JCM Proposed Methodology

Installation of Energy Management System and Battery Energy Storage System (EMS-BESS) with Solar PV System

Additional Information

1 Summary: Setting emission factor for EMS-BESS with solar PV system

Being an island country, almost all the islands generate its own electricity mainly by diesel generators (DG) and all grids in the Maldives are isolated.

It is studied that without EMS-BESS, the efficiency of DG connected to grids in the Maldives is decreased after the installation of solar PV system by 1) lower load operation of the DG and 2) absorption of solar fluctuation by the DG. In addition, 3) EMS and BESS can operate the DG at the most efficient load by the Economic Load Dispatching Control.

This methodology evaluates the improvement of the efficiency of DG by the contribution of EMS-BESS as above by setting the different emission factor from AM001 which considers only PV installation.

To set the reference emission factor to ensure the net emission reductions, the best efficiency among the installed DG in the grid is adopted to calculate the emission factor of the grid. The best efficiency is calculated from the record of generated power (kWh) and consumed fuel (liter) taken from the production report of electricity company or power producer (at least one year data) to ensure the net emission reductions. When available, recorded data before the installation of solar PV system(s) in the grid are applied.

The emission reductions are equal to the reference emissions since the project emissions are zero.

2 Calculation of reference emissions

2.1 Emission reductions by the installation of EMS-BESS with solar PV system

Feasibility study conducted in 2014 with the support of Ministry of Economy, Trade and Industry (METI) of Japan estimated the energy saving in the case of 1.7 MW solar PV introduction into the 4.5 MW mini grid in the Maldives as below. It is also noted that the amount of saved energy is dependent on the characteristic of the grids such as amount of solar PV, weather condition as well as the diesel generators (DG).

1) By introduction of solar PV of 1.7 MW into 4.5 MW mini grid, 8.7% of the electricity will be generated from Solar PV

2) Without EMS-BESS, by efficiency drop of DG by a) low power operation (in the range of lower efficiency) and b) absorption of PV fluctuation, it was estimated that 1.8% and 2.5% more consumption of fuel will be required. It is concluded that PV introduction can save 8.7% - 1.8% -

2.5% = 4.4%

3) With EMS-BESS, above efficiency drop of DG a) and b) can be solved by BESS, and furthermore, EMS will control DG to run at the most economical load, which will contribute 3.8% energy saving. Thus, in total, by introduction of EMS-BESS with solar PV, 12.5%

4) Thus, EMS-BESS can contribute to 12.5 – 4.4 = 8.1 % reduction of fuel when it is introduced together with solar PV.

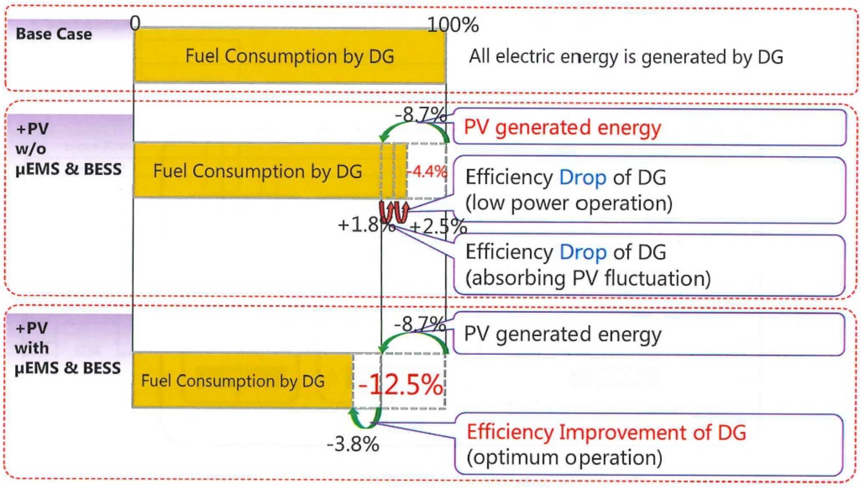

Figure 1 Image of Energy saving by EMS-BESS with solar PV system

In addition to the above, without EMS-BESS, it was not easy to absorb PV fluctuation only by DG operation in one grid in the Maldives, thus it was necessary to cut some inverters and to limit the unstable electricity from solar PV to be introduced into the grid. It indicates that without EMS-BESS, the feasible solar PV capacity for a grid will be affected to be smaller.

The above result was based on the simulation under the specific grid condition, thus, it is not appropriate to apply these figures of reduction ratio to the other cases. However, it is almost certain that the installation and operation of EMS-BESS is more effective for emission reductions. To evaluate the reference emissions for the installation project of EMS-BESS with solar PV system, it is proposed to apply the emission factor which is set based on the best efficiency among the installed DG in the grid. The best efficiency is calculated from the record of generated power (kWh) and consumed fuel (liter) taken from the production report of electricity company (at least one year data) to ensure the net emission reductions.

2.2 Background for setting emission factor

Although an emission factor of grid electricity is commonly used to calculate emission reductions achieved by implementation of renewable energy projects to displace grid electricity, it is not officially published in the Maldives.

2.3 Findings and rationales

2.3.1 Estimation for the existing power stations in the Maldives

In the Maldives, power is provided by STELCO (State Electric Company Limited, 35 powerhouses), FENAKA (FENAKA Corporation Limited, 148 powerhouses), MWSC (Male' Water & Sewerage Company Pvt. Ltd, 1 powerhouse), 4 local island councils, 1 private company in the inhabited islands. Resort islands have their own power supply.

