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Bulk System Reliability Assessment Needs under Evolving Smart Grid Implementations: EPRI Workshop Highlights

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SUMMARY

The increasing proliferation of Smart Grid technologies is raising questions about the need for tools and metrics capable of fully assessing the influence of these emerging technologies. However, the relationship between Smart Grid technologies and bulk system reliability assessment is a complex issue which does not necessarily fit directly within traditional assessment tools and approaches. For example, advanced information and communication technologies can improve system visibility and controllability, but they also further intensify dependency upon cyber assets as well as increase overall system complexity. Additionally, increasing levels of dispatched and uncontrolled distributed energy resources will significantly alter distribution characteristics seen by the bulk electric system. Achieving a future transmission grid which is both reliable and "Smarter" requires the creation of models, metrics, and analysis methods needed by system planners to evaluate the potential benefits and system impacts associated with an evolving portfolio of Smart Grid technologies.

Recognizing the benefits collaborative research can have in this area, EPRI hosted exploratory workshops bringing together a diverse group of utility, vendor, and academic experts across the industry. Workshops were held in both Europe and in North America to encompass the broad spectrum of industry activities and experiences in the Smart Grid arena. The goal of these workshops was to identify current and future assessment issues, gaps, and needs which would formulate the basis for directing future R&D efforts towards advancing reliability assessment tools. Highlights of some of discussion from these workshops are presented here and further details on the issues and future research efforts from these workshops is provided the associated workshop white paper [1].

KEYWORDS

Smart Grid, Reliability Assessment, Distributed Energy Resources, Active Distribution Networks

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INTRODUCTION

The relationship between Smart Grid technologies and bulk system reliability assessment is complex and involves numerous physical and cyber interactions across multiple physical and operational domains. Here the term "Smart Grid" refers to the integration of widespread distributed resources and controls as well as new sensors and monitoring technologies which improve visibility and awareness of system conditions. While these technologies can provide many benefits to the electric power system and end-user, they will also intrinsically change the nature of system reliability and subsequently its assessment. Seeing this need, EPRI hosted a set of workshops with the goal to identify current and future assessment issues, gaps, and needs directing future R&D efforts towards advancing reliability assessment tools. This paper highlights a number of the reliability issues and assessment gaps that were identified during the workshops and includes a brief description of the resulting R&D framework for the development of new models, methods, and metrics.

RELIABILITY ASSESSMENT CONCERNS AND GAPS

The Smart Grid encompasses a broad range of technologies and applications which have the potential to impact overall grid reliability. A brief synopsis of some of the reliability assessment concerns mentioned by workshop participants follows.

Model and Data Limitations

Workshop participants pointed out the current need for improved renewable sources, advanced HVDC, and generator control models. Load models, in particular, are increasingly important as load progressively becomes a more significant system resource as well as a major factor in the changing dynamics of the system. Characterization of load models will naturally become increasingly complex as they will involve distributed control systems, behavior elements, and new types of loads (e.g. electric vehicle charging).Additionally, an inability to "predict" the importance of the different sources of uncertainty means we cannot be unsure of the real significance of inadequacies of the data and changing operating conditions. More sophisticated tools providing the ability to perform robust numerical sensitivity analysis will be required to address this issue.

Variable and Intermittent Resource Integration

Participants indicated assessment methods, models, and metrics were required to evaluate system flexibility and reserve requirements in order to determine long term operation needs under changing system resource, capacity, and network portfolios. Additionally, the adequacy of deterministic analysis tools, in light of variable resources as well as smart grid technologies, was questioned with strong indications for further consideration and application of probabilistic risk assessment and planning tools such as ASSESS [2] and TransCARE [3].

Protection Coordination

Two-way flows of energy and information between the bulk and distribution system represent potential challenges for coordination of system protection. Particular interest was expressed concerning under-frequency load shedding (UFLS) and under-voltage load shedding (UVLS) programs. Distributed generation, demand response, conservation voltage reduction, and other smart grid applications can result in unplanned deviations from the assumed circuit demands. If the circuits are part of an under-frequency or under-voltage load-shed, the change in system demand can reduce the overall amount of load actual shed which in turn decreases the overall effectiveness of the planned load shed scheme.

