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CHALLENGING ISSUES AND OPPORTUNITIES IN ELECTRICAL POWER SYSTEM AUTOMATION

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Abstract: Energy is a fundamental element of economic development. The wealth that economic development brings stimulates demand for more and higher quality energy services. Many countries have created a virtuous circle of improvements in energy infrastructure and economic growth. However, today a large percentage of the world's growing population continues to live without energy. In the the developing regions of the world, the process is just getting off the ground. Distributed power technologies have the potential to play a key role in jump-starting the virtuous cycle of energy growth and economic development. Electrical energy is universally accepted as an essential commodity for human beings. Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources.
Key Words: Energy, power sector,

I. INTRODUCTION

Growing populations and industrializing countries create huge needs for electrical energy. Unfortunately, electricity is not always used in the same place that it is produced, meaning long-distance transmission lines and distribution systems are necessary. But transmitting electricity over distance and via networks involves energy loss. So, with growing demand comes the need to minimize this loss to achieve two main goals: reduce resource consumption while delivering more power to users.

Areas of application of Energy Conservation are Power Generating Station, Transmission & Distribution system, Consumers premises. Steps are to be taken to enhance the performance efficiency of generating stations. Energy Conservation technology adopted in Transmission & Distribution system may reduce energy losses, which were in tune of 35% of total losses in Power system. Acceptance of Energy conservation technology will enhances the performance efficiency of electrical apparatus used by end users. Implementation of Energy conservation technology will lead to energy saving which means increasing generation of energy with available source.

Fossil fuels like coal, oil that has taken years to form is on the verge of depleting soon. In last 200 years we have consumed 60% of all resources. For sustainable development we need to adopt energy efficiency measures. Today 85% of primary energy sources come from non-renewable and fossil sources. These reserves increasing consumption and will exist for future generations.

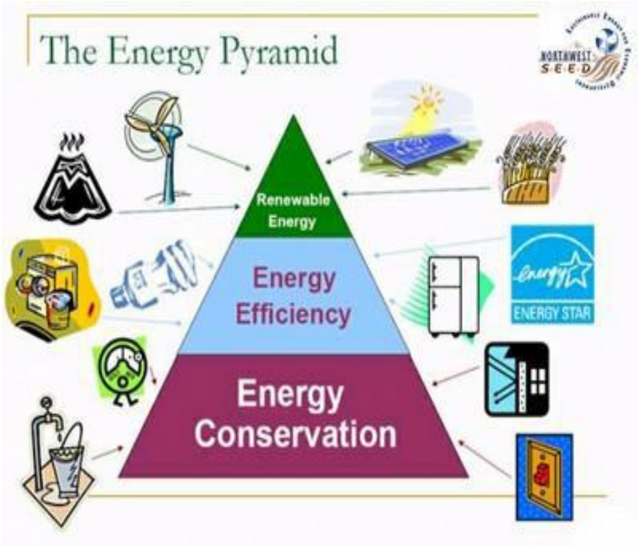


Fig 1. Energy Pyramid

Energy survey conducted reveled that there is requirement of improvement in energy generation efficiency, improvement in energy transportation (transmission & distribution systems) and enhancing the performance efficiency of use end apparatus. Fig 2 shows Grid Structure including various infrastructures.

