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Design Of PV Plant to Improve a Voltage Profile Of 11 KV Grid in The South West of Libya

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A B S T R A C T

The use of photovoltaic (PV) system for electricity generation is growing up in the last decades. The southern part of Libya suffers from voltage fluctuation and intermittence of electricity during the summer time. The aim of this paper is firstly to study and analysis a distribution grid of small village located in the southern west region of Libya. We analyzed the existed 11KV distribution overhead line supplied electricity of the village called Takarkibah using Power-World Simulator in order to integrate it with PV plant. The results obtained show that injection of PV power about 70 % of the grid power capacity gives good grid performance. After that, we use SAM simulation program to design PV plant to improve the voltage profile in the distribution grid. Six designs (scenarios) are simulated using different solar modules and inverters. The simulation results obtained from SAM illustrated the power capacity, energy yield, and losses of the designed PV plant.

تصميم محطة كهروضوئية لتحسين جهد شبكة 11 كيلوفولت بالجنوب الغربي الليبي

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الكلمات المفتاحية:
الطاقات المتجددة
محطة كهروضوئية
شبكة توزيع
مخطط الجهد
فاقد القدرة

الملخص

تطور استخدام الأنظمة الكهروضوئية (الفوتو فولتية) في توليد الطاقة الكهربائية في العقود الأخيرة. الجنوب الغربي الليبي يعاني في فترة الصيف تذبذب وانقطاع في التيار الكهربائي. الهدف من هذه الورقة أولا دراسة وتحليل شبكة توزيع الكهرباء لقرية بالجنوب الغربي الليبي. قمنا بتحليل شبكة 11 كيلو فولت لقرية تكركيبه باستخدام برنامج حاسوبي يسمى Power world simulator. النتائج المتحصل عليها وضحت ان ضخ طاقة كهربائية منتجة من الخلايا الشمسية بقدار 70 % من قدرة الشبكة الاستيعابية تعطي افضل أداء للشبكة. بعد ذلك تم استخدام برنامج حاسوبي يسمى (SAM System Advisor Model) لتصميم محطة كهروضوئية لتحسين جهد شبكة قرية تكركيبه. ستة تصاميم او سيناريوهات تمت محاكاتها باستخدام عدة الواح شمسية وعاكسات, نتائج المحاكاة المتحصل عليها بينت مكونات المحطة المصممة و الطاقة التي يمكن ضخها للشبكة الكهربائية و كذلك القدرة الفاقدة من المحطة.

1. Introduction

Renewable energies such as solar and wind energy become the fastest growing energy sources. These energies are pollution free and their efficiency, greatly enhanced. Nowadays, developed countries are seeking for low-carbon cities and have set an ambitious goal of intensifying the use of renewable energies and eliminating the use of fossil fuels in the nearest future. Libya Renewable Energy Authority plans to use renewable sources in the next decade to reduce dependence on fossil fuel and meet the future electricity demand [1].

Power stations in Libya, powered by steam, gas, or double type. These stations, distributed throughout the country. The locations of power stations vary according to the nature of their work and the voltage between electric power plants and electric conversion stations with different voltages. Libyan national electric grid consists of a high voltage 400 kV network of about 2,422 km of length, a high voltage 220kV network of about 13,706 km of length, a medium voltage 66kV network of about 14,477 km of length, a medium voltage 33 kV network of about 13,826km of length, and 43,230 km of low voltage network [2], [3].

The southern west part of Libya suffers from voltage drop and electricity intermittence in hot climate. Reduction of voltage drop exceeds permissible levels (more than 18%) during summer season. Several methods can be used to overcome voltage drop problems in

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electrical power systems. These include, On-load step changer (OLTC), Autotransformers, voltage regulator, switched capacitor, energy storage devices and utilizing renewable energy sources.

On-load step changer (OLTC) technique has not been widely used all over the world in electricity networks at high voltage and medium voltage levels due to its high cost, but in modern electric power networks it has been used at low voltage levels. [4] [5].

Auto-transformers are used as booster transformer to raise the voltage in AC feeders. They are differ from traditional transformers, as in traditional transformers the windings of the primary and the secondary are completely isolated from each other, but in the case of the auto-transformer the windings are electrically connected. Autotransformers are superior to two-winding transformers in following aspects, smaller exciting current, a less turns, smaller core, smaller overall size, hence lower cost, greater efficiency due to lower losses, better regulation and smaller equivalent power, hence smaller size[6].

The voltage regulator compares the output voltage to the reference voltage, and then change the tested voltage to value more or less than the reference voltage. Every voltage regulator consists of four elements a power dissipating control device, a stable reference voltage, a voltage comparator, and a voltage-sampling element. Switched capacitors is a static equipment because it does not contain moving parts that produce self- reactive power and connect to control bus. The goal of using switched capacitors to improve voltage regulation at loads, improve network stability and improve power factor[7].

Recent developments in energy storage technologies and advances in power electronic technologies have made energy storage technologies a viable solution, as these technologies contribute to enhancing system stability, aiding in energy transfer, and improving energy quality in power systems. Viable storage technologies include capacitors, flywheels, batteries and superconducting energy storage systems [4] [7].

