The Development of Photovoltaic Application in Indonesia: A Review

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Abstract: Indonesia has abundant solar energy potential because it is located near the equator. To reduce dependence on fossil energy sources, the government began to promote renewable energy sources; one of them is solar energy. The government has made a strategy for implementing solar energy by issuing regulations and also cooperating with private parties and foreign countries. However, the dissemination of photovoltaic are quite low and need to be encouraged by private investment support. At the same time, the government has to be more active in synchronising the rules in technical, administrative and financial point of views. This study presents the development of photovoltaic application in Indonesia which might be useful in improving the utilization of photovoltaic in Indonesia. The production of solar panels is also being encouraged, at this time the national industry has been able to produce solar panels with a composition of local content that continues to increase. The research to analyse the main function of photovoltaic for generating electrical power has also been carried out. For examples are for household electricity and street lighting and other automation systems. Additional advantages of photovoltaic technology to absorbing heat have been proposed in several studies on photovoltaic/thermal. Furthermore, there are some potential challenges to overcome. Those are the utilization of heat energy and the floating photovoltaic which solve the lacks of land area.

1 INTRODUCTION

The rapid growth of population and industrialization create a high increase of energy demand. Recently, the energy demand is supplied by fossil fuel; however, it generates pollutions which cruelly destruct the environment. Fossil fuel reserves are decreasing which means slowing down the economic growth in many countries, including in Indonesia.

Indonesia, as one of the archipelagic country in the world, is facing a challenge to fulfil the electricity supply and demand in remote areas and outer islands. In 2017, the electrification ratio was about 95.35%. However, there were some provinces had not reached 65% such as Nusa Tenggara Timur (59.85%) and Papua (61.42%) (Kementerian Energi dan Sumber Daya Mineral, 2017). There are some difficulties of being un-electrified areas such as isolated from knowledge insights and economic growth. Furthermore, the government is looking for the most useful methods to solve these problems; one of them is to utilize more renewable energy as a replacement for fossil fuel.

There are some renewable energy resources such as hydropower, geothermal energy, wind energy, solar energy and so on. Renewable energy resources are significantly worthy because the amount of the reserves is very large and environmentally friendly. Furthermore, the utilization of solar energy is the most favourable alternative since it is cheap, inexhaustible and abundant without any expense. In addition, the utilization is affordable and convenient for rural system.

As a tropical country, Indonesia has lots of solar energy resources. This becomes a way out to electrify the rural area which far from grid electricity (Hidayat, Wahjono, & Nansur, 2011a). Solar energy can be used to generate electrical energy and thermal energy. Recently, it becomes a common use of solar energy to produce electricity or thermal energy only. However, in the last couple of years, solar energy has been applied to generate hybrid energy, namely electricity and thermal energy.

This study presents the development of photovoltaic application in Indonesia which might be useful in improving the utilization of photovoltaic in Indonesia.

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2 ANALYSING ELECTRICITY DEMAND AND AVAILABILITY

There are lots of challenges in electrical operational systems; one of them is maintaining the effective and efficient electrical power supply to the customers, especially in remote islands area which is far away from the sources of power plant. Retnanestri, et, al. 2004 and Akhmad, 2014 examined the sustainability of PV system for rural and remote areas which far from electrical power generation resources by considering the sustainability of economic, social, environmental and institutional dimensions of system (Retnanestri, Outhred, & Healy, 2004), (Akhmad, 2016).

The study of supply and demand in the commercial industry has been done by Oxa, et. al 2012. This study discussed the impact of energy deficiencies on industrial production by analysing energy supply and consumption patterns by developing a model and simulation. The results showed the demand for industrial electricity in the industrial sector based on current conditions and predict industrial electricity demand in the future and how the availability of electrical energy in the future (Oxa & Erma, 2012).

The output voltage of photovoltaic might be unstable; it relies on solar intensity. However, in order to charge the accumulator, the output voltage of photovoltaic must be stable at 14.5 volts. So then, a regulator device such as buck-boost converter is used to govern the output voltage of photovoltaic. Hidayat, et, al. 2011, developed a system to utilize the solar energy to support household electrical energy provided by PLN by using a microcontroller. This system equipped by accumulator, inverter and microcontroller (Hidayat, Wahjono, & Nansur, 2011b).

