THE UNIVERSITY OF HONG KONG

Department of Electrical & Electronic Engineering

Centre for Electrical Energy Systems

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Future power grid architectures – nanogrids to super grids

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Outline

Introduction

Distributed energy resources (DER)

New problems and issues

New capabilities

New architectures

Future Hong Kong

Conclusions

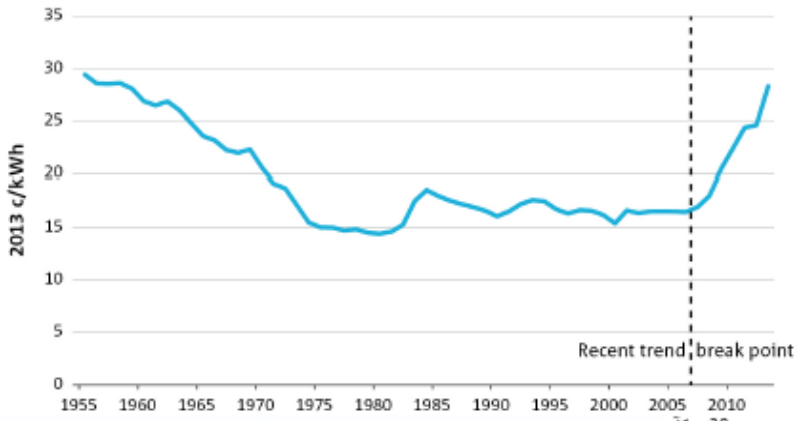
Changes at both ends

- Previously controllable generation together with random renewable power
  - ➢ less controllable

Enercon wind turbines, Albany, WA[1]

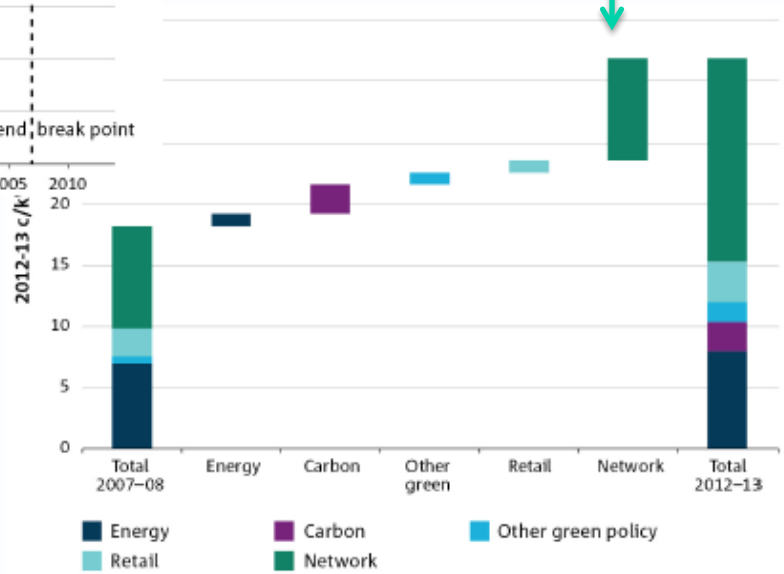
- New loads and changing customer engagement, e.g. rooftop PV, EVs
  - ➢ more controllable?

