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1.8 MW ROOFTOP SOLAR PHOTOVOLTAIC POWER PLANT

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ABSTRACT *Nowadays, renewable energy resources play an important role in replacing conventional fossil fuel energy resources. Photovoltaic energy is one of the very promising renewable energy resources which grew rapidly in the past few years. Renewable energy resources play an important role in electric power generation. There are various renewable resources which is used for electric power generation, such as solar energy, wind energy, geothermal etc. Solar Energy is a good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic modules. These modules are made up of silicon cells. When many such cells are connected in series we get a solar PV module. The current rating of the modules increases when the area of the individual cells is increased, and vice versa. When many PV modules are connected in series and parallel combinations we get a solar PV array, which is suitable for obtaining higher power output. This study aims to design and evaluate the grid-connected solar photovoltaic roof-top system. The performance of the system was simulated using PVsyst software and the results were analyzed. The analyses of the simulation results show that maximum total energy generation of 329.3 MW h was observed in the month of May and lowest total energy generation of 166.4MWh was observed in the month of December.The utilization of roof building will be increasing the amount of solar energy and achieving Dubai clean energy strategy 2050 goals which aims to provide seven per cent of Dubai's power through clean energy by 2020, 25 per cent by 2030 and 75 per cent by 2050." it will be implemented through Shams Dubai initiative, which aims to encourage building owners to place solar panels on the roofs and link them to the main network of DEWA.*

Keywords: *Grid Connection, Photovoltaic (PV), Roof Top PV, Performance Ratio, PV System, Solar Park.*

СОЛНЕЧНАЯ ЭЛЕКТРОСТАНЦИЯ С ФОТОЭЛЕКТРИЧЕСКИМИ ПАНЕЛЯМИ НА КРЫШЕ МОЩНОСТЬЮ 1.8 МВт

ХАЙДАР ДЖАФАР АБУДЖУХ

Харьковский национальный университет городского хозяйства имени А.Н. Бекетова, Харьков, Украина

АННОТАЦИЯ *В настоящее время возобновляемые источники энергии играют важную роль в замене традиционных источников энергии на ископаемом топливе. Фотоэлектрическая энергия является одной из самых перспективных источников возобновляемой энергии, интенсивно развивающейся в последнее время. Возобновляемые источники энергии играют важную роль в производстве электроэнергии. Существуют различные возобновляемые ресурсы, которые используются для производства электроэнергии, такие как солнечная энергия, энергия ветра, геотермальная энергия и т. д. Солнечная энергия является хорошим выбором для выработки электроэнергии, поскольку солнечная энергия напрямую преобразуется в электрическую энергию с помощью солнечных фотоэлектрических модулей. Эти модули состоят из кремниевых элементов. Последовательное соединение элементов дает возможность реализации солнечного фотоэлектрического модуля. Производительность системы была смоделирована с использованием программного обеспечения PVsyst, проанализированы полученные результаты. Анализ результатов моделирования показал, что максимальная суммарная выработка энергии в 329,3 МВтч наблюдалась в мае, а самая низкая суммарная выработка энергии - 166,4 МВтч - в декабре. Использование крыши здания будет способствовать увеличению количества солнечной энергии и достижению целей Дубайской стратегии чистой энергии до 2050 года, которые нацелены на обеспечение семи процентов энергии Дубая за счет чистой энергии к 2020 году, 25 процентов к 2030 году и 75 процентов к 2050.» он будет реализован в рамках инициативы Shams Дубай, цель которой - побудить владельцев зданий устанавливать солнечные панели на крышах и связывать их с основной сетью(DEWA) (Департамента электроэнергии и воды Дубая).*

Ключевые слова: *Солнечная энергия, Солнечный парк, Фотоэлектрика, Солнечная электростанция, GRID соединение*

Introduction

The vision of the leadership of Dubai has been strongly in favor of private sector engagement. Under the patronage of His Highness Sheikh Mohammed Bin Rashid Al Maktoum, we have seen the strongest commitments to the sector in the entire region. The unveiling of 1GW of IPP utility scale has demonstrated an extremely competitive electricity generation solution in line with the vision of diversifying the energy mix, reducing carbon emissions and establishing a regional leadership position. The introduction of the Dubai Shams Initiative as well as the Dubai Carbon initiative have invited the private sector to take part in transforming Dubai into the city with the "lowest carbon footprint in the world by 2050, quarter (in some cases, over 15% since the beginning of the year) has made solar a viable economic solution for businesses ensuring a sustainable future for us, and for generations to come."

