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Design Simulation of Micro-Grid Hybrid Solar Power Plant as a Power Supply

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ABSTRACT

Photovoltaic system (PV system) has enormous potential in Indonesia, especially in Java-Bali, which accounts for 70% of Indonesia's electricity needs. In this study, a simulation of the PV system design was carried out using a hybrid microgrid as a power supply using PVsyst software to simulate PV system performance. Power load requirements are adjusted to the specifications of electric vehicles. Meteonorm meteorological data were compared with field data to adjust for data variability. In the design simulation, there are three different slope angle scenarios, namely 10°, 13°, and 15°. The effective surface area for installing PV system on an unmeasured roof is 35 m x 14 m (490 m^2), so the number of modules that can be installed will be adjusted to the roof area. The PV system is capable of producing 169.3 MWh of power per year with an optimal tilt angle of 13° which has specific production of 1726 kWh/kWp/year and a performance ratio of 78.63%. In conclusion, PV system is able to supply the power needs of 103 units of electric vehicles every day.

1. Introduction

With the development of technology, sustainable development has become a top priority in maintaining environmental sustainability. In line with the Paris climate agreement, Indonesia needs to prioritize reducing greenhouse gas emissions in the transportation sector to keep the earth's temperature rising no more than 2°C. In Indonesia, the transportation sector is the largest energy user compared to other energy-using sectors, with a magnitude of 42%. Final energy demand per type is still dominated by fuel oil which is increasing with an average growth rate of 2.8% per year, and this is because the use of fuel oil equipment technology is still more efficient than other equipment. Transport electrification offers many additional benefits. Electric motor vehicles consist of various design aspects that contribute to better performance when compared to internal combustion engines, including efficient powertrain, higher combined, and reduced greenhouse gas emissions.[1-5]

Electric vehicle penetration will grow quite slowly, with only a 3.5% share in 2024, before starting to accelerate to reach a 38% market share in 2030. This delay can be largely attributed to the development of charging infrastructure. Improving public charging infrastructure commensurate with ambitious scenarios will significantly accelerate electric vehicle penetration. The power utility network aims to operate smoothly to supply local energy consumption with increased reliability and efficiency. However, the increased adoption of electric motorized vehicles will place a significant strain on the peak load demand profile for any distribution network, posing a challenge to the robust operation and integrity of its infrastructure. This peak load demand will be shaped differently depending on the charging behavior of electric motorized vehicle users, but this leads to a lot of power inefficiencies, and therefore, it is necessary micro-grid which is powered by new renewable energy sources that are able to meet demand, electricity supply and dynamically have interconnections with utility power grids.[6-9]

Photovoltaic system (PV system) can be used to supply and offset the demand for charging battery-based electric motorized vehicles. Energy storage can be used to increase energy utilization by storing excess energy supply during periods of low demand and then using it when the grid experiences high levels of demand. Battery storage allows the energy produced by PV system to be stored for use when there is no load and/or when the feed-in tariff (FIT) of the utility power grid is low, PV system produces minimal energy due to cloudy weather, or the electricity grid purchase tariff is higher. Several studies have considered battery integration and battery management in grid-connected solar systems. The consumption ratio is influenced by power rating from solar panels, available irradiation as well as daily load demand patterns. Battery storage combined with demand-side management can be used to maximize the consumption ratio.[10-15] This study aimed to simulate the design of a PV system hybrid microgrid as a power supply using PVsyst software version 7.2.11 to simulate the performance of PV system.

2. Methods

The research procedure consists of collecting data with a quantitative approach. The author uses simulation research as a research method using the PVSyst software. Simulation research was carried out with the aim of obtaining an overview of the potential for PV system development on the roof of a building as a power supply. The quantitative approach is a research method that relies on measuring variables using a numerical system, which analyzes measurements using one of the various statistical models, and reports the relationships and associations among the variables studied. The purpose of collecting quantitative data is to understand, describe, and predict the nature of a phenomenon, especially through the development of models and theories. Quantitative research techniques include experiments and surveys.