The application of photovoltaic in a remote island such as in Bengkalis has been done by Custer, et, al 2012. This study carried out a technical and economic analysis of photovoltaic application for housing with a capacity of 900 VA. Analysis consideration based on load requirements, the amount of solar intensity and the capacity of available solar panels. The results concluded that the usage of photovoltaic is relatively expensive but in the future, it is feasible to develop (Custer & Lianda, 2012).

In a small scale of supply and demand, electrical power study has been conducted by Ariani, et, al. 2014. This study analysed the sustainability of communal solar power generation (PLTSA) operation to determine the capacity of the solar power system. This study was conducted in Kaliwungu, Banjarnegara. The results showed that the daily load of 8,922 kWh can be supplied from the PLTS system with capacity of 2.85 kWp (Ariani & Winardi, 2014). Furthermore, Ruskardi, 2015 conducted technical and economic analysis of the off-grid solar system to supply electrical power in Dusun Sedayu. The technical assessments comprised the investigation of solar panel, battery, controller and inverter. While the economic analysis concluded that the energy price is about Rp.13.294,46, - / kWh and the payback period is about 4.01 years (Ruskardi, 2015). While Massarang, 2016 analysed the use of solar energy as the powerhouse at Puro'o village, Sigi. The demand for electrical load was 393,598 Wh / day which was supplied by 459 units of solar panels with the capacity of 250 Wp (Masarrang, 2016).

Another case in Madura, photovoltaic power plant is utilized to improve the sustainability of electrical power supply. Photovoltaic power plant is the best solutions since it is a fast and independent option. Furthermore, in real application, the electrical operating system must be analysed by creating a scenario model to determine the influenced factors and variables to the system. Quentara, et, al. 2017, analysed the electrical operational systems using system dynamics method. This study showed that a Rp 632 billion investment of photovoltaic power plant is needed to supply the electrical power for 58 remote villages in Pamekasan to generate 24,935 MW (Quentara & Suryani, 2017).

One of the advantages of photovoltaic panel that it is compatible with the electricity grid to afford credits and more lessen electricity expenditures. Naim, et, al. 2017 connected photovoltaic panel to a small scale electricity grid. This study designed a 1500 Watt on-grid photovoltaic system in Timampu village (Naim & Wardoyo, 2017). Joewonoo, et, al 2017 linked a 200 Wp solar panel into the electricity grid to drive submersible water pump (Joewono, Sitepu, & Peter R Angka, 2017).

In a large scale of established electricity grid such as in the Java-Madura-Bali (JAMALI) interconnected system, the photovoltaic has a future potential of utilization in supporting the JAMALI grid. Tanoto, et, al. 2017 analysed the potential of future use of PV in JAMALI grid. This study presented a detailed potential of PV output along JAMALI area. The results showed that PV has a significant contribution in fulfilling the demand of electricity in JAMALI area (Tanoto, Macgill, Bruce, & Haghdadi, 2017).

In a couple decades before, the high investment cost of photovoltaic installation made these devices were not attractive compared with the fossil fuel power generation. However, it is predicted that photovoltaic would be competitive against conventional power generation. Rahardjo, et, al. 2005 developed a MARKAL model to predict the competitiveness of photovoltaic in the future. The result of this study showed that the installed photovoltaic capacity would increase dramatically about four times in the year 2030 and would substitute the fossil-based power plant in some region in Indonesia (Rahardjo & Fitriana, 2005).

Based on these studies, it is cleared that the use of photovoltaic is feasible to fulfil the demand for electrical power in rural and remote areas in Indonesia.

3 THE STRATEGY OF PHOTOVOLTAIC IMPLEMENTATION

The utilization of photovoltaic system in Indonesia has been implemented in three stages: the first is the demonstration stage, the second is a repetition of demonstration stage and the third is the spreading stage (Dasuki, Djamin, & Lubis, 2001). Those programs had been done under a bilateral cooperation project. For example, the cooperation between the government of Indonesia and Germany, Dutch, Australia, Japan and World Bank had supported thousands units of photovoltaic for lighting, irrigation system, refrigerator system, public TV, street lights and solar home systems in remote and rural areas.

