Analysis and Development of the Kofr Al-Labad Well Solar Power Plant

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***Abstract*— Renewable energy technologies are becoming increasingly competitive with traditional energy technologies, due to their continually improving performance, low cost, and growing recognition of their environmental and economic benefits. Solar energy harnessing systems offer the advantage of emitting no pollutants into the atmosphere, unlike the combustion of fossil fuels. This project aims to study the design of the network connected to the photovoltaic system of the Kafr El-Labad Cooperative Society, by working with more than one scenario to achieve the best production and cost design. The capacity of the pump is approximately 120 horsepower, in addition to the presence of a few lighting loads. The project will analyze and develop the solar power plant from a technical and economic point of view, and present proposals and recommendations to raise the efficiency of the system.**

Keywords— Solar energy, pumping, Kafr El-Labad.

I. INTRODUCTION

Renewable energy is becoming increasingly important in meeting our electricity needs. It is a sustainable and environmentally friendly way to produce electricity, unlike fossil fuels, which are non-renewable and produce harmful emissions. Fossil fuels are the main source of electricity today, but their extensive use is depleting them at an alarming rate. Additionally, burning fossil fuels produces carbon dioxide and other greenhouse gases, which contribute to climate change. For these reasons, it is essential to transition to renewable energy sources, such as solar and wind power. Renewable energy sources are abundant and can be used to produce electricity without harming the environment [1]–[3].

Renewable technologies are a safer and more sustainable solution to the environmental and social problems associated with fossil fuels. As environmentally friendly energy resources, renewable energy sources can be used to supplement conventional energy plants and provide additional amounts of electricity. This offers a number of advantages, including: Reduced reliance on fossil fuels: Renewable energy can reduce the amount of fossil fuel energy that is consumed in conventional power plants to produce the same amount of electricity. Reduced dependence on imports: Renewable energy can reduce dependence on imported fuels, especially electricity. Economic development: Renewable energy can promote economic development, especially in the energy sector. Job creation: Renewable energy can create jobs in the installation, maintenance, and operation of renewable energy systems. Integration of economic development and energy policy: Renewable energy can help to integrate economic development and energy policy into a new field of managing national economies [4]–[7].

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The Tulkarm Agricultural Directorate has been assigned to receive a project to install 40-kilowatt solar energy units for the benefit of the Kofr Al-Labbad Cooperative Association's well within the agricultural projects' development plan. This project is part of the Ministry of Agriculture's plan to produce applied energy and support farmers by reducing production costs. The project has contributed to a 15% decrease in the consumption of electric energy, with the aim of reducing the price of a cup of water for farmers, where the proposed station is analyzed from an environmental, social, economic, and technical point of view, and then the developed proposals and recommendations to raise the efficiency of the system and fully cover the needs of the pump are provided [12]-[13].

The objectives of this study are to analyze the solar energy project at the Kofr Al-Labbad Cooperative Association well from a technical, economic, environmental, and social perspective. The proposed study focuses on making full use of the inverter's capacity to maximize electricity production, evaluating the project's impact on greenhouse gas emissions and supporting the local economy, and assessing the economic feasibility of the system over its lifetime. The study's findings used to develop recommendations for improving the efficiency of the solar energy system and ensuring that it meets the needs of the well. The study also provides valuable information on the benefits of solar energy in Palestine.

II. Study Description

The proposed work is located in the village of Kafr al-Labbad, east of Tulkarm. It is a water pump installed in a solar system with a capacity of 40 kW, funded by the Arab Organization under the supervision of the Palestinian Ministry of Agriculture within the plan to develop the agricultural mass and implemented by the International Facilities for Construction Company.

III. Methodology

The methodology used in this project revolves around the use of PV modules, a set of strings, to generate direct current for a 40 kW solar system. This DC power is then routed through a DC BOX, housing a Surge Protection Device (SPD) to redirect harmful impulse currents away from critical loads while reducing voltage to a safe level. It is further connected to DC fuses for short circuit protection.

From there, the current flows into a 50 kW inverter and subsequently into an AC box containing another SPD. In the AC box, there's a 4-pole Molded Case Circuit Breaker (MCCB), which responds instantly to short-circuit faults through electromagnetic principles. During normal operation, the MCCB's electromagnetic field is minimal. However, in the event of a short circuit fault, a strong electromagnetic field is generated, tripping the MCCB and opening the contacts. The circuit then connects to a 4-pole Earth Leakage Circuit Breaker (ELCB), which detects fault currents between live and ground wires within the installation.

Next in the sequence is the bi-directional energy meter. This meter measures energy consumption from the grid and any excess energy exported back to the grid. It plays a crucial role in receiving feed-in tariffs or payments through the Renewable Energy Buyback Scheme (REBS), as illustrated in the single-line diagram in Fig. 1.

