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ENGINEERING ANALYSIS OF BUILDING INTEGRATED PHOTOVOLTAIC (BIPV) AND PHOTOVOLTAIC POWER PLANT: A CASE STUDY

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Abstract- Solar energy applications such as BIPV and PV installations are gradually becoming a worldwide phenomenon because of their multiple advantages. Examples of such merits are clean, safer, and green energy sources, inexpensive, requiring less maintenance, no CO_2 emissions, no fuel bills, etc. Also, the growing emphasis on energy efficiency and environmental sustainability in building design drives the demand for BIPV technology. The purpose of this study is to use HelioScope software to examine the suitability of a utility-tied PV powerplant and BIPV system on the campus of NEU (Near East University). The utility-tied PV powerplant occupies an area of 1581.9 m^2 and has a capacity of 2.24 MW; 5596 solar panels and 8 inverters, each rated at 400W and 250kW respectively. The PV plant's estimated annual production energy is 2.995 GWh, with a 78% performance ratio. Five buildings were selected for the BIPV system. For example, the innovation building had 311 panels with a rated capacity of 76.4 kW integrated into the building structure, and the produced annual power is 125.1 MWh. Furthermore, selected campus buildings with BIPV systems generate considerable power output, with specific adaptations for high irradiance and temperature conditions. The investigation's findings reveal that the NEU campus can generate over 3 GWh of solar electric power annually, but this is not being harnessed. This research guides practical applications in electrical and structural engineering, with a focus on advancing grid-connected PV systems and embedding renewable energy into architectural design.

Keywords: PV Power Plant, Building Integrated Photovoltaics, Payback Period, Performance Ratio, Solar Energy.

1. INTRODUCTION

Ozone depletion caused by the use of fossil fuels, industrialization, population growth, and its effect on global warming has caused most countries to include renewable energy in the electric power generation mix. Also, more petroleum wells have been discovered in recent times however, global issues such as military conflicts, political unrest, violence and crime, inflation, etc., have made the pricing of fossil fuels unstable. Renewable energy resources comprising PV (photovoltaic) bioenergy, hydro, wind, etc., when deployed in significant numbers, reduce carbon emissions, and the electric power prices are competitive compared to fossil fuels [1-2]. According to IEA, if the capacity of 2022 renewable energy generations is tripled by 2023, resulting in 11,00GW, then the 2050 set target of zero net emissions is feasible [3]. Also, IEA reports that since 2020, there has been a 40% increase in clean energy investments, resulting in downward trends in emissions. Figure 1 shows the CO_2 emissions in the power sector, and Figure 2 shows battery and PV additions from 2022 to 2023 [4].

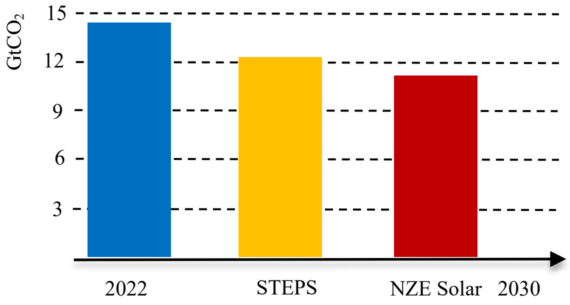

Figure 1. The CO_2 emission in the power sector [4]

Building integrated photovoltaics (BIPV) is an interesting and emerging research area for building and PV technology. BIPV is the application of various forms of solar PV cells in private, public, or commercial buildings. This is popularly done by considering the rooftops, facades, windows, etc., of the buildings where the PV solar cells are placed. Nonetheless, the rooftops and facades of the building receive the maximum share of PV building integration [5-8]. Upgrading a building into a green structure was proposed in [9], solar panels will be used to collect solar energy. Various LEED criteria are applied,

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and the reduction in cooling demand is achieved by insulating the walls, roofs, and glazed windows. This will lessen the need for conventional power sources.

Reference [10] introduced a PV parabolic reflector with a concentration ratio of 2 optimized for Building Facades. They carried out thorough testing to examine its thermal and electrical properties. Findings revealed that the Building Facade Integrated Asymmetric Compound Parabolic Photovoltaic (BFI-ACPPV) system doubled the power output per unit area relative to standard PV. The addition of phase change material led to higher efficiency. Tests at 280 W/m^2 and 69 W/m^2 revealed a maximum power output of 3.51 W at 280 W/m^2.

BIPV has the following advantages juxtaposed to non-BIPV systems: prevention of noise, offsetting building cost, thermal insulation, safeguarding, waterproofing, and power generation at the site [11]. It's reported that 40% of global power consumption is linked to buildings comprising factories, homes, and offices [12].

