Problems in the power system related to wind power

An inventory

Elforsk report 10:47

Daniel Wall and Christer Liljegren

May 2010

Vindforsk
Energimyndigheten
ELFORSK

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Preface

The purpose of this project is to gather problems that are, or possibly are, related to the connection of wind power to the power system. Firstly electrical problems should be considered. The purpose is not to explain the reported problems, instead interesting problems identified will be suggested to be investigated in separate projects.

The work was carried out by Christer Liljegren at CLEPS AB and Daniel Wall at Vattenfall Research & Development as a project within the Swedish wind energy research programme “Vindforsk – III”. The report is the final report for project V-339.

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Comments on the work and the final report have been given by a reference group with the following members: Kjell Gustafsson from Statkraft, Elisabet Norgren from Svenska Kraftnät, Göran Bjurell from Fortum, Jan Ahlbäck from Skellefteå Kraft AB and Urban Axelsson from Vattenfall Research and Development.

Stockholm augusti 2010

Anders Björck

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Summary

The production of electrical power has historically been using mainly synchronous machines with mainly large installed capacity. Introduction of wind power drastically changes this. The technology used is different and the wind turbines are installed in both small and large numbers and at remote locations far from strong transmission. This new way of producing electrical power then introduces new challenges for all parties involved and experiences needs to be learned. In this report an inventory of problems related to connection of wind power to the power system has been performed. The inventory was done mainly by a questionnaire sent out by e-mail to representatives of network owners, wind turbine manufacturers, consultancy companies and wind turbine operators and owners. Although most of the recipients expressed that this was an important project few had the time needed to provide information. The goal of the project was to identify some problems that were interesting to investigate further in future projects. This has been achieved with satisfaction despite of the poor response and that most of the received answers can be classified as administrative problems leading to electrical problems. Four suggestions of problems that should be investigated have been identified:

1. detecting islanding system
2. zero sequence voltage and VSC (2 studies in this area)
3. system earthing, harmonics and inter-harmonics problems and resonance problems in the system.

The reported problems that lead to this decision are described in the report. Beside suggestions on studies that should be made some general advices that relates to connection of wind power has been documented that should be of interest to involved parties. Some examples are:

1. the importance of relay protection coordination, judging from the answers poor relay protection coordination has resulted in many unnecessary stops
2. we recommend that fault recording is installed at every larger wind power project
3. network owners should follow up on their technical demands to ensure that they are reasonable

Sammanfattning

Historiskt har elgenerering skett via synkronmaskiner med i huvudsak stor installerad effekt. Introduceringen av vindkraft ändrar drastiskt detta då tekniken som används är annan och att vindkraftverken är placerade både i mindre och större antal samt ofta långt från starka transmissionsnät. Detta nya sätt att generera el på innebär nya utmaningar för alla inblandade parter och det behövs dra lärdom av erfarenheter. I denna rapport har en inventering av problem i samband med anslutning av vindkraft genomförts. Inventeringen har utförts huvudsakligen via utskick av en enkät via e-post till representanter för nätbolag, vindkrafttillverkare, konsultföretag och vindkraftägare. Trots att de flesta mottagare uttryckte att detta var ett intressant projekt hade endast ett fåtal tid att bidra med information. Målet med projektet var att identifiera några problemområden som var intressanta att utreda vidare i separata projekt. Detta har uppnåtts med belåtenhet trots den svaga responsen samt att de flesta av svaren kan klassas som administrativa problem som leder till elektriska problem. Fyra förslag på problem som bör utredas vidare har identifierats:

1. detektering av ö-drift
2. nollföljdssystem och VSC (två utredningar inom detta område)
3. systemjordning, problem kopplade till övertoner, mellantoner och resonans i systemet.

De rapporterade problem som dessa förslag baseras på beskrivs i rapporten. Förutom förslag på studier som bör genomföras har ett antal allmänna råd och tips med koppling till anslutning av vindkraft dokumenterats som bör vara av intresse för inblandade parter. Några exempel på detta:

1. vikten av reläskyddskoordinering, av svaren att döma orsakar bristande reläskyddskoordinering onödigt många stopp
2. vi rekommenderar att loggutrustning installeras vid större vindkraftprojekt
3. nätägare bör följa upp sina tekniska krav för kontroll om de är på en lämplig nivå

Terminology

In this project most of the material was given in Swedish and terminologies used has been translated in this report. To avoid misunderstandings some of the translations that have been done are listed in this section.

