

Energy Sharing Solution for Decentralized Off-Grid Power Systems

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1. The **ASEAN IVO** (http://www.nict.go.jp/en/asean_ivo/index.html) project, [Smart Energy-Sharing and Management Devices for a Low Carbon Society](#), was involved in the production of the contents of this publication and financially supported by NICT (<http://www.nict.go.jp/en/index.html>).

Under the collaborative project “*Smart Energy-Sharing and Management Devices for a Low-Carbon Society*,” involving Thailand, Lao PDR, Myanmar, Cambodia, and Japan.

2. The authors would like to express their sincere gratitude to the **Energy Regulatory Commission** of Thailand (**ERC**) for its financial support of the earlier Energy Sharing Devices (ESDs) development project. The foundational work funded by the ERC significantly contributed to the technical progress, field experience, and practical insights that enabled the present study.

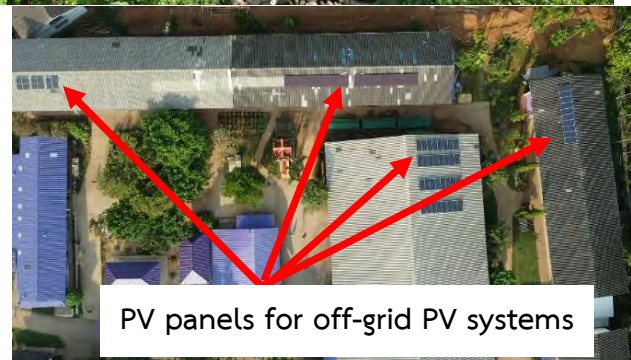
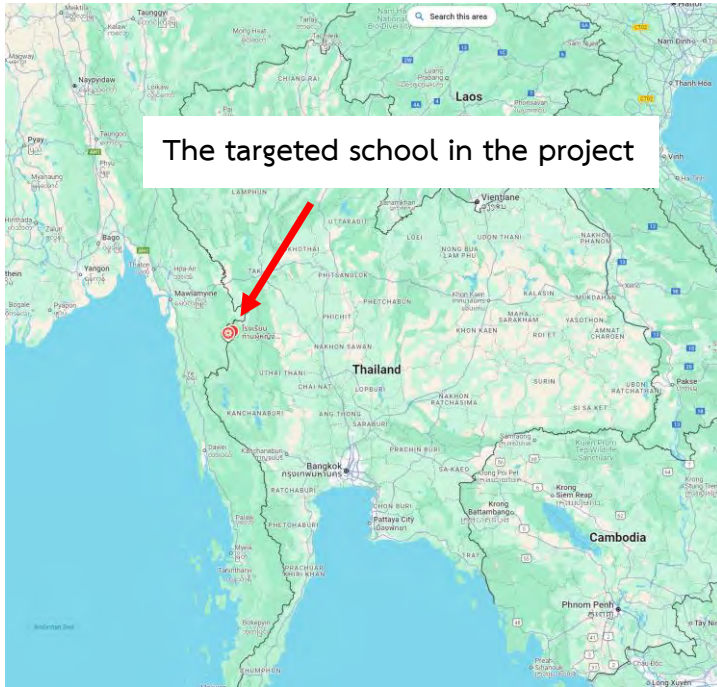


3. The authors would like to express their sincere appreciation to **Rajamangala University of Technology Lanna (RMUTL)** for its collaboration in system discussion and installation, as well as its connection with the local community, which were instrumental in enabling the successful implementation and evaluation of the proposed Energy Sharing Devices under real-world rural conditions.

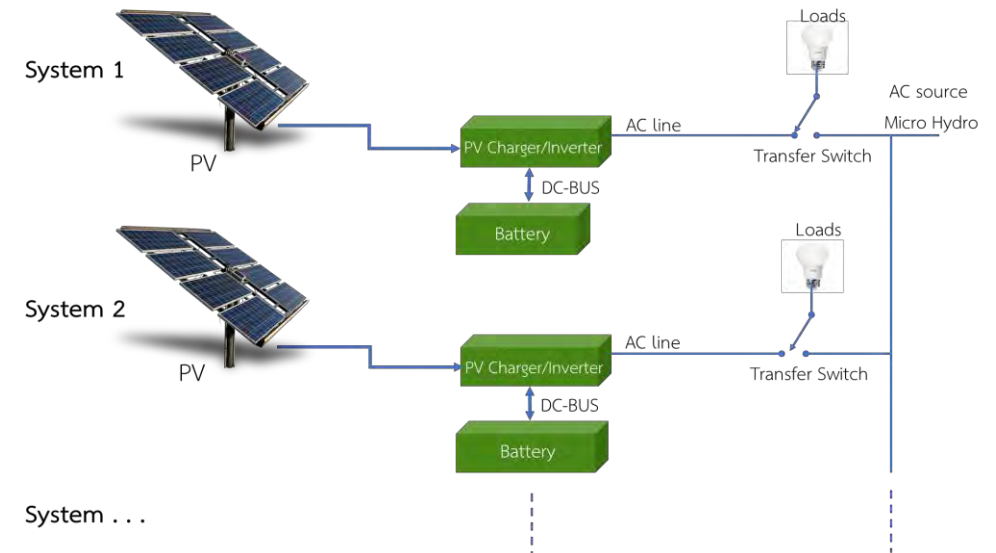


- Background and Motivation
- Proposed Energy Sharing Devices (ESDs): Concept, Design, and Validation
- Future/Ongoing Work: Toward a Smart Energy Sharing Network
- Conclusions

Energy sources for the targeted school



Original electrical systems in the school



Reserved forests: public utilities, such as national grid, are not permitted. However, people had already settled in before.