Figure 1 shows a hybrid-powered electric vehicle charging station (EVCS) connected to the network where the PV system produces 12 kWp of power whose maximum power point is tracked by MPPT. The charge controller regulates the voltage and current in the battery. When the battery is fully charged, it stops charging and sends excess power to the converter. Converter bidirectional is used to convert DC to AC. If battery or solar energy is not available, electricity comes from the utility power grid when low demand is used. Excess energy can also be sold to the power utility network, but this scheme is not implemented in this system. The electric vehicle is charged from the AC bus via a charger. This study used solar panels brand Seraphim model SRP-545-BMA-HV with a capacity of 545 Wp with specifications as shown in Table 1.

A roof area survey was carried out to determine the roof area that could be used for rooftop PV system installations. Meteorological data using database PVsyst at coordinates 8°47'42.2" South Latitude, 115°10'35.8" East Longitude. The PVsyst simulation is used to create a design model and estimate the performance parameters of PV system. The overall performance and effectiveness of the PV system system are assessed by providing the desired design conditions. PVsyst allows the calculation of system output with different parameters. In this study, the PVsyst software is used to estimate the annual power yield of a PV system designed for the parking lot of the Faculty of Engineering, Universitas Udayana, with the scheme-zero export hybrid on-grid.

3. Results and Discussion

Energy balance

The simulations were carried out at various tilt angles, and the results have been compared in Table 2. Among other tilt angles, an angle of 13° is the optimal choice. For specific production, the highest is 1726 kWh/kWp/year, and the performance ratio the highest is 78.63%. Performance ratio shows the overall effect of the losses on the output power array measured by temperature array, ineffective use of irradiation, and inefficiency of system components or system failure. However, in determining the optimal solution, other factors need to be considered.

Losses

Power losses originate at several levels of the PV system due to various factors. In a solar module array, some losses occur and are caused by module incompatibility, module quality, ohmic cables, converter losses during operation, converter losses due to threshold power, battery efficiency losses, and charging/current efficiency losses. Discharging, inverter threshold power losses. Figure 2 shows the losses diagram for PV system with a slope of 10° every year. Solar module losses due to radiation levels are 3.44%, solar module losses due to temperature are 7.35%, mismatch losses are 2.1%, ohmic losses are 1.09%, IAM losses are 2.28%, and far or horizon shading losses of 0.02%. Figure 3 shows the losses diagram for PV system with a slope of 13° every year. Solar module losses due to radiation levels are 3.44%, and solar module losses due to temperature are 7.34%. Mismatch losses are 2.1%, ohmic losses are 1.09%, IAM losses are 2.26%, and far or horizon shading losses of 0.03%. Figure 4 shows the losses diagram for PV system with a slope of 15° every year. Solar module losses due to radiation levels are 3.45%, and solar module losses due to temperature are 7.34%. Mismatch losses are 2.1%, ohmic losses are 1.08%, IAM losses are 2.25%, and far or horizon shading losses of 0.03%.

Table 1. Solar panel specifications.

Electric characteristics (STC)		**Unit**
Maximum power at STC (P_{mp})	545	W
Open circuit voltage (V_{oc})	49,60	V
Short circuit current (I_{sc})	13,90	A
Maximum power voltage (V_{mp})	41,80	V
Maximum power current (I_{mp})	13,04	A
Module efficiency at STC (ηm)	21,10	%
Power tolerance	(0,+3%)	-
Maximum system voltage	1500	V DC
Maximum series fuse rating	25	A
Temperature characteristics		**Unit**
P_{max} temperature coefficient	-0.35	%/°C
V_{oc} temperature coefficient	-0.27	%/°C
I_{sc} temperature coefficient	+0.05	%/°C
Operating temperature	-40~+85	°C
Nominal operating cell temperature (NOCT)	45±2	°C
Mechanical specifications		**Unit**
External dimensions	2278 x 1134 x 35	mm
Weight	27.0	kg
Solar cells	PERC Monocrystalline (144pcs)	-
Front glass	3.2 mm AR coating tempered glass, low iron	-
Frame	Anodized aluminum alloy	-
Junction box	IP68, 3 diodes	-
Output cable	4.0 mm^2, 255mm(+)/350mm(-)	-
Mechanical load	Front side 5400 / Backside 2400	Pa

Table 2. Energy production results and performance ratio at different tilt angles.

