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The Development of Photovoltaic Power Plant for Electricity Demand Fulfillment in Remote Regional of Madura Island using System Dynamics Model

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Abstract

The main problem of the electrical operational systems in Indonesia is how to maintain the continuity of effective and efficient services to the customers and meet the supply and demand for electrical power, particularly a lot of islands area in Indonesia are far distant from the power generation sources. Based on these problems, it is cleared that an electricity system is required for long-term solutions so that it can enhance the role of new and renewable energy, improve the electricity reliability and reduce the energy costs. Efficiency and effectiveness is expected to increase the sustainable electricity supply for remote and isolated area in Madura island by utilizing the available resources like potential solar energy as a new and renewable energy. The development of photovoltaic power plant is a fast and independent solution because the access and infrastructure in Madura island doesn't support yet for the conventional electrical facilities. System dynamics method is used to analyse the system by creating a scenario model to identify any factors and variables which affect the system. As the result of the scenario model, total demand for electricity supply in the 58 remote villages in Pamekasan is 24,935 MW, which cost Rp 632.812.500.000,- for the photovoltaic power plant investment. To complete the analysis feasibility in order to meet the fulfilment, it is also considered economics aspect with Payback Period, which is need 25 years to return the investment in optimistic scenario.

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Keywords: System Dynamics; Scenario; Electrification Ratio; Photovoltaic Power Plant; Electricity Supply and Demand

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1. Introduction

Indonesia is a vast archipelagic country, that's why the fulfillment of electricity supply and demand in remote areas, outer islands, and border areas is an important issue that requires a special review in its completion [2][5]. People in un-electrified areas tend to be isolated from economic developments, knowledge insights, and technology advances. In 2008, an articles of Indonesia Government Electricity Association (PLN) states in point number 3 that the purpose and business field is to provide electricity supply business for the public interest in sufficient quantity and quality as a form of implementation the Government's duties in order to support the national development [23]. Electrification ratio value showed increasing chart in Indonesia over the last five years (2010-2014). At the end of 2014 the ratio has reached 81.70%, which is 74.41% for Indonesia outside Java and 86, 69% for the Java island [3]. In 2015 there are still provinces in Indonesia with electrification ratio below 50%, Jambi (43.88%) and Papua (47.21%), whereas for Jakarta the capital region of Indonesia and its surroundings has been reached 100%.

Nowadays, the condition of East Java's electricity supply in 2016 still has surplus around 2,600 MW (Mega Watt) and the excess is channeled to West Java, Central Java, and Bali. Although in 2013 the electrification ratio of East Java was still 79.21%, then increased to 83.14% in 2014, and by the end of 2015 has reached 86.67% [18]. The number of new demand for electricity in 2014 of 605,832 households has decreased from the year 2013 which amounted to 657,536 households, but because of the electricity supply and demand that can't be met, this caused the waiting list surge from the previous 30,920 households in 2013 increased to 45,296 households by the end of 2014. However, the amount of electricity surplus is still very possible to increase the supply for Situbondo area whose electrification ratio is still 64.88% and also for Madura in particular. This program will support the achievement of 100% national electrification ratio target in 2020 by the government.

For Madura region its self, from a total of 219,439 households, which has been electrified is only about 129,522. The electrification ratio in 2014 reached only 59.02%, which increased to 60.55% by the end of 2015. But for the archipelago region, the electrification ratio still has not touched 40%. Data from the Department of Energy of Human Resources of East Java Province as December 2015 stated that the number of un-electrified villages in Madura spread in 4 districts, namely 50 villages in Bangkalan Regency, 78 villages in Sampang Regency, 58 villages in Pamekasan District, and 32 Village in Sumenep regency [21] [22] [24] [25]. Prior to the construction of the Suramadu bridge, which connected Java Island and Madura, in 2010, the available of electricity supply in Madura was 80MW, increasing to 200MW in 2012, and going to 260MW by the earlier 2016.

The majority of the un-electrified villages are on the North Coast of Madura (Pantura) and also some unreached islands from the main electricity source. For the archipelago, five islands are powered by Diesel Power Plant (PLTD), including Sapeken, Gili Genting, Mandangin which have been operating for 24 hours, while Kangean and Sapudi are still operating for 12 hours only. Based on data at the PLN office in Pamekasan area that takes care whole electricity operational in Madura, the uneven flow of electricity in the southern and northern regions is caused by the less supportive road infrastructure. Powerful electricity is in the southern region of Madura because the transmission networks are built in the south, ranging from Suramadu, Bangkalan, Blega, Sampang, Pamekasan and Sumenep. To provide the services to the northern region, namely Ambunten, Waru, Ketapang and Tanjung Baru, PLN requires long power lines for infrastructure revamping process. Madura topography becomes an investment constraint in building electricity infrastructure because in one village has only about 10 houses, and the distance of the villages are far from each other [11]. In addition to many villages located in the highlands and also some islands that are difficult to reach.

According to Solarex (1996), Indonesia as a tropical country has high solar energy potential with an average radiation of 4.5 kWh2 / m2 / day - 5.0 kWh2 / m2 / day, which means for 1 Kw photovoltaic (PV) can produce 4 to 5 kWh of electrical energy in one day [7]. These, became an advantage solution for PLN to build up some photovoltaic power plants in order to electrified the remote areas in Madura Island which far from the main power generation sources. The independency of photovoltaic power plant by processing the solar potency into electricity is a new trend in Indonesia to overcome the un-electrified islands [4].

From the observation of the situation, conditions and issues in electrical operational system in Indonesia, the research questions are: (1). How is the fulfillment condition of the electricity demand in remote area Madura Island? (2). What are the constraints and obstacles for electricity supply? (3). What kind of renewable power plant could be invested in remote area and how many capacity is needed?