Power source is predominantly diesel with a very small portion coming from solar PV in some islands. For example, in 2017 Annual Report of STELCO, it is reported that solar PV capacity is 1,500kW out of 129,206 kW. Island Electricity Data Book 2018 published by Ministry of Environment and Energy of Maldives, summarizes that total installed capacity in Maldives is 341 MW, while installed renewable energy capacity reaches 11MW. Some reference information on powerhouses and emission factor are summarized in Table 1 below.

Table 1 Reference information of Power generation and Efficiency of powerhouse in Maldives

Item	Unit	MALÉ	HULHUMALÉ	HOARAFUSHI	HANIMAADHOO
Population	People	127,079	15,769	1,826	1,920
Electricity Provider	-	STELCO	STELCO	FENAKA	FENAKA
Installed Power	kW	80,320	17,400	1,000	1,690
Electricity Production	MWh/yr	336,961,612	51,270,714	2,341,956	4,112,756
Oil Consumption	Liter/yr	86,055,128	13,536,795	726,135	1,238,996
Efficiency	kWh/liter	3.92	3.79	3.23	3.32
Emission Factor	tCO2/MWh	0.677	0.700	0.743	0.799

Reference: Excerpt and summary from Ministry of Environment and Energy. (2018). Island Electricity Data Book 2018. Male', Maldives: Author.

Table 2 Constants for calculation of CO_2 emission factor

Item	Values	Sources
Net calorific value of diesel oil	43 GJ/t	IPCC 2006[1] Volume 2 Energy
Default emission factors of diesel oil	72.6 kg-CO_2/GJ	IPCC 2006 Volume 2 Energy
Conversion factor of diesel oil	0.85 kg/litre	Petroleum Association of Japan[2]

2.3.2 Power generation efficiency using diesel fuel

Currently, grid electricity is produced largely through diesel generators in the Maldives. Though only the largest grid, or the grid in Greater Male, has a plan to introduce LNG based power generation system in the future, while grids in other islands will continue to be dependent on diesel engine. Considering the following facts, it can be concluded that diesel generation still tends to be the best available option for grid electricity generation in the future in the Maldives. There are also

1 "IPCC 2006" refers to "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
2 http://www.paj.gr.jp/statis/kansan/index.html (Japanese language only)

a few projects to introduce solar PV, however, it is noted that introduction of solar PV into mini grid or micro grid may not always reduce the overall efficiency of the grid due to the nature of unstable power generation by solar PV system.

- Diesel generator is one of the most energy efficient amongst generators using fossil fuel as a power source
- Lack of infrastructure for the supply of other fossil fuels such as gas pipeline

Existing diesel engines for the grid electricity are expected to be used, but they may be replaced in the near future upon reaching the end of its lifetime. Also, new capacity is always required to meet the increasing electricity demand.

In the current condition with more solar PV systems tend to be introduced, it could further reduce the efficiency of DG without EMS-BESS installation.

2.4 Setting emission factor for the reference emissions

To set the reference emissions to ensure the net emission reductions, the best efficiency of one DG among the installed DGs in the grid can be adopted.

By this, net emission reductions are secured by 1) not including efficiency improvement by economical control by EMS, 2) calculating the best efficiency from the record of generated power (kWh) and consumed fuel (liter) taken from the production report of electricity company (at least one year data) even though introduction of solar PV lowers the efficiency of DG, and 3) calculating the best efficiency to be applied from individual unit of DG, not the overall grid performance.

2.5 Emission factor of captive electricity

The emission factor of 0.8 t-CO_2/MWh, stated in the small-scale CDM methodology AMS-I.F. “Renewable electricity generation for captive use and mini-grid,” is commonly used as the emission factor for captive diesel generators. Thus, in any case, the emission factor will be equal to or less than 0.8 t-CO_2/MWh.

3 Calculation of project emissions

The project emissions can be calculated to be zero considering the additional emissions by the project can be evaluated as negligible. Following sections describe the reason why the emissions from the installation of EMS-BESS and monitoring equipment are negligible.

3.1 Electricity Loss by EMS-BESS

Electricity loss by EMS-BESS is negligible by following reasons.

1) Power consumption of EMS: EMS is basically a computer system which may require electricity for computer itself as well as air-conditioning system. These computer and air-conditioning system

are commonly introduced for solar PV systems.

2) Loss by BESS: In the mini-grid in Maldives, introduction of large scale solar PV requires careful design in order not to affect the grid stability. For example, to incorporate with the 1.5-2MW of solar PV, 400 kWh BESS at 3C could be enough depending on weather. And from the manufacture of BESS, 15% loss will occur by one cycle of charging and discharging.

In case 70% of 400 kwh BESS is charged and discharged every day, 400 kWh x 70% x 365 days x 15% loss = 15.3 MWh is the potential loss. This is approximately only 1% of the solar PV generation and this methodology calculate emission reduction much more conservatively by ignoring DG efficiency improvement by EMS-BESS. Thus, this loss is evaluated as negligible.

3.2 Electricity consumption by monitoring equipment

Electricity loss by monitoring equipment is negligible by following reason.

The electricity consumed by a typical monitoring system ranges from 1 W for a meter to 12 W for a communication and data logger system (see below), and this system will be powered by grid electricity of internal power grid. The electricity consumption is negligible compared to the power generated by the solar PV system.

Table Electricity consumption by monitoring equipment

Item	Power demand	Source
Monitoring equipment	Type 4W (Max 12W)	SMA SUNNY WEBBOX catalog
Electricity meter	Up to 5VA	Osaki Electric A3C-S27VR specification document