ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

Feasibility research for Optimal Planning the Micro-Grid system on Island using the HOMER

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Abstract.
BACKGROUND/OBJECTIVES: Many islands have been paying as high price electricity cost which cost of electricity generated by diesel power is about 5 to 10 times the selling price in terrene. So, it has been added to the micro-grid system to compensate for the losses caused by covering this difference.
METHODS/STATISTICAL ANALYSIS: It was used software tools that is hybrid optimization model for electric renewable (HOMER) and electromagnetic transient program (EMPT). Based on the findings of the studies into energy potential, a feasibility study had been carried out on how to supply electricity to a model community of 85 families. It makes it possible to expect of the provision of cheap electricity through micro-grid for long-term national cooperation.
FINDINGS: It has been significantly more expensive the island power costs were based on small diesel power generator than power rates based on large-capacity thermal power and nuclear power plants. Hybrid energy system has been replaced power shortages by using additional energy systems (solar and battery systems) in the island area. The system has been composed to solar generator, battery, inverter and diesel generator. It has been analysis equipment use of feasible power supply systems, according to power-grid present cost. The electric load has been consisted of comprised street light, industrial, commercial, and residential load.
IMPROVEMENTS/APPLICATIONS: It provides opportunities for the application of electricity culture and industrial development to the people of these countries.

Keywords: Diesel Power, Renewable Energy, Micro-Grid, Island, HOMER, EMTP.

1. INTRODUCTION

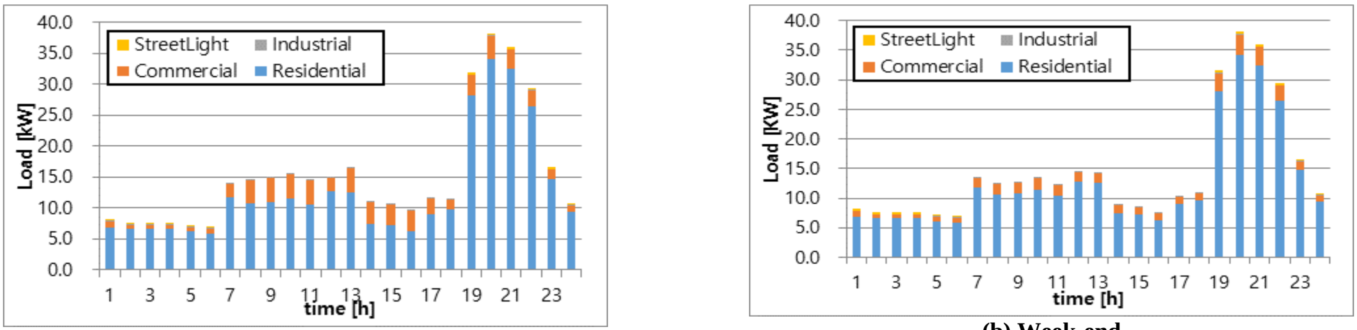
Micro-Grid is supported worldwide as one of method to secure economic competitiveness based on renewable energy such as solar power, wind power, and biomass to mitigate rising fossil fuels and global warming. Micro-Grid has been developed and supplied to meet the socio-economic needs of different countries. The share of renewable energy generation will increase to 44% by 2040, and the share of solar and wind power generation will increase from 7% present to 24% by 2040 according to the Stated Policies Scenario in the IEA's 2019 World Energy Outlook [1-3], and electricity will be supplied by mini or micro-grids. In particular, this has been an essential element as a national infrastructure for developing countries to enter the industrial society, and is rapidly spreading through domestic technology or international cooperation depending on the environmental characteristics of each region. In domestic, there are about 40 islands in which the power cost of diesel power generation in the west coast islands is 5 to 10 times the selling price. The government and KEPCO are actively promoting the micro-gridization for reducing the power cost. HOMER used in the paper has been a program that has been developed at the National Renewable Energy Laboratory (NREL) in the United States and is currently commercialized and is the most widely used program for reviewing new and renewable energy systems. This program is reflected the price and technical factors of each component and provides an optimal solution based on Dynamic Programming. HOMER has shown excellent properties for off-grid and grid connected micro-power systems for the most optimization, feasibility and sensitivity analysis of micro-grid renewable energy systems more than other program tools [4-9]. However, the Real micro-grid has been different from those required by the actual micro-grid system by the effect and conditions of power supply and demand due to the intermittentness of the power source according to the load and natural environment changes. So, the simulation results have been shown significant the difference by clearly undefined.

