History of the

Application of the Probability Methods (APM)

and

Reliability, Risk and Probability Methods (RRPA)

Subcommittees

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August 2015

Contents

1. Introduction

The Application of Probability Methods (APM) and the Reliability, Risk and Probability Methods (RRPA) Committees have been instrumental over many decades in developing concepts, ideas and techniques relating to power system reliability modeling and applications, and for propagating these developments in the form of reports, papers, tutorials and panel sessions. The details of these historical developments are easily lost or forgotten with the passage of time. Therefore our goal in initiating this effort was to highlight the history of the Application of Probability Methods Subcommittee which started in 1948 and renamed as the Reliability, Risk and Probability Applications Subcommittee in 1996.

This history document has been developed based on early subcommittee papers published, meeting minutes available since 1974 (with a gap of 1982-1988 minutes), and notes kept by individual members. The activity was initiated by RRPA SC Chair, Milorad Papic at the 2014 IEEE-PES GM. The overall preparation of this history document was coordinated by Murty Bhavaraju. The RRPA SC acknowledges the significant effort devoted by Roy Billinton and Ronald Allan in preparing this document. In addition, we received inputs from other members, in particular, Milorad Papic, Joydeep Mitra, Chanan Singh, James McCalley, Doug Logan and Lina Bertling Tjernberg.

The document highlights many of the aspects associated with this historical development including the historical evolution itself, together with details of the most important outcomes such as reports, papers, tutorials and panel sessions. It also includes recognition of those committee members who have received IEEE awards and/or who have chaired the committee and various task forces and working groups. Unfortunately a complete list of all task forces and working groups with start and end dates, scopes, and reports/papers published could not be included in this document due to lack of past information. Similarly membership lists could not be provided. Additional work is required to develop accurate information for these sections and hopefully these can be added in the future. It is intended to update the document on a regular basis (perhaps every four or five years).

The minutes of the APM and RRPA meetings are not included in the document but those that are available are posted at http://sites.ieee.org/pes-rrpasc/ . We acknowledge Roy Billinton for providing the scanned copies of the 1974-2000 meeting minutes. It would be appreciated if any members can provide the missing minutes from 1982 to 1988 so these can be added.

2. Formation of the Application of Probability Methods Subcommittee

2.1 Background and creation of the APM Subcommittee

This document is concerned with the history of the APM Subcommittee and its subsequent transition to the RRPA Subcommittee. It is important, however, to recognize that these subcommittees were preceded by early pioneering work and papers by a small group of enthusiasts who were true pioneers in the need to develop and utilize probability methods in power system planning and engineering. It is therefore important that this document begins outside the APM/RRPA domain by highlighting some of this early pioneering work and explains how this work led to the formation and subsequent development of the APM and RRPA Subcommittees.

The first published material on the application of probability methods in electric power systems occurred over eighty years ago. Some of the early publications in this area are:

> "Fundamental Considerations in Preparing a Master System Plan", W.J. Lyman, Electrical World, Vol. 101, No. 24, June 17, 1933, pp. 788-792.
>
> "Spare capacity fixed by probabilities of outage", S.A. Smith, Jr., Electrical World, Vol. 101, 1934, pp. 222-225.
>
> "Service Reliability Measured by Probabilities of Outage", S.A. Smith, Jr., Electrical World, Vol. 103, March 10, 1934, pp. 371-374.
>
> "The use of theory of probability to determine spare capacity", P.E. Benner, General Electric Review, Vol. 37, No. 7, 1934, pp. 345-348.
>
> "Considerations involved in making system investments for improved service reliability", S.M. Dean, EEI Bulletin, Vol. 6, 1938, pp. 491-496.

These five papers simply indicate some of the early pioneering work and are by no means an exhaustive list. In fact between 1933 and 1965, a total of at least 96 papers were published on these and related topics. All 96 papers are listed in the following bibliography paper:

> "Bibliography on Application of Probability Methods in the Evaluation of Generating Capacity Requirements", R. Billinton, IEEE Paper 31 CP 66-62, IEEE Winter Power Meeting, New York, 1966.

Papers continued to be published subsequent to the early ones noted above. The following four very important papers were presented in 1947 at a meeting of the American Institute of Electrical Engineering (AIEE) by G. Calabrese, W.J. Lyman, H.P. Seelye and C.W. Watchorn:

> "Generating Reserve Capacity Determined by the Probability Method", G. Calabrese, AIEE Transactions, 1947, Vol. 66, pp. 1439-50.
>
> "Calculating Probability of Generating Capacity Outages", W.J. Lyman, AIEE Transactions, Vol. 66, 1947, pp. 1471-77.

"Outage Expectancy as a Basis for Generator Reserve", H.P. Seelye, AIEE Transactions, Vol. 66, 1947, pp. 1483-88.

"Probability Methods Applied to Generating Capacity Problems of a Combined Hydro and Steam System", E.S. Loane, C.W. Watchorn, AIEE Transactions, Vol. 66, 1947, pp. 1645-57.

These four papers can be considered pioneering because they provided the stimulus for the creation of the first Application of Probability Methods Subcommittee in 1948. This was organized jointly by the AIEE and the Edison Electric Power Institute (EEI), and was known as the Joint Subcommittee on Application of Probability Methods (APM) to Power System Problems of the AIEE Committees on Power Generation and System Engineering. The APM Subcommittee's first Chair was G. Calabrese.

2.2 Early development of the APM Subcommittee (1948-1963)

The Joint APM Subcommittee was very active and produced the following AIEE Committee Report in 1949 under the chairmanship of G. Calabrese. The data in this report were collected by members of the EEI. The report also contains important comprehensive definitions on equipment outage classifications:

"Outage Rates of Steam Turbines and Boilers and of Hydro Units", AIEE Committee Report, AIEE Transactions, Vol. 68, Pt. I, 1949, pp. 450-57. G. Calabrese (Chair), W.R. Blakeley, H. Duryea, R.G. Hook, H.A. Lott, W.J. Lyman, K.W. Miller, H;.W. Phillips, C.A. Roberts, H.B. Smith, H.P. St. Clair, G.M. Tatum, V.A. Thiemann, C.W. Watchorn.

The data collection activity continued and the following report was published in 1954 by the Joint APM Subcommittee still chaired by G. Calabrese. The data and information in this subsequent paper are an extension of the material in the earlier paper:

"Forced Outage Rates of High-Pressure Steam Turbines and Boilers", AIEE Committee Report, AIEE Transactions, Pt. III-B, (Power Apparatus and Systems), Vol. 73, December 1954, pp. 1438-42. Also Combustion, New York, N.Y., October 1954, pp. 57-61. G. Calabrese (Chair), G.W. Bills, C.R. Cahn, V.M. Cooke, E.D. Early, R.N. Fitch, R.G. Hooke, L.K. Kirchmayer, W.J. Lyman, C.W. Minard, B.B. Mohr, H.B. Smith, H.T. Stranrud, V.A. Thieman, C.W. Watchorn.

The Joint APM Subcommittee, now chaired by C.W. Watchorn, published the following paper containing the final results of a five year nationwide survey of the forced outage rates (FOR) of horizontal steam turbines in 1957. The data described in this paper were collected by the Prime Movers Committee of the EEI:

"Forced Outage Rates of High-Pressure Steam Turbines and Boilers", AIEE Joint Sub-Committee Report, AIEE Transactions (Power Apparatus and Systems), Vol. 76, June 1957, pp. 338-43. Also Combustion, Vol. 28, February 1957, pp. 43-46. C.W. Watchorn (Chair), H.A. Adler, C.R. Cahn, G. Calabrese, V.M. Cook, W.G. Dempler, E.D. Early, R.M. Fitch, K.L. Hicks, A.P. Jones, C. Kirst, E.S. Loane, C.W. Minard, B. B. Mohr, H.B. Smith, V.A. Thiemann.

This paper is considered seminal because the discussion and closure led to positive forward steps in the activities and scope of the Joint APM Subcommittee. It can be seen from the above papers and reports that the early activities of the Joint APM Subcommittee centered primarily on generating plant and the associated outage data. Although the discussion to the above paper notes that the described surveys should be continued

and data collected to provide FOR values, in his closure, the chairman C.W. Watchorn, stated that data should be collected "*for all facilities of an electric power system that affect service reliability*". He also stated that "*the subcommittee stands ready to sponsor the publication of such data as they are made available*". These proposals led the Joint APM Subcommittee to expand its focus from just generating plant to the overall power system and fostered the subsequent scopes of the APM and RRPA Subcommittees.

The initial step in the expanding scope centered on the assessment of generating capacity. A Working Group of the AIEE APM Subcommittee, now chaired by L.K. Kirchmayer, published the following paper in 1961. This is also a seminal and important paper because it summarizes and illustrates basic power generation system reliability concepts that are still in use today:

> "Application of Probability Methods to Generating Capacity Problems", AIEE Committee Report, AIEE Transactions, Pt. III, (Power Apparatus and Systems), Vol. 79, 1960 (February 1961 section), pp. 1165-77. L.K. Kirchmayer (Chair), H.A. Adler, A.K. Falk, C.D. Galloway, K.L. Hicks, C. Kist, H.D. Limmer, E.S. Loane, C.W. Watchorn, H.S. Worcester.

The AIEE APM Subcommittee produced the following manual in 1961 that outlined a comprehensive procedure for recording outage data using digital equipment:

> "Manual for Reporting the Performance of Generating Equipment", AIEE Subcommittee on Application of Probability Methods", 1960, Revised January 3, 1961.

In 1963, the structure and responsibility of the APM Subcommittee changed because of Institutional changes. The American Institute of Electrical Engineering (AIEE) and the Institute of Radio Engineers (IRE) merged to form the Institute of Electrical and Electronics Engineers (IEEE) on January 1, 1963. The APM Subcommittee continued to function but now under the auspices of the Power System Engineering Committee of the IEEE Power Engineering Society. The history and activities of the APM Subcommittee subsequent to this change are described in Section 3.

3. Evolution of the APM and RRPA Subcommittees

3.1 Application of Probability Methods (APM) Subcommittee (1963 to 1996)

(a) Subcommittee Scope

The primary focus of the APM Subcommittee under the auspices of the AIEE was on generating plant outage data and generating capacity reliability evaluation as noted in Section 2. Following the creation of the IEEE in 1963, the scope and activities of the APM Subcommittee were considerably extended. In particular, significant attention was also given to the performance of transmission and distribution systems. The scope of the APM Subcommittee was reviewed and subsequently defined as the following:

> **APM Subcommittee Scope:** Study, review and foster the application of probability methods in the planning, design and operation of all phases of electric power systems. Sponsor technical sessions covering the application of probability techniques in the studies of generation, transmission, distribution and overall power systems. Cooperate with IEEE committees, other professional societies, and technical organizations in collecting and analyzing performance data needed in the application of these methods.

At this point in time, the APM Subcommittee was organized jointly with the Transmission and Distribution, Power Generation, Switchgear, and Nuclear Power Engineering Committees and had liaison members from these Committees. This joint sponsorship ended in 1995 when a major reorganization of committees occurred and the APM Subcommittee subsequently became the Reliability, Risk and Probability Applications (RRPA) Subcommittee (see Section 3.2).

A number of parallel efforts by task forces and working groups of the APM Subcommittee, electric power utilities and the Edison Electric Institute were created to extend the definitions, develop models and calculate performance indices for generation, transmission and distribution systems. Although the interest in transmission and distribution system reliability came somewhat later than for generating systems, it followed a similar pattern of creation and extension of procedures and requirements advanced by electric power utilities.

The time span between 1963 and 1996 was a prolific and productive period for the APM Subcommittee and its associated Working Groups and Task Forces. During this period, the subcommittee established many liaisons, both formal and informal, established two IEEE Standards, created a Reliability Test System that has been recognized throughout the world as being of considerable significance, organized a number of tutorials and panel sessions, and published reports and papers that highlighted current practices and state-of-the-art thinking as well as proposing forward ideas and thinking. These activities are summarized briefly in the following paragraphs.

(b) Subcommittee Structure

Initially, the APM Subcommittee was formed with only one working group (WG) designated as "Performance Records for Optimizing System Design (PROSD)" with the following scope:-

> **PROSD Scope**: Investigate the performance record activities of other power industry groups and the objectives of such activities, define and recommend performance record requirements for use in optimizing power system design, keep abreast of the developments in reliability analysis in the related fields, recommend methods of using performance data in optimizing system design and

encourage the dissemination of knowledge in this field, including the publication of technical papers.

The APM Subcommittee also formed ad-hoc task forces (TF). These were intended to be short-lived with specific tasks. Once these tasks had been completed, preferably by the publication of relevant reports and/or papers, the TF was disbanded. Sometimes a TF would be disbanded without appropriate reports or papers because the task, once studied, did not warrant such output.

