ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 8, August 2014

Study on Challenges in Integrating Renewable Technologies

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ABSTRACT: The process of Evolving the renewable generation technologies has many challenges, such as realize reduction in the capital costs and improving energy efficiencies of the different types of renewable energy systems, such as wind, solar PV, solar thermal, and tidal. Significant evolution is desirable in large-scale energy storage technologies. For consistent integration of renewable resources in a grid, the challenges of high penetration levels will have to be addressed in power system planning and operation, and in grid connection. The aspirants of power and energy engineering careers need to be educated so that they can foresee and evolve new approaches and technologies to maintain reliability and economy of grids intact. The challenges of integrating high penetrations of renewable energy technologies into the grid are seldom taken up as they need interdisciplinary innovations in areas as power systems analysis, communications, power electronics, economics, operations research, and industrial organization. In this paper some of the challenges in Integrating Renewable Technologies are discussed.

KEY WORDS: Renewable Technologies, challenges, grid operators, unpredictability, uncertainty.

I. INTRODUCTION

In 1973 OPEC(Organization of Petrol Exporting Countries, founded in 1960) imposed an restriction on oil production and started an oil pricing control strategy. Oil prices shot up sharply causing severe global energy crisis. This resulted in escalation of price rise of various commercial energy sources leading to worldwide inflation. Acknowledging this crisis very seriously, the idea of developing alternative sources of energy was felt essential. Alternate energy sources were given alarming consideration and huge funds were allocated for utility alternate energy resources. Following the oil crisis in 1973 two more oil shocks jolted the world in 1979 and 1990, which attracted further the global attention on alternate energy resources in the form of non-conventional energy resources[9].

The ever increasing use of fossil fuels and rapid depletion of these resources put the global ecology at stake and compelled for the development of alternative sources of energy, which are renewable and environment friendly. Hence it has become essential to explore and develop non-conventional energy resources to reduce unique dependence on conventional resources due to the following reasons [1],

1. The demand of energy is increasing in multi-fold due to rapid industrialization and population growth where the conventional energy resources will not be sufficient to meet the increasing demand.
2. Conventional sources (except hydro) are non-renewable and bound to get exhausted in the near future
3. Conventional sources (fossil fuels, nuclear) cause pollution, thereby adversely affecting the environment and global ecosystem.
4. Large hydro-resource based projects cause deforestation and pose significant eco-social problems, due to construction of big dams.

However, the present trend of development of non-conventional sources indicates that the renewable energy resources will serve as supplements rather than substitute for conventional sources. But if non-conventional resources are integrated successfully then it may be a substitute for conventional energy. This report discusses the challenges of

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ISSN (Online): 2278 – 8875

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synthesizing the renewable resources with rest of the power grid, including existing generation resources, customer requirements and the transmission system. The generation of electricity from Renewable sources includes wind power, solar power, tidal and wave power, geothermal power, and power from renewable biomass [9]. Wind and solar power are prominently discussed in this paper, for two reasons. First, they have promising energy potential which is subjected to natural variability and unpredictability in energy generation [1]. This fact poses a distinct challenge for integration of renewable energy into the larger power systems, called non dispatch ability. Secondly, wind and solar are relatively more potentially matured for utility in large capacities and in wide areas. Hence the proposed integration has a significant impact on the conventional power grid that is likely to increase over the time. Integration of Renewable energy is a poly-nodal problem involving multiple decision-makers at a variety of spatial and temporal scales and widely varying degrees of coordination with associated with uneven predictability. The decision-makers include operators of Renewable energy sources, energy storage resources, grid operators, energy market operators and transmission planning and management authorities [3]. The integration of the energy systems is not performed by any one entity in the power system, but instead involves the actions of many of entities, where some are adequately coordinated and others in discrete status. The rapidly growing development of smart grids adds many more tools and protocols, options and operators to the hybrid system governed by various technology standards, practices, procedures and policies for the operation of individual conventional generators, Renewable energy clusters, substations, and the broader electrical energy system as a whole[6].

II. RE(RENEWABLE ENERGY) GRID INTEGRATION CHALLENGES

Wind and solar generation both experience a) intermittency, b) a combination of uncontrolled variability and partial unpredictability, and c) dependency on resources that are location dependent [8]. These vital aspects along with some other aspects posing challenges for generation authorities and grid operators during the course of integrating wind and solar generation with the conventional grid.

