IMPROVING RURAL ISOLATED DIESEL POWERED ELECTRIC UTILITY SERVICES BY HYBRID SOLAR AND WIND ENERGY SYSTEM

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ABSTRACT

The increase of oil price during last five years has effected the performance of utility electricity services in remote area in Indonesia. Currently almost every isolated remote area electricity is powered by diesel generation system. This is due the inexpensive, quick set-up of diesel power plant installation in the past. However, since the oil price become more expensive the ever, the Utility Company suffers of high fuel and operation cost, resulting in less reliable electricity services, not only in electricity availability, but also the duration of service.

This paper describes a pilot project of Hybrid Solar and Wind Energy System that is developed for improving the rural diesel powered electricity. The system consist of 40 kWp PV system, 4 by 10 kW Wind Turbine, 135 kVA diesel, backed-up with 700 kWh battery system, serving about 300 household in Nemberala Village, Rote Island, East Nusa Tenggara Province in Indonesia, and in operation since March 2008. The design consideration is briefly described in this paper, while the expected performance is estimated using computer modeling.

The simulation using the computer modelling suggests that the system provide an improvement in services and generation cost. Using the Hybrid system, the electric utility may increase the duration of service from 12 hours to 24 hours, while keeping the energy cost at 0.55 US$/kWh as compare to if otherwise produced by diesel gen-set at 0.69 USD/kWh.

INTRODUCTION

Indonesia is the largest archipelagic nation, with more than 17,000 islands throughout the country. Among the islands, Java and Bali is the two most populated islands in the country, which have the most extensive electricity system. As other area are less populated, and often the population is located remotely in rural area or isolated in a smaller island, the electrification faces difficulties to provide electricity using conventional grid extension.

The utilization of diesel power plant in the past was favourable, especially for the remote and isolated area. Less expensive investment cost, quick set-up and flexibility in size was made diesel power as an appropriate power generation alternative for such area. However, the advantage of diesel power has now becoming less significant not only due to the ever increasing oil fuel price but also in many cases because of the lacking of fuel supply.

Until recently the electricity generation in Indonesia, particularly in outside Java-Madura-Bali system, consist of mainly diesel power generation. As shown in Table 1., as data from PT. PLN [1], the Indonesian Utility Company, in 2006 out of total 8,128 MW installed capacity at outside Jawa-Madura System, Diesel Power Plant capacity constitutes about 4,550 MW or equivalent to more than 50% of the capacity. According to a study in PT. PLN [2], there are about 987 MW total isolated diesel power plant, consists of 936 units of various size from 50 kW to 500 kW.

The considerably large number of diesel generation entails a high dependence of PT. PLN to oil fuel. As reported by PT. PLN [3], in 2006 the total oil fuel expenditure contributed about 76% of total fuel expenses, while only produced 33% of total electricity production. As the oil price was increased sharply in the last a year, PT. PLN suffers a severe financial burden for purchasing oil fuel, particularly to power the isolated diesel generation plants.

Table 1. Electric Generation Installed Capacity in Indoneisa year 2006.

