Open Energy System Project
Basis of Hyphae in LF Energy

October 2020
February 2021

OES Project
SDG Group
Sony Computer Science Laboratories, Inc.
Agenda

1. Who we are
2. What we have achieved
3. Our technologies
4. Next steps
Sony Computer Science Laboratories

Research Policy
We conduct researches for the future of humanity apart from existing business area of Sony Group
“Think extreme, Act beyond boarders”

Research Areas

Global Agenda
- SDGs – Energy (OES Project), Healthcare, Agriculture, etc.

Cybernetic Intelligence
- Data Analysis, AI, etc.

Human Augmentation
- Music, Language, Physical, Perception, etc.
For Sustainable energy society

OES Project History

Off Grid / Weak Grid: Stable energy access
- Ghana Public viewing
- Ghana Off grid system

2010

2011~2013

On Grid: Maximize renewable energy
- Okinawa DCOES platform
- KEIO SFC DCOES & DC house

2014~2020

2016~2020

Deploy the technology to realize Energy Sharing society

Core technologies
- Storage based solution
- Autonomous distributed control
- Active current control

Physical P2P Energy Exchange Platform
Locally produced energy is shared among local users using peer-to-peer distribution mechanism.
Microgrid in Okinawa

Physical Peer to Peer Energy Exchange Platform
With Okinawa Institute of Science and Technology Graduated University

- System installed to 19 Faculty houses located inside the university
- Behind the meter type of connection to the AC Grid.
- Each house has either 2.8kW or 4.2kW PV Panels and 4.8kWh batteries.

Operation & Maintenance activities for more than 5 years since 2014 to 2020
Increase 10% renewable energy up.
System configuration for OIST

Okina Power Utility

Transmission Line

OIST

AC Private Grid

PV + Battery

Microgrid

DC Private Grid

Priority of Energy resource: Solar > Battery > Energy Sharing > AC

No reverse current flow from DC to AC

2. What we have achieved
Effectiveness of energy sharing among batteries

**Self-sufficient rate in OIST 2015**

- **Actual data**

More Battery

W/.Energy sharing

W/o Energy sharing

Current system with improvements

**More Self-sufficient rate with more PV**

Simulation

- Battery capacity to achieve certain SSR (PV 7.5kW)
  - w/o exchange [kWh]: 13.0
  - w/ exchange [kWh]: 10.6
  - ▲ 18%
  - 33.2
  - 16.2
  - ▲ 51%

- Battery capacity to achieve certain SSR (PV 10kW)
  - w/o exchange [kWh]: 18.3
  - w/ exchange [kWh]: 14.4
  - ▲ 21%
  - 37.4
  - 19.0
  - ▲ 49%

**Energy sharing with battery consumes more renewable energy within a community effectively**

2. What we have achieved
Hardware in OIST case

- Battery system for energy exchange
  - ① Energy generation: DC
    » PV, FC, etc.
  - ② Energy storage: DC
  - ③ Energy supply for appliances: DC/AC
  - ④ Energy exchange: DC
  - ⑤ Backup energy source: (AC)

Share energy among batteries in the community by charge/discharge battery. Reserve backup energy source for the case of lack of battery.
System overview

System administrator

- System monitoring
- Trouble management
- Firmware management
- Scenario management

Service Center

Customer site

Cloud

Control Center

Client

EventBus

Save in cache

F004

F005

F006

DC private Grid

Sony CSL

OES Project
Physical P2P energy exchange

**APIS : Autonomous Power Interchange System**

**Physical P2P** : Energy exchange between certain nodes, certain amount.

**CVCC** : Control of power flow without having to worry about physical phenomena caused by location of the houses etc.

**DC Bus** : DC-DC converters are to be turned-on only during energy exchange in order to minimize the loss.
Autonomous distributed control

**APIS : Autonomous Power Interchange System**

Main points of the APIS
- No central control unit
- Each node has the same software
- Each node checks the battery and scenario to determine its action
Energy Exchange Scenario

- State of Charge (SoC) Target energy exchange

<table>
<thead>
<tr>
<th>SOC level</th>
<th>Amount</th>
<th>Discharge</th>
<th>Charge</th>
<th>Accept Discharge</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>level1</td>
<td>90-100</td>
<td>4320-4800</td>
<td>×</td>
<td>limitWh = 4320</td>
<td>×</td>
</tr>
<tr>
<td>level2</td>
<td>75-90</td>
<td>3600-4320</td>
<td>×</td>
<td>limitWh = 3600</td>
<td>×</td>
</tr>
<tr>
<td>level3</td>
<td>60-75</td>
<td>2880-3600</td>
<td>×</td>
<td>limitWh = 3600</td>
<td>×</td>
</tr>
<tr>
<td>level4</td>
<td>0-60</td>
<td>0-2880</td>
<td>×</td>
<td>limitWh = 2880</td>
<td>×</td>
</tr>
</tbody>
</table>
scenario.json

```
"00:00:00-24:00:00" : {
    "batteryStatus" : {
        "4320-" : "excess",
        "3600-4320" : "sufficient",
        "2880-3600" : "scarce",
        "<2880" : "short"
    },
    "request" : {
        "excess" : {
            "discharge" : {
                "limitWh" : 4320,
                "pointPerWh" : 10
            }
        },
        "sufficient" : {
        },
        "scarce" : {
        },
        "short" : {
            "charge" : {
                "limitWh" : 2880,
                "pointPerWh" : 10
            }
        }
    },
    "accept" : {
        "excess" : {
            "discharge" : {
                "limitWh" : 3600,
                "pointPerWh" : 10
            }
        },
        "sufficient" : {
        },
        "scarce" : {
        },
        "short" : {
            "charge" : {
                "limitWh" : 3600,
                "pointPerWh" : 10
            }
        }
    }
}
```