The dramatic drop in PV module costs over the last Customers can shave 5-15% off their operating electricity costs today and that has caught their attention. In a time where the global economy has slowed down, this has created a viable value proposition**.** In grid connected rooftop or small SPV system, the DC power generated from SPV panel is converted to AC power using power conditioning unit and is fed to the grid**.** These systems generate power during the day time which is utilized by powering captive loads and feed excess power to the grid. In case, when power generated is not sufficient, the captive loads are served by drawing power from the grid**.** Solar Rooftop System provides following technical benefits:

- Utilization of available vacant roof space;
- Low gestation period;
- Lower transmission and distribution losses;
- Improvement in the tail-end grid voltages and reduction of system congestion;
- Loss mitigation by utilization of distribution network as a source of storage through net metering;
- Long term energy and ecological security by reduction in carbon emission;
- Abatement of about 60 million tones of CO per year over its life cycle;
- Better Management of daytime peak loads by DISCOM/ utility;
- Meeting of the renewable purchase obligations (RPOs) of obligated entities which are targeted at 8% of electricity consumption;
- Minimal technical losses as power consumption and generation are co-located.

DEWA has announced mandatory rooftop installations for all buildings by 2030**.** In December 2014, the Emirate of Dubai provided for rooftop PV systems to operate under a net-metering system. This scheme was officially launched by DEWA in 2015 to encourage commercial and residential building owners to fit solar PV panels through the Shams Dubai framework. Companies already signed up to service clients as part of the Shams Dubai scheme include engineering groups expanding into the solar sector, as well as international PV contractors and developers**.**

The electricity consumption in the United Arab Emirates (UAE) has increased by 12% per annum from about 60,000 GWh in 2006 to 85,000 GWh in 2010. The electricity peak demand in Dubai is increase from 3.228MW in 2004 to 8,507MW in 2018. To meet this increasing energy demand, the Dubai relies heavily on gas and oil. As a matter of fact, 73% of the generation capacity is based on gas turbine generators (7,448MW), and 25% is based on steam turbine generators (2,542MW). As a result, the Dubai has a high ecological footprint per capita, and it actually had the world's highest in 2018. The government of Dubai has recently committed to have (1000MW) 1% of its generation capacity from renewable resources and mainly from solar energy by the year 2020 and 5000MW by 2030.The Mohammed bin Rashid Solar Park is the largest single-site solar park in the world with a planned capacity of 1,000MW by 2020, and 5,000MW by 2030, the solar park will use a range of photovoltaic and concentrated solar power technologies to provide clean energy to the citizens and residents of Dubai**.**

Components of GRID connected PV system

The basic Grid Connected PV system design has the following components:

- PV ARRAY: A number of PV panels connected in series and/or in parallel giving a DC output out of the incident irradiance. Orientation and tilt of these panels are important design parameters, as well as shading from surrounding obstructions.
- INVERTER: A power converter that 'inverts' the DC power from the panels into AC power. The characteristics of the output signal should match the voltage, frequency and power quality limits in the supply network.
- TRANSFORMER: A transformer can boost up the ac output voltage from inverter when needed. Otherwise transformer less design is also acceptable.
- LOAD: Stands for the network connected appliances that are fed from the inverter, or, alternatively, from the grid.
- METERS: They account for the energy being drawn from or fed into the local supply network
- DC Isolator: The DC isolator provides a safe means of disconnecting the solar array from the inverter, for example for periodic maintenance. Some inverters have integrated DC isolator
- AC Isolator: A main isolator is included to provide a means of disconnecting the solar PV system from the building electricity supply. This may be important if there is an emergency, but (more usually) is needed when electricians have to do work on the building supply.
- The Grid: The mains electricity network which supplies power to consumers may now also supply excess solar PV production to other consumers.
- Protective Devices: Some protective devices is also installed, like under voltage relay, circuit breakers etc for resisting power flow from utility to SPV system.
- Other Devices: Other devices like dc-dc boost converter, ac filter can also be used for better performance.