In this paper, for more accurate load estimation, the load is estimated by considering the power usage pattern of each load to the investigated load. It was conducted to present a plan to design the most optimal micro-grid system the sensitivity analysis of factors affecting the power cost, such as oil price fluctuation, interest rate fluctuation, and capacity shortage allowable rate fluctuation by Using the sensitivity analysis function of HOMER.

2. DESIGN OF MICRO-GRID SYSTEM

2.1. LOAD ESTIMATION

A survey was conducted on 10% of sample households to obtain basic data on the usage time of load, type and capacity of equipment used in order to estimate the prospect of electricity use in an independent area. It was different from the actual power used since each load has a rated value [10]. Therefore, each load has been synthesized based on the average power was calculated in consideration of the average hourly utilization rate of the device. it was weekly and weekly daily load curves for residential, commercial, and industrial use as shown in figure 1 and 2. The total load of the island, in which 787 people in total 208 houses, is 46 kW, and the average load is 16 kW (load rate 34.7%).

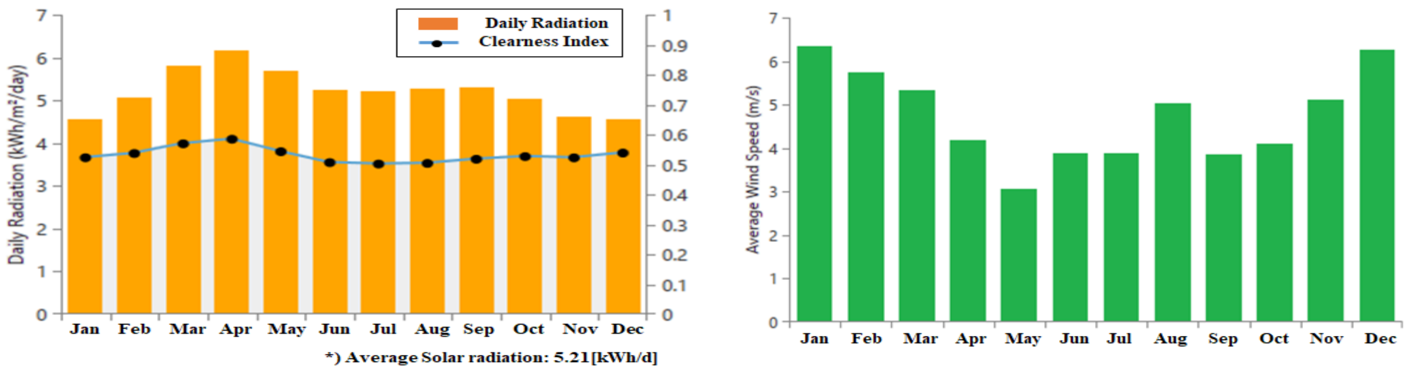


(a) Weed-day (b) Week-end

Figure 1. Daily load curve by load type of island location

2.2. GENERATION RESOURCE

Power generation resource was including diesel generators and renewable power, wind power sources. It has been considered monthly average sunlight and wind speed as wind as renewable power as shown in the following Figure 2.



(a) **Monthly average solar Irradiance data** (b) **Monthly average wind speed data**

Figure 2. Resource of sunshine and wind energy for applicable to island location

2.3. CASE STUDY

2.3.1. STUDY BY USING HOMER

Diesel power generation cost was calculated as 0.769[$/kWh], and the total net present cost(NPC) was calculated as 1,456,839[$]. The price information of the components of hybrid system is as following Table 1.

