Opening Statement of
Dr. Charles Rhodes

November 14, 2013

Good morning/afternoon Mr. Chairman and members of the Commission.

My name is Dr. Charles Rhodes.

BACKGROUND:
Let me start this presentation by summarizing my background:
I have 50 years of experience in the fields of electronics, electrical engineering, heat and electricity generation, energy management, mechanical engineering, nuclear engineering and physics. I have extensive experience with all phases of design, development, installation and maintenance of electronic and energy systems and with related financial matters. Specific details of my experience and education are contained in my CV which was filed as exhibit 186.03.

I was retained by Richard Secord of Ackroyd LLP., on behalf of his client, the Killarney Lake Group, to review the Bull Creek Project and to advise the Commission on whether the engineering and design work filed for this Project are sufficient to ensure protection of the buried steel pipelines in the Project Area that contain flammable and highly toxic gasses under pressure. The findings from my review are in my report filed as Ex. 186.02.

I have also reviewed the Reply Evidence filed by 1646658 Alberta Ltd. and I have read and evaluated the transcripts from the cross examination of Jim Pinter, electrical engineering witness for 1646658 Alberta Ltd.

In this introductory statement I intend to cover the following topics:
-BURIED STEEL PIPELINE LONG TERM EXTERNAL CORROSION PREVENTION
-PRACTICAL CHOICES AVAILABLE TO THIS PANEL
-THE CONCEPT OF REDUNDANT SAFETY DEVICES
-GROUND CURRENT IN WIND TURBINE TRANSFORMERS
-GROUND RESISTANCE
-INDUCED LOCAL GROUND VOLTAGE
-DECLINE IN INDUCED GROUND VOLTAGE WITH DISTANCE
-TOO MANY IFs
-MURPHY'S LAW
-REALIZATION OF A SAFETY SYSTEM USING SCADA EQUIPMENT
-ELECTRICAL CODE INSPECTION LIMITATIONS
-RESPONSE TO BLUEARTH EVIDENCE
-GENERAL COMMENTS ON THE APPLICATION AND REPLY EVIDENCE

MY WORK
My work with respect to the Killarney Lake Group has focused on the interaction between the electrical system of the proposed wind farm and the maze of buried steel pipelines in the proximity of the wind farm. The main concern is the potential for electrically accelerated

pipeline corrosion leading to a pipeline rupture and/or natural gas fire involving a high concentration of the highly toxic gas hydrogen sulfide with consequential damage to nearby residents.

A related concern is an apparent culture amongst both the wind farm proponents and the existing pipeline owners to the effect that because they have successfully built and operated isolated systems in rural locations they need not concern themselves with system interaction related safety matters.

EXTERNAL CORROSION PREVENTION OF BURIED STEEL PIPELINES:
Prevention of external corrosion of buried steel pipelines relies firstly on a conformal Fusion Bonded Epoxy (FBE) coating and secondly on a negative voltage electrical bias on the pipe with respect to the surrounding soil.

The quality of the FBE coating near the pipe welds is dependent upon the skill and care used by the pipe laying tradesmen. This quality is difficult to control, especially if the pipe is welded and laid in adverse weather conditions.

The last line of defense in prevention of external corrosion is provided by a negative voltage on the pipe, typically in the range -0.9 volts to -1.8 volts with respect to the surrounding soil. This negative bias prevents corrosion at imperfections in the FBE coating.

Our discussion today is about a project that potentially could compromise this negative voltage electrical bias on the pipe

CONSEQUENCES:
If a natural gas pipeline is approved for installation in an unpopulated rural area the pipe may be thin wall, because the cost consequences of a pipe failure are thought to be minor. However, uncontrolled urban growth may cause that same pipe to later be in an urban area where the cost consequences of a pipe failure can exceed $500 million.

Pipelines tend to be out of sight, out of mind. The corrosion mechanisms are slow. If a pipeline owner is faced with immediate cost pressures, one of the first programs to be sacrificed is long term corrosion prevention.

However, sooner or later a pipeline with inadequate corrosion protection will rupture, and if a rupture occurs in an urban area the costs can be enormous. Lethal concentrations of hydrogen sulfide in gas escaping from the pipeline can make control of secondary fires impossible. Frequently secondary fires cause more property damage than does the pipeline fire.

The anti-corrosion negative voltage protection on a pipeline can be defeated by proximity of the pipeline to a major grid connected electrical transformer. In the best of circumstances such transformers leak ground current and if there is a ground fault that ground current may increase many fold. The ground current causes significant local ground voltage variation out to a distance which is frequently much larger than the radius of the pipeline exclusive right-of-way.

The negative voltage pipeline protection can also be defeated by neglect by pipeline personnel of negative voltage maintenance. In order to distinguish which party is the cause of a pipeline rupture triggered by corrosion the pipeline bias current and bias voltage with respect to earth ground should be continuously monitored and periodically recorded. Similarly the ground current at each major transformer in the proximity of a buried steel pipeline should be monitored and recorded and a written record should be kept regarding the measured ground resistance and the installed ground mesh radius at the transformer location.

ELECTRICAL SYSTEM AND PIPELINE INTERACTIONS:
Electricity utilities have evolved grounding systems for generation stations and substations that work reliably in most circumstances. At generation stations and at substations electricity utilities use extensive buried copper cable or copper mesh to minimize ground resistance. IF the product of the local earth ground current in amperes multiplied by the local earth ground resistance in ohms is less than 0.5 volt RMS, and IF the pipeline is biased at -0.9 to -1.8 volts DC with respect to the same local earth ground, THEN the consequent nearby buried steel pipeline corrosion problems are negligible. If this condition is not met site specific anti-corrosion measures should be used.

