Integration of Conventional & Renewable Energy Resources for Sustainable Growth of Indian Power Sector

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Abstract- Every nation is facing a big challenge in meeting the ever increasing demand of clean electrical energy. This problem is even more severe in the developing nations like India and China. Ever increasing demand and the environmental concerns are forcing them to make their fossil fueled energy systems more efficient, reduce emissions and conserve conventional fuels by making extensive use of renewable energy resources. All these concerns necessarily require that the existing power grid should be extensively modernized with the application of advanced technologies including information and communication technologies, modern measuring devices like phasor measurement units, fast computational techniques etc. so as to reduce energy loss, conserve resources and increase quality of power supply. The modernized grid should allow generating companies to feed clean energy from renewable sources for sustainability. The grid should also be able to accommodate distributed generation in distribution networks. This work is an attempt to investigate new developments needed for sustainable generation and utilization of electrical energy with controlled emissions in Indian scenario.

Keywords – Renewable energy sources, hybrid solar and wind power, distributed generation, energy storage systems.

1. INTRODUCTION

Since independence India has made considerable efforts in meeting the growing demand of electricity. Since 2013, a single synchronous grid operating at a single frequency of 50Hz throughout the nation has been established. The Indian power grid has been demarcated into five regions and each region has its own regional load dispatch centre apart from a national load dispatch centre for optimal scheduling and dispatch of electricity among the regions. During the last decade the previously designed vertically integrated grid was deregulated to improve performance by introducing an element of competition among different private and state owned power generating companies. These private power companies are generating electrical energy using conventional and renewable sources of energy and selling to customers through existing networks. Due to deregulation and due to greater penetration of renewable energy resources like solar and wind have made the operation of grid highly challenging. The introduction of distributed generation in distribution network has added further complications. In the following sections problems caused due to deep penetration of solar and wind systems and complications introduced due to distributed generation have been discussed and techniques to alleviate these problems have been suggested.

2. INSTALLED GENERATING CAPACITY

Today India is the world's third largest power producer and third largest consumer of electricity. The Indian grid has an installed generating capacity of 364.17 GW as of October 31, 2019. During the fiscal year 2018-19 the gross electricity generated by both utilities and non-utilities was 1547 TWh. As on October 31, 2019 coal based power plants contributed 203.95 GW (56.1 %) of power. These coal based power plants consumed about 72% of coal produced in the country. The Indian coal has low calorific value and high ash content resulting in poor thermal efficiency as compared to European power plants. Burning of coal containing high percentage of ash and salphur pollutes atmosphere and contributes in global warming and climate change. The Ministry of Environment and Forests, Government of India, therefore mandated the use of coal whose ash content has been reduced to less than 34% in power plants located in urban, ecological sensitive and other highly polluted areas.

3. RENEWABLE ENERGY TARGETS

After the Paris agreement of 2015 India is vigorously pursuing the policy of increasing the share of renewable energy mainly wind and solar to control carbon footprint and arrest climate change by curtailing the use of coal. India submitted its Intended Nationally Determined contribution

(INDc) to the UNFCCC outlining the country's post 2020 climate actions. It has set a target of increasing the share of renewable to 175 GW by 2022 which includes 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydropower. In the recent meeting held at UN on climate change India declared its revised electrical power targets to be achieved by 2022 from renewable are 225 GW out of which 113 GW from solar, 66 GW from wind, 10 GW from biomass, 5 GW from small hydro and 31 GW from floating solar and off shore wind power. It also intends to increase its share of non-fossil based installed electric capacity to 40% by 2030.The INDC has also committed to reduce India's GHG emissions intensity per unit GDP by 33% to 35% below 2005 levels by 2030 and to create an additional carbon sink of 2.5 to 3.0 billion tonnes of carbon dioxide through tree plantations.

It is possible for India to achieve wind power target as it has a strong manufacturing base in wind power with 20 manufacturers of 53 different wind turbine models of international quality up to 3 MW in size with exports to the U.S., European and other nations. To achieve solar power target India has already set up 42 solar parks apart from roof top and other measures throughout the country. The largest among all the solar parks is located at Bhadla in Phalodi Tehsil (Jodhpur District). It is spread over 40 square kilometers with a total installed generating capacity of 2255 MW, out of which 1515 MW has already been commissioned and the remaining 740 MW will be completed by the end of 2019.

