

## TRACKING TRANSMISSION SYSTEM PERFORMANCE WITHIN SAUDI ELECTRICITY COMPANY (SEC) NETWORK

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### ABSTRACT

*This paper discusses the efforts and the achievements that have been done by Saudi Electricity Company (SEC)– Transmission Bushiness Unit - with the objective to collect, review, and analyze the critical reliability issues as reflected from major disturbances that experienced by the entire network of the kingdom of Saudi Arabia. Major fault incidents experienced by SEC transmission network have been collected and analyzed during three years of complete monitoring survey. The analysis processes of the collected data were useful in tracking the performance of SEC supplying system and determining their relative impacts upon their bulk customer. Some key accesses, reliability relative tasks, were introduced to figure the performance of SEC transmission system. Findings from the reliability survey were useful and indicative where:*

- *The potential causes of disturbances were categorized and described.*
- *The potential impacts of fault incidents on the overall system reliability and performance were evaluated.*
- *External non-transmission parties that effect the operation of the transmission system were determined*
- *And, additional recommendations and improvement tasks required for maintaining higher system reliability and integrity were stated and implemented.*

### INTRODUCTION

In recent years, major electric companies have started to realize the importance of reliability as an enterprise strategy that, when properly implemented, will improve financial performance [1-3]. Most of the utilities around the world use the commonly type of disturbances, **the outages**, when reporting on the reliability performance of their power systems. The calculation of the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI) were the traditionally indices used for addressing system performance and for benchmarking purposes [4-6].

This paper describes new approaches for collecting data and information relative to system reliability, and look at the results of the collected data from various surveys. Reported number of outages and durations that customers

experience each year still the main collected database while new statistical approaches for characterizing system reliability and quality performance will be introduced. The new statistical approaches include correlation with causes of disturbances, characterizing "major events" and their severity impacts up on the quality of power supply, and defining factors affecting the accuracy of reported performance such as the feasibility of implementing the recommendations.

### OVERVIEW OF SAUDI ELECTRICITY CO. TRANSMISSION POWER SYSTEM.

The network of the transmission system of the Saudi Electricity Company (SEC) is mainly of two sub-transmission areas which are the Consolidated Transmission Area (CTA) and the Developed Transmission Area (DTA). The CTA bulk transmission system comprises two major subsystems namely Central Operating Area (COA) and the Eastern Operating Area (EOA) which are tied together through two double circuits 380 kV and one double circuit 230 kV lines. On the other hand, the DTA comprises other two major subsystems namely Western Operating Area (WOA) and the South Operating Area (SOA) which are completely isolated areas.

In terms of total capacities and demands of power, SEC total capability is around 31,781 MW while the maximum demand recorded in 2005 is about 28,850 MW. These capacities shared among the four operating areas as shown in Table 1.

In terms of total numbers, SEC serves about 4.72 million customers. Electricity services conducts variety of customer classes which are industrial, residential, commercial, government, and agriculture sectors. Residential customers constitute more than 83 %, industrial customers constitute about 0.2 %, commercial customers about 12.3 %, agricultural customers about 1.1 %, government sector customers about 2.2%, and others services is about 1.3 %.

However in terms of the total annual energy sale, figure 1 shows the percentage party of consumption energy served by each sector via transmission system network.

Table. 1 Saudi Electricity Company - Transmission Business Unit - SEC Areas Total Capacities and 2005 Maximum Demands.

SEC Areas	OPERATING Regions	MW – Total Capacity	MW – 2005 Maximum Demand
CTA	COA	7144	9072
	EOA	12888	9247
DTA	WOA	9298	8358
	SOA	2451	2173
<b>TOTAL SEC</b>		<b>31781</b>	<b>28850</b>

• Exceeding power over COA capacity is usually imported from the EOA.

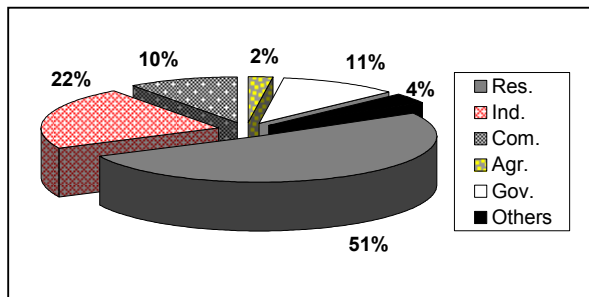


Figure 1 Consumption of Power Parties Served by Saudi Electricity Company – 2005 database source.

