

ONTARIO ENERGY BOARD

IN THE MATTER OF the *Ontario Energy Board Act, 1998, S.O. 1998, c. 15, Sch. B, as amended* (the “**OEB Act**”);

AND IN THE MATTER of an application by Summerhaven Wind LP (the “Applicant”) for an order under section 92 and subsection 96(2) of the OEB Act granting leave to construct an electricity transmission line and related facilities.

APPLICANT’S REPLY SUBMISSIONS TO INTERVENOR ARGUMENT

INTRODUCTION

1. Summerhaven Wind LP (the “**Applicant**”) has applied to the Board for leave to construct (the “**Application**”) an electricity transmission facility (the “**Facility**”) that is comprised of a transmission line (the “**Transmission Line**”) extending approximately 9 km from the collection substation to the point of interconnection to the IESO-controlled grid at a proposed switchyard (the “**Switchyard**”).¹
2. In the submissions to date, no parties have opposed this Application. Rather, the discussion has focused around potential impacts arising from certain aspects of the Facility as proposed, specifically:
 - (i) the potential impact of the Facility on distribution infrastructure owned by Haldimand County Hydro (HCHI) along Concession Road 5, and;
 - (ii) the rationale for not pursuing a jointly-owned switchyard with Capital Power.
3. As stated in the Technical Conference, the Applicant has always approached the development of the Facility with the view that the rate-payers of HCHI should not bear additional costs associated with said development. As will be detailed herein, the Applicant is of the view – based on its extensive experience – that any negative impacts associated with the parallel runs of the Transmission Line and HCHI’s infrastructure can be mitigated post-energization through a combination of simple, relatively inexpensive technical fixes rather than prescriptive design requirements placed as conditions of approval. The Applicant is willing and ready to negotiate and sign a commercial agreement with HCHI to perform and/or pay for these mitigation measures and related studies.
4. While the Applicant recognizes the valid concerns raised by various parties regarding the location of the Switchyard, it will explain in this submission how this scenario represents a relatively unique situation that could not have been reasonably anticipated or avoided at the time critical design decisions were required to be made based on various Provincial timelines.
5. The Applicant’s affiliate, Florida Power & Light Company (“**FPL**”), is one of the most experienced transmitters in North America, which company owns and operates over 110,000 km of distribution lines and over 12,000 km of transmission lines in the United States. Approximately 13% of FPL’s transmission structures have underbuilt distribution

¹ Application, Exh. B-2-1.

circuits.² The Applicant's parent, NextEra Energy Resources, ULC, is a large and growing player in the Ontario electricity market, and has committed vast amounts of resources to Ontario, and will continue to do so in the future. The Applicant has direct access to its affiliates' pool of expertise and its submissions are informed by its experience.

6. No parties have opposed this Application. Several parties commented upon whether the Switchyard, which is designed to accommodate the Transmission Line, should be shared with Capital Power, however no party has opposed separate switchyards. The Applicant adopts the submissions of Capital Power on this matter and provides the Board with further details surrounding its permitting process in paragraph [•] of these submissions. The Applicant also notes that parties have proposed that the Board conduct further policy reviews on this matter on a going forward basis. The Applicant intends to participate in any such a review with respect to its impact on other projects.
7. Both Board Staff and Haldimand County Hydro Inc.'s ("**HCHI**") have proposed a number of conditions to approval. As discussed further below, the Applicant has concerns regarding several of the proposed conditions. However, there are a number of proposed conditions the Applicant is prepared to agree with, though the Applicant does not believe that any of these conditions are necessary for reliability or safety reasons. These include:
 - HCHI Condition 2(a), Board Staff Condition B.1.1: The Applicant will take all reasonable measures to ensure that the Transmission Line is designed to accommodate the conversion (the "**Distribution Conversion**") of HCHI's distribution to double-circuit, three phase 26.7 kV distribution lines ("**HCHI Proposed Distribution**")³ provided that the Distribution Conversion is indeed imminent;
 - HCHI Condition 2(b): With the potential exception of the crossing at Concession Rd. 4⁴, all road crossings will be designed to meet HCHI Proposed Distribution. In compliance with this condition, the Applicant will rely on the County to provide the adequate clearances for its roads or meet the Canadian Electrical Code, whichever is greater. The Applicant assumes that any future upgrades to the HCHI distribution system will be known to the County (as sole shareholder of HCHI) and that any crossing permit will be designed to accommodate the HCHI Proposed Distribution where necessary.

² Summerhaven OEB IRR, Question 1(ii); Undertaking response TCK1.2.

³ HCHI Final Submissions dated June 22, 2011 (the "**HCHI Submissions**"), at par. 60.

⁴ This crossing has some complex environmental considerations.

- HCHI Condition 2(e): That span guys crossing over the road ways be built high enough to allow HCHI Proposed Distribution, including the neutral height of 25' above the crown of the road, provided however that HCHI is able to provide the exact location of the HCHI Proposed Distribution in advance of the Applicant finalizing the design of the Transmission Line.

8. The issue that remains in this proceeding is whether additional conditions and positions proposed by HCHI and Board Staff should be included as part of the order. These conditions and positions are:

- (i) HCHI's and Board Staff's position that the length of the adjacent Transmission Line and HCHI Proposed Distribution is 2 km as opposed to approximately 550 meters (Board Staff Condition B.1.2; HCHI Submissions, par. 36);
- (ii) Board Staff's condition that the Board's decision not be made until HCHI has carried out a final induction study using the Proposed Design and HCHI's Proposed Distribution (Board Staff Condition B.1.6);
- (iii) HCHI's and Board Staff's proposed condition that the Transmission Line be at least 10 meters from HCHI's Proposed Distribution (HCHI Condition 2(c); Board Staff Condition B.1.3);
- (iv) HCHI's and Board Staff's position that, when measuring induction, the default assumption should be a fault value of 63 kA (Board Staff Condition B.1.4; HCHI IRRs to Summerhaven, Question 2(a));
- (v) HCHI's proposed condition that the design of the Transmission Line ensures maximum swing arc/blowout and the Transmission Line conductor remains within the Applicant's easement;
- (vi) Board Staff's proposed condition that the Applicant be responsible for the costs of HCHI's consultant carrying out animal contact potential measurements after the Transmission Line is in service; and
- (vii) HCHI's condition that the guy wires be anchored outside of the municipal right of way ("**Municipal ROW**").

All of these will be addressed in turn.

9. The context of this Application is important. The context of this Application is important. The Applicant approached HCHI regarding joint use along right of ways in Haldimand County, for both transmission and collector lines. HCHI was not generally in favour of joint use and therefore the Applicant took action to bury its collector cables, and to build

the Transmission Line on private land.⁵ The Applicant has complied with this request and expended considerable effort and incurred costs to obtain easements from private landowners. Once it became apparent in the hearing process that HCHI had issues regarding the Transmission Line on private land, the Applicant offered to enter into a mitigation agreement⁶ and has, since then, reached out to HCHI, but with no response. To that extent, the Applicant believes it has attempted to engage numerous times with HCHI to see if there was a mutually agreeable position regarding many of the issues HCHI has raised at the hearing. The Applicant has not received any feedback from HCHI. The Applicant remains willing to engage with HCHI at their convenience.

BROADER POLICY ISSUES

10. Along with these detailed, project specific discussions (which are explored in further detail below), there are several broader issues raised by this Application.
11. For example, should an applicant who meets the requirements of a leave to construct application be required to design its transmission line to accommodate a utility or municipality's future infrastructure plans, without regard to how concrete and specific their plans are? The Applicant submits that this concept makes general sense, provided that the proposed plans have been approved and established/made public. In this case, HCHI has not demonstrated that the HCHI Proposed Distribution has been approved or formally tabled with Haldimand County.
12. Regarding public streets and highways, does a utility have a stronger right to a public street or highway than a generator, or is it accorded on a first-come, first-served basis? The Applicant submits that section 41 of the *Electricity Act, 1998* makes no distinction between public and private transmitters or distributors. Both presumably have a social license for their operations or they would not proceed, therefore no distinction should be drawn. Approvals should therefore be awarded on a first-come, first-served basis.
13. The Board also has the delicate task of balancing the interests of landowners against those of utilities. In these proceedings, at the request of HCHI, the Applicant has sought to build the Transmission Line on private lands. The impact to the landowner is substantially higher than it is to HCHI, and more so if HCHI's and Board Staff's conditions are imposed. What should take precedence - landowner accommodation or a utility's concerns regarding potential technical issues that, even if they are found to exist, can be mitigated? The Applicant submits that all factors need to be taken into account in any decision.

⁵ Summerhaven_APPL_redacted_20110126, at par. 38, 39.

⁶ Technical Conference, p. 48-49, lines 28 – 15; p. 53, lines 19-24

14. Finally, an application under section 92 of the OEB Act is not the ideal forum to determine the minute design details of the Transmission Line or to seek to create technical standards. The environmental permitting process plays a significant role in the final design of the Transmission Line, as do negotiations with landowners and geotechnical concerns. It is reasonable to assume that two sophisticated parties such as the Applicant and HCHI will be able to resolve commercial concerns, especially in this Application in which the Applicant is on the record as stating that they would cover any reasonable costs incurred by HCHI to mitigate adverse effects on the HCHI distribution system and arising directly from the Transmission Line.

PROPOSED TRANSMISSION LINE DESIGN

15. Board Staff Condition B.1.6 recommended that HCHI should file a final induction study within four weeks of receiving the Proposed Design including pole locations.⁷ The Board panel made a ruling on this issue and in Procedural Order No. 8, and ordered the Applicant to provide a final design for the Transmission Line as part of its reply submissions so that HCHI could complete a final induction study.⁸ The Applicant has complied with the Order to the extent possible, and provided a proposed final design (the “**Proposed Final Design**”), attached hereto as **Schedule ‘A’**. The Proposed Final Design is not deemed to be final by the Applicant since pole locations, conductor locations and pole height may change depending on negotiations with landowners, the results of the Ministry of Environment’s review of the Renewable Energy Approval (“**REA**”) and the result of archaeological studies (which are conducted outside of the REA process). However, the Applicant believes that the Proposed Final Design in the vicinity of the Adjacent Length will not likely change.
16. The Proposed Final Design is based on the following assumptions:
- The centerline for the Transmission Line shall be located 5 meters offset to the south of the HCHI Proposed Distribution on private land;
 - Electrical clearances to conductors and poles will be calculated in accordance with the Canadian Electrical Code and Ontario Electrical Safety Code and based on pole lengths and pole top configurations set out in the HCHI Proposed Distribution;
 - The Transmission Line has a delta phase configuration, with two phases on the south side of the structures, on the opposite side of the HCHI Proposed Distribution poles;

⁷ Board Staff Submissions, at p. 8.

⁸ Procedural Order No. 8, dated July 5, 2011.

17. The Applicant does not agree with the premise that the line should be designed to accommodate HCHI's Proposed Distribution because HCHI has not filed plans for these upgrades with the OEB. However, for the purposes of the design exercise requested by Board Staff, the Applicant has respected HCHI's request and the Transmission Line poles are placed in alignment with HCHI Proposed Distribution, not the current distribution infrastructure that is in place. The Applicant submits that, if the Board decides that the Applicant should take HCHI's future design into account, that HCHI should provide an in-service date for the HCHI Proposed Distribution. This latter point is important, as landowners along Concession Rd 5 have requested that the poles of the Transmission Line be aligned with the poles of the distribution infrastructure and the Applicant would like to be able to satisfy their concerns that the Distribution Conversion is indeed imminent.

DISTRIBUTION-RELATED ISSUES

(i) HCHI's and Board Staff's position that the length of the adjacent Transmission Line and HCHI Proposed Distribution is 2 km as opposed to 550 meters

18. Both HCHI and Board Staff claim that the Transmission Line will be adjacent to HCHI's distribution system along the south side of Concession Rd. 5 for a length (the "**Adjacent Length**") of 2 km. The Applicant notes that the actual Adjacent Length as shown in the Proposed Final Design, is 1.7 km rather than 2 km.⁹ This is based on the premise that the HCHI Proposed Distribution will be intentionally built on the south side of Concession Rd 5 alongside the Transmission Line. If the HCHI Proposed Distribution is built to simply replace the existing distribution, the Adjacent Length will only be approximately 550 meters, as it is now. In fact, the Adjacent Length could be zero kilometers if HCHI chose to place the HCHI Proposed Distribution entirely on the north side of Concession Rd 5, thereby alleviating all of HCHI and Board Staff's concerns raised herein.
19. In its interrogatory responses, HCHI stated that, where its existing distribution lines are on the north side of Concession Rd. 5, it does not intend to stay on the north side with the HCHI Proposed Distribution because of its principle to avoid lines on both sides of the roadway.¹⁰ Prior to receiving the interrogatory responses from HCHI, the Applicant was not aware that HCHI intended to apply this principle when private property is being used adjacent to the Municipal ROW.

⁹ Applicant's Proposed Design.

¹⁰ BS Submissions, p. 4; HCHI IRR #3 to Summerhaven.

20. Furthermore, the Applicant is not aware of any design or regulatory principle that states that electricity infrastructure should be built along the same side of the road. Nor did HCHI provide any documented basis for such a principle that could have been tested through the discovery process. As evidenced by the photographs in **Schedule 'B'** (which the Board may take judicial notice of) HCHI has previously put electricity infrastructure on both sides of the road. While the Applicant recognizes that these are clearly exceptions to a general effort to keep parallel lines on the same side of the road, it demonstrates that exceptions have been made when necessary. In the Applicant's view, the concerns raised by HCHI over the 1.7 km Adjacent Length that would result from such a move would justify such an exception to this general design principle.
21. If HCHI were to intentionally move the HCHI Proposed Distribution to be adjacent to the Transmission Line, this will force the Applicant to incur additional costs associated with the use of taller poles and upset impacted landowners, who would now have two sets of taller poles to deal with, as opposed to one. As a matter of public interest and in accordance with the Board's mandate under 96(2)(2.), a renewable generator should not be forced to implement a more expensive design when there is an option available to HCHI that would be less expensive for all parties involved, including potentially, HCHI ratepayers.
22. For the above reasons, the Applicant submits that the Board should accept the Applicant's position that, for the purposes of any future studies, the Adjacent Length is approximately 550 meters, or alternatively, 0 meters.

(ii) Board Staff's condition that the Board's decision not be made until HCHI has carried out a final induction study using the Proposed Design and HCHI's Proposed Distribution

23. The majority of the conditions imposed by Board Staff and HCHI are based on the *Induction Study for Haldimand County Hydro Inc.*, (the "**HCHI Induction Study**"), which was performed by Kinectrics Inc. on behalf of HCHI.¹¹ The Induction Study was based on a model that used HCHI Proposed Distribution, as opposed to HCHI's existing 4.8 kV distribution lines in the area, and examined four aspects of induction that may occur between a typical 230 kV transmission line and the HCHI Proposed Distribution.
24. The Applicant believes that the HCHI Induction Study studied the relevant issues for induction. However, as outlined in the sections below, the Applicant has reservations with the assumptions made by Kinectrics regarding (i) the magnitude of pole ground

¹¹ *Induction Study for Haldimand County Hydro Inc.*, Kinectrics Report 015949-RC-001-R00, dated May 31, 2011.

resistance, and (ii) the magnitude of fault current used for the region of concern, as well as the proposed solutions.

25. As part of the design process for the Transmission Line, the Applicant had its consultant, Peak Power Engineering (also known as Universal Pegasus International), carry out an induction study (the “**Peak Induction Study**”), attached hereto as **Schedule ‘C’**, to validate the conclusions of the HCHI Induction Study. The Peak Induction Study uses the Proposed Final Design and HCHI’s Proposed Distribution for the model and has been included in these submissions for the benefit of the Board and as part of the requested Proposed Final Design. With one exception related to induced voltage during fault conditions, the conclusions of the Peak Induction Study are not significantly different from the HCHI Induction Study.¹²
26. The Applicant submits that additional modeling in the form of induction studies would be of limited value in addressing HCHI’s concerns since it would not change the ultimate solution. Rather, the Applicant submits that mitigation measures based on actual field measurements of steady state neutral voltage is the appropriate way forward. For the transmission fault condition, the data provided in Schedule C of the Peak Induction Study should be sufficient for evaluation of arrestor quantity and requirements in the region of concern.
27. In particular, as further described below, the Applicant is willing to carry out a neutral voltage survey (“**Neutral Voltage Survey**”) to establish a baseline prior to commercial operation of the Transmission Line and a post-energization Neutral Voltage Survey that would be based on field measurements as opposed to models. These surveys would be used to identify areas where mitigation by the Applicant may be required.
28. For the foregoing reasons, the Applicant submits that it is not necessary to carry out a “final” induction study prior to the issuance of any decision by the Board. Both the HCHI and Peak Induction Studies conclude that there are no extraordinary mitigation solutions required, and no reasons to believe that mitigation, if required, will not be effective.

(iii) HCHI’s and Board Staff’s proposed condition that the Transmission Line be at least 10 meters from HCHI’s Proposed Distribution

29. HCHI proposes that the Transmission Line be placed a minimum of 10 meters from the edge of the Municipal ROW. Board Staff proposes that there should be a minimum 10 meter diagonal separation between the Transmission Line poles and HCHI’s distribution

¹² Generally speaking, the Peak Induction Study is more detailed and covers a broader range of footing ground resistances and mitigation measures.

poles. The Applicant respectfully disagrees with these proposals since neither is required by any standard related to safety, reliability or quality of service.

30. In addition, the landowner that is proposed to host the Adjacent Length (if taken to be 550 meters) along Concession Rd. 5 has stated that, as a condition to executing such easement, the Transmission Line must be within 5 meters of the Municipal ROW to minimize impact on existing agricultural operations. If the Applicant is not able to come to an agreement with this landowner, the Applicant may have to rely on section 41 of the *Electricity Act, 1998* to build the Transmission Line entirely within the Municipal ROW, contrary to HCHI's wishes.¹³
31. With respect to reliability and quality of service, HCHI and Board Staff base their proposals on the findings of the HCHI Induction Study. The HCHI Induction Study states that a "minimum distance of 10 m or more between the transmission and distribution poles be maintained to limit the GPR (Ground Potential Rise) transfer during lightning strikes to the transmission line and 60 Hz faults."¹⁴
32. The HCHI Induction Study did not provide a reference or basis for the 10 meter separation distance. In response to the Applicant's interrogatories, HCHI stated that this distance was based on CSA Standard CSA-C22.3 No. 6 (the "**Gas Pipeline Standard**"). The Applicant submits that the Gas Pipeline Standard is not applicable to the Transmission Line and supports this position with the *Underground Arcing and GPR Report* (the "**Peak GPR Report**", attached hereto as **Schedule 'D'**) it commissioned Peak to generate as part of the design process for the Proposed Final Design. As outlined in the Peak GPR Report, the 10 meter separation recommended in the Gas Pipeline Standard is given because this separation distance "has been established as a reasonable physical clearance during construction and maintenance activities."¹⁵ This distance is not intended to be understood as providing protection against damage to pipelines or pipeline coatings during faults on the electrical system and therefore no conclusion can be drawn from this portion of the Gas Pipeline Standard. Simply put, Gas Pipeline Standard has no application in this case.
33. Additionally, imposing this standard would have an adverse impact on landowners. Although the Applicant has a statutory right to use the Municipal ROW¹⁶, at HCHI's request not to use the Municipal ROW, the Applicant agreed to try to negotiate with

¹³ Based on negotiations with landowners, the Applicant does not believe that expropriating this particular landowner is an option, since this would drastically undermine the goodwill that the Applicant has developed with the landowners and the community and will need to rely on going forward as the Project is developed.

¹⁴ Induction Study, p. 3.

¹⁵ See Note 1 of CSA C22.3 No. 9-M91 Section 3.3.

¹⁶ See section 41 of the *Electricity Act, 1998*.

private landowners to use the private land along Concession Rd. 5.¹⁷ The Applicant and landowners along Concession Rd. 5 negotiated land rights based on the current rules and standards in place in Ontario at that time. Requiring the Transmission Line to move 10 meters from the Municipal ROW would, at this stage, involve changing the basis upon which negotiations were carried out, and potentially lead to an expropriation of private land.

34. For the foregoing reasons, the Applicant submits that its proposal to locate the Transmission Line within 5 meters of the HCHI Proposed Distribution should be accepted by the Board.

(iv) HCHI's and Board Staff's position that, when calculating induction under fault conditions, the default assumption should be a fault value of 63 kA;

35. The HCHI Induction Study also examines the induced voltage into distribution phases during a transmission line fault. The Induction Study used a fault value in the Transmission Line of 63 kA¹⁸, which fault level would induce voltage of 46 kV in the distribution line. Board Staff supports HCHI's use of the 63 kA value, citing the Transmission System Code as authority.¹⁹
36. The Applicant submits that the appropriate maximum fault current value to use in any induction study of the Adjacent Length is 23 kA, not 63 kA. A fault current of 63 kA represents the maximum system fault current allowed by the Transmission System Code. As detailed in the Peak GPR Study, the maximum fault current available in the modeled region of the Transmission Line is limited by the inherent impedance of the Transmission Line, which, as designed, is 23 kA.²⁰ This value is found using available information and assuming a maximum fault current at the Switchyard of 63 kA in accordance with the Transmission System Code. The 23 kA number for a 63 kA source at the Switchyard is therefore the best conservative number to use since it takes into account the fault current limitations imposed by the Transmission System Code and the impedance of the Transmission Line. Unless other sources of fault current such as additional large generating stations or additional transmission line interconnections were

¹⁷ Application, Exh. B-6-1, p. 4.

¹⁸ In practical terms, the ampere is a measure of the amount of electric charge passing a point in an electric circuit per unit time with 6.241×10^{18} electrons.

¹⁹ Transmission System Code, amended June 10, 2011, Appendix 2.

²⁰ Peak GPR Study, Section IV.A.

present very close to the modeled region, it would not be possible to attain the maximum fault current of 63 kA.²¹

37. There is very little chance that additional large generating stations or transmission lines would connect to the Transmission Line, and even if this were to happen, the IESO and Hydro One Networks Inc. would require upgrades to accommodate elevated fault currents (as per the requirements that would be outlined in the requisite system impact assessments (“**SIA**”) and customer impact assessments (“**CIA**”)).
38. For the foregoing reasons, the Applicant submits that the fault current value to be used in any evaluation of the Transmission Line in the current proceeding is 23 kA.

(v) Board Staff's proposed condition that the Applicant be responsible for the costs of Kinectrics conduct animal contact potential measurements after the Transmission Line is in service

39. Board Staff is of the view that animal contact potential is an issue for the 21 properties identified in HCHI's submission.²² Board Staff bases this concern on the following statement in the HCHI Induction Study:

“Kinectrics modeled the neutral to earth voltages considering 2 km length of parallel exposure. Calculations were performed for two ground rod resistances (transformer and customer service ground), 37 ohm and 75 ohm, on the neutral at 100 m spacing. The calculated neutral potential to remote earth remained below 7 V in both cases. The Ontario Electrical Safety Code limits the neutral potential to 10 V, which could be still exceeded depending upon the existing potentials that may be present. In addition, utilities must maintain their contribution to animal contact potentials at customer premises under 0.5V which could be exacerbated by the new line.”
40. According to HCHI, the resistance values of 75 Ohms and 37 Ohms for the ground rods used by Kinectrics approximately correspond to HCHI's distribution standard for the minimum number of grounds to be used for 4.16 kV systems and 27.6 kV systems respectively.²³ This appears to be the minimum design standard, and HCHI states that this is common practice with utilities in Ontario, but does not discuss how they came to these values.²⁴ Based on the Applicant's extensive experience, there is no reason that

²¹ Peak Induction Study, Section III.F.

²² Board Staff Submission, at p. 7.

²³ HCHI – IRR to Summerhaven, Question 4.

²⁴ HCHI – IRR to Summerhaven, Question 4(a).

every structure could not be grounded, possibly with multiple ground rods. Furthermore, the Applicant's soil resistivity measurements show low values and therefore it would be simple and cost effective to obtain ground resistances in the range of 3 to 15 Ohms.²⁵ The Applicant is not suggesting that HCHI ground every pole in their current system, however this approach represents an effective mitigation measure that could easily be implemented along the Adjacent Length once the HCHI Proposed Distribution is in place. As indicated in the Technical Conference, the Applicant would be willing to cover costs associated with this mitigation measure.²⁶

41. Board Staff recommends that HCHI should be required to complete an assessment of impact of the Distribution Conversion on animal contact potential in order to ensure that the source of any future problems is properly identified.²⁷ The Applicant agrees with this recommendation.
42. Board Staff also recommends that the Applicant be responsible for costs associated with having Kinectrics repeat the animal contact potential measurements post-energization of the Transmission Line. The Applicant does not believe that a post-energization animal contact potential study (which would involve carrying out testing at every farm within the vicinity of the Transmission Line) is necessary. Rather, the Applicant proposes to install neutral decoupling devices on HCHI's existing infrastructure at relevant customers' points of interconnection.²⁸ This would effectively pre-empt any possibility that animal contact voltage may arise as a result of the Transmission Line and be more cost effective.
43. For the foregoing reasons, the Applicant submits that the Board should not impose a post-energization animal contact potential study as a condition to approval.