Recent studies, according to [13], have explored materials, configurations, and optimization strategies to improve BIPV performance in cities. However, further research is needed to assess BIPV's adaptability to different climates and its feasibility in large-scale projects. It does not thoroughly cover BIPV application in distinct climate zones or the economic outcomes of widespread adoption over the long term. This research, by contrast, focuses on practical issues and financial sustainability in a particular region.

Focusing on Near East University (NEU) in Northern Cyprus, this study uniquely integrates local geographical and climate conditions, including high solar irradiance and temperature variation, into design of BIPV and PV systems.

In this case, HelioScope simulations are customized to NEU's site, unlike general PV system studies. The analysis covers both rooftop and Facade BIPV systems, optimizing energy yield. The building selection was strategic. By prioritizing orientations that maximize solar exposure and minimize shading, the study achieves distinct energy production results. The study includes unique metrics. It focuses on how performance ratio (PR) is affected by high ambient temperatures. It also considers the impact of module orientation under Cyprus's intense solar exposure. By examining local variables, this study uses HelioScope's real-time data. It enhances our understanding of BIPV system performance in areas with high solar exposure.

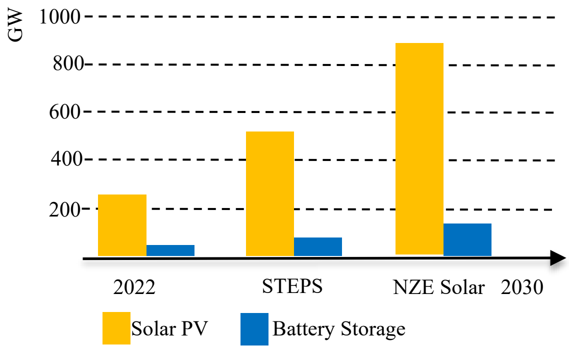

Figure 2. Battery and PV additions

This research proposes a case study or investigation of BIPV and Solar PV installations on the NEU campus. The ensuing parts of this paper are segmented into three sections. In section two, a review of solar energy potential and the electric power sector in Northern Cyprus is provided, in section three, the design and simulation of the BIPV and solar PV systems are provided, and section four is the conclusion section.

2. NORTHERN CYPRUS SOLAR ENERGY POTENTIAL

Countless research has been conducted on the potential of solar energy applications in Northern Cyprus, and they all point to positive outcomes primarily because of the location of Northern Cyprus. Also, a couple of private and commercial solar installations in Northern Cyprus are functioning optimally. Therefore, it's evident that Northern Cyprus has great prospects for domesticating solar energy due to its favorable climate and geographic position. Cyprus as a whole is divided between the Turkish and Greek-speaking sides, having a combined population of 1,200,00. In the moderate winter months in the Troodos Mountains, there is a chance of snowfall and a noticeable drop in temperature. With typical highs of 15-16 degrees Celsius, January and February are the coldest months. Temperatures below freezing are rare, even at night.

Although there will likely be a few rainy days in February and March, there won't be much precipitation from May through September. July and August are the hottest months in North Cyprus. If you are prone to extreme heat, September and October are the most suitable months to visit. In July and August, the average daytime temperature is around 47 degrees Celsius, with nighttime lows of over 20 degrees Celsius. Sunshine duration in Northern Cyprus averages 12 hrs in summer and 5.5 hrs in winter, and the daily solar radiation on clear and cloudy skies is 7.2 kWh/m^2 and 2.3 kWh/m^2 accordingly, and the annual radiations range from 1800 kWh/m^2 to 2000kWh/m^2. The landmass and human population in Northern Cyprus are 3,355 km^2 and 382,230 accordingly [14-19]. According to the 2023 electric power generation report from Kibtek, more than 90% of the annual electric power was generated from non-renewable, i.e., fossil fuel. This report is summarized in Table 1.

2.1 Overview of the Power Sector in Northern Cyprus

The power sector in Northern Cyprus is not fully diversified, i.e., Kibtek (public institution) is the majority shareholder or the only player in the generation, transmission, and distribution of electricity, and there are few private companies in the generation section. The combined capacity of all generating units is 409 MW, and it relies solely on fossil fuels as its energy source. The power lines in Northern Cyprus are segmented into three sections; the first is the transmission lines with 66kV/132kV ratings, and the second and third sections are the low and medium voltage distribution lines having 415V/240V and 11kV/22kV ratings accordingly. At the end of 2008, there were 554 km of transmission lines in total. Northern Cyprus's total installed capacity reached its peak in 2008 at 327.5 MW, having started at 60 MW in March 1995 and rising to 120 MW in March 1996 [20].

