Cycle Charge DC Power Systems For AT&T Canada

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Abstract

At a typical remote site powered by a diesel generator, moderate to average electrical demands exist most of the time. Occasionally, during short-time intervals, large amounts of power are required. In order to provide continuous power to the site conventional generating systems are sized large enough to handle these peak load situations. As a result, the generating set operates lightly loaded most of the time. This causes very poor operating efficiencies with high fuel and maintenance costs. The solution is a Cycle Charge system designed to minimize engine generator run time while providing continuous and reliable prime power. The system controls are focused on maintaining the charge on the battery.

Cycle Charge Systems are state of the art fuel-efficient diesel hybrid system complete with heating, ventilation and cooling (HVAC) and remote monitoring and control system (RMCS). The prime source of load power is the station battery, which is cycled with a shallow discharge down to 65% of full charge. Whenever the battery requires charging, the generating sets starts, recharges the battery and then shuts down

1. Introduction

In 1991 AT&T Canada (then Unitel Communications) started a network upgrade program to replace the analog microwave radio equipment with digital radio equipment. As part of this network upgrade the site power systems were to be upgraded as well.

Included in the network are several remote prime power sites. At these sites a power system provided power by running one of two diesel generators continuously. These remote prime power sites are located in the Province of Newfoundland (4 locations), the Province of British Columbia (6 locations) and the Province of Alberta (1 location).

These remote sites present several particular challenges to the maintenance crews servicing these locations and to the system designers specifying equipment. Although the sites are easily accessed during the summer season, they are very difficult to access during winter. Site environmental conditions vary greatly with the following typical:

- Altitudes vary from 1000 to 3000 meters.
- Temperatures vary from +40 ºC in summer to -30 ºC in winter.
- Wind speeds up to 150 km/hour

For most of the sites access in winter requires the use of a tracked vehicle. At one site, an AT&T owned tramway is the only access! Typical response time for a maintenance crew to reach the site is from 4 to 8 hours.

With the preceding environmental and site access criteria in mind, AT&T had to select a power system which was reliable, fuel efficient, possess remote communications capabilities, provide extended maintenance intervals and satisfy environmental protection concerns.
AT&T Canada selected Mechron Power Systems innovative alternative for continuous power, the Cycle Charge System over a traditional remote prime power system to realize the following tangible benefits:

- Engine run time reduced to 25% of the time required by traditional systems.
- Fuel costs reduced by up to 75%.
- Bulk fuel storage requirement reduced.
- Diesel engines operate at an optimal load level.
- Maintenance costs reduced by as much as 35%.
- Site visits due to trouble calls reduced due to remote monitoring and control system (RMCS).

2.0 Cycle Charge Background

At a typical remote site powered by diesel generators, low to moderate load demands exist most of the time. In the case of the AT&T sites, this load is the continuous draw of the microwave radio equipment and some small housekeeping loads. Occasionally, for brief periods, larger amounts of power are required. These loads can include electric heaters, air conditioners, convenience receptacles, … etc. Due to the need to provide continuous power at the remote site, conventional diesel generating systems must be sized with sufficient capacity to handle these periods of peak loading. A typical remote site often has a peak to continuous load ratio greater than 15 to 1!

The result of sizing the generating system for this maximum peak load is that the generating system spends most of the time operating lightly loaded. This causes very poor operating efficiencies together with high fuel consumption and maintenance costs.

There are other areas of concern that must be considered when operating the generating system continuously:

- High engine operating hours demand frequent site visits to perform preventative maintenance procedures.
- Dummy loads are often required to properly load the generating system during periods of low demand, (the majority of the time), wasting fuel.
- Large on-site fuel storage is required along with the associated environmental risks.
- The generating system exhibits poor adaptability to site expansion or downsizing.

The key to supplying efficient continuous power at a remote site is to use the station battery as the prime power source. Batteries are an excellent energy storage medium, excellent peak load handling capability and is a technology familiar to operation and maintenance personnel involved in the Telecom industry.

The station battery in a Cycle Charge is cycled with a **maximum** design depth of discharge of 35%. Typically the design depth of discharge used is 25%.

