Economic Feasibility Study of Rooftop Grid Connected PV System for Peak Load Reduction

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***Abstract*— This paper presented the economic feasibility analysis of grid-connected photovoltaic on the roof of building, to reduce peak electrical demand. The Engineering Faculty electrical system is used as case study of PV system economic feasibility. The economic calculation assumptions used are: electricity tariff IDR 1114.74 per kWh based on electricity tariff for medium voltage load, estimated annual module degradation 0.5% and the life expectancy of the solar panels 25 years. The interest rate using of Bank Indonesia (BI) rate for 2018 i.e. 4.25% and inflation rate 3% also considered. The initial investment required to build 117.5 kWp PV system is IDR 2,413 million. The operational and maintenance costs are estimated 1% of initial investment per year. The result of cash flow rate shows that a positive NPV is achievable and payback period less then solar panels life expectancy. The simple payback period is 11 years and discounted payback period calculated by consider multiple parameters to be 14 years. The result of economic analysis using current rate value indicate that the project is profitable.**

Keywords—grid connected PV system, economic feasibility, peak load reduction.

I. Introduction

The Indonesian government encourages the use of renewable energy as a source of energy in office buildings that almost entirely use electricity from National Electricity Company (PLN) grid so as to suppress the use of fuel oil and decrease carbon dioxide (CO_2) emissions. Utilization of renewable energy suitable for offices is photovoltaic (PV) system installed on the roof of the building [1], because most office buildings use electricity during the day or working hours. The PV system is one of the environmentally friendly power generation technologies and can be a solution to the future electrical energy crisis making it the most widely developed and reliable alternative. In addition to being environmentally friendly, the construction of PV System at the load center can reduce network losses, land investment costs and dependence on fossil energy, thereby enhancing energy sustainability and independence [2].

Several studies of designing PV systems on the rooftop of buildings have been done [3-5]. The hybrid system supply design on an institutional building rooftop of Udayana University, Indonesia and Minia University, Egypt have been presented in [3] and [4]. Another research conducted to design PV system for public building i.e for Ibeno Health Centre [5]. The design result justified that PV system have a potential and feasible to build on the load area, however the weather condition and actual performance need to consider and improve.

The previous research uses assumption data in the design process so that the treatment will likely differ when installed in certain areas. However, in this study, the grid system design is based on the PV system of the actual small-scale pilot project [6] to obtain important parameters in the design and subsequent economic analysis. The grid connected PV systems have been used in this study. The grid connected PV system have many technical advantages such as flexibility, simplicity to install in any area where the solar irradiation is available, as non-polluting, emitting no noise and requiring little maintenance. The Engineering Faculty of Andalas University electrical demand used as case study of PV system design for peak load reduction and common feasibility criteria used to examine the profitability of this PV system project.

II. Building Peak Load Reduction

Utilization of renewable energy suitable for offices is a solar power plant using photovoltaic solar modules installed on the roof of the building. Rooftop photovoltaic is a reliable solution for energy supply in office buildings because the majority of office buildings use electricity during the day or working hours because the cost of electricity procurement cheaper than diesel or fuel oil [7]. The integration of PV system close to load centers can reduce power losses and increase voltage profile [8]. In addition, maintenance and operation are also easy but significant impact to reduce pollution and greenhouse effect.

Global warming is an environment problem caused by the effect of greenhouses that occur in the Earth's atmosphere. The Kyoto Protocol was formed that agreed to collectively reduce 5.2% of greenhouse gas emissions. One of the biggest contributors to greenhouse gas emissions is carbon dioxide gas. Gas CO_2 produced through the combustion of motorized vehicle fuel, industry, and the biggest is in the process of generating fossil fuel-powered electricity. Through this design study use solar energy as an alternative power plant to reduce the work of fossil fueled power plants so that can reduce CO_2 gas emissions which is released into

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the air. Potential reductions of CO_2 emissions can be calculated using factors emissions of carbon dioxide power plant that is equal to 0.73 kg CO_2/kWh.