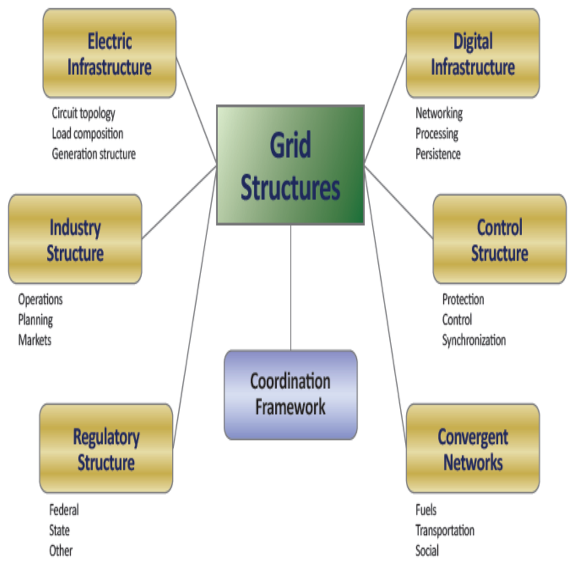


Fig 2 Grid Structure

Table- 1 Characteristics of Electrical System and R&D needs

Electric systems	Characteristics		RDD&D needs
	Traditional	Modern	
Generation	■ Centralized ■ Dispatchable ■ Large thermal plants ■ Mechanically coupled	■ Centralized and distributed ■ More stochastic ■ Efficient and flexible units ■ Electronically coupled	■ Planning tools ■ Energy storage ■ Control coordination ■ Flexible thermal generators
Transmission	■ SCADA for status visibility (sampling, not high definition) ■ Operator-based controls (primarily load following and balancing) ■ Destabilizing effects ■ Congestion, despite underutilized capacity (limited flow control) ■ Threats/vulnerabilities not well defined	■ High-fidelity, time-synchronized measurements ■ Breadth and depth in visibility ■ Automatic control ■ Switchable network relieves capacity constraints ■ Threats are considered and risks are appropriately managed	■ Multi-terminal, high-voltage direct current ■ Low-cost power flow controller technologies ■ Next-generation energy management systems (EMS) ■ Integrated planning tools ■ Security ■ Low-cost bulk storage
Distribution	■ Limited visibility ■ Limited controllability ■ Radial design (one-way flow) ■ Floating on transmission ■ Increasing fault currents and voltage issues stressing system ■ Aging assets (unknown effects)	■ Enhanced observability ■ Local, autonomous coordination ■ Network design and two-way flow ■ Backbone of delivery system ■ Self-healing ■ Active monitoring of asset conditions	■ Security ■ Microgrids ■ Advanced distribution management systems ■ Distribution and asset sensors ■ Solid-state transformer ■ Smart voltage regulation equipment ■ Community storage
Customers	■ Uniformly high reliability, but insensitive to upstream issues ■ Energy consumers (kilowatt hour) ■ Predictable behavior based on historical needs and weather ■ Interconnection without integration ■ Growing intolerance to sustained outages	■ Customer-determined reliability/power quality ■ Prosumers (integrated) ■ Variable behavior and technology adoption patterns ■ Plug/play functionality ■ Kept informed during outages (and before) ■ Hybrid alternating current/direct current distribution ■ Data access (outage/usage)	■ Single-customer microgrids ■ Building EMS ■ Distributed energy resource integration ■ Security ■ Transactive controls ■ Behind-the-meter storage ■ Low-cost sensors

II. INDIAN POWER SECTOR AT A GLANCE

The Indian power sector has made remarkable progress since Independence. The total installed capacity has gone up from 1,362 MW in 1947 to more than 2, 00,000 MW in 2012 and the transmission network has increased from the isolated system concentrated around urban and industrial areas to country wide National Grid. However, the demand of electricity has always been overstepping the supply. The importance of electricity as a prime mover of growth is very well acknowledged and in order to boost the development of power system the Indian government has participated in a big way through creation of various corporations viz State Electricity Boards (SEB), National Thermal Power Corporation (NTPC), National Hydro-Electric Power Corporation (NHPC) and Power Grid Corporation Limited (PGCL) etc. However, even after this the country is facing power shortage in terms of energy as well as peak demand to the tune of 10.9% and 13.8% respectively. Here are some facts about the scenario of power sector in India:

- 17 percent of world's population.
- Population growth rate of 1.58 percent annually.
- GDP growth rate of 6 – 9 percent.
- 6th (IEA Report) largest energy producer of the world.
- Ranks 5th in energy consumption.
- Energy consumption per capita among the lowest in the world (900 kWh/year approx.)

III. INDIAN POWER SECTOR ISSUES

According to planning commission report, in 11th Five-Year Plan (2007-2012), Indian government aims to add over 78,500 MW of new capacity to achieve the ambitious mission of Power for All by 2012‟. To meet its large and growing power needs, there are many shortcomings.

A. *Limited fuel*

In the Indian Power sector, primarily electricity production is from thermal power stations. The main fuel used is coal. Coal fuels about 55% of India's power generation and if current projections are accurate, that proportion will grow substantially in the next 20 years. Additional power generation is likely to require incremental amount of coal transportation by Indian Railways within the country and increasing unloading at ports in India for imported coal.

