Contents

- Introduction
- Active power filters
- Energy storage-based devices
- Smart hybrid power systems
Introduction
Merus Power Dynamics Oy

1 manufacturing plant
2 regional offices
35+ global partners

2008 year of establishment
40+ years of experience
40+ countries of installation

Headquarters and manufacturing plant located in Nokia, Finland

Nokia
Tampere
Helsinki

Manufacturing plant
Regional offices
Global partners
Modern electric power system

- Renewable generation
- Non-renewable generation
- Transmission & distribution
- Microgrids

End users

- Smart Grid
- Raw material extraction & processing
- Manufacturing & infrastructure
- Green buildings & smart cities

Renewable generation
- Mining
- Oil & gas
- Minerals & cement
- Steel & metals

Non-renewable generation
- Conventional manufacturing
- Critical process industries
- Transport
- Water & wastewater

Transmission & distribution
- Healthcare facilities
- Critical process facilities
- Industrial & office facilities
- Retail & leisure facilities

Microgrids

Controller

Power management system

EMS

Raw material extraction & processing
- Manufacturing & infrastructure
- Green buildings & smart cities

BMS
Modern electric power system

Power quality problems
- Waveform distortions
  - Harmonics
  - Interharmonics
  - Notching

- Short duration variations
  - Voltage sags
  - Voltage swells
  - Interruptions

- Long duration variations
  - Undervoltages
  - Overvoltages
  - Sustained interruptions

- Transients
  - Impulsive transients
  - Oscillatory transients

- Other problems
  - Voltage unbalances
  - Voltage fluctuations (flicker)
  - Power frequency variations
  - Low power factor (lagging/leading)

Grid code requirements
- Frequency support
  - Frequency containment reserve (FCR)
  - Frequency restoration reserve (FRR)
  - Active power control
  - Ramp rate control
  - Load following

- Voltage support
  - Voltage control
  - Reactive power control
  - Power factor control
  - Fast reactive current injection capability
  - Fault ride through (FRT) capability

- System restoration support
  - Black start capability
  - Islanding capability

- System stability improvement
  - Power system stability improvement
  - Power transfer capacity increase
  - Power oscillation damping (POD)
  - Subsynchronous resonance damping
  - Capacity firming

- Energy supply management
  - Peak shaving / Load levelling
  - Load shifting

- Power quality improvement
  - Black start capability
  - Islanding capability

Renewable generation

Non-renewable generation

Raw material extraction & processing

Manufacturing & infrastructure

Green buildings & smart cities

BMS

EMS
Modern electric power system

Power quality improvement

Grid code compliance

Energy system

- Voltage Dips
- Short interruptions
- Long interruptions
- Harmonics
- Transients and surges
- Others

Benefits

- Installations that respect the environment
- Intermittent renewable energy integration
- Maximise energy flows with minimum losses
- Increase sites’ stability, reliability and availability
- Meeting power quality & efficiency needs
- More resilient and reliable power supply

Benefits

- Market codes (Wider market integration)
- Connection codes (Greener power, smarter consumption)
- Operation codes (Reinforced security of supply)

European Union
150 billion Euros per year

Southeast Asia
1 billion Euros per year

Poor power quality costs

Requirements for generators (RfG)  Demand connection (DCC)  HVDC connection (HVDC)

System operation (SOGL)  Emergency and restoration (ER)

Capacity allocation and congestion management (CACM)  Forward capacity allocation (FCA)  Electricity balancing (EB)

Pedro Esteban – Innovative Microgrid Design with Power Electronics Solutions: Technologies and Applications
**Power electronics solutions**

### Active power filters
- Active harmonic filters (AHF)
- Static var generators (SVG)
- Active load balancers (ALB)
- Hybrid var compensators (HVC)

### Static compensators
- Static var compensators (SVC)
- Static synchronous compensators (STATCOM)
- Hybrid static synchronous compensators (hybrid STATCOM)

### Energy storage-based devices
- Uninterrupted power quality (UPQ) systems
- Battery energy storage systems (BESS)
- Energy storage inverters (ESI)

### Smart hybrid power systems
- On-grid hybrid power systems (on-grid HPS)
- Off-grid hybrid power systems (off-grid HPS)
- Solar inverters (SI)

