REVIEW OF A CENTRAL BUSINESS DISTRICT DISTRIBUTION NETWORK IN THE LIGHT OF THE AUCKLAND EXPERIENCE

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SUMMARY

The paper describes a review undertaken of the Christchurch Central Business District(CBD) in New Zealand. The experience and knowledge emanating from submissions to the Government Inquiry into the Auckland blackout are used to illustrate the steps a prudent and proactive network operator such as Orion, takes to deliver supply security in an economic manner. An overall commentary on the wider issues which might impact on the planning process and could contribute to a major incident will be included. In particular the paper discusses supply security and network planning standards, such as the UK P2/5 standard.

INTRODUCTION

EA Technology was asked to undertake a review of Orion's Asset Management Plans. This included comparing Orion's plans with best practices adopted elsewhere and particularly in the UK.

It might be worth starting by looking at a high level comparison of Transpower/Orion's network feeding the CBD of Christchurch with a typical UK network and noting the key differences. The two most obvious differences concern the selection of network voltages and the size of District substations.

Bulk transmission in NZ is predominantly 220-kV and Orion takes supply at either 66-kV or 33-kV. In the UK, the National Grid Company (NGC) undertakes bulk transmission at 400/275-kV (the "SuperGrid system") and most of the Regulated Electricity Companies (REC) take supplies at 132-kV. This is then transformed down via 33-kV and 11-kV to lv, a process that involves one extra step compared with NZ. The 400/275-kV system in the UK can be considered equivalent to Transpower's 220-kV and the UK's 132-kV and 33-kV systems are replaced by single 66/33-kV network in NZ. Many network planners in the UK would be happy to adopt the NZ system (SuperGrid, 66, 11-kV) since there is a popular view that the UK has too many steps (SuperGrid, 132, 33, 11-kV) and that some are too small.

District substations in the UK, which feed into the 11-kV network, tend to be smaller than in NZ (or at least in Christchurch CBD). In the UK the larger District substations would typically be 2 x 12/24-MVA, giving a firm capacity of 24-MVA. Many substations are smaller than this, perhaps 2 x 10/20-MVA or 2 x 7.5/15-MVA in urban areas. This compares with the two 2 x 20/40-MVA substations in the centre of Christchurch. Such large substations place considerable pressure on the 11-kV network and it is not surprising, therefore, to see that Christchurch has a large and very strong 11-kV network with a much greater number of embedded switchboards than would be found in the UK.

There are, of course, many other differences in detailed design and construction standards but the larger substations and fewer voltage levels represent the two most significant.

METHODOLOGY

Our methodology is set out in the following paragraphs.

Asset Management Plan Review

To undertake a review of the Asset Management Plan prepared by Orion. The Orion asset management process, condition assessment procedures, dataflows and maintenance policies will be included. These processes will be compared to international practice of a reasonable and prudent operator.

Review the distribution plans

To review the distribution plans that were prepared relating specifically to the CBD. These plans should be bench-marked against those that would be expected by a reasonable and prudent operator adopting internationally acceptable and prudent practice, as would be the case for a city the size of Christchurch.

Evaluate contingency plans

To evaluate Orion's contingency planning for failure of the major sources of supply. Compare this to that which might be expected for a city of a similar size. Specifically identify contingency planning which covers the loss of a number of major infeeds and identify the extent of preparedness for such a loss. Note: It is recognised that this contingency plan is currently being prepared by Orion.

Review the integration of processes with those of the Grid Operator

Review the integration of Orion's planning process with that of Transpower in regard of the establishment of both acceptable risk management for the CBD power supply and cost optimisation of that power supply. Specifically comment on the degree of integration between the distribution and the transmission planning process, particularly as it compares with international practice.

ASSET MANAGEMENT PLAN

A prudent Network Utility Company will regularly update a detailed Distribution Network Asset Management Plan (AMP) covering a 5 - 10 year period.

The fundamental purpose of such a plan is to demonstrate responsible stewardship of the Utility's assets to interested parties which includes shareholders, customers, regulators and financiers etc.

As a key business planning document the AMP enables the Network Company to manage its risks by identifying age, condition and performance of assets and forecasting capital investments required for asset replacement and extension to meet future growth, preferably for at least 10 years into the future.

