Solar PV-Diesel Hybrid System for Rural School Electrification Project in Sabah: SK Sungai-Sungai, Beluran, Sabah, Malaysia

Submitted to Board of Judges on ASEAN Renewable Energy Project Competition 2016 by Public Works Department (PWD), Malaysia

APPLICATION FORM

ASEAN Renewable Energy Project Awards
ASEAN Energy Awards 2016

Application Number *(Office Use Only)*	

Category	**OFF Grid**	
		☑ **Power**
		☐ **Thermal**
	ON Grid	
		☐ **National Grid**
		☐ **Local Grid**
		☐ **Cogeneration**

Title of Activity/Project/Theme
Solar PV-Diesel Hybrid System for Rural School Electrification Project: SK Sungai-Sungai, Beluran, Sabah, Malaysia

Source of Energy	Solar Photovoltaic (PV)
Age of Project/Commercial Operating Date (COD)	2 years / January 2014

Applicant General Information	
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Nature of Business	
Planning, design and construction of infrastructure ventures, etc. roads, Government buildings, airports, harbors, related engineering works, Maintenance of roads and selected Government buildings & Technical advisory services to the Malaysian Government.	

Project Abstract

Malaysia had a long and successful history of rural development since Independence. Through the various Malaysia Plans (5 years), **the Government has made rural development a key item on the national agenda.** The rural and remote community is not exception; in fact it has become one of the top priorities of the Government to provide them with adequate and sustainable infrastructure to precipitate the social and economic improvement on par to the more developed urban community.

In 2006, there was a significant numbers of schools in remote rural areas and isolated islands in State of Sabah, Malaysia that had no access to 24-hours electricity. Extending the national electricity grid to such areas is either financially not viable or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand. As a result, the electrical demand of such places is normally powered by stand-alone diesel generators or even with no power supply. The significant rise of diesel price and subsequent environmental pollution concerns, however, have drawn extensive public attention to the need of Renewable Energy applications such as solar Photovoltaics (PV) power, wind power or hybrids system.

In addressing the need to improve the learning and living standard at the rural schools as well as to ensure that rural Malaysians are not deprived of the basic amenities for a better quality of life, the **Ministry of Education (MoE) has initiated a large electrification program via Solar Hybrid System (SHS) for rural schools in Sabah.** For instance, by applying SHS, the total solar PV-diesel hybrid systems have been implemented in rural Sabah have reached **155 schools. During the first phase of this program, 78 schools were installed and electrified in 2009, while during the second phase of this program, which was started in 2010, a total number of 77 schools has been implemented.**

As a random sample, the impact of the implementation of solar PV-diesel hybrid system at **SK Sungai-Sungai Primary School in State of Sabah,** Malaysia (6.25N, 117.36E) has been analyzed in this report. The system was **commissioned in November 2013**. The power generated was to **supply electricity for every buildings in the school; class rooms, computer lab, guard house and teachers' quarters.**

Employment Opportunities

PWD has experienced and dedicated engineers, architects, technical expert, administrative and clerical staff shown as bellows: (For SHS Project Team)

Executive: (Technical): 6 (Non-Technical) :__
Non-Executive:8

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CERTIFICATION AND ENDORSEMENT

The **Public Works Department (PWD)** hereby agreed to allow the ASEAN Board of Judges and other experts that may be designated by ACE to visit the RE project site and verify the authenticity of the data. However, two weeks advance notice is required to allow for necessary arrangements.
We also hereby agreed that ACE can publish the whole submission in ACE publications and website, without any prior consent of the owner of the RE project. If the submission will be published in other publications, the consent of the concerned RE project owner would be required.
We, the undersigned certified that the information given is true and accurate and prepared with the consent of the party/ies involved.