Issues that motivated the sector to participate



Retail prices have risen

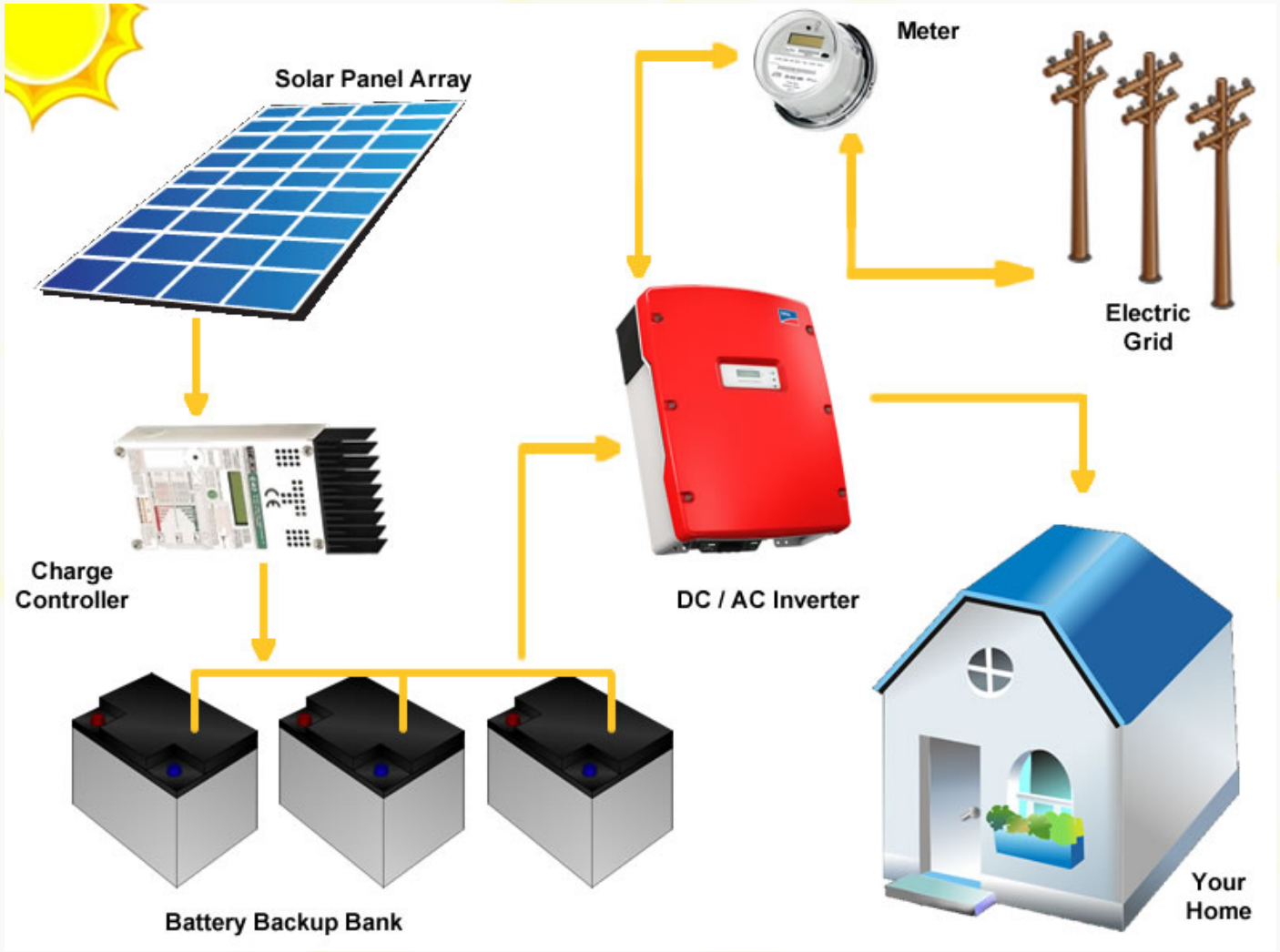
Networks have been the largest source



Scenarios

1. Set and forget – central peak demand management
2. Rise of the prosumer – consumers empowered (see later)
3. Leaving the grid – cheap storage (see later)
4. Renewables thrive – centralised and 80+%

Prosumers


Solar Panel Array
Meter
Electric Grid
Charge Controller
DC / AC Inverter
Battery Backup Bank
Your Home

