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Executive Summary

The Colville Confederated Tribes proposed construction of a 115 to 13.8 kV substation on reservation land to be connected with the Okanogan County Public Utility District (PUD) grid. This substation would obtain the majority of its power from that produced by the Colville Indian Power and Veneer (CIPV) power plant that provided electric power and process steam for the wood processing facility.

There were two major contributing factors to the Tribe's decision to construct its own substation: the ability to have a level of self-sufficiency with regard to electricity; and, the ability to recapture a five percent energy loss that was occurring by sending the power produced on tribal lands to a substation several miles away. Using a typical transfer of 3000 kW on average transferred across the original 13,200 Volt distribution line, a conservative estimate of 80,000 kilowatt hours each month are saved by the 115 kV interconnection.

The substation was built in 2003 as a joint effort between the Tribe through CIPV and the PUD. The substation is connected to an existing 115 kV transmission line that crosses CIPV property and is very close to the CIPV power plant. The installed capacity is 20 MVA. As such, the substation removes the 10.5 MW transfer capability bottleneck and if fuel economic conditions are favorable, the plant can generate as much as 15.6 MW if advantage is taken of the generator power factor loading capacity.

The substation provides substantially improved voltage and power transfer capability for both the plant and the Okanogan PUD. The power produced is considered "green" because it is derived from a renewable resource and the substation connection enables the production of 5000 kW more of this green energy to serve the area at full plant output.

Project Overview

The CIPV plant electrical system was interconnected with the Okanogan PUD by a link adjacent to the 13,200 Volt distribution line. This connection was rated at 10.5 mega-Watts for power produced by the plant and delivered to the PUD's substation busbar at the Okanogan Substation. The distribution line was only 4.3 miles long, but resulted in an average contractual loss of five percent (5%) of the energy generated and delivered to the substation. The electrical peak demand credited to the plant was assigned an average contractual loss of seven percent (7%) as peak demands occur at times when the electrical system is heavily loaded, hence more incremental loss occurs for the transfer of power.

In addition to the large losses imposed by the low voltage connection to the PUD, the generation from the plant was constrained to a 10.5 MW limit. Thus the plant could not deliver the full 12.5 MW nameplate output to the Okanogan substation busbar. Thus occasional opportunity of inexpensive fuel supplies could not be capitalized upon.

Along with the energy and production capacity loss suffered by the existing interconnection, the 13,200 Volt distribution line connection resulted in less than optimum voltage regulation for both the plant and the other PUD customers connected to the line at intermediate points. The voltage stability performance did not have a significant effect on energy losses, however.

The substation was built in 2003 as a joint effort between the Tribe through CIPV and the PUD. The substation is connected to an existing 115 kV transmission line that crosses CIPV property and is very close to the CIPV power plant. The installed capacity is 20 MVA. As such, the substation removes the 10.5 MW transfer capability bottleneck and if fuel economic conditions are favorable, the plant can generate as much as 15.6 MW if advantage is taken of the generator power factor loading capacity.

Objectives

Refurbishment of boiler #1 and #2
Construction of a one-bay substation to market excess biomass-generated power
Connection to the Okanogan PUD power grid
Retention of jobs at CIPV
Use or sell excess power for future development

Description of Activities Performed

Boiler #1 refurbishment was completed and power production commenced using this boiler by 7/16/2002.

The power purchase agreement was negotiated and finalized with the Okanogan Public Utility District. This negotiation carved out only the power produced and used by CIPV and excluded the Tribe's other load-bearing facilities. The Agreement also clearly outlined ownership of equipment and facilities and developed a maintenance agreement, metering test schedule, and gave the Tribe a level of discretion with regard to how much power would be surplused.

The fuel supply agreements were also negotiated and finalized for long-term supply of biomass from both external and internal sources.

Upgrades to Boiler #2 were also completed including replacing roof tubes and installing insulation on the piping. A new insulation blanket was also purchased for the boiler to increase efficiency. The steel tubing and lower super heater loops were also upgraded and new safety features were installed.

An engineering firm was selected through competitive bid to design and construct the substation including selecting the best site and conducting environmental analysis on the proposed location.

The substation was constructed in approximately 6 months in cooperation with the Okanogan Public Utility District and the Tribe.