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A. ORIGINALITY

A.1 Project Profile

Design

The solar PV-diesel hybrid system was **uniquely designed to suit the school loading and demand profile of 148kWh per day energy demand with power demand of three phase 45kW peak.** The system relied on renewable energy through **60kW PV array to generate 100% of total energy required by the school**. The sizes of the PV system components i.e. arrays, batteries and inverter were determined using the peak sun hour method. The **average insolation value of 4kWh/m^2/day** was used. The designed system has taken into consideration of the decrease in PV modules efficiency with the ambient temperature. **The array tilt angle and the array azimuth were set to 15 degrees and 0 degrees** respectively which are referring to the South direction in order to capture the maximum amount of energy from the sun. **The system architecture was based on SMA Solar Technology where AC bus bar was used to couple all the system components which give higher flexibility in accommodating additional generating capacities in the future once the local grid in-place**. In such architecture condition, this stand-alone PV component has employed two different types of inverters: **bi-directional inverter i.e. Sunny Island-SI5048 and PV inverter i.e. Sunny Boy-SB4000TL.** One day of Autonomy for battery bank storage capacity was designed in order to compensate low insolation and cloudiness, with the **maximum of discharge of battery power was assumed to be 0.**6. The battery bank was comprised of 144 deep cycle gel cells made by FIAMM. T**he main power generated from solar PV has made this system almost independent** meanwhile the diesel generator is used as a backup to assist during periods of high loads or low renewable power availability and **covers only 5% of total power need.**

Application

The solar PV-diesel hybrid system is one of the most promising power solutions for remote rural areas and isolated islands which are not connected to the grid (off-grid). **The battery storage and diesel generator are incorporated in the system to handle variability and flexibility to supply electricity to every buildings in the school. The schools has year 1 to year 6 grades with approximate average number of students are 320 and 20 teachers.**

Approach

The designed system has taken into consideration of additional 20% of daily energy used for future demand. Emphasis was also given to provide new teachers' quarters and retrofit existing building i.e. rewiring, minor repair for ensuring better utilisation of resources. The designed system also equipped with effective monitoring facility for evaluating system performance. **The solar PV arrays mounted on 21.4meter x 10.6meter and 9meter high galvanised elevated metal structure for ensuring security and safety to the PV. Moreover, the designed structure also provides multipurpose usage under the PV structures.**

Since the school is **located in flood prone areas**, **flood prevention** and mitigation factors were taken into consideration during planning stage. **Power house was designed at a height of 3 meter above ground level so that the system's components should not submerged during a flood, thereby reducing any damage.**

B. ENVIRONMENT CONSIDERATION

B.1 Amount of Emissions/Pollution Avoided

No.	Parameters	Value and unit		
		Before	**After**	**Carbon Emission Reduction**
1	Primary GHG emission (Carbon dioxide, Methane, Nitrous oxide, CFC)	*22,263 kgCO2/yr*	*636.4 kgCO2/yr*	*21,626.6 kgCO2/yr*
2	Electricity consumption			
3	Fuel consumption			
4	Water consumption			
5	Air pollution (e.g. SOx, Nox and CO)			
6	Banned materials (i.e. RoHS compliance, etc.)			
7	Dioxine level			
8	Water pollution (e.g. BOD, COD, NH_3 and pH)			
9	Energy efficiency/ Coefficient of Performance (e.g. COP)			
10	Indoor Environmental Quality			
11	Waste minimization			
12	Chemical use reduction (e.g. toxicity, volume)			
13	Other parameters Specify_______________________________			
	Total Potential Carbon Emission Reduction			*21,626.6 kgCO2/yr*

B.2 Discussion (Simple calculation of conversion)

Table 1: Calculation of CO2 Emission Reduction of the PV-diesel hybrid system vs standalone generator set

Year	Total School Demand (kWh)	Energy Generated (kWh)			Energy Stored in Battery (kWh)	CO2 Emissions (kgCO2/yr)	
		Solar PV	Generator Set	Total		Gen-set	PV-Diesel
2015	41,926	51,250	1,199	52,449	32,975	22,263	*636.4*

The total school load demand and the total PV energy generated was analyzed using available data from Sunny Webbox data logger. CO2 are made under the calculation of Energy Generation (kWh) by generator set before and after installation of PV-diesel system, with baseline CO2 for Sabah: 0.531 $kgCO_2$/ kWh. These environmental benefits from solar will continue throughout the life of the panels which could be upwards of 25 years.