The question of reorganizing the APM Subcommittee to include more than one WG was discussed at the Subcommittee meeting in July 1990 and a motion was passed to form a TF to consider an alternative structure to the APM Subcommittee. The TF Chair provided a summary of possible APM restructuring at the February 1991 meeting which was discussed in detail. It was agreed that three specific WGs should be formed with PROSD being one of them. The WG names and scopes were presented at the July 1991 meeting and Subcommittee members were asked to provide comments. A motion to accept this proposed structure was made and approved at the January 1992 meeting of the APM Subcommittee. The name of the PROSD WG was also changed to the Performance Records (PR) WG. The new names and scopes are as follows:-

Probabilistic Decision Making WG: To investigate and suggest the uses of probability techniques to support engineering decisions in the development of power systems. These techniques provide a framework for multi-objective trade-off analysis, resource analysis, value based reliability assessments, analysis of uncertainties, decision analysis, and cost/benefit analysis.

Probability Applications in Power System Analysis WG: To identify the needs and to develop probability techniques for the analysis of power systems. The scope of the activity covers new analytical applications and analytical techniques for the study of power system reliability assessment, probabilistic power flow, production costing, and similar probabilistic applications.

Performance Records WG: To define and recommend recording requirements of equipment and performance indices, methods of data analysis and the objectives of groups in power industry for the collection of performance records.

Chairs for the three WGs were appointed at the January 1992 APM Subcommittee meeting and a steering committee was established to assign the existing TFs to the three new WGs. Each WG Chair reported on the activities of their assigned TF at the July 1992 meeting. The Chairs of two WGs, the Probability Applications and the Probability Decision Making WGs, asked at the July 1994 meeting to be relieved of their chair duties due to work commitments and it was decided at the January 1995 meeting to merge these two WGs under a single Chair.

(c) Activities

The biannual meetings of the APM Subcommittee, generally held at the Winter and Summer Meetings of the IEEE-PES, were largely focused on the three areas of ongoing WG and TF activities, liaisons with other IEEE groups and external organizations, and new activities. As stated in Section 3.1(a), the Subcommittee was very active in the 1963 – 1996 period. A brief summary of its many achievements is presented in the following paragraphs.

Liaisons

Liaisons with groups and individuals external to the APM Subcommittee are important activities embedded in the Subcommittee scope. Liaisons present tremendous opportunities to obtain and disseminate information, knowledge and expertise. The biannual IEEE-PES meetings provide great opportunities to meet and discuss common problems and objectives with a wide range of individuals. Section 8 provides a brief sample of some of the liaison activities associated with both the APM and the RRPA Subcommittees.

Standards and Test Systems

The Subcommittee was instrumental in developing two IEEE Standards, one dealing with generating plant (IEEE Standard 762) and the other dealing with transmission systems (IEEE Standard 859). These have become widely accepted internationally and have been regularly reviewed, updated and reaffirmed. A detailed discussion of these activities is provided in Section 7.

In addition, the Subcommittee created a test system comprising generation units and transmission lines. Although not a standard in the true sense of the word, it is widely regarded as ***the system*** for testing new models, techniques and methodologies because results can be compared against known values, therefore establishing accuracy and precision of the approach. This test system in known as the IEEE Reliability Test System (IEEE-RTS) and is described in publication 9 of Section 6. An APM Subcommittee TF extended the RTS in 1999 (IEEE RTS-1996) to include multi-area networks, substation configurations and other enhancements (publication 25).

Bibliographies

A bibliography independent of the APM Subcommittee was published in 1972 ("Bibliography on the Application of Probability Methods in Power System Reliability Evaluation", IEEE Transactions PAS-91, No. 2, March/April 1972, pp.649-66). This publication illustrates the range and depth of the activity in generation, transmission and distribution reliability assessment prior to 1970. In addition it shows that the occupations and number of participants working and publishing in this area also increased considerably compared to the electric power utility dominance that existed prior to 1960.

The APM Subcommittee recognized that bibliographies of this type are extremely useful as a means of disseminating information and began regularly publishing bibliographies at 4-5 yearly intervals. These bibliographies are listed in Section 6 as publications 8, 10, 13, 17 and 24.

Tutorials and Panel Sessions

In order to disseminate knowledge and understanding, the APM Subcommittee organized a number of tutorials, given by internationally recognized experts in particular areas of activity. The first tutorial entitled "Probability Analysis of Power System Reliability" was presented in 1971 and was co-sponsored by the IEEE Power Engineering Education Committee and the IEEE Transmission and Distribution Committee. Details of this tutorial and others sponsored by the APM Subcommittee are presented in Section 5.

The APM Subcommittee sponsored/co-sponsored a number of panel sessions on a wide range of issues during the 1963-1996 period, providing considerable discussion and interest. The details of these activities are presented in Section 10. A panel session on "Reliability Issues in Today's Electric Power Utility Environment" at the 1996 Winter Power Meeting in Baltimore resulted in suggestions made following the presentation that the Panel TF should prepare and submit a paper on this subject for review. The resulting paper is shown as publication 23 in Section 6.

WG and TF Publications

The Task Forces set up by the APM Subcommittee dealt with a wide range of utility concerns regarding power system reliability and proposed new approaches for assessing data and evaluating system reliability. A basic aim of all WG and TF activities was to produce an authoritative report and/or paper describing the knowledge gained during the activity and proposals for future ideas and developments. The titles and participants of publications resulting from these activities are presented in Section 6. This section briefly reviews some of these activities and publications.

One of the first tasks under the IEEE APM Subcommittee was to extend the earlier work of the AIEE APM Subcommittee in regard to definitions of terms for reporting and analyzing outages of generating equipment, transmission and distribution facilities and interruptions. These activities resulted in publications 1 (dealing with generating plant) and 2 (dealing with transmission and distribution) in Section 6.

Publication 1 created a set of definitions for reporting and analyzing generating unit outage states. However, it was noted in 1968 by V.M. Cook that *"the instructions for generating unit reporting provided by the Edison Electric Institute included a list of definitions of terms which were sufficient for the proposed reports by EEI but which were not complete enough for use by groups making probability calculations for reserve problems in system planning"*. An Ad Hoc Working Group on Definitions chaired by V.M. Cook was formed following discussion by the APM Subcommittee at the 1968 IEEE Winter Power Meeting. The results of their work are presented in publication 3. In 1970, the Ad Hoc Committee on Definitions was expanded to create the TF on Models for Peaking Units and produced publication 4 in 1972. Publications 3 and 4 are important documents that laid the groundwork for the future development of IEEE Standard 762.

Publication 2 centered on developing a set of terms and definitions for reporting and analyzing outages in transmission and distribution networks. It was created in 1968 by a joint Working Group of the PROSD WG, the APM Subcommittee and the System Planning Subcommittee. A series of TFs were created under the PROSD WG to focus on specific areas of study, applications and research.

One concern that was raised during the 1970s was associated with common mode outages and their effect on system reliability. A TF was therefore set up to address this issue. The results of this activity were presented in publication 5 noted in Section 6. This addressed the definition and collection of data for common mode outages of multiple transmission lines which are on the same right-of-way for a measurable part of their length.

The PROSD WG continued to work actively within its scope on outage data collection and the evaluation of bulk electric system reliability indices. The WG presented their results in publications 6 and 7 and further extended the concepts almost a decade later in publications 11 and 12 noted in Section 6.

Publications 14, 15 and 18 in Section 6 are the output of a three stage process initiated by the APM Subcommittee in 1988 and center on identifying techniques and approaches for monitoring, measuring, predicting and applying reliability indices in the planning and operation of bulk power systems. Each paper focused on different aspects of the overall problem. The three papers were developed by three Sub TFs of the Bulk System Reliability Indices TF of the APM Subcommittee PROSD WG.

Publication 16 reviewed and summarized the current industry practices in bulk outage data collection and analysis.

Publication 19 presented the results of an APM Subcommittee TF that was set up to review the progress made in the past twenty years or so pertaining to the effect of protection systems on bulk power system reliability evaluation.

In response to questions regarding the pooling of generator outage data and concerns that there were no industry recommended standards or practices on data pooling, the APM Subcommittee agreed at the 1989 WPM to establish a TF on this subject. Publication 20 presents and explains some fundamental concepts of pooling data to improve estimators of generating unit performance indices. The paper delineates the two major reasons for pooling and recommends the correct method for pooling in both cases.

One ongoing activity in the APM Subcommittee since its inception was the advancement of probability methods in the analysis of generation and transmission system reliability. The publications in Section 6 clearly illustrate the attention given to bulk power system (BPS) concerns. The focus of publication 21 is on BPS delivery point performance with the objective of presenting a useful set of terms and procedures to consistently report BPS delivery point reliability.

Publication 22 illustrates the application of reliability and value of service analysis in system planning. This paper arose from additional work by the TF following their panel presentation in 1993 (Panel Session 2 in Section 10).

The APM Subcommittee established a TF in 1995 to investigate maintenance strategies and their effect on reliability. This involved sending a questionnaire to selected utilities concerning their strategies for scheduling maintenance. The TF concluded its work in 1999 and publication 26 is a summary of the full report.

3.2 Reliability, Risk and Probability Applications Subcommittee (RRPA) (1996-date)

(a) Subcommittee Scope

The APM Subcommittee was informed that in 1995 there would be a re-organization of the IEEE-PES committees and subcommittees. The APM Subcommittee was ultimately assigned to a new committee designated as the Power System Analysis, Computing and Economics (PSACE) Group. All the existing subcommittees were to be reviewed and there was a possibility that some subcommittees could be merged depending on their scope. The new Chair of the APM Subcommittee initiated a process to rename the APM Subcommittee and define a clear scope to justify a separate subcommittee. A poll was conducted concerning alternative subcommittee names and scopes. After discussion, the name approved at the January 1996 subcommittee meeting was the **Reliability, Risk and Probability Applications (RRPA)** Subcommittee with the following scope:

> **RRPA Subcommittee Scope**: Study, review, and foster the development, application, and dissemination of probabilistic and other methods for dealing with reliability, uncertainty and risk assessment in the planning, design, operation and management of all phases of electric power systems. Review technical papers and conduct paper sessions, organize panel sessions, update or develop industry guides and develop position papers. Cooperate with IEEE Committees and other professional and technical organizations in these activities.

The initial overall task for the RRPA SC was to satisfy the objectives of the existing TFs and WGs established by the APM SC and develop new objectives under the assigned scope. The work of the existing TFs and the discussion and formation of new activities continued throughout the changes in WGs and renaming the

subcommittee. This was accomplished over a period of time during which activities were completed and/or closed, and new activities resulting in TFs and WGs were initiated.

The following briefly illustrates the evolution of the RRPA SC structure under the new scope and some of the resulting activities and outcomes.

(b) Subcommittee Structure

The RRPA SC inherited the basic structure of the APM SC and therefore many of the early activities of the RRPA Subcommittee were continuations of those initiated by the APM Subcommittee. The Probability Applications (PA) and Probabilistic Decision Making (PDM) WGs held separate meetings with new Chairs at the IEEE-PES January 1996 WPM. The focus was on existing TF activities and new directions. The PDM WG was considered to be a valuable forum to identify trends and issues in probabilistic decision making and held a discussion with several presentations on current activities in the industry related to probabilistic decision making at the IEEE-PES February 1997 WPM. At this meeting, the PA WG discussed forming a new TF on probabilistic aspects of deterministic criteria. This TF designated as Probability Aspects of Reliability Criteria held its first meeting at the IEEE-PES February 1998 WPM. The TF Chair provided a working document on this subject at the IEEE-PES February 1999 WPM. This document was subsequently used to develop a paper on probabilistic security assessment for operations, which was presented by its Chair at the 2004 GM in Denver. The TF was then closed. The paper is listed as publication 27 in Section 6.

As noted in Section 7, Standard 762 and 859 needed to be reinstated in an unmodified form prior to making any changes and action was taken to accomplish this. Standard 762 provides the basis for the NERC GADS data collection which is structured on base load units and now needed to consider non-base load generation. The RRPA SC therefore created a new TF at the 2002 WPM to develop a major revision of Standard 762 to meet the new industry requirements. Members of the RRPA SC were also encouraged to join the Standards Association so that they could participate in the development and revision of IEEE Standards. The Standard 762 group was initially formed as a TF and upgraded to a WG in accordance with the Standard Association Revision requirements. A summary report on the progress of the Standard 762 WG was presented to the RRPA SC at the 2003 IEEE PES GM in Toronto.

The Winter Power Meeting in New York held in January 2002, was the last IEEE-PES WPM, as it was decided by the PES that only one General Meeting (GM) would be held each year. The first GM was held in Chicago in July, 2002, where it was reported that the PSACE Ad Committee had announced hard deadlines for meetings, sessions, etc. and the dates for proposed activities must be submitted 26 weeks prior to the Conference.

The existing Reliability of Distribution Systems TF, which was traditionally focused on data collection, was assigned a new mandate at the 2004 GM to promote distribution reliability by creating test systems, methods and results and new members were solicited.

In accordance with new directives, the RRPA SC commencing in 2002 began using reduced terms for the SC officers. Rather than 5 year terms, 2 or if necessary, 3 year terms became the norm.

Based upon extensive discussion at the RRPA SC meeting held at the Probability Methods Applied to Power Systems Conference in September 2004 at Ames, Iowa it was decided at the 2005 IEEE-PES GM meeting in San Francisco to create a TF designated as Planning Power Systems Operating under Competitive Electricity Market Conditions.