### Thyristor switched compensation devices
- Thyristor switched capacitor banks (TSC)
- Thyristor switched reactors (TSR)
- Thyristor controlled reactors (TCR)
- Thyristor switch modules (TSM)
- Thyristor valves (TV)

### Services
- Planning services
- Installation services
- Operation services
- Renewal services
Active power filters
Active power filters
Introduction

• Active power filters (APF) are devices connected in parallel with the load to be compensated.
• They can be understood as controlled current sources that provide any kind of current waveform (in terms of phase, amplitude and frequency) in real time (response time <100µs).
• APFs are flexible, high performance and cost-effective solutions used to mitigate all the power quality problems generated by the equipment installed in electric power systems, enhancing equipment operating life time, and improving power system capacity.
• APFs can combine different functions in one device:
  – Elimination of harmonics and interharmonics.
  – Power factor correction (lagging and leading).
  – Reduction of voltage variations (sags & swells).
  – Mitigation of voltage fluctuations (flicker).
  – Load balancing in three-phase systems.
  – Controlled and selectable harmonic generation.
Active power filters
Types

• APFs can be tailored to deliver specific functionalities depending on application
• Customized solutions include:
  – Active harmonic filters (AHF).
  – Static var generators (SVG) / Active power factor compensators (APFC).
  – Active load balancers (ALB).
  – Hybrid var compensators (HVC).

<table>
<thead>
<tr>
<th>Function</th>
<th>AHF</th>
<th>SVG</th>
<th>ALB</th>
<th>HVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase harmonics filtering</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Neutral harmonics filtering</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power factor correction (lagging or leading)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Voltage variations (sags and swells) reduction</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage fluctuations (flicker) mitigation</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load balancing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Controlled and selectable harmonic generation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Active power filters
Application: Solar inverters

Country: South Africa
Segment: Renewable generation

- Application: Grid integration of 8.8MW solar power plant
- Requirements
  - Grid code compliance at 11kV with South African grid code (harmonics, voltage unbalance, voltage flicker and network resonance)
  - Mitigation required up to the 31st harmonic order
- Solution
  - AHF 11/0.4kV 50Hz 800A
- Benefits
  - Grid code compliance and generation stability
  - Harmonics mitigation up to the 35th order harmonics
  - Power factor improvement
  - Reduction of the resonance with the grid
- Commissioning: 2017
## Active power filters

