Design of Hybrid Power System for a Remote Island in Maldives

Ahmad Agus Setiawan and Chem. V. Nayar
Department of Electrical and Computer Engineering
Curtin University of Technology
GPO Box U1987, Perth 6845
Australia
Email: setiawaa@vesta.curtin.edu.au

ABSTRACT

Maldives is mainly a group of atolls in the Indian Ocean and consists of 1,190 islands with a total land area is approximately 300 km^2. In the Boxing Day, 26 December 2004 Maldives was hit by tsunami, made the country devastated and many of infrastructures including power generation were destroyed. This condition left many communities especially in remote rural areas to live with limited access to reliable power supplies. This paper presents a scenario for supplying electricity and consumable water demand in Maldives after tsunami by using mini-grid hybrid power system consisting of renewable energy, battery and diesel generator with a reverse osmosis desalination system as a deferrable load. Some topologies of hybrid power system are considered, simulations are performed and the results are presented in order to achieve the most efficient and economic way for providing the power and water supply.

1. INTRODUCTION

Maldives is located between latitudes 7º 06' 35" North to 00º 42' 24" South and longitudes 72º 33' 19" East to 73º 46' 13" East (approximately 820 km from north to south and 130 km east to west). It is mainly a group of atolls in the Indian Ocean and consists of 1,190 islands with the total land area is approximately 300 km^2.

The main income for the country comes from tourist industry which supplies more than 20% of the GDP and tourism contributes to more than 60% of the foreign exchange receipts. The majority of the people works in the fisheries and makes it as the second largest industry. The main export from this country is related to the fisheries industry for example dried, canned or frozen fish. There are small industries as well such as garment production, handicrafts fabrication and boat building.

In the Boxing Day, 26 December 2004 Maldives was hit by tsunami, left the country devastated and many of infrastructures including power generation were destroyed. This condition left many communities especially in remote rural areas to live with limited access to the reliable power supplies.

This paper presents a scenario for supplying electricity and clean water demand in Maldives after tsunami by using mini-grid hybrid power system consisting of renewable energy, battery and diesel generator with a reverse osmosis (RO) desalination system as a deferrable load. Some topologies of hybrid power

system are considered, the simulations are performed and the results are presented in order to achieve the most efficient and economic way for providing the power and water supply.

2. HYBRID POWER SYSTEM

There is a huge potential for utilizing renewable energy sources, for example solar energy, wind energy, or micro hydropower, to provide a quality power supply to remote areas. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power to elevate the living standards of the people without access to the electricity grid.

The advantages of using renewable energy sources for generating power in remote islands are obvious such as the cost of transported fuel are often prohibitive fossil fuel and that there is increasing concern on the issues of climate change and global warming. The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties in regulating the output power to cope with the load demand. Combining the renewable energy generation with conventional diesel power generation will enable the power generated from renewable energy sources to be more reliable and affordable. This kind of electric power generation system, which consists of renewable energy and fossil fuel generators together with an energy storage system and power conditioning system, is known as a hybrid power system.

A hybrid power system has an ability to provide 24-hour grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to the diesel generator stand-alone system. The operational and maintenance costs of the diesel generator can be decreased as a consequence of improving the efficiency of operation and reducing the operational time which also means less fuel usage. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them[1].

3. SYSTEM COMPONENTS

In order to design a mini-grid hybrid power system, we have to provide some information from a particular remote location such as the load profile that should be met by the system, solar radiation for PV generation, wind speed for wind power generation, initial cost for each component (diesel, renewable energy generators, battery, converter), cost of diesel fuel, annual interest rate, project lifetime, etc[2, 3]. After that, we perform the simulation to obtain the best hybrid power system configuration, which in this project is done by utilizing HOMER software from NREL[4, 5].

For this project, we select one of remote islands in Maldives which after the tsunami disaster, this island is populated by approximately 300 people. Before tsunami, power supply was maintained by operating 2 diesel generators with the capacity of 40 kW and 32 kW. According to the Island Development Committee (IDC), the influential authority in the island who makes decisions on the island development including electrification, the estimated load distribution for the post

tsunami day is shown as in Figure 1. This primary load has annual average of 298 kWh/day with annual peak of 37.4 kW.

