STRATEGIC PLANNING FOR THE UPGRADE OF THE POWER SYSTEM IN NHULUNBUY

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ABSTRACT

The power distribution system servicing the town of Nhulunbuy has undergone limited upgrade since the completion of the town in 1971. As a consequence a large number of key system components are operating close to their capacity limits. The issue is further amplified by major expansion of accommodation facilities within the town. This paper discusses the long term load forecast of this distribution system and proposes two options for upgrade of system to ensure continuing security of supply. Currently there is monitoring of the condition of the system through regular load and protection surveys, however whilst these reports identify key issues with the system the recommendations are difficult to incorporate into the budgeting process as they indicate the current state of the system only, providing no opportunity for planning of upgrades. The desired outcome of this project is to provide an overview of the system improvement required as the town demand increases. This plan will also develop options for the improvement of current system limitations.

1. INTRODUCTION

Distribution system planning is an important task in the maintenance of an efficient, reliable and economical power system. A well developed planning process works to identify system deficiencies, balancing these with public interests such as reliability and environmental impact, and allocates scarce resources amongst potential investment options [1]. The goals of the planning process are to develop and maintain a profitable, reliable, safe and efficient network with minimal losses and environmental impact [2].

The utilisation of the planning process within the domestic utility environment varies with the majority of organisations employing a short range plan of 3-5 years and in several cases this is further supplemented by a long term plan with a planning horizon of up to 20 years [6]. In a multi level planning approach, long range planning maps out the anticipated evolution of the power system and provides a strategic framework for the development of the network for maximum economic life [4], [5], [6].

The town of Nhulunbuy in the Northern Territory includes the Alcan Gove alumina refinery, which is an integrated mine, refinery and port operation, supplying bauxite and alumina to the Alcan group and global market. In 2004 the addition of a third producing stage to the existing two stage operation commenced. The Alcan Gove operation is supported by the settlement of Nhulunbuy, the administrative centre for the East Arnhem Region. The power distribution system servicing this town has undergone limited upgrade since the completion of the town in 1971. As a consequence, a large number of key system components are operating close to their capacity limits. The issue is further amplified by major expansion of accommodation facilities within the town.

Statistics published in 2004 estimate the population of Nhulunbuy to be 3797 people, making it the fourth largest centre in the Northern Territory [3]. Due to the remoteness of the town, all essential services, including amenities such as power, water and sewerage are provided by the refinery. Dramatic increase in residential accommodation is required to house the increased population. With the addition or upgrade of a large number of dwellings, substantial pressure is to be placed on the town power distribution network.

This project has been proposed to develop a long term overview of system upgrade requirements due to the demand increases resulting from planned additions and characteristic system growth. Preferred options for upgrade will be recommended, along with approximate load and system preconditions, in a strategic plan for the development of the power system.

Load and protection studies of the Nhulunbuy town power system were carried out by engineering consultants in 1993 (BHP Engineering), 1999 (ALESA) and 2005 (IrwinConsult), and information from these studies has been used in the assessment of the system condition.

Within the Australian utility industry two planning methods appear prevalent – contingency and reliability based planning schemes. Contingency based, or 'N – x' planning schemes are the most widely utilised approach taken to distribution system planning [8]. The use of this deterministic standard in planning produces a network design that will provide continuity of service in the event of the failure of x number of components [6]. However this comes at considerable economic expense, as system utilisation is much lower than in cases where reliability based planning is utilised [9].

Budgetary restrictions have been a key factor behind the adoption of probabilistic planning methods within the Australian electricity market and Reliability, Assessment Planning, RAP, has been one of the most highly supported ideologies within this field [6]. Value based planning, particularly where focused on reliability enhancement, provides a balance between the cost of improvement to service quality and the economic benefits to the organisation [9].

Load forecast provides the basis for assessment of system upgrade requirements, providing information on how much energy is to be required at a certain location and time. Methods commonly utilised for forecasting can be identified as being either a spatial or non-spatial method. Long term transmission and distribution planning utilises the annual system peak loads as the measure for system suitability [7].

The planning guidelines utilised by domestic distribution system operators fairly consistent, taking into consideration the differing requirements of metropolitan, regional and remote rural regions [6], [10]. The main objective behind the development of planning guidelines within the utility is to ensure that network security and reliability are maintained [11], [12], [13].

The key planning considerations for distribution network design are as follows.

- Contingency Criteria
- Steady State Criteria
- Stability Criteria
- Quality of Supply Criterion
- Conductor Selection Criteria
- Construction Standards Criteria
- Environmental Criteria
- Financial Criteria

2. METHODOLOGY

2.1. PLANNING PERIOD

The planning horizon used for the generation of a load forecast model for the community of Nhulunbuy is twenty years.

