Transmission & Substation Maintenance Practices Assessment for Arizona Public Service, Inc. (APS)

Final Report

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Submitted By:

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Introduction

Arizona Public Service (APS) and EPRI Solutions completed an assessment of the practices and effectiveness of the transmission and substation maintenance program and processes in the third quarter of 2004. The focus of the assessment is on a comparison of APS's practices and effectiveness relative to Standard Practices, Standard Effectiveness and Standard Performance. Standard Practices, Standard Effectiveness, and Standard Performance are those practices, level of effectiveness and level of performance considered 'normal', 'common' or 'representative' for the industry. In this assessment, Standard Practices refer to 'normal', 'typical', 'representative' or 'common' practices, e.g. practices that are neither legally mandated nor universally agreed upon by the industry as recommended practices or associated with an expected or consensus 'minimum' or 'maximum' level of performance. Similarly, Standard Effectiveness or Standard Performance refer to 'normal', 'typical', 'representative' or 'common' levels of effectiveness or performance.

Results of the maintenance practices, effectiveness and performance assessment and the corresponding improvement plan and targeted recommendations are contained herein. The assessment is based on comprehensive interviews of nearly seventy (70) of Arizona Public Service's personnel, maintenance staff, contract workforce, construction crews, the inspection and engineering teams as well as the leadership. The comprehensive assessment focuses on more than 19 elements including all maintenance processes, 104 sub-elements and more than 1000 attributes. Applicable processes, documents, procedures, software tools and diagnostic technologies as well as program plans and performance indicators were also reviewed and evaluated. The goals of the maintenance practices, effectiveness and performance assessment were to:

- Provide an independent evaluation and perspective on the administration and operation of APS's transmission and substation maintenance program.
- Compare APS maintenance operations to industry 'normal', 'typical', 'representative' practices, level of effectiveness and level of performance.
- Compare APS's maintenance policies, procedures, processes, equipment replacement strategy, and maintenance basis against industry Standard Practices and Standard Levels of Effectiveness and Performance.
- Assess the maintenance team's application and implementation of maintenance policies, procedures, processes, and planned equipment replacement strategy and maintenance basis.

- Evaluate the effectiveness of respective transmission and substation inspection and maintenance programs at APS relative to industry Standard Practices, Standard Effectiveness and Standard Performance to identify the maintenance organization's strengths and opportunities for improvement.

- Identify areas not meeting industry Standard Practices, Standard Level of Effectiveness and Level of Performance and provide a high level risk and impact analysis associated with each area in need of improvement as well as estimate the effects on the current state of the system.

- Perform a high level analysis of the potential impact of recent failures on the health and performance of other substation equipment and determine any additional near-term inspection and/or maintenance tasks required as a consequence to the recent outage events to maintain system reliability and integrity.

The results of the assessment are presented in this document. EPRIsolutions assessment, observations and recommendations are based on over fifteen years of consulting experience in the area of asset management and maintenance optimization, assisting more than eighty (80) transmission and distribution organizations over the last five (5) years. EPRIsolutions maintenance experts completed the comprehensive assessment, interpreted the results, compared APS's current maintenance program and processes with industry Standard Practices as well as programs and processes of similar organizations applying Standard Practices methodologies. EPRIsolutions identified specific strategies and focus areas for consideration that will further improve the performance of the organization.

Overall Rating

EPRIsolutions staff performed a comprehensive assessment of APS's transmission and substation maintenance organization in each of the four major categories of maintenance processes, technologies, management and work culture, and people skills and human resources. The comprehensive assessment addressed all 19 elements of a 'standard' comprehensive maintenance program, 104 sub-elements and more than 1000 attributes. For each area, scores were developed based on a thorough review of current practices, process and other pertinent documentation and in depth interviews of APS personnel. Each attribute, sub-element, element and category was scored on a scale of 0 to 10. A score of 0 to 3 is assigned to those attributes, sub-elements, elements and categories in which the practices, effectiveness or performance of the organization is either completely absent or fails to register at a noticeable level. A score of 7 to 10 is assigned to those attributes, sub-elements, elements and categories in which the practices, effectiveness or performance of the

organization either noticeably lead the industry or indicate a significant leadership position in the industry. As score of 4 to 6 is assigned to those attributes, sub-element, elements and categories where the practices, level of effectiveness and level of performance is comparable to the Standard Practices, Standard Effectiveness and Standard Performance in the industry. A score of 5 is assigned when the organization's practices, effectiveness and performance meets industry Standard Practices, Standard Effectiveness and Standard Performance. Assigned attribute, sub-element, element, and category scores are consolidated to develop an overall rating for APS's transmission and substation maintenance organization.

The practices, effectiveness and performance of APS's transmission and substation maintenance organization was compared to the practices, effectiveness and performance of a peer group of 38 transmission and substation maintenance organizations. The assessment indicates that the overall practices, effectiveness and performance of APS's maintenance organization compare favorably with industry Standard Practices, Standard Effectiveness and Standard Performance (Figure 1). The overall score assigned to APS's maintenance organization is 4.45 on a scale of 0 to 10 compared to a score of 5.02 established for a peer group of 38 transmission and substation organizations (the peer group). The score of the top 25 percent (Q1) of the peer group exceeds 5.95 while the score of the bottom 25 percent (Q4) is less than 4.25. The score of the remaining 50 percent of the peer group falls equally above and below the median value of 5.02.

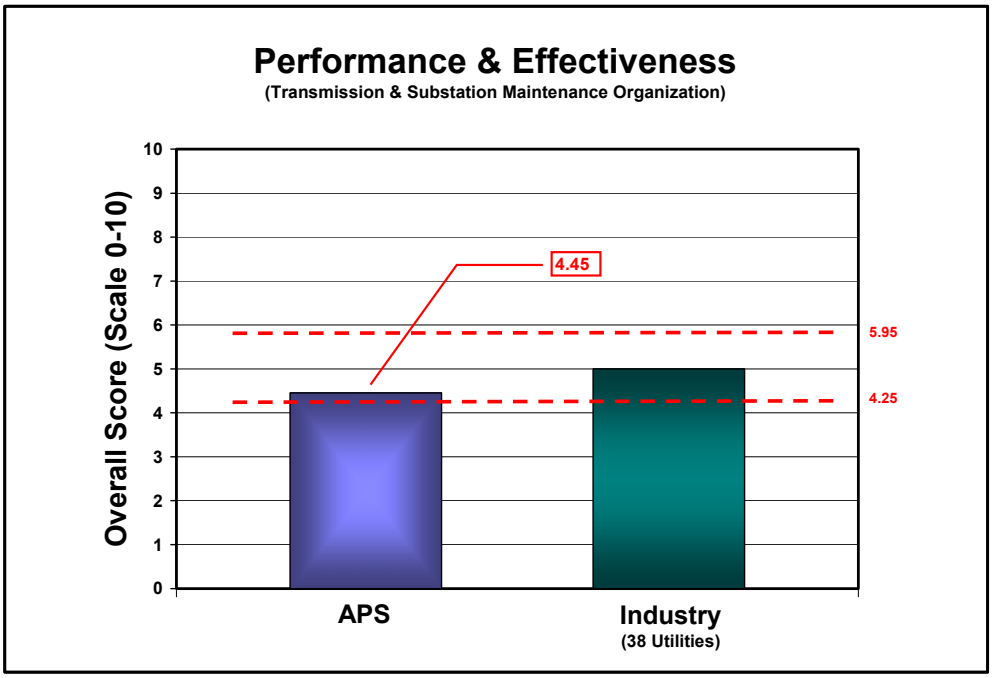

Figure 1
Overall Score (Performance & Effectiveness)

APS's overall score developed as part of the assessment clearly indicates that there are opportunities to improve the overall practices, effectiveness and performance of the transmission and substation maintenance organization. The score also clearly indicates that overall practices, effectiveness and performance of APS's transmission and substation maintenance organization are comparable to industry Standard Practices, Standard Effectiveness and Standard Performance.