Senior engineers at both electrical utilities and pipeline companies are aware of the dangers of interaction of electrical and pipeline systems and go out of their way to locate and condition equipment to avoid problems. Buried steel pipelines in the vicinity of electricity substations are often given additional dielectric coating protection when there is fore knowledge that the substations and pipes must safely co-exist.

Panel members are probably aware of an electrical safety device known as Ground Fault Interrupter (GFI). A residential single circuit GFI is typically constructed so that it shuts electrical things off if the ground current exceeds 5 mA (.005 amperes). Since the ground resistance at a single family home is generally less than 100 ohms, the induced ground voltage in the vicinity of a single family home is usually less than:
(.005 amps X 100 ohms) = 0.5 volts
and there is negligible electrically accelerated corrosion of local buried pipes.

THIS PROJECT:
In real 3 phase electrical systems there are many ways that inadvertent ground currents can occur. In most wind farms inadvertent ground currents are of little consequence due to no proximity of nearby buried steel pipelines.

However, due to multiple nearby buried gas pipelines containing highly toxic concentrations of hydrogen sulfide (Vol. 4, P. 959 Line 2 to P. 963 Line 11) this proposed wind farm has much less tolerance for inadvertent ground currents than most comparable wind farms. This wind farm as designed uses 2/0 copper common ground conductors which connect together the substation and all the wind turbine towers. These common ground conductors minimize peak voltages in the event of a direct lightning strike on a single tower.

These common ground conductors also assist in reducing induced local earth ground voltages. However, depending on installation detail not addressed on the drawings, this *common ground conductor may make identification and localization of certain types of equipment faults much more difficult than otherwise would be the case, which will increase maintenance costs. During such fault localization a common ground conductor might be repeatedly disconnected and reconnected. Disconnection of a common ground conductor, or an inadvertent break in this conductor, can increase induced local earth ground voltages leading to further unanticipated problems.*

ISSUE FOR THIS PANEL:
From a corrosion perspective the issue for this Panel is not whether it is technically possible to build and safely operate a wind farm over the existing maze of existing sour gas pipelines. The issue is whether the present and future wind farm owners are truly ready, willing and able to meet the entire spectrum of extra costs required to ensure ongoing protection of the both the existing buried steel pipelines and the nearby residents including members of the Killarney Lake Group. Are these wind farm owners truly ready to be responsible for the full extent of the risk?

CHOICES FOR THIS PANEL
In my view there are only two practical choices available to this Panel that do not put the Alberta taxpayers at risk.

CHOICE #1
Choice #1 is to simply deny wind farm approval at the Bull Creek site.

This panel could simply decide that it would make more financial sense for 1646658 Alberta Ltd. and other wind farm proponents to locate wind generators where there are fewer potential problems with nearby buried toxic and flammable gas pipelines and nearby residents. The present project location is fraught with hidden costs that make a wind farm at this location a risky investment.

The costs of defending litigation related to a single pipeline incident, even if the incident is not the fault of the wind farm owner, could easily swallow the entire wind farm income. Worse yet, a liability insurer might attempt to avoid its obligations via the law of torts in Alberta.

In the context of present legislation it may be difficult for the Panel to reasonably protect nearby residents, including the Killarney Lake Group at the present Bull Creek site.

There are many legal precedents for damaged third parties to recover from pipeline owners damages resulting from pipeline failures caused by pipeline owner negligence.

There are relatively few legal precedents for damaged pipeline owners to recover costs resulting from ground currents caused by electric utilities.

In the case of a major Enbridge oil pipeline passing close to a US wind farm the issue was recently resolved by Enbridge literally digging up the pipeline and reapplying the FBE coating for corrosion protection certainty. The fact that the pipeline companies at Bull Creek have so far not objected suggests that their senior management has yet to grasp the scope of their financial exposure. Up to the date of drafting this document there is nothing in the written communications between 1646658 Alberta Ltd. and the pipeline companies that suggests to the pipeline owners that due to proximity between the wind turbine transformers and the pipelines there may be a long term corrosion risk.(Ref. Undertaking titled Industry Contact and No Concern). This issue has recently become of much greater concern due to subtle equipment design changes implemented by GE to meet new regulations for real time wind turbine power control.

While victims of pipeline failure may normally recover damages from pipeline owners, it is not so clear that they can recover damages in cases where the pipeline failure is caused by ground current emitted by an electricity generator. In the case of a wind farm the electricity generator may not have either sufficient public liability insurance or sufficient net assets to make a legal case productive. The evidence indicates that 1646658 Alberta Ltd. will carry only $25 million in liability insurance (Vol. 4, P. 953, Lines 1 to 10). However, in recent years we have seen incidents of pipeline and other hydrocarbon fires in suburban areas where the losses per incident have exceeded $500 million (San Bruno, California and Lac Megantic, Quebec).

Where there are major damages to the public in excess of the approved insurance coverage, the taxpayers are at often risk. Hence a simple way of protecting the taxpayers is to deny any wind farm approval at the Bull Creek site.

