MEMORANDUM

TO: PEI Energy Corporation

From: Carl Brothers

Attn: Heather MacLeod, Blair Arsenault

Date: February 28, 2023

SUBJECT: **Preliminary Discussion Notes on Repowering Options for Hermanville Wind Plant**

Following declining availability within the Hermanville wind plant, where energy generation has fallen to half of the design levels, Frontier Power Systems was contracted to review the operating history of the wind plant and to comment on viable options to increase the production of the wind plant to design levels.

While waiting for more detailed operating information to become available, the urgency of the contract appeared to diminish following a discussion, with Acciona's special projects coordinator, who advised that approvals were in place to retrofit all of the nonoperating wind turbines in the summer of 2023, in order to return the wind plant to full production. The urgency then increased when it became clear that Acciona was prepared to carry out these repairs at the expense of the Corporation.

The initial review exercise began with the development of a spreadsheet (template attached) which was planned to be populated with the production summaries and service logs.

The monthly production summaries would show whether each of the turbines were performing to their business case, over time. If they were, fine. That provides an expected benchmark for subsequent analysis. If they were not, exploring why would be the next step. Expectations were that the wind plant, initially, achieved the business plan. Turbines would have high availability and the wind resource would be expected to be around the P50 values. If this was not the case, finding the cause of that, poor reliability, poor performance, incorrect wind flow modelling or low winds, would provide a reference for subsequent analysis.

Every wind plant has operational challenges categorized as minor (nuisance problems that are managed throughout the life of a project), or major, issues (problems required special intervention to remain operational). The service reports would assess the reliability of the plant equipment. Service logs would quickly differentiate between the minor and major problems.

It is known that wind plant yields, which have decreased over time, have been more dramatic in recent years and that much of this decrease is the result of poor availability arising from problematic components. So, regardless of whether the wind plant ever achieved business case

performance in the early years, it is clearly not achieving those results currently and the cause is reduced availability.

Because detailed monthly production and service log summaries are not available, this analysis has been deferred. This is still important data to track, and we would be pleased to compile, analyze, and comment if the data becomes available.

Without the requested data we were still able to sort through available information and to briefly speak with PEIEC staff, with consultants and with Acciona special projects personnel, to better understand the problems. We can offer some preliminary views on what options might be more favorable to increase the plant performance.

The most prominent point is that, while the turbines have a number of serious deficiencies, which will need to be resolved to return the plant to a high level of reliability, most of the wind plant appears performing in an acceptable manner. The electrical and civil systems seem to be operating with high reliability, although some deficiencies in the SCADA system may need further exploration. Towers, inverters, generators and gear boxes also appear to be operating with reasonable reliability. Our conclusion is that a total repowering of the wind plant, which would include removing the existing turbines and replacing them with equipment from an alternate supplier, customized to fit within some part of the existing plant infrastructure, is not the most financially attractive option. The time delay between removing and discarding existing equipment and installing and commissioning modified replacement equipment will take several years, present additional risks and will require significant write down of assets that may be unnecessary.

The major issues affecting the availability of the AccionaAW300-92-56.7, in Hermanville, are fleet wide problems, affecting as many as 1,000 wind turbines around the world. These issues are principally design or manufacturing defects within the low speed components in the drive train. Principally affected are the blades, the blade bearings and the low speed shaft.

The blades are most notable problem and have manufacturing flaws that has been identified and documented. Solution appear to be available with repair procedures or new components.

The mainshaft is a more worrisome issue because it is not clear Acciona understands the root cause. They certainly have not explained it and no RCA report has been provided.

Blades have numerous issues

- **Blade cracks**
    - Delaminating blade spars
    - Cracks in TE
    - Circumferential cracks at roots

Blair, we need to discuss these issues in more detail. I'm not sure I have a full understanding of the issues and the solutions.

Comments:

The DNV report, provided by PEIEC, and a separate discussion with a Canadian consultant who specializes in blade repairs, indicates that most of the blade problems are widely known, are related to manufacturing deficiencies for this series of blade and are repairable. This extent of this issue needs to be more closely studied.

A concerning comment from Sempra's consultant, who noted that analysis he reviewed indicated there is a fundamental design deficiency in the root, arising from the small diameter. The Acciona blade has a root diameter of 2300 mm and uses 64 M36 fasteners, while other manufacturers of this size blade, use a larger diameter root and 90 x M30 blade studs. This problem may be exacerbated in this case because of a production procedure that resulted in the multiple layers of the fiberglass cloth in the root, buckling during infusion. This has subsequently resulted in poor shear strength and cracking within the root. Over time, oil has seeped into these voids making retrofits impractical. The implications of this should be more closely studied.

