VOLTAGE SAGS – CUSTOMER NEEDS VERSUS WHAT DISTRIBUTORS CAN DELIVER

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Voltage Sags – Customer Needs Versus What Distributors Can Deliver

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Abstract

Electricity customers are becoming increasingly intolerant of voltage sags and are looking for improved performance from their Network Service providers. Electricity distributors have limits on the sag performance they can provide to customers due to the fundamentals of their networks and protection arrangements. The result in many cases is a voltage sag performance gap between customer needs and what electricity distributors can deliver. This paper is about examining:

a) *What is the magnitude of the voltage sag performance gap?*
b) *What are the fundamentals underlying the voltage sag performance gap?*
c) *How can the gap be closed?*
d) *Can new Power Quality standards address these issues?*

1 Introduction

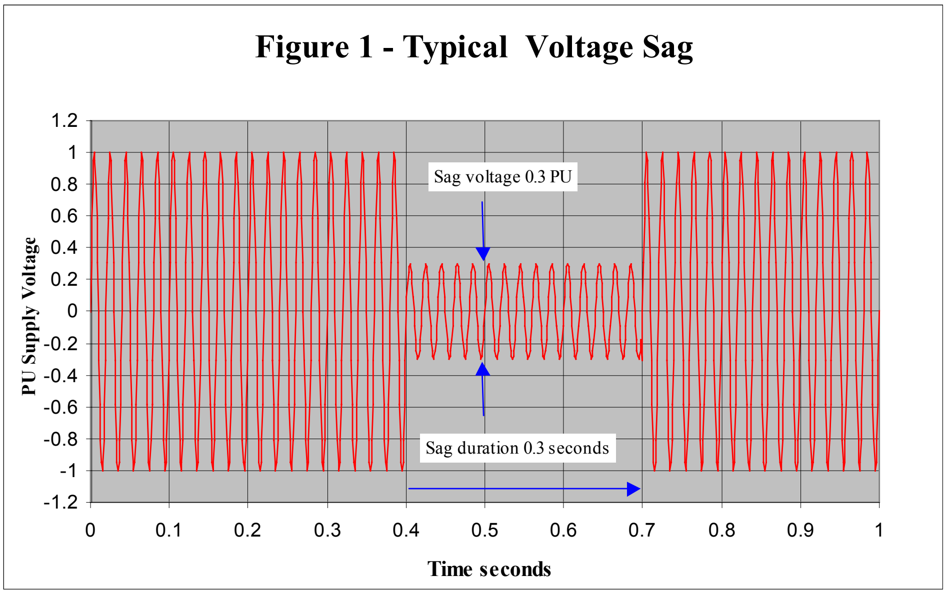
1.1 Voltage sags in electricity distribution networks are common unavoidable events. Many voltage sags cause customers great disruption particularly with the proliferation of the digital economy and the widespread use of computers and other digital electronic equipment.

1.2 Customer sensitivity to voltage sags has reached such a level that distribution companies now need to look very carefully at reducing the frequency and severity of sags and customers need strategies for improving their immunity to voltage sag events.

