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INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE

Talisman Energy Edson Cogeneration Plant Bumpless Steam and Power Switching

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Bumpless Steam and Power Switching

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Talisman Energy Inc.

I have more then 30 years of experience in the electrical field though various companies, ATCO Electric, Renaissance Energy, Husky Energy, and now in my current position with Talisman Energy Canada. I joined Talisman in January 2001 as the Power Manager for North American Operation and assumed the responsibilities of managing their electrical portfolio which includes, preparing the annual power budget, purchasing and sales of power, scrutinizing utility bills, Quality Management Plan Administer, demand side management administrator, building and maintaining 25 kV distribution systems, maintenance planning on the 240 kV transmission substation, and the design and completion of the Edson Cogen.

Memberships and Affiliations;
Past Director of Senior Petroleum Producers Association (SPPA),
Current Director of Industrial Power Consumers Association of Alberta (IPPCA),
Talisman Representative of Independent Power Producers Society of Alberta (IPPSA),
Talisman Representative on B.C. Hydro Power Smart Program
Member of Institute of Electrical and Electronics Engineers (IEEE)
Member of The Alberta Society of Engineering Technologists (ASET)

Executive Summary

Industrial sites using steam and electricity to drive their processes are now finding they have options as to their energy supplier. The traditional method of package boilers combined with a Utility power is being challenged by the introduction of Cogeneration Facilities. In the past Cogeneration was not aggressively considered as the rules for interconnection made projects uneconomical or interconnection was just not allowed. Now that most Utilities across North America are encouraging Cogeneration Plants a new partner to Industry has emerged.

The question now is what are the Risks and Rewards with having a Cogen Facility within a production Plant. The combination of Utility power with package boilers has proven to be fairly reliable and has an initial capital cost less then a Cogen Facility. The capital payout period for Cogen's are highly dependent upon fuel and power prices, and is subject to market conditions outside the control of the project. This uncertainty in long-term fuel and power prices drives a discounted price when performing initial economics. Although there are several side benefits associated with Cogen's, the one we found to attract the most interest was **"bumpless transfer on both steam and power"**. If we could design a Cogen Facility that could (a) transfer power between it's own supply and the grid without any interruption and, (b) transfer steam production from it's turbines to duct burners again without any interruption in service, we could increase the reliability of the Production Plant. Using historical data on lost production as a result of power outages can add to the economic benefits of a Cogen Facility.

This paper illustrates the design we used to implement a "Bumpless Transfer of Both Power and Steam" within our Edson Gas Plant.

Bumpless Steam and Power Switching

Table of Contents

Appendix

TALISMAN ENERGY

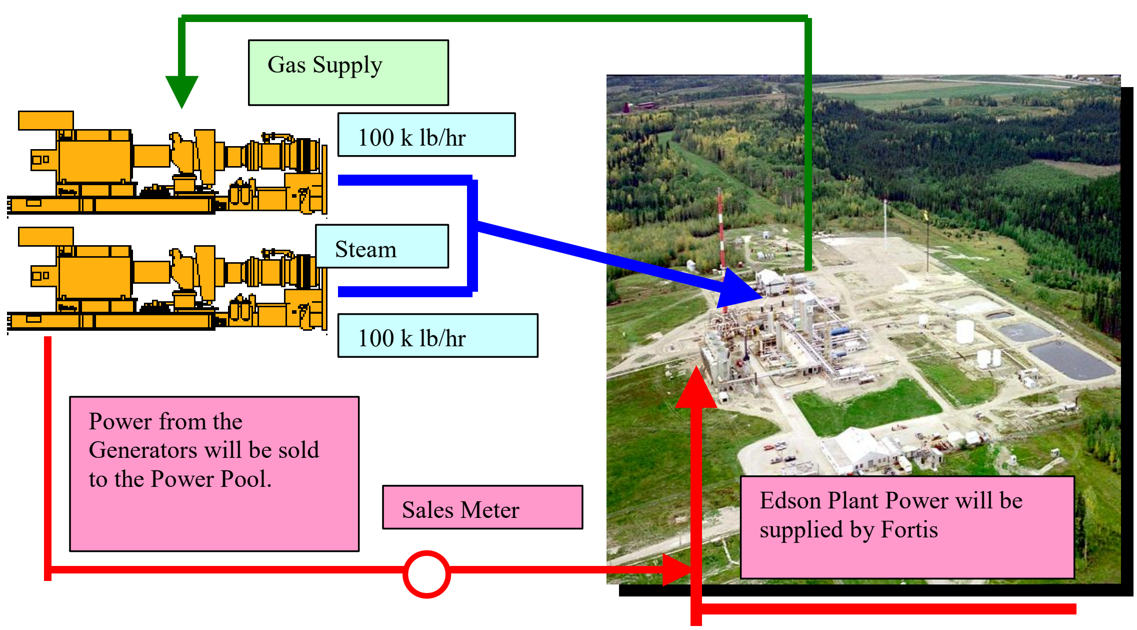
TALISMAN COGEN PROJECT
Bumpless Steam and Power Switching

1.0 Project Background

Talisman Energy Canada is the operator of the Edson Gas Plant (SW ¼ 11-53-18-W5M) on behalf of the working interest owners and holds the majority ownership with 59.43 %. Talisman Energy Inc. became an owner of the Gas Plant in 1993 with the acquisition of Encor Energy Inc. At that time, the plant was processing approximately 150 mmcf/d. With capital additions and strategic decisions, Talisman has increased inlet volumes to around 200 mmcf/d. The plant has become a "hub", producing gas through 9 inlet lines and shipping gas through 3 sales lines. Talisman's acquisition of the Central Foothills and Minehead lines has increased the reliability of gas streams and has extended the operated capture area to over 100 townships in one of the most active gas drilling areas in the province. The plant is ideally suited for a cogeneration plant since it has a high steam and power requirement with a ready supply of gas.

One of the major considerations in the Project is the reliability and control of the steam supply. The Gas Plant has a maximum steam requirement of 200,000 pounds per hour, and must maintain a minimum of 75,000 pounds per hour to avoid flaring. The basic principle of the Project is to ensure two sources of steam, each with the ability to supply a minimum of 75,000 pounds per hour and a maximum combined total of 200,000 pounds per hour. The redundancy required is of major concern to Talisman Energy Canada to minimize the environmental risk associated with flaring.