CHOICE #2

Choice #2 is to impose a clear risk acceptance and liability insurance requirement on any wind farm at the Bull Creek site consistent with the cost of the worst pipeline accidents elsewhere. In that case, in order to mitigate the liability insurance premiums, the safety margins and the safety measures engineered into the wind farm will almost certainly be much higher than are presently contemplated by 1646658 Alberta Ltd.

In my view it is unfair for this Commission to approve anything that has the effect of imposing extra costs on the existing pipeline owners or the existing home owners. Hence if 1646658 Alberta Ltd. wants to develop a wind farm on this site a condition of the wind farm operation should be that the present and future owners of the wind farm must meet all the extra costs of protecting the pipelines and home owners from damage that might occur as a result of electrically accelerated pipeline corrosion. The Wind Farm's liability insurance policy should name the pipeline owners, nearby residents and the Killarney Lake Group as insured parties.

The amounts of the insurance coverage should be sufficient to meet potential major fire related claims such as the $580 million loss that occurred in San Bruno, California in 2010. Safely fighting sour gas pipeline fires emitting 50X lethal concentrations of hydrogen sulfide gas requires specialized equipment and training. This Panel should consider the extent of the worst case possible damage, personal injury and loss of life that could occur before an appropriately trained and equipped team arrives on the scene, extinguishes the fire and caps the open pipe ends.

In this respect the Panel should consider adverse circumstances when a combination of communication, access, weather and time of occurrence problems lead to secondary fire and/or water damage that can easily be 100 fold times the damage directly caused by a pipeline rupture. I refer to this phenomena as the Murphy factor.

The Panel should remember that when pipeline fires occur outside of business hours the root cause of these fires is usually a fundamental safety system failure, and there may be problems related to identifying which party is responsible. In addition there may be delays in communicating with the appropriate party, there may be delays in field personnel dispatch, there may be delays related to facility access, there may be delays in accessing old documentation, and there may be delays in identification of appropriate pipes, valves and control circuits, especially at sites unfamiliar to the service person in the dark and/or with deep snow cover. Then there may be further delays related to authorization and deployment of expensive damage mitigating resources such as water bombers. Meanwhile affected people panic.

Illustrative of these frustrating delays is the reality that frequently no one answers the telephone at the AUC, even during business hours. The recent culture of voice mail, telephone queuing, private cell numbers and email has unreasonably extended emergency response times. One of the most important emergency functions for all organizations is prompt answering of the listed telephone number by a live person. In this respect I speak from over 20 years of experience at the head of a business that provided 24/7 critical equipment monitoring and maintenance over a wide geographical area.

When safety equipment works there is no fire. The concept of relying on automatic valves to isolate a sour gas pipeline rupture is a bit of an oxymoron, because if the pipeline equipment is properly designed, installed and maintained there are no pipe ruptures. Accidents occur when there is a culture of placing cost savings and personal convenience ahead of prudent safety. Additional equipment complexity does little to solve that cultural problem.

Extra Costs of Choice #2:
Operation of the proposed wind farm on top of the existing maze of buried pipelines triggers a collection of esoteric engineering and ongoing monitoring and service matters related to ground currents and induced ground voltage that seldom arise and for which there is no adequate regulatory regime.

With co-operation of all parties it is technically possible to install, operate and maintain the wind farm in a manner that does not cause accelerated corrosion of the pipelines. However, such equipment design, installation, operation and maintenance requires additional engineering, equipment, installation, operation, maintenance, administration and enforcement that someone has to pay for. In my view the only practical enforcement mechanism available to this Panel is requirement of very high liability insurance coverage for any wind farm on the Bull Creek site. Then if 1646658 Alberta Ltd. proceeds to develop a wind farm on this site it will likely install, operate and maintain the required safety equipment as an insurance premium mitigation measure. Most of the remainder of this presentation focuses on this additional safety equipment.

If Choice #2 is adopted this Panel must guard against a situation where 1646658 Alberta Ltd. simply contractually agrees to compliance with the insurance requirement. If 1646658 Alberta Ltd. later encounters financial difficulties and the wind farm equipment passes to a *new owner via sale of lenders security the new owner will not have the same contractual obligations as 1646658 Alberta Ltd. and the pipeline owners, nearby residents and the Killarney Lake Group will be deprived of their insurance protection.*

REDUNDANT SAFETY DEVICES:

The concept of redundant safety devices is not new. This concept was developed about a century ago to prevent boiler accidents.

A boiler is a closed pressure vessel containing water that has a controlled heat source. If the water absorbs too much heat the boiler will explode. Every approved boiler, in addition to being design and construction certified, has a redundant pressure safety device, a redundant temperature safety device and an automatic active control device. In addition there is a requirement for physical separation of boilers from the general public and a requirement for annual checking of the functionality of the redundant safety devices.

The relevant principle that this panel must grasp is that for a boiler over pressure explosion to occur three independent functional failures must occur simultaneously. Another way of viewing the issue is that the boiler safety system will continue to provide safety protection in spite of the functional failure of both the main control device and one of the two redundant safety devices.

This principle of redundancy in life safety systems indicates that to achieve adequate pipeline safety at the proposed wind farm, there should be in addition to the main ground current sensor at the substation, two fully redundant sensors that measure, record and alarm on excessive ground current at each wind turbine and there should be two fully redundant field safety devices that measure, record and alarm on improper bias voltage on each pipeline.

Then in the event of a pipeline leak or rupture the stored data can be used to distinguish whether or not electrically accelerated corrosion significantly contributed to the pipeline failure.

