Preliminary Study of Solar Energy Utilization for Rural Electrical Energy. Case Studies in Central Kalimantan

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***Abstract*— Indonesia gradually improves the electricity system's reliability and reaches the areas which contain frontier, outermost and underdeveloped areas by utilizing local energy potential. It can be done independently and in groups to meet the need for electrical energy in remote villages. Electrical power is obtained from generators and solar modules installed in each resident's house, where the capacity and quality are minimal. The initial study was completed in 2019 and took place in Central Kalimantan province, divided into three districts consisting of ten villages. Access to the village is a challenge in satisfying electrical energy needs, so alternatives are needed to meet the demands of electrical energy for areas that are difficult to reach by the electricity network. The solar power plant is one alternative to using new and renewable energy. The State Electric Company is an Indonesian state-owned enterprise that generates, transmits, and distributes electric power which also responsible to provide the electricity network in Indonesia. This study's village information was obtained from the survey results, village energy needs, and costs incurred when the solar power system was installed.**

Keywords*— *Central Kalimantan Electricity, New Renewable Energy, Solar Power Plants

I. INTRODUCTION

A. Overview of Central Kalimantan Province

Central Kalimantan, abbreviated as Kalteng, is one of the provinces in Indonesia located on the island of Kalimantan and has the capital city of Palangkaraya. The province of Central Kalimantan is located between 0°45' North Latitude and 3°30' South Latitude and 110°45'−115°51' East Longitude. Central Kalimantan is a province with the second largest area in Indonesia after Papua Province. The location of Central Kalimantan is 153,564 km^2, or 8.04 percent of the total area of Indonesia.

The administrative area of Central Kalimantan Province is divided into thirteen districts and one capital city. West Kalimantan and East Kalimantan border the northern part of Central Kalimantan province, East Kalimantan and South Kalimantan border the eastern part, the java sea borders the southern region, and west Kalimantan binds the western part. Central Kalimantan has eleven significant rivers and thirty-three small rivers that originate from the north and flow into the java sea. The Barito river is the longest in central Kalimantan, which a length of up to 900 km. The rivers are an essential mode of transportation in central Kalimantan, so the coastal area of the river becomes the primary location for settlement.

The electrification ratio is the ratio of the number of households that have electricity to the total number of households. Regarding the information of the Mining and Energy Office in central Kalimantan province in 2019, there are five provinces in Kalimantan that recorded central Kalimantan province had the smallest Electrification Ratio of 94.60% and the highest number south Kalimantan province with the number of 99.10%. Central Kalimantan is separated into 565,949 households, and the number of non-the state electric company electricity is around 65,000. This is a problem for the government to immediately expand the Electrification Ratio so that the distribution of electrical energy needs is evenly distributed throughout Indonesia, especially in the province of Central Kalimantan.

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B. Village Location Information

The initial survey was conducted in 2019 in three districts of ten villages in the province of Central Kalimantan. The selection of villages is based on remote locations where the electricity conditions of villages are difficult to reach by the electricity network of the state electric company due to inadequate access and infrastructure. The State Electric Company does not yet have a long or short-term plan to supply electrical energy to meet electricity needs in the area. In this issue, the team previously coordinated with the Central Kalimantan Electricity Project Development Unit regarding the electricity plan in place and coordinated with the Mining and Energy Office of Central Kalimantan Province regarding village information in the Central Kalimantan region.

One of the advantages of the electricity system for the area is using the solar power plant, alternative energy that is efficient, simple, and environmentally friendly without causing pollution. The solar power plant has two types of models, namely the distributed and the centralized model. The distributed model is more appropriate for settlements relatively far from one house to another. At the same time, the solar power plant model is more suitable for clustered settlements (communal).

The solar power plant is planned to be installed in ten villages, while the candidate villages have been surveyed, as shown in Table I. The United Nations Development Program (UNDP) will fund the solar power plant development plan, collaborating with the Ministry of Energy and Mineral Resources. However, based on information from the Mining and Energy Office of Central Kalimantan Province, three villages have the solar power plant installed, namely Sungai Tuat Village, Ginih Village, and Tanjung Beringin Village through the 2019 funding, and surveys are still being carried out for these three villages by the team.

