SUMMARY

This study has been conducted in response to a request from Saudi Electricity Company, Eastern Region Branch (SEC-ERB) dated 26 Jumada I, 1421H (26th August, 2000). The study started on 17th March, 2001 for a period of 10 working months. The goal of the study is to identify the causes the voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips. This is done through the study of the performance of the SEC-ERB system for the years 2001 and 2003 under various transient operating conditions.

The industrial city of Jubail is one of the major industrial hubs of the Kingdom's rapid industrialization program. Its electrical energy requirements are being supplied from SEC-ERB network. Electrical energy is transmitted to the industrial area at four voltage levels - 380 kV, 230 kV, 115 kV and 34.5 kV. There are four main substations that provide bulk power to the industrial area. The electrical network in this city has recently been reinforced in order to integrate the new power plant, Ghazlan-II. The major study objectives are:

1. Provide an overview of the voltage dip phenomena and associated characteristics such as duration, frequency, and magnitude.

2. Review international standards and practices, especially the practices followed by North American, European and other international utilities in characterizing and mitigating voltage dips.

3. Review the present and past power system contingencies in the Jubail industrial area that have caused voltage dips resulting in problems to the end users.

4. Review practices followed by Saudi Aramco in order to ride-through the voltage dip problems.

5. Study the steady state and transient behavior of the SEC-ERB electrical network for the years 2001 and 2003 at different loading conditions and analyze its voltage profile in Jubail industrial area.

6. Compare the results of voltage dips on SEC-ERB system with international standards and practices.

7. Conduct economic analyses to determine or compare costs of recommended ways and means to minimize the loss of load due to voltage dips, if required.

8. Based on the outcome of the study, provide recommendations to both SEC-ERB and its industrial customers.

The specific tasks that have been carried out were as follows:

- Review of voltage dip phenomena, international standards and practices of international utilities.

- Data collection from SEC-ERB.

- Data collection from Jubail industries.
- Data collection from Saudi Aramco.
- Steady state and electrical transient simulation of SEC-ERB network for the years 2001 and 2003.
- Analysis of the simulation results and comparison with the international standards and practices.
- Provide recommendations to SEC-ERB and customers in Jubail Industrial City (JIC).

The study team carried out an in-depth literature survey on the phenomenon of voltage dip. The purpose is to understand the complexities of the voltage dip incidents and to identify international standards and guidelines. The search is also aimed at gathering and documenting utility experiences. The results of the literature search reveal that voltage dip phenomena are well documented. A substantial body of literature is available about voltage dips, but there is no clear and formal international standard on the phenomenon. There exists no international standard as to the acceptable voltage dip magnitude, and duration. The rate of voltage recovery, following a fault, is system dependent. It is important to note that the electric network performance is also related to the number of dips. The project team decided, in consultation with the client, to use some of the widely used international experiences of South African Electric Utility (ESKOM), Computer Business Equipment Manufacturers Association (CBEMA) and Information Technology Industry Council (ITIC) criteria. These criteria are used by many utilities world wide to measure the performance of their networks.

The ESKOM criterion represents the voltage dips graphically according to voltage dip window. The compatibility levels are defined in the form of a maximum number of dips per year for the defined ranges of voltage dip and duration. The ESKOM criterion is adapted by IEEE 1564 Task force and is used by many utilities for monitored data.

The CBEMA power acceptability curves are the closest to a standard. However, the power acceptability curve may not capture all the complex phenomena of low and high voltage conditions and a casual use of the curve may give false conclusions. The curve is widely used by equipment manufactures and suppliers. It defines a threshold energy level to be delivered to the load. If the energy delivered during a voltage dip is less than the threshold, it could have an impact on the operation of the load.

The CBEMA curve was redesigned and renamed after the Information Technology Industry Council (ITIC). The ITIC curve describes an acceptable operating region in steps. It has an expanded acceptability region for portions of the voltage -time plane. The ITIC curve has been used by many utilities. The voltage reference is 0.8 per unit. The recovery time is considered to be critical if it falls along the limit line between 500 msec to 10 seconds.

System simulation studies were undertaken on the 2001 and 2003 SEC-ERB networks. The purpose was to determine the magnitude and duration of the dips following faults at selected locations. The locations were selected in consultation with SEC-ERB. The dip magnitude and duration were to be compared to ESKOM, CBEMA, and ITIC criteria.

An analysis of the incidents of voltage dip in JIC was also carried out. It involves the history, duration, and magnitude of the voltage dip incidents. This covered the period from 1997 to 2001. The characteristics of the voltage dip were compared to ESKOM criterion only.

The overall study results are summarized below:

- There is a substantial and marked reduction in the number of voltage dip incidents in JIC. This is because most of the industries have upgraded their supply to 230 kV and 115 kV levels.

- The majority of reported voltage dip incidents are caused by single line to ground (SLG) faults.

- The number of voltage dip incidents during the years 1997-2001, when compared to the ESKOM criteria, was found to be well below the acceptable number of events.

- There are no international standards or guidelines to be used for comparison. The IEEE has recently formed a task force to develop a guideline. The task force has not released its final recommendations.

- Several of the industrial facilities have indicated that their relay settings have been revised and are closely coordinated with SEC-ERB.

- Several industrial facilities have installed ride-through equipment such as Saudi Aramco and SADAF at the 480 kV auxiliary power supply. These measures reduced the impact of the voltage dip incidents on their equipment and facilities.

- The SLG fault simulation results for the years 2001 and 2003 show that the system performance is acceptable when compared with the CBEMA and ITIC criteria. The system performance is also acceptable when compared to the ESKOM criterion based on magnitude and duration of the voltage dip. It should be noted that the ESKOM criterion is based on the magnitude, duration, and the number of voltage dips per year. However, the simulation results provide magnitude and duration of the dips. The system performance will be acceptable if the number of dips per year is also within the ESKOM limits. The historical data (1997 – 2001) indicates that the number of voltage dip incidents are well below the ESKOM limits.

- The 3-phase fault simulation results for the years 2001 show that the voltage recovery times are within the ITIC limits. However the loss energy indices are well outside the CBEMA limits. The 3-phase simulation results for the year

2003 reveal that the voltage recovery times are high and exceed the 500 ms. These are considered to be critical. Also the loss energy indices are high and are outside the CBEMA limits. However it should be noted that the occurrence of a 3-phase fault within the SEC-ERB system is a rare event. The system performance cannot be judged on these simulation results.

- System simulation for the years 2001 and 2003 indicates that faults at Ghazlan and Berri produce voltage dips with the longest recovery time.

Based on the above, the study results indicate that there is no need for mitigation measures on the SEC-ERB system.

Even though the number, duration and magnitudes of voltage dip incidents are well below the limits set by widely used international criteria, SEC-ERB may continue to introduce fast relays and circuit breakers whenever the technology and cost permit.

Following are some general recommendations to industrial customers in Jubail.

- Carry out a detailed study on the operation of critical industrial processes following a voltage dip.

- Conduct technical and economical studies about the application of ride-through equipment.

- Create a database for voltage dip incidents and their impact on production.

- Install devices to help their critical equipment to ride-through voltage dips.

- Incorporate voltage dip ride-through capability in the design and specifications for their new/addition equipment.