4. CHALLENGES DUE TO GREATER PENETRATION OF WIND AND SOLAR POWER

India is characterized as a developing economy. Access to electricity plays a vital role in improving standards of living, education and health. As India marches forward, use of electricity tends to rise. According to current forecasts electricity consumption is expected to grow 60% by 2040. Expanding access to electricity while at the same time drastically reducing the emissions of GH gases is the main challenge confronting India in the 21st century. To meet huge future demand with limited hydropower, nuclear and biomass resources the only options available are wind power and solar power which do not contribute carbon emissions. This large scale penetration of wind and solar power in to the power grid creates several difficulties.

The variable nature of wind and solar power results in lower output per installed kW over the year. The solar power is available only when the sun shines. It is not available during night and also when clouds pass over solar panels or during solar eclipse. Although variation in solar energy output during the course of the day and the year is predictable but movement of clouds cannot be predicted precisely. Sudden fluctuation in the output of solar panels makes it impossible for the grid operator to predict precisely the additional electric power generation required during the next hour of the day. The impact of cloud cover can be reduced to some extent if solar power projects are spread over a large area as it is done in case of solar parks. Wind energy as compared to solar energy is less predictable. Significant up or down ramps in solar power generation at the time of sun rise, sunset and rapid movement of clouds and in case of wind generation during wind storm particularly during very low or very high load conditions can create consideration problems in maintaining system balance between generation and demand.

In conventional power plants synchronous generators are employed which produce electricity at a specified frequency. The rotating components of machines exhibit mechanical incrtia and as such they are capable of storing kinetic energy in the rotating mass. This kinetic energy can be extracted from or absorbed into the rotating masses during system disturbances and with the help of automatic controllers system stability can be maintained. In contrast, variable renewable energy technologies make use of different set of technologies for energy conversion and interfacing to the grid. These sources are connected with the grid through inverters which do not have rotating masses and hence mechanical inertia and as such they are capable of storing kinetic energy in the rotating mass. This kinetic energy can be extracted from on absorbed in to the rotating masses during system disturbances and with the help of automatic controllers system stability can be maintained. In contrast, variable renewable energy technologies make use of different set of technologies for energy conversion and interfacing to the grid. These sources are connected with the grid through inverters which do not have rotating masses and hence mechanical inertia. Thus with deeper penetration of these renewable energy sources, the grid will lack the inertia it has today to maintain stable voltage and frequency in the event of large disturbance. Wind turbines utilize induction generators and are connected to the grid through inverters. Induction generators are loosely coupled to the grid and do not produce synchronizing torque as in case of synchronous generators. Synchronizing torque along with damping torque and automatic controllers play an important role in the mitigation of large active and reactive power

imbalances in the conventional grid receiving power from synchronous generators.

5. IS HUNDRED PER CENT RENEWABLE ENERGY GRID POSSIBLE?

The focus on the use of renewable energy sources mainly solar and wind for power generation during the last five years have led to their greater penetration in the Indian power grid. Is it possible to achieve a 100 % renewable power grid as done in some countries? Iceland, for example, supplies 100% of electricity needs with hydropower and geothermal. Other countries that utilize renewable energy sources to a very large extent are Norway (97%), Costa Rica (93%), Brazil (76%) and Canada (62%). All these countries utilize hydropower. Harnesing hydropower depends upon natural rainfall and geographic topology. India is fairly rich in hydropower potential and is ranked fourth globally. Its hydropower potential has been assessed to be about 125.57 GW at 60% load factor. In addition there is an estimated 6.74 GW of potential for mini, micro and small hydropower plants. But due to huge capital investment, long gestation period, social and political problems, submersion of large chunk of land, displacement of population and their rehabilitation etc. hydropower potential has been underexploited. The current contribution of hydropower in the Indian power grid as on October 31, 2019 is 45.4 GW that is 12.5 per cent of total installed capacity. Mini, Micro and small hydropower plants contribute another 4.61 GW, which amounts to 1.3 per cent share only. Apart from hydropower the other renewable source excluding solar and wind is biomass. It contributes 9.27 GW, about 2.6 per cent of total installed capacity. Looking to the limited availability of hydropower and biomass power it will not be possible for India to meet its electricity demand 100% from these sources as has been done in some countries. Other available renewable energy resources such as wind and solar although available in plenty are variable in nature and introduces several technical problems as discussed in the last section, India will have to generate electricity using a combination of conventional and renewable energy sources for years to come till technical problems associated with variable nature of wind and solar power are solved satisfactorily.