415V/240V and 11kV/22kV ratings accordingly. At the end of 2008, there were 554 km of transmission lines in total. Northern Cyprus's total installed capacity reached its peak in 2008 at 327.5 MW, having started at 60 MW in March 1995 and rising to 120 MW in March 1996 [20]. Four main thermal power plants provide the majority of the required electricity. The power sector in Northern Cyprus is bedeviled with a few drawbacks, which were visible during the summer and winter seasons of 2022, 2023, and 2024, when power for cooling and heating are at peak levels. Most times, daily power rationing of 1-2hrs is experienced by all customers. Table 1 shows the mix of electricity output for Northern Cyprus in 2023.

Table 1. Northern Cyprus's generation mix

Unit	Power Ratings (MW)	Production Percentage (%)
Teknecik Steam Turb.S.U. 1	187.519	9.87
Teknecik Steam Turb.S.U. 2	202.672	10.66
Kalecik Diesel Generator	775.685	40.81
Teknecik Diesel Generator	539.183	28.37
Serhatköy Solar PV	1.061	0.06
Total PV Installation (MV)	110.371	5.81
Gas Turbines	42.948	2.26
Northern Cyprus Total Production	1.900.554	100

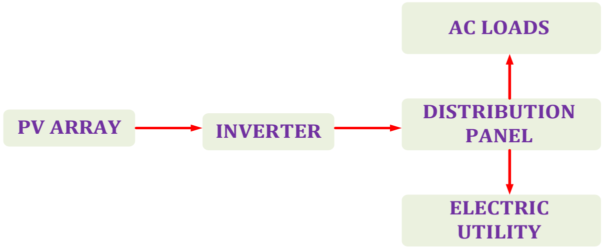

Figure 3. Utility-tied photovoltaic system

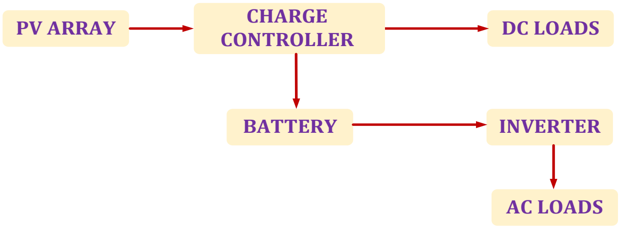

Figure 4. Stand-alone photovoltaic system

3. PV AND BIPV SYSTEMS DESIGN & SIMULATION

This chapter provides a complete description of the PV system, confirming its operating principles through generation design and simulation results. This chapter describes two HeliScope-based simulation outcomes. The first outcome involves BIPV-based analysis where standalone solar units are installed on some chosen rooftops of structures around the NEU campus. The selection of the structures is done considering the biggest rooftops devoid of shadow and also have a longer duration of sunshine. The other outcome is a proposed grid-connected photovoltaic plant. Figures 3 and 4 depict a block diagram representation of both systems, i.e., the stand-alone and utility-tied systems. The solar plant, a utility-tied photovoltaic system, is situated in an open field behind the veterinary medical department. The proposed plant can carry campus loads, and any surplus power is transferred to the grid.

3.1. Location of Near East University Campus

NEU is located in Northern Cyprus. Its area location in Cyprus has the geographic coordinates of 33.3264° E and 35.2267° N. Figure 5 shows the aerial shot of the NEU campus. The annual electric energy expenditure of NEU is 3MW. Suat Gunsel, a Turkish Cypriot and the company's only proprietor, founded NEU in Northern Cyprus in 1988. Unlike other universities and private businesses in Northern Cyprus, NEU has yet to take advantage of the beautiful weather to harness solar energy for application or research purposes.

Figure 6 details the flowchart of the system, first is identifying NEU campus buildings and assessing available space for BIPV and PV systems. The factors considered in choosing it, with an emphasis on environmental and structural data collected. The second step is defining system specifications (e.g., solar modules, inverters, array layout) and setting design parameters like tilt, azimuth angle, and performance targets. HelioScope software is used for performance modeling and input parameters and simulating expected energy production. Components layout and configuration of the modules and inverters include essential components (e.g., switches, safety measures). Energy production annually is calculated by analyzing potential energy losses from shading, wiring, and soiling. Then, performance metrics are evaluated, such as efficiency and performance ratio for all buildings on campus, and compared.

3.2. Photovoltaic Power Plant Design

Complex power generating units, also known as "power plants," provide medium and high voltages for electrical grids. These sites are typically powered by generators with kilowatt or megawatt capacities. PV power plants are similar to this category; however, they don't need generators to produce energy. Instead, PV power plants connect arrays of countless PV panels to generate as much power as possible. PV Panels are derived from series/parallel connected solar cells, which harvest photon energy from the sun, this energy is converted into DC voltage due to electron flow. Because PV power plants depend on a variety of parts and factors comprising the type of inverters and modules, their particular efficiency, and the weather at the plant site, the overall output power may vary when the weather is not conducive for photovoltaic applications [21-23].