B. *Equipment Shortage*

Equipment shortages have been a significant reason for India missing its capacity addition targets for the 11th five year plan. While the shortage has been primarily in the core components of Boilers, Turbines and Generators, there has been lack of adequate supply of Balance of Plant (BOP) equipment as well. These include coal-handling, ash handling plants, etc. Apart from these, there is shortage of construction equipment as well.

C. *Land Acquisition and Environment Clearance*

Land Acquisition poses an increasingly significant challenge in the Indian Power sector. Power plants and utilities face major constraints and delays regarding the availability of land and obtaining the requisite environment and other clearances for the projects. The new Bill relating to land acquisition has continued to face political opposition. While it provides for acquisition by project development agencies to the extent of 70 percent of the land required for a project, with the balance to be obtained by the Government. In addition, it has been reported that in some cases, even after land owners were asked to sell and handover their land in „Public Interest‟, the project was not completed for several years due to other delays, a fact that eroded the credibility of both the industry and the government. Consequently there is a significant mismatch of expectations from the Project Affected Persons (PAP).

D. *Transmission & Distribution Losses*

High distribution-line losses are among the most vexing problems in the Indian power sector. India's aggregate technical and commercial losses average about 32% of electricity which is very high as compared to those developed countries (6-11%). This is a matter of concern as well as potential for saving, which may reduce the demand supply gap. A reduction in Transmission & Distribution losses by 1% would result in a saving in capacity by about 800 MW.

E. *Aging Power Plants and Transmission network*
Since most of the power plants and transmission lines have been installed immediately after the independence; they have become old and inefficient. This is the main reason for low growth and transmission rate in electricity generation and transmission during the recent years. Old and inefficient plants and lines need to be replaced or renovated and modernized to achieve the electricity production and demand target.

F. *Sharp increase in demand*
Although India has large installed capacity but still there is large demand and supply difference. The following table describes the forecasted demand scenario.

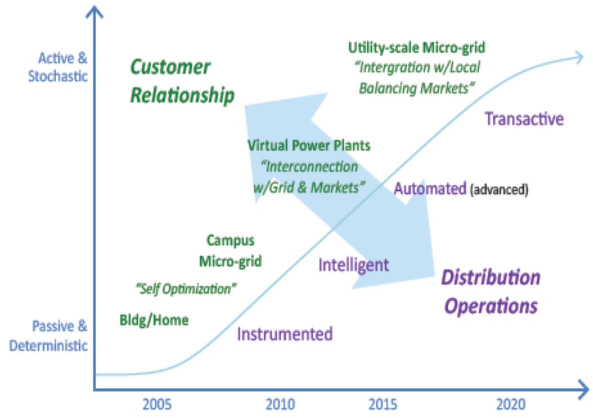
G. *Interstate Disputes*
India is a federal democracy, and because rivers cross state boundaries, constructing efficient and equitable mechanisms for allocating river flows has long been an important legal and constitutional issue. Due to this there is not availability of water all the times to operate hydro plants. Inter-state disputes also restrict the excess power exchange between the states.

H. *Delay in construction of projects*
The commissioning of new power projects have been delayed for too long. The main reason behind this is the lack of financing and long route of money flow from the departments. They left most of the utilities to rot away even as they were lacing their own pocket. Hence the recent power sector has remained without any improvement.

I. *Erratic monsoons*
India is a big country with different geographical conditions. The monsoon in India is very erratic so that the hydro plants can't be operating during whole year. Many times, the depletion of the reservoirs caused a shortage in generation from the hydro plants.

J. *Less inclination to renewable*
India is abundantly gifted with variety of renewable energy (RE) sources, not all States are endowed with same level of renewable energy sources. While some States have very high renewable energy potential, some States have very little renewable energy potential. But still the renewable resources are not explored, having only approx. 10% of total energy generation.

Transactive energy is an advanced concept that could contribute to the optimal balancing of supply and demand at all levels of the grid. Through the use of signals that include the cost of energy, operations, and customer-defined value, customer and third-party assets can compete or exchange for the provision of grid services and coordinate with grid operations. The evolution of this control concept is shown in Figure … Customers begin with self-optimization and intelligent coordination with the distribution operator. As participation becomes more numerous, active and geographically dispersed, automation and fully transactive distribution operations will be needed to maintain cost-effective grid operations. This could include advancements in distributed optimization and control. For this concept to work, the signal must be transparent and reflect the true value of the asset's contribution at all levels of the grid for all relevant value streams. Additionally, these signals must be communicated to the various distributed assets, the assets must have local intelligence and control capabilities to respond to the opportunities presented by these signals, and the assets must be capable of negotiating and transacting a range of market-driven energy services with the grid and each other. Before this concept can be realized, the theoretical foundation for combining economics with scalable system controls (while still ensuring robustness and stability) must be established.



