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# Distribution Interruption Performance Reporting: A Complete Solution

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## ABSTRACT

Most electrical distributors are required to report on the performance of their distributed electrical networks. These measures are required at operational and strategic levels within utilities.

Distribution Network Interruption Performance Reporting is the standardized reporting of measures that reflect the performance (reliability) of an electrical distributed network. The measures used for reporting network performance is guided by several international industry standards e.g. Institute of Electrical and Electronics Engineers (IEEE) and International Council on Large Electric Systems (Cigre).

Inconsistent, unreliable and non standardized reporting of reliability indices across distributors are the main problems within the industry. This is due to distributed application systems and different interpretations of international standards when calculating reliability indices.

This paper aims to give the electrical utility industry an insight into standardization of reporting distribution interruption performance indices by conforming to international standards. The reader will obtain a better perspective of the problems encountered in the industry as well as how a SAS® solution is utilized for reporting these reliability indices.

The paper will demonstrate how the problem areas are addressed by utilizing a pre packaged SAS® Business Intelligence solution comprising of: source data extraction, data storage, calculation of reliability indices in accordance with international standards and reporting these indices using SAS® standard reporting.

## INTRODUCTION

The *IEEE 1366* Standard *(Ref 1)* is a widely accepted international guide that stipulates the required reporting indices to reflect electrical distribution system performance. Additionally, the standard refers to how these indices should be calculated and defines data definitions, requirements and business rules that need to be applied.

"Along with the variety of definitions of reliability come a variety of ways to measure it. A metric for reliability is required for assessment of past performance, consideration of reliability in design, and setting of reliability goals. Many indices have been defined as measures of reliability. They measure different aspects of reliability or combinations of different aspects. Only a small number of these are common across several utilities, and the ones that are commonly used are not always defined in the exact same manner." *(EPRI White Paper- Ref 2)*

In today's competitive economic climate it has become imperative for utilities and supply companies to accurately measure the performance of their networks. Reporting reliability performance indices at customer level gives these distributors an in-depth insight to the operational effectiveness and health of their supply networks thus giving them a leading edge over their competitors. Additionally, most electrical distributors are required by statutory governance to accurately and consistently report on the performance of their networks.

Reliability reporting consists of a group of indices *(Table 1)* that are based on, and not limited by, the duration and frequency of supply interruptions experienced by a customer.

Reporting Reliability Performance Indices requires the following:

- Capturing of source data related to outages on the electrical networks
- Transforming the source data into the applicable formats using the business rules stipulated in international standards
- Calculating reliability indices using the formulae stipulated in the standards
- Presenting the results in a standard report format

One of the biggest challenges experienced by supply distributors and by different supply utilities is to consistently and accurately report reliability indices in conformance with international standards. Many factors can cause variation in the indices reported by different utilities. Some examples of differences are namely, the following:

- Level of automated data collection
- Geography
- System design
- Data classification (Application of business rules)

This paper describes a bundled SAS® Business Intelligence solution to report on Distribution Interruption Performance Indices based on International Industry Standards. (*Appendix A)*

**Table 1 – Distribution Interruption Reliability Indices**

| | | |
|---|---|---|
| SAIDI | SAIFI | SAIDI* (Tmed) |
| CAIDI | CAIFI | CTAIDI |
| MAIFI | MAIFIe | ASAI |
| CEMIn | ASIFI | ASIDI |
| CEMSMIn | SLI | |

## PERFORMANCE MANAGEMENT

Reliability indices for distribution systems are used by utilities and regulators to benchmark performance and prioritize investments in projects to improve performance. Many regulators apply financial penalties on distributors who do not meet target values of reliability performance. Furthermore, reliability indices are used by system planners and operators as a tool to improve the level of service to customers. Figure 1 below depicts the number of companies using given indices from an IEEE survey conducted in 1995 and 1997 (Ref 1).