Tilt angle	Specific production (kWh/kWp/yr)	Produced energy (MWh/year)	Normalized production (kWh/kWp/day)	Performance ratio (%)
10°	1726	169,3	4,57	78,62
13°	1726	169,3	4,57	78,63
15°	1724	169,1	4,56	78,63

Table 3. Comparison of the energy produced at different tilt angles.

Tilt Angle	GlobalInc (kWh/m2)	Global Eff (kWh/m2)	EArray (MWh)
10°	2121,8	2010,9	172,23
13°	2121,6	2010,8	172,23
15°	2118,8	2008,2	172,01

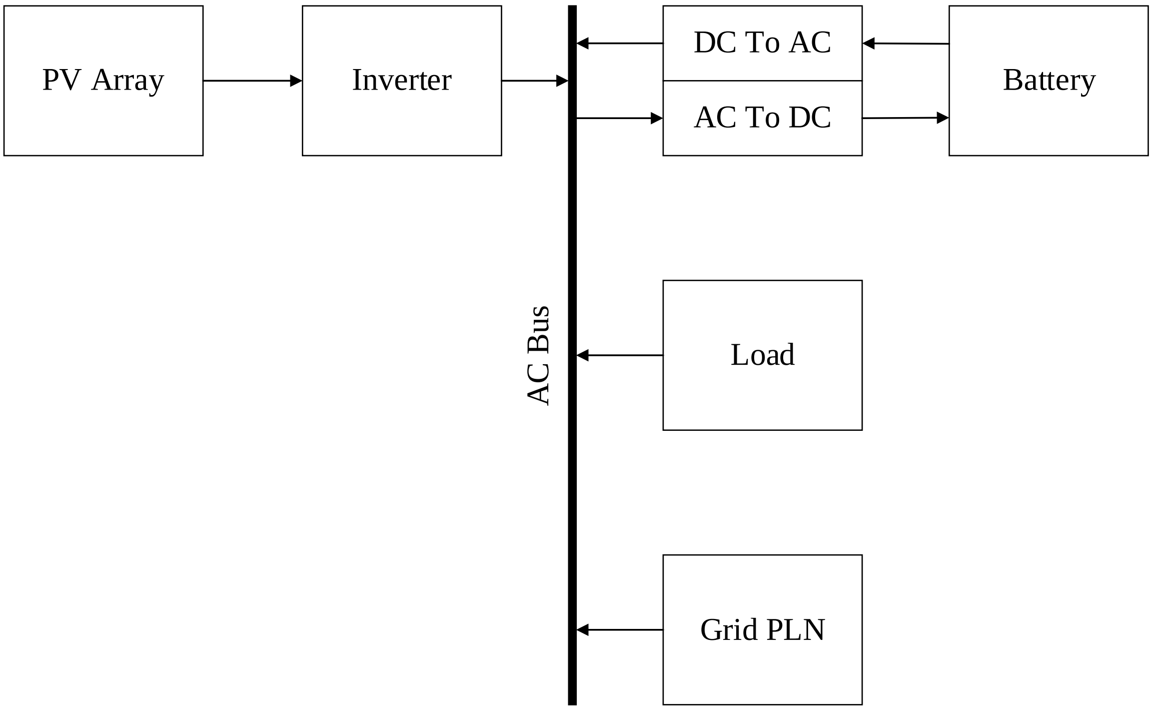

Figure 1. A diagram of the micro-grid hybrid PV system as the EVCS power supply.