Finally, the current is directed to power a solar water pump. This pump harnesses the energy to draw water from its source, with the water either being sent to farmers or stored in a water tank for use during periods when sunlight is unavailable.

The drew of the system using SKETCH UP program, using Jinko Solar JKM540M-72HL4 solar panels with a capacity of 540 watts, and the number of panels is equal to 75 panel is implemented as shown in the Fig. 2.

The modules were distributed on 4 strings, so that the first string contains 19 panel, the second 19 panel, the third 19 panel, and the fourth contains 18 panel. Fig. 3 shows the distribution of the strings, so that each string has a specific color.

Table I shows the main values in the project where the value of dc to ac ratio is 0.8.

The design process has been examined and the maximum, minimum, and optimal number of PV panels per string, as well as other relevant information have been calculated. This information is summarized in Table II.

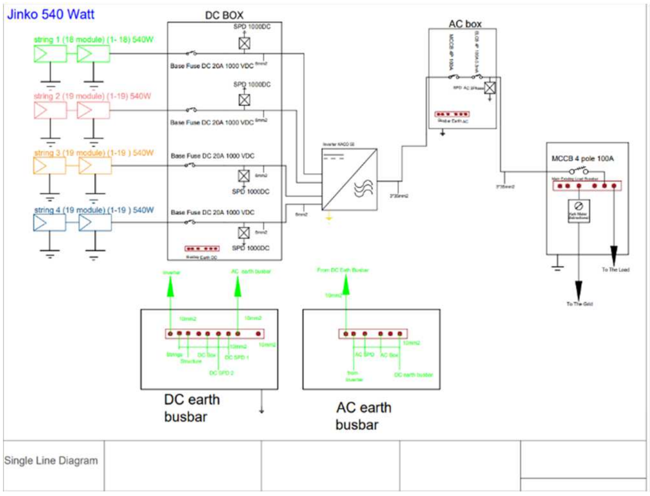

Fig. 1. Single line diagram of the study case.

Fig. 2. Sketchup for the case study.

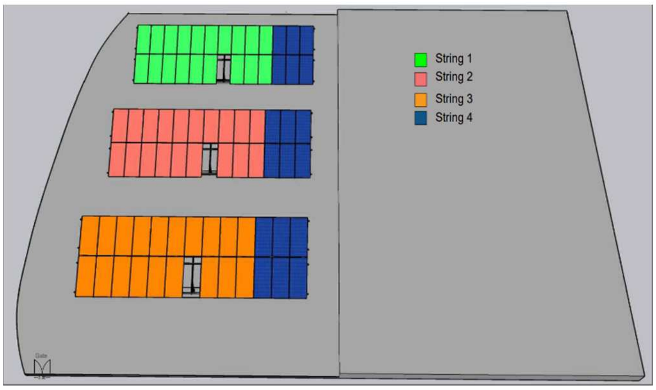

Fig. 3. String distribution using Sketchup program.

The distribution of panels in this project is designed to maximize efficiency as shown in the following table.

The inverter blue planet 50.0 TL3 has only one MPPT, which means that the entire solar array is limited to the performance of the lowest-performing module in the array, which leads to a significant drop in power yield if some panels are shaded or partially blocked. In the system described in Fig. 4, the first string has 18 modules, while the other three strings each have 19 modules, which means that the inverter operates at the voltage of the first string, which is 732.6 volts. The total current of the system is 53.08 amps, which is the sum of the currents of the four strings. The total capacity of the system is 38,886.4 W; however, the system is not operating at its full potential due to the mismatch in the number of modules per string.

TABLE I. PV PROJECT DATA.

Term	Value	Unit
PSH	5.944	h/day
# of Day per Month	30	day/month
# of Months per Year	12	months/year
The applied AC PV System Size	50	KW
PV System Size	40	KWP
PV Module Power	0.54	KWP
Number of PV Modules	75	Modules
Maximum Temperature in the site	45	°C
Minimum Temperature in the site	-5	°C
Temperature at STC	25	°C
Temperature at NOCT	20	°C
Latitude	32.297	°
Longitude	35.019	°
Tilt angle	24	°
Azimuth	0	°

TABLE II. DESIGN CALCULATIONS.