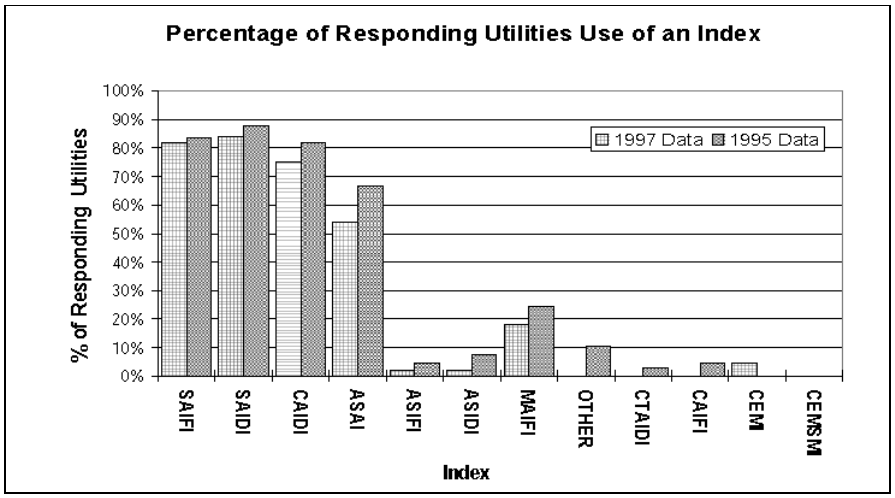


**Figure 1 - Percentage of Companies Using a Given Index**

A recent study conducted by L Berkeley (National Laboratory) on the costs of power outages to the U.S. economy, estimates annual losses from momentary and sustained power interruptions at $79 million annually. A preliminary statement sheet delivered by Southern California EDISON – 2004 (Ref 3) defines financial rewards and penalties based on 3 reliability indices as follows:

SAIDI:
- Benchmark: 56 minutes
- Deadband: +/- 6 minutes
- Liveband: +/- 9 minutes
- Unit of Change: 1 minute
- Incentive per unit: $2 million
- Maximum incentive: +/- $18 million

SAIFI
- Benchmark: 1.07 outages per year
- Deadband: +/- 0.13 outages
- Liveband: +/- 0.18 outages
- Unit of Change: 0.01 SAIFI
- Incentive per unit: $1 million
- Maximum incentive: +/- $18 million

MAIFI
- Benchmark: 1.26 outages per year
- Deadband: +/- 0.13 outages
- Liveband: +/- 0.18 outages
- Unit of Change: 0.01 MAIFI
- Incentive per unit: $200,000
- Maximum incentive: +/- $3.6 million

Considering the regulatory requirements, operational planning needs and financial implications mentioned above, the management of electricity supply networks performance is paramount within the electricity supply industry.

## THE SOLUTION

To address the inconsistency in reporting of reliability indices, a ready build SAS® Business Intelligence solution, DISTRIBUTION INTERRUPTION PERFORMANCE REPORTING SOLUTION (DIPS), has been developed based on the business rules and criteria stipulated in the IEEE 1366 – 2003 standard (Ref 1) and Cigre Publication ETL216-7 (Ref 4).

The SAS® DIPS Solution addresses:

- Data quality enhancement and standardization;
- Standard measure definitions;
- Consistent definition of measure components;
- Consistent calculation methods;
- Standard reporting

The DIPS solution can be described as a bundled application for the reporting of distribution reliability performance indices. The system consists of a ready built Data Warehouse (DWH) incorporating standardized data models, calculation processing, and report surfacing. Figure 2 depicts the process followed to extract source data, calculated measure components and surface reports. The source data is extracted into a standard format. Detailed subject area data is constructed and stored in standard dimension model formats. International calculation standards and business rules are applied to generate reliability measures. Standard formatted reports are utilized to surface the indices.

