YUKON ENERGY CORPORATION

Whitehorse, Yukon

Energy Storage and Yukon to BC Transmission Inter-tie Background Paper for 2011 Energy Planning Charrette

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Background Paper for
2011 Energy Planning Charrette**

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1. INTRODUCTION

Yukon Energy Corporation (YEC) is a public owned electrical utility, and is the main generator and transmitter of electrical energy in Yukon. YEC will soon run out of surplus energy and is in the process of revising their 20-year Resource Plan. Energy storage technologies and connecting the Yukon and BC networks together were studied in preparation for input into the revised plan. This report was prepared as a resource to be used by the participants of a planning workshop scheduled in early March, 2011.

2. ENERGY STORAGE

2.1 Background

Electrical energy can be stored by converting surplus energy into another form of energy such as potential, kinetic, or chemical. The energy in the alternate form is later recovered by converting it back into electrical energy. Typically, energy is stored during periods of low electrical demand and then the stored energy is used during periods of high demand. Recent technological developments have made energy storage useful for improving power quality and integrating non-dispatchable energy sources.

Yukon Energy Corporation (YEC) would like to have energy storage connected to the Yukon Interconnected System (YIS). Two types of energy storage are required: short-term and long-term. These two energy storage objectives result in differing requirements – especially on a small interconnected grid such as the YEC YIS.

2.2 Short Term Energy Storage (Spinning Reserve)

Short-term energy storage is an alternative to running unloaded generation (called spinning reserve). For normal power system operation, a spinning reserve to compensate for the loss of the largest generating unit in service is required at all times. Therefore, to maintain the spinning reserve, the total installed generating capacity must be larger than the load. The capacity of the largest hydro unit (WH4) is 20 MW;

therefore YEC requires a spinning reserve of at least this amount. The spinning reserve must be available to the grid nearly instantaneously (in seconds).

The loss of a generating unit is infrequent, but, the ability to replace quickly the generation using a backup unit in the event of an outage is critical. Presently, when generation is lost, it can take up to 15 minutes for diesel generators to be started and carry full-load. In the meantime, load is shed and those customers must go without power until replacement generation is brought on-line.

Non-dispatchable, or intermittent, energy sources are sources that are not continuously available and are outside direct control of the operator. These sources can be predictable (i.e. tidal power) or unpredictable (i.e. wind). In addition to spinning reserve being required to compensate for sudden loss of generation, it is also required to compensate for short-term production unpredictability of non-dispatchable energy sources. The spinning reserve required in this case must be available at all times and equal to the rated capacity of the non-dispatchable source (i.e. wind farm capacity).

2.3 Longer-Term Energy Storage (Storage Capacity)

On the YEC integrated system, longer-term energy storage is also required to integrate non-dispatchable energy sources for times when the non-dispatchable source is not available. A hydro system with a large amount of storage is best suited for non-dispatchable power generation integration. When the non-dispatchable energy production is high, the energy can be stored in a reservoir, and when it is low or not available, the potential energy of the water in the reservoir can be utilized to produce hydro power. Therefore, it is mandatory to have sufficient water storage capacity to both absorb and then return the non-dispatchable energy according to the load demands. The industry standard for non-dispatchable energy integration is a storage capacity that is at least equivalent to the non-dispatchable energy production (GWh) over a few days (minimum of two days, preferably four days).

3. TECHNOLOGIES

A variety of energy storage technologies were recently considered during a study performed for YEC. Refer to Table 1 for a list of the technologies and the recommendations for use in the Yukon Integrated System.

Table 1: Energy Storage Technologies

Energy Storage Technology	Recommended	Comment
Conventional battery energy storage system (BESS)	No	Mature technology, but not well-scaled to MW for many minutes. Must be recharged (hours) before re-use.
Flow battery system	No	Immature technology.
Sodium-sulphur battery system	No	Immature technology.
Flywheel energy storage system (FESS)	No	Technology immature and energy only available for a short-time (~15 minutes).
Ride-through system – electro-magnetic flywheel	No	Mature technology, but energy only available for a short-time (~15 seconds).
Compressed air energy storage	No	Immature technology, slow response time, limited sites.
Hydrogen production and storage	No	Immature technology, suitable sites, low efficiency.
Synchronous condensing peaking hydro units	Yes	Best candidate for adding spinning reserve using existing infrastructure.
Diesel rotary uninterruptible power supply (DRUPS)	Yes	Best candidate for adding new spinning reserve.
Pumped storage hydro	Yes	Best candidate for long-term storage of a large capacity (> 50 MW).