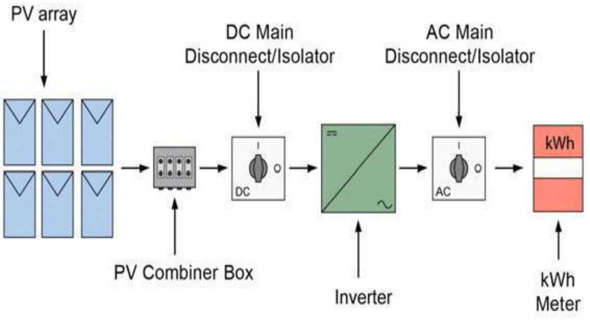
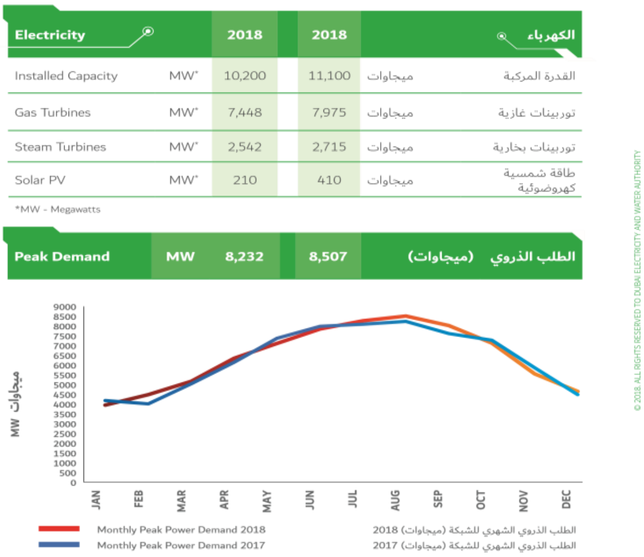


Fig.1 - Grid Connection



Electricity		2018	2018		الكهرباء
Installed Capacity	MW*	10,200	11,100	ميجاوات	القدرة المركبة
Gas Turbines	MW*	7,448	7,975	ميجاوات	توربينات غازية
Steam Turbines	MW*	2,542	2,715	ميجاوات	توربينات بخارية
Solar PV	MW*	210	410	ميجاوات	طاقة شمسية كهروضوئية

*MW - Megawatts

Peak Demand	MW	8,232	8,507	الطلب الذروي (ميجاوات)

Fig. 2 - DEWA –Power Generation

SYSTEM DESCRIPTION

The system description is given in table kWp rooftop system is chosen. The PV cell material chosen is mono-crystalline because of the higher efficiency. The system is of fixed stand type and can sufficiently power a household of a small family.

The grid connected PV system, consists of solar arrays to absorb and convert sunlight into electricity, a solar inverter to convert DC current to AC current, a mounting, cabling and other electrical accessories. Schematic of the grid connected PV system is shown in Fig. 2. The main component for grid-connected solar PV power systems comprise of: Solar PV modules, connected in series and parallel, depending on the solar PV array size, to generate DC power directly from the sun's intercepted solar power. Maximum tracker (MPPT), making sure the solar PV modules generated DC power at their best power output at any given time during sunshine hours Grid-connected DC/AC inverter, making sure the generated and converted AC power is safely fed into the utility grid whenever the grid is available .Grid connection safety equipment like DC/AC breakers fuses etc., according to the local utility's rules and regulations.