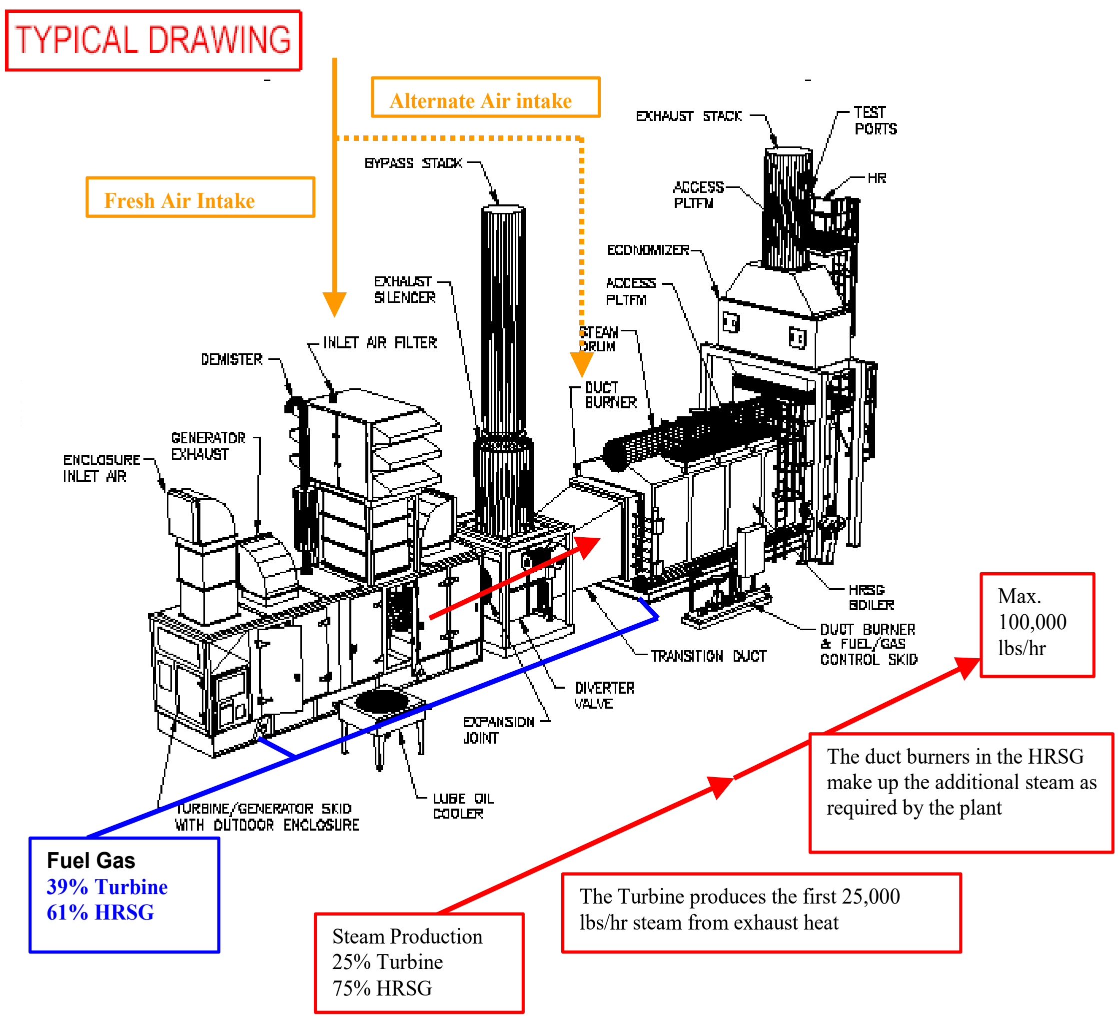
Although Talisman Energy did initially investigate using third party suppliers to own the Cogen, the decision was made to retain 100 % ownership of the Cogen. The Edson Cogen plant consists of two trains, each train consisting of a Solar Taurus 60 turbine complete with a Heat Recovery Steam Generator (HRSG). Each turbine is capable of producing 5MW of electrical power at 4160V and each HRSG is capable of producing 100,000 lbs of steam. All of the power produced is sold to the Alberta Power Pool at the hourly spot price, and the Edson Gas Plant buys its power requirements (approximately 7.5 MW) at the same spot price.



The exhaust from each turbine flows through an associated HRSG designed to produce 100,000 lb/hr of 600 psi superheated steam for use within the Edson plant. Approximately 40% of the heat duty required in the HRSG's is supplied by the turbine exhausts and 60% by supplementary duct firing. The duct burners are sized to provide the full heat duty if the turbine exhaust heat is not available. The plant presently consumes 160,000 lb/hr of 600psi steam but this figure is expected to increase in the future as more sour gas is processed. For maximum efficiency we will fire the turbines at 100% duty and the duct burners will modulate to maintain steam pressure.

Train 1 is a 300HP Induced Draft (ID) fan HRSG. The fan is driven by a steam turbine and operates continuously at slow roll.
Train 2 is a 150HP Forced Draft (FD) fan HRSG. The fan is driven by an electric motor and is not normally running.

Each Cogen train is equipped with it's own diverter (bypass) stack and isolation dampers. Each HRSG can operate with or without its turbine running and each turbine can operate in simple cycle without its HRSG firing. Each train can transition from simple to combined cycle without shutting down.



2.0 Bumpless Engineering Design

Why was bumpless transfer of the steam and electric systems so important to our project? The answer is simple, reliability.

The Edson Gas Plant had three package boilers with the ability of using a combination of any two of the three to keep the plant running at a reduced level. Any time the steam supply is reduced below 75,000 lbs, the plant is forced to shut down and flare all gas being processed within the plant. Talisman Energy's goal is reduce, as many flaring events as are possible and, operate in the most efficient, environmental and economical manner as possible. As for the plants electrical system, Fortis Alberta provides service to the plant by way of a 25 kV line. Although the line exposure of the 25 kV line is relatively short (7.5 km from the plant to the 230 kV transmission substation) to the Edson Gas Plant, the plant is not the only customer on the line. There is an additional 20 km's of line feeding an oilfield north of the plant, the majority of interruptions are a direct result of this line exposure, and is outside of our control. There is no data kept on the type or location of faults experienced on the local power grid. However, we do know there were 12 momentary and one sustained outage to the Edson Gas Plant in 2002. Further Fortis Alberta only keep one year's data on file so we have no way of knowing if 2002 was a typical year or not, but any fault, even momentary blips where the substation breaker trips and resets itself, have the potential to trip the Edson Gas Plant offline. Just to illustrate the importance of power reliability, the Edson Gas Plant did experience a 4 hour sustained outage in the fall of 2003. The combination of no power and the cold weather resulted in freezing up of sections of the plant, One 4 hour outage can result in weeks of reduced operations.