A test was conducted for the transmission of electricity through the newly constructed substation at varying levels of load. This was conducted over a long holiday weekend in which the CIPV plant was scheduled to be down to avoid potential disruption to employment, production or power supply.

Conclusions and Recommendations

The substation provides the Tribe with a substantial step toward energy self-sufficiency. It allows the Tribe's wood processing plant to retain employment, produce high quality veneer and provides the Tribe with an additional marketable resource.

It is recommended that, if at all possible, tribal leaders work with the local public utility district in the design process of any renewable energy project to leverage the existing knowledge of the marketing and transmission of power. If this is not possible, then tribal leaders should take full advantage of the Department of Energy's technical assistance resources, including contacting other tribes who have completed renewable energy projects.

Lessons Learned

The development of the substation is an important step for the Tribe, however, the project was not without some delays and decisions that may have been made differently had the outcomes been easier to project, such as:

Power-producing equipment

The boilers were upgraded and retrofitted to accommodate the increased load, and the generators were upgraded for efficiency. However, the increased demand on the equipment to produce excess power proved too much and the power-producing equipment had too much down time for repairs. Unidentified weaknesses in a steam line also created a lengthy delay in the project and a potentially dangerous situation. While all near crises were averted there still remains the reality that the existing equipment (boilers) need to be replaced. The Tribe is in the process of purchasing a new boiler and has plans to purchase another boiler within 12 months.

Working with the PUD

While the PUD offered a great deal of knowledge and expertise in the design process, there were some costs added to the project because of the PUD's preference to have the substation constructed a certain way and at a certain location. While these preferences were arguably wise, they also were not critical and did reflect in added costs. The PUD provided some cost-share to offset those costs and the maintenance agreement reflects the concessions made in the design and construction process.

Technical Report

Prepared by Ripplinger Engineering Laboratories as follows:

CIPV Substation Operations Manual

INTRODUCTION

Colville Indian Power and Veneer (CIPV) has commissioned the construction of a 115 / 13.8 kV substation to interconnect the Okanogan Public Utility District's 115 kV transmission line to CIPV's Omak veneer plant.

CIPV's veneer plant has a wood fired electric generating plant with an installed nameplate capacity of 12,500 kilowatts at 0.80 power factor. Under average veneer production operation, the plant consumes 5,500 kilowatts. Prior to the construction of the substation, the balance of generation was transmitted to the PUD via a 13.8 kV distribution line. The small distribution line resulted in a substantial electrical loss of up to 700 kW. As such, the distribution line was a bottleneck to CIPV generation output.

The CIPV substation has a full load rating of 20,000 kVA. This rating eliminates the bottleneck for CIPV generated power and reduces kW losses. The substation also provides the PUD with another source of power for future local industrial growth.

INTERCONNECTION & GENERAL LAYOUT

The CIPV substation is connected to the Omak-Okanogan 115 kV transmission line owned and operated by Okanogan PUD. Two 115 kV disconnect switches have been installed in series with the line on CIPV property. The midpoint of the switches has been tapped and connected to the 115 kV substation entrance structure. A 115 kV disconnect switch is included on the entrance structure to provide a local visible opening of the 115 kV supply.

HIGH VOLTAGE APPARATUS

115 KV DISCONNECT

A disconnect switch feeds 115 kV to the 115 kV substation bus and circuit breaker. The high voltage disconnect switch needs annual maintenance with regard to blade/holder engagement, phase synchronization and operator mechanism.

115 KV METAL OXIDE VARISTORS (LIGHTNING ARRESTERS)

Any lightning or switching surges are clamped to ground potential by a set of three station class metal oxide varistors (MOV). The MOV's have a non-linear resistance characteristic. The resistance of the MOV is very high when the applied voltage is low. As the applied voltage increases, the resistance remains fairly constant until a voltage "knee" is reached. Additional potential results in a steep decrease in resistance. This steep resistance decrease "clamps" the potential to a maximum value depending on the available energy of the potential surge.

The MOV has a "maximum continuous operating voltage" rating or MCOV. This is the maximum AC line to ground potential that the MOV can continuously withstand. If the applied potential is greater than the MCOV, the crest of the AC voltage may exceed the "knee" voltage. Therefore the arrestor will conduct current at each AC waveform crest. At the very high voltages used in AC power transmission, even a slight amount of conducted current results in large power dissipation by the MOV. The MOV can handle one-time dissipations of large amounts of energy but is not thermally designed to dissipate energy continuously. Therefore continuous conduction will result in rapid and excessive heating of the device.