TECHNOLOGY

Much of this presentation will involve technical matters related to pipeline corrosion protection including induced ground voltage, ground current, ground resistance, transformer leakage current, SCADA system design, current sensors, etc. I will try to simplify the presentation as much as possible. However, in the interest of panel comprehension I encourage panel members to interrupt me and ask questions if they do not understand something that I say. I understand that such a procedure may be against the rules of this commission, but in my view, when life safety matters are at stake, minor rules which obstruct understanding of the facts should be set aside.

I do not intend to elaborate on the issues of general good engineering and construction certification, other than to point out that very few wind farms have been built in close proximity to buried steel pipelines, and in the cases in which I have been involved, such as a major Enbridge oil pipeline in the USA, extraordinary measures were taken by the pipeline owner to protect the pipeline in the proximity of the wind turbines.

GROUND CURRENT IN WIND TURBINE TRANSFORMERS:
In an ideal three phase electricity system the individual phase to ground voltages are sinusoidal, equal and exactly 120 degrees phase shifted with respect to each other. Similarly the individual phase currents are sinusoidal, equal and exactly 120 degrees phase shifted with respect to each other. In an ideal three phase system 100% of the energy is at 60 Hz and there is no energy at harmonic frequencies such as 180 Hz. Thus in an ideal situation there is no current through the wye neutral connection of the substation transformer to ground and hence there is no ground current.

However, in a real situation such as the proposed wind farm there is ground current. This current arises from non-idealities in the wind farm itself and from non-idealities in the external electricity grid. Ex. 32, pdf 13, section 6.2.3 of the AESO document states “The WPF (Wind Power Facility) must not increase the voltage imbalance on the transmission system as measured at the Point of Connection to more than one and half percent (1.5%). However, 1.5% of the phase to neutral voltage of 19.94 kV is still 299.1 volts. This is a portion of the voltage that is potentially available to drive ground current in a wind farm with 34.5 kV power collection, even if there are no faults. An even larger contributor to voltage driving ground current is third harmonic energy produced by the substation transformers. Jim Pinter is aware of third harmonic energy in wind farms (Vol. 4, P. 897, Line 4) but he totally failed to take into consideration its effect on ground current flowing via turbine transformer delta winding ground capacitance.

In this respect there is an extraordinary problem with wind turbine transformers. There have been relatively recent changes in power system dispatch rules that affect generation constraint by wind farms. In order to meet these constraint requirements GE has introduced solid state generation constraint controls into its wind generators.

These constraint controllers produce large amounts of power harmonics. To control the harmonic output the wind generator transformer design has been modified to include an electrostatic shield between the delta winding and the other windings. However, an unintended consequence of this electrostatic shield is increased wind generator transformer ground current.

I spoke with GE personnel when I realized that BluEarth had not done the necessary engineering required to protect the public as well as the pipelines from consequences of this increased ground current. During my conversations with GE personnel, GE informed me that the ground current sourced by a 3.4 MVA wind turbine transformer is typically 0.5 amp to 1.0 amp. However, this current increases with grid imbalance and third harmonic generation by the substation transformer. This ground current becomes very much larger at even slightly above normal grid voltages or if there is an electrical defect.

I have asked GE and other wind turbine transformer manufacturers for quantification of this issue and I am hoping to receive data in time for presentation at this hearing.

During his cross examination Jim Pinter was asked about the anticipated wind turbine transformer ground current but he failed to answer, in spite of claiming prior experience in installation and check out of hundreds of similar wind turbines. (Vol. 4, P. 896, Lines 19 to 22; Vol. 4, P. 930, Line 24, Vol. 4, P. 931, Lines 18 to 21; Vol. 4, P. 932, Lines 15 to 23).

GROUND RESISTANCE:
Earth ground resistance Rg for a wind turbine is the electrical resistance between the wind turbine local earth ground connection and a theoretical earth ground formed by the magma core of the Earth.

Jim Pinter, VP Engineering and Technology for BluEarth indicated during his cross examination (Vol. 4, pdf 25, P. 942; Vol. 4, P. 935, Line 9) that under dry soil conditions the maximum ground resistance at each wind turbine would be 10 ohms. This ground resistance figure is contrary to the 25 ohm value that BluEarth presented in its application (Ex. 21, Attachment 11A, Note 5).

The resistance of the 2/0 copper wire common ground cable (0.255 ohms / km at room temperature) suggests that it provides an average cable equivalent ground resistance per wind turbine of about 9.1 ohms (.255 ohms / km X 12 wind turbines X 3 km). However, the cable impedance at 180 Hz is significantly higher than 9.1 ohms due to moisture in the ground.

INDUCED GROUND VOLTAGE:
The induced local ground voltage Va at a wind turbine is the product of the earth ground current Ig multiplied by the earth ground resistance Rg. The earth ground current Ig is approximately half of the maximum permissible transformer ground current of 2 amps. Hence under normal operating conditions the maximum induced local ground voltage at the wind turbine should be:
Va = Ig X Rg = 1.0 amp X 10 ohms = **10 volts.**

DECLINE IN INDUCED GROUND VOLTAGE WITH DISTANCE:
The earth ground connection at the wind turbine will have a characteristic radius **Ra,** which is typically the radius of the buried copper ground mesh or ring of copper ground rods. Using calculus it can be shown that for **uniform soil with no underlying bed rock** the induced ground voltage **Vb** at distance **Rb** from the wind turbine is given by :
Vb = Va (Ra / Rb)

Thus for **Ra = 5 m** and **Rb = 100 m**, the maximum induced ground voltage is:
Vb = 10 volts (5 m / 100 m) = **0.5 volts**.
Note that if achievement of a earth ground resistance of 10 ohms requires Ra greater than 5 m then Rb must be greater than 100 m to reduce Vb to 0.5 volts.