Distributed Energy Resource Integration

Here, a distributed energy resource (DER) is any distributed generation (DG), renewable energy resources (RES), energy storage (ES), and demand response (DR) connected at the distribution or end-user. These resources may have only local controls, could be controlled by distribution management systems, or could be controlled by an aggregator (e.g. demand response). A number of potential DER reliability issues and assessment concerns stemming from particular applications and characteristics were denoted:

- **Ancillary Services and Flexibility Participation –** Forecasting and assessment tools are needed to evaluate the reliability benefits and limitations of incorporating high levels of DER providing regulation and reserves while taking into account factors such as resource performance, availability, and sustainability.
- **System Event Ride Through –** Bulk system level events can result in low voltage and under frequency conditions which propagate down to the medium and low voltage levels. The potential then arises for such events to violate standardized disconnection requirements for distributed generation resulting in the disconnection of large numbers of distributed generation during these events.
- **Rotor Angle and Frequency Stability –** High penetrations of DER and renewable sources coupled with retiring generation could decrease overall system inertia and primary frequency response increasing stability concerns, [4] and [5]; however, industry development of new assessment methods and dynamic models has been limited.
- **Voltage Stability –**Displacement of traditional generation providing voltage regulation by DER which is prohibited by regulating voltage could result in voltage stability concerns. Even when DG and inverter based resources are operated to provide voltage or reactive power, the support to the bulk system may be limited [6].
- **Customer Behavior and Participation –** Dynamic pricing (time of use rates, critical peak pricing, and real-time pricing) are a key feature of the Smart Grid for many stakeholders; however, the reliability benefits or ramifications (price volatility) involve complex dynamic relationships between markets, end-use customers, and energy management systems which are not completely understood nor easily captured within currently available power system analysis tools.

Information Technology Dependence

By definition, smart grid applications will greatly increase the power system's reliance on advanced communications and information technologies. Hence, software or cyber network failures – whether unintentional or deliberate – will translate into undesirable operations or outages in the physical current-carrying portion of the system. Nonetheless, current reliability analysis techniques primarily have focused only on the current-carrying portion of the grid [7].

The development of tools for analyzing impacts of cyber failures by translating or mapping communication system integrity, device failures, and cyber security risks into physical system impacts are needed focusing on the following areas for further research:

- Incorporation of advanced communication/control failure modes and physical system interdependence into system contingency evaluations.

- Assessment of the physical and cyber operational impacts from cyber attacks and communication failure events.
- Data collection and model formulation concerning communication and control asset life cycles and failure rates.
- Assessment method derivation and event driven co-simulation of cyber and physical systems.
- Development of equivalent reliability models for aggregated demand response and other dispatched distributed energy resources.

RELIABILITY AND PERFORMANCE INDICES

Integration of distributed and variable resources, heightened reliance across increasing numbers of assets and technologies, and the changing nature of system domain interactions are just some of the contributing factors to consider. Understanding and gauging the performance of an increasingly complex system requires reliability and performance metrics for particular technologies/resources as well as the overall system.

However, the nature and formulation of these metrics may not necessarily fit traditional conventions. For instance, performance indicators of curtailment and demand response will also need to account for inconvenience to the end user as well as other extraneous factors such as ambient temperature [8]. Assessment gaps pointed out during the workshops requiring future research include:

- Effectiveness of peak demand based metrics, such as Loss of Load Expectation (LOLE), in the presence of variable resources, storage, and smart grid demand shaping capabilities.
- Flexibility indices and assessment methods for distributed resources, flexibility enhancement resources (e.g. storage and demand response), and overall system performance.
- Metrics quantifying reliability and performance of aggregate demand side management operations and microgrid operations.
- Visibility, controllability, and risk metrics associated with distribution centric smart grid applications.
- Identification of measurable cyber security parameters and potential risk metrics.
- Application and integration of probabilistic risk assessment methods and performance indices within system planning.

A summary of potential case studies areas frequently indicated during the workshops as needing further research are listed in Table 1. These examples represent only a sample of potential case areas to potentially be examined. As many of these research areas are inherently interrelated, directed case studies will provide insights into a particular issue as well as findings into other areas to be leveraged through collaborative research. Furthermore, cross-cutting case studies can be identified, as needed, to examine potential coincidence/interference from different phenomena.