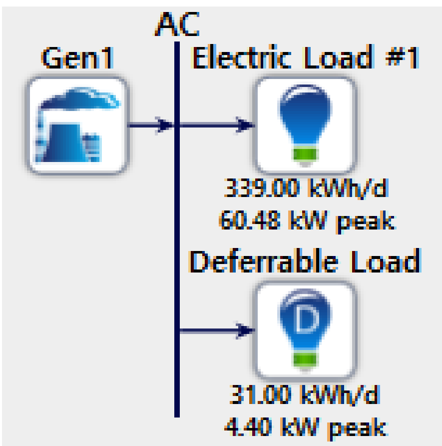


Figure 3. HOMER Diagram of Diesel generation

Table 1: Price information of Hybrid System component

Generator. Set		Converter		PV		Battery(Li-ion)
Life time	15000h	Life time	15 year	Life time	25 year	9940kWh
Min. Oper. Load	30%	Efficient	90%	Reduce rate	90%	92%
Fuel Slop	0.2545L/kwh	Price	800$/kW	Price	2782$/kW	2,542 $/kWh
Oper. Cond	Optimal	Replacement	700$/kW	Replacement	1,635$/kWh	2000$/kWh
Fuel cost	1.4 $/L					

It has been considered that the load ratio of the load is very low, 34.7%, economical result could be obtained by partially limiting the power supply during peak loads. The optimization simulation result has been appeared, when the maximum capacity deficit rate is set to 0% and 5% as shown in the following table 2. As a result, the maximum capacity shortage rate of 5%, the renewable rate could increase significantly from 40% to 64%, and it could be seen that the operating cost decreased significantly.

Table 2: Simulation Results using HOMER

Diesel[$/L]	Interest rate[%]	Max.Cap. Shortage[%]	PV[kW]	DG [kW]	Batt.[Li-ion]	Converter[kW]	Initial capital($)	Operating Cost($/yr)	Total NPC($)	COE ($/kWh)	Ren. Frac
1.4	6.0	0.0	50.0	40.0	48.0	20.0	409,877	51,550	1,068,862	0.609	0.4
1.4	6.0	5.0	75	20	72	20	535,126	39,027	1,034,028	0.612	0.64

It isn't requiring much cost for load management in case of many residential uses with simple load types. If it could be allowed certain portion of power failure or load control that was supply and demand, power cost can be reduced and the regeneration rate can be increased. It was the change in initial investment cost and total NPC when the capacity shortage is 0% and 5% as shown in the following Figure 4. As a result, it has been seen that initial investment cost increased by 30%, but NPC decreased by 3.2%.

In case of the oil price changed from 1.12$/L to 1.68$/L, it was 5% capacity shortage allowance and a change in levelized Cost of Energy (LCOE) according to the change in interest rate. Oil price was found to be about twice the effect of interest rate fluctuations. So, it has been shown benefit of the system with high solar system ratio.

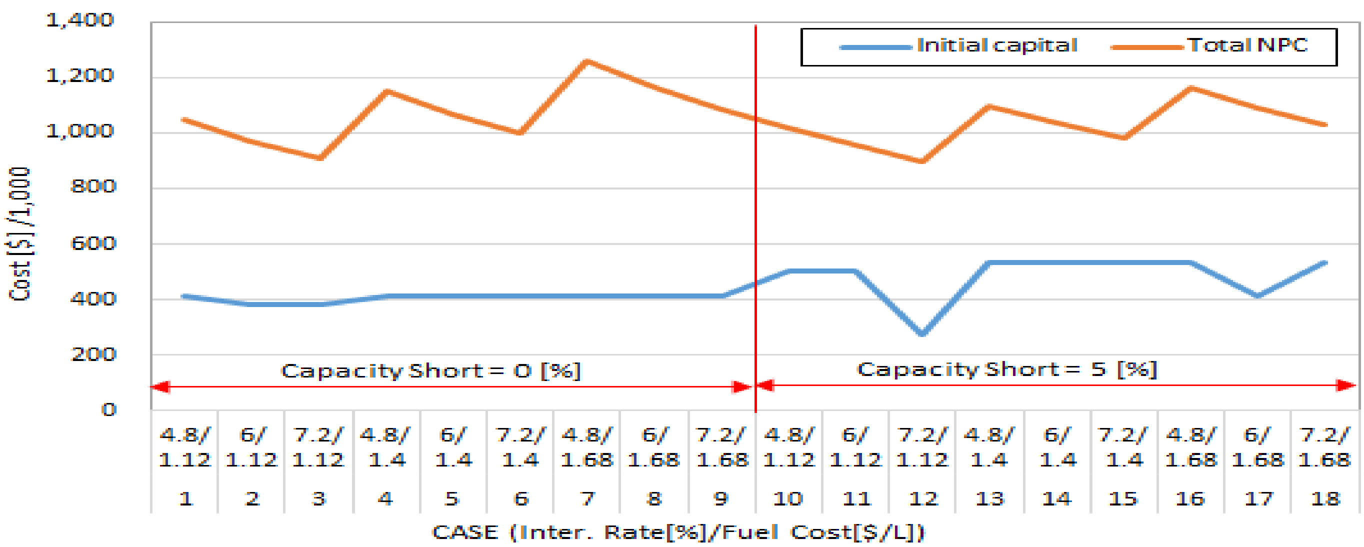


Figure 4. Analysis initial capital and NPC by capacity short, interest rate, and fuel cost

