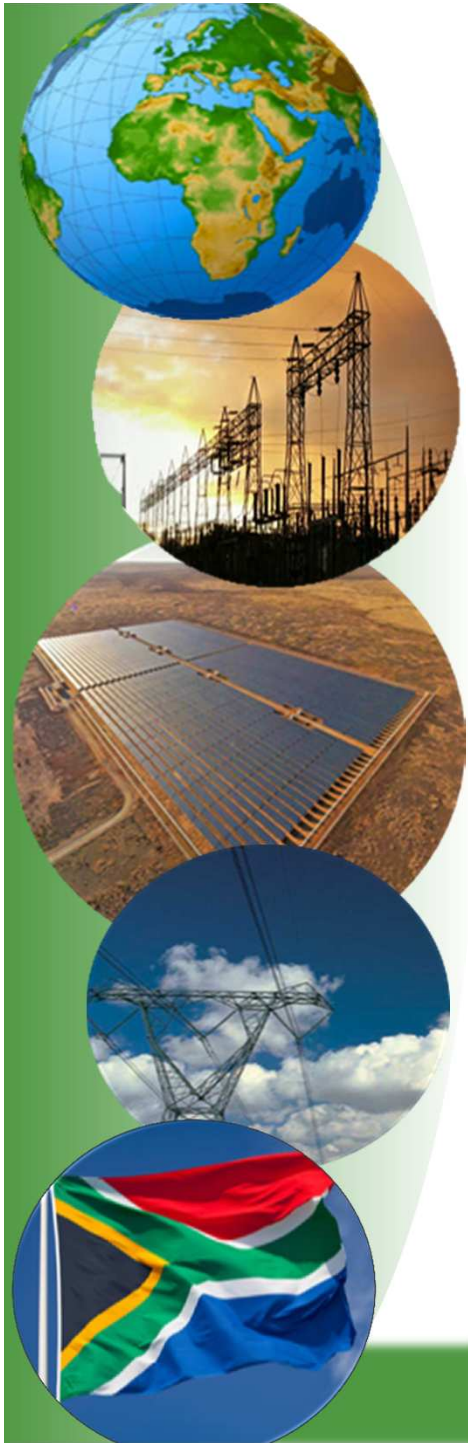

How Digital Microgrids contribute to resolving the electrification challenge

Sherwin Harris

General Electric Power – Grid Solutions

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Africa Electrification Challenge

Indicator	Value(s)
Population (billion)	1
Population growth rate (annual)	2.7%
GDP annual growth rate	5.4%
Rural population average growth rate (annual)	1.9%
Average rural electrification rate	14%
Electric power consumption per capita per year(kwh)	488 for all SSA 153 excluding South Africa
Transmission & Distribution losses (% of output)	12%

Source: World Bank

Four Trends Disrupting the Electricity Sector

4 Trends Disrupting the Traditional Power Sector

RENEWABLES

Decarbonization
60% increase in renewable & hydro generation by 2017

IMPACT
Generation becoming difficult to forecast & variable
Grid stability, Congestion
Volatility on electricity markets

DECENTRALIZATION

Growing penetration of distributed resources (renewable, storage, efficient devices)

IMPACT
End user become an active actor of the power system
Growing complexity of distribution grids

CROSS SECTORS ELECTRIFICATION

Electrification of energy uses, transport (EVs) and heating

IMPACT
Growth of Electricity demand, and an acceleration of decentralization of the power sector