(vi) HCHI condition that the design of the Transmission Line ensure maximum swing arc or blowout or the Transmission Line conductor remains within the Applicant's easement

44. HCHI submits that the maximum swing arc or blowout of the Transmission Line conductor should remain within the Applicant's easement, however HCHI does not

²⁵ Peak Induction Study, section III.D.

²⁶ Technical Conference, p. 48-49, lines 28 – 15; p. 53, lines 19-24.

²⁷ Board Staff Submissions, at p. 8.

²⁸ In the event mitigation measures are required prior to the Distribution Conversion, it is expected that HCHI would properly design the HCHI Proposed Distribution to prevent any animal contact potential and the Applicant would not be responsible for costs after the initial mitigation measures have been put in place.

provide a reason for this request. The Applicant disagrees that this is a reasonable request.

45. HCHI's reference to the Applicant's easement appears to be arbitrary and is not based on any standards or codes. The easement is 30 meters, which accommodates not only the placement of the Transmission Line, but also the space required to carry out construction, access, operations and maintenance of the Transmission Line. As stated above, the landowners that are party to the easements, or are currently negotiating the easements, have made very specific requests regarding the placement of the poles within the easement for commercial/agricultural reasons.²⁹ As such, while the Applicant has, or is attempting to, negotiate 30 meter easements, it is not always within the Applicant's discretion to use the centerline of the easement for placement of the Transmission Line.
46. The requirement to ensure that the maximum swing arc is contained within the Applicant's easement is not justified by any technical or design criteria. As evidenced by the pole cross-section diagram at Schedule 'E', the pole configuration will provide more than enough clearance, beyond what is required by code. The Applicant is designing the Transmission Line to meet code requirements not only to the existing HCHI distribution infrastructure, but also to the HCHI Proposed Distribution. Importantly, the swing arc is not addressed in the Induction Study, and the only evidence with respect to blowout has been provided by the Applicant. The Applicant is unclear as to the basis for HCHI's request.
47. If the Applicant cannot accommodate HCHI's proposal within the rights obtained, it may be forced to pursue the placement some of the Transmission Line in the municipal ROW, thus negating any perceived value of HCHI's request for separation.
48. For the foregoing reasons, the Applicant submits that a condition restricting the Transmission Line swing arc/blow out should not be required as a condition of approval of this Application.

(vii) ***HCHI's condition that the installation of the guy wires not be in the Municipal ROW***

49. The Applicant does not at this time anticipate it will need to install any guy wires in the Municipal ROW. Going forward, the Applicant will make commercially reasonable efforts to locate guy wires outside of the Municipal ROW. In instances where this may be

²⁹ Due to structure guying, in some places the structures are moved towards one side of the easement to fit the guys and anchors within the easement. This is in addition to the commercial and agricultural reasons.

required, the Applicant will make efforts to minimize any impact to HCHI. The Applicant respectfully submits that it has equal rights to the Municipal ROW and HCHI has not stated a reason for this request, nor has it referenced any standard or code for the Applicant to rely on.

COMMON SWITCHYARD

50. As noted above, the Applicant largely supports the submission of Capital Power regarding the joint switchyard discussion. As detailed in the Table below, the Applicant's project development has followed a similar path to that described by Capital Power. Notably, the Applicant had completed over 3 years of environmental field surveys and reports by the time the concept of a joint switchyard with Capital Power was raised. Similarly, the land for the Applicant's switchyard location had been under option for more than 2 years.
51. In designing the Project and performing the detailed, location-specific environmental studies (collectively with the environmental surveys, the "**Environmental Reports**") required by the permitting regime in Ontario, the Applicant had relied on the best available knowledge, including the SIA and electrical studies it had previously held and performed, which indicated no concern over their proposed Switchyard location. The Applicant also held several pre-contract meetings with the IESO and Hydro One Networks Inc. to discuss the Project and this concern was never raised. Unfortunately, the concern was only raised in September 2010, as the Applicant was finalizing the detailed environmental reports mentioned above.
52. Finalizing and submitting these reports kicked off a 9 -15 month REA permitting process that is on the critical path for the development of the Project. Any delay resulting from rework of the draft reports or requirements for additional field studies would have significantly delayed the Applicant's development and would risk exposing the Applicant to large financial penalties from suppliers and the Ontario Power Authority.
53. The Applicant respectfully submits that it acted in good faith using the best available knowledge at the time when selecting its proposed point of interconnect, and could not have reasonably been expected to change the location at such a late point in the development cycle. The IESO, in its submission³⁰ suggests that the Applicant bears the risk of a location change as a result of the SIA and CIA until the 150 day mandated processing period is complete. The Applicant respectfully submits that while it is true that requirements related to system reliability and safety are not conclusively determined until the SIA and CIA are complete, changing the physical location of a switchyard for

³⁰ IESO Submissions dated July 22, 2011, at par. 4.

reasons other than reliability and safety is not typically at risk during this period. Indeed, if such a change was required, it would not align with other Provincial processes and timelines (namely the REA process and the Feed-in-tariff (“**FIT**”) process) to allow for the development of renewable energy projects within a maximum 36-month window as required by the generic FiT contract.

54. Below is a table identifying the relevant milestones in the permitting process and how they are related to the issuance of the SIA and CIA:

Item	Date
Lease option signed for Switchyard land	August 15 th , 2008
Environmental & Archeological Studies	June 2007 - ongoing
Fit Contract Submitted & Previous SIA Rescinded	November 2009
Open House #1	December 2009
FiT Contract Executed (Milestone COD 01/19/2012)	April 2010
Draft environmental studies finalized	August 2010
Release of environmental studies to public and government (Ministry of Natural Resources, County, Ministry of Culture)	October 4 th , 2010
Joint meetings with HONI, IESO and Capital Power on potential joint interconnection location	September 2 nd , 2010 September 27 th , 2010 October 5 th , 2010
Open House #2	December 2010
SIA & CIA received	November 2010
Open House #3	January 2011

CONCLUSION

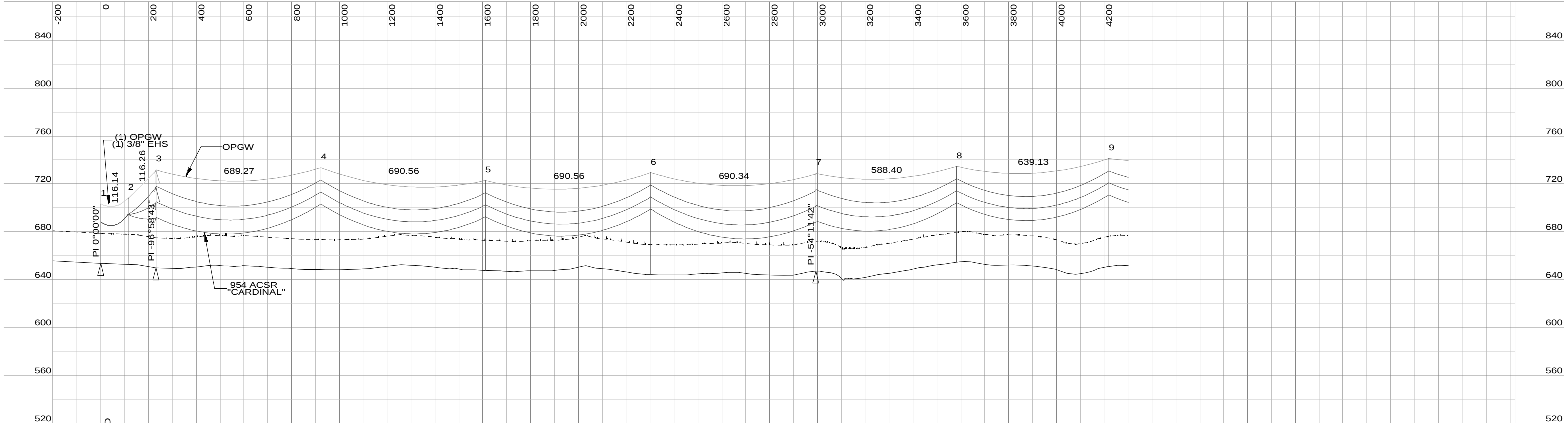
55. To summarize, the Applicant is proposing a Transmission Line design similar to the design in Schedule ‘A’. In addition, the Applicant is proposing the following mitigation measures, that which could be covered in a mitigation agreement with HCHI:
- (i) Conduct a baseline Neutral Voltage Survey on HCHI’s current distribution system;
 - (ii) Conduct a post-energization Neutral Voltage Survey using field data;
 - (iii) Install, at its cost, any mitigation measures to mitigate issues identified in the post-energization Neutral Voltage Survey;

- (iv) Install neutral decoupling devices on HCHI's existing infrastructure at the relevant customer's point of interconnection to pre-empt animal contact potential issues;

- 56. While the Applicant submitted the Proposed Final Design at the request of the Board, it notes that the Proposed Final Design is not "final". There are several outstanding issues such as the REA review, landowner considerations, etc. that may ultimately affect the design of the Transmission Line. As such, the Applicant should not be required to adhere to the Proposed Final Design as a condition of approval. Rather, the Proposed Final Design, taken together with the Applicant's proposed conditions of approval and mitigation measures are evidence that the Applicant will be able to meet reliability and safety standards and accommodate the reasonable concerns of third parties, including HCHI.
- 57. While the Applicant takes the issues raised by HCHI seriously, the Applicant firmly believes that transmitters can rely on existing codes and standards to design safe and reliable transmission infrastructure. One only has to look out the window to see multiple examples of transmission built to code within close proximity to distribution lines operating safely and reliably.
- 58. With respect to the Common Switchyard, the Applicant should not be penalized for carrying out Project development in good faith and according to the concurrent processes established by the Province. Although the IESO report recommends a common switchyard, it does not do so for reliability reasons.
- 59. The Applicant submits that approval of the Facility is within the public interest, and that the price, reliability and quality of electricity will be maintained, and particularly, that approval of the Facility, its sole use being to connect the Project, is consistent with the promotion of the use of renewable energy sources.
- 60. The Applicant therefore requests that the Board approve this application as proposed by the Applicant in these submissions.

ALL OF WHICH IS RESPECTFULLY SUBMITTED

Schedule A
Proposed Pole Design



- 1

sta=0.00
ht=49.70 ele=653.57
(3) T2
(1) GW-1, (1) OP-1
(1) FO-2
SUBSTATION DEADEND
- 2

sta=116.15
ht=55.50 ele=652.76
- 3

sta=232.40
ht=82.00 ele=649.94
ht adjust=-3.00
VDE-2
DA4
(2) AS-1
13' Embedment
85' Guy Lead
- 4

sta=921.67
ht=85.00 ele=648.45
TBP
DAL, DA3
13' Embedment
- 5

sta=1612.23
ht=75.00 ele=647.75
TBP
DA3
12' Embedment
- 6

sta=2302.79
ht=82.00 ele=644.26
TBP
DAL, DA3
13' Embedment
- 7

sta=2993.13
ht=82.00 ele=647.08
ht adjust=-3.00
VDE1
DA4, DA5
(2) AS-1
13' Embedment
85' Guy Lead
- 8

sta=3581.53
ht=80.00 ele=654.52
TBP
DAL, DA3
11.5' Embedment
- 9

sta=4220.66
ht=90.00 ele=651.01
TBP
DAL, DA3
12.5' Embedment

- NOTES
- 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
 - OPGW AND 7#7 AW SHOWN AT 60 DEG F.
 - GROUND CLEARANCE LINE SHOWN AT 25 FEET.
 - STRUCTURE 48 ONLY GUYED AGAINST TENSION TOWARDS STR 47. GUYS NOT USED IN SLACK SPAN TOWARD SUBSTATION DE
 - STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5

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ST: REG: EXP:

REV

DESCRIPTION

ENG

DWN

CHK

DATE

ENG: T. FRANCIS

E

REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE

TMF

TMF

BVB

07/20/11

DWN: T. FRANCIS

F

REVISED FOR FUTURE HCH CROSSINGS

BVB

TMF

BVB

07/27/11

CHK: B. VAN BRIESEN

C

ISSUED FOR ESA REVIEW

TMF

TMF

BVB

03/15/11

APP:

D

REVISED ROUTE

TMF

TMF

BVB

04/08/11

DATE: 03/15/11

NEXTERA ENERGY CANADA, ULC

SUMMERHAVEN 230KV TRANSMISSION LINE

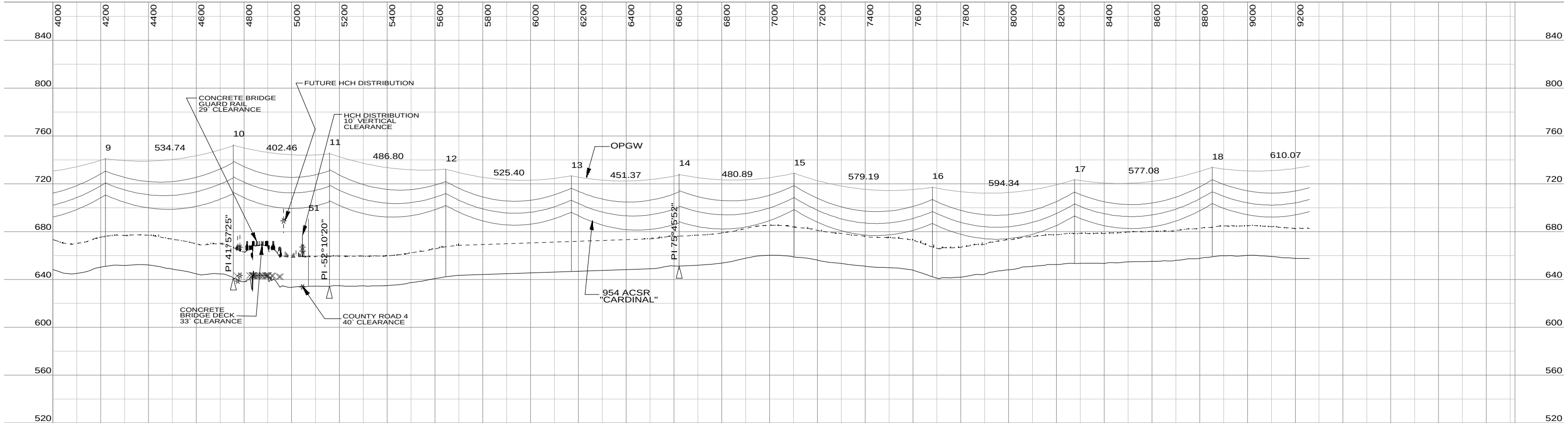
PLAN AND PROFILE SHEET 1 OF 5

SCALE

AS NOTED

DRAWING 17651-2101

REV F



9
sta=4220.66
ht=90.00 ele=651.01
TBP
DA1, DA3
12.5' Embedment

10
sta=4755.40
ht=111.50 ele=641.29
ht adjust=1.00
VDE-3
DA2, DA4, DA5
FON
SELF SUPPORTING

51
sta=25348.57
ht=56.50 ele=634.17
FUTURE DIST. STR.
11
sta=5157.86
ht=111.50 ele=634.43
VDE-3
DA4, DA5
FON
SELF SUPPORTING

12
sta=5644.65
ht=90.00 ele=642.29
TBP
DA1, DA3
11.5' Embedment

13
sta=6170.05
ht=80.00 ele=646.68
TBP
DA1, DA3
11.5' Embedment

14
sta=6621.42
ht=77.00 ele=651.25
VDE-3
DA4, DA5
(3) AS-1
(1) FO-1, (1) FO-2
12.5' Embedment
68' Guy Lead

15
sta=7102.31
ht=70.00 ele=658.85
TBP
DA3
11.5' Embedment

16
sta=7681.49
ht=75.00 ele=642.14
TBP
DA1, DA3
12' Embedment

17
sta=8275.83
ht=70.00 ele=653.43
TBP
DA3
11.5' Embedment

18
sta=8852.91
ht=75.00 ele=658.78
TBP
DA1, DA3
12' Embedment

- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
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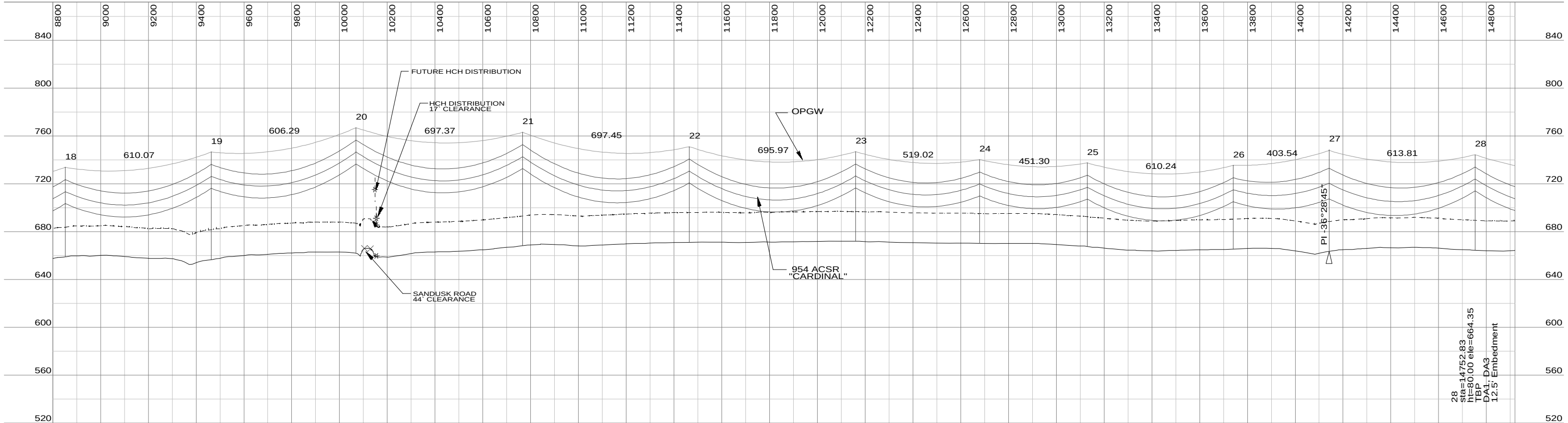
ST: REG: EXP:

NEXTERA
ENERGY

RESOURCES

REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE	TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS
F	REVISED FOR FUTURE HCH CROSSINGS	BVB	TMF	BVB	07/27/11	CHK: B. VAN BRIESEN
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

NEXTERA ENERGY CANADA, ULC SUMMERHAVEN 230KV TRANSMISSION LINE		
PLAN AND PROFILE SHEET 2 OF 5		
SCALE	AS NOTED	DRAWING 17651-2102
		REV F



18 sta=8852.91 ht=75.00 ele=658.78 TBP DA1, DA3 12' Embedment	19 sta=9462.98 ht=90.00 ele=656.57 TBP DA1, DA3 12' Embedment	20 sta=10069.27 ht=105.00 ele=661.96 TBP DA1, DA3 12.5' Embedment	21 sta=10766.63 ht=95.00 ele=668.13 TBP DA3 12' Embedment	22 sta=11464.08 ht=80.00 ele=671.04 TBP DA1, DA3 12.5' Embedment	23 sta=12160.05 ht=75.00 ele=671.86 TBP DA3 12' Embedment	24 sta=12679.07 ht=70.00 ele=670.20 TBP DA1, DA3 11.5' Embedment	25 sta=13130.37 ht=70.00 ele=667.49 TBP DA3 11.5' Embedment	26 sta=13740.61 ht=70.00 ele=665.38 TBP DA1, DA3 11.5' Embedment	27 sta=14141.57 ht=85.00 ele=663.46 VRA-1 DA3 AS-3 13' Embedment 72' Guy Lead	28 sta=14752.83 ht=80.00 ele=664.35 TBP DA1, DA3 12.5' Embedment
--	--	--	--	---	--	---	--	---	--	---

- NOTES
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NEXtera

ENERGY

RESOURCES

REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
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D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

NEXTERA ENERGY CANADA, ULC

SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 3 OF 5

SCALE

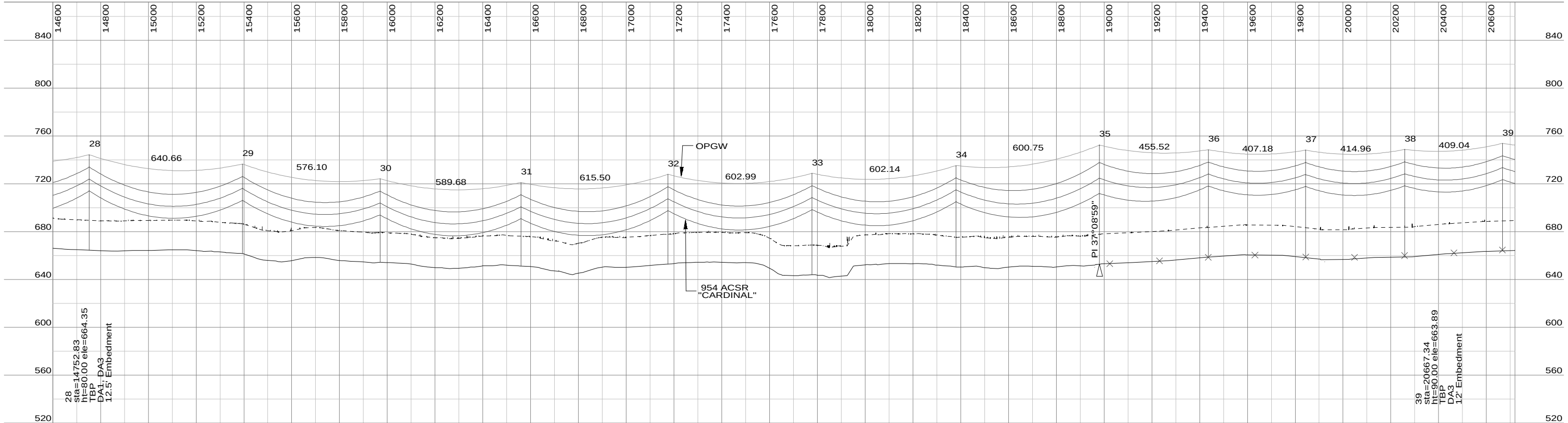
AS NOTED

DRAWING

17651-2103

REV

F



29
sta=15393.49
ht=75.00 ele=661.58
TBP
DA3
12' Embedment

30
sta=15969.59
ht=70.00 ele=654.30
TBP
DA1, DA3
11.5' Embedment

31
sta=16559.27
ht=75.00 ele=651.17
TBP
DA3
11.5' Embedment

32
sta=17174.76
ht=75.00 ele=652.85
TBP
DA1, DA3
12' Embedment

33
sta=17777.75
ht=85.00 ele=643.82
TBP
DA3
13' Embedment

34
sta=18379.89
ht=85.00 ele=650.29
TBP
DA1, DA3
13' Embedment

35
sta=18980.65
ht=100.00 ele=652.82
VRA-2
DA3
FDN
Self Supporting

36
sta=19436.16
ht=90.00 ele=658.54
TBP
DA1, DA3
12' Embedment

37
sta=19843.34
ht=90.00 ele=658.16
TBP
DA3
12' Embedment

38
sta=20258.30
ht=90.00 ele=658.71
TBP
DA1, DA3
12' Embedment

- NOTES
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C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