B.3 Project Objective & Criteria

The objective of the project **is to provide 24 hours (24/7) electricity supply** to every buildings in the school compound such as class rooms, hostel, canteen, dining hall, guard house and teachers' quarters through Solar PV-diesel Hybrid System. The solar PV-diesel hybrid system was uniquely designed and constructed to suit the school loading and demand profile. In general the solar hybrid system offers better power supply to the rural schools than the conventional standalone diesel generator sets. **This technology gives more benefit and impact to the students as well as teachers by creating more comfortable lifestyle and conducive learning environment.**

The main principle of this project is to **reduce the dependency on conventional supply with limited of electricity supply by standalone generators**. This objective has been achieved so far with a provision of the most technical and economic way of providing electricity supply to the remote schools by **Solar Hybrid System (SHS), which combines Solar PV, diesel generator set and battery for continuous 24 hours electricity scheme**.

The project improvements to the existing standalone diesel generator set system are listed below:

i. **Improved reliability** – the solar PV-diesel hybrid system **encourage continuous and reliable power supply to overcome system failure or disruption of diesel supply** as major problem of standalone diesel generator set;

ii. **Improved energy services** - the ability of integrating renewable energy sources with diesel generator, contributes **dynamic electricity services for 24 hours** per day whilst in a conventional system, which is standalone diesel generator set the operational hours limited only to 6 or 12 hours per day. The cost of PV power generation lies in the form of upfront capital expenditures whereby the operation and maintenance expenses are low;

iii. **Reduced emissions and noise pollution** - diesel generator emits pollution agents as well as loud noise, **reduced CO_2 emission of greenhouse gasses**, proving the essentiality of renewable energy in power generation which adopts an **environmental-friendly technology**;

iv. **Reduced cost** – solar PV-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.

C. SOCIAL CONSIDERATION

C.1 Benefits (User, Community, Country)

The students and the school management staff have directly benefited from the solar PV-diesel hybrid system implementation. Since the operation of the system, the registered student **attendance percentage has increased by 40%** due to the teaching and learning process in more comfortable environment. In addition, **teachers can use interactive teaching methods such as using computers and projector in order to make the learning process more attractive. Extra classes can be conducted during the night for intensive examination preparation.**

As the Rural Electrification Project involves tangible developments, the benefits of efforts have indeed been felt by the users and the rural communities. **The solar hybrid system also promotes sustainable development and a clean environment to the local community.** It also enhances the knowledge and awareness of the local community in green technology.

As the SHS in place, the school is now **less dependent on diesel generator**. Before this, the school need to spend from RM8,000–RM9,000 a month to buy diesel for generators. With SHS, the **school management has reduced their spending on the fuel and had enjoyed the free electricity supply provided by SHS**. **The average monthly spending for electricity is now reduced by 97%.**

As an alternative source of power generation, the solar PV-diesel hybrid system **is in line with the Government of Malaysia policies to increase the role and awareness on the importance of renewable energy for electricity supply and rural electrification. On the broader perspective, it provides a new alternative for energy source since November 2013 and subsequently reduces the dependency on this country's depleting non-renewable oil reserves.**

C.2 Community/People Participation

During the construction stage **the local community has directly participated and involved in the establishment of the solar PV-diesel hybrid system**. **Most of the workers were hired locally or nearby community.** Besides that, close contact with the relevant local authorities has been maintained **in making decisions and subsequently in managing the project deliveries.**

In addition, a **representative from the school has been appointed as the caretaker of the plant**. This **representative is required to attend training on solar hybrid technology and will be responsible to transfer the knowledge the other users.** The initiatives, participation and cooperation of the community and surrounding areas have led to the success of this project.

