BC Hydro
Power smart

Interconnection System Impact Study

[redacted]

Zonnebeke Wind Project

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Final

British Columbia Hydro and Power Authority

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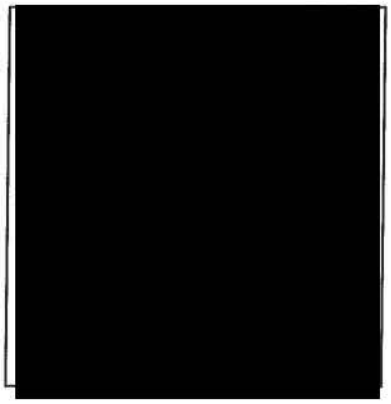

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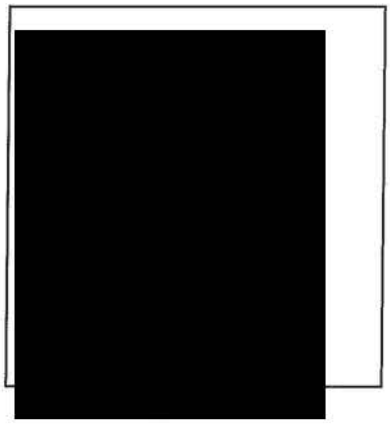

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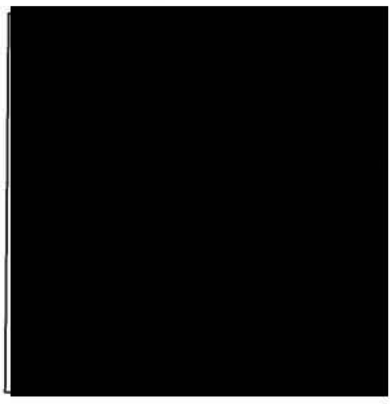

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Revision Table

Revision Number	Date of Revision	Revised By

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EXECUTIVE SUMMARY

[redacted] the Interconnection customer (IC), is proposing to develop the Zonnebeke Wind Project in the Peace Region of British Columbia. The wind farm uses 10 Enercon E115 wind turbines, rated at 3 MW each, installed along three 34.5 kV feeders. The IC will build an 8.2 km 230 kV line (designated as 2L393) from the wind farm to BC Hydro's (BCH's) Sukunka substation (SNK). The proposed Point of Interconnection (POI) is at the SNK end of 2L393. The proposed Commercial Operation Date (COD) is December 31 2018.

BCH is developing the Site C generating project and the "Peace Region Electricity Supply Project (PRES)". The Peace Region power grid configuration will be different from the present when both projects are in-service in 2024. The System Impact Study for connecting Zonnebeke Wind Farm in the Peace Region has been performed for both pre and post Site C and PRES scenarios.

This System Impact Study (SIS) has resulted in the following findings:

- Zonnebeke Wind Farm has not been observed to cause any abnormal voltage and new transmission equipment overload under system normal (N-0) and single contingency (N-1) steady state conditions. Zonnebeke Wind Farm will exacerbate existing overloads caused by the loss of circuits 2L308 (GMS-DKT) and 2L312 (SNK-SLS). Transient stability studies show that the wind farm dynamic performance is acceptable and with no transient voltage violation and instability issues.
- Peace Region Generation Shedding Remedial Action Scheme (RAS) will continually be relied on to address the existing thermal overloading on circuits 2L308, 2L312, 1L349 (SLS–CWD), and 1L377 (DAW–TAY). Zonnebeke Wind Farm is required to participate in the generation shedding RAS.
- Islanded operation is not allowed for Zonnebeke Wind Farm. A Direct Transfer Trip (DTT) will be utilized to disconnect the wind farm upon detecting an islanding situation. The IC is also responsible for equipping adequate anti-islanding protection to trip the wind turbines under abnormal system conditions.
- The Enercon E115 wind turbines are required to have the QUM2 mode feature set as one of its Under-Voltage-Ride-Through (UVRT) functionalities. The QUM2 mode will allow the turbines to provide system support as needed while automatically permitting the Zero-Power-Mode (ZPM) mode for close-in faults.
- A new 230 kV line terminal position and associated equipment is required at SNK to connect the IC's line 2L393. Existing Sukunka station will need to be expanded to accommodate the new line position and associated equipment.
- Line protection additions and changes for circuits connecting to SNK are required (2L393, 2L312, 2L313 and 2L309). Telecom work is required at GMS, SNK and WSN substations.

