PV Microgrids and Potential solutions

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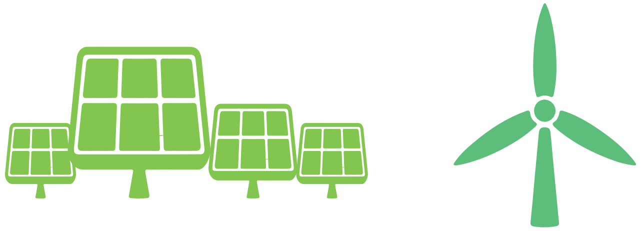
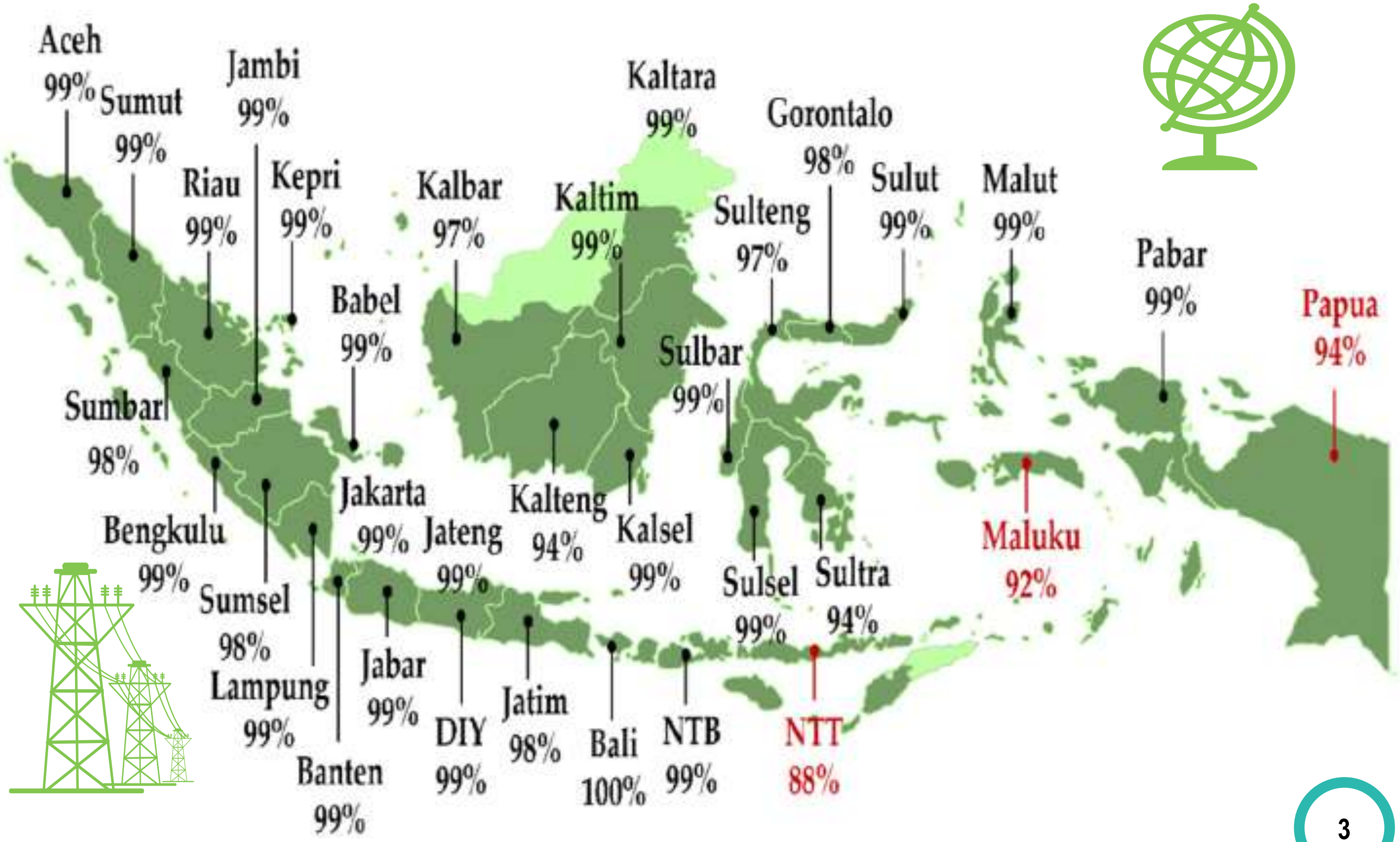
1. Introduction

- In Indonesia only the larger microgrids seem to have an impact on the energy mix target 2025.
- While smaller microgrids have less capacity, thus contributing relatively a small amount to the total renewable energy mix, they however are more suitable to reach isolated areas thus their potentials lie in the increased number of implementations.



Large remote microgrids • Normally used for mining, refuge, or military base • To reduce operational cost for commercial or industrial • As an emergency power for refugee camp or base. Examples: PV Bontang ITMG, Biogas Petapahan (PT Ramajaya) and Damit Hulu (PT Gawi).	**Small remote microgrids** • Isolated area • Mainly focus on diesel replacement • Limited power for housing Examples: Buta, Borme, Berau, Miang Island, Matutuang island, Lakatuli NTB, and Kariango, Ogan hilir, and Hydro Silina Baru, Nias.
Examples: PV Oelpuah, PV Gorontalo, Hydro Lubuk Sao II and Cibareno, Geothermal Ulumbu and Matalako, Biowaste Cengkong Abang • To inject power to grid • Connect to medium or high voltage grid (strong grid) • Can be used as an island mode **Large grid-connected microgrids**	Examples: Pramuka island, Nusa Penida, Medang, Semau, Mini Hydro Sindang Cai, Biowaste Kuala sawit, Sumut. • High load demand • To inject power to grid • Help long distribution line from voltage drop (weak grid) **Small grid-connected microgrids**



2. Why Off-Grid Is So Important

Target Renewable Energy

23% RE mix in 2025 and 31% by 2050.
Realization: 14.91% RE in May 2020.