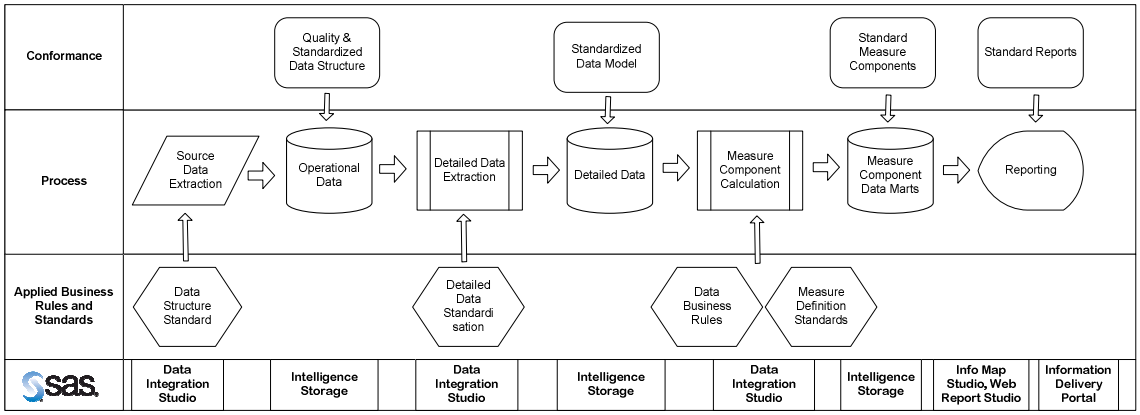


**Figure 2 - Reliability reporting process overview**

## APPROACH

The approach is to pre develop an optimum Operational Data Store (ODS), Detailed Data Store (DDS), Extraction Transformation and Loading (ETL) Processes, Data Marts and SAS® Strategic Performance Management (SPM) Reports that are required to surface the reliability indices (Figure 3). The data models are developed according to the data requirements and definitions defined by the International standards for reporting performance indices. A bundled ETL process, utilizing the defined data models, is used to generate the components required to calculate the performance measures. The indices are then surfaced through Data Marts on which SAS® OLAP Cubes and SAS® Strategic Performance Management scorecards reports are based.

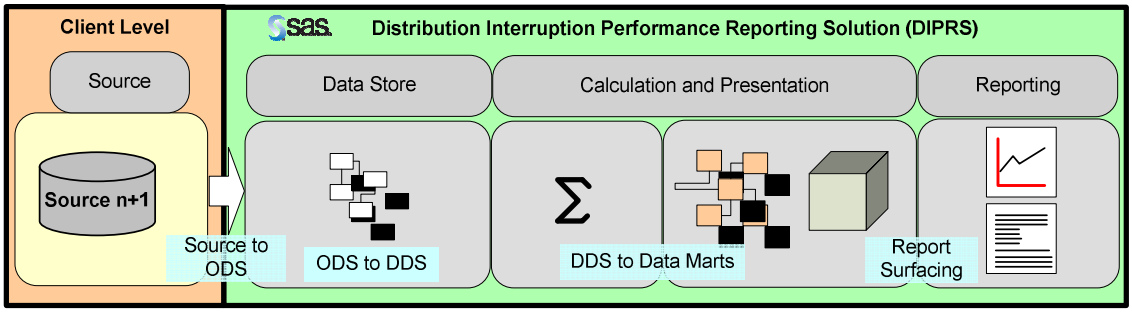


**Figure 3 - System Overview**

SAS® Data Integration Studio is utilized to integrate data from any client source, apply data quality rules as well as merge and transform the data into the target ODS tables. Standardized metadata is created and shared across the entire SAS Enterprise Intelligence Platform.

## SOURCE TO ODS

The objective of using a pre defined ODS model (Figure 4) is to ensure that the source data conforms to the structure required by the internal ETL process that calculates the components required for the reliability indices. To ensure data integrity and conformance to international standards, the source data is extracted and loaded into the pre defined ODS. This process allows for several client data sources to be utilized in obtaining the data required. E.g. Customer, Network and Operational repositories.

The process required to extract the data from the source repositories into the fixed data models in the ODS layer depends on the source data quality and structure. This requires custom extraction processes to be developed for each individual client. SAS® Data Integration Studio is used to create an integration process between the ODS tables and the DDS repositories. The data business rules are built into the process jobs ensuring data standardization throughout the process is maintained.

