ISSN No:-2456-2165

Implementation of 100% Electric Vehicle in Bali with the Supply of Potential Independent Solar Energy

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Abstract:- Electrical Vehicle is the future of transportation. This thesis is about how to transform the usage of fossil fuel vehicle to electrical vehicle in Bali. Bali is an island with the longest distance from one of its districts to Denpasar city is 95,6 km. This distance is reachable by the common electrical vehicle that available in the market now. The usage of the electrical vehicle requires good development and planning, otherwise it will cause problem for the electrical systems. The consumption of electrical energy will increase. In 2019, Bali used 5,908 GWh electricity in a year. And if all the 2 wheels and 4-wheels vehicles now are electrical vehicle, it will require extra 2,823 GWh per year. It will impact the planning of power generation in Bali.

Another challenge for the electrical systems is the duck curve problem. The habit of the user charges their vehicle will also impact the daily load curve of an electrical systems. If all the two wheels and four wheels vehicles now are electrical vehicle, and all users conduct the charging at the same time in 4 hours duration, the load will increase about 1,934 GW. The practical and applicable solution is the independent power producer concept by the solar PV. If every electric vehicle user installs the solar PV for their electrical vehicle consumption, this will solve all the problem.

Keywords:- *Electric Vehicle, Green Energy, Solar PV, Independent Power Producer, Load Forecasting.*

I. INTRODUCTION

Electric vehicle is the future of land transportation, it is currently the most promising technology due to economic and environmental benefit [1] [2]. Bali is one of an Island in Indonesia that suitable to start implement electric vehicle, by its geography and the tourisms aspect. Bali is an Island of 5,780 kilo meter square. Bali has nine districts, and Denpasar as the city or capital. The farthest district to Denpasar is 95.16 kilo meter. See table 1 for the distance every district to Denpasar city.

TABLE I. Bali district area and distance to Denpasar [2]

District/ City	Distance to Denpasar (km)	Area (km^2)
Jembrana	95.16	848.80
Tabanan	20.88	1,013.88
Badung	6.50	418.62
Gianyar	26.73	368.00
Klungkung	39.70	315.00
Bangli	41.39	490.71
Karangasem	77.60	839.54
Buleleng	78.00	1,364.73
Denpasar	0.00	127.78
Total		5,780.06

Bali has 4.3 million population, and about 50% of the population stay in Badung, Gianyar and Denpasar. So, most of the activity of 50% of the population are in these three districts. It is reflected from most of tourism activities and the hotels in Bali are in that area.

TABLE II. Bali Population

District/City	2010 (thousand)	2019 (thousand)
Jembrana	262.6	278.1
Tabanan	422.3	445.7
Badung	546.7	670.2
Gianyar	471.6	512.2
Klungkung	171.1	179.1
Bangli	216.1	227.3
Karangasem	397.8	416.6
Buleleng	626.2	660.6
Denpasar	793.0	947.1
Total	3,907.4	4,336.9

The distance from Badung and Gianyar to Denpasar are only 6.5 and 26.73 km. It is reachable by using the electric vehicle that available in the market. Based on the data from Table I and the Figure I Bali map, we can state that Bali is ideal area to implement or start using the vehicle car.

ISSN No:-2456-2165

It is aligned with what Indonesia government had promoted during the APEC conference in 2013. Indonesia government promoted green energy concept and use the electric car. A charging station had been built near the conference are at that time.

Sooner or later the fossil fuel vehicle will be change by the electric vehicle. The electric systems need to be ready to support the usage of electrical energy. Bali island electric systems has the peak load about 966 MW with 78.92% load factor in 2019 before the covid-19 pandemic.

