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ROLE OF DISTRIBUTED ENERGY RESOURCES AND MICROGRIDS IN SMART GRID

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Environmental issues of central power plants, inadequacy of the aging infrastructure, and the operational strategies based on the design philosophy of 1950s, have necessitated the utility power industry to transform itself into the next generation system which is widely referred to as the "Smart Grid". The smart grid integrates

i) conventional and leading-edge power apparatus,
ii) the state-of-the-art and the next generation sensing and monitoring technologies,
iii) the state-of-the-art and the next-generation communications information and communication technologies (ICTs),

through advances control, protection and power management strategies to:

- improve grid performance,
- address environmental issues,
- respond to the rinsing electricity demand in a sustainable manner,
- enable interactions among electricity stakeholders.

The smart grid concept transforms generation, transmission, distribution and utilization aspects of the electric power delivery and in particular those of the generation and distribution sub-systems. The transformation in the generation is mainly through the introduction of distributed energy resource (DER) units and renewables. The renewables can be integrated either as distributed generation (DG) units at the distribution voltage-class distribution lines, or as balk power generation units, e.g. wind farms, at the transmission and sub-transmission voltage levels.

The smart grid encompasses a wide-area electric power network that expands over a wide geographical area, e.g., the eastern continental network of North America, and:

- includes a vast number of large and small generation units, transmission lines, distribution systems, and millions of customers,
- utilizes an overlay communication network to enable information access at various physical nodes/locations for decision making, control and command in various time frames, e.g., in respond to transients (milliseconds) to hourly, weakly, monthly and seasonal load/generation variations,
- imbeds widely distributed advanced sensing and monitoring devices to extract the required information and data,
- exploits advanced technologies and devices, e.g. power electronic based converters and fast switches and superconducting materials, to achieve functionalities beyond those of the existing systems.

The "smartness" in the smart grid is provided by processing the information/data and enabling appropriate sequence of control measure, protective countermeasures, and/or other responses, through advanced control and protection strategies and the associated algorithms. The "smartness" can achieved based on the availability of massive computational power and resources accessible at various locations in the network.
Transition from the existing grid to the future smart grid will be a gradual process at different rates for different segments of the grid. This talk provides a new vision for transformation from the conventional grid to the smart grid, and elaborates on the concepts, technologies and R&D requirements.

It is imperative that the reliability of operation and continuity of supply must not be compromised in the transition process and the degree of implementation of smart grid concepts. To ensure reliability and maximize self-healing capability, our envisioned smart grid is based on a virtual division of the power network into a large number of zones. Each zone, for example, can represent a power plant, a transmission corridor, or a microgrid. Each zone has its own internal and external communication capabilities, sensors and monitoring devices, and control/protection strategies. Thus, each zone can be operated, controlled and/or protected based on internally generated and/or externally imposed commands.

The boundaries of each zone are determined based on a confluent of factors, e.g., geographical boundaries, utility system boundaries, and/or control, protection and operational regions and constraints. Multiple of adjacent zones may be equipped with a communication/monitoring layer and form a composite-zone. Composite-zones, in turn, can be clustered to form a super-zone and so on. This implies that multi-layer communications and hierarchical aggregated zones are permitted, primarily to enhance continuity of supply and minimize the extent of affected areas subsequent to disturbances.

In our vision of smart grid, the absolute majority of zones are of microgrid type, e.g., a distribution feeder. The main component that justifies the existence of a microgrid is the distributed energy resource. The microgrids and the other zones within the smart grid can i) intelligently interact with each other, and ii) collectively respond to the operational needs of the encompassing smart grid, for example to:

- enable energy conservation and operational efficiencies,
- minimize carbon footprint,
- defer non-green capital expenditure,
- accelerate and facilitate investments in renewable,
- facilitate high-depth of penetration of DER units,
- integrate plug-in vehicles and low-carbon transportation alternatives,
- provide a medium for interactions among customers, operators, power producers, service providers and the market.

This vision of smart grid is transformational not only in the context of the electric power delivery industry, but also in R&D of the next-generation communication architectures and information technologies, sensing and monitoring technologies, cloud computing, and other advanced technologies, e.g., superconductors and high power electronics.

This talk:

- provides definition of smart grid, microgrid, intelligent (cognitive) microgrid,
- elaborates on the technologies and concepts to realize such entities,
- describes hierarchical operational philosophy, control, protection and power management strategies for their realization,
- highlights the technical and economical merits and limitations,
- identifies the incentives and barriers,
- explains the R&D and training requirements to meet the target.