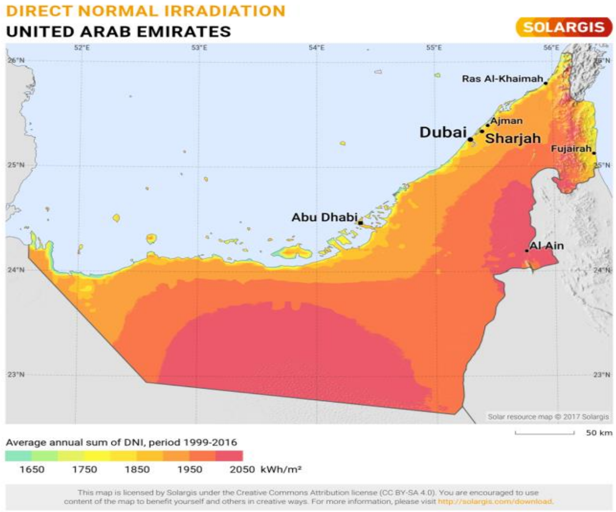


Fig. 3 - Normal irradiation –UAE

Description of the solar PV-GRID system

A grid –connected PV system consists of solar panels, inverters, a power conditioning and grid connection .It has effective utilization of power that is generated from solar energy as there are no energy storage losses. The grid –connected PV system supplies the excess power, beyond consumption by the connected load to the utility grid through smart meters.

- Geographical location of the site:

The solar plan located in Dubai at longitude of 55.20E.Latitude 25.12N and at an altitude of 1m.

- Specification of solar panel:

The solar panels mounted at the building are of 275Wp rating and made up of polycrystalline. These panels have an efficiency of 16.7% and are of fixed type. Polycrystalline panel ratings are open circuit voltage (VOC) of 31.94 V and short circuit current (ISC) of 9.16 A. It has a maximum operating temperature up to+ 80° centigrade.

- Creating a string of modules

A string comprises a number of PV modules connected in series. The electrical characteristics of PV modules connected in series to form a string are the same as PV cells connected in series to form a module: meaning the output voltage of the string will be the sum of the output voltages of all the modules and the output current of the string will be the lowest output current of any module.

Modules can also be connected in parallel. In this case the current output of the modules will add instead of the voltage. The output voltage is that of a single module.

Power conditioning units:

Inverter converts DC power into AC power. The inverter power rating is 50 kW. PV voltage of 610 V and supply DC current 32 A is fed as input to inverter. The output AC voltage and current from inverter are 400 V and 77 A respectively. The output of the inverter is synchronized automatically with same voltage and frequency as that of grid.

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PV Output Modeling

For the calculated utilizable roof area the energy production from the installed solar panels has been estimated with the help of PVsyst software.

Specimen energy yield calculations for the buildings are provided in Figure 6 and Table 1.

Specifically provides a detailed flow diagram of PV energy production from the buildings, while also highlighting the involved losses at various stages.

Solar Irradiance absorbed by solar modules is converted to useful power.The power output varies with the solar insolation and ambient temperature .The temperature increases the power output decreases even if there good amount of radiation.The power generation decreases with increase in temperature even when there is constant solar irradiance.

The simulation using PV SYSTEM

PV SYST software is one of the simulation software developed to estimate the performance of the solar power plan .it is able to import meteo data from many different sources .This software is capable of evaluating the performance of grid-connected, stand –alone and pumping system based on the specified module selection. The program accurately predicts the system yields computed using detailed hourly simulation data.

The maximum energy is generated in the month of May (322.3MW h) and minimum energy is in the month of December (166.4 MW h).The total amount of energy injected into grid for the year 3016 MWh.

Annual global horizontal irradiation is2003.8kW h/m2.Global Incident energy that is incident on the collector plane annually is 2003.9 kW h/m^2. Total energy obtained from the output of the PV array is 3089 MW h.

The annual average performance ratio is 75.06%.

