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Power Sharing at Rooftop Solar PV System Based Community Microgrid Using Helioscope Software

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Abstract

Due to increase in use of rooftop solar PV system and increase of electricity price, the power sharing among the prosumers of community microgrid become an interesting research area. This study proposes a power sharing mechanism that captures the interaction within a community microgrid. The efficient management of energy sharing is crucial for the efficient operation of community microgrids. To design rooftop solar PV systems, Helioscope software is employed. One of the key features of Helioscope is its ability to efficiently arrange arrays and blocks of solar panels based on the designated location within the software. The power sharing is obligated to coordinate the sharing of PV energy with maximization of the own profit, while the prosumers are autonomous to maximize their utilities with demand response availability. Finally, a load demand and PV generation mechanism is designed to deal with the uncertainty of PV energy and load consumption.

A. Introduction

Myanmar has a lot of solar energy potential with an average production of 4.6 kWh/m^2/day. The potential of national solar energy is a practical thing to stimulate its usage in Myanmar, together with the development of technology for converting solar into electrical energy and the reducing cost of the equipment required. As the penetration of distributed energy resources (DERs) such as rooftop photovoltaic (PV) increases, during certain hours of the day, power supplied by distributed generators is anticipated to exceed local consumption needs. This creates the potential to send power in the reverse direction, which may create technical challenges for the grid. Market operators have recently begun to explore transactive energy for a changing environment with an increasing number of DERs and flexible electric devices [1].

Transactive energy utilizes the flexibility of various generation/load resources to maintain a dynamic balance of supply and demand, which features real-time, autonomous, and decentralized decision making. Nevertheless, an essential characteristic of distributed renewable energy is its inherent variability and unpredictability. With the ever-increasing deployment of distributed PV panels, it is challenging to balance the energy supply and demand while fully utilizing their capacities. One innovative way to deal with this challenge is via a community energy market, which is formed among a group of prosumers being willing to share their excess resources. In comparison to the conventional electricity market, where a specific quantity of energy is traded at a set price, the community sharing market experiences fluctuations in the list of buyers and sellers throughout the day. This variability is influenced by the netload and sharing prices of the agents involved, resulting in a highly dynamic market. However, the uncertain and variable characteristics of Distributed Energy Resources (DERs) pose challenges for energy sharing.

In this paper, power sharing of rooftop solar PV system-based community microgrid is presented. Fifteen prosumers with different load characteristic are assigned to four groups and their load and PV output conditions are observed. To calculate the power output from the rooftop solar PV system, helioscope software is used. Then power sharing among these four groups is analysed. Microgrids can be categorized into various types based on several factors, including the number and type of consumers, the type of generation, and geographical considerations. Campus microgrids primarily concentrate on consolidating pre-existing on-site power generation sources alongside numerous loads situated in close proximity, allowing for convenient management by the owner [7]. Community microgrids have the capacity to cater to a substantial number of customers, reaching up to several thousand. Within these microgrids, certain households possess renewable energy sources that can fulfil their own energy requirements, as well as those of their neighbouring households within the community. Additionally, the community microgrid may incorporate either a centralized or multiple distributed energy storage systems [2].

B. Background Theory

In this research, the power sharing among the different load groups within community microgrid is observed. Each prosumer will supply the surplus power to the other whose need extra power. With such power sharing, the electricity taken from the grid can be reduced and the relibility of the communuty microgrid is improved. For the estimation of PV power generation from the rooftops, the Helioscope software is used.