2.2. PLANNING APPROACH

An 'N – 1' contingency scheme has been applied to the power system design for the 22kV system. For all 11kV distribution substations within the town system a normal transformer load not exceeding 76.7% on any phase has been utilised as the design loading. This is in accordance with the recommendations of AS2374.7-1997 Power Transformers, Part 7: Loading guide for oil-immersed power transformers. Single attribute plan optimisation has been undertaken, with the attribute to be optimised through this process being cost.

2.3. PLANNING CRITERIA

The planning criteria provided by the Power and Water Corporation in the document *Network Planning Criteria, Rev 2.0, April 2003*, has been utilised as the design criteria for this system. Nhulunbuy is considered to be an urban area in the context of these planning guidelines.

2.4. FORECAST OF FUTURE LOAD GROWTH

2.4.1. DATA COLLECTION

Daily peak load values from the PI data plant system were collected for the system for the period 1995 to 2005. The time of occurrence of these peak load values was not available.

2.4.2. APPARENT LOAD AND POWER FACTOR CORRECTION

Data for the apparent power load on the town zone substation could not be sourced, nor could data on power factor values. Power factor correction was undertaken during the first half of 2005. At the point of switching the power factor was recorded to show an improvement from 0.82 to 0.93. All loads prior to the 10/03/2005 (the assumed commencement date of power factor correction) are considered to have a power factor of 0.82, and all those after this date a power factor of 0.93.

2.4.3. DATA OF CONSTRUCTION PERIOD

All data for the year 2005 has been neglected from forecast calculations as this data shows high load increase at both the town zone substation and individual feeder levels. For the addition of approved and conceptual loads to the system a general construction period of three years to the end of 2007 has been assumed.

2.4.4. WEATHER NORMALISATION

Weather normalisation has not been undertaken for the gathered data as limited information on past weather conditions in the region was freely available.

2.4.5. FORECAST METHODS

There are a number of methods for load forecasting available in the literature [14] to [17]. Spatial small area forecasting using parametric linear regression methods have been utilised for the prediction of load growth with the town of Nhulunbuy based on the current demographic. Future load levels are determined by the use of simulation methods by application of the Lowry concept considering the local basic industry, as the Alcan alumina refinery.

2.5. TOWN ZONE SUBSTATION

2.5.1. HISTORICAL GROWTH CHARACTER

Peak load data for the Town Zone Substation (TZS) was only available after July 1997. Outliers were evident in the data, with a number of zero values returned in addition to peak values not representative of the load trend. High and low outliers were determined for each year through the utilisation of the 1.5IQR rule for the determination of outliers.

The peak values of the modified data set for each year were utilised in the determination of the historical growth experienced by the system. The average growth was calculated for the six year period from 1999 to 2004. For each of the periods a linear approximation to the historical trend data was made, revealing a growth rate of 107.6kW/year.

2.5.2. Major Developments

There are currently a number of significant developments taking place, or planned, within the community of Nhulunbuy, due largely to the expansion project. A review of the project requests for electrical connection was undertaken showing the total additional load for approved projects to be 3533kVA and 299kVA for projects yet to be approved. An assessment of each of these load increases was carried out to determine whether they are reflective of the growth character. Those loads determined to be due to the expansion project and greater than half of the annual growth were defined as atypical or special load additions. Special additional load for approved projects total 3394kVA and 185kVA for projects yet to be approved.

2.5.3. Future Growth Prediction

A prediction of the future growth to be experienced by the TZS was developed using simulation methods and the central concept of the Lowry Model – change of population in a region will be proportionate to changing in its basic industry. The current growth is due to a population of 3850 people, of which 1100 are employed at the refinery, either directly or through contractors. An estimated 150 additional plant positions will be required to service the expanded operation. Through application of the Lowry principle, the new population will stabilise at 4375. Based on current trends the per capita growth rate is approximately 30VA per annum, hence the growth rate expected after population stabilisation is 131kVA per annum.

2.5.4. Load Forecast

Two scenarios have been considered in the development of the load forecast for the Town Zone Substation, the first being the system load given the addition of the approved loads only, and the second being the system load given the addition of both approved and conceptual loads.

The predicted maximum load in the target year is the summation of current demand levels, growth during the construction period and growth from the end of construction to the target year at the predicted rate. The maximum predicted load in 2026 is that calculated to incorporate both approved and conceptual loads and yields a load figure of 15.825MVA. Where approved additions only are considered the predicted load in 2026 will be 15.640MVA.