Renewable energy systems: Independent off-grid PV systems, (inadequate and unstable) micro hydropower system

Benefits: Safe (low power, low voltage, 5kW/48Vdc, local people can take care of the systems)
Problems: energy is not shared among the systems. High energy waste, low overall reliability, cost ineffective, etc.
The Proposed Solution: Energy Sharing...

	PV (kW)	Average PVgen/Day (kWh)	Daily Load Demand (kWh)	Energy Surplus (+) / Shortage (-)
System 1	6.27	31.35	24	7.35
System 2	3.3	16.5	31.2	-14.7
System 3	6.93	34.65	25.2	9.45
System 4	4.98	24.9	33.6	-8.7
System 5	6.6	33	24	9
Total	28.08	140.4	138	2.4

Estimated energy waste:

25.8 kWh/day

Annual energy recovery:

$25.8 \times 365 \approx 9,417$ kWh/year

\approx USD 1,414.55 per year

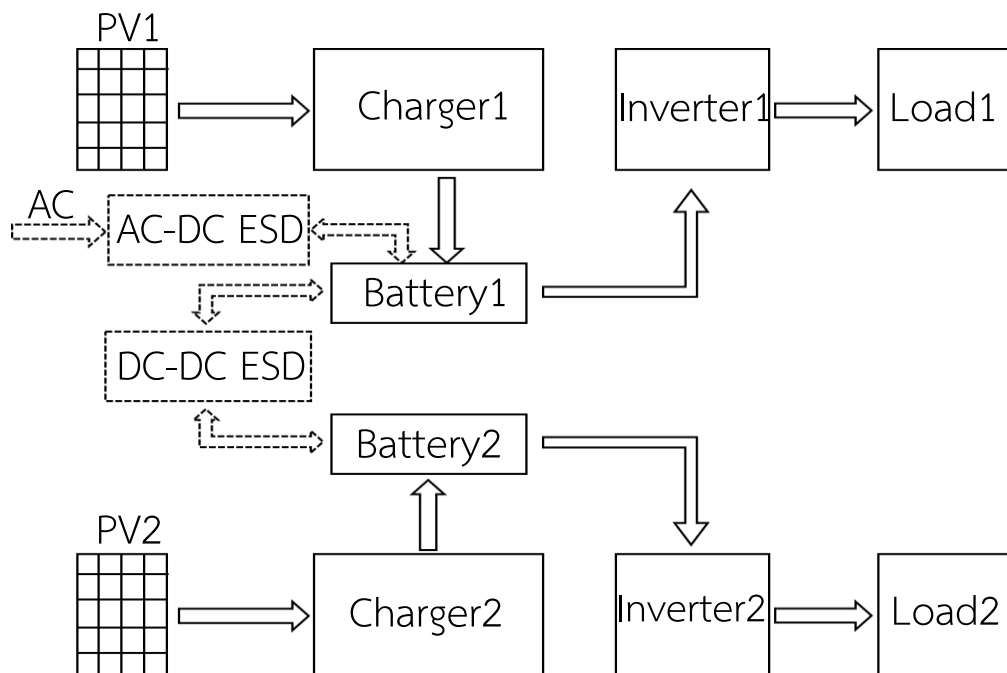
Estimated payback period:

1–2 years, depending on the number of deployed ESDs.

***** Assumption**

- DOD of the battery is 100%
- Power conversion loss is negligible.
- The electricity price/kWh is 5 Baht (0.15 USD)
- Daytime load demand is 60% of daily load demand.
- The costs of the DC-to-DC and AC-to-DC ESDs are 450 USD and 600 USD, respectively.

Proposed Energy Sharing Devices (ESDs)



In practice, the choice of devices is flexible and can be tailored to each system; not all devices must be used.

Why ESDs?

- No impact on existing system operation
- Preserve key advantages: **simple maintenance, safety, readily available components, and low cost**

1. DC-DC ESD (Bidirectional Power Flow)

Enables direct energy sharing between nearby battery systems Based on **Dual Active Bridge (DAB)** topology

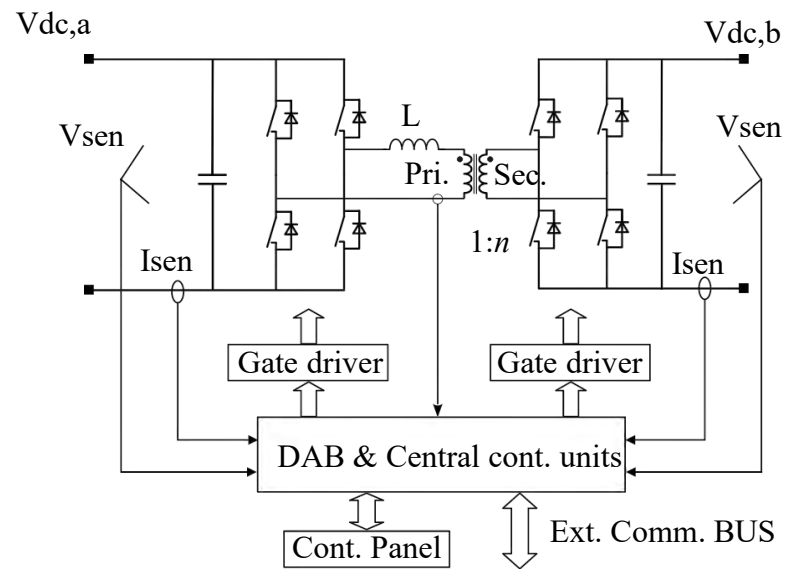
Key features: High efficiency, Bidirectional power flow, Galvanic isolation, Simple and robust control

2. AC-DC ESD (Unidirectional Power Flow)

- Transfers energy from an AC source (grid or remote inverter) to charge batteries

