Palestine Polytechnic University

College of Engineering and Technology

Department of Electrical Engineering

Introduction of Graduation Project

Design Solar System to Supply Alghebrena Farm

Team

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Palestine _ Hebron

2015

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Supervisor: Dr. Maher Maghalseh

Submitted to the College of Engineering

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Abstract:

The main object of this study is to design and model a solar system for Alghebrena farm. In this project, the potential and the cost-effectiveness of a solar photovoltaic power plant for meeting the energy demand of Aldahria zone at Alghebrena farm is analyzed. Also, the energy demand of Alghebrena zone for year 2013 has been estimated (154112.6984 kWh/year) which requires about 668.73 m^2 of roof area. . For the on- site solar PV power plant net profit after tax is 3710225$, deprecation is 883719 $simple payback period is 5.9 years, net cash is 2826506 $, and IRR is 16.76%.Technical study will be investigated using ETAP,Sketch Up , Auto CAD. Also, economic feasibility study will be evaluated and discussed.

Dedication

الى والدينا العزيزين،،، بكل الحب والاحترام والتقدير اهديكم هذا العمل ...

الى من احترقت ليلا ونهارا حتى تضئ لنا حياتنا ... الوالدة الغالية ...

الى اخوتنا واخواتنا ... الذين دعمونا وساندونا بكل حب ...

الى صديقاتنا الغاليات ... اللواتي عشنا معهن اجمل لحظات حياتنا ...

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الى كل زملاؤنا واصدقاؤنا ،،المهندس سفيان ،،والمهندس غسان،،،لما قدموه لنا من معلومات قيمة ،،،،

الى الدكتور الفاضل فؤاد الزرو،، والدكتور سمير خضر والدكتور عبد الكريم داود،، والدكتور نزار عمر،،،لما قدموه لنا من معلومات قيمة طالما رجعنا لها في اتمام هذا المشروع،،،،

List of Tables

Abbreviations

AC	Alternating current
C	Capacitor
DC	Direct current
D	Duration
EF	Earliest Finish
ES	Earliest Start
R1	First Relay
R4	Fourth Relay
F	Frequency
L	Inductance
IRR	Internal rate of return
Km	Kilo meter
KN	Kilo Neaten
KW	Kilo Watt (1,000 Watt).
KWh	Kilo Watt Hour.
LF	Latest Finish
LS	Latest Start
MPPT	Maximum Power Point
MW	Mega watt
M	Meter
MCB	Mintuire Circuit Breaker
MCCB	Molded Case Circuit Breaker
NIS	New Israeli Shekel
PV	Photo Voltaic.
PF	Power Factor
R2	Second Relay
ISC	Short Circuit Current
STC	Standard Test Condition
R3	Third Relay
TF	Total Float

Table of content

NO.	Title	Page
	Abstract	I
	Dedication	II
	Acknowledgments	III
	Abbreviations	IV
	Table of content	V
	List of Tables	VII
	List of Figures	VIII
	Chapter One: Introduction	
1.1	Introduction	1
1.2	Motivation	2
1.3	Back ground	2
1.4	Summery about the Report	4
	Chapter Tow: Block Diagram	
2.1	Introduction	6
2.2	Block Diagram	6
2.3	Sketch Up Design	7
2.4	Earthing Design	10
2.5	AutoCAD	11
2.6	Cleaning of Solar Panels	12
	Chapter Three : Desing of Solar Planet	
3.1	Design of Solar Power Plant	14
3.2	Load Analysis	14
3.3	Calculation	17
3.4	Protection Calculation	19
3.5	Land Required	19
	Chapter Four: ETAP Simulation and Result	
4.1	Introduction	20
4.2	ETAP Simulation	20
4.2.1	Load Flow Of Current Statues of Alghebrena Farm	20
4.2.2	Load Flow the Existence of Alghebrena Farm Solar Panels Only	23
4.2.21	Protection Simulation	23
4.2.3	Load Flow of Alghebrena Farm with Methan Generator and Solar Panels	28
4.2.4	Load Flow of Alghebrena Farm with Methan Generator and Solar Panels After Adding Single Tuned Filter	31
4.2.4.1	Harmonic in ETAP	31

	Simulation	
4.2.5	Short Circuit Analysis	36
4.2.5.1	Three Phase Fault on Utility Side	36
4.2.5.2	Three Phase Fault on Alghebrena Farm Side	38
4.2.6	Reliability	40
4.2.6.1	Protection Zone	43
	Chapter Five : Shading and Mechanical Design	
5.1	Introduction	44
5.2	Shade	44
5.2.1	Bypass Diode	44
5.2.2	Vertical Height Solar Panels	44
5.2.3	Pitch Distance	45
5.3	Mechanical Design	47
5.4	Barn Design	48
	Chapter Six: Economic Calculation	
6.1	Introduction	50
6.2	Project Cost	50
6.3	Time Period for Implementation of the Project	51
6.3.1	Determine theTime Period for Implementation of the Project	51
6.4	Economic Power Engineering	54
6.4.1	Power Factor Correction	54
6.4.2	Calculations Annual Saving When Adding Capacitors to Improve Power Factors	54
6.4.3	Depreciation Charge	55
	Chapter Seven: Conclusion	
7.1	Conclusion	56
7.2	Recommendation	57
	References	58
	Appendix	63

List of Tables

NO.	Title	Page
Table (4.1)	Load Flow Current Statues of Alghabrena Farm	22
Table (4.2)	Coordinate with Relays	24
Table (4.3)	PSM and TMS Setting for Over Current Protection	24
Table (4.4)	Data for Phase Relay Setting and Coordination	26
Table (4.5)	Load Flow of the Existence of Alghabrena Farm Solar System Only	26
Table (4.6)	Load Flow of Alghabrena Farm with Methane Generator and Solar System	30
Table (4.7)	Load Flow of Alghabrena Farm with Methane Generator and Solar System after Single Tuned Filter	34
Table (4.8)	Three Phase Fault on Utility Side	37
Table (4.9)	Three Phase Fault on Alghabrena Farm Side	39
Table (6.1)	Time Period for Implementation of each Activity	52

List of Figures

No.	Title	Page
Figure (2.1)	**The Current Statues of the Southern Side of theAlghabrena Farm**	7
Figure (2.2)	**The Current Statues of the Northern Side of theAlghabrena Farm**	8
Figure (2.3)	**The South Side of Alghabrena Farm after the Addition of Solar Pannels**	8
Figure (2.4)	**Earthing of Solar System**	9
Figure (2.5)	**Grid**	10
Figure (2.6)	**Earthing Design**	11
Figure (2.7)	**Electrical Distribution Board**	11
Figure (2.8)	**Hydro Tub**	13
Figure (3.2)	**Monthly Average Solar Potential Curve in Hebron Area**	16
Figure (3.3)	**Monthly Load Curve in Alghebrena Farm and Monthly Average Solar Potential Curve in Hebron Area**	17
Figure (4.1)	**Load Flow Current Statues of Alghabrena Farm**	21
Figure (4.2)	**Load Flow of Alghabrena Farm with Solar System Only**	27
Figure (4.3)	**Load Flow of Alghabrena Farm with Methane Generator and Solar System**	29
Figure (4.4)	**Load Flow of Alghabrena Farm with Methane Generator and Solar System after Single Tuned Filter**	35
Figure (4.5)	**Three Phase Fault on Utility Side**	36
Figure (4.6)	**Three Phase Fault on Alghabrena Farm Side**	38
Figure (4.7)	**Reliability of The Protection Devices**	40
Figure (4.8)	**Fault on Methan Generator**	41

Figure (4.9)	**Fault on Transformer Side**	42
Figure (4.10)	**Protection Zones**	43
Figure (5.1)	**Shadow Under Panels in Summer**	45
Figure (5.2)	**Shadow Extended to a Distance of 15 cm from the Solar Panels in Summer**	46
Figure (5.3)	**Shadow Extended to a Distance of 30 cm from the Solar Panels in Winter**	46
Figure (5.4)	**Mechanical Design of Solar Panel Structure**	47
Figure (5.5)	**Truss Construction**	48
Figure (6.1)	**Way to Find Project Period of Time**	52
Figure (6.2)	**Way to Find Project Period of Time**	53

Abstract:

The main object of this study is to design and model a solar system forAlghebrena farm. In this project, the potential and the cost-effectiveness of a solar photovoltaic power plant for meeting the energy demand of Aldahria zone at Alghebrena farm is analyzed. Also, the energy demand of Alghebrena zone for year 2013 has been estimated (154112.6984 kWh/year) which requires about 668.73 m² of roof area. . For the on- site solar PV power plant net profit after tax is 3710225$, deprecation is 883719 $simple payback period is 5.9 years, net cash is 2826506 $, and IRR is 16.76%.Technical study will be investigated using ETAP,Sketch Up , Auto CAD. Also, economic feasibility study will be evaluated and discussed.

ChapterOne:

Introduction

1.1 Introduction

Alghebrena farm located in the south of Hebron, a cows farm are required to provide Alghebrena factory of milk it contains pumps,cooling, lighting and services where depreciated farm per year of electricity 154,112.69kWh/year.

One of the most important renewable sources is the solar energy, as ultimate source of most of renewable energy sources. Solar energy can be used to generate electricity in a direct way with the use of photovoltaic, or by using solar thermal or concentrating solar power to heat a media or water and generate steam then electricity.

Palestine is located in a high solar power concentration area in the world, with an annually average irradiance of 5.4 kWh/m^2- day. This encouraged us to focus on utilizing the solar power as a source of electricity, to face our demand. Due to the lack of lands in Palestine because of the political situation and the occupation, on grid PV was the preferable clean source to choose for this study. [9]

In this project, the annual energy usage for Alghebrena farm is 154112.6984 kWh/year, such an expense often come as no big surprise, paying a big chunk of the farms profit to south electricity company, and here came the idea for the design of a system that provides loads for Alghebrena farm necessary for the operation of electric power loads. And that the system is not only provide loads of electric power, but must develop the system to become an investment project provides a profit for the owner of the farm. At the beginning of the collection of the information on the farm site and study the loads in the farm there are three different possibilities for renewable energy systems.

The first possibility Study is wind turbine. The major challenge in using wind as a source of power is that it is intermittent and does not always blow when electricity is needed. Wind cannot be stored, and not all winds can be harnessed to meet the timing of electricity, the answer was speed is not enough to design a turbine farm provide loads of electrical energy required. The second possibility to use methane gas resulting from the remnants of cows and make use of methane gas to produce electricity, but when we discussed this possibility with the farm owner his answer was that now this project is implemented on a Alghebrena farm.

A third possibility of the probabilities of renewable energy that can be designed for Alghebrena farm to provide loads, more effective in Palestine is a clean energy and non-polluting systems are solar energy, where through this system is to provide electrical power necessary loads for the operation of these loads, and the surplus of energy production after feeding the loads being pumped into the network. The agreement between the farm owner and the owners of the electricity company on the tariff on each kilowatt is pumped into the network.

1.2 Motivation

1) Utilize the solar energy which is free available and sustainable. Palestine weather is sunny throughout the year and can provide a very high electrical energy by using PV systems.

2) Palestine import and depend on Israelis for supplying the electricity for the customers as well as there is no central stations for generate electricity. Consequently, it is important to generate electricity from other resources, such as solar.

3) Using solar energy can provide clean, free, and sustainable energy.

4) Capital cost of Photovoltaic is high but offer money for user in later year.

1.3 Back ground

Bataineh, Dalalah [1] Design for a standalone photovoltaic (PV) system to provide the required electricity for a single domestic household in rural area in Jordan .Sit radiation data and the electrical load data of a typical household are taken into account .the output of PV array is related to the light intensity falling on the PV array, ambient temperature, cell temperature, load status and characteristics of PV modules.

Barsoum, Lee [2] Solar power on grid system it becomes a challenge to the grid operators to properly manage the grid system operation power flow changes from unidirectional power flow to bi-directional power flow Under Malaysia ninth development plan , renewable energies such as solar power were planned to be included in the grid system . Malaysia is aiming to have minimum of 220 MW of solar power in the composition of energy mix by year 2020.In this paper , usage of bi-directional inverter in solving the over voltage issue is discussed where bi-directional inverter function as either inverter or converter , without reducing the amount of solar power at the low voltage . The protection scheme for conventional radial grid system is based on the full load current and the short circuit current at each bus. Hence adjustments on the settings of the over current relay is required with reference to the distributed generation. Solar power injection reduces their electricity bill and the same time, assists in reducing power demand from generators and decrease the transmission losses. Electrical Transient Analysis Program (ETAP) we used for investigations.

Chandel [3] study has been carried out to assess the technical feasibility and economic viability of a 2.5MW capacity solar photovoltaic power plant for meeting the energy demand of garment zone. For this power generation total 22230 PV modules are required with 16 modules in each row. Seven inverter with MPPT controller of 3.5MW capacity and total area required 13.11 acres.

El Alami [4] the performance of the PV system generator is evaluated according to the standard conditions (STC): irradiance 1000w/m^2, and temperature 25c°.The performance of a PV solar system highly depends on the weather conditions, such as solar radiation, temperature and light, so does the performance of the PV generator degrade with increasing temperature, the decrease in intensity and the illumination load variations. To provide energy continuously throughout the year, a PV system must be properly sized and led by intelligent command to monitor MPPT for extracting the maximum energy.

Dehui Zeng [5] control the PV inverter to inject reactive current when the voltage drops. The influence of reactive power from PV system to the PCC voltage is analyzed and an adaptive voltage support control strategy is proposed to improve the fault ride through capability of PV inverter. The study indicates that when the difference between PV inverter short circuit capacity and the short circuit capacity at PCC supplied by system is not so large, with the proposed control strategy, the voltage can be improved effectively. The proposed control strategy can maximized the voltage support capability of PV plant while takes the safety of equipment into consideration as well.