SCALE

AS NOTED

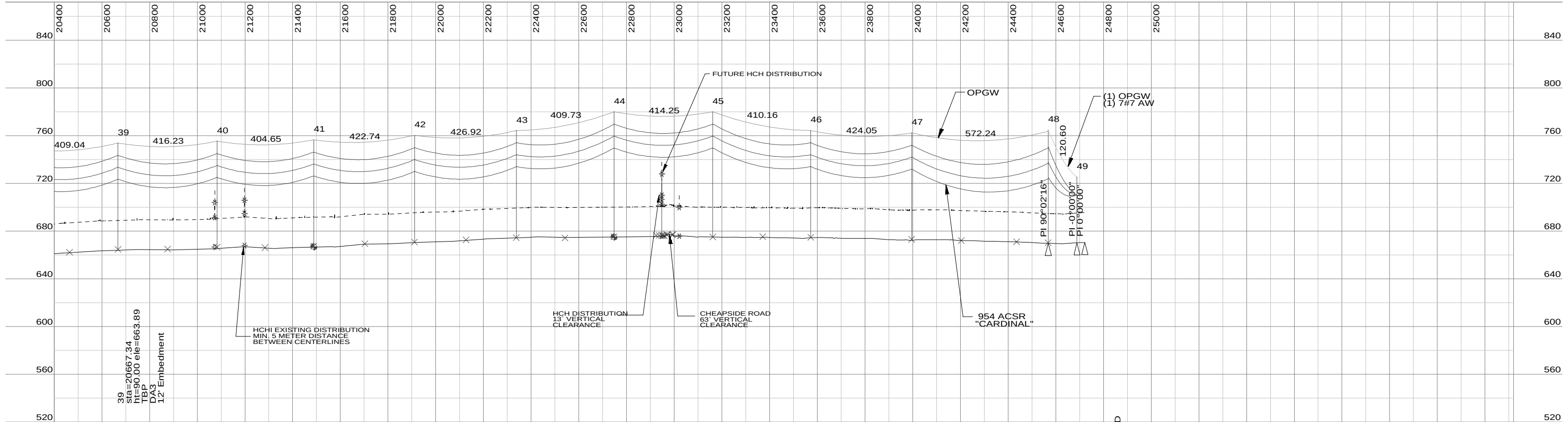
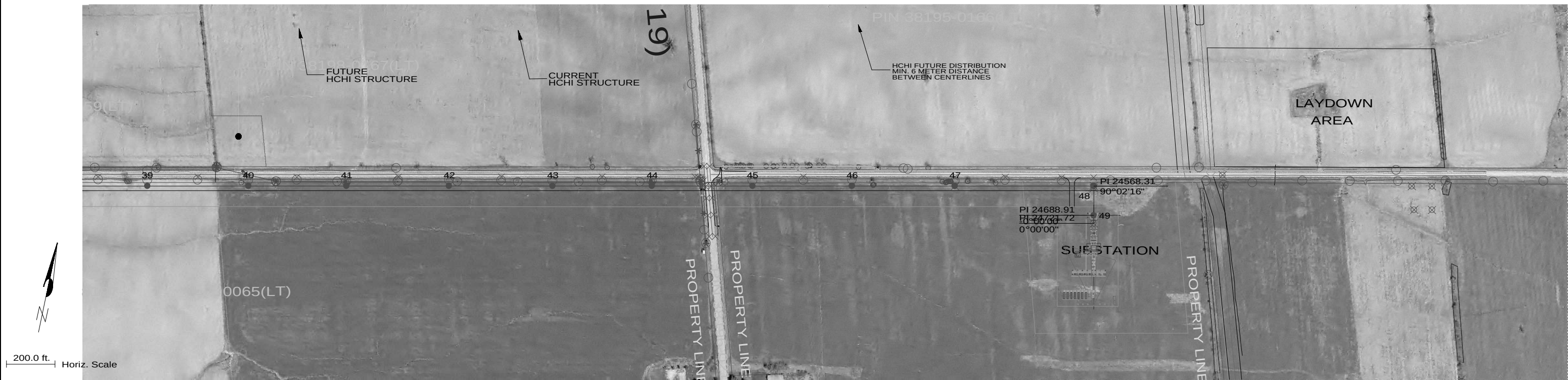
DRAWING
17651-2104

REV
F

NEXTERA ENERGY CANADA, ULC

SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 4 OF 5



39
sta=20667.34
ht=90.00 ele=663.89
TBP
DA3
1.2' Embedment

40
sta=21083.57
ht=90.00 ele=665.37
TBP
DA1, DA3
1.2' Embedment

41
sta=21488.22
ht=90.00 ele=666.59
TBP
DA3
1.2' Embedment

42
sta=21910.96
ht=90.00 ele=670.33
TBP
DA1, DA3
1.3' Embedment

43
sta=22337.87
ht=90.00 ele=674.35
TBP
DA3
1.5' Embedment

44
sta=22747.61
ht=105.00 ele=675.04
TBP
DA1, DA3
1.5' Embedment

45
sta=23161.86
ht=105.00 ele=675.05
TBP
DA3
1.5' Embedment

46
sta=23572.02
ht=90.00 ele=674.38
TBP
DA3
1.4' Embedment

47
sta=23996.07
ht=90.00 ele=672.36
TBP
DA3
1.3' Embedment

48
sta=24568.31
ht=95.00 ele=669.76
VDE-2
DA5
AS-1, NOTE 4
12.5' Embedment
80' Guy Lead

49
sta=24688.91
ht=95.00 ele=670.20
(3) GV-1, (1) OP-1
(1) EO-2
SUBSTATION DEADEND

- NOTES
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NEXTERA ENERGY CANADA, ULC
SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 5 OF 5

SCALE AS NOTED
DRAWING 17651-2105
REV F



**Schedule B
Photos**

Cheapside Road Near Conc Road 2



North of Selkirk Road on Rainham Road



North of Selkirk Road on Rainham Road #2



Schedule C
Peak Induction Study



INDUCTION STUDY REPORT

NEXTERA ENERGY SUMMERHAVEN TRANSMISSION LINE HALDIMAND COUNTY, ONTARIO

REPORT 18559-9001



Design Checking

- ☐ Preliminary for internal review
- ☐ Issue for client review and comment
- ☐ Issue for client approval
- ☒ Issue as final
- ☐ Issue as revised

		Eng	Date
Design	Engineer	PDB	7/6/11
Check	Transmission	TMF	7/7/11
	Electrical	KKC	7/7/11
Approve	Project Manager	PSF	7/26/11
	Client		

Gerhard G. Runge, P.Eng

Revisions

Rev	Description	Eng	Chk	Date
A	Preliminary for Review	PDB	TMF	7/7/11
B	Revised for updated transmission line design and HCHI line design	PDB	PSF	7/25/11
0	Issued for submittal	PDB	PSF	7/25/11

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	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

I. EXECUTIVE SUMMARY

The proposed Summerhaven 230 kV transmission line includes a section of approximately 1.7 km length in which the proposed transmission line route runs parallel to a road right-of-way in which Haldimand County Hydro, Inc. (HCHI) intends to construct a 27.6/16 kV distribution line. NextEra Energy contracted Universal Pegasus [also known as Peak Power Engineering] to perform an induction study that would estimate the expected levels of AC induction on the distribution line for steady state and fault conditions.

The study modeled the transmission line based on the latest transmission line design information and modeled the distribution line based on HCHI design standards for 27.6 kV distribution line. Specialized computer software was used to estimate the potential that would be induced onto the distribution line through electromagnetic coupling along the region of close parallel routing. The worst-case estimates for several of the quantities calculated are shown in Table 1 below. All quantities shown in the table are “worse” in increasing magnitude.

Table 1: Worst-Case Results

Quantity	Transmission Line Current	Scenario	Value
Maximum Neutral-to-Earth Voltage	Steady State	75 Ohm Ground	8.51 V
Maximum Voltage Unbalance	Steady State	3 Ohm Ground	0.011 %
Maximum Phase-to-Neutral Temporary Overvoltage	Fault Conditions	3 Ohm Ground, Middle-Phase Fault	1.97 p.u.
Maximum Neutral-to-Earth Voltage	Fault Conditions	75 Ohm Ground, Bottom-Phase Fault	15.1 kV

The values shown in Table 1 are the worst values resulting from all of the scenarios studied. While the actual in-service system may correspond to the modeled scenarios to differing degrees, the results indicate that mitigation measures may be appropriate to reduce the impact of the parallel routing on the distribution system. Mitigation measures can include the following:

- Reinforcement of distribution neutral grounds to reduce resistance to remote earth
- Load balancing
- Installation of neutral decoupling devices at service transformers
- Application of appropriately rated surge arresters
- Distribution line relocation and/or undergrounding

These mitigation measures are not specifically recommended, but are presented for consideration and discussion by the various interested parties.

	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

II. INTRODUCTION

The proposed Summerhaven 230 kV transmission line includes a section of approximately 1.7 km length in which the proposed transmission line route runs parallel to a road right-of-way in which Haldimand County Hydro, Inc. (HCHI) intends to construct a 27.6/16 kV distribution line. NextEra Energy contracted Universal Pegasus [also known as Peak Power Engineering] to perform an induction study that would estimate the expected levels of AC induction on the distribution line for steady state and fault conditions.

The study modeled the transmission line based on the latest transmission line design information and modeled the distribution line based on HCHI design standards for 27.6 kV distribution line. Specialized computer software was used to estimate the voltage that would be induced onto the distribution line through electromagnetic coupling along the region of close parallel routing.

Results of software modeling of the transmission line and distribution line were evaluated relative to applicable distribution standards, including the Ontario Electric Safety Code and the OEB Distribution System Code, and some possible mitigation measures for reducing the impact of the parallel routing on the distribution system are presented.

III. MODEL DEVELOPMENT

The transmission line and distribution line were modeled using the geometry of typical tangent structures, conductor electrical properties, conductor sag, typical span lengths, footing resistances, separation between lines, and line current flow. The following subsections describe the parameters used to develop the model for this study.

A. Transmission Line Cross-Section

The transmission line was modeled using typical single-pole braced post tangent structures with dimensions as shown on the latest revision of the structure detail drawing (UPI Drawing 17651-2201, Appendix A). The structure was shown with 3.05 m [10 ft] vertical spacing between the phases and 3.66 m [12 ft] vertical spacing from the top of the structure to the insulator base of the top phase. The insulator assembly used to support the phase conductors was found to have a horizontal offset of 2.42 m [95.4 in] relative to the center of the post insulator base and an upward angle of 12° (Insulator assembly drawing, Appendix B).

The transmission line structures were shown to be 27.4 m [90 ft] above grade in the latest revision of the transmission line plan & profile drawings (UPI Drawings 17651-2104 and -2105, Appendix C). Pole diameter and taper was not yet known, but it was estimated based on past experience that the diameter at the tip of the poles would be approximately 0.467 m [18 in] and that the poles would have a taper of approximately 3.58 cm/m [0.43 in/ft]. Taller structures were shown in the current design at the crossing of Cheapside Road to allow a distribution line to cross under the transmission line; however, the structures described in this paragraph characterized the majority of the line in the modeled section.

Using the structure geometry as described above, the coordinates of the conductor attachment points were calculated to be as shown in Table 2 below. X-axis coordinates are

	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

relative to the center of the transmission pole and y-axis coordinates are relative to the ground.

Table 2: Transmission Line Conductor Coordinates

Conductor	X (m)	Y (m)
Top Phase	2.71	24.28
Middle Phase	-2.76	21.24
Bottom Phase	2.82	18.19
Shield	0.84	27.44

B. Distribution Line Cross-Section

The distribution line conductor positions were modeled as shown on the Cross Section “A” drawing provided by HCHI as part of their supplemental evidence submittal dated July 13, 2011 [1]. The coordinates of conductor attachment points as used in the model developed for this study are shown in Table 3 below. X-axis coordinates are relative to the center of the distribution pole and y-axis coordinates are relative to the ground.

Table 3: Distribution Line Conductor Coordinates

Conductor	X (m)	Y (m)
Top Phase	0.91	14.25
Middle Phase	0.91	12.75
Bottom Phase	0.91	11.25
Neutral	0	8.05

C. Transmission & Distribution Line Conductors

The transmission line conductor types were as shown in the tangent structure bill of material on the structure detail drawing included as Appendix A. The distribution line conductor types were modeled as annotated on the Utilities Standards Forum drawing reproduced as Appendix B of the Kinetrics Report “Induction Study for Haldimand County Hydro Inc.” [2].

Conductor sags for the transmission line were determined from transmission line design summary information for conductor temperatures of 49 °C [120 °F] for the phase conductors and 25 °C [77 °F] for the shield. The conductor sag for the distribution line was unknown, so no sag was accounted for in the distribution line model; this represented the most conservative sag assumption possible for this study. The software used to model the system approximates the conductors as long, straight wires, so the average conductor height was used, calculated as the height at the structure minus two-thirds of the sag.

Conductor electrical parameters were taken from standard reference tables as published in the *Southwire Overhead Conductor Manual, 2nd Edition* [3] with the exception of the transmission line OPGW, which was modeled using the diameter and resistance provided by the manufacturer and a relative permeability of 1.0 to calculate the GMR. Conductor parameters were taken for a conductor temperature of 25 °C [77 °F] for all conductors except the transmission line phase conductor, which was taken at a conductor temperature of 49 °C [120 °F]. The conductor parameters used are summarized in Table 4 below.

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Table 4: Conductor Parameters

Conductor	Description	Diameter (mm)	GMR (m)	Assumed Conductor Temp. (°C)	Resistance (Ω/km)	Sag (m)
T-line Phase	954 kcmil ACSR "Cardinal"	30.38	0.0123	48.9	0.0684	3.53
T-line Shield	SFPOC SFSJ-J- 7085 OPGW	19.75	0.0077	25.0	0.2958	2.26
D-line Phase	556.5 kcmil AAC "Dahlia"	21.74	0.0082	25.0	0.1051	0
D-line Neutral	336 kcmil ACSR "Linnet"	17.37	0.0074	25.0	0.1695	0

D. Structure Footing Ground/Distribution Neutral Ground

The transmission line was modeled with footing ground resistance of 15 Ω at each structure based on the specified maximum footing ground resistance for the project. The distribution line was modeled with several different neutral ground resistances used uniformly at all structures: 75 Ω, 37 Ω, 15 Ω, and 3 Ω. The largest two distribution system ground resistances were used to match the modeling done in the Kinetrics study [2], which were understood to have been selected based on common utility practice in the area and the minimum neutral grounding needed to meet code requirements. The 15 Ω ground resistance value was selected to represent a typical single 3-m [10-ft] driven ground rod installed in soil with a resistivity of approximately 50 Ω-m. Since soil resistivity measurements at the Summerhaven substation site showed soil resistivity of approximately 15 Ω-m, the 3 Ω neutral ground value was selected to represent an achievable good ground connection and was based on the estimated approximate resistance of two parallel 3-m [10-ft] driven ground rods in 15 Ω-m soil.

The transmission line was modeled with span lengths of 131 m [430 ft] based on the average span length over the region of parallel routing. The distribution line was modeled with span lengths of 65.5 m [215 ft] based on the placement of transmission line structures next to every other structure shown in the HCHI preliminary 27.6 kV line design [1]. The 1.7-km section of the distribution line was modeled with 26 equal spans of distribution circuit and 13 equal spans of transmission circuit.

Neutral connections of the modeled section of distribution line to the rest of the distribution system multi-grounded neutral were modeled based on the map of existing distribution facilities shown as Appendix A of the Kinetrics report [2]. The map showed two connection points to the distribution system. First, the distribution feeder was shown extending for a length approximately equal to that of the parallel section to the west of the modeled section. Second, the distribution feeder was shown connecting to apparently extensive distribution system to the north and the south at Cheapside Road.

Using the calculated self-impedance of the distribution line neutral conductor and the selected distribution line neutral ground resistance values, the equivalent impedance of a cascaded series of pi circuits was calculated. The impedance for the section extending to the west was calculated for a length of 26 spans, and the impedance for each of the sections extending to the north and the south in the middle of the modeled section was calculated by solving for the equivalent impedance of an infinite series of pi circuits. The calculated impedances are shown in Table 5 below.

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Table 5: Equivalent Neutral Impedances to Ground

Footing Ground Resistance (Ω)	Equivalent Impedance of 26-Span Multi-grounded Feeder Neutral (Ω)	Equivalent Impedance of Long Multi-grounded Feeder Neutral (Ω)
75	$3.06 + j0.56$	$1.76 + j1.36$
37	$1.62 + j0.55$	$1.24 + j0.97$
15	$0.81 + j0.50$	$0.79 + j0.63$
3	$0.36 + j0.30$	$0.36 + j0.30$

The equivalent shunt impedance of a 26-span multi-grounded feeder neutral was added to the distribution line model at the starting end of the modeled section. To account for the distribution circuit extending in two directions at Cheapside Road, one-half the equivalent shunt impedance of a long multi-grounded feeder neutral was added to the distribution line model at the twentieth distribution circuit structure (Section 19).

E. Distribution Circuit Phase Conductor Voltage Reference

A reference voltage for the distribution circuit phase conductors was provided by connecting the phase conductors to ground through an arbitrary impedance at Section 19, where the modeled portion of the distribution circuit appeared to connect to a source either to the north or to the south. An impedance of 40Ω with an X/R ratio of 1 was used, which corresponds to the equivalent source impedance to give an available fault current of 400 A. Since the only other connection of the phase conductors to ground is through the shunt capacitance of the conductors, any practical source impedance could be used without affecting the results. Connecting the phase conductors to ground provided a reference voltage of zero for the phase conductors. By superposition, the potentials calculated to be induced on the phase conductors were then added to the normal 27.6 kV energization of the conductors to get the total conductor potential.

F. Transmission Line Current

The transmission line was modeled with steady-state balanced three-phase current of 351 A, which corresponds to the full load of the Summerhaven main power transformer of 140 MVA at the nominal system voltage of 230 kV.

Transmission line fault conditions were modeled with a fault current of 63 kA. This fault current represents the maximum allowed by the Transmission System Code. Even with an infinite source at the Point of Interconnection, the maximum fault current available in the modeled region of the line is limited by the inherent impedance of the transmission line to less than 35 kA as shown in Appendix D. To reach the maximum possible fault current of 63 kA, many transmission lines or a large generating station would need to connect to the Summerhaven project transmission line very near the area where the Summerhaven transmission line is proposed to parallel the HCHI distribution line.

Due to the arrangement of the circuits, it was not certain without running calculations whether faults on the lowest phase or faults on the middle phase of the transmission line

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would induce more potential on the distribution line. Therefore, transmission line fault conditions were modeled for both a fault on the lowest phase and a fault on the middle phase.

G. Circuit Separation

The transmission line and distribution line were modeled separated by 6 m [19.7 ft] centerline to centerline as shown in the current transmission line design. The lines were modeled oriented as shown in Figure 1 below.

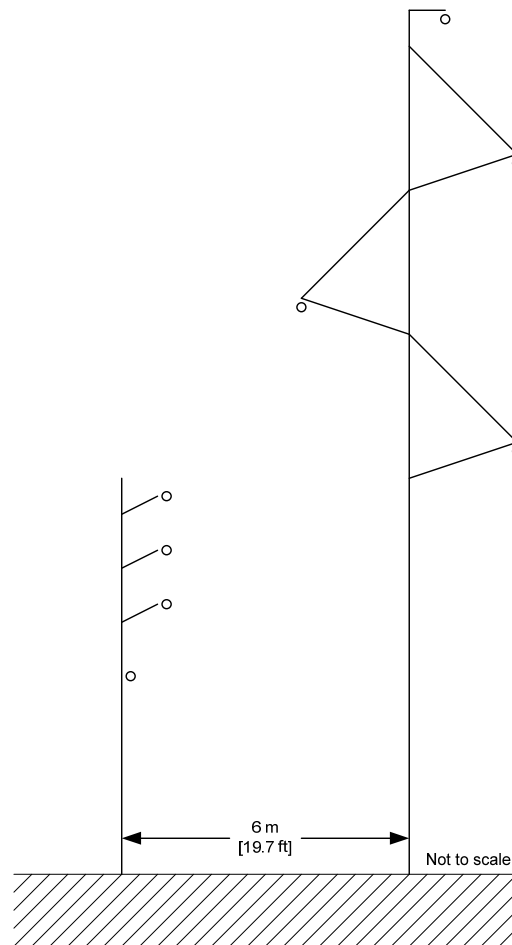


Figure 1: Circuit Separation and Orientation

IV. STUDY METHOD

A computer model of the region in which the transmission line and distribution line are proposed to be routed in close parallel proximity was developed using the parameters as described in the preceding section. The SES-Right-of-Way (SES-ROW) software package by Safe Engineering Services and Technologies was used to implement the computer model. The model used modules that calculate the self and mutual inductances of all conductors, including earth return, produce a circuit model of the distribution line and transmission line combined system, and evaluate the shunt voltage and section current for

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each modeled span for specified line currents. The model did not include electrostatic induction effects (capacitive coupling), nor did it include a soil model, computation of current flows in the earth, or any specific ground electrode configuration. Through-earth current flows are addressed in a separate study.

The computer model calculations resulted in computed section voltage, section current, and shunt current for each conductor of each section of the modeled region. This information was then processed further to calculate voltage unbalance for the steady-state cases and phase-to-neutral voltage for the transmission line fault cases. The methods used to calculate these quantities are described in the following sub-sections.

A. Steady-State Voltage Unbalance

The steady-state voltage unbalance was calculated by transforming the set of maximum induced potentials on the phase conductors to symmetrical components and then taking the ratio of induced negative-sequence potential to nominal positive-sequence potential. This approach was taken because the component of voltage unbalance that causes motor heating is the negative-sequence component. This approach produces similar results to using the NEMA definition of voltage unbalance, but eliminates having to select an arbitrary phase angle for the normal distribution system voltage relative to the transmission line current. Additional discussion of voltage unbalance definitions can be found in [4].

B. Phase-to-Neutral Voltage on Distribution Circuit for Transmission Faults

The voltage induced on the distribution circuit for single-phase faults on the transmission line can have the effect of increasing the phase-to-neutral voltage on the distribution circuit since the potential induced on the phase wires is not the same as the potential induced on the neutral wire. This additional phase-to-neutral voltage is of particular interest in evaluating the capability of distribution line surge arresters to withstand the temporary overvoltage.

The maximum phase-to-neutral voltage for each fault case was calculated by taking the magnitude of the phasor difference between the induced potential on each phase conductor and the neutral conductor and then adding this result to the nominal phase-to-ground voltage of the distribution circuit. This gives the worst-case phase-to-neutral voltage since it places the additional phase-to-neutral voltage induced on the line at the same phasor phase angle as the normal system voltage on that phase. The results of this calculation give the worst-case overvoltage on each phase, although in any given transmission fault, the induced potential will not be additive on all phases at the same time; voltage stress may be increased on one or two phases and decreased on the remaining phase(s).

The maximum temporary overvoltages induced on the distribution circuit by the transmission faults that were modeled were also converted to a per-unit basis on the base of 17 kV MCOV arresters since HCHI provided information that indicated this to be the standard arrester used on their 27.6 kV distribution lines [5]. This was done to facilitate comparison of the temporary overvoltages against the temporary overvoltage capability of the distribution utility's arresters.

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V. RESULTS

The results of the calculations done in this study are presented and briefly discussed in the following sub-sections.

A. Steady State

The calculated steady-state voltages induced on the distribution circuit neutral were as shown in Figure 2 below.

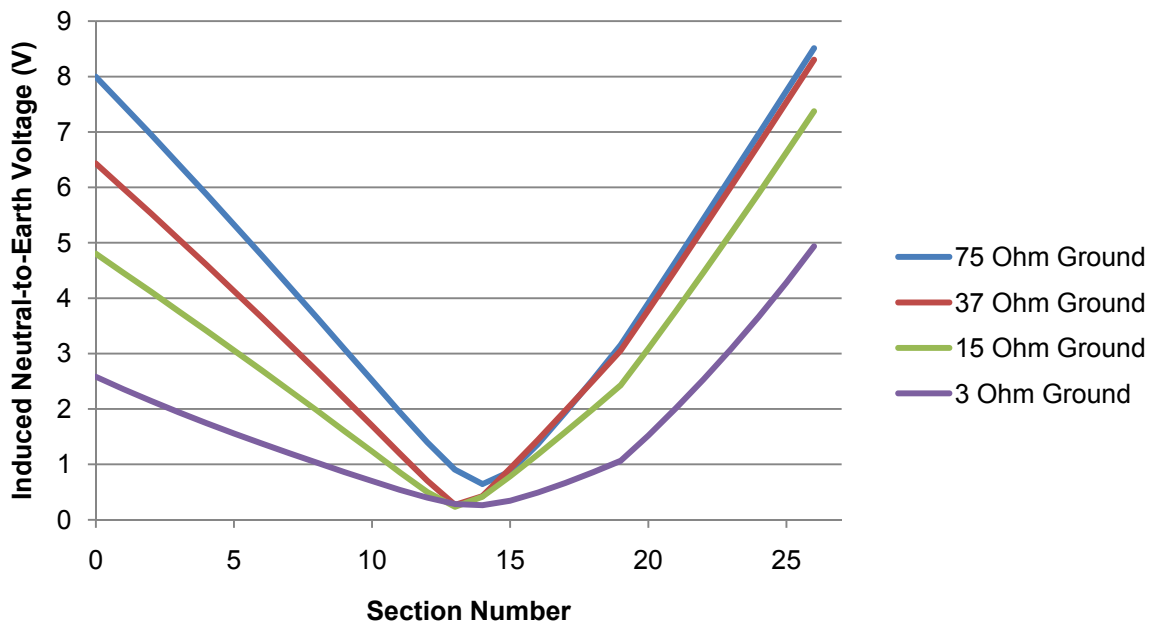


Figure 2: Steady-State Induced Neutral-to-Earth Voltage

The maximum steady-state neutral-to-earth voltage (NEV) allowed by the Ontario Electrical Safety Code [6] is 10 V. Although the computed neutral voltages did not exceed 10 V, depending on relative phase angles, it would be possible for the induced NEV to add to NEV caused by unbalanced loading of the distribution circuit or other distribution-related causes.