Why did we look into building a Cogen now? The answer to this question is timing.

As stated above the Edson plant has three power boilers that supply 600 psi superheated utility steam. Boilers "A" and "B" were installed in 1965, as part of the original construction of the plant. Each boiler is a John Inglis model 21 PK, rated for 96,000 lbs/hr at an efficiency of 75.3%. Boiler "C" was installed in 1971, the same model, but with a higher rating of 110,000 lb/hr and a higher efficiency of 81%. Even with our highly developed maintenance program, the boilers efficiency ratings have been slipping with age; the main cause is scaled boiler tubes, which significantly affected the heat transfer.
Also deregulation of the Alberta power industry started in 2001 giving industry the opportunity to develop new generation with a Power Pool to settle the hourly price. Up until then Cogen plants could only supply power to meet their on site power needs, and had no access to a power markets to sell any surplus energy. The Edson project gave Talisman the opportunity to take a positive step to increase the efficiency of the Gas Plant, reduce emissions and, having a means to recover the project capital through power sales.

How would the Cogen operate?

Under normal operating conditions we would have both turbines running at maximum load, generating a combined power output of 10MW to the grid and both HRSG's operating in the turbine exhaust gas (TEG) firing mode with supplementary duct firing modulating to provide 600psi steam to the plant header regulated on pressure control. The steam turbine driven BFW booster pump is operating with the electric motor driven unit on standby and the emergency generator set is not running. Parasitic loads for both trains are being fed from the 480 V MCC and critical control power from the UPS. All power generated by the Cogen would be sold to the Alberta Power Pool at the hourly spot price.

2.1 Bumpless Steam Switching

As stated before it is essential for this project to maintain a minimum of 75-80 kpph of steam production for the plant to remain sweet (not to go to flare). The existing power boilers will be shut down once the Cogen project is commissioned, therefore, one HRSG must remain in operation at all times. While either HRSG can operate in the Fresh Air Firing (FAF) mode without it's gas turbine running the problem occurs in ensuring the changeover from TEG to FAF mode takes place without losing steam production and with minimum disruption to the plant operation.

The HRSG design had to meet NFPA 85, Boiler and Combustion Systems Hazards Code which dictates that in the event of a loss of turbine exhaust flow the HRSG burner fuel gas valve must be driven to it's minimum fire position. The burners can stay at minimum fire (approx 10%) indefinitely as long as the turbine exhaust flow is maintained above 25% of it's maximum flow. Testing has shown that when a Taurus 60 unit is tripped the exhaust flow decays below the 25% level in 17 seconds. If this minimum 25% flow is lost then the burners must be shut off completely. When this happens the HRSG must go through a purge and relight procedure and steam production from that unit will be lost for approximately 5 minutes. In addition the purge flow cools the steam tubes and further collapses the decaying steam header pressure.

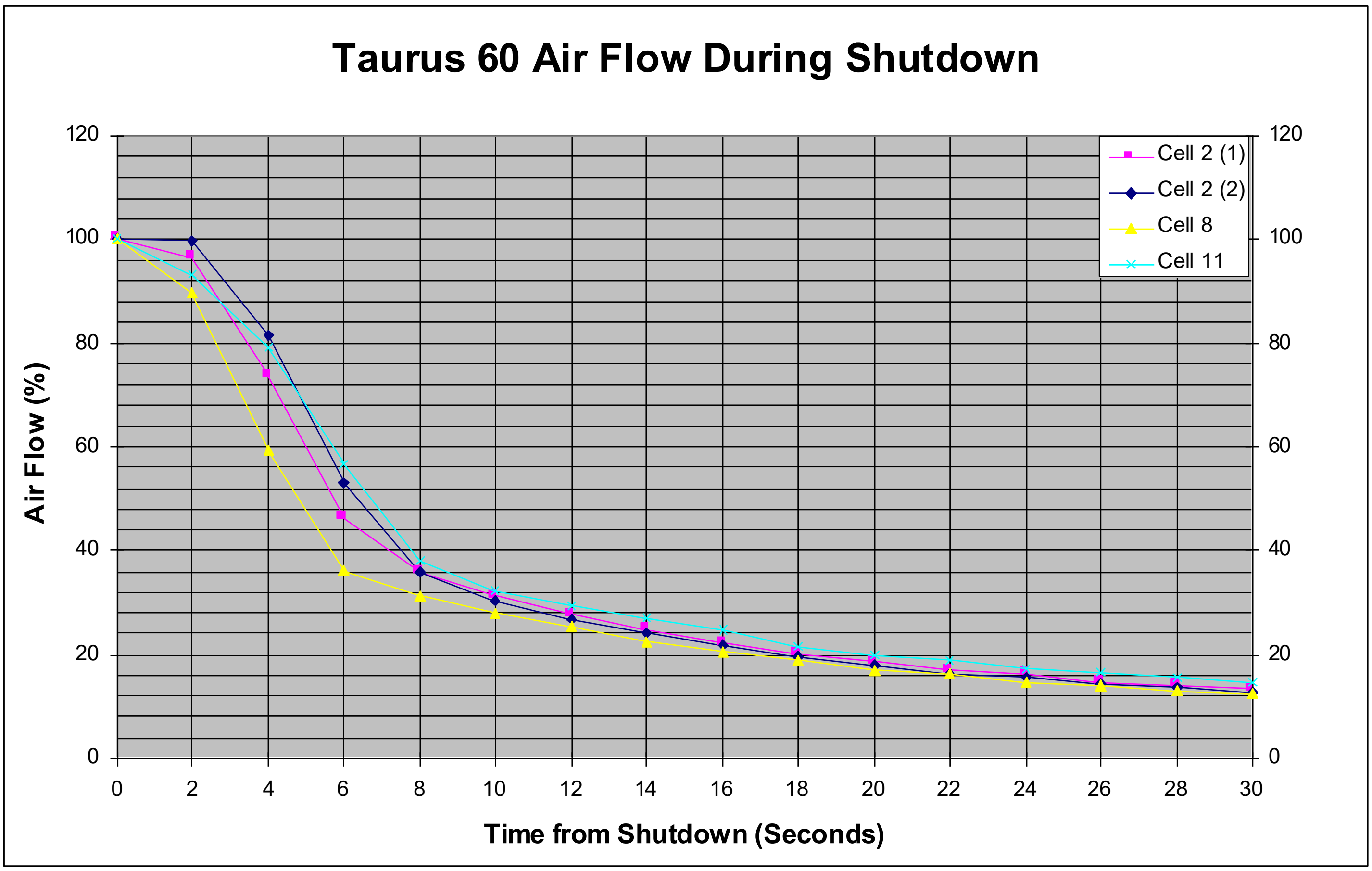
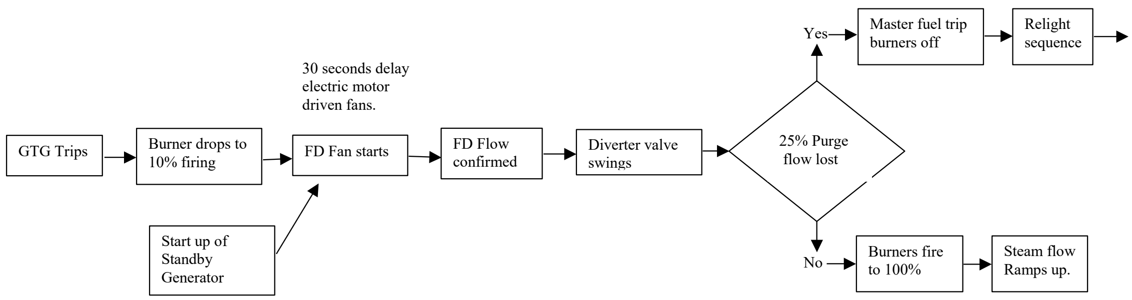