- Normalized productions:

The LC value is recorded as 1.27kWh/kW p/day and the LS value is recorded as 0.1 kW h/kW p/day in the same way YF is given as4.12kW h/kW p/day. See Figure 5

- Loss diagram:

The global horizontal irradiance is 2004 kW h/m2. The effective irradiation on the collector plane is 1853kW h/m2. Therefore, the loss in energy is 3.2%. The solar energy incident on the solar panels will convert into electrical energy.

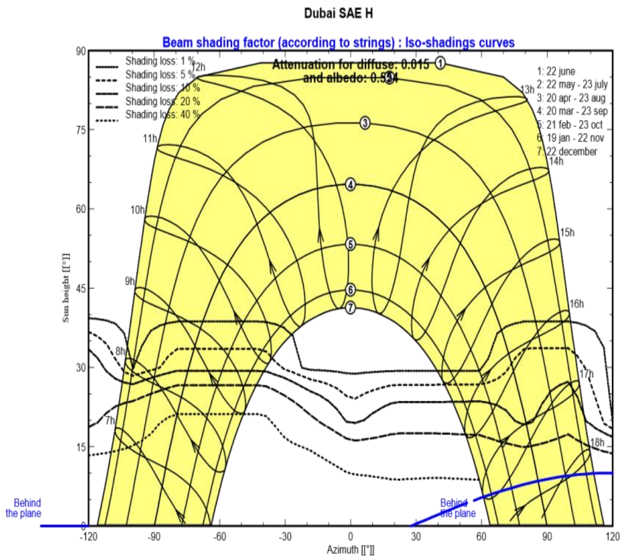

Fig. 4 - Path of the sun over a year

After the PV conversion, the nominal array energy is 3715MWh. The efficiency of the PV array is 13.3% at standard test condition (STC). Array virtual energy obtained is 3089 MW h. After the inverter losses the available energy obtained at the inverter output is 3016MWh. (Fig. 7).