Table 1 – Case Study and Assessment Areas

Reliability Issue	Example Case Study	Variables / Assessment Areas
DER Ancillary Service Participation	Identify constraints on demand response and other DER's ability to provide ancillary services.	• Aggregate DER performance and reliability • Market influence and constraints
Characterizing System Flexibility	System flexibility assessment and potential utilization of DER to accommodate variable generation.	• Flexibility requirements • System and resource flexibility metrics
Protection Coordination	Impact to UFLS and UVLS schemes from distribution smart grid applications.	• Visibility requirements • Aggregate DER characteristics • Evaluation of end-user based load shedding schemes
Increased System Complexity	Communication and control failure impacts to bulk system security and adequacy.	• Cyber-physical infrastructure mapping • Contingency and risk assessment • Co-simulation event analysis
Monitoring, Control, and Visibility	Evaluate reliability benefits of distribution level visibility and potentially adverse automated control system interactions.	• DER visibility requirements • Automated control design and evaluation tools
System Frequency Response	Calculate the system stability and frequency impacts from changing system inertia and high penetration of DER.	• Equivalent dynamic models • Application of advanced inverter response
Reactive Power Support	Assessment of volt/var interactions and voltage stability issues from high penetrations of DER.	• DER reactive power capabilities • Distribution deliverability constraints • DMS coordination
Incorporating Customer Behavior	Evaluate impacts from increasing reliance upon dispatched and non-dispatched demand response.	• Customer participation models • EV charging patterns • Market and DER co-simulation
Dealing with Contingencies	Assessment of system impacts of wide-spread disconnects of DER due to bulk system events.	• DER visibility and models • Probabilistic risk assessments • DER operations during system restoration

FUTURE RESEARCH FRAMEWORK

A collaborative case study driven approach is proposed to address potential reliability issues through the application of a detailed studies and analyses. The process of performing each case study, as illustrated in Figure 1, not only provides utility system specific results but also the catalyst for developing new models, analysis methods, and metrics necessary to bridge existing assessment gaps. Furthermore, the collaborative framework permits the sharing of findings and results – along with the developed tools – which increase the overall body of knowledge concerning advance technology behaviors and reliability assessment needs.

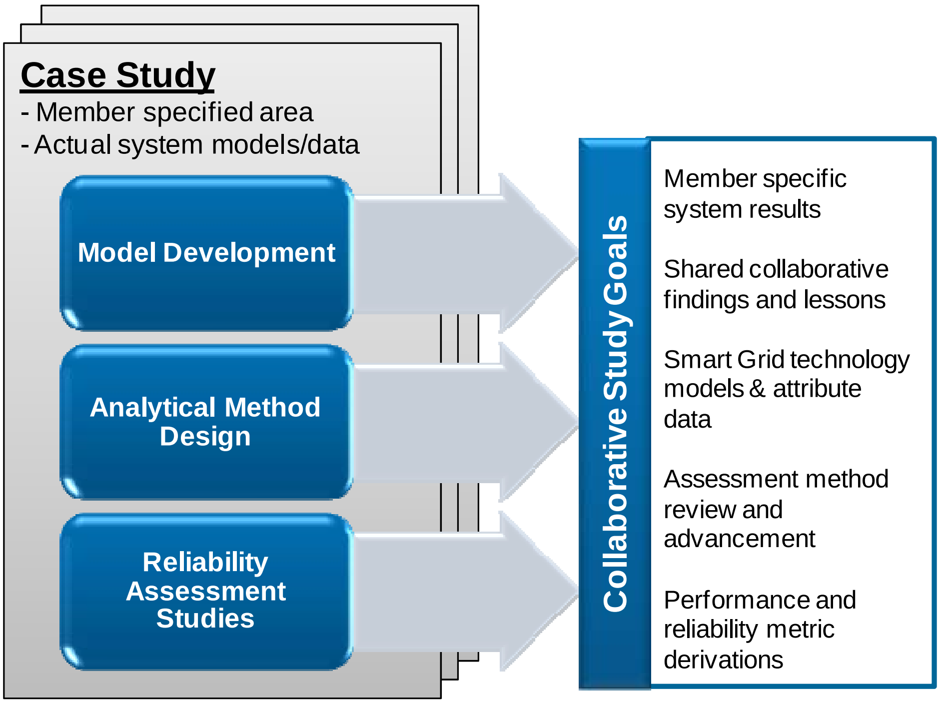

Figure 1 – Collaborative Case Study Based R&D Framework

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