Utility Networks world-wide are considered as natural monopolies which require more or less degrees of regulation to control outcomes such as price, rate of return and customer service performance levels.

In the UK the Electricity Regulator has directly determined the income of the Electricity Network Operators (ENOs) by a periodic price review process which is based on capital spending requirements, the cost of capital and expected operating costs.

In New Zealand, until relatively recently a "light handed" regulatory regime applied, using disclosure requirements without direct price control.

Recent changes, prompted largely by the Auckland CBD supply failure and also lack of perceived competition at residential customer level, have resulted in a number of more draconian measures being taken, i.e.:

- forced electricity network "Line Owners" to divest ownership in Electricity Retailer's business and generation stations larger than 5MW;
- proposed the introduction of tougher disclosure regulations to tighten up financial performance details and require details of asset plans to be disclosed, including security standards and plans for various classes of assets;
- proposed the introduction of a price regulation provision based on the trade-off between price of delivery service, rate of return on assets and reliability performance via a score rating system (0 - 100 points, above 75 price regulation possible).
- Although the regimes described above are structurally different, they have the same general intention and satisfying these regulatory requirements becomes a key business driver. In these circumstances the AMP provides a major input into the overall company business plans.
- An Asset Plan should include at least the following elements:
- classification of assets in terms of type and condition including quantities and age profiles;
- performance objectives in terms of supply reliability targets;
- assessment of major risks;
- details of asset maintenance and replacement policies, and detailed plans with projected budgeted costs over the period;
- details of forecast capital investments to cope with estimated growth requirements over the period;
- details of security of supply standards adopted at various loading levels in the network.
- A competent Network Company will also have well developed loss management or quality initiatives. Loss management includes all types of losses including accidents and injuries to staff, damage to plant and equipment, accident investigations and emergency plans as well as technical and procedural standards.
- The report of the Ministerial Inquiry into the Auckland Power Supply Failure found quite specific inadequacies in terms of asset management practices, including "lack of expertise, poor maintenance procedures and standards, lack of condition-based assessment and no well developed plan for specific 110kV cable assets".
- In terms of risk management and contingency planning the Inquiry was critical of the "lack of clear accountability for risk management practice and monitoring at both senior management and Board level".
- Many specific recommendations were made relating directly to the Network Operator involved in Auckland, but the Government was also recommended to:
- "Consider incorporating the electricity disclosure regulations - a requirement for every network operator to publish, every three years, its asset plan together with past and future security standards for each consumer class and supply area and each distinct voltage level". These recommendations are currently being implemented by the Ministry of Commerce NZ, as discussed above.
- The Auckland power supply failure has been a massive wake-up call for all New Zealand Electricity Network Operators and has had considerable international impact as well. The need for competent asset management planning and management has never been clearer.

REVIEW OUTCOMES

The EA Technology review of Orion's Network Asset Plan and CBD supply security was carried out over a nine month period and was concluded in December 1998. Using the methodology previously described, the following outcomes were achieved in the key areas listed below:

Supply Security Standards

Supply security planning standards in the UK are specified in Engineering Recommendation P.2/5 and compliance with this is a condition of the Public Electricity Supply License. Breeches of this standard are rare and must be notified to the Regulator who will, invariably, want an undertaking to remedy the position urgently. P.2/5 is a relatively simple document that specifies the maximum load that can be lost for a given outage. For instance class A supplies (for a group demand of up to 1MW) require no security and can be interrupted for the time it takes to repair the fault. For class E supplies (between 300 and 1500MW) no supplies can be lost for a single outage and two-thirds of the group demand must be maintained for a second outage. P.2/5 specifies no security for busbar faults, though all REC routinely exceed this and provide some busbar security at 11kV and above.

UK ENOs typically treat P.2/5 as a minimum standard and routinely exceed it, especially in urban and city centre areas. In addition it is widely recognised that P.2/5 does not fully match the requirements of the industry because it makes no provision for asset reliability. Making provision for unreliable (ageing) assets in the context of P.2/5 is an unresolved issue in the UK and most also set internal targets for availability (customer-minutes lost per connected customer and equivalent to SAIDI). It is these "SAIDI" targets that are currently driving security standards for the most part. Recent years have seen a steady improvement in supply security with most committing themselves to still better performance in the future.

This approach of monitoring performance standards, largely driven by regulation, is leading UK ENOs to look at probabilistic methods of evaluating these performance statistics for planning purposes.