Performance & Reliability

EPRIsolutions staff has compared the performance, reliability and service effectiveness achieved by APS's transmission and substation maintenance group in 2003 with the effectiveness and performance of other organizations in the WECC and the United States (USA). The performance and reliability benchmarking information was developed by EEI (Edison Electric Institute) and its use for the benefit of the overall assessment was granted by EEI for the benefit of this assessment. All performance and reliability indices and values referenced to EEI in this report exclude the effects of major events. It is commonly accepted in the industry that performance and reliability indices that exclude major events provide a more accurate assessment of the effectiveness and performance of an organization's transmission and substation maintenance program than comparable parameters that do not exclude major events.

Table 1 provides a comparison of the performance and reliability indices (exclusive of major events) recorded for APS maintenance organization relative to the performance and reliability levels of transmission and substation maintenance organizations within the WECC and the USA as benchmarked by EEI (5 Minute Basis) in early 2003. Based on EEI's benchmarking study, APS's performance and reliability is ranked 1st Quartile (Q1, Top 25 Percent) in ASAI, SAIDI, and SAIFI, and 2nd Quartile (50 to 75 % Percent of the Benchmarked Organizations are ranked at a level below APS) in CAIDI and MAIFI.

Table 1
Performance & Reliability – Comparison to Industry (Source: EEI, 2003)

Performance & Reliability Index & Metric	APS 2002 (Actual)	WECC 2002 (Actual)	USA 2002 (Actual)
ASAI	99.98 (Q1)	99.98	99.97
SAIDI	1.35 (Q1)	1.56	2.54
SAIFI	1.01 (Q1)	1.13	1.22
CAIDI	1.33 (Q2)	1.31	1.85
MAIFI	2.03 (Q2)	2.10	4.26

ASAI – Average System Availability Index; SAIDI – System Average Interruption Duration Index; SAIFI – System Average Interruption Frequency Index; CAIDI – Customer Average Interruption Duration Index; MAIFI – Momentary Average Interruption Frequency Index

The results of the investigation as well as the results of the EEI benchmarking study show that APS's effectiveness and performance in transmission and substation maintenance over the last few years produced performance and reliability indices close to or better (either Q1 or Q2 depending on the index used in the comparison) than the corresponding average value recorded for all utilities in the WECC. The review of the performance and reliability indices also indicate that APS's performance and reliability as evidenced by the organization's reliability performance records continues to improve year after year since 1996. Depending on the index evaluated, the performance of the organization has improved by nearly 42 percent in SAIFI, the System Average Interruption Frequency Index, 47 percent in SAIDI, the System Average Interruption Duration, and 21 percent in CAIDI, the Customer Average Interruption Duration.

Based on this premise, the reliability indices indicate a level of effectiveness, performance and reliability at APS that exceeds the level of effectiveness, performance and reliability considered industry Standard Effectiveness and Standard Performance within the WECC as demonstrated by the EEI benchmarking study as well as this investigation. Figure 2, 3, and 4 show APS's 'actual' (blue line) reliability and performance over a period of eight (8) years in conjunction with APS's 2004 'projection' and the long term trend (red line). It is important to notice that APS's transmission and substation maintenance organization internally tracks its performance and reliability based on the more stringent one (1) minute basis rather than the five (5) minute basis commonly encountered in the industry.

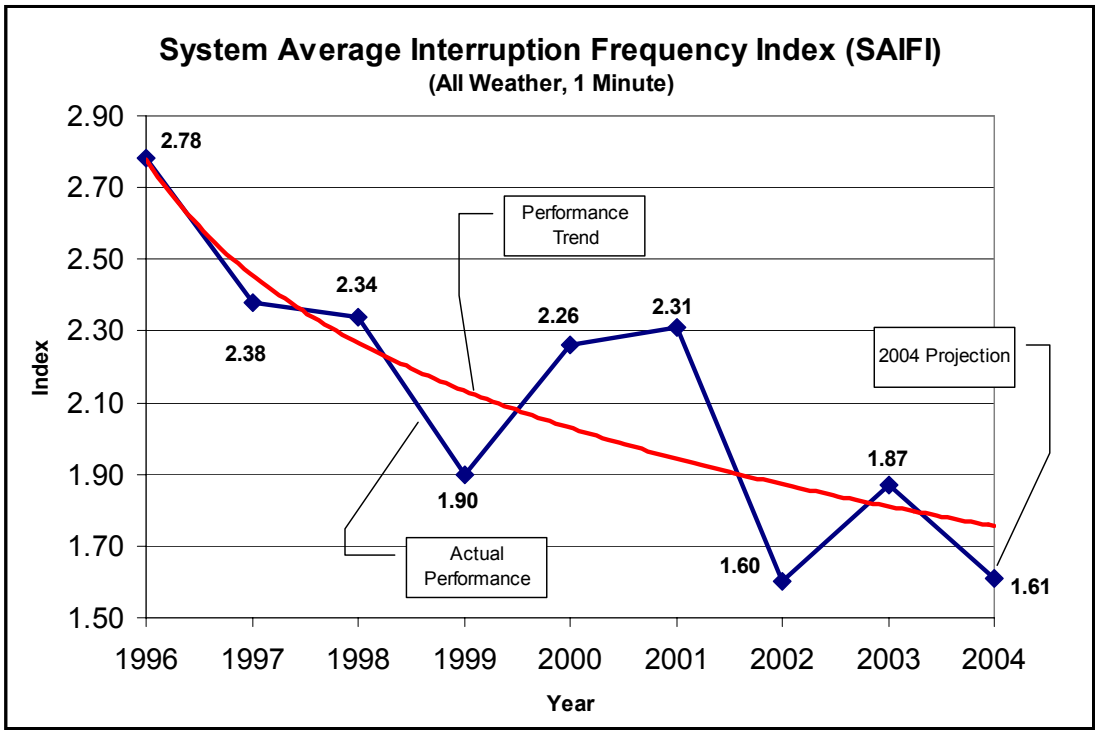

Figure 2
Performance & Reliability – System Average Interruption Frequency Index (SAIFI)

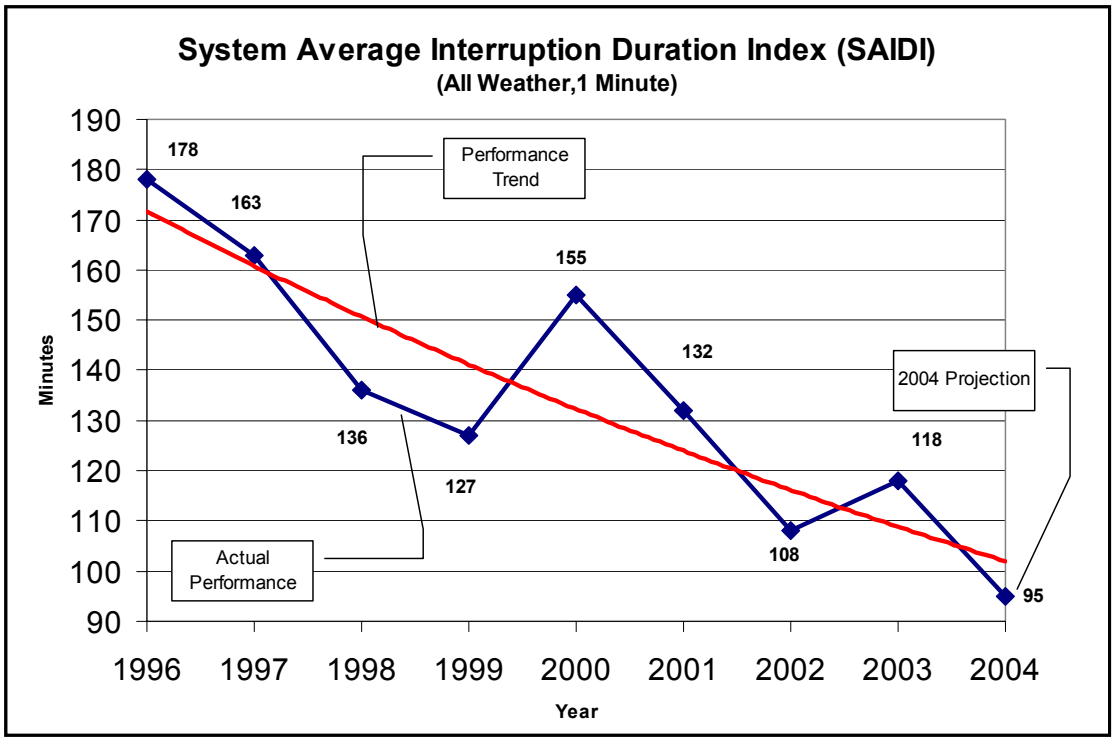

Figure 3
Performance & Reliability – System Average Interruption Duration Index (SAIDI)

