1. Introduction

Off-grid power generation is meant to supply remote or rural area, where grid connection is almost impossible in terms of cost and geography, such as island, aborigine's villages, and areas where nature preservation is concern. Harnessing an abundance renewable energy sources using versatile hybrid power systems can offer the best, least-cost alternative solution for extending modern energy services to remote and isolated communities [1, 2].

The conventional method for off-grid power generation is using diesel generator with a renewable energy (RE) technology utilizing solar photovoltaic, wind, biomass, biogas and/or mini/micro hydro. A hybrid technology is a combination of multiple source of energy, such as RE and diesel generator and may also include energy storage such as battery.

A hybrid system is a combination of one or more resources of renewable energy such as solar, wind, micro/mini-hydropower and biomass with other technologies such as batteries and diesel generator. Particularly, the solar hybrid system developed with a combination of solar with battery and diesel generator. As an off-grid power generation, the hybrid system offers clean and efficient power that will in many cases be more cost-effective than sole diesel systems. As a result, renewable energy options have increasingly become the preferred solution for off-grid power generation [3]. The system has been installed at the middle and top stations at the Langkawi Cable Car facilities. It is a resort area located in the Island of Langkawi, Malaysia.

2. Benefits of Hybrid Systems

Improved reliability

A robust power supply and downtime minimization during power outages could be achieved by virtue of varying the power sources, which is vital indeed due to its ability to provide backup power. System failure or disruption of diesel supply to the community are factors leading to utilizing an alternate generating system encompassing renewable energy / diesel hybrid system as to encourage continuous and reliability power supply. Photovoltaic and wind energy system attribute to fewer moving parts, requiring less maintenance than diesel, thus reduces downtime during repairs or routine maintenance. In fact, renewable energy sources being indigenous and free, is more secure than diesel thus, beneficial to facilities.

Improved energy services

The ability of renewable energy working in tandem with diesel, contributes to high quality and dynamic electricity services for 24 hours / day whilst in a conventional system, the high diesel operating costs limits the power supply only to 12
hours / day. The cost of photovoltaic or wind power generation lies in the form of upfront capital expenditures whereby the operation and maintenance expenses are low. Therefore, the generating cost via photovoltaic or wind is marginally more than a conventional system with respect to the additional generating capacity, nevertheless promises customer satisfaction of a continuous electricity supply.

**Reduced emissions and noise pollution**

Diesel generation emits air / water pollution agents as well as loud noise, proving the essentiality of renewable energy or diesel retrofits application in power generation which adopts an environmental-friendly technology. In fact, renewable energy system is also substantially quieter than diesel generators.

**Continuous power**

By incorporating diesel generator with renewable energy system, diesel generator is able to boost up the electricity supply during sudden increase in energy demand or when the batteries capacity decreases and thus, facilities face no supply interruption.

**Increased operational life**

The alternate operation at regular intervals and specific occurrences of renewable energy and diesel hybrids could prolong the life of the overall system on account of the discontinuous usage of the diesel set. Furthermore, the discharging level of the batteries is optimum, contributing to its increased operational life.

**Reduced cost**

Renewable energy or diesel hybrid system act as the most cost-effective way of generating electricity with regards to savings on fuel consumption and lower maintenance cost. For a conventional diesel system at remote area, the fuel and transportation cost is typically very high, as well as the service and spare parts cost which grossly excessive to rural community.

**Efficient use of energy**

Hybrid system promotes efficient use of power since renewable energy system could be configured to cope with base load whilst the peak load could be met via diesel generator.

**3. Components of the Hybrid System**

A hybrid power station typically includes (a) Inverter module with a continuous power rated at 60% of maximum demand of the community (b) One or two diesel engines, which are usually sized at an equal rating to the inverter to a maximum size of 1.5 times the inverter rating with automatic diesel generator control system. The system controller interfaces to the diesel generators via interconnections to the diesel generator control system. A fully automatic diesel generator control system enables automatic operation and automatic selection of power sources (c) A lead-acid battery storage system, with a specified minimum storage capacity (d) A solar photovoltaic array and solar regulator with a specified minimum power capacity at a specified temperature and insolation (e) A microprocessor based controller unit to monitor and manage the system automatically. It is advantageous if the controller unit has a remote monitoring capability since an off-grid power generation station is normally located at a very remote and isolated area.

**4. Operational Concepts of the Hybrid System**

The solar hybrid power system makes use of the solar PV to produce electricity that can be supplemented by diesel generators. The configuration of solar hybrid system is analyzed for various photovoltaic array sizes with respect to a diesel generator to operate in tandem with the battery system. The power controller unit will determine the AC conversion of the DC power in relation to optimum diesel generator operation following the load profile. The charge controller will charge the batteries with energy from solar modules as well as from the diesel generator. The main objective of solar hybrid system is to reduce the cost of operation and maintenance and cost of logistic by minimizing diesel runtime and fuel consumption. To achieve this the generator only runs as needed to recharge the battery and to supply excess load. It is started when the battery reaches a preset discharge level and is run at full capacity until the battery is fully recharged and then shut down. A schematic of normal daily operation of a typical solar hybrid system can be shown in a series of diagram in Figure 1.
During day time

In Figure 1(a), solar is the first choice and only source of energy while the generator is off. The inverter converts DC power from the solar PV to AC power for the load. The extra power produced is stored in battery system.

During night time

In Figure 1(b), battery is the only source of energy while the generator and solar PV are both off. The inverter converts DC power from the battery to AC power for the load. The battery will supply the load to its maximum discharge level.

During shortfall

Shortfall normally happens at night time. During shortfall, the battery reaches its maximum discharge level and therefore, the generator is on, as in Figure 1(c). At this time, the generator serves the load as well as charge the battery. The battery charge rate is adjusted to maintain the generator at full output.

The operations, which activate or deactivate genset and charging or discharging battery are managed and done by a micro-processor-based controller unit. The controller unit monitors and manages the load demand and energy supplied.

5. Performance of System

The solar hybrid system installed at Middle and Top Stations of Langkawi Cable Car at Gunung Machinchang as shown in Figure 2, is the first Solar Renewable Energy Project for a tourist complex in the country. The main objective of installing the system are to generate electricity while preserving the nature by avoiding trees cutting if a conventional grid system is used, reducing CO2 emission an noise pollution if diesel generator is used. The minimum running hours also reduces the maintenance cost of a diesel generator. The stations serve the electrical load for the cable car stations such as water pumps, cable car controller system, air-conditioners and lights. The project is owned by Langkawi Development Authority (LADA) and operated by Panorama Langkawi Sdn. Bhd. The capacity for each station is:

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To date, the system has been operating for 6 months. During this period, the stations have been getting 24-hours supply with genset running for only 300 hours. The genset has been started for 35 times. The genset only starts once a week with average running hours for about 8 hours. Currently, the load at Middle Station is about 60 kWh per day while the load at Top Station is about 40 kWh per day.

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6. Conclusions

Solar hybrid system has a great potential as one of renewable energy technologies for off-grid power generation. The hybrid technology offers solution to off-grid power generation in terms of reducing operation, maintenance and logistics problem and cost, providing 24-hours reliable supply at an effective cost as well as preserving the nature.

References