Recent experience and many published papers have given rise to concerns over the reliability, life and actual reserve time available when using valve regulated lead acid (VRLA) batteries. These concerns are relevant to experience with VRLA batteries operating in a system where a **float** voltage is applied continuously. In a Cycle Charge system a fully charged battery is discharged and then recharged. The battery never experiences long periods of float service.

A prime concern in a Cycle Charge system is the large number of discharge cycles that the battery must sustain. Published curves of cycle life versus depth of discharge for VRLA batteries indicates that for a depth of discharge of 35% or less, the cell life is determined by the age of the cell and not the number of cycles!

3.0 System Configuration

The power generation system supplied to AT&T Canada was designed to provide power for different types of loads. The load descriptions that follow are for the 48 Volt, 500 Amp DC sites that were supplied (48 Volt, 300 Amp DC sites were also supplied) to AT&T Canada. See figure 1, Cycle Charge Single Line Diagram, for a view of the interconnection of the power generation system.

3.1 Connected Loads

The Cycle Charge system is designed to accommodate many different types of loads. A brief description of the loads, bus voltages and power requirements follows.

3.1.1 -48 Volt DC Bus

The loads connected to this bus must be supplied with power at all times. The loads connected to this bus include:

- Customer radio load.
- 6 kVA inverter.
- Radio room DC lighting.
- Diesel room DC lighting.
- Radio room DC heating.
- Diesel generator unit A and B start battery chargers.

3.1.2 Common +24 Volt DC Bus

This bus is derived by diode coupling the diesel engine start batteries and provides power to ancillary controls of the power generation system and equipment in the diesel room. These loads require continuous power and include the following.

- Diesel room inlet, outlet and re-circulation damper motors.
- Remote monitoring and control system (RMCS).
- Power generation system controls.
- Fuel pumping system controls.
- Radio room ventilation system.

3.1.3 Non-Essential AC Bus

The Non-Essential AC Bus can be energized from either diesel electric generator (DEG) A or B. The loads connected to this bus require power only when a DEG is operating. A transfer contactor allows either DEG to connect to the Non-Essential AC Bus. Total capacity available is 50 Amps at 120/208, 3 phase. Loads connected to this bus include the following:

- Fuel pumping system.
- Ventilation system booster fans.
- Diesel and radio room convenience receptacles.
- Radio room electric baseboard heaters.
- Radio room auxiliary air conditioner.
- Diesel room auxiliary lighting