All PV modules include information on their nameplates that allows comparison of their power output and efficiency under standard test conditions, or STC. The grid-connected PV system components that are utilized to size a PV system are the modules (PV), inverter, distribution controller, and load. In certain grid-connected configurations, battery-based devices are not essential. It thus presents a possible advantage in terms of the system's total cost.

Figure 5. NEU campus

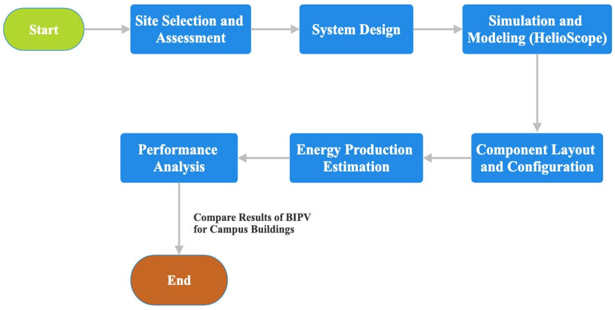

Figure 6. Flowchart of the system

We use the formula below, i.e., Equation (1), to calculate the system plant's maximum power ($P_{\max}$) [24]. This equation determines the system's maximum power output, factoring in real-world losses like temperature and shading. It is based on the power equation, modified to reflect photovoltaic module performance.

$$P_{\max} = \frac{E_{AC} P_i}{G_{SR} F_{PV} N_{inv}} \tag{1}$$

where, the STC irradiance, global irradiance, derating factor, daily expended power, and inverter yield are denoted by P_i, G_{SR}, F_{PV}, E_{AC} and N_{inv} accordingly.

The study relies on recent datasets to guarantee an accurate analysis. It includes key metrics like module efficiency, degradation rates, and cost details. These metrics come from contemporary engineering reports and industry sources. The data is relevant to high-irradiance areas, with input from the International Renewable Energy Agency. Material properties for PV modules, like temperature coefficients and efficiency, are taken from recent manufacturer reports. These values are validated with HelioScope simulations using solar irradiance data specific to the site.

Figure 7 depicts the module and inverter layout of the proposed PV plant (NEU). The entire structure, including the solar panels, modules, and inverters, occupies 1581.9 m^2 of land and is located behind the faculty of veterinary medicine.

It is necessary to reserve more room for the construction and placement of a mini-substation. 2.24 MW of electricity must be produced using 5,596 REC solar modules and 8 inverters rated at 250kW. This equation for module selection factors in arrangement and capacity constraints ensures maximum energy yield for the assigned area. Equation (2) is used in the module selection.

$$Panel_{selection} = \frac{Module_{capacity} \times Module_{efficiency}}{Module_{price} \times Module_{area}} \tag{2}$$

The azimuth angle and tilt angle orientation of the PV modules are 87° and 25°, respectively. The peak source voltage and open-circuit voltage of the modules are 1500V and 45V, respectively. Figure 8 shows the number of strings and the modules' features. According to the proposed PV plant's Single Line Diagram (SLD), three categories of strings are used. The initial set of strings comprises 279 modules, with each string containing 9 modules, each composed of 31 modules. The second set of strings consists of 420 modules, for a total of 14 strings (each string consisting of 30 modules). With a string count of 10 (each string consisting of 31 modules), the third set of strings consists of 310 modules. Lastly, the final set of ten strings consists of 390 modules, for a total of 13 strings (each string consisting of 30 modules).

Four inverters (CSI-30KTL-GS-FL) link the first and second groups of strings, that is, two groups of 500 modules and 23 strings of 500 modules. This system uses copper wire with a diameter of 10 AWG to connect the PV modules. Disconnect switches fasten these strings to the inverters. The system aggregates the output power of all the inverters through 20.0A-rated circuit interconnects, there are 51 of them. Two disconnect switches for protection purposes are used in the system. Each disconnect is placed in the DC/AC sections of the system. Figure 10 shows the energy production on a monthly and yearly basis. Figure 11 displays all of the system's losses, including those from the inverter, wiring, shading, soiling, solar irradiance, and reflection.