Sun, Li, Hong, Shen [6] necked PV system in Northwest China. They are mainly front row shading, plant and guano shading and nearby building shading. Then, aiming at nearby building shading phenomenon, some experiments have been done. From the experimental results, it can be seen that shading can affect the electrical properties of PV modules. Meanwhile, same shading area on different shading positions can cause different impacts on the identical PV module. The I-V curve test of PV modules, it can be seen that dust influence system performance of the grid-connected PV system.

Wu1, Tsai, Zou[7]This paper investigates the main technical impacts of large-scale PV generations on power grids and associated interconnection standards As the integration of large and commercial scale PV on the distribution level such systems can have considerable effect on the operation and protection of the system. This work investigates the main technical impacts of large scale PV generations on power grids and associated interconnection standards additionally; a case study by using the PSS/E software in the Kinmen power system was implemented to study the steady-state and transient characteristics for the high penetration PV systems. From the simulation results, several system disturbances, such as change of solar irradiance, tripping of PV generation, and three-phase short circuit fault would affect the maximum PV penetration as a grid. Moreover, PV generation penetration and configuration types would affect system voltage and power losses.

Anwari, Hiendro [8] the potential implementation of photovoltaic (PV) energy system in western region of Saudi Arabia was analyzed in this paper The feasibility of PV energy system was analyzed based on solar irradiances. Stand-alone PV systems with battery storage element will be evaluated and discussed It has been demonstrated that the use PV system with battery can significantly reduce the dependence on solely available diesel resource in Makah city and western region of Saudi Arabia in general.

1.4 Summery about the Report:

Chapter One: Introduction about this project.

Chapter Tow: In this chapter the block diagram module will explain the most important equipment and electronic devices that are used in solar systems and the principle work of each device. Will also explain protective equipment that is used in the solar system.SketchUp is an architectural concept design. It also includes features to facilitate the development of models to Google Earth, it is designed to be more intuitive, is flexible on the other three dimensional software enhancements include geographical location model with Google maps, color images and more accurate matching image and terrain improvements, and building integration. In this section, we have made a real solar system for Alghebrena Farm in real dimensions, and distribution of electrical panels in the appropriate places. We have also distributed the solar panels on the roof of the farm, and we have clarified the earthing system of the solar system with the appropriate dimensions and method of earthing. We draw electrical distribution panel on the AutoCAD program and the statement of the value of MCCB and MCB as whether AC or DC. And explaining solar panels cleaning method.

Chapter three: In this chapter the calculation we have 4 inverters, 4 array with 5 string in each string 17 module which requires about 668.73 m^2 of roof area.

Chapter Four:ETAP Simulation and Result, the project consists of develop a protective device coordination using a graphical software program (ETAP) to add features and flexibility in the area of electrical system protection.Also, this graphical software program it's going to be using for all kind of element that used these. We will select the software program, analyze all types of element protection that are utilizing in electrical system, and simulate the program using various management studies.

Chapter Five: Shading and Mechanical Design, In this section we did mechanical design for the structure of solar panels in a way that enables us to avoid the shade, and we draw this design on the AutoCAD program, and we have made a calculation of trussof Alghebrena Farm based on equations from **"Construction Book" in**Civil Engineering to see if truss could bear the weight of panels or not.

Chapter Six: In this chapter show time period for completion of the project and the cost of construction of the project also includes the cost of adding capacitors of the system to correct the power factor.

Chapter Seven: Conclusion

Chapter two:

Block Diagram

2.1 Introduction:

SketchUp is an architectural concept design. It also includes features to facilitate the development of models to Google Earth, it is designed to be more intuitive, is flexible on the other three dimensional software enhancements include geographical location model with Google maps, color images and more accurate matching image and terrain improvements, and building integration.

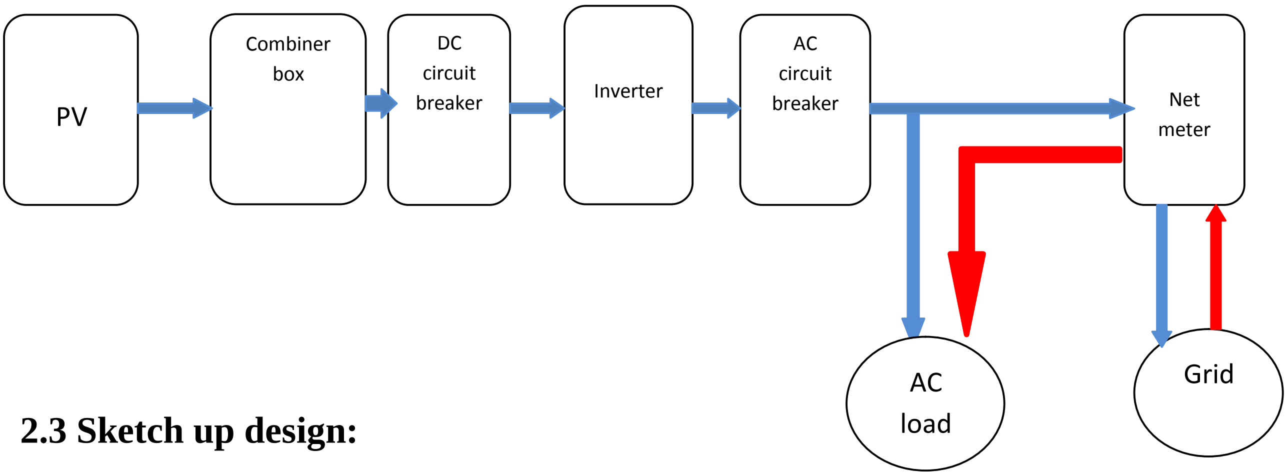
In this section, we have made a real solar system for Alghebrena Farm in real dimensions, and distribution of electrical panels in the appropriate places . We have also distributed the solar panels on the roof of the farm, and we have clarified the earthing system of the solar system with the appropriate dimensions and method of earthing .

We draw electrical distribution panel on the AutoCAD program and the statement of the value of MCCB and MCB as whether AC or DC.

2.2Block diagram

In this module will explain the most important equipment and electronic devices that are used in solar systems and the principle work of each device. Will also explain theprotective equipment that is used in the solar system.

Block Diagram for solar power system



2.3 Sketch up design:

In this section we will display a SketchUp figures to show each component of the block diagram which was introduced in the previous section,where we use the true dimensions in this program. The number of DC circuit breakers , AC circuit breakers, number inverters, distance from the grid to the Alghebrena farm , place for distribution boards and place of solar panels on the roof of Alghebrena Farm, all the previous thing were design in real statement .

1) Alghebrena Farm current situate :

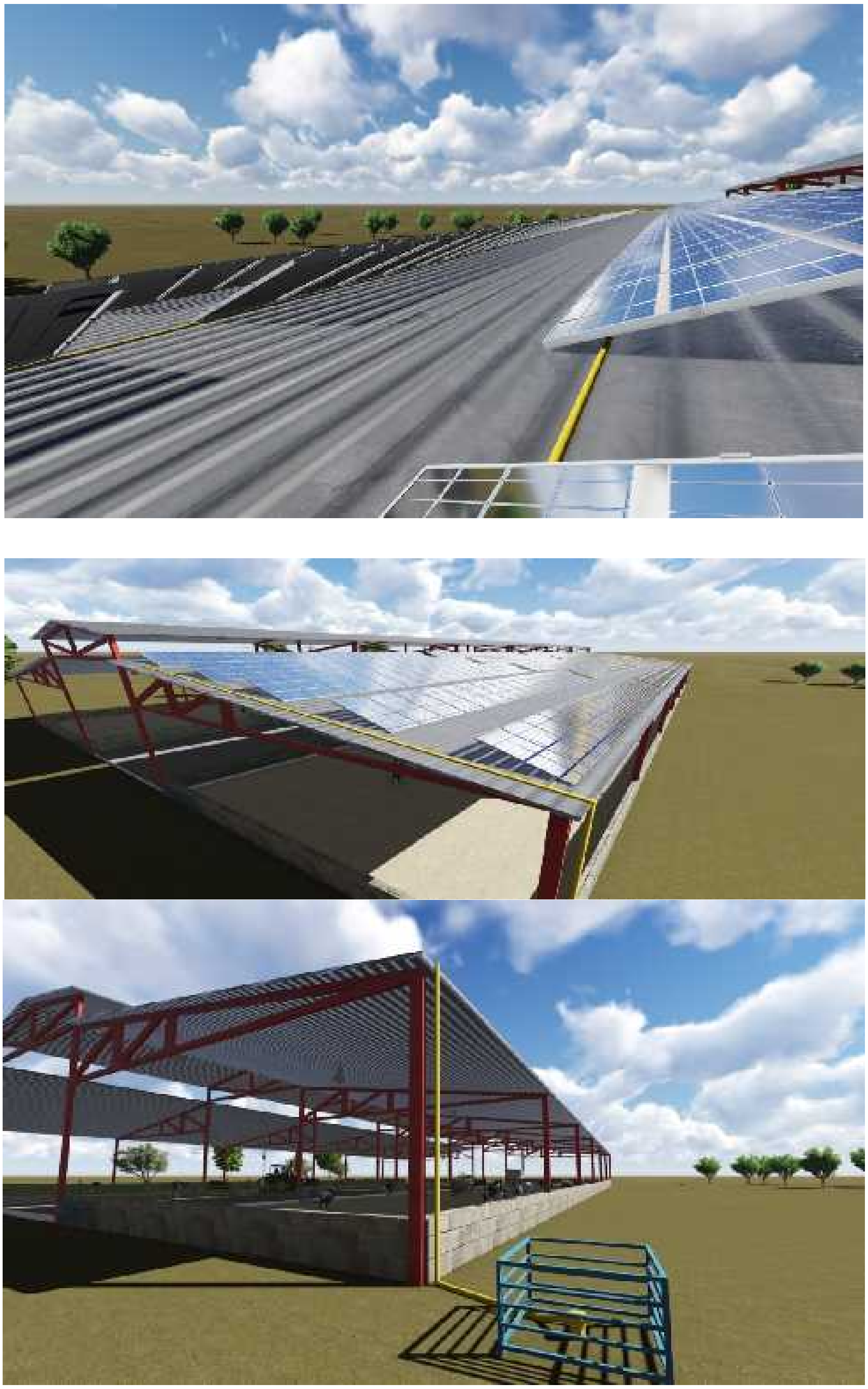
Fig(2.1): The Current Status of the Southern Side of the Alghebrena Farm

Fig(2.2): The Current Status of the Northern Side of the Alghebrena Farm

2) Alghebrena Farm after the addition of solar panels

Fig(2.3): The South Side of the Alghebrena Farm after Addition of Solar Panels

3)Electrode earthing system :



Fig(2.4): Earthing of Solar System

4)Grid :

Fig(2.5): Grid

Result:

1)Have solar panels on the roof of the farm, 5 array in each array 4 string in each string 17 modules, and it places on south side of the farm .

2) We put four cabinets, cabinet for DC circuit breakers, cabinet for AC circuit breakers , cabinet for inverters , cabinet for net meters .

3) Video design SketchUp shows how to arrange solar panels, earthing system, arranging cabinets, places for distribution panels, and the net metering movement by feeding source, from the grid or from solar panels.

2.4 Earthing Design

In this section will explain the grounding system used in solar system, using an Excel program to calculate the number of electrodes necessary for the completion of the grounding solar cell process, as shown in Figure (2.6)

Ministry of Public Works & Housing

Electrical Design Department

Calculations of Electrodes earth Resistance

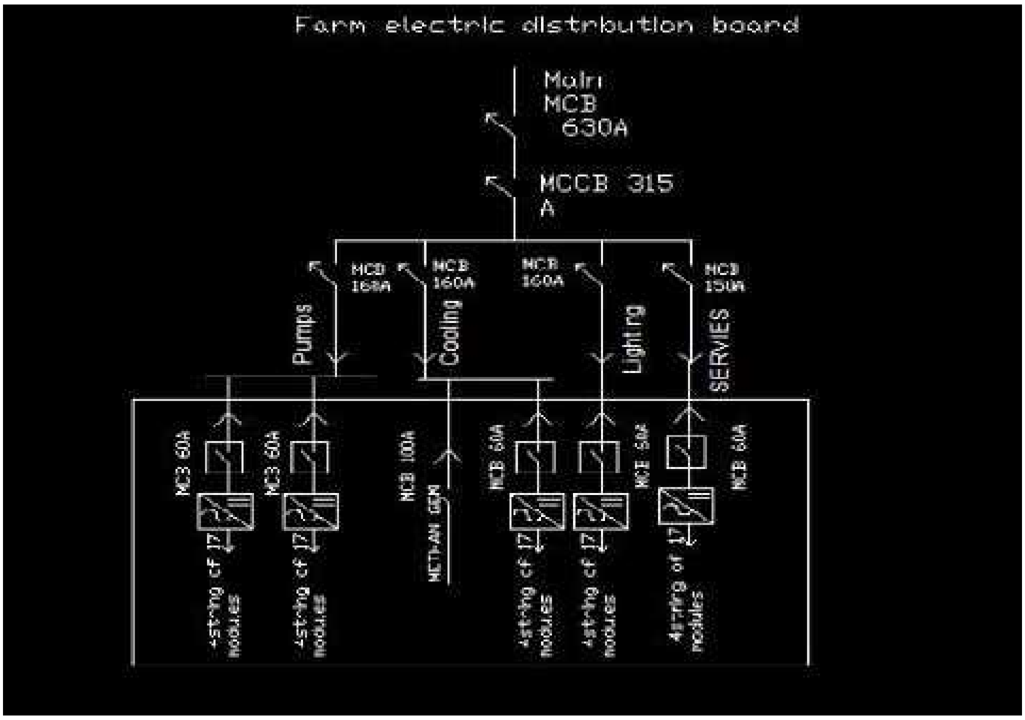
Project Name								
Soil Type	ρ=Soil resistivity, Ω.m	L = Length of electrode, m	d = Outer diameter of earth rod, m	n = Number of rods	Distribution Form of Electrodes	S = Rod spacing, m	R (ohm)	R_n (ohm)
تربة طينية زراعية	100	2	0.019	10	Parallel electrodes or Equilateral triangle	4	45.67	4.57

Fig (2. 6): Earthing design

Result :

The first variable is the type of soil surrounding the farm where this type of soil is clay soilEach type of soil have specific ρ through the program is to show the value of ρ, corresponding to the type of soil. Electrode length of 2 meters and a diameter of 0.019 meters was chosen as the number of electrodes according to the value of resistance electrode.And the space between two electrodes is 4 meter.