Utilizing renewable energy sources strategy aims to injected electricity generated from renewable sources, such as photovoltaic and wind generators, to distribution network. The injection of electricity into the network from renewable sources should be ensure the safe and reliable operation of the public electricity network and preventing over voltages and mitigating voltage fluctuation[4][5].

Solar energy, directly converted into electricity using solar cells. Photovoltaic (PV) system consists of solar panels and other components such as converters and batteries . PV power plant, which is a large-scale PV system, can supply hundreds MW power of electricity to utility grid during daytime to avoid peak load demand. Today, electricity from PV has become price competitive and photovoltaic systems are being deployed at large scales to help power the electric grid [8][9].

2. 11 kV Distribution Grid

Takarkibah is a village located in the southern west of Libya. It is one of the villages of the Wadi Al-Haya district. Its location is at Latitude 26° 33' 33.7" north and Longitude 13° 14' 27.2" east. The electricity supply for the village comes from 66/11 kV substation via 20 MVA transformer located at Alfajej village. The 11kv feeder of Takarkibah grid shown in Figure (1). The main feeder consists of 49 sub-feeders connected to 20 MVA power transformer as shown in Figure (3). There are two lines at the output of this transformer, a line (11/13) feeding Takarkibah) and line (11/15) feeding Alfajej village. This line cannot satisfy the increasing annual demand for electricity, which is about 6% -8% per year. High consumption of electricity and lack of development of the network since it has been constructed in1976, caused voltage fluctuation in the grid. The length of the distribution 11kV feeder of Takarkibah is 29.45 km, which is very long line compared to the economical transmission voltage, which should be less than 17 km to avoid large voltage drop in the line [10]. The distribution feeder has 49 nodes, which supplied the residential, commercial, and agricultural customers in the village.

2.1 Electricity Consumption

The consumption of electricity in the Takarkibah village varies throughout the day and the year. In summer months (June, July, and August), the electricity demand is high in the period from 2 pm to 8 pm as the households, commercial consumers using air conditioning. In addition, agricultural pumps and small workshops consumed high power in hot day. In winter months, December, January and February, the electricity consumption is lower than summer time. Most of consumption in winter due to space and water heating.

Figure (2) shows electricity consumption recorded on 28/06/2020 for Takarkibah village. The data taken from data logger at Alfajej substation. The graph shows the load varied between 1.8MW and 2.8MW during summer day. The highest consumption of electricity occurs at 8 pm because of switching of lights besides operation of air-conditioning and electric pumps for irrigation. The lowest loads are at 3 am because most people gone to sleep.

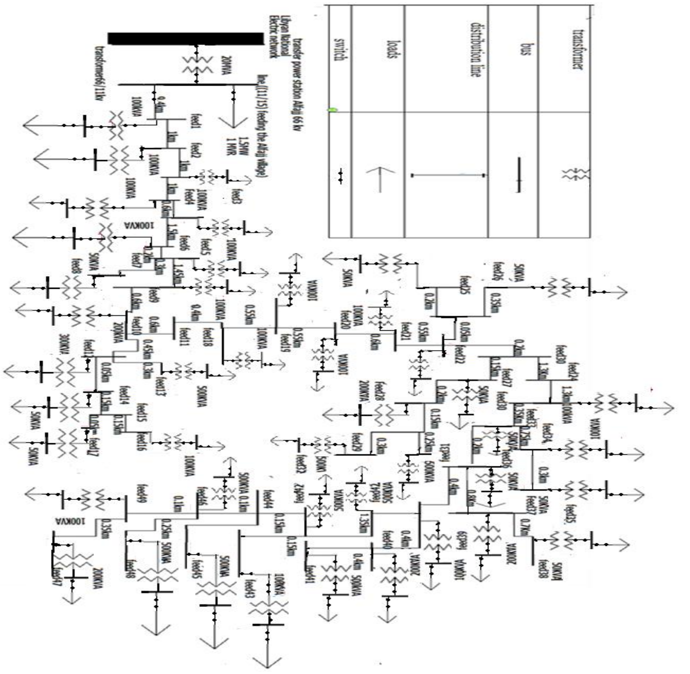

Figure 1: 11kV distribution grid in Takarkibah village.