D. TECHNICAL, ECONOMIC & MARKET CONSIDERATION

D.1 Technical Design

The main components and technical specification for the Solar PV-Diesel Hybrid System at SK Sungai-Sungai, Sabah are summarized as follows:

i. 60.06kW solar PV array. (231 pcs x 260W, 20kW per array @ Solar World, USA)
ii. 432kWh/9,000Ah battery bank. (144 cells, 24 cells/1500Ah per string @ Fiamm, Italy)
iii. 9 x 5kW bi-directional inverter. (Sunny Island –SI5048 @ SMA, Germany)
iv. 15 x 4kW grid inverter. (Sunny Boy – SB4000TL-20 (@ SMA, Germany)
v. 1 x 30kVA diesel generator. (Perkins @ UK)

This solar hybrid system has been equipped with **fully automated operations and monitoring facilities. AC configuration has been used due to its compatibility with SMA Inverters which were designed for on and off-grid electrification. The main battery inverters are the heart of the system** and provide a reference grid to which all loads and generation is connected. A **Multi-Cluster Box MC-Box-12** is used to combine the cabling from each of the Sunny Island inverters and provided contactors for the connection to the load and the back-up generator. Moreover, the **diesel generator has been configured to be automatically turned on for one hour weekly to warm up the engine and to prolong battery life.**

System Reliability & Durability;

The entire solar hybrid system performance was monitored and analyzed in term of daily energy consumption and system overall energy performance. The data collected shown that the solar hybrid system can **produce reliable power supply to meet the electricity need by school** as compare to **diesel generator set which have problems with limited operation hours and short durability**.

D.2 Technical Performance

Table 2: Performance values of the PV-diesel hybrid system at SK Sungai-Sungai based on data available (Dec 2014, Jan-Feb, Sept-Dec 2015)

Parameters	Average	Unit
BOS efficiency	99	%
PV Fraction	95	%
Charge Factor	1.3	
PV generator capacity	1.16	
Accumulator capacity	4.66	

In general, **the system shall continuously collects and record** all the data from the first day of operation **via Sunny Webbox data logger integrated with Sunny Sensor Box**. The data should be recorded every 15 minutes for parameters including the meteorology data; DC and AC voltage and current at the solar PV array, inverter and battery system; operation of diesel generator; and schools load consumption to examine the system's performance indices. Unfortunately, data missing did occurred during some periods of time.

Based on Table 2, system performance analysis describes below:

i. The **BOS efficiency** for the system was **above 90% with average at 99%**. This value shows that the system was installed to high quality and complied with standards and specifications;

ii. In 2015, **51.250MWh of electricity energy were generated by the solar PV** array to full fill the load demand and to charge the battery banks. Only **1.199MWh were generated by diesel generator which contributed only 2.29% of the total energy produced by the systems;**

iii. **Diesel generator set running hours is reduced by 98% in 2015.** Typically the standalone generator set has been operated not more than 12 hours per day, depending on the load demand;

iv. **The average solar PV fraction was 95%** and the lowest PV fraction recorded in January 2015, 86% due to low energy resources. The ratio of solar PV and diesel generator was as expected as system design, 9:1;

v. The reliability of the standalone PV system to supply electricity to the load can be analyzed by the capacity of the PV and the battery storage in a period of time. **The average charge factor for this system was 1.3;**

vi. **The PV generator capacity is found at 1.16 and the accumulator capacity at 4.66**. The solar PV systems generate sufficient electrical power that meet the demand by the user/school and the batteries;

vii. The system performance analysis highlights the reliability of the system as well as benefits of the hybrid system such as **high utilization rate of PV generation**; **optimal satisfaction of load; reduce diesel running hours with minimum maintenance; reliable power supply.**

D.3 Investment Indicator

Financial Model	**Capital Investment: RM4.156 million** **IRR:** *Not Applicable* **ROI:** *Not Applicable* **Payback Period:** **Effectiveness ratio (cost/kW): RM69,197.00/kW** **Note: The project was implemented purely to provide reliable electrical supply to this school which is located at rural area in Beluran, with fully funded by Government without focusing on the return and profits.*

D.4 Financial Scheme/Livelihood Projects

The Government is committed towards total rural electrification and this agenda is reflected in its program initiatives and development budget allocations, as part of the country's five-year national development plans (Malaysia Plans). **For the Nine Malaysia Plans (2006–2010), over RM600 million have been utilized in the implementation of this program in Sabah for the First and Second Phase project (2007-2014).** All expenditures including diesel and maintenance costs of the system for 2 years from the date which the station was commissioned are covered by the Government of Malaysia. **The consumer which is the school/users has been able to obtain free electricity supply without bill charges.**

D.5 Funder (Government and Non-Government)

This project is fully funded by Malaysia Government through Ministry of Education.
Project Cost : RM 4.156 million
Project's Funder & Owner : Ministry of Education, Malaysia.