2.5AutoCAD:



Fig(2.7): electrical distribution board

Result :

1)DC distribution panels and inverters should be about 30 meters from the source (solar panels) in order to reduce the voltage drop .

2)We have 4 strings, with 17 modules in each string, and 5 arrays that main 5 inverters.

2.6 Cleaning of Solar Panels :

Pure Water Window Cleaning System:

We want to use in our project the **HydroTube**, which relies on the use of pure water to clean solar panels, because of the risks in the use of chemicals on the solar panels, which reduces its effectiveness and impact on the semiconductor material used in the manufacture of these cells also affect the aluminum structure .

Product Details:

The HydroTube™ offers a better, faster way to clean windows up to 5 stories safely from the ground. The unique linear design (patent pending) allows us to build a sophisticated high volume reverse osmosis DI water purification system all in one portable tube. The result is spot free windows at a fraction of the cost and time of any other system.[10]

The HydroTube™ moves easily in and out of vehicles, up and down steps, and across any terrain. The HydroTube™ has the unique ability to product a high volume of pure water on normal tap pressure. The possibilities are endless and the system can be upgraded at any time with an electric or gas module. This includes a 4 stage filtration system which includes reverse osmosis, and deionization process to produce mineral free water providing for incredible cleaning action and spot free windows. Note figure(2.8)[10]

Fig(2.8): HydroTube™[11]

Chapter Three:

Design of SolarPlant

3.1Design of Solar Power Plant

Palestine is located in a high solar power concentration area in theworld, with an annually average irradiance of 5.4 kWh/m^2- day [9]. This encouraged us to focus on utilizing the solar power as a source of electricity, to face our demand. Due to the lack of lands in Palestine because of the political situation and the occupation, on grid PV was the preferable clean source to choose for this study.

3.2 Load analysis:

Introduction

In this section, we conducted an analysis of the loads in Alghebrena farm based on monthly bills value for the year 2013 and we work to collect information of the solar radiation and see value in each month , then make excel file to draw the following curve based on load and radiation information .

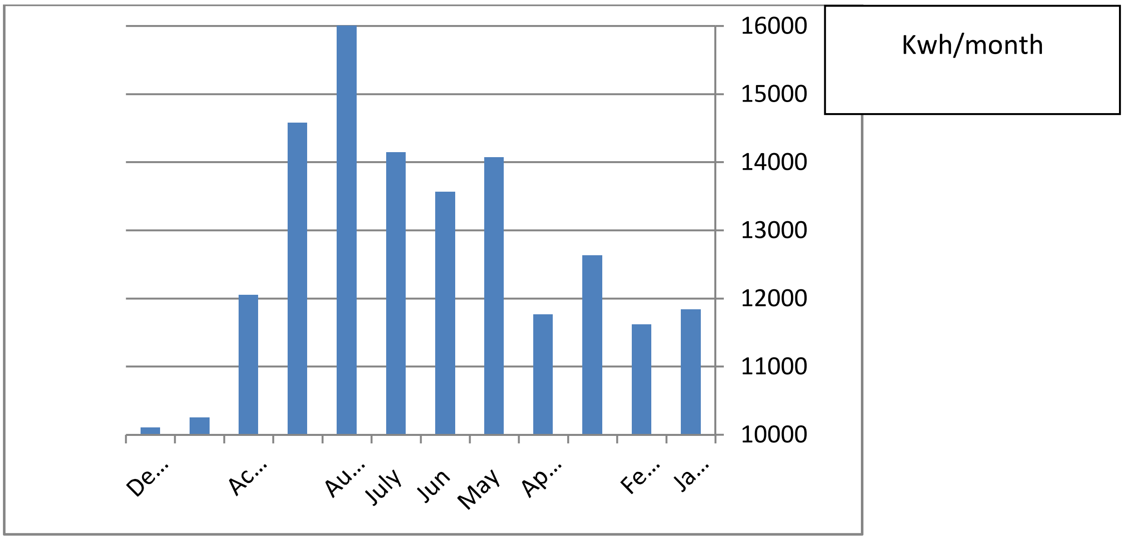


Figure (3.1): Monthly Load Curve in Alghebrena Farm.

1)Monthly average solar potential Curve in Hebron area.

In Hebron area the annual solar radiation on horizontal surface varies from 2.63 kWh/m² in December to 8.4 kWh/m² in Jun [9].

Palestine has an average solar radiation of 5.4 kWh/m² daily [9].

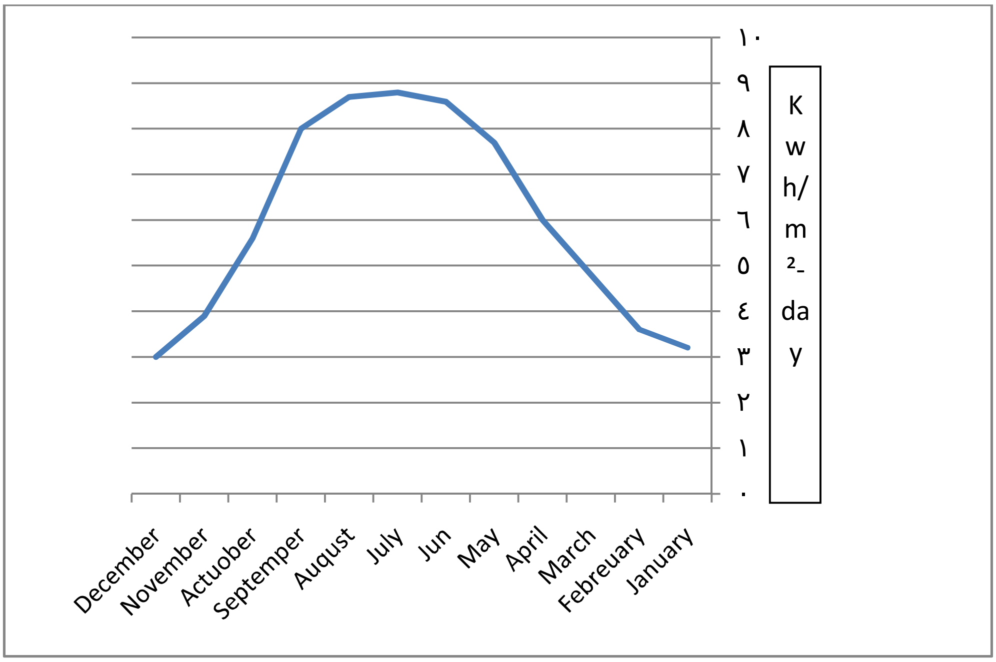


Figure (3.2): Monthly Average Solar Potential Curve in Hebron Area.

2) Monthly load of Alghebrena Farm and Monthly average solar potential in Hebron area curve:

Next curve shows loads Alghebrena farm and the amount of solar radiation per month in one curve in order to find out how much solar radiation covers of Alghebrena consumption and shows us that the figure of September and August the highest loads, in these two months loads exceeds solar radiation value.

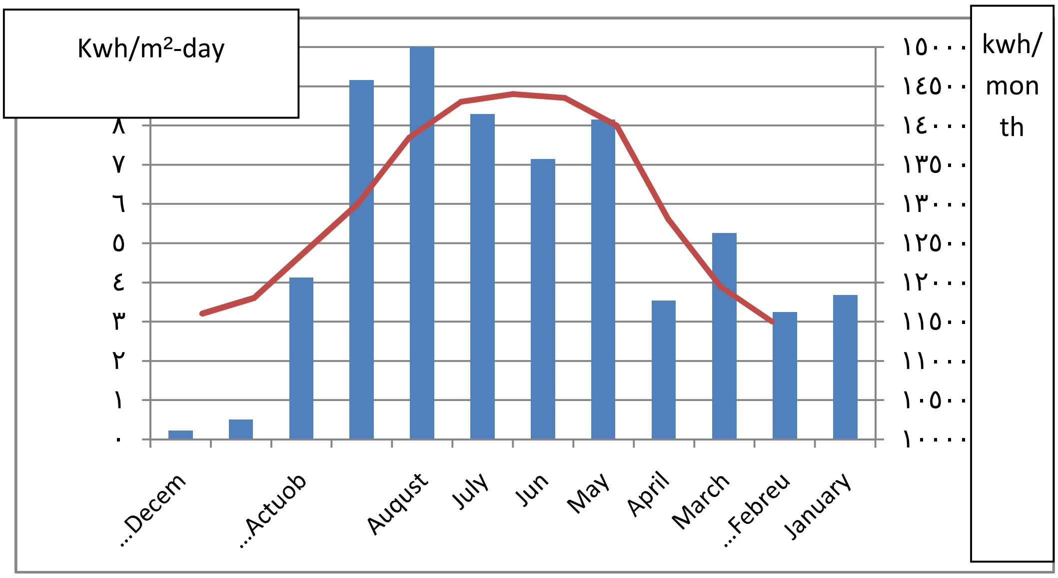


Figure (3.3): Monthly Load in Alghebrena Farm and Monthly Average Solar Potential in Hebron Area Curve.

3.3 Calculation

energy required from PV modules

Energy required from PV module can be calculated by multiplying peak energy requirement in kWh/day times 1.3(the energy lost in the system) to get the total kWh/day which must be provided by the panels.

total energy requirement per year =154112.6984kwh/year

total energy requirement per day =422.2265kwh/day

Energy lost in the SPV=30% [7]

Energy required from PV modules=1.3×422.2265= 548.89445kwh /day

3) Total watt peak rating of PV modules=energy required from PV modules/panel generation factor=$\frac{548.89445}{5.4}$=101.6471 kW

4) Number of PV modules required=total watt peak rating /PV module peak rated output

$=101.6471 \times 10^3/295=344.56$~=345modules

5) inverter sizing

Size of the inverter used in PV power plant depends on the total peak watts requirement .The Inverter must be large enough to handle the total peak watt requirement of the loads in Alghebrena farm at any time .

Number of module on each string on each inverter

= Vdcinv, max / Vdc PV

$= \frac{1000}{35.6} = 28.1$ module

Take 17 modules.

Number of string for each inverter $= \frac{36}{8.74} = 4.11 = 4$ string

Number of module in array =4×17 = 68 module

Number of array $= \frac{345}{68} = 5$ array

Number of inverter = 5 inverters

A= 3048 - 668.73 = 2379.27 m²

6) Area = Pdc,stc /(1kW/m²)×efficiency of PV

2379.27 =Pdc,stc \ 1kW×0.152

=361.64904 KW

7) Pdc,stc $= \frac{Pac}{0.75}$

Pac =271.23678 kW

8) Total numbers of PV modules required in the power plant =920 modules

Number of module in array =5×17 = 85 module

9) Number of array = $\frac{920}{85}$ =11 array

10) Number of inverter = 11 inverter

3.4 Protection Calculation

1) the value of combiner fuse =1.25*1.25*short circuit current =1.25×1.25×8.74=13.65625

2) the value of Array disconnect fuse =5×20=100A/Array
Total number of array disconnect fuse =4.

3) Inverter fuse = 1.25×($\frac{20000}{240}$)=60A

3.5 Land Required

Number of PV modules required=345

$P_{dc,stc} = P_{ac}/0.75$ = 101.647 /0.75 = 135.5 kW

Area = $P_{dc,stc}$ /(1kW/m²)× efficiency of PV

Area = 135.5kW \ 1kW×0.152

= 668.73 m²

Pitch Distance between two arrays(including module length of 1.956 m)=1/Tanα=1/Tan26°=2m(such that α:Projection of solar radiation angle)

ChapterFour:

ETAP Simulation and Result

4.1 Introduction :

The impact of computers has nowhere been more revolutionary than electrical engineering. The design , analysis and operation of electrical and electronic system has become completely dominated by computers and electrical systems ,and the promise of spectacular improvement in speed and efficiency .

Our project consists of develop a protective device coordination using a graphical software program (ETAP) to add features and flexibility in the area of electrical system protection .

Also , this graphical software program it's going to be using for all kind of element that used these. We will select the software program , analyze all types of element protection that are utilizing in electrical system , and simulate the program using various management studies .

4.2ETAP Simulation :

4.2.1Load Flow ofCurrent Status of Alghebrena Farm:

This case shows loads flow of farm Alghebrena without any other sources of electric power where it is provided with electric power from the network only, where it was taking into account all the real values for transformer or cables or fuses through their own data sheet .