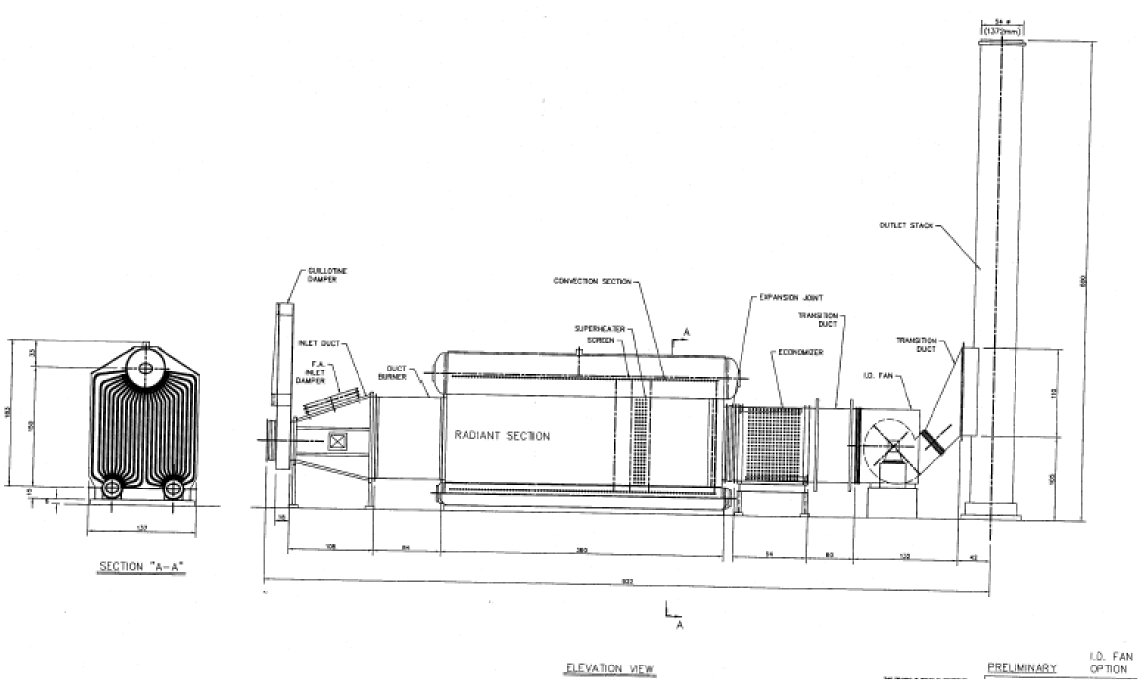
Chart #1 supplied by Solar Turbines
(the cell numbers on the chart refer to Solar test bays where the unit were tested)

Flow Chart on GTG Trip Sequence to FD Fan Operation



If steam production is lost at the plant the 600psi steam header pressure drops rapidly, approximately 40 psig in 30 seconds. Therefore a transfer from GTG exhaust firing to FD fan operation on the Cogen units would have to take place in 30 seconds or less to avoid upsetting the plant. If a burner relight sequence takes place and steam production is lost for 2 minutes this will result in the plant going down. Particularly as the purge cycle required for burner relight causes rapid collapse of the steam in the HRSG tubes. To avoid this purge and relight procedure it is necessary to ensure a fresh air supply to the burners is available, to replace the turbine exhaust, and is provided within 17 seconds from the turbine tripping. We are not aware of any installation that can make this transition with a FD design fan in 17 seconds. For this reason, train 1 employs an ID design fan.

