

A note from ILEX to the ISG

28 January 2003

Whose fault is it anyway?

Introduction

- 1.1 At the 2 December 2003 meeting of the Structure of Electricity Distribution Charges Project Implementation Steering Group (ISG) there was some discussion on distribution system fault levels. ILEX (Peter Williams) agreed to produce a discussion paper on fault level issues in the context of electricity distribution charges. Innogy (David Tolley) agreed to contribute to the paper.
- 1.2 This discussion paper is the first of two parts. This initial paper (Part I) aims to ‘set the scene’ by describing the factual issues associated with distribution system fault level – specifically:
 - contributors to distribution system fault level (who and what);
 - the impact of distributed generation on system fault levels; and
 - the costs and benefits of changes in system fault level.
- 1.3 The more challenging issues would seem to be those associated with identifying and allocating the costs and benefits of changes in system fault level. These will be explored in a follow-up paper (Part II). Developing this second paper at a later date will enable the thoughts and views of the wider ISG membership to be accommodated following the meeting on 28 January 2004.

Contributors to distribution system fault level

- 1.4 The fault level at a point on the system is loosely defined as the current which would flow in the event of a system short circuit. It provides some indication of the “electrical proximity” of the network location (in question) to the sources of fault current producing equipment in the system.
- 1.5 For example, in the UK (at present), the fault level at the 132kV level can be orders of magnitude higher than the fault level at the LV system level¹. This is due, primarily, to being electrically closer² to the principal sources of transmission connected generation.

¹ Note that the fault level, in MVA, maybe higher at the higher voltages but this does not necessarily mean a higher fault current. In many cases it is the fault current which determines the complexity of circuit breakers.

² ‘Electrical’ proximity essentially refers to the electrical impedance between the two network points in question. Two points on the network may be spatially remote but

- 1.6 There are a number of factors which determine the system fault level.
- transmission connected generation;
 - network configuration; (including impedance and substation earthing arrangements)
 - transmission;
 - distribution.
 - connected load (motors); and
 - distributed generation.

Transmission connected generation

- 1.7 Large, transmission-connected generation represents the majority of power producing elements of the system and usually accounts for the majority of distribution system fault level – especially at higher distribution voltage levels where the circuit ratings are generally higher and the source impedance lower. A radially connected distribution system without DG would see its major fault level contribution from the transmission system.

Network configuration

- 1.8 The configuration of both the transmission and distribution networks will have an impact on distribution system fault levels. The operating regime of the transmission network will, in particular, significantly affect fault levels. For example, the number of supergrid transformers (SGT) operating in parallel at a grid supply point (GSP) will have a material effect on the fault levels at all ‘downstream’ locations.

Connected load (motors)

- 1.9 In general, the connection of rotating machinery to distribution networks will have an effect on system fault levels. This relates to both generators and to connected motors. Both synchronous and induction generators can increase fault level although their behaviour under fault conditions is likely to differ.
- 1.10 Synchronous motors behave in a similar manner to synchronous generators under fault conditions.

electrical proximate – especially at higher voltage levels where ratings tend to be higher and impedances lower.

The impact of distributed generation on system fault levels

- 1.11 In terms of its impact on distribution system fault levels, the connection of DG can:
- increase fault levels;
 - reduce fault levels; or
 - have no, or little, affect on fault levels

Increase in fault levels

- 1.12 The direct connection of (traditional) rotating generation to distribution networks will usually reduce the source impedance and increase the fault level. The extent to which the DG will increase fault levels at any particular point will depend on the electrical characteristics of the generator (rating, impedances etc) and on the impedance between the DG and the point on the network where the fault level is being considered.

Reduction in fault levels

- 1.13 Where the connection of DG displaces larger, transmission connected generation, then fault levels on parts of the distribution network may reduce. Any reduction would depend on a net increase in source impedance and is, therefore, most likely to be seen at the 132kV system level when the displacing DG is connected at the lower distribution voltage levels (e.g. 11kV). It should be noted that in this example, whilst 132kV fault levels may reduce, the 11kV fault level (local to the connected DG) may increase.

No effect on fault levels

- 1.14 Where DG is connected through a frequency converter, or other power electronic interface, the contribution to system fault level is likely to be significantly lower (assumed to be zero in some cases).

The costs and benefits of changes in system fault level

- 1.15 The present approach to distribution charging allocates costs in accordance with thermal capacity only. Other costs (such as business rates, fixed operational costs etc.) are recovered either as a fixed (£/customer) charge or, effectively, as a levy on thermal capacity (£/kVA) charges.
- 1.16 However, distribution cost drivers extend beyond thermal capacity and it may be appropriate to include other ‘product attributes’ in any future cost-reflective pricing framework. These might include the following.
- security (e.g. number of interruptions);
 - reliability (e.g. customer minutes lost); and
 - fault level.