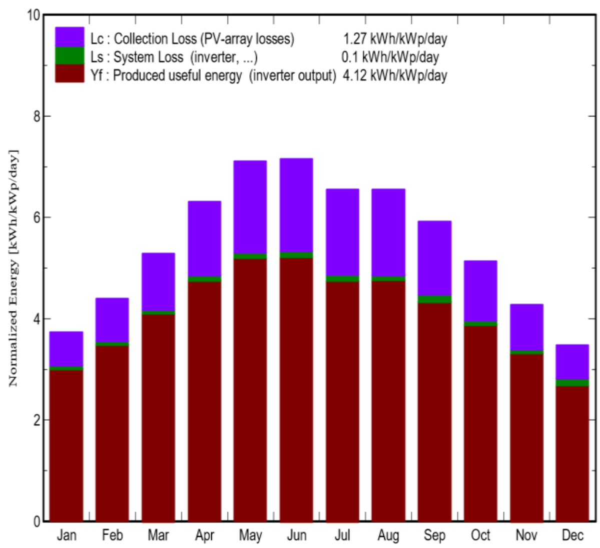

Fig. 5 - Normalized production for the building

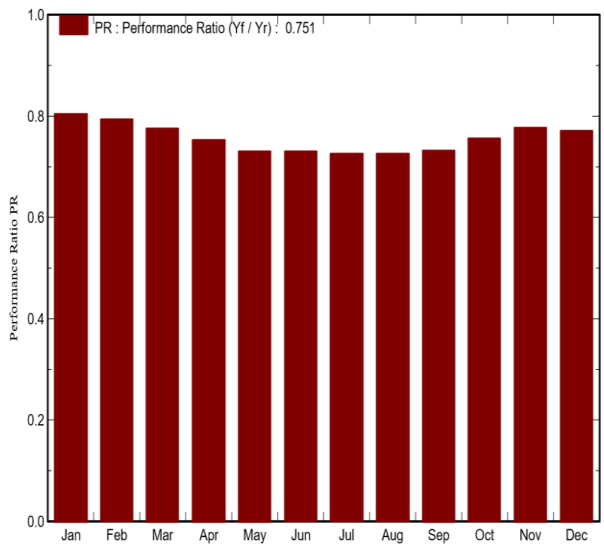

Fig.6 - Performance Ratio PR

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArR %	EffSysR %
January	115.5	18.46	115.5	106.0	190.4	186.4	13.74	13.45
February	123.0	20.29	123.0	113.3	199.7	195.7	13.53	13.26
March	163.6	23.84	163.6	151.1	259.5	254.5	13.22	12.96
April	189.1	27.93	189.1	175.4	291.7	285.7	12.86	12.59
May	220.1	32.86	220.1	204.5	329.3	322.3	12.47	12.21
June	214.2	33.85	214.3	198.9	320.2	313.6	12.45	12.20
July	202.9	35.87	202.8	188.0	302.1	294.9	12.41	12.12
August	203.1	35.75	203.2	188.5	301.9	295.5	12.39	12.12
September	177.6	32.38	177.5	164.5	269.2	260.5	12.64	12.23
October	159.2	29.64	159.2	147.2	246.1	241.1	12.88	12.63
November	127.8	24.86	127.8	117.3	203.2	199.3	13.25	13.00
December	107.6	20.84	107.6	98.2	175.3	166.4	13.59	12.89
Year	2003.8	28.09	2003.9	1853.0	3088.6	3015.9	12.85	12.55

Table 1-ABB - SEAP 275W – 002 Balances and main results

Table 2 – Description of the solar PV-GRID system

Description	1	2	3
Module Capacity, Wp	275	275	275
Total Number Strings	108	108	108
No of Modules in Strings	23	23	23
Total Number of Modules	2484	2369	2438
Total Array Capacity , KWp	683.1	651.4	670.4
Total Number Of Inverter	12	12	12
Each Inverter Capacity, KWac	50	50	50
Total capacity , KW ac	600	600	600
No of point of connection	1	1	1