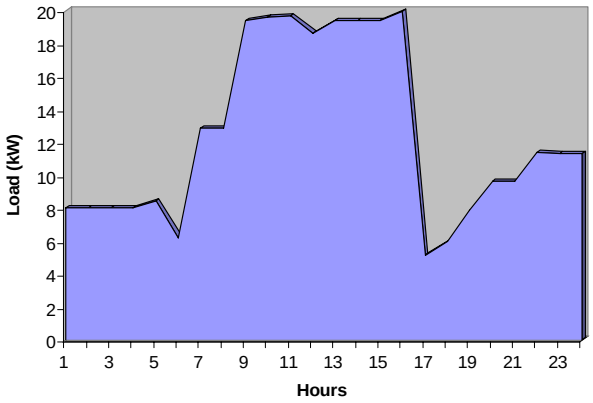

Figure 1 Estimated daily load profile

In order to provide consumable water supply, a reverse osmosis desalination plant is installed as a deferrable load. The RO system is capable of supplying 5 m^3 fresh water per day. This system consumes 2.5 kW power and needs to be operated 8 hours per day. A fresh water tank is designed to have storage capacity for two days demand. So, there will be a 20 kWh/day average deferrable load with 40 kWh storage capacities. The overall system configuration of the mini-grid hybrid system is shown in Figure 2.

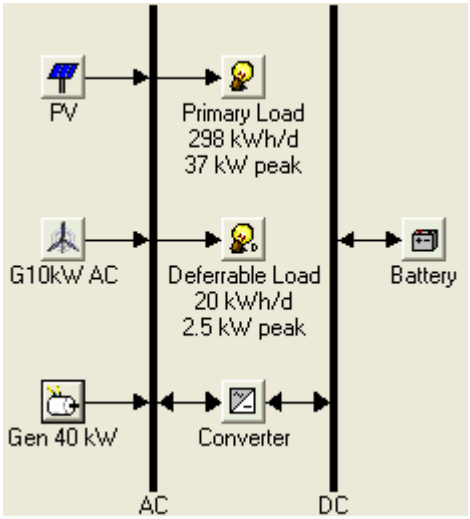

Figure 2 Hybrid power system configuration

4. SIMULATION RESULTS

Simulations were performed for two conditions: before and after tsunami. Before tsunami, power generation consists of two diesel generators, 40 kW and 32 kW. After tsunami power demand including reverse osmosis desalination system is supplied by using mini-grid hybrid power system with several topology options: PV/diesel, wind/diesel, and wind/PV/diesel.

Table 1 shows the comparison of simulation results for two different conditions, before and after tsunami. Diesel only system has the least initial capital

cost but highest total net present cost for the whole project. Furthermore, this system emits more CO_2, particular matter (PM) and NO_x as a result of burning a lot of fossil fuel with a low efficiency operation.

A new design by utilizing renewable energy generators (wind generator and PV) is simulated which results in three different topologies: PV-diesel, wind-diesel and PV/wind-diesel. PV-diesel system gives an opportunity for renewable energy to supply 14% of the energy demand. Wind-diesel system has ability for reducing the proportion of energy supplied by diesel genset to 80%. And finally the PV/wind-diesel system has the highest renewable energy penetration by supplying 24% of the energy demand. These hybrid system topologies need higher initial capital cost but it has less total net present cost as a result of less fuel consumption and higher efficiency operation for the diesel genset. Reducing fuel consumption also means less emission from the system as shown by the PV/wind-diesel system which has the lowest emission of CO_2, PM and NO_x. In addition, the hybrid system topologies also consider providing fresh water supply as needed by people in this particular remote area.

Table 1 Comparison of simulation results before and after tsunami

Parameter	Before Tsunami	After Tsunami		
	Diesel Only	PV-Diesel	Wind-Diesel	PV/Wind-Diesel
Initial capital cost	$57,600	$165,900	$185,900	$209,900
Total Net Present Cost	$709,055	$646,359	$630,394	$634,064
Cost of Electricity ($/kWh)	$0.510	$0.447	$0.436	$0.438
Annual fuel consumed (L)	55,494	40,919	37,084	35,113
Annual fuel cost	$35,516	$26,188	$23,734	$22,472
CO_2 emitted (kg/yr)	146,135	107,753	97,656	92,464
PM emitted (kg/yr)	27.2	20.1	18.2	17.2
NO_x emitted (kg/yr)	3,219	2,373	2,151	2,037
Energy production				
Diesel	100%	86%	80%	76%
PV	0	14%	0	4%
Wind	0	0	20%	20%
Diesel efficiency	21.9%	30.5%	30.4%	30.4%
Fresh water supply	NO	YES	YES	YES

5. CONCLUSION

The design of hybrid power system for supplying demand in a Maldives' remote island after tsunami disaster in the Boxing Day, 26 December 2004 is presented here. In general the hybrid power system offers a better performance to provide power supply than the diesel only system. The simulation results demonstrate that utilizing renewable generators such as PV and wind generator reduces the operating costs and the greenhouse gases (CO_2 and NO_x) and particulate matter emitted to the environment as an impact of improving diesel efficiency operation and also less fuel consumption. In addition the system also provides fresh water supply to the people in this area.

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