Community Sharing Market

Figure 1 illustrates a typical structure of a community sharing market, where the participants consist of various agents, including prosumers and consumers. These agents are permitted to engage in a fair exchange of energy through a centralized sharing platform, which is managed by a non-profit market operator. It is assumed that the community is always connected to the utility grid, which ensures a continuous supply of energy without any interruptions. Furthermore, there are no restrictions on the amount of excess renewable energy that households can feed into the grid. During each round of auction, the floor price and ceiling price are determined by the utility grid, specifically the utility price and buy-back rate. Acting as a supervisory third party, the market operator is responsible for collecting bids and asks from the community, processing the market transactions, and maintaining a balance between the energy supply and demand of both the community and the utility grid. Each household is assumed to have an energy management system (EMS) and an energy storage (ES) system in place to optimize their energy consumption. In practical terms, photovoltaic (PV) systems can be utilized in conjunction with energy storage systems to enhance energy efficiency [3].

This combination is referred to as PVES in Figure 1. Prosumers are expected to first consume the energy generated by their own PV systems. If their netload (i.e., the difference between their energy consumption and PV generation) is negative, indicating an excess supply, these agents have the capability to share their surplus energy with others in the community.

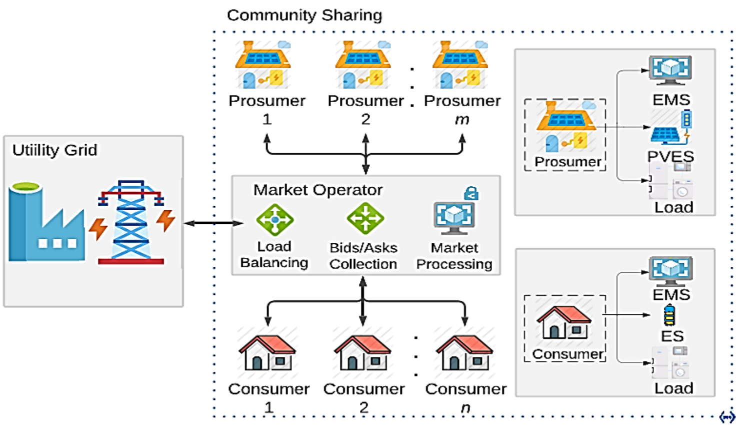

Figure 1. A community energy sharing market [4]

Helioscope Software

The Helioscope software is a web-based application that requires the longitude and latitude of a specific area as initial input. Alternatively, if the name of the area is entered correctly in the designated window, the software automatically downloads the area map. By selecting the appropriate type of panels and inverters, the software generates a comprehensive layout of the solar power plant. This layout includes relevant data such as power output, system loss, energy to grid, number of modules and inverters, and grouping of panels. In the realm of modern technology, Helioscope is a software that utilizes a telescope to project an image of the sun onto a white piece of paper in a darkened environment. It combines certain features of the System with the design functionality of AutoCAD, enabling designers to complete projects within a single package. To utilize Helioscope, users must provide information such as the location address, array arrangement, PV module, and inverter specifications. The software allows users to calculate energy production while considering weather and climate losses. Factors such as shading, wiring, component efficiency, panel mismatch, and age can be taken into account to make equipment and array arrangement recommendations [6].

This tool provides simulation results in the form of annual production, weather data, performance ratios, and other system variables. Being a web-based tool, Helioscope does not require any software installation and can be accessed from any computer with an internet connection. Developed by Folsom Labs, Helioscope combines the characteristics of PVsyst with the essential design functionality of AutoCAD and SketchUp, providing solar designers with a comprehensive design solution in a single package. Helioscope is a comprehensive software solution for solar design and energy estimation.

1. Global Horizontal Irradiance (GHI) refers to the cumulative solar radiation received on a flat surface. It encompasses the Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance, and the radiation reflected from the ground. The unit of measurement for GHI is kilowatt-hours per square meter (kWh/m^2).

2. The total electrical energy production of a solar photovoltaic system is determined by summing up the alternating current (AC) generated by the system over a specific time period. This measurement is expressed in kilowatt-hours (kWh).