MOVs do not require any maintenance. Generally MOVs fail catastrophically with resulting physical disintegration.

Care must be exercised to replace MOVs with the same type and style. The substation MOVs are the same as those supplied on the 115-13.8 kV power transformer and are Cooper # US096 station class arresters, 76 kV maximum continuous operating voltage.

115 kV Potential Transformers and Bus Structure

The 115 kV potential transformers are feed by a section of 2-inch national pipe size schedule 40 aluminum bus. The transformers step the high tension 115 kV down to 120/208 volts for metering and relaying use. The transformers supply synchronizing potential to synchroscopes in the substation and power plant as well.

The potential transformers are protected by secondary fuses located in a junction box directly below the transformers on the supporting structure. If any loss of metering/relay potential occurs, these fuses should be checked. The secondary fuses are 10 Amp slow type to provide PT protection and a wide coordination with the 3 and 6 amp fast fuses in the equipment panels. Thus, the fuses should be replaced with the same style and type.

The potential transformers are filled with mineral insulating oil. The level of this oil should be checked and inspected monthly for leakage.

115 kV Circuit BREAKER B-93

The 115 kV circuit breaker is capable of directly switching the power transformer and mill load on and off. In addition, the circuit breaker provides a substation disconnect means in the event of a substation or transformer fault. As such, the circuit breaker should be utilized for any switching operation requiring connection or disconnection of the 115 kV power transformer.

The 115 kV circuit breaker uses sulfur hexafloride gas (SF6) as an insulating medium. Despite the grand sounding name, SF6 is non-toxic although it displaces air so it is capable of asphyxiation. Its non-reactive properties make it extremely capable of quenching the electrical arc formed between the circuit breaker electrodes.

It is recommended that the circuit breaker be operated via the control switch inside the substation control building although a control switch exists inside the breaker auxiliary compartment. This is due to the violent nature of high voltage circuit breaker operation and the extremely remote possibility of an internal fault occurring during such operation.

The circuit breaker is a complex piece of high voltage apparatus and requires maintenance. Every month the following checks should be made to breaker subsystems:

1. Red light emitting diode (LED) on control house control panel adjacent to the breaker control switch should be lit if the breaker is closed. This indicates that the breaker trip circuit has continuity and the breaker is ready to respond to a trip signal from a protective relay.
2. The SF6 gas pressure is of sufficient density. Please refer to the instruction book gas density versus pressure-temperature graph. Low gas density is cause for

immediate refill operations and leak detection. A fluorocarbon (refrigerant) type leak detector provides an extremely sensitive method of detection.

3. The AC 120/240 Vac auxiliary power is energized. The auxiliary cabinet courtesy lamp may be operated for this check. Note that if the courtesy lamp is burned out, the bulb must be replaced with a rough service type in order to withstand the violent vibration of circuit breaker operation.
4. The AC aux. cabinet heaters have heat emanating from the surface. Note, use extreme caution as the surface of a properly operating heater is extremely hot and may cause severe skin burns.
5. The pneumatic air pressure system has proper air pressure in the receiver. Please refer to appropriate circuit breaker instruction manual.
6. The case-grounding conductor should be inspected for proper connection and damage.

Once every three to five years, the high voltage connections should be inspected and micro-Ohmmeter (Ductor) tests taken to verify connection integrity.

Instrument current transformers located in the circuit breaker apparatus bushings provide indication of electric current for each breaker phase for protective relay operation.

Tripping and closing of the 115 kV breaker is supervised by control house electronics. The control electronics provides a logical "and" function to ensure the 115 kV breaker is not closed when the 115 kV and 13.8 kV systems are out of phase or not synchronized. Please refer to the Control System Operation section of this manual for further information.

115 kV to 13.8 kV Power Transformer

The power transformer provides a step-down connection between the 115 and 13.8 kV systems. The transformer is a standard step-down design even though in this application power can flow either direction through the transformer. The PUD chose a standard design transformer so that the transformer is identical electrically to other PUD transformers, thus replacement and upgrade is facilitated.