The effect of underlying bed rock is to further increase the Rb value at which Vb = 0.5 volts.

ELECTROCHEMISTRY:
It can be shown from electrochemistry that if a steel pipe is biased **-0.9 to -1.8 volts negative** with respect to the surrounding soil, as is typical with use of magnesium blocks, then an AC RMS voltage of ***Vb* = 0.5 volts** superimposed on the local earth voltage will have negligible

effect on pipe corrosion.

SUMMARY:
I believe that it is reasonable to state that:
IF there are no electrical ground faults anywhere on the wind farm; and
IF the worst case ground resistance at every turbine tower is less than 10 ohms, and
IF there are no breaks in the proposed buried 2/0 copper common ground cable, and
IF the 3rd harmonic voltage generation by the substation transformer 34.5 kV winding is less than 20% of the 60 Hz fundamental voltage; and
IF the total turbine transformer delta winding capacitance to ground is less than 0.44 micro farads, so that the worst case total turbine transformer ground current is less than 2 amperes; and
IF the largest wind turbine tower ground mesh radius is less than 5 m; and
IF the smallest setback of a wind turbine tower from a pipeline is greater than 100 m; and
IF the soil resistivity is uniform and not significantly affected by underlying bedrock, water ponding or aquifers; and
IF the pipelines are conformally FBE coated and everywhere biased at least - 0.9 volts with respect to surrounding soil; and
IF every element of the wind farm system is fully checked and if all the sensors are appropriately calibrated during system commissioning; and
IF the wind farm is operated and monitored by expert personnel who make no significant mistakes; and
IF the wind farm is maintained by expert personnel who act promptly and who make no significant mistakes
THEN
electrically accelerated corrosion will not be significant in the surrounding buried steel pipes .

Comparable but more complex calculations must also be made for the substation where the maximum ground resistance should be 2.0 ohms but the maximum total ground current is about 92 amperes. The substation is extremely dependent on the buried copper common ground cable for reducing its induced ground voltage and hence minimizing its setback distance requirement.

From the perspective of nearby residents and members of the Killarney Lake Group the aforementioned conditions relating to pipeline safety contain far too many IF statements that have not been confirmed at this time and may not be true in the future.

MURPHY'S LAW
For more than 20 years I was responsible for supervising the installation, operation and maintenance of complex commercial energy systems spread widely over the Greater Toronto Area.

In the energy business, in spite of the best efforts of management, problems happen. Major commercial size energy systems are unforgiving of negligence, lack of knowledge or human error. One small mistake or oversight can easily lead to a death and/or a lifelong physical or psychological impairment.

In complex energy systems Murphy's Law rules. Murphy's Law in essence states that if there is a way for something to be done wrong, sooner or later someone will do it that way. Murphy's Law is particularly applicable to ground current matters that are often poorly understood.

Murphy's Law also applies to interpretation of codes and regulations. I have seen multi-million dollar accidents arise from strict compliance to regulations that were drafted with the best of intentions.

There are situations where mature engineering experience **guided by engineering ethics should take precedence over compliance** with contracts, codes and regulations. These codes and regulations are drafted by persons with good intent but cannot address every possible situation. In the context of this wind farm I believe that Jim Pinter understands his ethical responsibilities (Vol. 4, P. 973 Line 20 to P. 976 Line 13).

The primary risk to all parties at Bull Creek is Jim Pinter's present lack of understanding of the technical issues that create a threat on this project. A second risk is that Jim Pinter's requests to senior management of 1646658 Alberta Ltd. for a safety system commensurate with the risk may not be met due to insufficient financial resources. A third risk is that Jim Pinter may find himself in a situation where he cannot simultaneously meet both the requirements of 1646658 Alberta Ltd. and his ethical responsibilities as a professional engineer. A fourth risk is that Jim Pinter may be replaced by another individual.

I do not believe that either the authors of the Alberta electrical code or the GE general wind turbine installation specification, which is a collection of generic documents (Vol. 4, P. 902, lines 8-9 and Vol. 4, P. 904 line 22 to P. 905 Line 2), seriously contemplated installation of a wind farm directly on top of a maze of sour gas pipelines. Hence I do not believe that this Panel or any other party should rely on electrical code compliance and on GE standard installation compliance for pipeline safety at this site.

HUMAN LIMITATIONS

One of the realities of life is that everyone has a limited skill set. Often a maintenance person is well trained as an electrician or as a pipe fitter, but only a small subset of service persons have any knowledge of esoteric aspects of both trades such as ground current and the manner in which it affects corrosion of buried steel pipes. Thus, a safety system must to the extent practical protect against human knowledge limitations as well as equipment failures.

Jim Pinter is obviously a well intentioned practical engineer who has been involved in installation of hundreds of wind turbines at several other sites (Vol. 4, P. 896 Line 18 to P. 897 Line 10). However, none of these sites involved nearby buried steel pipelines (Vol. 4, P. 918 Lines 10 to 12). Jim Pinter has clearly never experienced a situation where the magnitude of induced ground voltage surrounding wind turbine transformers is critical. In his testimony (Vol. 4, P. 937, Lines 20 to 23; P. 942, Lines 6 to 15) he expressed confidence that he could make any system safe deal simply by adding more copper to the earth ground connection to reduce the ground resistance. That claim is not true if certain other aforementioned IF statements are invalid.

