Qulliq Energy Corporation

Response to "Conversion of Iqaluit Distribution Feeders from 4 kV to 25 kV"

By:

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Background

QEC is currently in the process of converting it's Iqaluit distribution system from 5 kV to a 25 kV class system over the period from 2006 to 2010. The approximate cost of the conversion is at a total cost of $4,87 M over four years.

The current direction of QEC's capital plan calls for a multi-year, multi-phase project to upgrade the Iqaluit distribution system based on historical information. The following materials were used to provide background and supporting data for this upgrade decision:

- "A Short Term load flow study of the Iqaluit distribution system" – Granville Roberts, July 24, 2000

- "Report on Iqaluit Distribution Study" – D.Buckle/G. French, April 30, 2000

- Peak load Measurements from the Iqaluit main plant control room readings over period of 2004-2005

After several years of study and information gathering, Engineering Department consolidated these materials and supporting analysis into a report entitled "Iqaluit Long Term Power Distribution System Study" in November of 2005.

The purpose of the technical paper was to propose a long term and sustainable solution to various operational and technical challenges facing the Iqaluit system. The key elements of those challenges were:

- Safety of the existing system for both employees and the general public

- Replacement of equipment that has reached the end of its useful life

- Increasing the reliability of the system

- Reducing operating/line losses and generating savings to the corporation

The report provided in-depth analysis and direction on where QEC should be heading in the future in order to accommodate load growth and improve reliability.

Along with historical data, the existing distribution system was simulated on load flow and stability computer software (Siemans PSS-ADEPT) to analyze key elements of the power system, mainly power loss and voltage regulation. The work was performed by A. Chubbs between September and November of 2005.

The system was then simulated at 25 kV to determine power losses present on each feeder and demonstrate the reduction in voltage regulation that is achievable. The previous year's peak load and average load (2005) was used as the basis of the report, along with generally accepted loss analysis calculations used by power utilities across

North America (Distribution System Loss Reduction Manual). This resulting report (Iqaluit Long Term Power Distribution System Study, 2005) is attached and will provide answers to many of the identified questions and concerns.

The key questions raised include:

1. Why commit to the high cost of a conversion project?

2. Why such a high distribution voltage?

A number of alternatives were reviewed in developing the recommendation to move to a 25 kV system, these options included;

1. Capacitor placement – This would be a cheaper approach, but does not satisfy the long term scope of the project. This is a short term fix.

2. Voltage Regulator installation – Again a cheaper but short term fix that would decrease line efficiencies and generate additional losses over the long term.

The use of a high distribution voltage would significantly reduce line losses and give a greater payback during a shorter period, while eliminating the need for extra installed equipment like capacitors and regulators.

Projects Related to the 25kV upgrade

This initiative is a long term solution to accommodate future load growth and implement a loss reduction program to achieve increased efficiency of the distribution system. Values have been calculated over the next 30 years and will support and coincide with other key upgrades within Iqaluit, mainly;

- Automatic Meter Reading (AMR) initiatives
- Wood pole replacement program
- Yearly feeder relocation and structure rebuild maintenance activities
- Protection & Control studies of the distribution system to implement an industry standard of reliability and safety
- Future interconnection of hydro sources at the new 25 kV substation site

Economic Impacts

With respect to technical and economic considerations, while there will be some costs to the implementation of the new system, these will be mitigated by the following:

- Existing "newer" wood pole structures (installed within the last ten years) can still be utilized at a 25 kV voltage class, the vintage 5 kV class structures are either slated for replacement under the current pole replacement program or are budgeted for in the upgrading project.

- Only equipment at the end of its useful life will be replaced. Key pieces of equipment in the upgrade of the system will be transformers and insulators, which will be salvaged and redistributed within QEC's existing 5 kV distribution systems, located in 24 other Nunavut communities. In doing so these replacements will offset costs associated with our yearly re-supply and further generate cost savings.

- An assessment of the existing 15 kV pre-built structures was carried out in the summer of 2006 and confirmed that existing cross arms have the required spacing at the current short span feeder length to accommodate a 25 kV class system as per CSA C22.3 standard for overhead systems.

Operational Considerations

The new 25kV system will require training and new equipment for line crews. The training is scheduled for April 2007 and cost of equipment has been incorporated into the project.

Work methods and safety procedures are currently being revised for work on the higher class voltage system. QEC Engineering has been working very closely with Operations on the development of new requirements (i.e. equipment, training, work procedures) and will be implemented prior to conversion of the system. At no time will QEC safety procedures be compromised for operation of this new system.

The new procedures will be added to QEC's existing work protection code to equip personnel to recognize and manage the risk, along with already employed qualified journeyperson's that are certified to work on the system.

The proposed layout of the new system will be a main trunked feeder line with fused lateral taps. This will allow for de-energizing smaller sections of the feeder for safe work and will minimize both the requirement for live line maintenance and the number of customers affected by any such outages.

The existing distribution system has no capability or overall flexibility to accommodate procedures such as emergency switching and load shifting, but the new system will provide this flexibility.

Design Assumptions

Critical review in past (Have, 2007) was founded on a number of erroneous design assumptions;

- The author was not aware that the new distribution system will be comprised of three radial fed, trunked feeders, as opposed to the existing eight partial feeders.

- The proposed design will combine existing feeders to take advantage of improved voltage regulation at the higher voltage class and further reduce the equipment at the substation/plant level (i.e. fewer feeder breakers, protective relays, cabling, etc., with commensurate savings).

- The proposed design will eliminate the 15 kV class underground cable plant located at the Baffin Regional Hospital site.

Future Considerations & Cost Savings

With a higher voltage class future additions to the system can be easily accommodated, such as customer owned co-generation facilities.

With the eventual interconnection of cheaper, more "rate stable" hydro power sources the possibility of newly connected domestic customers with efficient electric heating systems will potentially cause load growth and a shift in how electricity is used as a cheaper "one source" provider over oil fired heating systems.

With the full implementation of this loss control program, the conversion of the distribution system will reduce annual power losses by over 1.5 megawatt hours, which will generate savings of over $600,000 per year, and reduce carbon dioxide emissions by 1080 tonnes annually (Environmental Impact Tables, Natural Resources Canada).

The new system will also reduce the amount of equipment required in our distribution plant, mainly feeder breakers, bus work, associated protective relaying equipment, cabling, etc. Associated maintenance requirement will also be reduced generating further cost savings.

Conclusions

In conclusion, recommendations to install voltage regulators and capacitor banks have been considered and make technical short term sense.

The long term, cost effective, and viable approach has been incorporated into the QEC capital plan, which includes a phased conversion of the distribution system into a safer, more efficient, and reliable asset with the capability to accommodate Iqaluit's forecasted load growth over its entire life cycle, minimizing the operational and maintenance costs.

QEC engineering would be pleased to provide further clarification on this project, discuss further any aspect of our loss reduction program and would be happy to meet and satisfy any concern there may be.

References

1. "Distribution System Loss Reduction Manual" – Booth & Associates, November 1994

2. "Effectiveness of Distribution Protection" – Power System Analysts, June 1996

3. Communications and discussion with various Consultants and Canadian Utilities Planners – notes in project files.

Attachments

1. "Iqaluit Long Term Distribution System Study" - November 2005

Qulliq Energy Corporation

Iqaluit
Long Term Power Distribution System Study

Report Outline

Scope

This report will identify and assess current problems associated with electrical load growth on the Iqaluit distribution system in the past several years and projected future problems that will occur with continued load growth. The report will explore best cost alternative to correct problems through the standard engineering economic processes, such as simple pay back, rate of return, and cost/benefit ratios. Conceptual engineering drawing designs, calculations, and philosophies will also be included in this report to ensure proper direction on QEC standards and requirements.

System Background

The Iqaluit distribution system consists of eight (8) radial fed, overhead wood pole structured distribution lines of various vintages, ranging from 5 years to over 50 years old. The carried conductor ranges from AWG #4/0 AASC conductor (current utility standard) to AWG #2 soft drawn copper conductor (1950's post war utility standard). All eight feeders are connected via a switchgear lineup at the main plant, where the systems main generation exists. Two feeders are inter-connected (feeder's 3 & 4) intermittently to the "Federal" standby plant located at NPC's federal road building and provides a standby capability of approximately 3 Megawatts (Mw) for peak load shaving and local waste heat recovery/cogeneration for the facility. Refer to Appendix B for a key single line diagram of the Iqaluit System.

Applicable Codes, Standards, & Correspondence

The following codes, standards, and public documents were used to form the basis of this report and serve as the base line design philosophy;

- NFPA Standard 70B – "Recommended Practice for Electrical Equipment Maintenance"
- CSA Code C22.1-02 – "Canadian Electrical Code Part 1" (Safety Standards for Electrical Installations.)
- CSA Code C22.3 1-01 – "Overhead Systems"
- CSA Code CAN-3-C235-83 – "Preferred Voltage Levels for AC Systems, 0 to 50 Kv"
- EEMAC Standard Y1-2 – "Performance Specification for Finishing Systems for Outdoor Electrical Equipment"
- ANSI Standard C57.12.90 – "General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers"
- "Iqaluit Core Area and Capital District Redevelopment Plan" – City of Iqaluit development concept plan, 2005.
- Personal Correspondence – Mr. Clifton Rose, P. Eng, Senior System Planning Engineer, Newfoundland Power. 2005.

Problem Identification

Due to increased load growth within Iqaluit's capital core area and extensive development of multi-unit housing structures, significant demand has been placed on various sections of our distribution system that will eventually create problems as early as the winter of 2005-2006. The main problem will be voltage regulation, created by a low distribution voltage, high peak currents, and sub-standard conductor sizing.

Secondary to the issue of feeder loading is power loss, while it does not affect the customer's power quality directly it affects NPC's overall system efficiency and removes potential revenue that could be recovered through sales to the customer or it can be translated to fuel savings to the corporation by the releasing of system generation capacity.

Voltage Regulation Backgrounder

As a power utility we are required to maintain an acceptable power quality level to our customers, mainly standard North American voltages within a slight tolerance. These values are specified in the Canadian Standards Associations standard #C235, which is the benchmark for Canadian Utilities to follow with regard to voltage regulation. If a feeders load growth is projected to put voltage levels outside these guidelines corrective action must be taken. Various alternatives are available depending on the severity of the problem, such as capacitor placement, re-conductoring, load balancing, autotransformer tapping, and converting to a higher distribution voltage level.

I have developed following process to generate the best alternative;

I. Complete a long range load forecast of 30 Years, which forms the pay back period basis and the useful life cycle of the associated equipment involved.

II. Include financial projections, including lost revenue over 30 years due to power losses, outage time, costs of capital, inflation, and maintenance costs over the same period.

III. Develop each alternative and carry it over the life of the 30 year project, alternatives shorter than this life span should not be considered. The least cost alternative should then be examined.

IV. Consider energy costs for each alternative, since our energy costs are very high we want to give projects which reduce power loss priority (Example: initiatives that lower our distribution currents will improve voltage regulation and reduce power loss, such as a voltage conversion project.)

Feeder Assessment

The following section details each feeder section in Iqaluit and gives brief recommendations on upgrading and future load growth trends.

Feeder #1

Power Losses

Feeder one in Iqaluit feeds primarily the downtown (lower base) area of the city. The Connected load is mainly residential, with exception of the courthouse and the Northern Stores. The winter of 2005 the peak demand was 860 Kw. The projected Kilowatt hour (Kwh) losses are calculated to be 94,695 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standard, the base voltage is 344 volts (600Y/347 volt service located at the northern store), nominal at the furthest customer point. While voltage regulation does not present a problem, conversion of the feeder should be eventually completed to standardize the equipment and hardware; various sections of the feeder require replacement of the system neutral conductor and certain sections of the feeder have a vintage of over 30 years old. It is recommended that the feeder be upgraded to meet an acceptable safety and reliability standard.

Feeder #2

Power Losses

Feeder two in Iqaluit feeds the core section of town, mainly the hospital and the high rise buildings. It is physically the shortest feeder of the Iqaluit System. The connected load is mainly commercial with a peak demand of 1220 kW in the winter of 2005. The projected Kilowatt hour (Kwh) losses are calculated to be 290,832 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standard, the base voltage is 116 volts, nominal at the furthest customer point. While voltage regulation does not present a problem, conversion of the feeder should be eventually completed to standardize the equipment and hardware; various sections of the feeder require replacement of the system neutral conductor and certain sections of the feeder have a vintage of over 30 years old. It is recommended that the feeder be upgraded to meet an acceptable safety and reliability standard.

Feeder #3

Power Losses

Feeder three in Iqaluit feeds the West 40, tank farm, water booster station #2, and select loads in the North 40 area, while connecting to the federal plant's G5 and G6 standby units. The connected load is mainly commercial with a peak demand of 1340 kW in the winter of 2005. The projected Kilowatt hour (Kwh) losses are calculated to be 209,013 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standard, the base voltage is 113 volts, nominal at the furthest customer point. The far ends of this feeder are lightly loaded, while the main load center is closer to the main plant (source) which reduces line voltage drop and currently creates good voltage regulation. The use of the cogeneration source G5 & G6 located in the federal plant also gives improved voltage levels when connected to feeder four, raising the base voltage to about 122 volts. While the federal plant corrects voltage regulation slightly, it is recommended that it not be considered in the overall regulation of the feeder because of its standby function on the Iqaluit system.

Feeder #4

Power Losses

Feeder four in Iqaluit feeds North 40, upper base, and sections of the downtown core section of the city. The connected load is mainly commercial with a peak demand of 1450 kW in the winter of 2005. The projected Kilowatt hour (Kwh) losses are calculated to be 588,672 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standard, the base voltage is 115 volts, nominal at the furthest customer point. The far ends of this feeder are lightly loaded, while the main load center is closer to the main plant (source) which reduces line voltage drop and currently creates good voltage regulation. The use of the cogeneration source G5 & G6 located in the federal plant also gives improved voltage levels when connected to feeder four, raising the base voltage to about 118 volts. While the federal plant corrects voltage regulation slightly, it is recommended that it not be considered in the overall regulation of the feeder because of its standby function on the Iqaluit system.

While voltage regulation does not present a problem, conversion of the feeder should be eventually completed to standardize the equipment, hardware, and reduce power line loss associated with high currents experienced on the feeder section.

Feeder #5

Power Losses

Feeder five in Iqaluit feeds Happy Valley, 200's, and the 300's area of the city, the connected load is mainly residential, with the exception of water booster station #1. Load growth on this feeder has been slow, peaking at 750 kW in the winter of 2005. The projected Kilowatt hour (Kwh) losses are calculated to be 114,055 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standards. The base voltage value is projected to be 110 Volts, nominal at the furthest customer point. While voltage regulation does not present a problem, conversion of the feeder should be eventually completed to standardize the equipment and hardware; various sections of the feeder require replacement of the system neutral conductor and certain sections of the feeder have a vintage of over 30 years old. It is recommended that the feeder be upgraded to meet an acceptable safety and reliability standard.

Feeder #6

Power Losses

Feeder six in Iqaluit feeds the capital core district of Iqaluit and feeds the bulk of the commercial load growth over the next several years, mainly Innuksugait Plaza Phase two (400 Kw projected demand for 2006-2007), new plateau subdivision (80 Kw projected demand for 2006-2007), Nunavut Justice Centre (115 Kw projected demand for 2005-2006), City of Iqaluit sewage treatment plant (200 Kw projected demand for 2006-2007), RCMP "V" division Headquarters building (112 Kw projected demand for 2007-2008). In the winter of 2005 the feeder demand peaked at 1170 Kw prior to the connection of the previous mentioned loads. Power losses on this feeder section are also a concern; the projected Kilowatt hour (Kwh) losses are calculated to be 543,248 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder will be predicted to fall outside CSA C235 standards by the fall of 2006 when the Nunavut Justice centre and Innuksugait Plaza Phase two are completed. The base voltage value is projected to be 107 Volts, nominal at the furthest customer point. The current CSA C235 standard value for extreme operating value is 106 volts, indicating a borderline operating condition that will eventually case problems in 2006.

Feeder #7

Power Losses

Feeder seven in Iqaluit feeds sections of the road to nowhere, west view, cross winds, and Apex. It also feeds several commercial customers, mainly the AWG complex, the Middle School complex, and the Telesat radar site. Load growth since 2000 has been steady on this feeder section, peaking at 1090 Kw in the winter of 2005. While this feeder does not experience the highest load growth of the Iqaluit system or have a significant impact on the core development of the city, it has the longest length of any feeder in the system and large sections of this feeder are well over 35 years vintage (Apex Section). The projected Kilowatt hour (Kwh) losses are calculated to be 124,392 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls outside CSA C235 standards. The base voltage value is projected to be 94 Volts, nominal at the furthest customer point. The current CSA C235 standard value for extreme operating value is 106 volts, indicating a substandard operating condition. To mitigate this problem the use of distribution transformer winding taps set to the maximum (low) setting where employed to raise the voltage to approximately 105 Volts. This is a temporary solution and does not adequately correct the voltage at peak loading times (Mid January to late February).

The feeder also consists of a large gauge conductor, which impacts on the voltage regulation of the feeder over the long distance, causing voltage drop. Any further development in the area serviced by this feeder should be discouraged due to the low voltage levels being experienced.

Feeder #8

Power Losses

Feeder eight in Iqaluit feeds the road to nowhere and Tundra Valley sections of Iqaluit. The connected load on this feeder is primarily residential, with the exception of the Joamie School, which has a connected load of approximately 80 kilowatts. Load growth since the 2003 development has been slow, peaking at 780 kW in the winter of 2005. This feeder represents one of the smallest connected loads of any feeder within the Iqaluit system and has a vintage of about 10 years. The projected Kilowatt hour (Kwh) losses are calculated to be 98,112 for the 2005 Year.

Voltage Regulation

Voltage regulation on this feeder currently falls within CSA C235 standards. The base voltage value is projected to be 118 Volts, nominal at the furthest customer point. While voltage regulation does not present a problem, conversion of the feeder should be eventually completed to standardize the equipment and hardware; various sections of the feeder require replacement of the system neutral conductor. It is recommended that the feeder be upgraded to meet an acceptable safety and reliability standard.

Total System Power Loss

The total system losses for the Iqaluit system in 2005 are calculated at 2,062,499 kWh. At a cost of $0.40 per kWh this represents equivalent lost revenue of $783,428.52 annually. Iqaluit's generation efficiency is currently 3.90 kWh/L, which equates to 528,846 Litres of diesel fuel consumed in 2005 to generate power system losses. This loss will continue to rise proportional to the square of the current on each feeder, representing a sharp upward trend in projected losses over the next several years with a distribution voltage of 4.16 kV and an average load growth of 3-5% per year. Table 1 details system losses per feeder over the 2005 year.