The 115 kV winding of the transformer is connected in delta configuration. As such, no zero sequence current (line to ground) current can be supplied to the 115 kV system by the transformer.

The 115 kV apparatus bushings on the transformer contain instrument current transformers that are used by the protective relays to "look" out on the 115 kV transmission line. Protective relay operation shall be discussed in the section on instruments and controls.

The power transformer requires inspection and maintenance. Every month the following checks should be made to the transformer:

1. Nitrogen gas supply cylinder pressure should be recorded. Nitrogen usage is an indication of a leak in the gas space area or gas plumbing system.
2. Transformer tank and cooling system should be inspected for oil leaks.
3. Transformer fans should be engaged electrically and each fan checked for proper rotation.
4. Cabinet heater (if equipped) checked for heat output.
5. Oil containment area drained of water and accumulated precipitation.
6. Oil level in high voltage bushings checked by visual inspection.
7. The case-grounding conductor should be inspected for proper connection and damage.

In addition to the monthly checks, other periodic checks and test should be preformed:

A. Once a year a sample of transformer insulating oil should be taken from the sample valve and sent in to a liquid dielectric laboratory for analysis. A record of oil samples is vital in diagnosing transformer performance. Many failures may be predicted and/or prevented by proper oil sampling. Oil sampling may indicate the need for oil filtration and/or vacuum degassing.

B. Every three to five years a power factor (Doble) test should be preformed to verify transformer insulation integrity. A power factor test, like oil sampling, can provide a very accurate method of predicting and preventing catastrophic insulation and winding failure.

C. Every three to five years the H and X connections should be inspected and micro-Ohmmeter (Ductor) tests taken to verify connection quality.

D. Every three to five years all transformer protective relays and alarms should be tested to verify proper operation. These relays consist mainly of pressure and temperature devices attached to the transformer. Please refer to the transformer documentation and anunciator drawings.

13.8 kV Metering Transformers

The 13.8 kV metering system is composed of three 8400: 120 Volt transformers and three 600: 5 current transformers. The output of these transformers is sent to the PUD revenue meter that accounts for the electrical interchange between CIPV and the 115 kV system. The potential transformers also supply potential to protective relays and sychroscopes.

The potential transformers are protected by secondary fuses located in a junction box directly below the transformers on the supporting structure. If any loss of metering/relay potential occurs, these fuses should be checked. The secondary fuses are 10 Amp slow type; to provide PT protection and a wide coordination with the 3 and 6 amp fast fuses in the equipment panels. Thus, the fuses should be replaced with the same style and type.
The 13.8 kV potential and current transformers do not contain oil; they are insulated by a solid dielectric. Solid dielectrics are not "self healing" types. It is imperative that if any

cracks develop in the molded case, the transformer should be removed from service immediately and replaced with a spare.

13.8 kV Circuit Breaker B-1000

The 13.8 kV circuit Breaker provides a connection from the main 13.8 kV bus to the mill voltage regulators and the section of 13.8 kV line that runs to the 13.8 kV PUD normally open recloser. In normal operation, the 13.8 kV breaker provides a protection and disconnecting means for the CIPV mill.

The circuit breaker is a complex piece of high voltage apparatus and requires maintenance. Every month the following checks should be made to breaker subsystems:

1. Red light emitting diode (LED) on control house control panel adjacent to the breaker control switch should be lit if the breaker is closed. This indicates that the breaker trip circuit has continuity and the breaker is ready to respond to a trip signal from a protective relay.
2. The insulating oil level is sufficient.
3. Tank should be checked for oil leaks.
4. The AC 120/240 Vac auxiliary power is energized.
5. The AC aux. cabinet heaters have heat emanating from the surface. Note, use extreme caution as the surface of a properly operating heater is extremely hot and may cause severe skin burns.
6. The breaker operating spring is charged. Please refer to appropriate circuit breaker instruction manual.
7. The case-grounding conductor should be inspected for proper connection and damage.

Once every three to five years, the high voltage connections should be inspected and micro-Ohmmeter (Ductor) tests taken to verify connection integrity.

Also, once every three to five years, a sample of insulating oil should be taken from the sample valve and sent in to a liquid dielectric laboratory for analysis. A record of oil samples is vital in diagnosing breaker performance. Many failures may be predicted and/or prevented by proper oil sampling. Oil sampling may indicate the need for oil filtration and/or vacuum degassing

Instrument current transformers located in the circuit breaker apparatus bushings provide indication of electric current for each breaker phase for protective relay operation.