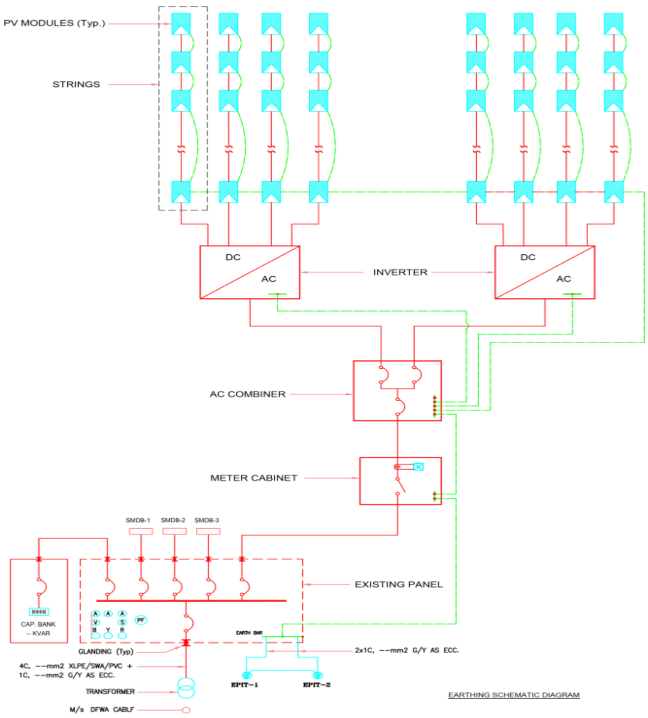

Fig. 7 - Plan Layout of PV System

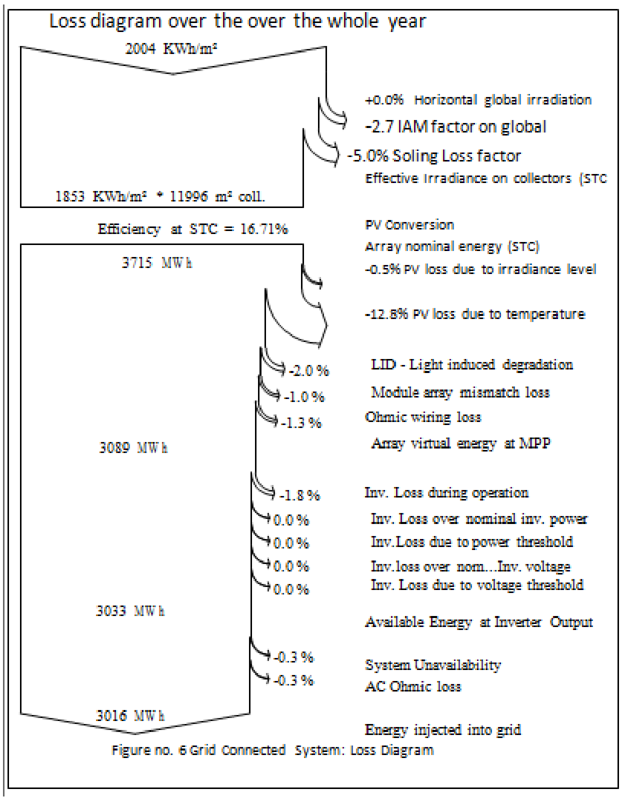

Fig. 8- Loss Diagram

Conclusion

A performance study of 1800 KW peak grids connected solar photovoltaic power plant installed at Dubai was evaluated on annual basis. The following conclusions are drawn from the study. Maximum total energy generation of 329.3 MW h was observed in the month of May and lowest total energy generation of 166.4MWh was observed in the month of December. The geographical location, weather and other atmospheric conditions at the installation site. The direction your panels face, the temperature they reach, the angle of tilt they are on, the amount of dust and shading they encounter all affect the ability of the system to perform at its peak level.

The utilization of roof building will be increasing the amount of solar energy and achieving Dubai clean energy strategy 2050 goals, which we have launched to turn Dubai into a global hub for clean energy and green economy and become the lowest carbon footprint in the world by 2050.

References

1. **Angelo Baggini University of Bergamo**. "Handbook of Power Quality", State of Energy Report Dubai 2014-www.dcce.ae/energyreport.
2. **Central Electricity Regulatory Commission** (2015) CERC, New Delhi.
3. **Gan CK, Tan PH, Khalid S** (2013) System Performance Comparison Between Crystalline and Thin-Film Technologies under Different Installation Conditions. IEEE Conference on Clean Energy and Technology 362-367.
4. **Ahmed MM** (2003) Design and Proper Sizing of Solar Energy Schemes for Electricity Production in Malaysia. National Power and Energy Conference.
5. **Scott Someras** Rooftop photovoltaic feasibility study.
6. **Dr P.Trichakis,Baringa, N.Carter, S.Tudhope, Baringa,I. Patel, Baringa,Dr S.Sgouridis, Dr S.Griffiths, Masdar Institute**-ENABLING THE UAE'S ENERGY TRANSITION-2018.
7. **S.Chowdhury**-Design & Estimation of Rooftop Grid-tied Solar Photovoltaic System-May2016.
8. Handbook for rooftop solar development in Asia-2014 Asian Development Bank.
9. **GSES India Sustainable Energy Pv-Installation, Operation & Maintenance of Solar PV Micro grid Systems**, April 2016.
10. **Rooftop Solar PV Power** : Potential, Growth and Issues related to Connectivity and Metering-JAN.2015.
11. **Rooftop Solar PV**-ARUP.COM
12. **M. Nafreen, Md.I. Hossen, A. Rahman , R. Islam, Z. Ferdous ,Md S.H. Sohag**,100KW Rooftop Solar Photovoltaic Power Plant: Block "B" of Ahsanullah University of Science and Technology,APRIL2017.

Список литературы

1. ***Ангело Баггини*** University of Bergamo. "Handbook of Power Quality", State of Energy Report Dubai 2014-www.dcce.ae/energyreport.
2. **Центральная комиссия по регулированию электроэнергетики** (2015) CERC, New Delhi.
3. ***Ган СК.Тан.БН.Халид*** (2013) System Performance Comparison between Crystalline and Thin-Film Technologies under Different Installation Conditions. IEEE Conference on Clean Energy and Technology 362-367.
4. ***Ахмед М.М***(2003) Design and Proper Sizing of Solar Energy Schemes for Electricity Production in Malaysia. National Power and Energy Conference.
5. ***Скутт Сумерас***,Rooftop photovoltaic feasibility study.
6. ***Д.П.Трешакис.Баренга.Н.Сартер.С.Тудхопе.Баренга.И.Рател***, **Masdar Institute** - ENABLING THE UAE'S ENERGY TRANSITION-2018.
7. *С.Щудрый*-Design & Estimation of Rooftop Grid-tied Solar Photovoltaic System-May2016.
8. **Справочник по солнечному развитию на крыше в Азии** -2014 Asian Development Bank.
9. ГСЕС Устойчивая энергетика Индии PV-Installation, Operation & Maintenance of Solar PV Micro grid Systems, April 2016.
10. **Солнечная фотоэлектрическая система на крыше**: Potential, Growth and Issues related to Connectivity and Metering-JAN.2015.
11. **Солнечная электростанция на PV** -ARUP.COM
12. ***М.Нфрен.МД.И.Носен.А.Ранман.Р.Эслам.З.Фэрдуз.МД С.Н.Сухаг***,100KW Rooftop Solar Photovoltaic Power Plant: Block "B" of Ahsanullah University of Science and Technology,APRIL2017.

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Будь ласка, посилайтесь на цю статтю наступним чином:
Алі Хайдар Гафар Абугоух. Сонячна електростанція з фотоелектричними панелями на даху потужністю 1.8 МВт / **Али Хайдар Гафар Абугоух** // *Вісник НТУ «ХПІ», Серія: Електричні машини та електромеханічне перетворення енергії*. – Харків: НТУ «ХПІ». – 2019. – № 20 (1345). – С. 35-41. – doi:10.20998/2409-9295.2019.20.05.

АНОТАЦІЯ. *В даний час поновлювані джерела енергії відіграють важливу роль в заміні традиційних джерел енергії на викопному паливі. Фотоелектрична енергія є однією з найперспективніших джерел відновлюваної енергії та інтенсивно розвивається останнім часом. Поновлювані джерела енергії відіграють важливу роль у виробництві електроенергії. Існують різні поновлювані ресурси, які використовуються для виробництва електроенергії, такі як сонячна енергія, енергія вітру, геотермальна енергія і т. Д. Сонячна енергія є хорошим вибором для вироблення електроенергії, оскільки сонячна енергія безпосередньо перетворюється в електричну енергію за допомогою сонячних фотоелектричних модулів. Ці модулі складаються з кремнієвих елементів. Послідовне з'єднання елементів дає можливість реалізації сонячного фотоелектричного модуля. Продуктивність системи була змодельована з використанням програмного забезпечення PVsyst, проаналізовані отримані результати. Аналіз результатів моделювання показав, що максимальна сумарна вироблення енергії в 329,3 МВт спостерігалася в травні, а найнижча сумарна вироблення енергії - 166,4 МВт - в грудні. Використання даху будівлі буде сприяти збільшенню кількості сонячної енергії і досягнення цілей Дубайської стратегії чистої енергії до 2050 року, які націлені на забезпечення семи відсотків енергії Дубая за рахунок чистої енергії до 2020 року, 25 відсотків до 2030 року і 75 відсотків до 2050. » він буде реалізований в рамках ініціативи Shams Дубай, мета якої - спонукати власників будівель встановлювати сонячні панелі на дахах і пов'язувати їх з основною мережею (DEWA) (Департаменту електроенергії і води Дубая).*
Ключові слова: *сонячна енергія, сонячний парк, фотоелектрика, сонячна електростанція, GRID з'єднання*

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