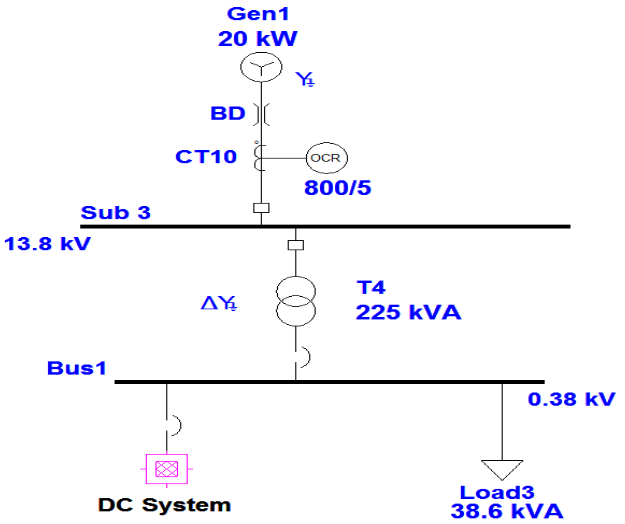
2.3.2. ANALYSIS OF POWER SYSTEM BY USING EMTP

The micro-grid has been used the EMTP S/W for simulation of the target island area as shown in figure 5. The solar environment of each system was set to April (peak load) and December (off-peak load), and load flow/fault calculation was performed as 6, 13, and 20 o'clock respectively.

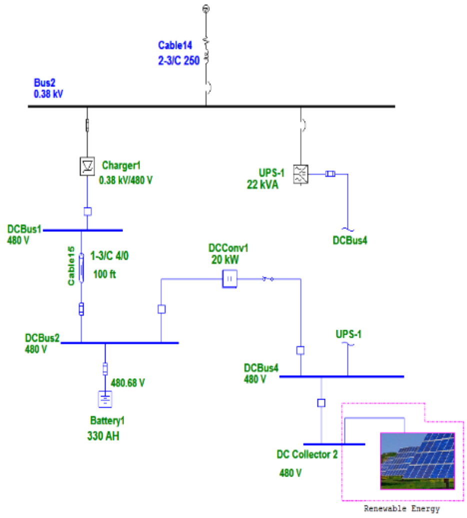
The sunlight energy was changed by the seasonal operation of PV system as shown in following Table 3. In April, the amount of sunlight reaches its maximum, and the daily solar power exceeds the load and is stored in the battery about 65[kWh/day].

The battery capacity was 360[Ah] and the charge/discharge ratio is 1.6:1 during the daily charge/discharge period of the battery, so it has been analyzed that it can be operated without diesel operation even with fluctuations in solar radiation.

In December, the amount of sunlight is the lowest, and the daily power generation was 232[kWh] and the load is 140[kWh]. The battery has been 81[kWh] to the load stored and supplied. It could be only about 12[kWh] extra considering the internal loss in case of supplied the battery. Therefore, it is necessary to keep in mind the operation of the diesel generator in case the power consumption increases or the amount of sunlight becomes poor during this period.