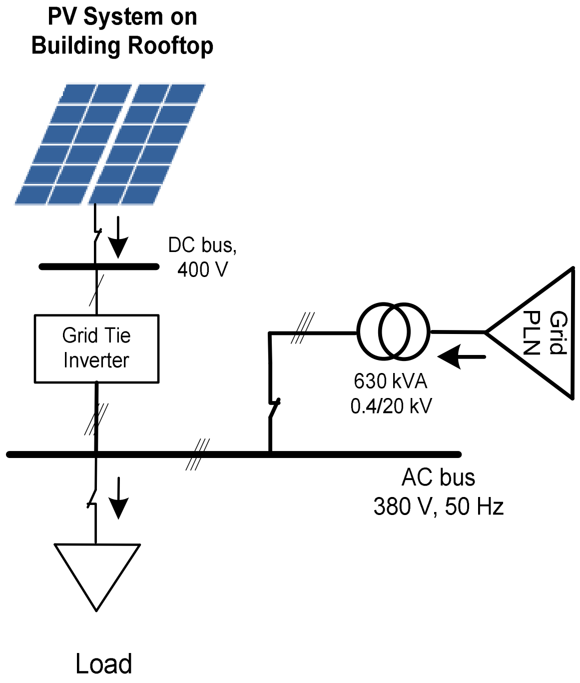

Fig. 1. Grid connected PV system

Grid connected PV as shown in Fig. 1 has been the most popular PV system choice in recent times, because it's can reduce investment funds and battery dependence. Some of the advantages of grid connected PV is the investment and maintenance costs are greatly reduced due to unnecessary battery. When the power of the PV system is greater than the load, the excess power can be send and sold to the power grid. So the electricity bill can be reduced. More environmentally friendly because it reduces battery waste that requires special treatment and not produce CO2 emissions. In addition to the above advantages, for the case in Indonesia, have supported by appropriate regulation. The scheme will be very helpful for the distribution of targeted electricity subsidies.

A grid connected PV system consists of the following components: solar panels, grid-tied inverter (GTI), solar cables and Mounting. GTI is a special type of inverter that converts direct current (DC) into alternating current (AC) and feeds into an existing electricity network and cannot be used in standalone applications where there is no electricity. Grid-tied PV systems are generally cheaper and simpler to install, as long as the grid is close to the load center. On sunny days, solar panels will usually generate more electricity than consume during the daylight hours. With net metering, the owners can tranfer this excess electricity onto the utility grid rather than store in a battery-bank storage system, which would involve a considerably larger initial investment.

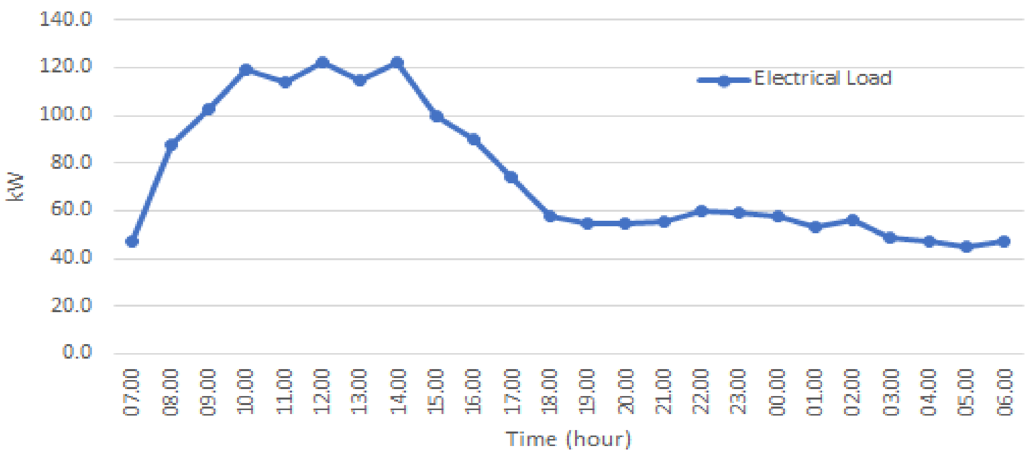

Fig. 2. Electrical load of Engineering Faculty building

The electrical load characteristics of an office building are generally shown in Fig 2. The use of electrical loads as illustrated in Fig 2 is as load characteristic of Engineering Faculty building, Andalas University. The design of grid connected photovoltaic on the roof of the Engineering Faculty building to reduce peak electrical demand have been presented in paper [9]. The result of design study using 470 units of solar module can be shaved maximum load of Engineering Faculty building as shown in Fig 3 with discontinuous line. The load consumed and PV system designed have been used in the study to achieve economic feasibility.