- **Broken LPS conductors**

This appears to be a design flaw that Acciona has opted not to repair. Repair is overly complex with five receptors, one at tip and two at intermediate locations on each shell. Rather, Acciona has accepted responsibility for any blade failures resulting from lightning.

Comment: Acciona have recently stated they no longer accept this responsibility. This is an issue that requires further study.

- **Broken blade studs**

This problem, which has frequently overwhelmed service technicians, has been traced to a manufacturing defect that has resulted in badly faced blade roots. Nordex-Acciona has a blade root facing machine which can mill the blades to correct specifications. In the interim Acciona has increased the preload on the studs which seems to have reduced the failure rate.

Comment This is one of the major deficiencies in the wind plant. To return the wind plant to reliable operation, each of these blades needs to be refaced. The increased stud loading may have reduced the stud failures in the near term, but it also increased the compressive loading on the root face, an area that has already been noted (above) to be compromised by manufacturing defects. This is an issue that requires more information and further study.

- **Broken blade bearings**

The broken blade bearings which were addressed with numerous, short term, desperate repairs to keep turbines on-line, is another fundamental deficiency in the turbine. As we understand it, the problem has been traced to a machining deficiency in the ball entry port. The problem has

been resolved with new bearings. All the bearings need to be replaced to achieve reliable operation.

- **Failed main shaft bearings.**

This problem has recently emerged and has some uncertainty. In a discussions with Acciona special projects, there was no confirmation that an RCA exists for this. In our discussion, there was a brief mention of wear on the gearbox anti-rotation blocks that were being investigated. This is concerning for two reasons. First, it is not possible that the anti-rotation devices are at fault. One of the most attractive features of this turbine is the use of a double bearing support on the man shaft, a configuration used to ensure all of the non-torsional loads from the rotor, are excluded for the gearbox. The gearbox sees only torsional loads. If the gearbox supports are wearing it is an effect and not a cause of the problem. Secondly, by considering this as a cause may suggest that Acciona does not understand the root cause of this problem. This is a bigger concern. With 5/10 turbines at Hermanville, scheduled for main bearing replacements, this is becoming systemic.

Comment – This issue needs more understanding and it is not clear this understanding will come from Acciona. It appears that all of the main shaft bearings will need to be replaced, and all of the main shafts repaired, in the near future.

How extensive is the blade related RCA and IRT/IMTO documentation? Are the reports noted below a comprehensive list? Are these, or more, available?

DNV Report identifies a number if IRTs

- Blades
  - (IMTOC0231 (Corrective maint. instruction - blade crack repairing 150907,
  - IMTOC0241 (Corrective maint. instruction - internal blade crack repairing" 151113,
  - IRT1462 and IMTOC-449
- LPS
  - IMTOC292 and
  - IRT1462
- Blade Bearings
  - IRT1010,
  - IRT1017, and
  - IRT1191
- Other IRTs noted by DNV
  - IRT0998 - Oil leaks outside of tower
  - IRT0988 - Protective planks for the yaw hole on AW300 lower cover
  - IRT1530 - Placement of Broken Studs Detection Kit"

Preliminary Conclusions - As noted above, there is still some uncertainty on each of the identified areas and further study and discussion is required.

The reliable operation of this wind plant is a critical part of the province's electricity supply. With current generation limitations, ensuring this facility remains productive may be more important than simple financial optimization.

It is our view that, while most of the wind plant can operate with expected levels of availability, the low-speed components need re-investment.

All the rotors on all of these turbines need to be removed and repaired.

- Blade roots need to be ground to eliminate the persistent stud failure problem.
- All blade cracks need to be fully repaired on the ground.
- Refurbishment of LPS systems should be a priority since the blades will be on the ground.
- All blade bearings need to be replaced.
- All main shafts need to be refurbished and bearings need to be replaced.

Because there are five turbines compromised, completing these tasks on an urgent basis is needed.

Some discussion on how best to do this would be useful. Acciona have described an option where they will cycle two refurbished main shaft through the wind plant upgrade, and have them refurbished in time for subsequent turbine upgrade, during the summer or 2023. But it is not clear that the extent of their repairs will address all the known deficiencies. With such a substantial investment, resolving all the known deficiencies on the first five turbines may be preferred.

Five turbines are presently, nearly out of service, entering a period of low wind. An alternative approach to discuss, might be to mobilize a crane, remove all the blades, hubs and main shafts on these turbines, and spend the next 6-8 months, repairing blades, procuring new bearings, and refurbishing main shafts to get the plant largely renewed by the fall of 2023.