Region	Installed Capacity, MW							
	Hydro	Steam PP	Gas PP	Combined Cycle PP	Geothermal PP	Diesel PP	Total	(%)
Sumatra	4,13	0	0	0	0	552,13	556,25	2,24
Kalimantan	30,25	130	55	60	0	692,96	968,21	3,65
Sulawesi	214,2	25	122,72	0	20	470,97	852,88	3,43
Maluku	-	-	-	-	-	196,65	196,65	0,79
Papua	4,04	-	-	-	-	165,9	169,94	0,68
Nusa Tenggara Barat	0,92	-	-	-	-	148,8	149,72	0,6
Nusa Tenggara Timur	1,1	-	-	-	-	121,85	122,95	0,49
PT PLN Batam	-	-	-	-	-	139,9	139,9	0,56
PT PLN Tarakan	-	-	-	-	-	19,22	31,64	0,13
Northern Sumatra Gen and Dist	253,55	260	166,33	817,88	-	109,16	1.606,92	6,47
Southern Sumatra Gen and Dist	611,54	485	318,42	-	-	215	1.629,96	6,56
OUTSIDE JAWA-BALI	**1.119**	**900**	**662,46**	**877,88**	**20**	**4.548,60**	**8.128,67**	**25,88**
Dist. Jawa Timur	2,45	-	-	-	-	11,21	13,66	0,05
Dist. Jawa Tengah dan Yogyakarta	0,64	-	-	-	-	-	0,64	0
Dist. Jawa Barat dan Banten	0,71	-	-	-	-	0,22	0,93	0
Dist. Jaya Raya & Tanggerang	-	-	-	-	-	-	-	-
PT Indonesia Power	1.116,20	3.900,00	846,36	2.675,73	375	91,9	9.005,19	36,24
PT PJB	1.289,38	2.100,00	360,4	2.727,36	-	-	6.477,14	26,07
P3B	-	-	-	-	-	-	-	-
Pembangkitan Muara Tawar	-	-	858	-	-	-	858	3,45
Pembangkitan Cilegon	-	-	-	740	-	-	740	2,98
Pembangkitan Tanjung Jati B	-	1.320,00	-	-	-	-	1.320,00	5,31
Dist. Bali	-	-	-	-	-	5,64	5,64	0,02
JAWA - BALI	**2.409**	**7.320**	**2.064**	**6.143,09**	**375**	**103,33**	**18.415,5**	**74,12**
INDONESIA	**3.529**	**8.220**	**2.727**	**7.020,97**	**395**	**2.941,49**	**24.846,2**	**100**
Percentage (%)	**14,2**	**33,08**	**10,98**	**28,26**	**1,59**	**11,84**	**100**	

As an alternative energy source, renewable energy such as solar, and wind power in particular location, is available in a significant amount. Figure 1 and 2 show the solar energy potential, and wind speed potential mapping in Indonesia respectively.

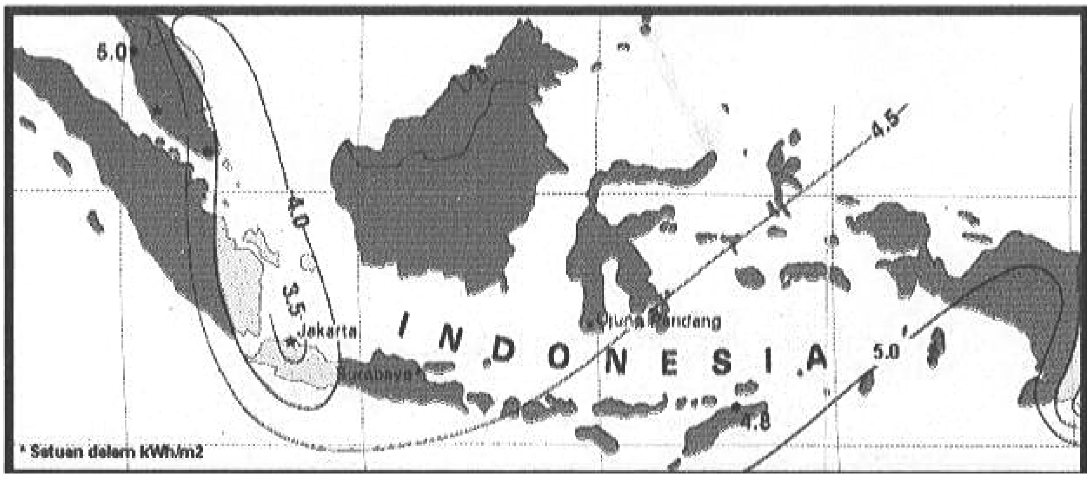

Figure 1. Solar Energy Potential Map, in kWh/m2 (source: Solarex)