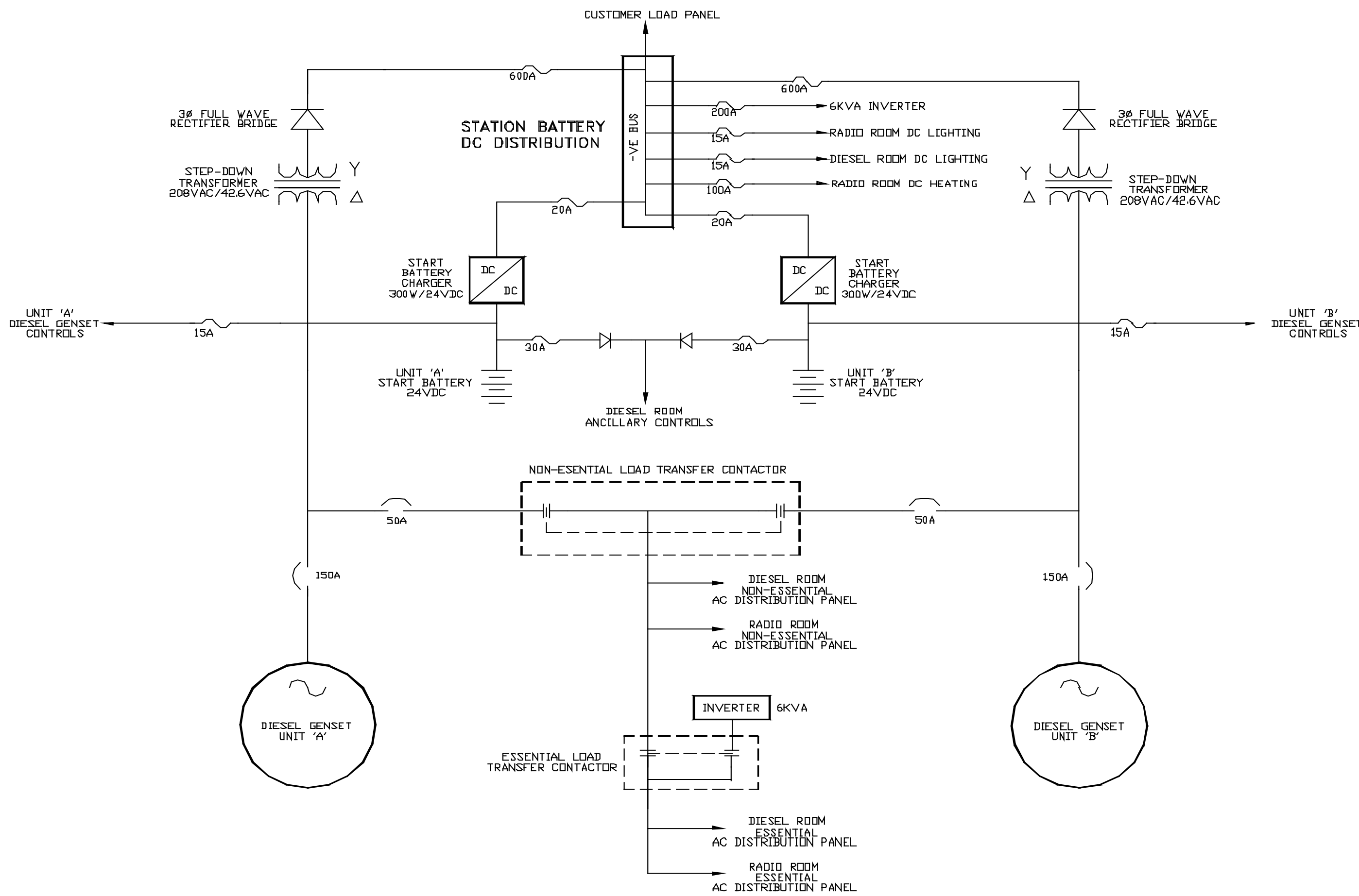

FIGURE #1
CYCLE CHARGE SINGLE LINE DIAGRAM

3.1.4 Essential AC Bus

The loads connected to the Essential AC Bus must be supplied with power continuously. This bus can be supplied from two possible sources. A 6 kVA, 120/240, single phase inverter is the primary source of power. In the case of an inverter failure, a signal from the inverter to the RMCS changes the configuration of power generation system from Cycle Charge mode to prime power mode. This mode keeps one of the DEG's running continuously, providing power to the Essential AC Bus. Loads connected to this bus include the following:

- Fuel fired furnace.
- Diesel and radio room primary lighting.
- Dehydrator.
- Diesel room ventilation fans.
- Fire alarm panel.
- Site terminal.
- Tower obstruction lights.
- Radio room primary air conditioner.
- Radio equipment bay receptacle.

3.2 Station Battery

The station battery selected for the power generation system used sealed valve regulated lead acid (VRLA) technology. Different sizes of station battery were provided depending on the expected site load and conditions. The station battery capacities ranged from 2000 to 6000 A-h.

3.3 Diesel Electric Generator (DEG)

Each remote site is provided with two DEG's. Power output from each DEG is specified as 500 Amps @ 56 VDC and 50 Amps @ 120/208 VAC. The design of the DEG incorporates many of the following features in order to prolong maintenance intervals and increase reliability.

The DEG unit is composed of the following major components:

- Air cooled diesel engine operating at 1800 RPM capable of extended running through the use of a dry sump lubrication system. This lubrication system includes a 160 litre lubricating oil tank and extended run oil filters. The design allows 3000 hours between oil changes.
- Alternator rated 52.5 kVA, 120/208 V, 3 phase.
- Transformer/Diode assembly. This assembly includes a 208 VAC, 3 phase to 42.6 VAC @ 30.3 kVA transformer and a 700 Amp 3 phase full wave bridge.

In order to provide increased reliability, each DEG is controlled using a microprocessor based engine/generator controller (EGC). This EGC performs all the functions needed to control and protect a DEG unit. The functions required include the following:

- Control of automatic start/stop of the diesel engine. This function incorporates analog and discrete engine and alternator sensing points to allow for safe, efficient and reliable operation of the DEG.
- Control of the DEG alternator excitation. This function allows independent control of the output voltage (AC or DC) and DC output current.

In order to perform these functions, the following analog and discrete I/O points are monitored:

- Analog inputs
  - I. AC output voltage
  - II. DC output voltage
  - III. DC output current
  - IV. Station battery temperature
  - V. Station battery voltage
  - VI. Engine speed
  - VII. Lubricating oil pressure
  - VIII. Engine temperature

- Discrete inputs
  - I. Auto start
  - II. EGC reset
  - III. Emergency stop
  - IV. DEG more selector switch position

- Discrete outputs
  - I. Fuel solenoid
  - II. Starter motor
  - III. AC voltage alarm
  - IV. Engine overcrank or loss of speed signal alarm
  - V. Low oil pressure alarm
  - VI. High engine temperature alarm
  - VII. AC frequency limits alarm
  - VIII. High battery temperature alarm
  - IX. Selector switch not in automatic
  - X. DEG running in extended mode

All parameters related to EGC operation are fully configurable via an RS-232C serial port. This port also allows an operator to view the current status of the DEG. The configurable parameters that can be modified include the time delay settings, analog alarm and hysteresis setpoints, access passwords and output voltage and current settings.

3.4 Fuel System

The fuel system is comprised of exterior and interior fuel storage and a fuel pumping system. All fuel storage vessels are protected with fuel containment dikes to eliminate the possibility of a fuel spill to the surrounding environment.

The external bulk tanks have a total capacity of approximately 25,000 litres. A dual redundant fuel pumping system draws fuel from the bulk tanks and maintains the level of the internal 225 litre day tank. The DEG units draw fuel from the day tank during operation.

3.5 Heating and Ventilation (HVAC) System

The heating and ventilation system supplied to the remote sites is designed to allow efficient and reliable operation of the power generation and radio systems. In order to satisfy the environmental operating requirements, the following equipment was provided:

- Dual redundant motorized damper system.
- Dual redundant fans.
- Fuel fired furnace with electric baseboard heater backup.

In order to maintain the environment the temperature control scheme was integrated into the RMCS. In the event of a RMCS failure a hardware backup allows the HVAC system to operate, although with reduced capacity.

The HVAC operating parameters are summarized as follows:

- One inlet damper is opened when either a DEG or the fuel burning furnace is operating. The second inlet damper opens when the diesel room temperature rises above 25 ºC. The second inlet damper closes at 21 ºC.
- The engine cooling air exhaust damper remains in recirculation mode until the diesel room temperature rises above 25 ºC. In recirculation mode the hot engine cooling air is returned to the diesel room, providing heat. When the diesel room temperature rises above 25 ºC the air exhaust damper position changes to the full exhaust position. In this position the hot engine cooling air is expelled to outside the building. When the temperature falls below 21 ºC the exhaust damper reverts to the recirculation mode.
- The fuel burning furnace is started when the temperature in the diesel room falls below 15 ºC. The furnace is shutdown when the temperature rises above 19 ºC.
- A low room temperature call-to-start, set at 5 ºC, causes a DEG to start and run. This provides power to operate the backup electric baseboard heaters. The call-to-start is cleared when the temperature rises above 9 ºC.

3.6 Remote Monitoring and Control System (RMCS)

The RMCS provides complete system monitoring, power generation system automatic control and allows local/remote system access. A 64 kbit/s multidrop data channel is provided by the communication equipment to connect the remote sites to a Gateway computer. This computer then provides dialup and dialout access for the remote sites.

In order to control the power generation system a number of analog input and discrete I/O points are used. The total number of points the RMCS monitors and controls is:

- 24 analog inputs
- 29 discrete inputs
- 36 discrete outputs

The local/remote system access allows an operator to perform many duties without the need to actually go to the remote site. The ability to view current status, past alarm history, reset alarms and reconfigure operating parameters allows the operator to make informed decisions regarding the remote site. In several cases a site trouble visit has been postponed or avoided entirely

4.0 AT & T Canada experience with Cycle Charge Systems 1991 -1996

The following section describes the AT&T Canada experience with Mechron Cycle Charge Systems during the period 1991 - 1996 with respect to:

- Reliability.
- Fuel efficiency.
- Battery condition and reserve time.
- Maintenance intervals.
- Remote communication access, benefits for operation and engineering.