Target Electrification Ratio

98.89% ER and 100% villages by 2019.
Realization: 98.99.% ER and 99.48% in 2019.

- RE IPPs grid connected (normally private companies). Example Bontang ITM.
- RE government utilities grid connected. Example PLTA Asahan 3, biomass PTPN XI and geothermal PGE.

RE expansion grid

RE Off-Grids

- Increase distribution lines for rural area.
- Utilize diesel generators for small communities.

"Program Indonesia Terang" (Bright Indonesia Program)

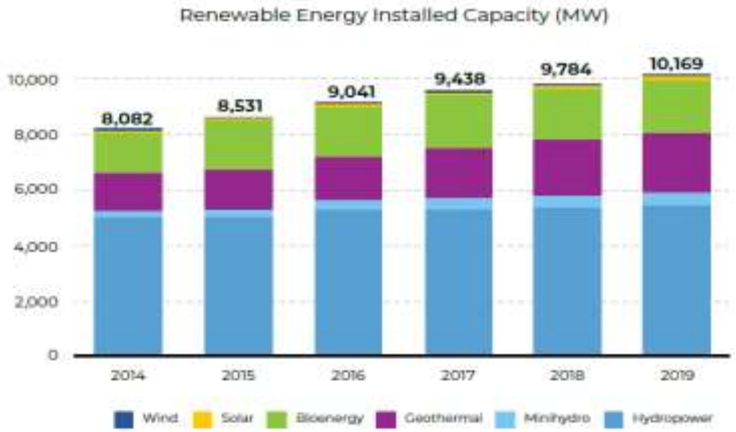
1. Target 2500 villages
2. More PV as an energy source
3. Lampu Tenaga Surya Hemat Energi (LTSHE)

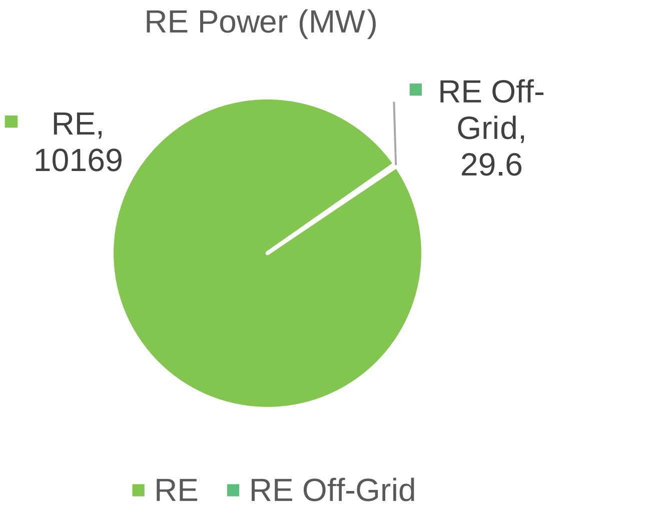
NO	PROVINSI	JUMLAH DESA	DESA BERLISTRIK			DESA BELUM BERLISTRIK	RASIO DESA BERLISRIK
			BERLISRIK PLN	BERLISTRIK NON PLN	BERLISTRIK LTSHE		
33	Papua	5.521	1.210	1.588	2.399	324	94.13%
34	Papua Barat	1.837	753	782	199	103	94.39%

laporan-kinerja-ditjen-ketenagalistrikan-2019

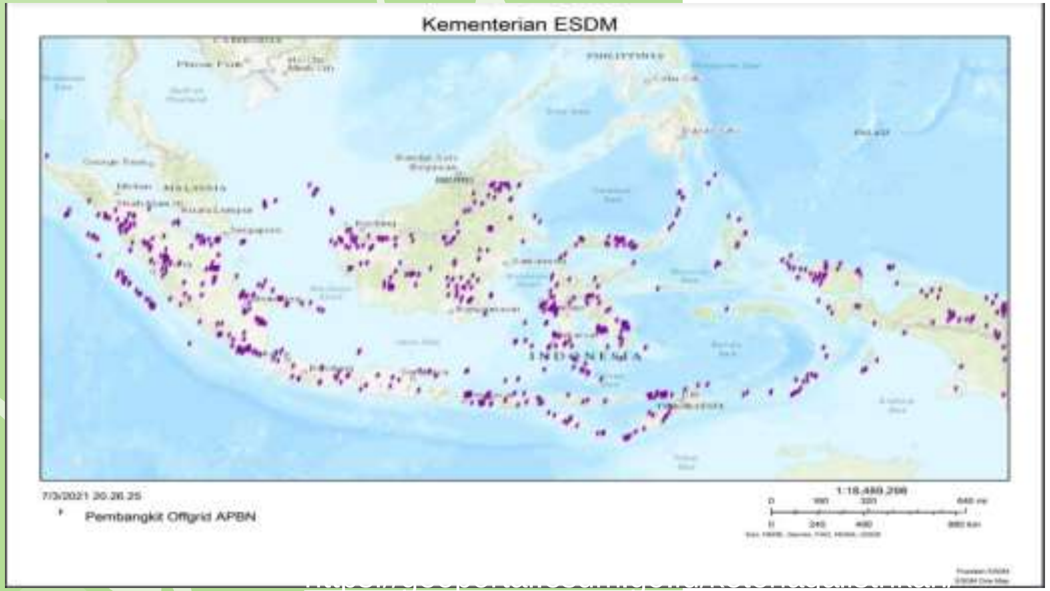
Sarana Distribusi PLN	887.301,40	920.522,24	953.560,46	953.560,46
25 - 30 kV	60,33	100,95	100,95	100,95
15 - 20 kV	359.738,69	373.825,50	388.953,99	388.953,99
10 - 12 kV	3,12	-	-	-
6 - 7 kV	5,43	-	-	-
<6 kV	527.493,83	546.595,79	564.505,52	564.505,52