The present state of each technology for utility applications was examined, and then the results used to compare the technologies in terms of design, benefits, and performance. The alternatives that could best meet YEC's objectives were further evaluated based on the storage efficiency, environmental effect, and cost effectiveness. The recommended technologies are discussed in the sections that follow.

3.1 Hydro Generator Units: Conversion to Synchronous Condense Mode

A peaking hydro system normally consists of hydro generating unit(s) and a large reservoir. Water flowing into the reservoir is stored during low-load periods and released through the generating unit(s) at high-demand periods to support the increased load. A hydro unit configured to run in synchronous (sync.) condense mode is driven as a motor by power from the grid, but does not have water running through it. When switching from sync. condense to generate mode, water is let into the turbine to provide power to spin the generator and power is then provided to the grid.

The peaking hydro units not configured as synchronous condensers can be started and stopped quickly (fractions of a minute) in response to the load demand. However, when configured to operate as synchronous condensers, peaking units can typically transition to generate mode in as little as a few seconds. The quick transition time can enable the generator to operate as spinning reserve (short-term energy storage). However, these generators are not necessarily useful for long-term energy storage because the existing reservoir water is used for operation (there is no additional storage). When the generators are operated in sync condense mode an additional benefit to the Yukon Integrated System would be that voltage/VAR support can be provided to the network.

Depending on the units selected for conversion to sync condense mode operation and the season of operation, most of the required 20 MW of spinning reserve could be met. Once the new Mayo B Generating Station is in service, conversion of the original two Mayo units could be performed to provide 5 MW of spinning reserve. In the winter, there is insufficient water to operate all the Whitehorse generators, so conversion of the WH1, WH2, and/or WH3 generators could provide up to 8 MW of winter spinning reserve. Also, in most past summers, the Aishihik AH1 and AH2 units have been seldom operated, so conversion of those units could provide 30 MW of summer spinning reserve. It must be noted that the Whitehorse and Aishihik generators are presently used as non-spinning reserve generation, but they must be manually started and synchronized, and this process takes minutes.

Conversion of the existing generators to sync condenser operation for spinning reserve would allow a transition time of seconds, and is the most technically advantageous and economic alternative for short-term energy storage. It is not long-term energy storage because the amount of stored water is not increased. The cost for conversion highly depends on the specific scope for each unit, but is expected to be much less than for purchase of new spinning reserve technology.

3.2 Diesel Rotary Uninterruptible Power Supply (DRUPS)

Diesel rotary uninterruptible power supply (DRUPS) units are a combination of a diesel engine, a clutch, an electro-mechanical flywheel (induction coupling), and a motor/generator. DRUPS units are a mature technology that have been utility-proven for over 30 years and are used in a variety of installations where maintaining quality power is absolutely required. DRUPS units are able to provide always voltage/VAR support and to provide instantaneously back-up power to the network.

During normal operation, when the utility power is within tolerance, the power system drives the motor and spins the flywheel that is isolated by the clutch from the stopped diesel engine. Figure 1 and Figure 2 illustrate a DRUPS system and installation.

When the utility power is out of tolerance, the diesel engine is started automatically. While the diesel engine ramps up to speed, there is enough energy stored in the flywheel to drive the generator (motor) until the diesel is ready. When the diesel engine is up to speed, the clutch engages, connecting the diesel engine to the generator to supply continuous power.