The Nature and Causes of Voltage Sags

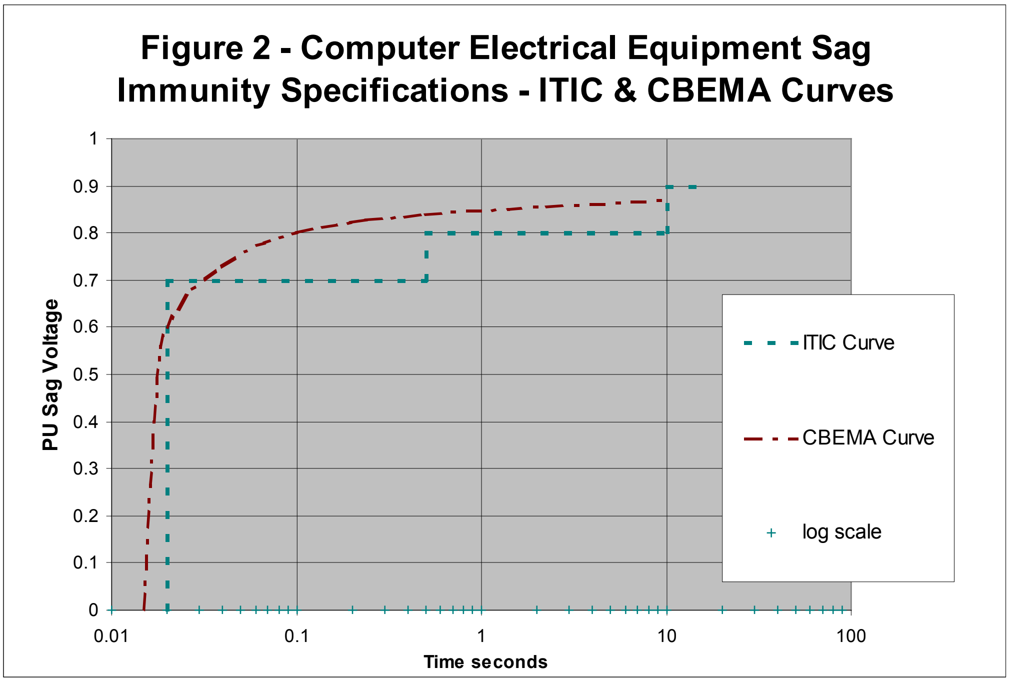
1.3 Figure 1 shows a voltage sag, typical of electricity distribution networks.

1.4 Although voltage sags can be caused by switching operations, motor starting, faulty intermittent electrical connections (going open circuit), faulty tap changers and other reasons, the most common source of customers sags result from short circuit faults in the distribution and transmission networks. Faults in customer installations can also cause voltage sags that can be reflected out into the network.



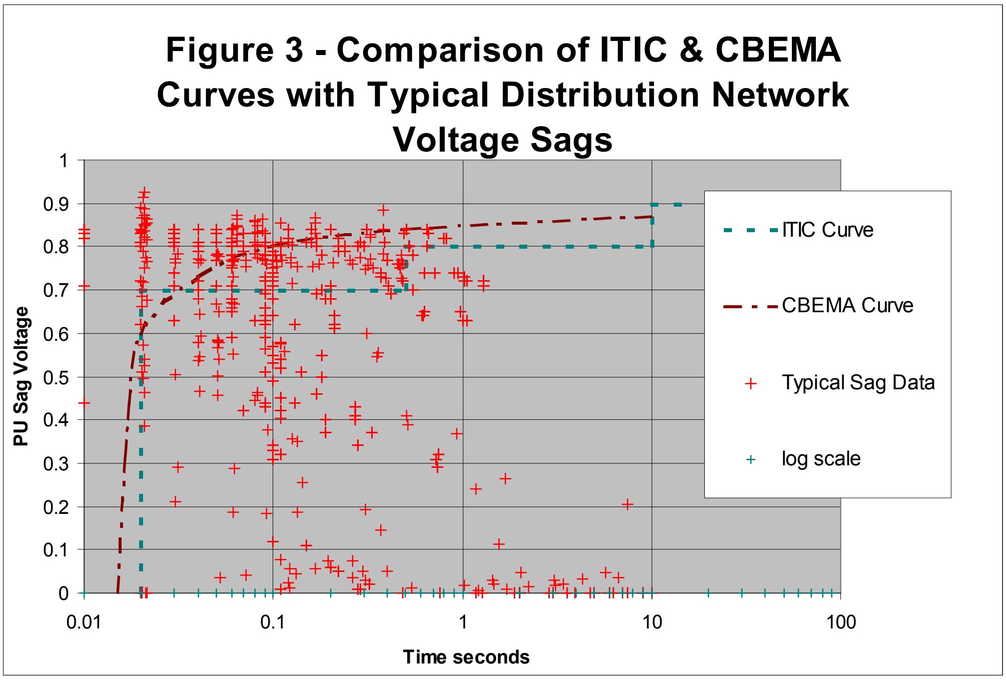
2 The ITIC and CBEMA Curves

2.1 The Information Technology Industry Council (ITIC) and the Computer and Business Manufacturer Association (CBEMA) curves are shown in Figure 2. These sag withstand performance curves represent standards that computer and other equipment manufacturers are required to comply with by many customers.