In contrast, New Zealand has no nationally adopted supply security planning standard in the distribution sector of the Electricity Industry. For the review it was agreed to use the UK P.2/5 standard as a "benchmark" with the view to Orion developing its own standard appropriate to New Zealand conditions.

Orion

Proposed
Distribution Network Security Standard

Class of Supply	Range of Group Demand (MW)	Example	Minimum Demand to be Met After First (Tx/cct) Outage	Second (Tx/cct) Outage	Busbar Fault
A1 Remote Rural	0 - 1	Remote Rural Feeder very small T/P GEPs	Repair time by switching		
A2 Rural	1 - 2	Rural feeder	Within 2 hrs - 50% group demand Within 6 hrs - 95% group demand In repair time - 100% group demand	In repair time or restoration of arranged outage	Repair time 100% group demand
A3 Urban	1 - 2	Urban secondary feeder	Within 1 hrs - 50% group demand Within 2 hrs - 95% group demand In repair time - 100% group demand		
B	2 - 10	Major Overhead lines Single TX subs Large urban radial feeders	By switching: Within 1.5 hrs - 50% group demand Within 3 hrs - 95% group demand In repair time - 100% group demand	100% of group demand	
C1 Normal Security	10 - 60	Primary Urban Network Network Centres Switching Stations District Substations	Immediate - 100% group demand	By restoration or switching within 2 hours 95% group demand within repair time 100% group demand	Inspection and switching time 2 hrs - 95% group demand
C2 High Security	10 - 60	Special Industrial/Commercial Load T/P GEPs CBD Loads	Immediate - 100% group demand	By restoration or switching within ½ an hour 95% group demand within repair time 100% group demand	Repair time 100% group demand
D	60 - 200	CBDs Major City Large Commercial Industrial areas Medium T/P GEPs	Immediate - 100% group demand	By restoration or switching immediately - 50% group demand within 1 hour, 100% group demand	Immediate 50% group demand
E	200+	Large T/P GEPs and Major Transmission System Nodes	Immediate - group demand	Immediate - group demand at time maintenance is usually done.	Repair time 100% group demand

Figure1: Proposed Distribution Network Security Standard

This was achieved as shown in Fig. 1, and the standard which was developed is an adaptation of the P.2/5 UK standard allowing for New Zealand's generally smaller capacity system but also including busbar security criteria. This is believed to be a first for a New Zealand Electricity Network Operator in the Distribution Sector. New Zealand's Transmission Grid Operator (Transpower NZ Limited) has published "guidelines" in terms of Grid Exit Point supply security levels, but significant variations from the guidelines are found in practice (see "Integration with Grid Operator" below).

Load Trend Forecasting

Orion has developed the practice of projecting historic load growth forward, adjusting it to account for a variety of demographic and other factors including population growth trends, forecast gross domestic product and local authority development plans, a practice in common with most other Electricity Network Operators.

Weather related "average cold spell" factors are produced annually and applied to "normalise" historic demand records. Growth forecasts for each High Voltage feeder in Orion's area typically fall within the 1% to 3% range and with some higher localised growth rate forecasts in rural areas where deep well submersible irrigation pumps are very popular. A feature of the UK demography in recent times has been the decline in some of the older industries which has produced load shifts resulting from falls in some areas being compensated for by increases in other areas and this trend has also been evident in the Orion network area as new technology industries replace older primary processing plants and the rural land use changes from sheep production to dairy and horticultural production.

The growth in air conditioning within CBD is a new phenomena which is leading to summer peaking in temperate areas. This combined with the poor power factor of these devices lead to some of the load problems in Auckland.

In the Christchurch CBD a similar summer loading trend is evident as shown in Fig. 2. This has lead to the need to review and reassess plant ratings for major cables and transformers, particularly in elevated ambient temperatures.

Load and Demand Management

Many larger customers connected to the Orion network have introduced relatively sophisticated maximum demand controllers which can be used to modify electricity consumption at peak times as well as improving energy efficiency.

Orion's pricing signals for delivery of electricity have provided clear economic price signals to encourage this behaviour.

Arrangements for smaller customers have historically placed emphasis on the use of off-peak storage water heating. This was largely introduced in New Zealand to manage peak Hydro generation capacity for the State owned generation company prior to 1988. Over the last 10 years considerable investment by customers in off-peak storage space heating has taken place in response to pricing signals.