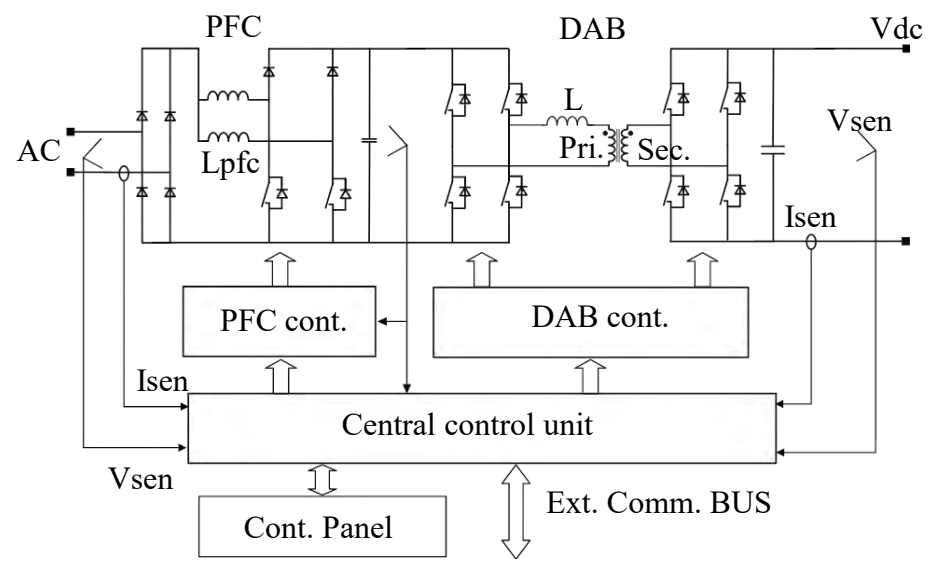
- Uses **interleaved boost converters** for PFC combined with **DAB** charging stage

Key features: High efficiency, Galvanic isolation, Easy control and integration



1. DC-to-DC Energy Sharing

- Main topology: Dual Active Bridge Converter (DAB)
- Control unit: Analog + Digital
- Communication BUS for communicate with BMS and others
- Monitoring/Control panel
- High frequency transformer for **galvanic isolation**

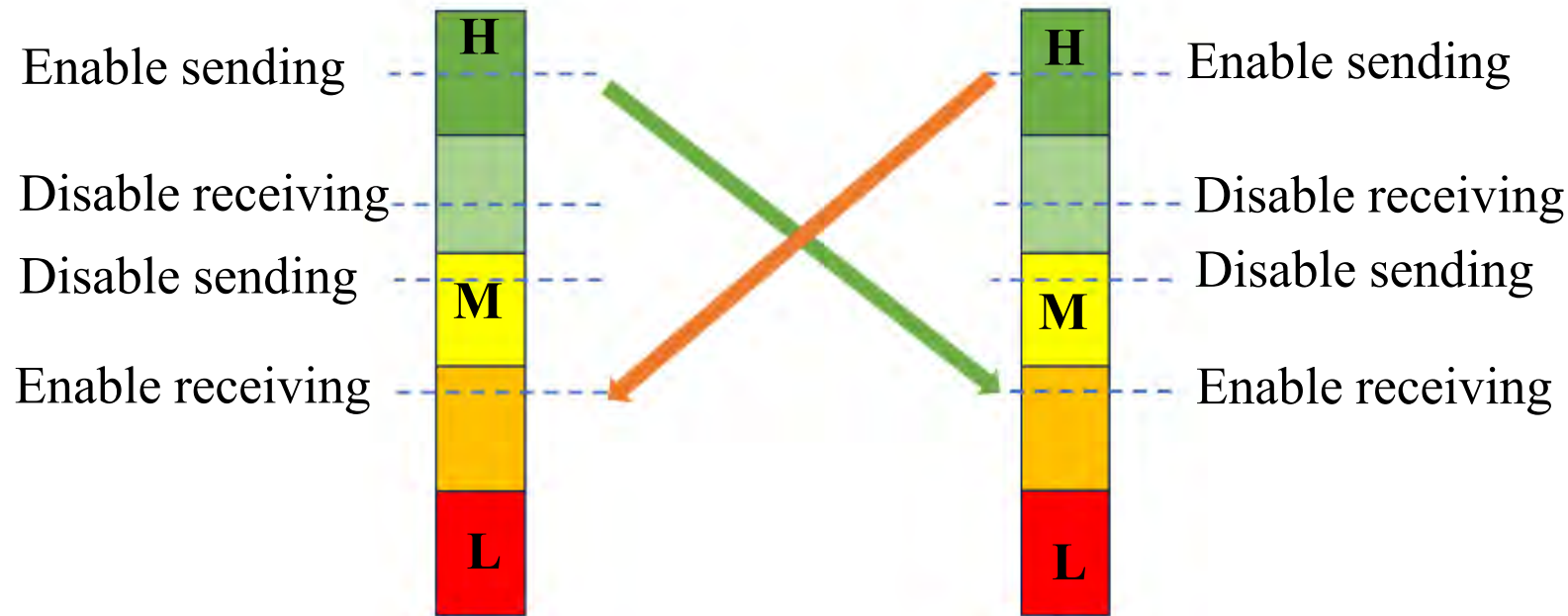


2. AC-to-DC Energy Sharing Device contains:

- Main topologies: Interleaved boost converter for PFC (Power Factor Correction) and DAB
- Control unit: Analog + Digital + (Optional) Energy Management Board
- Communication BUS for communicate with BMS and others
- Monitoring/Control panel
- High frequency transformer for **galvanic isolation**