* Note: Project procurement in 2009: 1.00USD:3.718MYR

D.6 Market Size (Potential Within 5 Years)

In the Ninth Malaysia Plan (2006–2010), the implementation of the rural electrification program has been intensified to improve the quality of life of rural communities, especially in Sabah. **Towards the end of the plan,** a **total number of 155 schools have been supplied with electricity through the solar hybrid system, including SK Sungai-Sungai, Beluran, Sabah**. Under the rural development strategies and substantial funding from Malaysia Government, **access to electricity supply for the poor in Malaysia has been improved.** The Government also has planned for several phases of electricity supply project for remote schools in Sabah as well as Peninsular Malaysia. Therefore, the SHS would be an appropriate option to provide electrification to these communities. **In line with that, this technology may also be extended to Sarawak where there is a wider range of remote and rural communities. The beauty of this designed system is that, when the local electricity grid is available within 7-10 years, the system can be directly connected in parallel with the grid.**

D.7 Local Manufacturing/Content of System

Most main components of the system especially PV modules, battery and inverter were imported from the foreign countries. Nevertheless**, most of the other electrical and structure components were procured from local equipment suppliers.**

D.8 Amount of Fossil Energy Avoided (ktoe, etc)

Table 3: Comparison of Diesel Consumption for Existing Solar Hybrid and Equivalent Standalone Genset

Year (2015)	Current Solar Hybrid System	Estimated Diesel Consumption for Equivalent Standalone Generator Set
Diesel Usage (liters)	441	15,446

The amount of **diesel consumption is reduced by 97%** with the current solar hybrid system compared to an equivalent of standalone generator set of the same capacity.

D.9 Life of Project

The **solar PV-diesel hybrid system has a lifetime of 25 years for the PV array system, 5-10 years for the battery and 10-15 years for the inverter.** The life expectancy may increase if appropriate operation and periodic maintenance is carried out accordingly as recommended by components manufacturer.

E. OPERATION & MAINTENANCE SCHEME

E.1 Operation Hours (Day/Month/Year)

The Solar PV-diesel Hybrid System for Remote Schools was designed mainly to cater for off-grid applications, as an alternative to standalone generator sets and where grid extension is not feasible. **The solar hybrid system was installed in order to operate for 24 hours per day where the power supply is mainly from the solar, battery and generator as a standby system.** By default, the battery inverter (Sunny Island) configuration was set to require the **diesel generator automatically started and run between 40% to 80% of state of charge (SOC).** This was designed to avoid deep cycling of the batteries and thus to increase the lifetime of the batteries.

<u>Load Management Strategies</u>

All loads should only be turned on when required. All the loads in the school buildings should be turned off when there is no occupant in the room, except for the equipment's that need 24 hours operation like refrigerator. **For the teacher's quarters, there were installed with load limiter device which is to manage the extra load used by the teachers or users**. The electricity will be cut-off automatically when the teacher's quarters' power consumption exceed the allocated power.

E.2 Maintenance Scheme (In-House, Contracted Out Service, Government, Others)

The scope of works also included providing maintenance services during Defect Liability Period (DLP) for two (2) years after date of final commissioning together with workmanship warranty, monitoring and reporting of the installed solar hybrid system. **During the DLP period, the Contractor should maintained the system to ensure that the solar hybrid system is performed according to the design.**

The end-user training has been conducted to the teacher for the basic introduction and operation on solar hybrid technology. The teacher should be responsible to give the information on the technology to the other users. **Proper transfer of technology training program** is required for the end users because the **awareness and knowledge on the system technology are equally as important as the adequate financing and institutional framework.**

E.3 Other Maintenance Measures (Training, After-Sales Service)

For the solar hybrid system, **the service and maintenance routine should be done at least twice a year excluding the corrective maintenance.** The generator has less services every year since the operation hours is minimum. After the end of the defects liability period, **Ministry of Education has allocated budget for maintenance programmed based on a yearly basis through Operating Budget (OB). The scope of works for the maintenance process should included inspection, cleaning, servicing as well as preventive and corrective activities.**