Table 1

Feeder	Peak Load (kW)	Loss Factor	Load Factor	Peak Loss @ 4.16 kV (kW)	Average Loss @ 4.16 kV (kW)
1	860	0.468	0.65	23.1	10.81
2	1220	0.468	0.65	71.1	33.2
3	1340	0.243	0.44	98.2	23.86
4	1450	0.352	0.55	190.9	67.2
5	750	0.261	0.46	49.9	13.0239
6	1140	0.418	0.61	149.7	62
7	1090	0.266	0.47	53.2	14.2
8	780	0.261	0.46	43	11.2

Potential Substation Losses

With distribution system voltage conversion a high voltage substation must be constructed to step-up the voltage from the main plant bus from 4.16 kV to the new distribution voltage of 25 kV. The main component of the substation will be the step-up power transformers, these units are projected to be approximately 20 MVA in size, talking into account the 35 Year load forecast of Iqaluit (See Appendix A) and a design life of about 25 Years. Based on nameplate loading, loss factor of 0.3 and an auxiliary loss factor of 0.1 the unit will produce the following losses;

Table 2

3Ø Power Rating (MVA)	Core Losses (kW)	Winding Losses (kW)	Auxiliary Losses (kW)	Annual kWh Losses
20/25	18	72	2	349,000

These losses must be subtracted from the savings of the distribution voltage conversion and be factored into the payback period over the life of the equipment to determine if a complete conversion of the system is feasible.

Recommendation

The priority with any power utility should be the control and reduction of lost energy within there distribution systems, unfortunately there will always be electrical energy lost in the delivery to customer and QEC must implement an energy loss program that will aid in making well informed decisions about the allocation of funding to reduce system loss. While financial performance is the main incentive for loss control, voltage regulation and the ability of the distribution system to properly accept load growth should also be a key factor. The loss reduction program in Iqaluit must be based on the concept of increasing the nominal distribution voltage to a higher industry standard, such as 25 kV. In deciding to convert the distribution voltage to take advantage of cost savings we must look at the "system wide" implications and complete an economic analysis of the key factors involved, mainly;

- ✓ New substation facilities to supply the required system voltage.
- ✓ Stocking of higher voltage distribution equipment (i.e. transformers, cabling, fuses, cutouts, etc.)
- ✓ Possible need for step-down power transformers to permit partial conversion of feeder sections.
- ✓ Installation of surge arrestors and line sectionalizers to deal with increased reliability requirements and longer feeder lengths.
- ✓ Procurement of new tools and equipment for maintaining a higher voltage class system.
- ✓ The training of personnel in working with higher voltages, (i.e. substation electrician certifications, safety requirements, etc.)

25 Kilovolt Distribution System

The total system losses for the Iqaluit system, based on the 2005 load are calculated at 444,494.13 kWh. At a cost of $0.40 per kWh this represents equivalent lost revenue of $177,797.65 annually. Iqaluit's generation efficiency is currently 3.90 kWh/L, which equates to 113, 973 Litres of diesel fuel consumed in 2005 to generate power system losses if the system were distributing at 25 kV. The following table depicts various elements associated with power loss.

Table 3

Distribution Voltage	4.16 kV	25 kV	Savings @ 25 kV
Annual Losses (kWh)	2,062,499	444,494.13	1,618,004.87
Equivalent Lost Revenue	$783,428.52	$177,797.65	$ 605,630.87
Equivalent Fuel Consumption (Litres)	528,846	113, 973	414,873

Operations & Maintenance Requirements

When converting a distribution system to a higher voltage class consideration must be given to the impact on the operational maintenance and overall safety requirements. Tools and equipment used by maintenance crews must be certified at the required voltage class and aerial devices such as bucket trucks must be regularly tested to meet proper insulation levels. It is also recommended that QEC develop standard work methods for distribution practice, such as replacing broken poles, hold off (protection code) procedures, and temporary working grounds. Regular training and certification must also be performed to keep personnel current to Canadian utility practice.

The installation of a high voltage substation in Iqaluit will also broaden the scope of the line maintenance department to perform periodic maintenance on various pieces of major equipment, such as high voltage cabling, air-disconnecting switches, breakers, and power transformers. It is recommended that a full maintenance strategy be developed to identify future requirements.

Salvageable Equipment

The salvageable equipment from a 25 kV conversion project would primarily be 15 kV class transformers (pole and pad mounted types). Transformers typically represent the largest capital cost of a voltage conversion project. Most of these units can be reused in our 15 kV systems in Resolute Bay and Coral Harbor. The Resolute Bay system would require upgrading of various sections in the 2008-2009 fiscal year, mainly converting 2,400 volt delta connected sections to standard 15 kV class (12.47 kV). The salvaged transformers from the Iqaluit upgrade would significantly reduce the capital cost of such a project and represent a large investment in reliability and safety for the community.

Project Costing

The scope of the system wide voltage conversion can be broken into a multi year, multi phase project that initially constructs the substation facility at the main plant, followed by upgrading at the federal plant. To coordinate with this will be the conversion of each feeder over a four year period to make the upgrade complete within five years. The Project can be divided into two key parts, substation construction and distribution feeder upgrading.

Distribution Feeder Upgrading

Feeder upgrading will involve the following key tasks;

I. Re-insulating of the entire primary system, including grounding and bonding or insulating of down guys and anchor rods.

II. Pole replacements at various feeder sections to improve safety clearance, aerial trespass, and proper right-of-way easements.

III. The replacement of transformers and associated fusing, including cutouts with proper pole mounting brackets (proper creep and flashover clearances).

The initial phase of this project (2006-2007) will see the temporary installation of automatic voltage regulators on two feeder sections to provide proper voltage regulation during the conversion process. This phase can be considered an intermediate measure to “create” an acceptable time frame to complete the system wide upgrade. Additional phases will see the conversion of feeders #7 and #8 (in 2007-2008), feeders #4, #5, #6 (in 2008-2009), and feeders #1, #2, #3 (in 2009-2010). Iqaluit system would then be reduced to three (3) trunk feeders, breaking the city into three larger zones of protection, which would improve reliability and reduce the amount of equipment required to be in service, such as feeder breakers, bus work, protection relays, and cabling. Table 4 below outlines the estimated costs over the life of the project.

Table 4

	Total Project Cost	Budget Year	Budget Year	Budget Year	Budget Year
Fiscal Year:		**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**
Total Project Cost:	$4,870,000	$170,000	$900,000	$1,900,000	$1,900,000

Substation Construction

The construction of a high voltage substation would be required in the Iqaluit upgrade to bring the current generation voltage from 4.16 kV to the distribution voltage of 25 kV. The proposed configuration of the substation would be a double ended, tie breaker configuration with redundant power transformers. The main consideration for this type of substation would be to take advantage of built in redundant systems that can be used in the event of emergency (i.e. transformer or incomer cable failure on "A" bus.) or for planned maintenance routines. As well it will maintain energized spare equipment for quick restoration and remove the down time required to replace failed equipment and preservation maintenance on spares that would be in storage.

The proposed configuration for the federal plant would be a single radial feeder, with in-plant switchgear modification and a simple outdoor pad mount transformer construction (refer to Appendix E for single line drawings). This system would not be of redundant design due to the fact that the federal plant is standby in nature and is not required for prime power use (i.e. the cost is unjustifiable).

Table 5 below outlines the estimated costs over the life of the project and breaks the project into two key phases; (1) main and federal plant, and (2) hydro interconnection. The phases should be related to give provision in the initial substation construction for future connection of additional power transformers and associated equipment. By making allowance in phase one QEC can easily integrate phase two once any potential hydro projects are developed in the future without incurring large capital costs involved with modifying high voltage substations.

System Grounding & Neutral Return Currents

An ongoing and common problem with electrical systems in Arctic regions with permafrost is proper grounding. Frozen earth exhibits very poor conductive properties which make proper low resistance earth ground paths nearly impossible and often results in high neutral return current to the source neutral point at the plant neutral bus and station ground grid. During summer months the top "active" layer thaws, giving a temporary ground path for only a few short months. The concept of grounding in the arctic requires further study, but one method of mitigating the effects of high neutral return (zero sequence) current is providing electrical isolation by means of a Delta/Wye transformer between the plant (source) and the connected system load. Construction of a high voltage substation will provide this isolation as well as a more stable system for protective relaying and selective coordination between generation, substation, and distribution fusing.

Conclusions

The conversion of the Iqaluit distribution system would generate various benefits, mainly:

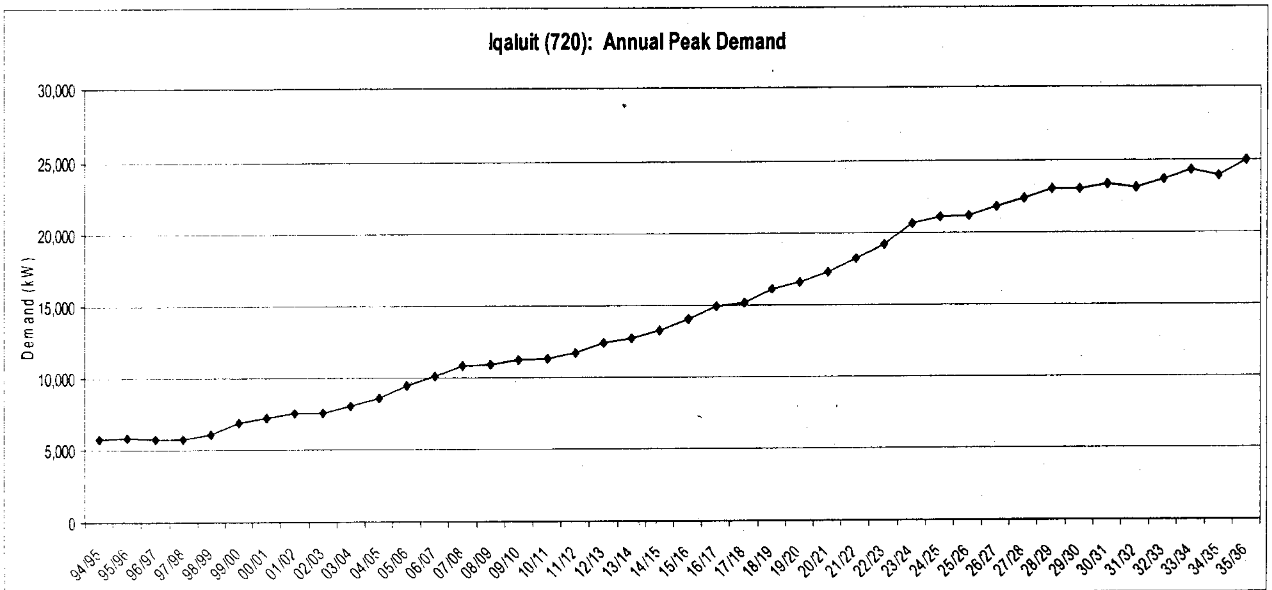
- Reduction of Carbon Dioxide emissions by approximately 1080 tonnes per year.
- Reduce diesel fuel consumption by approximately 411,000 liters per year.
- Reduce primary voltage regulation and allow for easy load growth within the city for the next 30-35 years.
- Standardize construction methods and improve safety of the overhead system to reduce overall maintenance cost and eliminate nuisance power outages during bad weather conditions.

The simple payback of this complete project would be approximately 8 years, and the average life expectancy of the major equipment is 30 years, making it a viable project for QEC to undertake.

Appendix A

Iqaluit 30 Year Load Forecast

Fiscal Year	Total Sales kWh	Domestic Sales kWh	Commercial Sales kWh	Streetlight Sales kWh	Losses kWh	Station Service kWh	Generation kWh	Peak Load Kw
94/95	28,220,815	9,325,094	17,587,206	372,887	1,231,360	1,719,908	31,172,083	5,725
95/96	28,607,696	9,477,449	17,727,383	370,611	1,433,304	1,570,000	31,611,000	5,800
96/97	28,749,317	9,369,117	17,994,301	379,270	1,598,964	1,487,622	31,835,903	5,725
97/98	29,220,601	9,541,799	18,295,628	372,808	1,641,154	1,565,972	32,427,727	5,750
98/99	30,468,598	9,347,163	19,629,513	388,285	1,343,842	1,973,619	33,786,059	6,050
99/00	32,873,218	10,356,316	21,108,022	377,451	2,823,118	2,600,691	38,297,027	6,900
00/01	36,648,814	11,943,607	23,992,819	385,740	1,935,835	2,280,205	40,864,854	7,194
01/02	39,107,191	12,972,268	25,729,550	405,372	2,365,771	1,959,718	43,432,680	7,488
02/03	40,676,193	12,944,756	27,352,429	379,008	2,353,679	2,286,808	45,316,680	7,473
03/04	43,229,269	13,811,120	29,039,141	379,008	908,946	2,519,855	46,658,070	7,943
04/05	44,726,644	15,191,974	29,127,976	406,694	419,740	2,407,296	47,553,680	8,575
05/06	49,367,145	16,556,950	32,400,254	409,941	463,289	2,407,296	52,237,729	9,420
06/07	53,003,833	17,970,787	34,614,629	418,416	497,417	2,407,296	55,908,546	10,082
07/08	56,895,991	19,508,637	36,959,529	427,825	533,943	2,407,296	59,837,231	10,790
08/09	57,089,782	21,170,500	35,491,458	427,825	535,762	2,407,296	60,032,840	10,825
09/10	59,118,965	22,956,374	35,734,766	427,825	554,805	2,407,296	62,081,066	11,195
10/11	59,624,914	21,136,322	38,060,768	427,825	559,553	2,407,296	62,591,763	11,287
11/12	61,408,457	22,865,136	38,115,496	427,825	576,291	2,407,296	64,392,044	11,611
12/13	65,640,699	24,699,360	40,513,513	427,825	616,009	2,407,296	68,664,003	12,382
13/14	67,394,273	26,638,995	40,327,453	427,825	632,465	2,407,296	70,434,034	12,701
14/15	70,195,949	26,996,744	42,771,380	427,825	658,758	2,407,296	73,262,003	13,211
15/16	74,761,728	29,020,703	45,313,201	427,825	701,605	2,407,296	77,870,630	14,042
16/17	79,524,610	31,143,871	47,952,915	427,825	746,303	2,407,296	82,678,209	14,909
17/18	81,105,227	33,366,249	47,311,154	427,825	761,136	2,407,296	84,273,660	15,196
18/19	86,073,282	35,687,837	49,957,620	427,825	807,759	2,407,296	89,288,337	16,101
19/20	88,973,537	38,108,634	50,437,078	427,825	834,977	2,407,296	92,215,810	16,629
20/21	92,615,075	40,628,642	51,558,608	427,825	869,151	2,407,296	95,891,522	17,291
21/22	97,946,248	43,247,859	54,270,564	427,825	919,182	2,407,296	101,272,726	18,262
22/23	103,461,472	45,966,286	57,067,361	427,825	970,940	2,407,296	106,839,708	19,266
23/24	111,005,331	48,783,923	61,793,583	427,825	1,041,735	2,407,296	114,454,362	20,639
24/25	113,748,634	48,469,471	64,851,338	427,825	1,067,480	2,407,296	117,223,410	21,138
25/26	114,271,843	47,877,223	65,966,796	427,825	1,072,390	2,407,296	117,751,530	21,233
26/27	117,578,511	48,047,730	69,102,956	427,825	1,103,422	2,407,296	121,089,229	21,835
27/28	120,825,954	48,074,172	72,323,957	427,825	1,133,898	2,407,296	124,367,148	22,426
28/29	124,327,813	48,270,190	75,629,798	427,825	1,166,761	2,407,296	127,901,870	23,064
29/30	124,199,669	50,829,862	72,941,982	427,825	1,165,558	2,407,296	127,772,523	23,040
30/31	126,234,415	53,463,941	72,342,649	427,825	1,184,654	2,407,296	129,826,365	23,411
31/32	124,726,329	53,363,806	70,934,698	427,825	1,170,501	2,407,296	128,304,126	23,136
32/33	127,611,485	54,042,378	73,141,282	427,825	1,197,577	2,407,296	131,216,358	23,661
33/34	131,211,678	54,601,150	76,182,703	427,825	1,231,363	2,407,296	134,850,338	24,317
34/35	129,186,437	53,953,609	74,805,003	427,825	1,212,357	2,407,296	132,806,090	23,948
35/36	134,691,324	56,458,706	77,804,793	427,825	1,264,018	2,407,296	138,362,638	24,950