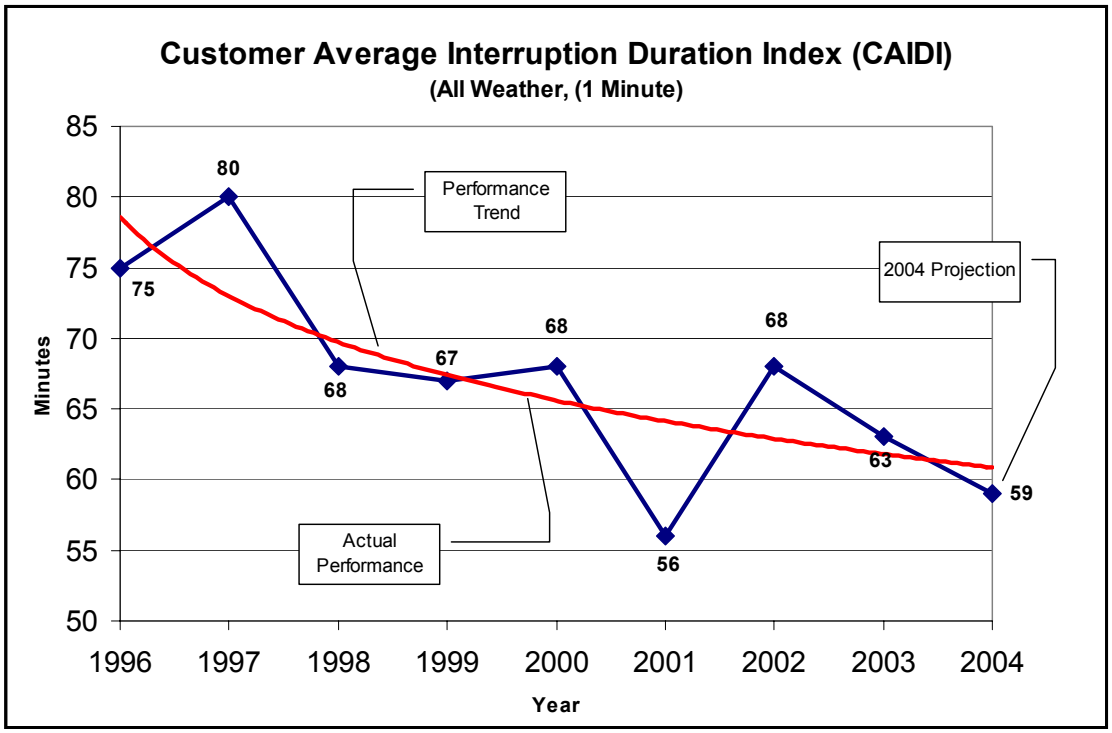

Figure 4
Performance & Reliability – Customer Average Interruption Duration Index (CAIDI)

Results

EPRIsolutions staff performed a comprehensive assessment of APS's transmission and substation maintenance organization in each of the four major categories of maintenance processes, technologies, management and work culture, and people skills and human resources. The comprehensive assessment (in comparison) with the industry's Standard Practices, Standard Effectiveness and Standard Performance addressed all 19 elements of a maintenance program, 104 sub-elements and more than 1000 attributes. For each area, scores were developed based on a thorough review of current practices, processes and other pertinent documentation and in depth interviews of APS personnel. The practices, effectiveness and performance of APS's maintenance organization were compared to the practices, effectiveness and performance of a peer group of 38 transmission and substation maintenance organizations.

Each attribute, sub-element, element and category was scored on a scale of 0 to 10. A score of 0 to 3 is assigned to those attributes, sub-elements, elements and categories in which the practices, effectiveness or performance of the organization is either completely absent or fails to register at a noticeable level. A score of 7 to 10 is assigned to those attributes, sub-elements, elements and categories in which the practices, effectiveness or performance of the organization either noticeably lead the industry or indicate a significant leadership position in the industry. As score of 4 to 6 is assigned to those attributes, sub-element, elements and categories where the practices, level of effectiveness and level of performance is comparable to the Standard Practices, Standard Effectiveness and Standard Performance in the industry. A score of 5 is assigned when the organization's practices, effectiveness and performance meets industry Standard Practices, Standard Effectiveness and Standard Performance.

At a greater level of detail, the results of the assessment indicate that the practices, effectiveness and performance of APS's transmission and substation maintenance organization in each of the 19 elements of maintenance vary from the overall score (i.e., Overall Score of 4.45) assigned to the organization. The composite evaluation chart (Figure 5) provides a "snap shot" of the practices, effectiveness and performance of the APS maintenance organization in all 19 elements of maintenance.

APS's scores in the areas of work identification, work control, work execution, work closeout, benchmarking, organization, leadership, continuous improvement, utilization, human performance, and qualifications exceed the overall score (i.e., 4.45) assigned to APS's transmission and substation maintenance organization. On the contrary, scores in the areas of the maintenance management system, M&D technologies, information integration system, goals/business planning, communication, metrics, accountability/ownership, and training fall below the overall score (i.e., 4.45) assigned to the organization. Similar to APS's maintenance organization, most utilities excel in some areas and lead in others as well as meet or exceed industry Standard Practices, Standard Effectiveness and/or Standard Performance in some areas and lag or require improvement in

other areas. It is important to note that differences in the score, both positive as well as negative, are not always indicative of 'incorrect' practices, effectiveness or performance in one area or the other but may also relate to differences in the practices, effectiveness or performance in the operation of particular segments of the organization.

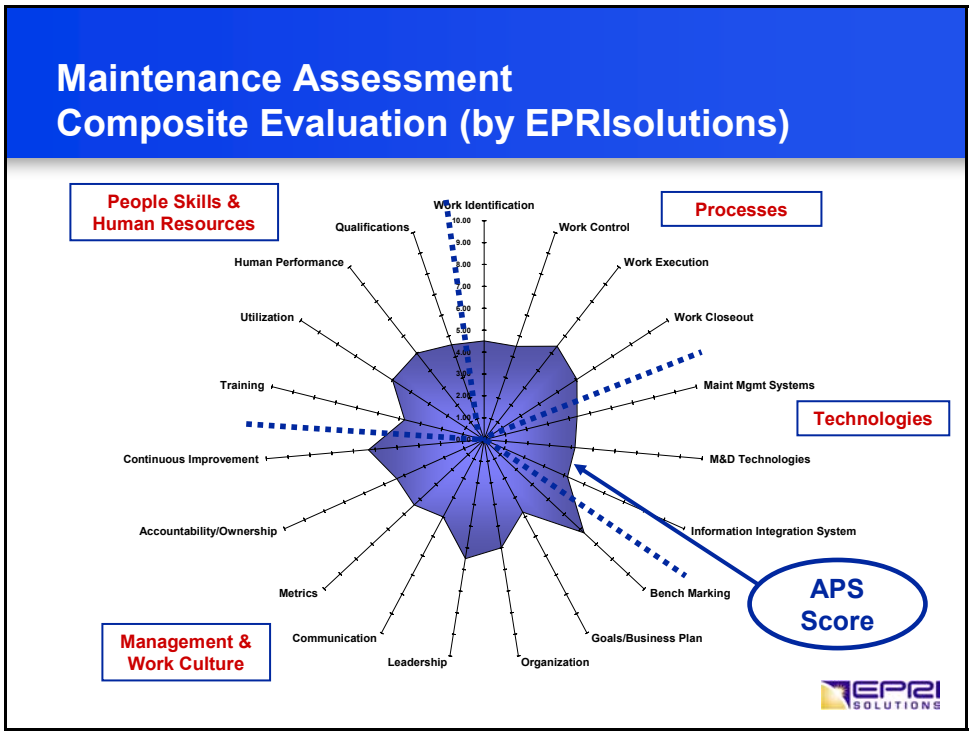

Figure 5
Practices, Effectiveness and Performance (Breakdown by Element)

As a reference point, the chart in Figure 6 compares the practices, effectiveness and performance of APS's transmission and substation maintenance organization relative to the combined average score and ranking of thirty-eight (38) other transmission and substation maintenance organizations (a group of peer organizations) that EPRIsolutions staff has worked with over the last 5 years. Regardless of the type of organization, it is important to recognize that each assessment included in the comparison is based on the same elements (19), sub-elements (104), attributes and characteristics (>1000) that were utilized in the assessment and evaluation of the APS transmission and substation maintenance organization.