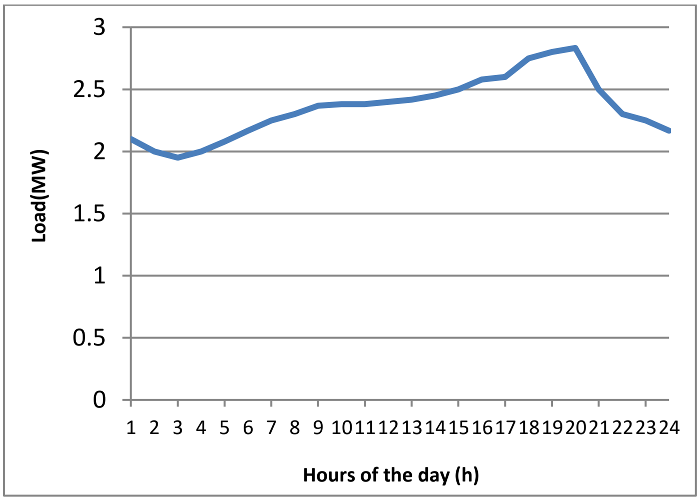

Figure 2: Daily electricity consumption in Takarkibah

2.2. Voltage Profile of 11kv Line

11 kV distribution grid of *Takarkibah* is simulated using simulation power program called, Power-World, developed by power World Corporation in 1990. This simulator is an interactive power systems package designed to simulate high volage power systems operation on a period ranging from several minutes to several days [11]. The program uses Per Unit System for the parameters of the electrical power network components. The per-unit value of any quantity defines as the ratio of the quantity to its base. In power system per unit is an aid used in the analysis of network. The percent and per unit methods of calculation are simpler and more informative than the use of actual volts, amperes and ohms. Additionally, powers, currents, impedances, voltages, and other electrical quantities, which are measured as fractions of some base level instead of conventional units [12][13]. The load bus specifies active power P and reactive power Q, while slack bus contains information of absolute voltage │V│, power angle δ and generator bus includes defined P and │V].

Voltage fluctuation, is defined as repetitive variations in the magnitude of the supply voltage. The magnitudes of voltage variations in *Takarkibah* usually exceed ±20 % of the nominal supply voltage during summer months. As an example, voltage profiles for feeders 26 and 32, recorded on 18/8/2021, are shown in Figure (3).
Table (1) shows voltages of some loads at different time during 2020. The measured voltages show a large voltage reduction during summer time. The nominal voltages for LV networks are 220, 380 volts, and tolerance for voltage fluctuation – 5 % to + 5%. However, fluctuation is exceed 20%, may causes a damage of electric appliances.
When all these powered together on a low ac power distribution lines, the operational state of any equipment will always remain at risk.

Table 1: Reading voltages for Takarkibah feeders.

Type of load	voltage (V)	Feeder number	date	Time
commercial	175V	30	24/9/2020	16:00
household	173V	30	5/4/2020	09:48
agricultural	343V	25	19/9/2020	19:13
household	185V	30	18/9/2020	12:34
agricultural	369V	35	18/6/2020	16:00
household	170V	41	14/5/2020	13:45
commercial	167V	45	20/5/2020	14:50

The characteristics of voltage fluctuations depend on types of load, size and the power capacity. Households use in summer air conditioners, washing machines, fridges, refrigerators, fans, water pumps, light bulbs, and water, etc. In farms submersible and surface pumps are for irrigation. These loads change all the time, through manual switching, thermostats or change in motor loads.

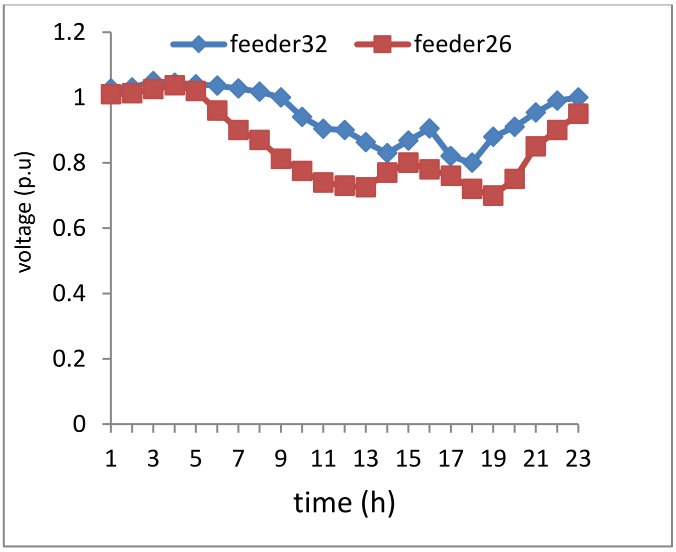

Figure 3: voltage profiles for feeders 26 and 32 of Takarkibah

2.3. Voltage Profiles with PV Penetration

PV penetration level refers to the amount of power supplies from PV system to electricity grid. It is defined as ratio of PV generation to the peak demand of load. To determine PV penetration, firstly, 11 kV of Takarkibah grid is simulated without any penetration of the photovoltaic systems to determine the voltage level at each bus. The simulation carried out at the lowest load of the network during the daylights. Secondly, the solar photovoltaic system introduced by 50% of the network load capacity. The penetration locations are at buses (6, 22, 27, 43). The simulated voltage profile across the buses at 50 % of PV penetration level is shown in Figure (4), note 0 % penetration (injection) is taken as reference. From this figure, injection of PV system at bus 43 gives the best improvement in voltage across the 11 kV line. Bus 30 has high voltage because there is no load connected to this bus.

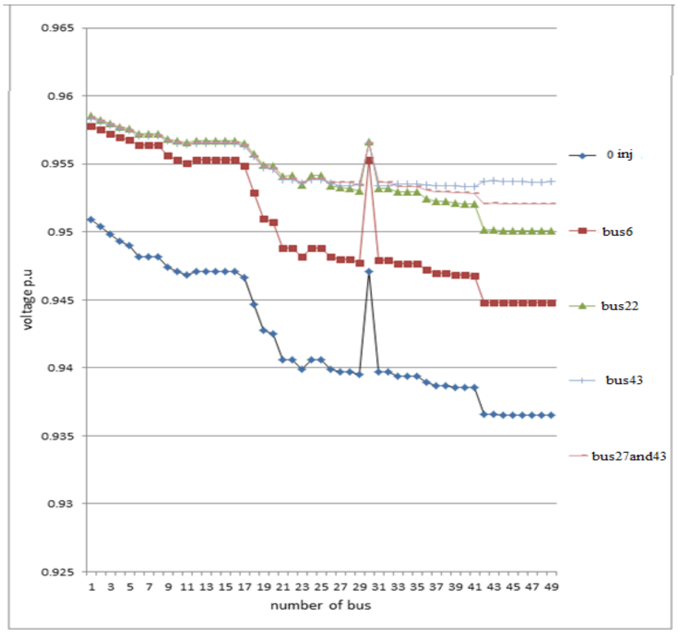

Figure 4: Voltage profile for 11 kV feeder at penetration level of 50 % at different locations.