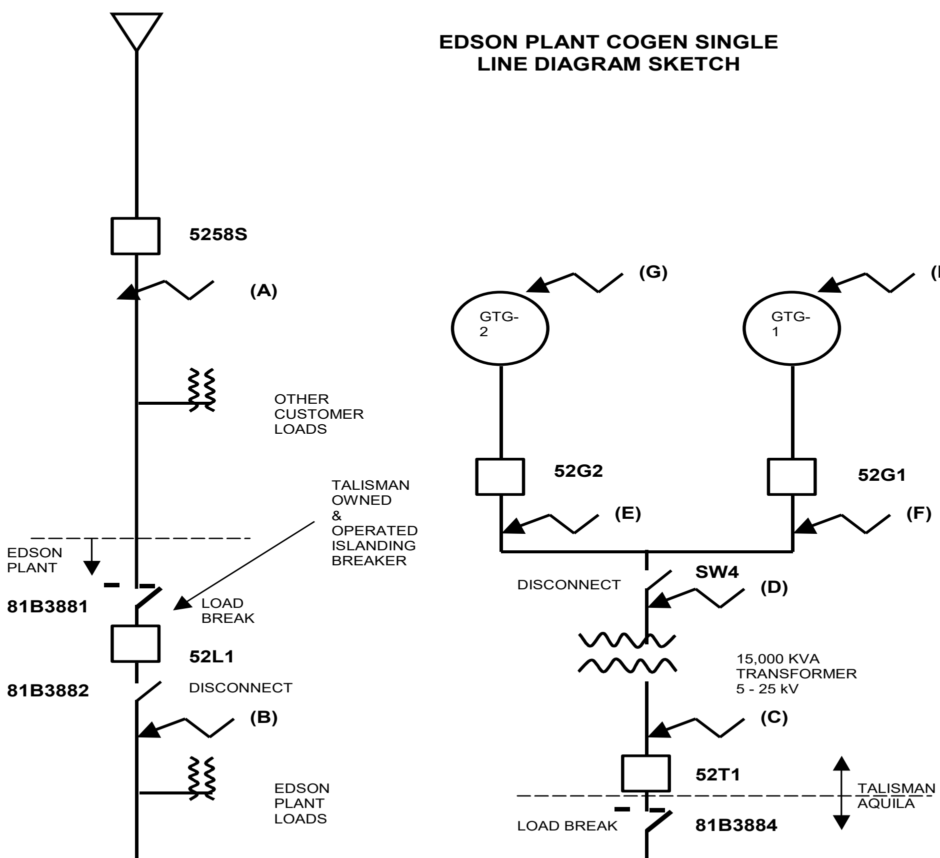
Deltak Heat Recovery Unit c/w ID Fan



The use of an ID fan design on train 1, combined with the selection of steam turbine drivers for the ID fan and two BFW pump (one steam and one electric drive), will guarantee steam reliability should the breaker trip and shut down both turbines. In the ID fan design, the fan is driven by steam and is running on slow roll continuously. This has the drawback of consuming 5600 pph of steam continuously but ensures that when the turbine trips the fan can ramped up immediately and combustion air to the burners is not lost. Steam production from the HRSG is almost continuous. By comparison the FD design is more efficient because the fan does not normally operate and consume steam. However, on a turbine trip it does take time to ramp the fan up to speed and then swing diverter valves to direct the fresh air into the burners. The time taken by this procedure is thought to be longer than the 17 seconds permitted by the Solar turbine exhaust decay curve and the HRSG burners will have to be shut off completely. The fastest time we believe that we can switch to fresh air firing is 24 seconds based on the experience from another facility. Electrically driven FD fan requires the emergency generator to start (12-15 seconds) and power the fan to speed (10 seconds). Then the airflow must be proved and the dampers swung over. However, if we can achieve Bumpless transfer of the power system the start up time for the standby generator is eliminated and we can meet the 17 second window. Should all other preventative measures fail and both turbines trip simultaneously the ID fan design of train 1 will ensure 100kpph of 600 psi steam is maintained to the plant until train 2 HRSG can be restarted.

2.2 Bumpless Power Switching

According to the historical data we collected, we found that lose of Grid power only resulted in causing the gas plant to go to flare approximately 50% of the time. It all depended on how the plant was configured at the time of the interruption and the duration of the power outage. With the addition of the Cogen we had to design a system to reduce the frequency of power outages from the grid and to insure that any interruptions within the Cogen did not impact the plant. This task was completed through a series of breakers and relay between the Utility Grid and the Cogen supply. The basic principle was to isolate the two power systems when one failed fast enough so as not to affect the Gas Plant.



Fortis Alberta (the local Utility) have agreed to allow power islanding of the Edson Gas Plant, this allows the Gas Plant to isolate its on site 25 kV power system from either the Utility grid or the Cogen during fault conditions. In order to achieve a bumpless transfer we installed an islanding breaker (52L as shown on line diagram) designed with a trip setting faster then any of Fortis's protection equipment. This breaker is also used to accommodate Altalink's (Area Transmission System Provider) requirement for a transfer trip signal used for tripping the Cogen off in the event of a fault condition on the 144 kV transmission system.

In the event of a fault within the Cogen or on the Gas Plant's 25 kV system we have installed an isolation breaker (52T as shown on line diagram). This breaker is designed to separate the Gas Plant from the Cogen in coordination with breaker 52L.

Each generator has it's own individual unit breaker (G1 and G2 as shown on sketch) and can be individually isolated. Both generators feed into the 4160kv line, which can then be isolated from the plant load and incoming power feed by the 52T breaker. Both generators are also connect to the 480V MCC that powers parasitic loads to both trains and essential building services. The standby natural gas engine powered emergency generator is also connected to the 480 V system. In the event grid power is lost the standby generator is designed to start and accept load in 15 seconds.

2.3 Bumpless Power System Upgrades

The most likely scenario that could cause both turbines to trip off line simultaneously is a fault on the Utility grid. To address this concern we determined the following measures be adopted.

- Fortis installed an additional Oil Circuit Recloser (OCR) to isolate the plant from faults occurring on the power line extension to the North and the extension to the South be rerouted to another feeder. These measures are expected to reduce the number of faults and improve grid reliability.

- Cogen miscellaneous electrical loads will be run off the 480V bus connection, which is backed up by the natural gas powered emergency generator. Control power will be fed from a UPS.

- The fault current values which trip the breakers will be set so that 52L breaker trips first, then 52T breaker then breakers G1 and G2 (generator breakers). This will provide the maximum opportunity for the plant and the Cogen's to be isolated during a grid power fault before the turbines trip offline.

- In the event of a grid fault the turbines will experience increased loading as they will be feeding fault and the turbines will slow down. Solar's normal logic is to immediately shut down the turbines on low speed, low frequency or high current. Our project will first remove the grid overload by opening 52L breaker to island the plant and reaccelerate the turbines carrying the plant load. This logic has been successfully demonstrated in the Solar test cell simulating a system load equal to 33MW with both turbines operating. Testing has shown the generator can sustain this load for 100 msecs (6 cycles) and disconnect itself, shedding the entire load without the turbine tripping. Further testing also proved the generator can also sustain the same load, disconnect the overload portion and reaccelerate with the equivalent 7.5 MW plant load connected. This gives excellent potential for the turbines to continue operating through all grid fault scenarios with both steam and power supply to the plant unaffected.

- Boiler feed water is provided by the existing BFW pumps to a new booster station consisting of two 100% duty pumps. One pump is steam turbine powered and one driven by an electric motor.