2.6. Town Distribution Feeder System

2.6.1. Historical Growth Character

Data for the town distribution feeders showed strong evidence of outliers, and the same method of assessment was applied as for the TZS. The peak annual value of the modified data set for each distribution feeder was used to calculate the linear approximation to the characteristic growth of each feeder. The period data used was 2001 to 2004. This was selected due to the reinstatement of feeder E-T2 in 2001 and the uncharacteristically high growth shown in 2005.

Due to the limited amount of data available, this estimation of the characteristic growth of each of the distribution feeders may not be representative of the actual growth experienced. In addition, no monitoring of feeder E-T2 is undertaken, so the figures provide for this feeder are an estimate established from the calculated difference between the load growth at the TZS and the summed load growth of the other feeders. Annual growth estimates for each of the feeders are provided in Table 1.

Feeder	Annual Growth	
A-T1	2.1 kW	2.3 kVA
B-T2	37.8 kW	40.6 kVA
C-T1	33.9 kW	36.5 kVA
D-T2	32.4 kW	34.8 kVA
E-T2	12.8 kW	13.8 kVA
UG-T1	2.7 kW	2.9 kVA

Table 1: Annual Growth on Distribution Feeders

2.6.2. Major Developments

Each of the major developments considered for the Town Zone Substation is to be supported by an individual distribution feeder. It is not specified which distribution substation will have additional load added. In many cases further substations are to be installed. As such the total additional load is considered to impact all distribution feeder segments. Values of approved and conceptual load additions on each feeder are provided in Table 2.

Feeder	Approved Load	Conceptual Load
A-T1	854 kVA	185 kVA
B-T2	771 kVA	0 kVA
C-T1	250 kVA	0 kVA
D-T2	250 kVA	0 kVA
E-T2	820 kVA	0 kVA
UG-T1	-100 kVA	0 kVA

Table 2: Approved and Conceptual Load

2.6.3. FUTURE GROWTH PREDICTION

Due to limitations in historical data and information on expansion siting, the utilisation of simulation methods for the development of a future growth prediction is not possible. A basic estimate of future load growth has been developed by the application of a growth factor to the current rates. This growth factor has been calculated from the current and predicted growth rates of the Town Zone Substation and is the proportional increase in growth rate attributed to the increase population. The predicted growth values are given in Table 3.

Feeder	Predicted Annual Growth	
A-T1	2.4 kW	2.6 kVA
B-T2	42.9 kW	46.1 kVA
C-T1	38.6 kW	41.5 kVA
D-T2	36.8 kW	39.6 kVA
E-T2	14.6 kW	15.7 kVA
UG-T1	3.1 kW	3.3 kVA

Table 3: Predicted Annual Growth on Distribution Feeders

2.6.4. LOAD FORECAST

Utilising information on the current system loading, project additions and predicted growth rates, the maximum load values to 2026 were estimated for each feeder. This data is given in Table 4.

Feeder	Load, 2026
A-T1	3091kVA (2906kVA)
B-T2	4937 kVA
C-T1	3779 kVA
D-T2	3268 kVA
E-T2	2575 kVA
UG-T1	690 kVA

Table 4: Demand on Feeders, forecast for 2026

2.7. SOUTH AND LIGHT INDUSTRIAL ESTATE

2.7.1. HISTORICAL GROWTH CHARACTER

Limited data is available for this area of the power system. Loading data for these areas is not available from the PI data management system. Historical Maximum readings from the 1993 Electrical Load Survey, completed by BHP Engineering, were used for calculation of transformer and feeder loading for the areas of Nhulunbuy South and the Light Industrial Estate (LIE).

As there is no historical loading trends available for this area trending methods cannot be utilised to determine system growth. Nhulunbuy South and the LIE are estimated to make up 3.6% of the total demand. For this project the growth characteristics of South and LIE and the Town system have been considered the same and growth rate established as proportional to that of Nhulunbuy proper.

$$AnnualGrowth = 116 \times 3.6\% = 4.2kVA / year$$

2.7.2. MAJOR DEVELOPMENTS

Total additional load due to approved projects on the South and LIE system is 1079 kVA, and load due to conceptual projects 194 kVA. The total additional load upon the area is 1273 kVA.

2.7.3. FUTURE GROWTH PREDICTION

As with the average annual growth, the future growth prediction for the areas of South and the Light Industrial Estate was calculated proportionally that determined for the Town Zone Substation. The predicted future growth is 4.7kVA per annum.

2.7.4. FORECAST LOAD

The maximum predicted demand in the South and LIA in the year 2026 is 2367kVA. This value includes the addition of both approved and conceptual loads. Failure of the conceptual projects will result in an estimated load on the system of 2173kVA.