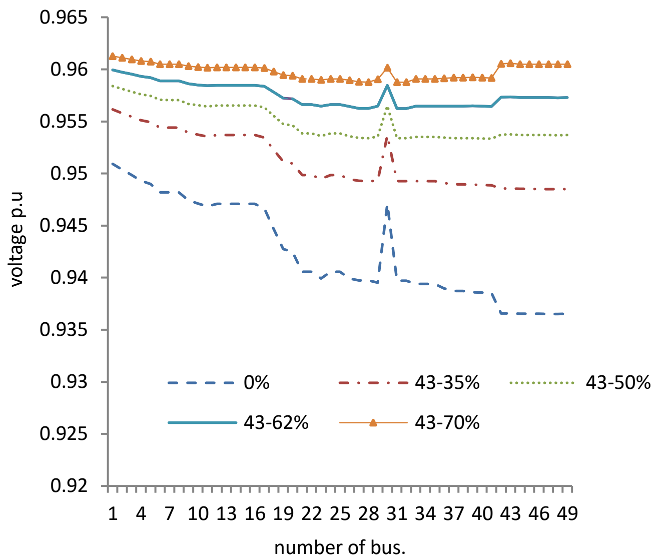

Figure 5: Different PV penetration levels at bus 43.

Figure (5) shows the effect of PV penetration levels imposed to bus 43. The imposed levels are 35%, 50%, 62%, and 70%. As we can see from the figure, 70 % penetration gives the best voltage profile. Penetration level higher than 70 % gives no improvement in voltage profiles and it may cause reverse flow of power and the thermal loading of the line.

3. Photovoltaic System

A direct conversion of light (photons) into electricity (voltage) called photovoltaic effect phenomenon. This phenomenon first discovered in 1954 by scientists at Bell Laboratories who manufactured solar cell from silicon. This cell generates an electric current when exposed to sunlight. Today, electricity from solar cells has become price competitive and photovoltaic systems are being deployed at large scales to help power the electric grid [9][114]. PV system or solar power system is a power system designed to supply solar power by means of photovoltaics. PV system consists of an arrangement of several components including solar panels, solar convertors, storage batteries, as well as mounting support, cabling, and other electrical accessories. The PV system may also use solar tracking system to improve the system's overall performance [15].
A solar module or panel is made of a series connection of solar cells. A simple structure of solar cell is p-n junction as shown in Figure (6). When a light radiation falls on solar cell, the solar cell absorb part of

light photons and produce a photocurrent I_{Ph}, which provides DC current to external circuit [9].

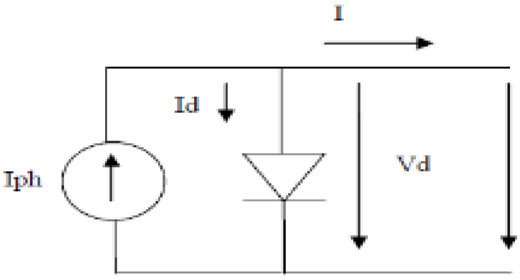

Figure 6: Equivalent circuit of a solar cell.

A typical I-V curve for this solar cell is shown in Figure 7, this curve represents the relationship between the voltage V and the current I supplied by the solar cell to the external circuit and can be described mathematically by [16]:

$$I = I_{Ph} - I_d = I_{Ph} - \left(exp\left(\frac{V_d}{V_T}\right) - 1\right) \quad (1)$$

$$I_s = A \times q \times {n_i}^2\left(\frac{D_N}{L_N \times N_A} + \frac{D_P}{L_P \times N_D}\right) \quad (2)$$

$$V_T = \frac{K \times T}{q} \quad (3)$$

Where

Is: saturation current of the diode, V_d: voltage across diode, V_T :thermal voltage, I_d : diode current of the diode. *Iph* : is the photocurrent.

L_N, L_P diffusion lengths of the electrons or holes, N_D : donor density, N_A : acceptor density, D_N :diffusion constant of the electron, *DP* : diffusion constant of the holes, *q* : electronic charge, n_i : intrinsic carrier concentration, *A* :is the area of the junction, *K* : Boltzmann constant, and *T* : absolute temperature in kelvin.