Fig. I. Bali Island District [2]

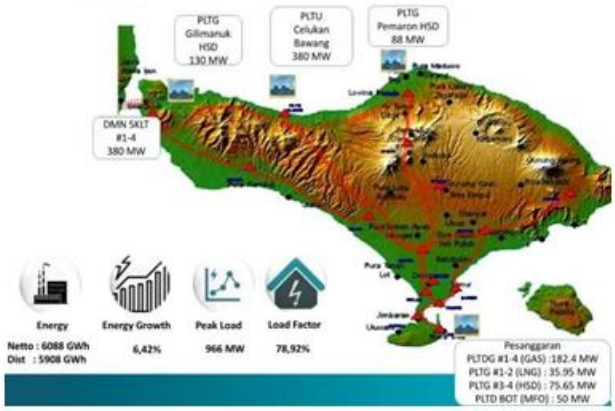

Figure II. Bali 2019 Electricity Data

In figure III, we can see the load curve on January 29th, 2021.The peak load was 980 MW at 7-8 pm.

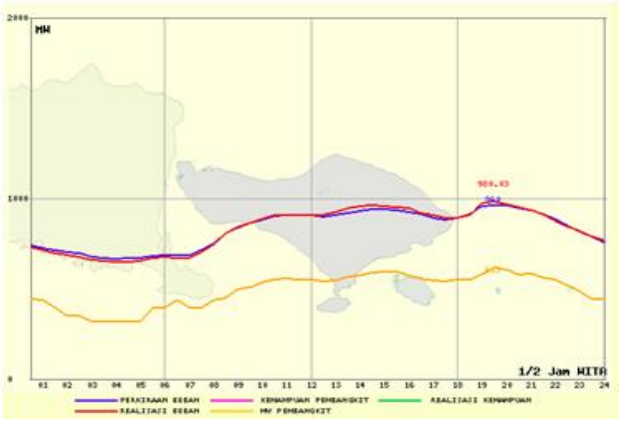

Figure III. Load Curve Bali Island

The electrical systems need to be ready for increasement of capacity needed to support electric vehicle. A forecast or calculation need to be done for the planning. Electric vehiclewill need big numbers of electricity [3] [4] [5] [7]. Another problem also the habit of electric vehicle user on charging the electric vehicle will impact the load curve. The power factor in Bali now is about 78.92%. If the electric vehicles users charge in the same time, it will make a duck curve in the systems. And it will become a problem for the systems to be efficient. An analysis and planning need to be done well.

II. RESEARCH METHODOLOGY

This research will calculate the energy needed if all the conventional two wheels and four wheels vehicles in Bali island convert to electrical vehicle. TABLE *III* show us the quantity of the vehicles in Bali by year. In this research, it only counts two wheels vehicle and four wheels vehicle in 2019.

TABLE III. Quantity of several type vehicles (000 units)

Type	2014	2015	2016	2017	2018	2019
Bus	7	7	8	8	9	9
Truck	124	133	138	143	148	154
2 wheels	2,811	3,015	3,185	3,337	3,517	3,739
4 wheels	326	350	372	397	423	450
Total	3,268	3,506	3,725	3,907	4,118	4,353

After the energy needed is calculated, to review if the Bali electricity systems, capacity and the planning of the systems are capable to accommodate the usage of electric vehicle.

A. Economic Comparison

This research will do the cost comparison between the cost of energy for conventional vehicle and electric vehicle. For the conventional vehicle, we can calculate the petroleum consumption for two wheels and four wheels vehicles.

And for the electric vehicles we can find out the electric vehicle electric energy consumption for each two wheels vehicle and four wheels vehicle. In this paper, it is assumed to use solar PV independent power producer in house level to produce the electrical energy.

B. Solar Energy

Bali has big potential of solar energy. It might be a source of energy for the electric vehicle energy consumption. Solar energy is clean energy, this will help to sustain the tourisms industry in Bali that based on nature.

Based on the study Bali has potential of solar energy about 98,738 GWh per year, which mean that average 270 GWh perday [6]. This might be enough for the electric energy requirement in Bali including electric vehicle energy requirement. It can create Bali 100% renewable energy for domestic house consumption including the transportation [7].