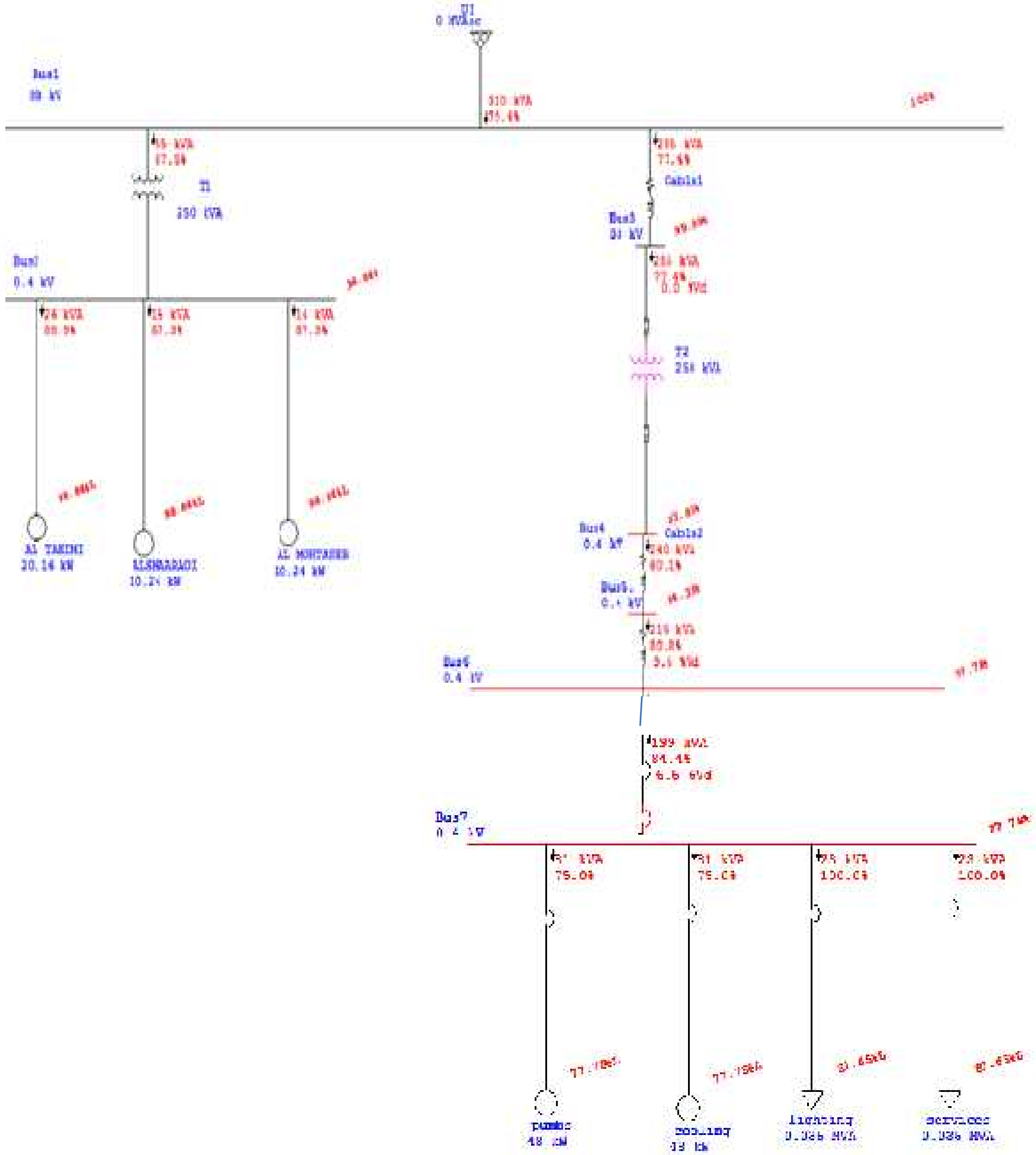


Fig (4.1): Load Flow of Current Status of Alghebrena Farm

Table(4.1): Load Flow of Current Status of Alghebrena Farm

Bus number	kVA	Vd	Voltage drop	PF	kV
Bus1	310		0%	79.4%	33
Bus2	250		1.6%		0.4
Bus3	255		.01%	77.4%	33
Bus4	240		6.15%	80.1%	0.4
Bus5	215		1.18%	80.8%	0.4
Bus6	199		22.3%	84.4%	0.4
Bus7	199		22.3%	84.4%	0.4
Cable1	255	0%		77.4%	33
Cable2	240	6.5%		80.1%	0.4
Transmission line	215	9.5%		80.8%	0.4
Transformer1	250				33/0.4
Transformer2	250				33/0.4
Pumb	81		22.22%	75%	0.4
Cooling	81		22.22%	75%	0.4
Services	23		18.35%	100%	0.4
Lighting	23		18.35%	100%	0.4
Tamimi	26		1.16%	88.9%	0.4
Shaaraoi	o15		1.16%	87.3%	0.4
Mohtaseeb	14		1.16%	87.3%	0.4

Result :

Note there's a voltage drop and low power factor on sixth bus, seventh bus as shown in previous table (4.1) ,and these two buses are the armed wings of the Alghebrena farm this low power factor because of the presence of huge machines work to reduce power factor and there's voltage drop .

4.2.2LoadFlow of Alghebrena Farm with Solar SystemOnly:

In this case we have to add over current relay and make calculation to fill it in ETAP program, we choose ABB over current relay .

4.2.2.1Protection Simulation :

1. **Protection Zones :**

   Protection zone is a region for which given relay or protective system is responsible.

   In order to cover all power equipment , the protection zones must meet the following requirements:

   1) All elements must be covered by at least one zone .
   2) Zones must be overlap to prevent any element from being unprotected .

2. **Primary and Back-up Protection :**

   Primary protection : provided to ensure fast and tripping to clear faults occurring within the boundary of its own zone . it removes the least amount of equipment .

   Back up protection : provided in case the primary protection fails to operate . it removes more equipment than necessary to clear the fault . relays for back-up are slower than those of primary protection .

3. **RelaysCalculation :**

   There is an upper limit on any fault clearing time in the system and it equals approximately 1 sec.

Step	Set Relays	Coordinate with relays

Step 1	R1,R2,R3,R4,R6	(NIL)Primary
Step2	R5	R5 with R1,R2,R3,R4

Table(4.2):Coordinate with Relays

Table(4.3): PSM and TMS Setting for Over Current Protection

Bus	Maximum load	Minimum fault current	Maximum fault current
Bus 8(R1)	36	250	500
Bus 9(R2)	36	250	500
Bus 10(R3)	36	250	500
Bus 11(R4)	36	250	500
Bus 3(R5)	400	1100	2000
Bus 2(R6)	400	1100	2000

Table(4.4) Data for Phase Relay Setting and Coordination

Relay	Max load current	Min limit on pick up current	Min fault current	Max limit on pick up current	Max fault current	PSM (A)	TMS
R1	36	36×1.25=45	250	⅔×250=167	500	160	
R2	36	45	250	167	500	160	
R3	36	45	250	167	500	160	
R4	36	45	250	167	500	160	
R5	400	500	1100	167	2000	400	
R6	400	500	1100	⅔×1100=733.3	2000	400	

$$PSM = \frac{\text{fault current}}{\text{actual pick up}} \quad [16] \qquad (4.1)$$

Set relay R1,R2,R3,R4 choose for R1,R2,R3,R4 TMS=0.025 No intentional time delay is provided because R1,R2,R3,R4 does not have backup responsibility .

For R1,R2,R3,R4 :

Max fault current = 500A

PSM = $\frac{500}{160}$= 3.125

TMS =0.025

top= $\frac{0.14\times TMS}{PSM^{0.02}-1}$ [16] (4.2)

top R1,R2,R3,R4 =0 .025 $\times \frac{0.14}{3.12^{0.02}-1}$=0 .15sec

Relay 5 :

Relay 5 as primary :

PSM= $\frac{2000}{400}$ = 5

TMS =0.025 sec [16]

top= $\frac{0.14\times TMS}{PSM^{0.02}-1}$

= $\frac{0.14\times 0.025}{5^{0.02}-1}$

=0.106 sec

Relay 5 as backup for R1,R2,R3,R4:

CTI =0.3 [16]

PSM= $\frac{500}{400}$ =1.25

Operating time of R5 = top R1,R2,R3,R4+CTI = 0.15+0.3=0.45 sec

top R5=0 .14×$\frac{TMS}{PSM^{0.02}-1}$

0.45=0 .14×$\frac{TMS}{1.25^{0.02}-1}$

TMS = 0.0144 sec

Note R5 slower than R1,R2,R3,R4 due to backup protection .

Relay 6 as primary :

PSM= $\frac{2000}{400}$ = 5

TMS = 0.025 sec

$$t\ op = 0.14\times\frac{TMS}{PSM^{0.02}-1}$$

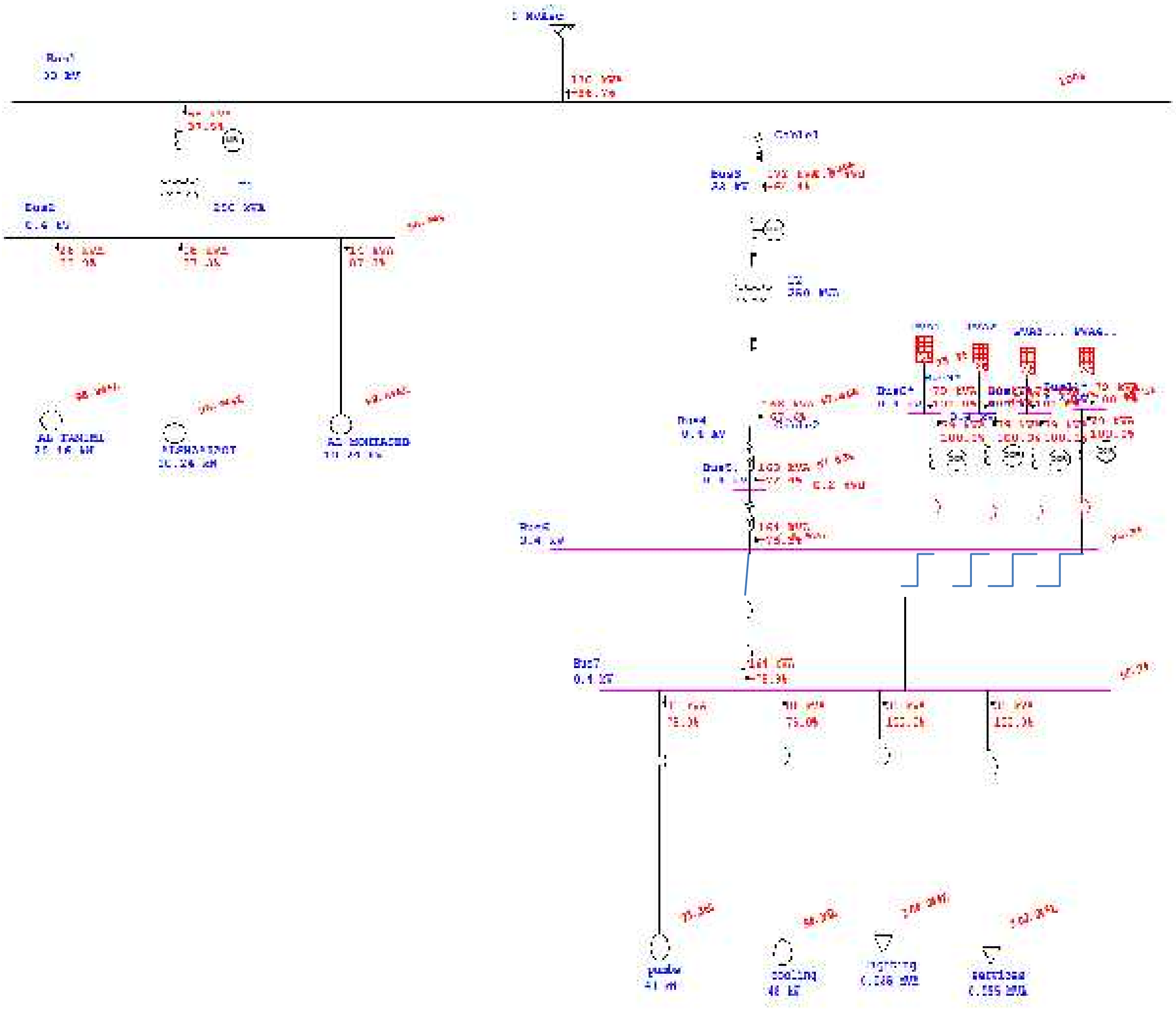
$$=0.14\times\frac{0.025}{5^{0.02}-1}$$

$$=0.106\ sec$$

4. **Fuse 400 A and 16 A on transformer**

Table(4.5):Loads Flow of the Existence of Alghebrena Farm Solar System Only

Bus number	kVA	Vd	Voltage drop	PF	kV
Bus1	170		0%	-36.7%	33
Bus2	250		1.16%	98.84%	0.4
Bus3	172		0%	-64.4%	33
Bus4	168		2.25%	-67.6%	0.4
Bus5	168		2.37%	-72.4%	0.4
Bus6	164		4.7%	-75.9%	0.4
Bus7	164		4.7%	-75.9%	0.4
Bus8	79		4.7%	100%	0.4
Bus9	79		4.7%	100%	0.4
Bus10	79		4.7%	100%	0.4
Bus11	79		4.7%	100%	0.4
Cable1	172	0%			33
Cable2	168	.2%			0.4
Transmission line	164	2.3%			0.4
Transformer1	250				33/.4
Transformer2	250				33/.4
Pumb	81		6.7%	75%	0.4
Cooling	81		4.7%	75%	0.4
Services	23		0%	100%	0.4
Lighting	23		0%	100%	0.4
Tamimi	26		1.16%	88.9%	0.4
Shaaraoi	15		1.16%	87.3%	0.4
Mohtaseb	14		1.16%	87.3%	0.4