**Application: Solar inverters**

<table>
<thead>
<tr>
<th>n</th>
<th>Harmonic Group limit</th>
<th>LL</th>
<th>LL</th>
<th>L3</th>
<th>Max. 11, L2, L3</th>
<th>Harmonic Group limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>424.7818</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.8777</td>
<td>0.6057</td>
<td>0.4590</td>
<td>0.8177</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.1648</td>
<td>1.2340</td>
<td>0.9985</td>
<td>1.3468</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.9054</td>
<td>0.9059</td>
<td>0.2972</td>
<td>0.9469</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5.516e+01</td>
<td>4.6532</td>
<td>0.8581</td>
<td>4.8696</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.2120</td>
<td>0.0210</td>
<td>0.2774</td>
<td>0.3723</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2.7124</td>
<td>2.2803</td>
<td>2.8034</td>
<td>2.2803</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0158</td>
<td>0.0077</td>
<td>0.0485</td>
<td>0.0287</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.3488</td>
<td>0.4014</td>
<td>0.4234</td>
<td>0.4024</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.0025</td>
<td>0.0123</td>
<td>0.0112</td>
<td>0.0113</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0.5473</td>
<td>0.8212</td>
<td>0.5057</td>
<td>0.5577</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.0076</td>
<td>0.0163</td>
<td>0.0102</td>
<td>0.0103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0.0356</td>
<td>0.8177</td>
<td>0.0200</td>
<td>0.0058</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0.0051</td>
<td>0.0034</td>
<td>0.0083</td>
<td>0.0034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.0150</td>
<td>0.2054</td>
<td>0.1044</td>
<td>0.0254</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>0.0078</td>
<td>0.0075</td>
<td>0.0075</td>
<td>0.0079</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>0.7115</td>
<td>0.0715</td>
<td>0.7115</td>
<td>0.7115</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0.0082</td>
<td>0.0063</td>
<td>0.0091</td>
<td>0.0091</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>0.3850</td>
<td>0.7548</td>
<td>0.6528</td>
<td>0.7548</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.0063</td>
<td>0.0079</td>
<td>0.0075</td>
<td>0.0075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>0.3294</td>
<td>0.9217</td>
<td>0.0920</td>
<td>0.0920</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>0.0061</td>
<td>0.0044</td>
<td>0.0065</td>
<td>0.0065</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>0.4014</td>
<td>0.4154</td>
<td>0.5009</td>
<td>0.5009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>0.0076</td>
<td>0.0085</td>
<td>0.0083</td>
<td>0.0083</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.0038</td>
<td>0.0094</td>
<td>0.0786</td>
<td>0.0786</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>0.0022</td>
<td>0.1071</td>
<td>0.0012</td>
<td>0.0012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>0.0037</td>
<td>0.0014</td>
<td>0.0047</td>
<td>0.0047</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>0.0040</td>
<td>0.0042</td>
<td>0.0045</td>
<td>0.0045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>0.1221</td>
<td>0.2275</td>
<td>0.2275</td>
<td>0.2275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.0042</td>
<td>0.0043</td>
<td>0.0045</td>
<td>0.0045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>0.1786</td>
<td>0.1786</td>
<td>0.1375</td>
<td>0.1786</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.0034</td>
<td>0.0034</td>
<td>0.0034</td>
<td>0.0034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>0.0034</td>
<td>0.0035</td>
<td>0.0035</td>
<td>0.0035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>0.0181</td>
<td>0.0034</td>
<td>0.0034</td>
<td>0.0034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>0.0031</td>
<td>0.0024</td>
<td>0.0034</td>
<td>0.0034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>0.0032</td>
<td>0.0012</td>
<td>0.0032</td>
<td>0.0032</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>0.0030</td>
<td>0.0030</td>
<td>0.0030</td>
<td>0.0030</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>0.0030</td>
<td>0.0011</td>
<td>0.0031</td>
<td>0.0031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>0.0029</td>
<td>0.0011</td>
<td>0.0031</td>
<td>0.0031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.0029</td>
<td>0.0011</td>
<td>0.0031</td>
<td>0.0031</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Active power filters
Application: Solar inverters

Country: Australia
Segment: Renewable generation

• Application: Grid integration of 250kW solar power plant
• Requirements
  – Grid code compliance at 11kV with Australian grid code (harmonics, voltage unbalance and voltage flicker)
  – Mitigation required up to the 13th harmonic order
  – Ensure that the existing 1MW natural gas microturbine is not adversely affected by the harmonic content of the solar inverters
• Solution
  – AHF 400V 50Hz 600A
• Benefits
  – Grid code compliance and generation stability
  – Harmonics mitigation
  – AHF easily expandable to 800A for the future extension of the plant
• Commissioning: 2019
Active power filters
Application: Solar inverters

Harmonic spectrum

THDi = 19.5%

AHF 600A
Energy storage-based devices
Energy storage-based devices
Range

UPQ system
- Voltage support
- Power quality improvement
- Uninterruptable power supply
- Peak shaving

BESS
- Frequency support
- Voltage control
- T&D stability
- Peak shaving
- Reactive power control
- Primary reserve
- Secondary reserve
- Blackstart
- Load levelling
- Load factor increase
- Capacity deferral

Process support

Energy management
- Energy trading
- Arbitrage

Duration of discharge
- Seconds
- Minutes
- Hours

Rated power
- 1kW
- 500kW
- 1MW
- 2MW
- 5MW
- 10MW
- 50MW
- 100MW
- 1GW

Cycle life
- Supercapacitors: 1-20 sec
- LTO batteries: Minutes
- Li-ion batteries: Hours

Pedro Esteban – Innovative Microgrid Design with Power Electronics Solutions: Technologies and Applications
Uninterrupted power quality systems
Introduction

• UPQ systems combine different functionalities
  – UPS system
  – Power quality improvement
  – Power & voltage conditioner

• Protection of low and high voltage electric power systems against
  – Short or long power supply interruptions
  – Voltage sags and swells
  – Losses caused by poor power quality in the system