The good faith non-binding cost estimate to complete the BCH Network Upgrades required for the Zonnebeke Wind Project is $7.80 million. The cost estimate for Revenue Metering is $82K. The Network Upgrades can be expected to complete in approximately 12 months after the implementation phase funding is approved.

The Interconnection Facilities Study report will provide greater details of the necessary requirements and the estimated timeline for the Network Upgrade to complete.

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1.0 INTRODUCTION

[redacted] the Interconnection Customer (IC), is proposing to develop the Zonnebeke Wind Project in the Peace Region of British Columbia. The project has 10 Enercon E115 type 4 wind turbines with a total capacity of 30 MW. An IC built 8.2 km, 230 kV circuit (2L393) connects its 230 kV station, Zonnebeke Wind Station (ZBW), to the BC Hydro (BCH) system at Sukunka substation (SNK).

Table 1 below provides a summary of the Zonnebeke Wind Project:

Table 1: Summary of the Project Information

Project Name	Zonnebeke Wind Project	
Proponent Name	[redacted]	
Point of Interconnection	Sukunka (SNK) end of circuit 2L393	
Applicant Proposed COD	Dec 31 2018	
Type of Interconnection Service	NRIS (yes)	ERIS (no)
Maximum Power Injection (MW)	30 (Summer)	30 (Winter)
Number of Generator Units	Ten 3MW Enercon E-115 type 4 wind turbines	
Plant Fuel	Wind	

Ten Enercon E-115 type 4 wind turbines will be installed inside Zonnebeke Wind Farm. The rated output from each turbine is 3 MW. The wind turbines are installed along three 34.5 kV feeders of different lengths which brings the generated power to a single 34.5 kV collector station. At this IC built station, Zonnebeke Wind Station or ZBW, voltage is stepped up from 34.5 kV to 230 kV. An IC built 8.2 km 230 kV overhead line, 2L393, connects ZBW to SNK.

The following diagram, Figure 1, shows the simplified configuration of the Zonnebeke wind farm connecting to the system with its equivalent generators, step up transformers and 34.5 kV feeders:

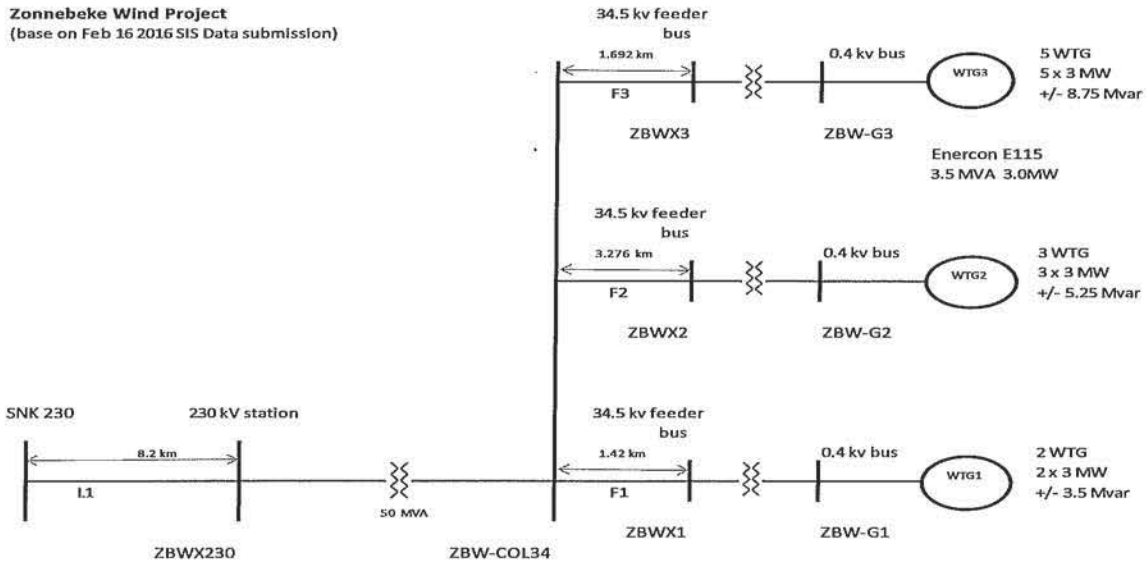

Figure 1: Zonnebeke Wind Farm Configuration

The proposed commercial operation date (COD) for Zonnebeke Wind Project is December 31, 2018.

With addition of the Site C project (STC), majority of the existing 138 kV lines from GMS to Taylor (TAY) and Fort St. John (FJN), 1L360 and 1L374 respectively, will be decommissioned, and their right of ways will be utilized to build two new 500 kV circuits (5L5 and 5L6) from the Site C 500 kV station or South Bank Substation (SBK) to Peace Canyon Substation (PCN). The remaining portion of 1L360 and 1L274 will be reconnected into SBK to serve the loads at FJN and TAY.

With more loads to be added in the Peace Region, the Peace Region Electricity Supply (PRES) reinforcement project was initiated to provide N-1 supply capability to the loads. There are a number of reinforcement options under consideration for PRES. At this time, the technically leading option is to build 230 kV double circuits from the proposed SBK substation to Shell Groundbirch substation (SGB).

Site C and PRES projects are expected to be completely in service by 2024, and are modelled in the study cases for year 2024.

The following diagram, Figure 2, shows the Peace Region with PRES and Site C.