Design calculations		
Term	***Value***	***Unit***
Maximun # of PV Modules per string	20.53339028	Modules
(New) Maximun # of PV Modules per string	20	Modules
Minimum # of PV Modules per string =	4.415759995	Modules
(New) Minimum # of PV Modules per string	5	Modules
# of PV Module to operate inverter	17.666	Modules
(New)# of PV Module to operate inverter	18	Modules
Min # of PV module to operate MPPT	12.367	Modules
(New)Min # of PV module to operate MPPT	13	Modules
Max# of PV module to operate MPPT	26.5	Modules
(New)Max # of PV module to operate MPPT	26	Modules
Optimum # of PV module to operate MPPT	17.078	Modules
(New)Optimum # of PV module to operate MPPT	18	Modules
Number of MPPT per Inverter	4	MPPT
Number of DC input per MPPT	1	String
Total Number of String	4	String
Category # 1	19	Modules
Number of String in Category # 1	4	String
Total # of PV Module	76	String

TABLE III. MPPT DISTRIBUTION.

MPPT Name	Modules	String
MPPT 1	19	1
MPPT 2	19	1
MPPT 3	19	1
MPPT 4	18	1

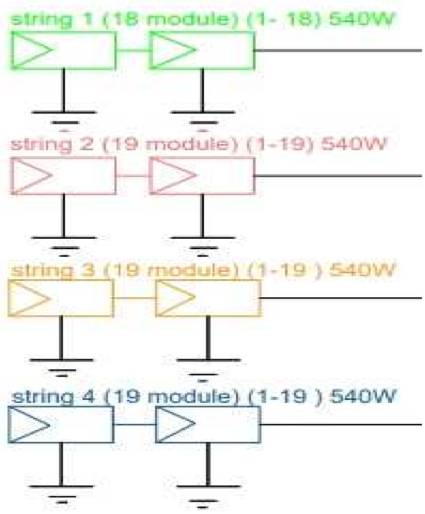

Fig. 4. Distribution of strings in the system.

To improve the performance of the system, it is recommended to use two inverters, each with one MPPT input as shown in Fig. 5. The strings should be connected in such a way that each inverter has strings with the same voltage, allowing the system to operate at maximum efficiency, regardless of whether any of the panels are shaded or partially blocked. In addition to the above, it is also important to note that the system in Fig. 5 is not designed optimally. The first string has one less module than the other three strings, which means producing less power. This mismatch in power also reduces the overall efficiency of the system. To improve the design of the system, it is recommended to have all four strings with the same number of modules to ensure that all of the modules are operating at their full potential and that the system is producing the maximum amount of power.

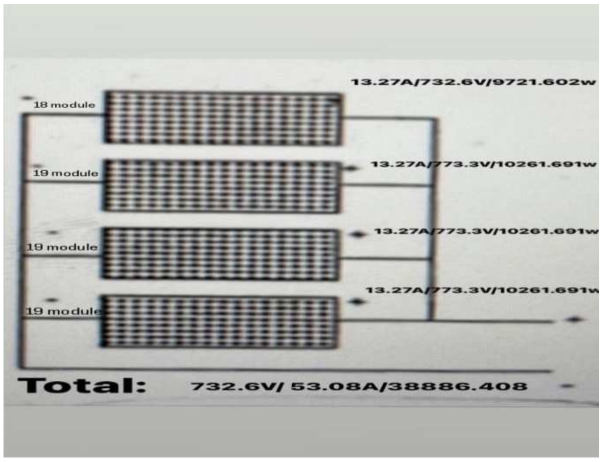

Fig. 5. Voltage and current per string.

IV. Results

The scenario is laid out so that the inverter capacity is fully utilized, with 100 panels distributed across 5 strings and 20 strings. The direct current to alternating current ratio is 1.08, which is an excellent value for high productivity and inverter efficiency. Table IV shows the expected throughput of the system without considering the effects of temperature and shade. In other words, the system is designed to operate at its maximum capacity, with all of the panels producing their full potential. The inverter is also sized appropriately for the system, so that it can efficiently convert the direct current produced by the panels to alternating current. The expected throughput of the system is high, and the inverter is expected to operate efficiently.

TABLE IV. PHOTOVOLTAIC SYSTEM PRODUCTION OF FIRST SCENARIO.

Months	PSH	Energy (KWH/Months)
Jan	105	5250
Feb	135.6	6780
Mar	165.4	8270
Apr	167.8	8390
May	181.66	9083
Jun	197.65	9882.5
Jul	198.7	9935
Aug	190.24	9512
Sep	175.07	8753.5
Oct	156.18	7809
Nov	141.22	7061
Dec	108.67	5433.5
Average	160.2658333	8013.291667
Total	1923.19	96159.5

The redesigned solar system is more productive than the original system by 19,000 kilowatts per year and saves 3384 dollars annually. The designed solar system using the Sketchup program, is shown in Fig. 6.

The system productivity is 93373 kWh/year, as shown in Fig. 7, taking into account the effect of shade and temperature.

