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Study of the potential for solar power plant at At Taqwa Mosque Using PV Syst

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***Abstract*— Countries located on the equator have a relatively high intensity of solar radiation. The thing that is most needed in a solar power plant is the intensity of solar radiation. Based on this, Indonesia is very suitable for implementing solar power plants. The power produced by a solar power plant is directly pro-portional to the intensity of solar radiation received by the solar panels. To maximize electrical power production, it is necessary to design a series of solar panel units to be connected in series or parallel. Solar panels connected in parallel will increase the nominal total voltage, whereas when connected in series they will increase the nominal total current. This research discusses the effect of the series-parallel configuration of solar panel installation on the power production received in a building in the campus environment. The method used to obtain the most optimal energy production is to use a combination of series and parallel solar panels. Daily sunlight data is simulated via PvSyst. The research results show that the most optimal energy production is obtained by designing a series circuit of 20 panels combined with a parallel circuit of 5 panels. The more modules connected in series, the total voltage will increase. The more modules that are connected in parallel, the total current will increase.**

Keywords: Equator, The Solar Panel, Series, Parallel.

I. Introduction

In the current era of globalization, the demand for electrical energy has become a key factor in everyday life. Energy has played a critical role throughout human economic[1]. Various daily human activities heavily rely on electrical devices, making electricity an essential necessity. The increasing demand for electricity has led to an improvement in the continuity of electricity supply, which, in turn, increases the workload on power generators and leads to the depletion of oil resources as a fuel source. Every year, the consumption of electrical energy in Indonesia continues to rise in line with national economic growth[2]. Growth in electricity loads that is not balanced with increases in electricity supply will result in several blackouts or other disruptions in certain areas[3].

The continuously increasing energy demand can be seen as an indicator of a nation's prosperity, but it also presents challenges in energy provision[4]. Most people still depend on fossil fuels to meet their energy needs, which means that over time, fossil energy resources will be depleted. Although Indonesia possesses abundant fossil energy reserves, data from BPPT indicates that these reserves, including oil, natural gas, and coal, will not be sufficient to meet long-term needs. Therefore, the government has taken steps to optimize the potential of renewable energy sources in Indonesia through regulations established in 2014 under policy number 79. This is done to prevent a scarcity of fossil energy due to the ever-increasing demand[5].

The Indonesian government is proactively addressing the depletion of fossil energy resources by promoting the use of New and Renewable Energy (NRE). Currently, the Republic of Indonesia, through its Power Supply Business Plan (RUPTL), has set a target that 23% of the energy produced by 2025 must come from NRE sources[6][7].

Electricity demand in Indonesia is always increasing over the year. Those demands spread through all-region in Indonesia from the capital area to the rural area[8]. Indonesia, situated along the equator, has significant potential for harnessing solar energy due to the high solar radiation in this region. This makes solar photovoltaic technology a primary avenue for generating electricity from sunlight. Factors affecting the efficiency of solar panels include solar radiation, solar cell temperature, panel orientation, panel tilt angle, and shading effects[9]. On earth, solar power panels consume a limited portion of their energy using photovoltaic technology. This technological innovation plays a crucial role in addressing the challenges of global warming and fulfilling our future energy needs. Apart from its clean energy profile, solar power actively contributes to reducing greenhouse gas emissions, thereby lessening our carbon footprint[10][11]. In recent times, the solar energy industry has achieved remarkable milestones in electricity generation and has a clear objective of diminishing our reliance on depleting fossil fuel resources[12]. Additionally, solar energy helps alleviate stress on the electrical grid and extends access to power in remote regions of developing countries. The installation of rooftop solar photovoltaic systems has proven to be a highly effective means of delivering social, economic, and environmental benefits[13]. It can enhance local energy security, lead to improvements in regional air quality[14][15], and also presents a viable alternative to large-scale solar plants on expansive agricultural lands.

In the context of Muhammadiyah University Semarang, the institution has a large number of students and staff, along with supporting facilities such as laboratories, cafeterias, mosques, classrooms, libraries, and more. All of these facilities require a stable supply of electricity, and power outages can disrupt all activities, including religious practices like the call to prayer (adzan) that signals prayer times. Therefore, one way to ensure the smooth operation of activities in the mosque and other facilities during power outages is to install a Solar Power Plant (PLTS) as the primary source of electricity and use batteries as backup power.