3. Performance Ratio (PR) is a metric that compares the actual AC electrical energy output of a Solar Photovoltaic system to the theoretically calculated output based on the assumption that the received irradiance is efficiently converted into electrical energy according to the system's generating capacity. The International Electrotechnical Commission (IEC) provides a comprehensive definition of PR. The complete PR can be computed using the following equation:

$$PR = \frac{\text{AC Yield (kWh)} \times (\frac{kW}{m^2})}{\text{DC Inst.Cap} (kW_p) \times \text{Plane Array Irrad} (\frac{kW}{m^2}) \times 100} \quad (1)$$

The factors calculated in PR encompass various aspects of Solar Photovoltaic, including module losses, reduced low light efficiency, temperature, inverters, shading, cables, and fouling. These factors collectively contribute to the overall losses associated with solar photovoltaic systems [9].

Case Study Area

The research objective of this study is the power sharing among rooftop solar PV systems located within an industrial park. The specific coordinates of this system are Latitude 21°53’ 06” N and Longitude: 96°06’ 47” E, in Industrial Zone, Pyi Gyee Tagon Township, Mandalay City, Myanmar. The selected community system encompasses a total area of 1830.7 ft and consists of fifteen different buildings. These buildings include seven residential building, one community hall, one restaurant and six industries. The available rooftop areas for solar PV application are selected by using Helioscope software. Based on load natures and locations, these fifteen buildings are grouped into four numbers as follow Table 1.

Table 1. Grouping of Loads for Power Sharing Study

Group No.	Participent Loads in Load Group
1	Residence 1, Residence 2, Residence 3 and Residence 4
2	Residence 5, Residence 6, Residence 7 and MIMC Hall
3	Restaurant, Farm Equipment, IEM (1), IEM (2) and Flour
4	Iron Melting Work and Woven Bag

Mandalay experiences predominantly clear and sunny weather for around 250 to 300 days per year across most of its areas. The data provided in Figure 2 has been obtained from the NASA surface meteorology and solar energy database. The total solar radiation received on a flat surface, known as Global Horizontal Irradiance (GHI), encompasses the combined values of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and the solar radiation reflected from the ground. The relationship between GHI and DNI on a horizontal surface can be mathematically expressed through the following equation.

$$GHI = DHI + DNI \times \cos(\theta Z) \quad (2)$$

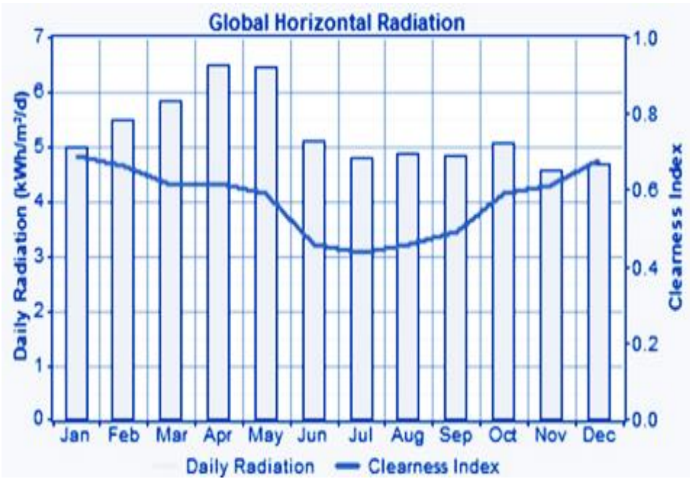

Figure 2. Global Horizontal Irradiance

DHI, which is also recognized as Diffuse Horizontal Irradiance, pertains to the dispersion of radiation horizontally over a specific region, quantified in kilowatt-hours per square meter (kWh/m^2). Conversely, DNI, or Direct Normal Irradiance, signifies the radiation that directly reaches the surface in a perpendicular manner, also measured in kilowatt-hours per square meter (kWh/m^2). The expression "cos (θZ)" represents the angle of radiation with respect to the horizontal surface [5].