Fig(4.2): Load Flow of AlghebrenaFarm with Solar SystemOnly

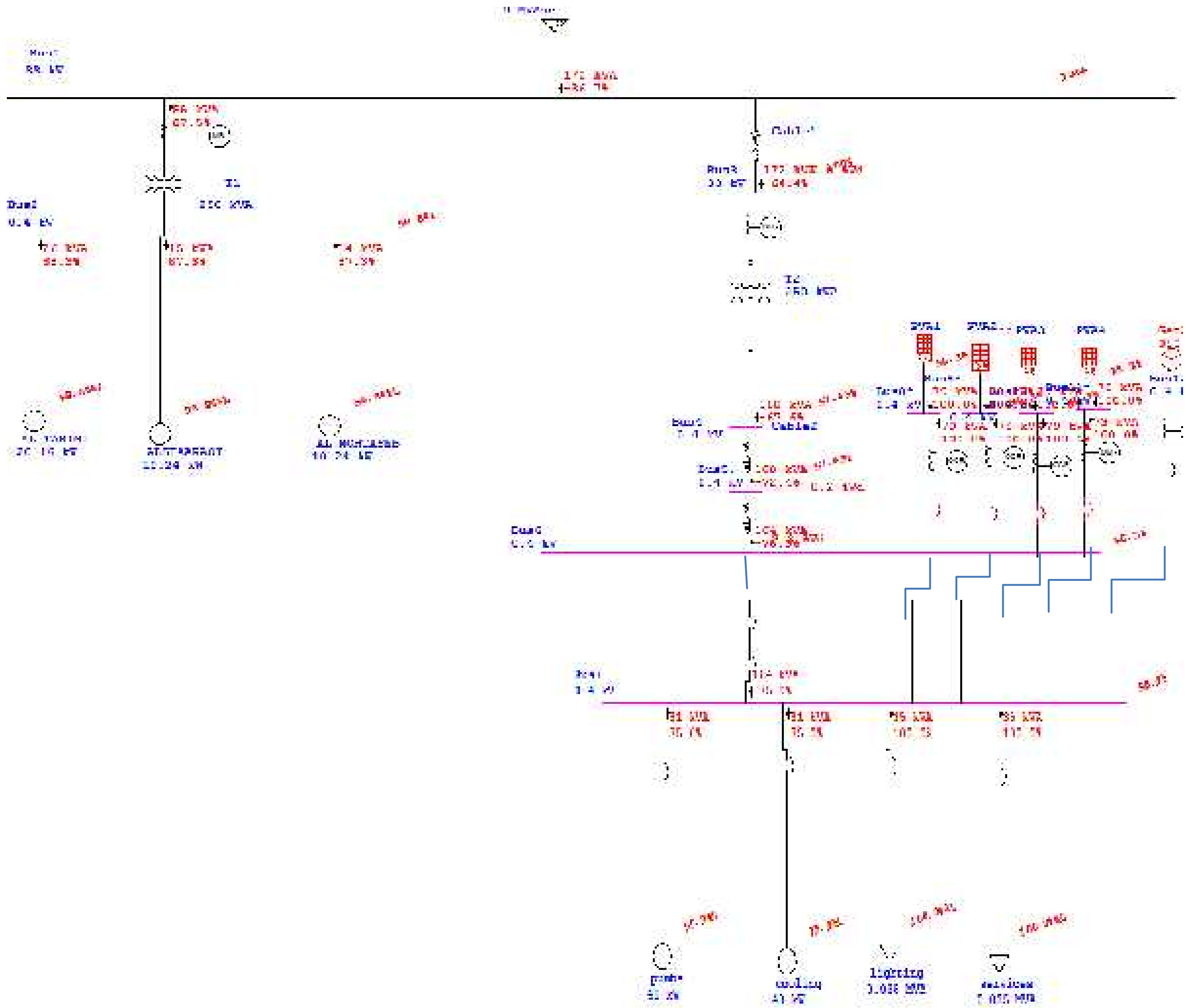
Result :

In order to mitigate the risk of false operation of Relay 33kV (R5,R6) and Relays 0 .4kV (R1,R2,R3,R4) due to reverse power flow to 33 kV bus under normal grid condition, the relay current settings are adjusted based on the maximum bi-directional current flow across the primary side of the associated current transformer, whichever direction where the current is greater. Considering the maximum active solar power injection is 101.64 kW.

Hence, the pickup current of relays 0.4kV (R1,R2,R3,R4) and relays 33kV (R5,R6) are increased. With the new pickup current, Relay 33kV and 0.4kV will not operate at maximum active solar power injection of 101.64 kW. Hence, there is no possibility of false tripping due to reverse power flow to 33 kV loads. However, all relays have to be regarded to ensure of the correct operation time during fault.

4.2.3Load Flow of AlghebrenaFarm with Methane Generator and Solar System:

In this case we want to analysisthe network with existence of methane generator and solar panels and note the change in the voltage, power factor and frequency Such as the following fig(4.3), and table(4.6).



Fig(4.3): Load Flow of AlghebrenaFarm with Methane Generator and Solar System

Table(4.6): Load Flow of Alghebrena Farm with Methane Generator and Solar System

Bus number	kVA	Vd	Voltage drop	PF	kV
Bus1	170		0%	-36.7%	33
Bus2	250		1.16%	98.84%	0.4
Bus3	172		0%	-64.4%	33
Bus4	168		2.55%	-67.6%	0.4
Bus5	168		2.37%	-72.4%	0.4
Bus6	164		4.7%	-75.9%	0.4
Bus7	164		4.7%	-75.9%	0.4
Bus8	79		4.7%	100%	0.4
Bus9	79		4.7%	100%	0.4
Bus10	79		4.7%	100%	0.4
Bus11	79		4.7%	100%	0.4
Bus12	412		4.7%	85%	0.4
Cable1	172	0%			33
Cable2	168	0.2%			0.4
Transmission line	164	2.3%			0.4
Transformer1	250				33/.4
Transformer2	250				33/.4
Pumb	81		6.7%	75%	0.4
Cooling	81		6.7%	75%	0.4
Services	23		0%	100%	0.4
Lighting	23		0%	100%	0.4
Tamimi	26		1.16%	88.9%	0.4
Shaaraoi	15		1.16%	87.3%	0.4
Mohtaseb	14		1.16%	87.3%	0.4

Result:

Having illustrated the overvoltage issue and false operation of overcurrent protection systems due to large amount of solar power injection, there are several solutions which are applicable to avoid the issues before implementation of the renewable energies on the grid.

In solving the overvoltage issue without reducing the amount of solar power injection at the low voltage network, one potential solution is to inverters in interfacing the solar system and methane generator with the grid ,where adjust the voltage to 0.41 kV and frequency 50.5 Hz , In order to be injected to the grid .

4.2.4Load Flow of AlghebrenaFarm with Methane Generator and Solar System after Adding Single Tuned Filter:

Induction motor are prim cause of low power factor and if the load has large X/R ratio . Then the power factor angle will be large .

The most common type of passive filter is the single tuned "notch filter ",we choose it because the notch filter is most economical type , it often want to filter out the undesired signal in the specific frequency andit also connect shunt with the power system .

4.2.4.1Harmonic in ETAP Simulation :

Harmonic Calculation :

1. Select tuned frequency for the filter:
   Lowest harmonic order 5^{th}
   Take lowest harmonic order 4.7^{th} to allow for tolerance in the filter components and variation in impedance .
2. Compute capacitor bank size and resonant frequency :
   On bus 7 the kVA=164 and PF =75.9%
   kVAR=kVA × sinα[17] (4.3)

$=1648 \sin \times (\cos^{-1} 0.76)$

$= 106.5$ kVAR

At PF = 98% lagging

kVAR=164 sin × $(\cos^{-1}0.98)$

= 164× sin 11.5

= 32.7 kVAR

Require compensation from the filter is 106.5-32.7 =73.8 kVAR

Xfilter$= \frac{kV^2}{\text{kVAR}}$ ×1000[17] (4.4)

$= \frac{0.4^2}{73.8}$ ×1000

=2.2 Ohm

For during the 4.7th harmonic

Xc $=\frac{n^2 \times Xfilter}{n^2-1}$

$=\frac{4.7^2 \times 2.2}{4.7^2-1}$

= 2.3 Ohm

kVAR $=\frac{kV^2}{Xc}$× 1000 [17](4.5)

$= \frac{0.4^2}{2.3}$ × 1000

=69.6 kVAR

Available size of the capacitor near the desired value is 70 KVAR .

3. Compute filter reactor size

XL fundamental = $\frac{Xc}{n^2}$[17](4.5)

$= \frac{2.3}{4.7^2}$

=0.1 Ohm

L=$\frac{\text{XL fundamental}}{2\times\pi\times f}$[17] (4.6)

$= \frac{0.1}{2\times\pi\times 50}$

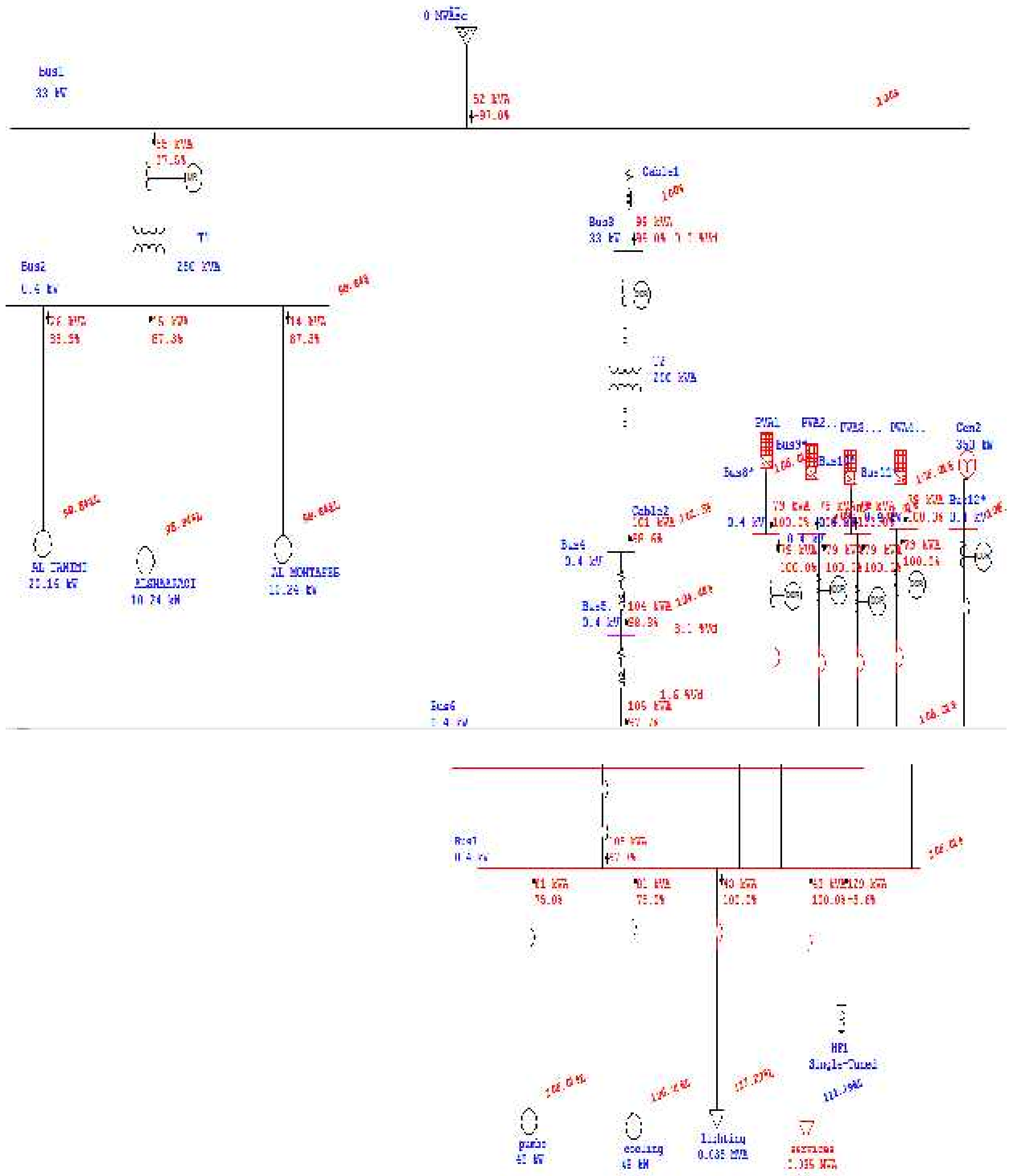
$=3.2$ mH

$C=\frac{1}{2\times\pi\times 2.3}$

$= 0.0796 \times 10^{-3}$ F

Table(4.7): Load Flow of Alghabrena Farm with Methane Generator and Solar System after Adding Single Tuned Filter

Bus number	kVA	Vd	Voltage drop	PF	kV
Bus1	52		0%	-97%	33
Bus2	55		1.16%	98.84%	0.4
Bus3	99		0%	99%	33
Bus4	101		1%	98.6%	0.4
Bus5	104		4%	98.3%	0.4
Bus6	105		1.8%	97.7%	0.4
Bus7	105		1.8%	97.7%	0.4
Bus8	79		1.8%	100%	0.4
Bus9	79		1.8%	100%	0.4
Bus10	79		1.8%	100%	0.4
Bus11	79		1.8%	100%	0.4
Bus12	412		1.8%	85%	0.4
Cable1	99	0%			33
Cable2	101	0.2%			0.4
Transmission line	104	2.3%			0.4
Transformer1	250				33/.4
Transformer2	250				33/.4
Pumb	81		1.8%	75%	0.4
Cooling	81		1.8%	75%	0.4
Services	23		1%	100%	0.4
Lighting	23		1%	100%	0.4
Tamimi	26		1%	88.9%	0.4
Shaaraoi	15		1.16%	87.3%	0.4
Mohtaeb	14		1.16%	87.3%	0.4
Single tuned filter	124		1%	-3.6%	0.4