6. HYBRID WIND AND SOLAR PLANTS

An integrated or hybrid wind and solar plant has a much better generation profile as compared to standalone wind or solar plants. Integration of wind and solar can be done either at the wind turbine level or PV array level or the farm level using appropriate controllers. In turbine or PV array level integration each convertor may be shared by wind turbine and solar array whereas in farm level integration electrical equipment such as transformers, switchgears, transmission system may be shared between the two. The advantages of hybrid plants are

- Saving in project development and installation cost
- Optimal use of available land
- Improved generation profile
- Saving in energy evacuation and transmission upgradation cost
- Saving in operation and maintenance cost

7. DISTRIBUTED ENERGY RESOURCES

Due to the policy of the Government of India and the falling prices of solar PV panels a large number of customers particularly small and medium scale industries, universities, institutes, hospitals, hotels, large government and private buildings are installing roof top solar PV systems and connecting them to grid in the distribution system. A target of 40 GW of roof top solar PV system has been set by the GOI to be achieved by 2022. This target may even be achieved earlier than 2022 due to massive cost reduction of solar PV installations and also due to ever rising electricity tariffs. It is predicated that generation cost by solar PV systems may fall further. International Energy Agency (IEA) has predicted that world over solar PV systems will grow by 600 GW by 2023, half of which will be in distributed applications. This large scale penetration of solar PVs at distribution level has given birth to a new debate. Will the future energy supply dominated by large-scale centralized power plants or by distributed energy systems (DER)? Both the systems have certain advantages and limitations. DERs have the ability to deliver the same electricity services as provided by centralized resources. However because of their distributed and modular nature, DERs are capable of providing services at locations in power grids where they are most valuable and needed. The advantages of DERs over large centralized systems are

- Increased system reliability
- Reduced distribution losses
- Capability to deliver energy in areas that experience high marginal losses
- Deferment of upgradation of transmission and distribution network
- Suitability in eliminating congestion in lines
- Reduction in effect of variable nature of solar and wind power generation due to their distribution over large area

To make advantages of DERs it is necessary to modernize the existing power grid as it was developed under the assumption that all electricity requirement would be generated by large centralized dispatchable power plants and connected to distribution systems via transmission lines and are provided with fault ride through devices which allows renewable energy sources to remain connected to the grid during the faults of small durations. But most inverters installed on small renewable energy systems connected in distribution network are dumb inverters. Although they supply a.c. at required voltage and frequency to stay synchronized with the distribution grid, they are otherwise passive. They cannot sense what is happening on the grid and adjust accordingly. By the use of smart inverters it is possible for DERs to remain connected to network during voltage sag and make the grid more stable by feeding energy into the grid when it is most needed. A smart inverter can not only ride through voltage of frequency dips but can also communicate with grid operators in response to changing conditions.

8. NUCLEAR POWER

To meet massive requirement of energy with constrained emissions of greenhouse gases it will be necessary for India to considerably increase the share of nuclear power. As of October 31, 2019 India has 6.78 GW of installed power generation, capacity which is just 2.0% of total installed generation capacity. Currently 18 pressurized heavy water reactors are in operation and another four will be commissioned soon. India is in the process of launching its first prototype fast breeder reactor using plutonium obtained by reprocessing of the spent fuel of pressurized heavy water reactors. It has a capacity of 500 MW and is located in Tamil Nadu near Chennai. All the current reactors including fast breeder reactor utilize natural uranium as fuel. Unfortunately India has very little reserve of uranium inspite of the discovery of a new uranium mine in 2011 at Tummalapalle which is claimed to be the country's largest uranium mine with an estimated reserve of about 64000 tonnes. India aims to generate 9% of its energy needs using nuclear power by 2032 and 25% by 2050.

Looking to the massive future demand of electricity, many experts feel that India cannot win the battle against climate change without a great expansion in the use of fission nuclear energy. India has a huge reserve of thorium. Reactors based on thorium fuel cycle could satisfy all of India's energy needs for 400 years. Since this technology is not presently available. India plans to create a fleet of fast reactors using fast fission neutrons that would create large amount of plutonium from natural uranium which can be used in reactors working on thorium fuel cycle. This process will take considerable time and therefore some experts suggest that India should bypass the intermediate or second stage of building fast reactors and go directly to third stage using molten salt breeder reactors (MSBRs) which will require less plutonium to convert the fleet to a thorium fuel cycle. MSBRs use epithermal neutrons rather than fast neutrons to make enough fissionable fuel to sustain the host reactor as well as extra fuel to expand the existing fleet. The biggest hurdle in the expansion of nuclear power after Fukushima Daiichi nuclear disaster is to convince public and social activists about the safety of nuclear power and the disposal of radioactive waste generated from the reactors. In fact the small mass and compact form of the spent fuel in reactors along with zero emissions of greenhouse gases are the most positive attributes of nuclear power compared to massive volumes of waste generated and discharged when fossil fuels are burned. Due to improved new technologies the cost of nuclear power generation and the cost of interim storage and for ultimate disposal of nuclear waste have come down considerably and therefore India should go ahead in increasing the share of nuclear power generation.

