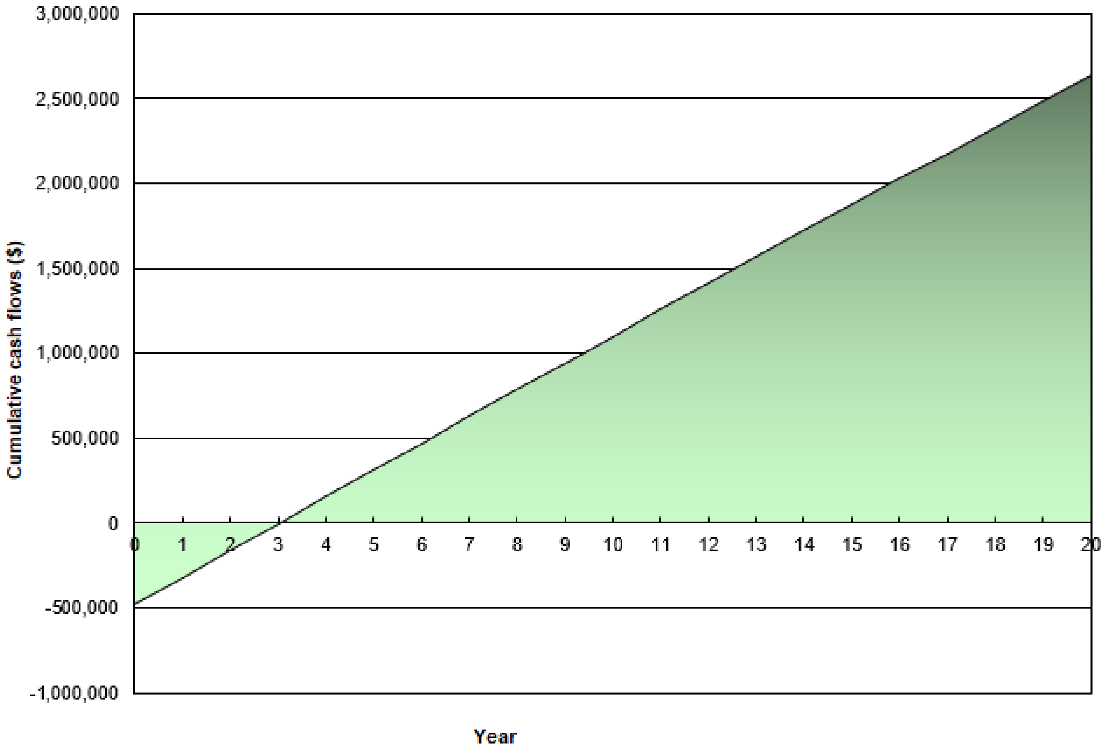



**Figure (8.23): Cash flow for installing 0.5MWp**

## Table (8.11): System viability using RETscreen software

| Viability Element | Unit | Result |
|---|---|---|
| Pre-tax IRR - equity | % | 32.80% |
| Pre-tax IRR - assets | % | 32.80% |
| After-tax IRR - equity | % | 32.80% |
| After-tax IRR - assets | % | 32.80% |
| Simple payback | yr | 3 |
| Equity payback | yr | 3 |
| Net Present Value (NPV) | $ | 2,071,096 |
| Annual life cycle savings | $/yr | 126,661 |
| Benefit-Cost (B-C) ratio | | 5.28 |
| Debt service coverage | | No debt |
| Energy production cost | $/MWh | 44.13 |

Salfit municipality can install 0.5 MWp of PV to the medium-voltage network. Any extra installation will make the grid suffer from severe impacts, regardless of the benefits that may come with PV system installation. The environment will suffer from several influences. Installing 0.5 MWp of PV needs at least 5.5 Dunms to be implemented. As for the PV system's waste, the EQA stated that it should be dealt as solid waste.

# Chapter Nine
# Conclusions and Future Work

## 9.1 Conclusions

The thesis is mainly intended to provide a detailed study for the impact of connecting PV systems to Salfit municipality grid and study the impact association with increasing the penetration level according to the voltage levels, power factor, short circuit and loading on each bus through running a load flow using ETAP software through different scenarios between the load percentage and the generation percentage and it shows that 0.5 MWp of PV connected to the grid is the highest limit until the load demand increase. The power factor levels decreased to reach 0.83 and the voltage levels showed a decrease be 12 V in the medium voltage levels. On the other hand, the short circuit currents increased in the first peak of the short circuit (Ip) from (0.830 t0 0.837)kA. A viability study was conducted by using the RETSCREEN software to decide whether this project is visible or not and calculate the energy production cost. Based on NPV calculation that was calculated as positive value and PBP calculation which was equal to 3 years, the project was found feasible and the production cost is 44.13 $/MWh.