Iqaluit (720): Annual Peak Demand
Demand (kW)
30,000
25,000
20,000
15,000
10,000
5,000
0
94/95
95/96
96/97
97/98
98/99
99/00
00/01
01/02
02/03
03/04
04/05
05/06
06/07
07/08
08/09
09/10
10/11
11/12
12/13
13/14
14/15
15/16
16/17
17/18
18/19
19/20
20/21
21/22
22/23
23/24
24/25
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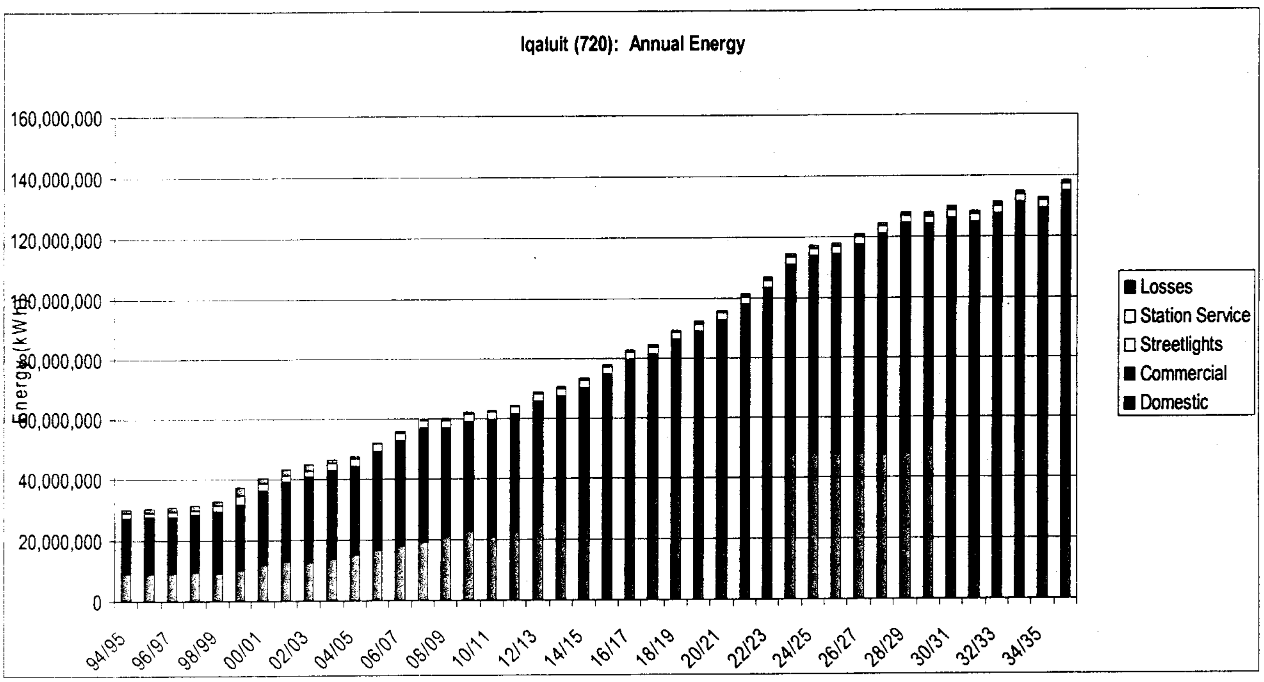
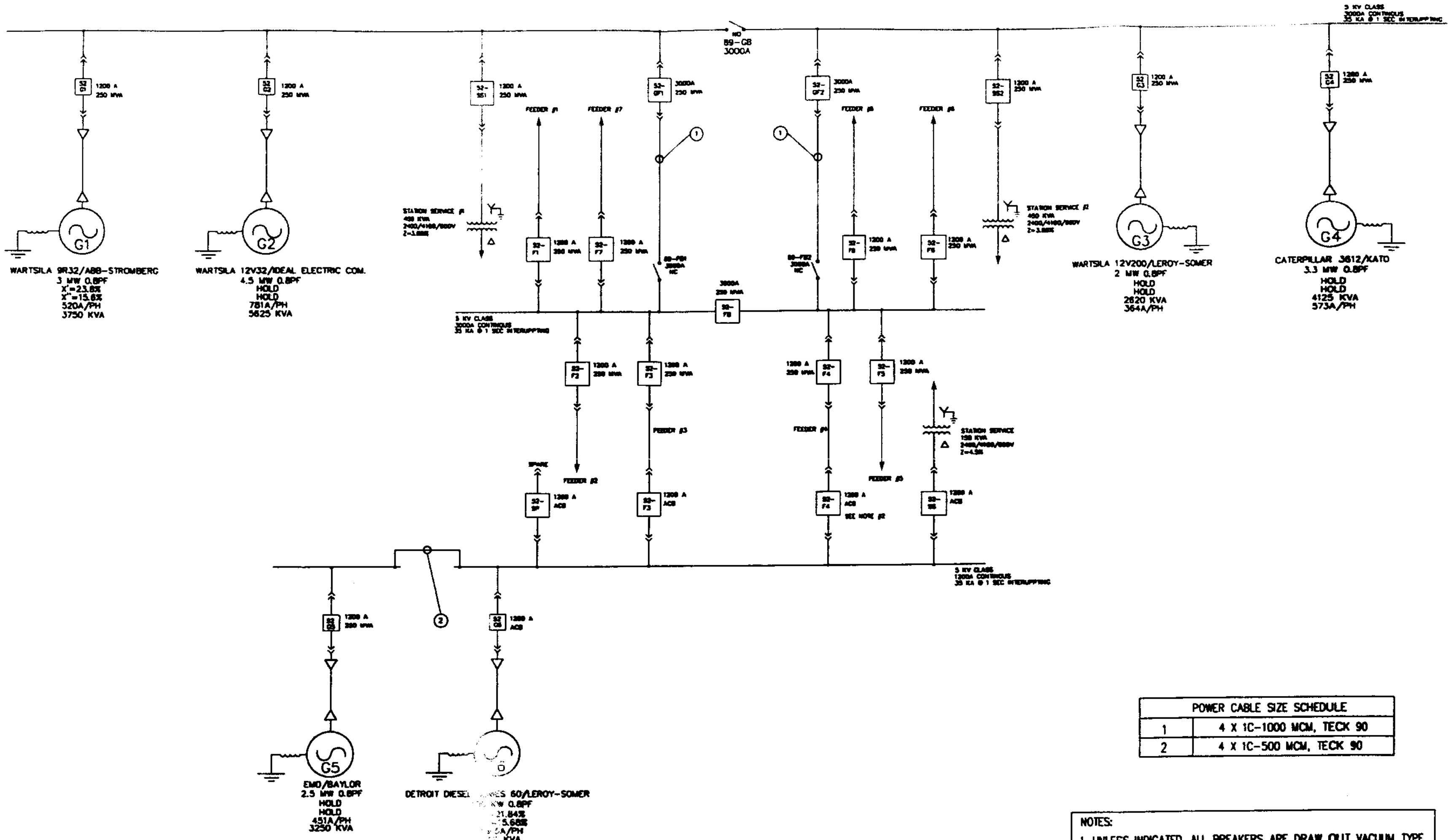
32/33
33/34
34/35
35/36



Iqaluit (720): Annual Energy
Energy (kWh)
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
94/95
96/97
98/99
00/01
02/03
04/05
06/07
08/09
10/11
12/13
14/15
16/17
18/19
20/21
22/23
24/25
26/27
28/29
30/31
32/33
34/35
Losses
Station Service
Streetlights
Commercial
Domestic

Appendix B

Iqaluit System Key Single line Diagram



POWER CABLE SIZE SCHEDULE	
1	4 X 1C-1000 MCM, TECK 90
2	4 X 1C-500 MCM, TECK 90

NOTES:
1. UNLESS INDICATED, ALL BREAKERS ARE DRAW OUT VACUUM TYPE.
2. BREAKER 52-F4 ONLY CLOSED WHEN G5 IS ONLINE.

PROFESSIONAL STAMP

PERMIT STAMP

LOCATION: IQALUIT, NUNAVUT

TITLE: IQALUIT SYSTEM KEY SINGLELINE DIAGRAM

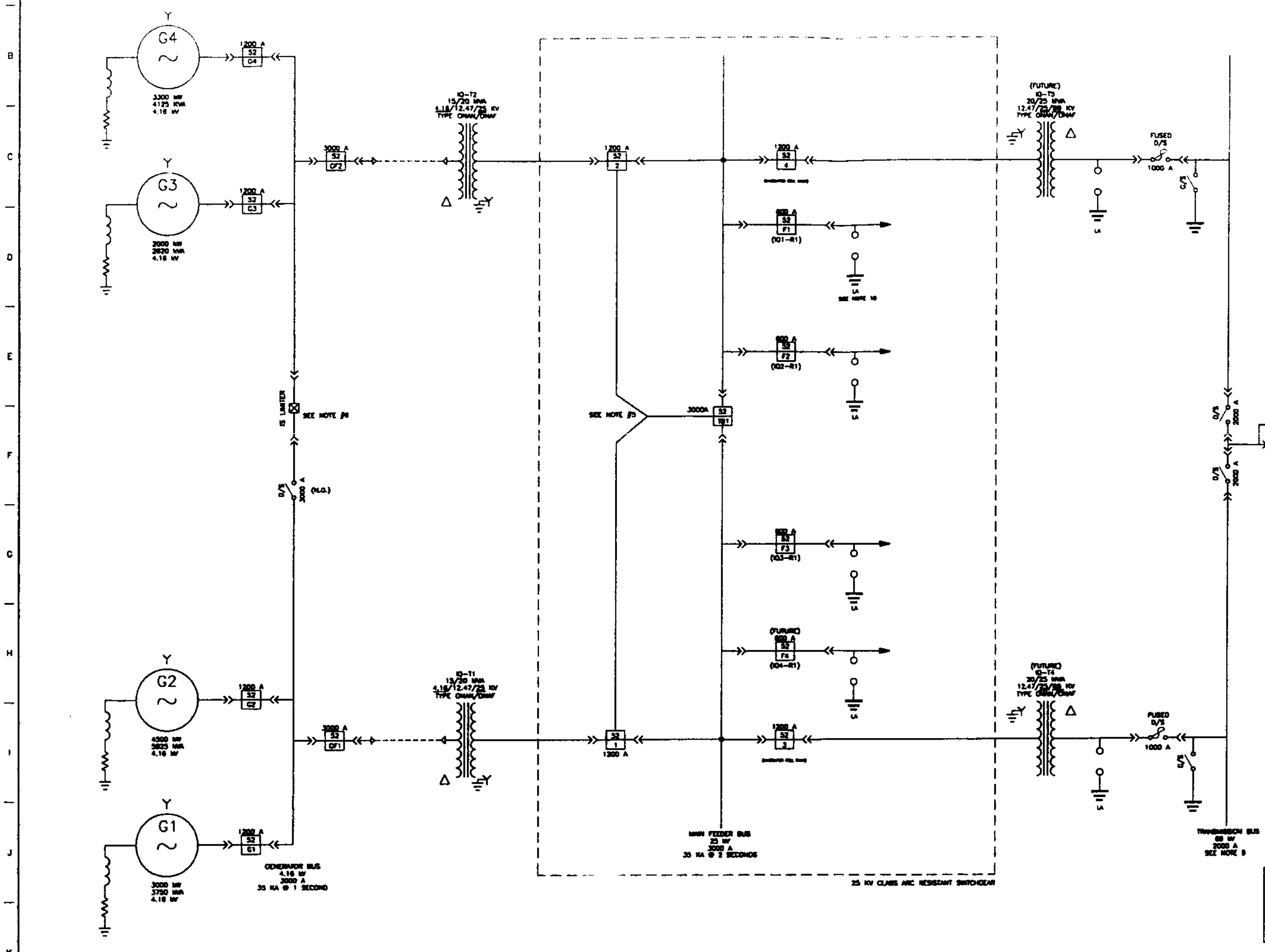
SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. 720-1 | REV. 0

DRAWING NO. | TITLE | REFERENCE DRAWINGS | REVISION LETTER: 0 | REVISION: ORIGINAL | WORK ORDER | DRAWN BY: A.CHABBS 22/03/04 | CHECKED BY | DESIGNED BY: A.CHABBS | STATUS OF DRAWING: DRAFT | DATE

AUTOCAD FILE\PROJECT\PLANT\WO.NO.\TRADE PLOT SCALE: SCALE

Appendix C

Proposed 25 kV Substation Singleline Diagram



NOTES.

1. ALL BREAKERS NORMALLY CLOSED UNLESS DESIGNATED NORMALLY OPEN (N.O.).
2. NORMAL MODE OF OPERATION SHALL BE FOR BREAKER 52-CF1 & 52-CF2 TO BE CLOSED AND BUS TIE BREAKER 52-TB1 TO BE NORMALLY OPEN. DUAL FEED INCOMERS.
3. BY-PASS SWITCH SCHEME, SWITCHES CAN ONLY BE OPERATED WHEN MAIN BREAKER IS CLOSED. NOT BE USED UNDER LOAD BREAK CONDITIONS.
4. GENERATORS ARE IMPEDANCE GROUNDED, COMPLETE WITH 59N STATOR GROUND FAULT PROTECTION.
5. BREAKER 52-1, 52-2 & BUS TIE BREAKER 52-TB1 SHALL HAVE A INTERLOCKING CAPABILITY.
6. INSTALLATION OF IS LIMITER MAY BE REQUIRED UPON COMPLETION OF SHORT CIRCUIT STUDY DUE TO ADDITION OF GENERATION CAPACITY IN THE 2008-09 YEAR.
7. GENERATOR BUS, GENERATOR SETS, BREAKER 52-CF1, & 52-CF2 ARE EXISTING PLANT EQUIPMENT.
8. SWITCHGEAR TO BE METAL-CLAD, DRAWOUT TYPE CONSTRUCTION.
9. HOLD FOR INTERRUPTING RATING (FUTURE).
10. ALL SURGE ARRESTERS TO BE STATION CLASS WITH PROPER MCOV RATINGS.
11. PARTIAL DIFFERENTIAL BUS PROTECTION PROVIDED VIA TRANSFER TRIP FROM BREAKER 52-2 & 52-1.

ISSUE FOR BUDGETARY ENQUIRY
PRELIMANARY USE ONLY

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		0	ORIGINAL		A. CHUBBS	OCT 2005	AC	AC		

REFERENCE DRAWINGS — DRAWN BY

PROFESSIONAL STAMP

PERMIT STAMP

NUNAVUT POWER

LOCATION: IQALUIT, NUNAVUT

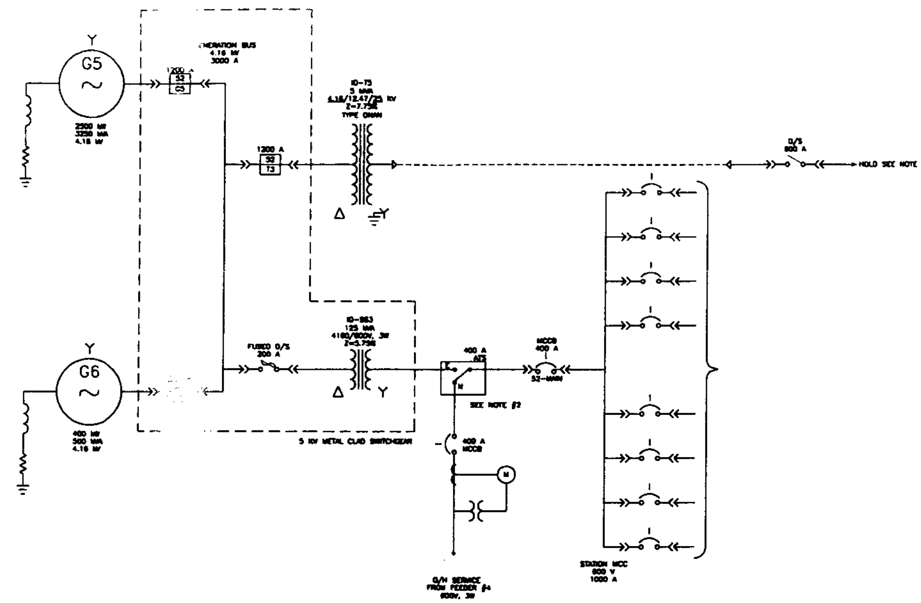
TITLE: PROPOSED KEY SINGLELINE DIAGRAM

SCALE: NTS — SHEET 1 OF 2 — DRAWING NO. — REV. DRAFT

AUTOCAD FILE: 1.DWG PLOT SCALE: 1:1

NOTES:

1. ALL BREAKERS NORMALLY CLOSED UNLESS DESIGNATED NORMALLY OPEN (N.O.).
2. AUTOMATIC TRANSFER SWITCH NORMAL MODE OF OPERATION WILL BE FROM O/H UTILITY FEED. CONFIGURATION FOR THE ABILITY TO DE-ENERGISE SWITCHGEAR AND MAINTAIN STATION SERVICES.
3. FEEDER DESIGNATION TO BE DETERMINED BY OTHERS.



ISSUE FOR BUDGETARY ENQUIRY
PRELIMANARY USE ONLY

DRAWING NO.	TITLE	0	ORIGINAL		A.CHUBBS	OCT. 14, 2005	AC	AC		
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
					DRAWN BY					

PROFESSIONAL STAMP

PERMIT STAMP

NUNAVUT POWER

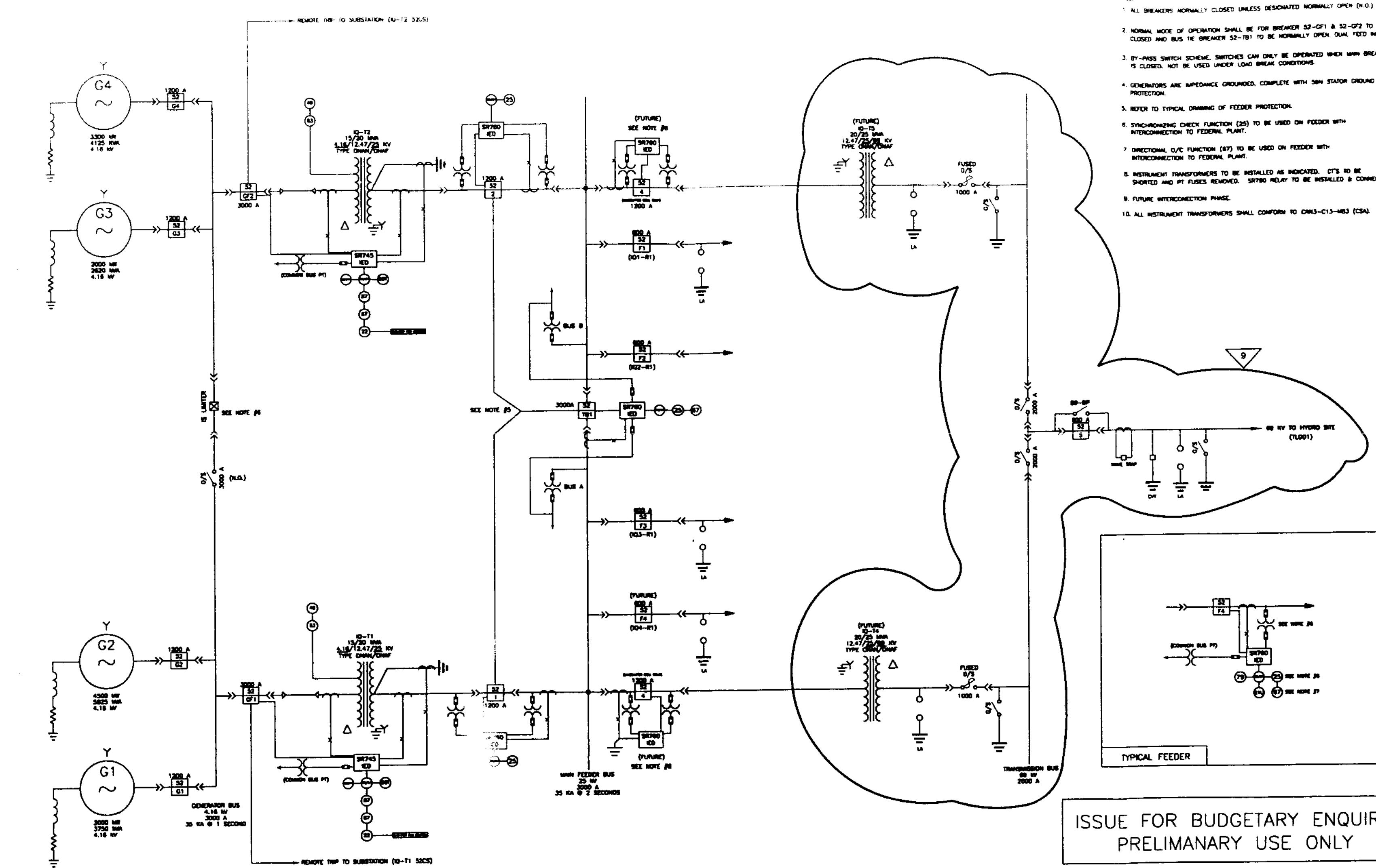
LOCATION: IQALUIT, NUNAVUT

TITLE: PROPOSED SYSTEM KEY SINGLELINE DIAGRAM

SCALE: NTS | SHEET 2 OF 2 | DRAWING NO. | REV. DRAFT

AUTOCAD FILE:

PLOT SCALE: 1:1



NOTES.