714 sites, 93,631 households and 29,567 kW

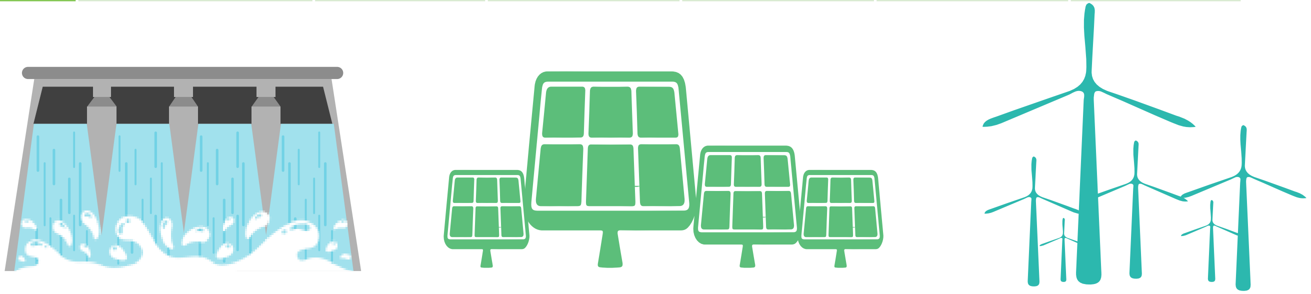




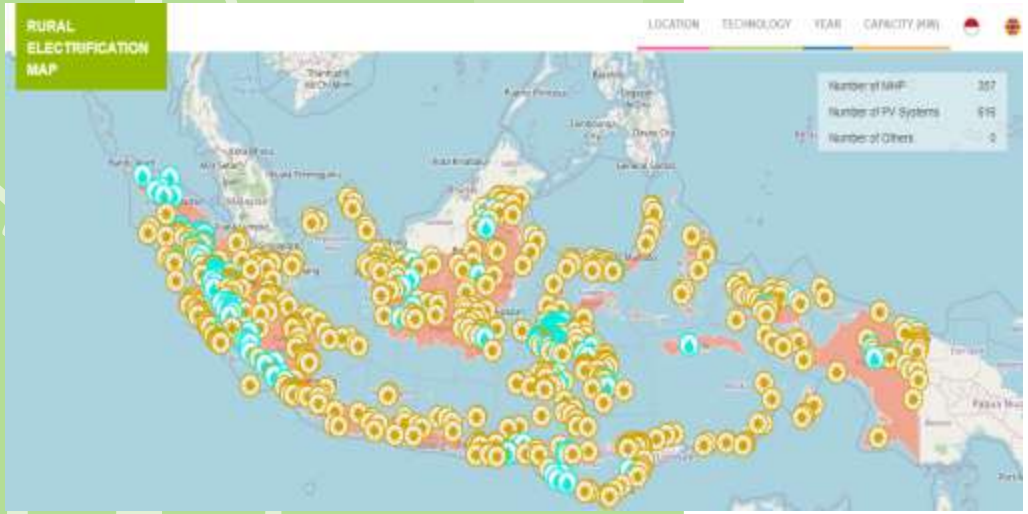
2. Why Off-Grid Is So Important



No.	Province	Total Villages	# Villages with Electricity			Percentage
			PLN[1]	Non-PLN[2]	Solar Light[2]	
1.	Maluku	1,233	871	294	68	100.00%
2.	North Maluku	1,180	967	163	50	100.00%



- 714 sites, 93,631 households and 29,567 kW
- 973 sites, 107,182 households and 29,427 kW