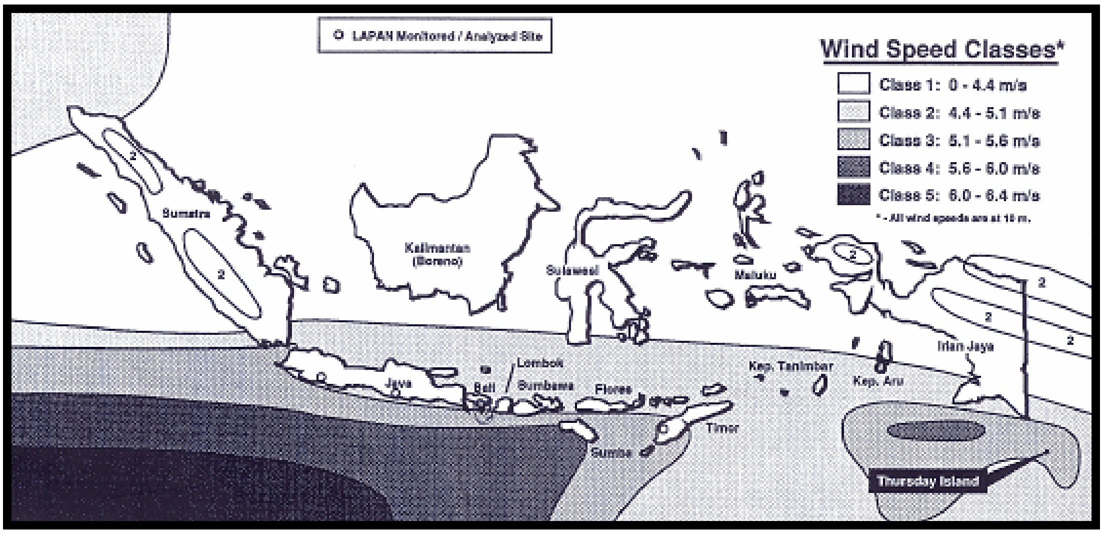

Figure 2. Wind Speed Mapping (source: Bergey)

A study by PT. PLN [2] shows that combining the available renewable energy resources to the existing diesel power may result in lower energy production cost. Depend on the site, an existing diesel power may be redesign as a hybrid power plant combined by solar and/or wind power.

As an effort to relief PT. PLN burden of relatively high electricity production cost of isolated diesel power plant, a research conducted by the Agency for the Assessment and Application of Technology, and PT. PLN, under coordination of Ministry for Research and Technology, has been undergoing on the assessment of hybrid solar-wind-diesel power plant technology assessment. A pilot project has developed at Nemberala village, Rote Island, East Nusa Tenggara Province as research and demonstration plant.

SYSTEM DESIGN

Nemberala is located at 10’53”0,21”’ South, and 122’49”49,8”’ East, in Rote Island, just southern of Timor Island, East Nusa Tenggara Province. Populated with about 300 households, the village is famous with its beach as an attractive place for surfing sport. Figure 3 shows the geographical location of Nemberala village.

At the time of the design is developed, PT. PLN supplied electricity to about 260 households. Peak load occurred at nighttime of 42 kW and with an average energy consumption of 310 kWh/day. The system is served by diesel power for 12 hours daily, started at 06.00 pm until 06.00 am.