TABLE I. PROSPECTIVE LOCATION OF THE SOLAR POWER PLANT DEVELOPMENT

No.	Districts	Sub-Districts	Village
1	South Barito	Dusun Selatan	Muara Ripung
2		Gunung Bintang Awai	Bintang Ara (Malungai Dalam)
3	Kapuas	Kapuas Hulu	Supang
4		Kapuas Tengah	Bajuh
5	Lamandau	Bulik Timur	Batu Tunggal
6		Bulik	Tamiang
7		Batang Kawa	Karang Mas
8			Ginih
9		Lamandau	Sungai Tuat
10			Tanjung Beringin

Currently, the source of electrical energy is obtained from generators and mini solar modules which installed in each resident's house, where the capacity and quality are minimal specifications. Some generators operate at 18.00 local time, and typically, they work 3 to 4 hours daily. The operational costs of the generator are prohibitive, and the problem is limited gasoline numbers. The other obstacle to the inaccessibility of the electricity network to the prospect villages for solar power plant location is because the distance from the city center is relatively far, and the road infrastructure is still inadequate. The detail of the site can be seen in Fig. 1.

FIG. 1. THE CANDIDATE OF THE SOLAR POWER PLANT LOCATIONS

The plan for developing the Solar Power Plant in Central Kalimantan Province is spread over three regencies, including Lamandau Regency: Karang Mas Village, Batu Tunggal Village, Tanjung Beringin Village, Sungai Tuat Village, Ginih Village, and Tamiang Village. The South Barito Regency is Bintang Ara Village and Muara Ripung Villages, while for Kapuas Regency is Supang Village and Bajuh Village.

II. METHODOLOGY

In carrying out this feasibility study project, the methodologies used include study preparation, secondary data collection where can be collect from Central Agency on Statistics. Primary data collection at the survey location, all information obtained includes the number of houses, the number of heads of families and the location of the solar power plant placement. After all data is collected, analysis is carried out covering all technical aspects and load requirements. The final stage of this project work is reporting, where all calculations are presented as consideration for further detailed feasibility studies.

III. SURVEY RESULT

A. Location, Access, and Availability of the Electric Network

The development Plan for the solar power plant is divided into three districts in Central Kalimantan. The South Barito Regency location consists of Muara Ripung and Bintang Ara Village; The Kapuas Regency area consists of Supang Village and Bajuh Village, and The Lamandau Regency area consists of Batu Tunggal Village, Tamiang Village, and Karang Mas Village. The distance from the district capital to the villages is relatively far, either by land or river transportation, and carries quite a long duration. So, to carry out a survey in Lamandau Regency, the team was divided into two teams that stayed in Lamandau Regency and the city of Palangkaraya. The electricity network is also included in the calculation as a long and short-term plan related to connecting state electric companies to the location. In particular, the general description of the area of the solar power located in the province of Central Kalimantan can be seen in Table II.

TABLE II . VILLAGE LOCATION DETAILS AND ACCESSBILITY

Village	Coordinate Location	Personnel and Material Construction Access	Nearest Electricity Network
Muara Ripung	S 1º 40' 975" E 114º 48' 716"	The distance is 190 km from Palangkaraya and can be reached by land also the Barito River.	Mabuan village and Buntok City.
Bintang Ara	S 1º 59' 518" E 111º 25' 185"	The distance is 287 km from Palangkaraya and can be reached by land	Malungai Raya Village is 7 km away.
Supang	S 1º 00' 689" E 114º 03' 535"	The distance is 178 km from Palangkaraya and can be reached by land	The District of Sei Hanyu' is 17 km away.
Bajuh	S 1º 26' 076" E 115º 15' 673"	The distance is 204 km from Palangkaraya and can be reached by land	The urban village of Pujon is 17 km away.
Batu Tunggal	S 1º 59' 815" E 111º 25' 442"	The distance is 488 km from Palangkaraya and can be reached by land	Melata village is 30 km away.
Tamiang	S 1º 33' 212" E 111º 12' 716"	The distance is 531 km from Palangkaraya and can be reached by land.	kabupaten Nanga Bulik city is 30 km away
Karang Mas	S 1º 49' 889" E 111 39' 292"	The distance is 545 km from Palangkaraya and can be reached by land and the Barito River.	kudangan village is 60 km away.

B. Socio-Economic and Environmental

The survey was conducted to obtain primary data, which was utilized in the technical design of the solar power plant to calculate the capacity of the system to be installed. The results of the survey can be seen in Table III.