However the location and type of grid fault will affect our ability to detect the fault level quickly enough to isolate the Cogen units before the turbines trip. Therefore with no previous trip data available to us there can be no guarantee of consistently and successfully avoiding the turbines tripping. But we do believe the majority of turbine trips will be avoided by the measures taken in the electrical design.

TALISMAN ENERGY

Power System Normal operating Conditions

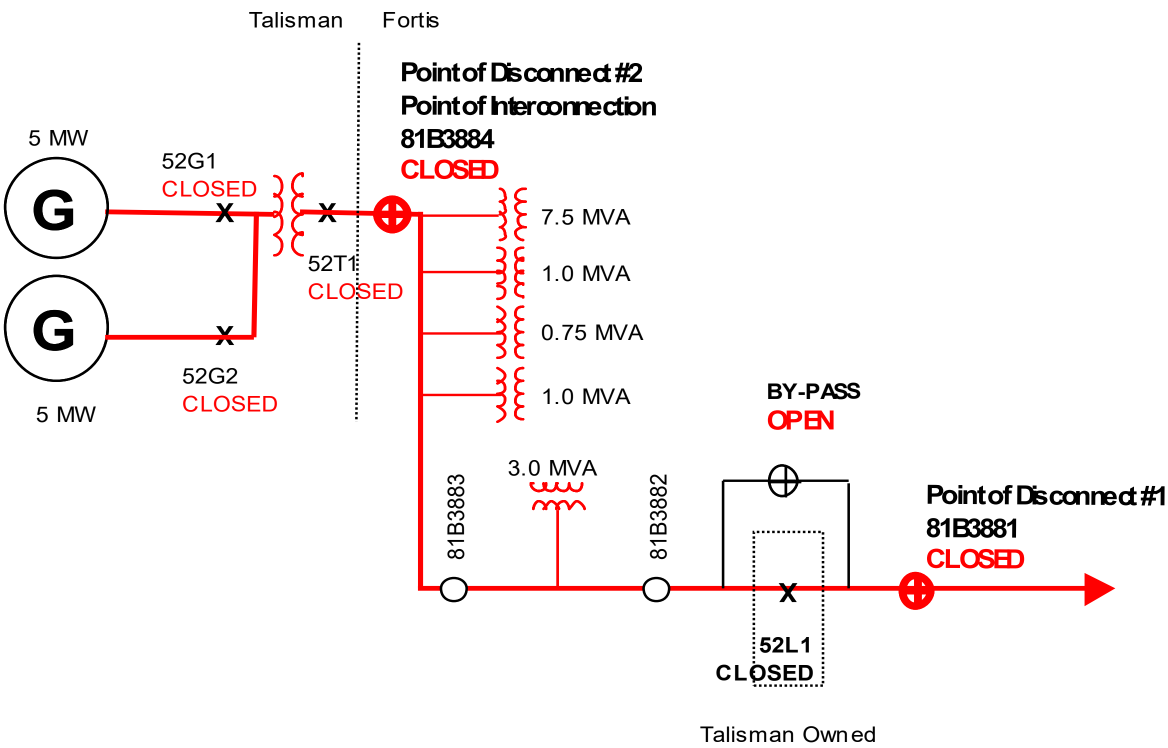
Altalink's 144 kV substation (58S) operating normally and providing power to the Edson Area. All of Fortis's 25 kV lines are operational and clear of any faults.

The Gas Plant is running at its operating load between 6.5 to 7.5 MW.

The GTG's will be generating power up to a maximum of 12.26 MW total and selling the power to the Alberta Power Pool (grid).

HRSG units will be supplying all the steam requirements to the plant. The HRSG's will be operating in the Turbine Exhaust Gas (TEG) mode.

Talisman Breaker's	**5258S, 52L1, 52T1, 52G1, 52G2 will be Closed.**
Fortis Switch's	**81B3884, 81B3881, will be Closed**
	By-Pass switch Open



** This SLD is NOT to be used for switching purposes

Power Grid Ground Fault
25 kV Line from the Edson Transmission Substation to the Edson Plant

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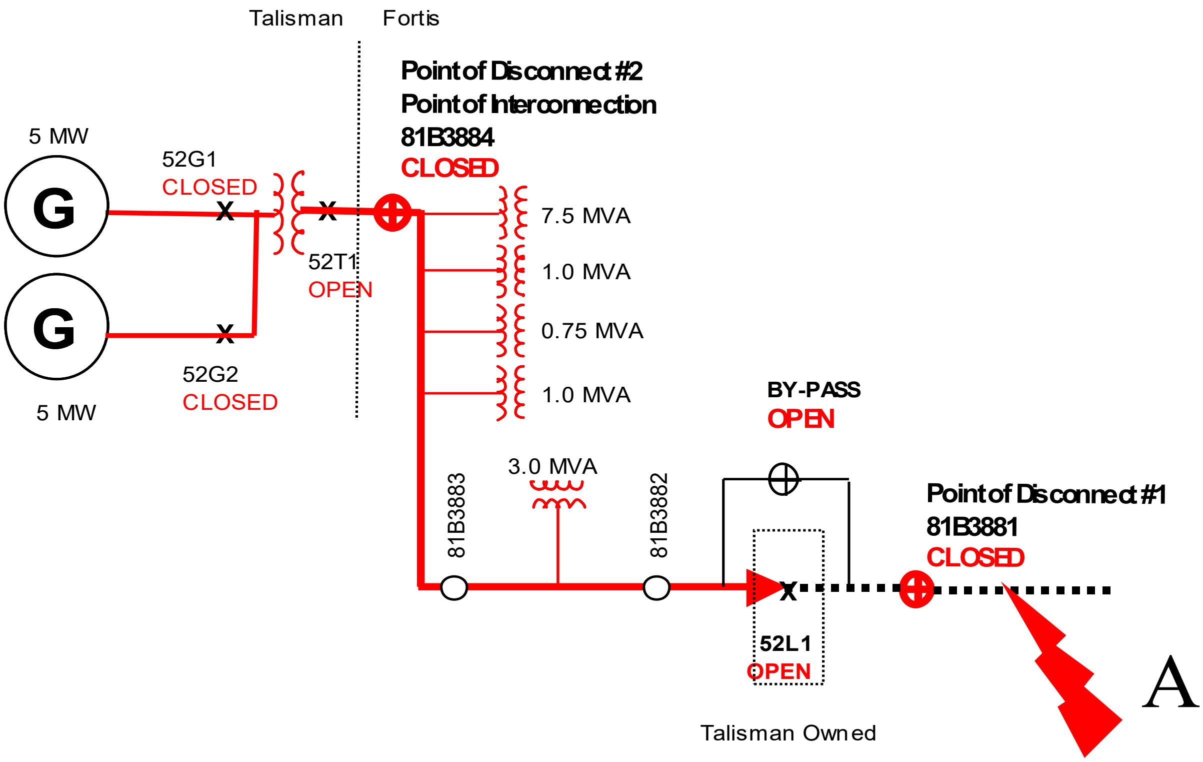
Ground fault (A), including faults caused by lightning strikes, can occur anywhere on Fortis's 25 kV distribution grid. This fault will be detected by the protection relays on islanding breaker (52L1), which will trip this breaker and isolate the Gas Plant from the grid. The islanding breaker is designed to trip before any of Fortis's or Altalink's equipment react. As a backup, the high-speed transfer trip signal from Altalink will deliver a trip signal from their substation (58S) to the 52L1 breaker to execute a trip.