E.4 Local Service Content
This system was designed by PWD engineers and was constructed by a local contractor. A local competence System Integrator (S.I.) was appointed by the contractor to do the system interconnection between components. All these works has been supervised by PWD engineers. Malaysia has already invested in the implementation of this solar PV system for the **rural electrification project over the past 10 years.** With this experience, it has enhanced our capacity and capability to **develop a competencies and skills designers, engineers as well as technical support related in renewable energy, mainly in solar PV.**

F. REPLICABILITY

F.1 Relevance, Impact, Efficiency
The Malaysia Government has shown high commitment in extending modernization to rural areas. The aspiration to reduce the gap in education excellence between urban and rural areas lead to the initiative of the solar PV-diesel hybrid systems being implemented in rural Sabah. **The Project has been able to address the issue of electrification of rural areas especially in islands and remote areas and their applications in rural schools for education using the same designed and similar technology.** This rural school electrification project is beneficial where the grid extension is not economic and sometimes are impossible and technically not feasible. **The system is also suitable to be implemented around the world which will provide a solution of an alternative 24-hour electricity supply especially to remote areas and islands.** Nowadays, **the teaching and learning process is more comfortable as teachers can use interactive teaching methods using computers and projector at any time during the learning and teaching session.** For the teachers who live in the teachers' quarters; they can access the latest news and entertainment from the television and radio, store food in the refrigerator, and stay awake for more time during the night. **Students are able to have longer access to electricity at night enabling them to increase their study time and hence, the results of passing marks have increased for the past one year.** The implementation of solar hybrid systems in rural areas also create awareness of the benefits and applicability of green technology to the communities and reduce the digital gap between the students due to access internet and distance learning. **This application is also efficient in terms of its diesel consumption and its system optimization.**

F.2 Cost Effectiveness (No, Low, High Cost)

In general, either diesel generator set only system or solar hybrid system, the **Cost of Energy (COE) is inversely proportional the size of the system**. For a bigger system capacity, it would reduce the COE. But, it will also increase the investment cost.

The total cost of this project in twenty five years of its lifetime has been projected and analysed. The PV-diesel hybrid system was the optimum system with the life cycle cost of energy (LCCOE) was at RM6.31/kWh, while LCCOE of standalone generator set was at RM8.67/kWh which is much higher than hybrid system. **The economic comparison clearly shows that the hybrid system has economic as well as technical advantages over a standalone diesel system**.

The requirement for a renewable power solution was primarily to reduce the on-going diesel fuel consumption and maintenance costs of the rural school facilities**. This system has high investment costs but is beneficial because the maintenance cost is low for the long term operation.**

F.3 Sustainability of Project

A long term system monitoring and evaluation enables a detailed understanding of the system operating performance from the technical point of view. It also provides **useful reference information for future PV system design and operation.**

In principle, this system should continue to work well over 25 years (based on PV modules lifetime) excluding replacement of the other main components such as batteries, inverter and generator. **The main advantage of hybrid system involving AC Coupled configuration is that it can deliver the required amount of energy directly from PV without discharging the battery as far as enough solar radiation on the site. This increases the lifetime of the battery and also prevents the frequent start and stop of diesel generator consequently saves the fuel cost of the system.**

F.4 Others

In summary, **the combination of the PV-batteries-generator reduces the dependency of the fuel consumption and fully utilizes the clean energy from the sun**. Even though a diesel generator system costs less than a solar hybrid system, but **the fact that it's operating costs in providing a proper service and maintenance makes the system less favourable compared to the solar hybrid system.**