### DATA COLLECTION AND STATISTICAL RESULTS

Saudi Electricity Co. conducted a large-scale reliability monitoring program started on 2003. The principle objective of the program is to better understand the nature of disturbances and to make the gathered information readily available in a form that is meaningful to the utility as well as to the consumers. The desired efforts were carried out through continuous monitoring of the fault incidents that are experienced within different parts of SEC specifically across the transmission system network. The collected data includes, but not limited to:

- Numbers of fault incidents in each operating area within SEC transmission network.
- Outage duration and restoration time of each record.
- Energy not supplied post fault records.
- Primary cause of interruption belongs to each fault incident.
- External non-transmission parties affect the operation performance of the transmission system.

To summarize the collected data and information, some key accesses, *reliability relative tasks*, were suggested. The suggested data management tasks are for enabling better understand of system reliability and establishing variety of analysis and benchmarking to improve system reliability.

### SEC- TRENDING DATA OF INTERRUPTIONS

In order to establish a base of measurement for reliability trends, the collected data of interruptions are averaged for the previous three years (2003, 2004, and 2005). This average is defined as the trending baseline reliability values. Comparing another period's values to this baseline reliability trend will help to recognize whether system reliability goes better or worst [7]. As shown in figure 2, for the year of interest (2005), comparing one year reliability to the trending baseline indicate for higher interruption rates than the trending baseline values. This would signal the utility to take action to restore system reliability to normal levels.

Other useful method for summarizing the collected data is by creating histograms as shown in figures 3 and 4. The constructed histograms are based on disturbances cumulative frequency calculations. For the 2005 outage records, figure 3 summarize the statistical results obtained by computing the relative frequency of occurrence of interruption per year while figure 4 shows the statistical results of the unavailability, hours of power not delivered.

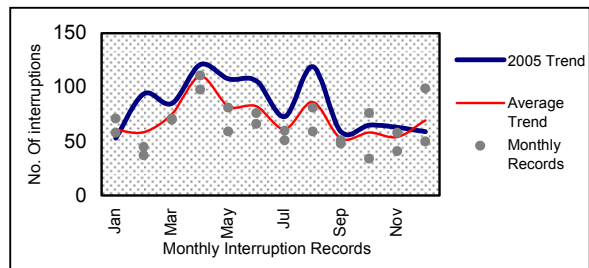


Figure 2 SEC Records Of Interruption – 2005 compared to the trending baseline values – Three Years Records.

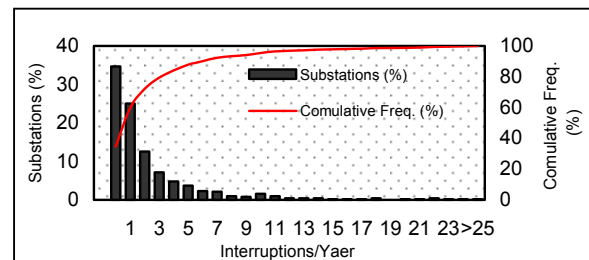


Figure 3 Substations-Interruption Rate Histogram (2005 database).

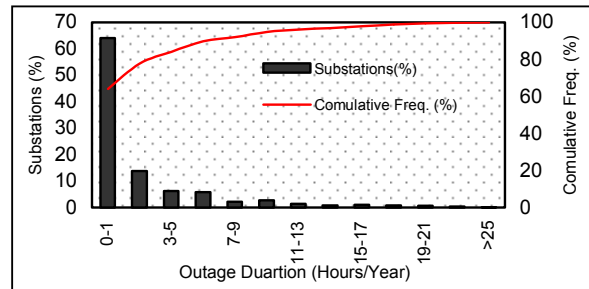


Figure 4 Interruptions-Outage Duration Histogram (2005 Database).

Histogram graphs represented through figures 3 and 4 indicate that:

- 10% of SEC transmission substations experienced worst reliability levels, not less than 5 Interruptions / Year.
- 50% SEC transmission substations experienced reasonable interruption records, one interruptions /Year.
- 10 % of the overall SEC Substations suffering real problems to deliver the intended energy within outage period more than 5 Hours per year while 50 % of the SEC Substations suffering energy not supplied problems within outage durations less than 1 hour per year.