Table 2. Daily Radiation and Clearness Index

Month	Clearness Index (0-1)	Daily Radiation (Kwh/m^2/day)
January	0.692	5.005
February	0.667	5.489
March	0.612	5.825
April	0.619	6.491
May	0.590	6.470
June	0.459	5.087
July	0.436	4.783
August	0.460	4.880
September	0.494	4.848
October	0.590	5.079
November	0.614	4.576
December	0.681	4.694

C. Research Method

The Helioscope software is an invaluable tool for determining the available roof area for a photovoltaic (PV) power plant. In order to effectively utilize this software, specific inputs are required, including the location's address, array configuration, PV module specifications, and inverter specifications. The inspection process involves evaluating various parameters such as roof area, roof type, roof pitch, and orientation [8]. During a site survey for roof-mounted PV arrays, it is crucial to assess factors such as building type, roof design, dimensions, slope, orientation, surface type, condition, and structural support. Additionally, considerations such as fall protection methods, access for installation and maintenance, and the division of the roof area into two sections are important. To ensure ease of movement for inspection, maintenance, and cleaning, gaps are left between rows and sidewalls based on shadow analysis [10].

For a roof-mount ballasted design, a tilt angle of 15° for the PV module has been chosen, as shown in the following figures. The azimuth orientation angle of the modules is determined by compass directions, with 90° representing east and 180° representing south. In this particular case, an azimuth of 253° has been adopted for the facility. The weather dataset used for simulation is TMY, with a 10 km grid, and metronome has been utilized for satellite-based weather files. For this project, the selected PV module is the Jinko JKM 550N-72HL (550W), which consists of high-performance monocrystalline silicon solar cells with a power output of 310W. The chosen inverter model is Growatt inverter (Max, 50 KTL3LV).

The rooftop solar PV design arrangements for the selected fifteen buildings are shown in Figure 3 through Figure 6. The simulations are carried out for each group. The main simulation outputs of Helioscope are the module total power, annual energy production, total numbers of modules, total numbers of inverters, and total numbers of strings. These simulation results with the loads energy demands are shown in Table 3.

Figure 3. Rooftop PV Design Layout for Group 1

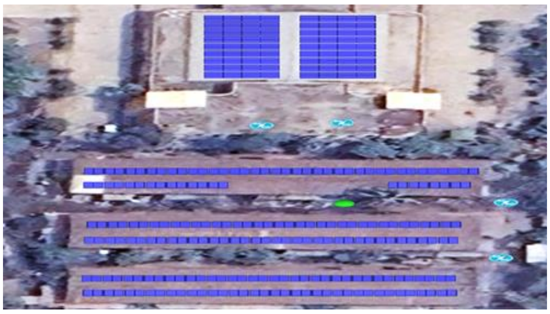

Figure 4. Rooftop PV Design Layout for Group 2

Figure 5. Rooftop PV Design Layout for Group 3

Figure 6. Rooftop PV Design Layout for Group 4

Table 3. Load Demand, Solar PV Generation and Helioscope Simulation Outputs

No.	Name	Energy Load Demand	Module Total Power	Annual Production Power	Total Number of Module	Total Number of Inverter	Total Number of String
1	Residentials (1,2,3,4) [Group 1]	3200 Unit/Month	231.0 kW	324.3 MWh	420 Nos.	4 Nos.	24 Nos.
2	Management Center and Residentials (5,6,7) [Group 2]	6000 Unit/Month	191.4 kW	266.5 MWh	348 Nos.	4 Nos.	20 Nos.
3	Restaurant, Agricultural Farming Tools and Equipment, Industrial Equipment Machinery (1,2), Wheat Flour Mill Factory and Iron Melting Factor [Group 3]	45500 Unit/Month	463.1 kW	636.0 MWh	842 Nos.	16 Nos.	48 Nos.
4	Iron Melting Factory and Woven Bag Factory [Group 4]	550000 Unit/Month	1380 kW	1.954 GWh	2,510 Nos.	46 Nos.	138 Nos.

