POWER QUALITY INITIATIVES IN SINGAPORE

S T Chang, K Y Chua, C C Siew and T L Tan

PowerGrid Ltd, Singapore

SUMMARY

PowerGrid Ltd, a subsidiary of Singapore Power Ltd, is responsible for the transmission and distribution of electricity in Singapore. The network comprises 400kV, 230kV, 66kV, 22kV and 6.6kV systems with cables spanning more than 15,000 kilometres. The uniqueness of Singapore power system is that the transmission and distribution system is a fully underground cable system. The operation of the system is immune to thunderstorms, lightning, fallen tress, wind and other adverse weather conditions.

The increasing presence of high-tech industries in Singapore has brought about new challenges on the deliverables of supply, particularly power quality in terms of voltage dip. The high-tech industries, particularly the wafer fabrication, semiconductor, petrochemical and pharmaceutical industries require a high quality of supply because controls used in their equipment processes are highly sensitive to voltage dip.

This paper describes the initiatives taken by PowerGrid in addressing the issues of power quality in Singapore with particular reference to voltage dip.

While PowerGrid strives to minimize the cause of voltage dips from the network end, there is presently no technology in place to produce equipment or cables that do not fail. It is not possible in practice to totally eliminate failures in the network. In view of this, the next best thing is for customers to do their part in minimizing the impact of voltage dips in the event of failures. To this, financial incentives are given to encourage customers to implement plant-end solutions.

PowerGrid will continue to work closely with high-tech customers and their consultants and plant manufacturers so that there is good understanding and working rapport in ensuring the compatibility between voltage sensitive equipment and the power quality that can be expected in practice.

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POWER QUALITY INITIATIVES

In meeting the challenges, PowerGrid has put in place a comprehensive power quality improvement plan to meet the needs of the high–tech industries. The plan covers the following power quality initiatives:-

- Power Quality Monitoring System
- Application of mitigation technologies for voltage dip ride-through
- Network Enhancement
- Cost-effective mitigation devices
- Condition monitoring
- Cable Damage Prevention

Voltage dips in Singapore are mainly caused by –

- Cable damage by earthworks
- System equipment and cable failures
- Customer installation failures

In terms of the number of voltage dip incidents, the main contributor is customer installation failures (see Fig. 1). However, such dips are localized in nature and of lesser impact. Failures on the network elements particularly in the transmission system although are few, the effects are usually wide spread and of more severe impact.

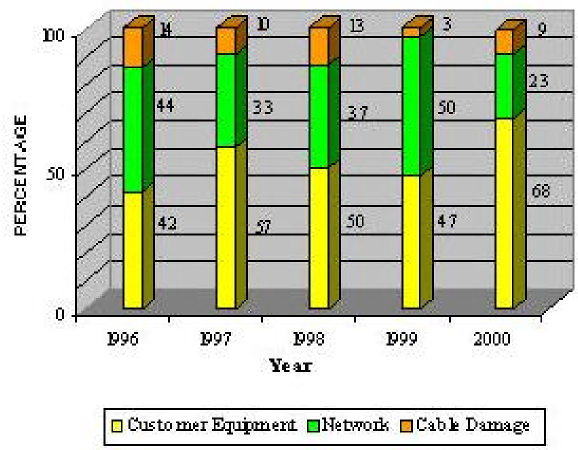

Fig. 1: Causes of voltage dips seen by high-tech customers.

Power Quality Monitoring System

PowerGrid is in the process of installing a Power Quality (PQ) Monitoring System to track power quality including the magnitude and duration of a voltage dip. The System, scheduled to be operational by the mid 2001 will enable PowerGrid to monitor and analyse power quality performance island-wide.

With the help of the monitoring system, the voltage dip database will be used for network analysis for power quality improvements. Such data will also be made available to customers for voltage dip sensitivity analysis and mitigation. The same data will be available to potential investors and new customers at the planning and design stage of their plants so that equipment specifications and plant design can be incorporated with adequate voltage dip ride-through or suitable power conditioning.

The power quality monitoring will be installed across the transmission and distribution networks from the 400kV to the distribution voltage levels including major customer intakes. A total of about 80 power quality monitors will be installed throughout the network. More power quality monitors will be added as the network expands. The selection of the monitoring points was based on the electrical blocks of the network, major customers' locations, geographical coverage and the type of load and capacities.

The major challenge of this project is to bring back the dip data swiftly to the Power Quality Monitoring Centre to facilitate the management of the voltage dip incident. Figure 2 shows the layout of the communication network for the PQ monitoring system. Riding on the "high-speed" communication link capability, the PQ monitoring system is designed and operated as a WAN network through TCP/IP protocol with full-time connectivity.

