USE OF REAL-TIME FAULT LEVEL VALUES TO GENERATE AN MVA PER MVA INFEED TEMPLATE FOR 11KV DISTRIBUTION NETWORKS

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ABSTRACT

This paper discusses the process of generating and the advantages of utilising real-time fault level values to produce MVA per MVA general load fault infeed templates for 11kV distribution network modelling. This paper is based on learning to date from Western Power Distribution's (WPD) Tier-2 Low Carbon Networks (LCN) Fund [1] project, FlexDGrid.

INTRODUCTION

In order to meet UK and global targets for carbon emission reductions associated with energy production, the installation and connection of Distributed Generation (DG) onto distribution networks has significantly increased. As these DG units connect to the distribution network, they contribute fault level to the network, along with providing low carbon energy.

A key element of determining the connection point and accessibility of the network for new DG to be connected is power system analysis modelling. Fault level for the connection of all new DG is a key consideration and therefore must be modelled accurately. The accuracy of the distribution networks' model is paramount in determining the change in fault level borne by the connection of additional DG in the system. DG is modelled accurately, through the provision of generator specific details in relation to sub-transient, transient and steady-state condition; however, the general load contribution to fault level is commonly modelled through one of two pre-evaluated contributions as determined in G74 [2].

This paper describes the process taken to generate site specific 11kV MVA per MVA general load fault level infeed values. This work is designed to provide greater granularity and accuracy of 11kV fault level data to more accurately assess the network for operational and safety requirements. The aim of the learning is to investigate the use of real-time fault level values to generate an MVA per MVA infeed template for 11kV distribution networks.

BACKGROUND

Fault level is generally considered to be an indicator as to the system strength of a network. Traditionally this has led to the desire for a large system fault level, which can safely operate protection and supress the effect of system harmonics. However, as the level of DG connecting to a distribution network increases, at all voltage levels but particularly at 11kV, fault level issues, where the connection of the DG increases the system fault level, become a significant barrier to connection.

Network fault levels are most commonly modelled using a power system analysis tool, examples of which are PSS/E, IPSA and DigSilent. Whilst generators are accurately modelled using their specific electrical properties, due to the vast and varying types of load connection on network substations a generic approach to modelling has been considered. Guidance is given in such documentation as G74 as to the values to be used to model the load connected to a substation, however, this is generally split by the voltage level at which it is connected.

As the availability to gather more sophisticated network data, such as real-time fault level values [3] and more specific load type characteristics the opportunity to further understand the contribution to fault level of general network load increases.

TRADITIONAL MODELLING METHODOLOGY

Network models are used by Distribution Network Operators (DNO) for system planning purposes and to analyse the impact of changes in network configuration and new connections. The information gathered can then be used to determine suitable network reinforcement requirements and operational restrictions. Over time, the accuracy and detail contained within the models has improved and increased, enabling additional confidence in the results produced and reducing required safety margins. In the UK, DNO models for the 11kV High Voltage (HV) network are traditionally maintained and run separately from the Extra High Voltage (EHV) network models. This is due to the complexity and size of the complete 11kV network having a potentially negative impact when running EHV system studies, due to increased computational time and potential for errors. In the majority of cases, this has led to the 11kV and Low Voltage (LV) models being created in a different software package to the EHV models.

In order to represent the HV and LV networks in the EHV models, an equivalent load and generator are created using information from the HV network model. These are placed on the Primary substation busbar that acts as the infinite source in the HV models. Typically, any large generation connected to the Primary substation via a dedicated feeder is also independently modelled.

Using the EHV network models, system fault levels are calculated based on the recommendations of G74. Section 9.5.1 of G74 states; for low voltage networks allow 1.0 MVA per MVA of aggregate low voltage network substation winter demand and for high voltage connected load 2.6 MVA. To complete network fault studies these values are applied to the whole substation load irrespective of load type.

FlexDGrid Method Alpha

As part of the Enhanced Fault Level Assessment (EFLA) process developed within FlexDGrid's Method Alpha, 11kV network models for each primary substation, within the project area, were created for inclusion within the existing EHV model. This allows for greater accuracy when assessing the impact on the 11kV network and the loads connected to it when modelling fault levels.

Each substation model accumulated network data from all available sources including installation and maintenance records, to ensure that the models were as close as reasonably practicable to the actual network conditions. The size of each LV load connected to the network was then estimated by either the installed transformer rating or the agreed supply capacity. A distribution factor was then applied to each one so that the total substation load was equal to the winter maximum demand, as per current WPD planning philosophy.

FAULT LEVEL MONITORING

FlexDGrid Method Beta

The aim of FlexDGrid's Method Beta was to install ten Active Fault Level Monitor (AFLM) devices throughout the project area. The AFLM is designed to place a non-customer affecting disturbance on the 11kV network with monitoring hardware within the device recording waveform disturbances of both the current and voltage [3]. During the open loop testing of the AFLM throughout 2015, a decision was made to operate all the devices every six hours to enable the device to provide a representative spread of fault level data for differing system load conditions.