II. METHOD

In this research, PvSyst software was used to design and simulate the modeling of a solar power plant.

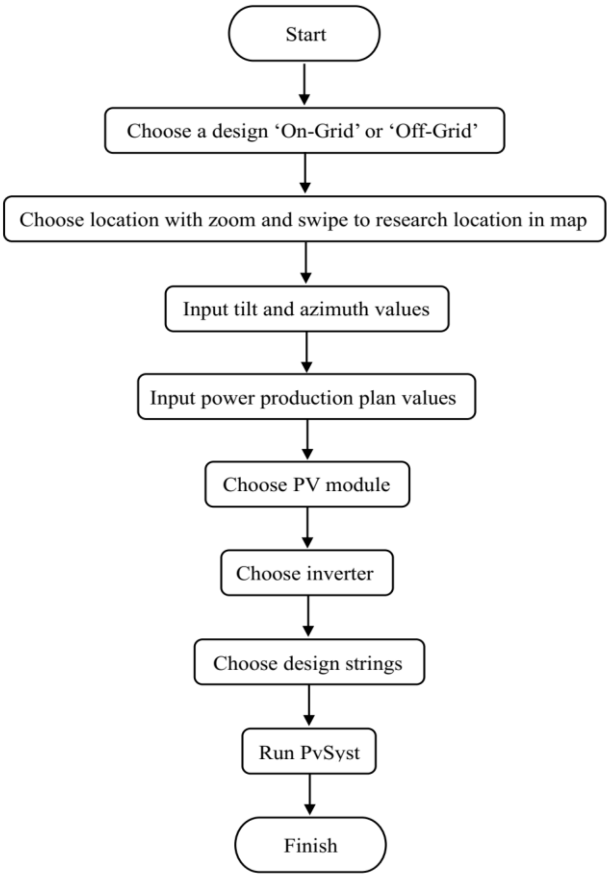

Figure 1. Flow diagram of research

This PvSyst software requires parameters as important variables which are used as input in the simulation process carried out to obtain the most optimal solar power plant model[16]. This simulation takes three solar power plant system scenarios with different variables. The flow of designing a solar power plant system using PvSyst is shown in Figure 1.

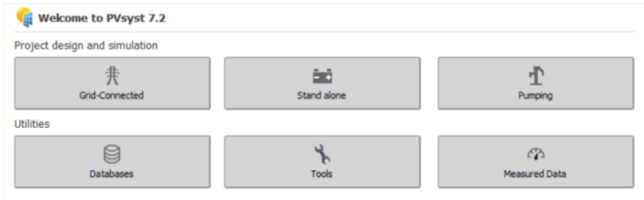

Figure 2. Project design

The first step is to choose the solar power plant design you want on-grid, off-grid, or pumping. This research uses an on-grid design. This research focuses on campus mosques for the application of renewable energy in public facilities. The second step is to choose a specific geographic location at the location of the campus mosque. The research location is located at the coordinates latitude -7.0222° and longitude 110.4615° shown in the PvSyst application.

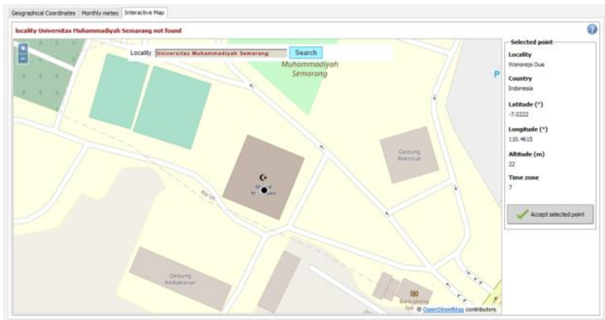

Figure 3. Location selection

This research does not use azimuth or tilt variations in its application. The installation design is more likely to remain inconsistent with changes in the optimal position of the sun. The slope and azimuth values in this study use a value of 15° for slope and 0° for azimuth. Around the location there are no trees or other buildings that could potentially block sunlight.