Tripping and closing of the 13.8 kV breaker is supervised by control house electronics. The control electronics provides a logical "and" function to ensure the 13.8 kV breaker is not closed when the 115 kV and 13.8 kV systems are out of phase or not synchronized. Please refer to the Control System Operation section of this manual for further information.

13.8 kV Voltage Regulators

The voltage regulators stabilize the voltage for the CIPV mill. In addition, the voltage regulators decrease the voltage slightly to 13.2 kV as many of the mill transformers are set to the 13.2 kV tap.

The voltage regulators are complex pieces of high voltage apparatus and require maintenance. Every month the following checks should be made to breaker subsystems:

1. The insulating oil level is sufficient.
2. The tank should be checked for oil leaks.
3. The surge suppressor/lightning arrester should be visually inspected for signs of damage.
4. The control panel should be checked for proper voltage output with an accurate voltmeter. The voltage of the source potential transformer is brought out on two binding posts on the lower part of the regulating panel.
5. The regulator should be manually stepped up one or two steps and then placed in automatic. The regulator should step down one or two steps automatically.
6. The regulator should be manually stepped down one or two steps and then placed in automatic. The regulator should step up one or two steps automatically.
7. Once a year a sample of regulator insulating oil should be taken from the sample valve and sent in to a liquid dielectric laboratory for analysis. Regulator operation is especially demanding of insulating oil. The regulator contains both transformer elements and operating metallic contacts, much like a circuit breaker. The regulator transformer insulation is subjected to arc induced oil breakdown products emanating from normal tap changing contact operation. A record of oil samples is vital in diagnosing regulator performance. Many failures may be predicted and/or prevented by proper oil sampling. Oil sampling may indicate the need for oil filtration and/or vacuum degassing. If regulator oil tests below 20 kV dielectric strength or appears very black, similar to used crankcase oil, oil should be simply discarded and new oil placed in the regulator.
8. Every three to five years a power factor (Doble) test should be preformed to verify regulator insulation integrity. A power factor test, like oil sampling, can provide a very accurate method of predicting and preventing catastrophic insulation and winding failure.
9. Every three to five years the H and X connections should be inspected and micro-Ohmmeter (Ductor) tests taken to verify connection quality.

13.8 kV Voltage Regulator Bypass Switches

The regulator bypass switches enable individual voltage regulators to be removed from service for repair or replacement. It is imperative that the regulator be placed on electrical "neutral" before the bypass switch is operated. If the regulator is not placed on neutral when the bypass is operated, a direct short circuit will result on the regulator buck/boost winding. This winding is essentially the secondary of a step down transformer supplied by the high voltage primary. Thus very high short circuit fault current will flow in the windings as well as the bypass switch. In most instances, this will result in immediate and catastrophic failure of the regulator buck/boost transformer and /or other internal apparatus. In addition, the fault current may be large enough to cause a large pressure increase inside the regulator tank. This pressure increase is usually large enough to result in failure of the regulator tank and seals. Upon release of this pressure, the regulator may spray operating personnel with hot or even burning insulating oil. Very serious injury or death may result from this failure.

Station Service Transformers

Two 10-kVA service transformers provide power for the station control house and all auxiliary equipment. The transformers are connected in open delta so that 240 Vac three phase as well as 120/208 is available. The transformers may be disconnected via 15 kV primary fuses adjacent to the transformers.

Low Side Lightning Arresters

Three USA010 Cooper lightning arresters are provided on the low side structure to prevent any lightning or switching surges from entering the substation. They are identical to the transformer low side arresters to simplify the provision of spare units. They have a maximum continuous operating voltage of 8.4 kV.

MOVs do not require any maintenance. Generally MOVs fail catastrophically with resulting physical disintegration.

Care must be exercised to replace MOVs with the same type and style.

Control System Operation

The control system operation is very complex. Schweitzer microprocessor relays are utilized to minimize wiring and maximize the available protective and control functioning. It is recommended that only personnel trained and experienced with this type of protective relay perform any testing or modification to the control system. In addition to microprocessor control, standard manual switches and autonomous synchronizing equipment has been included in the substation control for operator indication and back up should any automatic function fail.