4.1 Reliability

4.1.1 300 Amp Systems Commissioned in 1991 in Province of Newfoundland (4 sites)

At a system level, these sites have demonstrated an availability of 100% during the 5 year period from 1991 to 1996. A system level failure is defined as a loss or interruption of the 48 VDC bus.

However, component level failures were experienced, primarily in the first year following commissioning.

4.1.1.1 Inverter

Several inverter failures forced the systems to operate in prime power mode. This resulted in high operating temperatures, 34 ºC on the Diesel Room and 37.5 ºC in the Radio Room, and higher than expected fuel consumption.
An investigation into the cause of the inverter failures determined that brief overloads caused by fan switching were causing the inverter to shutdown. The resolution was to replace the 1800 VA inverters supplied at the sites with 3000 VA inverters and incorporate a 20 minute automatic overload reset feature. Also, the original fan switching scheme was modified to prevent the overload from occurring.

4.1.1.2 Fuel System

At two sites solenoid valve failures and frozen fuel pipes caused a failure of the fuel system.

In order to resolve this problem the fuel system at all sites have been upgraded. This upgrade moved an outdoor “T” connection, using solenoids valves, that connected the fuel feeds from the two external bulk tanks to a single feed into the indoor fuel pumping system. All external bulk tank piping now has separate fuel feeds to the indoor fuel pumping system and the solenoid valves are now located indoors. Since this modification, no further failures have been reported.

4.1.1.3 Fan Blades

At all sites the fan blades began to crack and fail due to heavy ice conditions. This caused a loss of cooling air leading to site overheating problems.

The fans blades have been replaced with a heavier duty unit and no further failures have been reported.

4.1.1.4 Nuisance Alarms

A software bug in the RMCS caused false momentary readings of voltages, current and temperatures. These erratic readings caused false alarms that affected the power generation system operation.
The RMCS Software will be upgraded in 1997 to eliminate these nuisance alarms.

4.1.2 300 Amp System Commissioned in 1992 in the Province of British Columbia (1 site) and 500A Systems Commissioned in 1993/1994 in Province of British Columbia and Alberta (6 sites)

At a system level, these sites have demonstrated an availability of 100% since site commissioning in 1992. A system level failure is defined as a loss or interruption of the 48 VDC bus.

Similar to the sites in Newfoundland, there were a number of component level failures in the period of time following commissioning.

4.1.2.1 RMCS CPU Failures

Three sites experienced suspected CPU failures. These failures caused the power generation to fall back to prime power operation. Of the three CPU's that were returned one proved to be faulty, the remaining two had no fault found.

4.1.2.2 Nuisance Alarms

This problem was similar to the nuisance alarms in Newfoundland.

The alarm that caused the greatest concern was the Battery Disconnect Alarm. This alarm indicates that the station battery has been disconnected from the load and causes the power generation system to operate in prime power mode.
The alarm history at four sites in a period of five months, September 1994 to January 1995, shows a total of 84 alarms. This gave an average of 4.4 alarms/month/site or 1 alarm/week/site. The vast majority (around 50%) were momentary/nuisance alarms lasting less than one second with the alarm clearing out. About 25% were minor alarms, 10% major alarms and 15% various others.

Since the RMCS software has been upgraded with the latest version, no further nuisance alarms have been reported.

4.1.2.3 Site Communication

For a considerable time following commissioning, communication to these site was extremely unreliable. During December, 1995 statistics regarding communication were gathered. These statistics indicated that for 300 polls by the Gateway computer, there were 58 communication failures. The distribution of failures per site varied from no failures per site up to 37 per site. The total system error rate was 19.3%.

Following a detailed investigation the problem was determined to be a hardware interface incompatibility between the RMCS CPU and the communication equipment. The incompatibility was corrected in the spring of 1996 and communications been trouble free since.

4.1.2.4 Site Overheating

During the summer months sites began to experience overheating problems.

The investigation determined that the relays used to control the damper motors were undersized. This resulted in the ventilation dampers remaining closed and site to overheat. The undersized ventilation system relays have been replaced and no further failures had been reported.

4.3 Battery Condition and Reserve Time

4.3.1 Four 300 Amp Systems in Newfoundland

Batteries for these systems are rated 2,000 Ampere-hours at the 8 hour rate. The batteries are manufactured using VRLA technology.