G. FIGURES, TABLES, PHOTOS

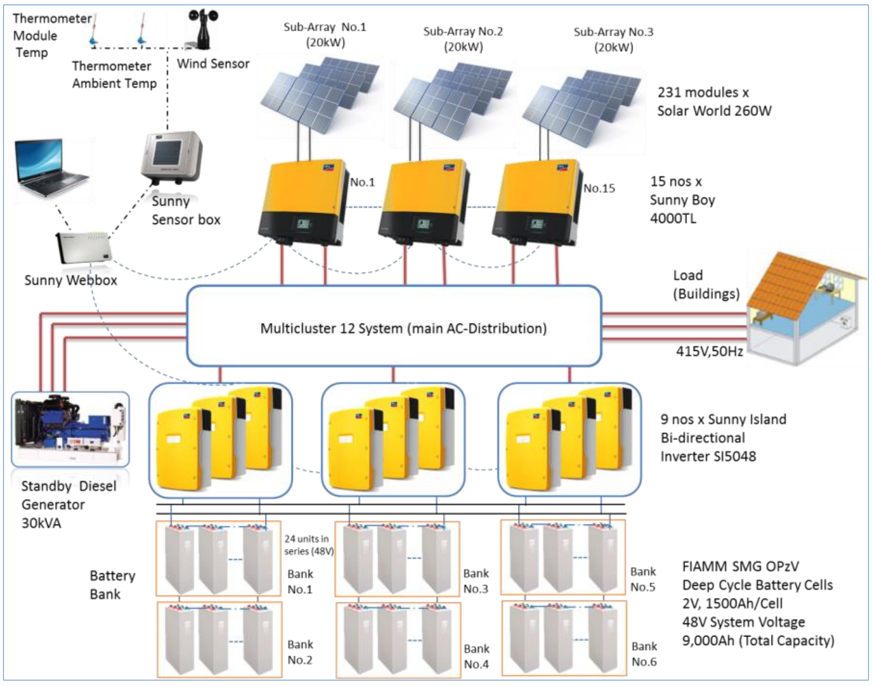

Figure 1: Schematic diagram of the solar PV-diesel hybrid system at SK Sungai-Sungai

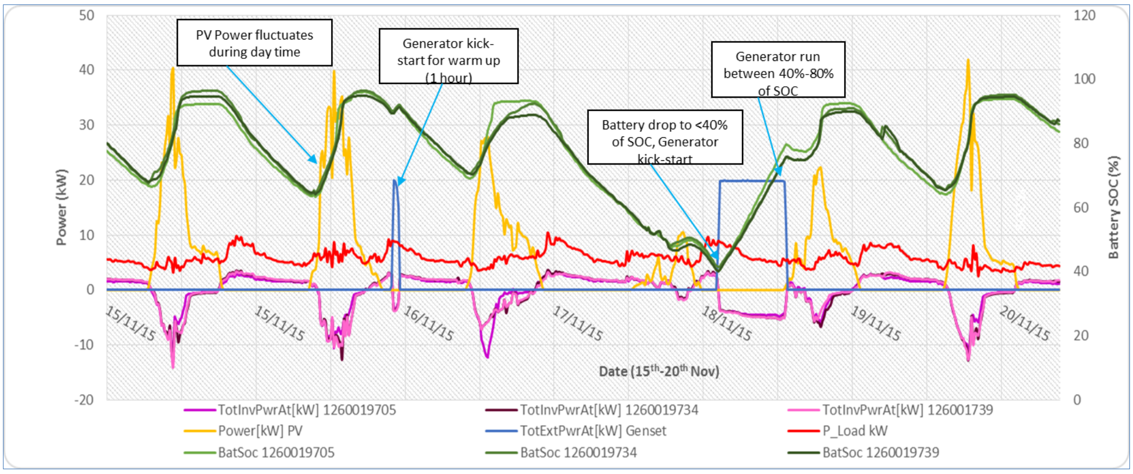

Figure 2: The status of system operation from 15th to 20th November 2015

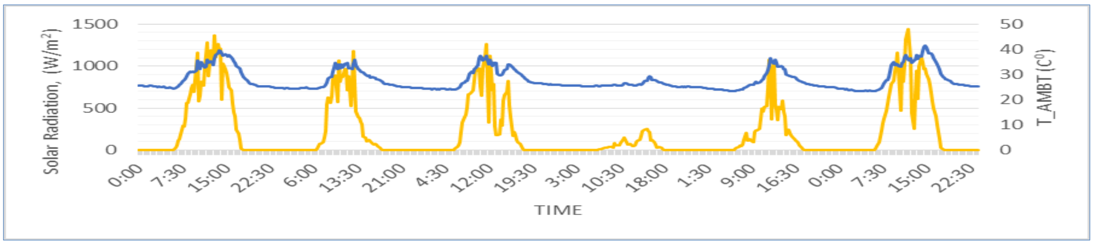

Figure 3: Daily solar radiation and temperature of ambient, 15th to 20th November 2015