Breakers 52T1, 52G1 and 52G2 would remain closed and feed the Edson Plant loads without interruption.

Should breaker 52L1 fail to operate, breaker 52T1 will be the next to trip. If breaker 52T1 should fail to trip, breakers 52G1 and 52G2 would trip. The turbines will continue to operate since the fault is not mechanical and a manual shut down would be completed.



** This SLD is NOT to be used for switching purposes

3.0 Trip scenarios

Altalink substation breaker trips due to upstream fault

The transfer trip scheme trips 52L breaker and the plant is islanded. The turbine-firing rate is reduced, as the surplus electrical power cannot be sent to the grid and the duct burner firing increases to offset the reduced turbine exhaust temperature. Steam production and electrical power to the plant are not affected.

Fortis Alberta 25 kV system fault downstream of the sub station

This scenario has three possible outcomes.

- The fault current is detected quickly and the plant islanded by opening 52L breaker. The turbines reaccelerate to 100% speed without tripping and power and steam to the plant are unaffected. This is the best possible result.
- The fault current is detected and the plant islanded but the turbines continue to slow down. Breaker 52T is then opened to shed all load before either turbine trips offline. The turbines reaccelerate unloaded and the duct burners increase firing to offset the fall in turbine exhaust temperature. Steam production is not lost but the plant loses electrical power until 52T breaker is closed again to enable the plant to be islanded.
- The grid fault is not detected in time and both turbines trip. Power is lost to the plant. Train 1 ID fan ramps to full speed and train 1 runs in FAF mode generating 100 kpph of steam. Train 2 HRSG trips and the emergency generator starts up. Train 2 goes through a purge and relight procedure in the FAF mode. The plant is islanded by opening breaker 52L and the turbines restarted. Power to the plant is restored.

Planned Grid Outage

The plant is isolated from the grid by opening breaker 52L and production is unaffected.

Single HRSG mechanical failure

The remaining HRSG increases burner-firing rate to produce 100,000 pph of steam. The turbine on the failed unit can be shut down or operated on simple cycle to maintain electrical generation.

Single Turbine fault

If either turbine trips due to an individual mechanical or electrical problem the associated HRSG will switch to FAF firing. Train 1 will accomplish this without tripping the burners and steam production will quickly resume. Train 2 will start its FD fan and attempt a fast changeover to FAF firing, which may or may not be successfully accomplished without tripping the burners completely.

On detecting the initial trip signal for either HRSG the PLC will instruct the remaining HRSG to ramp up firing immediately to full production for two minutes before reverting to steam header pressure control. High high header pressure will override this instruction.

BFW Booster pump failure

The standby BFW pump will start up and steam production will be unaffected.

Normal Start-up

Grid power is available. This is the normal start up mode and either turbine can be started and then it's associated HRSG fired.