Due to declining interest and attendance limitations it was agreed at the 2005 IEEE PES GM to close both the Probabilistic Decision Making Applications and the Probability Applications in Power Systems WGs and focus on other areas. The RRPA SC also formed a new WG to consider possible revisions in IEEE Standard 859-1987. A further TF in this area entitled Developments in Definitions and Terminology Associated with Collection of Transmission Outage Data was approved at the PES-GM-2007.

A procedure was discussed and approved for RRPA SC officer elevation and election at the 2009 GM in Calgary. This procedure involved the Vice-Chair stepping up to Chair and the Secretary stepping up to Vice-Chair, with normal terms of two years. A new Secretary is elected at the relevant RRPA SC meeting. It was noted at the 2013 GM meeting of the RRPA SC that according to recent PSACE policy and procedures, the office of RRPA SC Secretary should be appointed by the incumbent Chair and the immediate Past Chair.

The RRPA SC agreed at the 2009 GM to renew the Reliability of Distribution Systems TF for another three years with a scope focused on test systems under the title of Test Systems for Distribution System Reliability Analysis.

The following new TFs were established at the 2010 GM in Minneapolis.

- "Probability Applications for Common Mode Events on Power System Equipment"
- "Development of a Guide to address Wind Generation Compliance related to IEEE Std. 762 and the Reporting of Outage Events"
- "Probability Applications for Cyber Physical Energy Systems"
- "Probability Applications for Cascading Failures". This is an existing TF in another SC requesting RRPA participation.

The RRPA SC created a TF on Reliability Impacts of Demand Response Integration in 2012. This TF created considerable interest and generated the two panel presentations noted as Panel Session 21 and 24 in Section 10.

The TF on Probability Applications for Common Mode Events on Power System Equipment was upgraded in 2012 to a WG to incorporate the widening of this area of interest. The WG on common mode events has been very active since its inception in 2010. Its work over the last five years produced one panel session and three conference papers as shown in Sections 10 and 6 respectively.

Due to the present lack of activity and the need to increase focus in other areas, it was decided at the 2013 RRPA SC meeting to close the TF on Reliability of Distribution Systems.

The RRPA SC created a WG on Loss-of-Load Expectation Best Practices to extend an activity previously initiated and hosted by NERC, and held its first meeting at the 2012 GM in San Diego. The purpose of this WG is to organize at least a one whole day meeting each year at which participants in industry studies share their current experiences, propose and organize suitable panel sessions and produce review papers on the subject. The Loss-of-Load Expectation Working Group (LOLEWG) has been very active since its inception and has satisfied its objective to hold extended meetings at each IEEE-PES GM covering a wide range of topics on generation adequacy assessment. It also facilitated Panel Session 25 shown in Section 10. In 2014 it held an associated meeting at the 2014 PMAPS Conference in Durham, UK.

The RRPA SC continues to work in a wide range of important areas in power system adequacy and security as shown by the material in Sections 6, 7, 8 and 10. The RRPA SC introduced a new Organization, Policies and

Procedures Manual at its meeting on July 28th, 2015 during the 2015 IEEE PES GM in Denver. This manual defines the organization of RRPA SC, the scope of the SC and the duties of its officers. Membership qualifications are stipulated and certain relevant operating procedures are defined. The Manual contains a wide range of important information that will be discussed in detail at future RRPA SC meetings.

(c) Activities

As previously noted, the RRPA SC inherited the ongoing activities of the APM SC and instituted new tasks in accordance with its scope. A brief outline of some of the activities initiated by the RRPA SC is presented in the following paragraphs. The details are shown in the various Sections.

Liaisons

As with the APM SC, co-operation with IEEE groups and other professional and technical organizations is an important aspect of the RRPA SC mandate. Section 8 provides a brief sample of some of the liaison activities associated with both the APM and the RRPA Subcommittees.

Standards

As noted in Section 2.2(b), work continued on IEEE Standards 762 and 859. New rules and regulations in regard to IEEE Standards were set by the IEEE, to which the RRPA SC TFs and WG responded. These important ongoing projects are described in detail in Section 7.

Tutorials and Panel Sessions

The RRPA SC continued the educational approach used by the APM SC and sponsored/co-sponsored a number of tutorials and panel sessions. However there has been a significant change in the number of such activities. During the APM period, the SC organized three tutorials and a similar number of panel sessions. During the more recent and shorter RRPA period, the SC has organized four tutorials and 23 panel sessions, which is a significant increase. Initially this seems to be a remarkable development but there is an underlying and understandable reason for this change. Although partly dependent on the focus taken by PES in general, it is mainly due to the maturity of the subject matter underpinning the APM and RRPA SCs. In the early days, the focus was on developing ideas, techniques and methodologies for assessing and monitoring reliability. The output at that time was therefore mainly on creating transaction-type papers that documented, propagated and archived this information together with the occasional tutorial and panel session. More recently, the focus has been towards applications and implementations. These are more appropriately dealt with as panel sessions with the occasional tutorial. This change in focus is also reflected in the number and type of publications (*see next sub-section*). The following paragraphs highlight some of these tutorials and panel sessions.

The tutorial "Electric Delivery System Reliability Evaluation" initially created for the 2005 GM in San Francisco was also presented by request at the 2006 GM in Montreal. A modified version in the same area was presented at the IEEE T&D Conference & Exposition in Dallas in 2006. The tutorial on "Probabilistic T&D System Reliability Planning" presented in 2007 was primarily focused on the application of reliability techniques in transmission and distribution planning. In response to requests, a tutorial was designed and presented in 2007 entitled "Asset Management – Maintenance and Replacement Strategies" which illustrates how maintenance is a strategic element in asset management. The above noted tutorials were designed to provide a good balance between reliability theory and application, and appeal to a wide audience. Details on these tutorials are provided in Section 5.

As noted above, panel session activity at IEEE PES GMs increased significantly over the last two decades including those organized by the RRPA SC. The panel sessions sponsored or co-sponsored by the RRPA SC are listed in Section 10. These panel sessions cover a wide range of topics and associations. In many cases, they arise due to WG and TF activity in the RRPA SC. In other cases, they are due to requests for participation by another SC or TF.

Panel Session 7 was presented in Singapore at the 2000 IEEE PES WPM. This was the first IEEE PES WPM held outside North America.

The RRPA SC TFs and WGs were particularly active in creating panel sessions in the last few years. As shown in Section 10, thirteen panel sessions (14 – 26) were presented in the 2010 to 2015 period and were received very favorably.

WG and TF Publications

Section 6 presents the WG and TF publications developed by the APM SC and by the RRPA SC. This includes the publications initiated by the APM SC and completed under the auspices of the RRPA. Section 6 does not include the APM SC and RRPA SC tutorial documents published by the IEEE-PES. These publications are shown in Section 5 and designated by their IEEE Course Text Number.

It can be noted from Section 6 that the number and type of publications also show that there has been a significant change. During the APM period, the SC published a total of 25 papers, approximately one per year, made up of 24 transaction papers and one conference paper. During the RRPA period, however, the SC published only seven papers, approximately one every three years, made up by one transaction paper and six conference papers. This again reflects the comments made under "**Tutorials and Panel Sessions**" during the APM period where the focus was on developing ideas, techniques and methodologies for assessing and monitoring reliability which resulted in transaction-type papers that documented and propagated this information together with the occasional tutorial and panel session. More recently, the focus has been towards applications and implementations, which has resulted more appropriately in an increased number of panel sessions and conference-type papers.

Publications 27 to 32 with the exception of 28 were developments by the WG and TFs of the RRPA SC. Publication 28 arose from an activity by the Computer and Analytical Methods Subcommittee (CAMS) on which the RRPA SC was a co-sponsor.

The conference paper numbers are shown on publications 28 to 32 and can be used to obtain copies from the conference record.

4. Subcommittee Chairs

Subcommittee Chairs are listed below:

1948 - 1953	G. Calabrese	
1953 - 1958	C.W. Watchorn	
1958 - 1963	L.K. Kirchmayer	
1963 - 1968	Z.G. Todd	
1968 -1972	A.D. Patton	
1972 -1976	R.J. Ringlee	
1976 -1980	R. Billinton	
1980 -1984	M.P. Bhavaraju	
1984 - 1990	N.D. Reppen	
1990 - 1995	N.S. Rau	
1995 - 2002	C. Singh	(APM name changed to RRPA in 1996)
2002 - 2004	C. Grigg	
2004 - 2006	J. D. McCalley	
2006 - 2009	A. W. Schneider, Jr.	
2009 - 2011	J. Mitra	
2011 - 2013	L. Bertling Tjernberg	
2013 - 2014	A. Ford	
2014 - Present	M. Papic	

5. Tutorials

1. IEEE Tutorial Course, "Probability Analysis of Power System Reliability", 1971, Course Text 71 M 30-PWR.
   Coordinator: A.J. Wood;
   Contributors: P.F. Albrecht, A.D. Patton, R. Billinton, M.P. Bhavaraju, B.E. Biggerstaff, R.J. Ringlee, J.H. Cooper, P.B. Shortley.
   Scope: The need for educational activities in the area of applying probability methods for electric power system reliability analysis has long been recognized by the Application of Probability Methods Subcommittee of the IEEE's Power System Engineering Committee. Over the past two decades, this group has written reports comparing various analytical techniques and has actively encouraged the definition, collection and proper processing of the statistical data required. This tutorial session is devoted to continuing the first part of this work, the application of probability methods to the quantitative analysis of power system reliability.
   Topics: Basic probability and statistics for reliability analysis; Markov process and Monte Carlo simulation; Generating capacity reliability evaluation; Composite system reliability methods; Reliability methods for spinning reserve; Reliability procedures for substations; Reliability procedures for subtransmission and distribution systems; Bibliography on the application of probability methods in power system reliability evaluation.

2. IEEE Tutorial Course, "Power System Reliability Evaluation", 1982, Course Text 82 EHO 195-8-PWR;
   Coordinators: R. Billinton, M.P. Bhavaraju;
   Contributors: R.N. Allan, M.P. Bhavaraju, R. Billinton, J. Endrenyi, G.E. Marks, N.D. Reppen.
   Scope: This tutorial presents the basic concepts and the recent developments in the quantitative reliability evaluation of generation, transmission and distribution systems. It also illustrates the utilization of these concepts in reliability worth analysis. One important aspect which is not covered in this tutorial is that of outage data collection and analysis. This aspect is, however, briefly discussed under each type of reliability evaluation.
   Topics: Basic concepts in reliability evaluation; Generation system reliability evaluation; Bulk power system reliability evaluation; Station system reliability evaluation; Distribution system reliability evaluation; Reliability economics.

3. IEEE Tutorial Course, "Reliability Assessment of Composite Generation and Transmission Systems", 1990, Course Text 90EH0311-1-PWR.
   Coordinators: R. Billinton, R.N. Allan.
   Contributors: R.N. Allan, M.P. Bhavaraju, R. Billinton, C.C. Fong, M.V.F. Pereira, R.J. Ringlee, L. Salvaderi, C. Singh.
   Scope: This tutorial presents the basic concepts and the recent developments in quantitative reliability evaluation of composite generation and transmission systems. It also illustrates the utilization of these concepts in reliability worth analysis. One important aspect which is not specifically covered in this tutorial is that of outage data collection and analysis. This aspect is, however, briefly discussed under each type of reliability evaluation.
   Topics: Reliability concepts of composite power systems; Basic probability and reliability concepts; Concepts of data for assessing the reliability of composite systems; Bulk system reliability measurement and Ontario Hydro experience; Composite system adequacy assessment – the contingency enumeration approach; Monte Carlo simulation techniques; Monte Carlo based composite reliability evaluation modelling aspects and computational results; Application of contingency evaluation techniques to practical

systems; Thoughts on the applications of composite system reliability methods, cost benefit analysis and future trends.

4. IEEE Tutorial Course, "Electric Delivery System Reliability Evaluation, 2005, 2006 Course Text 05TP175.
   Coordinator: J. Mitra;
   Contributors: M.P. Bhavaraju, R. Billinton, R.E. Brown, J. Endrenyi, W. Li, A.P. Meliopoulos, C. Singh.
   Scope: In preparing this tutorial, the focus has been to cover issues that are both fundamental and of practical and contemporary relevance. The topics covered have been carefully selected and organized to meet these objectives. The electric delivery infrastructure consists of bulk power systems and distribution systems. The fundamental methods of analyzing these systems for reliability have been presented. Analytical, empirical and simulation-based methods have been discussed. It was recognized that the actual use and application of these methods are contingent upon the availability and understanding of data, and so a chapter has been devoted to the treatment of this important topic. Finally, some of the most important areas of application have been addressed – maintenance and planning. Over the past decade, the introduction of competition, open access and environmental issues have presented some unprecedented, complex challenges to the reliability operation of the electric power system. Some of the major issues and paradigms have been identified and discussed.
   Topics: Analytical techniques for bulk power system reliability assessment; Monte Carlo simulation and intelligent search methods; Distribution system reliability: analytical and empirical techniques; Data requirements, practices and recommendations, Reliability and maintenance, Generation system reliability in competitive markets; Application of reliability evaluation in transmission planning.