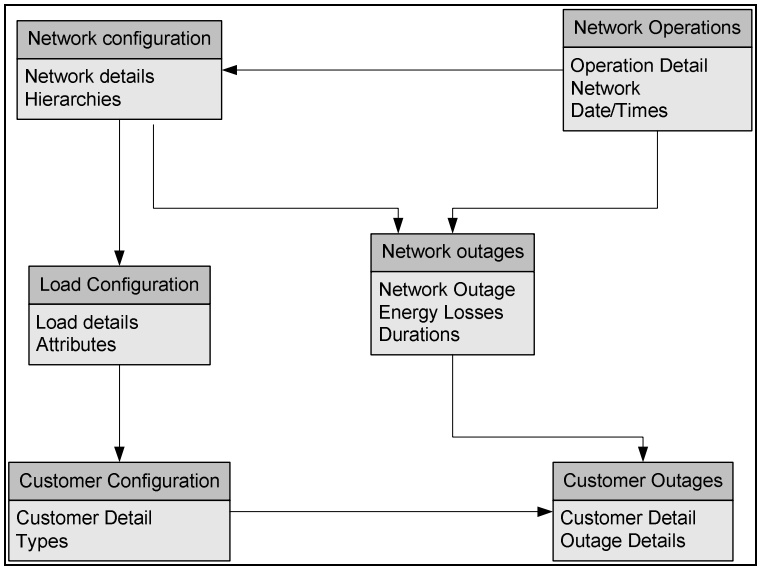


**Figure 4 - ODS Data Model Overview**

## DETAILED DATA STORE

The components required to calculate the performance indices are core to accurate and consistent reporting of indices. By applying the business rules and definitions of the industry standards, an ETL process extracts the data from the ODS tables and populates the required DDS tables. The DDS contains four data subject areas arranged in dimensional data models (Figure 5). The level to which reporting can be done is dependent on the level of detail of the data in the ODS layer; the finer the granularity of the source data the lower the level of reporting of the indices.

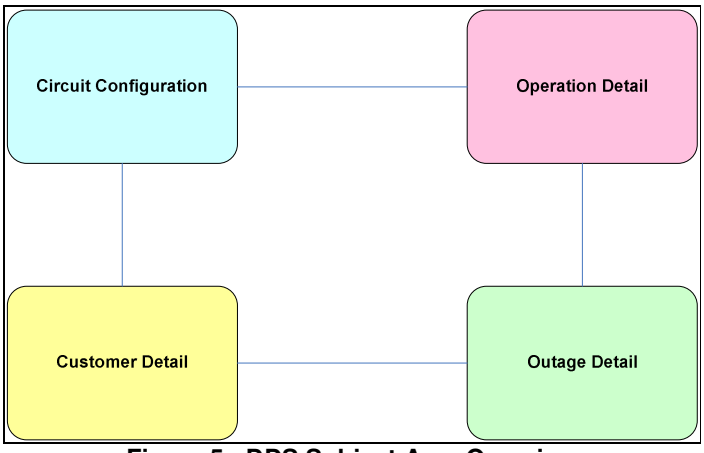


**Figure 5 - DDS Subject Area Overview**

## DDS TO DATA MART INTEGRATION

The ETL process from the detailed data store to the data marts is performed utilizing a Packaged Calculation Engine[1]. The ETL process uses the data in the pre defined DDS tables to calculate the reliability indices and populates the results in the required formats into the data mart tables (Figure 6).
Dynamic Constant tables are populated with business rules and definitions. These attributes are used as variables in the ETL process when calculating summation data. Forecasting values are included for indices and are calculated using historical trend data.

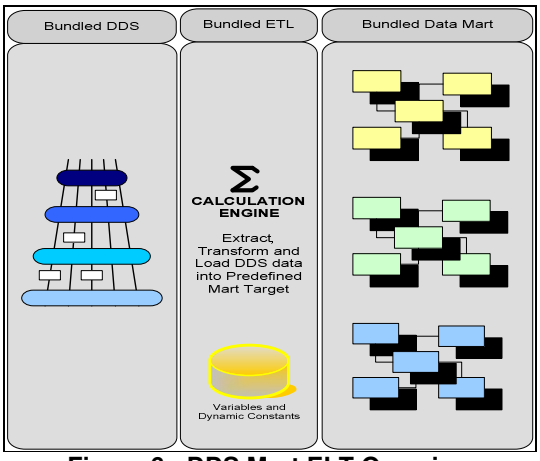


**Figure 6 - DDS Mart ELT Overview**

The integration process between the DDS layer and the Data Marts contains all the standards for calculating reliability indices. SAS® Data Integration Studio and Base SAS are used to develop a generic calculation process for populating the Data Marts.