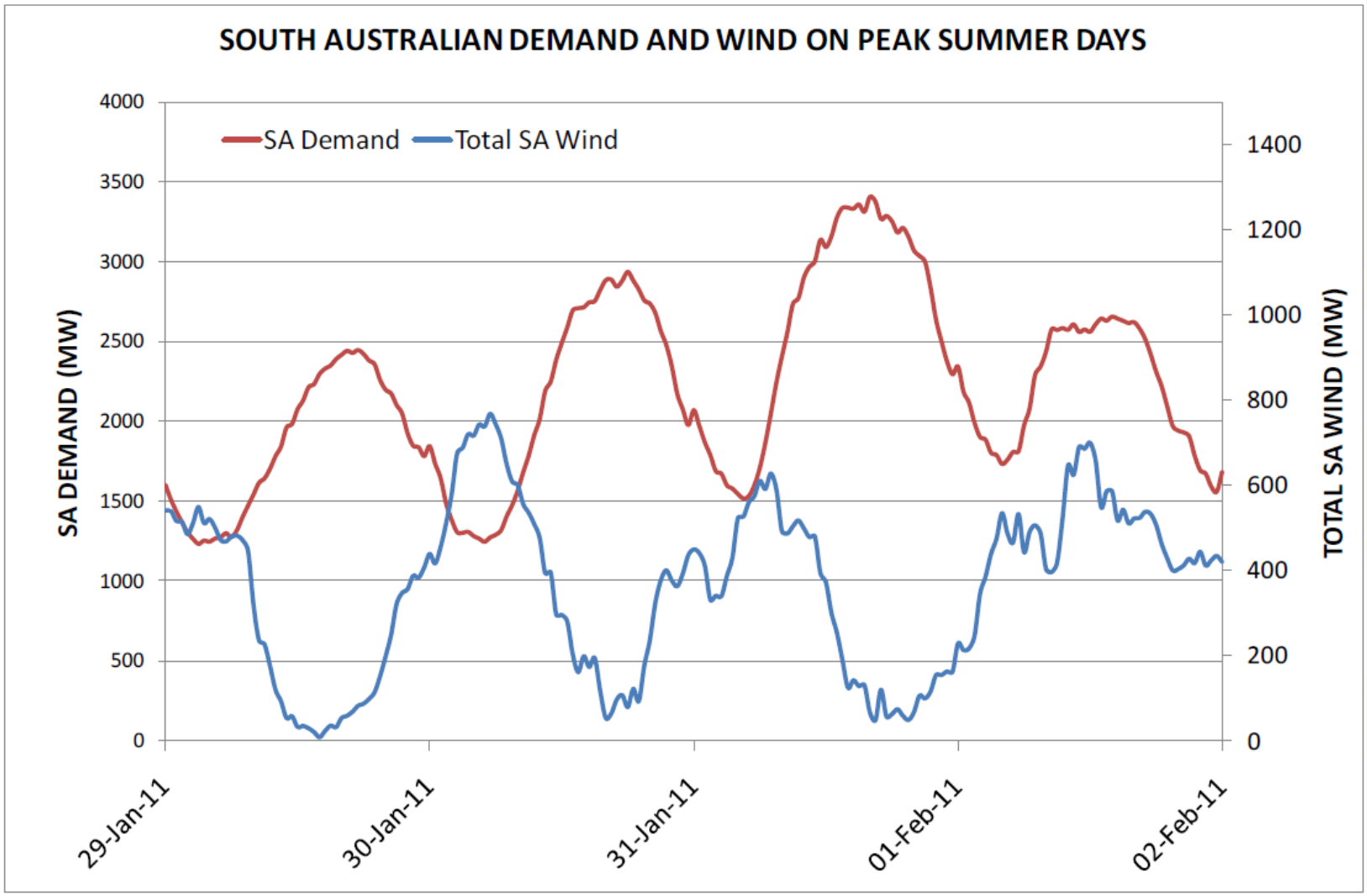
Bilateral flows

THE AUSTRALIAN

Rooftop solar panels overloading electricity grid

ANNABEL HEPWORTH THE AUSTRALIAN OCTOBER 13, 2011 12:00AM

South Australian demand and wind generation -
peak summer days



AEMO: Wind Integration In Electricity Grids

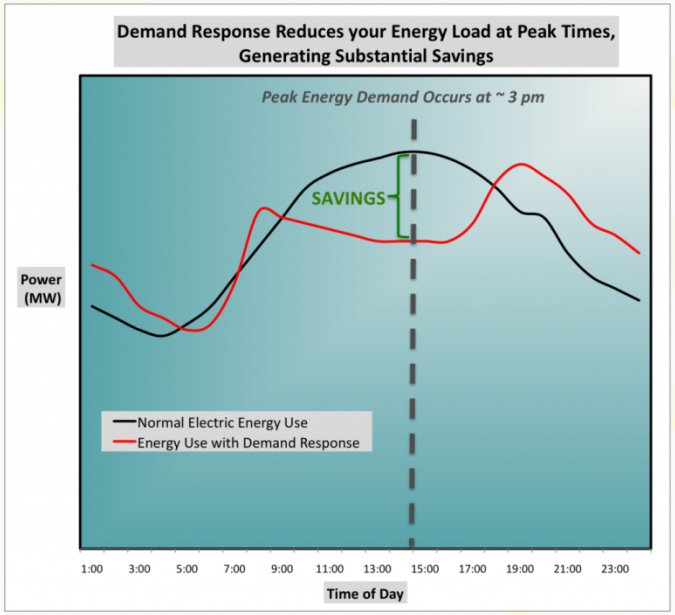
Definition of Smart Grid

- **USA DOE has summarized key features of a smart grid:**
  - Self-healing from power disturbance events
  - Enabling active participation by consumers in demand response
  - Operating resiliently against physical and cyber attack
  - Providing power quality for 21st century needs
  - Accommodating all generation and storage options
  - Enabling new products, services and markets
  - Optimizing assets and operating efficiently
  - Adaptable to generation/Load volatility