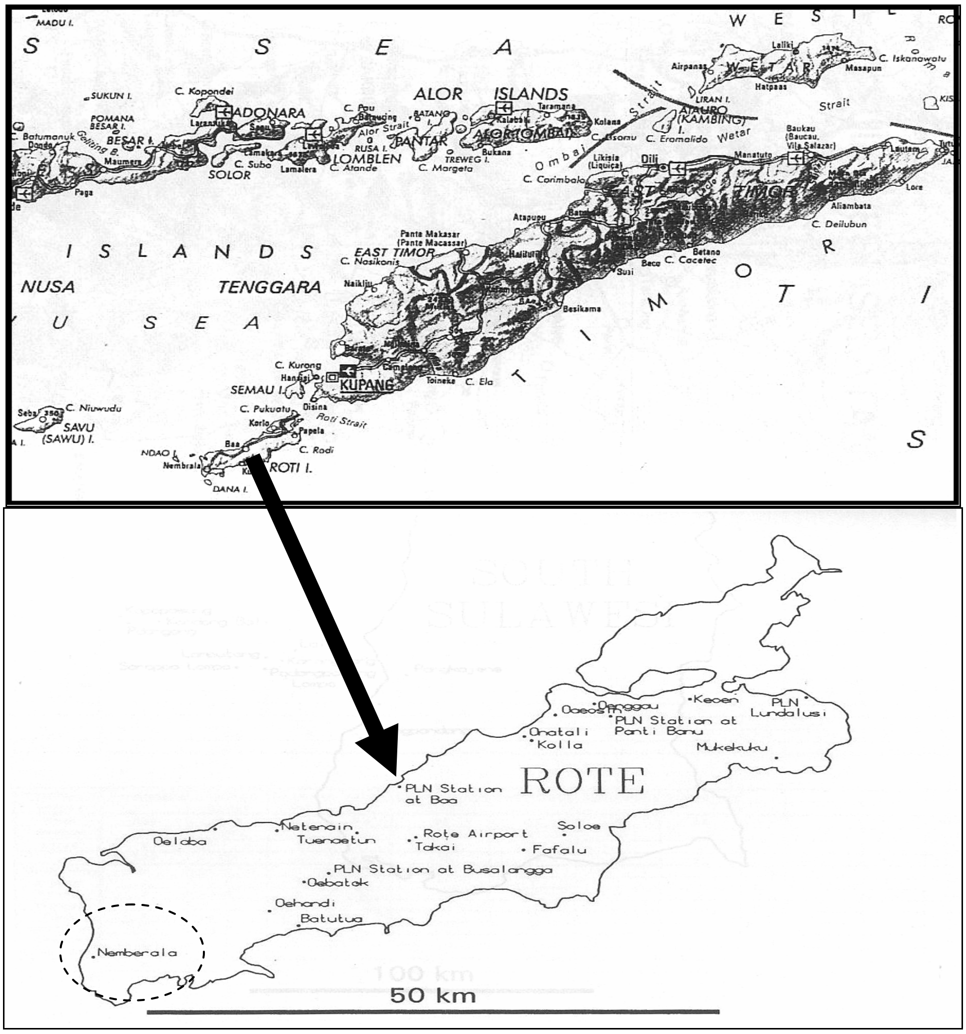

Figure 3. Nemberala Village Geographical Location

According to the site mearsurement, Nemberala has solar energy potential of average 5 kWh/m2/day, while the site also loacted in a preferable area for wind power with average wind speed of 4.2 m/s. This alternative energy resources may provide significant energy supply in addition to the diesel power plant.

The hybrid system design is intended to provide solution for serving more customer, or extending the operating hours, while keeping the electricity generating cost at the same level, or lower if possible. Taking into account the existing electricity load and anergy demand, and a reasonable future load growth, the Nemberala hybrid system is design with the following value:

- Predicted Peak load:	80 kW
- Predicted Energy Consumption	700 kWh/hari
- Designed Energy Contribution:	
Solar Power	33 %
Wind Power	12 %
Diesel Power	55%
- Solar PV Capacity	40 kWp
- Wind Power capacity	40 kW
- Battery Banks	560 kWh/day
- Bidirectional Converter	90 kW
- Working voltage	240 Vdc input
	380 Vac 3 phase output.

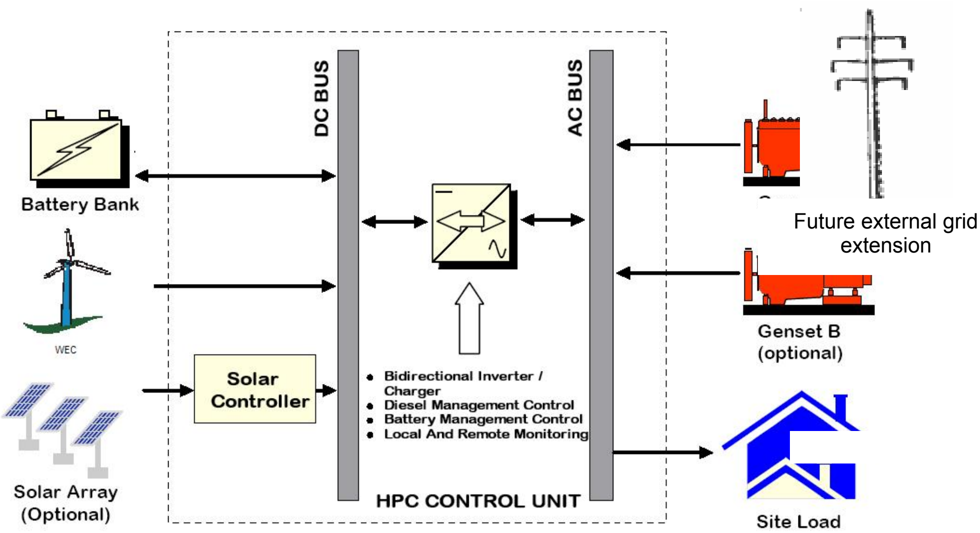

Figure 4. Schematic Diagram of Nemberala Hybrid Power Plant

SYSTEM DESIGN ANALYSIS

The system was analysed using HOMER© ver.2.64 [4] software developed by NREL USA, which is available to public through internet. The analysis was conducted upon three considered cases, the initial condition of Nemberala diesel powered, the 24 hour operation with diesel only, and the 24 hour operation with hybrid system.