Monitored Data

Using the recorded disturbances, the AFLM calculates the 10ms peak fault level and the 90ms RMS fault level at its point of connection. All the AFLM devices installed as part of Method Beta were connected to a section of the Primary 11kV busbar within the substation, producing results for the 11kV Primary substation fault level.

The fault level results along with the steady state current and voltage at the time of the AFLM operation are collected and processed. As part of this processing, the network topology is determined and results categorised accordingly. All the data is then amalgamated and averaged over various time periods in order to understand, at this stage, the general trend in MVA per MVA at each 11kV Primary substation over time.

MVA PER MVA CALCULATION

To calculate the 11kV MVA per MVA general load infeed value at each substation the EFLA network model was utilised. Steady state data collected by the AFLM was inserted into the network model and used to manipulate the model to replicate the general site condition over the specific time period being considered. This was completed by then fixing transformer set point voltages and scaling all 11kV loads using the distribution factors utilised during the development of the EFLA model.

Using the enhanced model, a G74 Fault Level calculation for the AFLM point of connection was carried out. With each calculation, the MVA per MVA general load infeed value for the 11kV load was refined until the calculated fault level closely matched the AFLM recorded value.

DATA ANALYSIS

Substation Load Distribution

The load at each substation was analysed and split into three categories based on available metering data. These were Domestic, Small Commercial and Industrial and Large Commercial and Industrial. The table below shows the percentage breakdown of customer types for each of the ten Primary substations.

Substation	% of Substation Load		
	Domestic	Small Commercial /Industrial	Large Commercial /Industrial
ELMD	7%	7%	86%
CHES	20%	19%	61%
CASB	24%	10%	66%
BOVI	32%	14%	54%
NECW	35%	24%	41%
KITG	52%	14%	33%
HALG	57%	19%	23%
CHAV	60%	24%	16%
SHIR	61%	25%	13%
BARG	66%	12%	22%

Table 1 - 11kV Substation Load Type

MVA per MVA Results

The average MVA per MVA general load infeed result for each 11kV Primary substation based on its percentage of domestic load is shown in Figure 1 below. The results are for fault levels calculated between June 2015 and January 2016.

Figure 1 shows that three primary substations, BARG, HALG and CHAV, generally follow the G74 recommendation of 1.0 MVA/MVA infeed for 11kV connected loads. These substations have a large domestic load with few large commercial or industrial customers connected.

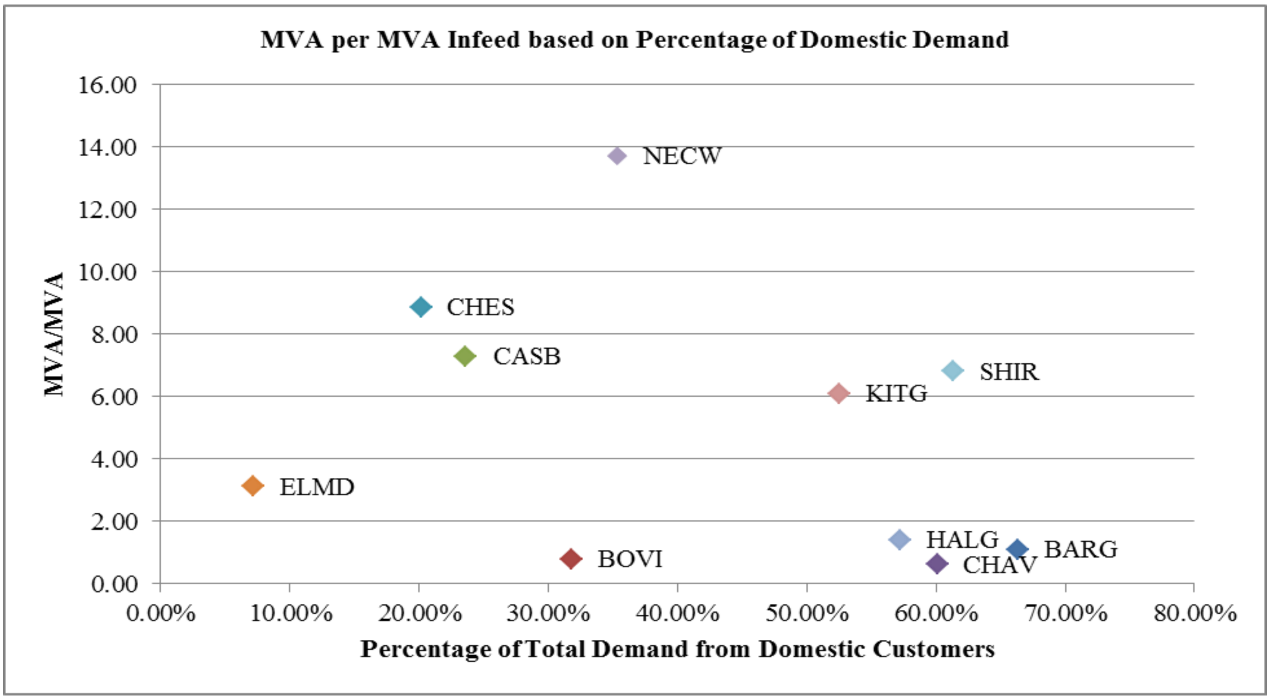

Figure 1: MVA per MVA Load Infeed based on % of Domestic Demand at each Substation