A. Non-controllable variability**:**

Wind and solar outputs vary with uncertainty making the generation uncontrollable as wind speeds and available sunlight may vary unpatriotically, affecting real time power output[8]. This fluctuation in power output results in the need for additional energy to balance supply and demand on the grid on a real time basis, as well as auxiliary services such as frequency regulation and voltage management. Variability in the context of wind and solar resources refers to the fact that their output is not constant. It is distinct from unpredictability, which we discuss in the following section. Even if operators could predict the output of wind and solar plants perfectly, that output would still be variable, and pose specific challenges to the grid operator. On the seconds to minutes time scale, grid operators must deal with fluctuations in frequency and voltage on the transmission system that, if left unchecked, would damage the operating system associated. To do so, operators may require to inject power (active or reactive) into the grid not for sale to consumers, but in order to balance the actual and forecasted generation of power, which is necessary to maintain frequency and voltage profile in the grid. These auxiliary services go by a plethora of names and specific descriptions. Typical services for an generalised overview include**:**

- Frequency regulation: It is performed on a seconds-to-minutes basis, and is done through automatic generation control (AGC) signals to generators.
- Spinning reserves: These generators meant to provide power typically within 10 minutes. These reserves are used when another generator on the system goes down or deactivates unexpectedly.
- Non-spinning reserves: These generators serve the same function as spinning reserves, but have a slower response time.
- Voltage support: These generators are used for reactive power management to adjust the voltage when necessary.
- Black-start capacity: These generators are available to re-start the power system in case of a cascading black-out.
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Additionally, grid operators must track loads – demand for electricity on the consumption side of the grid – and ensure that generation matches load at all times. This load tracking function becomes vitally important when the

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ISSN (Online): 2278 – 8875

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demand for electricity increases substantially during typical time periods in a day such as morning, a hot afternoon, or evening. Load tracking may be arranged through a class of ancillary service or through a "fast energy market", depending on the system operator. Grid operators have been regulating frequency and voltage, maintaining reserves and following shifts in load since the development of the electricity grid. This is because loads themselves are variable, and even conventional, controllable generation experiences problems and cannot perform as per the prescribed scheduled consistently.

Thus wind and solar generation does not introduce entirely novel problems with which operators have never struggled. Indeed, at low energy penetrations, the integration challenges are primarily device and local-grid specific, such as sub synchronous resonance and harmonics, which may be due to the turbine itself . However, high penetrations of wind and solar generation do add *more* variability to the energy system than that the grid operators have managed conventionally. Hence the integration of RE results in increased demand for ancillary services and overall balancing energy . It is more difficult, and sometimes impossible, to manage such challenges at the device level, and hence actions at grid-level , technologies and strategies are essential. Wind and solar resources in abundant amounts may also disturb load tracking process when large demand shifts occurs due to drastic weathervariations that alter power output from wind or solar resources. Grid operators located in more remote regions and serving for smaller loads may have less flexibility to provide ancillary services than that of their larger counterparts. Compounding matters, plentiful RE resources are often located in these remote locations. The IEA and other bodies have recommended consolidation of grid operators, in order to integrate RE sources over larger areas and so reduce the variance of the power produced, as well as easing of market restrictions on sales of ancillary services as a solution to this problem.

B. Partial unpredictability:

The availability of wind and sunlight is partially unpredictable. A wind turbine may only produce electricity when the wind is blowing.Solar PV systems require the availability of sunlight for a good yield. Unpredictability can be managed through improved weather and generation forecasting technologies, the maintenance of reserves that stand ready to provide additional power when RE generation produces less energy than predicted and ensuring the availability of dispatchable load to "soak up" excess power when RE generation produces more energy than the predicted energy. Partial unpredictability, also called uncertainty is distinct from variability. The variability of wind and solar generation is ever-present and as a result of dependence on the ever-changing wind and sun, and affects the grid system in real time at the moment-to-moment time scale. Whereas Partial unpredictability, refers to the inability for accurate prediction even though the wind and sunlight are generally available for energy production . This hour-to-day uncertainty is significant because grid operators manage the great majority of energy on the grid through "unit commitment". Unit commitment is the process of scheduling generation in advance, generally hours to a full day ahead of time, in order to meet the expected load. When actual production does not match the forecast, the grid operator must balance the difference. RE generation increases the cost of this function by increasing the spread between predicted and supplied energy, a cost that is ultimately borne by consumers. Unit commitment at present is largely deterministic, meaning that once a conventional generator is scheduled to run at its full capacity is expected to be available for use. This practice reflects the relative predictability and controllability of traditional coal, gas and hydropower generation resources. Operators ensure the availability of reserves – generators that withhold the supply of energy and available in ready status to balance the system in an emergency – so as to protect against a loaded transmission line outage or generator outage. But the process of unit commitment and the calculation of reserves needed to ensure reliability becomes more complex when dealing with uncertain generation through RE. Forecasting technologies aim to predict weather and thus generation output from wind and solar resources at various timescales more accurately, and communicates those predictions to the grid operators in integrated system so as to allow the operator to schedule the energy generation more effectively and dispatch energy from resources. Properly anticipating wind and solar output levels allows the operator to modify the scheduling of other generators so as to more optimally utilize all generating resources under the grid operator's purview. The operator must ensure that reserves are available not only to cover transmission line or generator outages, but also to respond to still unanticipated changes in wind and solar output. Advanced unit commitment methods enable the operator in this process of integrated grid operation , with an objective to prepare the system for multiple potential and uncertain outcomes that cannot be predicted by the forecasting technologies. Unlike deterministic unit commitment processes, advanced unit commitment methods must take into account the stochastic nature of wind and solar generation and their relative concentration on the system in