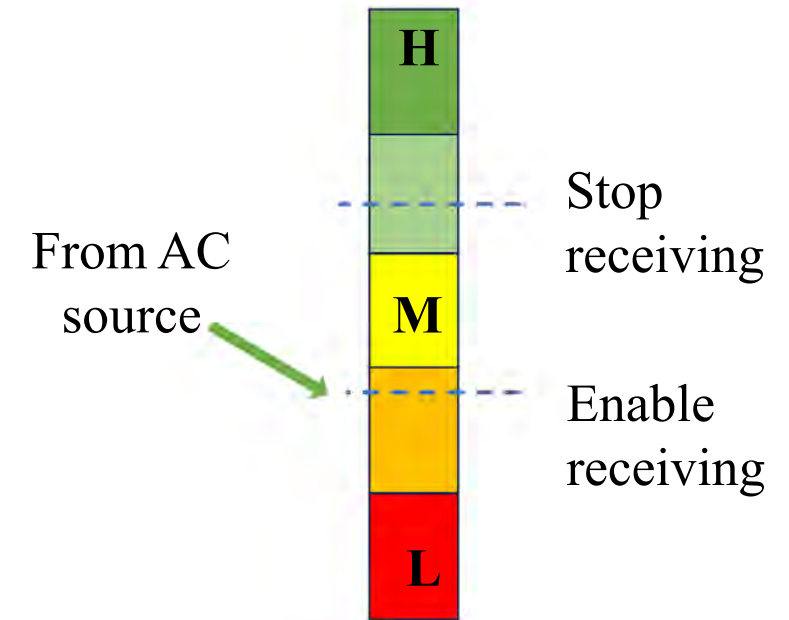
System1's SOC

System2's SOC

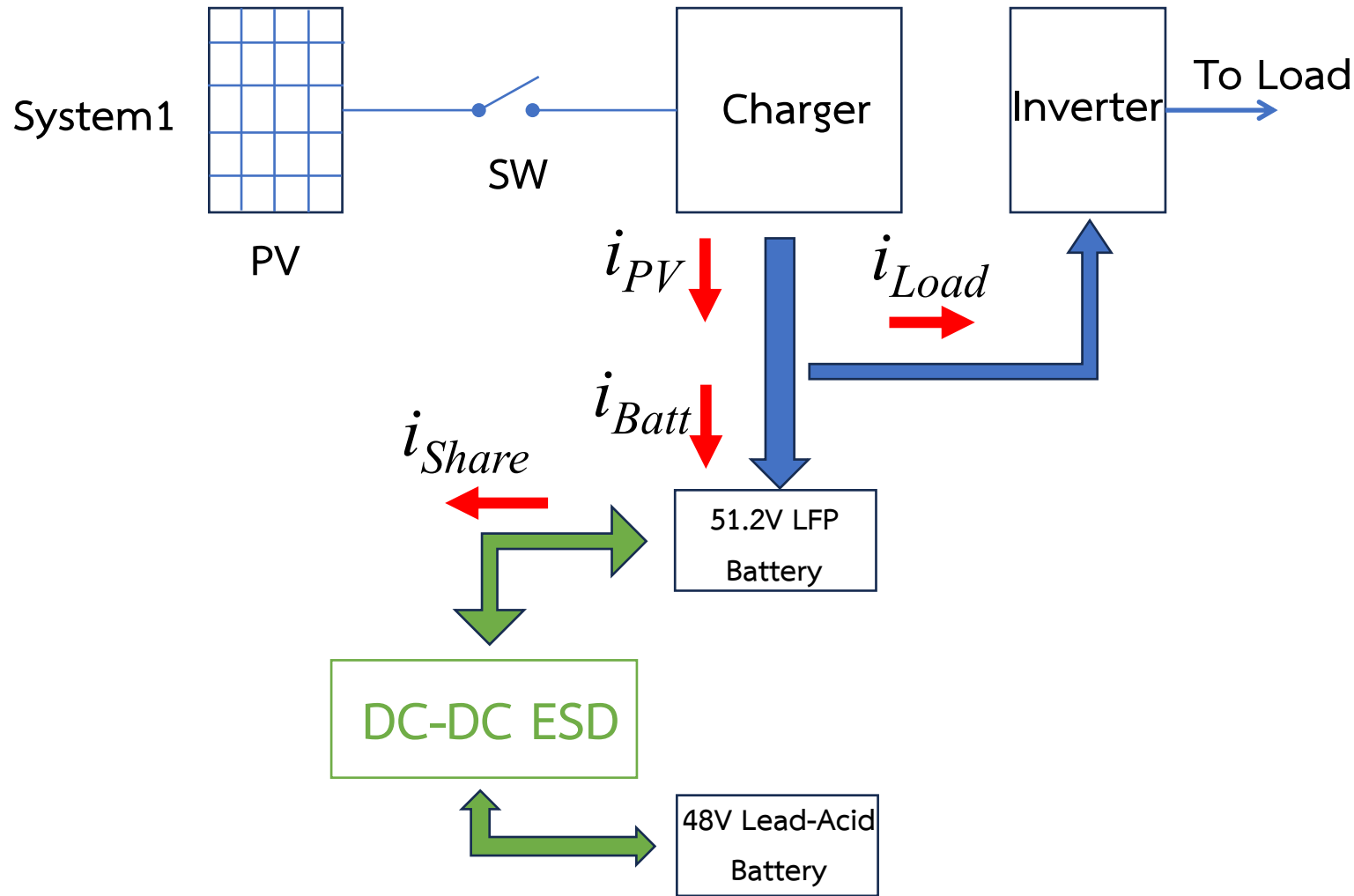


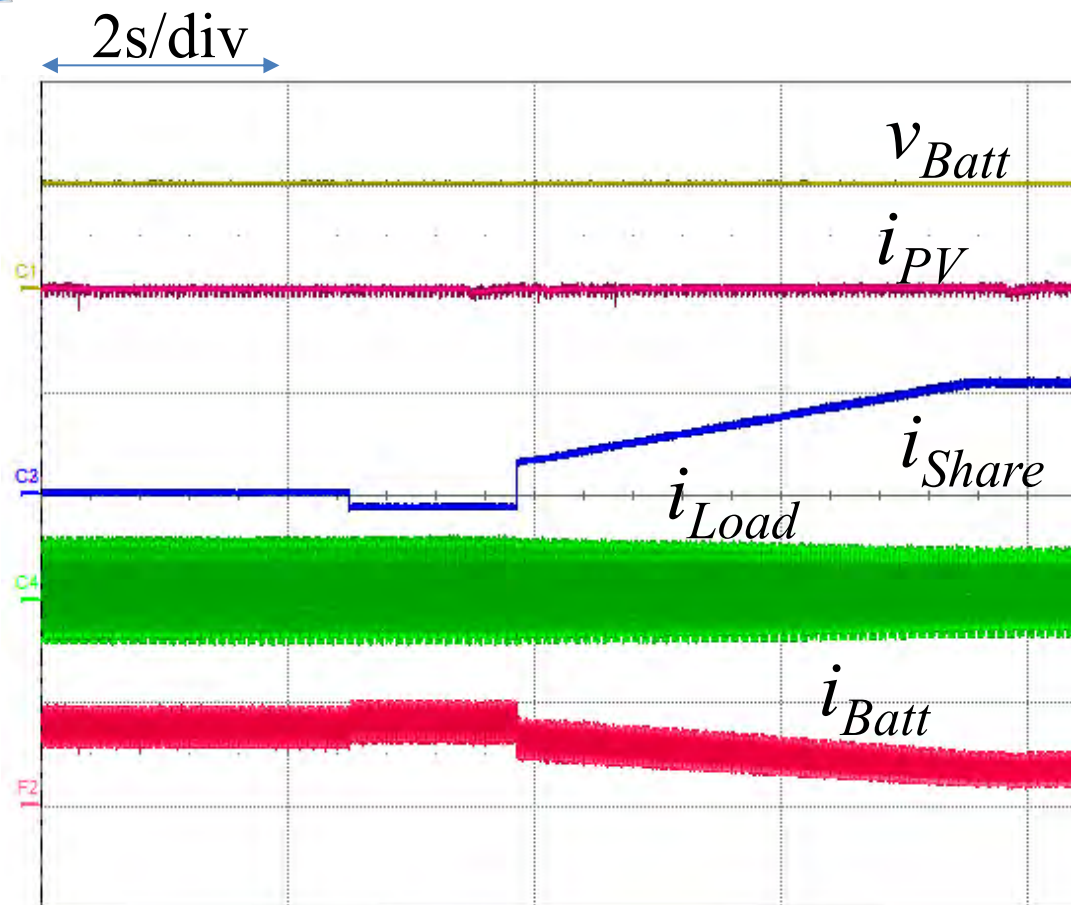
For DC-DC ESD

SOC