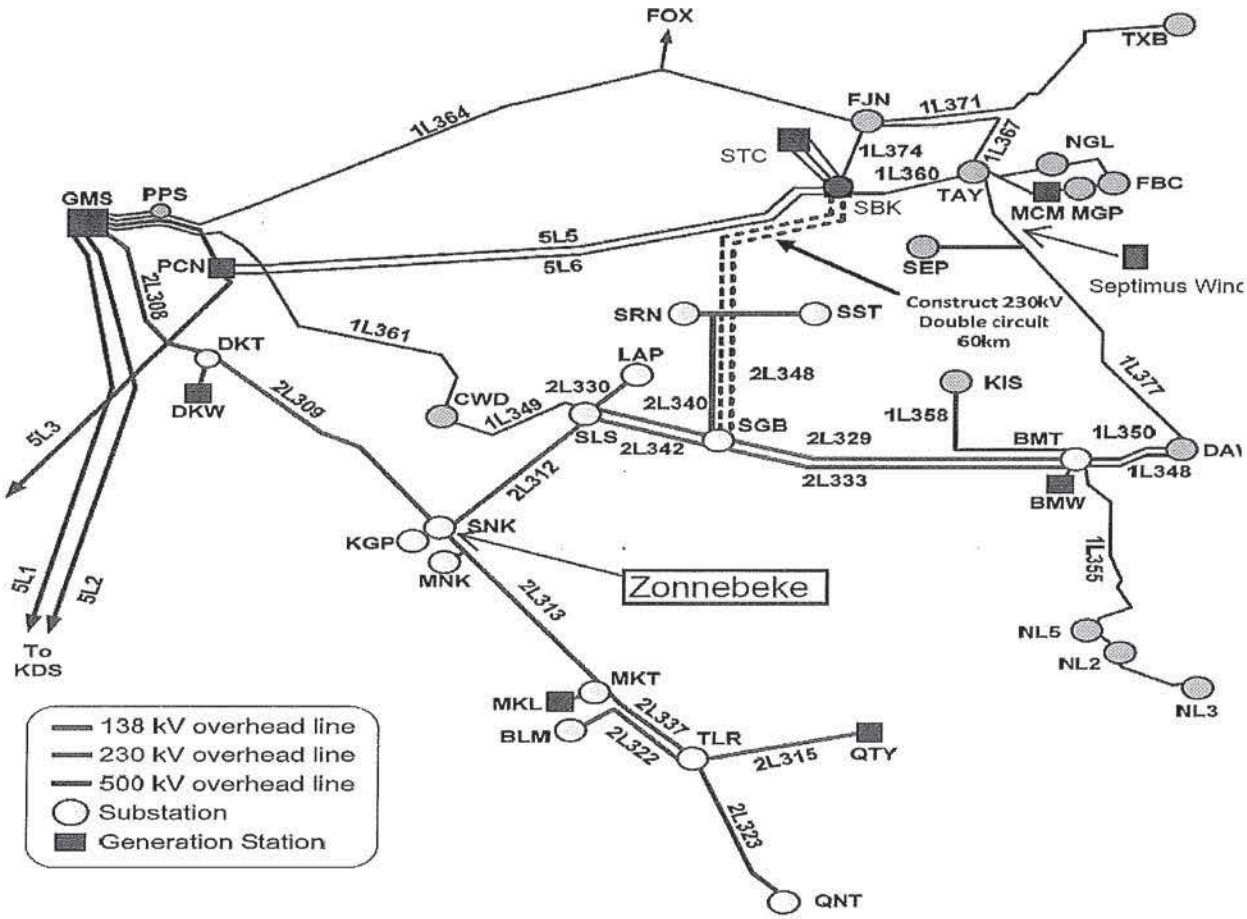

Figure 2: Peace Region with Site C and Technically Leading PRES Option

2.0 PURPOSE OF STUDY

The purpose of this system impact study (SIS) is to assess the impact on the BCH Transmission System due to the connection of Zonnebeke Wind Farm. This study identifies constraints and Network Upgrades required for interconnecting the wind farm such that its performance is compliant with the North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC) reliability standards, and meets the BCH transmission planning criteria.

3.0 TERMS OF REFERENCE

This study investigates and addresses the overloading, voltage deviation and stability issues of the transmission network in the Peace region as a result of integrating Zonnebeke Wind Farm. Topics studied include equipment thermal loading and rating requirements, system transient stability and voltage stability, transient over-voltages, protection coordination, operating flexibility and telecom requirements. BCH planning methodology and criteria are used in the studies.

The SIS does not investigate operating restrictions and other factors for possible second contingency outages. Subsequent BCH system studies will determine the requirements for reinforcements or operating restrictions/instructions for those kinds of events. Any use of firm or non-firm transmission delivery will require further analysis specific to the transmission service that may be requested later and will be reviewed in a separate study. Determination of any upgrades on the IC's facilities is beyond the SIS scope.

The work necessary to implement the network improvements identified in this SIS report will be described in greater detail in the Interconnection Facilities Study report for this project.

4.0 ASSUMPTIONS

This study relies on the data provided by the IC to BC Hydro on February 16 2016. The Enercon E115 wind turbine is required to have the QUM2 features in its Under-Voltage-Ride-Through (UVRT) capabilities. Reasonable assumptions have been made to complete the study and the report whenever such information is unavailable.

BCH 2019 and 2024 summer light load (LS), and 2019 and 2024 winter heavy load (HW) system configuration and load/generation patterns are used in the study. All projects ahead of Zonnebeke Wind Project in the Interconnection Queue are also included in the study.

The following assumptions are also made for this study:

- Peace Region Load Shedding and Generation Shedding RASs are fully in service by 2019.
- Site C project will be in service by 2024.
- PRES project will be in service by 2024.

- The installed Enercon wind turbines are capable of QUM2 operation to support the system voltage under stressed system conditions.