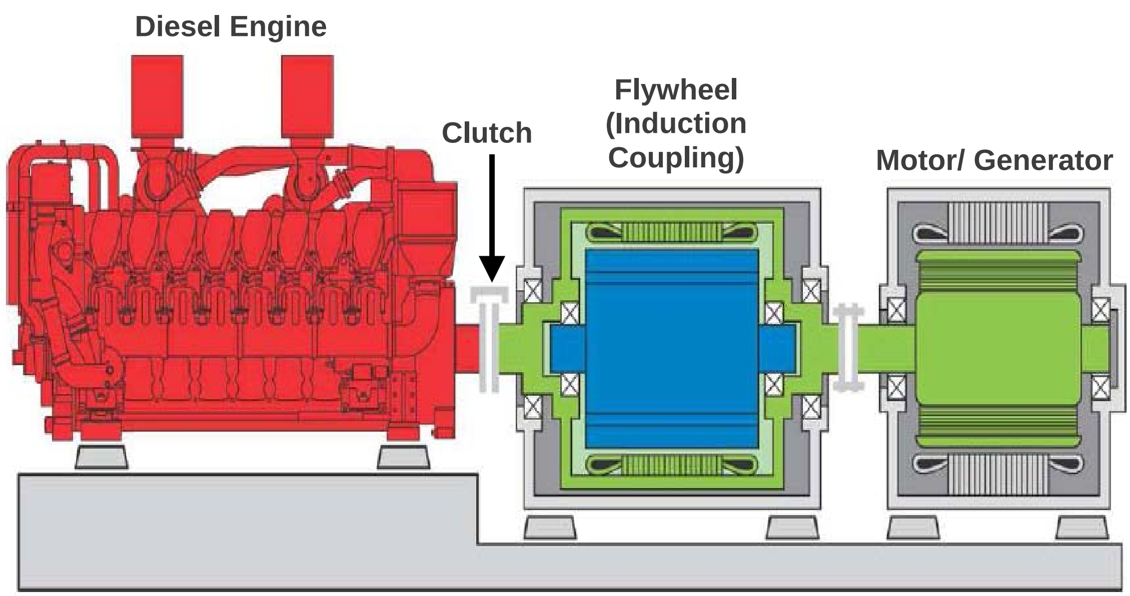

Figure 1. DRUPS System

(Courtesy: Hitec Power Protection)

Figure 2. DRUPS Installation

(Courtesy: Hitec Power Protection)

DRUPS units are available in a range of sizes with the largest being 2.5 MW. The units can be easily paralleled to achieve the desired 20 MW capacity requirement. Paralleling units also offers system redundancy and maintenance ease. In the event of a loss of grid power, and in order to reach a new equilibrium with the load, the number of DRUPS units to start could be based on the rate of change of frequency and power.

A DRUPS unit can provide emergency power for an unlimited period of time as long as the fuel is replenished. This is a key benefit of a DRUPS unit—to be able to supply power for days instead of minutes. However, except on emergency basis, DRUPS units are not suitable to provide long-term energy because it is diesel generation with high fuel costs, greenhouse gas production, and maintenance requirements.

From an electrical and maintenance perspective, the best location for a DRUPS system is the Whitehorse area, but there may be benefits to installing DRUPS in other locations such as near major load centres or transmission-grid hubs. The DRUPS units are rated for a lifetime of 25 years, and the cost is estimated to be approximately $2M/MW.

3.3 Hydro Generator Units: Pumped Storage

A pumped storage hydro system is one where energy is stored in the form of water. During periods of low electrical demand, water is pumped from a lower elevation to a higher elevation using network power to drive a specially-designed hydro generator as a pump. Then, during periods of high electrical demand, the water is released through the hydro generator and electricity is supplied to the network. Pumped storage systems offer the largest form of energy storage available and are about 75% efficient.

Pumped storage hydro is well-suited for a daily load cycle where other generation is required to run, or is available, on a continuous basis. Pumped storage is only appropriate for a load cycle that is easily predictable and only peaks a few times per day. This is because the transition from generation to pumping and vice-versa requires over 10 minutes and the permissible cycle is limited to 2 to 3 transitions per hour. Refer to Figure 3 for a diagram of a simple pumped storage system.

