Appendix E

Ampacity Study

Community Wind South Repower Project
Nobles County, Minnesota

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March 10, 2021

Community Wind South Wind Farm

Ampacity Study

Rev C

PROJECT NUMBER:
165320

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POWER ENGINEERS

REVISION HISTORY						
REV.	ISSUE DATE	ISSUED FOR	PREP BY	CHKD BY	APPD BY	NOTES
A	11/17/2020	For Review	SA	JB	MM	
B	02/12/2021	For Review	MK	JB	MM	Revised based on client comments
C	03/10/2021	For Review	MK	JB	MM	Revised based on client/UL comments

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1.0 INTRODUCTION

The purpose of this study is to show the current carrying capacity (ampacity) for below grade medium voltage (MV) collection cable is sufficient for future 2.2 MW Vestas Wind Turbine Generators (WTG) rated at 0.95 power factor.

The current collections systems consist of 1/0 AWG 2/3N, 4/0 AWG 1/3N, and 500 kcmil 1/6N aluminum conductors. The collection system is brought to Xcel Nobles substation on two feeders (home runs), with the full collection system showing in drawings 8258-2E-001 and 8258-3E-001.

Existing cables have been found to be sufficiently sized for the 2.2 MW Vestas Wind Turbine Generators (WTG) with the exception of the 500 kcmil home run cables at the entry of the Xcel Nobles substation.

2.0 ASSUMPTION OF AMPACITY ANALYSIS

POWER uses CYME's CYMCAP software, Version 7.3 Rev 2 to calculate the ampacity and temperature for electric power cable installed on site. The details for the analysis are the following:

- CWS collection system consists of 34.5kV Primary Cable – 345MIL TR-XPLE, Jacketed Concentric Neutral Aluminum Cable of the following sizes: 1/0 AWG, 4/0 AWG, and 500kcmil.
- Client provided the size of the cable and CME as the manufacture, the cables used in the study were the most conservative cable at those sizes made by CME.
- Soil conditions were determined via testing by Geotherm USA and according to the November 2011 report, the tested in situ soil thermal resistivity values (Rho) are between 53-119 C°-cm/W. Dry-out Rho was between 119-256 C°-cm/W.
- Soil ambient temperatures were not measured, and a value of 20° C was assumed as it is typical in the geographical area of this study.
- Unless otherwise indicated, Rho 200 C°-cm/W was the value used in this study based on client direction.
- The limiting factor for the max ampacity able to be achieved for each cable set was determined by evaluation of areas for road crossings or similar directional bored areas where the cable is in conduit at 48" deep. This situation is modeled with Rho 200 C°-cm/W backfill around the directional bored conduit with an ambient soil temperature of 20°C.
- For the direct buried areas, the soil was assumed to dry by moisture migration to a final value of Rho 200 C°-cm/W, installed at 48" deep in a trefoil or vertically stacked configuration, with ambient soil temperature of 20°C.The ampacity rating was not affected by the different configurations.
- Study did not account for cables buried more than the minimum depth as indicated from drawings 8258-2E-502 and 8258-2E-505.
- Study did not account for other possible underground heat sources with the exception of the area east of Xcel's Nobles substation where CWS collection system two home run feeders cross underneath existing two Xcel 1250kcmil UG cables as showing in drawing 8258-2E-520.

- Existing Xcel 1250kcmil cables info was obtained from Xcel drawings NF-185291 & NF-211639-2X. Cable manufacture was assumed to be CME and cables used in the study were the most conservative cable at 1250kcmil size.
- All cables in the Xcel crossing were simulated at 90° C degrees with an ampacity rating for Xcel 1250kcmil cables greater than 462A. If Xcel cables run at a higher temperature/ampacity then this will reduce the rating of CWS cables.
- All calculation choices were dictated by the "CWS As-Built drawings" provided by the client and "Xcel drawings NF-185291 & NF-211639-2X".

3.0 AMPACITY ANALYSIS RESULTS

Cable Size	Neutral	Direct Bury, 48", Dry out,	WTG allowed	In conduit or duct, Dry out	Burial dept of conduit	WTG Allowed	WTG Used
1/0	2/3	134 A	3.50 → 3	127 A	96"	3.32 → 3	3
4/0	1/3	201 A	5.25 → 5	188 A	72"	4.91 → 4	5
500	1/6	318 A	8.30 → 8	316 A	48"	8.25 → 8	8