ISSN No:-2456-2165

III. RESULT AND DISCUSSION

A study that had been made before, the electrical vehicle energy consumption are 0.033 kWh/km for 2 wheels scooter type, and 4 wheels is from 0.084 kWh/km until 0.165 kWh/kmfor different type of vehicle and driving mode. [8] In Indonesia, blue bird taxi operator has been using electrical vehicle, BYD and Tesla. Another type of 4 wheels electric vehicle that available in Indonesia market are Hyundai Kona and Hyundai Ioniq. By energy per km, these both types are more energy efficient, compare to BYD and Tesla type that used by Blue Bird taxi. The comparation is shown in TABLE IV.

For two wheels vehicle, Indonesia government have been promoting and supporting for two wheels vehicle production, Gesit. It is still quite less decent option for 2 wheels vehicle that available in Indonesia motorbike market. So, this research try to see what is the electric motorbike specification that offer by the big brand such as Harley Davidson and vespa. The datais available in TABLE *V*.

TABLE IV. 4 Wheels Electric Vehicle Energy Consumption

Type	Battery Capacity	Distance	kWh/km
BYD e6	80 kWh	400 km	0.2 kWh/km
Tesla Model X	72.5 kWh	355 km	0.2 kWh/km
Hyundai Kona	39.2 kWh	305 km	0.13 kWh/km
Hyundai Ioniq	38.3 kWh	373 km	0.103 kWh/km

TABLE V. 2 Wheels Electric Vehicle Energy Consumption

Type	Battery Capacity	Distance	kWh/km
HD Livewire	15.5 kWh	234 km	0.06 kWh/km
Vespa Elettrica	4.2 kWh	70-100 km	0.042 kWh/km
Gesit	1.98 kWh	85-100 km	0.022 kWh/km

From the electric vehicle manufacturer, we got the battery capacity and the distance with the capacity. We can calculate the average energy consumption of the electric vehicle by theformula below:

n = Quantity of vehicle (unit)e = energy per km (kWh/km)
d = distance travel per day (km/day)

TABLE VII. Energy Consumption Per Day

Type	Quantity	kWh/km	Km/day	kWh/day
4 wheels	450,239	0.2	55.5	4,997,653
2 wheels	3,738,803	0.022	33.3	2,739,047
			Total	7,736,700

TABLE VII is the result of the calculation. We can know that it requires 7,736,700 kWh per day for all the 2 and 4 wheels vehicles in Bali island. Figure II inform that Bali island require electric energy about 5,908 GWh, which mean that average 16,186,301 kWh per day. If suddenly we convert allthe vehicles into electric vehicle, the incremental of electric consumption per day is about 48.79%.

A good forecasting of electric vehicle growth in the market need to be done by the Bali government, electric energy provider (PT. PLN) and also the car manufacturer. For electric energy provider, it is for the electric systems planning in Bali. Bali has 980 MW peak load in early of 2020 before the Covid19, the power generation is only 598 MW installed and back up from Java systems about 380 MW.

A. Bali Electric Systems Planning

$$Average\ Energy = \frac{Battery\ Capacity}{Distance}$$

Latest RUPTL 2019-2028 shown some development ofthe electrical systems in Bali. TABLE VIII is the forecast of the demand of electric energy in Bali. Forecast was based on

- Average energy : kWh/km
- Battery : kWh
- Distance : Km

In order to know how much of electricity needed for the electric vehicle our energy usage to support the electric vehicle, we need the make assumption of the average distance travel per type of car. Some people may travel relatively far compares to the other. One way to make that assumption is based on vehicle maintenance schedule.

TABLE VI. Average Distance Assumption

Type	Time (months)	Distance (km)	Avg Distance
4 wheels	6	10,000	55.5 km/day
2 wheels	2 – 3	2000 – 3000	33.3 km/day

Vehicle manufacturer set the period service or maintenance by distance and timing. In TABLE VI we can see distance and timing for 2 wheels and 4 wheels vehicle. We can make assumption the daily average distance. The result shown in TABLE VI. We know that most of the population in Bali stay in Badung, Gianyar and Denpasar. Gianyar is 26.73 km from Denpasar, the return distance will be about 53.46 km, and normally 2 wheels will travel less distance.

The 100% 2 wheels and 4 wheels electric vehicles can be calculated by using the simple formula:

$$E = n * e * d$$

E = energy per day (kWh/day) energy economic growth, and the incremental of population, domestic usage, growth of business in Bali.