Recently, solar energy-based is commonly taken into account to be a reliable resolution for rural electrification. Unfortunately, the spread of the use of photovoltaic in Indonesia is quite low. With regard to scale-up, the dissemination of photovoltaic, private investments support are required. Schmidt, et, al. 2013 investigated the viewpoint of the risk/return projects in Indonesia. The findings stated that positive returns of solar energy could be achieved. The risk aspect could be minimized by choosing the appropriate business model. This study also mentioned that the government need to take action regarding enhance the risk/return outline, so then the photovoltaic project in Indonesia would be more attractive (Schmidt, Blum, & Sryantoro Wakeling, 2013).

The government has established two most important programs with regard to provide electricity in rural area; those are Super Extra Energy Saving that is financed by PLN and Solar Home System which belongs to the Ministry of Energy and Mineral Resources. Based on the East Nusa Tenggara experiences, it is clear that the government has to initiate some actions in order to synchronize the rules of administrative, financial and technical (Sambodo, 2015).

4 THE APPLICATION OF PHOTOVOLTAIC IN INDONESIA

4.1 Photovoltaic Manufacturing

A photovoltaic system includes the photovoltaic panel, energy storage, inverter and controller. The technology development of each sub-system has been well established by national industry except photovoltaic panel. Photovoltaic manufacturing in Indonesia resumed in 2009, however, national industry has a focus on the solar panel assembly where solar panel components such as photovoltaic panel, glass and frames are imported from abroad (Kumara, 2010).

From raw material point of view, Indonesia has an abundance of silica which is a vital substance in photovoltaic panel fabrication. Moreover, the government of Indonesia stated that will support photovoltaic manufacturing to fulfil the national demand (PT. Perusahaan Listrik Negara, 2019).

4.2 Photovoltaic Operational Setting

In order to increase the effectiveness of collecting solar radiation, the photovoltaic have to face the sun perpendicularly. So, the photovoltaic must always follow the sun's movement by using a solar tracker system. Manan, 2009, and Ramadhan, 2016 developed a solar tracker system to optimise received solar radiation on photovoltaic (Manan, 2009), (Ramadhan, Diniardi, & Mukti, 2016). While Ubaidillah, et, al. 2012 developed a solar tracker system by using microcontroller. The result showed that the average power output is 10% higher than the static panel (Ubaidilllah, Suyitno, & Juwana, 2012).

In terms of the position on earth, the inclination angle of the photovoltaic panel would be varied. Pangestuningtyas, et, al. 2013 analysed the influence of the inclination angle of the photovoltaic panel. This study was conducted in Semarang. This study concluded that the variation of the inclination angle of the photovoltaic panel depends on the position of the sun. it varies from 1□ to 24□ in wet and dry seasons, respectively (Pangestuningtyas, Hermawan, & Karnoto, 2013).

Other efforts to improve the performance of solar cells are also carried out by adding solar collectors. Ilyas, S, et, al. 2017 presented an experimental study to enhance the performance of the solar power plant. This study utilized two parabolic reflectors and showed an increase in efficiency for about 1.3% (Ilyas & Kasim, 2017).

Installation of photovoltaic can be applied in a centralized and distributed installation. Widiyantoro, 2015, discussed the comparison of the results of the efficiency and economic aspects between centrally installed photovoltaic and distributed installed photovoltaic (Widiyantoro, 2015).

4.3 Photovoltaic Electrical Power Generation

Photovoltaic is a device to generates electrical power by converting solar radiation. The generated electrical power could be used directly for any electrical appliances or stored in a battery. It is worthy that photovoltaic could be used for photovoltaic for lighting, irrigation system, refrigerator system, public TV, street lights and solar home systems.