SAFETY REALIZATION: - THE SCADA SYSTEM (Vol. 4, P. 928 Line 13 to P. 929, Line 3)
The way to make a complex system safe is to introduce and calibrate fully redundant safety devices. Each redundant safety device should trip an individual alarm so that the Supervisory Control And Data Acquisition (SCADA) operator is aware of a problem and its location. The SCADA operator may not understand the underlying cause of the alarm, but he/she has sufficient information to isolate the source of the excessive ground current to a specific wind turbine and to send an appropriately trained person with appropriate test equipment and appropriate support documentation to the appropriate equipment location to further diagnose the problem.

SCADA FEATURES:
In my view the SCADA system should be fitted with dual redundant ground current sensors at every wind turbine with sufficient resolution that excessive ground current can be quickly isolated to a single wind turbine and that wind turbine disconnected until the problem is rectified. If the problem lies in a defective wind turbine transformer a replacement unit may take 16 to 32 weeks to arrive (Vol. 4, P. 909 Line 10) after it is ordered, which order will not occur until the problem has been fully diagnosed by a competent service person dispatched to the wind turbine site.

REQUIRED SAFETY DEVICES:
Proper protection of the buried steel pipelines in proximity to this proposed wind farm requires the following SCADA features:
a) two redundant AC current sensors at each wind turbine tower that measure ground current above and below the common ground cable;
b) a redundant AC current sensor that measures total 34.5 kV wye neutral current at the substation;
c) redundant phase to ground voltage sensors monitoring voltage on all three phases of the 34.5 kV / 19.94 kV circuit at the substation;
d) redundant DC voltage sensors for each pipeline sensing bias voltage with respect to earth ground at each pipeline end;
e) if possible sensors that measure DC bias current for each pipeline.
The pipeline sensors will likely be located remote from the wind farm because they must be installed in existing pipeline operator owned equipment enclosures where AC power is available. Communicating with these pipeline supervisory devices may involve significant ongoing monthly costs.

REQUIRED SCADA SAFETY SOFTWARE:
-All system status data should be updated on the operator display at no longer than 10 second intervals. This same data should be available to a service person via a portable display unit plugged into any SCADA remote panel;

-Any loss of AC power or loss of communication to any SCADA remote panel should trip a diagnostic alarm;

-Each sensed current or voltage should have an individual programmable high and low limit that triggers an alarm if out of range;

-The voltage monitoring should calculate 3 phase voltage imbalance and trigger an alarm if that imbalance that exceeds 1.5%;

-The software should calculate the sum of all ground currents above the common ground cable. The software should compare this value to the substation wye neutral current and trip an alarm if the current difference is out of normal error range. Note that these two currents will change with external grid conditions but they should track each other. If either of these currents becomes out of range high a total wind farm shutdown might be required.

-The system should record to disk all alarm setpoint and status changes whenever they occur;

-Once per hour the system should record to disk all analog values, all binary status conditions and all alarm conditions;

-There should be a facility that produces an automatic backup of all of the collected data. This backup should be preserved on CDs for the life of the wind farm and pipelines for insurance litigation purposes.

-There should be a written record of the calibration and operation check history of each system input.

SCADA COST:
The cost of supply and installation of the additional SCADA equipment specified herein for this wind farm is likely to be in the range of $500,000. A further cost is employee salaries for: programming , installation, operation and maintenance of the equipment. There must be sufficient spare parts. SCADA equipment is often difficult to maintain late in its life due to limited availability of certain electronic components.

ELECTRICAL CODE LIMITATIONS:
Electrical codes are intended to meet a number of objectives:
- Electrical safety
- Fire safety
- Meet the load
- Comply with local distribution constraints
- Accomplish the desired primary objective (lighting, heating, pumping, etc)
- Accomplish desired secondary objectives (limit ground current, limit radio interference)

a) Electrical safety is sufficiently important that there are dedicated electrical safety inspectors.

b) Fire safety is addressed by a combination of engineering, electrical and building inspections.

c) Designing the electrical system to be sufficient to meet the load and comply with local distribution constraints is the province of electrical engineers. However, the financial consequences of not meeting this objective are so large that most electrical facilities are slightly over designed to ensure compliance.

d) Compliance with the primary objective such as lighting, heating, pumping, etc. is effectively regulated by primary customer complaints or lack of payment for facilities and services not provided.

e) Ground current, ground resistance and radio interference are minimized at the equipment manufacturing and installation stages but thereafter are not effectively policed. In Canada there are almost no inspectors that look for code compliance and good installation practice in these areas. Only a few engineers and master electricians are suitably trained.

Thus although the issues at this wind farm involving interaction of ground current with buried pipelines might at first glance seem to belong in the Alberta electrical code, I am far from convinced that putting them in the electrical code will guarantee an effective solution. Based on experience in Ontario the existing electrical inspectors simply are not trained in these matters. A better solution is to make the engineering community more aware of these matters so that positional conflicts between buried steel pipes and the grounds of major grid connected electrical transformers are minimized. At present the only viable resolutions of such conflicts are a change in pipeline bias voltage or an additional FBE coating on the affected pipeline so that it does not rely on electrical bias for corrosion prevention. However, these can be very expensive solutions for dealing with existing buried pipe. In the case of this wind farm the electrical transformers should be positioned to minimize ground voltage interaction with the buried pipe and the extent of the ground voltage interaction should be carefully monitored and recorded. If this interaction is too large the wind farm must be shut down.