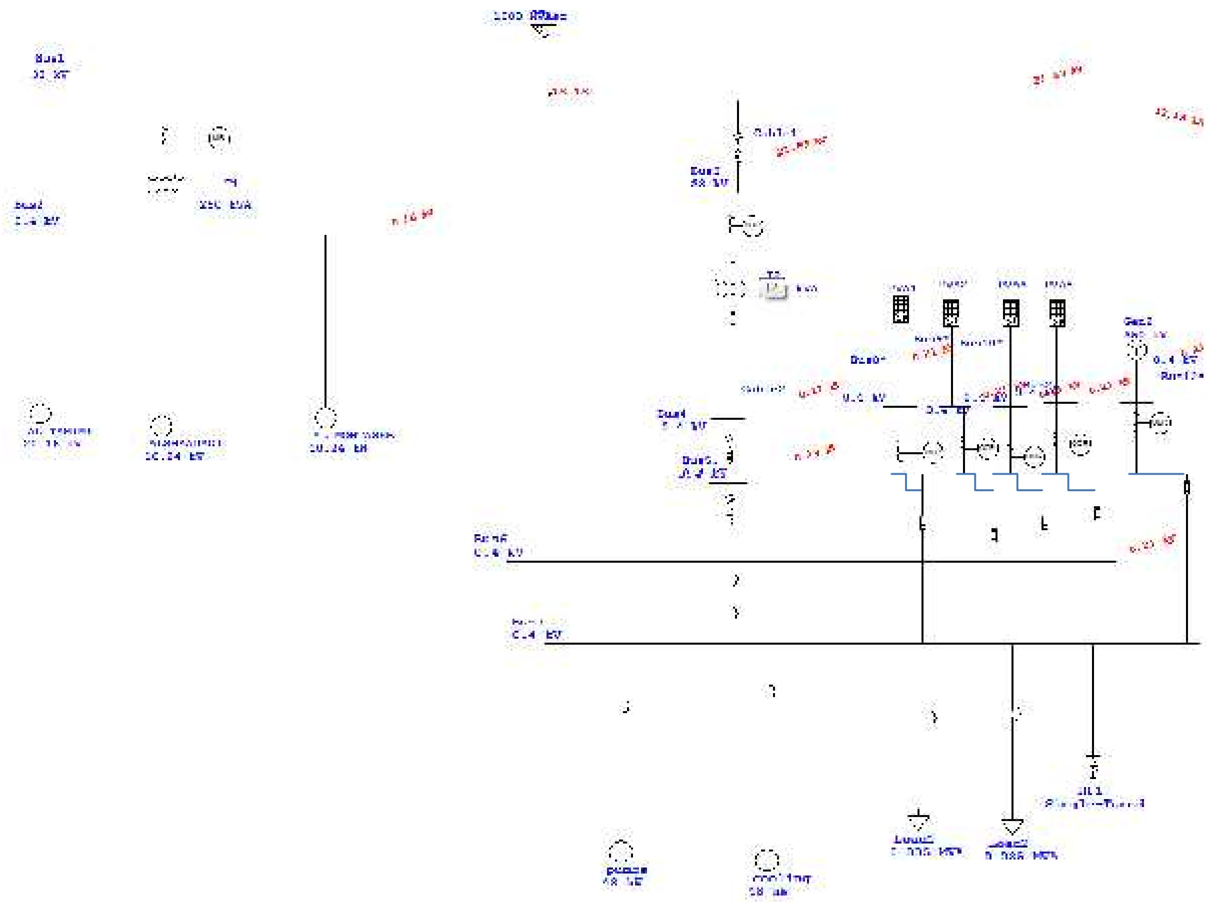
Fig(4.4): Load Flow of Alghabrena Farm with Methane Generator and Solar System after Single Tuned Filter

Result :

1) We note from this simulation that the harmonic problems are more common at end-user facilities than on the utility supply system .
2) Most nonlinear loads are located within end-user facilities, and the highest voltage 1distortion levels occur close to harmonic sources .
3) The most significant problems occur when there are nonlinear loads and power factor correction capacitors that result in resonant condition.
4) Not from table (4.7) the power factor and voltage drop be good because the addition of notch filter .
5) We choose TAI-SAW notch filter .

4.2.5Short Circuit Analysis :

4.2.5.1Three Phase FaultUtility Side :

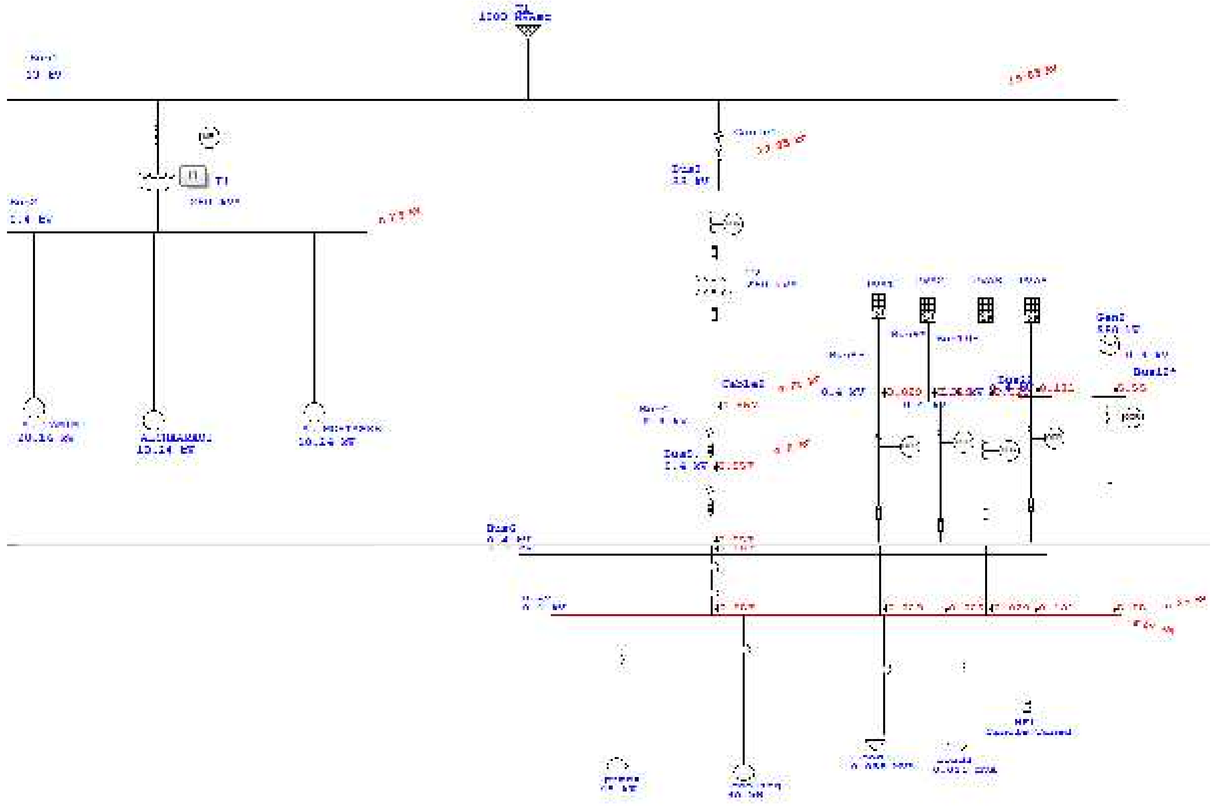


Fig(4.5):Three Phase Fault on Utility Side

Table(4.8): Three Phase Fault on Utility Side

Bus number	Fault voltage (kV)	Fault current (kA)	kVA
Bus1	0		17.5
Bus 2	0.02		0.256
Bus3	0.01		0.014
Bus4	0.09		1.13
Bus5	0.2		1.13
Bus6	0.3		1.13
Bus7	0.3	17.51 kA -86.2% PF	1.13
Bus 8	0.3		0.011
Bus 9	0.3		0.011
Bus 10	0.3		0.011
Bus 11	0.3		0.011
Bus 12	0.2		0.817

4.2.5.2)ThreePhase Fault on Alghebrena Farm:



Fig(4.6): Three Phase Fault on Alghebrena Farm Side

Table(4.9): Three Phase Fault on Alghebrena Farm

Bus number	Fault voltage (kV)	Fault current (kA)	kVA
Bus1	32.97		0.018
Bus 2	0.4		
Bus3	32.96		0.018
Bus4	0.28		1.5
Bus5	0.14		1.51
Bus6	0		1.5
Bus7	0	5.74 -75.9% PF	1.5
Bus 8	0.4		0.043
Bus 9	0.4		0.043
Bus 10	0.4		0.043
Bus 11	0.4		0.043
Bus 12	0.4		3.12

Result :

1)Note all the closer to the source, the fault current is higher ,note table (4.8) and table (4.9)

2)During short circuits :

1) Currents increase in magnitudes .

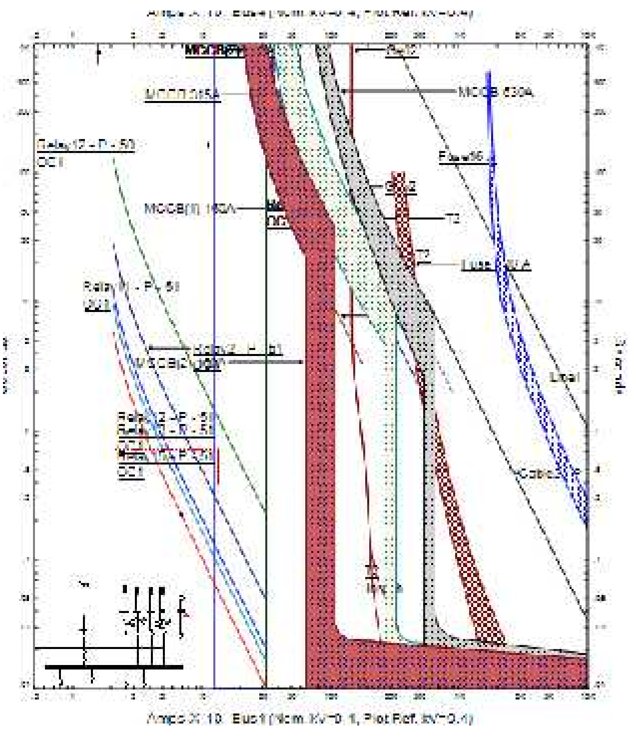
2) Voltages go down in magnitudes .

3) Changes in phase angles of V and I phasors .

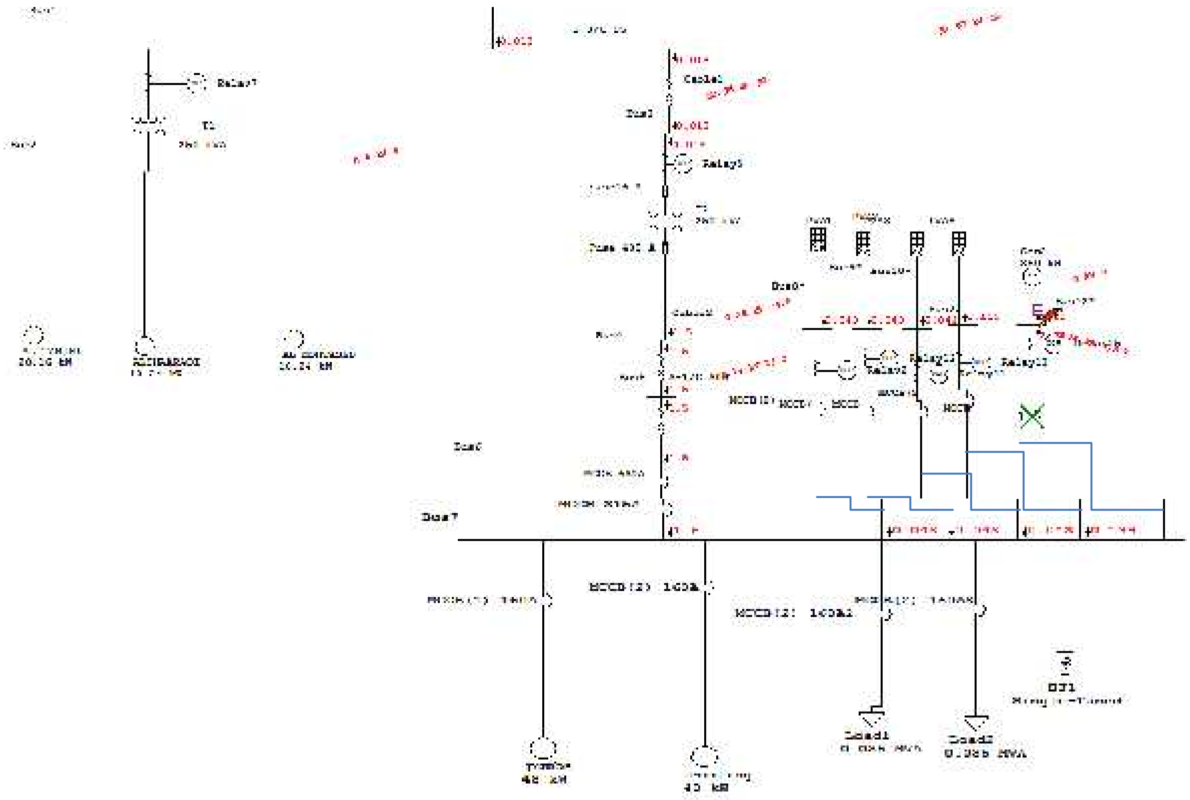
4) frequency, harmonic content , active and reactive power .

Note tables (4.8) , and (4.9).