The results of the assessment show that APS's practices, effectiveness and performance in the transmission and substation maintenance organization are at a level comparable to the composite average of those thirty-eight (38) organizations (the peer group) that have been included in the comparison and survey. At the same time EPRIsolutions staff identified that the practices, effectiveness and performance of APS's maintenance organization somewhat lags or trails the industry Standard Practices, Standard Effectiveness and

Standard Performance in the areas of work identification, work control, work execution, M&D technologies, goals and business planning, organization, communication, metrics, accountability and ownership, training, utilization, human performance, and qualifications.

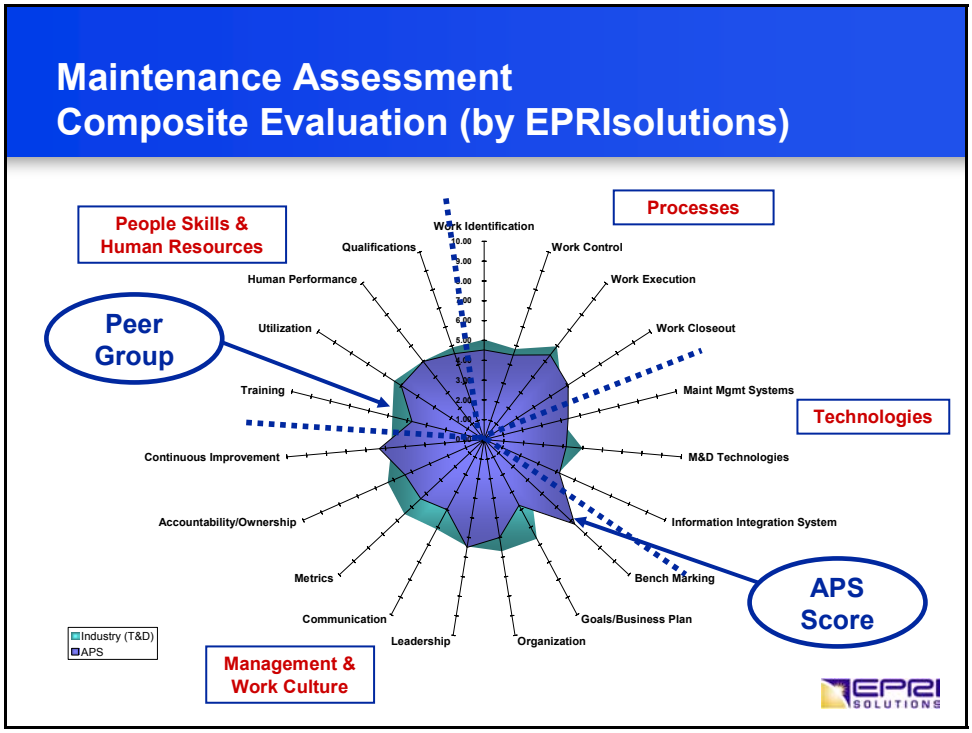

Figure 6
Comparison to T&D Industry Peer Group (38 Utilities)

Conversely, the APS's practices, effectiveness and performance generally exceeds the composite average (i.e., industry Standard Practices, Standard Effectiveness and Standard Performance) practices, effectiveness and performance of the thirty-eight (38) utilities (the peer group) included in the comparison and survey in the areas of work close-out, maintenance management system, information integration system, benchmarking, leadership, and continuous improvement. It is important to note that EPRIsolutions staff identified that the differences in the maintenance practices, level of effectiveness and in the level of performance between APS and the composite average performance of the organizations included in the comparison and survey, positive as well as negative, while notable are not significant. Therefore, overall, the practices, effectiveness and level of performance of APS's maintenance organization are comparable to industry Standard Practices, Standard Effectiveness and Standard Performance.

EPRIsolutions processed the data to create the organization's comprehensive maintenance practices, effectiveness and performance matrix (see Figure 7). The matrix provides a snapshot of the practices, effectiveness and performance

Maintenance Assessment
Excellence Matrix – A Company 'Dashboard'

Area	Element								
1.0 Management & Work Culture	Benchmarking	Within Industry	Outside Industry	N/A	N/A	N/A	N/A	N/A	N/A
	Goals/Business Plan	Org Perf Goals	Maint Dept. Goals	Individual Goals	Business Planning	N/A	N/A	N/A	N/A
	Organization	Roles & Respons.	Specialty Teams	Contract Mngmt	Facilities	N/A	N/A	N/A	N/A
	Leadership	Direction	Policies & Processes	Discipline	Empowermt	Motivation	N/A	N/A	N/A
	Communication	Ops,Maint, Eng	Mangers to Workforce	Workforce to Mgmt	Peer Group Meetings	Wkr to Wkr	N/A	N/A	N/A
	Metrics	Overall Goals	Maintenance Dept. Goals	Division/Region Goals	Customer Satisfaction	N/A	N/A	N/A	N/A
	Accountability/ Ownership	Personnel Performance	Bus. Plan Adherence	System/ Comp Ownership	Craft Ownership	N/A	N/A	N/A	N/A
	Continuous Improvement	Self-Assessment	Change Mgmt Program	Process Improvement	Use of Industry OE	CAP Program	R&D Activities	Team Problem Solving	Empl Ideas Solicited
2.0 Maintenance Processes	Work Identification	Work ID Procedures	Maintenance Basis	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance	Proactive Maintenance	Work Order Generation	N/A
	Work Control	Work Mgmt Process	Outage Mgmt Process	Prioritize Work	Risk Assessment	Stores/Inv. Management	Planning	Scheduling	Contract Mngmt
	Work Execution	Work Execution Procedures	Equipment Clear/Tagging	Tools/Material Control/Staging	Pre-Job Briefs	Perform Maint Tasks	Work Quality	Safety	N/A
	Work Closeout	Work Close Procedures	Post Maint Testing	Post Job Critique	Data Capture & Utilization	House Keeping	Return Equip to Service	N/A	N/A
3.0 People Skills/ Human Resources	Training	Processes & Policies	Personnel Skills Dvlpmnt	T&S Systems	Mgmt /Spvr Development	Business Literacy	Contractor Training	Specialty Training	Training Facilities
	Utilization	Mgmt/Union Interaction	Multi - Discipline	Mobile/Shared Workforce	Productivity / Metrics	N/A	N/A	N/A	N/A
	Human Performance	Behaviors & Values	Procedure Use	Self Check	Peer Check	CAP Program Utilization	Conflict Resolution	N/A	N/A
	Qualifications	Personnel Selection	Qualification Process	Re-Qualification Process	Contractor Qualifications	Qual Tracking Program	Succession Planning	N/A	N/A
4.0 Technologies	Maintenance Mgmt System	CMMS	Risk Assessment Tools	Scheduling Tools	Reporting & Decision Tools	N/A	N/A	N/A	N/A
	Maintenance & Diagnostic Technology	Execution Tools	On-line Cond. Monitoring	Periodic Cond. Monitoring	Technology Software	Process Data Utilization	Equip Perf Mon. Tools		
	Information Integration System	Financial	Budget & Schedule	Equip Cond. Data	Dispatch System	Industry Equip Databases	Equip Tech. Documents		

Figure 7
Excellence Matrix – A Company 'Dashboard'
(Yellow = Below Standard, White = Industry Standard, Green = Above Standard)

of the APS transmission and substation maintenance organization. The maintenance practices, effectiveness and performance matrix clearly highlights those areas where the APS maintenance organization performs at a level comparable to what is considered industry Standard Practices, Standard Effectiveness and Standard Performance (essentially at a level comparable to the peer group). Additionally, the maintenance practices, effectiveness and performance matrix points to those areas where the practices, effectiveness and performance deviates, positively and negatively, from industry Standard Practices, Standard Effectiveness and Standard Performance.