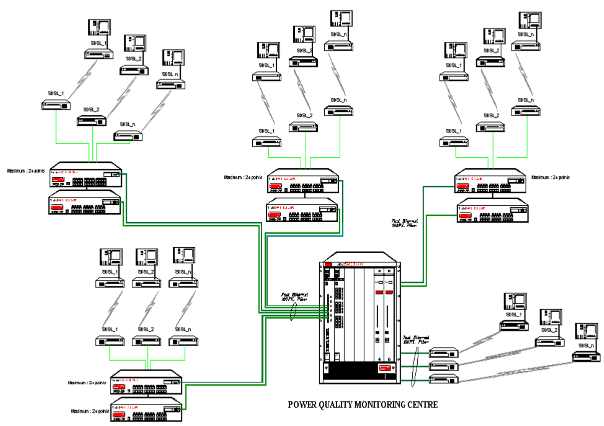

Fig. 2: Communications Network

The power quality monitor progressively being installed has the following features:-

- high sampling rate and fast computation speed
- data logging and disturbance recording functions
- ethernet port connection (RJ45) with TCP/IP address.

Two important requirements for the PQ monitoring system were identified -

- in the event of a disturbance, the Centre must be able to retrieve the waveforms recorded as fast as possible.
- the main database for the system must be "open" and not vendor dependent.

In order to capitalise on the "full time" connectivity of the communication network, any new disturbance event and data recorded by the power quality monitors will automatically be downloaded to the Centre.

All data retrieved from the power quality monitors will be processed and stored in the main open database. The main database is not vendor dependent so as to allow data from different manufacturers to be stored, retrieved and analysed using the System Power Quality (PQ) analytical software.

In the event of a voltage dip disturbance and after the system have downloaded records from all power quality monitors, the system PQ software will immediately analysed the records and automatically generate a system summary report on the event based on Power Quality Performance Standard like SARFI index. SARFI x stands for "System Average RMS (Variation) Frequency Index" and x is the remaining voltage reference. In short, SARFI x is the number of dips per year that a customer would experience where the remaining voltage during the dip is less than x%. The PQ monitoring system will also simultaneously display the power quality index at each site of the event onto the Singapore Island Map.

The dip information will be made available via PQ website for operational use as well as for customers so that customers can be better informed of the quality of supply at their site.

Application of Mitigation Technologies for voltage dip ride-through

PowerGrid is one of the few utilities in the world that has installed three different makes of medium voltage power quality devices (PQD) to test out the available technologies on power quality. The intention is to explore its application feasibility in mitigating the effects of voltage dip seen by high-tech customers. The results are mixed.

Many lessons were learnt from the pilot project -

- reliability and manufacturing quality of components such as repeated failures of IGBTs, filters etc affected overall performance
- the need to understand the dynamic load characteristics for correct applications eg. chiller motor start-up current
- fine tuning of PQD protection settings required eg. high over voltage due to close-up fault near the plant
- customers' agreement to put the PQD on line after a PQD problem which can be protracted and time consuming

On the whole, the technology of medium voltage compensating devices has proven to be workable in compensating voltage dips. However, the solution is expensive because of the high cost of the switchgear and transformer. It will be costly to protect the entire plant using such devices.

To meet the needs of the industries, a more cost effective solution to overcome the voltage dip problem has been developed by Singapore Power Systems, a subsidiary company of Singapore Power. This is a voltage dip compensator, the DynaCom, for direct connection into low voltage systems without the use of an interfacing transformer. A number of these units, rated at 250kVA, have been installed at 3 semiconductor manufacturing plants located in Singapore. Tests on prototype DynaComs of 500kVA and 1000kVA rating have been completed and a 2000kVA rated unit is under test. One on-site record, Fig 3, taken with one of these units shows the operations of a DynaCom and the complex nature of the voltage dip problem. When the voltage dip occurs the DynaCom compensates the dip in less than 3 msec, in this particular case. The result is that the power supply voltage wave at the consumer load is virtually undisturbed and with no significant transients.

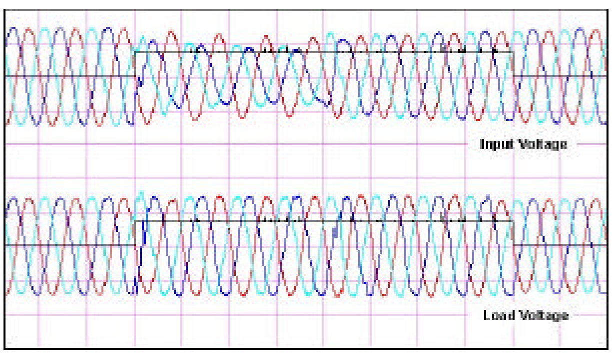

Fig. 3: Typical On-Site Operation of a 250kVA Dynacom Correctly Compensating a 45% Voltage Dip

Network Enhancement

A 400kV transmission system was developed in 1998 to meet the power transmission needs of Singapore into the new millennium. This new system will enhance the transmission capability through better fault handling and more economical power transmission.