Initial System Design of Nemberala System

At the time the Nemberala system was taken into consideration for a development of a Hybrid system in November 2006, the system was powered by a 65 kW diesel engine serve about 165 household with an approximately 42 kW peak load. Figure 5 depicts the system configuration, and the related load demand.

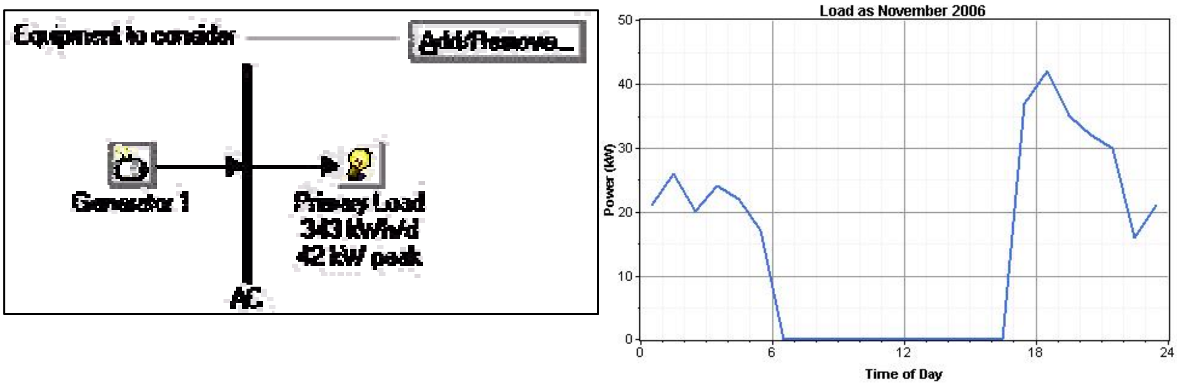

Figure 5. Initial Nemberala System, and Load Demand.

The system performance analysis output shows the following characteristics:

Table 2. Performance Characteristic of 12 hours operation with Diesel only

Electrical

Component	Production/ Consumption (kWh/yr)	Fraction
Generator 1	126,290	100%
Total	126,290	100%
AC primary load	125,195	100%
Total	125,195	100%

Cost summary

Total net present cost	$ 880,728
Fuel price	$1.2 / L
Levelized cost of energy	$ 0.613/kWh
Operating cost	$ 72,416/yr

Using the provided load characteristics and fuel price, the system produces electricity at the price of US$ 0.613 / kWh, and has an excess electricity of 1,095 kWh/year while emitting CO_2 gas of 143.1 kg/year. The system was not operated in 24 hours mode to avoid higher electricity production cost of US$ 0.68/kWh.

Improved System Design of Nemberala System

In order to improve the services for serving more customers, and providing the customer with 24 hours electricity, but without increasing the electricity production cost, a hybrid system with solar and wind energy is considered. As shown in Figure 1 and 2 above, Nemberala is located in the area with the most preferred potential of solar and wind energy in Indonesia. The solar irradiation potential is as high as 5 $kWh/m^2/day$ while the wind speed class is at 6.0 to 7.0 m/s. The system has been already developed and in operation since March 2008.

The new design of Nemberala system is as shown the following figure.