From Figure (7), the main parameters of solar cell are short circuit I_{sc} described by

$$I_{sc} = I(V = 0) = I_{ph} - I_S \times (e^0 - 1) = I_{ph} \quad (4)$$

Open Circuit voltage, *Voc*, is the voltage at which no current flows through the external circuit. Which described by

$$V_{OC} = V(I = 0) = V_T \times \ln\left(\frac{I_{SC}}{I_S}\right) \quad (5)$$

Fill factor *FF*, describes the relationship of maximum power point *MPP* and the product from open circuit voltage *Voc* and short circuit current *Isc* as shown in figure (2) and can be described by[9][16]:

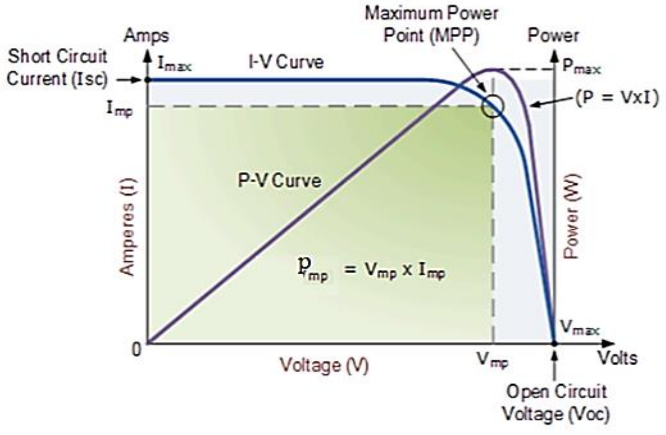

Figure 7: Current-voltage characteristics.

$$FF = \frac{P_{MPP}}{V_{OC} \times I_{SC}} = \frac{V_{MPP} \times I_{MPP}}{V_{OC} \times I_{SC}} \quad (6)$$

Where:

P_{MPP}: Maximum power point *MPP*.

V_{MPP}, I_{MPP}: Current and voltage values associated with the *MPP*.

Conversion efficiency η, calculated as the ratio between the maximal generated power (electrical energy *PMPP*) and the incident power (optical power P_{opt}) and can be described by [9] [16]:

$$\eta = \frac{P_{MPP}}{P_{OPt}} = \frac{I_{MPP} \times V_{MPP}}{E \times A} = \frac{V_{OC} \times FF \times I_{SC}}{E \times A} \quad (7)$$

Where, *E*: incident irradiance.

4. Photovoltaic Power Plant

A power plant or generating station is an installation used for electric power generation. Power station uses a number of generators to produce electric power where mechanical energy converted into electrical power by means of rotating parts in the generators. Photovoltaic (PV) power plants do not use generators but use solar photovoltaic modules to produce electricity. PV plants, made up of thousands of PV modules, which convert sun light directly into DC electric power. The DC power produced by the solar modules converted to AC power by using power inverter. PV power plant design depends on the rating power of the solar module, inverter efficiency and weather conditions at plant location. Step up transformer should be included in the plant to connected the inverter output to 11 kV distribution grid. In this paper, we used two methods to design the PV power plant, the first is calculation method, and the second is simulation method.

4.1. Calculation Method

The steps used in calculation method for design PV plant are, selection of site of PV plant, after that collection of radiation data for the selected site, then selection of PV modules and inverters to determination the DC power of the PV power plant. The proposed site for the installation of the solar PV plant is at *Takarkibah* 26.566N˚and 13.239E˚ shown in rectangular area in Figure (8). Beside the available area, other factors to be considered in PV plant design such as water availability, local regulations, environmental and social considerations. In addition, geotechnical conditions, geopolitical risk and accessibility are important as well as grid connection, module soiling, solar resource and local climate [17]. The irradiance and meteorological data for the selected site, obtained from PV GIS website. Figures (9), show the irradiance on horizontal plane during the hottest and coldest months, July and January for Takarkibah. From figure, the maximum irradiance reaches1000 watt per square meter during winter whereas in summer time, the irradiance approach 950 watt per square meter.

Figure 8: Proposed Site for PV Power Plant [18].

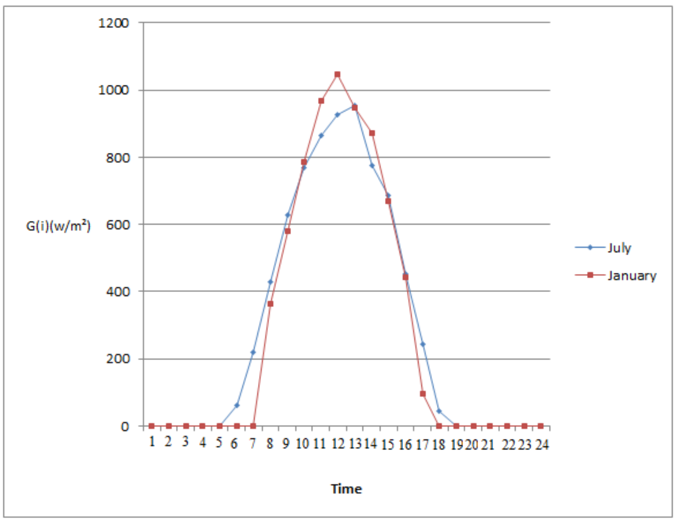

Figure 9: Global horizontal irradiance on July and January [19].