DIGITIZATION

Explosion in the number of connected devices & smart sensors

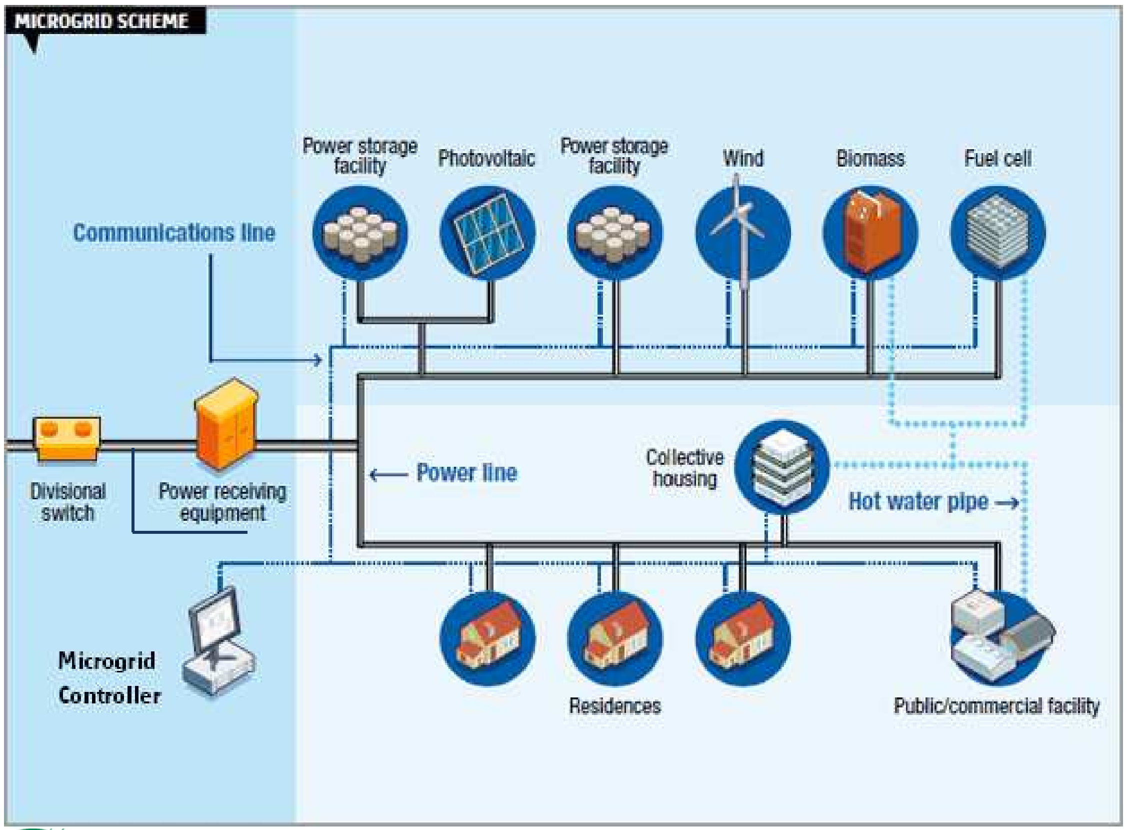
IMPACT
Allowing decision making based on dynamic and nodal prices

Electrify Africa: a two-pronged Strategy

- About 86% of the rural population but also 37% of the urban population have no electricity access.
- To reach universal access to electricity by 2030 through power infrastructure investment, an estimated $19.1 billion would be required per year.
- This level of investment is highly unlikely; it is more likely that electrification will occur progressively through the establishment of bankable business cases for distributed microgrids combined with investments in central grid infrastructure.

What is a MicroGrid ?

Integrated energy system and control + **Distributed Energy Sources (DG, DS)** + **Loads** =