(a) AC Grid



(b) DC Grid

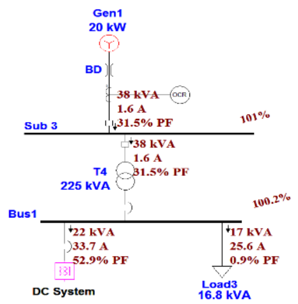
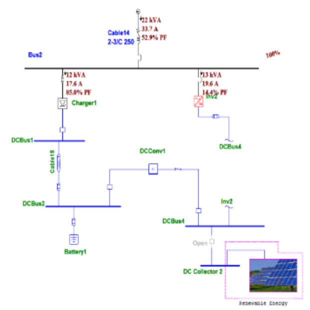
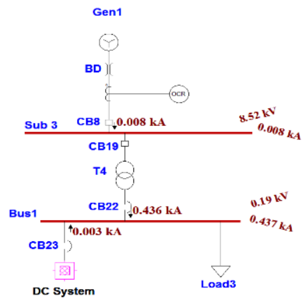
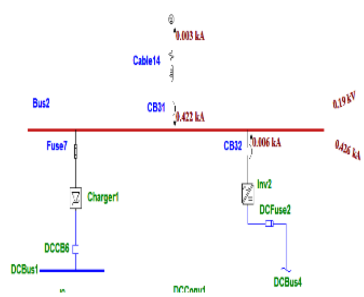
Figure 5. PV system by using EMTP in island location

Table 3: Energy balance by daily operation of PV system

		April Energy[kWh]	Current[Ah]	December Energy[kWh]	Current[Ah]
PV Generation		301.92		231.97	
Load		139.66		139.66	
Diesel Generation		0		0	
	Charging	-164.1204	342	-119.426	248
Battery	Discharging	99.358025	206	107.1358	223
	Residue	-64.76238	136	-12.2906	25

The solar power system was in case 1 (April, peak load) and case 2 (December, off-peak load) as shown in figure 6 and 7. It was performed that calculated the load-flow and failure for each 6, 12, and 20 o'clock according to time. It was showed when the current of the inverter flows from DC to AC, it is plus (+) value, and when it flows from AC to DC minus (-) value.

The faults were calculated with a fault impedance of 5% (0.36Ω), a base of 20kVA, and 380V as the fault points of the three-phase fault and one-line ground fault. In the case of a generator trip, a dynamic simulation was required. The simulation was performed for 3 seconds. DC fault was set to Rg = 5[%] (0.58[Ω]) one-line ground fault at the bus end part. As a result of the simulation, when the AC bus breaks down, there has been no injected current of the breakdown in DC.

	State	AC system	DC system
CASE 1	Steady State		
	1G Fault		

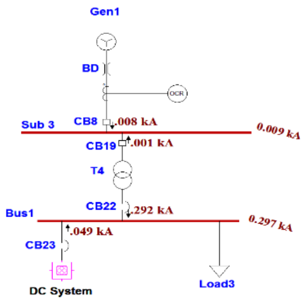
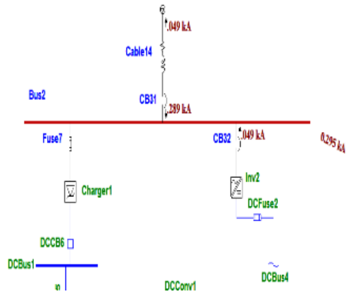
3p SC Fault		

Figure 6. PV system simulation by using EMTP (Case 1)

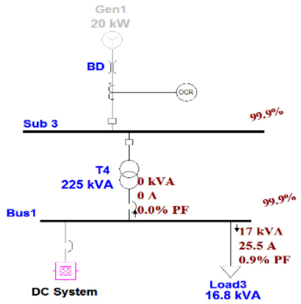
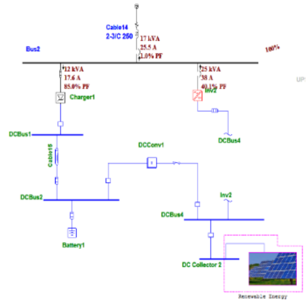
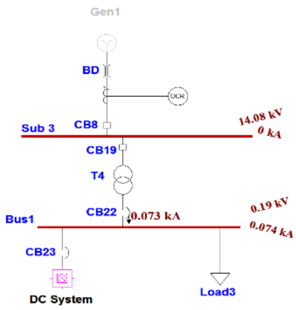
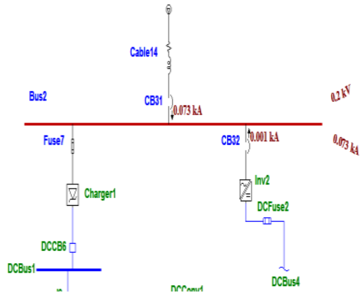
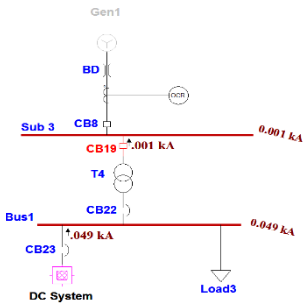
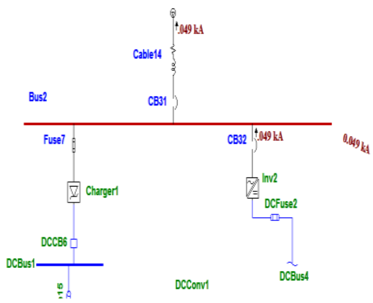
	State	AC system	DC system
	Steady State		
CASE 2	1G Fault		
	3p S.C. Fault		