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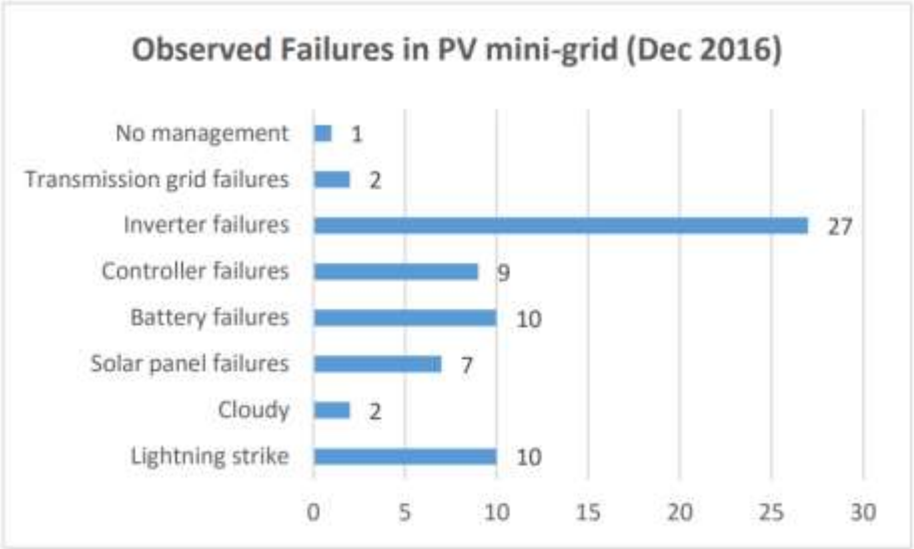
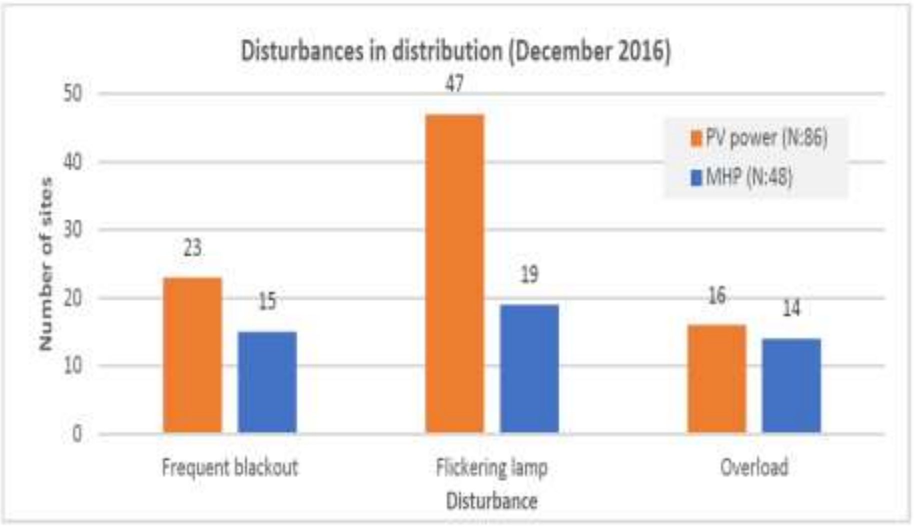
- To achieve both mixed renewable energy mix and power quality targets, the PV microgrids can be a solution.
- The PV off-grids can help to improve attributes of energy access (capacity, availability, reliability, quality, and affordability), increase the electrification ratio, reduce the economic gap between rural and urban areas.

Endev Survey

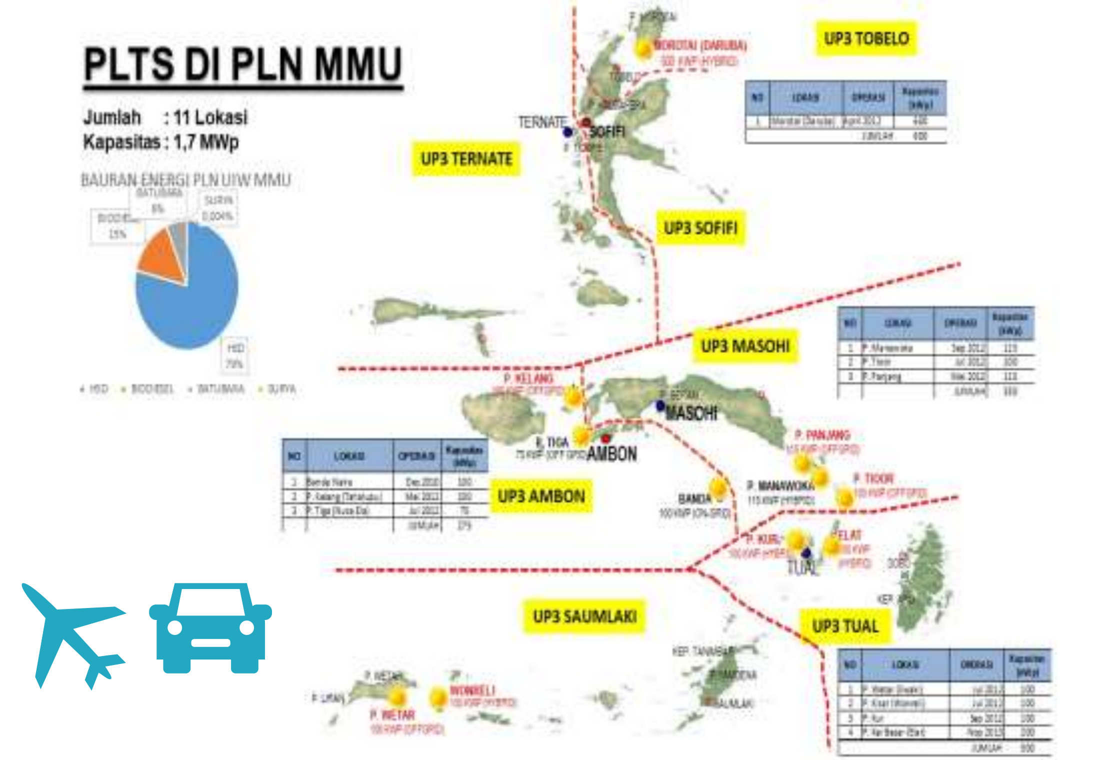




- The survey successfully contacted 117 PV mini-grid sites. Among these sites, 84% were operational, while 16% were disrupted for PV and 23% were disrupted for MHP.
- There were 38 PV mini-grids operating with problems and 19 sites were not operating at the time of survey.
- Inverter disturbances were the most reported cases in PV mini-grids, followed by battery disturbances and lightning strikes.
- Unavailability of local technical support might contribute to the high numbers of disturbances on PV mini-grids.