CHES and CASB substations by contrast have a relatively low domestic demand and a high percentage of large commercial and industrial customers connected. The combined average infeed calculated for these substations is 8.08 MVA/MVA. This is considerably above G74 recommended values. KITG substation has a high percentage of both domestic and large commercial and industrial loads. As such the calculated infeed is between the value when a substation is dominated solely by commercial and industrial loads and a domestic dominated load, as described previously, at 6.09 MVA/MVA.

The four remaining substations are considered anomalous results at this stage. ELMD and BOVI, from the data provided in Table 1, indicate that the fault level infeed for these substations should be similar to that of CHES and CASB, around 8.08MVA/MVA, however, both are significantly lower than this. Further investigation of the loads connected at the primary substations showed that whilst both ELMD and BOVI have large amounts of commercial and industrial load connected, they are likely to be mixed use load connections. NECW should, based on load type data, have a value between that of 6.09 and 8.08 MVA/MVA and SHIR should follow the G74 recommendation of around 1.0 MVA/MVA, however, based on investigation of load types and connection points the amount of commercial and industrial connections at each substation is situated close to the Primary substation, meaning that it is likely to have an increased impact on the system fault level due to minimal impedance between the load and substation.

PRODUCTION OF TEMPLATES

In order to utilise the analysis presented the generation of a template for 11kV MVA per MVA general load infeed is required, therefore enabling the wider utilisation of the general load fault level infeed types based on load make up of a Primary Substation.

From the evidence presented it is clear that for a domestic load percentage greater than 55% the existing fault level infeed value presented in G74, whereby it can be considered that most load is LV connected, for LV connected load of 1.0 MVA/MVA is appropriate.

Similarly it can be shown that where a Primary substation has less than 25% of its load made up of domestic load that neither of the existing values presented in G74 are appropriate. A value closer to that presented of the average between CHES and CASB of around 8.0 MVA/MVA is required.

A key value to be considered is that where a split between domestic and commercial and industrial load is around 50%. This scenario is presented through Primary substation KITG, where the value is around 6.0 MVA/MVA.

UTILISATION AND BENEFITS

The ability to have a significantly increased level of granularity as to the 11kV fault level general load infeed and therefore the overall system 11kV fault level has many applications.

The employment of this enhanced network data can be utilised to more accurately assess the network for future load and generation connections to the network. This benefit centres on the increased level of network security and safety based on the utilisation of this data. Increased safety of the 11kV system can be realised through more accurately understanding the network conditions for current and future network connections to ensure that no fault level limits of equipment such as switchgear and cables are exceeded.

Utilising a robust fault level infeed an 11kV general load template would mean that this information could be utilised for any network of which the load type by percentage on an 11kV Primary substation is known.

LEARNING

Key learning centres on the fact that the largest fault level general load infeed value presented in G74 is 2.6 MVA/MVA, however, the evidence presented shows that for certain load types the fault level infeed is in excess of 8.0 MVA/MVA. More widely it can be considered that greater importance on the load type of a substation, irrespective of voltage, should be given when considering the fault level of that substation.

Finally, the anomalous data presented in the form of four substations is driven by the fact that although a substation has a particular split of load type the AFLM connected to the system only considers a certain element of the network. As the AFLM is connected to a single busbar within the substation and there is no available data to accurately determine the load type of an individual section anomalous data at the monitored sites will continue. Therefore, a methodology to determine the load type per section of a particular substation is required to remove these anomalies and more accurately represent an 11kV general load fault level infeed template.

NEXT STEPS

The data presented considers a six month period, therefore a significant next step is to further understand the patterns of data presented over a longer period of time, specifically to more accurately ascertain the viability of the large commercial and load infeed value of around 8.0 MVA/MVA and the domestic dominated value of around 1.0 MVA/MVA.

The voids presented in the template, due to the load type being split over several sections of Primary substation, are to be more accurately determined. This work will focus on the development of a methodology to determine the load type for the area of network where each AFLM device is connected. This analysis will allow a full template of fault level infeed values to be generated, which from current available data, appears to trend towards a generic hysteresis curve.

Once a full template is produced the final step will be to trial and demonstrate its value on an unmonitored network (where an AFLM is not present) and to retrospectively monitor the real-time general load infeed values.

REFERENCES

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