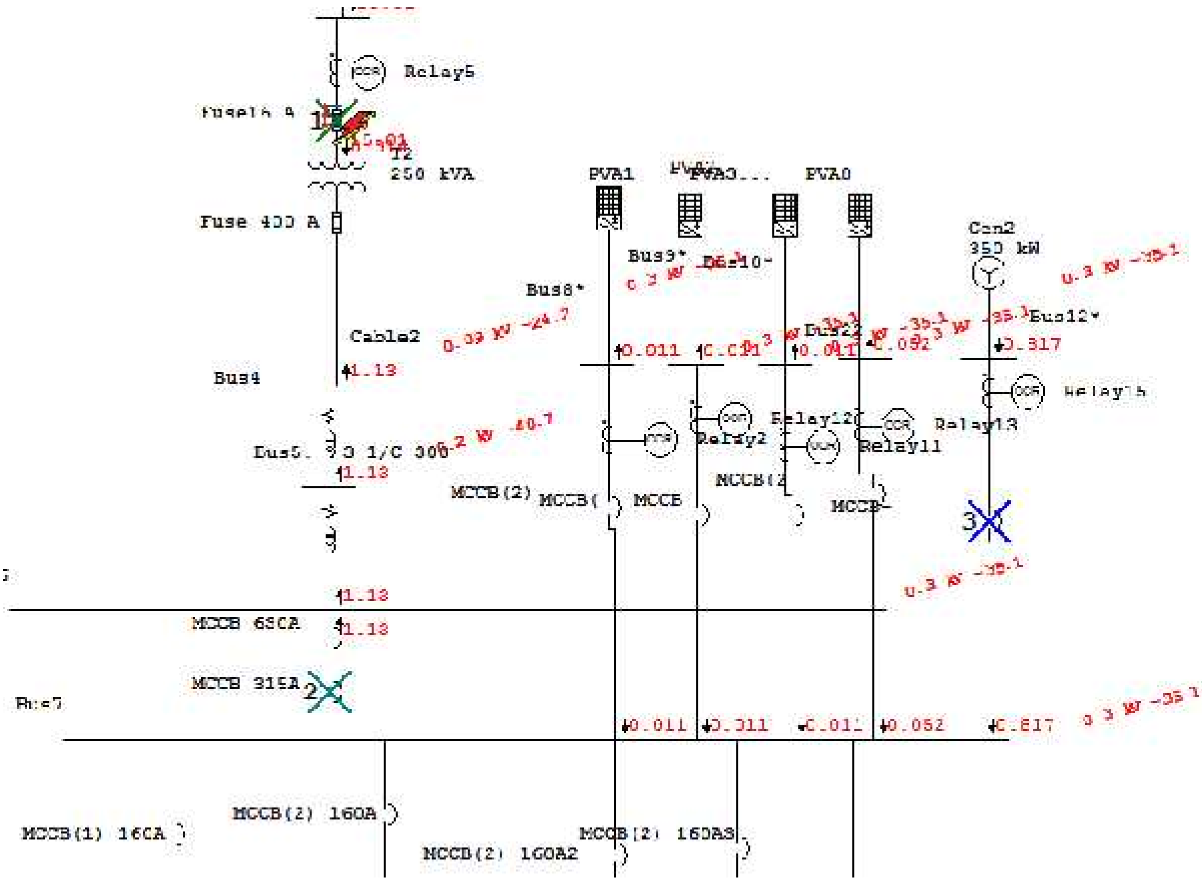
4.2.6Reliability:



Fig(4.7): Reliability of the Protection Devices

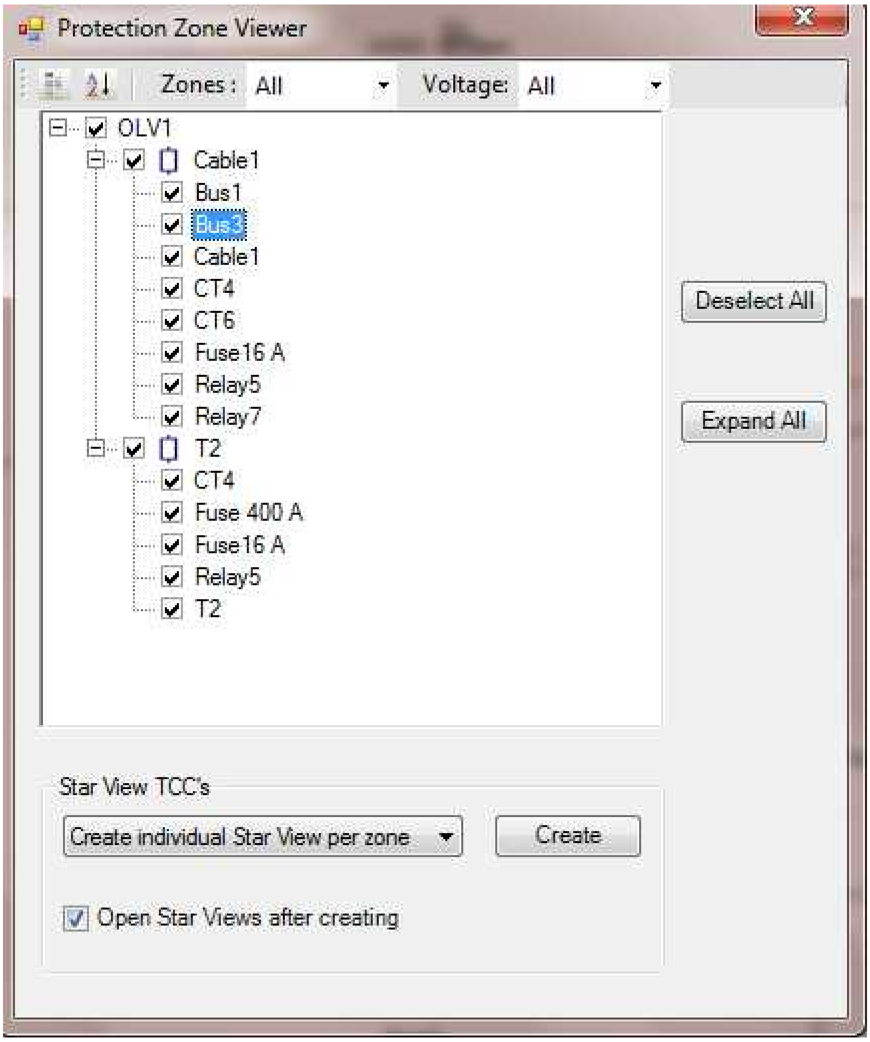


Fig(4.8):Fault on Methane Generator Side



Fig(4.9):Fault on Transformer Side

3.2.6.1)Protection zone :



Fig(4.10):Protection Zones

Result :

1) There are two settings that must be applied to all time delay over current relays :
   1) The pickup
   2) The time delay

2)The greater operating current ,the less time it takes to travel from the reset position to the operating position .

3)The purpose of the time delay setting is to enable relays to coordinate with each other .

ChapterFive:

Shading and Mechanical Design

5.1Introduction :

In this section we did mechanical design for the structure of solar panels in a way that enables us to avoid the shade, and we draw this design on the AutoCAD program, and we have made a calculation of truss of Alghebrena Farm based on equations from **"Construction Book"** in Civil Engineering to see if truss could bearthe weight of panels or not .

5.2Shade :

Basically, Shade is the enemy of solar panel efficiency, Three criteria were taken to avoid the arrival of the shade to the solar panels :

5.2.1 Bypass Diode

The majority of modules have bypass diodes between each cell or string of cells that minimize the effects of shading and only losses power of the shaded portion of the array. The main job of the bypass diode is to eliminate hot spots that form on cells that can cause further damage to the array, and cause fires.

A bypass diode is connected in parallel, but with opposite polarity to a solar cell.

5.2.2 Vertical Height Solar Panels:

The design is high solar panels based on the mechanical design of the structure, which will be explained in mechanical design department.

Where the adoption of this mechanical design to ensure non-arrival shadow of solar panels in previous row to the solar panels in the next row.

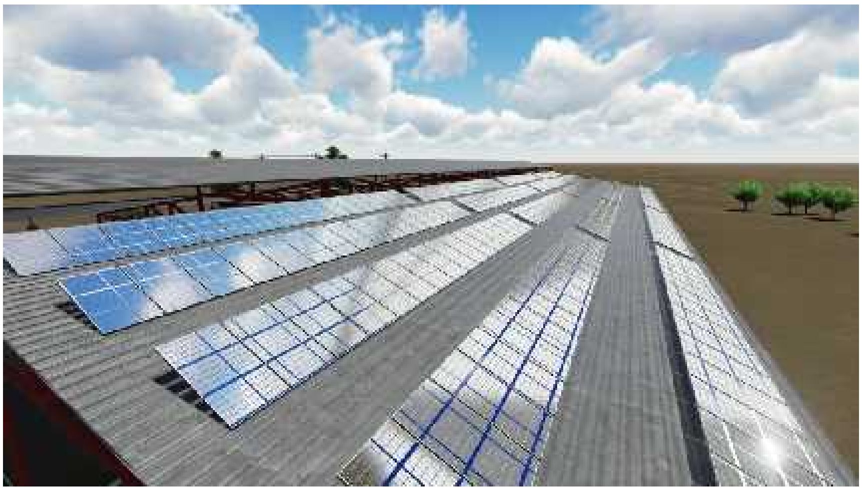
5.2.3Pitch Distance:

- Pitch Distance between two strings (including module length of 1.956m)
- $=\frac{1}{\tan\alpha}=\frac{1}{\tan 26°}$=2m[9] (5.1)
- (such that α: Projection of solar radiation angle**)**

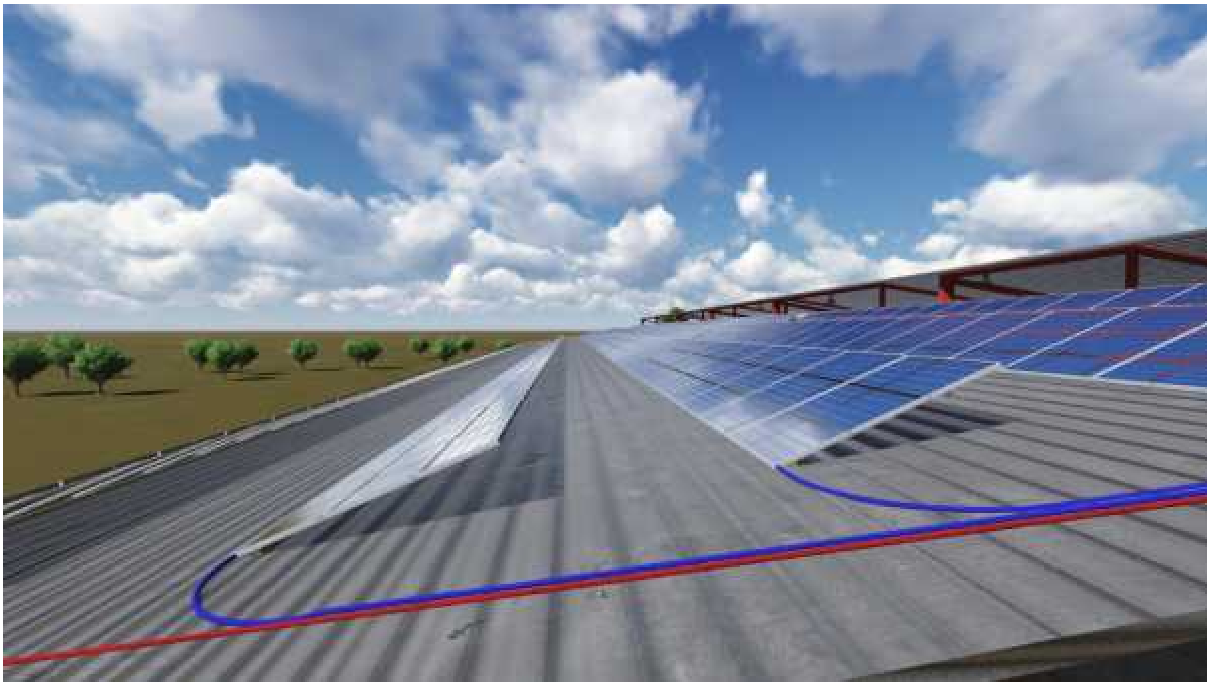
Result :

All these factors helps non-arrival of the shade to the solar panels in the following rows where these factors have been applied to the Sketch Up program and show it in the summer the shade under panels or in the worst case extends the shade for a distance of 15 cm.

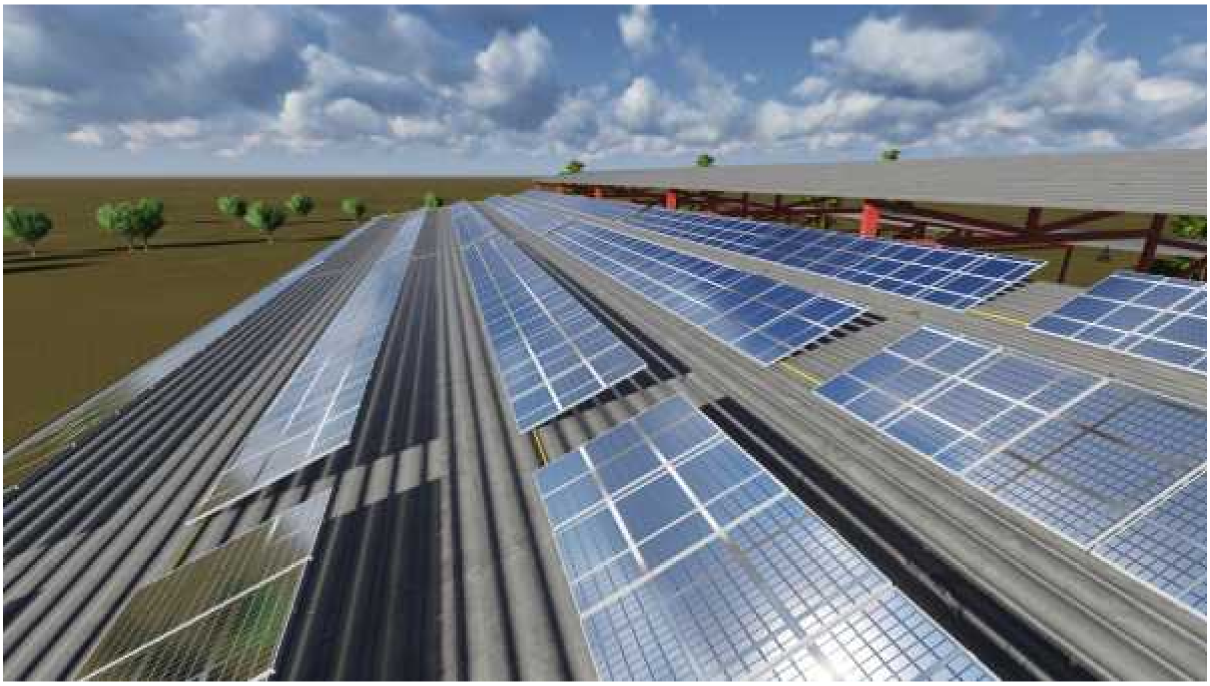
In winter, the shade extends for a distance of 30 cm, in the worst case,by taking these three factors, it solved the problem of shade , as shown in the followingSketchUpfigures(5.1) ,(5.2),(5.3) :



Fig(5.1):ShadowUnder Panels in Summer



Fig(5.2): ShadowExtendedto a Distance of 15 cm from the Solar Panels in Summer



Fig(5.3): Shadow Extended to a Distance of 30 cm from the Solar Panels in Winter

5.3Mechanical design:

Metal structures, made from Aluminum or galvanized iron, that are used to support the solar systems on the roofs of barn these structures are characterized by its ability and strength to withstand wind speeds with at least 100 km / h and its longevity. These structures can be movable or static.