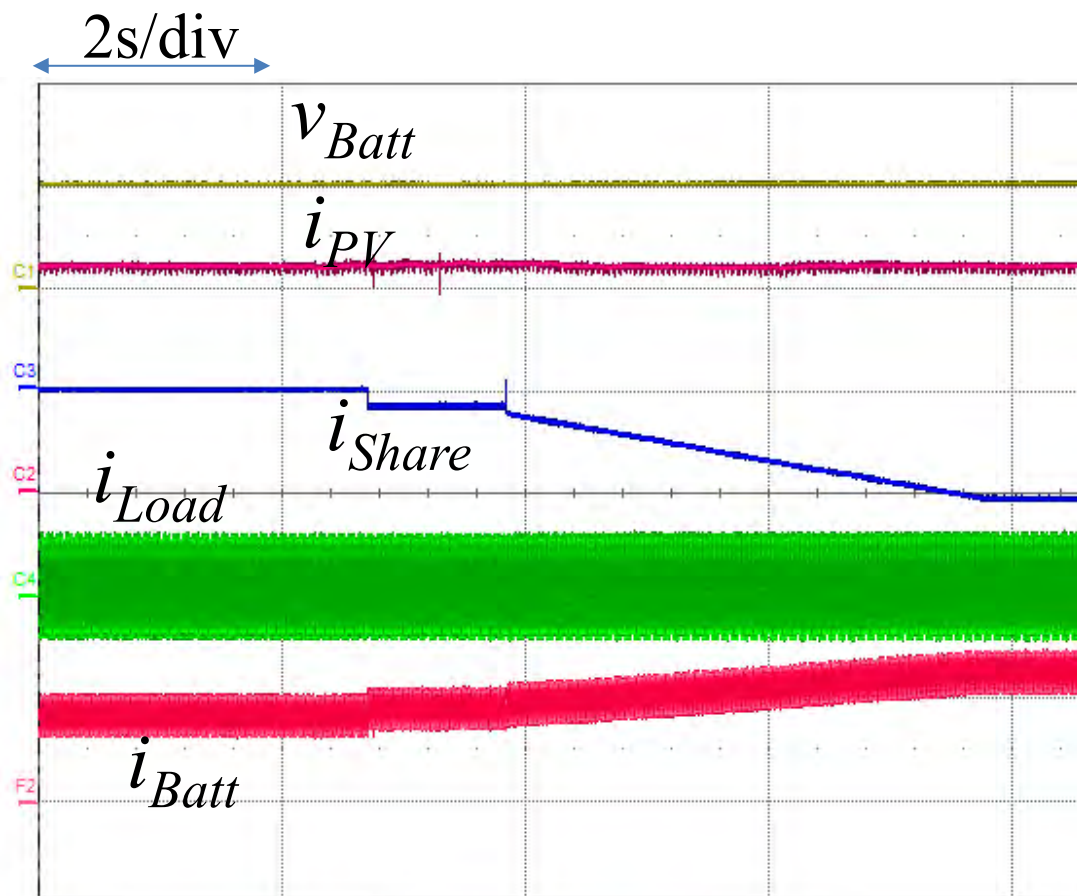
For AC-DC ESD





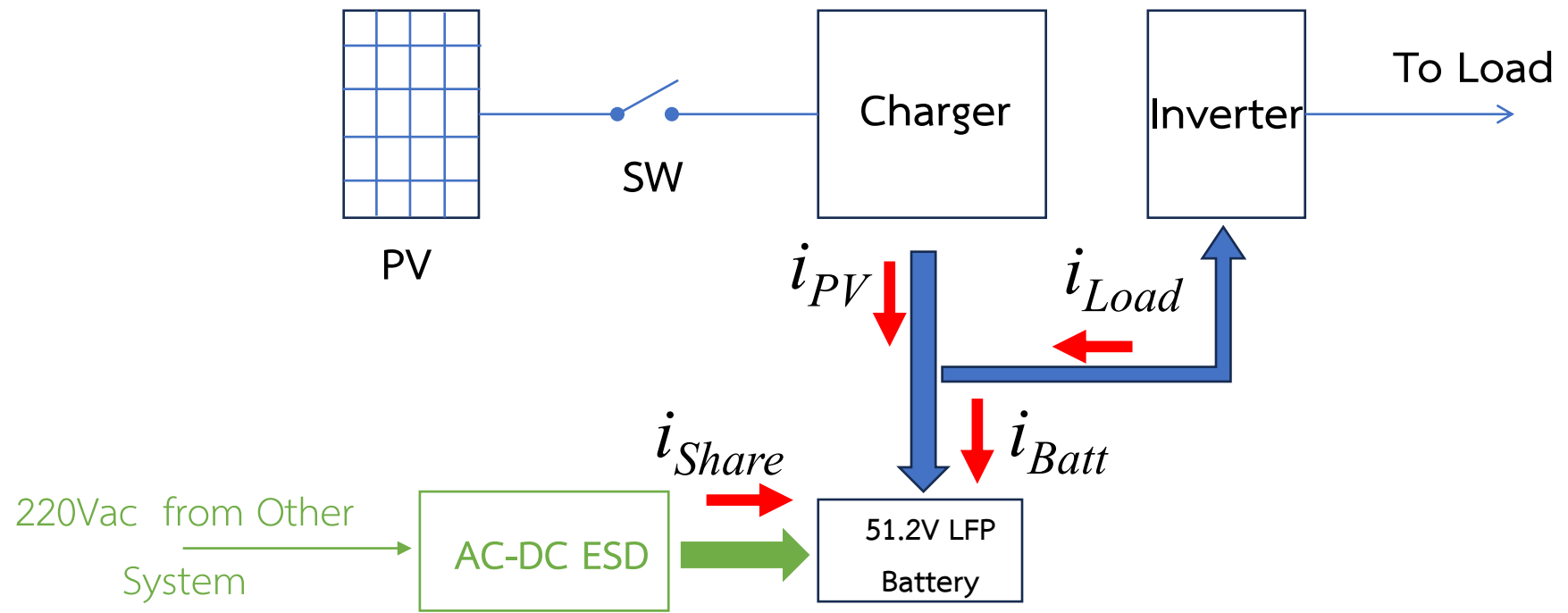
Measure	P1:mean(C1)	P2:mean(C2)
value	51.06 V	39.35 A
status	✓	✓

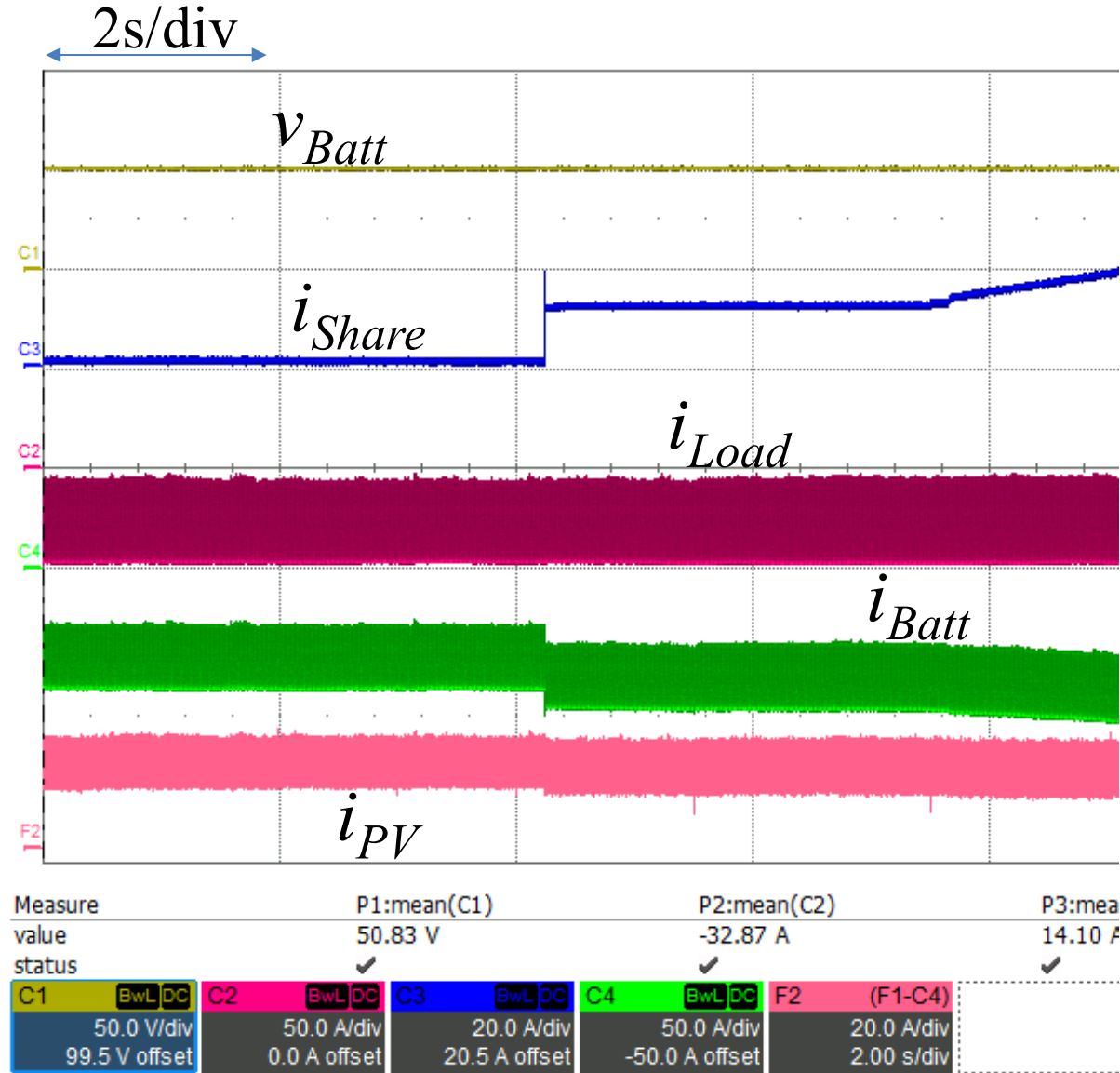
Channel	Scale	Offset
C1	50.0 V/div	99.5 V offset
C2	20.0 A/div	500 mA ofst
C3	20.0 A/div	500 mA ofst
C4	20.0 A/div	-20.0 A offset
F2 (F1-C4)	50.0 A/div	2.00 s/div