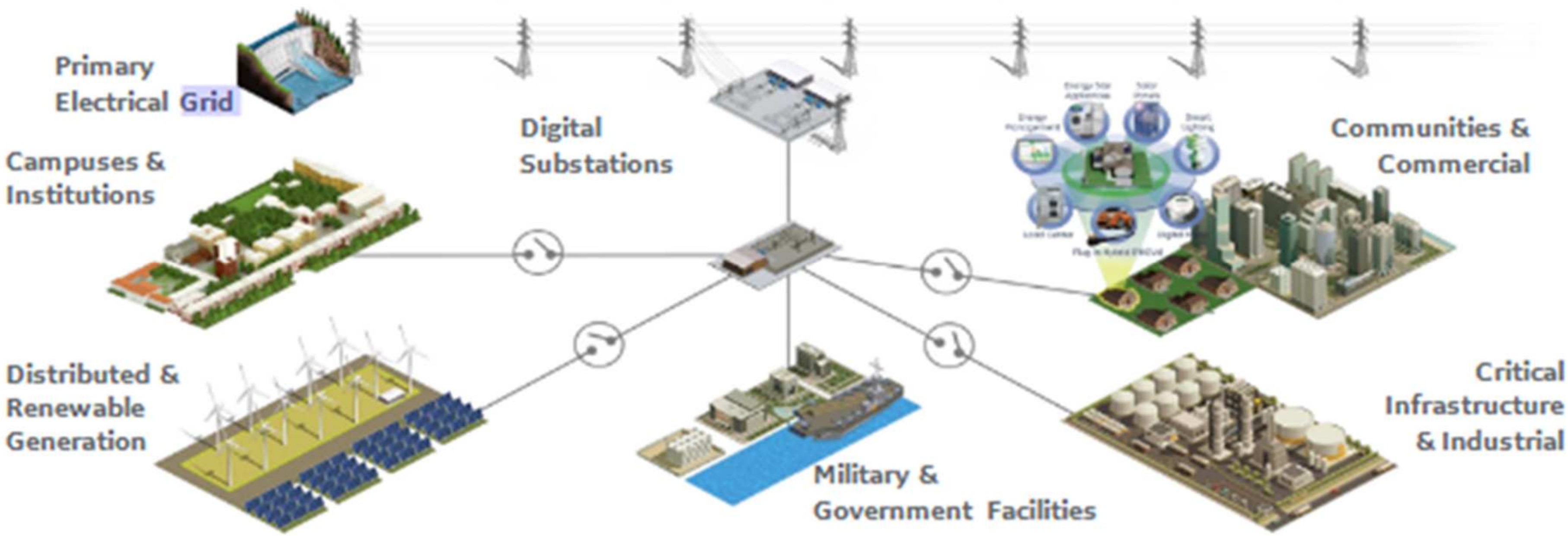
Microgrid

A Microgrid is an **integrated energy system** consisting **of interconnected loads and distributed energy resources** which can operate **in parallel with the grid** or in an intentional **islanded mode**

Key Characteristics

- ✓ Provides sufficient and continuous energy to a significant portion of the served load
- ✓ Possesses independent controls and can island and reconnect
- ✓ Seen as a single "Point of Control" from the grid system operator.
- ✓ Enables flexible power delivery system configuration and operation
- ✓ Enables optimization of a large network of load, local Distributed Energy Resources and the broader power system

Microgrid Segments



Microgrids rising interest For End users & Market players

The combination of **ICTs** and various **distributed energy resources (DER)** — including DG, DS, EVs, and DR — will allow the creation and proliferation of **new distributed energy systems (DES)** *Source: MIT utility of the Future Study*

Before: Microgrids as safeguards in specific areas

Provides reliable, continuous power for critical loads like in hospitals or smelters factories

Improvement in the cost and performance of a range of DG

Potential breakthroughs in distributed energy storage

Changing uses and use patterns of electricity (EV, DR…)

Growing expectation s on Grid resiliency (Vs weather conditions….)

Ahead: Microgrids is seen as new way of operating the network

Combines local DERs, including DG, DS, and/or DR, to enable a business model that **provides valued services to energy end users or upstream electricity market actors.**