A clear picture of the practices, effectiveness and performance of the organization is provided by coding (in color) elements relative to the individual and overall score assigned to each sub-element, element, and area. Consistent with the approach used in the development of the overall score, elements and sub-elements colored in 'yellow' indicate a score below 5, essentially providing an indication that the practices, effectiveness and performance of the APS maintenance organization was assessed at a level below industry Standard Practices, Standard Effectiveness and Standard Performance as established by the average practices, effectiveness and performance of the peer group of 38 utilities. Similarly, elements colored in 'green' indicate a score above 5, essentially providing an indication that the practices, effectiveness and performance was assessed at a level above industry Standard Practices, Standard Effectiveness and Standard Performance. Last, elements colored in 'white' indicate practices, effectiveness and performance that is generally comparable to the practices, effectiveness and performance observed in the industry overall (based on the practices, effectiveness and performance established by the thirty-eight (38) organizations in the peer group).

The review of the APS management and work culture indicates practices, effectiveness and performance above industry Standard Practices, Standard Effectiveness and Standard Performance (i.e., elements colored in green) in the areas of benchmarking within the industry, specialty teams, empowerment and motivation, craft ownership, self assessment, and team problem solving. Similarly, in the category of maintenance processes, APS's transmission and substation maintenance organization demonstrates practices, effectiveness and performance significantly above Standard Practices, Standard Effectiveness and Standard Performance in the areas of work quality, safety, work close-out procedures, and house keeping. Finally, in the categories of people skills, human resources, and technologies APS's maintenance organization exhibits practices, effectiveness and performance above Standard Practices, Standard Effectiveness and Standard Performance in the areas of management and union interaction, behaviors and values, and execution tools.

On the contrary, APS's practices, effectiveness and performance in the areas of maintenance department goals, business planning, policies and processes, communication (between operations, engineering, and maintenance), peer groups, maintenance department goals, business plan adherence, system and component ownership, and change management program somewhat trails

industry Standard Practices, Standard Effectiveness and Standard Performance (i.e., elements shown in yellow) providing opportunities for improvement.

APS's practices, effectiveness and performance in the area of work identification procedures, maintenance basis, corrective maintenance, predictive maintenance, planning, scheduling, post job critique, process and policies, personnel skills development, transmission and substation systems, contractor training, specialty training, productivity and metrics, corrective action program (CAP) utilization, and contractor qualifications slightly lags the industry's Standard Practices, Standard Effectiveness and Standard Performance. Finally, APS's practices, effectiveness and performance in the area of scheduling tools, on-line and periodic condition monitoring, technology software, equipment condition data and technical documents offer opportunities for improvement to raise the practices, effectiveness and performance to a level equal to or above industry Standard Practices, Standard Effectiveness and Standard Perfomance.

In all other cases, the practices, effectiveness and performance of the APS transmission and substation maintenance organization has been identified as generally comparable to industry Standard Practices, Standard Effectiveness and Standard Performance, essentially neither exceeding the industry nor being significantly challenged. Essentially, categories, elements and sub-elements colored in white indicate a practices, effectiveness and performance in APS's maintenance organization that are comparable to industry Standard Practices, Standard Effectiveness and Standard Performance.

Conclusions & Recommendations

EPRIsolutions' maintenance experts performed a comprehensive assessment of APS's maintenance practices, effectiveness and performance. The results indicate that the level of service practices, effectiveness and performance as indicated by the organization's reliability (as indicated by the organization's SAIFI, SAIDI, and CAIDI performance indicators) achieved by APS's transmission and substation maintenance organization compares well to the practices, effectiveness and performance of other transmission and substation organizations in the WECC. The results of the assessment also indicate that the organization exhibits competency and even excellence in many areas but also that there are challenges and opportunities for the organization to address to meet or exceed industry Standard Practices, Standard Effectiveness and Standard Performance in transmission and substation maintenance.

Practices, effectiveness and performance are Competencies and Strengths wherever the areas of practice, effectiveness and performance of APS's transmission and substation maintenance organization exceeds the industry Standard Practices, Standard Effectiveness and Standard Performance. On the contrary, challenges and opportunities are assigned wherever the maintenance organization's practices, effectiveness and performance do not meet industry Standard Practices, Standard Effectiveness and Standard Performance. APS's strengths and competencies as well as challenges and opportunities are:

Competencies & Strengths

- Employee Morale, Motivation, and Empowerment
- Craftsmanship, Equipment, and Tools
- Infrared (IR) Diagnostic Program
- Vegetation Management Program
- Wood Pole Management Program
- Battery Maintenance & Replacement Program
- Safety Program & Record
- Reliability Performance Metrics and Management
- Construction, Design, and Material Standards
- Proactive Culture & Commitment to Continuous Improvement
- Benchmarking
- Work Quality & Housekeeping
- Management & Union Interaction
- Behaviors & Values

Challenges & Opportunities

- Industry Standard Diagnostics
- Maintenance Basis & Discipline
- Work Prioritization & Backlog Management
- Equipment Maintenance Procedures
- Data Automation & Maintenance Intelligence
- Planning, Scheduling & Outage Coordination
- Productivity, Planning & Scheduling Metrics
- Ownership, Roles, and Responsibilities
- Staffing Levels, Resource Availability, and Overtime Use
- Periodic & On-Line Monitoring
- Training (Non OTJ)

EPRIsolutions' project team formulated specific recommendations for the APS transmission and substation maintenance organization to address each of the challenges and opportunities identified in the assessment of APS's maintenance practices, effectiveness and performance. In each case, EPRIsolutions' maintenance experts compared APS's maintenance practices, effectiveness and performance to industry Standard Practices, Standard Effectiveness and Standard Performance to identify those specific actions required to raise the organization's practices, effectiveness and performance to a level to meet or exceed comparable industry values. Individual actions and recommendations derived from the gap analysis were consolidated and grouped into functional and process areas and are provided in this report.

EPRIsolutions prioritized (Column 'P') each recommendation based on the perceived (as perceived by EPRIsolutions maintenance experts) value to APS, its customers, and the public, where 'value' is a parameter (column 'V') that considers the cost to APS, the expected financial return to the organization, and the impact to the operation and reliability of service. Priority and value are differentiated in this report as either 'high', medium' or 'low'. The objective of assigning a priority and value to each recommendation is to allow APS's transmission and substation maintenance organization to sequence tasks and allocate sufficient resources. The objective is not to indicate that some recommendations are more important than other recommendations or the need to address one item supercedes the need to address another.

Clearly, to support improvement and to increase APS's effectiveness and level of performance, the organization needs to take action to address each of the recommendations provided in this report. However, it is recognized that the priority with which to address some recommendations is higher relative to the priority of others. Similarly, the relative value associated with one action differs from another. Therefore, it should be recognized that the premise of the prioritization and valuation (on a relative basis) is to allow APS to sequence the actions that should be taken first and to plan those actions that are to follow upon completion of leading steps and improvement initiatives. Similarly, the value (on a relative basis) assigned by EPRIsolutions to each action or recommendation provides APS with an indication as to the anticipated effect on the organization's practices, effectiveness and performance to support the allocation of appropriate resources to each initiative.