Measure	P1:mean(C1)	P2:mean(C2)	P3
value	51.27 V	43.74 A	-1
status	✓	✓	✓

Channel	Scale	Offset
C1	50.0 V/div	99.5 V offset
C2	20.0 A/div	500 mA ofst
C3	20.0 A/div	20.5 A offset
C4	20.0 A/div	-20.0 A offset
F2 (F1-C4)	50.0 A/div	2.00 s/div





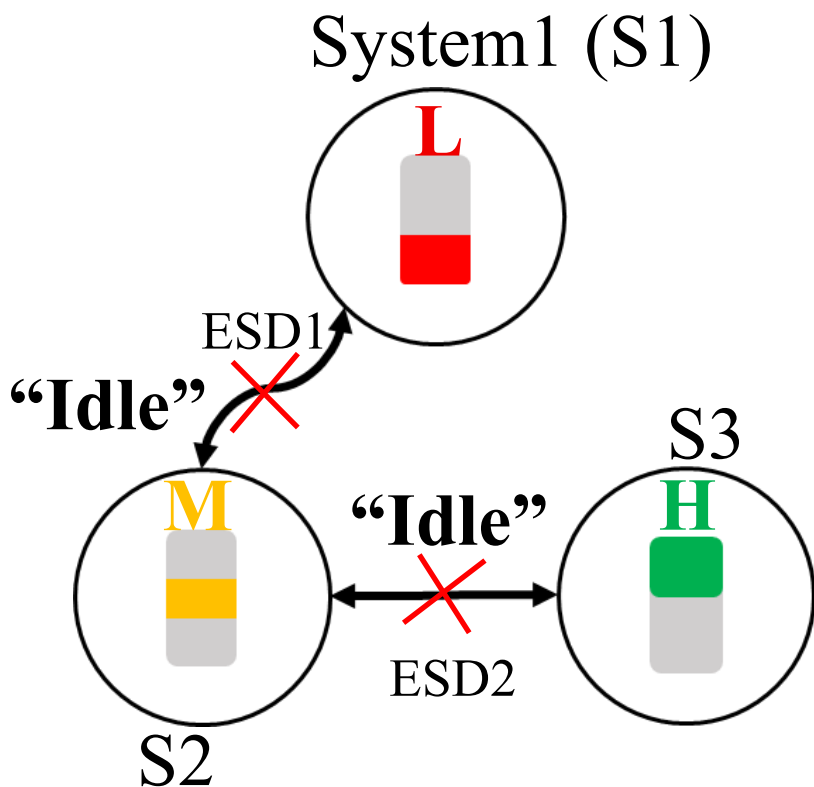
Item	DC-to-DC type	AC-to-DC type
Rated Power	3 kW, Bidirectional	3 kW, Unidirectional
Power converter topology	Dual Active Bridge (DAB)	DAB, 2-phase Interleaved PFC boost converter
Switching frequency	50kHz	50 kHz
Isolation transformer	Ferrite, 3 kV Hi-pot test	Ferrite, 3 kV Hi-pot test
Electrical standard (passed)	IEC 60950-1 (Hi-pot) , IEC 61000-6-1 (Surge and EFT)	IEC 60950-1 (Hi-pot, Electric strength, Touch current and protective conductor current), IEC 61000-6-1 (Surge and EFT)
Input voltage:	30 – 70 Vdc : 30 – 70	85 – 265 Vac : 30 – 70 Vdc
Output voltage	Vdc	
Battery	Lead-acid, Li-ion	Lead-acid, Li-ion
Maximum efficiency	96%	94%