Area	RDD&D opportunities
Grid design and interoperability	■ Development, analysis, and refinement of grid architecture, designs, and associated structures ■ Standards to ensure interoperability between various resources and with control systems
Control systems for transmission and distribution	■ Development of advanced software, models, and visualization tools using high-speed data from PMUs and other sensors to provide robust "real-time" monitoring, control, detection, and mitigation of system conditions ■ New distribution-level technologies and tools to interpret and visualize data, predict conditions, and enable faster control to ensure reliability and safety ■ Innovative control approaches to coordinate and manage distributed resources in conjunction with transmission system operations
Transmission and distribution components	■ Material innovations for high-power, high-frequency, and high-reliability grid applications, including wide bandgap semiconductors ■ Component designs, topologies, and systems based on solid-state devices that lead to higher performance, increased reliability, resilience, and lower costs
Distributed energy resources	■ Advanced "smart" technologies (e.g., loads, generators, electric vehicles) with embedded local intelligence, communication, and control capabilities ■ Controllers for integrated systems such as smart buildings and microgrids
Electrical energy storage	■ Materials research to lower costs, increase energy density; increase capacity; improve performance; and reduce lifetime impacts, including disposal ■ Full system designs that address costs (e.g., subsystem, installation, and integration) along with round-trip efficiencies, cycle life, depth of discharge, ramp rates, and safety ■ Solid-state control systems to better integrate storage in the grid
Planning tools	■ High-fidelity models, tools, and simulators that are user-friendly and accessible to decision makers ■ Common framework for modeling and co-simulation of tools from disparate technical domains (e.g., power flow, communications, and markets)
Physical- and cybersecurity	■ Tools for nontraditional contingency planning and situational awareness of the security posture, both cyber and physical ■ Resilient and adaptive control systems that can survive an incident while sustaining critical functions ■ Innovative technologies to assess system trust, identify and eradicate embedded malware, and techniques to validate security of supply chain

IV. POTENTIAL AREA OF RESEARCH IN POWER SYSTEM USING COMPUTATIONAL INTELLIGENCE

There are several problems in the power systems which cannot be solved using the conventional approaches as these methods are based on several requirements which may not be true all the time. In those situations, computational intelligence techniques are only choice however these techniques are not limited to these applications. The following areas of power system utilize the application of computational intelligence.

• Power system operation (including unit commitment, economic dispatch, hydro-thermal coordination, maintenance scheduling, congestion management, load/power flow, state estimation, etc.)

• Power system planning (including generation expansion planning, transmission expansion planning, reactive power planning, power system reliability, etc.)

• Power system control (such as voltage control, load frequency control, stability control, power flow control, dynamic security assessment, etc.)

• Power plant control (including thermal power plant control, fuel cell power plant control, etc.)

• Network control (location and sizing of facts devices, control of facts devices, etc.)

• Electricity markets (including bidding strategies, market analysis and clearing, etc.)

• Power system automation (such as restoration and management, fault diagnosis and reliability, network security, etc.)

• Distribution system application (such as operation and planning of distribution system, demand side management & demand response, network reconfiguration, operation and control of smart grid, etc.)

• Distributed generation application (such as distributed generation planning, operation with distributed generation, wind turbine plant control, solar photovoltaic power plant control, renewable energy sources, etc.)

• Forecasting application (such as short term load forecasting, electricity market forecasting, long term load forecasting, wind power forecasting, solar power forecasting, etc.)

V. THE RESEARCH ISSUES

The main research issues addressed in this area are:

A. Fundamental Transmission Engineering Challenges

These challenges and research issues include high voltage DC technologies (including voltage source converter technologies, multi-terminal HVDC, networked DC, limitations imposed by DC circuit interruption limitations and difficulties): new technologies in overhead transmission such as high temperature low sag conductors, non-circular cross-section conductors, compact phase spacing designs, new insulation concepts, ultra high voltage (e.g., > 1000 kV), high phase order (e.g., six phase and higher phase order): the role of energy storage and transmission expansion and design: underground cable technologies.