But it might not cover the electric vehicle transformation. If the electric vehicle getting popular, the growth will not bea linier line.

ISSN No:-2456-2165

TABLE VIII. Bali Electric Energy Demand Forecast *[9]*

Year	Economic Growth (%)	Sales (GWh)	Production (GWh)	Peak Load (MW)
2019	5.29	5,549	5,585	932
2020	5.17	5,866	6,180	982
2021	6.08	6,284	6,007	1,049
2022	6.00	6,717	7,057	1,120
2023	5.91	7,168	7,526	1,194
2024	5.89	7,634	8,010	1,269
2025	5.77	8,110	8,503	1,349
2026	6.23	8,658	9,071	1,435
2027	6.17	9,230	9,663	1,528
2028	6.11	9,828	10,281	1,625
Growth (%)	5.86	6.51	6.39	6.31

Base on study that had been made, Bali has 354 MWe geothermal energy in Banyuwedang, Buleleng, Seririt Buleleng, Batukao Tabanan, Penebel Tabanan, Buyan-Bratan Buleleng, and Kintamani-Batur. Mini or micro hydro potential about 30 MW, wave energy in Nusa Penida about 10-50 MW, and solar energy about 100 MWp. [9]Bali has quite a lot of potential renewable energy including the wave energy and also ocean thermal energy [10].

TABLE IX. Bali Power Generation Planning

Type	Location	Capacity (MW)	Target (COD)	Status
Wave	Nusa Penida	10.0	2020	Delay
Solar	Bali	50.0	2020	Delay
Biomass	Bali	0.9	2022	Planning
Waste	Bali	15.0	2022	Planning
Geothermal	Bali	65.0	2025	Planning
Solar/Wind	Bali	50.0	2025	Planning
Total		**190.9**		

TABLE IX is the power generation planning in Bali, all of them are considered as clean energy, this is aligned with Bali government program for clean energy tourism area. Total of the planning is 190.9 MW until 2025. And most of the project will be delayed because of the covid-19 pandemic. There are still about 403 MW still in study period for mini/micro hydro, geothermal, solar, wind, biomass and waste to energy.

It looks like the planning is still align with the growth of the demand, but if suddenly electric vehicle become popular and get political incentive by government, the demand of electricity will increase exponential, and the planning will be not enough to cover the demand.

B. Duck Curve Problem

The growth of electric vehicle usage in several countries have side effect for daily load curve in electric systems [2]. Normally, we travel or use the vehicle during the daytime, so most possibility that we electric vehicle will be charged during nighttime when we finish our daily business [12] [13]. This habit of charging will change the daily load curve. We know that the peak load of Bali is at 7.00 pm.

We know that it requires 7,736,700 kWh per day for the electric vehicle usage. This energy demand requires Energy Management Systems, Demand Side Management or smart grid to separate the demand of energy it to 24 hours or when the load is low [11]. But it is a challenge to implement the demand side management, the electric systems in Bali might be not ready for it. If this daily energy requirement separate by only 4 hours at evening, that's mean the electric systems in Bali will increase 1934 MW. And if happen during the 07.00 PM that mean that the peak load in Bali will be 2,914 MW. The power factor in Bali will become low. This issue is called duck curve.

C. Solar PV Independent Power Producer

The study shown that electric vehicle usage will bring some affect those are the increase of the electricity demand sharply and duck curve issue. Electricity demand incremental could be solve by good forecasting about the incremental. The challenge is to predict when the electric vehicle will become popular or when most of the vehicle user will change their conventional fossil fuel vehicle to electric vehicle.

Duck curve issue might be solved by the demand side management. Demand Side Management help the utilities to manage the residential load, in this case the charging load from electric vehicle usage, to form the curve to avoid duck curve [15]. The concept is managing the when the user charges their electric vehicle. Demand side management motivate the user charge their electric vehicle when the electric systems load is low by giving some incentive such as lower cost [12]. Or in other way, the provider can set the higher cost for user to charge during the peak time. But the challenge, is PLN ready to apply the Demand Side Management? It required smart grid facility, advance billing systems, and support by good IT dan data systems.

