BROAD PRINCIPLES IN INTEGRATING NETWORK ANALYSIS DATA.

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Summary.

Based on the past ten years work in the integration of engineering technical data for the Electrical Distribution Industry, a number of key issues have been identified. These can be broadly entitled;

The size of the problem
The location of specialist data
Circuit display requirements
Response time needs
Updating and concurrency issues
Holding "connectivity" information
Database designs
Data responsibility and conflicting data

Most of the above headings have differing interpretations in different Depts, and the earlier concept of putting all possible network analysis data into one big "pot" is proving questionable. On the other hand, substantial engineering resources are regularly absorbed in simply tracking down data relevant to a current problem, or in responding to management requests, and hence as much mechanisation and automatic retrieval as possible has important financial and organisational advantages.

The paper summaries the author's findings in the above areas, and discusses a suggested practical forward path.

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1. Introduction.

The astonishing growth of computer capacity and terminal access facilities over the past 10 years has substantially reduced what used to be considered Information Technology practical limitations. Instead, the problem to be solved is now more to find workable solutions, bearing in mind that engineering data flow is the life blood of any technically based organisation such as an Electricity Distribution Plc.

However, even with the modern computer powers available, it is still not practical to assume that all data can be made "instantly accessible", and good data traffic engineering will still be an essential element of any integrated system.

2. The size of the problem.

The basic size of Distribution networks within one Plc is substantial, for example, secondary (11kV/415v) substations can number up to 40,000, the 11kV network may have up to 1 million supporting wood poles (all expecting to be uniquely identified), and for network analysis studies, inter-connected networks of several thousand active nodes can be quickly generated. Indeed, solutions of up to 100,000 nodes have been reported.

Apart from the size of the network itself, the supporting data needed for detailed planning studies can be equally large. For example, some users are finding the need for over 1,000 different line codes, with all possible combinations of different conductor types in each phase and neutral.

When considering a normal three phase transformer itself, the current data fields have grown to over 100 for accurate modelling, plus a 6 by 6 primitive impedance and a 9 by 9 connectivity matrix for unbalanced analysis. When studying banked single phase transformers such as open Wye/open Delta, the GE (USA) Distribution Transformer Manual lists over 40 recommended standard connections.

Furthermore, when considering digitised map background requirements and other associated (GIS) data, current technology is indicating over 1 Mbyte for each 1:10,000 stored map, so that putting all the information together is generating data storage needs in the multi Giga byte range.

Finally, it must be accepted that the growth of this data will never stop. For example, current considerations of demand side management could lead to an intelligent meter in every house, ie over 1 million complex units within the next 10 years all needing and generating unique additional data.

Thus apart from the sheer data volumes involved, even by modern computer standards, the complexity of the data management task itself becomes the prime consideration.

3. The location of specialist data.

As mentioned earlier, the volume of data that is needed by a specialist dept. such as Network Planning and Design can be extensive, and more importantly, a high percentage is never required by other Depts, even if they could understand it. In network analysis for example, programs now exist to fully model the behaviour of a three phase transformer unit under unbalanced loading, which requires details of the mutual cross coupling fluxes between phases, and reasonable estimates of the positive and zero sequence magnetising circuits. Another example is the division of unbalanced phase currents between neutral wire and earth return which once again require specialist understanding and data derivations.

Thus, when comparing this detail of information with a centralised GIS system for example, the central system could well argue, to take an extreme view, that the only <u>generic</u> data items they need hold for a transformer is about six fields; ie. the Manufacturer, the rating, the date of purchase, the primary and secondary voltages, and the leakage impedance, ie 6 fields per transformer instead of 150. Many central databases hold little more than the former, and yet most of these 150 fields are used in modern network analysis.

Another good example of specialist, but very important information of considerable detail and complexity is the protection details, ie the device types, their position on the network, and their settings. Also related documentation on calculation checks carried out to equate settings with the system fault behaviour. Here is a good example of where detailed, easily accessible <u>system</u> knowledge is of considerable assistance to the protection engineers, but their resultant output is only of value to relatively few.

As analysis extends to even more detail to cover unbalanced loadings with time-of-day distribution profiles, the data volume will continue to grow, and need increasing attention to its on-going accuracy and updating procedures.

The main commercial interest in all this increase of expertise is that <u>all</u> of the above mentioned areas of detail are needed to properly calculate the total running economy of a large system. With network electrical losses on Plcs costing between £60m and £100m per annum, and with increasing complex analysis required to assess the impact of cross customer feeding, embedded generation etc., such continuing increase in examining detailed network behaviour is inevitable.

Thus the practical data design principle becomes to leave the main bulk of specialist data in a simple direct access and updatable form <u>within the Dept responsible</u>, but retain keys to this via a generic central data recording system.

4. Circuit Display Requirements.

A separate, but quite emotive area of network analysis is that of the visual display of the system being studied. For the EHV network, where simple network analysis has been carried out for many years, the traditional schematic network display, with or without a clear diagram of the substation busbars has been well proven and semi-standardised. This type of display lends itself well to limited volume networks say 500 or 600 nodes, and is particularly well suited to Control Room SCADA requirements where skilled design of the schematic layout greatly assists in the Operational decision making process.

The flexibility, and artistic licence possible with schematic drawing does however lose geographic position appreciation, and also means that the most convenient schematic for say the EHV network will probably not spatially match with areas of HV schematic, thus leading to the retainment of two different diagrams. Furthermore, within specialist planning and protection departments, quite separate schematic views are often developed for particular studies.

The alternatives to a schematic are an accurate geographic display, which has major limitations in congested areas, or a "pseudo-graphic" display, as naturally drawn by network planning engineers. The latter also employs some artistic licence to ensure all line connection clarity, but still retains a very close proximity to the map background, and is the most common form of planning network display at distribution levels world-wide.

The "psuedo-geographic" view of the network has the following points in its favour;

a) It is permanent, and lends itself to direct data capture.

b) The data thus collected, particularly below 132kV level, can be automatically converted to its electrical impedance values, thereby cutting out major errors (such as factors of 10), that can remain undetected for years in schematic diagrams.

c) For advanced analysis, such as network extension planning, earthing studies, load category growth analysis, re-positioning of split points etc. the geographic detail is essential.

d) In Control Rooms, there are emergency conditions, where a quick view of the psuedo-geographic network layout is also useful, and in some dense city areas they are now being adopted.

Thus when considering corporate data, one proposal is that all networks should be held corporately in a GIS system as pseudo-geographic, but that the network analysis system should be able to;

a) Convert any network into various equivalent schematics as users require, including introducing substation layouts, and then retained as required in personal files.

b) All central updating of the system should be by pseudo-geographic view and data only.

c) User should be able to "flip" from schematic to geographic view at any time, or retain both views concurrently on the screen.

d) User must be able to display network analysis results on the screen on either view or both concurrently as required.

5. Response times needed.

Basically, all users would prefer immediate display of any requested information, including complicated parameter driven searches. However, no system can do this, and indeed, there are situations where this would be a nonsense, Thus the following response times are proposed, and have been achieved, but are dependant upon the positioning of the data within the system.

a) Any network in the system, from EHV to 415 Volt LV should be capable of access by Planning Depts. or Operating Depts within 5-10 seconds for analysis purposes.

b) Re-configuring of networks, by screen puck switching for new analysis, including significant re-routing between alternative primary substations, should be immediately available.

c) Having re-configured, network analysis for up to 2,500 nodes, should be within 10 seconds including results display,

d) Circuit and phase connectivity checking should be instantaneously displayable for any new network switching.

e) If conducting "what-if?" studies in the Control Room, retrieval of any particular network loading and switching state from SCADA files can afford to be at a more leisurely pace, say 30 seconds, and only after initial state estimating has been conducted within the SCADA system.

f) All standard detailed queries on any plant or network item, such as global displays of plant ratings; line codes, voltages, phases, or impedances; load kvas and phases; segment markers, should all be instantly displayable for any part of the network on the screen.

g) Other, more general data analysis or data survey reports, including those obtained using search parameters, will vary according to their complexity and data base locations, but cannot be part of the semi instantaneous facilities outlined above.

Discussion with users planning to introduce general network analysis into the Control Room has suggested that such analysis, ie. lv load allocation, energy management, optimisation of the network, automatic loss minimising studies, optimum capacitor switching studies etc. should be time-wise divorced from all on-line decision making activities. Thus, although the individual studies in the Control Room environment need the time responses indicated in points a) to d) above, the interface with SCADA will have positive benefits in being relatively slow.

6. Update times and concurrence.

When considering ordinary network analysis, users will normally be addressing two different types of network;

a) Network areas where users are experimenting with alternative connectivity, or unexpected behaviour of the existing network. For such studies, data for can be updated from corporate data at say monthly intervals, since, as the real network only changes slowly, there is no need for an access every time a study is required. The same remarks apply to customer load information.

b) Network areas where the user is planning fundamental changes to the system, such as extensions, the introduction of embedded generation, or major plant substitutions for example. For such studies,necessary information is not usually available in a central database at all, as the majority will still be speculative at this stage. Thus local carrying of such information is essential, and cannot be subject to formal update procedures.

For the central database system, several standard data base disciplines are essential such as the dating of plant and connectivity changes. New network extensions may be agreed up to 2 years before they are implemented, and it is important that new planning in any area takes full cognisance of any extensions already committed. In the Control Room on the other hand, nothing is relevant until it is commissioned and part of the live network.

A similar concurrence problem has to be resolved where users working on adjacent or possibly overlapping District borders are engaged in system growth activities. This is an area where the use of geographic base data, plus geographic compare and update facilities are particularly important.

Thus, one practical solution is for the local users to have the facility to extract data from a central source whenever they requires an update, to be able to store as many personal files as are needed for current studies, to seal approved networks for future use ("authorised files" that are read only), and a mechanism whereby such files can be integrated back into the main system via a visual "compare and update" procedure when required by the network controller.

7. Holding "connectivity" or "circuit" information.

It is the common accepted wisdom that all central databases should hold the connectivity of all items of plant that comprise one circuit. However, even with relational data base designs, there are fundamental limitations in this concept as follows;

a) It is an unnecessary and a fundamental straight jacket approach to attach a "circuit" label to a particular primary feeder, as future analysis may well indicate that major re-configuring could greatly improve the network efficiency. In reality, if viewed in geographic mode, it is clear that most 11kV networks are spread relatively evenly across the ground, and that the number of "circuits" that could be assembled is almost without number.

b) As plant items move around for maintenance or enhancement reasons, all connectivity data requires maybe several date labels.

c) There is more than one sort of connectivity in data management terms. For example, the electrical "circuit" is not the same as an integrated protection "circuit", or a maintenance or helicopter inspection "circuit", where, in the latter, quite different voltage networks may be included.

d) When holding data for full 3 phase unbalanced analysis, which may become the norm in time at 11kV and below, the detailed phase connectivity of all components will add another dimension to an already very complex central database facility. For example, a simple re-phasing of a long two phase spur off a 3 phase spine will require the tracing through of all load items on that network to correct their database phase information, and it only needs a change of one switch point to re-hash this connectivity once more.

One solution to this large central database connectivity overhead can be to simply centrally concentrate on the relative static information such as plant position, and leave all connectivity issues to specialist network analysis programs once the area data has been assembled and the switching positions set.

8. "Database" designs.

From the preceding sections, various conclusions can be drawn as follows;

a) The first essential is that any database needs to be extremely flexible in itself, or have a flexible interface with other corporate systems. Local databases will constantly change as new requirements and technical options emerge.

b) The next essential is to ensure that any central "pot" only holds genuine data of a corporate need, thereby giving utmost freedom of manoeuvre to other responsible specialist departments.

c) Distributed databases are needed that are linked together so that all common data is only entered once by one responsible dept. and immediately available to others. The agreement on the primary owner of key data is a significant management decision to be made.

d) Network analysis on a large global basis is proving to be best served by a strictly geographically based file structure for all components. This ensures that new network extraction is quick and effective and the "connectivity" for network analysis purposes is then automatically derived from the visible drawing after all required switches are set. Current speeds enable 2,000 lines and nodes to be connected and displayed within 2 seconds.

e) The type of databases themselves is a secondary IT design issue, and should not affect the above principles. Within one specialist Dept. it should be "horses for courses" as data extraction between different computer files and systems is becoming increasingly straightforward and standardised. This is a key area for the initial Network design to consider.

f) To aid the easy and prompt traffic between different data systems, it would appear attractive to interpose a universal database system, probably using relational database tools, to act as a general purpose gateway between all other systems. Not only can this ensure a common point of information access, but enables any major new system developments to immediately become part of the data system, and hence enable technical users to extract any data for new technical programs or queries .

9. Conclusions.

The transfer of data between any systems is not a major issue with modern facilities. The main concern is the overall design of the engineering data structure that the Distribution PLC wishes to achieve. The volume and diversity of data used in Network Planning Departments is extremely large, and does not lend itself to all being contained in one magic central database.

The ownership of integrated data needs organising carefully so that the future flexibility is not impaired. Decisions are important on the ownership and responsibility of basic primary information. So far, all attempts at corporate data assembly have found major problems in these areas, and a substantial amount of conflicting data between different sources has been the norm, and often the amount of common data between specialist depts has been found to be a small percentage of the whole.

For the purposes of flexible network analysis both for Planning, and for future Control Room features, it is very important that any final data traffic and display solutions do not "impose" any unsatisfactory restraints on any specialist Departments. For integrated data, the best solution is clearly fast access to the same data where appropriate, but with total flexibility of use once obtained, including for example immediate "flips" between different types of network displays, access to their own specialist analysis routines, and local re-draw and storage of personal working files. This leads to increased interchange of skills between different functions, and helps ensure future flexibility in both Planning and Operations to the technical and efficiency interests of all parties.