Microgrid Energy Management Systems (MEMS) as Infrastructure Support to Future Singapore Distribution Systems

by

H B GOOI, P L SO and F L LUO

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Singapore Power System

- High voltage network 66 kV and above
- Medium voltage network 22 kV and 6.6 kV
- Low voltage network 400 V

- Energy Management System (EMS) manages 66-kV, 230-kV and 400-kV generation and transmission system
- Distribution Management System manages 22-kV and 6.6-kV distribution system
Singapore Market Operation

Key players

- Regulator (EMA)
- Power system operator (PSO)
- Market operator (EMC)
- Electricity retailers
- Gencos
- Transco (SP PowerGrid)
- Market support services
- Wholesale electricity traders
- Contestable consumers
- Non-contestable consumers

MEMS would enable non-contestable consumers to participate in the market as a single entity.
Is Singapore Ready for Microgrid?

- Government support and its national policy framework
- Energy research at institutions and universities
- Global cry on CO2 emission and demand for energy efficiency
- Deregulated power market and its promotion by the government
- Advanced telecommunication infrastructures
- Software and hardware capabilities
- More firms choose to own DGs in the form of trigeneration (CCHP), e.g. pharmaceutical plants of Pfizer and Schering Plough
- Industrial parks, science parks, HDB residential blocks could serve as launching pads
What MEMS Can Offer?

- All loads in district are aggregated
- Renewable and traditional generation systems CHP, CCHP
- Central control of heat and air conditioning
- MEMS would collect data and make decisions for control & optimization
What MEMS can offer?

Features

– The MEMS will be responsible for decisions
  • When to commit and dispatch each generator
  • When to store energy
  • Purchase and sale with upstream networks
  • Manage load priority and security of microgrid
– Incorporate renewable sources and control DERs
– Combined electricity, hot water and air conditioner (district cooling) loads
– Handle offers/bids submitted by DGs and price responsive elastic loads
– Participate in the wholesale energy and reserve market.
MEMS (Microgrid Energy Management System)

Advantages

– Open up scope for new services and new opportunities
– Improve energy efficiency as a single entity
– Thermal energy utilization
– Responsive to changes in market
– Power management at district (distribution) level
– Process optimization and improve reliability
– Could offer islanding operation and enhance power quality
Smart Meters for MEMS

Singapore EMA and PA are working out smart meters (based on wireless technology) which could be exploited for MEMS

- **Features of smart meters**
  - Time-of-the-day pricing
  - Daily reading of consumption periods
  - Daily retail settlement
  - Daily wholesale settlement
  - Innovative pricing and service packaging
  - Consumers can plan their consumption
    - Interruptible and elastic loads
  - Consumers can choose to buy/sell electricity when they have storage or own generation

- **What it can offer for MEMS**
  - Collect information and help to make collective decision
  - Optimize the use of installed DERs, elastic loads, storages, heating and cooling
  - Allow consumers to plan their consumption or MEMS to take control
  - MEMS can take decision to generate own electricity when the market prices are high with its storages or own generation
OBJECTIVES

- To design software algorithms and control schemes for minimizing schedule cost or maximizing revenue of MEMS while ensuring its secure operation.
  - Economic aspect: Predict total customer loads and perform economic scheduling of distributed energy resources (DERs).
  - Security aspect: Monitor & control MEMS.
- To design hardware controllers and demonstrate how proposed prototype can coordinate and schedule one or more DERs and price-sensitive loads.
- To develop a web-based GUI and incorporate sensing and communication devices for interfacing with local DERs and loads, distribution networks and market operators.
SCOPE

- Support interconnected or islanding operation mode.
- Design load forecasting algorithms, e.g. ANN, for predicting total load.
- Engage Unit Commitment (UC) in economic scheduling of DERs.
- Optimal Power Flow (OPF) recommends maximum customer loads to connect and tap positions of on-line tap changers.
- Implement recommended tap positions, MW shedding, Var switching and interruptible loads via active management.
- Perform on-line probabilistic security assessment based on normal operation or sudden disconnection from MV network.
- Design DC-DC and DC-AC converters for DERs.
- Implement web-based communication and control for various components of MEMS.
Advanced Sensing and Communication System

DSO: Distribution System Operator
MEMS: Microgrid Energy Management System
IES: Intelligent Energy Sensor
SM: Smart Meter
MV: Medium Voltage
LV: Low Voltage

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Advanced Sensing and Communication System

- Require a cost-effective and reliable wireline or wireless communication and control network interconnecting centralized MEMS, distributed energy resources, power converters, electrical loads and energy storage devices

- Intelligent Energy Sensors (IES)
  - Provide energy production and power flow information

- Smart Meters (SM)
  - Monitor energy consumption at each time-interval
  - Perform real-time power measurement such as peak usage and power quality

- Microgrid Energy Management System (MEMS)
  - Controls power outputs from energy sources via power converters
  - Monitors electricity consumption of the loads and dynamically regulates power and energy distribution
  - Manages active and reactive power flow
Design of DC/DC and DC/AC Converters

All renewable energy sources such as photovoltaic cells, fuel cells, and wind turbines have unstable output voltage. We need the Power DC/DC and DC/AC converters to obtain stable output AC voltage and frequency, and then link to Utility network. A block diagram is shown below.

Solar panels have output DC voltage depending on the sunlight strength. Usually the output voltage is unstable. For example, a solar panel has standard output voltage 186 VDC. The voltage changes from 163 VDC at 8:30 am to 198 VDC at 11:30 am. Sometimes the voltage variation can be ±10%.
DELIVERABLES

Software prototypes:

- Scheduling and forecasting functions – LF, UC, and ED.
- Network applications functions – MU, SE, OPF and SA.
- Controller schemes
- Web-based applications.

Hardware prototypes:

- Advanced sensing and communication system
- Energy sources & conversion and energy storage.

Potential contributions to research: Proposed MEMS system can be used for test-bedding of future RES, storage devices and control schemes.

Potential applications: Proposed MEMS algorithms and prototypes can be used in Singapore industrial and residential distribution system.

Benefits: Lower electricity bills and avoid unnecessary cable installation costs.

Software and hardware prototypes can be further developed for commercialization.

Industry partner - Power Automation.
Intelligent Energy Distribution System (IEDS) Projects at NTU

- Power Converter & Grid Architectural Design for Future Intelligent Energy Distribution Networks (S$0.96 million), **PI: Andrew Loh**.
- Microgrid Energy Management System (S$0.96 million), **PI: Gooi HB**.
- Open Architecture for Intelligent Power Quality Monitoring & Evaluation System (S$0.6 million), **PI: Chen S**.
- Design of a Voltage Collapse Monitoring Instrument using Local Information (S$0.48 million), **PI: Haque MH**.
- Intelligent Trading/Metering/Billing System for Future Smart Distribution System (S$0.48 million), **PI: Wang P**.

A Combined Grant of S$3.48 million.

In addition, **PI Choo FH** received from National Research Foundation (NRF) S$10 million on his ‘zero energy’ green water production and recycling system using Membrane Distillation (MD) and Membrane Distillation Bioreactor (MDBR) powered by solar energy.
Building Blocks of Our MEMS

Lab resources for building a microgrid
- LV simulator
- SCADA infrastructure
- Solar panels
- Gen-set controllers
- Power electronics converters

On order
- 5-kVA M-G Sets and VFD
- DC programmable power supply (0-600 V and 0-25 A)
- 4-Channel 1.5 GHz Oscilloscope
- Energy meters, power sensors and associated software

Proposed
- Client-Server SCADA system for application software development
- Renewable energy sources
Where We Are Currently

- Developed a small microgrid system using two synchronous generators connected to grid
- Software development for controlling the microgrid
- Next
  - Develop DC-DC and DC-AC power converters and application software
  - Integrate energy storage, solar and other renewable energy sources
- Integrate the whole system into LV simulator to form an expanded microgrid.

MEMS can serve as not only test-bedding of future sub-systems and control algorithms but also a command & control center.

Manpower: need 2 more research fellows
Q & A Session