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Integration of Renewable Energy Sources in Smart Grid Systems, and their constraints

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Abstract: With the ever increasing growth of renewable energy sources, in the years to come it is really a challenge to integrate the same into the smart grids in a country like India. This is basically on account of unevenly distributed renewable resources. With 5 regional grids gradually getting connected, formation of national grid in totality is a reality. Smart Grid technologies provide enhanced opportunities for the utility of the future. Smart grid comprises of a number of technologies and concepts. These technologies can provide greater advantages when used co-actively with other smart grid technologies. The importance of integrating these technologies grows, as carbon control and environmental policies and standards evolve and come increasingly into action. Integration is the process of connecting a distributed generation system to the electric grid. With a growing array of diverse distributed and renewable generation, utility managers face complex technical and capital challenges in planning, designing, and maintaining transmission, distribution, and generation assets. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well. Smart grid considers enhancement of all parts of power systems (from a generation part to a consumer part). This paper presents the overall study of integrating renewable energy in smart grid and the various challenges that are faced during integration.

Keywords: Smart Grid, Distributed Generation, Renewable Energy Sources, Energy Storage System, Power Quality, Demand Side Management

I. INTRODUCTION

A smart grid is considered as a next generation power network utilizing ICT technologies. It delivers power from suppliers to consumers using two-way communications, which leads to energy efficiency and grid reliability enhancement. It basically has the capability to sense grid conditions, measure power, and control appliances with two-way communications to electricity generation, transmission, distribution and consumer parts of the power grid. Economic growth, automation, and modernization mainly depend on the security of energy supply. Global energy demand is rapidly growing, and, presently, the worldwide concern is on how to satisfy the future energy demand. To supply this energy demand, fossil fuels have been used as primary energy sources. Fossil fuels emit greenhouse gases that highly affect the environment and the future generation.

The emissions largely depend on the emission factor of primary energy sources (i.e., input fuel of the plant). Among all energy sources, the emission factor of fossil fuels (i.e., coal, natural gas, and oil) is very high. Fossil fuels are widely used as the main fuel in power generation. Renewable energy sources (solar, wind, hydro, geothermal, biomass, etc.) are emission-free energy sources in the world. Renewable energy technologies are an ideal solution because they can contribute significantly to worldwide power production with less emission of greenhouse gases. Renewable-energy resources vary widely in type and scalability. They include biomass, waste, geothermal, hydro, solar, and wind. Renewable-energy resources can be used for standalone or islanded (system isolated) power generation, but their benefits are greatly enhanced when they are integrated into broader electric power grids. With

greater use of smart grid technologies, higher degrees and rates of penetration can be accommodated. Each resource is different from the grid's perspective and some are easier to integrate than others. Variable generation, provided by many renewable-energy sources, can be a challenge to electric system operations, but when used in conjunction with smart grid approaches, responsive distributed generation also can be a benefit to system operations if coordinated to relieve stress in the system. At present, the solar power generation capacity of the country is about 3,000 MW. Small hydro power projects are plants with up to 25 MW generation capacity. At present, renewable energy contributes about 12 per cent to the electricity mix. It is proposed that this would be taken to about 12 per cent in the next three years. Smart grid also has the capability of integrating
New-renewable energy such as solar and wind power

II. NEED FOR INTEGRATING RENEWABLE RESOURCES

Salient features of Renewable Energy sources that impact their integration into power grids are their size of generation capacity as compared to other sources of power generation on a system, their geographical location with respect to network topology, and their variability of output which critically depends on time and climatic conditions. Smart grid technology can control renewable resources to effect changes in the grid's operating conditions and can provide additional benefits as distributed generation assets or when installed at the transmission level. Small, electricity-generating systems located at or near the place where the energy is used and connected at the distribution level are referred to as distributed generation.

Residential-scale wind and solar energy projects are examples of distributed generation. Distributed generation assets can support weak grids, adding grid voltage and improving power quality. Having generation close to load can reduce transmission losses and infrastructure costs and can support the operation of local islands of electricity to reduce impacts of wide scale black-outs. The integration of renewable resources is dependent on the size and diversity of the load, with an upper limit of 20% to 25% without additional spinning reserve capacity to reduce intermittency or the use of smart grid communication and control strategies. Smart grid integrates advanced sensing, communication and control functionalities in the power grid's operation, for the purpose of enhanced efficiency, reliability, security and reduced emission. Smart grid technologies and concepts can significantly reduce barriers to the integration of renewable resources and allow power grids to support a greater percentage of variable renewable resources. Enabling smart grid technology, such as distributed storage, demand response, advanced sensing, control software, information infrastructure, and market signals, increases the ability to influence and balance supply and demand. With smart grid technology, grid operators can better coordinate and control the system in response to grid conditions, thus allowing integration of increasingly greater levels of renewable resources more effectively and at lower cost. As renewable-energy integration increases, more advanced control of the power system will be required to maintain system reliability. This control is dependent on having information about the resources. A smart grid relies on information to "make" smart decisions. Intermittent renewable-energy resources, such as wind and solar, cannot be operated in a conventional manner because their "fuel" supplies are variable, but as the fuel availability can be predicted and this forecast information can be used to manage renewable-energy integration.