RESPONSE TO BLUEARTH EVIDENCE:

a) The electrical engineering witness for the wind farm proponent 1646658 Alberta Ltd., Jim Pinter, has indicated to this Panel that accepted good engineering and installation would be used.

b) Mr. Pinter indicated that detailed electrical design would be done by or under the direct supervision of a registered professional engineer (Vol. 4, P. 912, Lines 5-9; Vol.4, P. 914, Lines 12-15; Vol. 4, P. 925, Lines 16-21), that he would review the detailed designs (Vol. 4, P. 914, Lines 16-17), that the turbine transformers would be purchased by an EPC contractor (Vol. 4, P. 908, Lines 2-5), that he would do site inspections (Vol. 4, P. 913, lines 9-12) consult with and direct the installation contractors (Vol. 4, P. 913 Lines 17-24), that he would be extensively involved in system testing (Vol. 4, P. 932, Lines 17-23) and that there would be a Supervisory Control And Data Acquisition (SCADA) system (Vol. 4, P. 904, Line 25 to P. 905 Line 1) which would utilize ground current measurement at the substation (Vol. 4, P. 930, Lines 20-24) for ground fault detection. All of these measures are commonly used in other wind farms that are not in proximity of a maze of buried steel pipelines carrying flammable and highly toxic gases.

c) Mr. Pinter further indicated that he has no personal expertise in matters of buried pipe corrosion and that he relies on the opinions of others in this regard (Vol. 4, P. 919 Line 22 to P. 920 Line 8; P. 920 Line 19 to P. 921 Line 5). His testimony further indicates that he claims no personal knowledge or expectation regarding the ground current through the wind turbine transformers (Vol. 4, P. 931, Lines 13 to 21). Moreover, his statements reveal total lack of knowledge about the causes of this ground current including delta winding capacitance to ground, third harmonic generation within the substation transformers and 3 phase 34.5 kV voltage imbalance. (Vol. 4, P. 910, Lines 2 to 8 and GE Document titled "Commercial Documentation Wind Turbine Generator Systems 2.75-dfig-50 Hz and 60 Hz" Section 2 Turbine Transformer).

d) The ground current issue is not addressed in the GE specification that Jim Pinter proposed to provide to the EPC contractor relating to specification and purchase of the wind turbine transformers (Vol. 4, P. 903 Lines 8 to 25, P. 904 Line 1 to 10).

e) Further, Jim Pinter's statements indicate that he sees no necessity for confirming the decline in induced ground voltage with distance before selecting the wind turbine position and hence its setback from existing buried pipes (Vol. 4, p.917 Line 8 to P. 918 Line 19) and of the checking the earth ground current after the wind farm becomes operational (Vol. 4, P. 929 Line 21 to P. 930 Line 1).

f) Jim Pinter, a professional engineer who is directing and supervising both the electrical engineers and the electrical tradesmen with respect to this project, does not have sufficient understanding of the physics of delta connected wind turbine transformers to grasp that they leak ground current, in spite of there being no physical connection (Vol. 4, P. 965 Line 20 to P.966 Line 4) between the delta windings and ground. The same comment applies to Dean Rookes of Corrosion Services (Vol. 4, P. 921 Lines 6 to 15), Mr. Pinter's corrosion consultant. The source of this ground current is a transformer parameter known as delta winding capacitance to ground. The voltage driving that capacitance arises from harmonics generated in the substation transformer and from voltage asymmetry in the three phase network.

g) The testimony indicates that Jim Pinter and Dean Rookes are unaware that in circumstances where ground current is critical the design of the substation transformers needs to be modified by use of additional core material to raise the core saturation voltage and hence reduce third harmonic generation.

h) The testimony further indicates that Jim Pinter is unaware that an unusual aspect of modern wind turbine transformers is inclusion of an electrostatic shield between the low voltage and medium voltage windings to prevent harmonics generated in the wind generator control system leaking over to the medium voltage collector system. However, an unintended consequence of this electrostatic shield is additional delta winding capacitance to ground which increases the transformer's ground current. For most wind turbines this additional ground current is academic because there are normally no nearby buried steel pipelines. For most delta/wye connected transformers used in other applications there is no electrostatic shield, so the issue of ground current much is less severe. However, delta/wye wind turbine transformers in proximity to buried steel pipelines present a bad combination.

i) Contrary to the claims of Jim Pinter and Dean Rookes there is significant ground current even with fault free wind turbine transformers.

j) Jim Pinter does not realize that if there is underlying bed rock the wind turbine set back distances from nearby buried steel pipelines need to be extended, which may require relocating some of the wind turbines. (Vol. 4, P. 916 Line 17 to P. 918, Line 4; P. 946, Lines 1 to 4).

k) I have determined the approximate magnitude of the maximum safe ground current when there are no defects in the grounding system. This maximum safe current is 2 amperes measured above the common ground conductor and one ampere measured below the common ground conductor.

l) The relationship between the wind turbine transformer ground current and the parameters that cause it is set out on a new document titled "Wind Turbine Ground Current". This document was created as a result of multiple teleconferences and emails with GE representatives and the GE Prolec factory in Monterrey, Mexico.