The PV modules and inverters are selected to operate at hot climate condition, since the temperature reaches more than 45 C˚ in summer time. The selected PV modules and inverters are given in Table 2

The capacity of PV plant is selected to be less than the maximum injected power to the grid utility. The maximum AC power injected to the grid is selected to be 70 % of the total load power drawn from 11 kV grid. The peak load for Takarkibah is around 3 MW (AC). Therefore, the injected AC power to the grid should be equal or less than 2.1MW.

The steps used in calculation methodology for design of PV plant of output power of the PV plant are shown Figure 10 [19].

Where, P_{DC}, is DC power of the PV plant, $P_{M,STC}$, is Power of a single module at standard test condition, P_{ac}, is output AC power of PV plant at inverter output, p inj is the AC injected power from PV to the grid, Ni is number of inverters, Ns, Np are the number of modules in series and parallel connection respectively, N_{finl} is the total number of modules, V_f is the voltage drop percent in DC able, $\eta_{ivv, T, cable}$ are efficiencies of inverter, transformer, and AC cable respectively. The number of series modules depends on the inverter and module voltages, while the number of parallel modules depends on inverter and module currents.

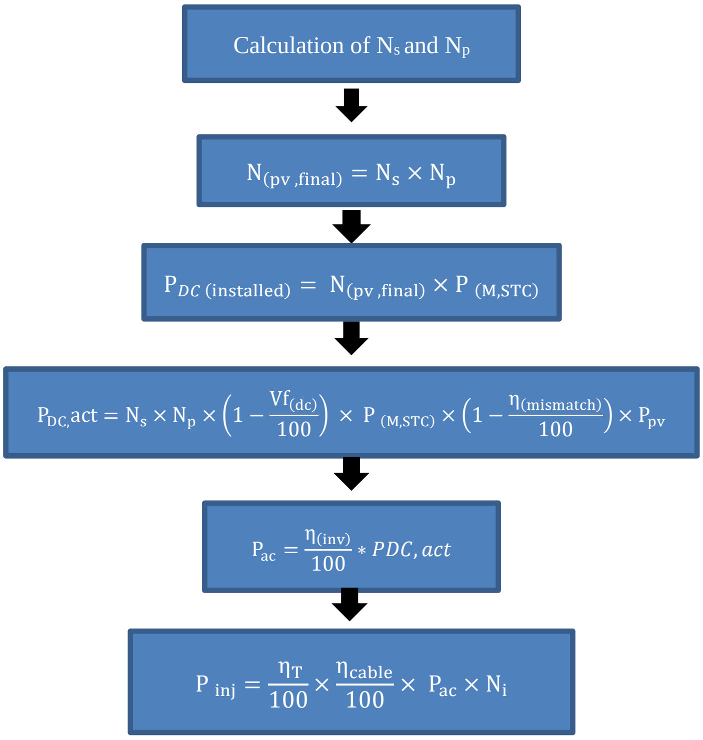

Figure 10: Steps for calculation of AC power of PV pla**nt**

4.2. PV System Simulation

Many different computer software are available for designing PV power plant. Some of these are free and other need paid licenses. The most commonly used to design PV plants are, PVsyst, developed by PVsyst SA, Switzerland (licensed), Homer, developed by Homerenergy, USA (licensed), RET screen, National Resource, Canada (free), and System Advisor Model (SAM), developed by National Renewable Energy Laboratory (NREL), USA (free).

In this paper, we use SAM software developed by (NREL) [20]. SAM is performance and financial software; it predicts the performance and calculate the cost of PV plant. SAM can model many types of renewable energy systems such as photovoltaic, wind power, thermal solar systems. SAM software contains many models for photovoltaics; in our case, we use no financial model. This model requires definition of site location, weather resources, module and inverter types. Also, the model requires specification of system design and grid limits, shading and system losses

5. Results And Discussions

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5.1. Plant Parameters

The modules and inverters given in table 2 are selected from SAM library. The installed DC power capacity of the plant is set to 3 MW. The number of the modules, azimuth and tilt angles are automatically calculated by SAM software. Soiling losses of the PV module surface is set to 5 % and the electrical losses including DC and AC losses are set to 5 %.

After entering module and inverter types, we run the software. The parameters obtained by SAM simulation, given in Table (3). We can see that tilt angles obtained are 20˚ for all designs, and fixed for all seasons. The azimuth angle is 180˚, south facing. The number of PV modules obtained for design 2, 3, and 4 are the same. But, the total number of modules for design 5, and 6 are similar. The modules in design 1 slightly different from the other designs. Comparing to calculation method, the number of modules obtained by calculation is slightly different from that obtained by simulation. For example, in design 1 the total number of modules is 8824, whereas by simulation is 8835 modules.

Table 2: PV module and inverter for each of the different design.

	PV module	Technology	Inverter
Design 1	Amerisolar, Worldwide Energy, 340 watt	Poly Crystalline	SUNGROW SC2500U
Design 2	Jinko Solar, Eagle 72P 320-340 Watt	Poly Crystalline	SUNGROW SC2500U
Design 3	Amerisolar, Worldwide Energy, 340 watt	Poly Crystalline	SMA sunny 2500 EV
Design 4	Jinko Solar, Eagle 72P 320-340 Watt	Poly Crystalline	SMA sunny 2500 EV
Design 5	SunPowerSPR-A420	Mono Crystalline	SUNGROW SC2500U
Design 6	SunPowerSPR-A420	Mono Crystalline	SMA sunny 2500 EV

In design 3, the total number of modules obtained by calculation is 8816 modules whereas by simulation is 8820. The number of inverters obtained in simulation and the calculations are the same for all design which is one central inverter.