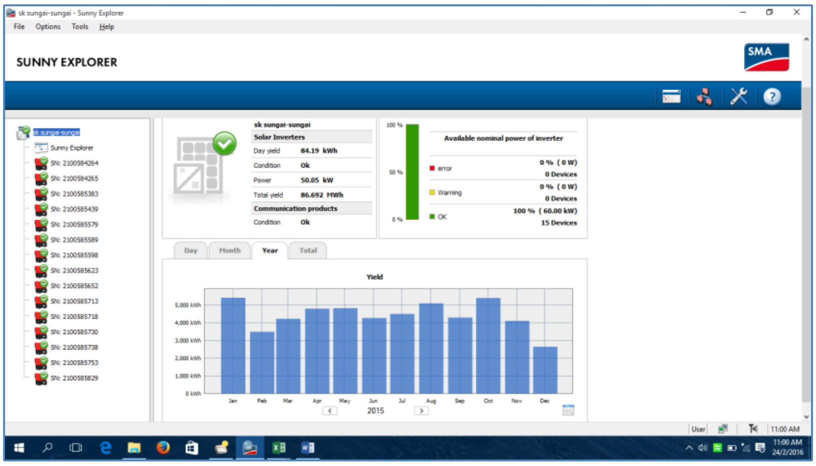

Figure 4: Monthly energy generation from solar PV in 2015, extracted from Sunny Explorer

Photo 1: Power house under the solar array structure

Photo 1: Solar array structures complete with handrail and walkway for maintenance access

Photo 3: Power house (for inverter, battery & generator's room) & PV inverter (Sunny Boy).

Photo 4: Battery inverter (Sunny Island)

Photo 5: Diesel Generator, Generator control panel & diesel tank (2,000liter)

Photo 6: Battery banks, fire protection type: Sapphire Clean-Agent Fire Suppression System

Photo 7: Load energy limiter, at teachers' quarters

Photo 8: Electrical facilities (Hostel)

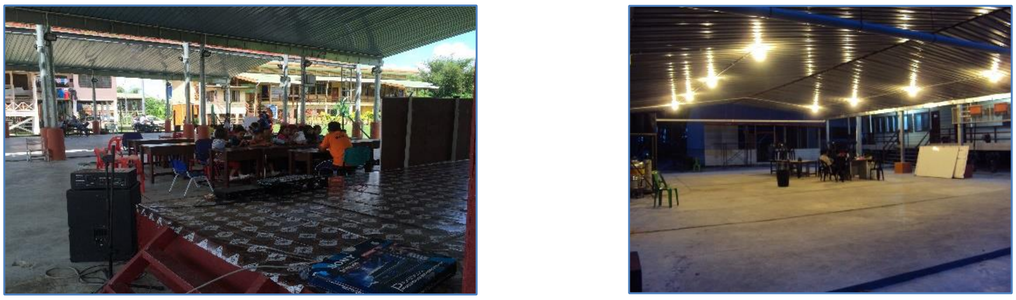

Photo 9: Multipurpose usage under the solar structures i.e. Co-curricular activities, awards ceremony

Photo 10: End user training

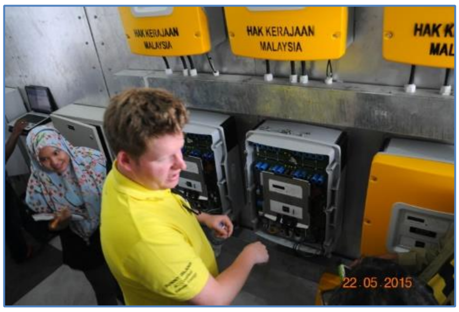

Photo 11: Hands-on training with SMA, inverter manufacturer

Photo 12: PV modules cleaning services