5.0 SYSTEM STUDIES AND RESULTS

Power flow, short circuit, and transient stability studies were carried out to evaluate the impact of the proposed interconnection. Studies were also performed to determine the protection, control and telecommunication requirements and to evaluate possible over-voltage issues and remedies.

5.1 Steady State Power Flow Studies

A series of pre-outage (N-0) and post–contingency (N-1) steady state power flow analysis have been performed to confirm whether the area voltages and facility loadings are within acceptable performance limits.

Load flow study results concluded that with the interconnection of Zonnebeke Wind Farm, no voltage violations are observed under system normal (N-0) and single-contingency (N-1) steady state conditions.

Under single contingency (N-1) conditions, thermal overloading on circuits 2L312 (SNK–SLS), 1L349 (SLS–CWD), and 1L377 (DAW–TAY) were observed for the loss of circuit 2L308 (GMS–DKT) during light load conditions. Similarly, a thermal overload on 2L308 was observed for the loss of 2L312. The Peace Region Generation Shedding RAS will be relied on to address these thermal overload scenarios under contingencies.

5.2 Transient Stability Study

Using the best available dynamic models for the nearby wind farms in the Peace Region, transient stability studies are performed for the 2019 summer light load scenario to assess the impact on the transmission network due to injecting 30 MW of generation from Zonnebeke Wind Farm at SNK.

The Enercon E115 wind turbine to be used in Zonnebeke Wind Farm is required to be capable of QUM2 operation as one of its Under-Voltage-Ride-Through (UVRT) functionalities. During QUM2 operation, the wind turbines according to the IC's submission will continue to provide system voltage support to the grid even when the voltage falls as low as the 0.2 p.u. For a close-in fault when the voltage drops below 0.2 p.u., it will permit Zero-Power-Mode (ZPM) operation and ceases supporting system voltages. Once the voltage recovers to above the cut-off threshold, the wind turbines will resume supporting the grid voltage.

Using Enercon E115 wind turbines capable of UVRT QUM2 operation, transient stability studies show that the dynamic performances of Zonnebeke Wind Farm are within acceptable limits. UVRT and frequency performances are satisfactory, and the wind turbines are able to recover to their pre-disturbance output levels after the contingencies are cleared. No transient instability phenomenon and transient voltage violations have been observed based on the studied scenarios and contingencies.

Islanded operation is not arranged for the Zonnebeke Wind Farm. The IC is responsible for equipping adequate anti-islanding protection (i.e. under and over voltage/frequency protection) to trip the wind turbines under abnormal system conditions.

The Transient Stability study results for Zonnebeke Wind Farm are shown in the following table:

Table 2: 2019 Summer Light Load Transient Stability Study Results for Zonnebeke Wind Project

Case	Outage	3Φ Fault Location	Fault Clearing Time (Cycles)		Max. Transient Voltage			IC Low Voltage Ride Through Performance	Min. Transient Voltage		
			Close End	Far End	SNK 230 kV	DKT 230 kV	SLS 230 kV		SNK 230 kV	DKT 230 kV	SLS 230 kV
1	2L308 (GMS – DKT)	Close to GMS	GMS 7	DKT 9	1.19	1.22	1.18	Acceptable	>0.95	>0.95	>0.95
2	2L308 (GMS – DKT)	Close to DKT	DKT 7	GMS 9	1.12	1.22	1.17	Acceptable	>0.95	>0.95	>0.95
3	2L309 (DKT – SNK)	Close to DKT	DKT 7	SNK 9	1.19	1.1	1.17	Acceptable	>0.95	>0.95	>0.95
4	2L309 (DKT – SNK)	Close to SNK	SNK 7	DKT 9	1.18	1.1	1.17	Acceptable	>0.95	>0.95	>0.95
5	2L312 (SNK – SLS)	Close to SNK	SNK 7	SLS 9	1.16	1.1	1.02	Acceptable	>0.95	>0.95	>0.95
6	2L312 (SNK – SLS)	Close to SLS	SLS 7	SNK 9	1.18	1.14	1.02	Acceptable	>0.95	>0.95	>0.95
7	2L313 (SNK – MKT)	Close to SNK	SNK 7	MKT 9	1.1	1.09	1.1	Acceptable	>0.95	>0.95	>0.95
8	2L313 (SNK – MKT)	Close to MKT	MKT 7	SNK 9	1.1	1.09	1.1	Acceptable	>0.95	>0.95	>0.95
9	2L337 (TLR – MKT)	Close to MKT	MKT 7	TLR 9	1.13	1.1	1.12	Acceptable	>0.95	>0.95	>0.95