5. IEEE Tutorial Course, "Reliability of Electric Delivery Systems", 2006. No Course Text;
   Coordinator: J. Mitra;
   Contributors: C. Singh, S.S. Venkata, R.E. Brown. (Offered at the T&D Conference & Exposition in Dallas).

6. IEEE Tutorial Course, "Probabilistic T&D System Reliability Planning"; 2007, Course Text 07TP182;
   Coordinator: A.A. Chowdhury;
   Contributors: R. Billinton, R.E. Brown, A.A. Chowdhury, G. Gross, G. Hamoud, J.D. McCalley, C. Singh, S.S.(Mani) Venkata.
   Scope: This tutorial would prove useful to anyone interested in gaining deeper understanding of transmission and distribution systems reliability evaluation, and engaged in conducting the business of electric power and energy - practicing engineers, regulators, transmission service providers, energy traders, students and academics. The materials included in the tutorial present a strong balance between basic reliability theories and their practical applications, and are presented by some of the renowned experts in the power system reliability field.
   Topics: Application of reliability techniques in transmission system planning and analysis; Monte Carlo simulation techniques for transmission system reliability analysis; Predictive distribution reliability and risk assessment; Data concepts and requirements for value based T&D reliability planning; Estimating component reliability indices for electric transmission decision problems; Use of the probabilistic value-based approach in transmission planning and asset management; Assessment of economic impacts of reliability in transmission planning.

7. IEEE Tutorial Course, "Asset Management - Maintenance and Replacement Strategies", 2007. No Course Text;
   Coordinator: L. Bertling;
   Contributors: G. Anders, L. Bertling, G. Cliteur, J. Endrenyi, A. Jardine, W. Li. Offered GM 2007 in Tampa, FL.
   Scope: The focus of the tutorial is on how maintenance is turned into a strategic tool for asset management. It gives a review of maintenance policies, and shows the link to probabilistic approaches, and the reliability-centered maintenance methods. It shows how condition based monitoring could be used for optimizing maintenance decisions. Furthermore, it introduces computer programs for decision support in the management of equipment maintenance. Finally, it shows applications at transmission companies using risk based asset management.

8. IEEE Tutorial Course, "Understanding Cascading Phenomenon: Methodologies and Industry Practice for Analysis of Cascading Failures" PES GM 2015, No Course Text (Presentations are available)
   Coordinators: M. Vaiman and M. Papic
   Contributors: B. Cummings, I. Dobson, M. Forte, P. Hines, M. Kezunovic, E. Litvinov, V. Madani, D. Novosel, M. Papic, R. Quint, D. Subatki, V. Terzija, M. Vaiman, V. Vittal
   Scope: Interconnected power grids throughout the world are operated reliably but occasionally suffer massive blackouts with multibillion dollar costs to society. Cascading failures present severe threats to power grid reliability and security, and thus reducing their likelihood, and timely detection, mitigation and prevention of cascades are of significant importance. This tutorial developed by the IEEE Cascading Failures Working Group and PACME Working Groups provides an overview of the cascading phenomenon and explains methods, technologies and tools that are currently being used to predict, detect, mitigate and restore from cascading failures. This full day tutorial covers the existing industry practices for analysis of cascading failures and presents relevant industry standards and guides. Close attention is given to the new technologies such as synchrophasor technology for better detection and mitigation of cascading outages. The tutorial also explains the root causes and mechanisms of propagation of the past blackouts and discusses the lessons learned. The tutorial is intended for power system engineers and power engineering students.
   Topics: Overview of Cascading Outages Phenomenon; Framework for Analysis of Cascading Outages; Current Tools and Emerging Technologies for Prediction and Detection of Cascading Outages; Current Tools and Emerging Technologies for Prevention and Mitigation of Cascading Outages; Industry Experience in the Analysis of Cascading Outages; Restoration from Cascading Failures; Analysis of Past Blackouts Caused by Cascading Outages: Lessons Learned.

6. Subcommittee Papers

1. "IEEE Committee Report on Proposed Definitions of Terms for Reporting and Analyzing Outages of Generating Equipment", IEEE Transactions, Vol. PAS-85, No. 4, April 1966, pp. 399-393.
   APM Members: H.A. Adler, R.N. Fitch, J.L. William, Jr.

Definitions prepared by a Working Group of the IEEE Joint Subcommittee of the Application of Probability Methods and the Power Generation Committee in co-operation with the Equipment Availability Subcommittee of the Prime Movers Committee of the Edison Electric Institute.

2. "IEEE Committee Report on Proposed Definitions of Terms for Reporting and Analyzing Outages of Electrical Transmission and Distribution Facilities and Interruptions", IEEE Transactions, Vol. PAS-897, No. 5, May 1968, pp. 1318-1325.
   Members of the Joint Working Group: Z.G. Todd (Chair), D.T. Edgly, M.C. Galyano, W.D. Masters, A.D. Patton, K.G. Richardson, S.W. Shields, A.L. Taalston, A.J. Wood.

Definitions prepared by the Joint Working Group on Performance Records for Optimizing System Design of the Subcommittees on the Application of Probability Methods (A.D. Patton, Chair) and System Planning of the IEEE Power System Engineering Committee.

3. "Suggested Definitions Associated with the Status of Generating Station Equipment and Useful in the Application of Probability Methods for System Planning and Operation". Conference Paper C 72 599-9 1972 IEEE Winter Power Meeting,
   V.M. Cook (Chair), R.J. Ringlee, J.P. Whooley.

Ad Hoc Working Group on Definitions of the Application of Probability Methods Subcommittee (R.J. Ringlee, Chair).

4. "A Four-State Model for Estimation of Outage Risk for Units in Peaking Service". IEEE Transactions on Power Apparatus and Systems, Vol. PAS-91, No. 2, March/April 1972, pp. 618-627.
   A.B. Calsetta (Chair), P.F. Albrecht, V.M. Cook, R.J. Ringlee, J.P. Whooley.

A report prepared by the Task Force on Models for Peaking Service Units of the Application of Probability Methods Subcommittee (R.J. Ringlee, Chair).

5. "Common Mode Forced Outages of Overhead Transmission Lines".
   IEEE Transactions on Power Apparatus and Systems, Vol. PAS-95, No. 3, May/June 1976, pp. 859-863.
   H.G. Saddock (Chair), M.P. Bhavaraju, R. Billinton, C.F. De Sieno, J. Endrenyi, G.E. Jorgensen, A.D. Patton, D.L. Piede, R.J. Ringlee, J.A. Stratton.

A report prepared by the Task Force on Common Mode Outages of Bulk Power Supply Facilities of the Application of Probability Methods Subcommittee (R. Billinton, Chair).

6. "List of Transmission and Distribution Components for Use in Outage Reporting and Reliability Calculations".
   IEEE Transactions on Power Apparatus and Systems, Vol. PAS-95, No. 4, July 1976, pp. 1210-15.
   M.B. Guertin (Chair), P.F. Albrecht, M.P. Bhavaraju, R. Billinton, G.E. Jorgenson, A.N. Karas, W.D. Masters, A.D. Patton, R.J. Ringlee, R.P. Spence.

A report prepared by the Working Group on Performance Records for Optimizing System Design (M.B. Guertin, Chair), of the Application of Probability Methods Subcommittee (R. Billinton, Chair).

7. "Reliability Indices for Use in Bulk Power Supply Adequacy Evaluation".
IEEE Transactions, Vol. PAS-99, No. 4, 1978, pp. 1097-1103.
M.B. Guertin (Chair), P.F. Albrecht, M.P. Bhavaraju, R. Billinton, G.E. Jorgensen, A.N. Karas, W.D. Masters, A.D. Patton, N.D. Reppen, R.P. Spence

A report prepared by the IEEE PROSD Working Group on Performance Records for Optimizing System Design (M.P. Bhavaraju, Chair), of the Application of Probability Methods Subcommittee (R. Billinton, Chair).

8. "Bibliography on the Application of Probability Methods in Power System Reliability Evaluation 1971 – 1977".
IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, No. 6, Nov/Dec. 1978, pp. 2235-2242.
R. Billinton (Chair), D. Taylor, A.D. Patton.

A Report prepared by the Bibliography Task Force of the Application of Probability Methods Subcommittee (R. Billinton, Chair).

9. "IEEE Reliability Test System".
IEEE Transactions, Vol. PAS-98, Nov/Dec. 1979, pp. 2047-2054.
P.F. Albrecht (Chair), M.P. Bhavaraju, B.E. Biggerstaff, R. Billinton, G.E. Jorgensen, N.D. Reppen, P.B. Shortley,

A report prepared by the Reliability Test System Task Force of the Application of Probability Methods Subcommittee (R. Billinton, Chair).

10. "Bibliography on the Application of Probability Methods in Power System Reliability Evaluation 1977 – 1982".
IEEE Transactions on Power Apparatus and Systems, Vol. PAS-103, No. 2, February 1984, pp. 275-282.
R.N. Allan (Chair), R. Billinton, S.H. Lee.

A report prepared by the Bibliography Task Force of the Application of Probability Methods Subcommittee (M.P. Bhavaraju, Chair).

11. "Proposed Terms for Reporting and Analyzing Outages of Electrical Transmission and Distribution Facilities".
IEEE Transactions, Vol. PAS-104, 1985, pp. 337-348.
D.W. Forrest (Chair), P.F. Albrecht, R.N. Allan, M.P. Bhavaraju, R. Billinton, G.L. Landgren, M.F. McCoy, N.D. Reppen.

A report prepared by the Transmission and Distribution Outage Definition Task Force of the Application of Probability Methods Subcommittee (N.D. Reppen, Chair).

12. "Bulk Power System Reliability Concepts and Applications".
IEEE Transactions on Power Systems, Vol. 3, No. 2, February 1988, pp. 109-117.
J. Endrenyi (Chair), M.P. Bhavaraju, K.A. Clements, K,J. Dhir, M.F. McCoy, K. Medicherla, N.D. Reppen, L.A. Salvaderi, S.M. Shahidehpour, C. Singh, J.A. Stratton.

A report prepared by the Task Force on Bulk Power System Reliability of the Application of Probability Methods Subcommittee (N.D. Reppen, Chair).

13. "Bibliography on the Application of Probability Methods in Power System Reliability Evaluation 1982 – 1987".
IEEE Transactions on Power Systems, Vol. 3, No. 4, November 1988, pp. 1555-1564.
R.N. Allan (Chair)", R. Billinton, S.M. Shahidehpour, C. Singh.

A report prepared by the Bibliography Task Force of the Application of Probability Methods Subcommittee (N.D. Reppen, Chair).

14. "Bulk System Reliability – Measurements and Indices".
IEEE Transactions, PWRS, Vol. 4, No. 3, August, 1989, pp. 829-835.
C.C. Fong (Chair), R. Billinton, R.O. Gunderson, P.M. O'Neill, J. Raksany, A.W. Schneider Jr., B. Silverstein.

A report prepared by the Bulk System Reliability Indices Task Force (R. Billinton, Chair), of the Performance Records for Optimizing System Design Working Group (M.G. Lauby, Chair), of the Application of Probability Methods Subcommittee (N.D. Reppen, Chair).

15. "Bulk System Reliability – Predictive Indices".
IEEE Transactions, PWRS, Vol. 5, No. 4, November 1990, pp. 1204-1213.
R.N. Allan (Chair);, R.B. Adler, R. Billinton, C.C. Fong, G.A. Hinschberger, R.P. Ludorf, M.F. McCoy, T.C. Mielnik, P.M. O'Neill, N.D. Reppen, R.J. Ringlee, L. Salvaderi

A report prepared by the Bulk System Reliability Indices Task Force (R. Billinton, Chair) of the Performance Records for Optimizing System Design Working Group (T.C. Mielnik, Chair), of the Application of (Probability Methods Subcommittee (N.S. Rau, Chair).

16. "Current Industry Practices in Bulk Transmission Outage Data Collection and Analysis"
IEEE Transactions on Power Systems, Vol. 7, No. 2, February 1992, pp. 158-166
R.O. Gunderson (Chair), M.P. Bhavaraju, R. Billinton, D. Klempel, M.A. Klopp, M.G. Lauby, R.P. Ludorf, M.F. McCoy, T.C. Mielnik, A.W. Schneider, Jr., E.P. Weber, S.T. White.

A report prepared by the Task Force on Bulk Transmission Outage Data Collection of the Working Group on Performance Records for Optimizing System Design, (T.C. Mielnik, Chair), of the Application of Probability Methods Subcommittee (C.H. Grigg, Chair).

17. "Bibliography on the Application of Probability Methods in Power System Reliability Evaluation 1987 – 1991".
IEEE Transactions on Power Systems, Vol. 9, No. 1, February 1994, pp. 41-49.
R.N. Allan (Chair), R. Billinton, A.M. Breipohl, C.H. Grigg.

A report prepared by the Bibliography Task Force of the Application of Probability Methods Subcommittee (N.S. Rau, Chair).

18. "Bulk Power System Reliability Criteria and Indices, Trends and Future Needs".
IEEE Transactions on Power Systems, Vol. 9, No. 1, February 1994, pp. 181-190.
R.J. Ringlee (Chair), P.F. Albrecht, R.N. Allan, M.P. Bhavaraju, R. Billinton, R.P. Ludorf, B.K. LeReverend, E. Neudorf, M.G. Lauby, P.R.S. Kuruganty, M.F. McCoy, T.C. Mielnik, N.S. Rau, B. Silverstein, C. Singh, J.A. Stratton.