1. ALL BREAKERS NORMALLY CLOSED UNLESS DESIGNATED NORMALLY OPEN (N.O.)
2. NORMAL MODE OF OPERATION SHALL BE FOR BREAKER 52-GF1 & 52-GF2 TO BE CLOSED AND BUS TIE BREAKER 52-TB1 TO BE NORMALLY OPEN. DUAL FEED INCOMERS
3. BY-PASS SWITCH SCHEME. SWITCHES CAN ONLY BE OPERATED WHEN MAIN BREAKER IS CLOSED. NOT BE USED UNDER LOAD BREAK CONDITIONS.
4. GENERATORS ARE IMPEDANCE GROUNDED, COMPLETE WITH 59N STATOR GROUND FAULT PROTECTION.
5. REFER TO TYPICAL DRAWING OF FEEDER PROTECTION.
6. SYNCHRONIZING CHECK FUNCTION (25) TO BE USED ON FEEDER WITH INTERCONNECTION TO FEDERAL PLANT.
7. DIRECTIONAL O/C FUNCTION (67) TO BE USED ON FEEDER WITH INTERCONNECTION TO FEDERAL PLANT.
8. INSTRUMENT TRANSFORMERS TO BE INSTALLED AS INDICATED. CT'S TO BE SHORTED AND PT FUSES REMOVED. SR760 RELAY TO BE INSTALLED & CONNECTED
9. FUTURE INTERCONECTION PHASE.
10. ALL INSTRUMENT TRANSFORMERS SHALL CONFORM TO CAN3-C13-M83 (CSA).

ISSUE FOR BUDGETARY ENQUIRY
PRELIMANARY USE ONLY

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
	REFERENCE DRAWINGS	0	ORIGINAL		A. CHUBBS	OCT 2005	AC	AC		
					DRAWN BY					

PROFESSIONAL STAMP

PERMIT STAMP

NUNAVUT POWER

LOCATION: IQALUIT, NUNAVUT

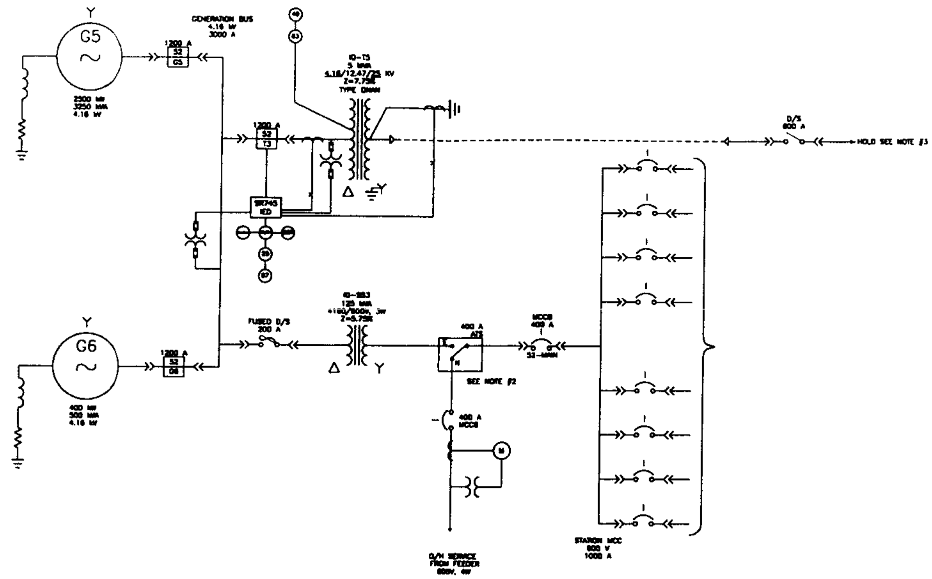
TITLE: PROPOSED KEY SINGLELINE DIAGRAM (PROTECTION & CONTROL DIAGRAM)

SCALE: NTS | SHEET 1 OF 2 | DRAWING NO. | REV. DRAFT

AUTOCAD FILE: 1.DWG PLOT SCALE: 1:1

NOTES:

1. ALL BREAKERS NORMALLY CLOSED UNLESS DESIGNATED NORMALLY OPEN (N.O.).
2. AUTOMATIC TRANSFER SWITCH NORMAL MODE OF OPERATION WILL BE FROM O/H UTILITY FEED. CONFIGURATION FOR THE ABILITY TO DE-ENERGISE SWITCHGEAR AND MAINTAIN STATION SERVICES.
3. FEEDER DESIGNATION TO BE DETERMINED BY OTHERS.



ISSUE FOR BUDGETARY ENQUIRY
PRELIMANARY USE ONLY

DRAWING NO.	TITLE	0	ORIGINAL		A.CHUBBS	OCT. 14, 2005	AC	AC	
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME / DRAWN BY	DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING / DATE

PROFESSIONAL STAMP

PERMIT STAMP

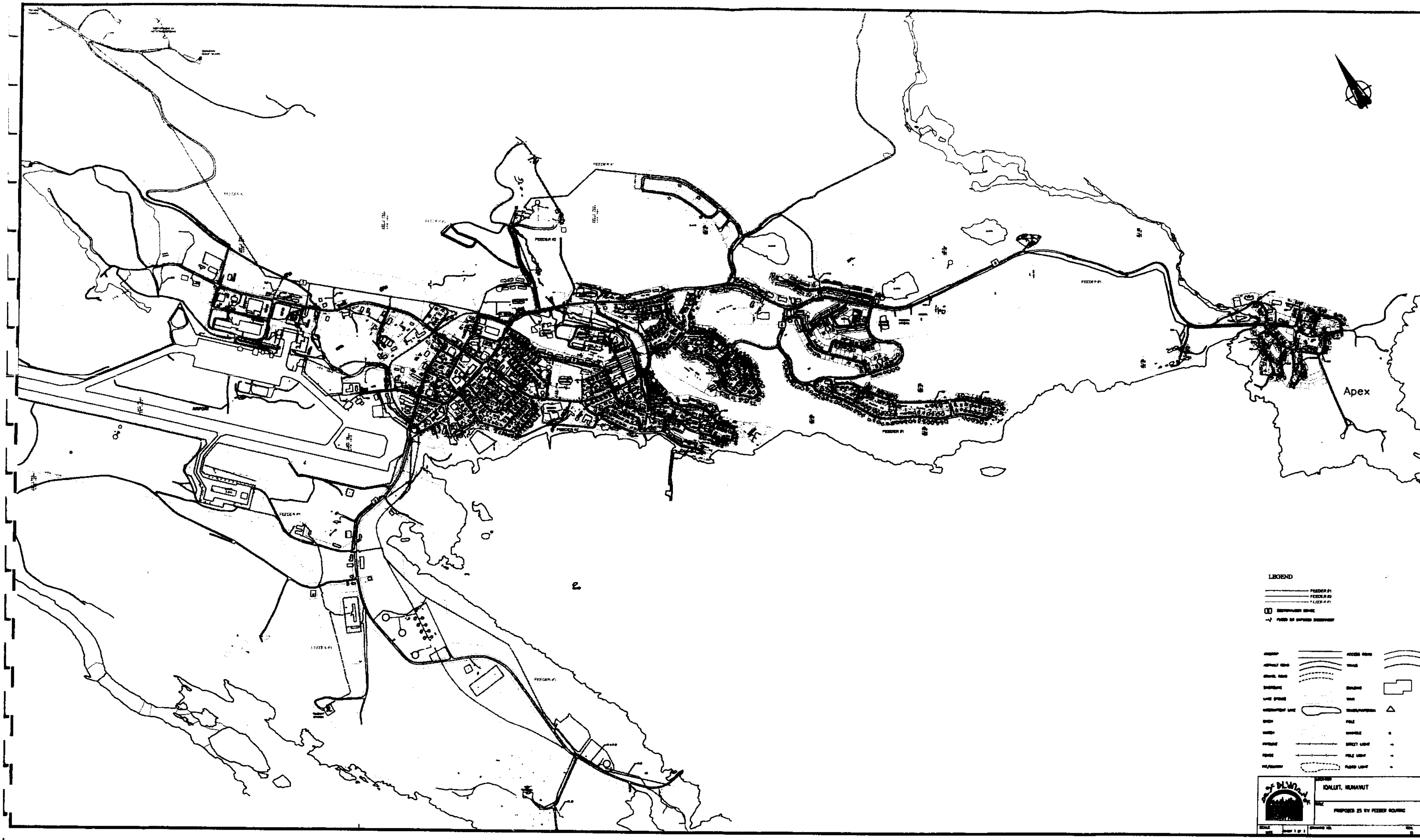
NUNAVUT POWER

LOCATION: IQALUIT, NUNAVUT

TITLE: PROPOSED SYSTEM
KEY SINGLELINE DIAGRAM
(PROTECTION & CONTROL DIAGRAM)

SCALE: NTS | SHEET 2 OF 2 | DRAWING NO. | REV. DRAFT

AUTOCAD FILE: PLOT SCALE: 1:1


Apex
LEGEND
FEEDER #1
FEEDER #2
IQALUIT, NUNAVUT

Appendix D

Calculations

Calculations

JOB NUMBER	
FILE NUMBER	
SHEET	1 OF 3
REF. DWG.	
BY A.Chubbs	DATE JAN/06
CHK'D	DATE

SUBJECT: FEEDER LOAD AND LOSS FACTOR

$$\text{LOAD FACTOR (LF)} = \frac{\text{Avg. Load}}{\text{Peak LOAD}}$$

$$\text{LOSS FACTOR (LOF)} = 0.2(LF) + 0.8(LF)^2$$

FEEDER #1

$$LF = \frac{557}{860} = .64767$$

$$LOF = (0.2)(.65) + (0.8)(.65)^2$$

$$= .468$$

FEEDER #2

$$LF = \frac{795}{1220} = .65$$

$$LOF = (0.2)(.65) + (.8)(.65)^2$$

$$= .468$$

Calculations

SUBJECT:

JOB NUMBER	
FILE NUMBER	
SHEET	2 OF 3
REF. DWG.	
BY	DATE
CHK'D	DATE

FEEDER # 3

$$LF = \frac{592}{1340} = .44$$

$$LOF = (0.2)(.44) + (0.8)(.44)^2$$

$$LOF = .243$$

FEEDER #4

$$LF = \frac{790}{1450} = .55$$

$$LOF = (0.2)(.55) + (0.8)(.55)^2$$

$$LOF = .352$$

FEEDER # 5

$$LF = \frac{347}{750} = .46$$

$$LOF = (0.2)(.46) + (.8)(.46)^2$$

$$LOF = .2612$$

FEEDER # 6

$$LF = \frac{702}{1140} = .61$$

$$LOF = (0.2)(.61) + (0.8)(.61)^2$$

$$LOF = .418$$

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 3 OF 3
REF. DWG.
BY DATE
CHK'D DATE

FEEDER # 7

$$LF = \frac{508}{1090} = .465$$

$$LOF = (0.2)(.465) + (.8)(.465)^2$$

$$LOF = .266$$

FEEDER #8

$$LF = \frac{360}{780} = .46$$

$$LOF = (.20)(.46) + (0.8)(.46)^2$$

$$LOF = .261$$

Appendix E

Feeder Branch Losses @ 4.16 kV

Branch Loss Report

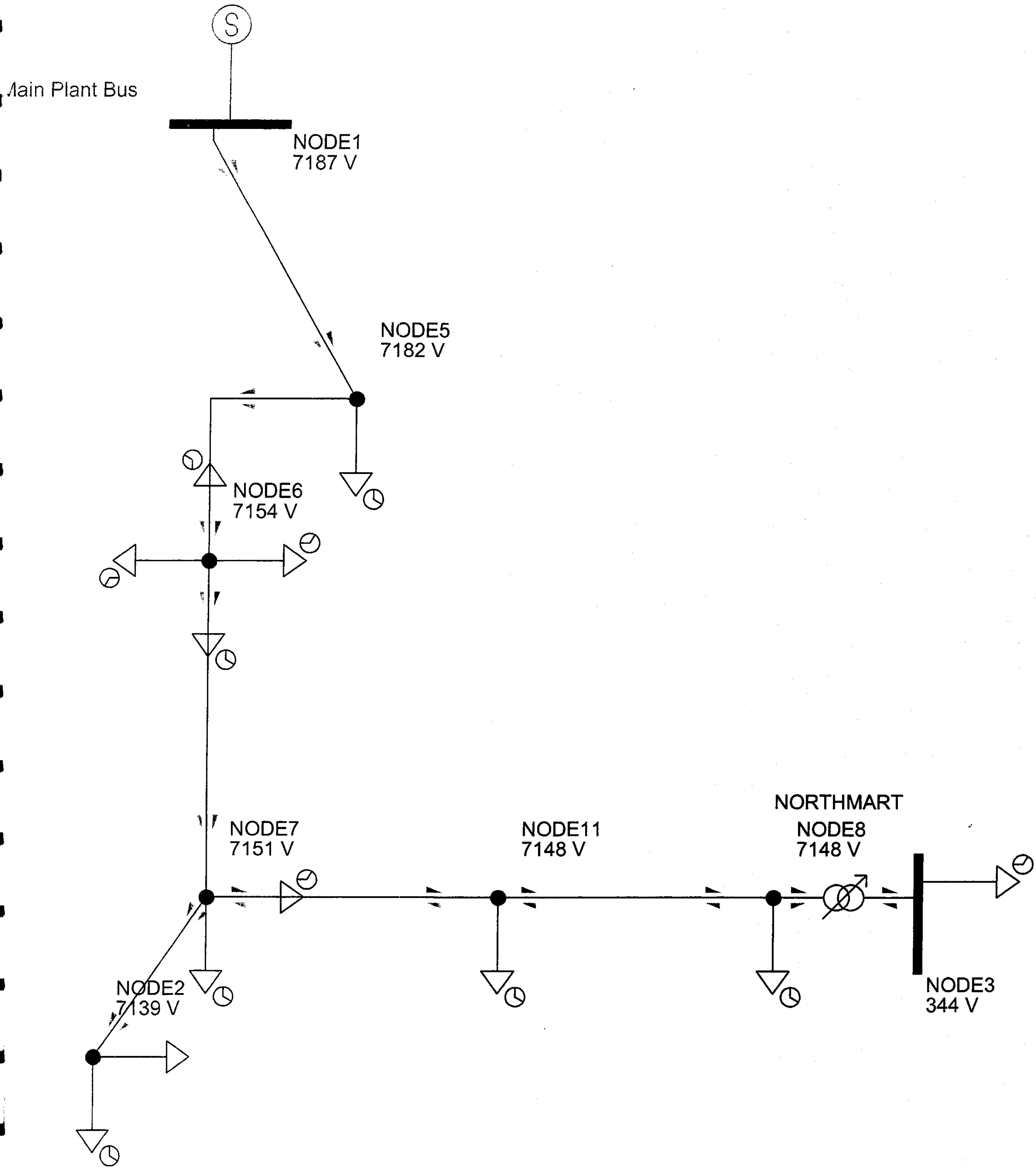
12/29/2005
1:45:47PM

Iqaluit F1 @ 4.16 kV

System Base kVA: 1000.00
Iqaluit F1

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	3	6
Line4	NODE5	NODE6	Line	ABC	1.000	16	20
Line6	NODE6	NODE7	Line	ABC	0.250	1	2
Line7	NODE7	NODE11	Line	ABC	1.000	0	0
Line8	NODE11	NODE8	Line	ABC	0.250	0	0
Tran1	NODE8	NODE3	Transformer	ABC		0	0
Line1	NODE7	NODE2	Line	ABC	1.000	2	3
					Total losses:	23.136	31.490


S
Main Plant Bus
NODE1
7187 V
NODE5
7182 V
NODE6
7154 V
NODE7
7151 V
NODE11
7148 V
NORTHMART
NODE8
7148 V
NODE3
344 V
NODE2
7139 V

Branch Loss Report

12/29/2005

1:17:09PM

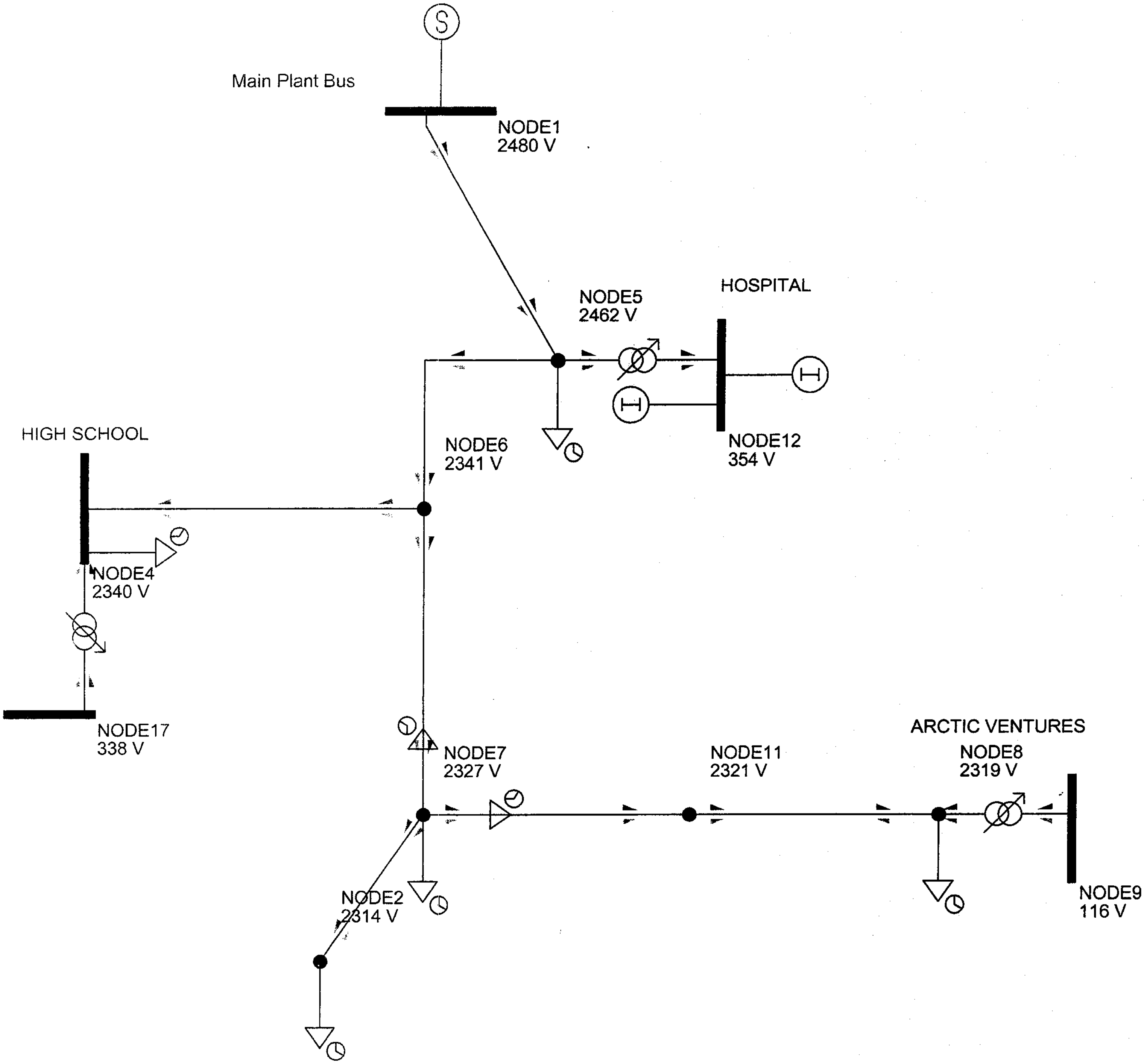
Iqaluit F2 @ 4.16 kV

System Base kVA: 1000.00

Iqaluit F2

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.750	8	14
Tran2	NODE5	NODE12	Transformer	ABC		1	4
Line4	NODE5	NODE6	Line	ABC	1.000	56	72
Line5	NODE6	NODE4	Line	ABC	0.250	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	0.250	6	9
Line7	NODE7	NODE11	Line	ABC	1.000	0	0
Line8	NODE11	NODE8	Line	ABC	0.250	0	0
Line1	NODE7	NODE2	Line	ABC	1.000	1	1
					Total losses:	71.143	99.455