III. CONSTRAINTS IN INTERCONNECTION OF RENEWABLE ENERGY SOURCES

A proper coordination among the generation, transmission, distribution and utilization of the power is essential for proper and reliable functioning of the grid. For a developing nation like India, possible challenges that represent the main obstacles for development of smart grid in India are described below in detail. The several constraints taken into account are listed below and they are classified on the basis of technical, business and financial, and societal issues.

3.1 Technical: Constantly changing technologies means that a heterogeneous mix of technology must be accommodated. Existing generation and delivery infrastructure (i.e., legacy) systems must be adapted to work with new technologies. Being flexible to changing technologies requires identifying the important interfaces between technology components. Achieving alignment across service providers, end-users, and technology suppliers is difficult particularly in a growing, international marketplace. Interoperability can allow multiple parties to connect their devices and systems for proper interaction, but attaining interoperability is difficult.

3.1.1 Energy Storage System (ESS): With the incorporation of RES in forthcoming times, it is desirable to integrate energy storage devices such as batteries, flywheel, electrical vehicles etc. Being at the prolific stage of development in India we often face issues like; complexity and non-flexibility, design considerations, high capital investment, and lack of technical conscience about ESS.

3.1.2 Automation, Protection and Control: Automation facilitates high level quality and reliable power for both consumer as well as utility sectors. For consumers, automation means receiving hourly electricity price signals and for utility sector, automation means automatic islanding of distribution feeder with local distributed energy sources in an emergency. In developing nation like India, million dollar investment is required with high design skills. Automation, protection and control will benefit for proper operational utilities of smart grid. Complex distribution network, lack of satisfactory sensors and actuators, communication link delay, aging of the devices etc. are few direct challenges faced by Indian power grid.

3.1.3 Intelligent Electronic Devices (IEDs): Intelligent Electronic Devices (IEDs) are the electronic based multipurpose meters used in existing grids. IEDs receive data from sensors and power equipment, and can issue control commands, such as tripping circuit breakers if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level. Unlike other measurement devices, it issues challenges in IEDs like conversion from electromechanical to static metering, standardization in design, Fast data acquisitions and its management with advance state-of-art communication data wiring.

3.1.4 Telecommunication: The fundamental of the smart grid transformation is the use of intelligent communications networks or the implication of information and communication technology with systems as the platform that enables grid instrumentation, analysis and control of utility operations from power generation to trading, and from transmission and distribution to retail. In India such as power line carrier communication (PLCC), land line, and other wired and wireless communications are installed. The major challenges of telecommunication in smart grids are evaluation of system reliability, security and availability, collection of data, storage, design of architecture and monitoring system, physical and cyber security, threat defence and access control.

3.1.5 Power Quality: Proper knowledge of power quality issues and its low cost mitigation measures is required in India. The power quality problems are broadly classified into two categories viz. variations and events. As the advent of power electronic based circuits is essential part of smart grids, quality of power must be analyzed. The technical challenges of power quality like analysis of discharge of new devices connected in smart grid and its allocation, measurement of power quality indices, reduced voltage support and large problem of voltage sag, weak transmission system, lack of awareness in consumers, and high cost of mitigation methods are the foremost concerns.

3.1.6 Reliability: In India, due to lack of energy available, problems like blackouts and brownouts are common, which is required to reduce effectively within niche timeline. The following are possible challenges in achieving improved reliability; grid automation, grid reconfiguration, dwindling human interaction, high speed fault locators and repairing, preserving generation-demand equilibrium.

3.1.7 Demand Side Management (DSM): DSM is widely recognized as a definitive and practical source of information. DSM is the planning, implementation and monitoring of those utility activities designed to influence customer use of electricity in ways that will produced desired changes in utility's load shape. The challenges subjects are; smart metering, load research and dispatch, Load control and scheduling and development of software for DSM. As the existing power grid has professed aforementioned technical challenges and issues so to prevail such, smart grid is essential in India. While developing smart grid, various technical problems might occur as discussed above. The solution of these challenges is possible through proper research initiatives under the collaboration of government and state-of-art highly equipped skill test facility. In addition, power system engineers have to now be trained more deeply about the smart grid and its related challenges, which would able to resolve these technical challenges.