Demand following generation

Two new control resources

- Demand response
- Use energy storage to fill gaps



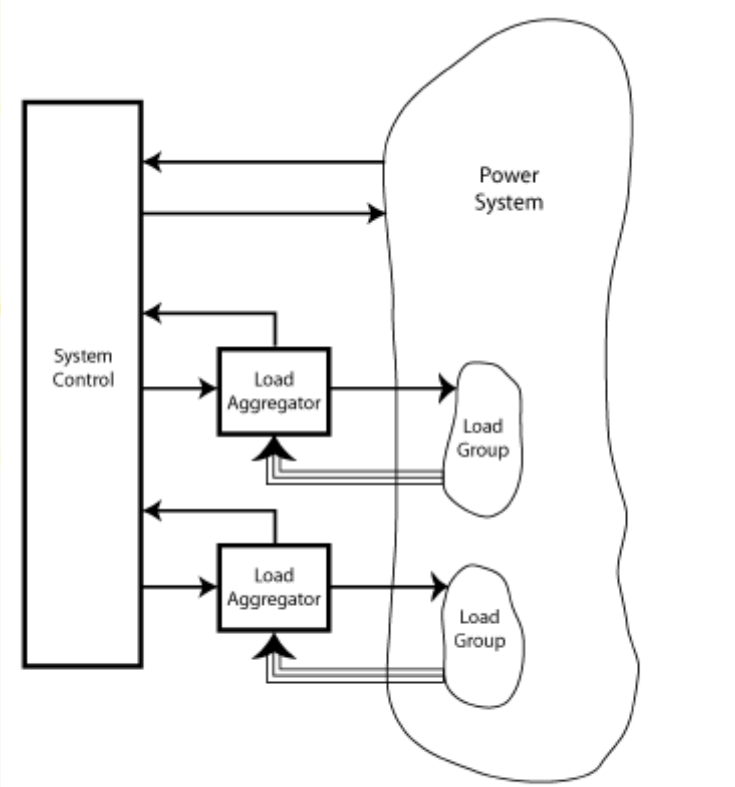


Fig. 6. *Schematic representation of a hierarchical load control strategy.*

Distributed control

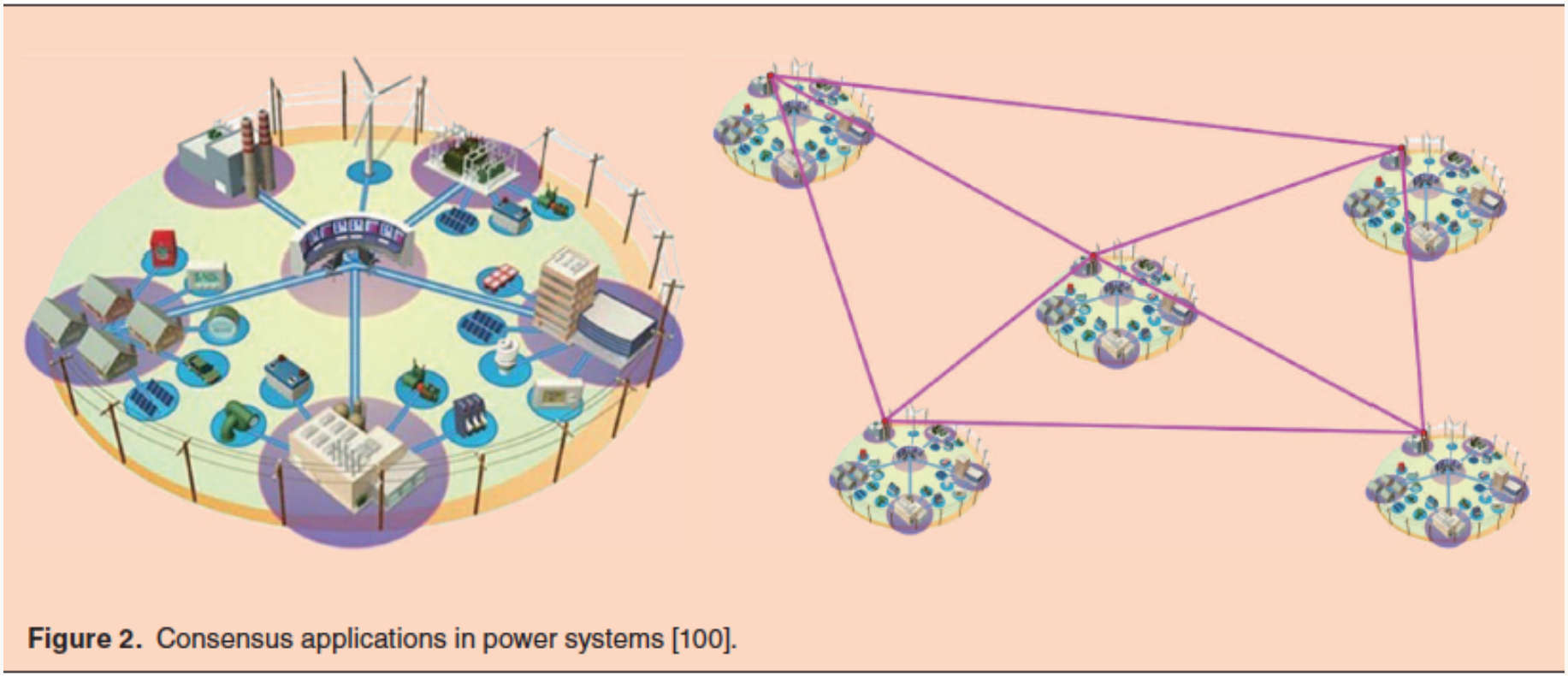


Figure 2. Consensus applications in power systems [100].

What structures work for power systems?
How will they be different for the various tasks?