The easier option is available. The option is the solar energy. We know that Bali has enough potential solar energy, and the solar energy technology is available in the market, it is mature, and the investment cost is decreasing while the trend is getting popular. But not the solar energy power station, it is every house to install the solar PV panel. At least the family who owns the electric vehicle, they need to install the solar PV panel to supply the energy.

TABLE X shown the estimation of solar PV implementation by one of solar PV contractor in Jakarta. The capacity is 445 Wp per panel. And it required 7 panel for 3 kW capacity. Each panel area is 2 meters square, and it required the 14 meters square.

ISSN No:-2456-2165

TABLE X. Solar PV Implementation Data

Capacity	3,000 Watt
Efficiency	80%
Net Capacity	2,400 Watt
Electricity Production (Peak Hour)	4 Jam
Electricity Production Per Day	9,600 Wh
Electricity Production Per Year	3,504,000 Wh
	3,504 KWh
Electricity Price Incremental	10%
Investment Estimation	16,000 IDR/Watt
Total Investment	48,000,000 IDR

We believe that the renewable energy will become more advance in technology, low cost in investment and more efficiency in near future, it is including the solar PV [7].

If we take example for the calculation by using Hyundai Kona electric vehicle. The battery capacity is 39.2 kWh, range 305 km. We take the assumption daily travel is 55.5 km. That means the user need to charge his car once is minimum 5 days. Electricity production per day is 9.6 kWh by the solar PV. In 5 days, the solar PV panel can produce 48 kWh. By install 3,000 watts solar PV, 14 meters square, enough to produce the energy that require by the electric vehicle.

Now how about the 2 wheels vehicle. The Gesit has 1.98 kWh, range from 85 – 100 km. If we assume charging every 3 days. The battery is 1.98 kWh. 1 panel 445 Watt can produce 4.27 kWh per 3 days. It is also enough for Vespa Elettrica, battery 4.2 kWh, range 70-100 km.

D. Economic Comparison

Electric Vehicle offer clean transportation and cost per km [4] [13]. The cost needed for per km transportation can be calculated. TABLE XI shown the cost per km for each type of vehicle.

Gasoline for the fossil fuel in TABLE XI is using the Pertamina Pertalite, Rp. 7,645 per liter. If using higher type, it will be higher. The EV is shown lower energy cost per km compare the conventional fossil fuel vehicle.

TABLE XI. Cost Per KM Calculation

Type	Ratio	Unit Cost (rupiah)	Cost/km
4 wheels fossil fuel	10 km/litter	7,645	764.50
2 wheels fossil fuel	50 km/litter	7,645	152.90
4 wheels EV	0.2 kwh/km	1,467.28	293.46
2 wheels EV	0.042 kwh/km	1.467.28	61.61

If the electricity supply from independent solar PV, the investment cost is Rp. 48,000,000 for 25 years warranty operation. Assume the fossil fuel vehicle spend Rp. 250,000 per week, Rp. 13,000,000 per year. Payback period for solar PV investment is only 3.7 years.

IV. CONCLUSION

The conclusion of this study about electric vehicle possibility and suitability to be implemented in Bali are:

1. Electric vehicle is suitable in Bali, by its area, distance of travel and align with Bali green tourism program.
2. Electric vehicle implementation will impact the electric systems in Bali, the challenge of forecasting the demand growth and planning of additional new power generation. Its also will impact the daily curve load.
3. A model of forecasting the electricity demand. When the demand incremental will increase sharply must be answered in the future.
4. Bali has big potential for the green energy, especially the solar energy.
5. Electric vehicle cost per km is lower than conventional fossil vehicle. The price of electric vehicle is more expensive compare fossil fuel car. Electric vehicle price will decrease if it become more popular in the market.
6. Solar PV technology is more and more efficient and advance. The investment cost will decrease slowly if more and more people using the solar PV.
7. Independent solar PV to supply electricity to electric vehicle will be the easy way out if the grid does not have enough supply and for the duck curve problem.

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