1 The Calculation Engine is a generic sub system for the population of data marts.

## REPORTING

The distribution interruption performance indices are reported as SAS Data Cube reports and SAS® SPM Scorecards via the SAS® Information Delivery Portal. This enables the business to analyze the indices by using the drill down functions in the cubes. Ranges can also be set on aggregated indices reported in the scorecards. All international standard reliability indices are reported across all business levels. The definitions of these indices are available in the standards (Table 1). Apart from reporting on the indices, standard reports for Pareto[2] analysis and customer outage profiles are surfaced from the data marts. Figures 7 to 9 depict typical application graphic reports.

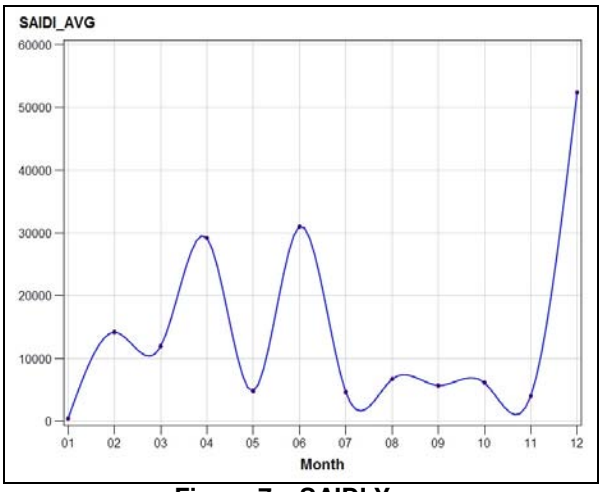


**Figure 7 – SAIDI Year**

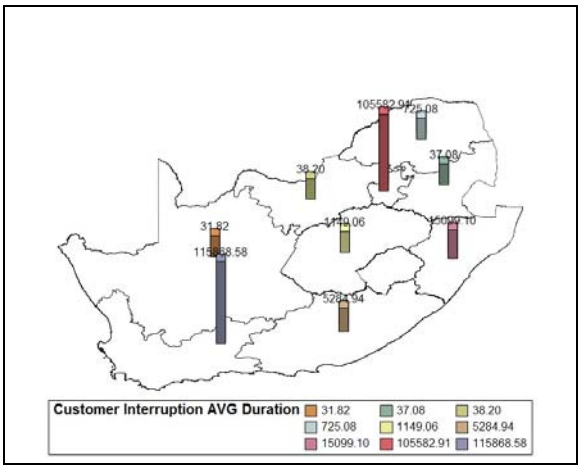


**Figure 8 – Customer Interruptions Year**

2 Pareto reports are defined as the 20/80 reporting principle.

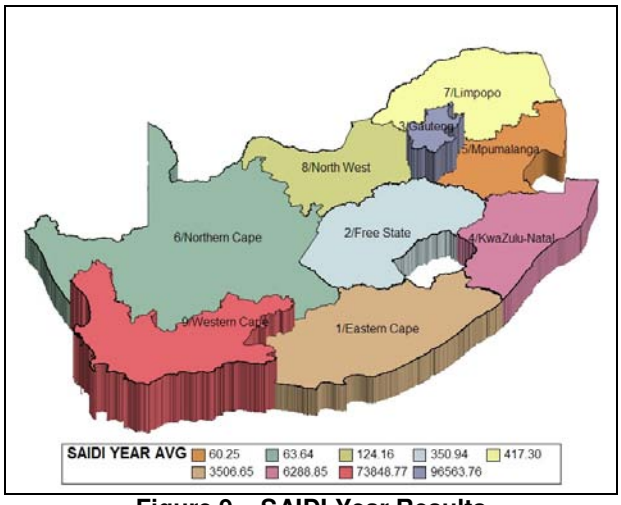


**Figure 9 – SAIDI Year Results**

The reliability indices are presented in SAS® OLAP Cube reports. The results are sliced into business hierarchy levels, time dimensions and reporting data types e.g. Planned/Unplanned. SAS® Scorecards display aggregated values at Business levels with range settings, defined by the client.