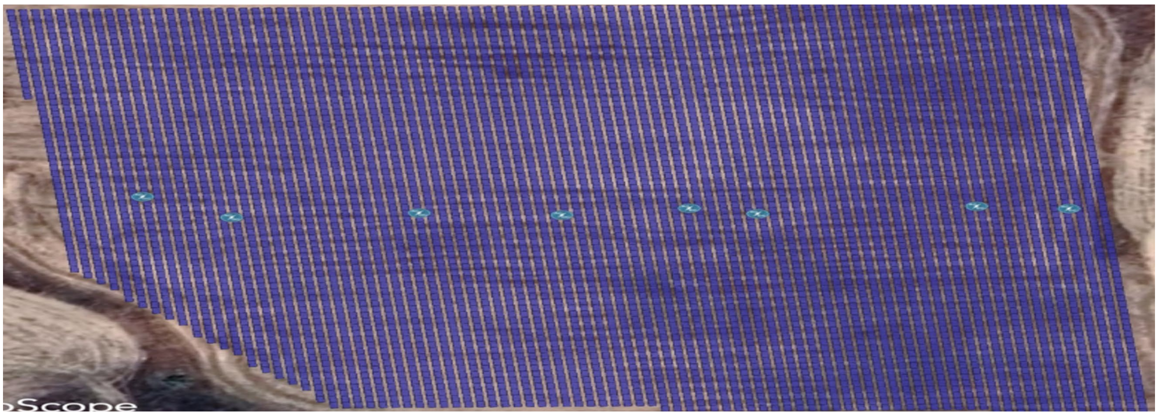

Figure 7. The proposed PV plant of (NEU) modules and inverters

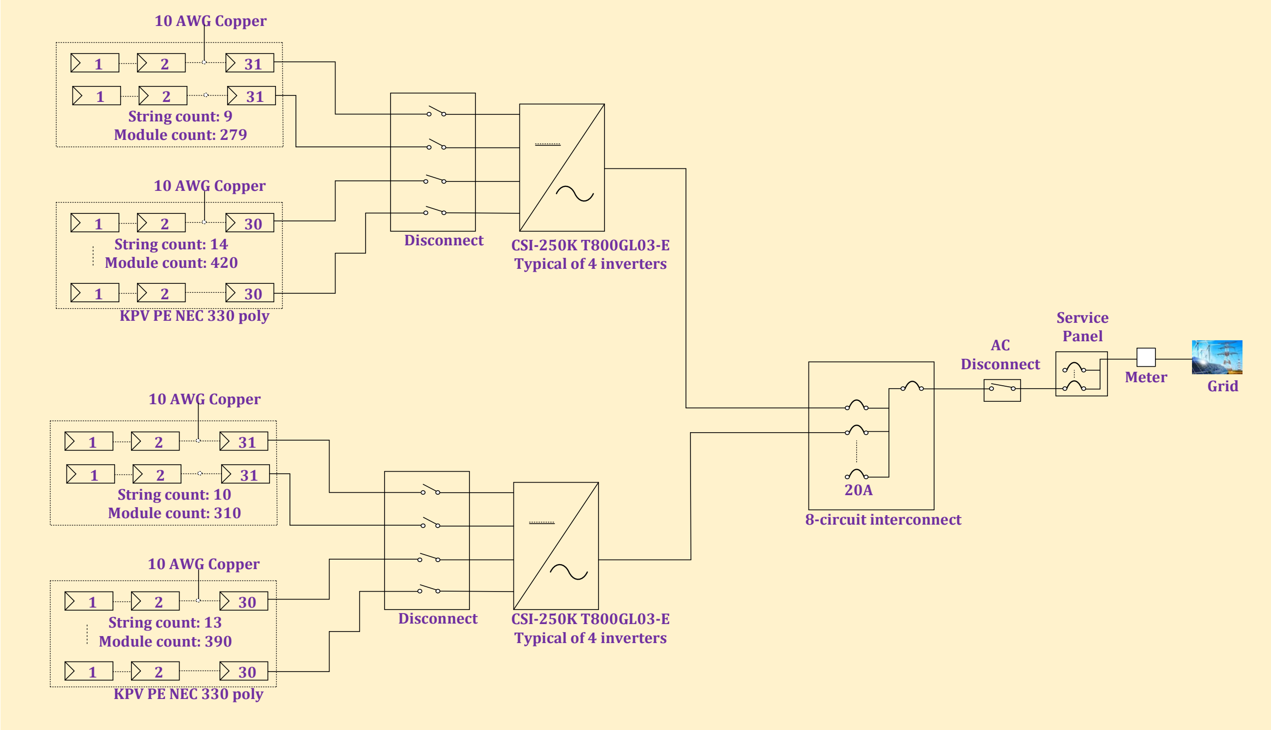

Figure 8. NEU proposed PV plant single line diagram details

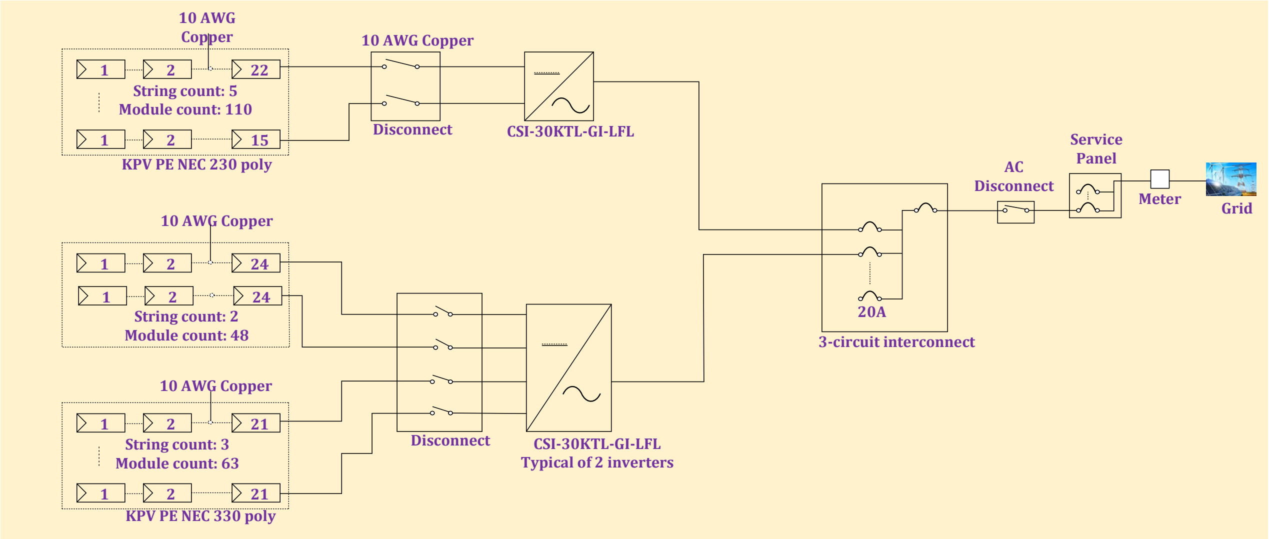

Figure 9. Single line diagram of innovation center string and module details

Table 2 displays the system metrics comprising performance ratio, yearly production, inverter nameplate, DC module, etc. There are a total of 24.5% losses. The peak plant output occurs from May to August. June recorded the maximum grid power injection of 249,207.1 kWh, and a minimum production of 88,785.8 kWh was recorded in December.

The system's performance ratio is 77.8%, and its yearly grid output is 2.995 GWh. PV system efficiency is estimated using the performance ratio. The performance ratio is unaffected by radiation exposure, specific locations, or even module orientation. We can use the performance ratio to assess the same system at a different location, for an equivalent system over a longer period, or different types of PV systems. However, the high-temperature sensitivity of the PR will lead to a reduction in the performance ratio in colder regions. The PR equation measures system efficiency. This metric is commonly used in photovoltaic engineering. It shows the ratio of actual to theoretical energy output. The PV system PR (performance ratio) is computed using Equation (3):