The common use of photovoltaic is for solar home system to supply electrical power for home appliances. As'ari, et, al. 2014 and Bachtiar, 2016 proposed a procedure of designing a solar home system. The result of the study could be a reference of the user to determine the specifications of the photovoltaic panel that can satisfy the electrical demand of a house (Asy'ari, Rozaq, & Putra, 2014), (Bachtiar, 2016). While Abidin, et al. 2017 conducted an implementation study of photovoltaic for street lighting system in Lamongan Regency. This study also installed an optical concentrator in order to increase the efficiency which achieve an increase of 15% (Abidin & Bachri, 2017).

In the agriculture and farming industry, photovoltaic also has a significant contribution to supply electric power. Subandi, et, al. 2015 and Joewono, et, al. 2017 discussed the implementation of photovoltaic in driving the water pump. Those experimental studies included photovoltaic, battery and solar charger controller (Joewono et al., 2017), (Subandi & Hani, 2015). Those studies concluded that the photovoltaic is compatible to supply electrical power for agriculture purposes.

Another application of photovoltaic in Indonesia is conducted by Julisman, et al. 2017. The aim of this study is to develop a prototype of an automatic system of open-close stadium roof. The source of electrical power is from 50 Wp photovoltaic. The system includes a microcontroller and electrical motor (Julisman, Sara, & Siregar, 2017).

4.4 Photovoltaic/Thermal (PV/T)

Combinations of photovoltaic and solar thermal modules are called photovoltaic/thermal (PV/T). This combined system generates electricity and heat simultaneously. PV/T is made up of thermal collectors and PV layer.

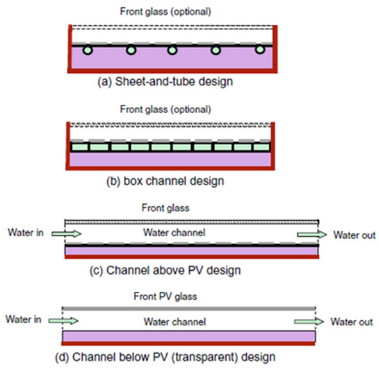

Figure 1. Cross-section of PV/T (Chow, 2010)

The thermal collectors absorb heat then transported away by air or water as working fluids, and simultaneously the photovoltaic modules generate electricity (Jia, Alva, & Fang, 2019). This combined system enhances the efficiency of the PV systems. The schematic of PV/T is as shown in Figure 1.

One of the benefits of PV/T is reducing the PV temperatures which increase the efficiency of electrical power generation. This results as can be proven by a study conducted by Subarkah, et al. 2014. The study showed that the PV temperatures decrease up to 8□C and the efficiency increase as 1.6% (Subarkah et al., 2015). Another PV/T study was conducted by Ubaidillah, et, al. 2012 which designed and built up the power scale household utilise the photovoltaic and thermoelectric cells of solar radiation (Ubaidilllah et al., 2012).

5 CONCLUSIONS

Indonesia has abundant solar energy potential because it is located near the equator. To reduce dependence on fossil energy sources, the government began to promote renewable energy sources; one of them is solar energy. Several studies on the potential of solar energy prove that solar energy can be relied upon as an energy source in the future.

The government has made a strategy for implementing solar energy by issuing regulations and also cooperating with private parties and foreign countries. The production of solar panels is also being encouraged, at this time the national industry has been able to produce solar panels with a composition of local content that continues to increase. However, the dissemination of photovoltaic are quite low and need to be encouraged by private investment support. At the same time, the government has to be more active in synchronising the rules in technical, administrative and financial point of views.

Technically the use of solar panels is well understood. Several studies on equipment settings have been carried out to determine the orientation of the solar panels. The research to analyse the main function of photovoltaic for generating electrical power has also been carried out. For examples are for household electricity and street lighting and other automation systems. Additional advantages of photovoltaic technology to absorbing heat have been proposed in several studies on photovoltaic/thermal.

Furthermore, there are some potential improvements in the photovoltaic application in Indonesia. Such as the utilization of heat energy which comes with the photovoltaic. The knowledge of absorbing heat from the photovoltaic surface need to be explored more. Thermosyphon and heat pipe could be introduced as a superconductor. Moreover, the lacks of potential land area need to be solved by presenting the floating photovoltaic. It means that the photovoltaic is installed on the surface of the water such as in lake, pond or sea.

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