Microgrids Business Models

	Utility Model	Hybrid Model	Private Model (Unregulated)	Private Model (Regulated)	Community Model
Owners of Power Generation and Distribution Assets	Utility	Private/Utility/ Community	Private	Private	Community
Brief Description	Government or parastatal utility manages all aspects of microgrid	Private players generate and utility distributes electricity (or the reverse), or private entity to commercialise electricity generated by and distributed through public assets	Private company manages all aspects in the absence of government regulation	Private company manages all aspects in a regulated environment	Community members organise to manage generation and distribution in a regulated environment, with support and/or coordination from an NGO or private company
Pros	• Can absorb funds easily • Less regulation needed • Connection of microgrid to central grid can be easier • Cross-subsidisation or tariffs, thus affordability easier ensured • Aim to fulfil national electrification targets	• Different actors contribute their strengths and technical and management know-how • Scalable, profitable • Less conflict potential with customers in case of distribution by utility with cross-subsidised tariffs	• Commercial sustainability for long-term operation • Ability to act fast without government interference • Profitability ideally allows for scaling up of operations	• Scalability through private capital • Technical know-how, high reliability • Profitability ideally allows scaling up operations • Legal security of regulated market attracts private finance	• Self-managed public infrastructure • Less conflict potential with customers and officials • Creating assets and local ownership • Enabling self determination and economic development
Cons	• Not the core business • Unsuited company structure for smaller projects • Strain on limited budget • Political interference • Possibility of corruption in procurement	• Complex management, feasibility of models depend on regional /local context/structures • Non-fulfilment of contracts due to conflicts between business partners • Insolvency of one partner puts full operator model at risk	• No financial support from public obtainable • Grid-interconnection challenging/impossible • Changes in regulation and fixed tariffs can reduce profitability • Conflicts with customers due to monopoly • Insufficient quality and safety risks of service can occur if it is not supervised, which can contribute to a bad image of microgrids	• Reliable regulation needed, dependency on lengthy approval procedures • Debt financing needed for scaling up • Vulnerable to changes in regulation, fixed tariffs, conflict with customers, • High transaction costs • Potential risk: grid interconnections	• Insufficient local human capacity (technical, managerial) • Often unclear ownership structure • Usually high grants needed • Tariffs not covering operation and maintenance and reinvestment costs • Corruption risk due to overlapping of management and social and family connections

Source: EUEI; Frost & Sullivan

Microgrids Business Models Pros & Cons

	Utility	Hybrid	Private - unregulated	Private - Regulated	Community
Owner	Utility or Government Body	Private / Utility / Community	Private	Private	Community
Main Characteristics	100% managed by utility	Private company generates and sells, Utility distribute	100% managed by private company	100% managed by private company in a regulated environment	Community manages generation and distribution in a regulated environment
Pros	• Secured funding • No additional regulation required	• Replicable business model • Limited risk of unpaid bills	• Scalability thru private capital • Fast deployment	• Scalability thru private capital • Te	• Less conflict potential with customers • Local assets creation • Economic growth enablement
Cons	• Not core business • High cost structure • Strain on budget • Political interference	• Complex structure • Potential conflicts among partners • Additional regulation may be needed	• No financial support from public funding • Additional regulation may be needed • Potential conflict with	• Additional regulation needed • Vulnerable to changes in utility regulation framework	• Lack of skills and expertise locally • Funding requires grants • Electricity tariffs too low to cover full

PROJECT EXAMPLES

US DoE - Philadelphia Navy Yard Case – Hybrid Regulated Business Model

- Main objectives:
  - Energy surety and Back-up & service quality
  - Reduce Outages impact on Grid
  - Optimal use of DER
- Highlights:
  - Seamless transition interconnected/islanded mode of operation;
  - Stable operation in islanded mode (V, F control)
  - Adaptative protection schemes
  - Critical load supply control
  - Optimal DER (PV) operation in interconnected mode

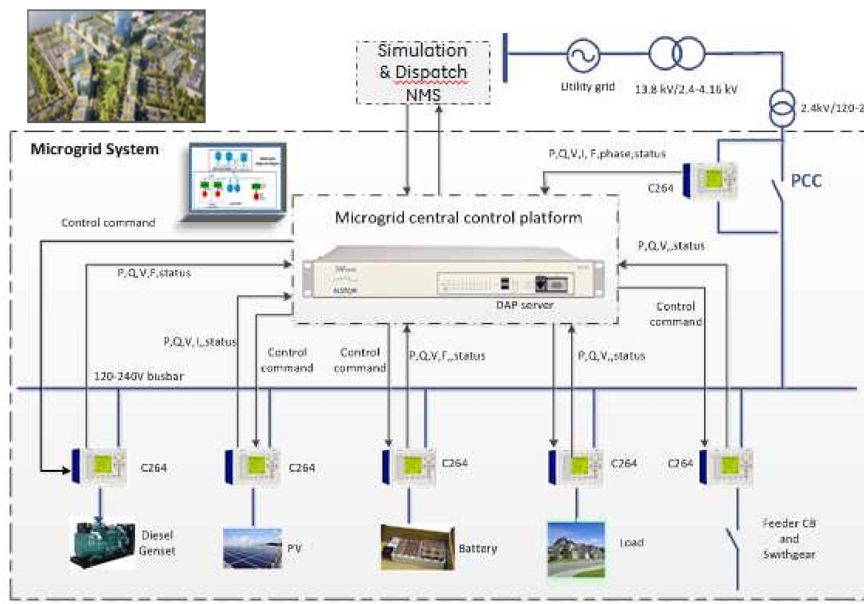
Solution:

Automation

- MG AFBs embedded in DAP server , IEC61850 system with Micom IEDs, C264

Analytics

- Simulation forecast & dispatch, e-terra*distribution*



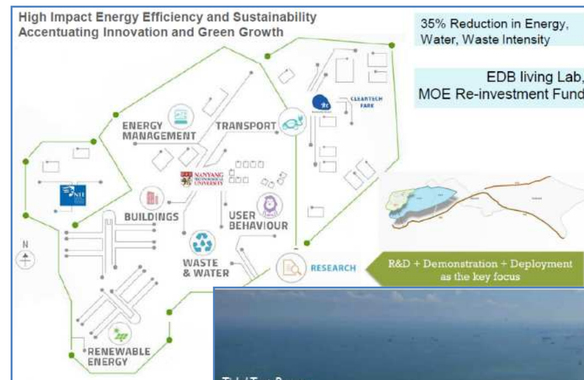
NTU Singapore - Private Business Model

- Main objectives:
  - Develop Microgrid Power Mix optimization and management application with NTU for Semakau Island and NTU ecocampus
- Highlights:
  - Optimal RT automated DER
  - Maximization of RES penetration with reduced operational losses and cost.
  - Improvement of system observability (RT Local State Estimation).
  - Strong/weak grid-connected mode.
  - Field installation in 2 sites Ecocampus and Semakau island

Solution:

Automation

- MG AFBs embedded in DAP server , IEC61850 system with Micom IEDs, C264



University of Ontario - Private Business Model

Main objectives:

- Energy surety and Back-up & service quality
- Reduce Outages impact on Grid
- Optimal use of DER

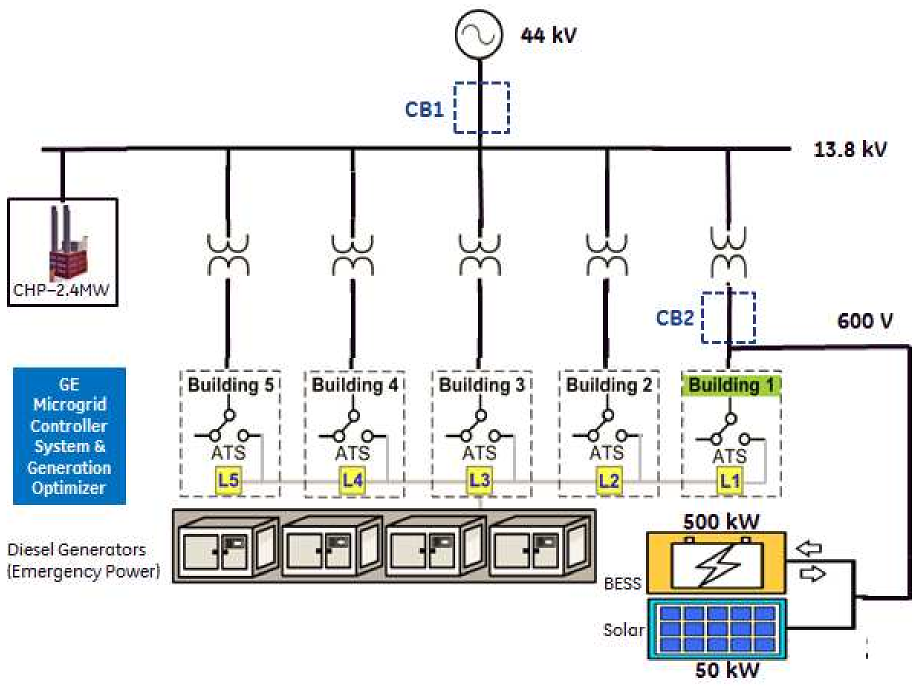
Highlights:

- To operate in both grid-connected and islanded modes.
- In grid-connected mode, optimally utilize batter storage, and solar to reduce energy and demand charges.
- In Islanded mode provide, uninterrupted power to the critical loads and reliable power to pre-determined supported loads through the CHP
- In case of grid failure, provide power to critical loads with a seamless transition

Solution:

Automation

- MicroGrid-EMS in D400 and DNP 3 IEDs system for Optimal dispatch.