5.3 Remedial Action Scheme (RAS)

Zonnebeke Wind Farm is required to participate in the Peace Region Generation Shedding RAS. The identified thermal overloads on circuits 2L312 (SNK – SLS), 1L349 (SLS – CWD), and 1L377 (DAW – TAY) due to loss of 2L308, and thermal overloads on circuit 2L308 due to loss of 2L312, will be addressed by the revised RAS.

5.4 Fault Analysis

The short circuit analysis for the System Impact Study is based upon the latest BCH system model, which includes project equipment and impedances provided by the IC. The model included higher queued projects and planned system reinforcements but excluded lower queued projects. Thevenin

impedances, including the ultimate fault levels at POI, are not included in this report but will be made available to the IC upon request.

BCH will work with the IC to provide accurate data as required during the project design phase.

5.5 Analytical Studies

Based on the IC's submission that the IC will provide a point on wave (POW) controller for its 230 kV circuit breaker (CB) at ZBW, Analytical Studies concluded the following:

- No adverse system performance has been observed with the connection of the 30 MW Zonnebeke Wind Project;
- A direct transfer trip is required and the existing Peace Region shedding RAS scheme should be modified to include tripping 2L393 at SNK when any islanding status is detected for Zonnebeke Wind Farm;
- There is no voltage sag concerns during transformer energization due to the installation by the IC of POW controller for its 230 kV CB at ZBW station;

5.6 Transmission Line Upgrades

No transmission line upgrade requirement has been identified for existing BCH circuits.

The IC will build and own the new 230 kV, 8.2km transmission line (2L393) from its ZBW station to BCH's SNK. Coordination between BCH and the IC to install the last span of 2L393 into SNK will be needed.

To meet the telecommunication requirements stated in Section 5.8, the IC shall install All-Dielectric Self-Supporting (ADSS) fiber-optic cables on 2L393. BCH will be responsible for accommodating the ADSS link within SNK.

5.7 BCH Station Upgrades or Additions

The following station upgrades are identified for Zonnebeke Wind Project:

- A new line position at SNK needs to be added to accommodate the IC's 2L393 circuit. New line position equipment (circuit breaker and disconnects) and line terminal equipment (CVT, surge arrestor and disconnect) need to be added.
- The addition of this new line position and its associated equipment will require the expansion of the existing SNK station.
- This line position shall exit SNK to the south and head east towards the IC's 230 kV station.

5.8 Protection & Control and Telecommunications

BC Hydro's standard line protection practice providing 100 ohms ground fault resistive coverage is assumed for IC's new 230 kV circuit 2L393, and the following Protection, Control and Telecommunication requirements are identified.

Protection Requirements:

- Primary (PY) and Standby (SY) line protection is required using line current differential protection relays at SNK for 2L393 protection. The IC will provide PY and SY protections at ZBW 230 kV station for 2L393 protection. BCH will provide guidance to the IC with the implementation of the line current differential protection scheme, and will also provide the IC with the relay core settings.
- Line protection modifications are required for circuits 2L312 from SNK to SLS, 2L313 from SNK to MKT (Meikle Terminal) and 2L309 from SNK to DKT (Dokie Terminal).
- Existing Peace Region Generation Shedding RAS needs to be modified for tripping the IC's line, 2L393, at SNK when an islanded status occurs for Zonnebeke Wind Farm.
- The IC is required to provide adequate ant-islanding protection (i.e. under and over voltage/frequency protection) that complies with BC Hydro and WECC requirements in case an island is inadvertently formed. The IC will also comply with all the protection requirements as listed in BC Hydro's "60 kV to 500 kV Technical Interconnection Requirements for Power Generators".
- The IC will need to provide sufficient information (including wind farm models) about its power system to allow this system to be modeled in adequate detail for fault current calculation.