D. Result and Discussion

For the power sharing among the groups of community microgrid, the hourly load distribution is executed. Similarly, the hourly electricity generation of each group is also observed. Therefore, the study is emphasized on day time between 7 AM and 5 PM where the solar PV electricity is available.

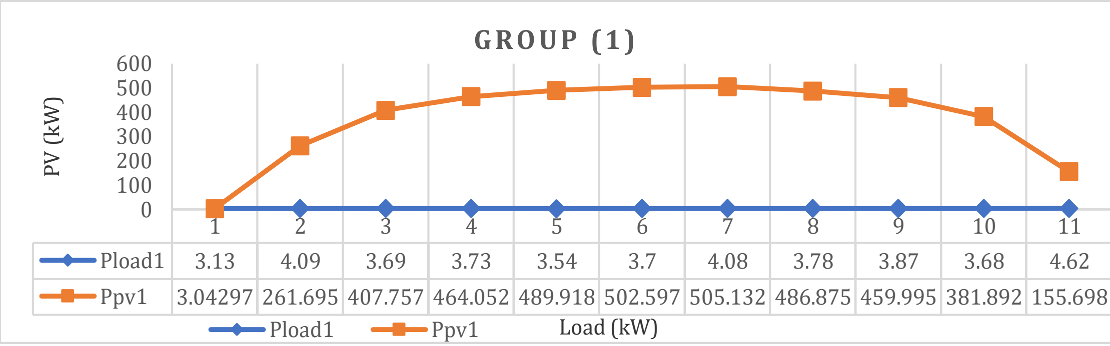

Figure 7. Load Power Demand and PV Power Generation at Group 1

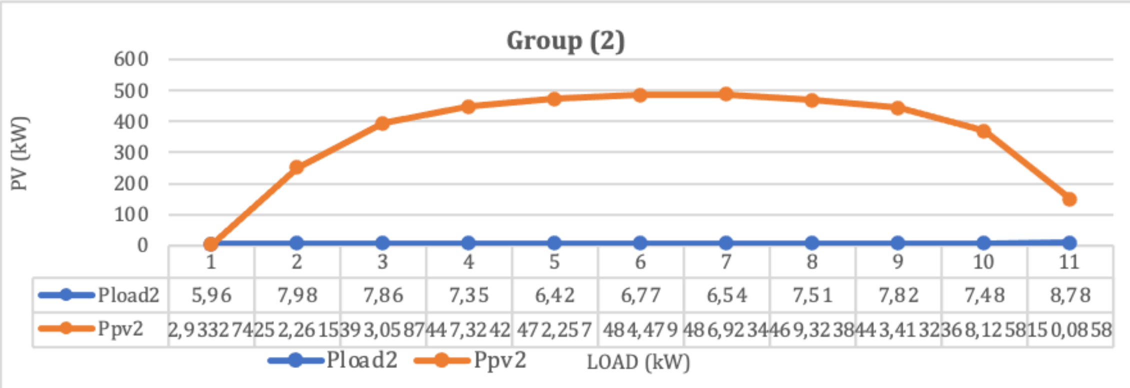

Figure 8. Load Power Demand and PV Power Generation at Group 2

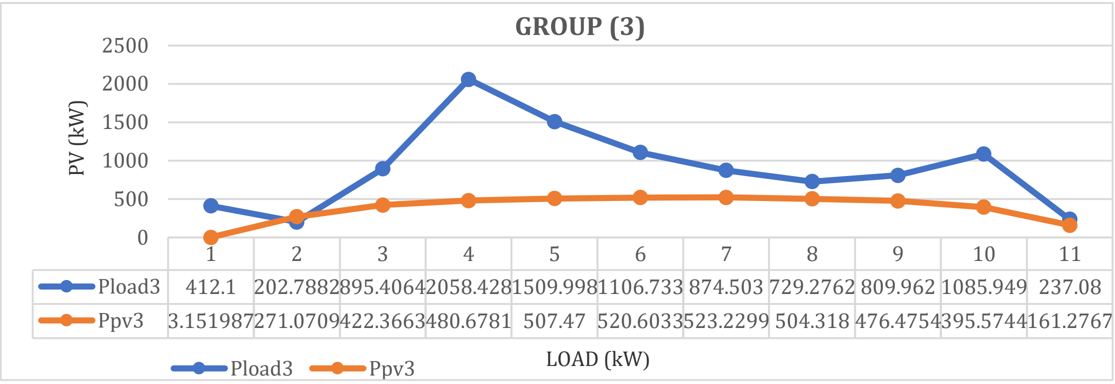

Figure 9. Load Power Demand and PV Power Generation at Group 3

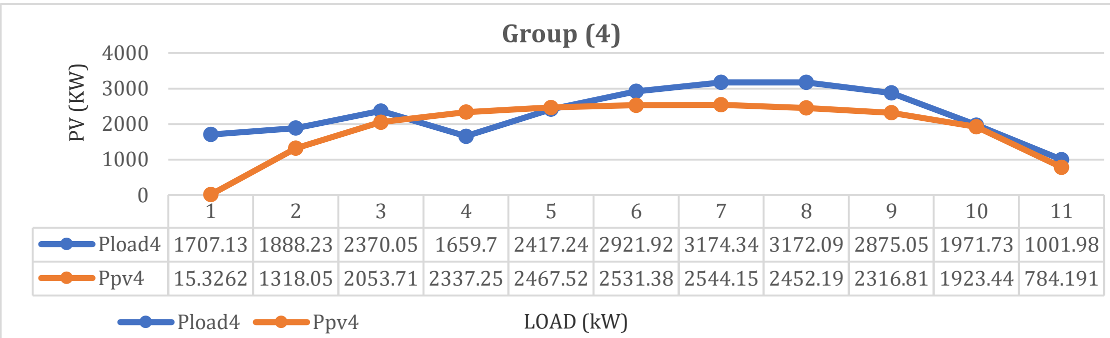

Figure 10. Load Power Demand and PV Power Generation at Group 4

In Group 1 and Group 2, there are mostly residential loads. The PV power generations are much larger than the load demand. The excess power can supply or sell to the other groups where they need extra power.

There are mostly industrial loads in Group 3 and Group 4. In these groups, the load demands are larger than the PV power generations. The required extra electricity can be obtained from Group 1 and Group 2. The comparison for the total load demand and PV power generation for four group during day time are shown in Table 4.

Table 4. Comparison for Total Load Demand and PV Power Generation

NO.	Name of Load Group	Total Load (kWh) (8AM -5PM)	Total PV Output (kWh) (8AM -5PM)
1.	Group 1	38.8	4115.6
2.	Group 2	74.5	3967.3
3.	Group 3	9510.1	4263.1
4.	Group 4	23452.3	20728.7
	Total	33075.7	33074.6