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Vol. 3, Issue 8, August 2014

recommending the scheduling of other resources. Ultimately, the objective of advanced unit commitment is to maintain sufficient flexibility in the system with cost effectiveness, such that the integration of RE resources neither exposes the system to unacceptable reliability risks nor over schedule the reserve generation.

C. Location dependence:

The amount of wind and solar resources are based in specific locations and, unlike coal, gas, oil or uranium, cannot be transported to a generation site that is grid-optimal. Generation must be collocated with the resource itself, and often these locations are far from the load centres where the power is ultimately be used. New transmission capacity is often required to connect wind and solar resources to the rest of the grid. Transmission costs are especially important for offshore wind resources, and such lines often necessitate the use of special technologies not found in land-based transmission lines. Because the availability of wind and sunlight are both temporally and spatially beyond human control, integrating wind and solar generation resources into the conventional electricity grid involves managing other controllable operations that may affect many other parts of the grid, including conventional generation. These operations and activities occur along a multitude of time scales, from seconds to years, and include a) new dispatch strategies for rampable generation resources, b)load management,c) provision of auxiliary services for frequency and voltage control,d) expansion of transmission capacity, e)utilization of higher capacity energy storage technologies, and e) linking of grid operator dispatch planning with weather and resource forecasting[8]. The essential insight to integration of variable RE is that its variability imposes the need for greater flexibility on the rest of the grid. Discussion of variable generation operation alone is insufficient to describe the full impact of high penetrations of RE on power system operation. Thus this paper explores RE integration from both a generation plant operator and a grid system operators perspective, so as to identify the full range of operations involved. Far removed from the day-to-day management of the grid is its long-term planning – specifically the siting and utilization of new transmission lines. Here RE generation plays a significant role and introduces new challenges. Because wind and solar resources are often located in remote locations, far from load centres, developing sufficient transmission facility to move RE to markets is vital in the process of integrated grid operation. Transmission planning processes are subjected to high variations, and tend to be influenced by regional politics. For example, a transmission line may provide capacity for energy produced in one country or state, passed through another territory, and consumed in yet another. These disparities in generation capacity, transmission location and load size between locations can make the development of transmission for RE contentious and complex, particularly with respect to cost allocation. Because new transmission lines built for RE generation resources will carry primarily renewably generated, variable and partially unpredictable electricity where technical needs arise regarding the transmission technology to be used. On the other hand, distributed energy resources provide for an alternative vision of the future grid, where energy is generated and used locally on a micro-grid, avoiding the cost of line losses and the high capital cost of transmission lines. In such a scheme, the electricity grid could be conceptualized as a collection of independent micro-grids with significantly reduced long-distance energy transmission needs.

D. Power System Planning and Risk Management:

Maintaining the balance between generation supply and real-time customer demand becomes more difficult with variable generation resources without large-scale, economical energy storage capacity and demand-responsive loads. Existing conventional planning methods, tools, metrics and standards for resource adequacy need to be developed for an operating environment with variable generation, energy storage, demand- responsive loads, renewable energy standards, and GHG emission policies. Research is needed to understand and respond to the implications of emerging smart grid and customer owned technologies on grid reliability. New planning and risk management tools must be developed to support decision-making in an electric system with much more uncertainty than that experienced here before.