Although not directly addressed by this study, elevated neutral-to-earth voltage can contribute to animal contact voltage (ACV), also known as stray voltage, at the premises of agricultural customers served by the distribution system. The Ontario Electric Board Distribution System Code provides a procedure for evaluating ACV at locations where a livestock farm customer has evidence that “farm stray voltage may be adversely affecting the operation of the livestock farm customer’s farm.” [7] In cases where the distribution system is found to contribute more than 0.5 V to ACV, the distributor is required to mitigate the contribution of the distribution system to less than 0.5 V.

The steady-state voltage unbalance induced on the distribution line by current on the nearby transmission line was also evaluated. The induced potentials and the calculated unbalance are shown in Table 6 below. Since the phase conductors are in relatively close proximity,

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there is not much difference in the potential induced on each of the phases, so the induced potential is primarily zero-sequence. The negative-sequence voltage unbalance was calculated to be relatively small and unlikely to have any adverse affect on motors or other customer equipment.

Table 6: Steady-State Induced Voltage Unbalance

Scenario	Max. Induced Potential (Top, Middle, Bottom Phase)		Induced Potential Sequence Components (Positive, Negative, Zero)	Induced Voltage Unbalance (%)
	Magnitude (V)	Angle (degrees)	Magnitude (V)	
75 Ohm Ground	22.2	-57	2.9	0.011
	18.0	-70	2.8	
	15.6	-80	18.4	
37 Ohm Ground	21.5	-57	2.9	0.011
	17.2	-70	2.8	
	14.8	-81	17.6	
15 Ohm Ground	20.6	-56	3.0	0.011
	16.2	-69	2.9	
	13.7	-81	16.5	
3 Ohm Ground	19.2	-54	3.0	0.011
	14.5	-67	2.9	
	11.9	-81	14.9	

B. Transmission Line Fault

The voltage induced on the top distribution circuit phase and the distribution circuit neutral are shown in Figure 3 and Figure 4 below, respectively. Faults on both the bottom phase and the middle phase were calculated, but results were very similar, so for clarity only the worse of the two cases is shown in the figures. The worse case for the top distribution circuit phase was a fault on the middle transmission line phase, and the worse case for the distribution circuit neutral was a fault on the bottom transmission line phase.

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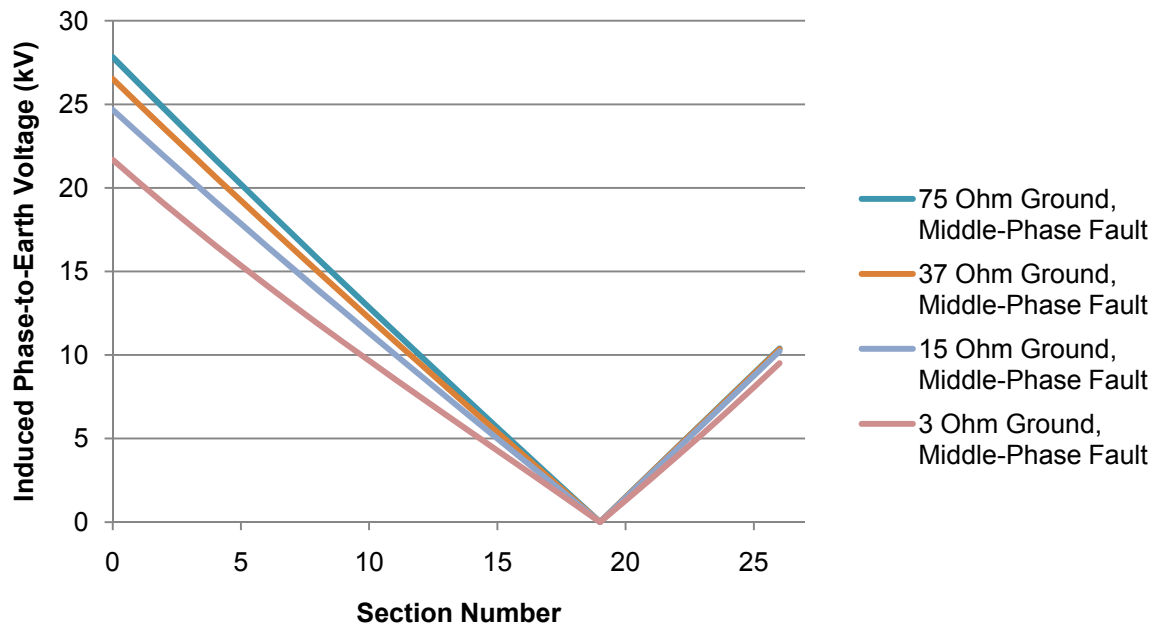


Figure 3: Fault-Condition Induced Phase-to-Earth Voltage

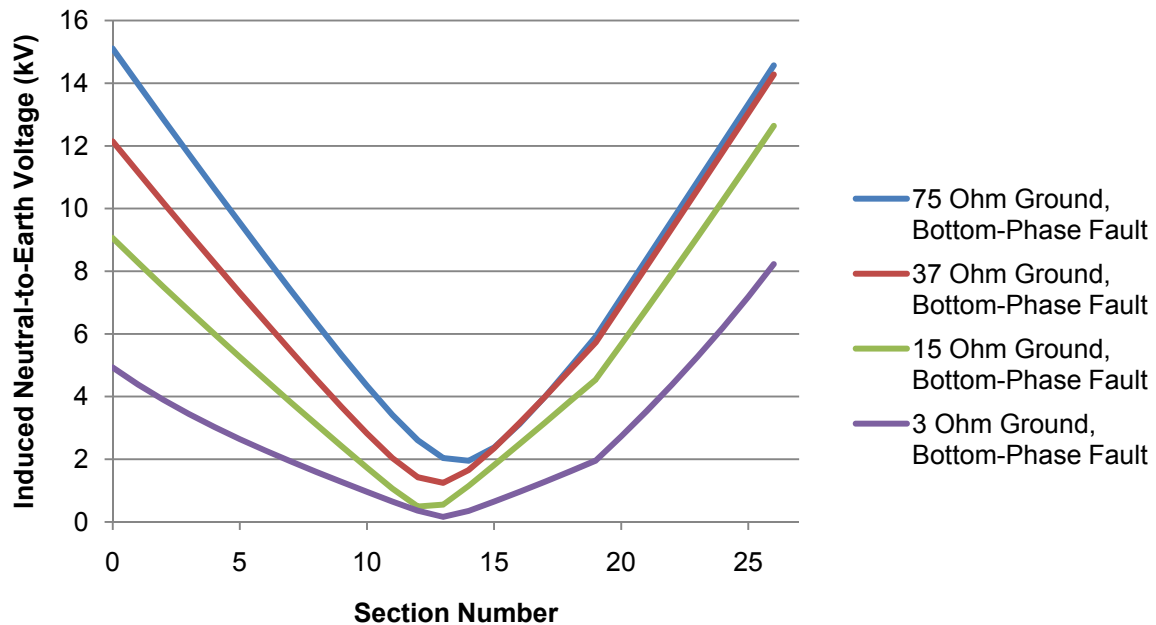


Figure 4: Fault-Condition Induced Neutral-to-Earth Voltage

High-magnitude induced phase-to-earth potentials are not necessarily a problem as long as the distribution neutral provides the ground reference for the structure; however, high-

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magnitude neutral-to-earth voltages may be transferred into customer premises through the grounded neutral connection. As discussed previously by HCHI/Kinetrics [8], recent electrical codes require bonding of metallic plumbing and equipment cases to the facility's reference ground; however, older facilities and equipment may still be in service and not have these safety features, and in some cases some level of hazard may still exist even with current code requirements met. This possible hazard is not unique to the neutral-to-earth voltages that could be induced by faults on the parallel transmission line; the same type of hazard can exist for faults on the distribution system or within the customer's facilities.

The maximum phase-to-neutral voltage for each of the conductors and both fault scenarios was calculated. Results for bottom-phase fault and middle-phase fault were similar, with the middle-phase fault having slightly higher phase-to-neutral voltages; therefore, results for middle-phase transmission faults are shown in Table 7 below.

Table 7: Maximum Fault Condition Phase-to-Neutral Voltage

Scenario	Max. Induced Potential (Top, Middle, Bottom Phase, Neutral)		Max. Phase-to- Neutral Voltage (kV)	Temporary Overvoltage on Voltage Base of 17 kV MCOV (p.u.)
	Magnitude (kV)	Angle (degrees)		
75 Ohm Ground, Middle-Phase Fault	27.8	-46.5	30.0	1.76
	26.3	-47.6	28.4	1.67
	25.1	-48.7	27.0	1.59
	15.1	-63.3	-	-
37 Ohm Ground, Middle-Phase Fault	26.5	-47.6	31.5	1.85
	25.0	-49.0	29.8	1.75
	23.7	-50.4	28.4	1.67
	12.2	-66.6	-	-
15 Ohm Ground, Middle-Phase Fault	24.7	-48.2	32.4	1.90
	23.0	-49.8	30.6	1.80
	21.6	-51.6	29.1	1.71
	9.1	-68.0	-	-
3 Ohm Ground, Middle-Phase Fault	21.7	-47.7	33.5	1.97
	19.9	-49.6	31.6	1.86
	18.2	-51.8	29.9	1.76
	4.9	-76.9	-	-

The maximum temporary overvoltage on a per-unit basis of 17 kV was calculated to be 1.97 p.u. on the top distribution phase for a fault on the middle phase of the transmission line. Typical temporary overvoltage (TOV) capability of heavy duty distribution arresters was found to be in the range of 1.6 – 1.7 p.u. of MCOV rating [9, 10]. If actual fault currents approach the 63 kA maximum possible fault current modeled for this study, then temporary overvoltages could exceed the TOV capability of 17 kV MCOV distribution arresters applied in and electrically near the area of paralleling.

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VI. MITIGATION

The results of the induced voltage study indicated that some possible issues could arise due to the close parallel routing of the transmission line and the distribution line. In the steady-state condition, induced potential could contribute to neutral-to-earth voltage (NEV) in excess of levels allowed by code and to animal contact voltage (ACV). In the case of a fault on the transmission line, induced potential could result in high neutral-to-earth voltage being transferred into customer premises and, for the extreme high fault current studied, temporary phase-to-neutral voltages possibly in excess of distribution arrester capabilities.

Although the study results do not necessarily demonstrate that any issues on the distribution system will in fact be realized, some possible mitigation measures are presented below to provide a basis for discussion as to what can be done should any of these issues arise. More extensive discussion of mitigation methods for stray voltages and neutral-to-earth voltages may be found in the Kinetrics report “Stray Voltage Mitigation” [11] and the Ontario Energy Board staff discussion paper “Farm Stray Voltage: Issues and Regulatory Options” [12].

A. Distribution neutral grounding

The most direct method of reducing electric potential on the distribution system neutral is to reduce the impedance of the connection between the neutral wire and remote earth. This can be done by installing additional ground electrodes or augmenting existing ground electrodes to improve the connection to earth. Improving the distribution neutral grounding near the ends of the parallel routing will be most effective due to the tendency to have higher neutral voltages in those areas.

B. Load balancing

In addition to measures to reduce the buildup of induced electric potential on the distribution system neutral, measures such as load balancing can be used to reduce the distribution utility’s contribution to neutral-to-earth voltage. Load balancing involves distributing the loads connected to a three-phase distribution line such that the loads are balanced among all the phases, thus reducing the current flow on the neutral and the resulting NEV.

C. Neutral decoupling devices at service transformers

Although this study did not investigate animal contact voltages directly, in general, the presence of neutral-to-earth voltages can contribute to farm stray voltages. One relatively inexpensive method of addressing problematic animal contact voltages caused by distribution system NEV is to install a neutral decoupling device at the affected customer’s service transformer. This device acts to separate the customer’s grounded neutral from the distribution system neutral for the relatively low neutral voltages present in steady-state conditions while allowing the neutrals to be electrically connected for detection and clearing of fault conditions.

There are a number of devices that can serve this purpose, including the variable-threshold neutral isolation device (VTNI) available from Dairyland Electrical Industries [13] and the Blocker available from Ronk Electrical Industries [14]. Additional information about the farm stray voltages and neutral decoupling devices can be found in Hydro One’s resource, “Stray

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Voltage Solutions Guide for Electrical Contractors” [15], as well as numerous publications and presentations gathered by the Midwest Rural Energy Council [16].

Care should be taken in the long-term application of neutral decoupling devices to ensure that if the neutral decoupling device fails, the failure is detected and corrected in a timely manner [12].

D. Surge arresters

Distribution systems typically include arresters applied to protect the phase conductors and connected transformers against voltage surges. If the temporary overvoltage due to induced potential on the distribution system phase conductors for transmission system faults is of excessive magnitude or duration, then the arresters may fail. There is little that can be done to reduce the potential induced on the phase conductors other than significant physical reconfiguration of the system to increase the distance between the distribution circuit and the fault current flowing on the transmission system. The failure of arresters may be mitigated by applying arresters with greater temporary overvoltage characteristics or with greater voltage ratings. Use of arresters with greater voltage ratings is recommended and common for systems with long ground-fault clearing times or weak grounding, but care should nonetheless be taken to ensure that equipment insulation remains adequately protected.

E. Distribution line relocation

The inductive coupling between the transmission line and distribution line can be decreased by increasing the distance between the transmission line and the distribution line. One survey of distribution and transmission lines in close parallel routing and underbuild configurations concluded that locating distribution lines underground across the road from a transmission line was a recommended method for minimizing the contribution of an active transmission line to neutral-to-earth voltages on the distribution system [17]. Land use can be a complex and difficult issue, so this option may or may not be viable in any given situation, but, from a technical perspective, relocating the distribution line underground across the road can be a relatively simple alternative that deserves to be considered when circumstances might allow it.

VII. CONCLUSIONS

The proposed close parallel routing of the Summerhaven transmission line and the HCHI distribution line for approximately 1.7 km has been modeled and evaluated with regard to induced potential on the distribution line for steady state and fault conditions. Some possible issues have been noted:

- Induced steady-state potential could contribute to neutral-to-earth voltage (NEV) in excess of levels allowed by code.
- Induced steady-state potential could contribute to animal contact voltage (ACV).
- Induced potential during fault conditions could result in high neutral-to-earth voltage being transferred into customer premises

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- For the extreme high fault current studied, temporary phase-to-neutral voltages could exceed distribution arrester capabilities.

Mitigation measures that can address these issues have been presented, including the following:

- Reinforcement of distribution neutral grounds to reduce resistance to remote earth
- Load balancing
- Installation of neutral decoupling devices at service transformers
- Application of appropriately rated surge arresters
- Distribution line relocation and/or undergrounding

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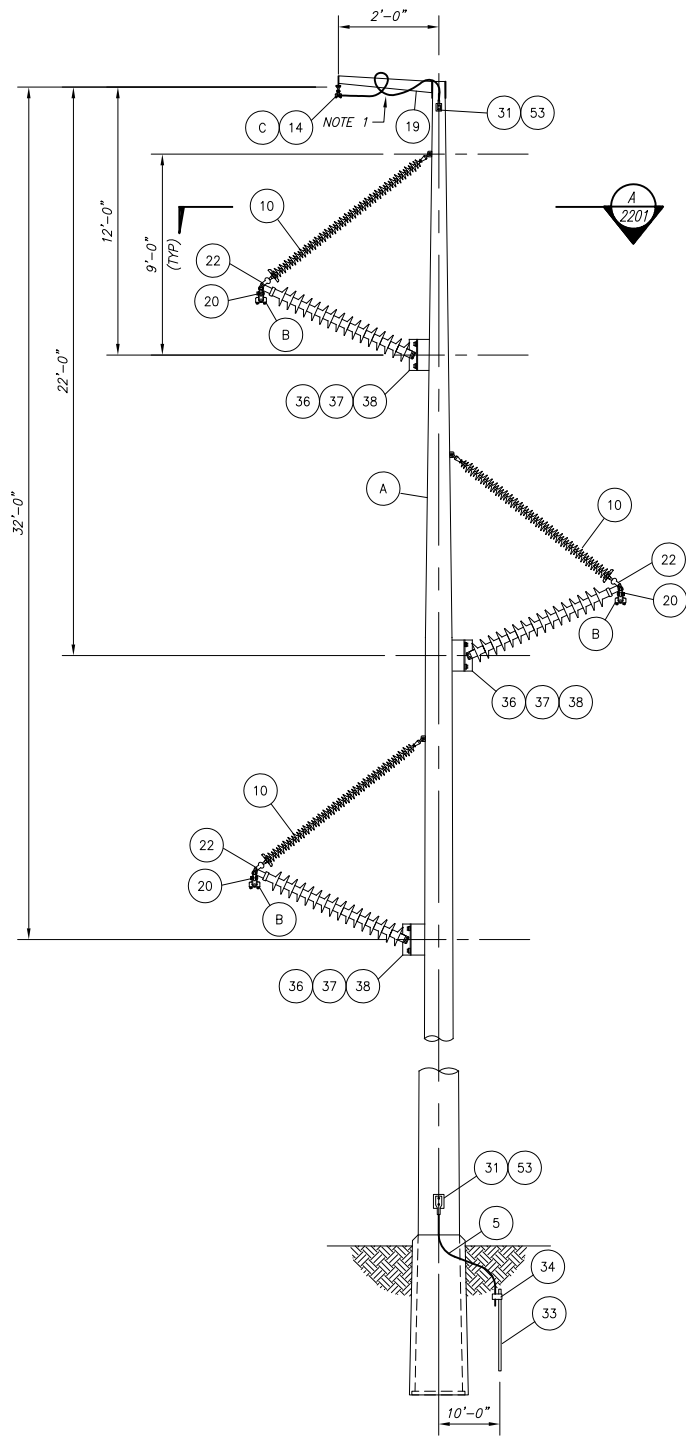
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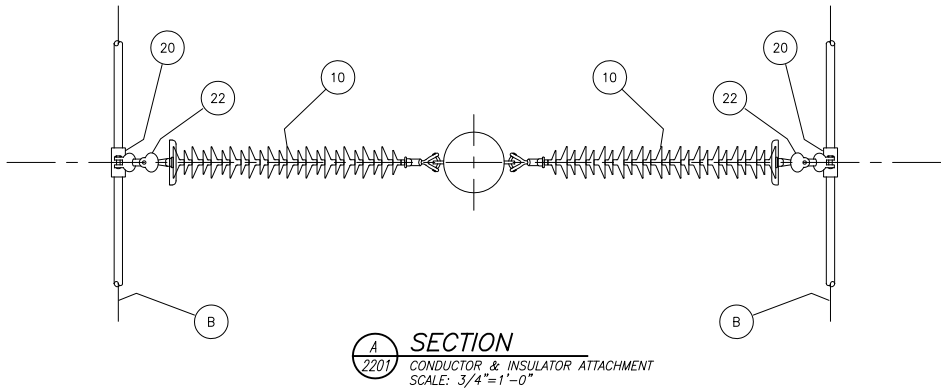
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Appendix A: Transmission Line Tangent Structure Detail Drawing

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DETAIL
 TANGENT BRACED POST STRUCTURE
 SCALE: 1/4"=1'-0"



SECTION
 2201 CONDUCTOR & INSULATOR ATTACHMENT
 SCALE: 3/4"=1'-0"

BILL OF MATERIAL CONTRACTOR FURNISHED				
ITEM	QTY	UNIT	DESCRIPTION	MANUFACTURERS C/N
5	AS REQ'D	FT	CONDUCTOR: #4 AWG STRANDED COPPER	
10	3	EA	INSULATOR ASSEMBLY: BRACED LINE POST, 230 kV, FLAT BASE, LONG LEAKAGE	NGK-LOCKE CAT.#: HV-682 OR EQUAL
14	1	EA	CLAMP: FIBERLIGN CUSHION, FOR 48 FIBER, 0.530" DIA. OPGW, W/Y-CLEVIS EYE	PERFORMED CAT.#: 4700105YC OR EQUAL
19	AS REQ'D	FT	BRAIDED SLEEVE: TINNED COPPER, FITS #4 CU CONNECTORS, 500' REEL	BELDEN CAT.#: DMNI 8669-500
20	3	EA	CUSHION GRIP: SUSPENSION, FOR 954 kcmil ACSR, 25,000 LB ULTIMATE STRENGTH	PERFORMED CAT.#: CGS-1112 OR EQUAL
22	3	EA	AGS Y- CLEVIS EYE: 90 DEGREE, 25,000 LB ULTIMATE STRENGTH	BURNDY CAT.#: YH2929 OR EQUAL
31	2	EA	TERMINAL: #4 AWG COPPER TO 2-HOLE PAD, COMPRESSION COPPER	BURNDY CAT.#: YGHA2C-2N OR EQUAL
33	1	EA	GROUND ROD: 3/4" DIAMETER 10'-0", COPPER BONDED	JOSLYN CAT.#: J8350 OR EQUAL
34	1	EA	CLAMP: FOR 3/4" GROUND ROD TO #4 AWG SOLID COPPER	JOSLYN CAT.#: J3493 OR EQUAL
36	12	EA	MACHINE BOLT W/NUT: 3/4" X 2 1/2"	
37	12	EA	MF LOCKNUT: 3/4"	
38	12	EA	WASHER: 3/4" FLAT	
53	4	EA	BOLT: 1/2" X 1" LONG WITH WASHER AND LOCKWASHER, SILICON BRONZE	

BILL OF MATERIAL OWNER FURNISHED				
ITEM	QTY	UNIT	DESCRIPTION	MANUFACTURERS C/N
A	1	EA	POLE: STEEL, HEIGHT AND EMBEDMENT LENGTH AS SHOWN ON PLAN AND PROFILE DRAWINGS	
B	AS REQ'D	EA	CONDUCTOR: 954 ACSR "CARDINAL"	
C	AS REQ'D	EA	OPGW: 48 FIBERS OPTICAL GROUND WIRE, 0.530" DIA.	SFPOC CAT.#: SFSJ-J-4388R2

NOTES

1. LOOP BRAIDED WIRE TO PROVIDE ENOUGH SLACK FOR OPGW MOVEMENT.

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ST: REG: EXP:



REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
A	ISSUED FOR BID	TMF	KKM	PMG	2-28-11	DWN: K. MEYER
B	REVISED ISSUED FOR BID	TMF	VLM	PMG	03/08/11	CHK: B. VAN BRIESE
C	ISSUED FOR ESA REVIEW	TMF	KKM	BVB	03/14/11	APP:
						DATE:

NEXTERA ENERGY CANADA, ULC.
 SUMMERHAVEN 230 kV TRANSMISSION LINE

STRUCTURE DETAILS

SCALE	AS SHOWN	DRAWING	17651-2201	REV	C
-------	----------	---------	------------	-----	---

	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix B: Insulator Assembly Manufacturer's Cutsheet

REVISIONS	
0	MAR. 07, 2011

- NOTES:
1. DIMENSIONS ARE IN INCHES, METRIC EQUIVALENTS (mm) ARE SHOWN IN ().
 2. MECHANICAL VALUES ARE FOR SINGLE LOADS IN THE SPECIFIED DIRECTION.
 3. ELECTRICAL VALUES ARE THE MINIMUMS OF THE HORIZONTAL VEE.