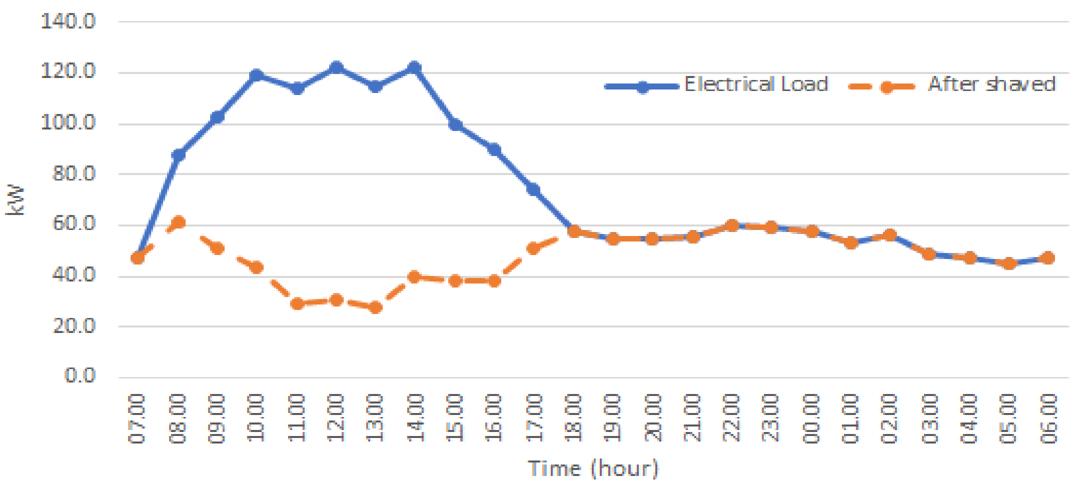

Fig. 3. PV installation reduce EF peak load

III. Economic Feasibility Criteria

The economic analysis of the PV system for government buildings uses a business feasibility study calculation system to determine investment criteria. These criteria can be used to determine the profitability of a project. The most common criteria used to examine the profitability of a PV project are net present value (NPV), payback period and internal rate of return (IRR). Net present value (NPV) is applied in capital budgeting to analyze the profitability of an investment or project and this formula is sensitive to the reliability of future cash inflows that an investment or project will yield. NPV compares the value of money received today and the value of that same amount of money in the future by taking inflation and rate of return into account. NPV is based on discounted cash flow (DCF) techniques with three basic steps.

The first step is to find the present value of each cash flow, including all inflows, outflows, and discounted at the project's cost of capital. NPV is the ratio between the value of the market investment and the cost itself. The formula for determining NPV is as follows [10]:

$$NPV = \sum_{t=0}^{n} \frac{CIF_t}{(1+k)^t} - Invest \qquad (1)$$

Where:

k = Discount rate

CIF_t = Cash in flow for t period

n = last period of cash flow expected

Invest = Initial investment

The result can be evaluated that if the NPV value is negative, then the project is not recommended to be implemented, if the value is positive, then the project is feasible to implement. NPV value is zero means there is no difference if the project is still implemented or rejected.

Payback period is a period of time required to recoup the fund expended in an PV investment or to reach the break-even point. The calculation of payback period is done to know the financial risk to the project be done. The smaller payback period will be better, with the risk factor for return on capital will be faster in a short time. In calculating the payback period is usually called the payback method by dividing the initial capital issued with income received by investors for a year. The use of payback period in calculating the effectiveness of investment still has limits. The payback period does not calculate the profit earned after the payback period and has limitations in comparing the two projects.