3 Typical Distribution Network Sag Performances

3.1 Figure 3 shows the typical range of sag performance that customer see from distribution networks across a wide range of locations. There are clearly very many voltage sags on the right hand side of the ITIC/CBEMA curves that threaten the satisfactory performance of sensitive equipment. It can be seen that there is a high level of incompatibility between the equipment voltage sag immunity curves and what typical distribution networks are delivering to customers.



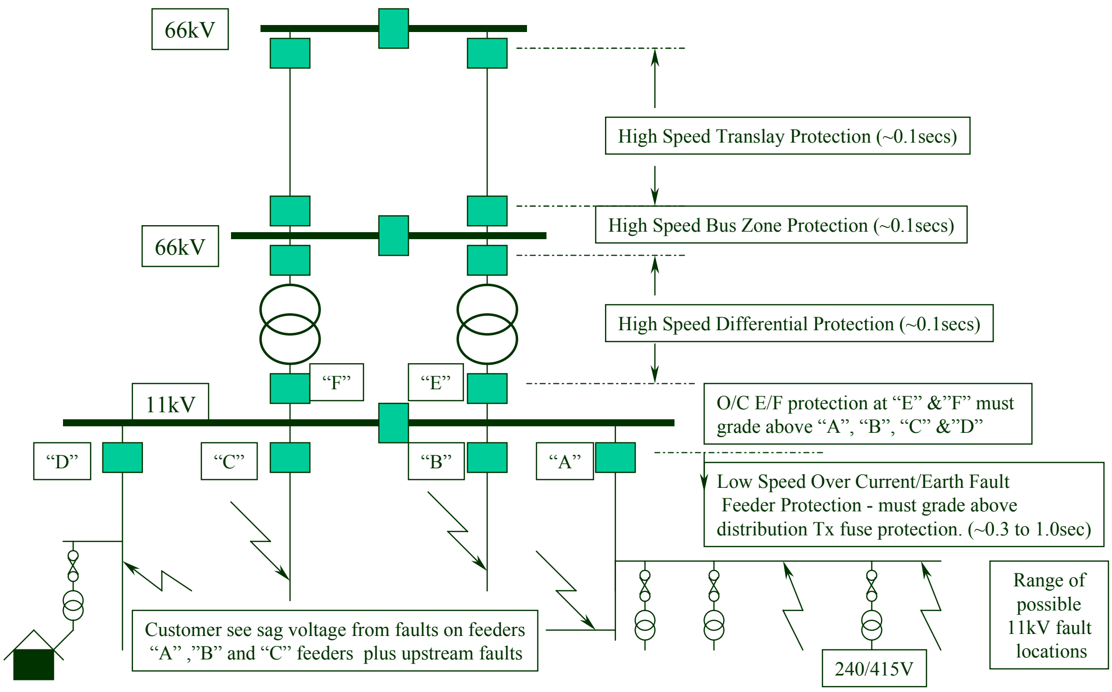
3.2 Figure 3 shows clearly why voltage sags are a major problem for electricity customers with digital equipment. While Figure 3 gives no indication of the frequency of voltage sags a customer may experience, it does indicate that when they do occur, a significant proportion of the sags have the potential to cause major customer disruption.

3.3 To understand the underlying reasons for these effects, an understanding of the protection and fault level characteristics of typical distribution networks is required.

4 Typical Distribution Network Arrangements

4.1 Figure 4 shows a typical distribution network arrangement consisting of a translay protected 66kV subtransmission system, differential zone substation transformer protection and overcurrent/earth fault protected radial 11kV feeders.

Figure 4 - Typical Distribution Network



4.2 In networks of this type, by far the most common source of voltage sags is the 11kV network. Voltage sags from faults in the 11kV network are reflected widely across the 11kV network affecting thousands of customers. The "network exposure" of the 11kV system is usually far greater than the upstream subtransmission system because of greater aggregate km length and more faults per km of line. The impedance of 11kV/415V distribution transformers limits the extent to which low voltage faults can generate sags across wide areas of the medium voltage network.