2.8. TOWN FEEDERS

The town feeders supply both the area of South and LIE and the Town Zone Substation.

2.8.1. HISTORICAL GROWTH CHARACTER

The growth characteristic of both Nhulunbuy and the area of South and the Light Industrial Estate have been assumed to be in same in absence of historical data for the latter. The total average annual growth, neglecting major developments for the town feeders is the summation of the values calculated for each of the areas.

Annual Growth = 116 + 4.2 ≈ 120kVA pa

2.8.2. MAJOR DEVELOPMENTS

Total additional load on these components is the summation of the loads for each of South and LIE and Town. Additional load figures for the town feeders are:

Approved Load = 3394 +1079 ≈ 4473 kVA

Conceptual Load = 195 + 185 ≈ 379 kVA

2.8.3. FUTURE GROWTH PREDICTION

The future growth rate prediction for the town feeders is the summation of the future growth rates calculated for each of Nhulunbuy and the area of South and the Light Industrial Estate. This is based on the assumption that the same growth characteristics are shown by each of the areas.

Predicted Growth = 131 + 4.7 ≈ 136 kVA pa

2.8.4. FORECAST LOAD

The maximum predicted load in 2026 is that calculated to incorporate both approved and conceptual loads and yields a load figure of 18.404MVA. Where approved additions only are considered the predicted load in 2026 will be 18.025MVA.

2.9. IDENTIFICATION OF RESTRICTIONS IN DISTRIBUTION SYSTEM

An assessment of the capacity of key network components was undertaken to determine upgrade requirements of the system. The following issues were identified

- The town feeder conductors are underrated for supply of the system with one feeder past a demand level of 13.7MVA.
- There is no system support for the TZS, in the event of major fault prolonged outage expected
- The TZS transformers are each rated at 12MVA, demand is expected to exceed this value by 2007 – total system load cannot be supported by a single transformer
- Underground segments of distribution feeders are rated to only 185A, they are underrated in emergency conditions, and in some cases under normal operating conditions
- Peak load due to switching is expected to exceed capacity of main distribution feeder segments, rated at 325A, in the future. Further information on substation loading required.
- Loading of distribution substations appears to be within capacity limits from 1993 figures. New data is required for confirmation.
- HV supply to LIE is not separate from South. No supply to LIE when South supply is isolated.
- No control over non-essential load in South or LIE. Audio frequency load control used elsewhere.

2.10. UPGRADE OPTIONS

A range of upgrade options was proposed for each of the identified system restrictions. Each of the identified upgrade options was evaluated against key aspects of the Power and Water Corporation Network Planning Criteria, Rev 2, 2003. This assessment included the development of a cost estimate for each option based on information from Ergon Energy.

Two proposals for the upgrade of the town power system were presented. The first detailed the suggested upgrade plan without the addition of a second substation to the town, the second considered the addition of a new town substation. The proposed upgrades are detailed below. Due to small capacity margins in the current system and large levels of proposed increase, planning for upgrades is required as soon as possible.

2.10.1. UPGRADE PROPOSAL 1 – EXISTING TZS

- Install new feeder from main plant-mine line to TZS. Parallel existing feeders
- Install additional transformer at town zone substation. Parallel existing transformers
- Replace underground line segment for feeder UG-T1. Replace underground line segment for distribution feeders B, C and D.
- Relocate South and Light Industrial Estate Feeders to the Town Zone Substation

2.10.2. UPGRADE PROPOSAL 2 – ADDITIONAL TZS

- Install new feeder from main plant-mine line to the Light Industrial Estate.
- Install new substation
- Move feeder from Light Industrial Estate to new substation. Install separate feeders to South and the Light Industrial Estate
- Move feeders A and B to new town substation.
- Replace underground line segment for feeder UG-T1. Replace underground line segment for distribution feeders C and D. More information required on feeder E.

3. RECOMMENDATIONS

- Take new readings demand readings at each of the distribution substations
- Confirm correct loading of distribution transformers
- Install online monitoring for feeder E-T2.
- Review LV distribution system for voltage.
- Assess capacity of distribution feeders under contingency conditions
- Undertake condition assessment of TZS Transformers

4. CONCLUSIONS

This paper described the upgrade requirements of the power distribution system for the town of Nhulunbuy. The system is currently operating with many components close to their capacity limits, and major expansion to residential facilities is being undertaken.

Results of load forecast models have shown that major system components including the town feeders, TZS transformers and segments of the town distribution feeders require upgrade immediately to ensure continued security of supply.

Two proposals for system upgrade have been presented, one considering the upgrade of existing system components, and the other considering a plan for the installation of a second town substation.

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