Control Requirements:

- The IC is required to provide telemetry, status and meteorological information via a DNP3 RTU/IED (Distributed Network Protocol 3, Remote Terminal Unit/Intelligent Electronics Device) to the BCH Control Centres in accordance with TIR requirements.
- The IC is required to provide to BCH their protection event records from their line protection relays under the following circumstances:
    - Fault on the interconnecting line.
    - Relay mis-operation for faults outside of interconnecting line.
    - Relay operation due to Power Quality Protection elements.
- The database and displays at BCH Control Centres will need to be updated to accommodate the SCADA points for Zonnebeke Wind Farm.

Telecommunication Requirements:

It is assumed that the IC will install a single mode ADSS, minimum 48 strand, fibre optic cable on its new transmission line (2L393) to SNK. The 9600 bps SCADA channel can be carried on this fiber circuit.

In order to support the identified Protection and Control requirements, the following telecommunication circuits are required:

- PY & SY WECC Class 2 64 kbps synchronous circuits between SNK and ZBW for 2L393 DIGITAL TELEPROT. Interface shall be 1300 nm single mode fibre using ST connectors.
- One 9600 bps SCADA channel, this circuit can be carried on the IC built fibre link to SNK, and then transported to WSN DCP (Williston Data Collection Point).
- Metering circuits will be carried on the ZBW-SNK fibre and then transported to EDM (Edmond Office).

Implementation tasks for the required telecom facilities are required at BCH GMS, SNK and WSN stations. The actual work to be performed at these stations will be described in more detail in the future Facilities Study report.

The IC is also responsible for the termination of the fibre cable at ZBW and connecting the PY and SY relays to fibers facing the SNK relays.

5.9 Islanding

Islanded operation is not arranged for Zonnebeke Wind Farm. A Direct Transfer Trip (DTT) scheme will be utilized to isolate the wind farm by opening the 2L393 230 kV circuit breaker at SNK when an island status is detected. The back-up to the DTT is the wind farm's anti-islanding protection.

5.11 Black Start Capability

BCH does not require the proposed Zonnebeke Wind Farm to have black-start (self-start) capability.

However, if the IC desires their facilities to be energized from the BCH system, the IC is required to apply for an Electricity Supply Agreement (ESA).

5.12 Cost Estimate and Schedule

The good faith non-binding cost estimate to complete the BCH Network Upgrades required for Zonnebeke Wind Farm connection is $7.80 million. This cost estimate has an accuracy range from +100% to -35%, and includes 20% contingency, 2.0% annual inflation and annual interest during construction.

The BCH Network Upgrade identified in this report can be expected to complete in approximately 12 months after the implementation phase funding is approved. This duration assumes that all necessary outages, acquisition, permits and materials are available in time.

The Interconnection Facilities Study report will provide greater details of the necessary requirements and the estimated cost and timeline for this interconnection project.

The work required within the IC facilities and BCH Revenue Metering costs are not part of this estimate and schedule.

6.0 REVENUE METERING

An n+1 metering scheme consisting of 3 Metering Points is used for the Zonnebeke Wind Project. The main Point of Metering (POM) is located on the high voltage side of the main power transformer at ZBW station. The other two POMs are located at the ZBW station end on each of the two 34.5 kV feeders.

The main POM will have 3-element metering scheme with 3 CTs and 3 VTs connected L-ground, and the other two POMs will each have a 2-element metering scheme with 2 CTs and 2 VTs connected L-L. The CTs and VTs used for the metering scheme should be of a model/type approved by Measurement Canada, and must be pre-approved by BC Hydro's Revenue Metering Department. These meters are for metering purposes ONLY. Power Quality meters are to be supplied by the IC.