Many NZ ENOs have come to rely on demand management regimes to manage short term capacity constraints in an emergency on the distribution network. In the future this may not be so readily available as independent energy retailers and generators drive to maximise profits by increasing sales. Plans to deal with this potential conflict of network capacity constraint versus generation energy pricing fluctuations are under consideration.

Network Investment Criteria & Decision Making

AMP budgets should reflect the bottom-up approach where the budget is built up from specific projects or programmes of work. This requires projects to be identified in advance of budgeting and has the benefit of setting a more flexible budget according to actual demands and not historic trends. Of course the overall capital budget is still constrained and rationing will occur, but this is applied more at budget category level as funds are switched from under-utilised categories. This can typically mean varying the refurbishment budget to accommodate fluctuations in new business projects.

Budgeting categories should be specified in the document. In the UK it is normal practice to split the capital budget into four main "system categories; New Business, Reinforcement, Refurbishment and Other. The first two are referred to collectively as "load related" and all categories are further subdivided according to the activities within them. In addition there would be a separate non-system budget covering other business requirements including Information Technology. Metering is the responsibility of a separate business unit that would produce its own budget. The budgeting process tends to be different for each category as follows:

New Business

These projects are to meet specific customer requirements and are beyond the control of the ENO. The main budgeting problems concern predicting which projects will go ahead in the budget year. Larger projects (say >1MVA) will usually be known well in advance but, because of uncertainty, confidence factors are often applied to scale down the funds made available in the expectation that some will not proceed. In addition funds, based on historic trends and growth forecasts, are added for small and unspecified projects that are unknown at budget time. At Orion this category is generally referred to as New Connections and Land Subdivision developments.

Reinforcement

This category includes network extensions and modifications to strengthen the network in response to general load growth (i.e. not attributable to a specific customers). All of the larger projects are usually specified and require some justification to be included in the budget in terms of overloading or security problems or confirmed voltage complaints. Once again funds are set aside for smaller or unknown problems which might arise and which are not known at budget time and this is typically based on previous history. Unlike the top-down approach this can produce a highly variable budget as big individual projects come and go.

At Orion all major projects have been identified 10 years ahead with the proviso that the first 5 years of the plan are considerably firmer than the last 5 years.

Refurbishment

Most (possibly all) of the refurbishment budget would comprise specified programmes of work, for instance switchboards to be replaced. These would typically be prioritised according to the number of customer minutes lost within the zone in previous years or the categorisation of a switchboard according to its type and conditions. This budget category would often provide some flexibility to adjust for variations elsewhere but would also be constrained in the UK over the regulatory five year cycle, to meet commitments included at the time of the price review.

At Orion this category is known as replacement capital expenditure and up to recently has not included re-poling of overhead lines which have traditionally been expensed as "maintenance".

Other

This category includes any other system projects and is usually dominated by environmental projects (undergrounding overhead lines, bunding, transformers, distribution automation/SCADA etc). This tends to be built up in a similar way to the refurbishment budget.

Once a budget is fixed it will comprise specified projects and funds for unspecified projects that were too small or unknown at budget time. The subsequent financial authorisation process tends to treat the two types (specified and unspecified) differently and often requires authorisation at a higher level for unspecified projects.

Other Issues

The AMP should include some long term objectives for asset utilisation, asset replacement and environmental improvements where appropriate. In the Orion review it was noted that overall system load factor was increasing, with a current (1997) value of 58% and a 10 year target set in 1992 of 65%. A trend of declining utilisation of distribution transformer capacity was observed, partly due to individual rural loads being supplied by single transformer(s).

Asset replacement policies are a key issue in determining expenditure on maintenance or replacement, e.g. do assets have an expected fixed life after which they are replaced?

A typical classification of assets might include:

Class A
Modern equipment currently approved for new installations.

Class B
Recent equipment having no significant problems and fully supported with spare parts etc.

Class C
Older equipment that may have a history of minor problems and for which limited spares are available (e.g. through recovery off the system) that could be replaced if the opportunity or need presents itself.

Class D
Unsatisfactory equipment that should be replaced as early as possible.