- Most of disturbances in the distribution line is flickering lamp.
- It is an indication of voltage instability in the distribution grid which might be caused by poor cable connection, high impedance in the distribution line, overload, and poor performance of voltage regulator including ELC in MHP.
- Based on the survey only 20 among 117 sites that have access to electricians with low competencies on PV. Moreover, only 13 out of 63 MHP sites have technicians who live in the (nearby) village

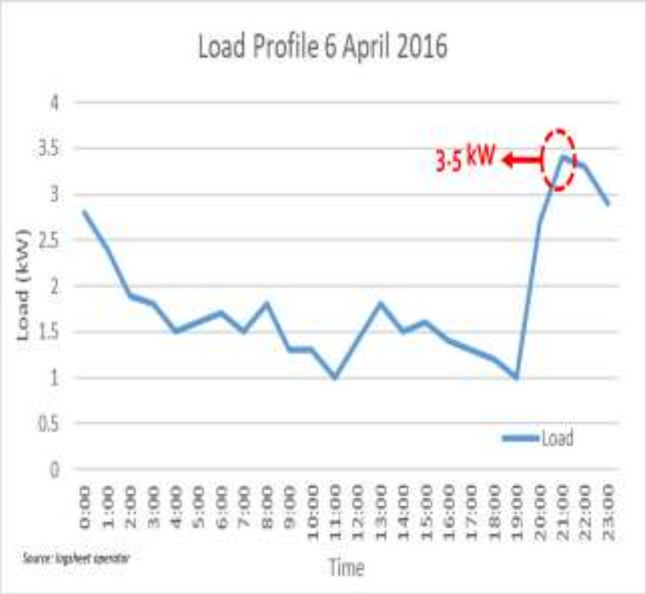
3. Actual cases

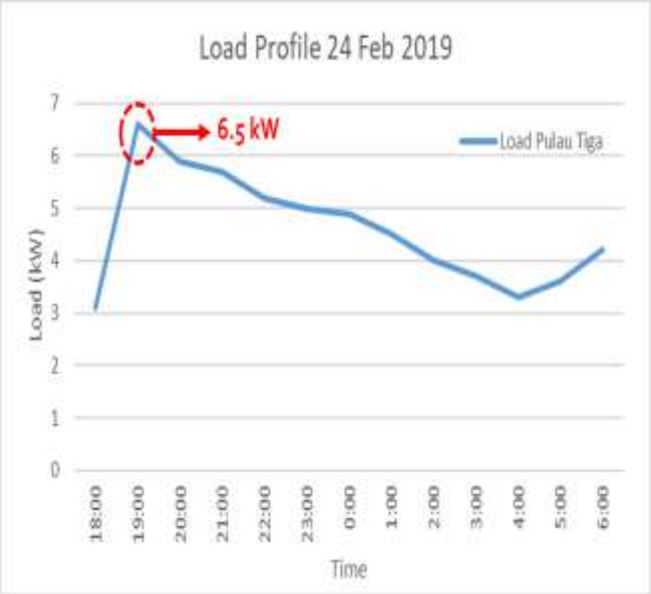


PV Designator	Year of Operation	Location	Funded by	Type	PV Designator	Year of Operation	Location	Funded by	Type
Site 1	4	Ambon	PLN	Off-grid	Site 9	3	Saumlaki	MEMR	Hybrid
Site 2	8	Ambon	PLN	Off-grid	Site 10	3	Tual	PLN	Hybrid
Site 3	3	Ambon	PLN	Off-grid	Site 11	2	Tual	MEMR	On-grid
Site 4	3	Masohi	PLN	Off-grid	Site 12	3	Saumlaki	MEMR	On-grid
Site 5	5	Masohi	PLN	Off-grid	Site 13	6	Tobelo	PLN	Hybrid
Site 6	5	Masohi	PLN	Off-grid	Site 14	2	Saumlaki	PLN	Hybrid
Site 7	3	Tual	PLN	Hybrid	Site 15	5	Tobelo	MEMR	On-grid
Site 8	4	Tual	PLN	Hybrid					

3. Actual cases

Planning Phase





1. The peak load was 3.5 kW in 2016, but since the energy access boosted the local economy, the peak load increased to 6.5 kW in 2019
2. Due to the high discharging rate, 16 out of 120 batteries were damaged resulting in an inadequate battery voltage for charging.

Another case:
As the PV system was connected to the diesel generator as a hybrid, it made the specific fuel consumption (SFC) of the diesel generator not efficient.

The PV inverter power was 100 kW while the nominal daily load was around 200 kW. It is known that SFC diesel generator is typically optimum at 75-80% of the nominal rated capacity but degrades very rapidly when the diesel generator is operated below 40% of its rated capacity.