4.3 When an 11kV feeder short circuit fault occurs, the voltage at the fault location will be zero. The voltage will also be depressed as we look back toward the zone substation 11kV busbar and up into the subtransmssion system.

4.4 For the duration of the fault, the voltage sag experience at the zone substation 11kV busbar will be determined by the ratio of the impedance between the 11kV busbar and fault location compared to the total source impedance including zone substation transformer and upstream subtransmission system. The calculation of fault voltage at the 11kV zone substation 11kV busbar is simply that of a voltage divider.

4.5 If a fault occurs on 11kV feeder "A" of Figure 4, the voltage sag created on the 11kV busbar will reflected across all customers supplied on feeders "B", "C" and "D". This is the mechanism for most voltage sags that occur on electricity distribution networks. Customers on the "A" feeder will also see a voltage sag followed by a interruption as the protection causes circuit breaker "A" to trip. If circuit breaker "A" is set for auto reclose and the reclose is successful this will create a voltage sag down to zero volts for the full reclose time (typically 1 to 10 seconds). Sags associated with successful trip and reclose events are evident in Figure 3.

5 Key Factors Governing Network Sag Performance

5.1 The range of possible sag voltage/time characteristics from network faults is almost entirely predetermined by branch impedances within the network, the types of protection used and the protection settings.

5.2 The need to grade 11kV feeder protection over 11kV fuses on 11kV/415V distribution transformers in combination with the requirement to set protection pickup above maximum anticipated emergency load currents, governs the maximum speed the 11kV feeder protection can operate.

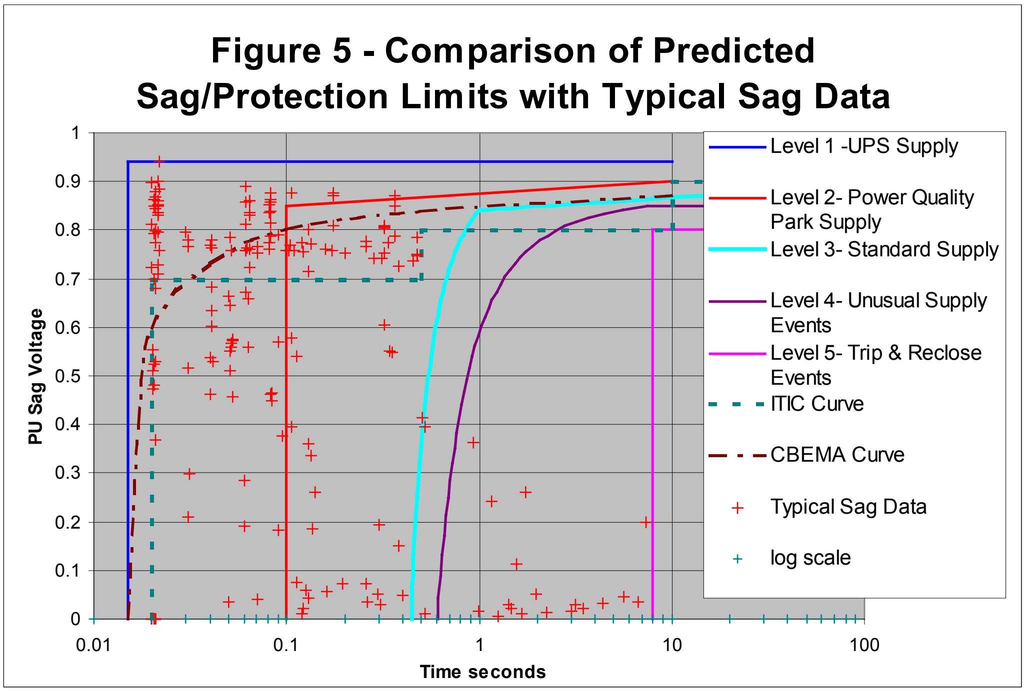
6 Zones of Voltage Sag Performance

6.1 A review of typical protection settings for medium voltage feeders indicates that the boundary of voltage sags reflected across the network should normally be to the left of "Level 3 - Standard Supply" curve of Figure 5. It can be seen that most of the voltage sags are in fact to the left of this curve. Sags to the right of this curve are most likely direct trip and successful reclose events generating a near zero sag voltage or possibly fault events where the primary protection has failed and backup protection has been called upon to clear a fault.