At the time of the assessment, APS's organizational management and leadership was actively engaged in improving the organization's practices, effectiveness and performance based on the direction received from previous maintenance assessments and benchmarking studies. It should be noticed that these initiatives continue today and the existence of these ongoing improvement initiatives as well as their status (column 'S') are indicated in the Summary of Recommendations included in this report.

	Recommendation	P	V	S
Industry Standard Diagnostics	While APS uses a number of industry recognized diagnostic tools in the condition assessment of APS's transmission and substation systems and equipment, there are some commonly used diagnostic technologies that are not currently used by APS. It is recommended that APS use industry Standard Practices diagnostic tools at intervals as determined by industry recognized Standard Practices maintenance bases and practices.	**H**	**H**	**IP**
Maintenance Basis & Discipline	APS started the process of defining the maintenance basis for transmission and substation systems and components in 2000. While a maintenance basis (maintenance templates) exists for a significant number of substation systems and components the assessment indicates that the existing templates are not currently executed with the appropriate level of discipline and that the development of maintenance basis templates for the remaining systems and components has stalled. APS should continue the development of a comprehensive maintenance basis for all non-trivial transmission and substation systems and components. The maintenance basis should be documented and integrated into the Computer Maintenance Management System (CMMS), effectively communicated to all stakeholders and executed by operations.	**M**	**H**	**IP**
Work Prioritization & Backlog Management	APS's maintenance organization should define system and equipment prioritization criteria in accordance with the corporate strategic objectives and values. The current prioritization of all non-trivial transmission and substation systems and equipment should be reviewed, documented, and integrated in APS's Maximo work management system (CMMS) and effectively communicated to all stakeholders. APS should also develop an effective process for the analysis, forecasting and management of the maintenance backlog.	**H**	**H**	**NS**
Equipment Maintenance Procedures	A significant number of APS's current maintenance procedures for transmission and substation systems and equipment are manually developed for each work order and these procedures are not readily available to all stakeholders. APS should develop standard maintenance procedures in electronic format for all non-trivial transmission and substation systems and equipment. This work will facilitate the creation of a library of standard procedures to be issued with each work order, ensure the availability of these procedures to all stakeholders, the integration of standard procedures in the CMMS for the automated creation of effective work packages, and the capture of the maintenance staff's current knowledge and expertise to develop new employees and address future training needs.	**L**	**M**	**IP**
Data Automation & Maintenance Intelligence	The collection, analysis, management and forecasting of transmission and substation conditions as well as the extraction of intelligence from the data is not exercised as well as generally encountered in the industry. Specifically, APS should review the process used in the identification and reporting of transmission and substation system and equipment conditions as well as tools to facilitate the automated collection and processing of field conditions to an enterprise application that is integrated with APS's Maximo system. Therefore, it is recommended that APS develop the appropriate processes and tools to acquire and integrate all transmission and substation condition data to facilitate the effective analysis, forecasting and management of corrective, preventive and predictive maintenance tasks and processes. Processes and/or tools should be integrated with the CMMS to provide the organization with high level, near-time intelligence and condition status.	**M**	**M**	**NS**
Planning, Scheduling & Outage Coordination	APS should develop a planning and scheduling organization as well as the appropriate processes and tools to increase the effectiveness of the planning and scheduling processes. The implementation of improved planning and scheduling processes and tools will maximize the effective use of the current work force and minimize outage requirements	**H**	**H**	**PL (05)**

	Recommendation	P	V	S
	as well as the number of outage requests. In support of this change it is also recommended that APS continue to improve the effectiveness of current backlog management processes and tools.			
Productivity, Planning, & Scheduling Metrics	APS's leadership should develop the appropriate process metrics to evaluate and track the transmission and substation maintenance organization's effectiveness in the areas of planning, schedule adherence, productivity, and the management of the maintenance backlog. The development of these metrics shall not distract from the organization's strong focus and performance in the area of reliability metrics but rather serve to extend the organization's focus.	**H**	**H**	**NS**
Ownership, Roles & Responsibilities	Equipment and technology ownership as well as employee roles and responsibilities are not clearly defined, documented and communicated in APS's maintenance organization. APS's maintenance leadership and management should clearly define system, component, and process ownership within the organization. The development, documentation, and effective communication of roles, responsibilities, and system and component ownership will allow the organization to quickly adapt to organizational changes and succession planning challenges as well as to significantly reduce employee start up training time.	**M**	**M**	**NS**
Staffing Levels, Resource Availability & Overtime Use	APS's maintenance organization is not sufficiently staffed at this time to adequately service and maintain the system in accordance with the organization's current maintenance basis without the extensive use of craft overtime. A review of the existing backlog, the current maintenance basis, current work force availability, the applied time (wrench time) of the work force and the level of overtime worked in 2001, 2002, and 2003 demonstrates the need to at a minimum add positions for a maintenance planner, a maintenance scheduler, two predictive maintenance (PdM) technicians, two substation maintenance teams, and two linemen to support the transmission system. Upon review of the current maintenance basis, it is recommended that a more detailed staffing and resource analysis is performed to accurately define the resources required to support industry Standard Practices maintenance requirements (Industry Standard Practices Maintenance Basis	**H**	**H**	**IP**
Periodic & On-Line Monitoring	APS should increase its investment in on-line monitoring technologies in out years to maximize its maintenance intelligence while maintaining an economic labor cost structure. On-line monitoring technologies should be leveraged wherever the risk or impact associated with a failure or loss of a particular system or component is significant and poses a threat to the organization. On-line monitoring technologies should also be used where the technologies significantly reduce craft wind shield time. APS should review and modify current periodic monitoring tasks to increase the type and frequency of diagnostic and inspection tasks to a level comparable to industry Standard Practices.	**L**	**H**	**PL (05)**
Training (Non OTJ)	APS provides training to develop personnel skills; supervisory skills; and other human resource (HR) related training. APS's leadership should develop, document and effectively communicate a comprehensive strategy for the technical training and skills development (as it relates to systems and components). The strategy should address the on-the-job as well as technical training in alignment with corporate training goals and opportunities.	**L**	**L**	**NS**

P – Priority; V – Value; S – Status; IP – In Progress; PL – Planned (Year); NS – Not Started; H – High Priority or Value; M – Medium Priority or Value; L – Low Priority or Value

Appendix A - Glossary of Terms

Accountability & Ownership addresses how all maintenance personnel recognize what is expected of them and how they perform accordingly at every level within the maintenance organization.

Benchmarking addresses the maintenance organization's process and proficiency, with benchmarking of the assets performance to allow for a direct comparison of the organizational practices with those considered ‘best-in-class’ within the utility industry and among all other industries.

Communication addresses the quality (formal and informal) of communications and information exchange between Maintenance, Management, Operations, Engineering, and others within the organization.

Continuous Improvement addresses the organization's ability to be a 'Learning' organization that is able to avoid repetitive mistakes.

Contract Management addresses the organization’s methods and practices associated with managing contractors used to complete specific maintenance work.

Corrective Maintenance tasks (CM) result from, loss-of-performance, component breakdown or catastrophic equipment failure that must be dealt with immediately.

Data Capture and Utilization addresses the effective capture of equipment maintenance history, performance, and reference information.

Goals and Business Plan addresses the maintenance organization's process for creating a business plan that clearly addresses the maintenance organization’s vision and mission, internal and external customers, strategy, goals and objectives, key performance indicators and initiatives as well as their associated benefit.

House Keeping addresses the material conditions, cleanliness, and housekeeping of facilities, systems, and equipment upon completion of work activities.

Human Performance addresses the evaluation of maintenance leadership desired behaviors for maintenance personnel that will ensure the appropriate level of professionalism by all workers.

Information Integration Systems addresses the use of integration systems that relay on the local area networks, and web-based Intranet and Internet networks.

Leadership provides direction for the organization by clearly defining expectations and providing the necessary support and budgets for initiatives to be successful.