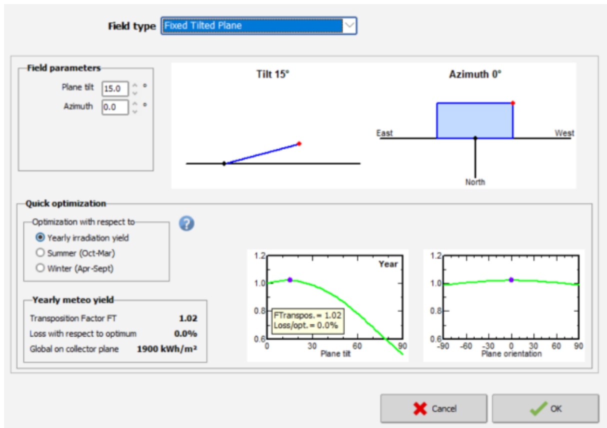

Figure 4. Project design

The next step is to enter the power plan value that will be generated by the solar power plant. The value entered in PvSyst is an estimated 25 kWp of the power required so that later the need for PV modules and inverters can be estimated.

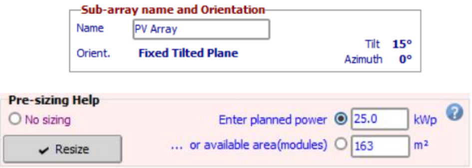

Figure 5. Planned power

This research uses PV modules with specifications Generic 250 Wp 25 V Si-poly 60 Cell. Where this module has a polycrystalline type and can produces 250 Wp as much power as each module.

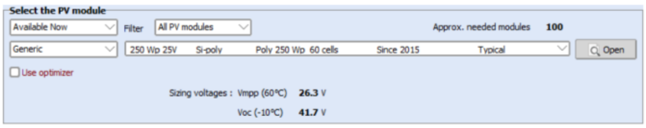

Figure 6. Select the PV module

This research uses inverter with specifications Huawei Technologies 5kW 140-980V SUN2000-5KTL-M1 220Vac. Where this inverter has a frequency 50 Hz and can convert dc power to ac power 5.0 kW for each inverter.

Figure 7. Select the inverter

This research focuses on variations in array parameters that can be applied to the roof top of campus mosques. The modified parameter is a combination of the number of PV modules connected in series and parallel.

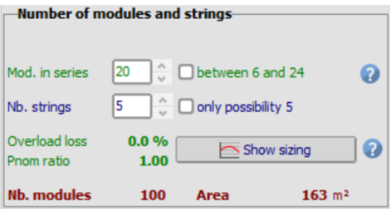

Figure 8. First design the array

After determining how many modules are connected in series and how many modules are connected in parallel, the next step is to run the simulation on PvSyst. The first design plans for the modules to be connected in series with 20 module and in paralel 5 modules. The second design plans for the modules to be connected in series with 10 modules and in paralel 10 modules. The three planned module designs will be assembled in series of 5 modules and string together paralel 20 modules.

III. Result and Discussion

Based on the results of the PVSyst simulation using a PV module design connected in series with 5 modules and connected in parallel with 20 modules, the solar power plant at the Universitas Muhammadiyah Semarang Campus Mosque has the optimal potential to produce electrical energy of 35.34 MWh per year. Where the solar power plant system requires components of 100 solar modules with a capacity of 250 Wp/module with the Generic Poly 250 Wp 60 Cells type and 5 inverter units with a capacity of 5 kW/inverter with the Huawei Technologies SUN2000-5KTL-M1 220Vac type. The results of the PVSyst simulation in this design planning can be seen in Table 1.

Based on Table 1, the electrical energy produced by solar power plant with a design of 5 modules in series and 20 modules in parallel is 35.34 MWh per year. The electrical energy produced by solar power plants in this study has varied and fluctuating results every month. In this research, the results showed that the largest electricity production was in August and the smallest electricity production was in January.