 NGK-LOCKE	DWG. NO.	LP-12891
	BRACED LINE POST ASSEMBLY	

REFERENCE DATA

CHARACTERISTICS

ELECTRICAL VALUES

- Power Frequency Dry Flashover, kV
Power Frequency Wet Flashover, kV
Critical-Impulse Flashover, Pos., kV
Critical-Impulse Flashover, Neg., kV

RATING

- 765
670
1255
1350

LEAKAGE DISTANCES

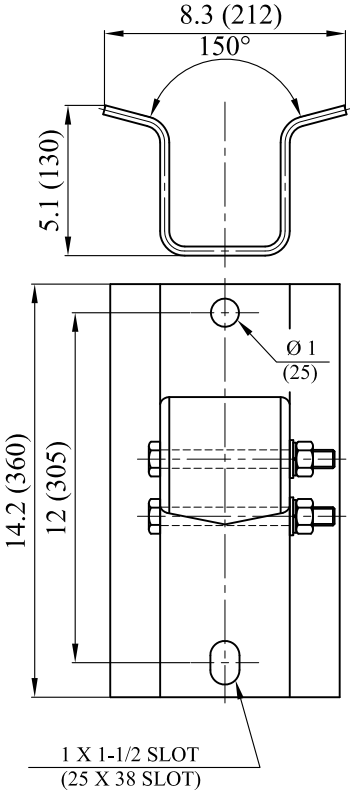
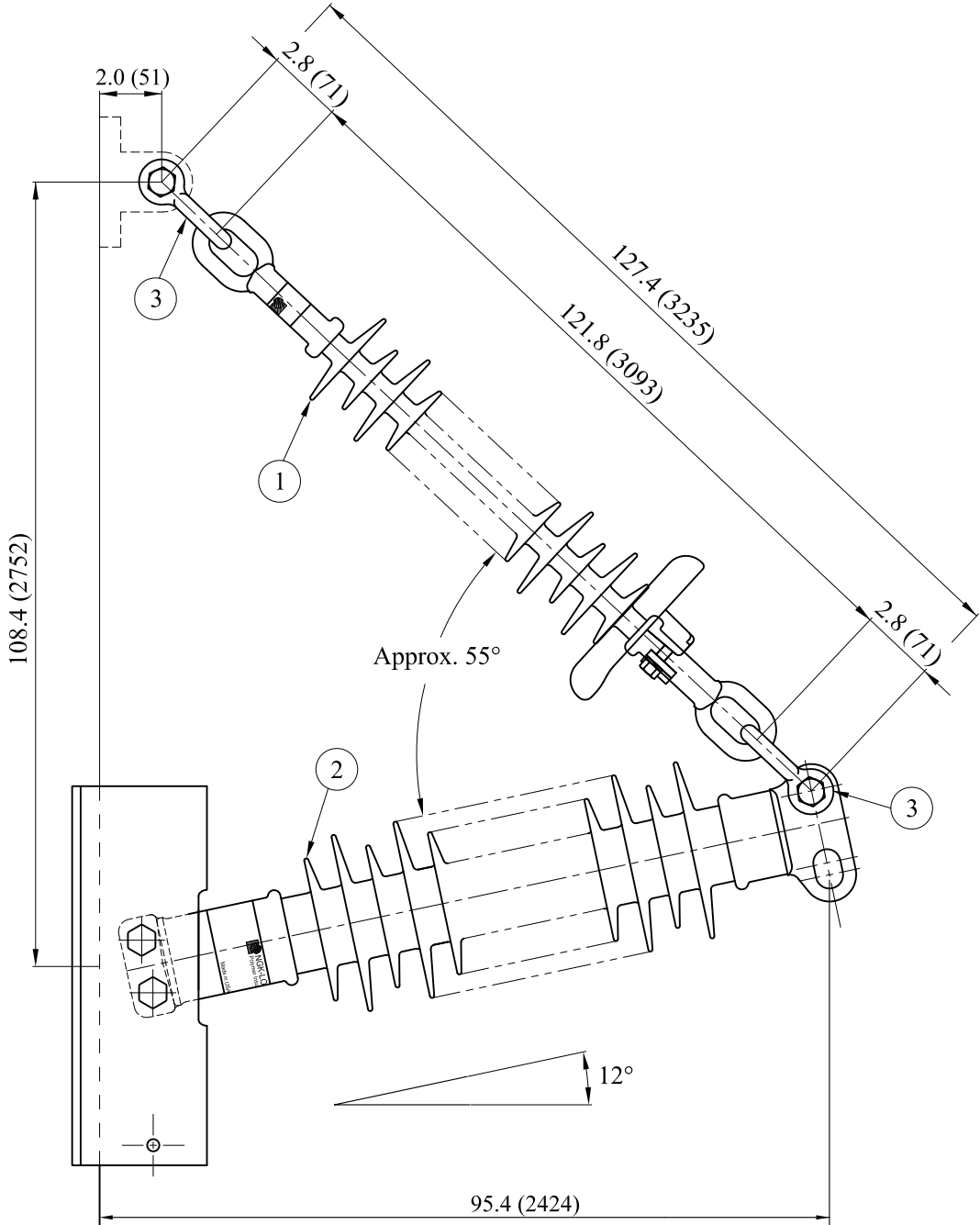
- Stay Insulator (Item #1), in. (mm)
Strut Insulator (Item #2), in. (mm)

- 310.6 (7889)
289.1 (7344)

MECHANICAL VALUES

- Maximum Design Vertical Load, lbs.
(Single load value w/o any other applied loads.)
Maximum Design Longitudinal Load, lbs.
(Single load value w/o any other applied loads /
50% of the minimum average cantilever breaking
load of the Strut Insulator.)
Maximum Design Tension Load, lbs.
(Single load value w/o any other applied loads /
50% SML of the Strut Insulator.)
Maximum Design Compression Load, lbs.
(Single load value w/o any other applied loads /
Less than 80% of the critical buckling load of
the Strut Insulator.)

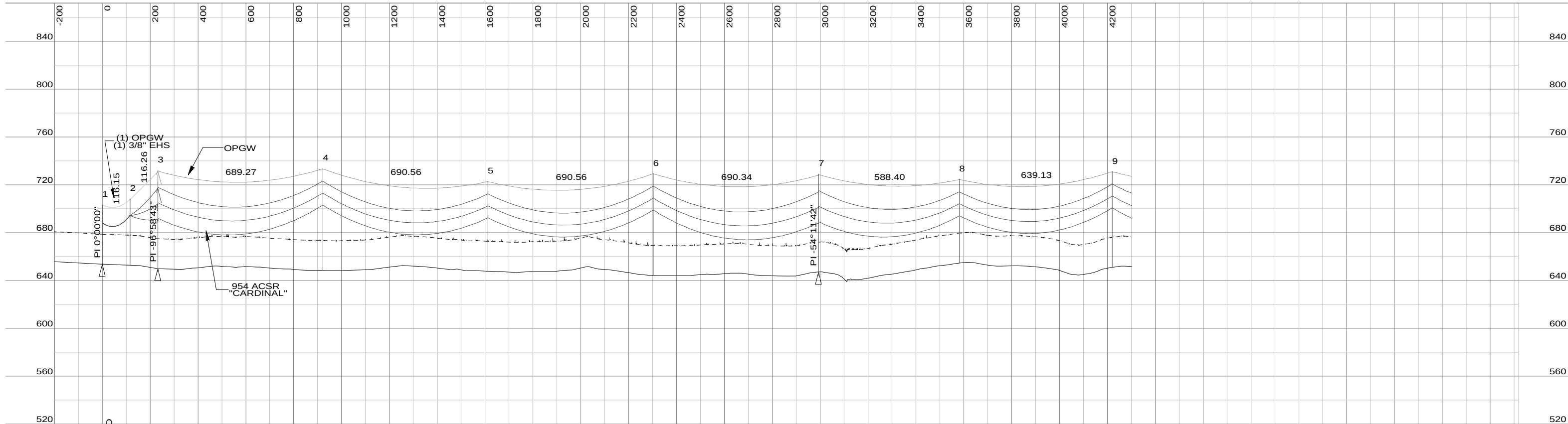
- 8565
885
7500
7500



③	Anchor Shackle	Anderson: AS-25-L-BNK or Equal	2
②	Strut / Line Post Insulator	L2-SL721-13	1
①	Stay / Suspension Insulator	251-SS920-EE-08	1
ITEM	COMPONENT	PART NUMBER	QTY
MADE BY	MM	NGK-LOCKE POLYMER INSULATORS, INC. VIRGINIA BEACH, VA 23455	CAT. NO. HV-682
APPROVED	KE		

	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix C: Transmission Line Plan & Profile Drawings



1 sta=0.00 ht=49.70 ele=653.57 (3) T2 (1) GW-1, (1) OP-1 (1) FO-2 SUBSTATION DEADEND	2 sta=116.15 ht=55.50 ele=652.76	3 sta=232.40 ht=82.00 ele=649.94 ht adjust=-3.00 VDE-2 DA4 (2) AS-1 13' Embedment 85' Guy Lead	4 sta=921.67 ht=85.00 ele=648.45 TBP DAL, DA3 13' Embedment	5 sta=1612.23 ht=75.00 ele=647.75 TBP DA3 12' Embedment	6 sta=2302.79 ht=85.00 ele=644.26 TBP DAL, DA3 13' Embedment	7 sta=2993.13 ht=82.00 ele=647.08 ht adjust=-3.00 VDE1 DA4, DA5 (2) AS-1 13' Embedment 85' Guy Lead	8 sta=3581.53 ht=70.00 ele=654.52 TBP DAL, DA3 11.5' Embedment	9 sta=4220.65 ht=80.00 ele=651.01 TBP DAL, DA3 12.5' Embedment
--	--	--	--	--	---	---	---	---

- NOTES
- 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
 - OPGW AND 7#7 AW SHOWN AT 60 DEG F.
 - GROUND CLEARANCE LINE SHOWN AT 25 FEET.
 - STRUCTURE 48 ONLY GUYED AGAINST TENSION TOWARDS STR 47. GUYS NOT USED IN SLACK SPAN TOWARD SUBSTATION DE
 - STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5

Peak Power Engineering, Inc.

Universal Pegasus INTERNATIONAL
P.O. Box 340 | Delmar, Maryland 20624 | (301) 457-1102

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REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE	TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS
B	REVISED ISSUED FOR BID	TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

NEXTERA ENERGY CANADA, ULC

SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 1 OF 5

SCALE

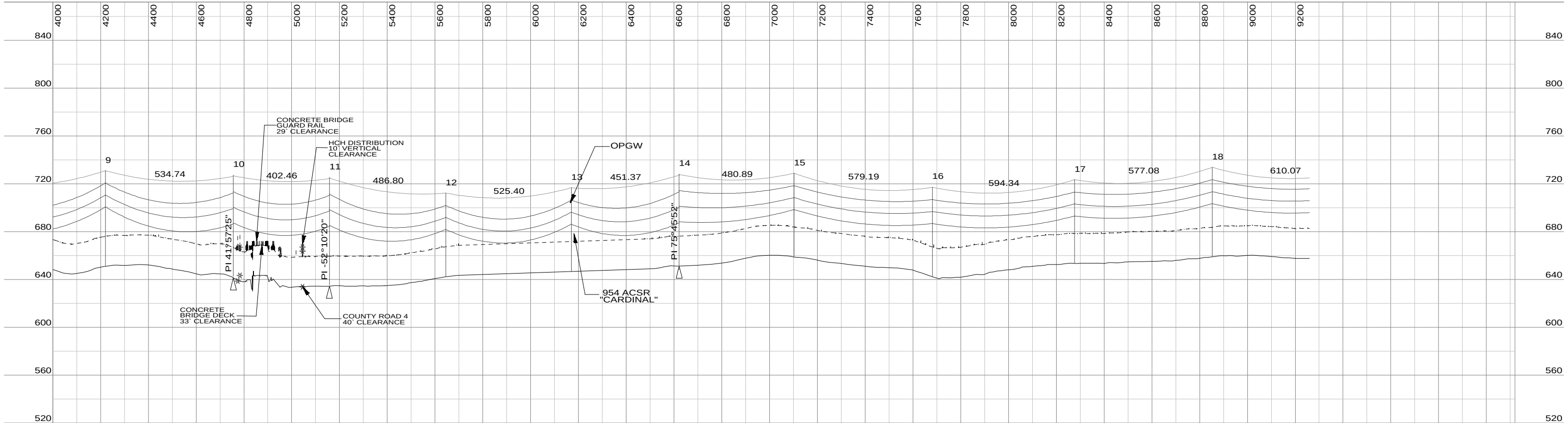
AS NOTED

DRAWING

17651-2101

REV

E



9
sta=4220.65
ht=80.00 ele=651.01
TBP
DA1, DA3
12.5' Embedment

10
sta=4755.40
ht=86.00 ele=641.29
ht adjust=1.00
VDE-3
DA2, DA4, DA5
FDN
SELF SUPPORTING

11
sta=5157.86
ht=91.00 ele=634.43
ht adjust=1.00
VDE-3
DA4, DA5
FDN
SELF SUPPORTING

12
sta=5644.65
ht=70.00 ele=642.29
TBP
DA1, DA3
11.5' Embedment

13
sta=6170.05
ht=70.00 ele=646.68
TBP
DA1, DA3
11.5' Embedment

14
sta=6621.42
ht=77.00 ele=651.25
VDE-3
DA1, DA5
(3) AS-1
(1) FO-1, (1) FO-2
12.5' Embedment
68' Guy Lead

15
sta=7102.31
ht=70.00 ele=658.85
TBP
DA3
11.5' Embedment

16
sta=7681.49
ht=75.00 ele=642.14
TBP
DA1, DA3
12' Embedment

17
sta=8275.83
ht=70.00 ele=653.43
TBP
DA3
11.5' Embedment

18
sta=8852.91
ht=75.00 ele=658.78
TBP
DA1, DA3
12' Embedment

- NOTES
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 3. GROUND CLEARANCE LINE SHOWN AT 25 FEET.
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 5. STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5

Peak Power Engineering, Inc.



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ST: REG: EXP:

NEXTERA
ENERGY

RESOURCES

REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE	TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS
B	REVISED ISSUED FOR BID	TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

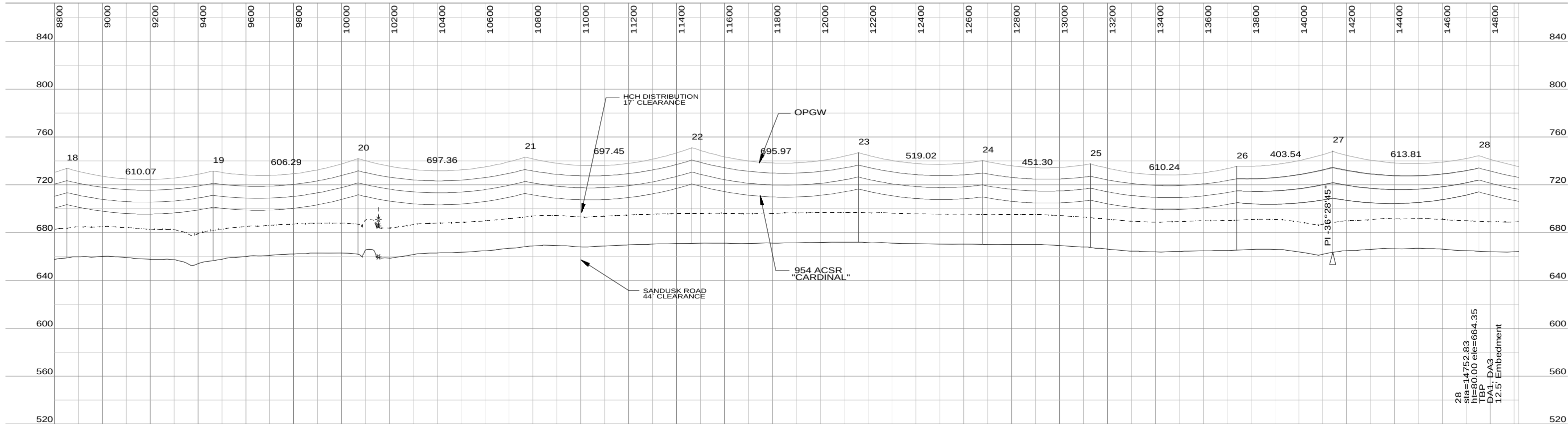
NEXTERA ENERGY CANADA, ULC
SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 2 OF 5

SCALEAS NOTED

DRAWING17651-2102

REVE



18
sta=8852.91
ht=75.00 ele=658.78
TBP
DA1, DA3
12' Embedment

19
sta=9462.98
ht=75.00 ele=656.57
TBP
DA1, DA3
12' Embedment

20
sta=10069.27
ht=80.00 ele=661.96
TBP
DA1, DA3
12.5' Embedment

21
sta=10766.63
ht=75.00 ele=668.13
TBP
DA1, DA3
12' Embedment

22
sta=11464.08
ht=80.00 ele=671.04
TBP
DA1, DA3
12.5' Embedment

23
sta=12160.05
ht=75.00 ele=671.86
TBP
DA1, DA3
12' Embedment

24
sta=12679.07
ht=70.00 ele=670.20
TBP
DA1, DA3
11.5' Embedment

25
sta=13130.37
ht=70.00 ele=667.49
TBP
DA1, DA3
11.5' Embedment

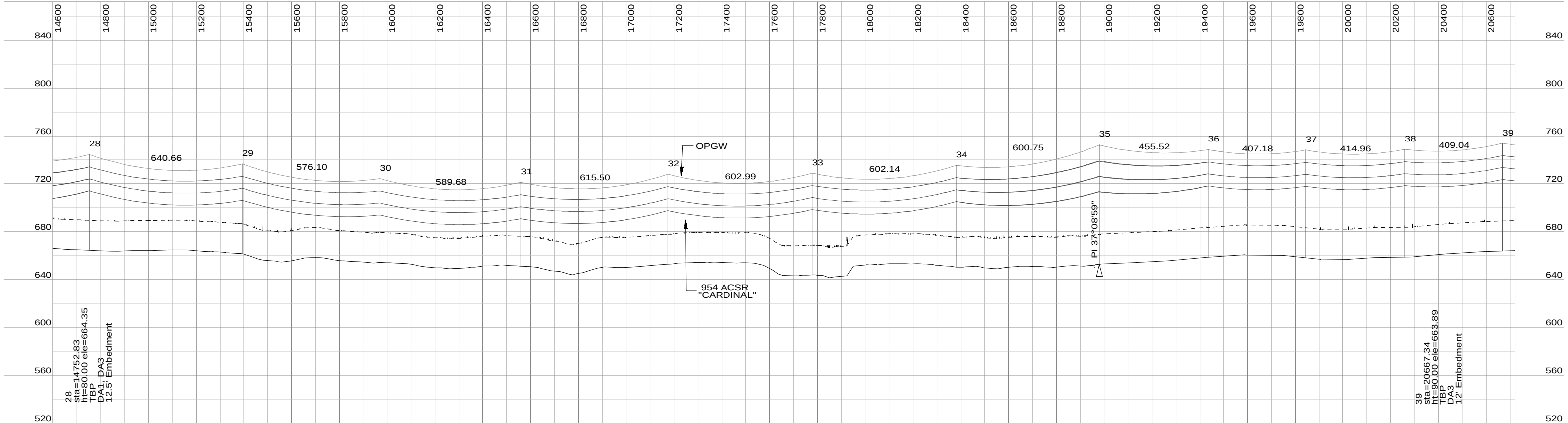
26
sta=13740.61
ht=70.00 ele=665.38
TBP
DA1, DA3
11.5' Embedment

27
sta=14141.57
ht=85.00 ele=663.46
VRA-1
DA3
AS-3
13' Embedment
72' Guy Lead

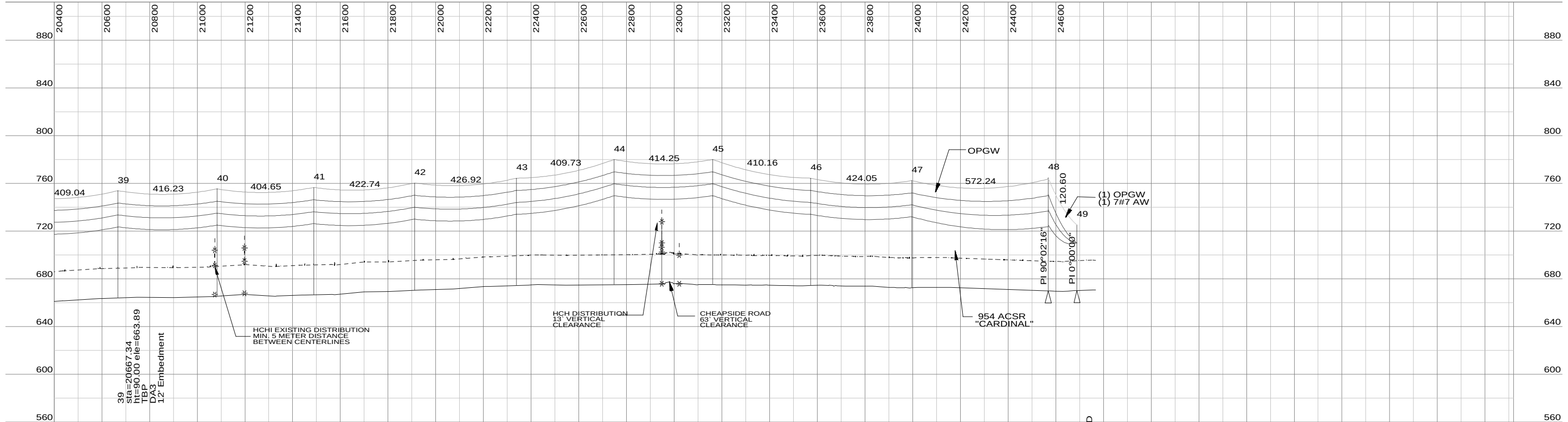
28
sta=14752.83
ht=80.00 ele=664.35
TBP
DA1, DA3
12.5' Embedment

- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
 2. OPGW AND 7#7 AW SHOWN AT 60 DEG F.
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 5. STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5

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 Universal Pegasus INTERNATIONAL P.O. Box 340 Nelson, Canada B0C 2P0 (203) 459-1102				E		REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE		TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS		PLAN AND PROFILE SHEET 3 OF 5								
				B		REVISED ISSUED FOR BID		TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN										
				C		ISSUED FOR ESA REVIEW		TMF	TMF	BVB	03/15/11	APP:		SCALE			AS NOTED		DRAWING 17651-2103		REV E	
				D		REVISED ROUTE		TMF	TMF	BVB	04/08/11	DATE: 03/15/11										
				ST:		REG:		EXP:														



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	Document Title: Induction Study Report	Report No.: 18559-9001
	Project: Summerhaven Transmission Line	Issue Date: 7/7/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix D: Transmission Line Impedance and Maximum Fault Current at Concession Road 5 (Structure 35)

Project 17651
DAV

SUMMERHAVEN 230kV T-Line

Line Impedance and Imbalance Calculations

This worksheet calculates the impedance of a transmission line with and without transposing.

Line Description

These calculations have been done for the 230 kV Summerhaven Substation to PCC transmission line. It uses single-pole post insulator structures. Conductor is single-conductor 954 ACSR 54/7 (Cardinal).

References

Bergen and Vittal *Power Systems Analysis*, Section 3.6 "Impedance of three phase lines including ground return"

EPRI *Transmission Line Reference Book 345 kV and Above* (Redbook), Section 3.4 "Transmission Line Unbalance"

Southwire Company Overhead Conductor Manual, 2nd edition.

Model Parameters:

Radius of individual phase conductor within bundle

$$r_{\text{phase}} := \frac{1.196}{2} \cdot \text{in}$$

GMR of individual phase conductor within bundle

$$\text{GMR}_{\text{phase}} := 0.0404 \cdot \text{ft}$$

Resistance of individual phase conductor @ 25 deg C

$$R_{\text{phase}} := 0.1100 \cdot \frac{\Omega}{\text{mi}}$$

Radius of overhead ground wire

$$r_3 := \frac{0.7776}{2} \cdot \text{in}$$

GMR of overhead ground wire

$$\text{GMR}_3 := 0.0252 \cdot \text{ft}$$

Resistance of overhead ground wires

$$R_3 := 0.4760 \cdot \frac{\Omega}{\text{mi}}$$

Earth resistivity

$$\rho := 15 \cdot \Omega \cdot \text{m}$$

System electrical frequency

$$f := 60 \cdot \text{Hz}$$

Conductor locations defined by x,y coordinates as it is based on pole structure dimensions, including ground wires. (y=0 is the earth). Subtract 2/3 sag amount from tower height to get conductor heights.

$$x_0 := 8.88 \cdot \text{ft} \quad y_0 := 58.94 \cdot \text{ft} \quad \text{Phase A}$$

$$x_1 := -9.06 \cdot \text{ft} \quad y_1 := 48.94 \cdot \text{ft} \quad \text{Phase B}$$

$$x_2 := 9.24 \cdot \text{ft} \quad y_2 := 38.94 \cdot \text{ft} \quad \text{Phase C}$$

$$x_3 := 2.75 \cdot \text{ft} \quad y_3 := 72.05 \cdot \text{ft} \quad \text{Shield}$$

Intermediate Calculations for Impedance Matrix

Bundled conductor single conductor equivalent (NO BUNDLING)

$$\text{GMR}_0 := \text{GMR}_{\text{phase}} \quad R_0 := R_{\text{phase}}$$

$$\text{GMR}_1 := \text{GMR}_0 \quad R_1 := R_0$$

$$\text{GMR}_2 := \text{GMR}_0 \quad R_2 := R_0$$

Distances between conductors (m)

$$D(k, m) := \sqrt{(x_k - x_m)^2 + (y_k + y_m)^2}$$

$$d(k, m) := \sqrt{(x_k - x_m)^2 + (y_k - y_m)^2}$$

Define elements of impedance matrix.

$$R_d := 9.865 \cdot 10^{-7} \cdot \frac{\Omega}{\text{Hz} \cdot \text{m}} \cdot f$$

$$D_e := 658 \cdot \sqrt{\frac{\rho \cdot \text{Hz}}{f \cdot \Omega \cdot \text{m}}} \cdot \text{m}$$

$$k(\text{mm}, n) := 2.81 \cdot 10^{-3} \cdot \frac{D(\text{mm}, n)}{\text{m}} \cdot \sqrt{\frac{f \cdot \Omega \cdot \text{m}}{\rho \cdot \text{Hz}}}$$

$$\theta(m, n) := \text{asin}\left(\frac{|x_m - x_n|}{D(m, n)}\right)$$

$$\begin{aligned} P(m, n) := & \frac{\pi}{8} - \frac{1}{3\sqrt{2}} \cdot k(m, n) \cdot \cos(\theta(m, n)) + \frac{k(m, n)^2}{16} \cdot \cos(2 \cdot \theta(m, n)) \cdot \left(0.6728 + \ln\left(\frac{2}{k(m, n)}\right)\right) \dots \\ & + \frac{k(m, n)^2}{16} \cdot \theta(m, n) \cdot \sin(2 \cdot \theta(m, n)) + \frac{k(m, n)^3 \cdot \cos(3 \cdot \theta(m, n))}{45\sqrt{2}} - \frac{\pi \cdot k(m, n)^4 \cdot \cos(4 \cdot \theta(m, n))}{1536} \end{aligned}$$

$$\begin{aligned} Q(m, n) := & -0.0386 + \frac{1}{2} \cdot \ln\left(\frac{2}{k(m, n)}\right) + \frac{1}{3\sqrt{2}} \cdot k(m, n) \cdot \cos(\theta(m, n)) - \frac{\pi \cdot k(m, n)^2}{64} \cdot \cos(2 \cdot \theta(m, n)) \dots \\ & + \frac{k(m, n)^3 \cdot \cos(3 \cdot \theta(m, n))}{45\sqrt{2}} - \frac{k(m, n)^4 \cdot \theta(m, n)}{384} \sin(4 \cdot \theta(m, n)) \dots \\ & + \frac{-1 \cdot k(m, n)^4 \cdot \cos(4 \cdot \theta(m, n))}{384} \cdot \left(\ln\left(\frac{2}{k(m, n)}\right) + 1.0895\right) \end{aligned}$$

$$PQ(m, n) := P(m, n) + j \cdot Q(m, n)$$

$$Z_{mm_carson}(m) := R_m + \mu_0 \cdot f \cdot \left(j \cdot \ln \left(\frac{D(m,m)}{GMR_m} \right) + 2 \cdot PQ(m,m) \right)$$

$$Z_{mn_carson}(m,n) := \mu_0 \cdot f \cdot \left(j \cdot \ln \left(\frac{D(m,n)}{d(m,n)} \right) + 2 \cdot PQ(m,n) \right)$$

$$Z_{mm_approx}(m) := (R_m + R_d) + j \cdot \mu_0 \cdot f \cdot \ln \left(\frac{De}{GMR_m} \right)$$

$$Z_{mn_approx}(m,n) := R_d + j \cdot \mu_0 \cdot f \cdot \ln \left(\frac{De}{d(m,n)} \right)$$

Full Impedance Matrix

Using the Carson form:

$$Z_{kk}(k) := Z_{mm_carson}(k) \quad Z_{km}(k,m) := Z_{mn_carson}(k,m)$$

$$Z_{full} := \begin{pmatrix} Z_{kk}(0) & Z_{km}(0,1) & Z_{km}(0,2) & Z_{km}(0,3) \\ Z_{km}(1,0) & Z_{kk}(1) & Z_{km}(1,2) & Z_{km}(1,3) \\ Z_{km}(2,0) & Z_{km}(2,1) & Z_{kk}(2) & Z_{km}(2,3) \\ Z_{km}(3,0) & Z_{km}(3,1) & Z_{km}(3,2) & Z_{kk}(3) \end{pmatrix}$$

This matrix relates the current and voltage drop vectors so that $V = Z I$.

Reduced Impedance Matrix

Since the shield conductors are grounded, the voltage drop on these conductors may be set equal to zero and the impedance matrix reduced by Kron reduction to only include the phase currents and voltage drops.

$$Z_p := \text{submatrix}(Z_{full}, 0, 2, 0, 2) \quad Z_{pg} := \text{submatrix}(Z_{full}, 0, 2, 3, 3)$$

$$Z_{gp} := \text{submatrix}(Z_{full}, 3, 3, 0, 2) \quad Z_g := Z_{full}_{3,3}$$

$$Z_{abc} := Z_p - Z_{pg} \cdot Z_g^{-1} \cdot Z_{gp}$$

In Symmetrical Components

The order of components in the symmetrical component vectors is Zero, Positive, Negative

$$Z_s := A^{-1} \cdot Z_{abc} \cdot A$$

Shunt Capacitive Admittance

$$r_0 := r_{\text{phase}}$$

$$r_1 := r_0$$

$$r_2 := r_0$$

$$P_{km}(k, m) := \frac{1}{2 \cdot \pi \cdot \epsilon_0} \cdot \ln \left(\frac{D(k, m)}{d(k, m)} \right) \quad P_{kk}(k) := \frac{1}{2 \cdot \pi \cdot \epsilon_0} \cdot \ln \left(\frac{2 \cdot y_k}{r_k} \right)$$

The potential matrix relates line charge to voltage by $V = P Q$.

$$P_{\text{full}} := \begin{pmatrix} P_{kk}(0) & P_{km}(0, 1) & P_{km}(0, 2) & P_{km}(0, 3) \\ P_{km}(1, 0) & P_{kk}(1) & P_{km}(1, 2) & P_{km}(1, 3) \\ P_{km}(2, 0) & P_{km}(2, 1) & P_{kk}(2) & P_{km}(2, 3) \\ P_{km}(3, 0) & P_{km}(3, 1) & P_{km}(3, 2) & P_{kk}(3) \end{pmatrix}$$

For grounded shield wires, the potential matrix can be reduced by Kron reduction in the same way as the impedance matrix.

$$P_p := \text{submatrix}(P_{\text{full}}, 0, 2, 0, 2)$$

$$P_{pg} := \text{submatrix}(P_{\text{full}}, 0, 2, 3, 3)$$

$$P_{gp} := \text{submatrix}(P_{\text{full}}, 3, 3, 0, 2)$$

$$P_g := P_{\text{full}}_{3,3}$$

$$P_{abc} := P_p - P_{pg} \cdot P_g^{-1} \cdot P_{gp}$$

In Symmetrical Components:

$$P_s := A^{-1} \cdot P_{abc} \cdot A$$

Shunt admittance matrix

The shunt admittance matrix relates shunt current and line voltage as $I = Y V$.

$$Y_{\text{full}} := j \cdot 2 \cdot \pi \cdot f \cdot P_{\text{full}}^{-1} \quad Y_{abc} := j \cdot 2 \cdot \pi \cdot f \cdot P_{abc}^{-1} \quad Y_s := j \cdot 2 \cdot \pi \cdot f \cdot P_s^{-1}$$

Results (No transposition)

Line Impedances

$$Z_{abc} = \begin{pmatrix} 2.14 \times 10^{-1} + 1.04i & 9.81 \times 10^{-2} + 3.12i \times 10^{-1} & 9.55 \times 10^{-2} + 3.26i \times 10^{-1} \\ 9.81 \times 10^{-2} + 3.12i \times 10^{-1} & 2.03 \times 10^{-1} + 1.09i & 9.15 \times 10^{-2} + 3.42i \times 10^{-1} \\ 9.55 \times 10^{-2} + 3.26i \times 10^{-1} & 9.15 \times 10^{-2} + 3.42i \times 10^{-1} & 2.00 \times 10^{-1} + 1.11i \end{pmatrix} \cdot \frac{\Omega}{\text{mi}}$$

Order of sequence component vectors is ZERO, POSITIVE, then NEGATIVE.

$$Z_s = \begin{pmatrix} 0.3960 + 1.7331i & -3.4817 \times 10^{-3} - 0.0284i & 0.0155 - 0.0249i \\ 0.0155 - 0.0249i & 0.1109 + 0.7538i & 3.5835 \times 10^{-3} - 3.2886i \times 10^{-3} \\ -3.4817 \times 10^{-3} - 0.0284i & -2.2403 \times 10^{-3} - 4.2838i \times 10^{-3} & 0.1109 + 0.7538i \end{pmatrix} \cdot \frac{\Omega}{\text{mi}}$$

Positive Sequence

$$Z_{s1} := Z_{s1,1} = (0.06889 + 0.4684j) \cdot \frac{\Omega}{\text{km}}$$

Negative Sequence

$$Z_{s2} := Z_{s2,2} = (0.06889 + 0.4684j) \cdot \frac{\Omega}{\text{km}}$$

Zero Sequence

$$Z_{s0} := Z_{s0,0} = (0.24606 + 1.07692j) \cdot \frac{\Omega}{\text{km}}$$

Shunt Admittances

$$Y_{abc} = \begin{pmatrix} 3.08j \times 10^{-6} & -4.552j \times 10^{-7} & -4.679j \times 10^{-7} \\ -4.552j \times 10^{-7} & 3.027j \times 10^{-6} & -4.419j \times 10^{-7} \\ -4.679j \times 10^{-7} & -4.419j \times 10^{-7} & 3.078j \times 10^{-6} \end{pmatrix} \cdot \frac{\text{S}}{\text{km}}$$

Order of sequence component vectors is ZERO, POSITIVE, then NEGATIVE.

$$Y_s = \begin{pmatrix} 2.15j \times 10^{-6} & -1.1 \times 10^{-8} + 2.45j \times 10^{-9} & 1.1 \times 10^{-8} + 2.45j \times 10^{-9} \\ 1.1 \times 10^{-8} + 2.45j \times 10^{-9} & 3.52j \times 10^{-6} & -2.2 \times 10^{-8} + 2.21j \times 10^{-8} \\ -1.1 \times 10^{-8} + 2.45j \times 10^{-9} & 2.2 \times 10^{-8} + 2.21j \times 10^{-8} & 3.52j \times 10^{-6} \end{pmatrix} \cdot \frac{\text{S}}{\text{km}}$$

Fault current at Structure 35 (18981 ft)

Fault current estimate at Structure 35 based on an infinite source at the interconnect substation.

$$I_{\text{SLG}} := \frac{230 \cdot \text{kV} \cdot \sqrt{3}}{(Z_{\text{S1}} + Z_{\text{S2}} + Z_{\text{S0}}) \cdot 5787 \cdot \text{m}} = \left(6.288 \times 10^3 - 3.299j \times 10^4 \right) \text{A}$$

$$\left| I_{\text{SLG}} \right| = 33.58 \cdot \text{kA}$$

Schedule D
Peak GPR Report



UNDERGROUND ARCING AND GPR REPORT

NEXTERA ENERGY SUMMERHAVEN TRANSMISSION LINE HALDIMAND COUNTY, ONTARIO

REPORT 18559-9002



Design Checking

- ☐ Preliminary for internal review
- ☐ Issue for client review and comment
- ☐ Issue for client approval
- ☒ Issue as final
- ☐ Issue as revised

		Eng	Date
Design	Engineer	PDB	7/25/11
Check	Transmission		
	Electrical		
Approve	Project Manager	PSF	7/26/11
	Client		

Gerhard G. Runge, P.Eng

Revisions

Rev	Description	Eng	Chk	Date
A	Preliminary for Review	PDB		7/25/11
0	Issued for submittal	PDB	PSF	7/26/11

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	Project: Summerhaven Transmission Line	Issue Date: 7/26/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

I. EXECUTIVE SUMMARY

The proposed Summerhaven 230 kV transmission line includes a section of approximately 1.7 km length in which the proposed transmission line route runs parallel to a road right-of-way in which Haldimand County Hydro, Inc. (HCHI) intends to construct a 27.6/16 kV distribution line. HCHI has submitted evidence to the Ontario Energy Board (OEB) requesting that various conditions be included in any order(s) granting leave to construct for the Summerhaven project, including a request that the Summerhaven transmission line structures be located at least 10 m from planned future distribution line structures. NextEra Energy contracted Universal Pegasus [UPI, also known as Peak Power Engineering] to investigate the reasons provided by HCHI for requesting the 10 m separation of structures and to utilize any applicable standards or engineering methods to assess the proposed design of the Summerhaven transmission line with regard to the concerns raised by HCHI.

The 10-m structure separation requested by HCHI and supported by the Board staff report was examined. The standard and underlying research cited to support this request were examined in detail. Engineering calculations were performed to assess the impact of the Summerhaven project transmission line on the HCHI distribution line in accordance with the research cited by HCHI/Kinetrics.

It was found that the standard cited to support the 10-m separation request was not applicable to the situation. If the threshold of sustained underground arcing presented by HCHI/Kinetrics is accepted, the distance between the proposed Summerhaven transmission line and the planned HCHI distribution line is more than sufficient to prevent sustained underground arcing. Even if underground arcing were to occur, a lightning outage rate estimate for the transmission line indicated that lightning initiation of this type of arcing would be rare, and examination of the arc-damage research cited by HCHI/Kinetrics indicated that underground arcing would not cause damage to distribution system ground electrodes. Finally, it was determined that ground potential rise (GPR) transferred through the earth from the transmission line to the distribution line would not be of sufficient magnitude to be of concern.

In summary, on the basis of the engineering calculations described in this report, the design separation of 6 m [19.7 ft] between the transmission line ground electrodes and the distribution line ground electrodes was determined to be more than adequate to avoid underground arcing.

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II. INTRODUCTION

The proposed Summerhaven 230 kV transmission line includes a section of approximately 1.7 km length in which the proposed transmission line route runs parallel to a road right-of-way in which Haldimand County Hydro, Inc. (HCHI) intends to construct a 27.6/16 kV distribution line. HCHI has submitted evidence to the Ontario Energy Board (OEB) requesting that various conditions be included in any order(s) granting leave to construct for the Summerhaven project, including a request that the Summerhaven transmission line structures be located at least 10 m from existing or planned future distribution line structures. NextEra Energy contracted Universal Pegasus [UPI, also known as Peak Power Engineering] to investigate the reasons provided by HCHI for requesting the 10 m separation of structures and to utilize any applicable standards or engineering methods to assess the proposed design of the Summerhaven transmission line with regard to the concerns raised by HCHI.

A. HCHI Intervener Evidence: The Kinetrics Induction Study Report

HCHI submitted a report prepared by Kinetrics to the Board as evidence of the concerns that HCHI has regarding the proposed transmission line route. The induction issues related to the parallel routing of the transmission line and distribution line have been addressed in a separate report by UPI. Of interest to the issues addressed in the present report is the following statement from the conclusions of the Kinetrics report:

Due to its proximity, the transmission line will provided lightning protection against direct lightning strikes. It is recommended to maintain a minimum distance of 10 m or more between the transmission and distribution poles to limit the GPR (Ground Potential Rise) transfer during lightning strikes to the transmission line and 60 Hz faults. [1]

The Kinetrics inductions study report did not include any further discussion, calculations, or references to clarify or explain this recommendation.

B. Response to Board Staff and Summerhaven Interrogatories

Both the Board Staff and Summerhaven presented interrogatories to HCHI/Kinetrics requesting clarification and justification of the recommendation presented in the original Kinetrics induction study report. HCHI/Kinetrics provided similar responses to both parties. Their response to the Board staff was as follows:

The recommended 10 m separation is a diagonal distance, including the direction along the line. This distance is mentioned in CSA Standard CSA-C22.3 No. 6 "Principles and Practices of Electrical Coordination between Pipelines and Electric Supply Lines" as recommended offset between high voltage lines and gas pipelines in order to prevent sustained underground arcing between these utilities. As part of this review, we need to ensure that a lightning strike to the 230-kV line leading to a 60 Hz fault will not cause sustained arcing below grade to ground rods associated with HCHI distribution poles. Such arcing could cause the failure of the equipment of HCHI and HCHI's ratepayers. [2]

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The HCHI/Kinetrics response goes on to describe research that investigated underground arcing:

Power Tech Labs in Surrey, BC, tested the 60-Hz potential required to sustain a high current arc following initiation of a conducting path by lightning [Craig Webster, "Powerline Ground Fault Effects on Pipelines", CEA Report 239 T 917[sic], October 1994]. The measurements showed that about 10 kV per metre of arcing distance was required to sustain an arc in soil. Thus the 230-kV structure would have to rise to 100 kV in order to sustain an arc in soil over a 10 metre distance to the distribution pole. There is some uncertainty as to whether such extrapolations are valid and whether the tests themselves properly simulated transient recovery potentials.

The potential rise of the Applicant's 230-kV structures would depend upon the fault current, shield wire type, span between structures and footing resistances. This is likely to be much less than 100 kV, reducing the concern regarding the uncertainty and transient recovery voltages. [2]

C. Board Staff Submission

After receiving the evidence and clarification by HCHI/Kinetrics, the Board staff included the following in their submission to the Board:

Board staff is of the view that in the absence of any other standard by another standard organization whose authority is valid in Ontario, a minimum of 10 m diagonal separation between any proposed 230 kV pole and HCHI's planned 27.6/16 kV pole line for the 2 km stretch along Concession 5 Road should be applied. This required separation should be included as part of the Conditions of Approval in the event the Board grants the applied for leave to construct. [3]

III. MODEL DEVELOPMENT

Calculations were done to estimate the ground potential rise (GPR) of a transmission line footing ground during fault conditions, the GPR transferred to a nearby distribution line ground electrode, and the lightning outage rate of the transmission line. The calculations done were based on computer models of the transmission line. The following subsections describe the parameters used to develop the models for these calculations.

A. Transmission Line Cross-Section

The transmission line was modeled using typical single-pole braced post tangent structures with dimensions as shown on the latest revision of the structure detail drawing (UPI Drawing 17651-2201, Appendix A). The structure was shown with 3.05 m [10 ft] vertical spacing between the phases and 3.66 m [12 ft] vertical spacing from the top of the structure to the insulator base of the top phase. The insulator assembly used to support the phase conductors was found to have a horizontal offset of 2.42 m [95.4 in] relative to the center of the post insulator base and an upward angle of 12° (Insulator assembly drawing, Appendix B).

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Since the transmission line structures shown in the latest transmission line design are generally taller throughout the region of parallel routing with the HCHI distribution line than they are in the rest of the transmission line, the transmission line was modeled in two regions: one representing the line from the Point of Interconnection (POI) to first structure next to Concession Road 5, and one representing the line as it runs along Concession Road 5. The transmission line structures in the first region were shown to have an average height of 23.5 m [77 ft] above grade in the latest revision of the transmission line plan & profile drawings (UPI Drawing 17651-2101 through -2105, Appendix C). Transmission line structures in the second region were shown to have a typical height of 27.4 m [90 ft] above grade. Pole diameter and taper was not yet known, but it was estimated based on past experience that the diameter at the tip of the poles would be approximately 0.467 m [18 in] and that the poles would have a taper of approximately 3.58 cm/m [0.43 in/ft].

Using the structure geometry as described above, the coordinates of the conductor attachment points were calculated to be as shown in Table 1 below for the first modeled region, from the POI to Concession Road 5. X-axis coordinates are relative to the center of the transmission pole and y-axis coordinates are relative to the ground.

Table 1: Transmission Line Conductor Coordinates

Conductor	X (m)	Y (m)
Top Phase	2.71	20.32
Middle Phase	-2.76	17.27
Bottom Phase	2.82	14.22
Shield	0.84	23.48

Coordinates of conductor attachment points for structures along Concession Road 5 were the same as those shown in Table 1 but with the y-axis coordinates 4 m [13 ft] higher.

B. Transmission Line Conductors

The transmission line conductor types were as shown in the tangent structure bill of material on the structure detail drawing included as Appendix A.

Conductor sags for the transmission line were determined from transmission line design summary information for conductor temperatures of 49 °C [120 °F] for the phase conductors and 25 °C [77 °F] for the shield. The software used to model the system approximates the conductors as long, straight wires, so the average conductor height was used, calculated as the height at the structure minus two-thirds of the sag.

Conductor electrical parameters were taken from standard reference tables as published in the *Southwire Overhead Conductor Manual, 2nd Edition* [4] with the exception of the transmission line OPGW, which was modeled using the diameter and resistance provided by the manufacturer and a relative permeability of 1.0 to calculate the GMR. Conductor parameters were taken for conductor temperatures of 49 °C [120 °F] for the phase conductors and 25 °C [77 °F] for the shield. The conductor parameters used are summarized in Table 2 below.

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Table 2: Conductor Parameters

Conductor	Description	Diameter (mm)	GMR (m)	Assumed Conductor Temp. (°C)	Resistance (Ω/km)	Sag (m)
T-line Phase	954 kcmil ACSR "Cardinal"	30.38	0.0123	48.9	0.0684	3.53
T-line Shield	SFPOC SFSJ-J- 7085 OPGW	19.75	0.0077	25.0	0.2958	2.26

C. Structure Footing Ground

The transmission line was modeled with footing ground resistance of 15 Ω at each structure based on the specified maximum footing ground resistance for the project. The 15 Ω ground resistance value represents a typical single 3-m [10-ft] driven ground rod installed in soil with a resistivity of approximately 50 Ω-m. Since soil resistivity measurements at the Summerhaven substation site showed soil resistivity of approximately 15 Ω-m, this ground electrode resistance value is expected to be achievable in the soil along the transmission line route even where soil resistivity is higher than was measured at the substation site.

The transmission line was modeled with the shield wire connected to ground at every structure. Since designed span lengths vary between the region prior to parallel routing with the distribution line and the region that parallels the distribution line, the line was modeled with different uniform span lengths in the two regions based on the average span lengths of the design. The region before the parallel routing was modeled with 35 equal spans of 165 m [540 ft]. The region of parallel routing was modeled with 13 equal spans of 131 m [430 ft].

In models that model the transmission line and distribution line footing ground electrodes and the surrounding soil, each ground electrode was modeled as a driven ground rod 1.9 cm [0.75 in] in diameter, 3 m [10 ft] long, and driven to 46 cm [18 in] below the earth's surface. Earth was modeled with a uniform resistivity of 50 Ω-m. Where both transmission line and distribution line ground electrodes were modeled, they were modeled with a separation distance of 6 m [19.7 ft] as shown in the latest transmission line design and illustrated in Figure 1 below.

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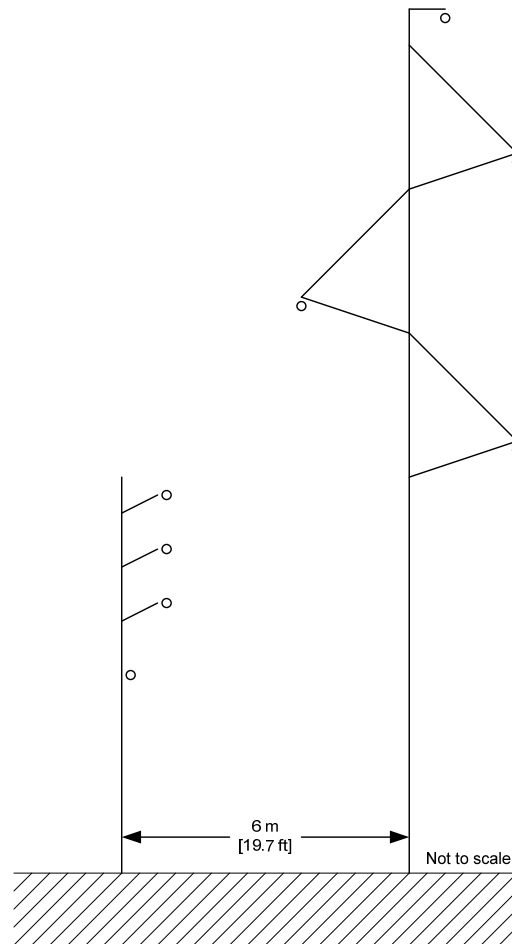


Figure 1: Circuit Separation

D. Transmission Line Fault

The transmission line was modeled as connected at each end to an independent fault source represented as a voltage behind a reactance. The source at the Point of Interconnection (POI) was modeled to represent a fault current of 63 kA at the POI. This fault current represents the maximum allowed by the Transmission System Code. The source at the Summerhaven project was modeled to represent a fault current of 2 kA, which is approximately the fault contribution of the wind farm substation to close-in transmission faults as indicated by the project short-circuit model.

Since the fault current source at the POI is significantly stronger than the source at the project substation, the maximum available fault current is at the end of the parallel region that is nearest to the utility interconnection. This is also farthest from the project substation ground grid, so the split of fault current to the ground electrode of the faulted structure is maximized.

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E. Transmission Line Insulators

For the transmission line outage rate estimate, the transmission line insulator flashover length was modeled using a flashover distance of 6.8 m [81.8 in]. This length was used to correspond to the insulator flashover voltages shown on the insulator cutsheet of the insulator assembly being used for the transmission line (Appendix B). The insulator strike distance is not shown on the insulator cutsheet, however, the flashover voltages were identical to those of the HV-560 insulator assembly listed in the manufacturer catalog, which does include strike distances [5].

F. Lightning Activity

The lightning activity level for the project area was estimated at 4.1 Flash/km² based on a map of the greatest single-year lightning flash density for southern Ontario published by Environment Canada [6].

IV. CALCULATIONS AND RESULTS

A. Tower Ground current and GPR Calculations

In order to address the concerns raised by HCHI, engineering calculations were performed to estimate the worst-case ground potential rise (GPR) at a transmission line structure in the area of proposed parallel routing with the HCHI distribution line. A computer model of the transmission line was developed using the parameters described in the preceding section. The SES-Right-of-Way (SES-ROW) software package by Safe Engineering Services and Technologies was used to implement the computer model. The model used modules that calculate the self and mutual inductances of all conductors, including earth return, produce a span-by-span circuit model of the transmission line, and evaluate the shunt voltage and section current for each modeled span during a line-to-ground fault.

The fault current at the faulted structure was calculated to be 23.0 kA. The current split at the faulted structure was calculated to be 13.3 kA flowing over the OPGW toward the utility interconnect switchyard, 9.4 kA flowing over the OPGW toward the Summerhaven project substation, and 740 A flowing to ground through the faulted structure ground electrode. The total ground potential rise (GPR) at the faulted transmission structure was calculated to be 11.1 kV. The calculated potential magnitude on each phase and neutral conductor along the transmission line is shown in Figure 2 below.

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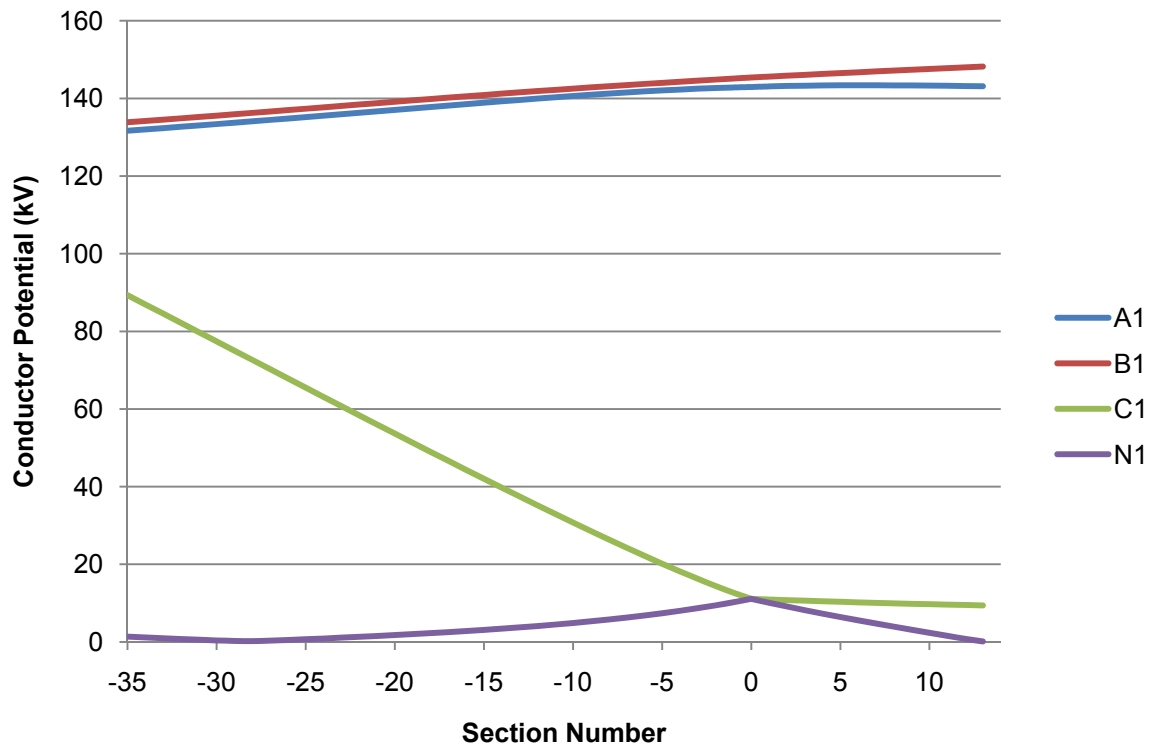


Figure 2: Shunt Potentials for a Transmission Line Fault

B. Transferred Potential

In order to assess the possible hazard associated with potentials transferred through the earth to the distribution system neutral during a ground fault on the transmission line, a simple ground model was developed using the MALZ module of the CDEGS software package by Safe Engineering Services and Technologies. The simple model included a single ground rod for the transmission structure ground electrode and a single ground rod for the distribution structure ground electrode as described in the previous section. The ground rods were modeled separated by 6 m [19.7 ft]. The transmission structure ground electrode was energized with a ground potential rise (GPR) of 11.1 kV in accordance with the results presented in the previous subsection.

The ground potential rise transferred through the earth to the distribution structure ground electrode was calculated to be 860 V. The calculated soil potential at 1 m [3.3 ft] below the surface is shown in Figure 3 below.

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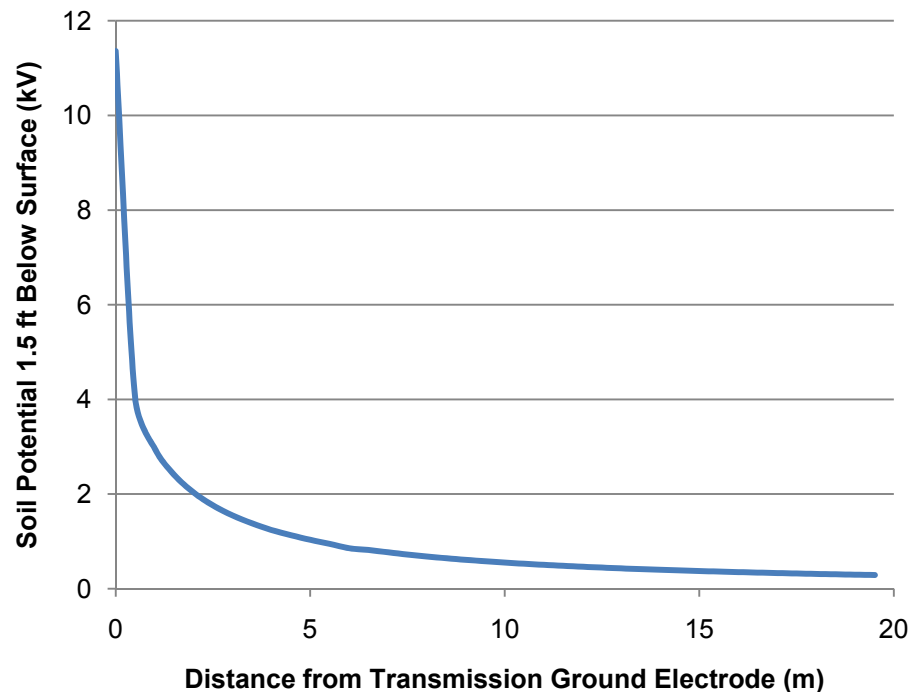


Figure 3: Profile of Soil Potential

C. Lightning Outage Rate Estimate

Lightning outage rate estimates for the existing line case where the transmission line includes shield wires were made using the IEEE FLASH program provided with IEEE 1243-1997 "Guide for Improving Lightning Performance of Transmission Lines" [7] and updated by the IEEE Working Group on Estimating the Lightning Performance of Overhead Transmission Lines. This program is largely based on work presented in the *EPR/Transmission Line Reference Book 345 kV and Above* [8], also known as the Redbook, with some updates as described in Annex B of IEEE 1243-1997. The program used also included some corrections made by the author of this study.

The lightning flashover rate for the transmission line was calculated to be 1.67 flashes/100 km/year. For the 1.7-km region of close parallel routing, the lightning flashover rate was calculated to be 0.0285 flashes per year or an equivalent mean time between failures (MTBF) of 35.1 years.

V. DISCUSSION

HCHI/Kinetrics have put forth CSA C22.3 No. 6-M91 "Principles and Practices of Electrical Coordination Between Pipelines and Electric Supply Lines" [9] as the basis for requesting 10 m separation between transmission line structures and HCHI's planned distribution line structures [2]. The board staff has supported this recommendation in the absence of any relevant standard with authority in Ontario [3].

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Buried pipelines and overhead electrical distribution lines are quite different infrastructure and have quite different electrical properties. The following differences may be noted:

- Buried pipelines are buried in the ground whereas overhead electrical distribution lines are supported above-ground by an insulated connection to supporting structures.
- Buried pipelines are often insulated from ground with a protective coating to resist the corrosion process acting on the pipe whereas electrical distribution line is given a ground reference intentionally connecting the neutral to ground through ground electrodes, which do not have any insulating coating.
- Buried pipelines typically have diameters ranging from a few inches to a few feet whereas distribution system ground electrodes are typically driven ground rods with diameter less than one inch.
- Buried pipelines are often made of steel whereas distribution system ground electrodes are typically made of copper-clad steel rods.

Despite these differences, HCHI/Kinetrics has presented C22.3 No. 6-M91 as at least providing guidance and at most listing requirements to be followed when locating electrical transmission and distribution facilities in relative proximity. In order to assess the applicability of this standard, the specific section being invoked was examined in further detail, following reasoning provided by HCHI/Kinetrics. The relevant portion of the standard is reproduced below:

Except where there is mutual agreement between the pipeline and power line companies, it is recommended that pipeline be located not less than 10 m from power line footings and other below-ground fault current discharge facilities.

Notes:

- (1) The 10 m separation distance has been established as a reasonable physical clearance during construction and maintenance activities. Research has demonstrated that line-to-ground faults can cause damage to pipeline coatings or pipelines even with clearances in excess of 10 m. [9]*

A. Arc Damage

The standard cited suggests 10-m separation for reasons other than underground arcing. Note 1 states that the basis for the recommended separation distance is physical clearances during construction and maintenance activities. No mention of underground arcing is made in the standard, although this may well be one of the mechanisms by which line-to-ground faults were understood to be able to damage pipeline coatings or pipelines.

Although C22.3 No. 6-M91 does not cite this work, in [2], HCHI/Kinetrics reference research related to underground arcing and damage to pipeline coatings and pipelines as reported in CEA Report 239 T 817 "Powerline Ground Fault Effects on Pipelines" [10]. The research

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described in this report investigated several issues, including damage to pipelines and pipeline coatings, voltage required to initiate underground arcing in various soil conditions, and voltage required to sustain underground arcing in various soil conditions.

In the research done on bare pipes, underground arcing was found to cause minimal damage to the uncoated pipes. The researchers suggest that this is because the arc is able to travel on the pipe and thus does not concentrate the arc energy on a small area. The pipes covered with more resilient coatings sustained greater damage to the pipe because the coating contained the arc energy to a small exposed area of the pipe. This description is consistent with the description of damage to a pipeline due to fault current entering the earth in the vicinity of the pipeline in C22.3 No. 6-M91, Paragraph A1.3.1.

If any information with regard to damage to buried distribution system electrodes may be gleaned from the underground arcing tests described in CEA Report 239 T 817, the research seems to indicate that there would not be any significant damage to the distribution line ground electrode due to the lack of insulating coating to focus the arc energy on a spot of weakened coating.

B. Probability of Underground Arcing

The mode of underground arcing about which HCHI/Kinetrics have expressed concern is the situation in which a lightning strike to the transmission line initiates an arc through the earth and establishes a conductive path between the ground electrode of the stricken transmission structure and a distribution line ground electrode, and the arc causes flashover failure of one of the transmission line insulators on the stricken structure.

Although research indicates that the arc may not cause direct damage to the distribution line ground electrode itself, it is nonetheless plausible that underground arcing, if it occurred, could cause damage or disruption to the electrical distribution system or customers' equipment. Calculation of the expected ground potential rise (GPR) at the tower footing as described previously in this report estimated the maximum expected GPR to be 11.1 kV.

HCHI/Kinetrics summarized the results of the sustained arc tests from CEA Report 239 T 817 [10] stating that approximately 10 kV/m was needed to sustain an arc in soil. This summary was found to be consistent with the results shown the CEA report, where tests of sustained arcing in topsoil with 8 kA arc current showed a linear regression slope of 10.6 kV/m. Other soil types showed lower arcing distances, but the differences are not dramatic, with tests of sustained arcing in the native soil of the test site showing a linear regression slope of 14.2 kV/m and sustained arcing in sand showing a linear regression slope of 11.8 kV/m.

If HCHI/Kinetrics 10 kV/m estimate for sustained arcing in soil is used, then based on the calculated transmission structure GPR, the maximum distance at which underground arcing would be sustained is 1.1 m [3.6 ft]. The proposed transmission line structure placement is well beyond this distance.

Finally, the likelihood of the lightning flashover event of concern was evaluated. The mean time between failure (MTBF) for lightning outages on the transmission line was calculated to be approximately 35 years. This is only an estimate based on industry-standard methods and is probabilistic in nature and should be understood as such. Nonetheless, the

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estimated lightning outage rate for this portion of the transmission line indicates that the failure mode that is of concern to HCHI/Kinetrics may be expected to be relatively rare.

C. Ground Potential Rise Transfer

Beyond the issue of underground arcing that has been the focus of discussion to this point, there is the issue of potential being transferred through the earth from the transmission line structure ground electrode to a nearby distribution line ground electrode. Calculations were done to estimate how much of the GPR at the transmission line ground electrode would appear on a nearby distribution line ground electrode and be transferred onto the distribution system neutral for non-ionized soil. Calculations showed that with 11.1 kV GPR applied to the transmission structure ground electrode, 860 V appeared on the distribution line ground electrode due to through-earth coupling. This relatively small transient voltage on the distribution neutral would not be expected to cause any problems.

VI. CONCLUSIONS

The 10-m structure separation requested by HCHI and supported by the Board staff report was examined. The standard and underlying research cited to support this request were examined in detail. Engineering calculations were performed to assess the impact of the Summerhaven project transmission line on the HCHI distribution line in accordance with the research cited by HCHI/Kinetrics.

It was found that the standard cited to support the 10-m separation request was not applicable to the situation. If the threshold of sustained underground arcing presented by HCHI/Kinetrics is accepted, the distance between the proposed Summerhaven transmission line and the planned HCHI distribution line is more than sufficient to prevent sustained underground arcing. Even if underground arcing were to occur, a lightning outage rate estimate for the transmission line indicated that lightning initiation of this type of arcing would be rare, and examination of the arc-damage research cited by HCHI/Kinetrics indicated that underground arcing would not cause damage to distribution system ground electrodes. Finally, it was determined that ground potential rise (GPR) transferred through the earth from the transmission line to the distribution line would not be of sufficient magnitude to be of concern.

In summary, on the basis of the engineering calculations described in this report, the design separation of 6 m [19.7 ft] between the transmission line ground electrodes and the distribution line ground electrodes was determined to be more than adequate to avoid underground arcing.

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	Project: Summerhaven Transmission Line	Issue Date: 7/26/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

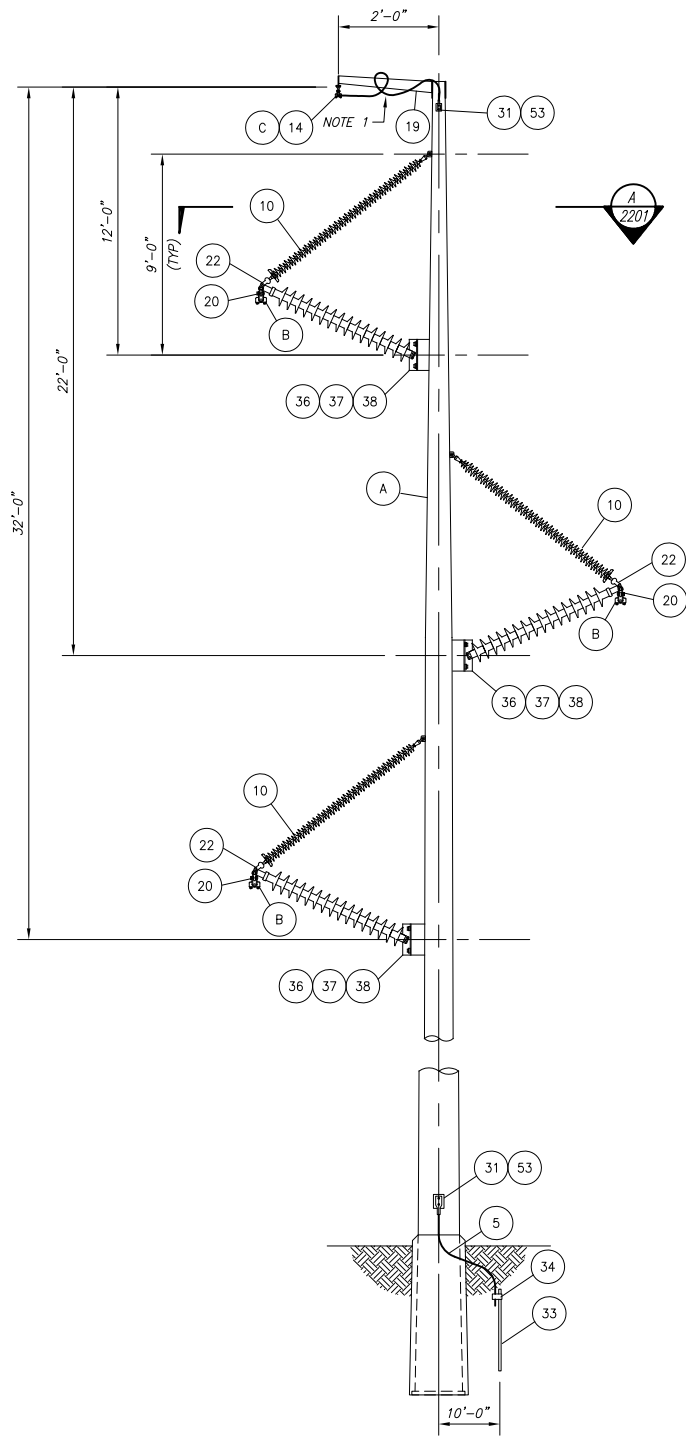
VII. REFERENCES

- [1] "Induction Study for Haldimand County Hydro Inc." Kinetrics Report 015949-RC-0001-R00. May 31, 2011.
URL: <http://www.rds.ontarioenergyboard.ca/webdrawer/webdrawer.dll/webdrawer/rec/275277/view/>
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URL: <http://www.rds.ontarioenergyboard.ca/webdrawer/webdrawer.dll/webdrawer/rec/279400/view/>
- [3] Board Staff Submission. EB-2011-0027. June 22, 2011. p 6.
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- [7] "IEEE Guide for Improving the Lightning Performance of Transmission Lines," *IEEE Std 1243-1997*
- [8] *Transmission Line Reference Book, 345 kV and Above, Second Edition*. EPRI. 1982
- [9] CAN/CSA-C22.3 No. 6-M91. "Principles and Practices of Electrical Coordination Between Pipelines and Electric Supply Lines".
- [10] Webster, Zawadzki, and Stefanski. "Powerline Ground Fault Effects on Pipelines". CEA Report 239 T 817. December 1994.

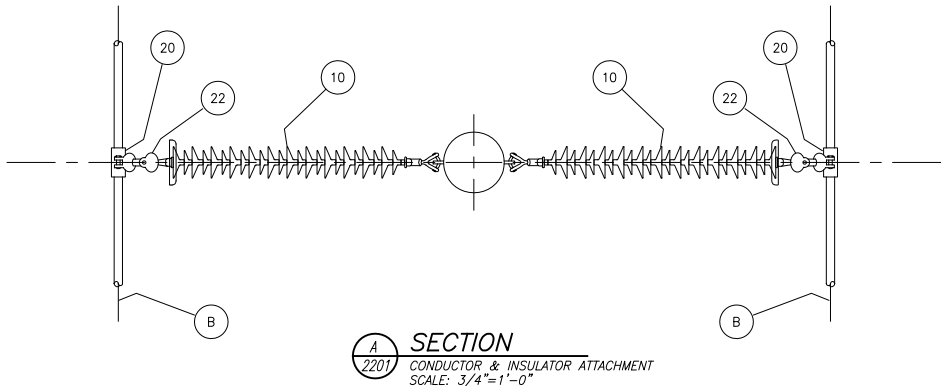
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	Project: Summerhaven Transmission Line	Issue Date: 7/25/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix A: Transmission Line Tangent Structure Detail Drawing

PLOTTED: 05/15/11 07:05:14 AM FILENAME: F:\apao\17647.50.51 - Summerhaven\17651 Summerhaven 230 kV T-tie\3.0 Design\3.2 Drawings\17651-2201.dwg USER: gary.jefferson



TBP DETAIL
 TANGENT BRACED POST STRUCTURE
 SCALE: 1/4"=1'-0"



SECTION
 2201 CONDUCTOR & INSULATOR ATTACHMENT
 SCALE: 3/4"=1'-0"

BILL OF MATERIAL CONTRACTOR FURNISHED				
ITEM	QTY	UNIT	DESCRIPTION	MANUFACTURERS C/N
5	AS REQ'D	FT	CONDUCTOR: #4 AWG STRANDED COPPER	
10	3	EA	INSULATOR ASSEMBLY: BRACED LINE POST, 230 kV, FLAT BASE, LONG LEAKAGE	NGK-LOCKE CAT.#: HV-682 OR EQUAL
14	1	EA	CLAMP: FIBERLIGN CUSHION, FOR 48 FIBER, 0.530" DIA. OPGW, W/Y-CLEVIS EYE	PERFORMED CAT.#: 4700105YC OR EQUAL
19	AS REQ'D	FT	BRAIDED SLEEVE: TINNED COPPER, FITS #4 CU CONNECTORS, 500' REEL	BELDEN CAT.#: DMNI 8669-500
20	3	EA	CUSHION GRIP: SUSPENSION, FOR 954 kcmil ACSR, 25,000 LB ULTIMATE STRENGTH	PERFORMED CAT.#: CGS-1112 OR EQUAL
22	3	EA	AGS Y- CLEVIS EYE: 90 DEGREE, 25,000 LB ULTIMATE STRENGTH	BURNDY CAT.#: YH2929 OR EQUAL
31	2	EA	TERMINAL: #4 AWG COPPER TO 2-HOLE PAD, COMPRESSION COPPER	BURNDY CAT.#: YGHA2C-2N OR EQUAL
33	1	EA	GROUND ROD: 3/4" DIAMETER 10'-0", COPPER BONDED	JOSLYN CAT.#: J8350 OR EQUAL
34	1	EA	CLAMP: FOR 3/4" GROUND ROD TO #4 AWG SOLID COPPER	JOSLYN CAT.#: J3493 OR EQUAL
36	12	EA	MACHINE BOLT W/NUT: 3/4" X 2 1/2"	
37	12	EA	MF LOCKNUT: 3/4"	
38	12	EA	WASHER: 3/4" FLAT	
53	4	EA	BOLT: 1/2" X 1" LONG WITH WASHER AND LOCKWASHER, SILICON BRONZE	

BILL OF MATERIAL OWNER FURNISHED				
ITEM	QTY	UNIT	DESCRIPTION	MANUFACTURERS C/N
A	1	EA	POLE: STEEL, HEIGHT AND EMBEDMENT LENGTH AS SHOWN ON PLAN AND PROFILE DRAWINGS	
B	AS REQ'D	EA	CONDUCTOR: 954 ACSR "CARDINAL"	
C	AS REQ'D	EA	OPGW: 48 FIBERS OPTICAL GROUND WIRE, 0.530" DIA.	SFPOC CAT.#: SFSJ-J-4388R2

NOTES

1. LOOP BRAIDED WIRE TO PROVIDE ENOUGH SLACK FOR OPGW MOVEMENT.

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REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS	NEXTERA ENERGY CANADA, ULC. SUMMERHAVEN 230 kV TRANSMISSION LINE		
A	ISSUED FOR BID	TMF	KKM	PMG	2-28-11	DWN: K. MEYER			
B	REVISED ISSUED FOR BID	TMF	VLM	PMG	03/08/11	CHK: B. VAN BRIESEN	STRUCTURE DETAILS		
C	ISSUED FOR ESA REVIEW	TMF	KKM	BVB	03/14/11	APP:			
						DATE:			
							SCALE	AS SHOWN	REV
								DRAWING 17651-2201	C

	Document Title: Underground Arcing and GPR Report	Report No.: 18559-9002
	Project: Summerhaven Transmission Line	Issue Date: 7/25/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix B: Insulator Assembly Manufacturer's Cutsheet

REVISIONS	
0	MAR. 07, 2011

- NOTES:
1. DIMENSIONS ARE IN INCHES, METRIC EQUIVALENTS (mm) ARE SHOWN IN ().
 2. MECHANICAL VALUES ARE FOR SINGLE LOADS IN THE SPECIFIED DIRECTION.
 3. ELECTRICAL VALUES ARE THE MINIMUMS OF THE HORIZONTAL VEE.

 NGK-LOCKE	DWG. NO.	LP-12891
	BRACED LINE POST ASSEMBLY	

REFERENCE DATA

CHARACTERISTICS

ELECTRICAL VALUES

- Power Frequency Dry Flashover, kV
Power Frequency Wet Flashover, kV
Critical-Impulse Flashover, Pos., kV
Critical-Impulse Flashover, Neg., kV

RATING

- 765
670
1255
1350

LEAKAGE DISTANCES

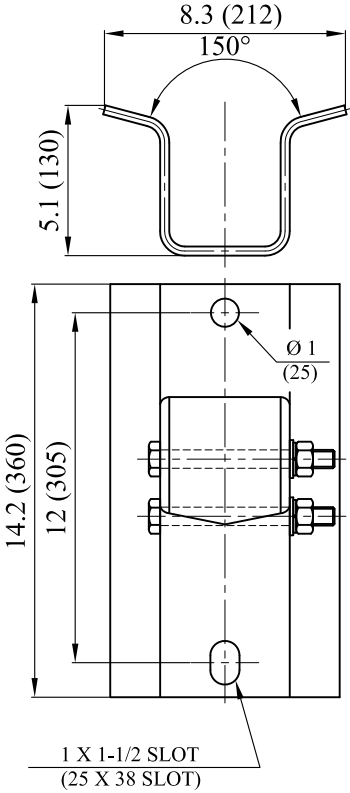
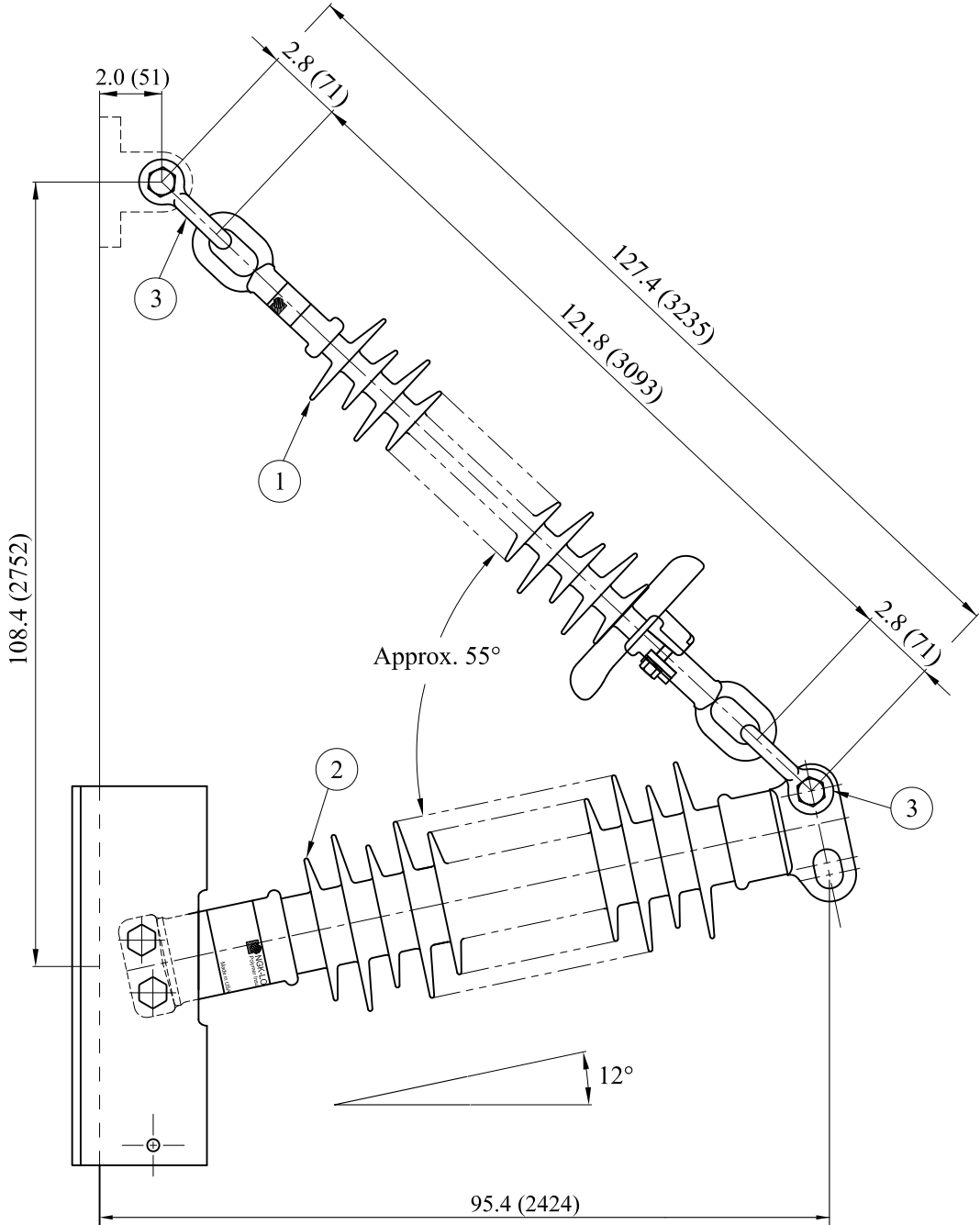
- Stay Insulator (Item #1), in. (mm)
Strut Insulator (Item #2), in. (mm)

- 310.6 (7889)
289.1 (7344)

MECHANICAL VALUES

- Maximum Design Vertical Load, lbs.
(Single load value w/o any other applied loads.)
Maximum Design Longitudinal Load, lbs.
(Single load value w/o any other applied loads /
50% of the minimum average cantilever breaking
load of the Strut Insulator.)
Maximum Design Tension Load, lbs.
(Single load value w/o any other applied loads /
50% SML of the Strut Insulator.)
Maximum Design Compression Load, lbs.
(Single load value w/o any other applied loads /
Less than 80% of the critical buckling load of
the Strut Insulator.)

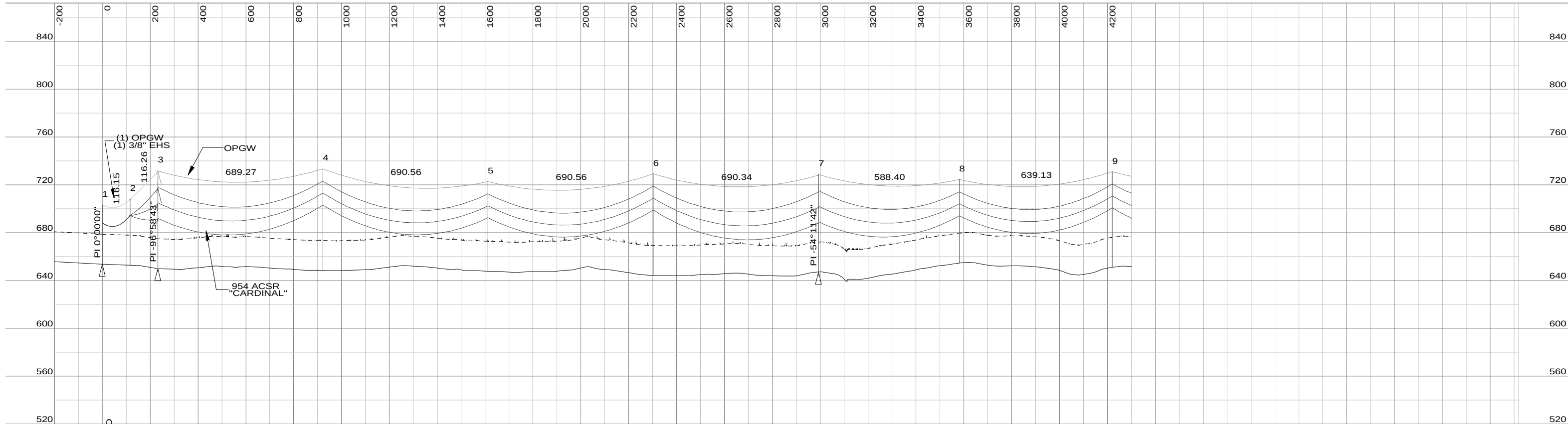
- 8565
885
7500
7500



3	Anchor Shackle	Anderson: AS-25-L-BNK or Equal	2
2	Strut / Line Post Insulator	L2-SL721-13	1
1	Stay / Suspension Insulator	251-SS920-EE-08	1
ITEM	COMPONENT	PART NUMBER	QTY
MADE BY	MM	NGK-LOCKE POLYMER INSULATORS, INC. VIRGINIA BEACH, VA 23455	CAT. NO. HV-682
APPROVED	KE		

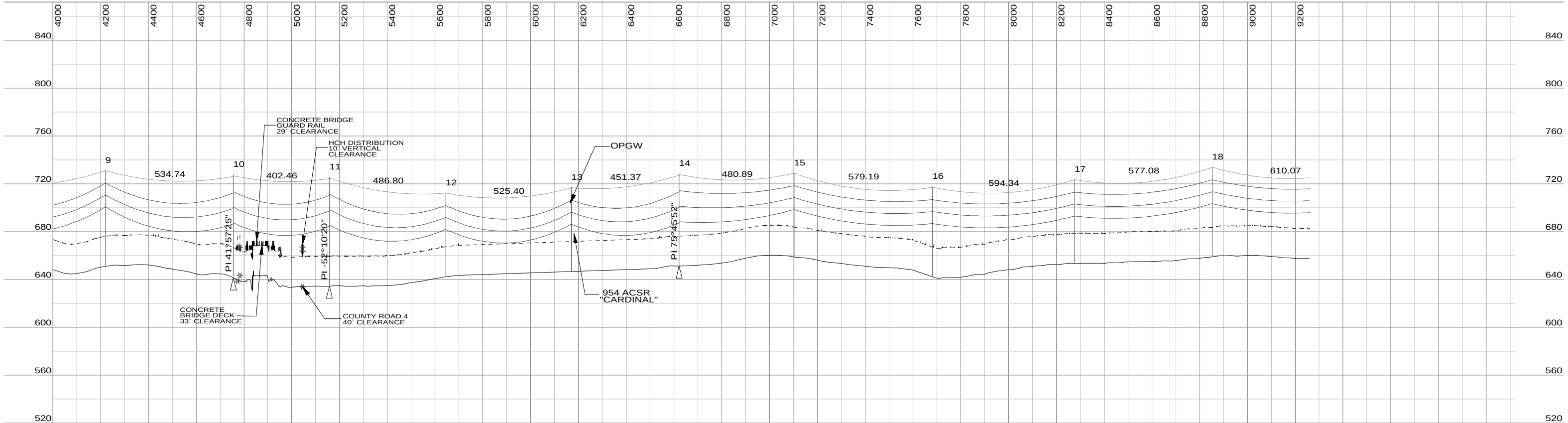
	Document Title: Underground Arcing and GPR Report	Report No.: 18559-9002
	Project: Summerhaven Transmission Line	Issue Date: 7/25/11
	Client: NextEra Energy	Revision: 0
	Project Number: 18559	Revision Date: 7/26/11

Appendix C: Transmission Line Plan & Profile Drawings



- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
 2. OPGW AND 7#7 AW SHOWN AT 60 DEG F.
 3. GROUND CLEARANCE LINE SHOWN AT 25 FEET.
 4. STRUCTURE 48 ONLY GUYED AGAINST TENSION TOWARDS STR 47. GUYS NOT USED IN SLACK SPAN TOWARD SUBSTATION DE
 5. STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5

Peak Power Engineering, Inc.		COPYRIGHT © PEAK POWER ENGINEERING, INC.		NEXteraENERGY RESOURCES	REV		DESCRIPTION		ENG	DWN	CHK	DATE	ENG: T. FRANCIS	NEXTERA ENERGY CANADA, ULC SUMMERHAVEN 230KV TRANSMISSION LINE		
UniversalPegasus INTERNATIONAL "D. Box 340 Delson, Ontario R0A 2P7 (303) 457-1102"		THIS DRAWING IS A COPYRIGHTED INSTRUMENT OF SERVICE OF PEAK POWER ENGINEERING, INC., A WHOLLY OWNED SUBSIDIARY OF UNIVERSALPEGASUS INTERNATIONAL, INC., AS OF THE DATE SHOWN ON THIS DRAWING. ANY RE-USE OR COPYING OF ANY PORTION OF THIS DRAWING WITHOUT WRITTEN PERMISSION FROM AN AUTHORIZED EMPLOYEE OF PEAK POWER IS STRICTLY PROHIBITED. ONLY DRAWINGS MARKED "FOR CONSTRUCTION" AND CONTAINING AN ORIGINAL P.E. STAMP AND SIGNATURE SHALL BE USED FOR CONSTRUCTION. ANY MEDIA TRANSMITTED ELECTRONICALLY SHALL NOT BE CONSIDERED A CERTIFIED DOCUMENT.			E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE		TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS				
					B	REVISED ISSUED FOR BID		TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN	PLAN AND PROFILE SHEET 1 OF 5			
					C	ISSUED FOR ESA REVIEW		TMF	TMF	BVB	03/15/11	APP:				
					D	REVISED ROUTE		TMF	TMF	BVB	04/08/11	DATE: 03/15/11	SCALE		AS NOTED	



9
sta=4220.65
ht=80.00 ele=651.01
TBP
DA1, DA3
12.5' Embedment

10
sta=4755.40
ht=86.00 ele=641.29
ht adjust=1.00
VDE-3
DA2, DA4, DA5
FON
SELF SUPPORTING

11
sta=5157.86
ht=91.00 ele=634.43
ht adjust=1.00
VDE-3
DA4, DA5
FON
SELF SUPPORTING

12
sta=5644.65
ht=70.00 ele=642.29
TBP
DA1, DA3
11.5' Embedment

13
sta=6170.05
ht=70.00 ele=646.68
TBP
DA1, DA3
11.5' Embedment

14
sta=6621.42
ht=77.00 ele=651.25
VDE-3
DA1, DA5
(1) AS-1
(1) FO-1, (1) FO-2
12.5' Embedment
68' Guy Lead

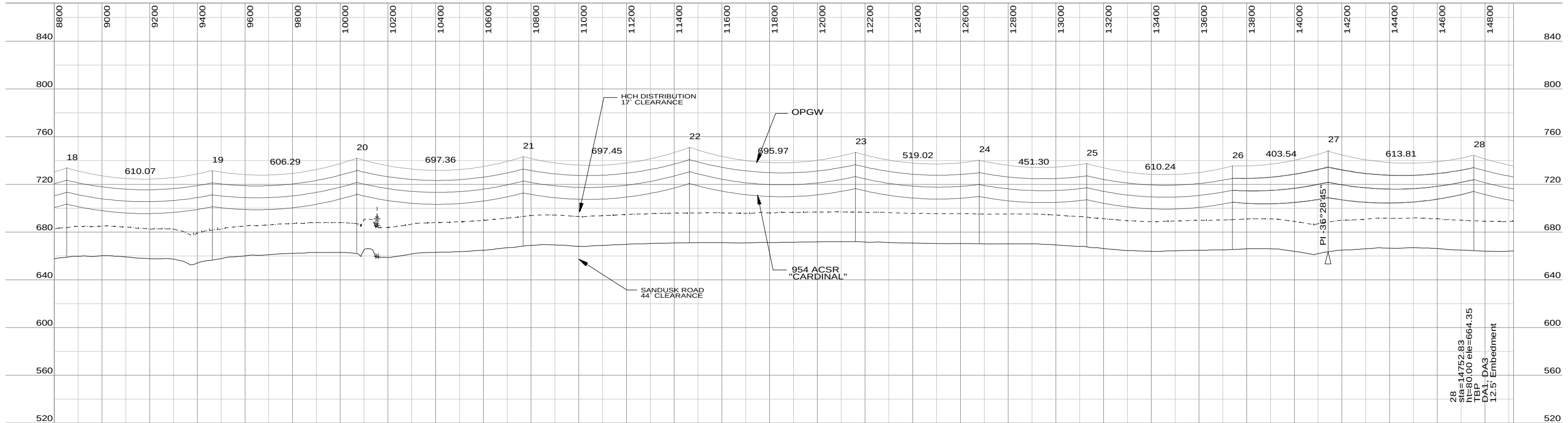
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sta=7102.31
ht=70.00 ele=658.85
TBP
DA3
11.5' Embedment

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sta=7681.49
ht=75.00 ele=642.14
TBP
DA1, DA3
12' Embedment

17
sta=8275.83
ht=70.00 ele=653.43
TBP
DA3
11.5' Embedment

18
sta=8852.91
ht=75.00 ele=658.78
TBP
DA1, DA3
12' Embedment

- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
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 3. GROUND CLEARANCE LINE SHOWN AT 25 FEET.
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 5. STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5



18
sta=8852.91
ht=75.00 ele=658.78
TBP
DA1, DA3
12' Embedment

19
sta=9462.98
ht=75.00 ele=656.57
TBP
DA1, DA3
12' Embedment

20
sta=10069.27
ht=80.00 ele=661.96
TBP
DA1, DA3
12.5' Embedment

21
sta=10766.63
ht=75.00 ele=668.13
TBP
DA1, DA3
12' Embedment

22
sta=11464.08
ht=80.00 ele=671.04
TBP
DA1, DA3
12.5' Embedment

23
sta=12160.05
ht=75.00 ele=671.86
TBP
DA1, DA3
12' Embedment

24
sta=12679.07
ht=70.00 ele=670.20
TBP
DA1, DA3
11.5' Embedment

25
sta=13130.37
ht=70.00 ele=667.49
TBP
DA1, DA3
11.5' Embedment

26
sta=13740.61
ht=70.00 ele=665.38
TBP
DA1, DA3
11.5' Embedment

27
sta=14141.57
ht=85.00 ele=663.46
VRA-1
DA3
AS-3
13' Embedment
72' Guy Lead

28
sta=14752.83
ht=80.00 ele=664.35
TBP
DA1, DA3
12.5' Embedment

- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
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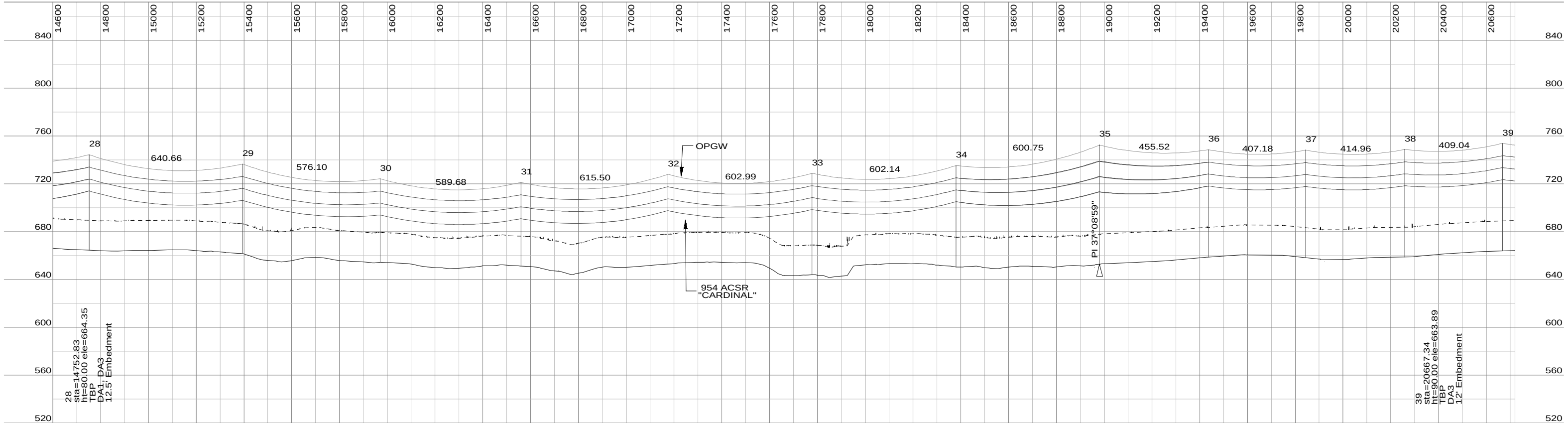
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ST: REG: EXP:

REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS
E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE	TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS
B	REVISED ISSUED FOR BID	TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

NEXTERA ENERGY CANADA, ULC SUMMERHAVEN 230KV TRANSMISSION LINE	
PLAN AND PROFILE SHEET 3 OF 5	
SCALE	DRAWING
AS NOTED	17651-2103
REV E	



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sta=15393.49
ht=75.00 ele=661.58
TBP
DA3
12' Embedment

30
sta=15969.59
ht=70.00 ele=654.30
TBP
DA1, DA3
11.5' Embedment

31
sta=16559.27
ht=75.00 ele=651.17
TBP
DA3
11.5' Embedment

32
sta=17174.76
ht=75.00 ele=652.85
TBP
DA1, DA3
12' Embedment

33
sta=17777.75
ht=85.00 ele=643.82
TBP
DA3
13' Embedment

34
sta=18379.89
ht=85.00 ele=650.29
TBP
DA1, DA3
13' Embedment

35
sta=18980.65
ht=100.00 ele=652.82
VRA-2
DA3
FDN
Self Supporting

36
sta=19436.16
ht=90.00 ele=658.54
TBP
DA1, DA3
12' Embedment

37
sta=19843.34
ht=90.00 ele=658.16
TBP
DA3
12' Embedment

38
sta=20258.30
ht=90.00 ele=658.71
TBP
DA1, DA3
12' Embedment

39
sta=20667.34
ht=90.00 ele=663.89
TBP
DA3
12' Embedment

- NOTES
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B	REVISED ISSUED FOR BID	TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11

SCALE

AS NOTED

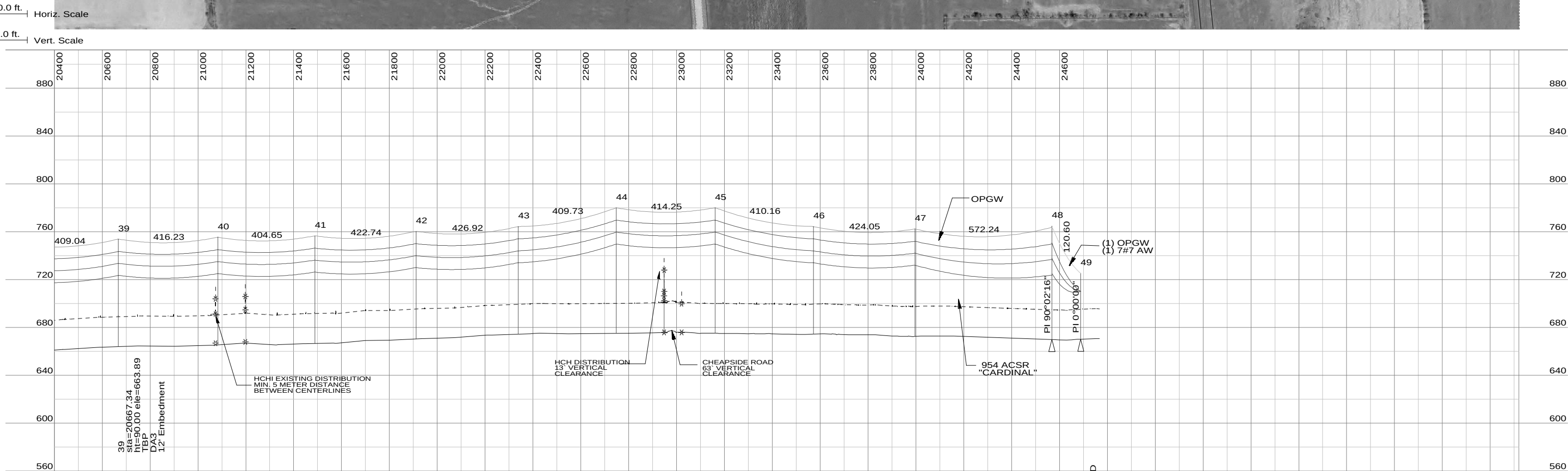
DRAWING
17651-2104

REV
E

NEXTERA ENERGY CANADA, ULC

SUMMERHAVEN 230KV TRANSMISSION LINE

PLAN AND PROFILE SHEET 4 OF 5



- NOTES
1. 954 ACSR "CARDINAL" SHOWN AT 212 DEG F.
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 5. STRUCTURES 36 THROUGH 47 ALIGNED WITH FUTURE HCHI STRUCTURES PER DWG 477_CON_5



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ST:	REG:	EXP:
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REV	DESCRIPTION	ENG	DWN	CHK	DATE	ENG: T. FRANCIS	NEXTERA ENERGY CANADA, ULC SUMMERHAVEN 230KV TRANSMISSION LINE			
E	REVISED DESIGN FOR FUTURE HCHI DISTRIBUTION LINE	TMF	TMF	BVB	07/20/11	DWN: T. FRANCIS	PLAN AND PROFILE SHEET 5 OF 5			
B	REVISED ISSUED FOR BID	TMF	TMF	PMG	03/08/11	CHK: B. VAN BRIESEN				
C	ISSUED FOR ESA REVIEW	TMF	TMF	BVB	03/15/11	APP:	SCALE AS NOTED		DRAWING 17651-2105	REV E
D	REVISED ROUTE	TMF	TMF	BVB	04/08/11	DATE: 03/15/11				

Schedule E
Pole Cross Section