A report prepared by the Bulk System Reliability Indices Task Force (R. Billinton, Chair) of the Performance Records for Optimizing System Design Working Group (T.C. Mielnik, Chair), of the Application of Probability Methods Subcommittee (N.S. Rau, Chair).

19. "Effect of Protection Systems on Bulk Power Reliability Evaluation".
IEEE Transactions on Power Systems, Vol. 9, No. 1, February, 1994, pp. 198-205.
S.M. Shahidehpour (Chair), R. N. Allan, P. Anderson, M. Bhuiyan, R. Billinton, N. Deeb, J. Endrenyi, C. Fong, C.H. Grigg, S. Haddad, J. Hormozi, M.G. Lauby, A.W. Schnieder, Jr., C. Singh, L. Wang.

A report prepared by the Task Force on Protection System Reliability of the Performance Records for Optimizing System Design Working Group (T.C. Mielnik, Chair), of the Application of Probability Methods Subcommittee (N.S. Rau, Chair) .

20. "Pooling Generation Unit Data for Improved Estimates of Performance Indices".
IEEE Transactions on Power Systems, Vol. 10, No. 4, 1995, pp. 1912-1917.
A.M. Breipohl (Chair), P. Albrecht, R.N. Allan, S. Asgarpoor, M. Bhavaraju, R. Billinton, M. Curley, C. Heising, M. Mazumdar, M. McCoy. R. Niebo, A.D. Patton, N.S. Rau, R.J. Ringlee, A.W. Schneider Jr., C. Singh, L. Wang, M. Warren, P. Wong.

A report prepared by the Task Force on Generator Data Pooling of the Performance Records Working Group (C. Grigg, Chair) of the Application of Probability Methods Subcommittee (N.S. Rau, Chair).

21. "Reporting Bulk Power System Delivery Point Reliability"
IEEE Transactions on Power Systems, Vol. 11, No. 3, August 1996, pp. 1262-1868.
E. Weber (Chair), B. Adler, R.N. Allan, S.K. Agarwal, M.P. Bhavaraju, R. Billinton, M. Blanchard, R. d'Aquanni, R. Ellis, J. Endrenyi, D. Garrison, C.H. Grigg, M. Luchmann, J. Odem, G. Preston, N.S. Rau, L. Salvaderi, M. Schilling, A. Vojdani, T. White.

A report prepared by the Task Force on Bulk Power System Reliability Reporting Guidelines of the Performance Records Working Group (C. Grigg, Chair) of the Application of Probability Methods Subcommittee (C. Singh, Chair).

22. "Experience with Application of Reliability and Values of Service Analysis in System Planning.
IEEE Transactions on Power Systems. Vol. 11, No. 3, August 1996, pp. 1489-1496.
A.F. Vojdani (Chair), R.D. Williams, W. Gambel, W. Li, L. Eng.

A report prepared by the Task Force on Utility Application of Reliability in Least-Cost System Planning of the Application of Probability Methods Subcommittee (C. Singh, Chair).

23. "Reliability Issues in Today's Electric Power Utility Environment".
IEEE Transactions on Power Systems, Vol. 12, No. 4, November 1997, pp. 1708-1714.
R. Billinton (Chair), L. Salvaderi, J.D. McCalley, H. Chao, Th. Seitz, R.N. Allan, J. Odem, C. Fallon.

A report prepared by the Reliability, Risk and Probability Applications Subcommittee (C. Singh, Chair).

24. "Bibliography on the Application of Probability Methods in Power System Reliability Evaluation 1992 – 1996".
IEEE Transactions on Power Systems, Vol. 14, No. 1, February 1999, pp. 51-57
R.N. Allan (Chair), R. Billinton, A.M. Breipohl, C.H. Grigg.

A report prepared by the Bibliography Task Force of the Reliability Risk and Probability Applications Subcommittee (C. Singh, Chair).

25. "The IEEE Reliability Test System – 1996".
IEEE Transactions on Power Systems, Vol. 24, No. 3, August 1999, pp. 1010-1020.
C.H. Grigg, and P. Wong (Co-Chairs), P.F. Albrecht, R. N. Allan, M.P. Bhavaraju, R. Billinton, Q. Chen, C.C. Fong, S. Haddad, P.R.S. Kuruganty, W. Li, R. Mukerji, A.D. Patton, N.S. Rau, N.D. Reppen, A.W. Schneider Jr., S.M. Shahidehpour, C. Singh.
A report prepared by the Reliability System Task Force of the Probability Applications Working Group (C. Grigg, Chair) of the Reliability, Risk and Probability Applications Subcommittee (C. Singh, Chair).

26. "The Present Status of Maintenance Strategies and the Impact of Maintenance on Reliability".
IEEE Transactions on Power Systems, Vol. 16, No. 4, November 2001, pp. 638-646.
J. Endrenyi (Chair)", S. Aboreshaid, R.N. Allan, G.J. Asgarpoor, R. Billinton, N. Chowdhury, E.N. Dialynas, M. Fipper, R.H. Fletcher, C.H. Grigg, J. McCalley, A.P. Meliopoulos, T.C. Mielnik, P. Nitu, N.S. Rau, N.D. Reppen, L. Salvaderi.
A report prepared by the Task Force on Impact of Maintenance Strategy on Reliability of the Probability Applications Working Group (C.H. Grigg, Chair), of the Reliability, Risk and Probability Applications Subcommittee (C. Singh, Chair).

27. "Probabilistic Security Assessment for Power System Operations".
PES General Meeting, 2004.
J. McCalley (Chair), S. Asgarpoor, L. Bertling, R. Billinton, H. Chao, J. Chen, J. Endrenyi, R. Fletcher, A. Ford, C. Grigg,, G. Hamoud, D. Logan, A.P. Meliopoulos, M.N. Rau, L. Salvaderi, M. Schilling, Y. Schlumberger, A. Schneider, C. Singh.
A report prepared by the Task Force on Probabilistic Aspects of Reliability Criteria, (J. McCalley, Chair), of the Reliability, Risk and Probability Applications Subcommittee (J. McCalley, Chair).

28. "Initial Review of Methods for Cascading Failure Analysis in Electric Power Transmission Systems",
PES General Meeting, 2008. Conference Paper No. 08GM0856
A report prepared by the IEEE PES CAMS Task Force on Understanding, Prediction, Mitigation and Restoration of Cascading Failures.

29. "On Use of Reliability Test Systems: A Literature Survey".
PES General Meeting, 2011. Conference Paper No. 2011GM1328.
L. Bertling (RDTS TF Chair), P. Bangalore, L. Tuan,

30. "Overview of Common Mode Outages in Power Systems".
PES General Meeting 2012. Conference Paper No. 2012GM1460.
M. Papic (PACME WG Chair). K. Awodele, R. Billinton, C. Dent, D. Eager, G. Hamoud, G.P. Jirutitijaroen, M. Kumbale, J. Mitra, N. Samaan, A. Schneider, C. Singh,

31. "Effects of Dependent and Common Mode Outages on the Reliability of Bulk Electric System – Part I: Basic Concepts".
PES General Meeting 2014. Conference Paper No. 14PESGM0423
M. Papic, (PACME WG Chair); S. Agarwal, J. Bian, R. Billinton, C. Dent, I. Dobson, P. Jirutitijaroen, W. Li, T. Menten, J. Mitra, A. Schneider, C. Singh, V. Vadlamudi,

32. “Effects of Dependent and Common Mode Outages on the Reliability of Bulk Electric System – Part II: Outage Data Analysis”.
PES General Meeting 2014. Conference Paper No. 14PESGM0424
M. Papic, (PACME WG Chair); S. Agarwal, J. Bian, R. Billinton, C. Dent, I. Dobson, P. Jirutitijaroen, W. Li, T. Menten, J. Mitra, A. Schneider, C. Singh, V. Vadlamudi

7. Standards

7.1 Introduction

The IEEE is a world-class organization in the creation and maintenance of standards, with these being recognized by many utilities and technical organizations around the world. Each committee and subcommittee is responsible for creating and maintaining standards relevant to their scope. The APM and RRPA Subcommittees have been responsible for developing two relevant standards, namely IEEE Standard 762 and IEEE Standard 859. The histories of these are presented in the next two subsections.

7.2 IEEE Standard 762

The APM Subcommittee created the Ad Hoc Working Group on Definitions in 1968 at the IEEE Winter Power Meeting in New York to prepare a document on required reliability definitions associated with generating station equipment that could be used in the application of probability methods in system planning and operation. The Ad Hoc Working Group presented its work in the following Conference Paper given at the 1972 IEEE Winter Power Meeting:-

> "Suggested Definitions Associated with the Status of Generating Station Equipment
> and Useful in the Application of Probability Methods for System Planning and Operation"
> C 72 599-9
> V.M. Cook (Chair), R.J. Ringlee, J.P. Whooley
> Ad Hoc Working Group on Definitions of the Application of Probability Methods
> Subcommittee (R.J. Ringlee)

The Ad Hoc Working Group (V.M. Cook, R.C. Chan, R.J. Ringlee) continued its work in this area and presented updates at subsequent meetings. Revision No. 8 was presented at the January 31, 1977 Meeting of the APM Subcommittee. In view of ongoing parallel work being conducted by the Ad Hoc ANSI Steering Committee on Power Plant Productivity and Reliability Definitions, it was decided to delay publication until agreement was reached. Draft Revision 1 of the ANSI Steering Committee on Power Plant Data Systems Ad Hoc Committee on Power Plant Productivity was issued to members of the APM Ad Hoc Committee and several other APM Subcommittee members prior to the July 28, 1977 meeting in Mexico City.

The activities of the ANSI Committee and the then-present status of the Power Plant Productivity Definitions were briefly summarized by R.J. Ringlee at the January 30, 1978 meeting of the APM Subcommittee. This summary included a brief comment on the APM Subcommittee involvement in this area prior to formation of the ANSI Committee. J. Fragola informed the Subcommittee of the decision taken at the January 26, 1978 meeting of the ANSI group regarding the possibility and desirability of appending the Ad Hoc ANSI Committee to the APM Subcommittee for the purpose of transforming the present definitions into an IEEE Standard. The Subcommittee expressed their general approval of this intent and requested Chairman R. Billinton to act accordingly when approached by the Ad Hoc ANSI Committee Chairman E.E. Haddad.

The next meeting of the APM Subcommittee was scheduled for October 3, 1978 in Alexandria, Minnesota. It was reported to the Power System Engineering Committee at their meeting in Los Angeles on July 28, 1978 that the ANSI Committee was in the process of preparing a final draft of this report and that it would be available for circulation to APM Subcommittee members prior to the October Meeting. The final draft of the proposal prepared by the ANSI Ad Hoc Committee on Power Plant Productivity Definitions was circulated to all APM Subcommittee members prior to the meeting by P.F. Albrecht. Approval had been received from the IEEE

Standards Board for the development of a Standard on this subject. In order to facilitate this, the ANSI Committee became a Task Force of the APM Subcommittee. Written submissions on the draft received from APM Members were ordered and presented by P.F. Albrecht at the session on Monday morning, October 2, 1978. These topics were discussed at length at this session and in a further session on Monday afternoon. Specific comments and suggested modifications were prepared and discussed at a session commencing at 8:30 p.m. on Tuesday evening. The session concluded at 2:30 a.m. P. Albrecht subsequently compiled a list of comments and suggested changes and this material was forwarded to E.E. Haddad, Task Force Chairman for consideration by the Task Force at their next meeting.

The final draft of the Task Force report was presented by P.F. Albrecht at the February 7, 1979 meeting of the APM Subcommittee in New York. A copy was circulated to each member of the APM Subcommittee on January 19, 1979. The changes incorporated since the discussion in Alexandria were detailed by P.F. Albrecht. Several minor corrections were noted by members of the Subcommittee and were subsequently incorporated by P.F. Albrecht. It was unanimously agreed that the corrected report should go forward for balloting by the PSE Committee. Chairman R. Billinton agreed to co-ordinate this with P.F. Albrecht.

The balloting by the PSE Committee on this proposed Standard was initiated and as of June 22, 1979, of the 96 members, 63 voted Yes, 15 voted No, and 18 did not vote. Several additional votes were subsequently received. This response was sufficient to permit the activity to proceed to the next phase involving reconciliation by the Power Plant Productivity Task Force of the comments contained in the negative ballots.

Chairman M.P. Bhavaraju formally informed the APM Subcommittee at the February 3, 1981 meeting in Atlanta that the Power Plant Productivity Definitions had been published as the following Trial-Use Standard (762-1980):-

> "IEEE Trial-Use Standard Definitions for Use in Reporting Electric Generating
> Unit Reliability, Availability and Productivity"
> IEEE Standard 762-1980, Published December 18, 1980
> E.E. Haddad (Chair), P.F. Albrecht, G.H. Applegren, B.E. Biggerstaff, S.M.
> DeSalvo, J.R. Fragola, J. Krasnodebski, W.L. Lavallee, R.J. Niebo, R.J. Ringlee,
> J.L. Weiser, J.P. Whooley,
> Power Plant Productivity Definitions Task Force of the APM Subcommittee.