Main Plant Bus
NODE1
2480 V
NODE5
2462 V
HOSPITAL
NODE12
354 V
HIGH SCHOOL
NODE6
2341 V
NODE4
2340 V
NODE17
338 V
NODE7
2327 V
NODE11
2321 V
ARCTIC VENTURES
NODE8
2319 V
NODE9
116 V
NODE2
2314 V

Branch Loss Report

12/22/2005

4:50:10PM

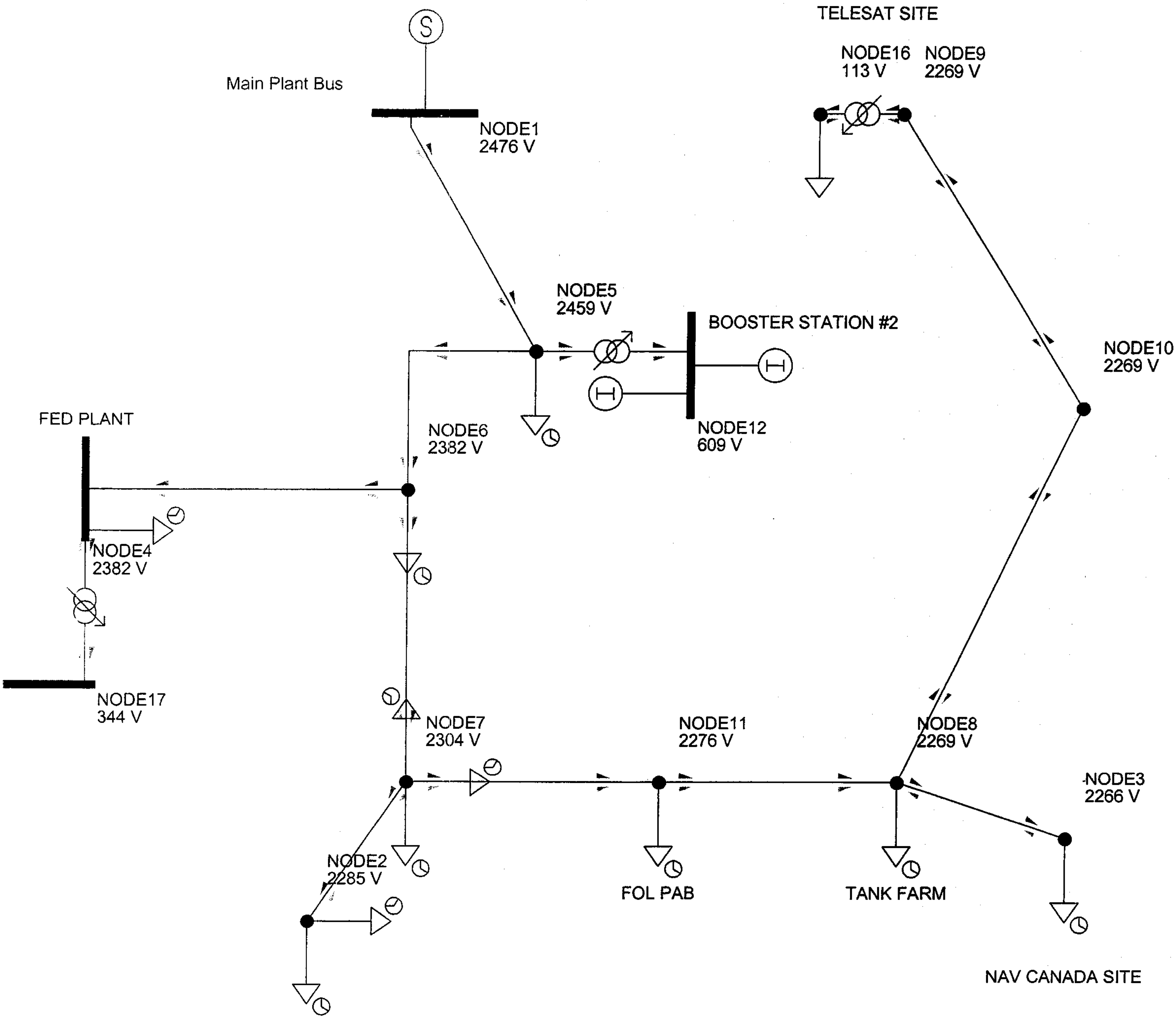
Iqaluit F3 @ 4.16 kV

System Base kVA: 1000.00

Iqaluit F3

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.750	7	12
Tran2	NODE5	NODE12	Transformer	ABC		0	1
Line4	NODE5	NODE6	Line	ABC	1.000	57	74
Line5	NODE6	NODE4	Line	ABC	1.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	31	49
Line7	NODE7	NODE11	Line	ABC	1.000	1	1
Line8	NODE11	NODE8	Line	ABC	1.000	0	0
Line9	NODE8	NODE10	Line	ABC	1.500	0	0
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		0	0
Line2	NODE8	NODE3	Line	ABC	1.000	0	0
Line1	NODE7	NODE2	Line	ABC	1.000	2	2
					Total losses:	98.212	138.924


TELESAT SITE
NODE16
113 V
NODE9
2269 V
Main Plant Bus
NODE1
2476 V
NODE5
2459 V
BOOSTER STATION #2
NODE10
2269 V
FED PLANT
NODE6
2382 V
NODE12
609 V
NODE4
2382 V
NODE17
344 V
NODE7
2304 V
NODE11
2276 V
NODE8
2269 V
NODE3
2266 V
NODE2
2285 V
FOL PAB
TANK FARM
NAV CANADA SITE

Branch Loss Report

12/22/2005

4:05:27PM

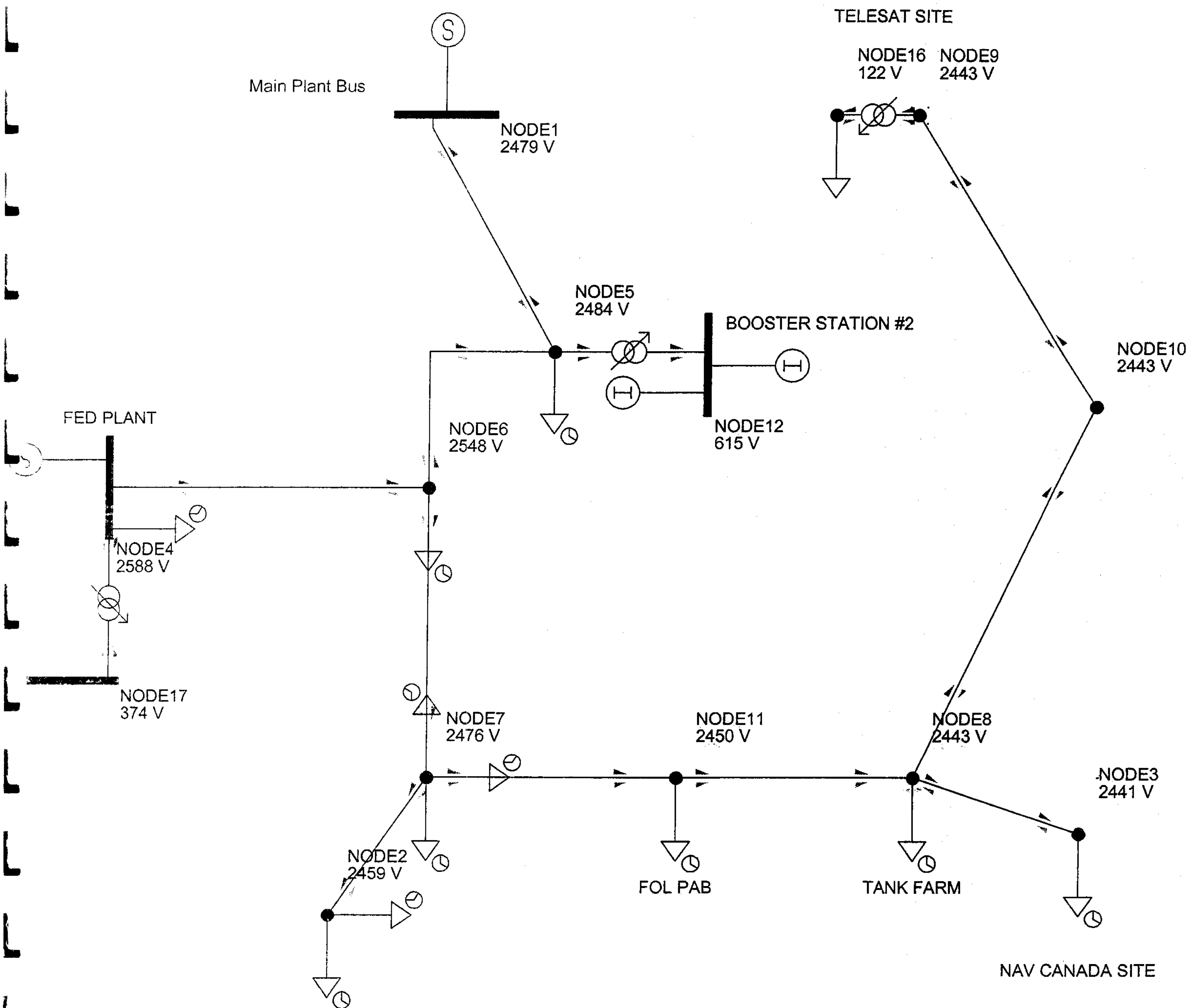
Iqaluit F3 @ 4.16 kV (G5 ONLINE)

System Base kVA: 1000.00

Iqaluit F3

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.750	6	11
Tran2	NODE5	NODE12	Transformer	ABC		0	1
Line4	NODE5	NODE6	Line	ABC	1.000	27	61
Line5	NODE6	NODE4	Line	ABC	1.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	30	47
Line7	NODE7	NODE11	Line	ABC	1.000	1	1
Line8	NODE11	NODE8	Line	ABC	1.000	0	0
Line9	NODE8	NODE10	Line	ABC	1.500	0	0
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		0	0
Line2	NODE8	NODE3	Line	ABC	1.000	0	0
Line1	NODE7	NODE2	Line	ABC	1.000	2	2
					Total losses:	66.041	123.315


TELESAT SITE
NODE16
122 V
NODE9
2443 V
Main Plant Bus
NODE1
2479 V
NODE5
2484 V
BOOSTER STATION #2
NODE10
2443 V
FED PLANT
NODE6
2548 V
NODE12
615 V
NODE4
2588 V
NODE17
374 V
NODE7
2476 V
NODE11
2450 V
NODE8
2443 V
NODE3
2441 V
NODE2
2459 V
FOL PAB
TANK FARM
NAV CANADA SITE

Branch Loss Report

12/22/2005

2:22:31PM

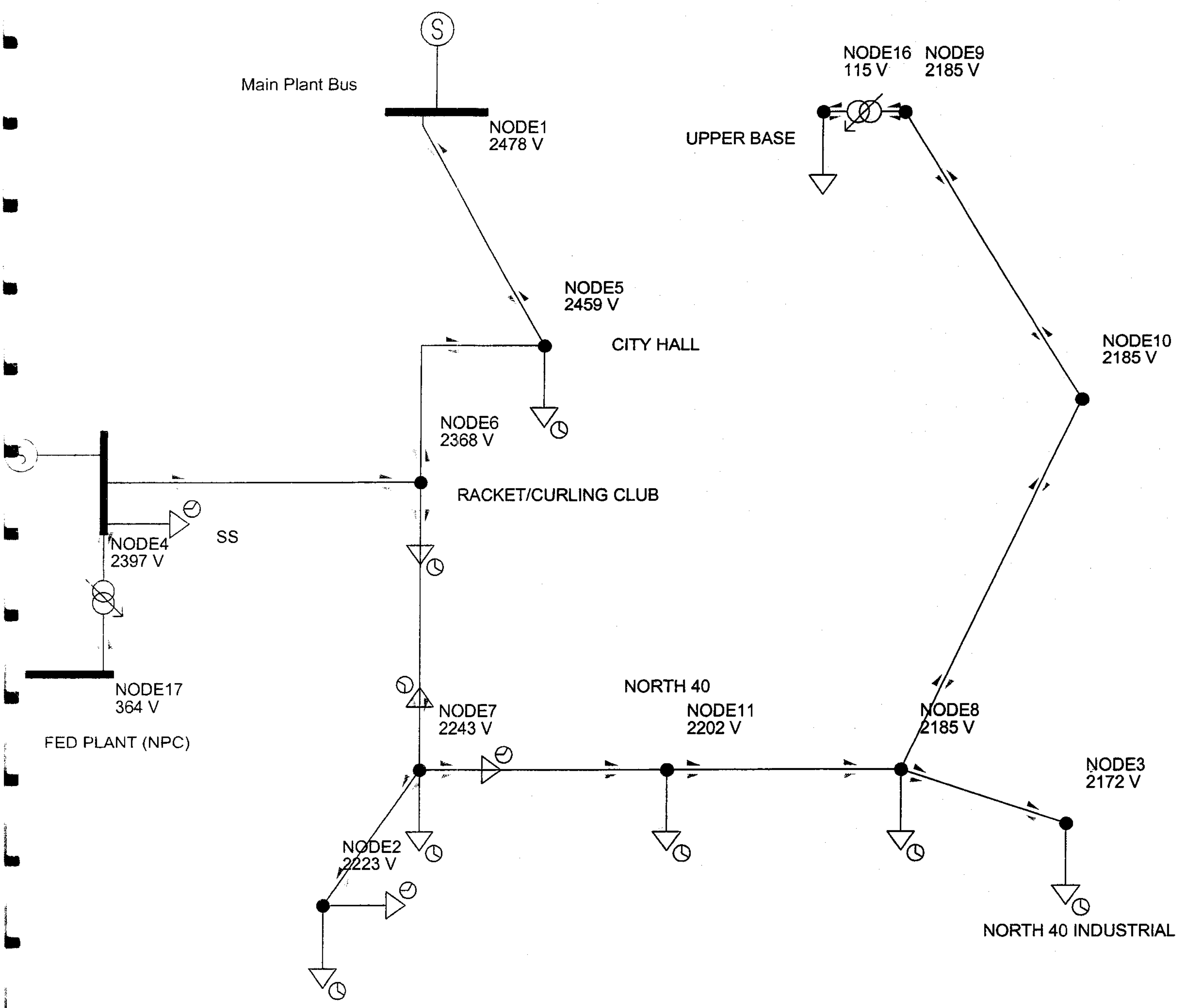
Iqaluit F4 @ 4.16 kV (G5 ONLINE)

System Base kVA: 1000.00

Iqaluit F4

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	7	12
Line4	NODE5	NODE6	Line	ABC	1.000	24	55
Line5	NODE6	NODE4	Line	ABC	2.000	65	111
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	87	138
Line7	NODE7	NODE11	Line	ABC	1.000	3	3
Line8	NODE11	NODE8	Line	ABC	1.000	1	2
Line9	NODE8	NODE10	Line	ABC	1.500	0	0
Line10	NODE10	NODE9	Line	ABC	1.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		0	0
Line2	NODE8	NODE3	Line	ABC	1.000	1	1
Line1	NODE7	NODE2	Line	ABC	1.000	2	2
					Total losses:	190.957	324.780



Main Plant Bus
NODE1
2478 V
NODE16
115 V
NODE9
2185 V
UPPER BASE
NODE5
2459 V
CITY HALL
NODE10
2185 V
NODE6
2368 V
RACKET/CURLING CLUB
NODE4
2397 V
SS
NODE17
364 V
FED PLANT (NPC)
NORTH 40
NODE7
2243 V
NODE11
2202 V
NODE8
2185 V
NODE3
2172 V
NODE2
2223 V
NORTH 40 INDUSTRIAL