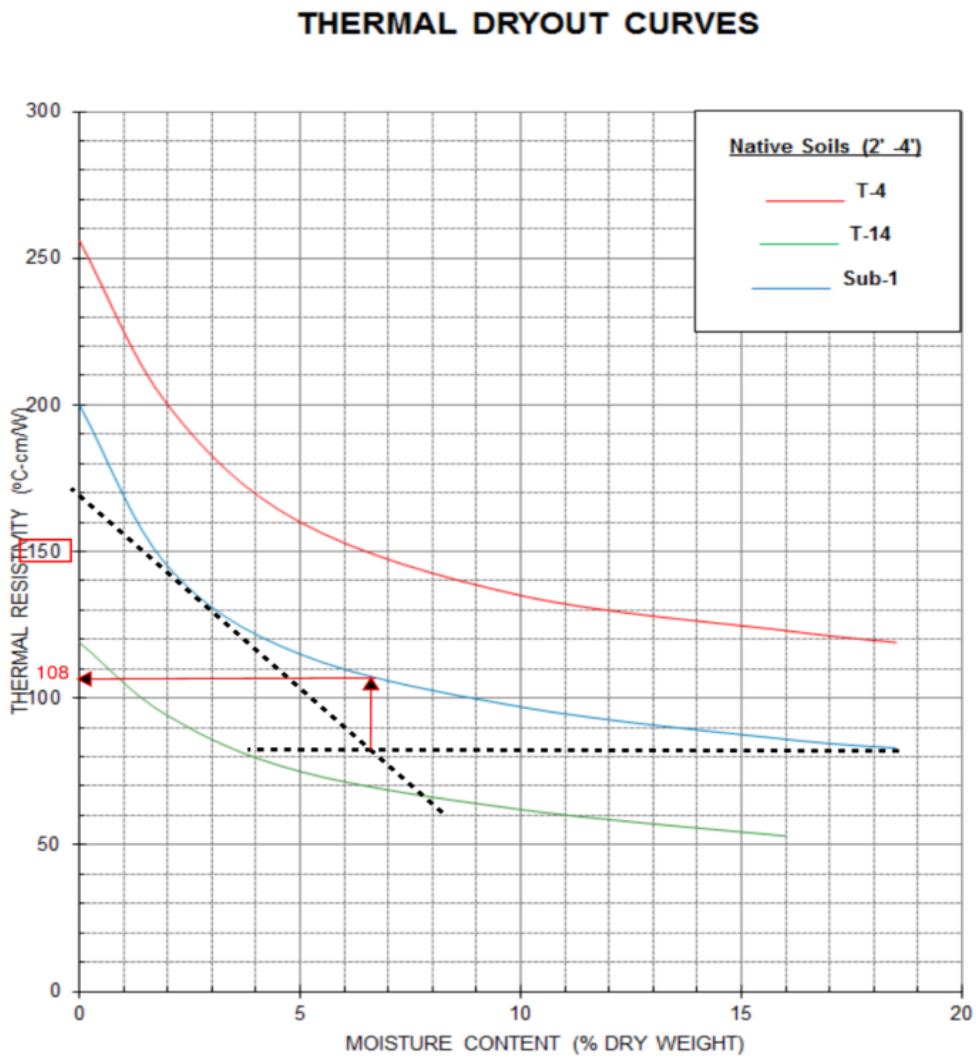
Notes:
1) Red indicates cable exceeds limit required for the WTG needed

The limiting condition for 1/0 AWG and 4/0 AWG was the bore conduit. For existing 1/0 cable, the number of allowable WTGs does not exceed the maximum number of WTGs installed on that cable. As showing below, the 4/0 cable in conduit is overloaded by 3A, which is 1.6 % short of ampacity required for 5 used WTGs. We recommend Greenbacker to evaluate this operational risk before deciding to upgrade these cable segments. To minimize the risk of failure due to cable overload, POWER recommends upgrading these segments.

4.0 HOME RUN PARALLEL CABLES

For the collection system home runs in parallel between switchgear yard and Xcel Nobles substation, two parallel direct buried circuits were modeled with maximum depth of 94" as indicated in as-built drawing # 8258-2E-502. Nominal mode spacing is 10'-0" as indicated by the drawing notes #7 on 8258-2E-502. Installed spacing should be 10' or greater.

For this analysis, the dry-out curves in Geotherm USA geotech report were evaluated based on discussions with the client to determine a more realistic Rho value for the soil in the area of the home runs. It was determined that Rho 108 C°-cm/W is the average value based on below dry-out curves. However, a value of Rho 150 C°-cm/W was select to be more prudent.



4.1 PARALLEL CABLE ANALYSIS RESULTS

Cable Size	Neutral	Direct Bury, 94", Dry out,	WTG allowed	Direct Bury, 94", Dry out, with Xcel cables crossing on top	WTG Allowed	WTG Used
500	1/6	320 A	8.35 → 8	263 A	6.87 → 7	8

Notes:
1) Red indicates cable exceeds limit required for the WTG needed
2) Rho 150 C°-cm/W is used for this analysis

For the parallel home runs, two separate simulations were completed. One to analyze the cables with maximum depth of 94" and the second is to analyze the cables with maximum depth of 94" with Xcel 1250 kcmil cables crossing on top. For the first analysis, the ampacity for two circuit of 500 kcmil cable at 90° C is 320A each. Therefore, with an installed maximum usage of 8 turbines on 500 kcmil conductors are within acceptable temperature range.

For the second analysis, the ampacity for two circuit of 500 kcmil cable at 90° C is 263A each. Therefore, with an installed maximum usage of 8 turbines on 500 kcmil conductors are not within acceptable temperature range due to heating from Xcel cables.

To mitigate failed segments on each home runs, we recommend that these segments to be upsized to larger cable using Horizontal Directional Drilling (HDD). Other alternatives like running parallel cables and temperature monitoring were deemed more expensive and prone to problems.

Proposed cable sizes with maximum allowed ampacity are showing below:

Cable Size (CME)	Neutral	Direct Bury, 94", Dry out, with Xcel cables crossing on top	WTG Allowed
750	1/6	320 A	8.35 → 8
1000	1/6	374 A	9.76 → 9
1250	1/6	421 A	11.00 → 11

Notes:
1) Proposed cables are recommended to demonstrate potential ampacity. Manufacturer, neutral size and other specifications may vary
2) Rho 150 C°-cm/W is used for this analysis
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5.0 PROFESSIONAL ENGINEER APPROVAL OF REPORT

Signed:

POWER Engineers Inc.
Office 913-304-7901

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am duly licensed professional engineer under the laws of the state of:
Michigan
License Number:

POWER Engineers Inc.

March 10, 2021

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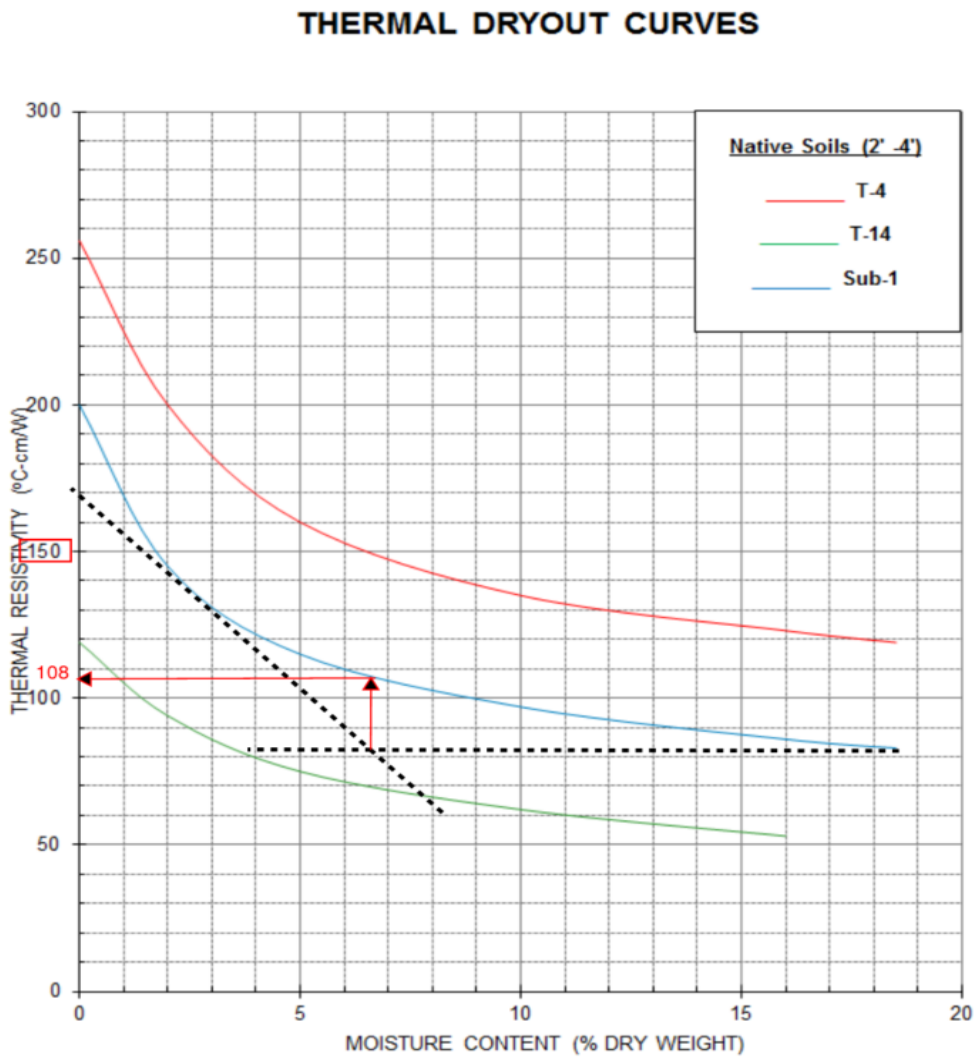

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5.0 PROFESSIONAL ENGINEER APPROVAL OF REPORT

Signed:

POWER Engineers Inc.
Office 913-304-7901

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am duly licensed professional engineer under the laws of the state of:
Michigan
License Number:

POWER Engineers Inc.