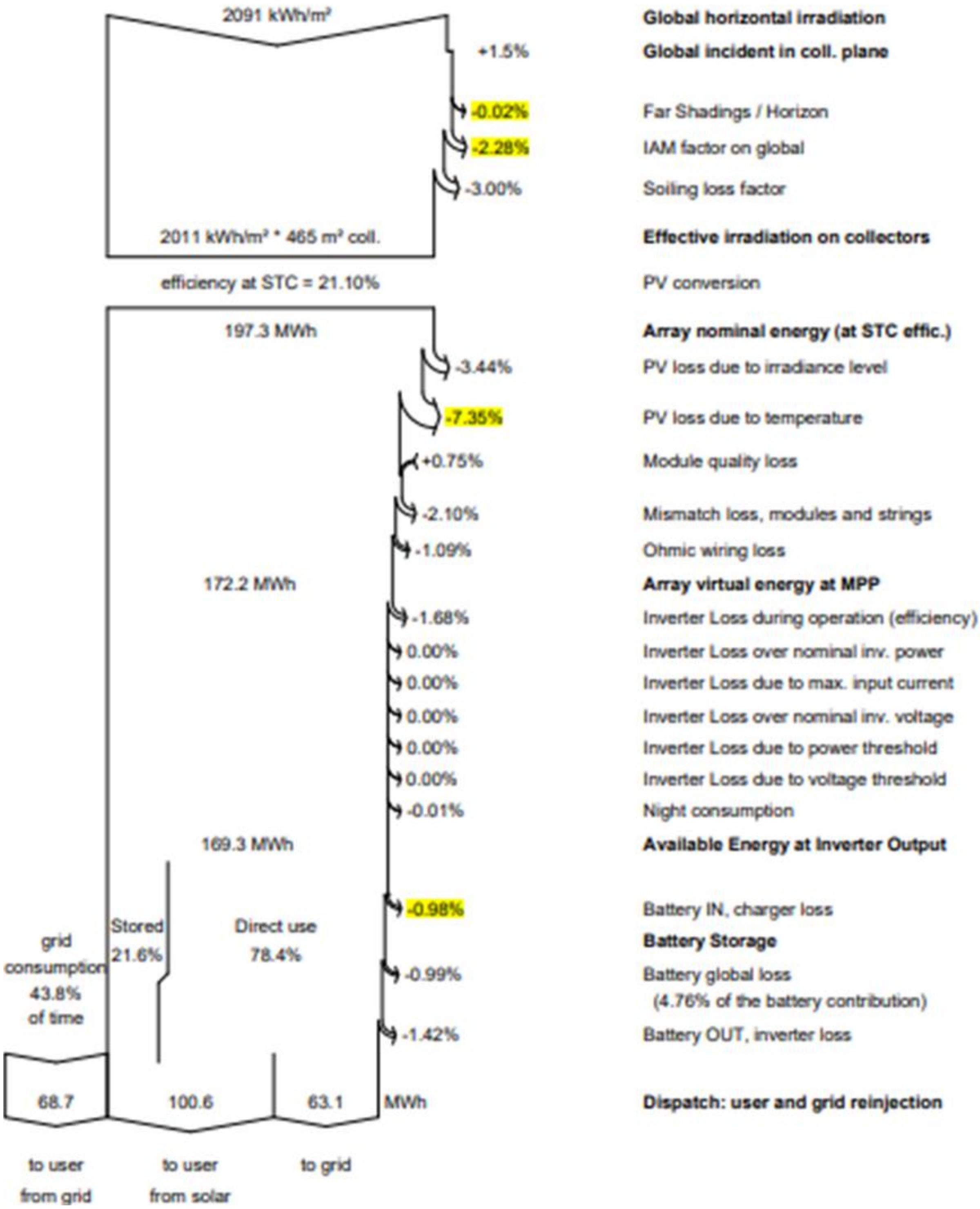

Figure 2. Losses diagram for PV system simulation with a tilt of 10º.

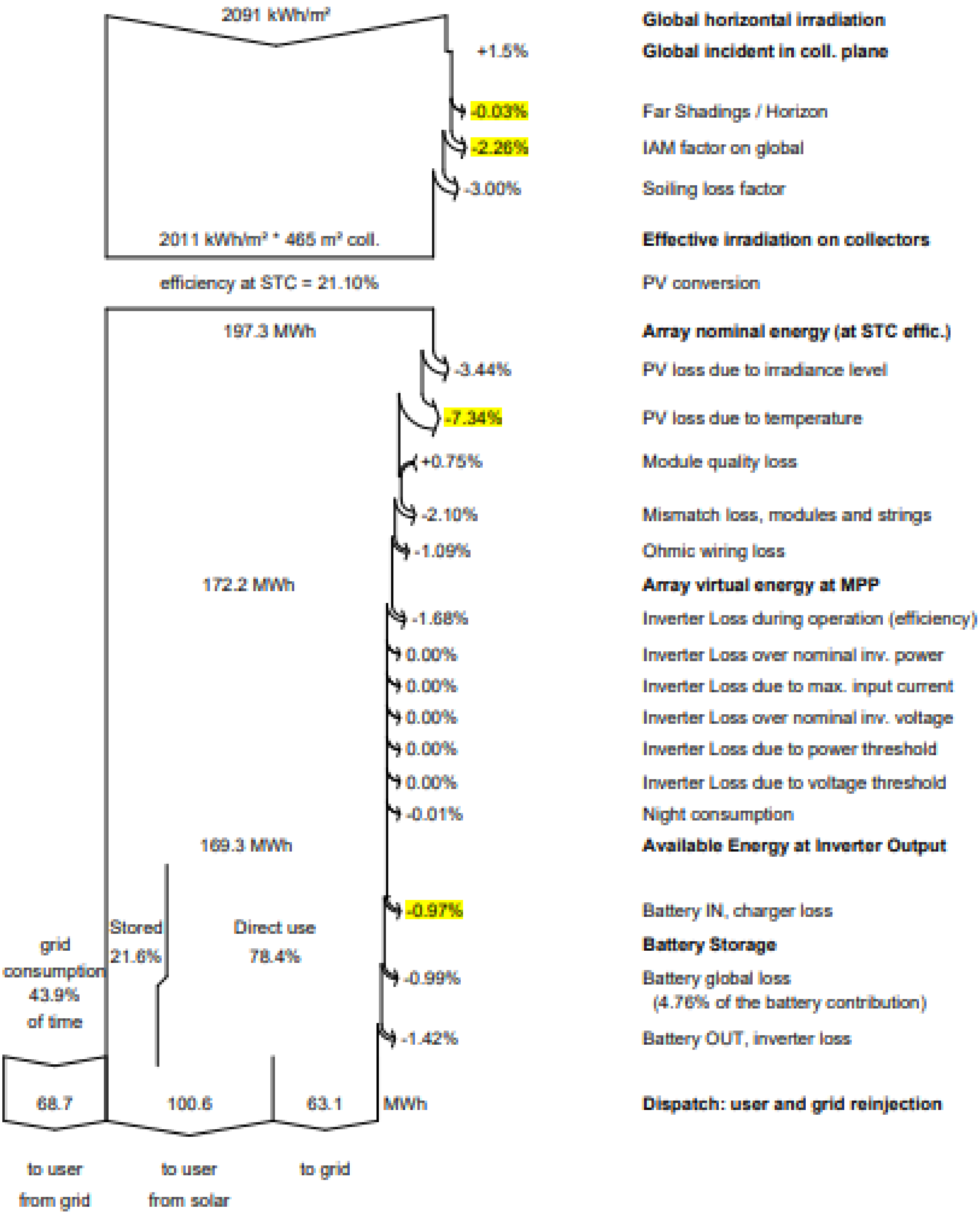

Figure 3. Losses diagram for PV system simulation with a tilt of 13°.

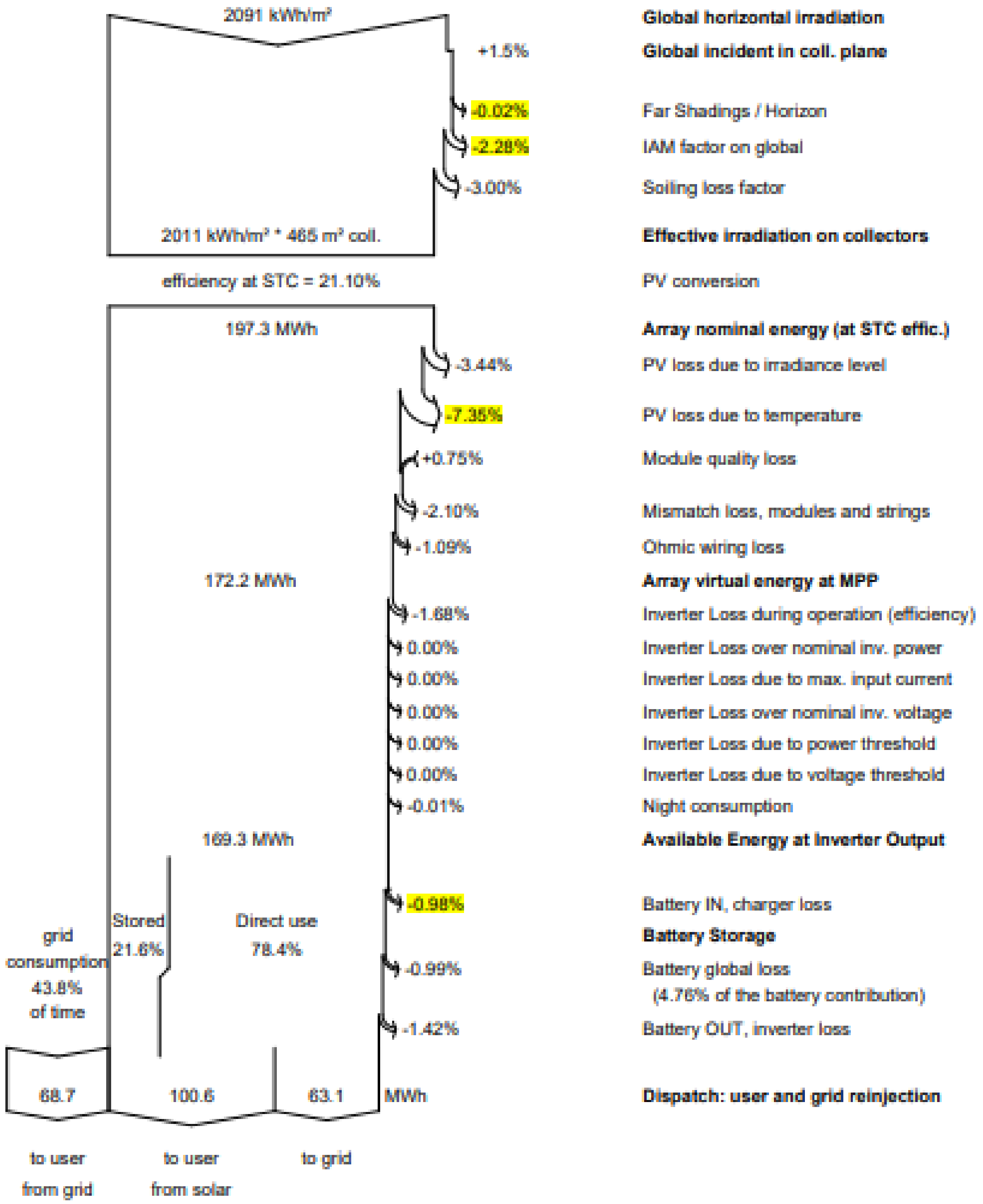

Figure 4. Losses diagram for PV system simulation with a tilt of 15°.

In determining the ratio of energy produced at different slope angles, three variables are determined, namely GlobalInc, which is the global incident on the collector field, and GlobalEff, which is the global effective. The correspondence to incident *angle modifier* (IAM) and *shading*. EArray, which is the effective energy at the output *array*. It was found that the angle of inclination 10^0 receives the most radiation to produce the highest energy. Based on the simulation obtained, the amount of energy produced annually is 169.3 MWh or 463,836.616 Wh per day.[16-20]

4. Conclusion

The PV system design uses 180 solar modules with a capacity of 545 Wp each and a 100 kWp inverter. A tilt angle of 10° has specific production of 1726 kWh/kWp/year, a performance ratio of 78,62%, and PV loss caused by a temperature of -7.35%. The tilt angle has 13° specific production of 1726 kWh/kWp/year, a performance ratio of 78,63%, and PV loss caused by a temperature of -7.34%. The tilt angle of 15° has specific production of 1724 kWh/kWp/year, and performance ratio of 78,63%, and PV loss caused by a temperature of -7.34%. Therefore, an angle of 13° is the optimal angle because it has specific production and performance ratio high and value loss due to low temperature. The amount of energy that can be produced by PV system in one year is 169.3 MWh or 463,836.616 Wh per day.

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