$$PR = \frac{Produced\ Power\ (\text{kWh})}{Nominal\ Plant\ Output\ (\text{kWh})} \tag{3}$$

The PV systems [nominal output power is computed as:

$$Nominal\ Plant\ Output = \frac{Panel\ incident\ radiation}{Irradiadince \times Area \times Efficiency} \tag{4}$$

The calculations below verify the PV system's energy requirements or the quantity of modules and inverters required.

$$P_{ac} = P_{dc_{STC}} \times Conversion\ efficency \tag{5}$$

$$P_{ac} = 2.24 \times 0.98 = 2.1952\,\text{MW} \tag{6}$$

Conversion efficiency is affected by conditions comprising the inverter's efficiency, dirt buildup at the module's surface, module mismatch, and the influence of variations in the surrounding environment [25-26]. The lowest allowable conversion efficiency is 95%, according to the Features Report of 2018. The selected inverter has a conversion efficiency of 98%. From Equation (6), $P_{dc,STC}$ and P_{ac} represent the DC and AC powers at standard test conditions.

$$Module\ quantity\ needed = \frac{Rated\ Power}{One\ module\ power} \tag{7}$$

From Equation (7):

$$Module\ quantity = \frac{2.24\,\text{MW}}{400\text{W}} = 5596\ \text{modules} \tag{8}$$

Similarly, the quantities of inverters required are expressed by:

$$Quantity\ of\ inverters = \frac{Rated\ Power}{Inverter\ Power} \tag{9}$$

$$Quantity\ of\ inverters = \frac{2.24\text{MW}}{250\text{kW}} \approx 9\ \text{inverters} \tag{10}$$

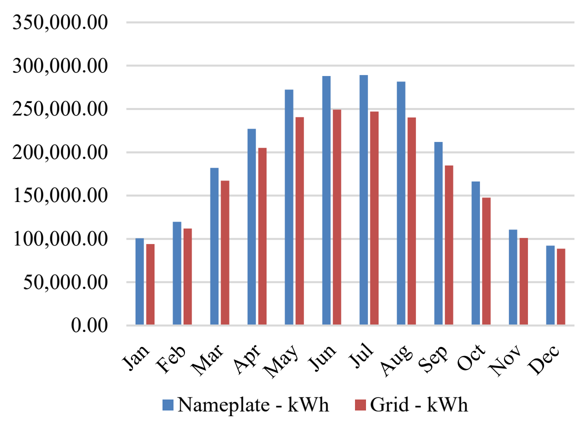

Figure 10. Monthly energy production of the proposed PV plant (NEU)