m) There is additional ground current due to grid differential phase angle errors that are difficult to easily represent in mathematical closed form.

o) Jim Pinter is relying on other professional engineers for detailed electrical design (Vol. 4, P. 914 Lines 4 to Line 23). However these other engineers follow instructions and design guide lines provided by Mr. Pinter (Vol.4, P. 903 Lines 14 to 22). Hence it is a case of the blind leading the blind.

p) Jim Pinter is relying on an electrical foreman and other electrical tradesman for field installation. These tradesmen are following instructions provided by Mr. Pinter. (Vol. 4, P. 913 Lines 6 to 24). Again it is a case of the blind leading the blind.

q) The electrical situation is sufficiently complicated that its risks were not understood by Dean Rookes, a purported corrosion expert. (Vol. 4, P. 921 Lines 6 to 15)

r) Both Jim Pinter and Dean Rookes failed to consult the GE factory about ground current related to wind turbine transformers. I knew about this current because I have previous relevant experience with distributed grid parallel electricity generators interacting with pipelines and piping systems and with transformers incorporating electrostatic shields. However, not many people have my skill set. I took it upon myself to communicate with the GE Prolec factory to address this issue.

s) Jim Pinter displayed his limited knowledge of SCADA systems (Vol. 4, P. 932 Line 9 to P. 933, Line 8). There are several ways that alarms can be bypassed via either operator control, data base definition or software modification.

t) With sufficient study Jim Pinter could probably learn to properly deal with the safety aspects of the ground current issues himself. However, the practical implication of that route is that Jim Pinter would have to debug all 46 wind turbines himself and would have to remain available for the life of the wind farm for ongoing fault diagnosis and repair.

u) I suggest that this Panel adopt a solution that is less dependent on the skill and ongoing availability of a single individual.

SUBSTATION GROUND CURRENT SENSING:
Jim Pinter talked about sensing ground current at the substation (Vol. 4, P. 927 Lines 2-13, P.930, Lines 22-24). From the wind farm owner's capital cost perspective that method is simple and inexpensive. The problem with that method is that it measures total ground current on a string of wind turbines. It can indicate the presence of a problem but it does not localize the problem. If there is no one at the wind farm site sufficiently skilled to localize the problem, an issue like this can continue for months, because the wind farm owner cannot afford to keep an entire string of wind turbines shut down for a prolonged period.

For example, let us suppose that there are 15 wind turbines on a string (Vol. 4, P. 924, Lines 9-10). Let us suppose that each string has a ground current sensor at the substation. If the measured ground current on the string increases by 3.0 amps there is no certainty as to whether the increase is 0.2 amp per wind turbine caused by an electricity grid voltage change or if the increase is due to a 3.0 amp ground fault at one wind turbine somewhere on the string. The operator cannot easily dispatch a service person (Vol. 4, P. 933, Lines 14-16) because the operator does not know where to send the service person. The alarm winds up being bypassed by the system operator because it persists without immediate resolution. With turnover of monitoring personnel the history of this alarm may be forgotten and seeds of a future disaster are sown.

The second problem with current monitoring only at the substation is that it does not provide clarity as to the source of a ground current. Someone who has a very clear understanding of electrical ground matters has to do sophisticated fault diagnostics on an entire string of different wind turbines to identify the source(s) of a problem. This diagnosis can be very difficult due to ongoing changes in the external grid balance that affect the measured ground currents. Meanwhile, in the absence of certainty about the source of the problem all the wind turbines keep operating. Even after a partial wind turbine transformer failure is identified getting a replacement transformer may take 16 to 32 weeks (Vol. 4, P. 909, Lines 9 to 10).

ISSUES RELATING TO SETBACK:
Minimization of local ground current under normal operating conditions is a matter of ordering the right substation transformer. However, Jim Pinter's testimony (Vol. 4, P. 903, Lines 10-13, P. 910 Lines 2 - 8)) indicates that specification of substation transformers with low third harmonic output to minimize ground current in the wind turbine transformers is not currently contemplated by 1646658 Alberta Ltd.

The setback distance of wind turbines from pipelines arbitrarily chosen by BluEarth (Vol. 4, P. 962 Lines 9 to 13) at 100 m should be a function of the subsurface bedrock geometry, which has not been studied or electrically measured (Vol. 4, P. 918, Lines 15-19). Simply reducing the worst case ground resistance at a turbine to less than 10 ohms is not sufficient to guarantee no electrically accelerated corrosion at a radius of 100 m unless other factors such as the subsurface bed rock depth and the radius of the wind turbine ground mesh are taken into consideration.

There have not been any discussions with the pipeline owners specifically addressing the issue of the pipeline bias voltage (Vol. 4, P. 919, Lines 4 to 20).

GENERAL COMMENTS ON THE APPLICATION AND THE REPLY EVIDENCE:
Almost nowhere on any of the submitted drawings and specifications is the issue of ground current and induced ground voltage adequately addressed, especially considering the proximity of a maze of buried sour gas pipelines. There is an oblique reference to overall 3 phase balance in the AESO Interconnect Functional Specification 6.2.3 but this refers to generating system imbalance and does not address 3 phase non-idealities introduced by the external electricity grid and harmonics generated by the substation transformer. These 3 phase non-idealities are additive.

Conflicting statements, conflicting drawings and lack of technical detail supplied by the 1646658 Alberta Ltd. illustrate the scope of the problem.

Thank you for your attention. I would be happy to respond to your questions.