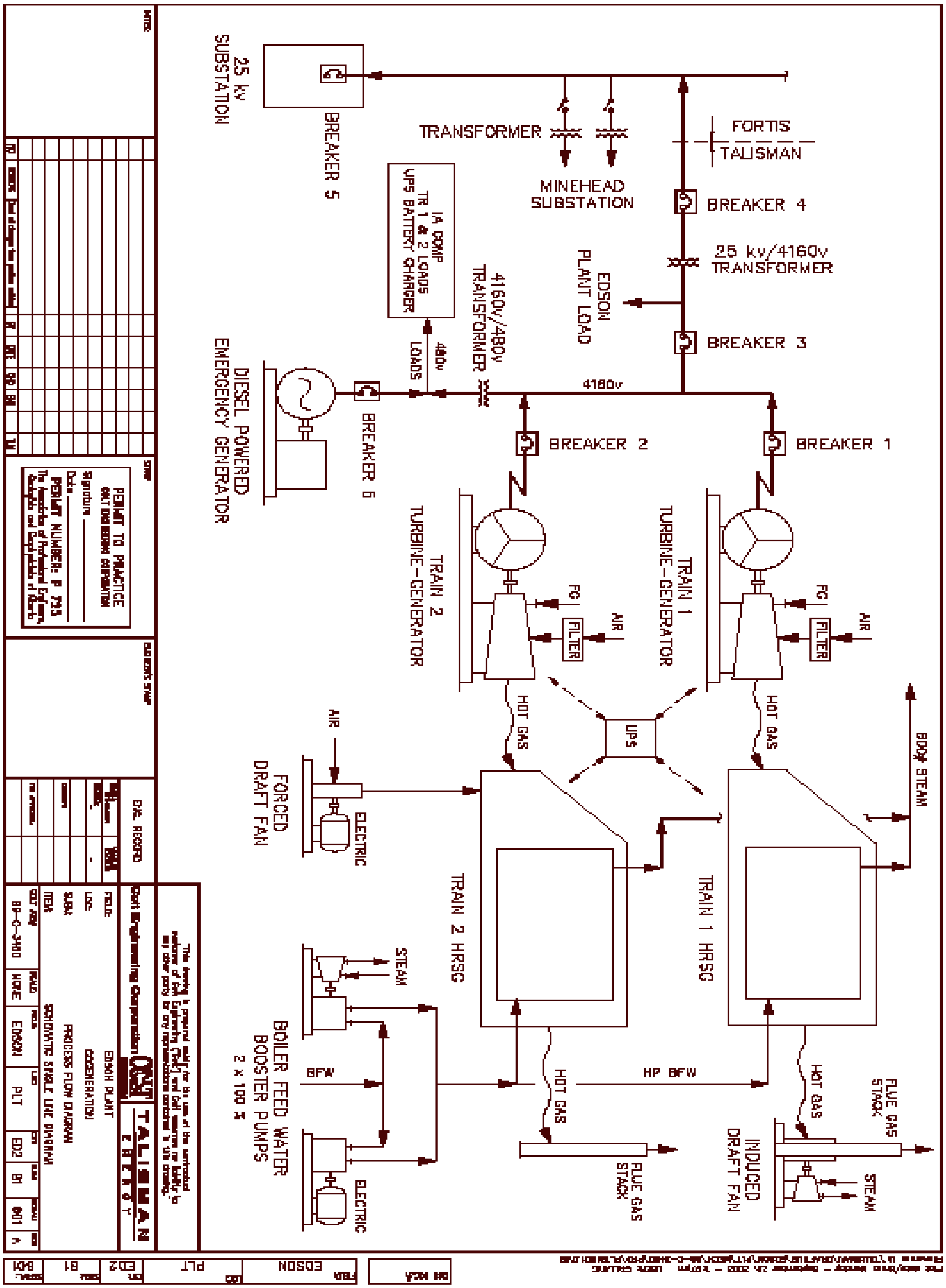
Black Start Without Grid Power

The plant is islanded by opening breaker 52L and the emergency generator is started. Both turbines are started and power is available to the plant. The HRSG's are then fired to provide steam.

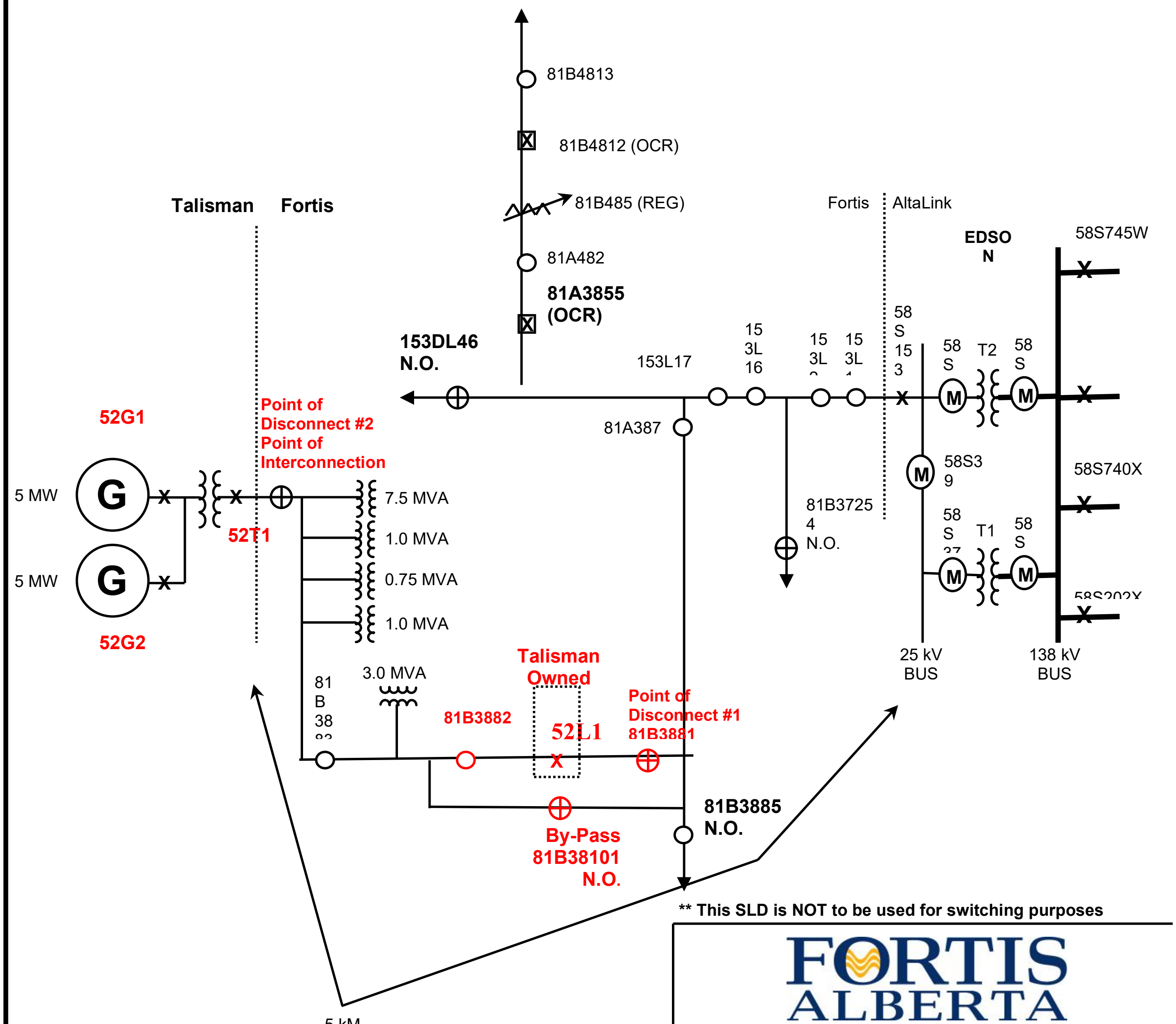
Double Jeopardy Situations Outside Design

Loss of fuel gas will cause both turbines and HRSG's to shutdown.

Appendix A – Project Flow Diagram



Appendix B – Fortis Alberta SLD Diagram



FORTIS ALBERTA

Distribution Asset Management

Talisman Energy Canada
10 MW Synchronous Generation
Export
LSD 4-11-53-18W5

DATE:
2004--06--03

BY:
KWW

Talisman Energy Canada:
Edson Gas Plant Control Room
780-723-9813

FortisAlberta Inc.:
FortisAlberta Dispatch
Phone: (403)-717-5377

FIELD NOTES:
Follow the switching procedures as given in the Operating Procedures for isolating
the Generator. Dispatch will have a copy of the Operating Schedule on hand to assist.

References.

Fortis Alberta SLD - **2004--06--03**
Talisman Energy Canada
10 MW Synchronous Generation
Export
LSD 4-11-53-18W5

Solar Turbine - September 26, 2003
Talisman Energy Company
Solar Taurus 60 Turbine Overload Test Report
(RFC-28251)