Maintenance & Diagnostic Technologies addresses the use and availability of monitoring and diagnostic technologies, including both periodic and continuous on-line systems.

Appendix A - Glossary of Terms (Cont'd)

Maintenance Basis (MB) addresses the process used in determining the basis (i.e., what and how maintenance work is performed for specific equipment as well as the timing of such work)) for identifying the optimum maintenance work task balance as well as the overall strategy for maintaining reliability.

Maintenance Management System addresses the technologies required to support the workforce in the maintenance optimization process, which includes all technical advances such as: automation, condition monitoring technologies, maintenance management systems, process data historians and distributed control systems.

Metrics addresses the quality and effectiveness of a maintenance organization's key performance indicators including global goal measurements, such as: availability; cost and reliability; and specific maintenance department goal measurements.

Organization addresses the organizational structure in place to provide for coordinated maintenance decision-making, and successfully accomplishing system and equipment maintenance (e.g., process teams, component and process ownership, fix-it-now, etc.).

Outage Management Processes/Procedures addresses the organization's formal policies and procedures that are in place to manage 'How' maintenance is accomplished in a planned maintenance or rehabilitation outage including work initiation, planning and scheduling, risk assessment, and contract management.

Perform Maintenance Tasks addresses the actual as measured performance of the maintenance task.

Planning addresses the organization's proficiency and effectiveness of work activity planning including determining what activities will involve detailed planning (infrequently performed work, complex tasks, work requiring specialty resources, work requiring post maintenance testing, etc.).

Post Job Critique addresses the supervisory review and comparison of the work accomplished as well as the post-maintenance testing or inspection performed to determine that work is acceptable before the system is returned to normal service.

Post Maintenance Testing addresses post-maintenance or post-modification testing, inspection, or surveillance performed following maintenance or modification installation to verify that performance is based on design criteria, that the original deficiency was corrected, and that no new deficiencies were introduced due to maintenance.

Predictive Maintenance tasks (PdM) are tasks that must be performed as a result of detecting an equipment problem based on a diagnostic technology.

Pre-job Briefings addresses the guidance for the performance of routine pre-job briefings for maintenance activities.

Appendix A - Glossary of Terms (Cont'd)

Preventive Maintenance tasks (PM) are scheduled tasks that are time based recurring work that has been demonstrated to be necessary to keep equipment in optimum running condition.

Proactive Maintenance tasks (PAM) are improvement projects that have been initiated to resolve recurring maintenance problems.

Qualifications addresses the maintenance organization's methods associated with the qualifications and skills of functions within the organization, with a focus on whether qualifications and skills are capable of supporting program goals.

Return Equipment to Service addresses the processes required to return equipment to service to ensure that the proper testing has been accomplished and that the equipment is ready for service.

Risk Assessment addresses the process of establishing the risk associated with planning and execution of work as well as safety and reliability concerns.

Safety addresses the awareness of the personnel of the importance of safety. It is the processes/procedures that are in place and being followed to address safety concerns.

Scheduling addresses an organization's proficiency and effectiveness with scheduling of maintenance tasks, resource loading and monitoring schedule adherence throughout the work control, execution, and closeout processes.

Standard Effectiveness addresses a level of effectiveness considered 'normal', 'typical', 'common' or 'representative' in the industry. In this assessment, Standard Effectiveness refers to a level of effectiveness considered 'normal', 'typical', 'representative' or 'common' level of effectiveness, e.g. a level of effectiveness neither legally mandated nor universally agreed upon by the industry as a recommended level of effectiveness or associated with an expected or consensus 'minimum' or 'maximum' level of effectiveness.

Standard Performance addresses a level of performance considered 'normal', 'typical', 'common' or 'representative' in the industry. In this assessment, Standard Performance refers to a level of performance considered 'normal', 'typical', 'representative' or 'common' level of performance, e.g. a level of performance neither legally mandated nor universally agreed upon by the industry as a recommended level of performance or associated with an expected or consensus 'minimum' or 'maximum' level of performance.

Standard Practices addresses those practices considered 'normal', 'typical', 'common' or 'representative' for the industry. In this assessment, Standard Practices refer to 'normal', 'typical', 'representative' or 'common' practices, e.g. practices that are neither legally mandated nor universally agreed upon by the industry as recommended practices or associated with an expected or consensus 'minimum' or 'maximum' level of performance.

Appendix A - Glossary of Terms (Cont'd)

Stores/Inventory Management addresses an organization's proficiency with ordering, handling, storing, and issuing all parts and materials for the maintenance tasks.

System and Equipment Clearance and Tagging addresses the process of clearing and tagging out equipment in a timely manor in preparation for maintenance work.

Tools & Materials Staging and Control addresses the accessibility of tools including specialty and diagnostic tools needed to execute maintenance tasks effectively.

Training addresses the policies, processes and procedures in place to govern the maintenance Training and Qualification program.

Utilization addresses the organization's effectiveness in actively and positively managing the relationship between Management and Craft (Union or Non-Union) to provide a win-win situation in most or all cases.

Work Close-Out includes the maintenance organization's proficiency with prescribing and performing post maintenance testing, post job critique, housekeeping practices upon completion of work, transfer of equipment ownership to operations for return to service (Return Equipment to Service), the capture and documentation of 'as-found' and 'as-left' information and the effective utilization of the information to proactively improve future maintenance and equipment reliability.

Work Close-Out Procedures addresses the administrative procedures and policies in place to govern and guide the maintenance work closeout processes.

Work Control signifies those processes and procedures that address the 'How' an organization accomplishes all of maintenance tasks. Therefore Work Control includes work and task prioritization, risk assessment (where the risk associated with the completion is considered equally important as the risk associated with not completing a maintenance task), and the planning and scheduling of maintenance work.

Work Execution addresses the performance of work and execution procedures, clearance of equipment, staging of materials, pre- job briefing, quality assurance and verification programs, safety practices and processes, and post-job critiques.

Work Execution Procedures addresses the existence and quality of work execution procedures that an organization uses to ensure the safe and effective operation and maintenance of the assets.

Work Identification provides the overall strategy and approach applied to determine what specific task(s) are required to ensure that the appropriate work is performed to achieve high levels of equipment reliability at the lowest or reasonable cost.

Work Management Processes/Procedures addresses the organization's formal policies and procedures that are in place to manage 'How' maintenance is

Appendix A - Glossary of Terms (Cont'd)

accomplished including work initiation, planning and scheduling, risk assessment, and contract management.

Work Order Generation (WOG) addresses the processes associated with how a request to perform work is initiated in the organization and administered at the facility.

Work Prioritization addresses the process of 'How' an organization screens, and determines and tracks the priority of all work requests identified.

Work Quality addresses the process of assuring that the work performed maintains a high standard and that all aspects of ensuring quality are employed.

Appendix B - Biography

Mark Ostendorp, PhD, PE
Director, T&D Asset Management

SUMMARY

Dr. Ostendorp manages EPRIsolutions' Transmission and Distribution Maintenance and Asset Management Optimization Services and the Engineering & Test Center in Haslet, Texas, USA. The Center is the utility industry's premiere resource in developing, implementing, and applying power delivery asset management, inspection and maintenance, engineering and planning, and testing processes, methods, tools, and systems. Dr. Ostendorp manages a staff of more than 20 of EPRIsolutions' 90 employees. He serves as the technical lead on asset management, strategic planning, risk assessment, maintenance optimization, construction management and execution, engineering analysis and design, structural and mechanical testing, inspection and maintenance issues, and software development projects for transmission, distribution, and substation owners and organizations.

WORK EXPERIENCE

Dr. Ostendorp has more than 15 years experience in analyzing, designing, inspecting, maintaining, and managing transmission and distribution systems. Dr. Ostendorp is the technical lead in the area of asset management and maintenance optimization providing targeted utility solutions via the development of sustainable asset management and maintenance strategies, reliability management, risk management processes, asset valuation, short and long range business planning, performance optimization, and change management.