• Several energy storage technologies can be used depending on the application
  – Supercapacitors
  – LTO (lithium–titanate) batteries
  – LIB (lithium-ion) batteries
  – Lead-acid batteries

• Ideal for applications that have high single interruption cost or frequent interruptions
In the normal operation mode, the UPQ system delivers in real time:

- Elimination of harmonics and interharmonics.
- Power factor correction (lagging and leading).
- Reduction of voltage variations (sags & swells).
- Mitigation of voltage fluctuations (flicker).
- Load balancing in three-phase systems.
- Direct-On-Line motor starting capability.
Uninterrupted power quality systems
Power protection operation mode

In case of an event in the power supply, the UPQ system provides active and reactive power to the loads and voltage control, ensuring complete immunity from

- Interruptions
- Voltage sags / undervoltages
- Voltage swells / overvoltages
Country: Finland
Segment: Healthcare facilities

- Application: Critical hospital loads
- Requirements
  - 500kW of critical loads to protect
  - Back-up time needed 30 seconds
  - System needs to operate in connection with a standby diesel generator
  - Containerized solution
- Solution
  - UPQ system 400V 50Hz 500kW 500kVA 30s
  - Energy storage: Lead-acid batteries
- Benefits
  - Continuous power supply guaranteed
  - Power quality improvement of the installation
  - Very compact footprint
Uninterrupted power quality systems
Application: Critical hospital loads
Uninterrupted power quality systems
Application: Critical hospital loads

Network voltage
Load voltage
Network current
Load current
Inverter current
DG current
DG voltage

1. UPQ system working in power quality mode
2. Power supply interruption in network begins
3. Control system opens static switch and voltage is restored to load bus. UPQ system switches to power backup mode. Genset starts
4. DG synchronized, DG breaker closes
5. UPQ system switches back to power quality improvement mode
6. Network voltage restored. DG starts to synchronize to network voltage
7. DG synchronized to network voltage. System closes static switch
8. DG breaker opens and DG is stopped. UPQ system starts to recharge batteries from network
Battery energy storage systems
Introduction
Battery energy storage systems
Smart Grid applications

**Generation**
- Wind, solar, fuel cells, hydro, biomass and hybrid power systems

**Transmission & distribution**
- Transmission and distribution lines

**Microgrids**
- Islands, remote locations, green buildings and industrial applications

**Main functions**
- Peak shaving
- Ramp rate control
- Load shifting

**Main functions**
- Frequency support
- Optimal load flow
- Power quality improvement

**Main functions**
- Energy supply management
- Black start capability
- Power quality improvement
Battery energy storage systems

Operation modes

<table>
<thead>
<tr>
<th>Dispatch mode</th>
<th>Frequency support</th>
<th>Frequency regulation</th>
<th>Load power sharing</th>
<th>Power limiting</th>
<th>Load / voltage balancing</th>
<th>Active harmonic filtering</th>
<th>Voltage regulation (AVR, Q/V droop)</th>
<th>Power factor regulation</th>
<th>Voltage flicker</th>
<th>Ramp Rate Control</th>
<th>Generation Following</th>
<th>Block start functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dispatch mode</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2 Frequency support</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3 Frequency regulation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4 Peak power shaving</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5 Power limiting</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6 Load / voltage balancing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7 Active harmonic filtering</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>8 Voltage regulation (AVR, Q/V droop)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>9 Dynamic reactive power compensation / power factor regulation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>10 Intermittent Resource Support</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>11 Voltage Flicker</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>12 Ramp Rate Control</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>13 Generation-Following</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>14 Block start functionality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Battery energy storage systems
Application: Distributed energy system

Country: Finland
Segment: Microgrids

• Application: Energy self-sufficient microgrid mainly operating as part of the public electrical grid. It can also operate on demand as a frequency support reserve system or independently off-grid

• Requirements
  – Participation in the national frequency regulation market
  – Integration of EMS to external energy trading system
  – Islanding capability: BESS could control the microgrid voltage

• Solution
  – BESS 20kV 50Hz 1.6MW 1.3MWh
  – Storage: Li-ion batteries

• Benefits
  – Frequency containment reserve (FCR) market participation
  – Power quality improvement and black start & islanding capability
  – Grid connection and management of 130kW of fuel cells