Nice Grid – Utility Business Model

Main objectives:

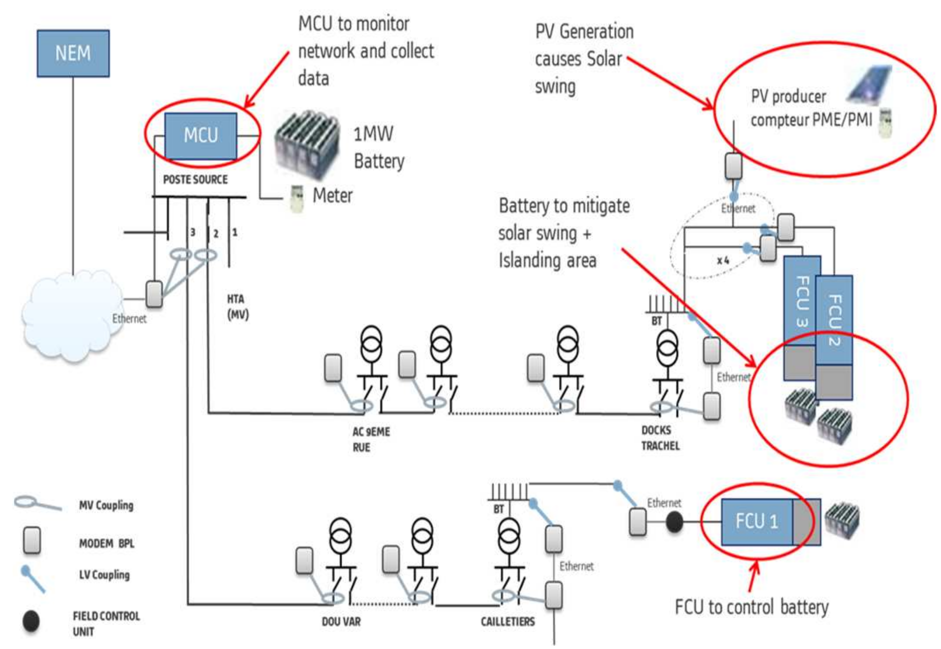
- Optimal use of DER (mostly PV)
- Planned and unplanned islanding operations
- Active customer participation to grid balancing

Highlights:

- To operate in both grid-connected and islanded modes.
- In grid-connected mode, optimally utilize battery storage, and solar to balnce grid and minimize losses
- In Islanded mode provide, uninterrupted power running on local PV and storage

Solution:

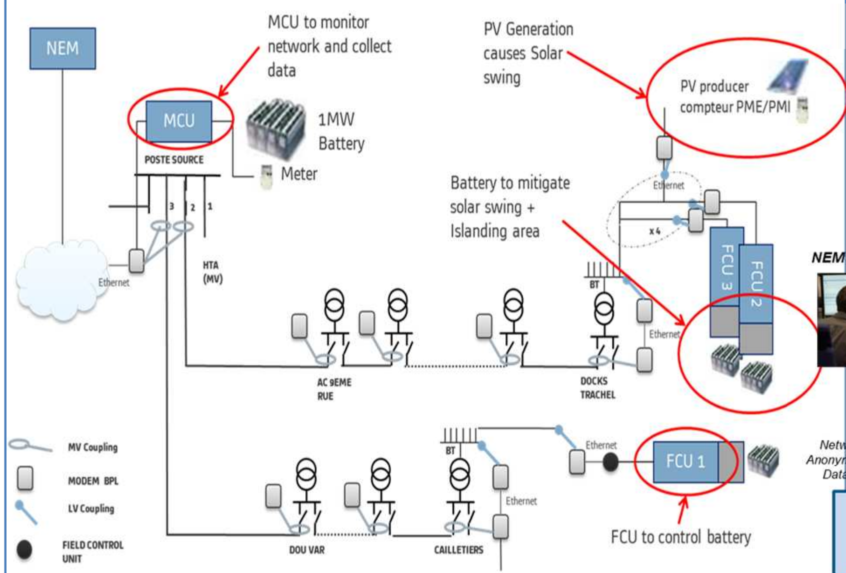
1. NEM is the energy management platform that manages the smart solar district
2. MCU: is the master field control unit that supervise and manage a part of the network (Microgrid).
3. FCU is an intelligent gateway between the MCU and DER. It can supervise the DER and handle simple control functions