TABLE III. SOCIAL ECONOMIC AND ENVIRONMENTAL SURVEY

No	Survey Data	Muara Ripung	Bintang Ara	Supang	Bajuh	Batu Tunggal	Tamiang	Karang Mas
1	Number of houses	114	93	416	310	235	147	70
2	Number of Head of Families	157	88	431	477	251	189	75
3	Number of Population							
	Man	232	189	865	620	383	358	85
	Woman	268	139	792	591	339	256	77
	Widow	21	9	20	20	10	25	10
4	Public Facilities	12	7	13	14	12	13	7
5	Number of Public Street Lighting	-						7
6	Dimension of Houses (meter)	4 x 12	5 x 10	6 x 10	6 x 10	5 x 12	6 x 10	4 x 8
7	Land availability (m^2)	2500		3000	2500	3250	2500	

In the villages surveyed, the lives of the people of Central Kalimantan Province are diverse, whereas people in South Barito Regency rely on livelihoods from farming and fishing. In contrast, people in Kapuas Regency rely more on traditional gold mining. People in Lamandau Regency rely on the oil palm sector.

IV. SPECIFICATIONS AND TECHNICAL DESIGN

A. Technical Specification

The leading equipment of the solar power plant consists of photovoltaic (PV) modules, batteries, battery controllers (Solar Charge Controller), inverters, low voltage distribution networks, home connections, and customer installations. The technical specifications of the main components of the solar power plant operated are as follows:

1. Photovoltaic Cells and Modules

Photovoltaic cells convert solar radiation into electricity and obtain the desired power and voltage. Photovoltaic cells are connected in series, parallel, or a series-parallel combination and laminated to form a single circuit called a photovoltaic module. The technical specifications are as follows:

- Type : Mono/Polycrystalline
- Tolerance : + 5%
- Efficiency : 15~16%
- Working Voltage : 24 Vdc
- Power : 330 Wp
- Nominal Voltage : > 32 Vdc
- Max Current : > 8.8 Amp
- Warranty : Minimum 20 years

2. Battery

Batteries perform two important purposes in photovoltaic systems: to provide electrical power to the system when the array of solar panels does not supply energy and to store the excess power generated by the panels whenever the power is exceeded. The technical specifications are as follows:

- Type : Deep Cycle, OpzV Battery
- Technology : Valve Regulated Lead Acid
- Capacity : 2 VDC 1000 Ah
- Efficiency : 15~16%
- Certification : Indonesian National Standard
- Technical life : 10 years at an ambient temperature of 20° C
- Cycling ability : minimum 1200 cycles at 80% DOD

3. Inverter

The inverter is a device that converts direct current (DC) generated by the photovoltaic module system and stored in the battery into alternating current (AC) so that it can be distributed and used to satisfy electricity needs as provided by conventional generators. (diesel generator from the state electric company). The technical specifications are as follows:

- Capacity : Adapted to load requirements
- Input voltage : 48 ~ 240 Vdc, adjusted to the battery voltage
- Output Voltage : 220/230 VAC for 1 phase and 380 VAC for 3 phase.
- Waveform : Pure Sine Wave
- Total Harmonic Distortion : < 3%
- Frequency : 50 Hz
- Efficiency : > 95%
- Warranty : Minimum 3 Years
- Completeness : Display, Data Logger, and Remote Monitoring System.

4. Solar Charge Controller

The function of the battery controller, in general, is as follows:

- The controller regulates the energy transfer between the load, battery and photovoltaic module efficiently and as much as possible.
- Prevent the battery from overcharging and under-discharge.

a. Over Charge: Disconnection of charging (charging) the battery at the upper voltage to avoid gasing, which can cause evaporation of battery water and corrosion of the battery grid.
b. Under Discharge: Termination of discharging (discharging) the battery at the lower limit voltage to avoid overloading, which can cause sulfonation of the battery.

- Limiting the working voltage area of the battery.
- Extend battery life.
- Protects against reverse polarity errors.
- Provide system condition information to the user

The technical specifications of solar charge controller are as follows:

- Capacity : Customize by user.
- Input Voltage : Adjusted to the solar module array voltage
- Battery Input Voltage : Minimum 48 Vdc
- Charge Control : Maximum Power Point Tracking (MPPT)
- Efficiency : > 93%
- Warranty : Minimum 3 Years
- Display : Data Logger and battery temperature sensor.