3. Actual cases

Design Phase

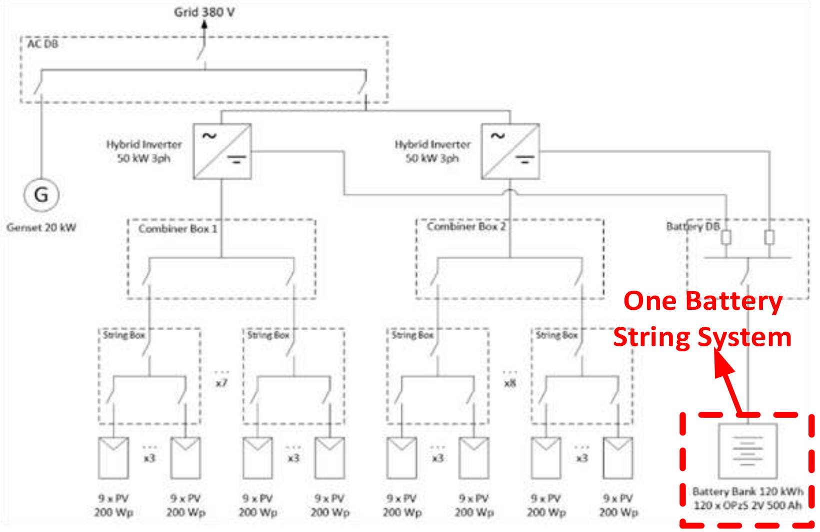
Air conditioning is mandatory for designing a battery room as per IEEE std. 937 – 2019 since the battery lifetime has a strong relationship to the temperature and humidity

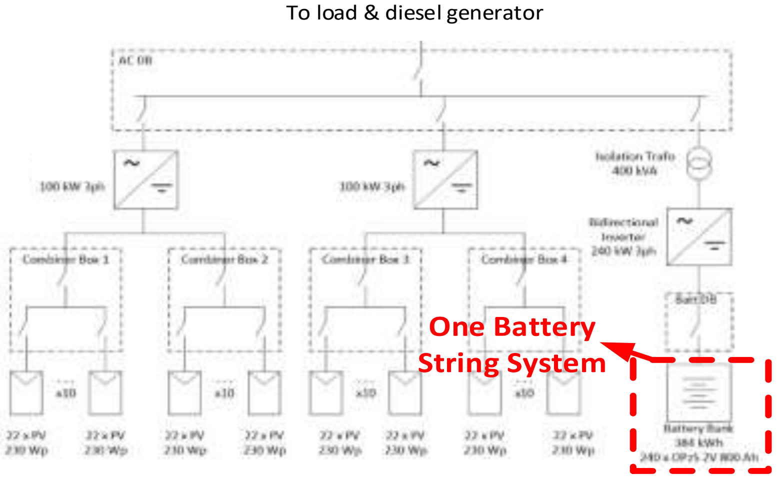
Another case:

- The 100kWp PV-diesel site 14 was designed for the isolated load condition, of which in the afternoon, the PV will cover the load, and in the evening, the load will be covered the diesel generator.
- The operator needed to manually switch between the PV system and diesel generators. Due to this inefficient way of operation, the PV system were not used anymore (availability and reliability MTF). As a consequence, the inverter, combiner boxes, and powerhouse slowly decayed over time

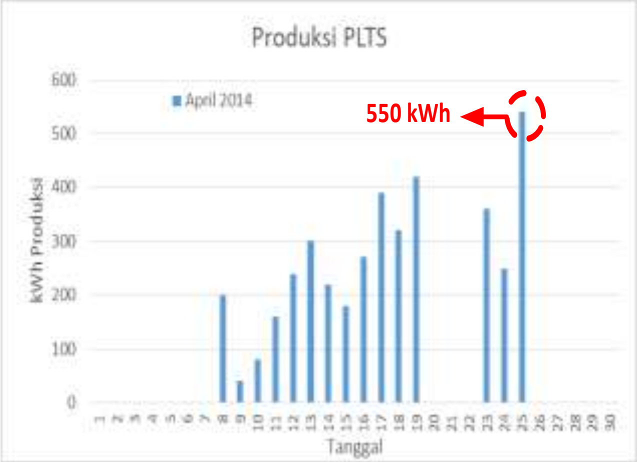
3. Actual cases

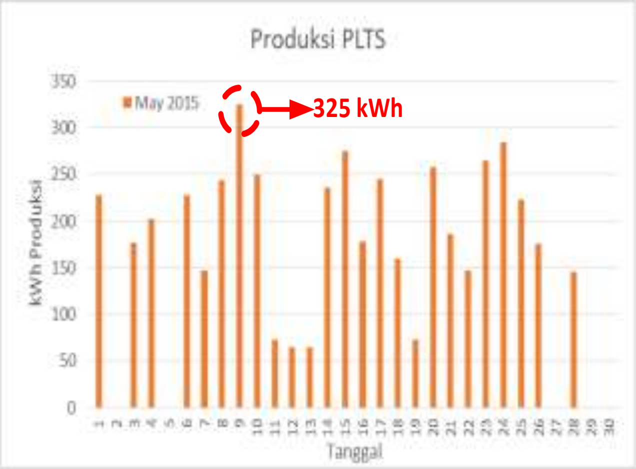
Operation & Maintenance





The IEEE Std 1561 – 2019 recommends applying two parallel strings of batteries for redundancy in case of maintenance. The second string provides at least some storage for continued operation





Another case:

- The energy generated from the PV system was around 550 kWh/day, but in 2015, this decreased to a maximum of 325 kWh/day.
- During a year of operation, the PV site 7 degraded more than 40%.