The control system is best broken down into groups of equipment that serve the respective outdoor high voltage apparatus:

115 kV Circuit Breaker B-93:

Synchronizing: In order to close the 115kV breaker the control switch handle has to be turned toward the close position and at the same time the 115 kV and 13.8 kV systems have to be within 10 degrees of phase and within a set frequency margin (0.2 Hz) from each other. The SEL 421 protective relay receives a close request from the control switch and determines if the two systems are within proper phase and frequency margins. The synchroscope displays phase and frequency information to the operator. The 115 kV breaker has dual control switches and synchroscopes; one set in the substation control house and the other in the CIPV powerhouse. Thus, closing of the 115kV breaker may be preformed at either location.

To close the breaker, the operator observes the synchroscope. The synchroscope indicates "fast" and "slow" directions of rotation with respect to an "incoming machine". Thus the direction is with respect to the 115 kV system being the "running" system and the 13.8 kV system being the "incoming". Speeding up the generators in the CIPV powerhouse will tend to move the synchroscope in the "fast" direction. The speed of the synchroscope needle rotation is determined by the heterodyne of the two power systems (frequency difference). The incoming system must be speeded up or slowed down so that the synchrosope needle moves very slowly.

Two heterodyne lamps are included above the synchroscope to aid the operator in synchronizing and to provide a final check on proper phase rotation. The left lamp displays the voltage vector difference between phase B of the 115 and 13.8 kV systems. The right lamp displays the voltage vector difference between phase A. Both lamps should illuminate and extinguish in synchronism. Both lamps should extinguish as the synchroscope reaches the 12 o'clock needle position. If the phase rotation on the 115 or 13.8 kV systems have, for some reason, been changed and the rotation of one system is reversed, the heterodyne lamps will not flash in synchronism. Under this condition no attempt should be made to close the breaker. An investigation should be carried out to determine the reason for the reverse rotation.

Phase shift Note:

A phase shift greater than 10 degrees may exist across the 115 kV breaker due to the particular status of the 115 and 13.8 kV systems. Power transfer across the 115 kV system results in a phase shift along the transmission system. In addition, if the CIPV plant load is being fed via the 13.2 kV Okanogan – CIPV distribution line, the distribution line introduces a large phase shift. In general, electrical phase shift leads toward areas of generation (upstream so to speak) and lags toward areas of load (downstream). A positive phase shift (lead) of approximately 5 degrees with respect to the 115 kV system can occur through the substation's step up transformer at a generation level of 12.5 MW. A negative phase shift (lag) of approximately 9 degrees with respect to the local 115 kV system can occur with a plant load of 5.5 MW and a total load at the Okanogan substation of 9.5 MW. The difference of these phase angles is 14 degrees. This phase shift may exist across an open 115 kV or 13.8 kV circuit breaker. The phase shift may be displayed on the SEL 351A or SEL 421 protective relays by entering the metering function from the front panel.

As explained earlier in this explanation a phase shift greater than 10 degrees does not allow closing of the open breaker. The remedial action to allow closing of the breaker is to reduce the CIPV generation or load to reduce the phase shift to less than 10 degrees. This has to be conducted only for a long enough time to allow a close command to the breaker via the control switch.

Protection and Control:

The 115 kV circuit into the substation is protected by the SEL 421 relay. This relay is a multifunction unit that contains a great many protective functions. It is beyond the scope of this manual to explain all of the 421 settings and control logic, please refer to the 421 CD ROM instruction manual for a detailed explanation. The 421 is utilized for four major functions in the CIPV substation:

A. Supervision of synchronizing across the 115 kV circuit breaker. The circuit breaker cannot be closed unless the 421 synchronism check functions are satisfied. The two systems must be within 10 degrees and 0.2 Hertz of each other. The 421 also allows the breaker to close if the line or the substation is de-energized or if both are de-energized. This provides operational flexibility for unforeseen circumstances.

B. The 421 will trip the circuit breaker for 115 kV line faults within 10 miles of the substation. For faults further out on the 115 kV system, the 421 will allow Omak and Okanogan breakers time to clear the fault. If these breakers fail, the 421 zone 2 function will operate.