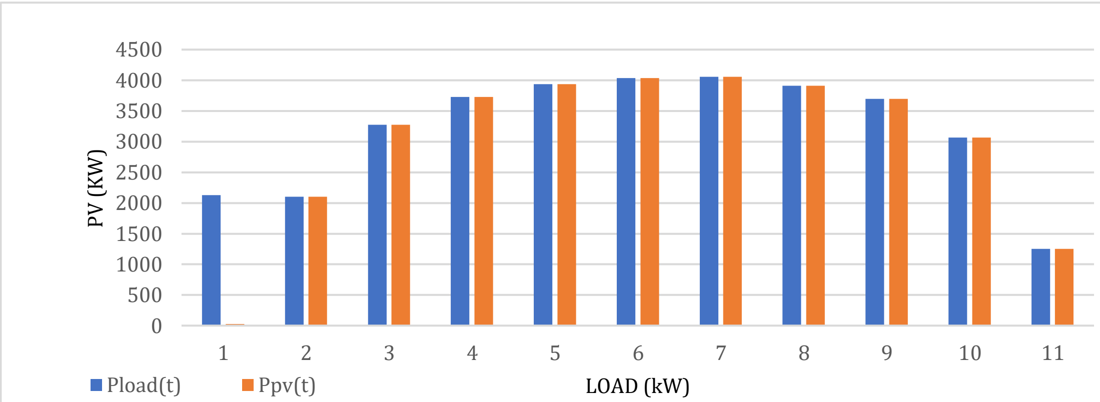

Figure 11. Load Power Demand and PV Power Generation for Whole Community Microgrid

For the power sharing among different groups of community microgrid, the power demand and PV generation is studied for each hour during day time. According to the study, the excess power of some groups can supply to the required power of the other group without power taking electricity from the external grid. As shown in Table 3, the total load demand of four groups is about 33075.7 kWh whilst the total power generation from PV systems are about 33074.6 kWh. The unbalance in energy (i.e., requirement) is negligible.

E. Conclusion

The increase use of renewable energy resources worldwide and the need for sustainable clean source of energy leads to the development of Microgrid. Microgrid system become one of the leading topics in energy, many studies and practical implementations are done in this field. This paper investigated the power sharing among PV prosumers within a community microgrid. The detail study is carried out at difference loads of Mandalay Industrial Zone, Myanmar. To obtain the reliable and cost-effective design of rooftop solar PV system, Helioscope software is utilized. The case study demonstrated the effectiveness of the proposed community energy sharing market in cost saving and reliability improvement.

F. Acknowledgment

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G. References

[1] Sujoy Barua, R. Arun Prasath, Dwipen Boruah; "Rooftop Solar Photovoltaic System Design and Assessment for the Academic Campus Using PV syst Software," International Journal of Electrical Engineering Vol. 5, No. 1, February 2017.

[2] D J Damiri S Legino, S Amboro.; "Engineering design development of 525KW peak solar photovoltaic system for industrial Rooftop building," 4th Annual Applied Science and Engineering Conference, 2019.

[3] Y.Pradeep Kumar, V. Tejaswitha; "Design and Development of Solar Rooftop PV Power System," International Journal of Electronics and Techniques Vol. 4, No. 1, Jan- Feb 2018.

[4] He, L. and Zhang, J., Energy Trading in Local Electricity Markets with Behind-The-Meter Solar and Energy Storage, *IEEE Transactions on Energy Markets, Policy and Regulation*, Vol. 1, Issue 2, 2023, pp. 107-117.

[5] Md. Roni Islam; "Feasibility of Grid-Tied Rooftop Solar System Installation at Khwaja Yunus Ali University," International Journal of Electronics and Knowledge Management Vol. 2, No. 1, 23 June 2018.

[6] Najibhamisu Umar, "Comparison of different PV power simulation software: case study performance analysis of 1MWgrid-connected PV solar power plant International Journal of Engineering Science vol 7, June, 2018.

[7] Ali H.Assi, Rabih Rammal,Ibrahim Assi; "Toward Green LIU campuses using PV systems", Conference Paper, December, 2017.

[8] Hong Xian Li, Yitao Zhang, David Edwards, M.Reza Hosseini; "Improving the energy production of rooftop solar PV system through roof design", https://doi.org/10.1007/s 12273, 23, September,2019.

[9] Fatima T. Ahmed, Hazim H. Husain, Naseer K. Kasim; "Use Pvsyst And Helioscope Simulation Tools To Evaluation Of On Grid Pv System Performance Under Baghdad City Climate" Annals Of Forest Research, Ann. For. Res. 66(1): 1158-1170, 2023.

[10] Mitesh S. Bhangare, Prof. Peter Dsouza, Prof. S.V.Diwan; "Design, and Energy Estimation of 165kWp Grid Connected Solar PV Plant Using Helioscope" International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 04, Apr 2020.