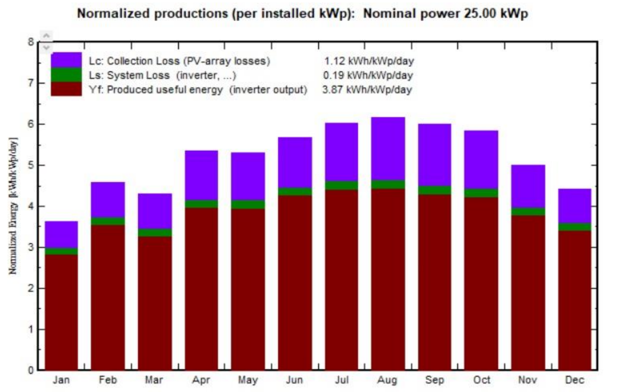

Figure 9. Normalized Energy per installed kWp in series 5 modules and parallel 20 modules

In the other case, based on the results of the PVSyst simulation using a PV module design connected in series with 10 modules and connected in parallel with 10 modules, the solar power plant system has the optimal potential to produce electrical energy of 37.75 MWh per year. The results of the PVSyst simulation in this second design planning can be seen in Table 2.

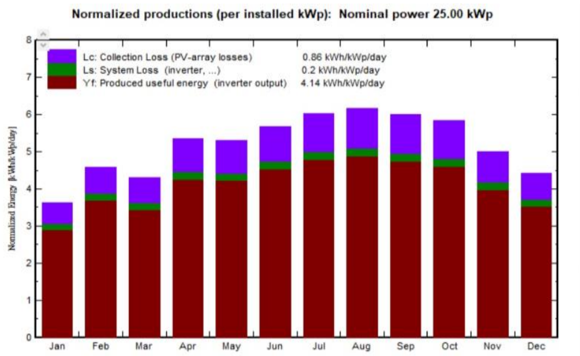

Figure 10. Normalized Energy per installed kWp in series 10 modules and parallel 10 modules

Based on Table 2, the electrical energy produced by PLTS with a design of 10 modules in series and 10 modules in parallel is 37.75 MWh per year. The electrical energy produced by solar power plants in this study has varied and fluctuating results every month. In this research, the results showed that the largest electricity production was in August and the smallest electricity production was in January.

In the third case, based on the results of the PVSyst simulation using a PV module design connected in series with 20 modules and connected in parallel with 5 modules, the solar power plant system has the optimal potential to produce electrical energy of 38.37 MWh per year. The results of the PVSyst simulation in this third design planning can be seen in Table 3.

TABLE 1. SIMULATION OF ELECTRICAL ENERGY POTENTIAL WITH PV MODULES CONNECTED IN SERIES 5 MODULES AND PARALLEL 20 MODULES

	GlobHor kWh/m^2	**DiffHor** kWh/m^2	**T_Amb** ºC	**GlobInc** kWh/m^2	**GlobEff** kWh/m^2	**EArray** MWh	**E_Grid** MWh	**PR** ratio
Januari	120.0	88.26	27.27	112.3	107.8	2.331	2.200	0.784
February	135.1	84.59	27.25	128.5	124.1	2.622	2.490	0.775
March	134.2	88.67	27.67	133.3	129.0	2.677	2.538	0.762
April	153.1	78.72	27.78	160.4	156.1	3.126	2.979	0.743
May	150.7	76.35	28.60	164.5	160.2	3.218	3.068	0.746
June	151.0	65.79	27.95	170.1	166.0	3.357	3.205	0.754
July	166.2	63.22	27.90	186.6	182.4	3.588	3.428	0.735
August	177.2	71.87	28.14	190.9	186.6	3.611	3.449	0.723
September	177.1	78.10	28.37	180.2	175.6	3.381	3.228	0.716
October	187.0	94.27	28.97	181.1	176.1	3.438	3.278	0.724
November	161.4	92.24	28.08	150.3	145.1	2.982	2.835	0.755
December	149.7	91.71	27.62	137.1	131.8	2.790	2.645	0.772
Year	1862.6	973.80	27.97	1895.2	1840.7	37.122	35.343	0.746

TABLE 2. SIMULATION OF ELECTRICAL ENERGY POTENTIAL WITH PV MODULES CONNECTED IN SERIES 10 MODULES AND PARALLEL 10 MODULES

