THE DEVELOPMENT OF A TOOL TO HELP PRIORITISE MAJOR INFRASTRUCTURE REINFORCEMENT BASED ON ASSESSMENT OF NETWORK DEMAND, TRANSFER CAPABILITY AND PERMISSIBLE DG CONTRIBUTIONS

Matthew FREEMAN
EDF Energy Networks Branch, UK
matthew.freeman@edfenergy.com

ABSTRACT

This paper describes ongoing work to develop processes and tools to assess the theoretical performance of an electrical substation at times of peak demand for planned (maintenance) or unplanned (fault) outage conditions.

INTRODUCTION

EDF Energy Networks is the licensed Distribution Networks Operator (DNO) for three network areas in Great Britain (GB). Its principal objective is to provide and maintain a secure supply of electricity to London, the East and the South East of England, which accounts for approximately 25% of the GB population.

One of the key challenges facing all DNO's is the optimum management of their capital programme. With an ageing network and investment subject to regulatory review, making the correct major infrastructure decisions is essential if capital is to be used to best effect. There are a number of business drivers that contribute towards network reinforcement decisions, although the principal among these is of course the capability of the network to meet growing demand; i.e. security of supply.

With increased penetration of distributed generation (DG), demand assessment will continue to become more involved. The recent introduction of Engineering Recommendation P2/6[1] in GB has provided guidance on how distributed generation can contribute to supply security, while indicating an option to defer or remove the need for reinforcement in some situations.

P2/6 suggests a method of considering the capability of a network to meet demand under outage conditions, this being assessed as the sum of:

- The cyclic rating of the remaining circuit(s) following the outage of the most critical point or circuit;
- The transfer capacity that can be made available from alternative sources within the times specified in P2/6;
- Allowable contribution from Distributed Generation as laid out in P2/6 and its supporting technical guidance documents.

1 P2/6: published by the Electricity Networks Association is a planning guidance document relating to Security of Supply considerations.

The generic approach to P2/6 assessments is laid out in the flow diagram below:

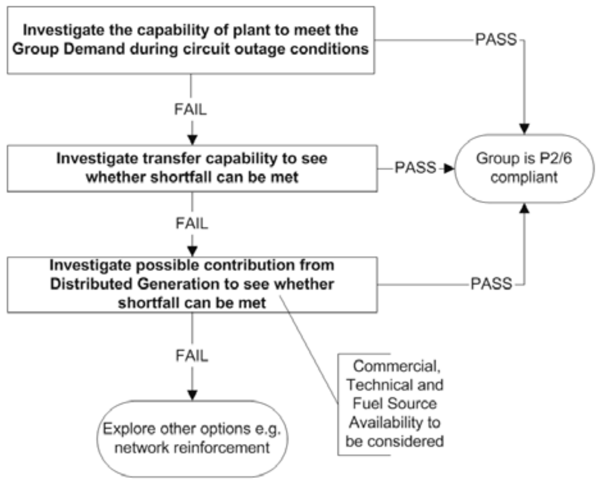


Figure 1: Standard P2/6 Process

GROUP DEMAND

P2/6 defines the demand to be secured on a substation or area of network as the Group Demand.

For low levels of DG connected within the Group, the Group Demand is taken as the maximum measured demand, on the assumption that inputs to the group from DG account for none, or a small percentage, of the figure.

If higher levels of DG exist (DG aggregate is greater than 5% of the maximum measured demand) the Group Demand is defined as:

Maximum measured demand
+
Latent demand (at time of maximum measured demand)

Where:

- Maximum measured demand is the aggregate of all the utility owned network infeeds to the group;
- Latent demand is the demand that would appear as an increase in measured demand if all DG within the group were not producing any output. This includes any site demand(s) masked by the generator(s).

PROJECT INCEPTION

Demand forecasting provides the first indication that a substation is nearing its ‘firm capacity’[2]. However, this information alone does not trigger investment decisions.
The forecasting process eliminates any abnormalities relating to atypical network running conditions and spurious half-hourly demand data and provides:

- Summer and winter maximum measured demand figures for the current year;
- Summer and winter projected maximum demand figures for future years, based on anticipated new connections and base load growth activity, with appropriate probability and diversity factors applied.

Having completed the demand forecasting, a number of sites will have been highlighted as requiring further investigation. These need to be analysed in more detail, to see whether the maximum demand can be met. The first stage of this investigation involves analysing the transformer and circuit capabilities. It is at this point that an ‘At Risk’ process is employed.