Fig. 7. PV system simulation by using EMTP (Case 2)

3. RESULTS AND DISCUSSION

The results of this study are summarized as follows.

1. Based on the data obtained from the house-to-house survey of the load, the daily, weekly, and monthly load curves were derived by reflecting the operating characteristics of electrical products and reflecting the user's usage pattern.
2. It was less sensitive to rising oil prices to use international interest rates, and designing a micro-grid by using proper load management techniques. It is possible to build a hybrid system that can reduce power costs by 30[%] (COE 0.791 to 0.53) compared to the current diesel power generation.
3. The calculated system was system composed of PV 50kW, generator set 40kW, 48 lithium Battery, 20kW Converter. If the capacity shortage of 0.05 is allowed, solar system has been strengthened with PV 75kW, DG 20kW, Battery 72, and Converter 20kW.
4. Through the modeling of the dynamic system, the solar power design and utilization plan were calculated through the analysis of the normal and fault conditions of the system.
5. In this paper, it is proposed that the use patterns of diesel, solar, and battery that were classified and used in a hybrid system as shown in following Figure 8.

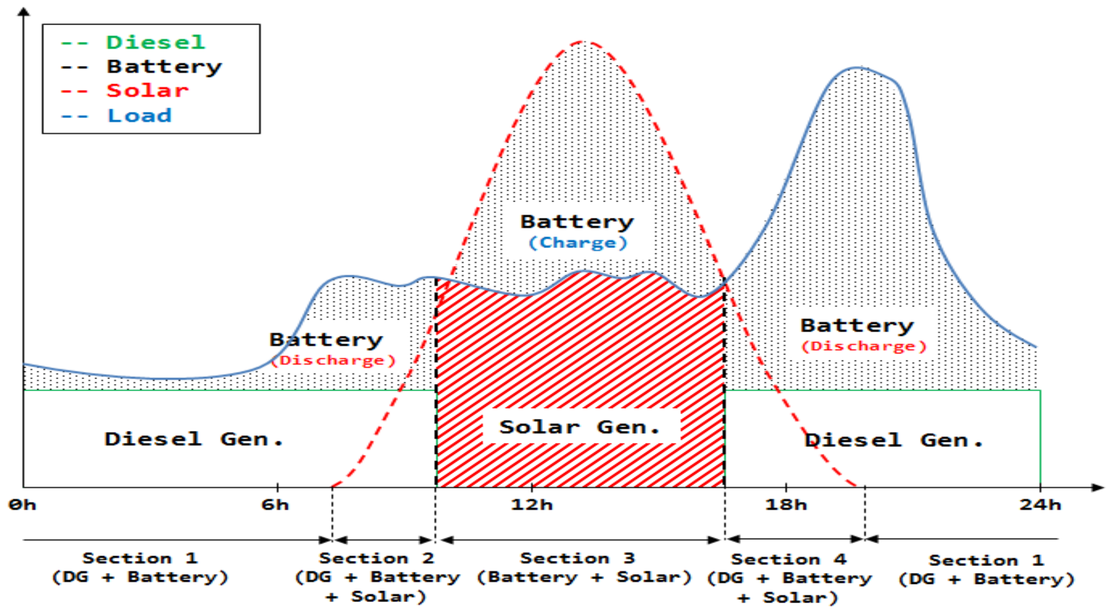


Figure 8. Scenario for case study of renewable system (solar, battery, diesel energy)

4. CONCLUSION

The micro-grids are expected to play an important role in the power system in island regions in provision of inexpensive electricity. Therefore, it is expected by providing opportunities to utilize electricity culture and providing opportunities for industrial development to the people of these countries.

6. ACKNOWLEDGMENT

This study was supported by the research grant of Wonkwang University in 2020.

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