M.P. Bhavaraju stated that comments on the Standard were invited by IEEE, and that the Task Force working on this project were charged with reviewing any comments and revising the Standard, if necessary, by the end of the trial period (December 1981).

In 1983, M.P. Bhavaraju replaced E.E. Haddad as the Chair of the Power Plant Productivity Task Force. The task force resolved the comments received on the Trial Standard and re-balloted the standard in 1984. The standard was finally approved by IEEE Standards Board in September 1985, by American National Standards Institute in February 1986, and was published as ANSI/IEEE Standard 762-1987 "IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity".

Standard 762 was further considered by the APM Subcommittee at the IEEE Winter Power Meeting in New York held in January 1992. The Subcommittee unanimously voted to reaffirm the Standard. The reaffirmation process involved the resolution of a small number of comments and suggested modifications. The APM Subcommittee was informed by the Standards Board at the IEEE Winter Power Meeting in Columbus held in February 1993 that the reaffirmation was approved.

Subsequently it became clear that Standard 762 needed considerable modification to meet the needs of a changing electric power industry and a major revision was initiated at the IEEE Summer Power Meeting held in Vancouver in July, 2001.

Revision of IEEE Standard 762 (2002-2005)

A. Ford agreed to Chair the Working Group for revising the Standard; R. Fluegge served as Secretary. The WG met at the regular PES conferences as well as over several conference calls held between July 2002 and June 2005. Throughout the process, G.M. Curley served as liaison with NERC, maintaining consistency between GADS reporting practices and Standard 762. He also provided input on UNIPEDE practices.

Four key changes were made in Standard 762:

- Demand-based indexes were defined as a measure of probability of forced outage 'when needed'.
- Un-weighted (time-based) and capacity-weighted indexes were defined suitable for pooling data on multiple generating units.
- Indexes were defined to account for the exposure to fail during non-generating functions such as pumping hours and synchronous condensing hours.
- Outside Management Control (OMC) conditions such as natural disasters, loss of transmission lines, and strikes were defined.

The revision was completed in late 2005 and the new version was balloted on in June 2006. It was approved by the IEEE in September 2006 and by the ANSI in December 2006.

In subsequent RRPA meetings, discussions continued regarding the need to include variable energy resources in the scope of the Standard. There was debate as to whether an extension of the Standard should be developed or a stand-alone guide should be prepared. In July 2010 a Task Force was formed, Chaired by G.M. Curley, to develop a guide to address wind generation compliance related to IEEE Standard 762 and the reporting of outage events. However, this activity has not progressed much. Meanwhile, the Standard 762-2006 became due for reaffirmation. A Task Force was formed with A.W. Schneider as Chair for this purpose. The 2006 version of the Standard was successfully reaffirmed in December 2011, thereby extending its status as an active standard until 2016. Reviews lead by A.W. Schneider are presently underway to revise Standard 762 with the specific intent to incorporate renewable generation and other pertinent and related facilities.

7.3 IEEE Standard 859

The APM Subcommittee was advised at the October 3, 1978 Meeting in Alexandria, Minnesota that the IEEE had authorized a revision of IEEE Standard 346-1973, IEEE Standard Definitions in Power Operations Terminology Including Terms for Reporting and Analyzing Outages of Electrical Transmission and Distribution Facilities and Interruptions to Customer Service. The purpose of revising this standard was to include definitions of a broader scope of outage events and to specify certain common terms and indices to provide a basis for information exchange. The revision task was assigned to the Performance Records for Optimizing System Design (PROSD) Working Group which set up a Task Force to review the existing standard and subsequently draft a new or revised standard.

After much deliberation it was decided to eliminate any consideration of distribution systems and to focus on transmission facilities; the reasoning being that transmission systems and distribution systems are different in design and purpose, and therefore could not reasonably be described by the same terms and definitions. This

decision had two consequences: (a) distribution systems should be considered separately and later, (b) the transmission standard should be assigned a new number to prevent confusion between the present work and the previous Standard 346. The project was assigned as Standard 859 and designated as IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electrical Transmission Facilities.

The Task Force then created a series of drafts over a significant period of time. Each draft increased the number of terms and definitions with some terms and definitions added to qualify others. There were many reasons for this including individuals having different perspectives of needs and applications, the need for measuring different design and performance parameters, utilities having different requirements and operational considerations, etc. All these differences were understandable, but the resulting document became one that would not be useful or useable, nor a document that all could agree. For this reason, it was agreed that a draft was required that itemized only those terms and definitions that could be considered basic, fundamental and acceptable by all. Individual organizations and utilities could then build on these basic terms and definitions to suit their own requirements provided these did not conflict with those in the proposed standard. To achieve this objective, a small sub-TF comprising two global industry experts (R. Billinton and R.N. Allan) were authorized to review the then-current draft and identify those terms and definitions that satisfied the above requirements. This sub-TF duly reported back to the main TF with their proposed set of terms and definitions. Their proposed draft was unanimously accepted with only a few small changes needed.

This final version was submitted for balloting to the Standards Board for the required coordination and a ballot total of 75% was received. Only two negative ballots were received, which changed to acceptance after minor modifications. Standard 859-1987 was approved by the IEEE Standards Board on June 11, 1987, as:-

> "IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electrical Transmission Facilities"
> IEEE Standard 859-1987. Published July 11, 1987
> M.G. Lauby (Chair), P.F. Albrecht, R.N. Allan, M.P. Bhavaraju, R. Billinton, D.W. Forrest, G.I. Landgren, M.F. McCoy, N.D. Reppen, A.W. Schneider, Jr.
> Transmission and Distribution Outage and Interruption Definitions Task Force of Performance Records for Optimizing System Design Working Group of the APM Subcommittee.

The APM Subcommittee continued its interest in Standard 859-1987 and A.W. Schneider was assigned at the February 6, 1991 IEEE WPM to lead a group to review and/or reaffirm Standard 859-1987. The APM Subcommittee unanimously approved a motion to reaffirm Standard 859-1987 at its meeting at the IEEE SPM held in July 1993 in Vancouver. The IEEE Standards Board advised the APM Subcommittee that Standard 859-1987 had been officially reaffirmed on February 1, 1994 at the IEEE WPM in New York.

The RRPA SC was informed at the 2001 SPM in Vancouver that Standard 859-1987 had expired and needed to be re-instated in an unmodified form prior to making any modifications. The balloting processes began on January 3, 2002 and required 30 days. The ballots were completed successfully and Std. 859-1987 was subsequently re-installed for an additional five years. The reaffirmation of Std. 859-1987 was approved by the IEEE-SA Standards Board on March 21, 2002.

The RRPA SC formed a WG at the 2005 GM in San Francisco to consider possible revision of IEEE Std. 859-1987. This WG was titled "IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electric Transmission Facilities" and chaired by A.W. Schneider. After considerable discussion, the WG completed its work and recommended at the 2006 GM in Montreal that Standard 859-1987 be reaffirmed without change. The RRPA SC subsequently voted unanimously to recommend reaffirmation of

the existing standard. It was reported by A. Ford at the 2008 IEEE-PES GM in Pittsburgh that Std. 859-1987 was now reaffirmed and would stand for the next five years.

The IEEE-SA Standards Board announced a new process on October 18, 2011 for maintaining active standards. This new process took effect on January 1, 2012. The major changes include extending the maintenance timeline of IEEE standards from five years to ten years and phasing out the reaffirmation and stabilizing processes by 2013. The focus is placed primarily on the revision process, and revision or withdrawal are the only available actions for maintaining active standards. In order to remain an active standard the RRPA SC is required to revise Std. 859-1987 by December 31, 2018.

A process was initiated at the 2007 IEEE-PES GM in Tampa to assemble a TF on "Developments in Definitions and Terminology Associated with Collection of Transmission Outage Data". This process will now be renewed in the near future to prepare a revised Std. 859 for review and balloting prior to the noted deadline. Reviews lead by C. Dent are presently underway to assess the relevance of Standard 859 in regard to future requirements and to determine the need for substantive changes to meet these requirements.

8. Liaison Activities

The scope of the APM Subcommittee noted in Section 3.1 includes cooperation with IEEE Committees, other professional societies and technical organizations in collecting and analyzing performance data required to apply probabilistic techniques. This mandate extends from the initial creation of the APM SC to the present RRPA SC. The scope also includes a broad range of possible liaisons that involves more than just the basic requirement of collecting and analyzing equipment and system performance data.

The initial liaison between the APM SC and the Edison Electric (Power) Institute (EEI) was created by the need for suitable equipment data that could be used for probabilistic evaluation, in addition to providing useful equipment performance data. The first APM SC was a joint committee with the EEI and chaired by G. Calabrese, a leading proponent of probabilistic analysis. As shown in Section 2, the liaison with the EEI was an important component in the successful evolution of performance data evaluation and application and lasted for many years.

The creation of the IEEE in 1963 and the establishment of the APM SC under the Power Engineering Committee created a wide range of opportunities for cooperation with other IEEE groups, in addition to liaisons with external technical organizations. It is not possible to list all the liaisons enjoyed by the APM/RRPA SC over the years. Instead, the following illustrates a range of some of the major and minor liaison activities that took place.

The first SC paper listed in Section 6 illustrates a liaison with a different IEEE Committee and the continued cooperation between the APM SC and the EEI. As noted in Section 3, the EEI liaison played an important role in the subsequent work on peaking unit model development and the creation of IEEE Std. 762.

As noted in Section 3.1, the APM SC presented its first tutorial in 1971 in cooperation with the Power Engineering Education Committee and the IEEE Transmission and Distribution Committee. Similar arrangements existed for subsequent tutorials noted in Section 5.

Liaisons between external groups and organizations were often maintained by having an APM SC member attend external meetings and report to the APM SC at its next meeting. The following paragraphs summarize some of these.

P.F. Albrecht served as APM SC liaison to Subcommittee SC-5 Reliability of the IEEE Nuclear Power Engineering Committee (NPEC). The NPEC WG on Failure Rate Manual included both P.F. Albrecht and R.J. Ringlee from the APM SC as liaison members. This activity continued for several years. The title of the proposed report was later changed from "Reliability Data Manual" to "Guide for the Collection and Presentation of Reliability Data for Nuclear Power Plants" and considered as an IEEE Standard.

In 1974, A.D. Patton served as a liaison member with the Industrial Application Society (IAS) and reported to the APM SC on Society activities and particularly on the surveys being conducted on electric power interruption costs. The APM SC was asked to review the "Reliability Measurement and Prediction" report prepared by the EEI Reliability Task Force and the APM SC Chair, R.J. Ringlee, submitted some suggestions for possible changes.

As noted in Section 7 on Standards, R.J. Ringlee served as a liaison with the Ad Hoc ANSI Steering Committee on Power Plant Productivity and Reliability Definitions, which ultimately resulted in this group assisting in the development of IEEE Std. 762.

P.F. Albrecht served as the APM SC representative on a TF on Coordination of Availability Engineering Activities (CAEA) Among IEEE PES Technical Committees. A draft report was prepared based on the individual PES Committee reports with the intention of forwarding possible recommendations for the Technical Operations Department (TOD).

R. Billinton served as the APM SC representative on a TF on Probabilistic Security Assessment sponsored by the System Dynamic Performance SC which resulted in a panel session on this subject at the 1981 WPM in Atlanta.

M.P. Bhavaraju reported to the APM SC at the 1981 WPM in Atlanta that a team set up by the APM and System Planning SC had reviewed Volume 2 of the PURPA 209 report and had sent comments to the U.S. Department of Energy. He also reported that Draft Std. 831, "Guide for Qualitative Common Cause Failure Analysis of Engineering Systems" prepared under the IEEE Reliability Society was reviewed and commented on by selected members of the APM SC.

The APM SC and RRPA SC had considerable association over a number of years with the HVDC Reliability Task Force through liaison member J. Hormozi, who reported extensively at APM and RRPA SC meetings on their activities regarding future panel sessions and proposed reports and papers. J. Hormozi also advised the APM SC of relevant papers such as "A Summary of North American HVDC Reliability Specifications" presented at the 1992 SPM.

Several APM SC members (R.N. Allan, M.P. Bhavaraju, R. Billinton, J. Endrenyi, L. Salvaderi) provided relevant current information on CIGRE activities to the APM SC, particularly with respect to CIGRE WG 38.03. This working group published a guide showing how to apply reliability to a system. The APM SC was also briefed on the CIGRE reliability symposium held in Montreal.

The following list briefly highlights some of the liaisons created by the RRPA SC.