E. Distribution and Transmission Planning:

The electric power grid is becoming an increasingly automated network and is expected to have evolved functionality, higher efficiency, better programmability, and more flexibility. Specifications are needed for the communication networks that are interconnected to the electric grid for sensing, monitoring, and control. Increased

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penetration of renewables could result in low use of transmission lines unless large scale storage is available[1]. Distributed energy resources, storage, and demand-responsive load at the distribution level make line loading much more uncertain. Planners have to be able to determine the network topology best suited for this new integrated operating environment, and the effects on system performance and reliability of having a large number of spatially distributed generation sources. New network topologies need to be designed to outperform traditional networks with lower transmission losses, and lower susceptibility to performance and reliability problems under contingencies. The new topologies must enable vastly increased levels of renewable generation while considering legacy systems and incorporating emerging technologies in HVDC, FACTS, distributed electronic power-flow controllers, and power conversion devices for interfacing renewable resources. Protection systems must be designed to accommodate the new operating conditions. Advances in computational methods will allow network topologies to be co-optimized as a part of resource dispatch hence and network designs must not be designed as static assets and allow for dynamic reconfiguration driven by technical and economic objectives. Finally, new customer use and storage technologies pose distribution planning challenges due to increased uncertainties about line and transformer loading.

F. Operations:

Operations (day-ahead) planning have to account for variability of renewable resources and demand-responsive loads[1]. Market designs must assure adequate business incentives for new generation while providing sufficient opportunities for compensation of embedded generation owners. Increased market price variability could become an important added risk for market participants, particularly under new environmental policies. Maintaining reliability and meeting NERC standards (e.g., for balancing and ancillary services) become difficult at high penetration levels. The standards themselves may need to be reviewed in focus of new technologies and customer choices. Dynamic load control for balancing generation with load demand will require much higher levels of demand-responsive loads. Wide-scale use of PHEV's and EV's calls for even greater management on the load side. Applications are needed for using data from phasor measurement units (PMU's) in(WAM) wide area monitoring systems. PMU's effectively monitor the dynamic state of the grid, including voltage and angular stability and thermal limits, and can provide early warnings to network operators of probablet failures, stress, or potential instability, thus enabling the operators to take preventive action. Operators of the future control system will have to have a new set of decision-making tools to assure power system reliability and stability under uncertainty.

G. Interface between the Grid and RE resources:

Basic power quality requirements must be met as regards harmonics, voltage, frequency, etc. for interconnecting any equipment to the grid[1]. Renewable energy generators with their associated power electronics generate harmonics and have electrical characteristics under voltage and frequency deviationss that may make it difficult to meet power quality requirements. Large-scale wind farms and large-scale PV systems present a series of technical challenges arising mostly from the expanding application of power electronic devices at high power ratings. The connection of renewables at the distribution levels also requires significant modification of the distribution system design to accommodate bidirectional power flow. Facilitating the integration of distributed energy resources requires innovations in microgrid and energy management systems that transparently provide control and regulation.

New tools for operations and planning are needed to efficiently and effectively allow analysis under the greater uncertainty and the diverse technology options resulting from the new generation and smart grid technologies. New operation tools are needed to incorporate renewable resources with their particular characteristics. These tools include:

- optimal power flow studies with low to high penetration of renewable resources
- power market analysis under environmental policy constraints including low to high penetration of renewable resources
- Contingency analysis, stochastic power flow studies, dynamic security assessment and security analysis with stochastic models that capture the uncertainty of renewable resources.
- Resource scheduling algorithms that co-optimize the network topology along with resource commitment.

New tools for planning are also needed for:

- long-term infrastructure assessment including generation planning under uncertainty, again including short term uncertainty of renewable resources

- distribution and transmission planning that includes locations of likely renewable resource development
- system resource planning to accommodate all resources including generation and demand resources while considering the structure and flexibility of the transmission topology and higher levels of resource uncertainty.

Finally, the changes in electric energy system technologies, operation and planning methods, and Analytical tools require an empowered education system. New students need to be ready to make contributions when they enter jobs and existing engineers must have their skills upgraded. It is the workforce not just the technologies that will make high penetrations of renewable technologies possible.

III.CONCLUSION

Achieving high penetration of renewable technologies with their variable generation characteristics will require many fundamental changes in the ways that electric power systems are planned and operated to ensure reliable service and to do so economically. By implementing better grid technologies these challenges can be overcome. A systematic study of electric power system operations and planning with high penetrations of renewable generation technologies should be done to meet these challenges. Industry should be calling for and supporting more research and education on grid integration challenges.

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