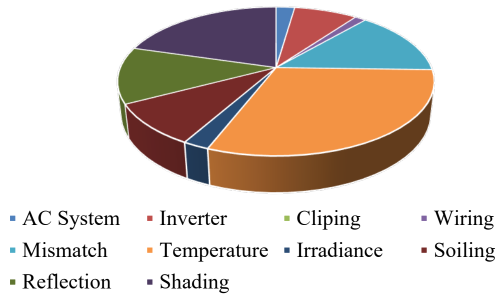

Figure 11. System loss sources

Table 2. System metrics

Design	NEU PV Plant
Module DC Nameplate	2.24MW
Inverter AC Nameplate	2.0MW
Yearly Production	2.995GWh
Performance Ratio	77.8%
kWh/kWp	1,638.3
Weather Dataset	TMY, 10km, Grid

3.3. Module Power Variation

In this section, the module powers are varied to ascertain the corresponding effect on the generated power from the PV plant. The plant location's size of 1581.9 m^2 is maintained for this investigation. The modules' powers are varied from the least magnitude of 240 W to a maximum magnitude of 400 W, as indicated in Table 3. The corresponding effect of the module power variation is the increase in the yearly generated power. The performance ratio, on the other hand, does not experience any significant variation.

Table 3. Changing the magnitude of the module (Watt)

Module Size (W)	Module Nameplate (MW)	Inverter Nameplate (MW)	Yearly production (GWh)	Performance Ratio (%)
240	1.52	1.53	2.078	78.8
270	1.75	2.00	2.315	76.8
300	1.65	2.00	2.195	77.5
350	1.89	2.00	2.494	76.8
390	2.18	2.00	2.895	77.1
400	2.24	2.00	2.995	77.8

3.4. BIPV System Design

BIPV, as the name implies, is the integration of PV modules/panels/cells in buildings for electric power generation. This is achieved by considering the rooftops, facades, windows, etc., of the buildings where the PV solar cells are placed. Therefore, PV plants and BIPVs are the same technology but differ in the module location and power magnitude. This research considers the rooftops of buildings for the BIPV analysis because relatively large surface areas are available juxtaposed to facades. Hence, four buildings are selected for the rooftop BIPV and one building for the facade BIPV.

Table 4 provides a detailed comparison of BIPV and conventional PV systems, examining aspects such as energy efficiency, cost of installation, maintenance, impact on aesthetics, thermal insulation benefits, and lifespan.

Table 4. Comparison of BIPV and conventional PV systems

Metric	BIPVsystems	Conventional PV Systems
Energy Efficiency	Offers high efficiency when installed on facades or roofs. Helps to reduce heat loads within the building	Offers strong efficiency but does not affect building thermal dynamics
Installation Cost	Increased upfront costs due to integration needs	Decreased installation cost, notably on flat rooftops
Maintenance	Generally requires expert maintenance because of the integration	Easy to access and maintain with standard procedures in place
Impact on Building Aesthetics	Integrated into the building's design, adding to its visual appeal	Often visually noticeable; additional space may be required
Thermal Insulation Benefit	Enhances insulation, reducing the load on cooling systems	Does not substantially affect building insulation
Longevity	Depends on the building's lifespan; materials are built for long-term exposure	Their lifespan could decrease with inadequate maintenance

3.5. Innovation Centre Photovoltaic System (NEU)

The departmental buildings on campus always have adequate roof space available for the installation of a photovoltaic system for power generation. PV modules may be installed in certain places. If the root-top space is insufficient for high-voltage production, one may employ ground-mounted PV systems. While many academic buildings have roofs, they are not always well-used. For example, an illustration of the Innovation Center's roof-top installation of PV modules/panels and inverters will be similar to that of Figure 7 but on a much smaller scale. These are 311 Canadian solar panels having ratings of 230W, covering an area of 1209.4 m^2. The maximum input voltage and open-circuit voltage of the modules are 29.6V and 36.8V, respectively. The system achieved its highest recording of 13512.4 kWh in August, with a performance ratio of 80%. Table 5 shows the system metric for the Innovation building BIPV. Installing PV modules on the roof has the added benefit of reducing the amount of heat transferred to the building's top. Solar radiation directly affects the structures' rooftops. With great care, the solar PV array is constructed to completely avoid any shadow that could be created by nearby buildings, sidewalls, columns, and water tanks.