	GlobHor kWh/m^2	**DiffHor** kWh/m^2	**T_Amb** ºC	**GlobInc** kWh/m^2	**GlobEff** kWh/m^2	**EArray** MWh	**E_Grid** MWh	**PR** ratio
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Year	1862.6	973.80	27.97	1895.2	1840.7	37.122	35.343	0.746

TABLE 3. SIMULATION OF ELECTRICAL ENERGY POTENTIAL WITH PV MODULES CONNECTED IN SERIES 20 MODULES AND PARALLEL 5 MODULES

	GlobHor kWh/m^2	DiffHor kWh/m^2	T_Amb ºC	GlobInc kWh/m^2	GlobEff kWh/m^2	EArray MWh	E_Grid MWh	PR ratio
Januari	120.0	88.26	27.27	112.3	107.8	2.331	2.200	0.784
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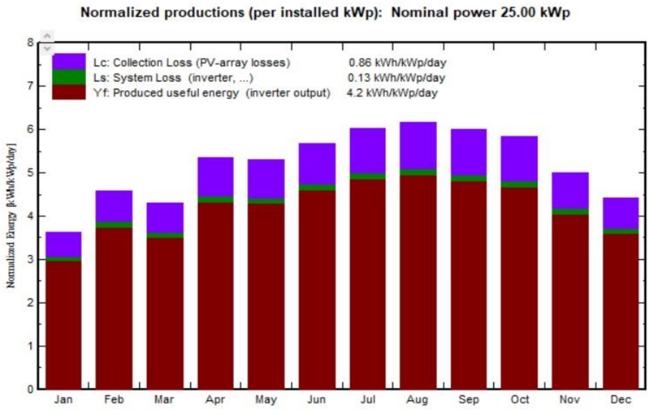

Figure 11. Normalized Energy per installed kWp in series 20 modules and parallel 5 modules

Based on Table 3, the electrical energy produced by solar power plants with a design of 20 modules in series and 5 modules in parallel is 38.37 MWh per year. The electrical energy produced by solar power plants in this study has varied and fluctuating results every month. In this research, the results showed that the largest electricity production was in August and the smallest electricity production was in January. The more modules connected in series, the total voltage will increase. The more modules that are connected in parallel, the total current will increase. This is as seen in Table 4.

TABLE 4. SIMULATION OF ELECTRICAL ENERGY POTENTIAL WITH PV MODULES CONNECTED IN SERIES 20 MODULES AND PARALLEL 5 MODULES

Simulation	P_{mpp} (kWp)	V_{mpp} (V)	I_{mpp} (A)	Energy (MWh/year)
5 modules in series and 20 modules in parallel	22.62	138	164	35.34
10 modules in series and 10 modules in parallel	22.62	276	82	37.75
20 modules in series and 5 modules in parallel	22.62	552	41	38.37

Based on table 4, P_{mpp} has the same value for all variations of design cases. The P_{mpp} value is the maximum power value at the highest point of illumination. V_{mpp} and I_{mpp} have varying values, the more modules connected in series, the V_{mpp} value will increase and the more modules connected in parallel, the I_{mpp} value will increase. The V_{mpp} value is the maximum power point voltage and I_{mpp} is the maximum power point current. The V_{mpp} and I_{mpp} values that best match the characteristics of the inverter will produce the highest electrical energy. In the case above, with the characteristics of the inverter operating at a voltage of 100V-980V, the highest energy is obtained in the third series-parallel design.

IV. CONCLUSION

Based on the research results, study of the potential for solar power generation on campus mosque roofs of 25 kWp can be applied on-grid. The choice of method for installing solar panels in series and parallel affects the resulting energy production.

The electrical energy produced by solar power plants in this study has varied and fluctuating results every month. In this research, the results showed that the largest electricity production was in August and the smallest electricity production was in January. The more modules connected in series, the total voltage will increase. The more modules that are connected in parallel, the total current will increase.

The V_{mpp} and I_{mpp} values that best match the characteristics of the inverter will produce the highest electrical energy. In the case above, with the characteristics of the inverter operating at a voltage of 100V-980V, the highest energy is obtained in the third series-parallel design.

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