C. The 421 will trip the circuit breaker for unbalanced 115 kV system voltage. If the 115 kV system becomes disconnected from the Omak and Okanogan substations and the 115 kV system becomes unbalanced for any reason, the 421 will trip the circuit breaker in 12 cycles. The intentional 12-cycle delay provides a measure of protection from false trips. This function provides protection yet allows the CIPV system to support the 115 kV system as a small "island" if conditions allow.

D. The 421 provides over and under frequency protection for the CIPV generation. If the 115 kV system does become islanded and the CIPV turbine governors cannot provide frequency regulation within 0.2 Hertz of 60 Hertz, the 421 will open the 115 kV circuit breaker. This function allows the CIPV system to support the 115 kV system if the prime movers have adequate power available. If the prime movers capability is not matched to the load or the governors cannot control the speed properly, the CIPV generation must be isolated from the 115 kV system very quickly. If the prime movers do not have enough power to supply the resulting island, the frequency will decay, thus tripping the breaker at 59.8 Hertz. This will automatically shed 115 kV load and give the prime movers a chance to regain proper speed. If the prime movers are operating at a power level in excess of the island load and the governors cannot react quickly enough to prevent over-speed, the 421 will protect the 115 kV system from over frequency by tripping at 60.2 Hertz.

115 – 13.8 kV Transformer:

Protection:

The power transformer is protected by a combination of SEL 387E and a SEL 551 for back up. The SEL 387E supervises a "protection zone" that consists of the 115 kV circuit breaker, the 115-13.8 kV power transformer, the 13.8 kV circuit breaker, the substation 13.8 kV bus-work, the short transmission line to the power plant, the power plant bus, and the power plant 13.8 kV circuit breakers. A fault in any of this apparatus results in high speed tripping of the substation "86" lockout relay. The "86" relay will trip and lock out the 115 and 13.8 kV circuit breakers and send a transfer trip to the generator "86" lock out relays. Even though this may seem to be a lot of equipment protected by the SEL 387E zone, the exposure to lightning and nuisance trips is minimal. A fault in this transformer and bus-work zone is considered critical, however, and requires fast tripping of all connected equipment. If a 387 lock out trip does occur, a careful and thorough investigation as to the cause of the fault must be determined before an attempt is made to re-energize this zone.

The 387E provides over-fluxing protection for the transformer also. The 387E will send a trip to the "86" if the voltage exceeds 110 % of the normal "Volts per Hertz".

The SEL 551 provides simple overcurrent backup for the transformer and trips the 115 kV and 13.8 kV breakers.

Annunciator:

The transformer annunciator provides illuminated targets for various transformer alarms and trips.

A brief description of each of the transformer inputs to the annunciator is:

A. 63SP - Sudden pressure relay – trips lockout.
B. 63PR- Pressure relief device – trips lockout
C. 26Q - Oil temperature gauge 105^0 C. – trips lockout
D. 26Q- Oil temperature gauge 100^0 C. – Alarms
E. 71Q- Oil level gauge – Alarms
F. 49T- Winding temperature gauge – trips lockout
G. 63V- Vacuum switch (-) 7 psi- Alarms

H. 63P- Pressure switch (+) 10 psi- Alarms
I. 63L- Nitrogen cylinder, set at 150 psi – Alarms

13.8 kV Circuit Breaker B-1000:

Synchronizing: In order to close the 13.8 kV breaker the control switch handle has to be turned toward the close position and at the same time the 115 kV and 13.8 kV systems have to be within 10 degrees of phase and within a set frequency margin (0.2 Hz) from each other. The SEL 351A protective relay receives a close request from the control switch and determines if the two systems are within proper phase and frequency margins. The synchroscope displays phase and frequency information to the operator. The 13.8 kV breaker has dual control switches and synchroscopes; one set in the substation control house and the other in the CIPV powerhouse. Thus, closing of the 13.8kV breaker may be preformed at either location.

To close the breaker, the operator observes the synchroscope. The synchroscope indicates "fast" and "slow" directions of rotation with respect to an "incoming machine". Thus the direction is with respect to the 13.8 kV PUD system being the "running" system and the CIPV 13.8 kV system being the "incoming". Thus speeding up the generators in the CIPV powerhouse will tend to move the synchroscope in the "fast" direction. The speed of the synchroscope needle rotation is determined by the heterodyne of the two power systems (frequency difference). The incoming system must be speeded up or slowed down so that the synchrosope needle moves very slowly.