Table 3: Plant parameters for six designs.

	Design 1	Design 2	Design 3	Design4	Design 5	Design 6
Til angles[°]	20	20	20	20	20	20
Azimuth [°]	180	180	180	180	180	180
No. of PV modules	8835	8820	8820	8820	7140	7140
No. of ser. modules	31	30	30	30	28	28
No. strings in parallel	285	294	294	294	255	255
modules area [m2]	17139	7110	17110	17110	51	13351
Capacity [kWac]	2507	2507	2353	2353	2507	2353
Inverters	1	1	1	1	1	1

The total AC power capacity obtained in the designs used SUNGROW SC2500U-MV inverter is higher than that total obtained in designs used SMA sunny 2500 EV inverter. The total module area obtained in the designs used poly crystalline module is higher than that obtained in the designs used mono crystalline module. Because the power rating of the mono crystalline module is higher compared to poly crystalline module.

5.2 Power Generation

The variation of the weather and solar radiation falling during the year affects the amount of power produced by PV solar systems. From the results obtained from the SAM program, it was found that the AC output power reaches 2 MW during 2-3 pm in December for all designs as shown in Figure 11a. In contrast, the amount of power produced during summer (August) is the highest during the year, and power reaches 2.3MW in design 5, as can be seen in figures 11b.

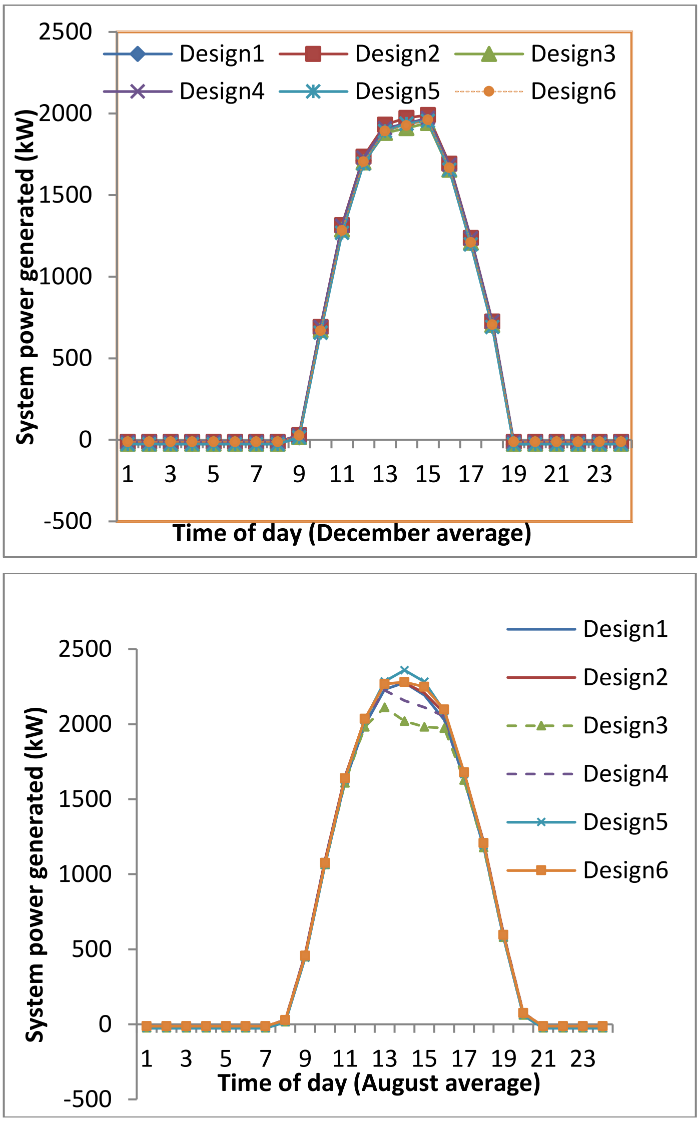

Figure 11: PV power generation for all design in December and August **(b)for all design**

5.3 Energy Losses

Energy losses are composed from soiling, reflection, wiring losses and other losses in all designs. Figure 12 illustrates energy losses for Design 1 as an example. Soiling loss is 5%, reflection loss is 2.733%. Additionally, mismatch losses about 2%, diodes and connections around 0.5%, DC wiring is about 2%. Module deviation form STC losses are slightly difference in designs. This because of using of different modules which its characteristics depend on module temperature. These losses are 6.178% for designs 1 and 3, and 5.633% for designs 2 and 4, 5.153% for designs 5 and 6. Inverter power consumption is 0.23% for design 1, 0.226% for design 2, 0.234% for design 3, 0.229% for design 4, 0.225% for design 5, and 0.224% for design 6. design 5, and 0.051% for design 6. Inverter efficiency, 2.47% for design 1and 2, 2.844% for design 3, 2.913% for design 4, 2.486% for design 5, and 2.95% for design 6. AC wiring losses is, 0.166% for designs 1, 3 and 5, and 0.666% for designs 2, 4 and 6. Illustrate losses in all designs. Designs 1, 2, 3, and 4 have polycrystalline modules and designs 5 and 6 contain monocrystalline modules.

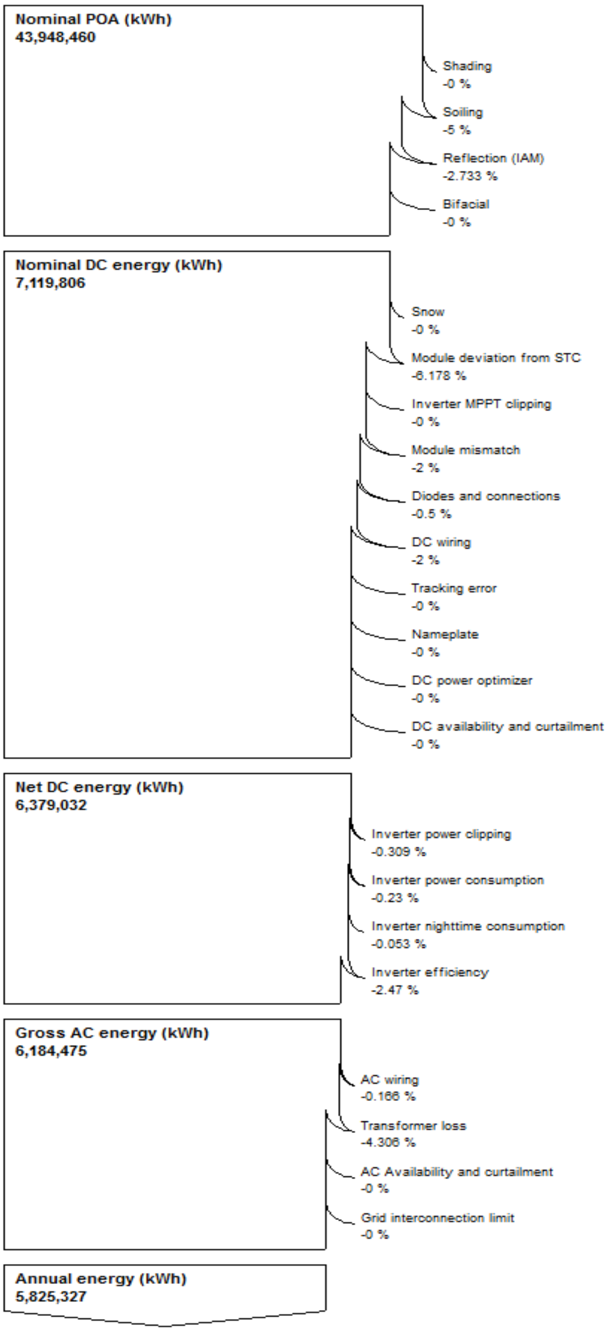

Figure 12: Energy losses diagram for Design 1.

5.4. Annul Electric Energy

Annual energy for all six designs are summarized in Table 4:

Table 4: Annual electric energy for six design.

	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
POA (MWh)/yr	43950	43875	43875	43875	34500	34500
DC output energy MWh	7120	7110	7110	7110	7100	7100
AC energy MWh/yr	5830	6000	5700	5910	5870	5910

POA (plane of array) means the total incident irradiance on a tilted panel (module) of the array. The DC output energies of all designs are similar about 7000 MWh annually, although the incident irradiance on design 1, 2, 3,4, are greater than that fall on design 5 and 6. This due to modules in in design 5, 6 have much rated power and efficiency. After subtracting all losses, the output AC energy feed to the grid is similar to all designs, it is about 6000 MWh per year. From the obtained results of previous sections, the AC power produced by PV plant for all designs is about 2.3 MW. Therefore, there is no optimum design to choose from these six designs. As the temperature during summer exceeds forty degree in the south of Libya, it is preferable to choose mono crystalline silicon modules, which can operate at high temperature with high efficiency and high rated power. However, monocrystalline module is more expensive than polycrystalline. Therefore, design of PV plant should take into accounts many factors such module performance at high temperatures, inverter efficiency, and the total cost of PV plant.

6. Conclusions

The purpose of this paper is to design photovoltaic plant to reduce voltage fluctuation in 11 kV line feeding a village called Takarkibah in the south west of Libya. This includes analyses of existing 11 kV line, and simulates its voltage profiles at certain buses and then study the effect of injection PV power at different locations at different penetration levels using Power-Word Simulator. The design of PV plant carried out by calculation method and SAM software simulation as well. Simulation results showed that PV penetration level of 70 % produced the best improvement for the voltage profile of 11 kV line. Additionally, results reveal that bus 43 of the line is the best location for injection of PV power. The design of PV plant including selection of solar modules, inverters. and system layout Six designs (scenarios) contain different combinations of solar modules and inverters are simulated using SAM software. The module makers are SunPower, Amerisolar, and Jinko Solar. The determined number of solar modules is in range of 7140-8835 modules. For all designs, one central inverter is used. Two types of inverters are used in the simulation. The simulated DC output energy for all designs is about 7100 MWh per year. The AC power produced by PV plants for all designs is about 2.4 MW. In conclusion, PV plant is the most suitable effective solution for voltage fluctuations
in the south west of Libya, because it can compensate voltage drop happening during peak load demand time.

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