The annual maintenance and operational costs for PV system, generally accounted for 1 - 2% of the total initial investment cost [11]. The large percentage of annual maintenance and operational expenses for the PV power plant covering costs for solar panel cleaning work, maintenance and inspection costs of equipment and installations will be set at 1% of the initial total investment because Indonesia only have two seasons i.e. the rainy season and the dry season so that the cost of cleaning and maintaining the solar panel is not as large as the country that have four seasons in one year. In addition, the determination of this percentage is also based on the level of wage labor in Indonesia which is cheaper than the wage rate of labor in other countries.

IV. Economic Feasibility of PV System for Peak Load Shaving

The process of economic feasibility analysis is carried out to calculate the feasibility of developing the PV system by comparing the amount of investment cost to income/return (revenue) obtained during the review time (time horizon). In other words, this financial analysis is carried out by forming cash flow from the project plan from the perspective of investors. The time horizon is limited by the estimated of the PV system components lifespan. The review time chosen in this study is 25 years same as solar panel lifespan.

Table 1. Cost estimate of PV system installation

PV System Components	Total price (IDR)
PV module, 470@250Wp Poly	1,903,265,000
Grid-Tied PV Inverter, 3P	195,000,000
MCB, Cables, busbar and fuses (15 % of PV system cost)	314,739,750
Total cost	2,413,004,750

The initial investment cost estimation used in this study is as shown in Table 1. The amount of electrical energy that can be generated by the 470 units of solar panels for a year is calculated based on actual small-scale PV data for various weather conditions with upscaling factor 94. The weather condition data for Padang city obtained from Meteorological, Climatological, and Geophysical Agency (BMKG) data is shown in Fig 4. Based on the BMKG data the average weather condition can be summarized in percentage/year as show in Table 2. By using this data, the potential of energy of PV system designed can be generated 428.16 kWh/day.

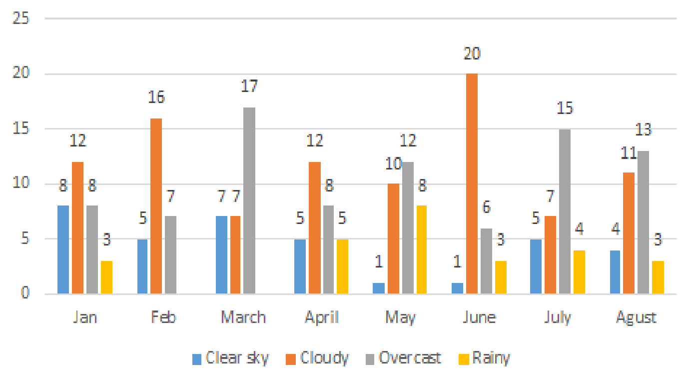

Fig. 4. West Sumatera weather condition

TABLE 2. PV SYSTEM ENERGY GENERATION

Weather	Data Jan-August	Percentage	Energy (kWh)/day
Clear	36 days	15 %	94.60
Cloudy	95 days	39 %	198.55
Overcast	86 days	35 %	119.20
Raining	26 days	11 %	15.82
Total	243 days	100 %	428.16

The electric tariff IDR 1114.74 per kWh based on electricity tariff for medium voltage load 20 kV by PLN 2018 is used. The estimated annual module degradation 0.5% and the life expectancy of the solar panels were assumed to be 25 years as determined by the most of solar companies [11]. The Bank Indonesia (BI) interest rate for 2018 i.e. 4.25% and inflation rate 3% are used in economic calculation based on present value. The result of cash flow rate calculation is shown in Fig 5.

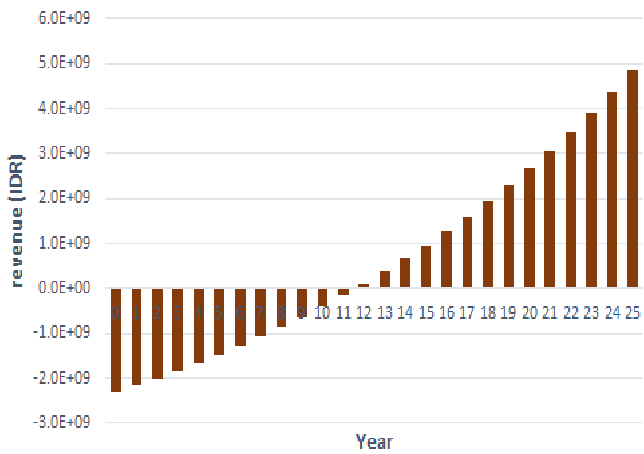

Fig. 5. Cash flow rate

Net present value compares the value of an investment today to the future value of the money based on inflation and returns. NPV is a simple calculation of difference between the present value of cash inflows and outflows using equation (1) as below:

NPV = 3,757,591,476 -2,413,004,750

= 1,344,586,726

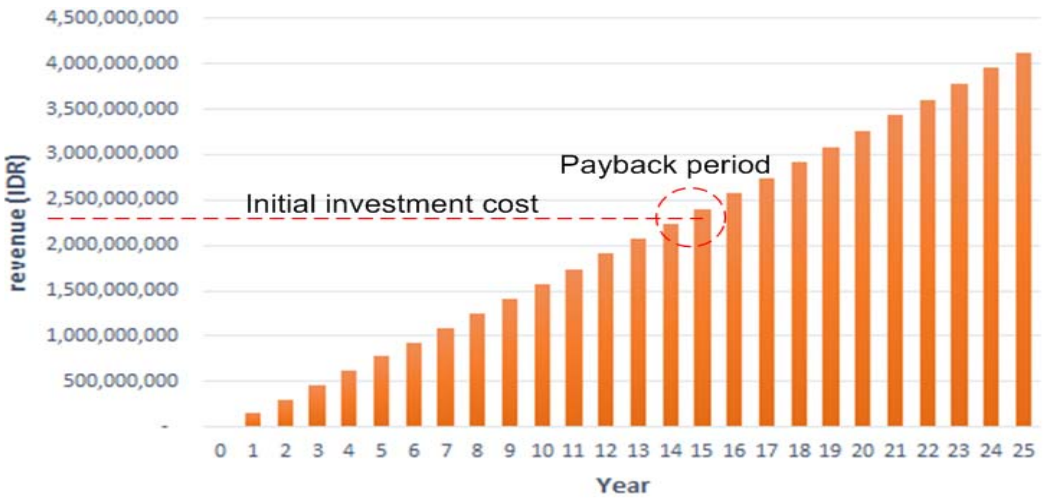

Fig. 6. Present value cumulative Net Cash flow (NCF)

A positive value of NPV indicates a favorable investment. Then, the simple payback period can be calculated by dividing total PV system investment cost by yearly savings. The simple payback period for this PV system is 12 years. The discounted payback period can be determined from Fig 6 for DF 4.25% is equal to 14 years and 5 months. The simple method for calculating the cost of energy is the ratio of total investment plus the O&M cost over the total energy produced over project period.

The result for both simple and net present value method shown in Table 3.

TABLE 3. ECONOMIC FEASIBILITY

Feasibility Criteria	DF = 4.25%	DF=7.25%
Simple Payback period	11 years	11 years
Payback period	14	18
NPV	1,344,586,726	456,709,878

By knowing the amount of energy that can be generated by PV system and the factor of carbon dioxide gas emission of 0.730 kg CO_2/kWh [12], it can be known amount of emissions that can be reduced. The design results show that the potential of solar energy which can be generated by the PV system in one year amounted to 156,280 kWh, so that can be obtained the potential of of CO_2 emissions that can be reduced in one year is 118.08 tons.

V. CONCLUTION

The economic feasibility study of grid connected photovoltaic on the roof of the building for electrical peak load shaving have been done. The potential of energy of PV system designed can be generated 428.16 kWh/day. The economic feasibility study have used actual data of PV system of 1.25 kWp with upscaling factor 94 times, and considering weather conditions from BMKG data per year. The result of economic analysis shows that NPV for Engineering Faculty is IDR 1,344,586,726, simple payback period is 11 years and discounted payback period is 14 years. The result of cash flow rate shows that a positive NPV achievable and payback period less then PV panels life time. The economic feasibility results indicates that the development of PV system in the Faculty of Engineering, Andalas University building is feasible.

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