The average load at these sites is 20 Amps at 48 VDC. In 1995 the cycles were monitored for a period of 7 months. During this period the sites cycled an average of once per day. This indicated that in the 5 year operational period the batteries had been shallow cycled 1800 times. The number of cycles for the period was compared with data collected in 1991. The data showed no significant change in number of cycles. A comparison of the number of cycles is useful in determining the health of the battery. If the number of cycles over a period of time is different from the same period of time the previous year, a degrading battery may be the problem. This method of battery evaluation will be repeated in 1997.

No cell failures occurred with the batteries until 1994. In that year two cells failed. The cells failed at two different sites.

4.3.2 One 300 Amp System and Six 500 Amp Systems in British Columbia and Alberta

Batteries for these systems are rated 4000 - 6000 Ampere-hours at the 8 hour rate. These batteries are manufactured using VRLA technology.

The average load at these sites range between 60 and 100 Amps at 48 VDC. Discharge curves were taken in the winter of 1995. These curves showed a severe loss of reserve time. Particularly at the 300 Amp site, where the rated 20 hour off time (the period of time from the end of charge to the call to start voltage) had dropped to less than 5 hours, creating a dangerous situation.

At the 300 Amp site the charge regimen is set to cut off when the battery charge current drops to 110 Amps. This design specification was used to obtain a 25% duty cycle and to protect the engine running with less than 50% load. To correct the loss of reserve time, a refreshing charge lasting 72 hours is applied every six month. Subsequent tests have shown that the off cycle time, has increased to 16 hours.

Cell failures occurred at the 300 Amp site. In 1995, four cells failed and were replaced.

4.4 Fuel Efficiency

The site fuel consumption figures are shown in table 1 for the four sites in Newfoundland and table 2 for the seven sites located in British Columbia and Alberta.

From an analysis of the information in the tables, the 300 Amp system in British Columbia (BC) has a fuel consumption 85% higher than the 300 Amp systems in Newfoundland. This higher fuel consumption is attributable to two differences in the system design. In BC the system load is higher and the DEG supplied was 36 kW instead of the 20 kW unit supplied in Newfoundland. A larger DEG was required in BC for reserve capacity.

Newfoundland				
Site ID	Rating	Fuel	Fuel	Site Fuel
		Consumption	Cost	Cost
	Amps	Litres	$/litre	
1	300	5,480	0.43	$2,356
2	300	4,900	0.41	$2,009
3	300	4,230	0.43	$1,819
4	300	No Data Available		
	Total Site Fuel Costs=		$6,184	
Average Site Fuel Consumption=			4870	litres/site
	Average Site Fuel Cost=		$2,061	per site
TABLE 1				

To determine the fuel savings per site/year, we compare the actual site fuel consumption with the yearly fuel consumption of a traditional prime system where the engine runs 24 hours per day.

The average duty cycle for the 300 Amp systems in Newfoundland is 15%. Therefore compared to a prime power system the fuel savings in Newfoundland are;

$$4 \cdot \text{sites} \cdot \left(4870 \cdot \frac{\text{litres}}{\text{site}} \cdot 0.43 \cdot \frac{\text{dollar}}{\text{litre}} \cdot \frac{1}{15 \cdot \%} - 2061 \cdot \frac{\text{dollars}}{\text{site}} \right) = 47598.67 \cdot \text{dollars}$$

In BC and Alberta the 500 Amp systems are performing with 20% duty cycle, the 300 Amp system has a duty cycle of 25%. The fuel savings for the 300 Amp system in BC is;

$$1 \cdot \text{site} \cdot 9000 \cdot \frac{\text{litre}}{\text{site}} \cdot 0.4 \cdot \frac{\text{dollar}}{\text{litre}} \cdot \frac{1}{25 \cdot \%} - 3600 \cdot \text{dollars} = 10800 \cdot \text{dollars}$$

The fuel savings for the 500 Amp systems in BC and Alberta are;

$$6 \cdot \text{sites} \cdot \left(13716 \cdot \frac{\text{litres}}{\text{site}} \cdot 0.40 \cdot \frac{\text{dollar}}{\text{litre}} \cdot \frac{1}{20 \cdot \%} - 5456 \cdot \frac{\text{dollars}}{\text{site}} \right) = 131856 \cdot \text{dollars}$$

In total AT&T Canada saves **$190,255CDN in fuel costs per year.**

4.4. Maintenance

The Cycle Charge system is designed specifically to reduce routine maintenance and service calls. Engine maintenance procedures are based on engine running time. At the AT&T Canada Cycle Charge sites the engines are running between 15% and 25% of the time, compared with 100% of the time with a traditional prime power system. Therefore, engine maintenance and overhaul intervals are between 4 and 5 times greater.