- 1.17 A network with a high fault level is sometimes referred to as being electrically ‘strong’ or ‘stiff’. Such systems have the following characteristics:
- low source impedance and high fault levels;
 - a higher required fault capability/duty for switchgear (and other system components);
 - better transient and dynamic stability post-fault performance³
 - effective protective systems; and
 - enhanced power quality (less susceptible to voltage dips/sags and harmonic distortion).
- 1.18 Adequate fault levels are required by both the network operator – for the effective operation of protection – and also by the network *users* in order to ensure acceptable levels of power quality.

Make and break duties

- 1.19 Distribution switchgear is usually allocated both a *make* rating and a *break* rating. The contribution of additional ‘fault in-feed’ can result in system fault levels being increased beyond either, or both, of these ratings on existing switchgear.
- 1.20 Switchgear *make* rating is the ability of an item of switchgear to close onto a network fault and is usually defined at the time of maximum asymmetry, 10ms. Asynchronous (induction) generators – wind turbines, for example – are likely to increase the system fault level associated with switchgear *make duty* but are unlikely to contribute to system *break* fault level⁴. *Make duty* issues may often drive switchgear replacement costs in rural areas.
- 1.21 The break duty of a item of switchgear defines the ability to remove a fault from the system by interrupting the fault current. Directly connected synchronous machines will continue to deliver fault current during steady-state network conditions. *Break duty* issues may often drive switchgear replacement costs in urban areas⁵.
- 1.22 The break-duty requirements of an item of switchgear will depend on the level of fault current which the switchgear is required to break. This will depend on the following:

³ This usually mean fewer oscillations and better damping of voltage and power variations after faults – although this is presently of more consequence on transmission networks.

⁴ The absence of external excitation on induction generators means that the short circuit current decrements comparatively quickly and is not likely to contribute (significantly) to the current required to be interrupted by opening circuit breakers.

⁵ The typical switchgear rating at 11kV of 250 MVA is a *break rating*. The *make rating* is 2.55 times the *break rating*⁵.

- amount of rotating machinery (motors and generators) connected at both distribution and transmission networks;
- impedances of the connected network; and
- characteristic of the protection system (particularly ‘break’ times)⁶.

1.23 The conclusion is that the ‘cost’ of DG’s contribution to fault level is not always straightforward. The use of a simple ‘rule of thumb’ multiplier should be used carefully – and may need to differ according to voltage of connection.

Conclusion

1.24 Distribution system fault level is determined by a number of factors. Whilst DG can increase fault level there may also be circumstances when the connection of DG can lead to reductions in fault level. Furthermore, there may be instances where an increase in fault level improves system operation and power quality and may therefore be desirable.

1.25 The more challenging issue is the identification and allocation of the costs and benefits associated with the fault level attribute or ‘product’. Specifically, how to recover the cost of (fault level driven) switchgear replacement through ongoing use of system charges in a way that is fair to both demand and DG. This will be the focus of the second paper but we offer below some key questions in an attempt to stimulate ideas and discussion.

Allocating the cost and benefits of distribution system fault level

- should (fault level driven) switchgear replacement costs be recovered through connection charges or through ongoing use of system charges?
 - to what extent can specific assets be directly attributed to individual connectees?
 - how important is it to be able to reflect the *ongoing* costs and benefits of DG (and other connectees)?
- *average* apportionment of costs or *marginal* cost allocation?
 - is a marginal approach more readily accommodated through ongoing distribution use of system charges?
 - does the average, cost apportionment, approach lead naturally lead to recovery through a one-off connection charge?
 - what other options are there?

⁶ For example, 132kV network connections are likely to employ fast-acting unit or distance protection which may require an examination of the contribution from DG at very short timescales (sub-transient period). Conversely, for 11kV connections, where IDMT protection is employed (with the exception of Manweb), contribution to break duty may be determined at much longer times (approaching 1 second).

FAULT LEVELS AND DISTRIBUTION CHARGES

- should any enduring pricing framework be capable of calculating and allocating the costs (and benefits) associated with both the *provision* and *use* of fault level?
- most of the distribution pricing models used by the GB DNOs⁷ do not (explicitly) consider the fault level product attribute and do not attempt to allocate the true costs (and benefits) of fault level. Do these models need re-building?
- as a simple solution, can any correlation between maximum demand (import or export) and contribution to fault level be exploited?
- is the introduction of entry-exit charges (where charges are made for power entering the distribution network from the transmission system) the only way that the contribution to distribution fault level of transmission connected generation can be factored into the charging methodology?

Answers on a postcard please...

⁷ Such as the Distribution Reinforcement Model (DRM) or ‘500MW’ model.



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ILEX
King Charles House
Park End Street
Oxford, OX1 1JD, England

Tel: +44 (0)1865 722660
Fax: +44 (0)1865 722988
E-mail: energy.consult@ilexenergy.com
www.ilexenergy.com

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