Virtual Power Plant (VPP)-Integration of Distributed Energy Resources

Presenter: Professor Hong-Tzer Yang
Affiliation: Dept. of E.E., NCKU, Taiwan
Developments of Smart Grid
Power System Energy Dispatch

- **Day-ahead (DA) Market**
- **Real-time (RT) Market**
- **Balancing**
- **Ancillary Service**

**Scheduling**
- Dynamic voltage/freq. control

**Unbalancing**
- Actual load
- Scheduled power

**Forecasting Error**
- Actual load
- Scheduled power

**Unexpected Tripping of RE**
- Actual load
- Scheduled power

- Energy trading
- Day
- 5~15 mins
- 1s~ms
- Responding time

- Load forecasting
- Energy & Power System Laboratory
Meter (AMI) is the interface between customer loads and energy management systems and the grid.

In Data Center:
- Billing/Customer service
- Distribution automation
- Energy management
- Outage management
Integration between the VPP and Grid Operators

Integration of Distributed Energy Resources (DER)
Integrated Applications of DERs

Substation-EMS
- Digsilent PowerFactory based system model
- Regional Load Forecasting
- Distribution System analysis
- Renewable Generation Forecasting
- Energy Dispatching Optimization

DER-EMS
- DER generation cost analysis
- DER Dispatching Optimization

SCADA
- Application
- Data processing
- Comm. link
- Data Base
- DNP 3.0/IEC 61850

ADAS
- Application
- Data processing
- Comm. link
- Data Base
- DNP 3.0/IEC 61850

Substation
- OLTC
- Distributed Generator
- Energy Storage system (ESS)
- PV system
- Smart meter
- Load
- Wind power system

Home Energy Management System (HEMS)
- Building Energy Management System (BEMS)
- Home Area Network (HAN)
- Appliances

B(H)EMS Gateway
- Demand Response Control
- Optimal control of household appliances
- OpenADR 2.0

Energy Conversion and Communication Interface (ECCI)
- Power electronics interface
- Real/reactive power control

HMI
- Ethernet

Comm. link
- Modbus/TCP
- Socket/TCP
- ICCP

Ethernet
- DNP 3.0/IEC 61850

Substation-EMS
- DER-EMS
- DER-EMS
- DER-EMS

DER
- DER
- DER

B(H)EMS
- ADR Server
- OpenADR 2.0

B(H)EMS Gateway
- HMI

HMI
Demonstration System

• Building Taipower Research Institute DER-EMS System and Technical Verification

Microgrid demonstration system

- P,Q output control
- ESS
- 250kW

- Power conversion interface
- DG
- PV, WT, Diesel generators, Micro-turbines

- DER-EMS optimal decision-making platform
- IEC 61850 DNP 3.0

- (ESCO/Aggregator)
- IEC 61850 DNP 3.0

- DER-EMS optimal decision-making platform
- IEC 61850 DNP 3.0

- Automated Demand Response
- OpenADR 2.0

- ADRS

- H(B)EMS

- (TPRI)

- H(B)EMS

- H(B)EMS

- Utility side

- Reinforcement Energy dispatch decision-making platform

- BEMS

- BEMS

- DR control
- Load saving control

- Diesel-Engine Generator

- PV

- Wind-turbine

- ESS

- PV

- PV
**Demonstration System**

**SCADA and UI**
- SCADA Server

**System topology**

**BSS/Diesel**

**RTU DI/DO**

**250kW energy storage**

**10kW wind turbine**

**PV smart inverter**

**PV 3 & 15 kW**

**Diesel 50kW**

**Control box**

**SS3 high-voltage meter**

**BEMS and Smart Meters**

**Microgrid Demonstration**

**Energy & Power System Laboratory**
Home (Building) Energy Management System
H(B)EMS
HEMS in a Smart Grid Architecture

Residential Renewable Energy Systems

DC and AC Microgrid

User and machine control system

Home Gateway

LAN

AMI System

Data Center

WAN

AMI Control Center

AMI

Sensor

Smart phone

EV

Advanced Distribution Automation System (ADAS)

Leading Project on Power Energy Management System of Smart Home (Building)
Air-conditioner Fuzzy Control

- **Temperature and humidity**: Calculate HI Value
- **Electricity Tariff**: Regulatable
- **Fuzzy Rule**:
  - Cold: 28, 27, 26
  - Medium: OFF, 28, 27
  - Expensive: OFF, 28, 28

- **Home Gateway**
- **Zigbee module**
- **IR**
- **Behavior learning**
Optimization objective

Min (Cost)
Subject to:
- Comfort levels
- Security

Optimization solving methods:
- Particle swarm optimization (PSO)
- Simulated Annealing (SA)
- Genetic Algorithms (GA)

Residential load forecasting result

Renewable energy generation forecasting

Scheduled Loads of a Typical Medium House

Time-of-use

PV Output Power of a SP75 Module

Non-Schedulable Load Forecast of a Typical Large House on July 10th

Actual Data
Forecasted Data
User Interface Design – Web Based
User Interface Design

Appliances Control

Renewable Energies and Forecasting

Air-Conditioner Control

Load Scheduling
Suggestions of Load Scheduling

- System best scheduling recommendation: Estimated annual cost: 200元
- Manual: Estimated annual cost: 120元

- Estimated carbon reduction: 38 kg CO₂e
- Estimated carbon reduction: 25 kg CO₂e

- Appliance scheduling:
  - Electric kettle
  - Dishwasher
  - Dehumidifier
  - Washing machine
BEMS Demonstration System

Smart Meeting Room

Auto-curtains

Illuminance sensor

Temp., humidity, and CO₂ sensor

Motion detector

BEMS user interface
Automatic Demand Response (ADR)
Evolution of Demand Response Systems

- **Demand Response (DR)**
- **Auto-Demand Response (ADR)**
- **Open Automated Demand Response (OpenADR)**
Automated Demand Response Systems and OpenADR Standards

Operator

Demand management operator (Power company or Wholesale industry)

OpenADR 2.0

VTN

Automated Demand Response Server (ADRS)

Using SOAP/REST Web Service way Send XML message

Internet

OpenADR 2.0

XML

VEN

EMS/LMS

Control network

N
N
N

Site Server

XML

ADR Aggregators

VEN

EMS/LMS

Control network

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EMS/LMS

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BEMS-integrated Auto-DR System

• Development of VEN pull-mode system according to Open ADR 2.0a and 2.0b
  – Meet Open ADR 2.0a and 2.0b consistency regulation
  – Pass and obtain the VEN pull-mode certification
    • VEN Pull Positive/Negative Test Scenarios
    • VEN Pull Security Test Scenarios
    • Transport Test Cases

• Interface with BEMS for DR control
  – Integrated Testing with the EMS developed
AMI and Demand Response Framework

- AMI meters installed in Taipower test site
- Automatic Demand Response Server (ADRS)
- Energy Management System (EMS)
Automatic Demand Response

SBEMS / TPRI

當有事件時，預設選項

預設參與狀態：●參加 ○不參加

初始化設定

供應組(A) 供應組(B)

B1F  1F  2F  3F

使用者登出

預設卸載量
190 kW

列表卸載量
200 kW

低量 中量 高量

電燈熄滅(黑)  ×
電燈熄滅(紅)  ×

閣覽室
空調主機室
震動實驗室

200 kW 200 kW
190 kW 190 kW
Thank You