Thermostatic Control of Frequency

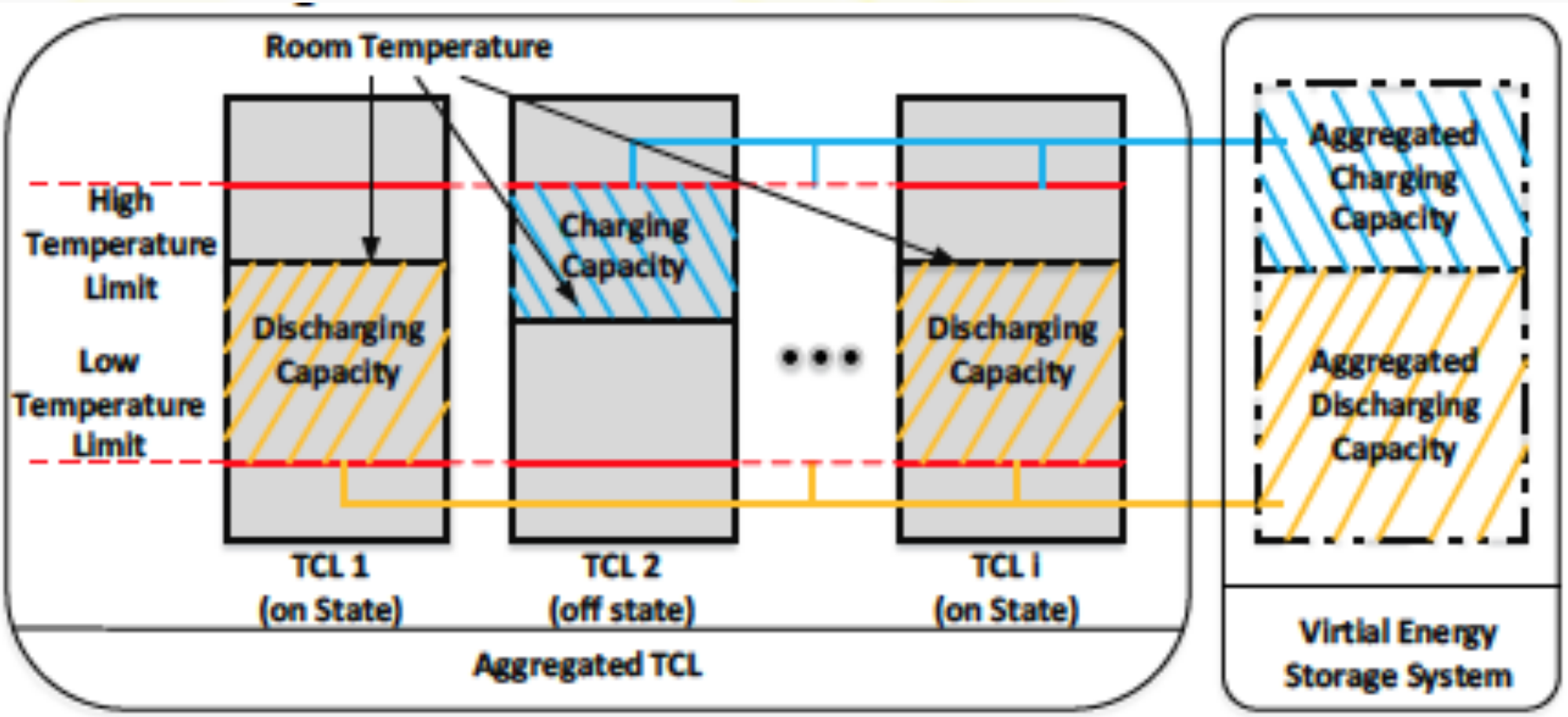


Fig. 1. VESS concept

IEEE 9-bus system

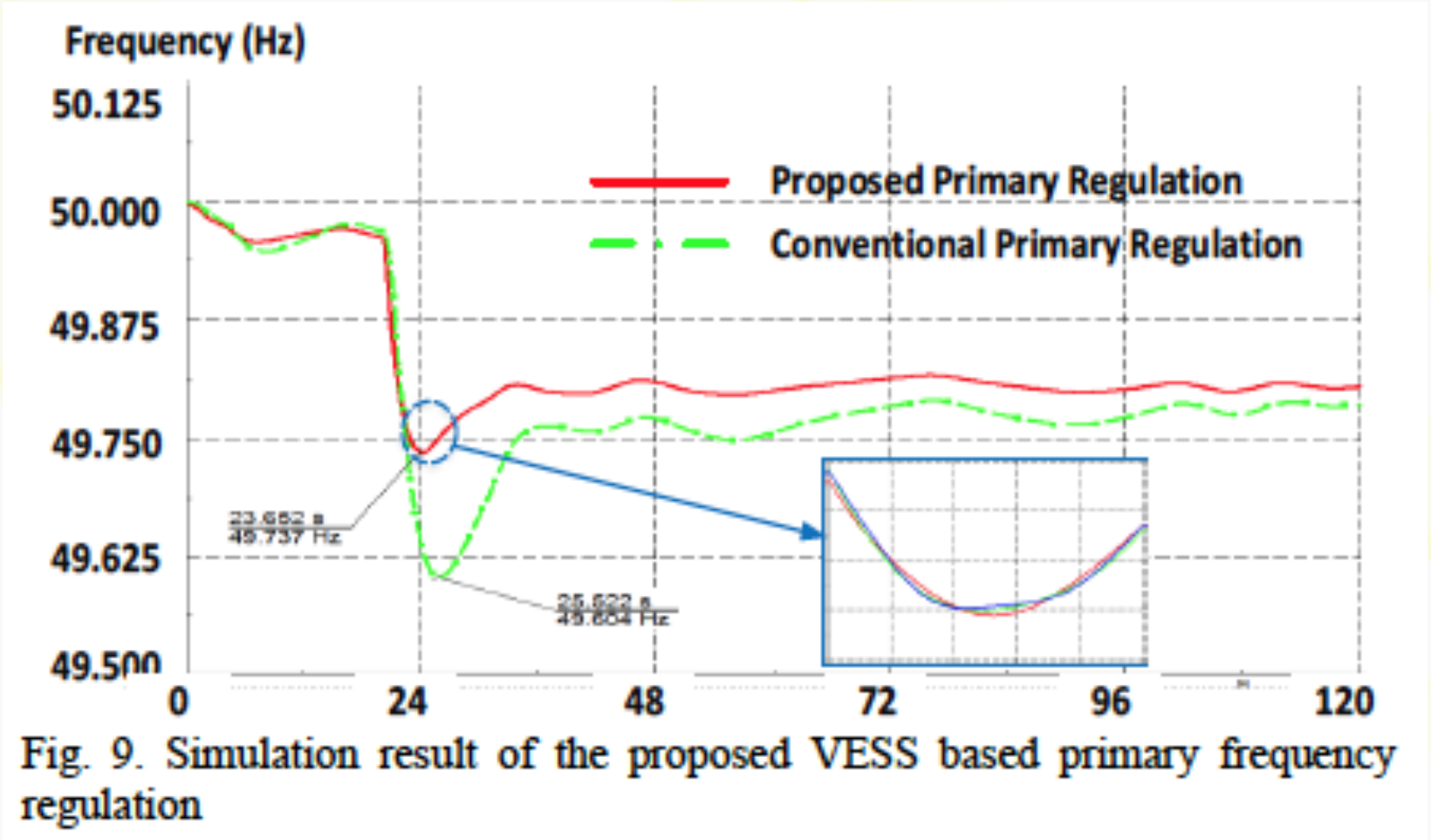
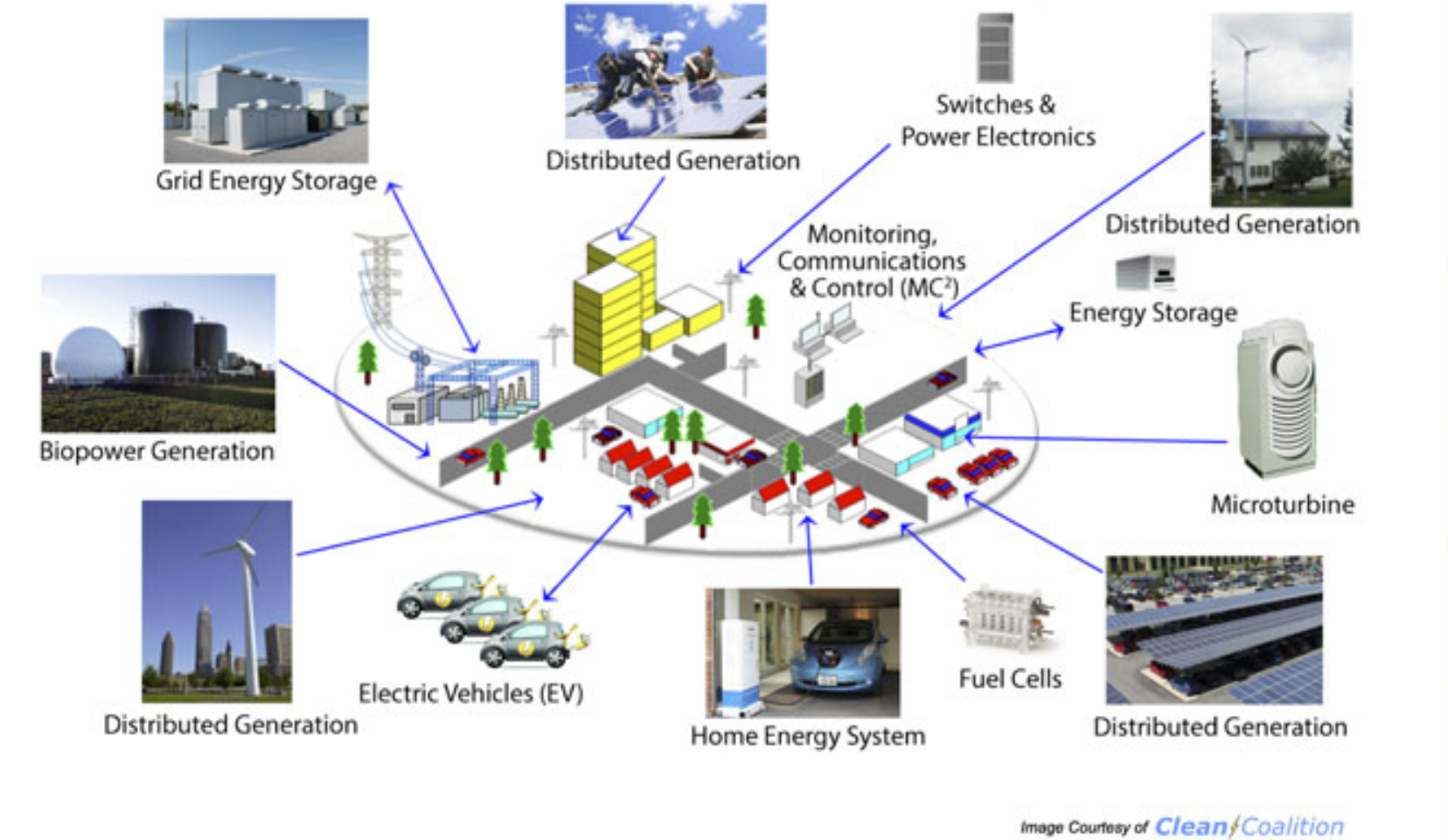
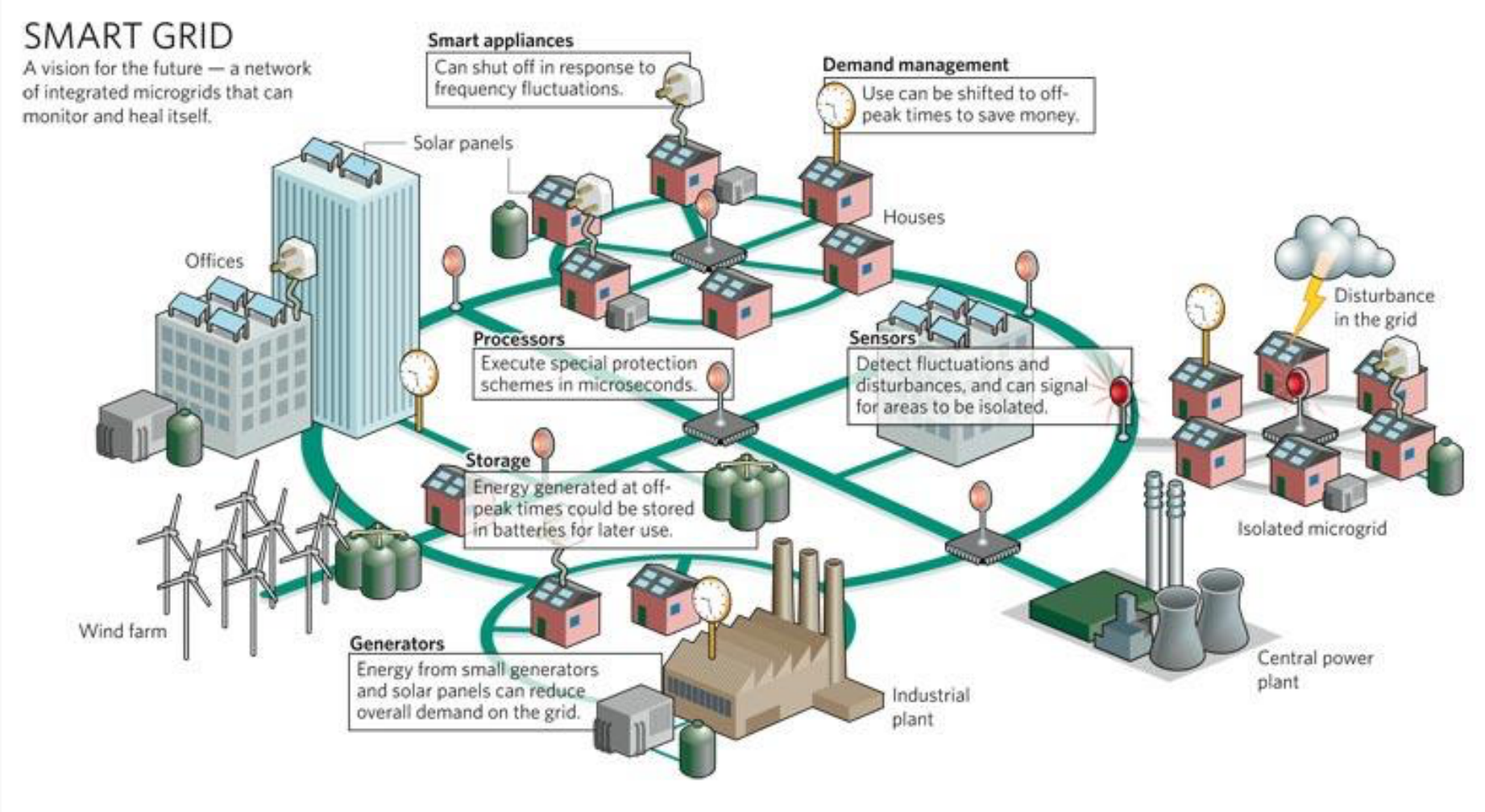