B. Technical Design

Technically, the calculation of the required solar power plant capacity for locations in Central Kalimantan province has been obtained through primary survey data and technical specifications, so the calculation of the required solar power plant capacity for each component includes:

1. Total load requirement.
   The total load requirement is needed to calculate the required large kWp capacity. In this estimation, the energy needs of each village are different, calculated based on the capability of the residents and the resulting contributions. Energy is divided according to per house, public facilities, public street lighting, productive economy, and energy needs in the powerhouse. Energy reserves and system losses get a portion of the energy to be calculated into the total demand, where the values are 30% and 10%, respectively.
2. Solar module capacity requirement
   In determining the capacity, the photovoltaic needs of solar cells are taken based on the minimum value of solar insulation. The value of the sundial in the calculation used is 4 hours of sunshine, and the coefficient of environmental temperature with a value of 0.8.

$$Number\ of\ PV = \frac{Energy\ Requirement\ per\ day}{(PV\ Capacity \times Sundial \times 0.8)} \quad (1)$$

3. Battery capacity requirement
   The battery requirement must be the same as the energy produced by the photovoltaic solar module due to the amount of Depth Of Discharge (DOD), in which the battery is 80%, and the calculation of the number of days without the sun is 2 days.

$$Number\ of\ Ah\ Energy = \frac{Energy\ Requirement\ per\ day}{System\ voltage} \quad (2)$$

$$Ah\ Requirement = \frac{Number\ of\ Ah\ Energy \times days\ without\ the\ sun}{Depth\ of\ Discharge} \quad (3)$$

$$Total\ Battery = \frac{Ah\ Requirement}{Battery\ Ah\ Capacity} \quad (4)$$

4. Inverter and Solar Charge Controller capacity requirements
   The inverter used is an inverter whose capacity is the same as the maximum power capacity of the photovoltaic solar module. Generally, the capacity is around 10, 30, 50, and 100 kVA.
5. Management Aspect
   The Construction of the solar power system, operation, and maintenance of the network requires the support of residents appointed and trusted to implement and operate the solar power system. Periodic solar power system maintenance requires all villagers' active role by charging monthly household fees.

Based on the data from the social, economic, and environmental surveys at the site, including several technical designs from the parameters above, the data obtained from the analysis of the solar photovoltaic system requirements for each location can be seen in Table 4.

TABLE IV. TECHNICAL DESIGN AND OPERATIONAL COSTS

No	Survey Data	Muara Ripung	Bintang Ara	Supang	Bajuh	Batu Tunggal	Tamiang	Karang Mas
1	Total Energy Load per day (Wh)	186,336.15	85,360.28	510,712.70	464,117.40	265,630.37	170,029.86	70,345.28
2	Capacity of PV System (kWp)	60	30	180	150	85	55	25
3	Number of Photovoltaic	212	97	580	527	302	194	80
4	Number of Battery	240	48	480	480	360	240	48
5	Electricity Production (MWh/year)	78.828	39.439	211.18	197.09	109.73	72.104	28.842
6	Contribution per family (IDR/month)	190,000	120,000	115,000	151,000	145,000	150,000	150,000

V. CONCLUSION

1. Technically, a survey conducted for seven village locations that did not yet have electricity in the province of Central Kalimantan has a reasonable value for constructing the solar power system to satisfy rural communities' energy necessities. This issue can be seen in the availability of land to construct solar power systems. The village officials included the village communities' support for the construction of the solar power plant by marking the location through a land certificate and a letter of willingness to build the solar power plant.
2. Regarding the socio-economic aspects of the villages surveyed, the lives of the people of Central Kalimantan Province are diverse. In contrast, people in South Barito Regency rely on livelihoods from farming and fishing. In contrast, people in Kapuas Regency rely more on traditional gold mining, and people in Kapuas Regency rely more on conventional gold mining. Lamandau

Regency relies on the palm oil sector, where the large area is the palm field.

3. All surveyed villages need the solar power system in general. The problem is based on the condition of settlements in groups, the number of customers and public facilities that are a pretty lot, as well as the socio-economic conditions of each village that are able and willing to manage, operate and maintain the solar power plant by agreeing with monthly fees as a form of profound commitment for the development of the solar power plant.
4. Regarding the survey results, the capacity of the solar power system is obtained where the smallest capacity is 25 kWp for Karang Mas Village, and the largest capacity is 580 kWp for Supang Village.
5. The analysis of cost energy is carried out through two funding scenarios, namely the Grant and the Business scenarios. The scenarios can be used in the future to fulfill the growing load that will increase yearly.

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