Branch Loss Report

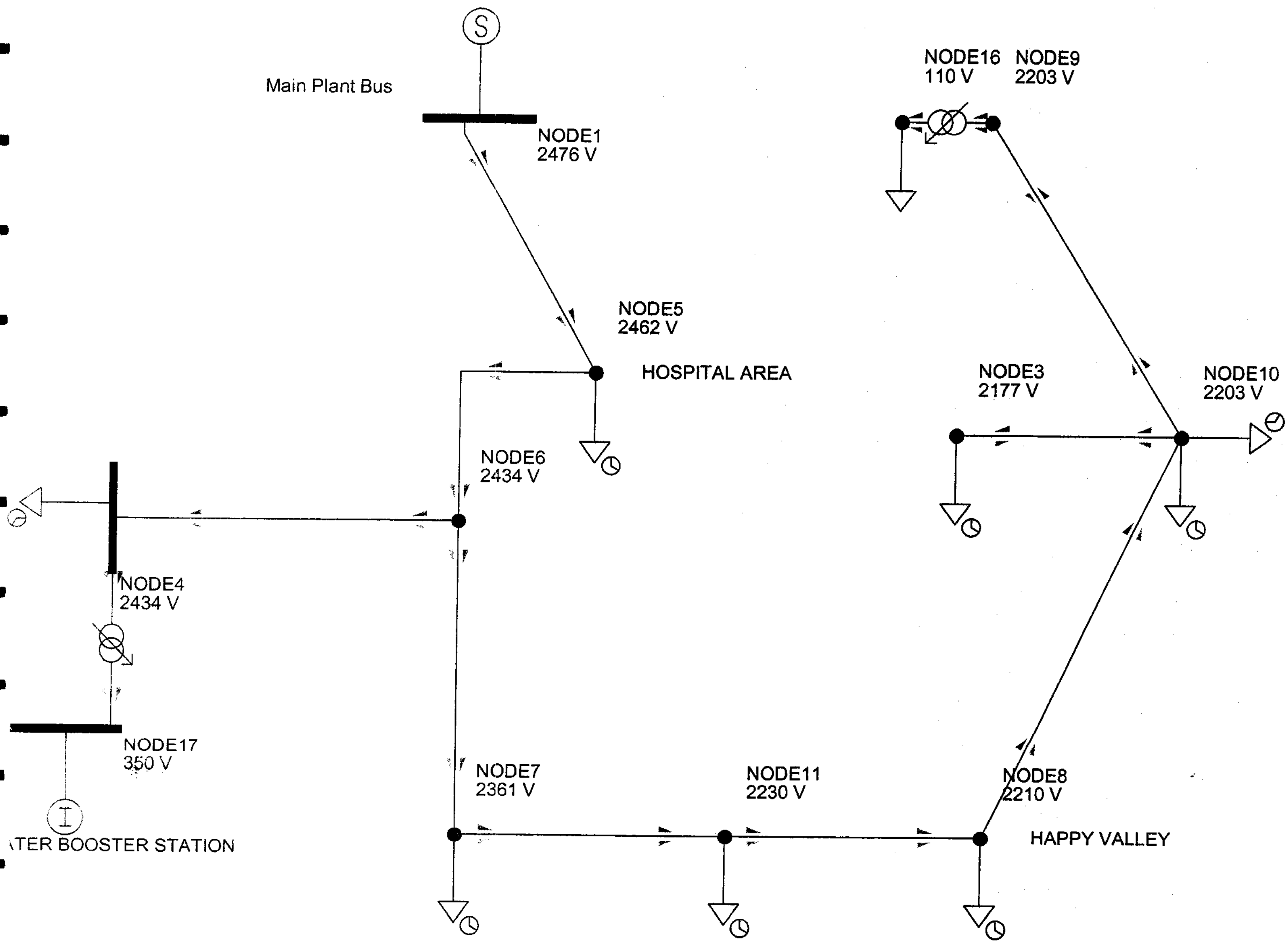
12/20/2005
11:02:43AM

Iqaluit F5 @ 4.16 kV

System Base kVA: 1000.00
Iqaluit F5

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	2	4
Line4	NODE5	NODE6	Line	ABC	0.750	3	13
Line5	NODE6	NODE4	Line	ABC	0.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	13	16
Line7	NODE7	NODE11	Line	ABC	1.000	24	11
Line8	NODE11	NODE8	Line	ABC	0.500	3	4
Line9	NODE8	NODE10	Line	ABC	0.500	1	1
Line1	NODE10	NODE3	Line	ABC	1.000	3	4
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		0	0
					Total losses:	49.910	54.158


Main Plant Bus
NODE1
2476 V
NODE5
2462 V
HOSPITAL AREA
NODE6
2434 V
NODE4
2434 V
NODE17
350 V
ATER BOOSTER STATION
NODE7
2361 V
NODE11
2230 V
NODE8
2210 V
HAPPY VALLEY
NODE16
110 V
NODE9
2203 V
NODE3
2177 V
NODE10
2203 V

Branch Loss Report

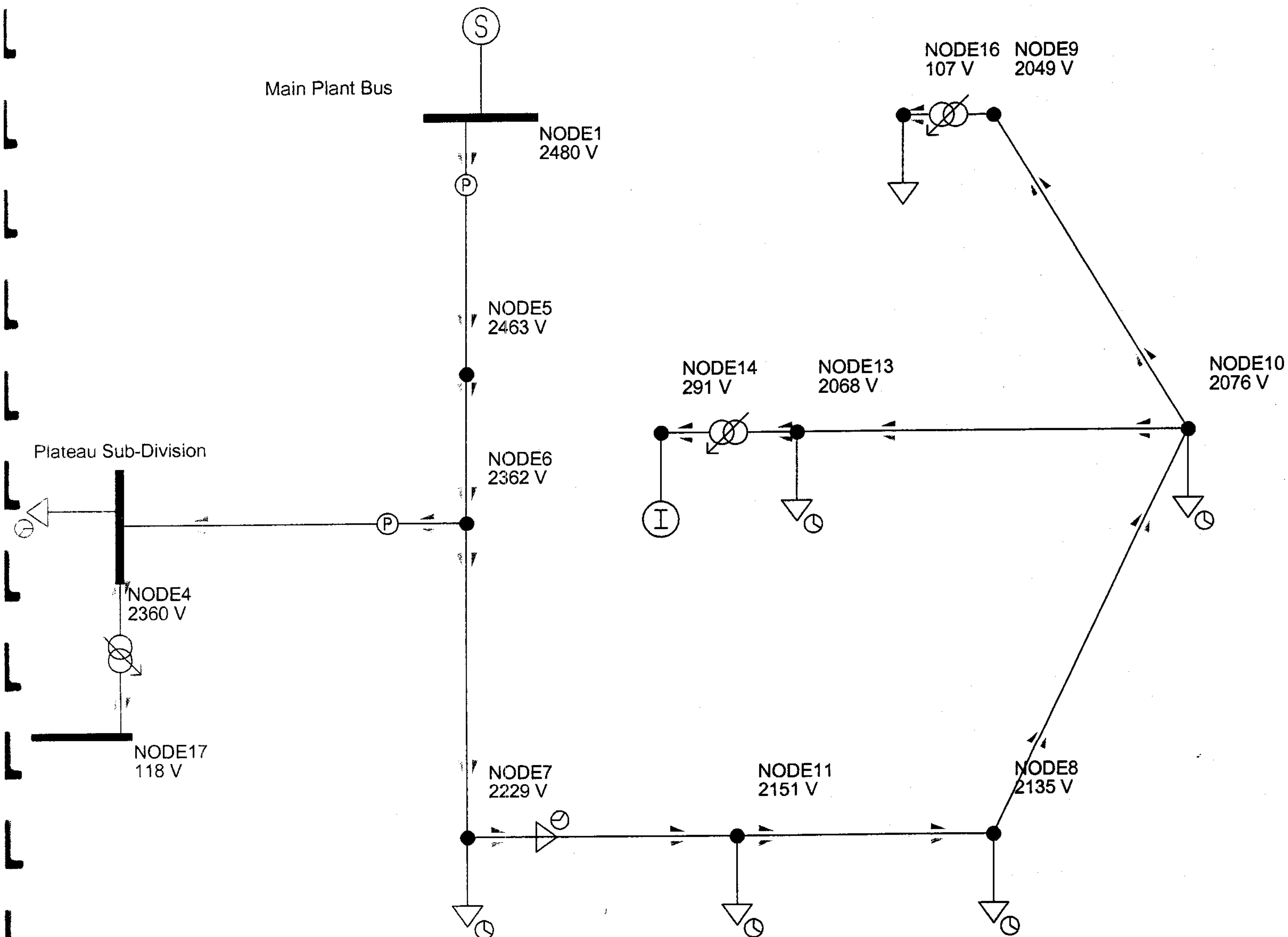
12/5/2005
3:34:23PM

Iqaluit F6 @ 4.16 kV

System Base kVA: 1000.00
Iqaluit F6

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.500	6	10
Line4	NODE5	NODE6	Line	ABC	1.000	22	90
Line5	NODE6	NODE4	Line	ABC	2.000	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	2.000	70	44
Line7	NODE7	NODE11	Line	ABC	1.500	31	20
Line8	NODE11	NODE8	Line	ABC	0.500	5	3
Line9	NODE8	NODE10	Line	ABC	3.000	10	6
Line11	NODE10	NODE13	Line	ABC	1.000	1	0
Tran1	NODE13	NODE14	Transformer	ABC		0	1
Line10	NODE10	NODE9	Line	ABC	3.000	2	1
Tran3	NODE9	NODE16	Transformer	ABC		2	16
					Total losses:	149.724	192.510



Main Plant Bus
NODE1
2480 V
NODE5
2463 V
NODE6
2362 V
Plateau Sub-Division
NODE4
2360 V
NODE17
118 V
NODE7
2229 V
NODE11
2151 V
NODE8
2135 V
NODE10
2076 V
NODE13
2068 V
NODE14
291 V
NODE16
107 V
NODE9
2049 V

Branch Loss Report

12/7/2005

4:36:38PM

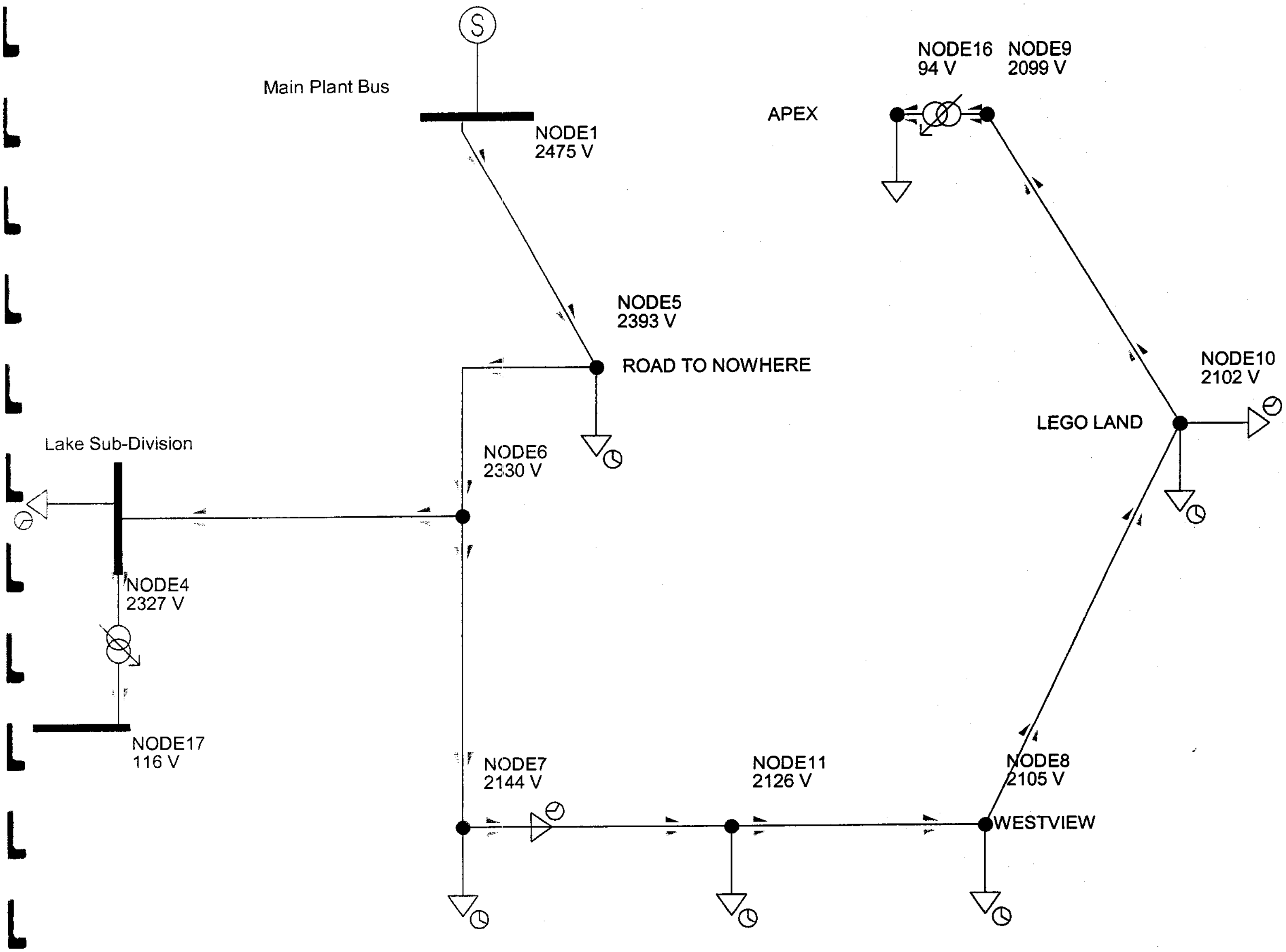
Iqaluit F7 @ 4.16 kV

System Base kVA: 1000.00

Iqaluit F7

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	4.000	14	24
Line4	NODE5	NODE6	Line	ABC	1.000	6	23
Line5	NODE6	NODE4	Line	ABC	1.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	2.000	27	34
Line7	NODE7	NODE11	Line	ABC	1.000	2	1
Line8	NODE11	NODE8	Line	ABC	2.000	2	1
Line9	NODE8	NODE10	Line	ABC	0.500	0	0
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		2	16
					Total losses:	53.232	100.302



oad Flow: Voltage (LN) in V; Total Power (Branch loss) in kW and kvar; Phase: Min. of A,B,C.

PSS/ADEPT v5.2 12/07/2005 16:36

Branch Loss Report

12/20/2005

9:26:16AM

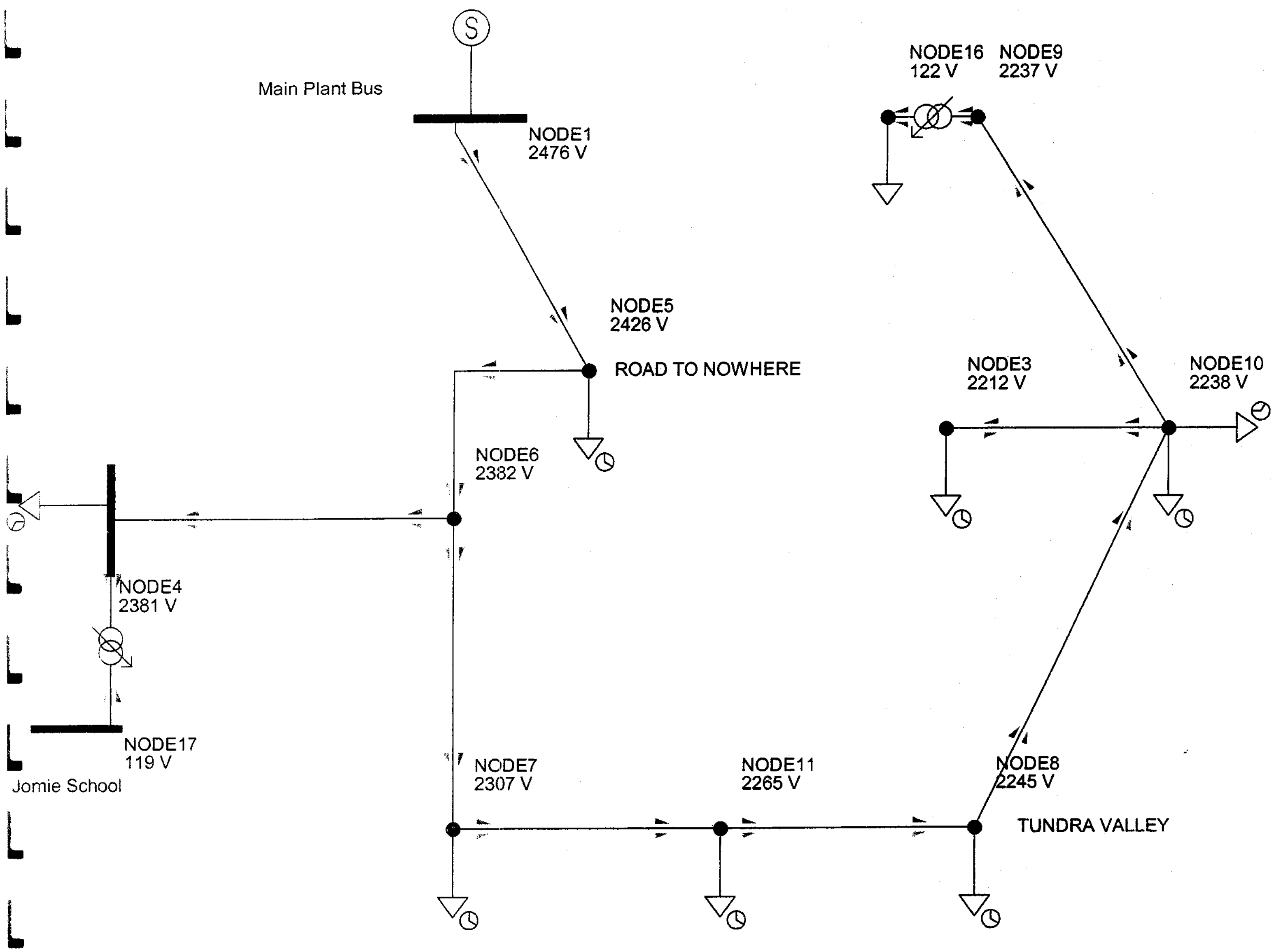
Iqaluit F8 @ 4.16 kV

System Base kVA: 1000.00

Iqaluit F8

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	3.000	11	18
Line4	NODE5	NODE6	Line	ABC	1.000	5	22
Line5	NODE6	NODE4	Line	ABC	0.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	13	17
Line7	NODE7	NODE11	Line	ABC	1.000	6	10
Line8	NODE11	NODE8	Line	ABC	0.500	3	4
Line9	NODE8	NODE10	Line	ABC	0.500	1	1
Line1	NODE10	NODE3	Line	ABC	1.000	3	4
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		0	0
					Total losses:	42.912	75.716


Main Plant Bus
NODE1
2476 V
NODE5
2426 V
ROAD TO NOWHERE
NODE6
2382 V
NODE4
2381 V
NODE17
119 V
Jomie School
NODE7
2307 V
NODE11
2265 V
NODE8
2245 V
TUNDRA VALLEY
NODE16
122 V
NODE9
2237 V
NODE3
2212 V
NODE10
2238 V