• Commissioning: 2019
Battery energy storage systems
Application: Distributed energy system

Fuel cells (130kW) connected to the same DC link with the batteries. The PCS takes care of the power exchange in behalf of both systems.
Country: Finland
Segment: Industrial & office facilities

• Application: Distribution center operation improvement
  – Integration of a solar PV system with the electric utility supply
  – Participation in the national frequency regulation market

• Requirements
  – On-grid and off-grid operation
  – Integration of EMS to external energy trading system
  – Remote monitoring and O&M support system

• Solution
  – BESS 20kV 50Hz 2.6MW 1.35MWh
  – Storage: Li-ion batteries

• Benefits
  – Energy management and consumption optimization
  – Frequency containment reserve (FCR) market participation
  – Power quality improvement, peak shaving & black start capability

• Commissioning: 2019
Battery energy storage systems
Application: Distribution center operation improvement
Smart hybrid power systems
Smart hybrid power systems
Features

• SHPS can work connected to the grid or as stand-alone off-grid systems providing
  – **Clean energy generation**: By introducing renewable sources into the generation mix, the use of fossil fuels is reduced.
  – **Power quality & energy efficiency**: Stable current and voltage by eradicating flicker, harmonics, balancing loads and improving the power factor of the installation.
  – **Energy storage**: Storing when excess is available and to provide it when required
  – **Uninterrupted power supply**: If there is a voltage sag, swell or interruption in the supply network, they inject active power to the loads, ensuring complete immunity to critical processes and equipment against short or long duration voltage variations.
  – **Supply surge currents**: Provide surge currents to loads like motors when required.
Smart hybrid power systems

Features

- SHPS can work connected to the grid or as stand-alone off-grid systems providing
  - **Clean energy generation**: By introducing renewable sources into the generation mix, the use of fossil fuels is reduced.
  - **Power quality & energy efficiency**: Stable current and voltage by eradicating flicker, harmonics, balancing loads and improving the power factor of the installation.
  - **Energy storage**: Storing when excess is available and to provide it when required.
  - **Uninterrupted power supply**: If there is a voltage sag, swell or interruption in the supply network, they inject active power to the loads, ensuring complete immunity to critical processes and equipment against short or long duration voltage variations.
  - **Supply surge currents**: Provide surge currents to loads like motors when required.
Smart hybrid power systems
Implementation

MCC master controller

- Energy storage inverters
  - Lq and Id

- Batteries - Battery management system

- Solar inverters
  - Pset

- Fossil fuel generators
  - Pset / V droop

- WTGs
  - Pset

- TSO
  - Operation modes

- On Line
  - Monitoring
  - Reporting
  - Service
  - Maintenance

- Loads - Substation
  - I/O - Measurements

IloT
Smart hybrid power systems
Power management system (microgrid controller)

• Power management philosophy is defined by the type and capacity of the power generation sources.
• SHPS are typically controlled based on the cost of electric energy
  – Priority is to minimize operation hours of the fossil fuel generator resulting in cost savings in fuel and tear and wear parts.
  – Secondary aim is to maximize utilization of low cost energy provided by renewable sources.
  – This optimization is achieved with the help of operation modes in the power management system.

• Functions
  – Renewables generation management
    • Monitoring of overall generator status
    • Display of detailed information per generation unit
    • Operation control per generator
  – Fossil fuel generation management
    • Monitoring of overall generator status
    • Display of detailed information per generation unit
    • Operation control per generator
  – Energy storage system management
    • Monitoring of storage system status
    • Real-time monitoring and control per inverter
Country: Southeast Asia  
Segment: Microgrids

- Application: Diesel power station replacement
- Requirements
  - Average load demand of 520kWh/day and peak demand of 139kW
  - Annual load demand: 187MWh
  - Loads to supply: 21 village houses, water treatment plant, school and clinic
- Solution: Off-grid HPS 415V 50Hz
  - Solar power plant: 200kWp
  - BESS 415V 50Hz 185kW 552kWh
    - Storage: Li-ion batteries
  - Emergency generators: 60kW 75kVA and 128kW 160kVA
- Benefits
  - Fuel savings
  - Stable and continuous power supply
  - Self-sufficiency and reliability
Off-grid hybrid power systems
Application: Diesel power station replacement