The flowchart below highlights the key stages of this process which includes the use of a Transformer Thermal Analysis Tool [1], [2].

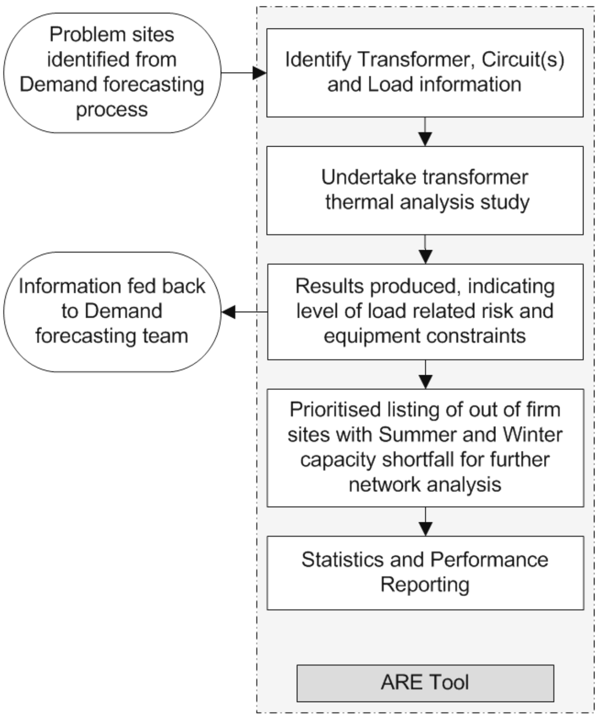


Figure 2: At Risk Process

2 Firm capacity is defined as the capacity of a substation following the loss of the highest rated circuit.

By incorporating these stages into one tool, many benefits can be realised:

- Reduced time to carry out studies
- Ability to run ad-hoc assessments
- Improved audit trail
- Results and data files stored in generic format
- Ability to monitor targets/performance progress
- Statistical analysis for reports
- Prioritised lists

In light of these benefits a new MS Excel™/Visual Basic for Applications™ tool has been developed – the ‘At Risk Evaluation Tool’ (or ‘ARE Tool’).

FUNCTIONALITY

The diagram below shows the basic principles of operation of the ARE Tool.

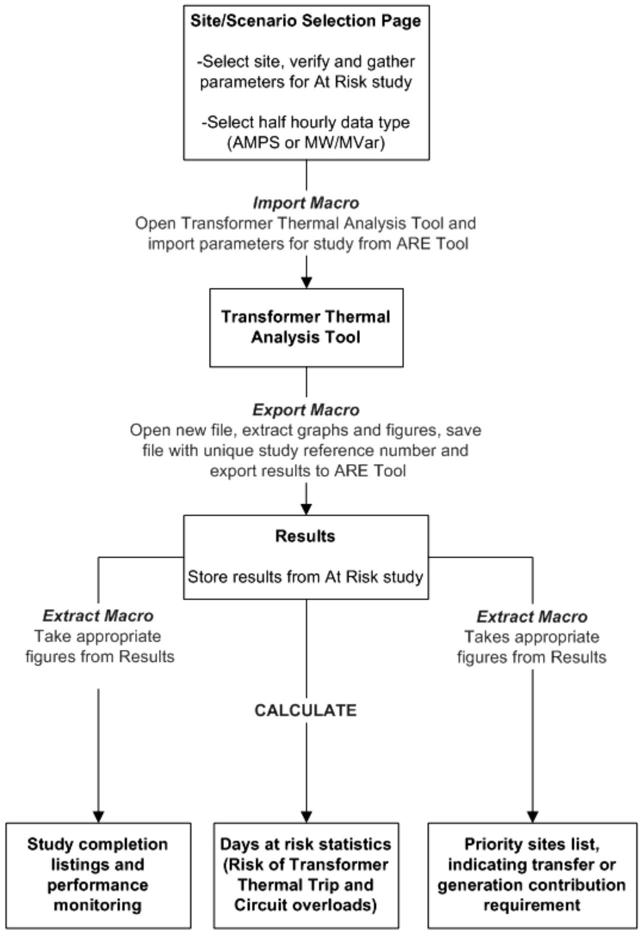
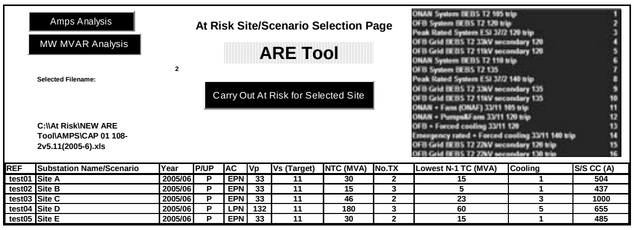


Figure 3: ARE Tool Operation

Inputs

The site/scenario selection page (below) holds all the information required for an ‘At Risk’ study. This includes transformer and circuit data, pointers to load data, site details and user details.