Possible Messages to Acciona for Consideration / Further Discussion

Clearly, Nordex are entering an uncertain time. On the one hand it seems improbable, given the need to urgently add as much wind power to the world's electricity supply, that a national government would let a large manufacturer disappear. Still, the financial conditions of Nordex appears to be worse than many of the large turbine manufacturers, who are all distressed. Whether they offer a reliable partner for the future operation of the wind plant is something that needs to be carefully considered.

I expect you have under preparation or have already submitted a response to their recent visit. I have some suggestions on points you might consider raising with them.

- You will be unsurprised that your news left us in a worried state. This will likely end in a legal quagmire that we cannot afford to have fully resolved before we take steps to return the non-operating turbines to service.

- Provide details on itemized task list with proposed scope of supply and deliverables as well as a detailed cost summary of the work proposed.

- We would appreciate your comments on some key points moving forward.
- What warranty is proposed to apply to this work?

- What does this work imply for the other components of the current service contract? Is it Nordex's intention to abandon the project at the end of the current contract?

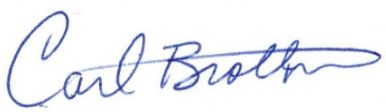
- What options are there for PEIC pursuing a third party supply and retaining access to Nordex supply for critical components and a service subscription to ensure we have access to updates service instructions on the turbine mechanical, electrical and control components and for the SCADA system.

- Will Nordex provide a frank assessment of the known problems? Do they have detailed RCAs and are they adequately competent and economic to continue to provide support to the wind plant.?

- We wish to differentiate supply costs and service costs to better present the options to management.
- Can you please provide price and delivery details on the following items and detailed costs on equipment and labor to carry out the work proposed?
    - 6 x AW56.7 Blades (assuming that some of the damaged blades are beyond repair)
    - Blade Bearings 30 - replace required (Blair can you recall the number neded?)
    - Rental of blade end grinding equipment.
    - Main bearing - Front - 10 required.
    - Main Bearing - Rear - 10 required.
    - Refurbished main shaft - 10 required.
    - Repaired gearbox once extent of collateral damaged is understood.

I am available for further discussion on this at your convenience.

Regards,



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Hermanville Operating Status -February 2023

Blair, is this correct?
T1 – Paused - Blade crack.

- Longitudinal Crack – Turbine Paused
- Blade Scheduled for repair Summer 2023

T2 - Operating - Curtailed to 1.5 MW with main bearing concerns.

- Main bearing scheduled for replacement Summer 2023

T3 – Operating - No curtailment.

- Split Tip (repaired 2022) and another blade with trailing edge crack (currently in run until crack progresses to shear web), another blade was hit by lightning and replaced in 2021
- Scheduled inspection Summer 2023

T4 - Operating - Curtailed to 1.5 MW - Main bearing concerns

- Main bearing scheduled for replacement Summer 2023

T5 - Operating - Curtailed to 1.5 MW - Main bearing concerns

- 230126 - Blair reports turbine out of service due to blade cracks recently repaired.
- Main bearing scheduled for replacement Summer 2023

T6 - Paused - Failed Main Bearing

- Acciona plans to replace the main bearing at T6 in Q3-2022 postponed. Main bearing scheduled for refurbishment was beyond repair. Acciona is currently removing another in Texas which he hopes can be refurbished and the plan is to use this one at T6 and then start a cycle of remove and refurbish.
- RCA bearings?
- Main bearing scheduled for replacement Summer 2023

T7 – Paused - Blade Crack and Main Bearing

- Structural crack, which hasn't yet reached the shear web – Turbine Paused

- Leading edge cracks needs to be repaired on the ground - Spare Blade is at T10
- Main bearing scheduled for replacement Summer 2023

T8 – Operating - No curtailment.

- Transverse crack, repaired in 2022, in run

T9 – Paused - Blade crack

- Two x Transverse crack, Blade C is a weird one because the drone photos show a crack beside the repair that was previously completed but Acciona inspected from inside and no damage was found. New drone inspections upcoming should help confirm this. Turbine paused because Blade A crack.
- Blade Scheduled for repair Summer 2023

T10 – Operating - Curtailed to 1.5 MW with main bearing concerns

- Blade replaced in 2021 due to Transverse Crack, I performed internal inspection of the blade that came down and it had already been repaired for Transverse Crack and the crack moved approximately 2 meters down the blade.
- Do you mean the crack propagated 2 meters toward the trailing edge or another crake started 2 meters further out on the blade?
- May be useful to get consultant or Nordex comment on this observation
- Main bearing scheduled for replacement Summer 2023