Two heterodyne lamps are included above the synchroscope to aid the operator in synchronizing and to provide a final check on proper phase rotation. The left lamp displays the voltage vector difference between phase B of the PUD and CIPV system. The right lamp displays the voltage vector difference between phase A. Both lamps should illuminate and extinguish in synchronism. Both lamps should extinguish as the synchroscope reaches the 12 o'clock needle position. If the phase-rotation on the PUD or CIPV kV systems has, for some reason, been changed and the rotation of one system is reversed, the heterodyne lamps will not flash in synchronism. Under this condition no attempt should be made to close the breaker. An investigation should be carried out to determine the reason for the reverse rotation.

Phase shift Note: The same discussion on phase shift applies to the 13.8 kV breaker as the 115 kV breaker.

Protection and Control

The 13.8 kV circuit out of the substation is protected by the SEL 351A relay. This relay is a multifunction unit that contains a many protective functions. It is beyond the scope of this manual to explain all of the 351A settings and control logic, please refer to the 351A CD ROM instruction manual for a detailed explanation. The 351A is set up for basic overcurrent protection of the CIPV mill feeder. It has reclosing capability but has not be set up to reclose, as the mills system is small.

Station DC Battery Bank System

A 135 Vdc battery system provides dc power to the protection and control system. It consists of a 135 Vdc switching power supply and battery bank. The switching power supply output has negligible voltage ripple and can be used to operate the DC system with or without the battery bank connected. It is capable of 10 Amps of current and is feed from a 120 Vac circuit breaker in the AC station service panel.

The battery bank consists of ten 12 V batteries connected in series. The normal float voltage as set by the power supply is 2.25 volts per cell or 2.25x60 = 135.0 Volts. The bank is connected to the DC bus by a 100-Ampere circuit breaker adjacent to the bank.

Each cell of the bank should be checked monthly for proper electrolyte level. Only distilled water should be used to top off the bank cells. Once per year the bank cells can be equalized by first toping off the cells with distilled water and then setting the power supply for an equalize of 2.35 volts per cell or 2.35x60 = 141.0 Volts. Care should be used when setting the equalize voltage on the power supply as the supply has a "square" volt/current curve. If an attempt is made to increase the voltage to 141 Volts and the battery requires more than 10 Amps of current, the power supply will limit the terminal voltage to the battery to less than 141 Volts in order to maintain the output current at 10 amps. Thus, it is possible to turn the equalize setting too high. When the bank comes up to equilibrium the equalize voltage may be too high causing bank damage. The proper way to adjust the equalize voltage is to increase the equalize setting slowly while observing the power supply output current. If the output is less than 10 amps, the equalize setting may be increased. If the output approaches 10 amps, the operator must wait to increase the setting until the current drops, then the equalize voltage may be again increased toward 141 Volts. Once the equalize voltage reaches 141, the bank may be left on equalize for about 4 hours. After the 4 hours the power supply may be switched back to the float setting and the bank cells again checked for proper water level.
Under and overcharging, as well as the failure to use distilled water for topping cells off are the leading cause of premature battery bank failure. Even inexpensive batteries should last more than ten years if properly maintained.

Heating Ventilating and Air Conditioning System (HVAC)

The control house is heated and cooled by a combination of baseboard electric heaters and large air conditioner. Both heaters and air conditioner are over sized to minimize operating time and thus lengthen operating life span. This is especially important in an unmanned facility. If heaters or air conditioner should require replacement, they should be replaced by a comparable sized units.

The heating and air conditioning system is supervised by a three-thermostat system. One thermostat senses outdoor temperature to determine the selection of heating or air conditioning mode. If the heating mode is selected, the heating thermostat becomes active and regulates indoor temperature. If the air conditioning mode is selected, the air conditioning thermostat is selected and regulates operation of the air conditioner. The factory controls on the air conditioner should be set such that the air conditioner runs as soon as power is applied to it. This system prevents the heating and air conditioning systems to run at the same time no matter what the individual temperature settings are. It also enables different heating and air conditioning thermostat settings to be used.

Care should be taken by operating personnel to completely understand the system before changes are made to temperature settings.

APPENDIX

CIPV Substation
Simplified One Line Diagram: