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Audit Energy and Developing Photovoltaic (PV) Model for Refrigeration Laboratory Building Application

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Abstract. Based on National energy policy, Blueprint National energy management 2005-2025 and Bali clean energy forum recommendation that building should be doing save energy efforts and apply renewable energy. Strategy and efforts to decrease energy consumption in building significantly can be done if the energy demand profile is known. Furthermore, depend on the audit energy result (energy demand) so it can be designed and analysis a photovoltaic model with good accuracy. As we known that in tropical countries such as Indonesia, the solar energy will be very beneficial because the peak energy load of the building occurs during the day where the use of the dominant energy of air conditioning system (AC) and at the same intensity of sunlight radiation is high. While at night most of the commercial building, such as laboratory are not used so that no operational use of energy and solar cell energy will not contribute because there is no sunlight. More specifically, Bali State Polytechnic as a leading institution in green building concept research should be more aggressive to conduct research in this field. This research will be carried out in two stages: energy building utility assessment /audit and photovoltaic application design. Detailed data retrieval will be conducted and the assessment is done by zoning and statistical analysis method, where the building is divided into several zones based on the difference of cooling load. Measurements will be conducted on room and environment temperature and humidity, power consumption of each building utilities, the intensity of radiation and sunlight temperature to get a detailed profile every hour of the day. Thus, it can be mapped profile of building energy usage so that it can be formulated efforts to get energy saving from the building and then can be planned the use of photovoltaic (PV) with Building Integrated Photovoltaic (BIPV) system. The output energy calculation method adopts the calculation model developed by RET Screen, the analysis is done by Life Cycle Cost (LCC) and Life Cycle Assessment (LCA) method, so that it will be get the right model from solar energy

1. Introduction

Because of global environmental issues, especially related to the increase of greenhouse gases (carbon dioxide) as a result of excessive use of energy from fossil fuels, the efforts of fossil energy efficiency and renewable energy applications will become excellent solutions. This is in line with the Indonesian Government program with Regulation no. 5 of 2006 on National Energy Policy and has been followed up by preparing the National Energy Management Blueprint (BP-PEN) 2005 – 2025 [1], which set the role of new and renewable energy by 5% in 2025. However, global climate change is very fast and in accordance with the existing developments then in 2014, the House of Representatives set a target for

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renewable energy in the energy mix of 23% by 2025 and by 31% by 2050 and currently, about five percent of energy is renewable energy [2].

With regard to energy use in commercial buildings in tropical countries such as Indonesia, energy consumption is dominant for air conditioning system, so energy efficiency effort in building become very important. With an average outdoor temperature of 23ºC -32ºC and average relative humidity ranging from 70% -90% yearly (Data: BMKG Year 2015)[3] then commercial buildings (as an example of hotels and offices) will operate its air-conditioning system for 24 hours full day to get the comfort zone of the room ranging from temperature and humidity of 24ºC-60% [4], causes the high load of AC system. In addition, the awareness of the user is still low in energy saving efforts within the building.

As large buildings in the Politeknik Negeri Bali is a building with light construction where every room in direct contact with the surrounding environment (ambient condition). Besides, the conventional building (wall and roof) construction is still conventional with relatively high thermal conductivity, the building with such construction has a relatively high refrigeration load[4]. Thus detailed assessment is indispensable for this type of building to obtain significant energy-saving strategies.

Furthermore, Bali State Polytechnic as the leading institution in developing green campus concept must have strong character as the development of green building concept. Demonstrating that strong character is the development of new and renewable energy use for energy supply in the building. One of the most eligible energy to apply is solar energy with the Building Integrated Photovoltaic System (BIPV)[5]. Where photovoltaic applications can be integrated with the power grid from the national grid. It is therefore necessary to plan with detailed data and calculations to get the feasibility study appropriate for the application of BIPV system at the Building of Refrigeration Lab Polytechnic of Bali.

2. State of the art

The use of energy in buildings at this time influenced by various factors, including internal and external factors. Lam et al. [6] examined the influence of climate on energy use in building. They formulated the characteristic of annual energy use in each different climate (cold, medium and warm climates). It was found that Hong Kong, which has a temperate climate (subtropical) get the lowest peak energy compared to other regions that have a hot, cold and quite cold climate. Utama and Gheewala [7] conducted research on the choice of materials for building places in Indonesia related to energy needs, especially energy for air conditioning needs (AC). It was explained that the construction of residential buildings in Indonesia is very influential on the energy demand of air conditioners. This is caused by high heat gain, especially from the roof and wall, with a total heat gain of 50-60% of the total heat gain in the building. To overcome this matter examined model of wall with cavity to decrease requirement of AC energy. However, the results obtained are still not applicable in Indonesia because the costs incurred to make walls with low U-value are still relatively expensive compared to the monthly electricity bill. This is because at that time electricity is still subsidized by the government so the awareness of people to use the building with good isolation is still low. Zhao and Magoulès [8] reviewed the prediction of energy consumption in buildings. Energy in the building is determined by many factors such as the surrounding environment, structure and characteristics of the building, lighting operation and HVAC (Heating Ventilation Air conditioning), the number of occupants and the behavior of the occupants. So the prediction of energy consumption is still complicated to be determined precisely. The study was conducted in France and they recommend the easiest and most effective method for building energy assessment is the statistical method.

Building energy assessments for energy saving efforts are also conducted by designing controls on the use of lamps by daylighting saving time [9] and can reduce the peak demand of electricity by 0.14% from government buildings, commercial or household, while with more detailed auditing from Roslizar et al. [10] get 20% energy saving mostly from air conditioning system. Industrial requirements are also investigated by applying automation systems to lighting, heat recovery and door opening and obtaining a significant energy derivative [11]. While Campaniço et al. [12] conducted an energy assessment of the building by applying the method of passive cooling (direct night ventilation, water-soil heat exchangers, controlled thermal phase-shifting, evaporative cooling and found that the best energy saving estimates

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at the resolution of the day (31%) and also the energy decrease on monthly data ranges from 6% -11%. The retrofit measured method can be made 33% annual energy saving for lighting and 37% for air conditioning [13].

Along with the policy of most countries in the world to encourage the use of renewable energy, various modifications of solar technology (photovoltaic) are applied to buildings with Building Integrated Photovoltaic (BIPV) system [14],[15],[16]. This system can integrate energy sourced from renewable energy with energy from national power grid (PLN). In tropical countries such as Indonesia, this system will be very useful during the day, where the intensity of sunlight is very high and on the other hand the need for cooling system (AC) is also high [5], and it is found that photovoltaic is more advantageous to used in the building because of its stable output energy, low maintenance and operational cost and free from noise pollution compared to energies from wind turbines. Braun and Rüther [17] conducted research by applying BIPV to commercial buildings. Associated with the seasonal energy building load and regulation in a country, it is found that BIPV system is very profitable applied especially in hot and sunny season. Commercial buildings operated during the day have a profile of energy consumption that matches the trend of solar radiation. In accordance with the space available for BIPV in the building, there is a sufficient supply of energy supply for the building's energy needs. In this study, BIPV can generate 1 MWp of electric power. Based on the electricity requirement in 2016 and simulation profile observed within a year it is found that with 1MWp can meet the energy needs of 30% of the total electrical needs of the building concerned. Another advantage of peak load during the day can be lowered by the BIPV system because at the same time the solar radiation for PV is the maximum.

3. Methodology

This research will be carried out with two main stages, the first is the next energy assessment of photovoltaic (PV) modeling for energy supply that is integrated with PLN power supply. For the energy assessment and PV modeling needs to collect primary and secondary data are needed and then performed the assessment by statistical methods. Once the energy profile is obtained in detail then the energy saving strategy and photovoltaic system modeling are in accordance with the building requirements and cost optimization (LCC)[21].

3.1. Data acquisition

The data required are primary and secondary data for conducting assessment and designing a photovoltaic design model that is appropriate to the real condition of the building being the object. Taking primary data by experimenting on photovoltaic trainer unit in TPTU Prodi Lab, by measuring on, solar intensity, solar cell surface temperature, ambient air temperature, PV power output profile, additional data is required from some solar power that has been installed in the area of Bali Province so that required several field surveys. These data will be used to validate the designed PV calculation model.

While for the data retrieval is done by measuring every utility of buildings that require electrical energy that includes: air conditioning, lights, tools practicum, water heater, computer, etc. While additional data of environmental conditions consist of room temperature, humidity of the room and the surrounding.

Secondary data were obtained from previously published journals and references as well as data from BMKG on weather covering sun intensity and clearness index. Other data required are the specification of PV products designed in accordance with the needs of the building.

3.2. Audit energy

The general audit method also disrupts the audit methods and standards developed by ASHRAE. More specifically the method is the statistical method in which analysis includes the mean energy profile, the

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highest (peak) energy and the minimum daily and monthly energy. Variations in energy requirements can be described in detail and are very clear. So is the energy consumed by each building utilities and the energy needs profile of each room based on zoning, which is based on the direction of the sun (facing) north, east, south and west. And the type of construction of insulation from the space in the building (there are two types of insulation that dies in the building).

Air conditioning in air-conditioned rooms in sets of 24ºC and RH 60% (comfort zone based on SNI workspace is with temperatures ranging from 24ºC to 27ºC with relative humidity between 55% to 65%). Data taken for 24 hours include temperature and humidity data of the room, temperature and humidity environment, electric power consumption of each building utility, radiation intensity and sunlight temperature. Observations made on all rooms and types of rooms within the building. Measurements are made with standard equipment that has a high accuracy, with data logger system recorded in the computer per unit of a certain time.

4. Results and discussions

4.1. Energy demand of the building and Building Integrated Photovoltaic Design

Energy calculation result for energy requirement data from building which include energy usage for air conditioning system, lighting, etc. obtained from one of the energy audit results of refrigeration lab building where the power requirement is 10 kW, as shown in Figure 1.

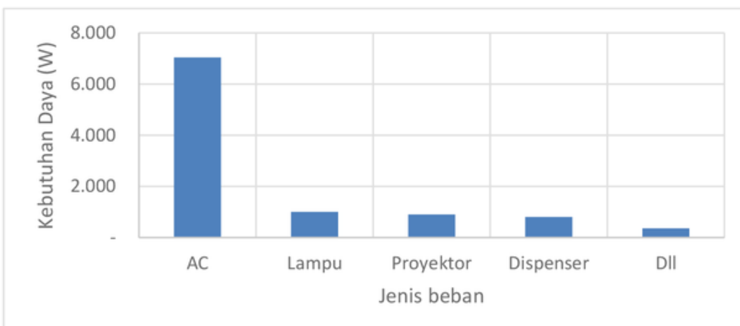

Figure 1. Energy demand of Refrigeration Laboratory Building

BIPV model was done by designing a photovoltaic system for buildings. The next design steps are done by adopting from the modeling system developed by BP Solar, RETScreen, PV Watts[18][19][20], whereas the data needed is the acquisition data for the solar beam especially related to the intensity of light radiation and daily temperature then analyzing the output energy produced by the PV system. The system consists of a series of photovoltaic (PV), power conditioner (PCU) and the required measurement / meter (e.g. a two-way meter). Power conditioners generally consist of inverters with control equipment and security protection systems. The design of the BIPV system is shown in the figure below.

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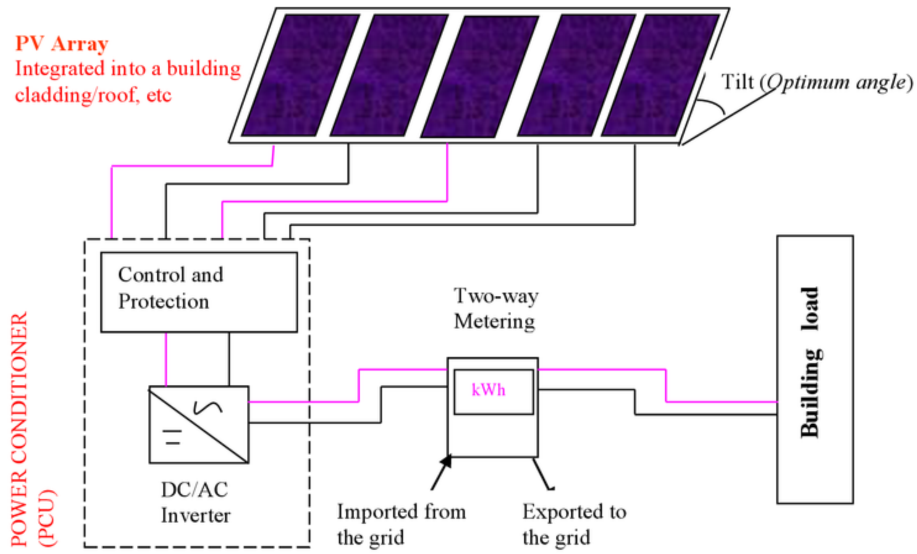

Figure 2. Building Integrated Photovoltaic design

4.2. Photovoltaic energy output and cost

Depend on survey result obtained that the photovoltaic that were installed in Bali (Bangli regency) has a total efficiency approximately 13.8% . In this model the photovoltaic was modelled with capacity of 10 kWp and the output approximately 4.3 kW. So, the additional energy should be fed by national grid. The proportion of photovoltaic and national grid yearly are constant as shown in Figure 3.

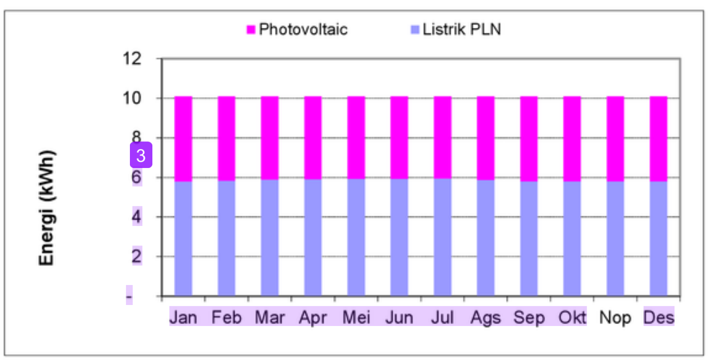

Figure 3. Photovoltaic and national grid proportion

Using life cycle cost (LCC) with life time of the photovoltaic of 25 years and considering some main cost item as i) initial cost including: feasibility study, engineering design, equipment, balance of plant and misc. ii) operation and maintenance cost. It was obtained the electricity cost from photovoltaic as much as 2500 IDR and comparing with the electricity tariff of national grid is 1.467,28 IDR per kWh.

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5. Conclusions

- In terms of climate and intensity of the sun Bali is perfect for developing photovoltaic in buildings with BIPV (Building integrated Photovoltaic) system.
- Photovoltaic also very eligible in building because this building use in the daytime and the photovoltaic getting peak energy output also in the daytime , because the main energy demand of the building is form air conditioning.
- Cost of electricity from photovoltaic compare with the national grid tariff is still more expensive, this problem need to be solved by government by incentives.

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