DC-to-DC ESD



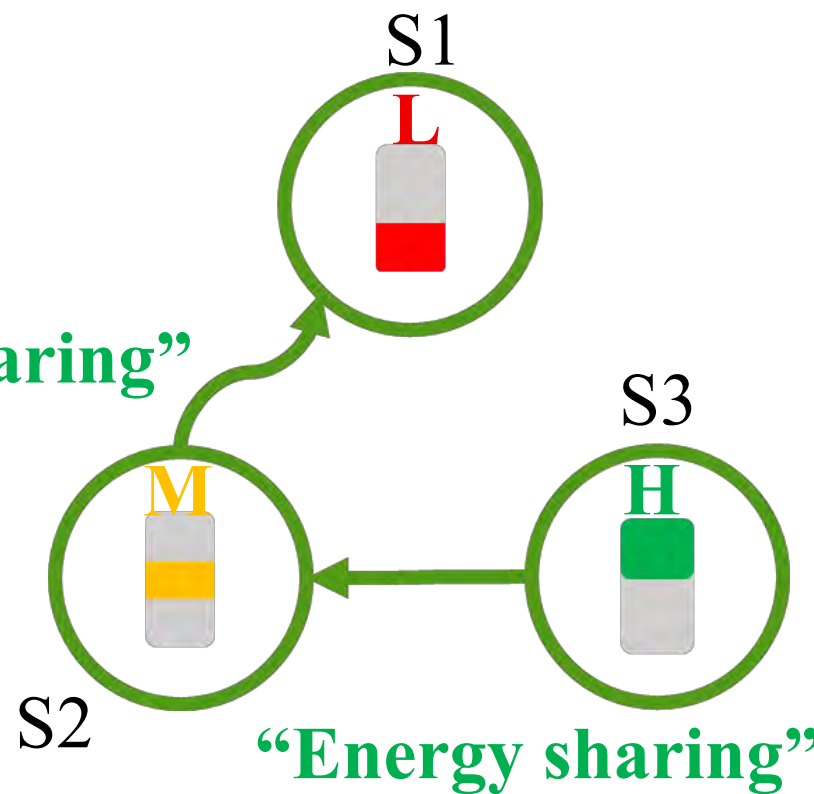
DC-to-DC ESD





Offline Energy Sharing

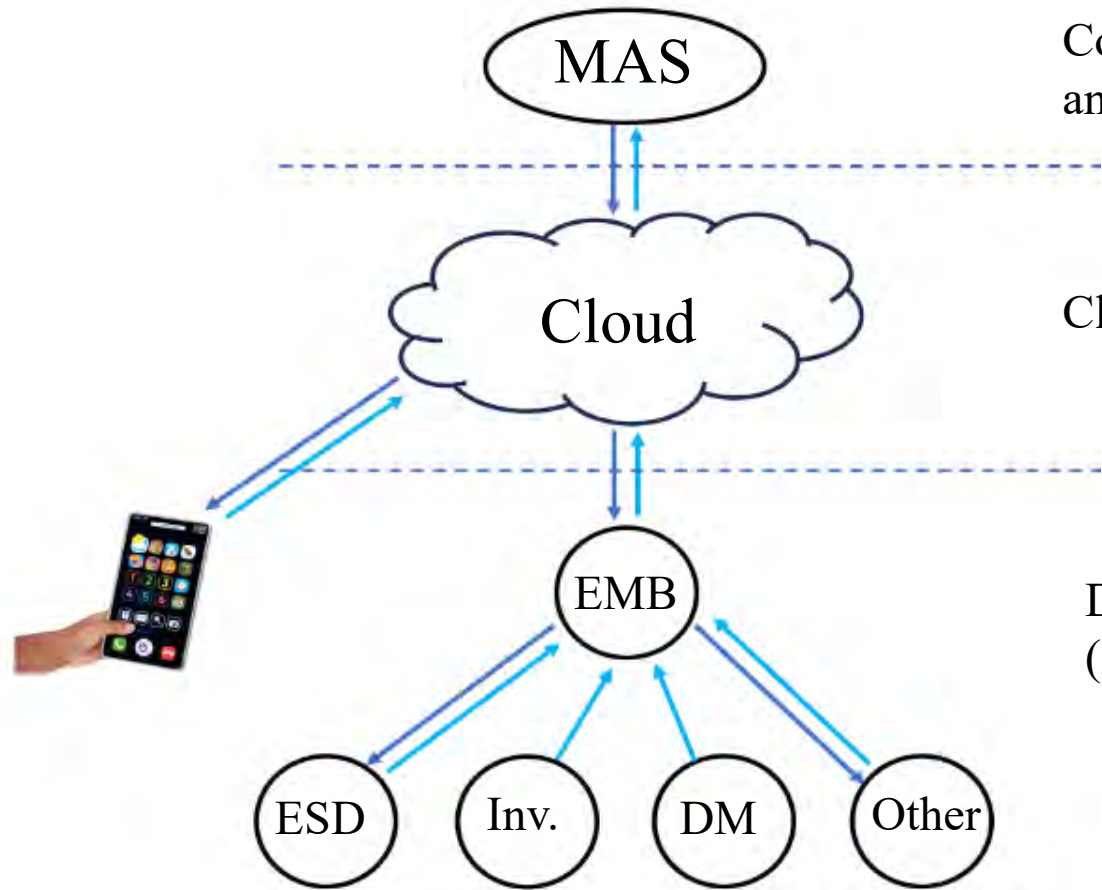
“Energy sharing”



Online Energy Sharing

Future Work

Offline energy sharing cannot dynamically redirect surplus energy to deficit systems.



Computation Layer: Multi-Agent optimization and coordination

Cloud Data Layer: Data exchange via a lightweight cloud data hub

Device Layer: Power hardware and sensors (ESD, Inverter, EMB, Meter)

Communication structure

- This work demonstrated **Energy Sharing Devices (ESDs)** as a practical solution for rural off-grid communities
Both **DC–DC** and **AC–DC** ESDs were successfully
 - Designed
 - Implemented
 - Deployed in real field conditions
- The proposed approach
 - Improves **overall energy utilization**
 - Reduces **energy waste**
 - No modification of existing system control or operation is required.
- The solution preserves key advantages of small off-grid systems:
 - Low voltage and safe operation
 - Simple maintenance
 - Use of widely available components
- Ongoing Work is also shared to address the limitations of offline energy sharing.

Thank you
For Your Kind Attention!