Appendix F

Feeder Branch Losses @ 25 kV

Branch Loss Report

1/3/2006

4:34:32PM

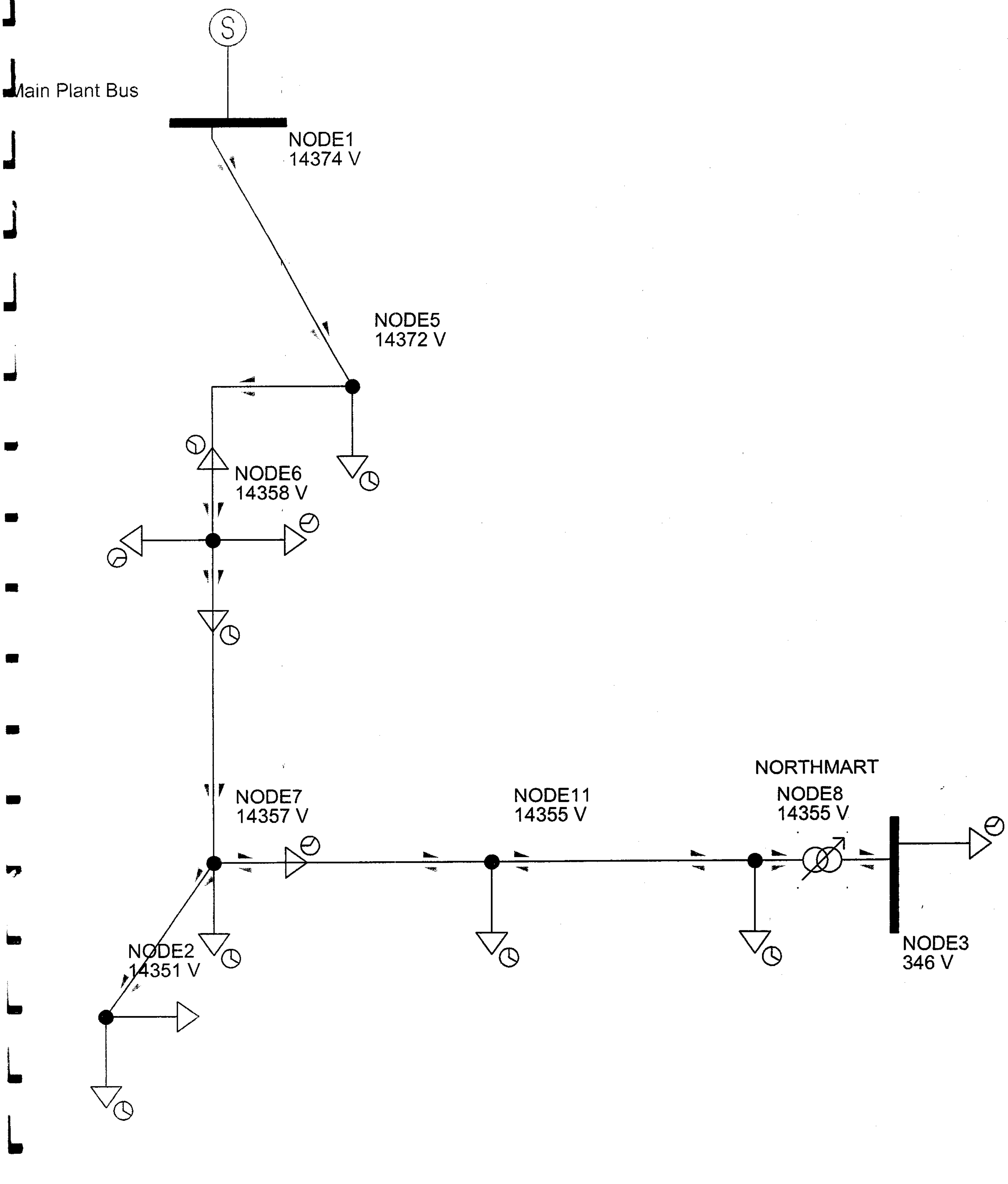
Iqaluit F1 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F1

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	0	-1
Line4	NODE5	NODE6	Line	ABC	1.000	0	-3
Line6	NODE6	NODE7	Line	ABC	0.250	0	-1
Line7	NODE7	NODE11	Line	ABC	1.000	0	-4
Line8	NODE11	NODE8	Line	ABC	0.250	0	-1
Tran1	NODE8	NODE3	Transformer	ABC		0	0
Line1	NODE7	NODE2	Line	ABC	1.000	0	-4
					Total losses:	0.632	-13.627


S
Main Plant Bus
NODE1
14374 V
NODE5
14372 V
NODE6
14358 V
NODE7
14357 V
NODE11
14355 V
NORTHMART
NODE8
14355 V
NODE3
346 V
NODE2
14351 V

Branch Loss Report

1/3/2006

4:37:20PM

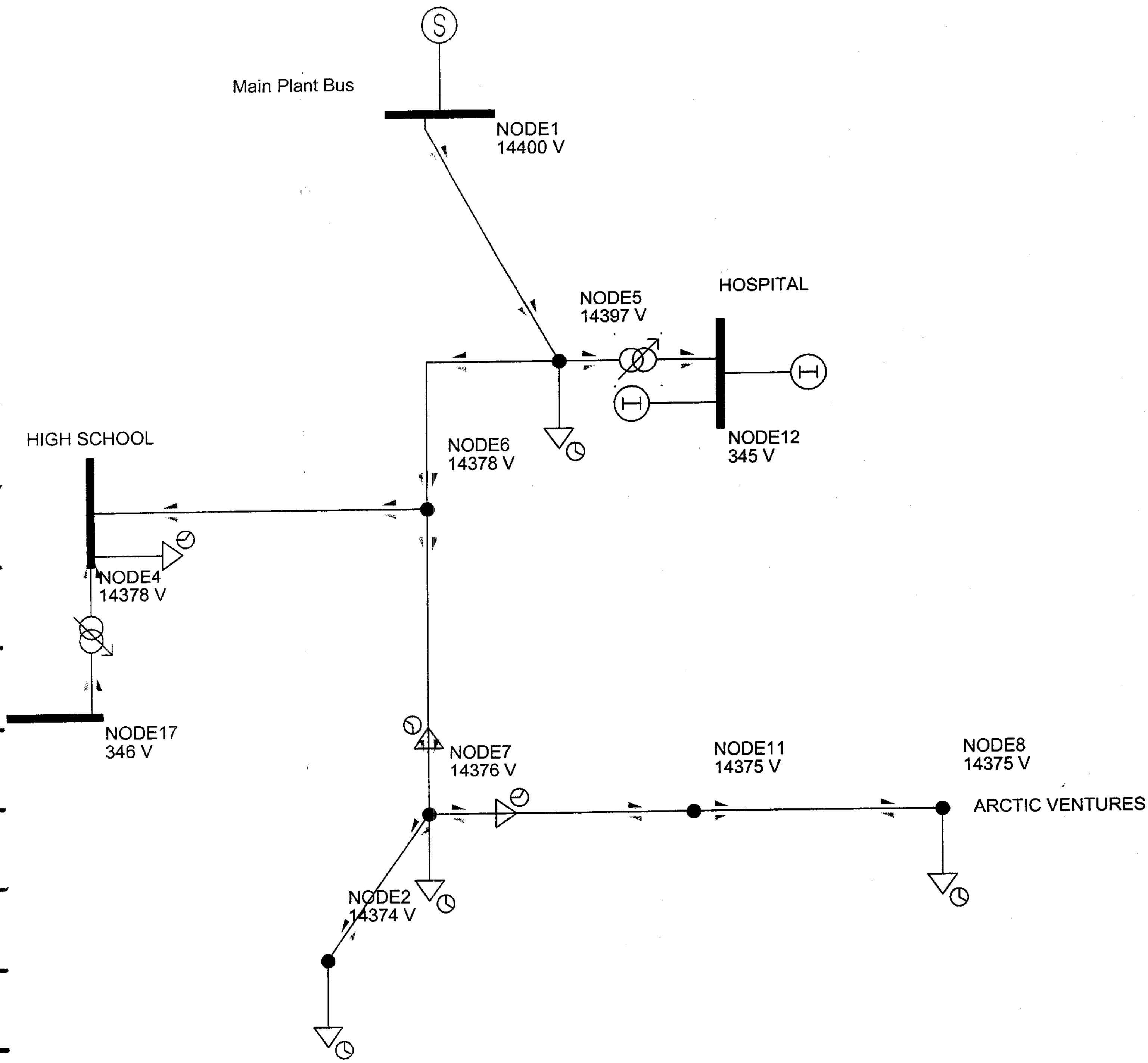
Iqaluit F2 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F2

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.750	0	0
Tran2	NODE5	NODE12	Transformer	ABC		0	0
Line4	NODE5	NODE6	Line	ABC	1.000	1	-2
Line5	NODE6	NODE4	Line	ABC	0.250	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	0.250	0	-1
Line7	NODE7	NODE11	Line	ABC	1.000	0	-4
Line8	NODE11	NODE8	Line	ABC	0.250	0	-1
Line1	NODE7	NODE2	Line	ABC	1.000	0	-4
					Total losses:	1.923	-11.490


Main Plant Bus
NODE1
14400 V
NODE5
14397 V
HOSPITAL
NODE12
345 V
HIGH SCHOOL
NODE6
14378 V
NODE4
14378 V
NODE17
346 V
NODE7
14376 V
NODE11
14375 V
NODE8
14375 V
ARCTIC VENTURES
NODE2
14374 V

Branch Loss Report

1/3/2006

4:41:10PM

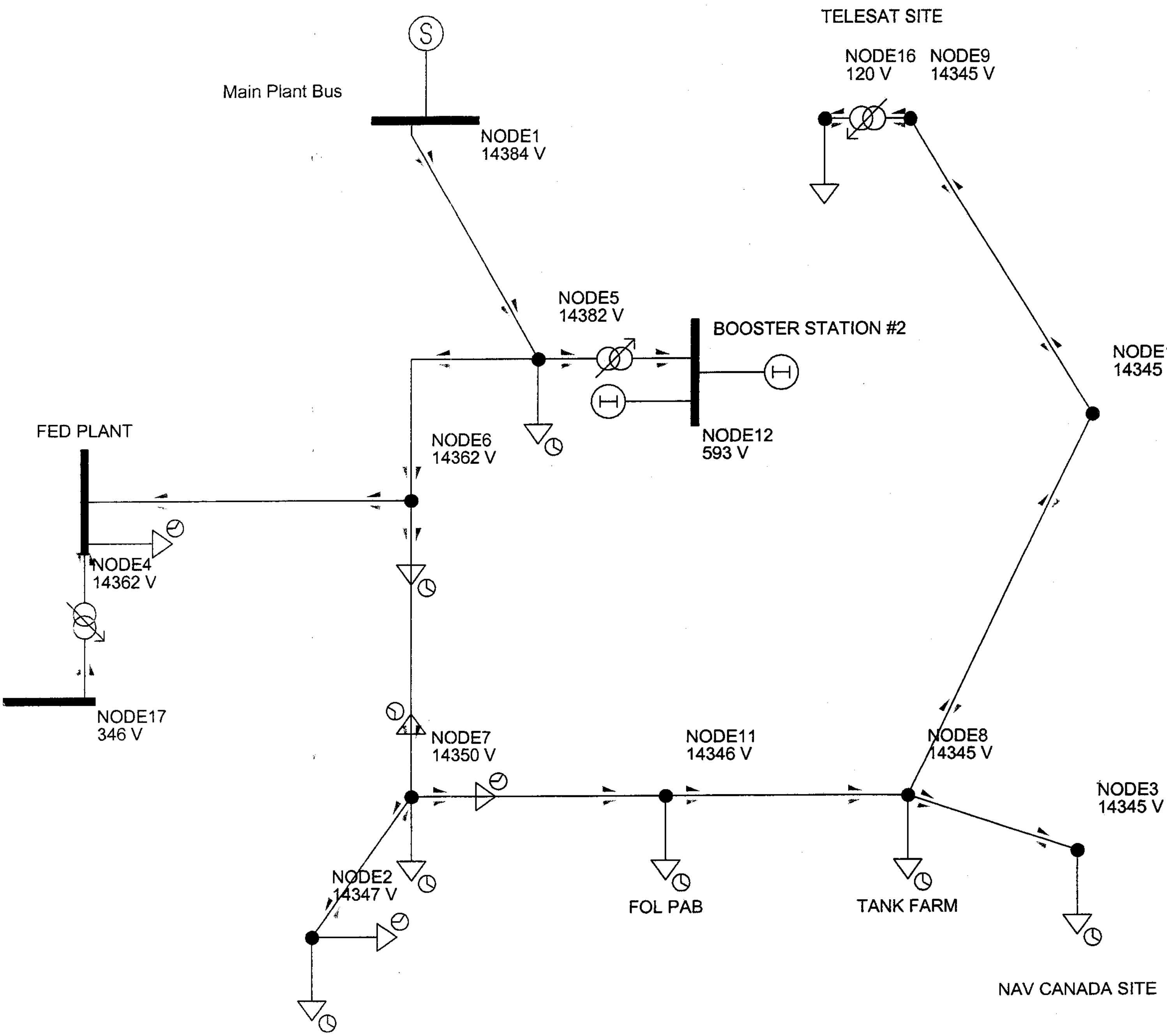
Iqaluit F3 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F3

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.750	0	0
Tran2	NODE5	NODE12	Transformer	ABC		0	1
Line4	NODE5	NODE6	Line	ABC	1.000	1	-2
Line5	NODE6	NODE4	Line	ABC	1.500	0	-1
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	1	-4
Line7	NODE7	NODE11	Line	ABC	1.000	0	-4
Line8	NODE11	NODE8	Line	ABC	1.000	0	-4
Line9	NODE8	NODE10	Line	ABC	1.500	0	-1
Line10	NODE10	NODE9	Line	ABC	0.500	0	-2
Tran1	NODE9	NODE16	Transformer	ABC		0	0
Line2	NODE8	NODE3	Line	ABC	1.000	0	-4
Line1	NODE7	NODE2	Line	ABC	1.000	0	-4
					Total losses:	2.557	-24.377


TELESAT SITE
NODE16
120 V
NODE9
14345 V
Main Plant Bus
NODE1
14384 V
NODE5
14382 V
BOOSTER STATION #2
NODE10
14345 V
FED PLANT
NODE6
14362 V
NODE12
593 V
NODE4
14362 V
NODE17
346 V
NODE7
14350 V
NODE11
14346 V
NODE8
14345 V
NODE3
14345 V
NODE2
14347 V
FOL PAB
TANK FARM
NAV CANADA SITE

Branch Loss Report

1/3/2006

4:43:41PM

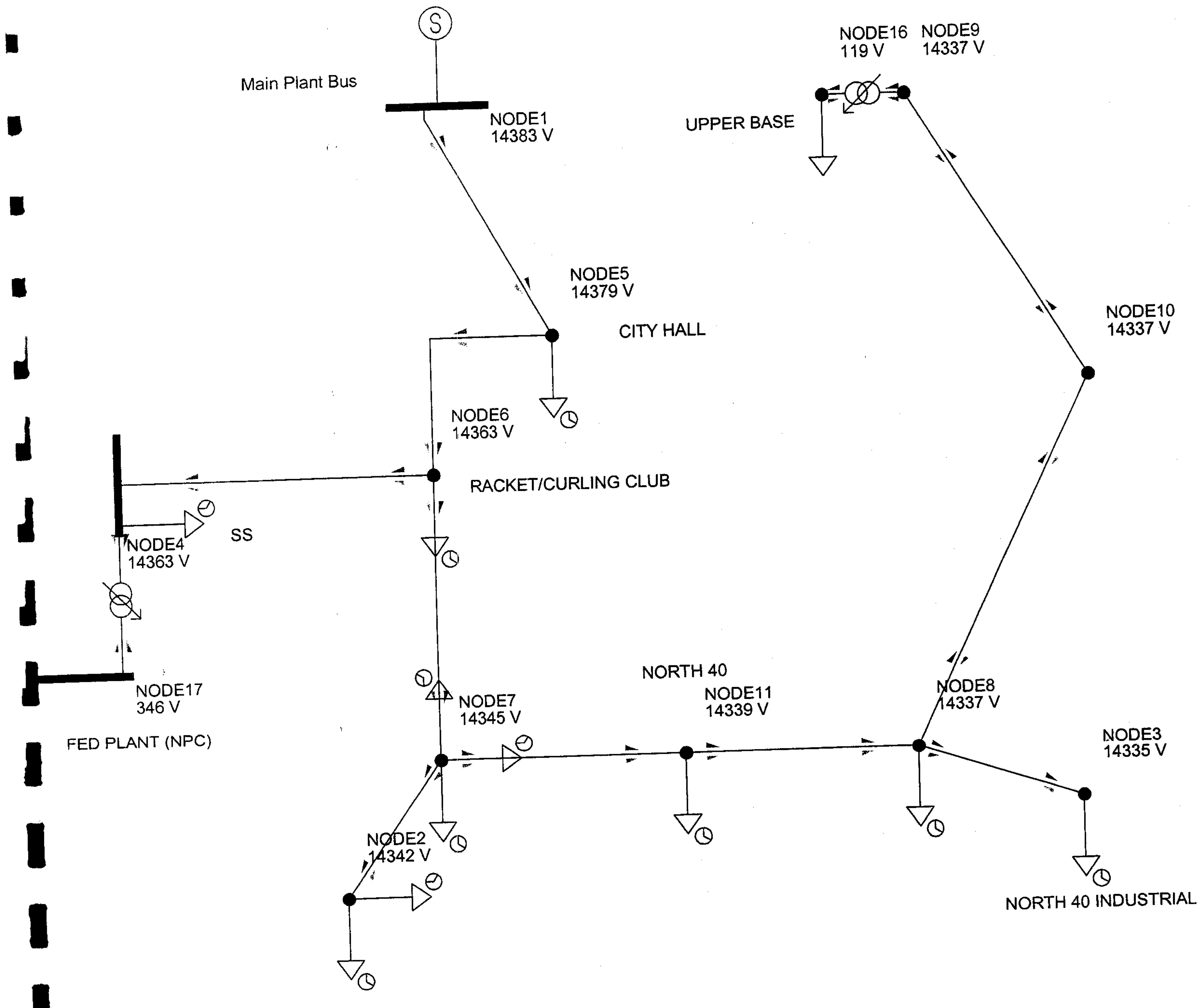
Iqaluit F4 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F4

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	1	0
Line4	NODE5	NODE6	Line	ABC	1.000	2	0
Line5	NODE6	NODE4	Line	ABC	2.000	0	-1
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	2	-1
Line7	NODE7	NODE11	Line	ABC	1.000	0	-4
Line8	NODE11	NODE8	Line	ABC	1.000	0	-4
Line9	NODE8	NODE10	Line	ABC	1.500	0	-1
Line10	NODE10	NODE9	Line	ABC	1.500	0	-6
Tran1	NODE9	NODE16	Transformer	ABC		0	0
Line2	NODE8	NODE3	Line	ABC	1.000	0	-4
Line1	NODE7	NODE2	Line	ABC	1.000	0	-4
					Total losses:	4.711	-24.588



Load Flow: Voltage (LN) in V; Total Power (Branch loss) in kW and kvar Phase: Min. of A,B,C.