https://github.com/SonyCSL/apis-main/blob/master/exe/scenario.json
1. The software checks battery level and evaluates scenario (target battery level).
Autonomous distributed control (2)

1. The software checks battery level and evaluates scenario (target battery level).
2. If battery level is lower than scenario, the software sends request messages to other units.

Messages from E0004 to all request:
{"type":"charge","amountWh":607,"pointPerWh":10.0,"efficientGridVoltageV":312.0,"dateTime":"2020/01/01-00:14:40","dealGridCurrentA":1.0,"unitId":"E004"}
1. The software checks battery level and evaluates scenario (target battery level).
2. If battery level is lower than scenario, the software sends request messages to other units.
3. If the software receives a request from other unit, it evaluates its own battery level and checks if it can accept the request.
1. The software checks battery level and evaluates scenario (target battery level).
2. If battery level is lower than scenario, the software sends request messages to other units.
3. If the software receives a request from other unit, it evaluates its own battery level and checks if it can accept the request.
4. If the request is acceptable, it replies with an accept message.

Messages from E0001 to E0004
accept:
{"type":"discharge","amountWh":1096,"pointPerWh":10.0,"efficientGridVoltageV":312.0,"dateTime":"2020/01/01-00:14:40","dealGridCurrentA":1.0,"unitId":"E001"}
1. The software checks battery level and evaluates scenario (target battery level).
2. If battery level is lower than scenario, the software sends request messages to other units.
3. If the software receives a request from other unit, it evaluates its own battery level and checks if it can accept the request.
4. If the request is acceptable, it replies with an accept message.
5. If requested unit receives an accept message, it sends deal information to Grid Master (GM).
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Messages from E0004 to Grid Master
Deal:
{"unitId":"E004","negotiationId":"9a9b3fd6-dcf0-4673-bdd1-a7c707172f2c","requestUnitId":"E004","acceptUnitId":"E001","requestDateTime":"2020/01/01-00:14:40","acceptDateTime":"2020/01/01-00:14:40","requestPointPerWh":10.0,"acceptPointPerWh":10.0,"requestDealGridCurrentA":1.0,"acceptDealGridCurrentA":1.0,"type":"charge","chargeUnitId":"E004","dischargeUnitId":"E001","pointPerWh":10.0,"chargeUnitEfficientGridVoltageV":312.0,"dischargeUnitEfficientGridVoltageV":312.0,"dealGridCurrentA":1.0,"requestAmountWh":607,"acceptAmountWh":1096,"dealAmountWh":50,"dealId":"ac085f02-73b4-44bf-80ad-6dd5313bece","createDateTime":"2020/01/01-00:15:40","compensationTargetVoltageReferenceGridCurrentA":-1.0,"activateDateTime":"2020/01/01-00:16:00","isMaster":true},
1. The software checks battery level and evaluates scenario (target battery level).
2. If battery level is lower than scenario, the software sends request messages to other units.
3. If the software receives a request from other unit, it evaluates its own battery level and checks if it can accept the request.
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5. If requested unit receives an accept message, it sends deal information to Grid Master (GM).
6. GM controls DCDCs to execute energy exchange.
Linux based system

Our technology
3. Our technology

Services in apis-main

apis-main

User Service
- Request negotiation

Mediator Service
- Control GridMaster

GridMaster Service
- Control DCDC Converter
- Get DCDC Converter & EMU information

Controller Service
- Control Deal & DC Grid

Symbol legend
- DC Grid
- Battery
- Scenario
- Control

Evaluate the unit’s demand by Scenario and battery status
Negotiate the energy exchange with other units
“Networked Electricity” - Example local grid network
“Networked Electricity” - Example local grid network

APIS can be applied
4. Next steps

- **APIS with Physical P2P Energy sharing** can accelerate more renewable energy installation with smaller amounts of batteries.

- **Targets**
  
  - **Developed Countries**
    - Microgrid
      - Resilience and decarbonization
    - Microgrids/Distribution Grid
      - More Renewable Energy
  
  - **Developing Countries**
    - Off Grid
      - Behind the meter
      - Microgrid/Minigrid
        - Electrification
    - On Grid
      - Microgrids/Distribution Grid
        - Stable energy supply
  
  - DC
  - AC
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