**FAULT INCIDENTS - CAUSES OF INTERRUPTIONS**

Tracking and targeting fault types helps identify where to focus improvements [8]. Causes of interruptions at each of the SEC operating areas have been identified and different categories of interruption causes have been assigned. Transmission system interruptions might be due to weather related conditions, equipment failure, protection mal-operations, human errors, system deficiencies, and miscellaneous. For the year of interest, 2005, tracking causes of interruptions is summarized in the representative plot shown in figure 5. The plot shows that, majority of interruptions are due to weather related conditions (34%), while human errors represent the minority (7% of the total recorded interruption records).

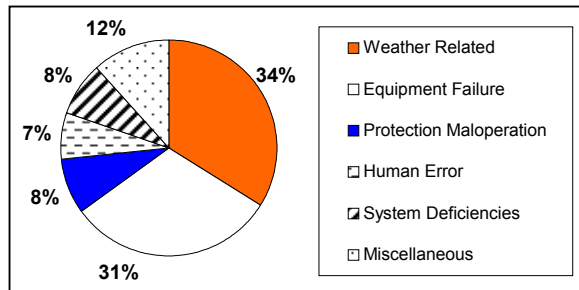


Figure 5 SEC Incidents Cause of Interruption Percentages.

**IMPACTS FROM NON-TRANSMISSION PARTIES**

Not all transmission incidents are attributable to transmission Business Unit. External Parties (Non Transmission) can also cause disturbances in the transmission network. External Parties that may significantly affect transmission system performance include Generation, Distribution, Independent Power Producers (IPPs), Bulk Customers, and Contractors.

Review of the 2005 transmission fault incidents revealed that, 14 % of the total incidents initiated by external parties. As this number are quite significant, SEC

attempts to quantify their impact by defining a number of indices to facilitate the evaluation of the influence and impact of such external parties on the performance of the Transmission Network. Definitions and formulas used to compute these indices are based directly on two factors, which are, numbers of transmission incidents due to external non-transmission faults and the total number of transmission incidents.

As an example, the distribution index (D. Index) that reflects the impact of distribution faults that disrupt the operation of the transmission system can be defined as:

$$D. Index = \frac{\text{No. of transmission incidents due to distribution failures}}{\text{total number of transmission incidents}}$$

Based on the 2005 records, a summary of the external parties (non-transmission) impact on the performance of the transmission system and their respective indices are illustrated in figure 6. Review of the results indicates that:

- The dominant party external to transmission which affected the performance of the transmission system was the Distribution External Party (6.3 % of the total transmission incidents).
- Contractor's errors caused significant number of transmission disturbance incidents (3.4 % of the total transmission incidents). This calls for the safety rules and procedures governing the Contractor performing projects at SEC Transmission facilities to be strictly enforced.

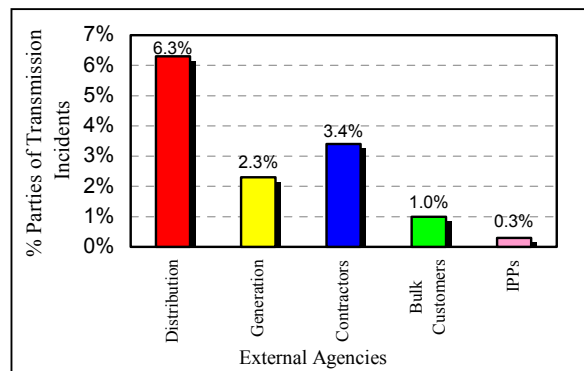


Figure 6 External Parties Impact on Transmission Network.

**MAJOR INTERRUPTIONS SELECTED FOR DETAIL REVIEW AND ANALYSIS**

Not all events are severe. Depends on some of reliability factors such as number of customer interrupted, interruption duration, and MW lost, some of the fault incidents deserve to be handled with much care while others can be ignored. Following the analysis of the incidents, some of fault incidents have been selected for more detail investigations and review. SEC believes that the experiences gained and lessons learned from these incidents would be of interest and value to enhance the reliability and performance of the transmission system.

