Basic Module: Smart Grids and Grid-Connected Systems

❖ ModuleObjectives

- Understandthe concept of smart grid technologies and their application to existing and modern power systems.
- Understand the benefits and limitations of grid connected systems in existing and modern power systems
- Recognize and experience practical and theoretical techniquesthat are used to evaluate and compare smart grid technologies and grid connected systems.

❖ Learning Outcomes

On successful completion of the module the student/trainee will be able to:

- Describethe background motivation for the adoption of smart grid technologies with reference to the financial, reliability and environmental landscape.
- Discussthe fundamental terminology used to describe electrical power systems.
- Illustrate the challenges and possibilities broughtby smart grid and grid-connected systems.
- Distinguish betweenmethods foroperating the smart grid and optimising smart grid functions.
- Analyze the application ofinformation and communication technology to smart grid applications.
- Apply theirknowledge of the technology typesneeded for microgrids, integration of renewable energy and energy storage to power system design and operation.
- Describe the role of uncertainty analysis in the modelling and simulation of energy systems.
- Demonstrate the use of methods that predict the performance of smart gird technologies and grid connected systems, in terms of cost, reliability and environmental impact.
- Demonstrate the use of hardware-in-the loop testing of a smart grid system controller.

❖ Prerequisites

Basic undergraduate mathematics and physics are assumed. It is expected that students/trainees have Power Engineering as their background or/and have taken the Introduction to Power Systems course and are familiar with its content. Students/trainees will, as a minimum requirement, be competent with units of measurement, power system components, circuit theoryand engineering mathematics.

❖ ModuleDescription

The module discusses the international and national development towards the future's renewable electric energy system, and the concept known as smart grid. The starting point is the understanding the benefits, characteristics, and pillars of smart grids. The module gives a basis to understand the role of energy storage system, active network management, optimal power flow and voltage control techniques. The module provides the students/trainees with basic knowledge about the uncertainty in power system and the use of Hardware-in-Loop simulation for testing smart grid components.

❖ ModuleContent

Chapter 1: Introduction to the Smart Grid concept

- Definition of the Smart Grid
- Characteristics of the Smart Grid
- Smart Grid benefits
- Smart distribution networks versus conventionaldistribution networks
    - Why distribution networks need to be smart
    - Evolution of distribution networks into Smart Grids
        - Flexible electricity networks to integrate the expectedenergy evolution
        - Active distribution network with full integration of demand and distributed energy resources
- Examples of Smart Grid projects/initiatives
    - US Smart Grid efforts
    - European Smart Grid efforts
- Summary
- References

Chapter 2: Pillars of Smart Distribution

- The relationship between Smart Grids and Smart Markets in distribution systems
- Pillar 1: Automation and remote control of local distribution networks
    - Voltage control

- Opportunities for power flow control
- Automated and remote-controlled recovery of supply after fault trips
- Enhanced MV protection concepts
- The economics of the smart grid enhancement in distribution

- Pillar 2: Flexibility from virtual power plants: smart aggregation
  - Introduction to virtual power plants
  - Demand side management: the roleof storage and controllable loads
  - Business models of virtual power plantson prospective markets
- Pillar 3: Smart metering and market integration of the consumers
  - Introduction to digital metering technology
  - Dynamic tariffs
  - The impact on consumer behaviour: demand side response
  - Electric vehicle management
- Communication needs for smart distribution
- Summary
- References

Chapter 3: Microgrids

- Introduction to Microgrids
- Energy Management in microgrids
  - Supply and demand management in microgrids
  - Energy generation scheduling in microgrids
- Summary
- References

Chapter 4: Energy Storage& FACTS

- Energy storage services
- Characteristics of energy storage
- Energy storage for grid systems
  - Technologies types and properties
  - Interface to grid

- Locating and sizing storage
- Service combinations
- Case study

- FACTS
  - Technology
  - Applications
  - Power quality study
- Summary
- References

Chapter 5: Active Network Management

- Introduction to active network management (ANM)
- Drivers for active network management
- Impacts of distributed generation on distribution/transmission
- Planning of active network management
  - Ancillary services
  - Distribution network planning
- Network reconfiguration
  - Typical MV network configuration
  - Reconfiguration reasons: power ratings, voltage limits, reduce losses, planned maintenance, faults
  - Reconfigurationmethods: manual, radio-controlled, fully automated. Requirements, consequences and advantages or disadvantages of each
- Active control management
  - Control hierarchy of ANM
  - Protection system
  - Automatic control system (decentralized)
  - Area control level (centralized)
- Information and automation systems as a heart of ANM
  - Control centre information system

- IT architecture of ANM
- Automation systems

- Summary
- References

Chapter 6: Uncertainty in power system

- Sources of uncertainty
- Load and generation forecasting: long- and short-term forecasting methods
- Planning and operation under uncertainty
- Case study
- Summary
- References

Chapter 7: Hardware-in-Loop (HIL)simulation for testing Smart Grids

- Benefits of HIL simulation
- Model-based design
- Real-time simulation concepts
- Architecture/Hardware
- Commercial software
- Case studies and applications
- Summary
- References

❖ References

1. Momoh, James A. Smart grid: fundamentals of design and analysis. Vol. 63. John Wiley & Sons, 2012.
2. Sioshansi, Fereidoon P., ed. Smart grid: integrating renewable, distributed and efficient energy. Academic Press, 2011.
3. Buchholz, Bernd M., and ZbigniewStyczynski. Smart grids-fundamentals and technologies in electricity networks. Vol. 396. Heidelberg: Springer, 2014.
4. Guo, Yuanxiong, Yuguang Fang, and Pramod P. Khargonekar. Stochastic Optimization for Distributed Energy Resources in Smart Grids. Springer, 2017.

5. McMillin, Bruce, and Thomas Roth. "Cyber-physical security and privacy in the electric smart grid." Synthesis Lectures on Information Security, Privacy & Trust 9.2 (2017): 1-64.
6. Chakrabortty, Aranya, and Marija D. Ilić, eds. Control and optimization methods for electric smart grids. Vol. 3. Springer Science & Business Media, 2011.
7. Tuballa, Maria Lorena, and Michael LochinvarAbundo. "A review of the development of Smart Grid technologies." Renewable and Sustainable Energy Reviews 59 (2016): 710-725.
8. Wang, Ran, Ping Wang, and Gaoxi Xiao. Intelligent Microgrid Management and EV Control Under Uncertainties in Smart Grid. Springer Singapore, 2018.
9. Gungor, Vehbi C., et al. "Smart grid technologies: Communication technologies and standards." IEEE transactions on Industrial informatics 7.4 (2011): 529-539.
10. EA Technology, A Technical Review and Assessment of Active Network ManagementInfrastructures and Practices, UK, May 2006, DTI New and Renewable Energy Programme,DG/CG/00068/00/00 URN NUMBER 06/1196, 77p.