## BRINGING IT ALL TOGETHER

Source data from the client is loaded into standard table structures within the ODS layer. This process ensures the standardization and quality of the data that is required to calculate reliability indices. The 'boxed' solution consists of: transforming the ODS source data into the DDS maintaining data integrity. The measure components required to calculate the reliability indices are calculated by applying industry standards and business rules that are bound within the ETL process ensuring calculation conformance and consistency. The Distribution Interruption Performance Reporting Solution enables the client to obtain a single point of view of standardized, consistent and high quality reliability measures through the SAS® Information Portal.

The DIPS does not limit the client to the reports shipped with the solution. Additional reports can be compiled based on the standardized data and data structures within the DDS and Data Mart layers. This customized reporting is required by most supplier companies. The data content and structure of the DIPS creates further analytical opportunities for the client to investigate non conforming indices and contributing network outage data.

## CONCLUSION

As discussed in earlier chapters of this paper, there are many challenges to consistently report accurate distribution reliability indices. Not all of the issues can be addressed by an automated reporting system i.e. poor quality of source data. Standardizing source data and applying consistent business rules and measurement definitions on the source data can increase the quality of performance reliability indices and the consistency of reporting within, and across, supply companies. The DIPS, SAS® Business Intelligence solution, ensures consistent conformance with business rules and measure definitions throughout the total process of reporting reliability indices.

This paper has discussed the following:

- Importance of Distribution Performance Reliability Reporting within the electricity supply industry.
- Challenges facing the industry in delivering consistent, quality reports across a wide spectrum of business and company levels.
- Difficulties in benchmarking reported indices within the industry.
- A SAS® Business Intelligence solution that address the issues of data standardization, application of business rules, conformance to international industry standards and delivery of standard reliability reports.

## REFERENCES


1. IEEE 1366 – 2003 *"Guide for Electrical Power Distribution Reliability Indices"*
2. *EPRI White Paper 2006 "Reliability of Electric Utility Distribution Systems"*
3. *Southern California EDISON - Employee Safety and Distribution Reliability Performance Incentive Mechanism (2004)*
4. *Cigre ETL216-7 Power Quality Indices and Objectives*
5. *NERC - Reliability Standards for the Bulk Electric Systems of North America*


## BOOKS TO READ


1. *Electric Power Distribution Reliability* By Richard E. Brown Published by CRC Press, (2002)




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## APPENDIX A

Description of Reliability Performance Indices

| KPI Measure | Definition | Formulae |
|---|---|---|
| **SAIDI** | System average interruption duration index | SAIDI= Sum(Customer Interruption Durations)/Total Number of Customers Served |
| **SAIDI* (Tmed)** | System average interruption duration index (Excluding Major event Days) | SAIDI= Sum(Customer Interruption Durations)/Total Number of Customers Served |
| **SAIFI** | System average interruption frequency index | SAIFI= Sum(Total Number of Customers Interrupted)/Total Number of Customers Served |
| **CAIDI** | Customer average interruption duration index | CAIDI= Sum( Customer Interruption Duration)/Total Number of Customers Interrupted |
| **CAIFI** | Customer average interruption frequency index | CAIFI= Sum( Total Number of Customers Interrupted)/Total Number of Customers(Unique) Interrupted |
| **CTAIDI** | Customer total average interruption duration index | CTAIDI= Sum(Customer Interruption Duration)/Total Number of Customers(Unique) Interrupted |
| **MAIFI** | Momentary average interruption frequency index | MAIFI= Sum(Total Number of Customer Momentary Interruptions)/Total Number of Customers Served |
| **MAIFIe** | Momentary average interruption event frequency index | MAIFIe= Sum(Total Number of Customer Momentary Interruption Events)/Total Number of Customers Served |
| **ASAI** | Average service availability index | ASAI= Customer Hours Service Availability/Customer Hours Service Demands |
| **CEMIn** | Customers experiencing multiple interruptions | CEMIn= Total Number of Customers that experience more than n sustained interruptions/Total Number of Customers Served |
| **ASIFI** | Average system interruption frequency index | ASIFI= SUM(Total Connected kVA of Load Interrupted)/Total Connected kVA Served |
| **ASIDI** | Average system interruption duration index | ASIDI= Sum(Connected kVA Duration of Load Interrupted)/Total Connected kVA Served |
| **CEMSMIn** | Customers experiencing multiple sustained interruption and momentary interruption events | CEMSMIn= Total Number of Customers Experiencing more than n Interruptions/Total Number of Customers Served |