B. The Role of Energy Storage

In the integration of renewable resources into interconnected power systems, a key consideration is the role of energy storage. This is the case because of the variability of wind and solar energy resources. As convenient storage is augmented into the systems, the energy available system wide may be stored or discharged based on need (i.e., based on the price of one megawatt-hour).

The role of storage includes alleviating transmission expansion, reducing generation reserve requirements, maximizing the use of variable generation resources such as wind and solar. The negative side of this observation is that energy storage generally involves multiple energy conversions (e.g., DC/AC), consideration of losses in the energy storage and conversion processes, and the cost of energy storage devices. Concomitantly there is the issue of the inconvenience of large scale energy storage devices. The main elements of energy storage deployment, in the 2012–13, time frame are that any one specific advantage of energy storage may not have a favorable cost to benefit ratio, and the commercial unavailability of large scale storage units may not favor their use. Pumped hydro is an obvious solution, but this technology has limited applicability due to the land, topography, and water resources required. Moving to the time frame 2033, one can envision breakthroughs in energy storage and its commercial viability. The main breakthroughs needed are:

- Resolution of unfavorable cost to benefit ratios, either by advances in storage technologies, acceptance of governmental subsidies, consolidation of benefits, or otherwise realizing the benefits of storage.
- Realization of electric vehicle technologies that include distributed storage of energy in the distribution system.
- Increases in renewable penetration with the percentage of variable resources being high enough to render the cost to benefit ratio of energy storage to favorable ranges.

C. Robust and Dynamic Reserve Requirements

There are opportunities to greatly improve upon today's methods of determining reserve levels and reserve zones. There is a need for more systematic ways to determine the optimal reserve requirements. Also contemporary practices do not reflect the true flexibility that exists in the grid and they do not account for the uncertainty of future resources (wind, solar, PHEVs). Zones today are static and do not change with the operational conditions of the grid. Research objectives in this area are: the examination of contemporary practice in calculating reserve requirements: analysis of the impact on reserve requirements due to the integration of new resources and proposing of necessary changes: analysis of the impact on reserve requirements due to the development of a more flexible transmission grid and proposing of necessary changes: optimal determination of reserve zones and analysis of *dynamic* reserve zones; and the risk assessment of reserve requirements and the proposed changes.

VI. FUNDAMENTAL TRANSMISSION ENGINEERING CHALLENGES

Integration of renewable resource generation.

- Maintaining reliability at historical levels despite restrictions in transmission expansion and the variability of wind resources.
- The utilization of newly developed transmission technologies which include high temperature, low sag overhead conductors: ultra-high voltage transmission cables suitable for high population density locations and marine applications.
- Utilization of compact transmission designs, and potentially developing new standards for overhead conductor spacing to attain high power use of rights of way.
- Investigation of the relaxation or modification of design standards to obtain the best tradeoff of reliability, safety, cost, and land use. This area includes the potential loosening of the tight frequency standards in North America. Another area is the relaxation of some protection practices, e.g. protection of certain transmission system components.
- Rendering the transmission system robust to problematic conditions. This area is a wide area which exceeds the bounds of traditional transmission engineering. For example, how would the transmission system react to a large earthquake in California or the central Midwest? There are some transmission designs which are more robust than others to accommodate natural occurrences, and these need to be examined to include more extensive use of underground technologies, wider disbursal of transmission facilities, decentralization of substations.
- The full development of transmission expansion technologies, including multi-objective optimization of cost.

VII. CONCLUSION

There is an immediate need for change in planning strategies from the traditional approach of increasing generation to meet in disciplined consumption to need, resource and conservation based approach for economic and environmental benefits. Considering the scale of the target, multipronged strategies are envisaged. Some of these are partial solution for power shortages, yet these are important measures in context of resource crunch since these would enable reducing the requirement for new generating capacity. These include removing obsolescence, optimum utilization of existing assets, reducing transmission and distribution losses, demand side management through greater conservation of electrical energy, policy changes in pricing mechanism, shift and emphasis on renewable energy sources for power generation, total energy systems.

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