REF	Substation Name/Scenario	Year	P/UP	AC	Vp	Vs (Target)	NTC (MVA)	No.TX	Lowest N-1 TC (MVA)	Cooling	S/S CC (A)
test01	Site A	2005/06	P	EPN	33	11	30	2	15	1	504
test02	Site B	2005/06	P	EPN	33	11	15	3	5	1	437
test03	Site C	2005/06	P	EPN	33	11	46	2	23	3	1000
test04	Site D	2005/06	P	LPN	132	11	180	3	60	5	655
test05	Site E	2005/06	P	EPN	33	11	30	2	15	1	485

Figure 4: Site/Scenario Selection Page

Having selected a site for study and a load data type (Amps or MW/MVar), an input macro is run, which opens a Transformer Thermal Analysis Tool and populates it with the site data.

Transformer Thermal Analysis Tool [1], [2]

This MS Excel™ based tool is built around principles and parameters described in a loading guide for oil immersed transformers [3] and analyses the demand profile for the substation over the previous full year, based on half-hourly demand data and average temperature data. Demand data is retrieved from a loading database using a data pointer (or Tag[3]). The thermal analysis tool simulates the loss of one transformer (an N-1 fault condition) and calculates the emergency cyclic rating of the remaining units. Both an average hot spell (AHS - summer) and average cold spell (ACS - winter) firm capacity are deduced.

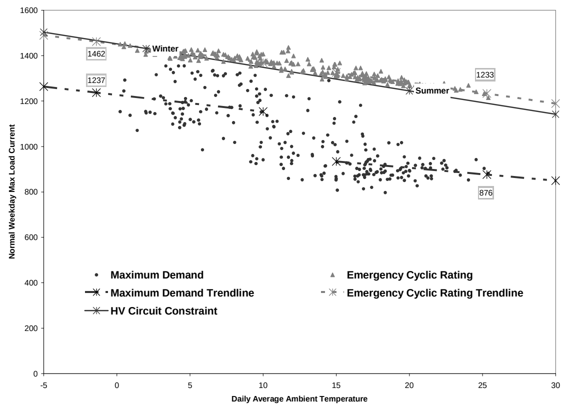


Figure 5: Substation demand and capacity (cyclic rating) against average ambient air temperature.

3 Tags act as pointers to a specified data stream within a Plant Information System (PI, made by OIL Systems, Inc™) and enable the relevant half hourly load data to be extracted for analysis.

Figure 5 is a scatter plot of daily maximum demands and firm capacities (emergency cyclic ratings) against daily average ambient temperatures, taken over a period of twelve months.

The graph in Figure 5 highlights that for this particular substation:

- The demand on the transformers is well within the N-1 firm capacity;
- The incoming circuits are adequately rated.

ACS/AHS demands and N-1 firm capacities can be read from the graph, the difference between the two being the rating margin, which is one measure of the level of risk on the substation. Extrapolation to higher and lower temperatures is also possible using the trend lines.

The ARE Tool exports a variable that is used to select a list of parameters for the specified transformer type. Transformers vary in their construction and method of cooling and hence have different thermal properties. The parameters selected act as constants for use in the thermal analysis calculations.

Other features of the tool include:

- An option to explore the effects of a load transfer, additional demand on the substation or additional transformer capacity;
- A theoretical indication of the time available to reduce load before thermal trip becomes imminent;
- Where a risk is predicted, the ability to determine whether the circuits OR the transformers are the limiting factor.

Outputs

Once the Transformer Thermal Analysis has been undertaken, the ARE Tool uses the export macro to extract the results. A slimmed-down version of the analysis file is saved with its unique reference number within the filename. Variations to the base scenario can be recorded by repeating the Transformer Thermal Analysis with different parameters and reference numbers.

Results from all the studies are held in a worksheet, which can be accessed by other macros to produce tables and graphs.

A performance monitoring screen has been set up in order to allocate (to each month) a proportion of the overall number of studies to be undertaken during the year. Progress against targets can be recorded, the results of which can contribute towards the company’s performance targets.

Scorecard 2007	Update Balanced Scorecard					
System Coordination - Programme and achievement on At Risk (P2/6) studies						
Sites for analysis	Additional sites					
	Jan	Feb	Mar	Apr	May	Jun
Planned sites completed						
Additional sites completed						
Total in month						
Programme (Planned sites)						

Figure 6: Performance Monitoring

Statistics are produced to indicate the number of studies undertaken (by network area) that have identified a transformer trip or circuit constraint risk:

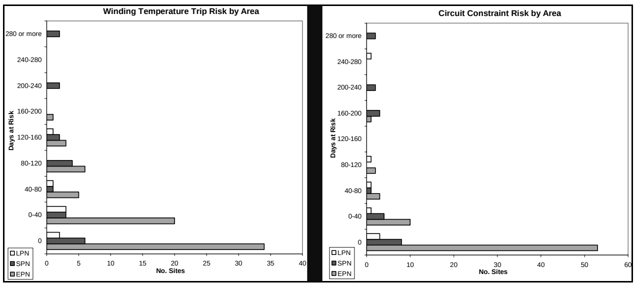


Figure 7: Risk Statistics

Another feature of the ARE Tool is a macro used to produce a prioritised list of all the studies undertaken, an example of which can be seen below. The capacity shortfall is calculated for the winter and summer months.

P2/6 PRIORITY SITES					UPDATE PRIORITY SITES						
							WINTER DATA				
WINTER	SUMMER	Study No	Site Name	P or UP	Study Date	Assessor	PF	Corrected Demand (MW)	Latent Demand (MW)	Group Demand (MW)	W/TGR (MW)
OK	OK	jul001	Site A	P	07/07/2006	matt	0.96	19.11	0.00	19.11	0.00
ASSESS	OK	jul002	Site B	P	07/07/2006	matt	0.96	77.76	0.00	77.76	1.00
OK	OK	jul003	Site C	P	07/07/2006	matt	0.96	11.23	0.00	11.23	0.00
ASSESS	OK	jul004	Site D	P	07/07/2006	matt	0.96	11.22	0.00	11.22	2.00
OK	OK	jul005	Site E	P	07/07/2006	matt	0.96	18.14	0.00	18.14	0.00

Figure 8: P2/6 Priority Listings

Many of the sites analysed using the ARE Tool have shown sufficient transformer capacity to meet the Group Demand. Assuming there is no proposal to imminently connect significant new load, these sites can be classed as P2/6 compliant based on transformer capacity alone and may require no further analysis until the following year's review.

Those sites with a small shortfall in capacity relative to the substation size and general network geography will, in many cases, have sufficient transfer capability to meet the shortfall. Load flow studies using a network analysis tool can be undertaken to ensure the network capability is sufficient to meet the required transfer.

Sites which are already close to or exceeding their firm capacity and those with large forecast load growth may need a more detailed analysis. Generation (if significant and available) should be explored for a potential contribution to secure any capacity shortfall. For these cases it is desirable to carry out a full P2/6 assessment using network analysis tools, diagrams and spreadsheets. Connection enquiries for a large Distributed Generator may also trigger the need for a detailed P2/6 assessment. The process and tools are being extended for these situations.

FURTHER DEVELOPMENT

A large number of substations, particularly in the London area, have been seen to experience their peak annual demand during the summer period. In these cases high summer temperatures will significantly reduce the cyclic capability of transformers at the time when the demand is highest.

A programme is underway to install temperature transducers at main substation sites to enable more refined modelling. At present, a global temperature data set is used and a correction factor applied [2].

The Transformer Thermal Analysis Model will be developed to analyse the relationship between site demand data and a localised ambient temperature profile. This may produce particularly interesting data during long periods of hot weather as underground substations may not have time to cool down sufficiently overnight, resulting in a day-on-day worsening situation.

Work is also underway to verify the modelled internal transformer temperature with real measurements.

Power factor has been seen to reduce significantly in periods of hot weather. Air conditioning load is likely to be a big contributor to this effect but studies are underway to investigate this phenomenon as it is very relevant to the studies described in this paper.

REFERENCES

[1] D. Ellis, 2003, "The Impact of Summer Peaking Demands on Distribution Network Supply Security Assessments at Main Substations", *ERA Technology*

[2] A. Watson, R. Weller, 2005, "Temperature Correction Factor applied to Substation Capacity Analysis", *CIRED*

[3] "Loading of oil immersed power transformers", BS7735:1994 (IEC 60354:1991)