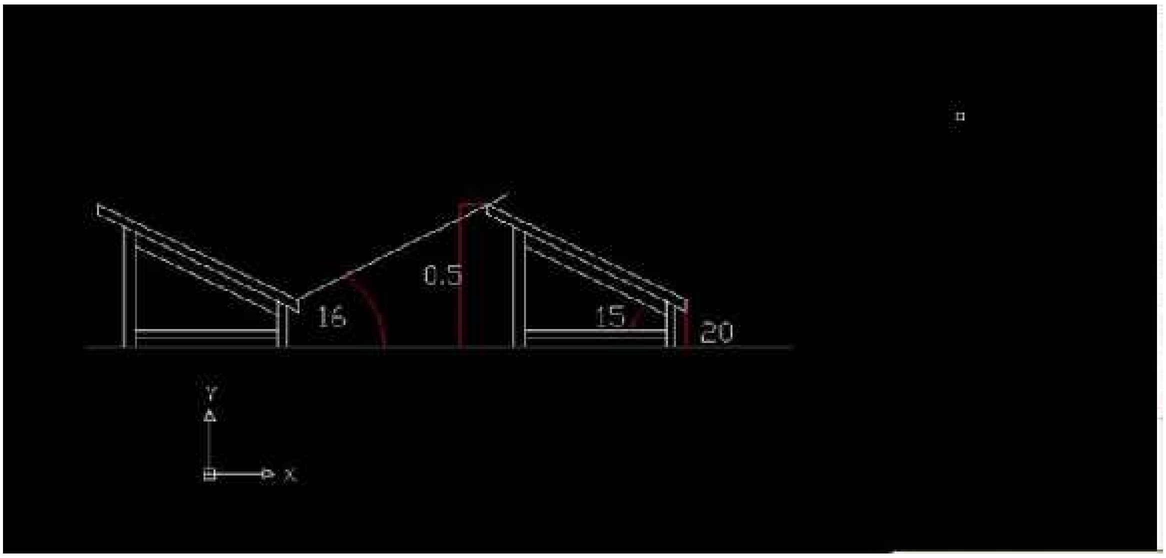
Metal Support Structures length depends on the dimensions of the solar panels and the angle of the solar panels placed.

In this project the solar panels dimensions are(1.956m×0.992m) and Angle of solar panels are placed 15º.

$$\sin 15 = \frac{x}{1.956} \tag{5.2}$$

X =0.5m

Such that x: metal Support Structures length



Fig(5.4): Mechanical Design of Solar Panel Structure

Result :

Note AutoCADfigure (5.4), Shows the mechanical design of solar panels, which we have adopted in the design of structure for these panels to avoid the shadow problem and get the most amount of solar radiation to obtain a higher power, tending solar panels at an angle of 15 degrees and rise by0 .5 meters and its highest from the opposite side by 20 cm, as this rise based on the corner of the next solar panels to be 16 degrees from the opposite side and therefore have high the previous board of the opposite side is 20 cm.

5.4BarnDesign

Barn can be divided according to static behavior in two :

1)Bearing wall construction

2)Skeleton construction:

1)Frame   construction

2)Truss construction

Fig (5.5): Truss Construction

The static system for Alghebrena Farm is Skeletontruss, and it is known that the maximum value of live loads in static buildings are 5 kN/m^2[18]

Types of loads over the farm building:

1)Live load: snow and solar panels weights.

2.Dead load: sheet metal weights.

To sure that the farms bear the load of solar panels through the following calculations: [18]

The Weight $= \frac{25.8\,Kg}{100}$ =0.258 kN   (5.3)

The force per unit area =$\frac{0.258\,KN}{1.956m \times 0.992m}$ =0.1329 kN/m^2 (5.4)

The snow force per unit area is constant = 1.3 kN/m^2

Total force per unit area = the snow force per unit area is constant + the force perunit area

Total force per unit area = 1.3 + 0.1329 = 1.4329 kN/m^2

Result :

Through previous calculations,we have been calculating the value of live load that are coming from snow and solar panels, The result was less than 5 kN/m^2, therefore we can put solar panels on the roof of the barn because it bears the weight of the solar panels.

Chapter Six:

Economic calculation

6.1 Introduction :

In this chapter show time period for completion of the project and the cost of construction of the project also includes the cost of adding capacitors of the system to correct the power factor.

6.2Project cost

IRR :(the internal rate of retune**)** is the discount rate that equates the two streams of costs and benefits of the project .

Payback period:the time after initial investment until accumulated net revenues equal the investment .

Module and inverter cost

Cost of each PV module =$63795

Total cost 5 inverters=5x3250 = $16250

IRR =$\frac{\text{net profit}}{\text{Investing cost}}$ x 100% [19] (6.1)

=$\frac{37102255}{22126190.68}$ x100%

=16.76 %

Payback period = $\frac{\text{Investment cos}}{\text{Net profit}}$ [19] (6.2)

=$\frac{22126190}{3710225}$

=5.9 years

Cash flow from operating activities:

Net profit after tax	$3710225
Deprecation	$883719
Net cash	151800$

6.3Time period for implementation of the project:

6.3.1 Determine the time period for implementation of the project:

To determine the time period for implementation of the project the way we use ‘Network Programming Activity ON Load ‘Since the relationship between the activities arestart to finish Which means every activity depends on the previous activity.

Table(6.1): Time period for implementation of each activity

Activity Name	Previous activity	Time period
ToolsBuy 'A'	-	60 days
Design structures 'B'	A	30 days
Installingstructures 'C'	B	15 days
Put solar Panels 'D'	C	15 days
Put DC breakers 'E'	D	2 days
Put Inverters 'F'	E	4 days
Put AC breakers 'G'	F	2 days
Put net metering 'H'	G	1 days
Work of earthing system 'I'	H	4 days
The connection between the system equipment using cables 'G'	I	10 days
SystemChecking 'K'	J	2 days

Fig(6.1): Way to Find Project Period of Time

Such that:

ES: Earliest Start

LS: Latest Start

TF: Total Float

EF: Earliest Finish

LF: Latest Finish

D: Duration

Note:

If 'TF' is greater than zero this means increasing the total project time and thus delay achievement.

6.3.2)Laws:[20]

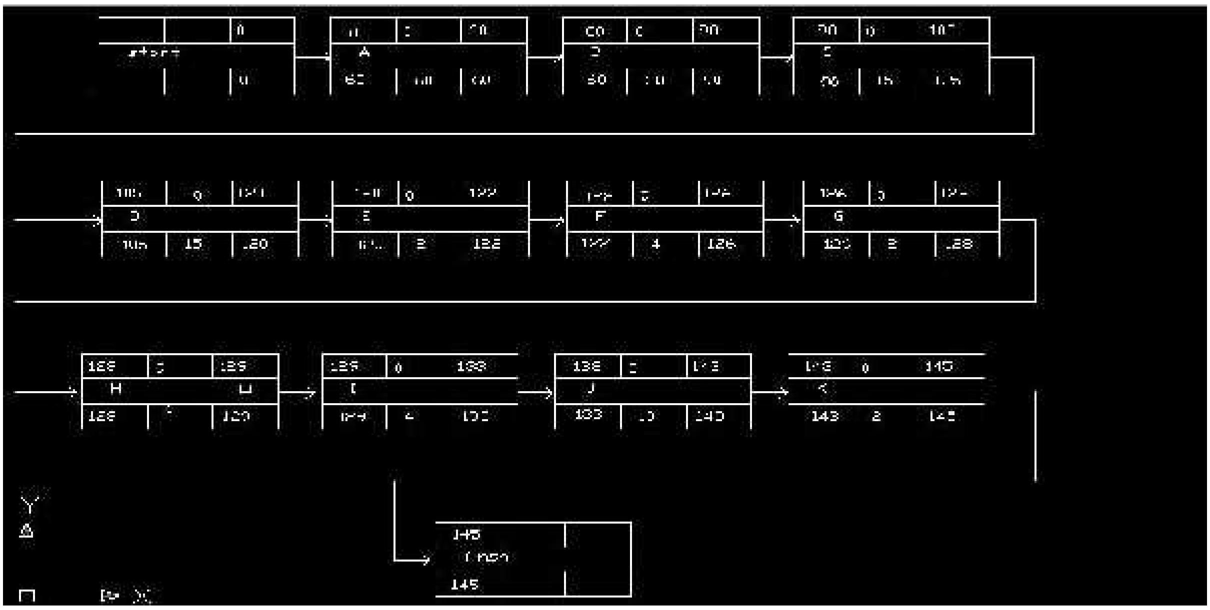
LF =LS+D(6.3)

EF=ES+D (6.4)

LS=LF-D (6.5)

TF=EF-ES(6.6)

ES=EF-D(6.7)



Fig(6.2): Way to Find a Project Period of Time

Result :

The time period for the construction of the project is 145 days .

6.4 Economic power engineering :

6.4.1PF correction:

Must correct the value of Power Factor because of the disadvantages of the low PF are:

1)Large kVA rating of equipment (kVA=$\frac{kW}{PF}$).

2)Greater conductor size.

3)Large copper losses.

4)Poor voltage regulation.

5)Reduced handling capacity of the system.

6.4.2Calculations annual saving when adding capacitors to improvePF:

1)before adding capacitors :

1)If Total Power 452 kW (Total Power of the solar system and methane) 0.75 PF, 5700 h/day, the PF improved to 0.97 by capacitors costing 60 NIS [21].

2)To calculate the annual saving allows 10% per annum interest and depreciation on capacitors.

3)Tariff =100 kVA+0.6 kWh NIS [21].

$$\cos\theta 1 = 0.75$$

$$\tan\theta 1 = 0.88$$

$$\cos\theta 2 = 0.97$$

$$\tan\theta 2 = 0.25$$

kVAR =P (tan $\theta 1 - \tan\theta 2)[21]$ (6.8)

=452(0.88-0.25) =284.76

Cost before PF correction:

Max kVA =$\frac{452}{0.75}$=602.66kVA

kWh/years=452×5700=2576400kWh/years

Cost per year=100×602.66+0.6×2576400=1606106 NIS

2)Cost with PF correction:

Max kVA =$\frac{452}{0.97}$=465.98kVA

Capital cost of capacitor=60×284.76=17085.6 NIS

Annual interest and depreciation=0.1×17085.6=1708.56

Total annual cost=100×456.98+0.6×2576400=1591538 NIS

Annual saving =1606106-1591538=14568 NIS

If installed capacitor this cost =14568 NIS.

6.4.3 Depreciation charge

Transformer In this project capital cost is =90000 NIS .

useful life =25 years, scrap value =10000 NIS to find depreciation charge by using straight line method:

Depreciation charge= $\frac{90000-10000}{25}$=3200 NIS [21] (6.9)

Such that **depreciation charge** means: The price of the machine consumption

Scrap value: Selling price after use.

ChapterSeven:

Conclusion and Recommendation

7.1Conclusion :

In conclusion, solar power injection reduces the output power from generators and decreases the transmission losses. However, overvoltage in distribution feeder due to solar power injection is to be avoided. The potential solution is to interface embedded generation with the distribution feeder using inverters without reducing the amount of solar power or methane generator at the low voltage network. An-other issue is false operation of overcurrent protection system. This issue can be mitigated by adjusting the relay current setting and the pickup current of the relays which experience bi-directional power flow. The adjustment of the relay current setting is based on the maximum current flowing across the current transformers in both directions. However, all relays have to be regarded to ensure correct operation time during fault. Solar power injection reduces their electricity bill ,and at the same time assists in reducing the power demand from generators and decrease the transmission losses.

In this project we work with computer software , called ETAP , to analyze the protection coordination of an electrical design . We started analyzing and searching information aboutAlghebrena farm network . All the coordination of the system was make manually and in the ETAP program .

Other programs that we used in this project SketchUp program to draw the real dimensions facility, and installation of solar panels and note the results. And we used AutoCAD program to draw a distribution circuit breakers in electrical panels, and drawing the solar mechanical design of solar panel structure .

7.2 Recommendation:

1)Implementation of the solar system on the roof of Alghebrena farm.

2) Regular maintenance of the solar system and maintain it to take advantage of it as much as possible

3)Employment engineers with a full knowledge and ability to deal with the solar system and how to maintain

4)The solar system is not limited only to farm Alghebrena but we hope to apply to government institutions because they contain the roofs of empty untapped.

5)The application of the solar system at all industrial facilities and buildings of various kinds.

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Appendix