Table 5. System metrics

Design	Innovation Building
Module DC Nameplate	76.4 kW
Inverter AC Nameplate	90.0 kW
Yearly Production	125.1 MWh
Performance Ratio	80.0%
kWh/kWp	1,638.3
Weather Dataset	TMY, 10 km, Grid

Comparative analysis of the rooftop BIPV system metrics for the four buildings is illustrated in Table 6 by considering the system ratings/capacity, module count, module ratings, system area, grid power, and performance ratio. The yearly generated power for building rooftops is more than 50 MWh. NEC school building, with a system capacity of 84 kW, generated the maximum annual power of 136.9 MWh, followed by the Innovation building.

Table 6. Rooftop BIPV analysis

Building	Innovation	NEC School	Library	NEC Cafeteria
Ratings	55.9 kW	84.0 kW	55.9 kW	52.9 kW
Module Count	243	365	243	220
Module W_p	230	230	230	230
Area m^2	888.9	1335.18	888.9	733.2
Grid MWh	85.85	136.9	58. 5	57.10
PR %	78.5	79.9	78.5	79.1

The facade BIPV system was integrated into the veterinary faculty building. The system capacity is 30 kW, comprising 79,230 W-rated modules and one inverter. The average monthly output power and PR of the system are 3,144.9 kWh and 81%. The position of the building is perfect considering the sun's path thus, the module position receives longer hours of sunshine devoid of shadowing.

4. CONCLUSIONS

This research offers a low-cost, ecologically responsible, and sustainable method of producing power for the Near East University campus. Over time, photovoltaic (PV) systems have gained significant prominence in renewable energy technology by converting solar light into electrical energy. Despite years of neglect and technological challenges, China, the US, and Europe have contributed to the rapid growth of the photovoltaic (PV) industry and the steady rise in photovoltaic installations over the last few years. This study aims to ascertain power production prospects when BIPV is deployed in some buildings on the NEU campus. This paper also discusses the possibility of producing electricity on the NEU campus using a grid-connected solar power plant. The idea is to employ BIPV in conjunction with a grid-tied PV system to create a distributed power source that can provide cheaper, greener energy.

The proposed solar-power-rated investigations are designed and simulated using a PV system software named Helioscope. This software uses real satellite data, thus eliminating the requirement for practical resource-intensive analysis. Both academia and industrial researchers often utilize PV system software. The grid-connected solar power station, rated at 2.24 MWh, comprises 5596 REC solar photovoltaic modules and 8 250 kW inverters. The system's average annual grid output is 2.995 GWh, and its performance ratio is 77.8%. This investigative outcome shows that the NEU campus "wastes" approximately 3 GWh of solar electric energy annually due to the lack of investment. Furthermore, the BIPV technology is investigated by choosing four buildings and one building for rooftop and facade installations accordingly. The results of both systems show optimal workings with an average performance ratio above 75% annual power generation of about 95% of system-rated capacity.

This study's results are relevant across several engineering disciplines. In electrical engineering, optimized designs for grid-connected and standalone BIPV systems are highlighted. This research is relevant to materials engineering. It analyzes PV module performance under Cyprus's intense solar exposure. Insights gained include material durability, degradation rates, and efficiency in extreme conditions. In structural engineering, this research has practical applications. BIPV integration into building facades and rooftops involves assessing load-bearing, insulation, and aesthetic design.

A hypothetical scenario is used to demonstrate BIPV system benefits across various NEU campus buildings. In this setup, BIPV modules are installed on rooftops and facades of major buildings, including lecture halls, library, and hospital. These systems would generate a large portion of the campus's electricity. This decreases fossil fuel reliance and aligns with sustainability efforts. Additionally, BIPV offers thermal insulation, which reduces cooling loads in summer—a crucial benefit in Northern Cyprus's warm climate.

There are several challenges in implementing BIPV systems. The high cost of installation is a major concern. Maintenance can be complicated. Environmental factors, such as shading and temperature, also play a role. BIPV installation costs are typically higher than conventional PV systems because BIPV modules are integrated into building structures. BIPV system efficiency can be affected by environmental conditions, particularly in high-temperature regions. Selecting PV materials with high-temperature resilience and using coatings to minimize heat absorption are practical solutions to improve efficiency.

Conclusively, it's evident that Northern Cyprus is situated in an ideal location for solar-PV-related energy harvesting, applications, and research purposes. Any investment in this area will yield positive returns.

Future studies should aim to refine the engineering of BIPV systems for greater efficiency and cost reduction. Research could look into advanced materials for better energy yield in different climates. Innovative installation approaches to minimize labor costs are also worth exploring. Creating standardized methods for BIPV integration with construction materials would increase both accessibility and adaptability. Integrating BIPV with other renewable systems, such as solar thermal or energy storage, could create more effective and resilient solutions for sustainable architecture.

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