The revenue metering VT and CT secondary windings are not permitted to be shared with any other equipment therefore no other devices shall be connected to the revenue metering VT and CT secondary windings.

Metering equipment including CTs and VTs are provided by the IC and subjected to approval by BCH Revenue Metering department. The IC is responsible for securing the real estate for the Metering Points, installing the metering transformers and conducting primary terminations. The IC is also responsible for supplying auxiliary power and telecom for revenue metering use. The IC is responsible for the maintenance of the CTs and VTs, and BCH is responsible for the maintenance of meters, metering cabinets, junction boxes and secondary terminations.

The estimated Revenue Metering cost is $82k which covers electrical work only. These Revenue Metering costs will be paid for by the IC directly to BCH, and is not included in the estimated costs for completing the Network Upgrades in Section 5.12.

The table below shows the summary of metering requirements:

Metering Voltage (kV)	230 kV (POM main) 34.5 kV (POM1) 34.5 kV (POM2)
Max Current	~75 A @ 230 kV (POM main) ~251 A @ 34.5 kV (POM1) ~251 A @ 34.5 kV (POM2)
Point-of-Metering	On the primary side of the main transformer in the customer station. (POM main) On the feeder, downstream of breaker 35CB1 (POM1) On the feeder, downstream of breaker 35CB2 (POM2)
Voltage Transformers	3 x VTs (L-grd) – 230/1.732 kV-120-120V (to be supplied by the IC) (POM main) 2 x VTs (L-L) – 34.5 kV-120-120V (to be supplied by the IC) (POM1) 2 x VTs (L-L) – 34.5 kV-120-120V (to be supplied by the IC) (POM2)

Current Transformers	3 x CTs 100-5A (to be confirmed by IPP; to be supplied by the IC) (POM main) 2 x CTs 300-5A (to be confirmed by IPP; to be supplied by the IC) (POM1) 2 x CTs 300-5A (to be confirmed by IPP; to be supplied by the IC) (POM2)

The IC is requested to work closely with BCH Revenue Metering Department for more detailed information and requirements.

7.0 CONCLUSIONS & DISCUSSION

The Enercon E115 wind turbine used in the Zonnebeke Wind Farm is required to be capable of QUM2 operation as one of its Under-Voltage-Ride-Through (UVRT) functionalities. As per submitted PSS/E model settings, the QUM2 mode will allow the turbine to provide system support as needed while automatically permitting the Zero-Power-Mode (ZPM) mode for close-in faults.

In the Peace Region, there are pre-existing thermal overloads on circuits 2L308, 2L312, 1L349 and 1L377 when circuit 2L312 or 2L308 is loss. With the addition of Zonnebeke Wind Farm, these existing overloads are exacerbated, and no new overload was introduced. Existing Peace Region Generation Shedding RAS will be relied upon to address these overload issues.

Zonnebeke Wind Farm is required to participate in the Peace Region Generation Shedding RAS.

No abnormal voltage in the area due to the addition of Zonnebeke Wind Farm was observed in the (N-0) system normal steady state, and in (N-1) post-contingency steady state conditions.

Transient stability simulations indicated that Zonnebeke Wind Farm's dynamic performance is acceptable. The wind farm's Under-Voltage-Ride-Through (UVRT) and frequency protection performance is acceptable. No abnormal transient voltage and instability concerns in nearby areas were noted during the study.

A new line position and associated equipment are needed at SNK to terminate the IC's 230 kV line from its wind farm. Existing SNK station needs to be expanded to accommodate added equipment.

The cost estimate to implement all the BCH Network Upgrade identified in this report is $7.80 million. These Network Upgrades can be expected to complete in approximately 12 months after the implementation phase funding is approved.

The Interconnection Facilities Study report will provide greater details of the necessary requirements and estimated timeline for this interconnection project.