Smart Grid Technologies

India has declared targeted capacity addition of 175 GW by 2022 from Renewable Energy Sources, in particular Solar, Wind and Bio energy (100 GW Solar, 60 GW Wind and 15 GW Bio Energy). This is partly due to growing concerns about energy security and also because of voluntary commitment to reduce its CO2 intensity by 20–25% by 2020. These targets are for utility scale grid connected plants as well as off-grid decentralized plants for rural applications. There is a need to re-engineer the energy infrastructure to absorb such high level of renewable generation without causing any grid instability as explained below.

Research Challenge

The present energy infrastructure is engineered for large-scale centralized conventional generation, transmission and distribution. The present share of renewable sources such as solar and wind power is less than 2% in India. A future energy infrastructure capable of large scale renewable integration presents the following challenges:

Managing Intermittency

Solar and wind are inherently intermittent sources. Large variations cause serious operational difficulties, as experienced in several countries. Large-scale wind and solar power, on the other hand, require quick ramp-up generators and storage devices to off-set the variability in generation.

Energy Storage

At present, pumped hydro is the only cost effective technology for grid level energy storage. Future capacity addition is, however, limited given the ecological concerns with building reservoirs for water storage and the strict geological/geographical requirements for pumped hydro. There is a critical need to develop other cost effective energy storage options for both grid-connected and off-grid power systems.

Demand Response

Renewable power generation does not coincide with the load curve. Therefore, there is a need for ‘management’ of the load curve, in particular shifting the peak load. This requires both, strategies for load management and control such as ‘demand response’ and innovative tariffs such as ‘time-of-use’ or ‘real time pricing’.

Micro–Grids

Decentralized power generation is an important option to pursue. In India, utility-scale generation would take several years to provide quality electricity to consumers, particularly to remote villages. The rapidly declining price of Solar PV makes it possible to envisage decentralized (especially rural) micro grids with energy storage in India.

The entire Multi-Micro Grid architecture can be effectively realized through Multi Agent Systems. Multi Agent Systems (MAS) consist of multiple interacting elements which have the ability to compute, react to changes in its surrounding environment and accordingly take decisions to achieve specific goals. A layered hierarchical structure of autonomous agents can be evolved which can effectively manage entire multi micro grid architecture. Each distributed generating unit and individual loads will act as agents and will constitute the primary level of agents. A secondary set of agents will be formed at the substation level which is the point of interconnection of the micro grid with the utility, which will be monitoring power flow across the point of interconnection.

Agents at the primary level (micro grid level), will be continuously interacting amongst themselves and with the agents superceding them in the hierarchical order of control. The load and generation agents will share information regarding their current status which will in turn be monitored by the agent at substation level. In this way, a very fast and reliable agent based architecture can assist in an efficient operation of the multi-micro grid model

Research Objective, Thrusts and Novelty

Given the scale and inter connectedness of the challenges, National Power Training Institute brings together academic and industrial partners to undertake an ambitious, multi-disciplinary program of R&D on two key research thrusts:

1. Distributed and grid level energy storage.
2. Smart controls and communication

The research thrusts and objectives as shown in Table 1 have several cross-cutting competencies and themes: materials synthesis and processes; device development; modeling and simulation; economic and policy assessment and a pilot project.

Summary of Research Thrusts and objectives

Distributed and grid level storage

Objectives

- Engineering economic analysis and assessment of energy storage options for utility scale and off-grid systems
- Multi-disciplinary design and optimization of advanced Na-S and sodium metal halide battery systems
- Design & optimization of energy storage with renewables
- Novel process technologies & prototype device fabrication
- Battery stability & reliability assessment
- Economic assessment of chosen storage systems

Smart Controls and Communications

Objectives

Architecture design of various options for smart grids	Engineering, Economic and policy assessment of smart grid based systems	Design and implementation of pilot project for two feeders	Analysis of HVDC for large scale renewable integration

Distributed and Grid level Storage

Research includes: (a) the design of new low temperature Na-S and Na-MX systems, including accelerated degradation studies; (b) rigorous optimization of energy storage technologies (including mechanical and electrochemical) for renewable integration; (c) design of controllers for frequency/voltage support in smart grids; (d) design of communications & control architectures and robust control strategies for smart grids; (e) a rigorous investigation of grid dynamics, supply uncertainty and resilience with new pricing models and power flow control mechanisms.

Smart Controls and Communications:

Smart grid technologies are expected to be a key focus area for the distribution sector. Smart grids and smart metering using two-way communication can enable (a) an advanced metering

infrastructure; (b) time-of-day metering (including consumer home energy management systems); (c) the integration of renewables with the grid and (d) self-healing grids. In this project, the focus will be placed on the following areas.

The research will take into consideration evolving metering and communication technologies to develop several options for a smart grid infrastructure. This will include an AC/DC micro-grid demonstration for improving reliability and power quality, energy storage schemes for improving the reliability of sensitive loads, development of intra-operable standards and protocols for energy metering, load research (load modelling), and IT applications in the distribution and smart grids. The deliverables would be:

1. Analysis of communication and control technologies for demand response (DR) including wireless sensors, cloud computing, cyber security and wide area monitoring.
2. Design of communication and control architectures for smart energy grid deployment.
3. Design of smart grids, with energy storage options, for rural loads and distributed energy.
4. Develop robust intelligent control strategies with on-line and off-line learning algorithms.

The major thrust areas include:

1. Intelligent Grid Architecture for Energy Security
2. Operational Complexities of Large Interconnected Grid- Indian perspective
3. Microgrid Conceptualization with Renewable Sources and Grid Interface
4. Redefining a Large Grid into Microgrid built with both classical and renewables along with islanding mechanism
5. Evolving Technologies in Microgrid operations and control
6. Design and Development of an Intelligent Grid Architecture for Energy Security within Microgrid framework
7. Sustainable Microgrid Conceptualization with Energy Storage-a detailed feasibility analysis
8. Advance Energy Storage options both at Microgrid and Regional Grid level- Comprehensive analysis and design issues
9. An Intelligent Coordination of Microgrid with Multi-Agent Technology- a thorough design and analysis
10. Study of an Intelligent Grid Architecture with Energy Storage- in utility framework
11. Implementation of an Intelligent Grid Architecture with Energy Storage – Pilot Project