- A one day tutorial on Risk Assessment and Financial Management coordinated by P. Nitu and co-sponsored by the System Economics SC was presented at the 1999 WPM.
- The RRPA SC was represented on the Power System Planning and Implementation Committee by G. Hamoud, M. Papic and W. Li, each for three year terms.
- The RRPA SC maintained contact with the Probability Methods Applied to Power Systems (PMAPS) conference series through presentations on timing and conference planning. In particular, a meeting of the RRPA SC was held at the PMAPS Conference in Ames, Iowa in September 2004.
- The RRPA SC has been represented on the Wind Power Coordination Committee (WPCC) by C. Dent. The WPCC is a coordinating committee with the goal of coordinating, stimulating and assisting technical work in the area of wind power and the existing PES committees.
- The activities of the RRPA SC TF on Reliability of Distribution Systems were coordinated with related activities within the Computer and Analytical Methods (CAMS) SC by L. Bertling, who also served on the Smart Grid Coordinating Committee.
- Standards Coordinating Council (SCC) – Stds. 762 and 859 - A.W. Schneider, C. Dent.
- PSACE Committee Activities - J. Mitra.

9. Awards and Recognitions

9.1 IEEE Fellow Awards

Election to the grade of Fellow of the IEEE is a recognition of excellence. Fellows are outstanding individuals who have demonstrated exceptional performance in the fields of electrical, electronic, and software engineering.

The following list are IEEE PES members of the APM/RRPA Subcommittee who were elected to the grade of Fellow since 1974:-

1974 - R.J. Ringlee
1978 - R. Billinton
1980 - A.D. Patton
1980 - P.F. Albrecht
1987 - J. Endrenyi
1987 - M.P. Bhavaraju
1988 - R.N. Allan
1990 - V.T. Sulzberger
1990 - N.D. Reppen
1991 - C. Singh
1993 - A. Meliopoulos
1998 - N.S. Rau
1999 - G. Anders
2000 - A.M. Leite Da Silva
2002 - W. Li
2004 - J. McCalley
2005 - M. Schilling
2006 - A. Chowdhury
2006 - I. Dobson
2012 - M.G. Lauby
2013 - L. Goel
2014 - M. Fotuhi-Firuzabad

9.2 Outstanding Young Engineer Award (prior to 2008 named the Walter Fee Outstanding Young Engineer Award)

The IEEE PES Outstanding Young Engineer Award was established to recognize engineers 35 years of age or under "for outstanding contributions in the leadership of technical society activities including local and/or transnational PES and other technical societies, leadership in community and humanitarian activities, and evidence of technical competence through significant engineering achievements."

The following IEEE PES members of the RRPA Subcommittee received the Outstanding Young Engineer Award:-

1992 – M.G. Lauby
2003 – R.E. Brown
2012 – A.D. Dominguez-Garcia

9.3 IEEE Power & Energy Society Lifetime Achievement Award

2014 - V.T. Sulzberger

For pioneering leadership in developing reliability analysis methods, performing reliability assessments of interconnected transmission systems, and establishing transmission reliability planning standards applied in North America during a 50-year career.

9.4 IEEE Charles Proteus Steinmetz Award

2008 – R. Billinton

For contributions and influence in the development of power system reliability standards.

9.5 IEEE Richard Harold Kaufmann Award

2000 – A.D. Patton

For contributions to power system reliability analysis and its application to industrial power facilities.

9.6 IEEE PES Outstanding Power Engineering Educator Award

For outstanding contributions to power engineering education:-

1992 – R. Billinton

1998 – C. Singh

2009 – L. Goel

9.7 IEEE PES Roy Billinton Power System Reliability Award

IEEE PES established the IEEE PES Roy Billinton Power System Reliability Award in 2009 to honour Roy Billinton and recognize outstanding individuals for their achievements in reliability of electric power systems. The RRPA subcommittee is proud of the establishment of this major and unique award in the power system reliability area, which represents recognition of contributions to the industry made by the reliability community including the RRPA subcommittee.

2010 – C. Singh

For contributions to the methodological developments, education and practice of power system reliability evaluation

2011 – W. Li

For contributions to theoretical methods, computing tools, databases and industrial applications in reliability and probabilistic planning of power systems.

2012 – A.M. Leite Da Silva

For contributions to analytical and Monte Carlo simulation based methods in power system reliability assessment

2013 – R.N. Allan

For his inspiring vision of a safer, more efficient and reliable electric power system, his personal involvement with new technologies and his energetic support of power engineering students and professionals.

2014 – M.G. Lauby
For contributions in the development and application of techniques for bulk power system reliability assessment, composite reliability, and data analysis.

2015 – M.P. Bhavaraju
For pioneering contributions to applications of reliability methods to energy and capacity markets and leadership in gaining industry acceptance of such methods in North America.

9.8 IEEE PES Prize Paper Award

Each Technical Committee is entitled and encouraged to present an award to the author(s) of an outstanding technical paper. Committees can choose to submit the same paper for the IEEE PES Prize Paper Awards. The following colleagues received the award:-

1976 - L. G. Leffler, G. A. Cucchi, R. J. Ringlee, N. D. Reppen, and R. J. Chambliss
Operating Reserve and Generation Risk Analysis for the PJM Interconnection

2014 – W. Wangdee and R. Billinton
Probing the Intermittent Energy Resource Contributions from Generation Adequacy and Security Perspectives

9.9 IEEE-PES Technical Committee Recognition Award

2015 – R. Billinton

For 50 Years of Involvement with the APM/RRPA Subcommittee.

9.10 IEEE-PES Technical Committee Recognition Award

2005 - IEEE Standard 762 Working Group (Chair: A. Ford).

2007 - Electric Delivery System Reliability Tutorial Working Group (Chair: J. Mitra)
.
2015 - Understanding, Prediction, Mitigation and Restoration of Cascading Failures (Chair: M. Papic).

10. Panel Sessions

1. 82 WM 147 7 September 1982. "Bulk Power System Reliability Assessment. Why and How? Part I: Why?" A Panel Discussion sponsored by the Application of Probability Methods Subcommittee. Chair: J. Endrenyi, P.F. Albrecht, R. Billinton, G.E. Marks, N.D. Reppen, and L. Salvaderi.

2. Panel Session: "Utility Application of Reliability in Least Cost System Planning", 1993 PES SPM, Chair: A. F. Vojdani.
   a) Introduction. A.F. Vojdani
   b) Value-of-Service Based Generation Reliability Analysis. R.D. Williams
   c) Development of Reliability Based Transmission Planning Techniques for the Southern Company. W. Gambel.
   d) Reliability Planning: BC Hydro's Practice. W. Li.
   e) Value-Based Transmission Reliability Studies Using a Composite System Reliability Evaluation Program. L. Eng.
   f) Value-Based Planning Lessons Learned at Duke Power Company. B.N. Suddeth.

3. Panel Session: "Reliability Issues in Todays' Electric Power Utility Environment". 1996 PES WPM. Later published as a paper. R. Billinton, L. Salvaderi, J.D. McCalley, H. Chao, Th. Seitz, R.N. Allan, J. Odom, C. Fallon, "Reliability Issues in Todays' Electric Power Utility Environment", IEEE Transactions on Power Systems, Vol. 12, No. 4, November 1997.

4. Panel Session: "What is Planning in a Competitive Industry". 1996 PES SPM, Chair: D. Logan, R. Bordely, J. Eschbach, D. Fromholzer, T. Myers, R. Phillips.

5. Panel Session: "Power System Dynamic Performance with Reference to Recent Cascading Outages", 1997 PES WPM. Chair: C.W. Taylor.
   a) Analysis of the Power Blackout of June 8, 1995 in the Israel System. Y. Hain.
   b) Overview of Recent WSCC Cascading Outages, C.W. Taylor,
   c) NERC Perspective, V.C. Sulzberger,
   d) NERC Monitoring of Disturbances, J. F. Hauer,
   e) Simulation of July 2 and August 10 Power Failures. K. Morrison, M. V. Venkatasubramanian, B.H. Chowdhury.
   f) Transmission Line Protective Relaying Considerations. G. L. Michel, M. Adibi, J.C. Agee, B.L. Agrawal, S.R. Brockshink, J.H. Doudna, K. Kozminski.
   g) Pacific Gas & Electric HVDC, SVC and TCSC Performance, C.W. Taylor.
   h) Advance Reactive Power Compensation Control, M. Bahrman.
   i) Dynamic Security Assessment, Y. Mansour.
   j) Technical Issues Raised by the Western System Outages of July 2 and August 10, 1996, G. Cauley.

6. Panel Session. "Risk-Based Dynamic Security Assessment". 1999 PES SPM, Chair: P. Kundur.
   a) An Overview of Risk Based Security Assessment. J.D. McCalley, V. Vittal, N. Abi-Samra
   b) Voltage Risk Assessment. J.D. McCalley, V.Vittal, N. Abi-Samra, H. Wan, Y. Dai.
   c) An Application of a Risk Based Methodology for Defining Security Rules against Voltage Collapse.
   C. Lebrevelec, Y. Schlumberger, M. De Pasquale.

d) WSCC Voltage Stability Criteria, Undervoltage Load and Shedding Strategy, and Reactive Power Reserve Monitoring Methodology. A. Abed.
e) Dynamic Security Risk Assessment. A.M.L. Da Silva, J.L. Jardim, A.M. Rei, J.C.O. Mello.
f) Transient Instability Risk Assessment. V. Vittal, J.D. McCalley, V.Van Acker, W.Fu, N. Abi-Samra.
g) Probabilistic Angle Stability Index. J.A. Momoh, M. Elfayoumy, W. Mittelstadt, Y.V. Makarov.
h) A Framework for Incorporating Voltage and Transient Stability Considerations in Well-Being Evaluation of Composite Power Systems. S. Aboreshaid, R. Billinton.

7. Panel Session. "Are Generating Capacity Markets Working?" 2000 PES WPM, Singapore.
Chair: D, Logan, Speakers: G. Doorman, N., N. Rau, D. Shirmohammadi. G. Thorpe

8. Panel Session: "Reliability Information in a Competitive Market", 2000 IEEE PES SPM,
Chair: D. Logan
a) Network Augmentation for Reliability Reasons, H. Outhred
b) European Perspective, K. Staschus
c) Power Marketing Perspective, P. Barber
d) Equipment and System Reliability Data Collection in Canada, R. Billinton
e) GADS and the Competitive Market, M. Curley
f) U.S. Utility Reliability Data, D. Logan

9. Panel Session: "Market Based Generation Adequacy: How do we achieve it?" 2001 IEEE PES WPM,
Chair: M.P. Bhavaraju
a) A Generating Company's Perspective, B. Bleiweis
b) An Independent System Operator's Perspective, A. Ford
c) The Naysayers Have Been Proved Wrong, D. Logan

10. Panel Session. "Reliability Centered Maintenance. 2005 PES GM. Chair: L. Bertling,
a) On Evaluation of RCM for Maintenance Management of Electric Power Systems, L. Bertling
b) **E**xperience of RCM for Substation Equipment at Fingrid, P. Yli-Salomaki
c) Measuring the Impacts of an RCM Program on Power System Performance, I.P. de Siqueira
d) Managing the Introduction of RCM - Experiences from a Swedish Hydro Power Company, F. Backlund.
e) Reliability – Centered Asset Maintenance Method for Assessing the Impact of Maintenance in Power Distribution Systems, L. Bertling, R.N. Allan, R. Eriksson.
f) Maintenance Management as Part of Asset Management, G. Cliteur.

11. Panel Session, "Prevention and Mitigation of Cascading Scenarios and Blackouts". 2006, Dallas T & D Conference and Exhibition, Chair: J. McCalley.
a) A Comprehensive Approach for Prevention and Mitigation of Power Grid Blackouts. P. Kundur.
b) The Role of Real-time Field Data Processing in Monitoring and Mitigating Cascading Events, M. Kezunovic.
c) Wide Area Protection and Emergency Control. D. Karlsson.
d) Prevention vs. Coping Strategies. S. Talukdar.
e) Toward Understanding Catastrophic Failure Modes in Power Systems. J. Mitra, S. Ranade.
f) Defense Plan Against Wide Area Disturbances. D. Novosel.

g) Preventing Blackouts by Means of Enhanced Control. M. Ilic.
h) The Black Hole in System Security – Emergency Reactive Power Control. W. Lachs.
i) Operational Defense of Power System Cascading Outages. J. McCalley.

12. Panel Session, "Updated Data for Use in G&T Reliability Models". 2006 PES GM;
Chair: A. A. Chowdhury.
a) 06GM0478 - Are Reliability Measures Unreliable, R. Richwine
b) 06GM0501 - Transmission Reliability Performance Assessment, E. Kram.
c) 06GM0507 - Impacts of Deregulation and Power Market Design on Electric Supply Reliability Measures and Indices, S. Stallard
d) 06GM1034 - Outage Data Concepts for Generation and Transmission Equipment, D. Koval, A.A. Chowdhury
e) 06GM1164 - Power Plant Performance Indices in New Market Environment, IEEE Standard 762 Working Group Activities and GADS Database, G. Curley.

13. Panel Session, "Towards a Balanced, Flexible, and Diversified Energy Portfolio". 2006 PES GM.
Chair: P. Nitu.
a) 06GGM1101 - Contributions of Renewable Energy Resources to Resource Diversity. G. Gross.
b) 06GM1111 - Better Prediction Models for Renewables by Training with Entropy Concepts. V. Miranda.
c) 06GM1248 - An Analysis of the Impacts of Wind Generation on the Ontario Electricity System. L. Lauzon, M. Brower, B. Bailey, P. Nitu
d) 06GM0959 - Determining and Exploiting the Distribution Function of Wind Power Forecasting Error for the Economic Operation of Autonomous Power Systems, A. Tsikalakis, Y. Katsigiannis, P. Georgilakis, N. Hatziargyriou.
e) 06GM1043 - A Quantitative Analysis of the Net Benefits of Grid Integrated Wind, E. Denny, G. Bryans, J. Fitzgerald, M. O'Malley.
f) 06GM1255 - Canadian Tax Incentives for Using Energy Efficient and Alternative Renewable Resources, V. Munroe, M. Brown.