British Columbia & Alberta				
Site ID	Rating	Fuel	Fuel	Site Fuel
		Consumption	Cost	Cost
	Amps	Litres	$/litre	
1	300	9,000	0.40	$3,600
2	500	14,464	0.39	$5,641
3	500	12,460	0.39	$4,859
4	500	14,500	0.39	$5,655
5	500	15,039	0.39	$5,865
6	500	13,000	0.39	$5,070
7	500	12,831	0.44	$5,646
500 Amp Site				
Average Site Fuel Consumption=			13,716	litres/site
	Average Site Fuel Cost=		$5,456	per site
TABLE 2				

Data collected for the four 300 Amp systems show average engine run time at 1200 hours/year/site. Major engine service was performed in 1996 on engines that had reached 6000 hours at an average cost of $9,000CDN per engine. The average annual site engine maintenance costs are therefore $1800CDN. The comparable yearly cost savings per site to maintain these sites versus prime power systems are;

$$8760 \cdot \frac{\text{hours}}{\text{year}} \cdot \frac{1}{6000 \cdot \text{hours}} \cdot 9000 \cdot \text{dollars} - 1800 \cdot \frac{\text{dollars}}{\text{year}} = 11340 \cdot \frac{\text{dollars}}{\text{site}}$$

Comparable data for the six 500 Amp sites shows average site engine time at 2,000 hours per year. The comparable yearly cost savings per site to maintain these sites versus prime power systems are;

$$8760 \cdot \frac{\text{hours}}{\text{year}} \cdot \frac{1}{6000 \cdot \text{hours}} \cdot 9000 \cdot \text{dollars} - 3000 \cdot \frac{\text{dollars}}{\text{year}} = 10140 \cdot \frac{\text{dollars}}{\text{site}}$$

The total savings for maintenance is therefore;

$$5 \cdot \text{sites} \cdot 11340 \cdot \frac{\text{dollars}}{\text{site}} + 6 \cdot 10140 \cdot \frac{\text{dollars}}{\text{site}} = 117540 \cdot \frac{\text{dollars}}{\text{year}}$$

All the calculations are based on estimates only as overhauls have not been required at all sites. Also, the estimates do not take into account inflation rates or price increases.

4.5 Remote Communication (RMCS)

The RMCS has been configured as an operational tool to provide a second level alarm system and forecasting tool for engineering technical support. The RMCS architecture consists of two sections, one for the four sites in Newfoundland and one for the seven sites in BC and Alberta. Each is monitored by Area Operations Supervisors.

Engineering has access to both systems in order to monitor system performance, provide technical support and to perform forecasting. Technicians have used laptop computers to call-up the sites from locations such as their residence, hotels, etc. On several occasions technicians were able to avoid trips to the site by using the RMCS to diagnose and correct problems remotely. AT&T estimates that this system capability avoided an average of 6 trouble calls per site/year. With a cost of $500CDN per site visit, a yearly savings of $33,000CDN was realized for the 11 sites.

5. Conclusion

Overall the Mechron Cycle Charge Systems installed at AT&T Canada remote sites have proven to be reliable, fuel efficient power systems providing continuous uninterrupted reliable 48 VDC power to the critical telecommunication load. The early component failures, described in this paper, were corrected promptly. The RMCS has proven to be an important tool for real time troubleshooting and evaluation of conditions such as the battery reserve time situation. Lastly, total operating costs for the systems has been reduced by an estimated **$340,795CDN per year.** Cost saving estimates assume initial capital cost of Cycle Charge system is the same as traditional Prime Power system and do not include additional capital costs for possible earlier batteries replacement due to shorter life expectancy then in a float application.

6.0 Acknowledgment

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