Fig. 9. Simulation result of the proposed VESS based primary frequency regulation

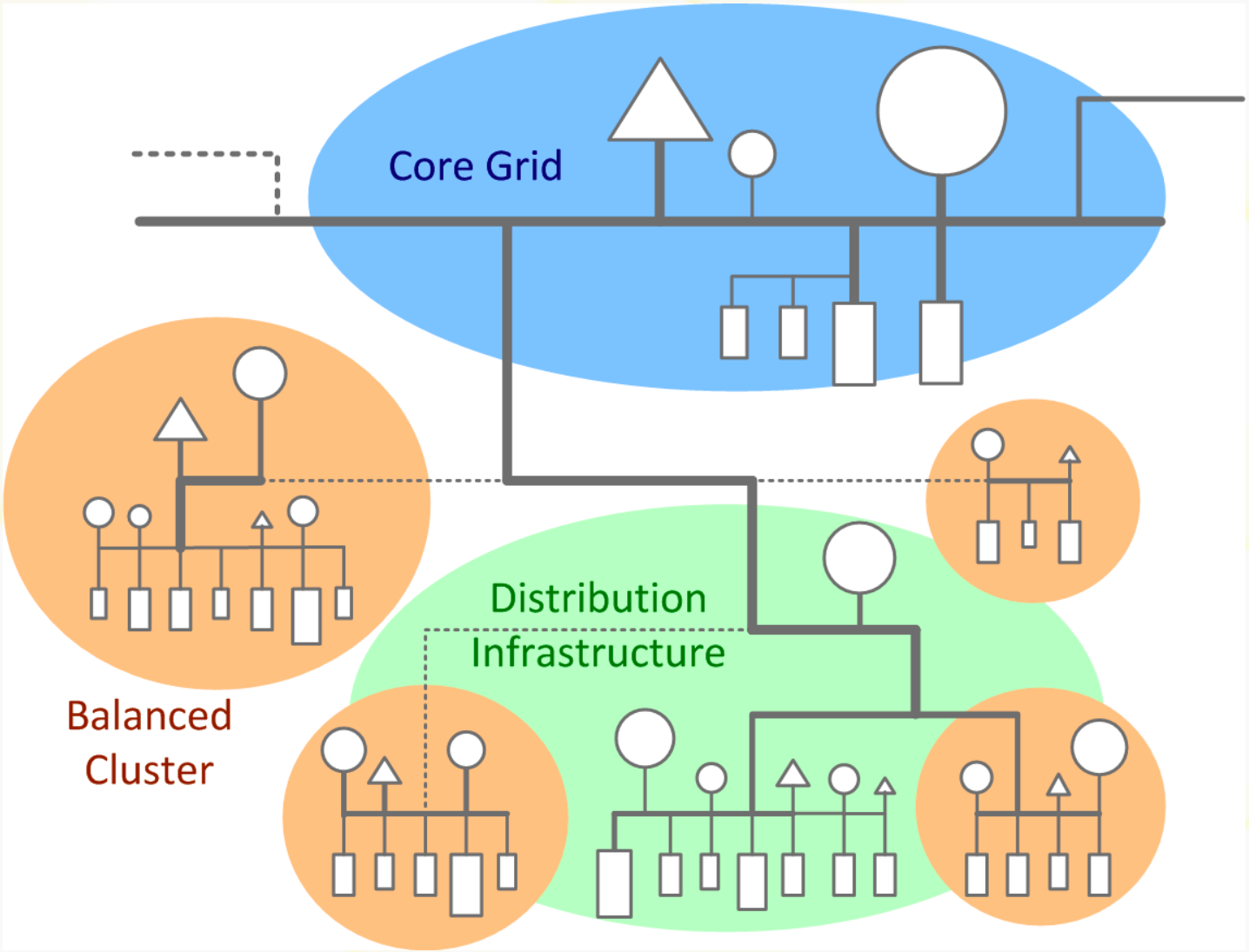
Microgrids


Grid Energy Storage
Distributed Generation
Switches &
Power Electronics
Distributed Generation
Monitoring,
Communications
& Control (MC²)
Energy Storage
Biopower Generation
Microturbine
Distributed Generation
Electric Vehicles (EV)
Home Energy System
Fuel Cells
Distributed Generation
Image Courtesy of CleanCoalition

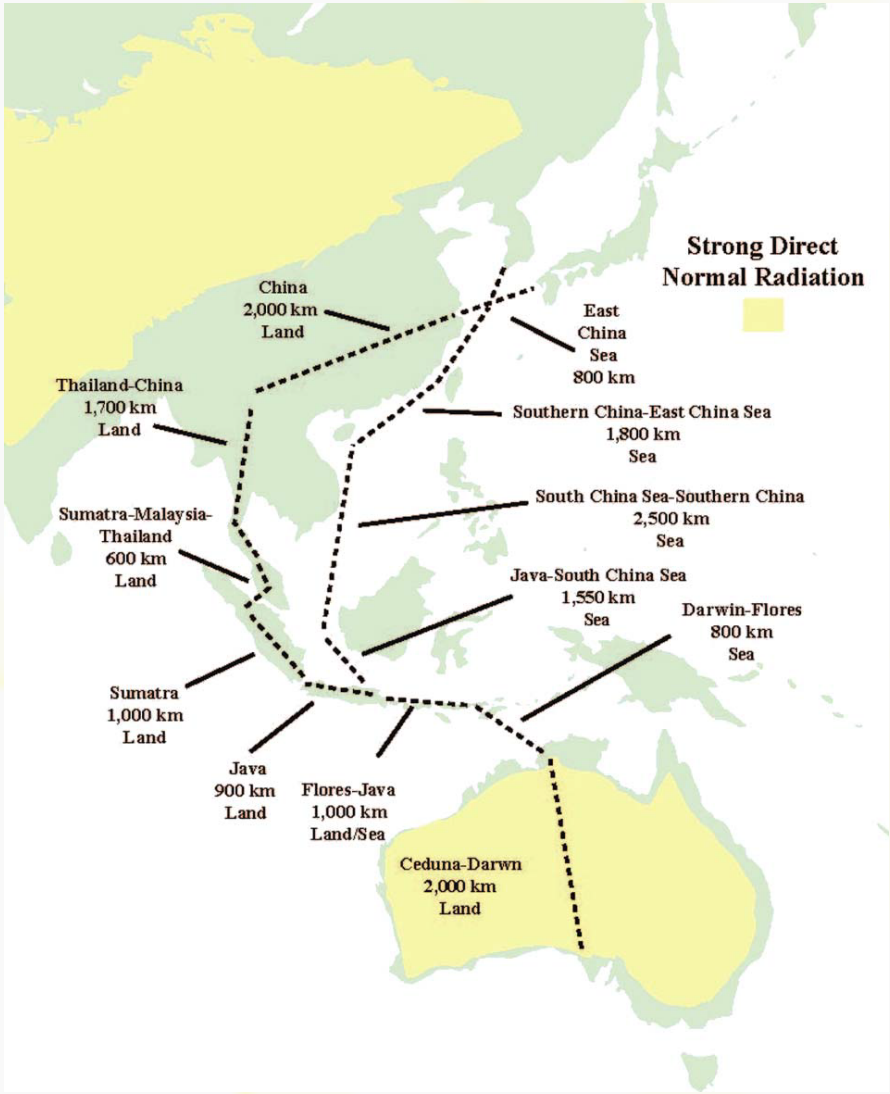
Smart grids


SMART GRID
A vision for the future — a network of integrated microgrids that can monitor and heal itself.
Smart appliances
Can shut off in response to frequency fluctuations.
Demand management
Use can be shifted to off-peak times to save money.
Solar panels
Houses
Offices
Disturbance in the grid
Processors
Execute special protection schemes in microseconds.
Sensors
Detect fluctuations and disturbances, and can signal for areas to be isolated.
Storage
Energy generated at off-peak times could be stored in batteries for later use.
Isolated microgrid
Wind farm
Generators
Energy from small generators and solar panels can reduce overall demand on the grid.
Industrial plant
Central power plant

Grid2050 Architecture (Bakken et al.)



Supergrids



Ref: Taggart, et al.,
Proc IEEE, 2012

Future HK

- Recent fuel-mix ignored renewables
- But China is the largest installer of RES in world
- Possible future electricity markets, across PRD?
- HK microgrid
  - » tall buildings?
  - » rural villages

Future buildings