The selected fault incidents, for detail review, should meet certain criteria that assigned by SEC Disturbance Analysis Working Group (SEC-DAWG). Incidents that meet one of the following criteria are considered by the working group for detail review:

- All incidents in the transmission system resulting in load loss (measured in system-minutes)  $\geq 1.0$ .
- All incidents in the transmission system caused by human errors.
- All incidents in the transmission system caused by variations in the system voltage and/or frequency, resulting in loss of load.
- All incidents in the transmission system which occurred frequently, even resulting in no loss of load.
- A disturbance incident can be included, even if it didn't meet the above criteria, if it is recommended and agreed upon by DAWG members.

With respect to the interruption records during the year of 2005, 17 % of the total 2005 interruptions were meeting the DAWG criteria. Among these incidents, Thirteen (13) MAJOR fault incidents were selected for detail reporting. The detail of the selected incidents report include: full description of that fault incidents, define and follow fault incidents origins, tabulate lessons learned, and state recommendations to decrease the possibility of fault incidents re-occurrence and to improve the supply continuity. Table 2, shows the distribution of the selected major faults and how they correlated the DAWG criteria.

Table 2 SEC-DAWG Selected Major Fault Incidents for Review

DAWG Criteria	# of Incidents
(Measured In System-minutes) $\geq 1.0$	5 of 13
Incidents Caused By Human Error.	3 of 13
Variations In The System Voltage And /Or Frequency, Resulting In Loss Of Load.	6 of 13
Incidents Which Occurred Frequently	2 of 13
Incidents Selected By DAWG Members	4 of 13

- Some incidents met more than one category of the SEC - DAWG criteria.

**FEASIBILITY OF IMPLEMENTING THE RECOMMENDATIONS**

Regarding to the detailed analysis of the selected MAJOR fault incidents, SEC provides recommendations to be executed with the objective to enhance the performance of the transmission system. The recommendations were categorized as recommendations to be followed by transmission system groups and recommendations to be followed by non-transmission parties. Moreover, SEC classifies the recommendations within different classes as

shown in Table 3. The feasibility of implementing the recommendation can be taken in consideration as another reliability issue when comparing performances of different regions entire the transmission system network.

Table 3 – SEC – DAWG Recommendation Classes

SEC RECOMMENDATIONS CLASSES	
Forward To Transmission Groups	Forward to Non- Transmission Parties
Transmission system reinforcement	Distribution system
Protection	
Equipment specifications	Generation system
Maintenance	
Operation philosophy & procedures	Independent Power Producers
Ongoing projects schedule	
SCADA & Communication	Contractors
Safety precaution	Customers

With respect to 2005 SEC-DAWG recommendations, the salient points of Table 3 are as follows:

- Seventy two percent (72%) of the total SEC recommendations are for actions by the transmission Business Unit, while the remaining recommendations (28% of the total) are for actions by Non-Transmission Parties (Distribution, Generation, customers, .....etc.)
- For Transmission BU, majority of the recommendations (24 % of the recommendations) are for actions under Operation Philosophies and Procedures.
- For Non-Transmission Parties, majority of recommendations (48 % of the Non-Transmission recommendations) are for actions by Generation System.
- 80 % of the recommendations were either completed or under progress which indicate for the feasibility of implementing the recommendations

**CONCLUSIONS**

This paper has presented valuable experience gained by Saudi Electricity Company (SEC) in setting up its reliability monitoring and assessment strategies. The paper describes new approaches for collecting information on reliability, and look at the results of the collected data from various surveys. Some key accesses, *reliability relative tasks*, were suggested that enabling better understand of system reliability issues and establishing a wide variety of analysis and benchmarking to improve system reliability.

Regarding to interruption database monitoring survey, the analysis procedures indicate for the following reliability related observations:

- Weather related conditions are the major cause of interruptions, accountable for 34% of the total SEC fault incidents.
- Parties external to the transmission Business Unit were responsible for almost 14% of the total number of fault incidents. The dominant external parties are: distribution (6.3%) and contractors (3.4%).
- SEC Disturbance Analysis Working Group (SEC-DAWG) assigned criteria for selecting MAJOR fault incident with the objective of detail reporting. SEC believes that the experiences gained and lessons learned from these MAJOR incidents would be of interest and value to enhance the reliability of the system.
- Certain categories of recommendations were assigned for transmission BU as well as for Non - Transmission parties. Majority of recommendations are for actions under Transmission System Reinforcement and Protection categories.

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