9. ENERGY STORAGE SYSTEMS

Provision for energy storage is one of the most effective methods to provide flexibility in balancing requirement to overcome the stability problem to certain extent and to enhance the reliability of power grid particularly when the share of renewable energy feeding into the grid is high. It is an efficient mechanism to convert infirm power of renewable energy sources to firm power within a short period. It is capable of absorbing excess energy generated from RE sources during low demand and supply energy during peak load or reduced generation period. Energy storing devices also help in mitigating the ill effects of high ramp up or ramp down situations.

No single energy storage system is adequate to satisfy the power grid requirements. It is thus desirable to develop hybrid storage system. India recently amended its, 'hybrid wind- solar with storage' policy to clarify that any form of storage system could be used in hybrid projects including pumped hydro system, batteries, compressed air, fuel cells, fly wheel etc. Hybrid storage system should employ devices having complementary characteristics so that both low and high frequency fluctuations can be mitigated. In India pumped hydropower system is currently used as grid level energy storage system. Its installed capacity is 2.6 GW and another 3.1 GW capacity is under

construction. The central Electricity Authority (CEA) has identified 63 sites across India for location of pumped hydropower systems with a capacity of 96 GW. One of the most significant pumped hydropower systems currently under construction is Sillahalla Plant in Nilgiris district of Tamil Nadu having a capacity of 2 GW. Although pumped hydropower system has several advantages but unfortunately it is location dependent and cannot be easily expanded. Also these projects require high initial cost and long gestation period.

Due to recent technological development and cost reduction the application of battery energy storage system (BESS) is now picking up world over. Over the last one decade U.S. energy sector has demonstrated substantial progress in developing BESS technologies. In the year 2015 energy storage market in U.S. grew 243% and is projected to reach 1.5 GW by 2020. Up to mid-2015 there were about 21 GW of energy storage devices in the U.S., mainly in the form of pumped hydropower storage system. But currently a number of new storage installations have been developed which deploy lithium- Ion batteries. The major advantages of integrating BESS with electric grid as compared to other forms of energy storage systems are location independent, low initial cost and requires less time to install. However batteries have relatively low specific energy, the storage of electricity in them is not cheap. The components often contain toxic or corrosive compounds.

To overcome the ill effect of deeper penetration of renewable energy resources, another good option for India is to install gas based power plants. These plants can be kept standby to mitigate the intermittent nature of RE resources. The installed capacity of natural gas based power plants as on March 2015 is nearly 26.765 GW only which needs to be enhanced. According to the U.S. EIA report of 2015 India has got technically recoverable shale gas of 96 Trillion cubic feet which is sufficient to meet the demand of clean energy for many years to come. The shale gas reserves are found in Cambay, Krishna-Godavari, Cavery, Damodar Valley, Upper Assam and Rajasthan. In addition India has got reserves of other natural gases like coal bed methane, coal mine methane and tight gas. These resources must also be exploited in order to provide clean and reliable energy to the citizens of India.

10. CONCLUSIONS

India is determined to provide access of uninterrupted quality power supply to all its citizens by 2020 and also wish to become manufacturing hub. After Paris agreement on climate change to which India is a signatory there is no option but to increase the share of RE resources considerably. It has been forecasted that India will have to increase production of electrical energy by 60% up to 2040. In order to meet this challenge with constrained emission of greenhouse gases India will have to adopt a policy to generate electricity using a combination of dispatchable and variable generation, centralized and distributed for several decades. In order to off-set the effect of variable nature of energy output from wind and solar energy it is necessary to develop emission free nuclear power technology based on thorium cycle, expand nuclear power generation using thermal and fast breeder reactors and develop effective energy storage devices such as pumped hydropower storage system and battery storage systems. Smart inverters suitable for roof top solar PV systems with fault ride through capability and virtual oscillator control invertors need to be developed and installed with solar systems to improve the reliability of power supply and to reduce cascade tripping of solar and wind generating systems of future. The effective integration of renewable energy resources with the conventional thermal, hydro and nuclear power resources and natural gas based power plants can only fulfill the energy needs of the citizens of India and at the same time limit the emissions of greenhouse gases.

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