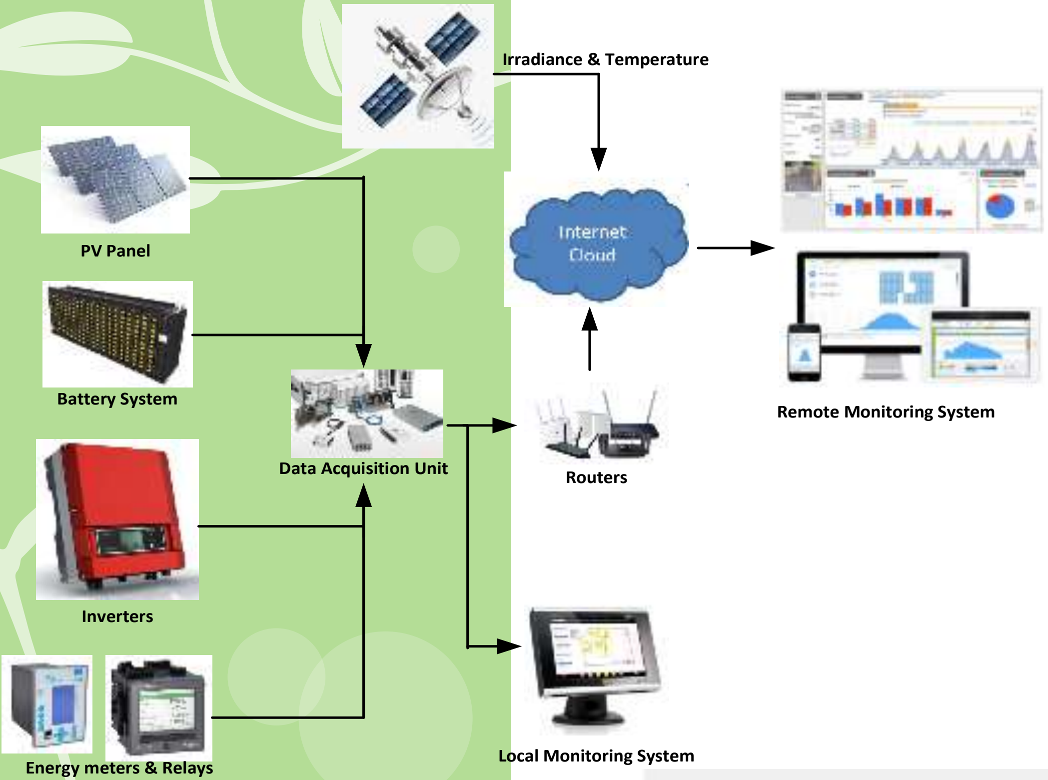
3. Actual cases

Another case (Spare part):

PV site 2 was not in operation due to IGBT failure, and PV site 3 was not in operational because of batteries failure (480 kWh/OPzS FIAMM LM 1000ah (120 pcs)) with the actual voltage is 112 V only, which is lower than the rated battery system voltage in the range of 192 - 240 V.

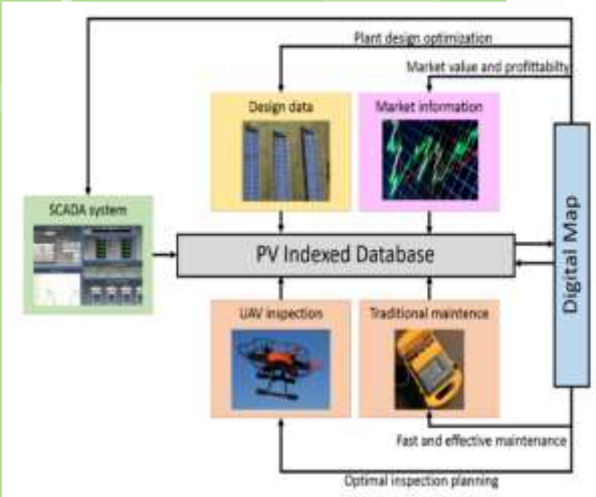
PV Designator	First Component failure	Impact to the other components (✓ = in good condition; ✗ = not in good condition; ? = no information)					
		Inverter	Battery	Battery Charger	PV Panel	Combiner Boxes	Local Internet
Site 1	Battery	✓	-	✓	✗	✓	n/a
Site 2	IGBT Inverter	-	n/a	n/a	✗	✗	✗
Site 3	Battery	✗	-	✗	✗	✗	n/a
Site 7	Battery	✓	-	?	✗	✗	✓
Site 8	Inverter	-	✓	✓	✗	✗	n/a
Site 12	See 2.3.1 Planning Phase	?	?	?	✗	✗	✗
Site 14	See 2.3.2 Design Phase	✓	✓	✓	✓	✗	✗

4. Potential Solutions



Online monitoring solution

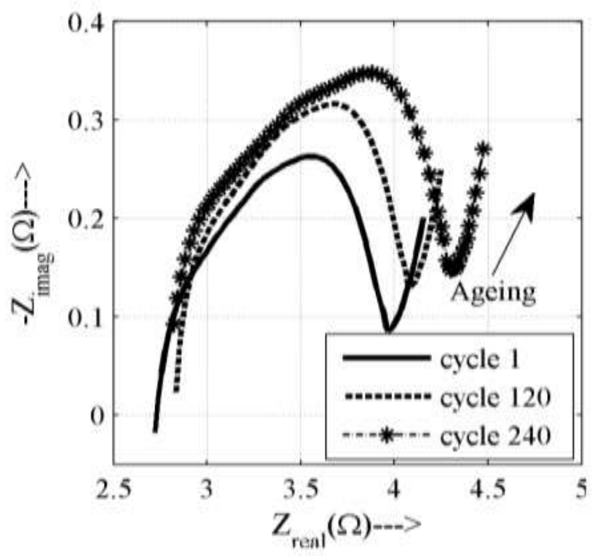
The current, voltage, power, and energy are the main data to be monitored, but due to the technology development, the batteries and the PV panels lifetime can also be monitored.