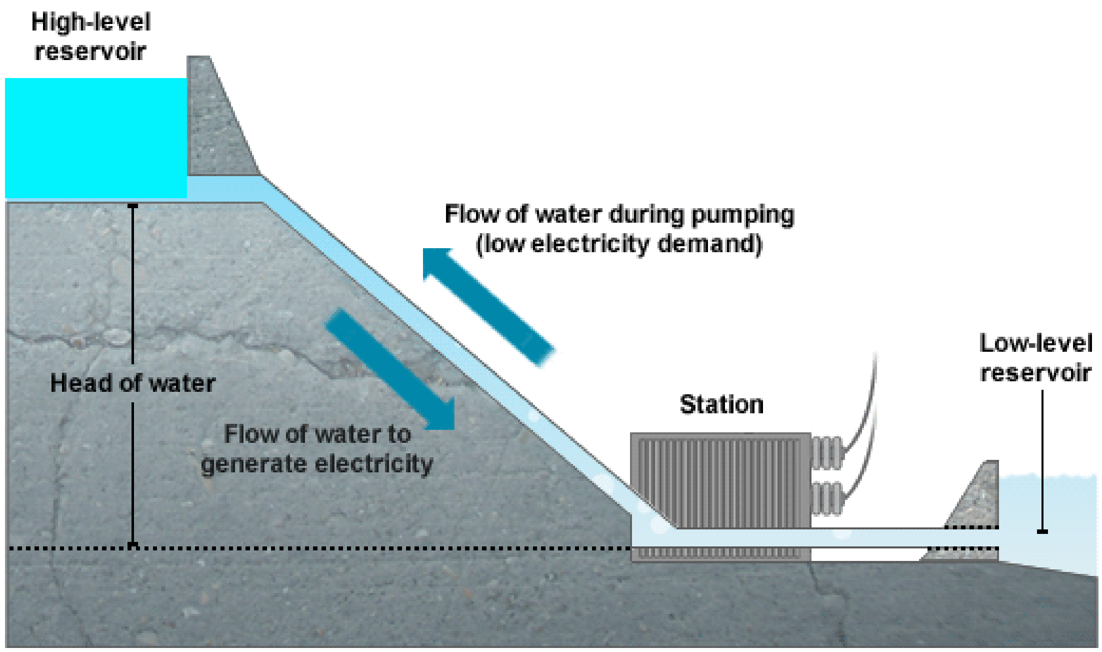

Figure 3: Pumped Reservoir Storage System

Possible types of pumped storage reservoirs include natural bodies of water, man-made dam sites, and abandoned mines. Geological and hydrological studies would need to be conducted to accurately identify suitable pumped hydro storage locations in the Yukon.

New pumped storage technology is not well-suited to meet YEC's present needs because new facility construction requires long construction times (most of a decade) and would cost in the order of $6-10M per MW, which is much higher than the cost of other alternatives. In general pumped storage would be the least cost option for only large-scale energy storage (greater than 50 MW).

4. YUKON TO BRITISH COLUMBIA TRANSMISSION INTER-TIE

A conceptual-level study estimated the cost of connecting the YEC electrical grid at Whitehorse to the BC Hydro grid at the terminus of the planned Northwest Transmission Line that is expected to start near Skeena, BC and end at Bob Quinn Lake, BC. The transmission line would be approximately 900 km long, and in addition to the terminal substations, requires three intermediate substations: at Dease Lake, BC; Watson Lake, YK; and Teslin, YK. Refer to Figure 4 for a map of the proposed route.