3.2 Business and Financial: For better implementation of smart grid share of renewable energy sources must be increased to 30% to 40% of total generating capacity which requires large investment with high technical knowledge. Renewable energies such as small hydro plants, solar PV, wind, biomass, and tidal based generations have many technical and commercial challenges viz., forecasting and dependency, reliability, grid connection requirements, power flow optimization and stability issues, reactive power compensation, involvement of power electronic devices etc. To eradicate such issues the government and power agencies has amended an optimized grid connection codes for the reliable and flexible operation of RES and integration in to classical grid. To accommodate changes in markets of retail power, market-based mechanisms are need. This will offer incentives to market participants in ways that benefit all stakeholders. In India, there is lack of co-ordination in suppliers and service providers. Following are the challenges of power market: Financial management, open access of data, development of data and communication standards for emerging market, development of market simulation tools.

3.2.1 Understanding and communicating the value proposition of a smart grid deployment for each stakeholder in the electricity supply chain is daunting.

3.2.2 The financial environment for risk and reward can challenge business plans for smart grid investments.

3.2.3 Regulatory understanding and sensitivity to providing an appropriate environment for smart grid investment takes time. Regulatory decisions (or lack of decision) can create new challenges.

3.2.4 Developing an appropriate incentive structure that aligns economic and regulatory policies with energy-efficiency and environmental goals needs to be tailored to each member economy.

3.3 Societal: Active participation of consumers is the foremost concern for the development of smart grid. A smart grid incorporates consumers' equipment and behaviour in grid design, operation and communication. A bi-directional data link enables consumers to better control of smart appliances and equipment in homes and business. Even though challenges in consumer's participation in smart grid implementations viz., lack of bidirectional communication data link between consumers and utilities, security of consumers, reliability of supply authority, awareness about the use of energy efficient smart appliance and energy management, complication in billing process and, high capital investment involved for designing smart building.

3.3.1 Strategies need to account for a variety of policy objectives like affordability, sustainability, growth, and cultural values.

3.3.2 Assigning value to externalities, such as environmental impacts, is difficult, but necessary, in balanced decision-making.
3.3.3 Understanding and accounting for the beneficial aspects of smart grid investments as a mechanism for job creation and advancing a technically skilled workforce needs development.

IV. BENEFITS OF SMART INTEGRATION OF RENEWABLE RESOURCES

Renewable resource facilities range in size from, smaller distributed energy resources to, larger transmission interconnected facilities. Smart grid technologies can help integrate both small and large facilities. Large facilities can help manage peak load capacity and provide grid balance. Distribution-level facilities can provide energy security to limit the extent of a system disturbance and allow for faster recovery. Distributed generation can also reduce the need for investments in grid reinforcement infrastructure, particularly if installed in conjunction with active distribution system management that provides controls and operational metrics.

Smart grid technologies, such as transmission and distribution automation and active distributed energy resources, allow a diverse and changing mix of renewable-energy resources to be accommodated on the grid. When an intermittent resource cannot produce energy for a long period of time, replacement energy is needed. Replacement energy typically comes from large-scale power plants that can ramp up or down to follow the load and provide grid balance. These "regulating" power plants can generate energy from both conventional fossil fuels, such as natural gas or coal, or renewable resources, such as biomass and hydro-electric.

If a renewable resource can provide replacement energy instead of fossil fuel power plants, the potential for carbon reduction is substantial. The potential indirect reductions are based on the assumption that the capital cost savings from avoiding new construction of fossil fuel power plants is reinvested in cost-effective energy efficiency or renewable generation facilities. In conjunction with more widespread smart grid technologies and forecasting, supply from renewable resources can be viewed more reliably and used as an integral contributor to system capacity.

V. CONCLUSION AND FUTURE WORK

Adding renewable energy resources into the existing bulk generation power system can be accomplished through a smarter power grid when the integration includes complex, end-to-end control strategies and consumer incentives to participate. Various issues and challenges needed in grid integration of renewable energy sources are discussed. The power system Engineers still face the challenge of integrating renewable energy sources into power system grids. Renewable energy system is an innovative option for electricity generation, especially the solar PV system as it is a clean energy resource. Recognizing the advantages of PV system, many such systems have been installed worldwide in recent years. To achieve the commercialization and widespread use, a number of issues need to be addressed. Integration of RES is expected to play significant influence on the operation of the power system for sustainable energy in future. Future work involves:

- Distributed renewable interconnection technologies with advanced functionality.
- Integration of renewable energy with dispatch able load and storage.
- Electric power systems technologies, controls, and operations that enable high penetration of distributed renewable energy systems.
- Models for renewable energy systems that allow them to be included in the planning and analysis tools.

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