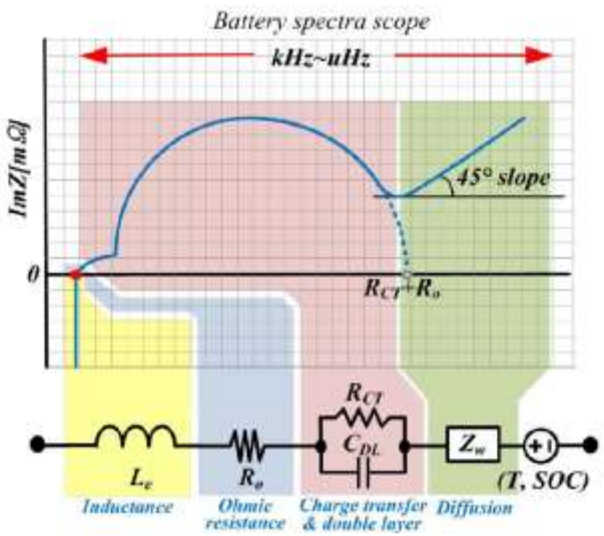


PV Panel Lifetime Estimation

To reduce the visual checking time and to predict of the PV panel degradation, machine learning (ML) algorithms could be implemented. In [29], the authors proposed unmanned aerial vehicles (UAVs) with electroluminescence (EL) and ultraviolet (UV) fluorescence (FL) techniques to estimate the RUL of the PV modules.

4. Potential Solutions





Battery Lifetime Estimation

- The EIS injects a ripple current to the battery, and the battery output terminal voltage will respond to the current and the battery internal impedance can be obtained.
- The impedance of the battery has a strong relationship to the battery RUL which is typically the battery's internal impedance will increase due to the cycle time

String Inverter vs Micro Inverter vs DC Optimizer

Type	Company	Model	Power (kW)	Efficiency	Multiple points of failure	Individual PV panel monitoring
String Inverter (Site 2)	Sungrow	SG100K3	100	96.4 %	✘	✘
String Inverter (Site 8)	Solar power solution	SR5KTLA1	50	96.8 %	✘	✘
Microinverters	Enphase	IQ 7X	0.32	97.5 %	✓	✓
	Chilicon Power	CP-250E	0.29	96 %	✓	✓
DC Optimizers/ Power Optimizers	SolarEdge	P300	0.30	99.5%	✘	✓
	Huawei	SUN2000	0.45	99.5%	✘	✓

1. Lee, Y.; Park, S.; Han, S. Online Embedded Impedance Measurement Using High-Power Battery Charger. *IEEE Transactions on Industry Applications* **2015**.
2. Guha, A.; Patra, A. Online Estimation of the Electrochemical Impedance Spectrum and Remaining Useful Life of Lithium-Ion Batteries. *IEEE Trans. on Instrumentation and Measurement* **2018**.

4. Potential Solutions

Load Forecasting

- Load forecasting strategies are part of the planning issues which need to be well estimated as a basis of PV, diesel generator, and battery sizing.
- While the short-time load forecast (STLF) needs to be calculated for the source load balancing and the energy fluctuation in the battery system.
- medium-term load forecast (MTLF) and long-time load forecast (LTLF) need to be accurately estimated at the beginning of the design phase since this estimation will affect the expansion area, spare, and space in the substation cubicles, inverter-diesel generator synchronization, and automatic switch.

Purpose	Model	Year	Mean Absolute Percentage Error	Location
STLF	FS (IT2FS) [36]	2011	1.034%	Indonesia
STLF	LR (WOA-DWT-MLR) [37]	2019	1.30%	Taiwan
STLF	SOM-K ANN [38]	2014	2.71%	Spain
MTLF	SVM [39]	2018	0.196%	China
MTLF	SVP + SVB [40]	2013	7.00%	No data
LTLF	RNN with hybrid GRU [41]	2020	6.54%	No data

5. Conclusion

- First the lack of practical and technical knowledge and inadequate preliminary survey were observed. Second was the lack of local skilled personnel. Third the lack of O&M standards.
- It can be concluded that during the planning phase, load characterization didn't anticipate (heavy) growth patterns thus PV and battery were undersized. Estimation strategies have to be implemented to ensure the correct sizing.
- During the design phase it was observed that local climate was often not considered.
- Using a proper O&M standard or protocol, the degradation of the batteries could be taken into account, thus ensuring high energy generation.
- Lastly, the technology recommendations are added in this paper to reduce the O&M costs and to keep the PV microgrid lifetime as long as possible such as online monitoring solution, PV and battery lifetime estimation, load forecasting, and PV inverters technologies.


Do you have
any questions?