Branch Loss Report

1/3/2006

4:46:52PM

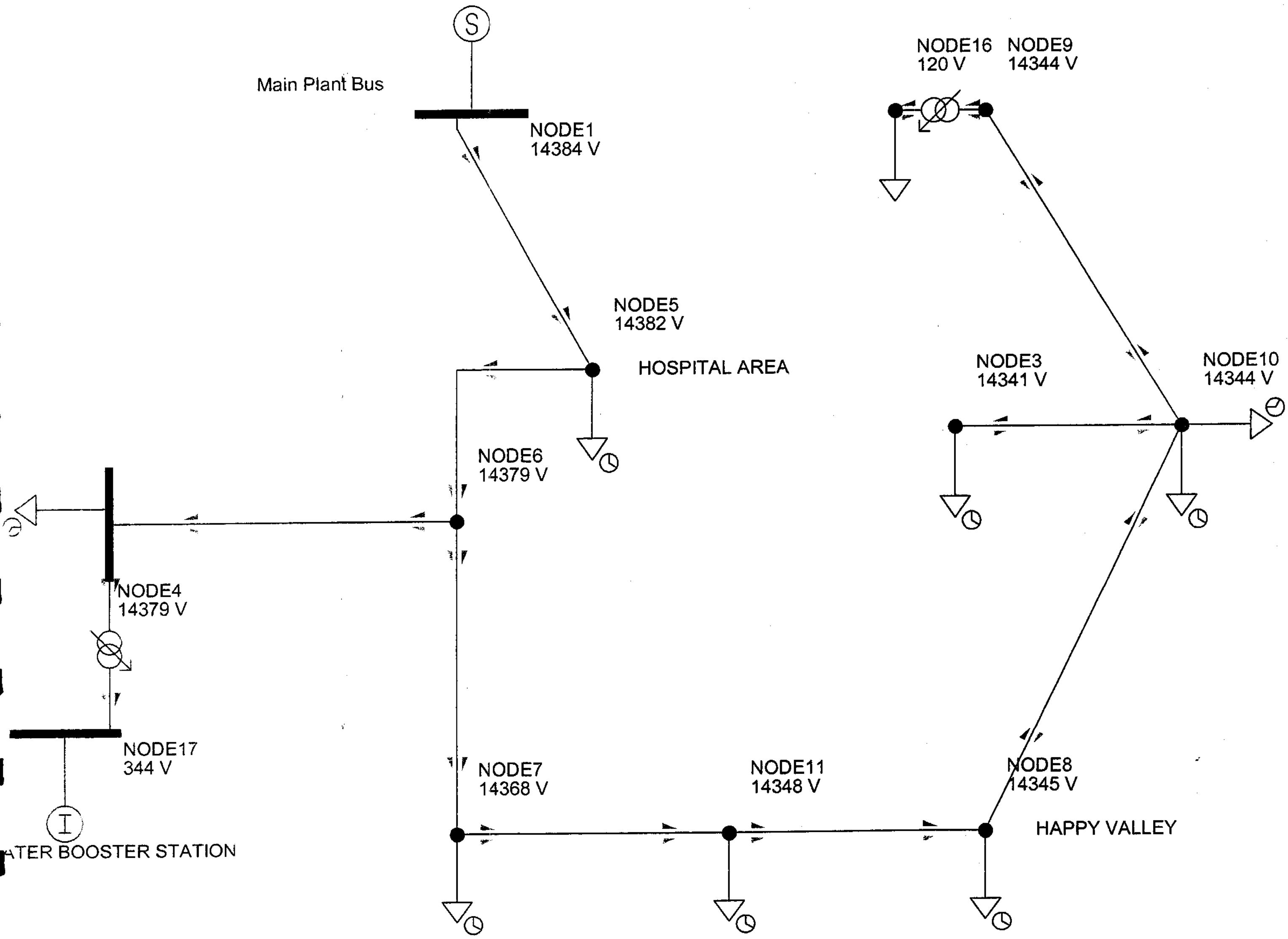
Iqaluit F5 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F5

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	1.000	0	-1
Line4	NODE5	NODE6	Line	ABC	0.750	0	-3
Line5	NODE6	NODE4	Line	ABC	0.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	0	-3
Line7	NODE7	NODE11	Line	ABC	1.000	1	-4
Line8	NODE11	NODE8	Line	ABC	0.500	0	-2
Line9	NODE8	NODE10	Line	ABC	0.500	0	0
Line1	NODE10	NODE3	Line	ABC	1.000	0	-4
Line10	NODE10	NODE9	Line	ABC	0.500	0	-2
Tran1	NODE9	NODE16	Transformer	ABC		0	0
					Total losses:	1.269	-18.704



Main Plant Bus
NODE1
14384 V
NODE5
14382 V
HOSPITAL AREA
NODE6
14379 V
NODE4
14379 V
NODE17
344 V
ATER BOOSTER STATION
NODE7
14368 V
NODE11
14348 V
NODE8
14345 V
HAPPY VALLEY
NODE16
120 V
NODE9
14344 V
NODE3
14341 V
NODE10
14344 V

Branch Loss Report

1/3/2006

4:51:04PM

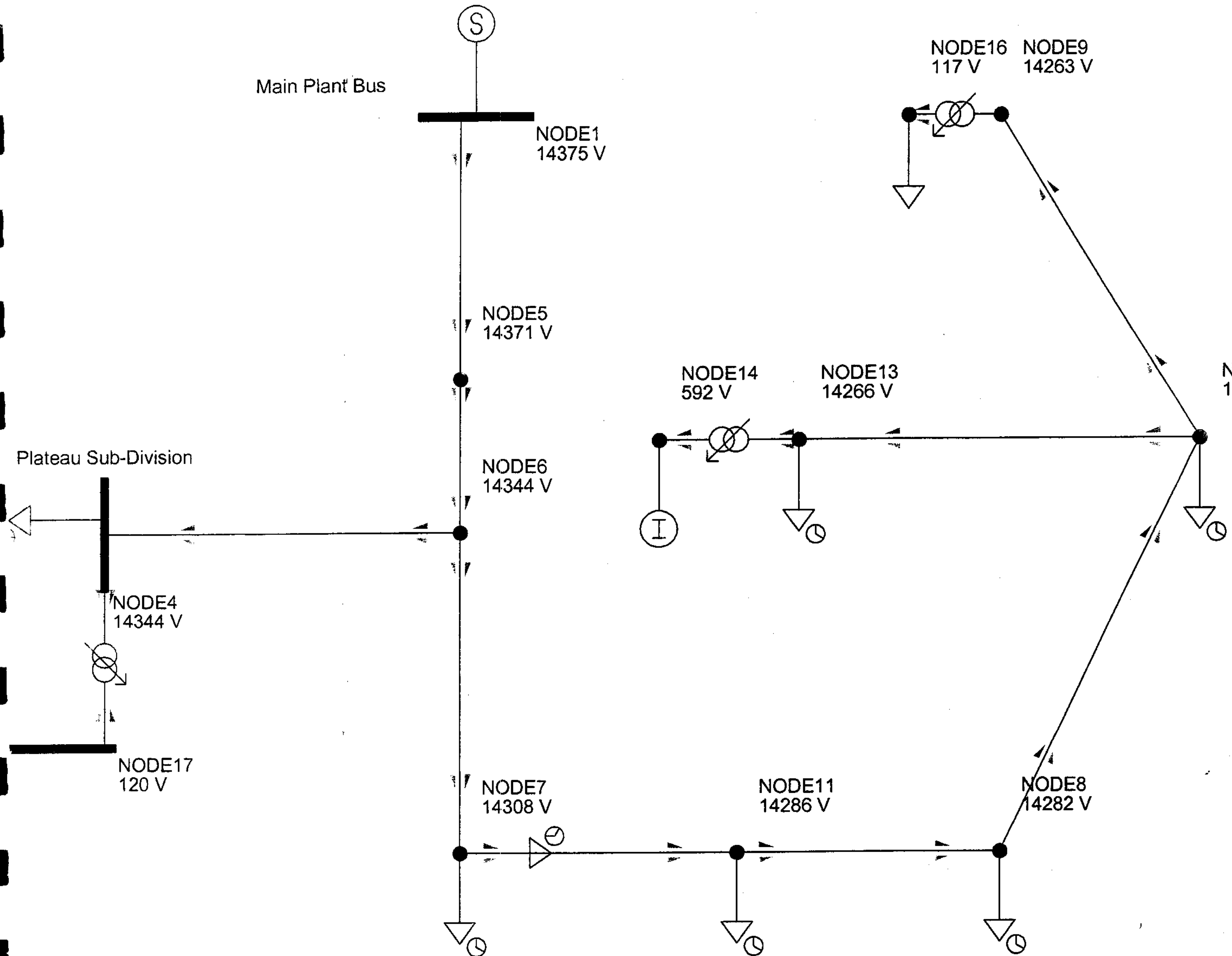
Iqaluit F6 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F6 14

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	0.500	0	0
Line4	NODE5	NODE6	Line	ABC	1.000	2	2
Line5	NODE6	NODE4	Line	ABC	2.000	0	-1
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	2.000	5	2
Line7	NODE7	NODE11	Line	ABC	1.500	2	0
Line8	NOD[illegible]1	NODE8	Line	ABC	0.500	0	0
Line9	NODE8	NODE10	Line	ABC	3.000	1	-2
Line11	NODE10	NODE13	Line	ABC	1.000	0	-1
Tran1	NODE13	NODE14	Transformer	ABC		0	0
Line10	NODE10	NODE9	Line	ABC	3.000	0	-2
Tran3	NODE9	NODE16	Transformer	ABC		1	6
					Total losses:	11.352	5.074



Main Plant Bus
NODE1
14375 V
NODE5
14371 V
NODE6
14344 V
Plateau Sub-Division
NODE4
14344 V
NODE17
120 V
NODE7
14308 V
NODE11
14286 V
NODE8
14282 V
NODE10
14268 V
NODE13
14266 V
NODE14
592 V
NODE16
117 V
NODE9
14263 V

Branch Loss Report

1/3/2006

4:52:43PM

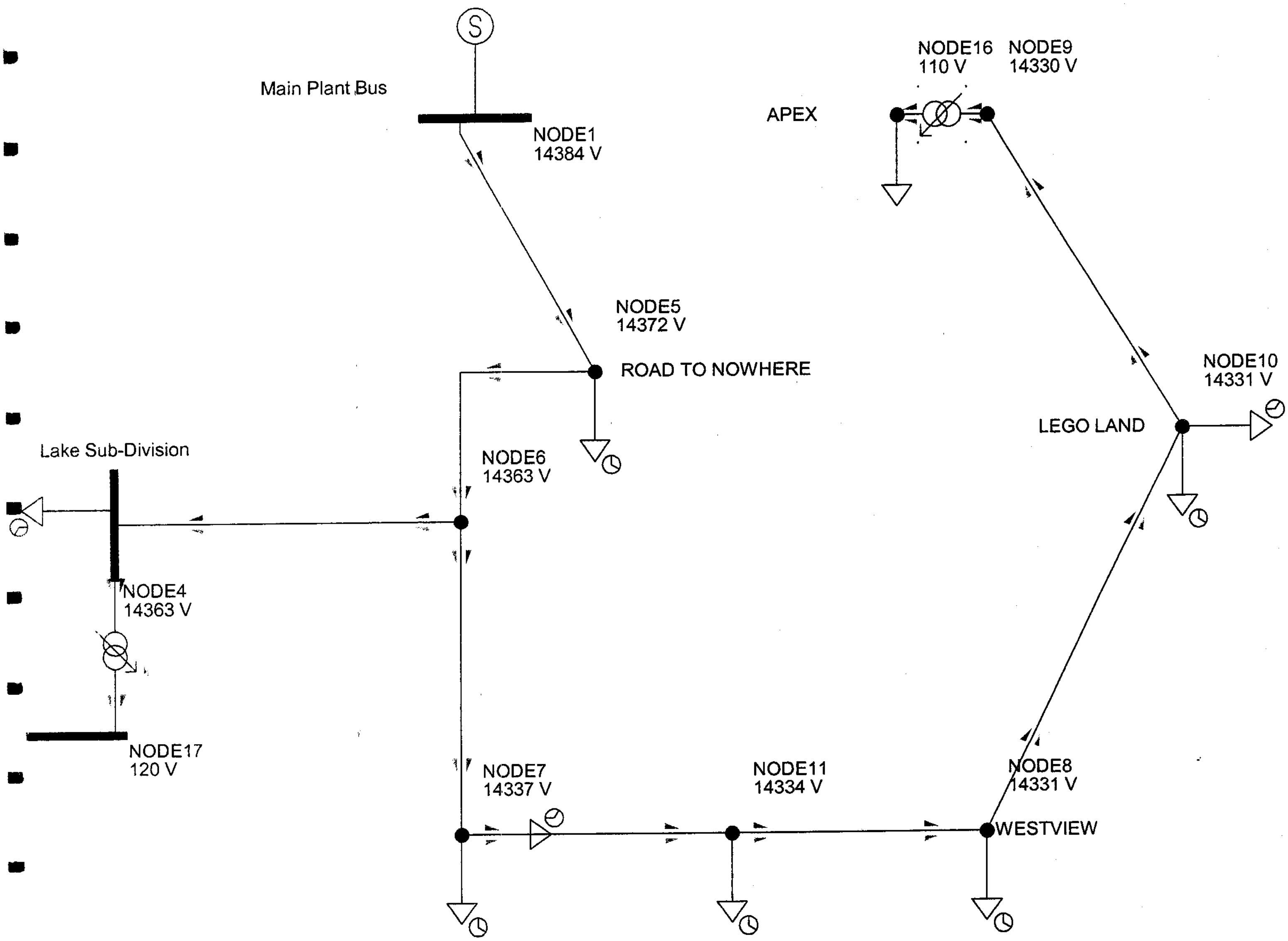
Iqaluit F7 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F7

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	4.000	0	-2
Line4	NODE5	NODE6	Line	ABC	1.000	0	-4
Line5	NODE6	NODE4	Line	ABC	1.500	0	-1
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	2.000	1	-7
Line7	NODE7	NODE11	Line	ABC	1.000	0	-1
Line8	NODE11	NODE8	Line	ABC	2.000	0	-1
Line9	NODE8	NODE10	Line	ABC	0.500	0	0
Line10	NODE10	NODE9	Line	ABC	0.500	0	0
Tran1	NODE9	NODE16	Transformer	ABC		2	12
					Total losses:	2.935	-4.681



Main Plant Bus
NODE1
14384 V
NODE5
14372 V
ROAD TO NOWHERE
NODE6
14363 V
Lake Sub-Division
NODE4
14363 V
NODE17
120 V
NODE7
14337 V
NODE11
14334 V
NODE8
14331 V
WESTVIEW
LEGO LAND
NODE10
14331 V
APEX
NODE16
110 V
NODE9
14330 V

Branch Loss Report

1/4/2006

11:38:08AM

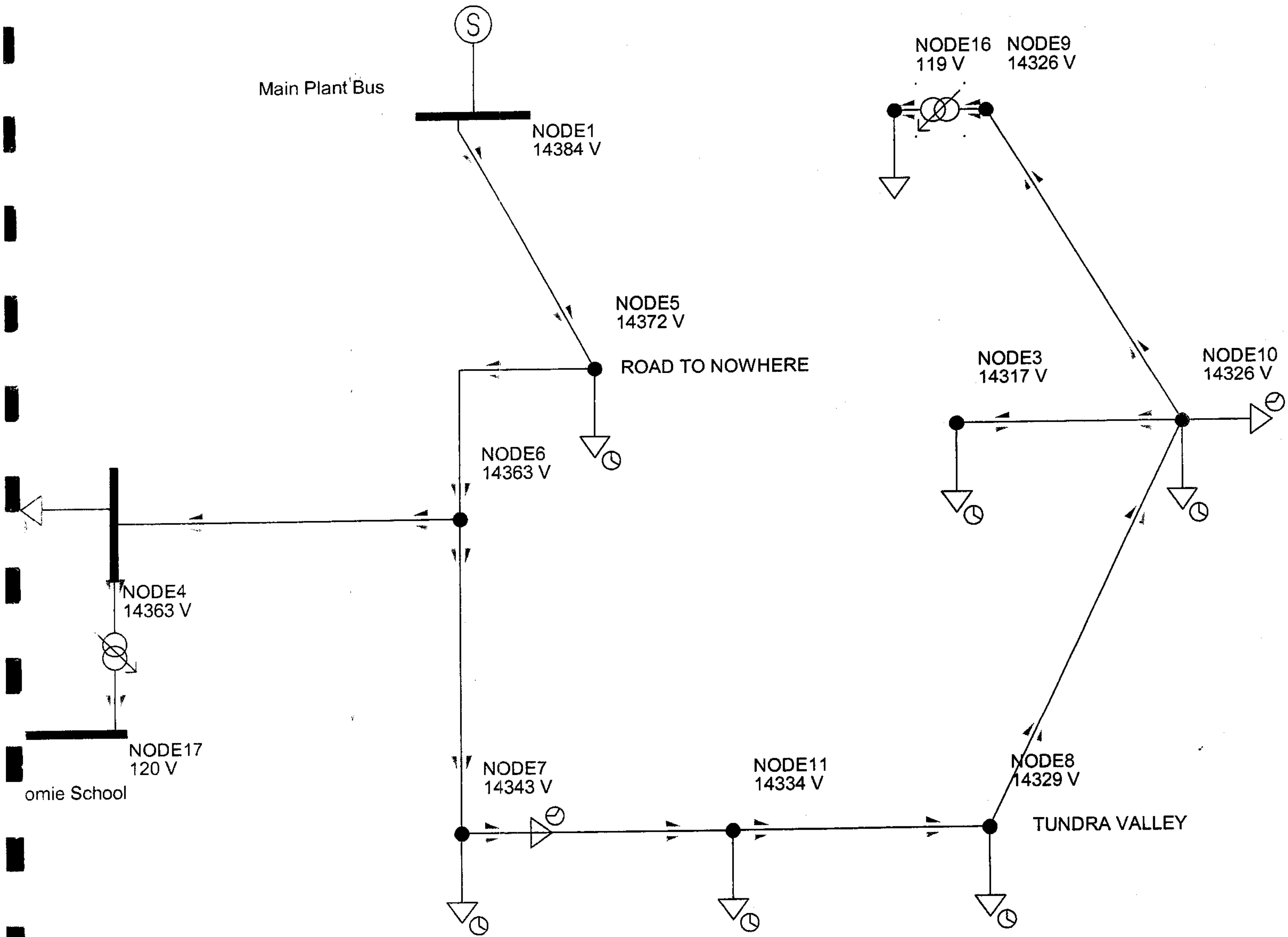
Iqaluit F8 @ 14.4 kV

System Base kVA: 1000.00

Iqaluit F8

Losses: kWatts, kvars

Name	1st Node	2nd Node	Type	Phase	Length	Loss (P)	Loss (Q)
Line3	NODE1	NODE5	Line	ABC	3.000	1	-1
Line4	NODE5	NODE6	Line	ABC	1.000	0	-3
Line5	NODE6	NODE4	Line	ABC	0.500	0	0
Tran4	NODE4	NODE17	Transformer	ABC		0	0
Line6	NODE6	NODE7	Line	ABC	1.000	1	-2
Line7	NODE7	NODE11	Line	ABC	1.000	0	-4
Line8	NODE11	NODE8	Line	ABC	0.500	0	-2
Line9	NODE8	NODE10	Line	ABC	0.500	0	0
Line1	NODE10	NODE3	Line	ABC	1.000	0	-3
Line10	NODE10	NODE9	Line	ABC	0.500	0	-2
Tran1	NODE9	NODE16	Transformer	ABC		0	0
					Total losses:	3.760	-17.288


S
Main Plant Bus
NODE1
14384 V
NODE5
14372 V
ROAD TO NOWHERE
NODE6
14363 V
NODE4
14363 V
NODE17
120 V
omie School
NODE7
14343 V
NODE11
14334 V
NODE8
14329 V
TUNDRA VALLEY
NODE16
119 V
NODE9
14326 V
NODE3
14317 V
NODE10
14326 V