The introduction of the 400kV system also helps in the improvement of power quality. PowerGrid has since early 2000 split the 230kV network into two electrical blocks, the North and South blocks using the 400kV network (see Fig. 4). This significantly helps to reduce the severity of the dip seen by a customer in the Northern block for a 230kV fault that developed in the Southern block and vice versa.

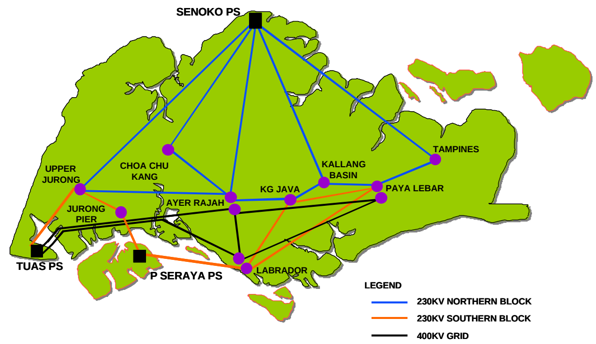

Fig. 4: 400/230kV underground transmission network

The effectiveness of splitting the 230kV network in improving power quality has been proven in practice based on actual events. Petrochemical industries in the Southern block were not affected by a 230kV fault in the Northern block. Similarly the wafer industries in the Northern block were not affected by a fault in the Southern block.

Cost-Effective Mitigating Solutions

It is well acknowledged by the industries that the most cost-effective solutions are the in-plant solutions within the customers' premises. Devices such as:

- coil-lock to help to ride through contactors
- constant voltage transformers
- low voltage sag compensators

are many of the equipment end devices available in the market. These technologies and applications have been proven with many case studies published in technical papers. Towards this end, Singapore Power, the holding Company of PowerGrid, has set up a Power Quality Solution Fund of S$150 million to provide financial incentives to industries to implement Power Quality Solutions (PQS) at customer end. Singapore Power will contribute 50 per cent of the cost incurred by customers in implementing the solutions. The voltage dip ride through solutions to be implemented should meet the ride through capability curve, which is based on the SEMI F47.

Condition Monitoring

PowerGrid has also invested on on-line condition monitoring systems for 400kV substations and new 230kV substations. Existing 230kV substations will be retrofitted progressively with the same capability. With the system, PowerGrid is able to detect incipient faults before they develop into failures leading to voltage dips.

Included in its early-warning systems is the Distributed Temperature Sensing (DTS) system incorporated in all 400kV and new 230kV cable networks. PowerGrid is one of the few utilities in the world to use the DTS technology. The system detects 'hot spots' which could affect network efficiency and long-term reliability thus enabling timely corrective actions to be taken.

In addition to regular thermal scanning, SF6 gas quality checks and dissolved gas analysis are also carried out on transmission and distribution equipment as part of the comprehensive maintenance.

Disturbance Recorders are installed at strategic points across the system to capture changes in system parameters before, during and immediately after any disturbance in the network. The information obtained helps in the post-fault analysis and enables PowerGrid to plan, develop and maintain an efficient and reliable network, which contributes to better quality.

Cable Damage Prevention

Recognising that one contributing factor to voltage dips is cable damaged by earthworks, PowerGrid has set up a Cable Damage Prevention Unit (CDPU) focusing efforts on prevention of cable damage. One of its tasks is to patrol all its transmission cable routes island-wide on a daily basis. On an average, CDPU staff cover about 50,000 km of cable route a month. The reason for going through such lengths to patrol the cable route is that indiscriminate earthworks could cause damage to cables resulting in voltage dips. PowerGrid's daily patrol would ensure that earthworks are carried out with due care and consideration for its underground cables.

In the course of their patrolling, CDPU staff also visits sites where major earthworks are being carried out to advise contractors on measures to prevent cable damages. Sites that are considered high-risk are monitored closely. In this way, illegal earthworks, if any, can be detected and control measures taken to prevent damages.

Apart from daily patrols, CDPU also conducts regular dialogue sessions with consultants, developers, and contractors on measures to take on cable damage prevention. Consultation meetings are held from the start till the completion of the work. Briefing sessions are conducted for site personnel to ensure that proper precautionary measures are understood and practised.

The cable damage prevention measures taken by PowerGrid have been effective in reducing the number of damage on transmission cables from an average of four cases per year in the last 4 years to one case in 2000.

Legislative measures are also provided under the Public Utilities Act to prevent cables from being damaged. The Act provides for penalties for errant contractors who damage cables. Offender can be fined up to a maximum of S$1 million and/or imprisoned for up to five years.

WORKING IN PARTNERSHIP

While PowerGrid strives to minimize the cause of voltage dips from the network end, there is presently no technology in place to produce equipment or cables that do not fail. It is not possible in practice to totally eliminate failures in the network. In view of this, the next best thing is for customers to do their part in minimizing the impact of voltage dips in the event of failures. To this, financial incentives are given to encourage customers to implement plant-end solutions.

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