Previous experience includes but is not limited to optimizing maintenance processes as well as developing inspection and maintenance tools, optimizing maintenance strategies and processes, and developing sustainable inspection and maintenance processes and key performance indicators and performance monitoring processes. He has designed and evaluated concrete, steel, masonry, and timber building, communication, transmission, and substation structures subjected to static and dynamic loads using Allowable Stress Design (ASD), Ultimate Stress Design (USD), and Load Resistance Factor Design (LRFD) methods in accordance with the International Building Code (IBC), the Unified Building Code (UBC), American Society of Civil Engineers (ASCE), and Institute of Electrical and Electronics Engineers (IEEE) standards. He has more than 10 years' experience performing forensic engineering and failure investigation of foundations, structures, high-voltage systems, and communication equipment and components.

EDUCATION/AFFILIATIONS

Ph.D., Civil Engineering – Systems Science, MS degree, Civil Engineering, BS degree, Civil Engineering, Portland State University, Portland, OR

Member of the American Management Association (AMA), the American Society of Civil Engineers (ASCE), the Institute of Electrical and Electronics Engineers (IEEE), the International Electrical Commission (IEC), the Conference Internationale des Grand Reseaux Electriques (CIGRE). Dr. Ostendorp is a registered Professional Engineer.

Appendix B – Biography (Cont'd)

James Alligan
Senior Consultant, T&D Maintenance Optimization

SUMMARY

James Alligan is a Senior Consultant, T&D Maintenance Optimization at EPRIsolutions, Inc.. He leads and manages the organizations various transmission, substation and distribution consulting services on EPRI's family of asset management programs which include T&D maintenance optimization, condition assessment and strategies for equipment end-of-life asset management. Mr. Alligan is a recognized industry expert in the areas of reliability centered maintenance (RCM), substation diagnostics and asset inspection strategies, practices, tools and technologies.

WORK EXPERIENCE

National Grid Company, London Area Manager responsible for forty engineers and technicians undertaking maintenance and construction work on all peak load generation, substation and transmission equipment from 13kV to 400kV.

Asset strategy experience includes preparing T&D engineering financial justification, insurance loss adjustment assessments, transmission infrastructure security assessments, environmental improvements, project planning, operations, safety, equipment health assessments, system reliability studies, equipment predictive performance, and root cause failure analysis.

As a US utility company maintenance optimization project manager, Mr. Alligan was a leader in the application of T&D RCM (reliability centered maintenance) studies, equipment assessments and end of life strategies. In his role he closely worked with US companies to pioneer leading practices, tools and technologies to advance asset strategy, maintenance and diagnostics.

EPRIsolutions project lead for enhancing the sub-transmission reliability performance of the Taiwan Power Company at critical system locations.

Undertaken distribution overhead line inspection program process reviews, audits and route cause analysis studies. Performed line component RCM studies. Developed sub-transmission key performance indicators for T&D clients.

Currently responsibilities are managing and providing advice on asset management programs including reliability centered maintenance, asset condition assessment, equipment end-of-life assessment, maintenance optimization, power system equipment life cycle management and maintenance policy.

Mr. Alligan is a member of the IEEE, has an HTD in Power Engineering and is a graduate from the UK Central Electricity Generating Board Student Engineer program 1979.

EDUCATION/AFFILIATIONS

HTD Power Engineering, UK Central Electricity Generating Board, 1979.

Appendix B – Biography (Cont'd)

Garry Sparks
Senior Consultant, T&D Maintenance Optimization

SUMMARY

Mr. Sparks, a reputed expert in the area of maintenance optimization has over 29 years of electric utility experience in the power industry. His extensive experience in maintenance optimization spans more than 17 years covering 300 substations and 5,000 miles of transmission lines. Previously, he worked for more than 12 years in the construction of substations and hydro/steam generation facilities, transmission lines ranging from 4 kV to 500 kV providing a pragmatic understanding that greatly contributes to his expertise in the inspection and maintenance area. During his career, he performed in-depth analyses of transformer and circuit breaker equipment failures that ultimately led to the development and implementation of updated maintenance practices and procedures in the industry. Based on the success of this work, he was tasked to support the development of computerized maintenance processes and tools that assist utilities in the evaluation of field maintenance data and the implementation of preventive, proactive, reliability centered, and predictive maintenance practices.

WORK EXPERIENCE

Early in his career, Mr. Sparks managed the installation and commissioning of complex substation monitoring systems in a challenging business environment to the complete satisfaction of the organization's clients. In support of this effort, Mr. Sparks developed a significant number of industry leading processes and tools for the real-time monitoring of high voltage substation equipment. In this challenge, Mr. Sparks was directly responsible for the development of the technical direction as well as the eventual implementation in industry facilities. Advances made by the work and guidance provided by Mr. Sparks has resulted in numerous installations of this technology worldwide.

Later in his career, Mr. Sparks provided technical consulting services on substation equipment maintenance practices, protection device installation and testing, as well as on the development of electronic devices that enhance system performance. Additionally, he has served clients in improving the use and benefit derived from telecommunication technologies by providing his extensive experience to the installation of microwave equipment, the integration and testing of mobile field communication systems, and the maintenance and testing of power line carrier systems.

Mr. Sparks served as the Project Engineer and primary technical lead for General Electric Substation Automation Services responsible for the protection and control development for substation control rooms. In this development, Mr. Sparks analyzed and synthesized specifications from ComED's three major principles (Protection, SCADA and Communications) to deliver the final system to the General Electric Protection and Control Group as part of a significant change management effort.

EDUCATION/AFFILIATIONS

BS in Management and Organizational Behavior, University of San Francisco, DOG 1993

Appendix B – Biography (Cont'd)

Nick Abi-Samra, PE
Director, T&D Planning & System Operations

SUMMARY

Nick Abi-Samra is the Senior Technical Director in the area of transmission and substation operations, planning, and design of distribution and transmission systems; system control; reliability studies; risk assessment; capital transmission planning studies; system stability and security; FACTS and Custom Power applications; and transmission ancillary services. In his career, Mr. Abi-Samra has contributed to or led a significant number of in-depth electric utility system assessment investigations for utilities as well as regulators and independent system operators.

WORK EXPERIENCE

Mr. Abi-Samra joined the Electric Power Research Institute (EPRI) in 1997 as a manager in the Grid Operations & Planning business area. There he had the fiscal and technical responsibility of a number of projects at the (EPRI) dealing with system planning; system reliability; energy tracking; generation and transmission pricing; services; risk and decision making; least cost planning and system operation. He also led the development of a number of strategic and cutting edge projects dealing with the future of power delivery and utilization.

Mr. Abi-Samra spent most of his career at Westinghouse Electric. He joined the Advanced Systems Technology (AST) Division of Westinghouse (Pittsburgh, PA) in 1977 where he held positions of increasing responsibilities (including the management of a large utility and industrial consulting group). There he conducted and supervised projects in the areas of: transient analysis; transmission and distribution systems expansion an planning; Sub-synchronous resonance; HVDC protection; industrial systems applications; power quality; turbine generator protection; and insulation coordination. In 1982, he designed an engineering center, high-voltage test laboratories and consulted on insulator contamination while on loan from Westinghouse to Saudi Arabia.

In 1991 Mr. Abi-Samra joined the Power Generation Business Unit where was instrumental in building Westinghouse's consulting and training services in the Western Region of the USA. As the Operations Manager, he conducted and directed projects on the design and analyses of industrial and utility power systems. He had the responsibility of trouble-shooting and implementing cost effective solutions to problems at several industrials and utilities. He also led the modeling, application and analyses efforts of Westinghouse's Custom Power devices (DVR, and DSTACOM, and solid-state breaker) and developed numerous courses in power systems assessment, protection and design.

EDUCATION/AFFILIATIONS

BS in Electrical Engineering, American University of Beirut, MS in Power Systems, University of Missouri, Post Graduate Work at Carnegie Mellon University. Mr. Abi-Samra has published over 50 technical papers and articles in IEEE, IEE, CIGRE and other trade magazines as well as over 100 technical reports in various venues. In addition, he has developed and taught numerous courses in power systems assessment, protection and design.