6.2 Based on typical protection settings, it is expected that medium voltage backup protection would generate reflected voltage sags to the left of the "Level 4 - Unusual Events" curve. Figure 5 shows that in fact the vast majority of measured voltage sags are to the left of this curve.

6.3 The "Level 5 - Trip and Reclose Event" curve represents the boundary that could be expected where a successful reclose occurs. This curve has been set at eight (8) seconds however some distributors may have settings up to ten (10) seconds and apply multiple reclose events.

6.4 Two high performance curves have also been included to provide some comparisons. The "Level 1 - UPS Supply" curve is an estimate of what might be achievable with a Uninterruptable Power Supply. The "Level 2 - Power Quality Park Supply" is an estimate of what might be achievable if a distributor specially designed and built a "Power Quality Park".



6.5 To achieve voltage sag performance at the "Power Quality Park" level a distributor would need to have a medium voltage distribution network that was fully circuit breaker protected (i.e no medium voltage fuse protection) and operated in a closed ring with unit protection (e.g. translay) or a comparable scheme. In addition, such a scheme would not only need to be provided to the "Power Quality Park" itself, but to all parts of the distribution network where network faults could reflect voltage sags into the "Power Quality Park". Networks supplying the CBD of Sydney and other high performance/capital intensive systems may have a sag performance close to this level.

7 The Voltage Sag Incompatibility Gap

7.1 The CBEMA and ITIC curves are totally incompatible with what electricity distributors can provide to electricity customers. There is a very wide gap between the voltage sag immunity levels of electric equipment and the voltage sag performance the electricity distribution networks can deliver.

7.2 Due to the proliferation of customer digital electronic equipment, customers are very exposed to data loss and equipment malfunction resulting from voltage sags. In addition, it is impossible for distributors to significantly improve their voltage sag performance without completely redesigning their networks and expending vast sums of capital.

8 Implication for Network Protection Arrangements

8.1 The severity of voltage sags is mostly predictable from the network impedances in combination with the networks' protection arrangements and settings. The frequency of voltage sags on the network is related to the environment and the quality of network design and maintenance.

8.2 In order to satisfy new customer needs, protection engineers now need to consider the magnitude and duration of fault generated voltage sags. This is in addition to protection coordination and I^2t considerations that have been their prime considerations in the past.

9 Need for New Standards

9.1 There is a need for the development of new voltage sag standards that clearly defines the voltage sag performance requirements for electricity distributors and matching electrical equipment voltage sag immunity levels.

9.2 Extensive Power Quality monitoring is required to establish base levels of voltage sag performance across Australia and overseas to ensure that any new standards are realistic. The electricity industry needs to develop voltage sag standards that are consistent with what distributors can reasonably deliver. Any new standards could be based on the level 1 to level 5 concept described in this paper.

9.3 The ESAA has a key role to play in developing new standards.

10 Conclusions

10.1 The CBEMA and ITIC voltage sag curves are totally incompatible with what most distribution networks can deliver.

10.2 The voltage sag severity of networks is closely related to the prevailing protection schemes and network impedances.

10.3 The voltage sag frequency is closely related to the environmental conditions in which the network exists and the network design and maintenance arrangements.

10.4 Some distribution protection design arrangements will need to be "re-engineered" to ensure minimum voltage sag performance standards are achieved.

10.5 The design of digital electrical equipment will need to be enhanced to achieve new minimum voltage sag immunity levels.

10.6 Distributors, customers and equipment manufacturers need to be much better informed of the incompatibility gap between the voltage sag immunity levels of digital equipment and the voltage sag capability of distribution networks.

10.7 The incompatibility gap between sag voltage equipment immunity and distribution network performance needs to be closed from both sides.

10.8 The development of new standards is an essential part of bridging the voltage sag incompatibility gap.

The Authors

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