14. Panel Session, "Test Systems for Economic and Reliability Analysis". 2010 PES GM.
Chairs: L. Bertling, C. Schaffner.
a) 2010GM0991 - Test System Requirements for Modeling Future Power Systems. K. Bell, N. Tleis.
b) 2010GM1073 - Test Systems for Economic Analysis – An Introduction. C. Schaffner, X. Zhang.
c) 2010GM1499 - Test Systems for Reliability and Adequacy Assessment of Electric Power Systems. R. Billinton, D. Huang.
d) 2010GM1554 - Test Cases for Unit Commitment and Hydro Thermal Scheduling Problems. A. Diniz.
e) 2010GM1594 - The Chilean Test System for Economic and Reliability Analysis. R. Palma-Behnke.
f) 2010GM1202 - Small Test Systems for Power System Economic Studies. F. Li, R. Bo.

15. Panel Session, "Engineering Reliable Cyber-Physical Electrical Energy Systems". 2010 PES GM.
Chair: A. Dominguez-Garcia.
a) 2010GM1511 - Reliability Assurance of Cyber-Physical Power Systems. C. Singh, A. Sprintson.
b) 2010GM1522 - Data Integrity Attacks and their Impacts on SCADA Control Systems.

S. Sridhar, G. Manimaran.

c) 2010GM1637 - Progress Towards a Resilient Power Grid Infrastructure. W. Sanders.
d) 2010GM1646 - Models and Techniques for the Reliability Analysis of the Smart Grid, A. Bose.
e) 2010GM1719 - Electricity Infrastructure Security: Towards Reliable Resilient and Secure Cyber-Physical Power and Energy Systems. M. Amin.

16. Panel Session: "Advances and Applications of Test Systems for Economic and Reliability Analysis". 2011 PES GM. Chair: L. Bertling.
    a) 2011GM0020 - The Development of a Smart Distribution Grid Testbed for Integrated Information Management Systems. N. Lu, P. Du, P. Paulson, F. L. Greitzer, X. Guo, M. Hadley.
    b) 2011GM0942 - Reduced Network Modeling of WECC as a Market Design Prototype. J. Price, J. Goodin,
    c) 2011GM1082 - Validation of Hydrothermal Test Cases for Economic Analysis. R. Palma-Behnke, A. Diniz.
    d) 2011GM1277 - Use of Common Information Model (CIM) In Electricity Market at California ISO. E. Haq, D. Haller, K. Rahman, B. Iverson.
    e) 2011GM1328 - On Use of Reliability Test Systems: A Literature Survey. L. Bertling, P. Bangalore, T. Le.
    f) 2011GM1527 - Operating-Conditions and Decisions-Driven Test Systems (OCDTS), M. Ilic.

17. Panel Session: "Practical Aspects of Probability Applications for Common Mode and Dependent Outage Events". 2012 PES GM, San Diego. Chair: M. Papic.
    a) 2012GM0066-Basic Models and Methodologies for Common Mode and Dependent Transmission Outage Events, R. Billinton.
    b) 2012GM1460 - Overview of Common Mode Outages in Power Systems, PACME Task Force.
    c) 2012GM0950 - Dependent Mode Outages in Analysis and Prediction of Multiple Outage States, A.W. Schneider, Jr.
    d) 2012GM0244 - NERC's Transmission Availability Data System and Analysis, M. G. Lauby, J.J. Bian. A.D. Slone.
    e) 2012GM0640 - Common Mode Event Perspectives from the Canadian Electricity Association. J. Schaller.
    f) 2012GM0805 - Western Electricity Coordinating Council Experience in the Collection of Transmission Common-Mode and Dependent Outages. B. Keel, M. Papic, D. Tucker.

18. Panel Session: "Statistical Resource Modeling for Renewable Integration" Sponsored by RRPA SC and WSPCC, 2013 PES GM, Vancouver. Chair: C, Dent.
    a) GM0326 - Forecasting and Scheduling of Renewables in North American Power Systems: Current Status and Future Trends, M. Ahlstrom.
    b) GM0330-Space - Time and Multivariate Aspects in Probabilistic Forecasting, P. Pinson, J. Tastu, H. Madsen.
    c) GM0328 - Recent Advances in Time Series Related to Renewables, I. Eckley.
    d) GM0839 - Network Planning in Renewable Integration Studies: Changing the Planning Paradigms, P. Ruiz.
    e) GM0850 - Distribution Estimation for Generation Adequacy Assessment, C. Dent.

19. Panel Session: "Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications" Sponsored by RRPA SC and CAMS of PSACE Committee. 2013 PES GM, Vancouver. Chairs: M. Papic, P. Hines
    a) Ex-post Analysis of the Blackout on 8 September 2011 in the US Southwest. M. Papic, R. Cummings.
    b) Ex-post Analysis of the Blackouts on 30 and 31 July 2012 in India. A. Gaikwad.
    c) Ex-post Analysis of the Blackout on 4 November 2006 in Europe. V. Terzija.
    d) Ex-post Analysis of the Blackout on October 26 2012 in Brazil. M. Veiga Pereira.
    e) Wide-Area Measurements in Prevention of Cascading Outages. D. Kosterev.
    f) Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications. M. Vaiman.
    g) Preventing Cascading Outages by Islanding. J. Bialek.
    h) Benchmarking Models and Data for Cascading Failure Analysis. S. Miller.
    i) Using Branching Processes to Estimate Cascading Blackout Risk. I. Dobson.
    j) Using Random Chemistry and Influence Graphs to Estimate Cascading Blackout Risk. P. Hines.

20. Panel Session: "HVDC Grid Reliability". 2013 PES GM, Vancouver.
    Chair: L. Bertling Tjernberg,
    a) GM0994 - Experiences from HVDC Technologies, A. Gole
    b) GM0995 - Industry Experience of HVDC Reliability Data Collection an Utilization, N. Dhaliwal.
    c) GM0996 - Preliminary Results from Cigré B4 60 on HVDC Grid Reliability, N. Macleod.
    d) GM0997 - HVDC Grid Developments in China, L. Cheng.
    e) GM0998 - Examples of HVDC Grid Projects, N. Kirby
    d) GM0999 - Examples of HVDC Grid Projects, J. Giri

21. Panel Session: "Reliability Impacts of Demand Response Integration". 2014 PES GM.
    Chair: M. Parvania, Co-Chair: M. Fotuhi-Firuzabad.
    a) 14PESGM1197 - Where Is Demand Response Going? J. Bian.
    b) 14PESGM0794 - Demand Response Applications to the Co-optimization Planning of Generation and Transmission. M. Shahidepour.
    c) 14PESGM1282 - Demand Response for Ancillary Services, D. Callaway.
    d) 14PESGM0938 - Characterizing Statistical Bounds on Aggregated Demand Response-Based Reserve Resources A. Abiri-Jahromi, F. Bouffard.
    e) 14PESGM1765 - Mitigating Uncertainty with Flexibility: Analytical Models for the Risk of Following Distributed Renewable Generation with Demand Response. A. Scaglione.
    f) 14PESGM0805 - Impacts of Demand Response on Power Systems with High Penetration of Wind Generation. L. Wu.
    g) 14PESGM0813 - Demand Response and Reliability in ComEd. S. Bahramirad.
    h) 14PESGM0811 - Demand Response: Good or Bad for Reliability? M. Bollen.

22. Panel Session: Adequacy of Power Systems with Renewable Energy Sources. 2014 PES GM.
    Chair: W. Li,
    a) 14PESGM2312 - Risk Based Methods for Short Term Wind Power Commitment. R. Karki, R. Billinton, S. Thapa.
    b) 14PESGM2315 - Geographical Diversity of Renewable Sources and Power System Adequacy. C. Singh.
    c) 14PESGM2317 - Chronological Power Flow for Planning Transmission Systems Considering Intermittent Sources. A. Leite Da Silva.

d) 14PESGM2313-Simulation Tools for Reliability Analysis of Power Systems with Renewable Sources. P. Jirutitijaroen.
e) 14PESGM2311 - Web Based Online Adequacy Reliability Information System for Power Systems Including Intermittent Resource Generators, J. Choi/
f) 14PESGM2316- M icrogrid Reliability Evaluation including Storage and Control Strategy K. Xie.
g) 14PESGM2314-Engineering of Storage for Mitigation of Variability J. Mitra.

23. Panel Session "Cascading Failures: Advanced Methodologies, Restoration and Industry Perspectives", 2015 PES GM, Denver, Chair(s): M. Papic and W. Sun (Sponsor: CAMS, Co-Sponsor: RRPA SC)
    a) 15PESGM1075 - Dynamic probabilistic risk assessment of cascading outages, P. Henneaux
    b) 15PESGM1074 - Estimating Cascading Failure Risk with Random Chemistry, P. Hines
    c) 15PESGM1070 - Extracting information from observed cascading data, I. Dobson
    d) 15PESGM1091 - An Innovative Tool for Probabilistic Risk Assessment of Power and ICT system Subjected to Wide Area Disturbances Due to Weather/Environment Events, E. Ciapessoni
    e) 15PESGM1073 - Current industry practice with cascading outage events, M. Papic
    f) 15PESGM1080 - NERC Event Analysis of Cascading Outages, B. Cummings
    g) 15PESGM1081 - Applications and Analysis Tools for monitoring dynamics on the grid, P. Overholt
    h) 15PESGM1079 - Impacts of Blackouts, M. Adibi
    i) 15PESGM1076 - Addressing Restoration Issues in New England and Future Challenges, M. Henderson
    j) 15PESGM1078 - Microgrid in restoration, C. Liu
    k) 15PESGM1071 - Review of Restoration Methodologies, Blackstart Capabilities Using Renewable in Restoration, W. Sun
    l) 15PESGM1072 - Restoration Methods and Applications in China and Development of EPRI's Restoration Tool, Y. Hou

24. Panel session "Demand Response for Reliable Integration of Variable Renewable Energy" 2015 PES GM, Chair(s): M. Parvania and M. O'Malley
    a) PESGM2015 - 003055. Drivers for the Value of Demand Response Under Increased Levels of Wind and Solar Power, E. Hale
    b) PESGM2015 – 003075. Experience with Demand Response and Renewable Resources in the PJM Market, P. Sotkiewicz
    c) PESGM2015 – 001177. Grid Integration of Variable Generation Considering Demand Response Forecasting Errors, J. Wang
    d) PESGM2015 – 001205. Integrating Variable Renewable Energy and the Synergies with Demand Response, S. Nolan
    e) PESGM2015 – 003073. Reducing Renewable Generation Integration Barriers with Demand Response, M. Hummon
    f) PESGM2015 - 001176. Whole System Approach to Assessing Benefits of Demand Response in Supporting Cost Effective Integration of Renewables, G. Strbac

25. Panel Session: "Industrial Resource Adequacy Studies: Current Practices and Research Needs", 2015 PES GM, Chair(s): C. Dent and J. Fazio
    a) 15PESGM3065 - Practical Experience of LOLE Calculation in the Western Interconnection, M. Papic
    b) 15PESGM3066 - Uncertainty Impact on Operation and Planning of North American Bulk Power System, N. Abdel-Karim
    c) 15PESGM3067 - Inclusion of solar generation in adequacy studies: a survey by the PES "Capacity Value of Solar Power" Task Force, J. Black

d) 15PESGM3068 - MISO Resource Adequacy Studies, J. Cole
e) 15PESGM3069 - Infrastructure planning in power systems at EDF: from theoretical considerations to operational tools and current practices, T. Hinchliffe
f) 15PESGM3071 - Expanding Adequacy Assessment: a Case Study from the Pacific Northwest, B. Kujala
i) 15PESGM3072 - Statistical modeling for inclusion of variable generation in industrial adequacy studies, A.Wilson

26. Panel Session: "Probabilistic System Planning", 2015 PES GM. Chair(s): W. Li and M. Henderson, Sponsor: PSPI Committee, Co-Sponsor: RRPA Subcommittee.

a) 15PESGM0730 - Overview of Probabilistic System Planning, W. LI
b) 15PESGM0731 - Increased need for probabilistic system planning in the 21st Century, M. Lauby
c) 15PESGM0732 - Outage Data and Application of Probabilistic Indicators in System Planning, M. Papic
d) 15PESGM0733 - Probabilistic Inputs to Transmission Planning - A New England Case Study, M. Henderson
e) 15PESGM0734 - Probabilistic Methods in Resource Adequacy Planning at PJM, P. Rocha-Garrido
f) 15PESGM0735 - Probabilistic Expansion Planning of a Distribution System Considering Reliability and Cost Analysis, K. Xie
g) 15PESGM0736 - Probabilistic Method for Optimizing the Number and Timing of Substation Spare Transformers, A. Leite Da Silva