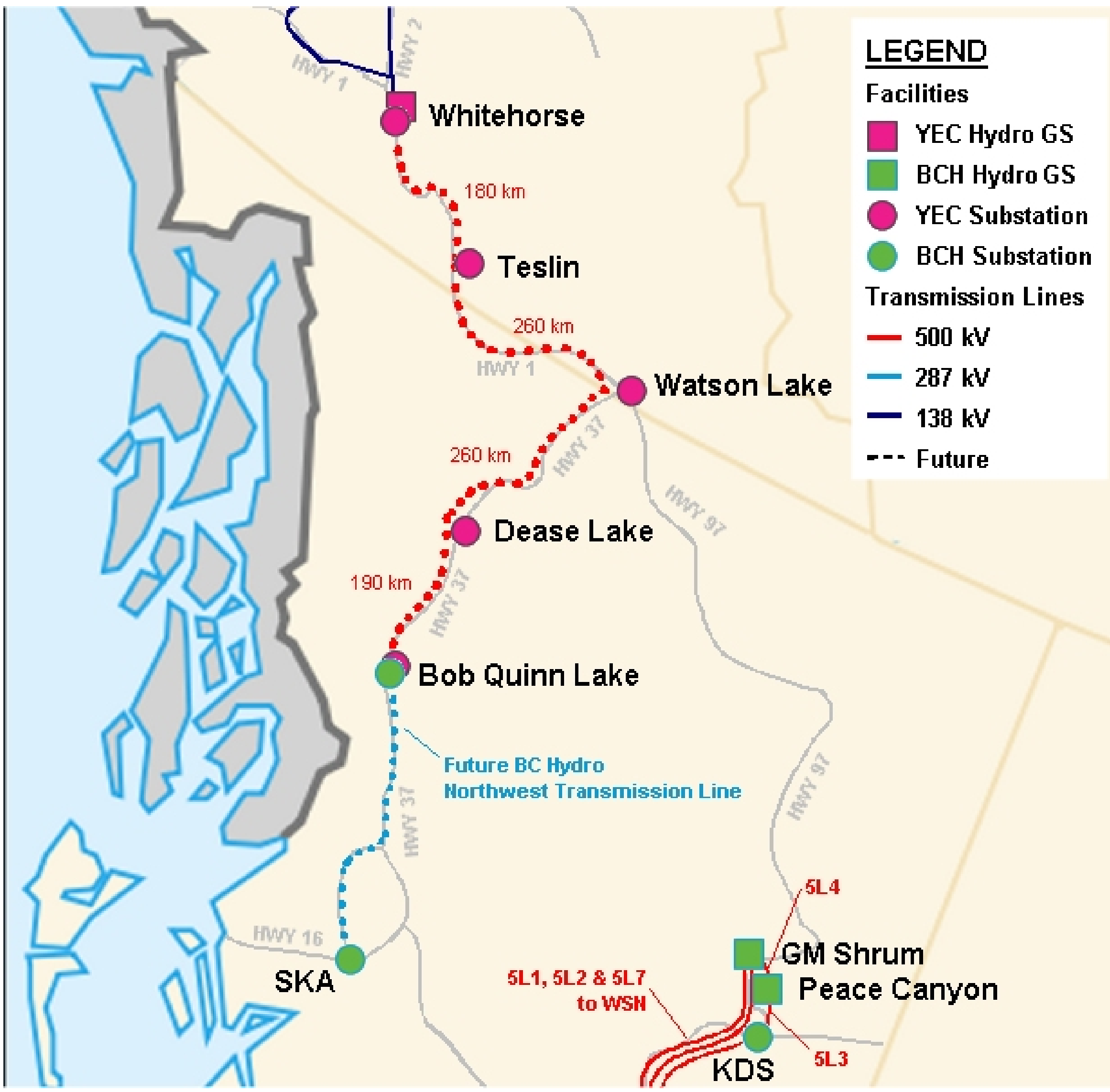

Figure 4. Yukon to BC Transmission Inter-tie

The study looked at both ac and dc transmission line alternatives (refer to Table 2). Alternative 1 was a 287 kV transmission line and it was considered to be the base case. The lowest practical voltage for power transmission over the required distance is 287 kV; and this voltage is also the proposed voltage of the Northwest Transmission Line.

Alternative 2 was a 525 kV transmission line that increased the possible power transfer by approximately a factor of four. The 525 kV voltage was selected because it is the voltage of the BC Hydro bulk transmission network, and it would allow for a relatively straight-forward, future connection to the BC Hydro grid near the G.M. Shrum and Peace Canyon generation stations.

Alternative 3 was the Alternative 2 525 kV transmission line, but initially operated at 287 kV. It was included as a way to reduce initial equipment costs, but allow for expansion to the ultimate 525 kV capacity.

Alternative 4, a ±350 kVdc transmission line, was included for comparison purposes. This line could transfer approximately 25% more power than the ultimate 525 kV alternative, but intermediate connections along the transmission line each require a dc-ac converter station or a lower voltage transmission line (increasing cost).

For any of the ac-line alternatives, inductive and capacitive shunt compensation would be required. Additionally, for any of the ac alternatives, the maximum power transfer could be doubled by the addition of series compensation, and therefore lines without and with series compensation were included in the study.

Table 2: Yukon to BC Transmission Inter-tie Summary

Alternatives	1A	1B	2A	2B	3A	3B	4
Voltage [kV]	287 ac		525 ac		287/525 ac		±350 dc
Series Compensation	No	Yes	No	Yes	No	Yes	N/A
Power Transfer [MW]	135	270	510	1,020	150	300	1,270
Cost [$M]	1236	1395	2146	2446	1871	2037	2054
Cost [% of Alt 1A]	100	113	174	198	151	165	166

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