The other part of the thesis discussed the environmental impact associated with implementing this project through using the world bank environmental and social framework by applying the environmental and social safeguards that were found stricter than the regulation and laws in Palestine. By understanding the risks, grievance mechanism, stakeholder different parties, and environmental and social management plans are conducted to understand the measure and the laws. According to the EIA report and the management plan, the environmental impact of the system was found high on water, air, flora and fauna, transportation, noise levels, traffic and the solid waste from the excavation. On the other hand, the project shows a positive impact regarding the employment, education, health, the recovering part of Salfit city electricity bill and reducing the $CO_2$ emissions.

## 9.2 Future Work

Increase the capacity of PV systems with minimum cost by using the batteries as buffering zone and study the impact of using the smart grid technology to increase the penetration level installation and putting a future for waste material disposal (PV panels) after 25 years.

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جامعة النجاح الوطنية

كلية الدراسات العليا

# تقييم تأثير الشبكة والأثر البيئي لنظام طاقة كهروضوئية 0.5 ميجاوات متصل بشبكة توزيع كهرباء محافظة سلفيت

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قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك، بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2021

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الطلب المتزايد على الطاقة الكهربائية والمتزامن بإيجاد حلول ومصادر توليد جديدة، أدى إلى التوجه نحو استخدام مصادر الطاقة المتجددة، بصيانتها وتكلفتها القليلة أصبح التوجه نحو المصادر المتجددة خيارا عالميا. كما أصبحت عملية شبك مشاريع الخلايا الكهروضوئية المربوطة بشبكة الكهرباء تتزايد بشكل متسارع منذ العقد الماضي. وهذا التزايد في المشاريع المربوطة الذي يقابله تغييرات تحدث على مستوى الجهد ومعامل القدرة وتيارات القصر، فضلاً عن التغيرات التي تحدث على خطوط النقل وتأثيرها على جودة الكهرباء الواصلة للمستهلك يجب ان تؤخذ بعين الاعتبار، إلى جانب التأثيرات البيئية الواقعة على أرض المشروع من نباتات، حيوانات، ضجيج، مياه. في هذه الرسالة، يتم دراسة مدى قدرة شبكة كهرباء سلفيت على ربط مشروع طاقة شمسية بقدرة 0.5 ميجا واط وتحديد أعلى قدرة من المشاريع التي يمكن ربطها من جانب، ومن جانب آخر تقوم بدراسة الأثر البيئي للمشروع بناء على متطلبات وآلية العمل لدى البنك الدولي في دراسة الاثر البيئي والاجتماعي. وتبدأ الدراسة الفنية للمشروع من خلال اربع سيناريوهات، الاول حمل كامل وتوليد كامل، الثاني نصف حمل وتوليد كامل، الثالث نصف توليد وحمل كامل، والحالة الأخيرة نصف الحمل ونصف التوليد. اما الشق الاخر من الرسالة يُعنى بدراسة الأثر البيئي من خلال المعايير البيئية والاجتماعية للبنك الدولي. وأظهرت هذه الرسالة تغيرات على مستوى الفولتية في بعض خطوط النقل وتغير في معامل القدرة من 0.87 الى 0.82، بالإضافة إلى زيادة في الطاقة الضائعة حيث تمت دراسة الشبكة وتأثير ربط الخلايا من خلال برنامج (ETAP). إلى جانب الدراسة الفنية والدراسة البيئية، تمت دراسة الجدوى المالية للمشروع على طريقتين؛ طريقة فترة الاسترداد وطريقة صافي القيمة الحالية باستخدام برنامج (RETSCREEN)، حيث أظهرت نتائج

التحليل المالي أن فترة الاسترداد هي ثلاث سنوات وأن صافي القيمة الحالية موجبة بمعدل عائد على الاستثمار هو 3.2 %، وتكلفة انتاج الطاقة هي 44.13 دولار \اميجا واط ساعة. كما توضح هذه الرسالة الآثار السلبية البيئية المحتملة على منطقة المشروع فيما يتعلق بالعناصر البيئية، مثل المنطقة الملوثة بالغبار، وزيادة الضوضاء اثناء العمل، والتنفيذ، وقضايا النقل، ومشاكل المياه، وقضايا النفايات. كما أنه يضع خطة لتخفيف الأثر البيئي وخطة لمراقبة التحكم في العواقب والاثار المرتبطة بالمشروع والعمل على على تقليلها قدر الإمكان، خلال مرحلة ما قبل البناء ومرحلة البناء ومرحلة التشغيل والصيانة من ناحية، ومن ناحية أخرى يظهر المشروع تأثيراً إيجابيا على العمالة والصحة وخفض انبعاثات ثاني اكسيد الكربون بمقدار 2559.2 طن سنوياً.