Transaction Management
Nicegrid Implementation

Transactions Management

- Architecture overview (Layered)



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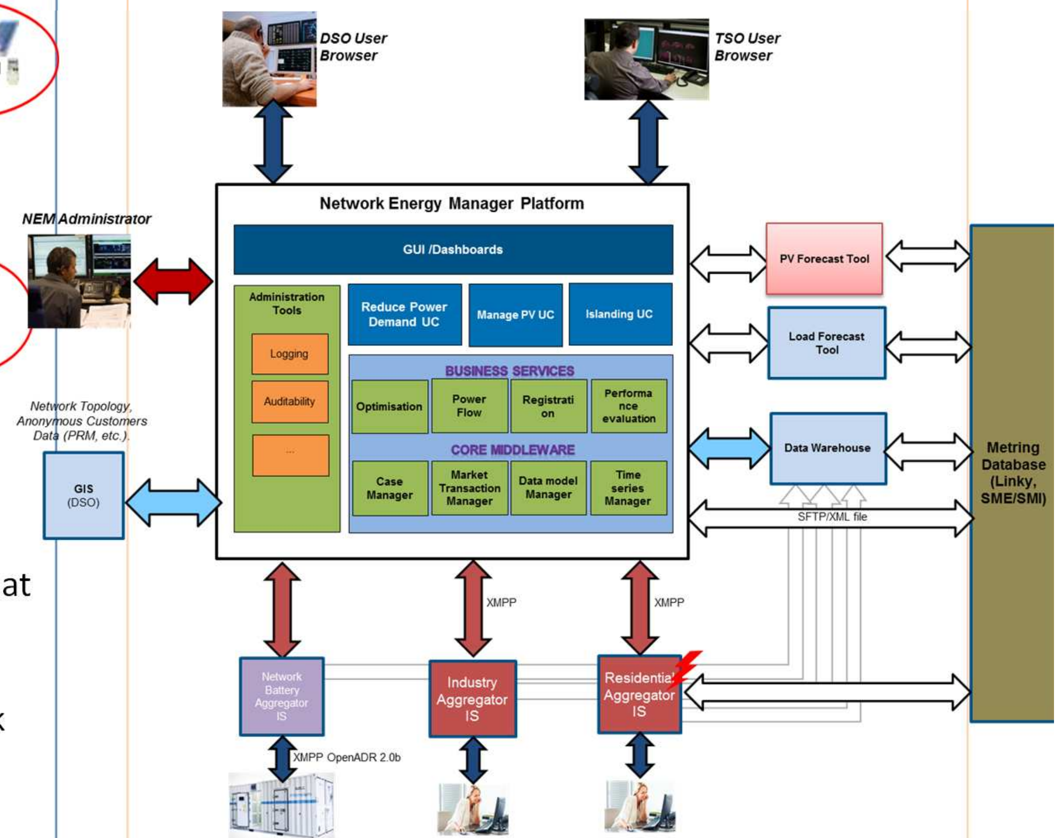
2. MCU: is the master field control unit that supervise and manage a part of the network (Microgrid).
3. FCU is an intelligent gateway between the MCU and DER. It can supervise the DER and handle simple functions to control the DER.

Functional Design



Transaction Management Nicegrid Usecase

Transactions Management

Multi-level coordination & Transaction Management