PLANNING PROCESS

Timeliness of Planning Decision

It has been recommended that an AMP be based on at least a 10 year time scale and be reviewed annually. The first five years of such a plan will contain relatively firm commitments to particular projects, particularly to meet load growth. Beyond 5 years specific project definition may be less developed, but it is important that longer term planning issues be addressed. This is particularly important in the UK and New Zealand where the growth spurt of the 1960's in electricity asset investment has left a large "bump" in the age profile which post 2000 will mean network assets in excess of 40 - 50 years of age will increase dramatically which could affect network performance unless specific refurbishment/replacement plans are in place.

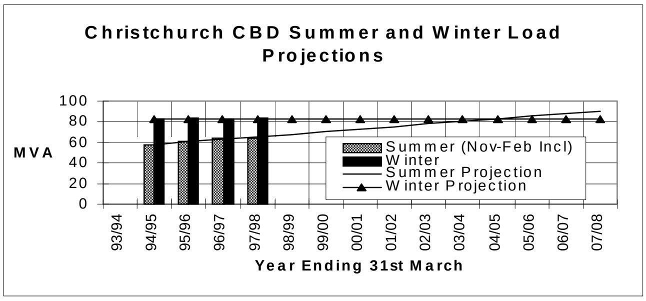

Figure 2: Christchurch CBD Load Projections

In this respect it is suggested that network asset replacement profiles be projected out beyond the 10 year period to better plan and resource any maintenance or refurbishment strategy. At Orion this process clearly demonstrated the extent of future programmes and their likely budget impact. See Fig. 2.

Project Review & Audit Procedures

The document should include information concerning project reviews or audit procedures. A prudent operator will review all capital projects, particularly if expenditure on the project is significantly different to that authorised. For instance a project that spends more than 10% above the authorised amount (subject to a minimum for small schemes) may require automatic scrutiny while others might be subject to random audits.

Increasingly ENOs are looking not just at the financial aspects but also to review the assets installed to see if these match those authorised. This might include comparison of the length of cable or line installed, any transformer capacity or other plant provided and also the incremental revenue received in terms of delivery charges from newly connected customers.

Asset Maintenance and Policy & Procedures

Most ENOs will place greatest emphasis on maintaining assets that supply the largest number of customers. Giving priority to important assets could imply a rationing process that allocates an insufficient resource to best advantage. Maintenance according to condition and consequence of failure would be an alternative strategy that would ensure that assets receive the attention they require to keep them in good order, regardless of their perceived importance.

There is an increasing international trend to employ Reliability Centred Maintenance (RCM) techniques in the Utility Network Industry. This is a process used to determine what must be done to ensure that any physical asset continued to do whatever its users want it to do in its present operating context. The RCM process entails asking the following questions about the asset or system under review:

What are the functions and associated performance standards of the asset in its present operating context?

In what ways does it fail to fulfill its functions?

What causes each functional failure?

What happens when each failure occurs?

In what way does each failure matter?

What can be done to predict or prevent each failure?

What should be done if a suitable proactive task cannot be found? (Proactive tasks are undertaken before a failure occurs, e.g. preventative maintenance).

RCM principles are starting to be used by some UK ENOs and traditional regimes are being replaced with asset specific programmes based on historic performance and condition monitoring of individual items of plant.

RCM is intended to ensure that maintenance, and the potential threats implied by it, are only undertaken when it is actually required and not according to a prepared regime.

The cost of achieving this is a significant increase in function tests and condition assessments and the development of sophisticated information systems to spot problem trends.

In recent years handheld computer terminals have been introduced both to allocate work to field staff directly from the computer based work management system and also to collect field data to update records. One of the main applications of handheld devices has been collection of condition reports in order to facilitate RCM.

AT Orion, initial results in applying RCM have been successful, e.g. older concrete power poles which although low cost and practical and relatively maintenance free have been shown to fail under certain storm conditions, thus causing more widespread disruption to reliable supply than was acceptable. The “RCM outcome” of that project is that Orion now uses a locally grown treated softwood pole (in place of concrete poles) which provides superior resistance to shock loading in its pole replacement programme.

Decision Making Criteria

Many UK ENOs have major asset replacement programmes underway intended to avoid future problems with failures and to manage long term workload/resource issues. This policy has been introduced to avoid a large peak in failures, roughly following the asset age profile, which could lead to significant increases in supply interruptions coupled with peak workloads and loss of financial control.

The graph below shows the impact a short variation in asset life can have on fault rates if they are left to fail in service. Each curve shows the number of failures occurring for an asset whose entire population was installed over a short period, 5 years in this case. The lower curve shows failures based on a normal distribution, with a mean life of 40 years and a standard deviation of 10 years so that failures are spread over a long period. If the standard deviation is reduced to 5 years then the cure shows a peak of 7.7% of assets failing in a single year.

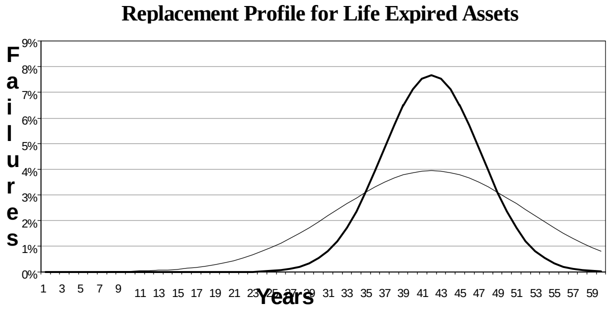

Figure 3: Replacement Profile

Of course this may not happen and there could be a huge variation life expectancy leading to failures spread over a long period. In the UK different asset replacement policies are typically applied to different types of plant. Not all assets are being routinely replaced according to age since they can have a different impact on performance. The following is a typical approach taken by a UK ENO.

Cables

Lower voltage cables (up to 11kV) are expected to have a long life and are showing no significant signs of age related failures. Many of these are naturally replaced because they outlive their purpose, as the areas they serve are redeveloped and replacement programmes are not required at this time. Higher voltage cables can sometimes fail prematurely but tend to be duplicated and well protected so that failures can be accommodated without disruption. Cable performance at 33kV and above is monitored and replacement of drum lengths is typically undertaken if more than two cable faults occur within a 10 year period. Replacement programmes are undertaken for some problem cables, for instance 132kV gas compression cables are being replaced.

Switchgear & Protection

Because of the critical safety role undertaken by switchgear and protection this is replaced before the risk of age related failure. This is also expected to assist greatly with security issues if other ageing plant started to fail. A programme to replace oil-based switchgear has focused first on outdoor units and auto-reclosing switchboards and recently all main switchboards. Planning for the replacement of distribution substation switchgear (mainly RMUs) has not been finalised. Programme selection is prioritised according to type, known problems, availability of spares, age and condition.

Transformers

Transformers have (so far) been found to have long lives and consideration has been given to a policy of allowing transformers fail in service where the system can tolerate it. Most transformer replacements to date (excluding failures) have arisen following a condition assessment demonstrating tank/radiator corrosion problems; difficulty with spares, oil contamination and this is often combined with environmental risks from possible oil spillage.

CBD DISTRIBUTION PLANS

Although not strictly required by planning standards most UK ENOs recognise the special problems posed by CBDs and consequently apply higher security standards in these areas. Special problems include the widespread use of lifts, computer systems and problems for the ENO's own staff in moving around during an emergency to get access to operational plant.

In the case of the Auckland failure the network configuration supplying the CBD meet quite reasonable supply security standards in terms of configuration.

Problems with cable specification, installation and maintenance practices and ongoing reliability performance were major contributory factors to the failure.

In considering supplies to a Central Business District (CBD) it is necessary to take account of the wider issues and not simply the basic security standards. We believe a modern city should seek to achieve the highest "World Class" standards of supply security within reasonable economic limits.

Many city centres throughout the world have, in the past, been served by city centre power stations. For economic and environmental reasons they have been closed and replaced by very large single points of supply containing ageing switchgear. There are many examples of ageing 11kV switchgear failing, often without warning. One of the most common reasons for catastrophic failure includes contamination of the circuit breaker oil due to water ingress or maintenance materials problems. The subsequent risk of explosion can destroy the switchboard and its housing and has lead to fatalities. Other problems include oil/compound leaks and corrosion. A "stuck breaker" can disrupt supplies and sometimes cause damage to other assets. Consideration should be given to replacement of these assets with more diversified supply points thus enhancing the security of supply. Such plans will have long lead times and should be part of the asset management plan. These plans should be supported by probabilistic supply availability analysis.

In the UK P.2/5 assumes summer maintenance periods will coincide with a two thirds demand and N -2 outages are intended to cope with this condition. This potentially poses a problem in areas such as the CBD where summer demands are high. The summer demand for many CBD is 100% of the winter peak due to air conditioning.

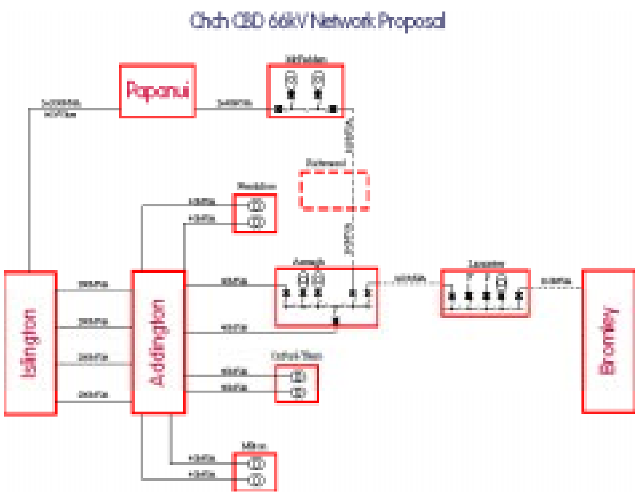

Figure 4 - CBD Supply Arrangements

The Orion CBD Network services the City of Christchurch (population 320,000), which is the major city of the South Island of New Zealand.
The specific review process of existing CBD supply arrangements revealed a number of areas for concern (see Fig. 4) e.g.:

- dependence almost entirely on one Grid Exit Point connection to the Transmission Network;
- large central substations with ageing oil filled switchgear;
- a trend towards increased summertime loading with higher ambient air and soil temperatures (see Fig. 2).
- Grid Exit Points with poor security in respect to single fault contingencies due to lack of busbar zone protection and in some cases limited transformer capacity.

CONTINGENCY PLANNING

Any prudent ENO will have prepared contingency plans. These plans should contain the following sections:

Risks and Threats to Supply Security

This should be a comprehensive, systematic and thorough consideration of likely risks and threats to supply security and recommended ways to treat such contingencies. In principle, the probability of simultaneous faults decreases with the number of these faults. This probability, in distribution systems, again in principle may even more decrease if the related faults are considered however, it is right to consider some such cases (with a relatively large number of simultaneous and related faults). When it comes to faults caused by damage to network elements by third party or adverse weather conditions, the probability of simultaneous outages of adjacent cables. When a cable is cut in a trench with, for example three 11kV cables or two 66kV cables, it is quite possible that all cables will be cut. This would formally create N -3 and N - 2 operation condition, respectively. On the other hand the probability for such an event might be similar to an N -1 case.

Emergency Plans for CBD

A prudent operator will have a well prepared set of emergency plans to deal with the special case of failure to supply a major business district. This will include procedures for dealing with Risks and Threats to Supply Security highlighted in the previous section. The grid operator's network supplying the CBD should also be taken into consideration in system operation planning when producing the emergency plans.

Embedded Generation

The emergency plan should list all customers with embedded generation and standby power units. In the event of an emergency these can be used to reduce demand. Consideration should be given to their ability to synchronise to the network so that maximum benefit can be obtained from them in the event of an emergency. The ability to assemble and connect additional emergency generators into the network at key locations must be assessed and documented. Emergency generators assembled in "Farms" played a major role in the Auckland incident.

Restoration and Repair Procedures

There should be a clear distinction between the emergency network restoration procedure and the procedure for network elements repair. Although the repairs have to be done as quickly as possible (and in LV network this may be the only course of action) the network restoration is of an even greater urgency. A procedural distinction would help establish an undistracted priority of the restoration.

Communication with the Consumers

In terms of communication with consumers two functions should be recognised, fault reporting by the consumers and informing the consumers on the supply and repair progress status. In some cases the information gathered from the consumers may help in fault analysis and location. There should be clear guidance on what level of communication with consumers should be set (mobilising telephone operation staff, using mass media) for which level of emergency (degree of affected load demand/number of consumers).

Plant Capacities

As stated earlier, summertime peaking is now becoming a feature of city centre demands. This means that plant capacities must have their ratings reviewed for summertime operating. Having variable (seasonal) cable rating (and similarly transformer rating) will have operational consequences. System operation planning should take this into account and seasonally change the setting of overloading protection relays, as well as warning thresholds in the SCADA system (assuming they exist). Contingency plans, particularly those affecting the CBD, should be varied in accordance with the seasonal rating of network elements.

Orion's 66kV cable and 66/11kV zone substation transformers required a complete review in terms of particularly their summertime capacity. On line (SCADA system) temperature monitoring of the major cables have been commenced and heat runs on four CBD 66/11kV transformers have been carried out as part of an ongoing reassessment of plant capacities.

INTEGRATION WITH TRANSPOWER

Careful integration of Orion and Transpower's plans is especially necessary because of Transpower's ownership of key 66kV distribution assets feeding the CBD in addition to their ownership of 220kV transmission assets.

Communications

Orion now holds regular meetings with Transpower to discuss network issues and the Plan includes a brief description of some projects that are currently being considered.

This is similar to arrangements in the UK where regular meetings are held between the ENOs and NGC. Several groups may meet separately and include Operations, Planning and Commercial groups. NGC prepares an annual Seven Year Statement that provides all present and potential future customers with detailed information about the SuperGrid system, its performance, forecast loading, planned developments etc. It is the production of this document that largely drives the meeting timetable and enables NGC to collect all required data from ENOs.

In addition NGC publishes the Grid Code, which describes NGC operational requirements and working practices. The ENOs also produce a common Distribution Code for the same purpose. All of these documents are available in the public domain.

All UK ENOs and NGC are legally required to provide potential connection customers with all the information they require to independently assess the technical issues associated with a new connection. This includes network records, demands and a “Statement of Opportunities” containing a commentary on network capabilities for a particular area. Few ENO customers take advantage of this and most of the information required from NGC is included in the Seven Year Statement.

In New Zealand Transpower NZ Limited publishes its Asset Management Plan and various technical and operating standards which are made available to companies like Orion.

CONCLUSIONS

The specific outcomes of the Review of the Orion Asset Management Plan and CBD Supply Security are summarised as follows:

1. Orion adopted a supply security standard based on P.2/5 adapted for NZ conditions including busbar security criteria, a NZ first!
2. Orion adopted, in principle, an investment programme of reducing the CBD’s dependence on one only grid exit supply point by providing for a cross city interconnection at 66kV, a $NZ15M programme over 3 years (see Fig. 4).
3. Orion adopted a new target replacement age for oil filled switchgear of 40 years reduced from 55 years, but targeted especially where the consequences of catastrophic failure could seriously impact on supply security.
4. Orion revised its asset replacement expenditure in other areas including recognising pole replacement as a capital investment (previously expensed as maintenance) and recognised the impact of asset age profiles beyond 10 years on the AMP. Total financial impact of items (3) plus (4) is $NZ4M extra Capex per annum.
5. Orion recognised the need to revise and considerably improve its contingency plans to include emergency line construction, emergency generator sourcing and connection, switching contingency plans for each zone substation outage, and emergency material supplies and emergency stocks were reviewed.
6. Orion identified significant weaknesses with existing grid connection arrangements with the Transpower Transmission Network.
7. Orion recognised the trend towards increased summer loading on its CBD network and the need to reassess plant ratings for major cables and transformers particularly in elevated ambient temperatures.

Overall, we recommend for any future reviews of this type that the following key issues be addressed:
When replacing ageing switchgear in major city centre points of supply consider how these points of supply can be diversified.

Consider the use of interconnects to improve transformer utilisation and reliability of supply.

Review equipment ratings to reflect seasonal variations in capacities and increased summertime demand.

In view of summertime peaking of demand, consider the applicability of demand side management of air conditioning plant.

Ensure appropriate security of supply standards are incorporated into the network design process.

REFERENCES

[1] "Restoration Following HV Network Faults - Standard"; Network Services; NW 21 03 02, 20/11/96, referred to in the text as *The Standard.*

[2] "Storm/Equipment Failure Contingency Plan - Procedure"; Network Operations; NW 20 40 01, 05/05/97, referred to in the text as *The Contingency Procedure.*

[3] "Christchurch City, Central Business District, Contingency Plan", a copy of presentation slides, referred to in the text as *The Contingency Plan.*