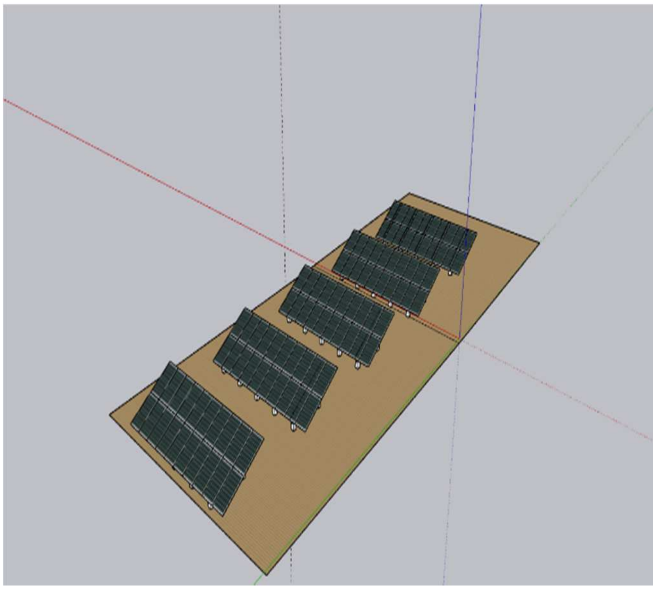

Fig. 6. The design of the second scenario via Sketchup.

The single line diagram of this scenario is shown in the following figure.

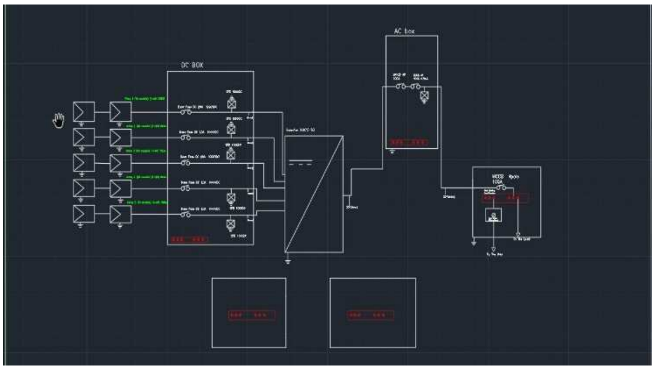

Fig. 7. Signle line diagram of the system using AutoCAD software.

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	90.0	33.88	12.27	127.3	124.2	6304	6154	0.895
February	99.3	45.89	13.45	125.5	122.3	6172	6026	0.889
March	146.9	66.16	16.29	168.5	164.1	8135	7942	0.873
April	173.5	74.97	19.00	182.6	177.5	8678	8474	0.859
May	211.8	81.64	22.65	206.2	200.1	9630	9406	0.845
June	234.0	67.28	25.25	219.3	212.9	10095	9860	0.833
July	221.8	72.10	27.73	211.6	205.3	9655	9432	0.826
August	200.8	74.13	28.11	205.4	199.6	9383	9168	0.827
September	166.3	61.69	26.18	186.5	181.7	8615	8417	0.836
October	127.1	57.29	23.47	155.0	151.0	7304	7136	0.852
November	92.8	39.86	18.53	125.3	122.4	6054	5913	0.874
December	80.2	36.71	14.39	113.3	110.3	5576	5446	0.890
Year	1844.6	711.60	20.65	2026.4	1971.3	95601	93373	0.853

Fig. 8. Production coordinates for the first scenario using PVsyst.

The solar energy project reduces the dependence on traditional energy sources and supply renewable energy to the grid, which covers an area of 5 dunams and have a total capacity of 274 kilowatts. The project components are solar panels, inverters, transformers, base fuses, surge protection devices, circuit breakers, earth leakage circuit breakers, kilowatt meters, solar panel support structures, and DC cables. The project is located 9 kilometers from the city of Tulkarm in the Kofr-Labad area, at a distance of approximately 3900 meters in the Al-Kharaba area. The project area is characterized by moist soil at an altitude of 400 meters above sea level.

The project is a long-term investment with an estimated design life of 25 years. The project provides a source of electrical energy used to operate the submersible type pump, which generates economic benefits.

V. Conclusion

This study has investigated the design and optimization of a solar energy system connected to the Kafr El-Labad Cooperative Society well. The study's findings highlight the significant potential of solar energy to reduce energy costs, support farmers, and mitigate environmental impact. The redesigned solar system demonstrates increased productivity and cost savings, underlining the value of careful design and optimization. The project also contributes renewable energy to the grid, reducing dependence on traditional energy sources and promoting environmental sustainability, economic viability, and long-term energy security. The study's recommendations can serve as a foundation for further development and implementation of solar energy projects, both in Palestine and globally, to meet our electricity needs sustainably while promoting economic growth and environmental stewardship. In essence, this study provides valuable insights into the multifaceted benefits of solar energy in the agricultural sector and beyond, emphasizing the need for continued investment in renewable energy solutions.

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