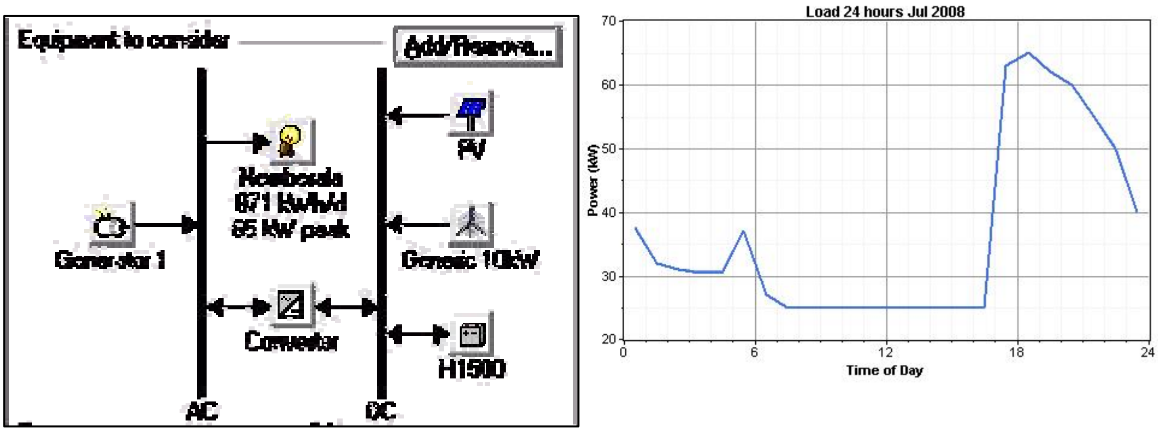

Figure 6. Improved System Design of Nemberala System, and Load Demand

As it can be noticed, the load curve indicates that there is an increase of peak load at approximately 67 kW which reflects an increase of number of customer, as well as increase in electricity usage. The load curve also suggests that the service is now for 24 hours.

The system performance of the improved design resulted in the following characteristics.

Table 3. Performance Characteristic of 24 hours operation with Hybrid System

Electrical

Component	Production/ Consumption (kWh/yr)	Fraction
PV array	71,004	19%
Wind turbines	138,768	37%
Generator 1	163,573	44%
Total Generation	373,345	100%
AC primary load	317,906	100%

Cost summary

Total net present cost	$ 1,874,662
Fuel Price	$ 1.2/L
Levelized cost of energy	$ 0.514/kWh
Operating cost	$ 82,035/yr

As it can be observed, that with the new design, the system is able to serve the load for 24 hours with higher load, but with less expensive electricity generation cost of US$ 0.514, as oppose to the Diesel Only costs. The hybrid system gives PT. PLN as the utility company an opportunity to conserve their cash flow, by lowering the diesel oil consumption and hence decreasing fuel cost.

SUMMARY

Electricity development in Indonesia generally faces various problems, mainly in the dependence to oil fuel, and particularly in out side Java-Bali System in the remoteness, and dispersed load. To overcome such of problem, the distributed generation utilizing locally available energy source, which is usually renewable energy resource, may provide a favourable alternative solution.

With abundant solar energy throughout the country, and considerable potential of wind speed in some particular area, the remote and rural electricity could be served in a more cost effective fashion using hybrid system, as compare to conventional stand alone diesel power. The high price of fuel and maintenance costs at remote area make the high investment cost of renewable energy generation technology more competitive.

In the case of Nemberala System, the design improvement to a hybrid system shows that not only the system could operate at a higher load and longer operation time, but also more importantly at the lower costs. Comparing to the previous Diesel Only system, the Hybrid Generation System of Solar, Wind and Diesel Power enable the Nemberala system to provide electric power 50% higher, at 67 kW peak load, and 100% longer operation time of 24 hours, but with a lower production cost at US$ 0.514 as compare to US$ 0.68 if otherwise system is used.

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BIOGRAPHY

Arya Rezavidi was born in Semarang, Indonesia in 1959, completed his B.Sc in Engineering Physics from Bandung Institute of Technology in 1985. He graduated from the University of Delaware in 1990 with a Master degree in Electrical Engineering. He obtained his Ph.D degree in 1995 from Salford University in the UK. He is currently a research engineer in energy system and the Director of the Centre for Energy Conversion and Conservation Technology, Agency for the Assessment and Application of Technology, Government of Indonesia. His areas of interest are energy and environmental system, renewable energy and photovoltaic technology.

Andhika Prastawa was born in Makassar, Indonesia in 1965, graduated from Bandung Institute of Technology, Indonesia in 1989 with a B.Sc in Electrical Engineering. He received his Master degree in Electrical Engineering from Virginia Polytechnic Institute and State University in Blacksburg, Virginia, in 1998. Currently he is pursuing his Ph.D degree at University of Indonesia. He is now a research engineer in energy system and Head of Energy Conversion Technology Division in the Agency for the Assessment and Application of Technology, Government of Indonesia. His research interest includes power system planning, alternatives energy and environmental system.

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