English expression	Swedish expression
circulating currents	vagabonderande strömmar
invoice metering	debiteringsmätning
machine directive	maskindirektivet
nominated person in control of an electrical installation	eldriftansvarig
network impedance phase angle	kortslutningsvinkel
notice of completion	färdiganmälan
preliminary application	föranmälan
regulations on electrical safety	elsäkerhetskrav
torodial current transformers	kabelströmtransformator
touch voltage	spänning på utsatt del
zero sequence voltage protection	nollpunktsspänningsskydd

Contents

1 Introduction

The production of electrical power has historically been using mainly synchronous machines with mainly large installed capacity. Introduction of wind power drastically changes this. The technology used is different and the wind turbines are installed in both small and large numbers and at remote locations far from strong transmission. This new way of producing electrical power then introduces new challenges for all parties involved and experiences needs to be learned. This report has the ambition to present some of the electrical problems experienced when connecting wind turbines to the power system. The problems have been collected from representatives from network owners, wind turbine manufacturers, consultancy companies and wind turbine operators and owners. It should be stressed that this collection of problems experienced not in any way can be used for statistical purposes.

Not only problems has been reported but also solutions and descriptions of methods on how to work in order to prevent having problems. Some solutions are given that might be useful to others that has described problems which could be resolved by the reported solution.

2 Methodology

A total of 47 persons representing network owners, wind turbine manufacturers, consultancy companies and wind turbine operators and owners were identified as potential contributors to this report. They represented Sweden, Denmark, Norway, Germany and Spain. All of them were sent a questionnaire via email describing the project, its purpose and a list of areas where problems could occur to be used as a support. The English version of this questionnaire is appended in Appendix A.

After a reminder sent via email, just under half has replied on the questionnaire. Some of the answers have been that they either have no problems to report or that they cannot spend the time needed to give this information.

On the answers containing problems follow up for clarifications has been made on either email or phone. From Spain, Norway or Denmark no answers containing problems has been received.

3 Purpose

The purpose of this project is to gather problems that are, or possibly are, related to the connection of wind power to the power system. Firstly electrical problems should be considered. The purpose is not to explain the reported problems, instead interesting problems identified will be suggested to be investigated in separate projects.

4 Reported problems

In this section the reported problems are presented. They are divided into sections that correspond to the grouping in the questionnaire. The reported problems are not individually presented and described, we have for each type of problem lead a discussion that involves our experiences and thoughts.

We have, in order to highlight problems that, according to us, need attention, chosen not to present the received answers explicitly. The purpose of the questionnaire was not to gather statistical data but to discover problems not yet known. The reasons for not presenting the answers explicitly are:

1. it would probably be regarded as statistical data while in fact answers received reflect who had the time to answer
2. most of the reported problems are not related to phenomena that need investigation but are a result of poor communication between producer and network owner. This is of course an important problem but doesn’t fit in to the scope of this project.

Description of the areas where further studies are recommended are given in section 5.

4.1 Relay protection

4.1.1 Over current, fault current and selectivity

The most common problems relates to coordination, either between network owners and wind turbine owners or relay protection coordination. The problems that are often reported aren’t related to any theoretical or significant technical issues but related to basic relay protection coordination.

The larger network companies such as E.ON Elnät Sverige AB and Vattenfall Distribution AB don’t state relay settings values for connecting plants. This is a method to force the producer to be involved in the problems and start to have a dialogue on the settings of the relay protection.

Regarding fault current contribution from the wind turbines it is difficult to receive values that are relevant. In the cases where the wind turbine supplier gives this information it relates to the point of the connection or to the generator clamps. If there is impedance between the generator or the connection point and the fault, relevant values can be difficult to receive.

Gotlands Energi AB has performed measurements showing that when using older wind turbines it is required to use directional over current relays. This applies also to other wind turbines when the network is weak in relation to installed power. This is addressed in AMP, se [1] page 12, where the estimate is that when the short circuit ratio is lower than 1:10 this should be studied in more detail. Using directional over current relays enables low settings for faults within the wind farm that don’t come into conflict with the current being fed from the turbines to the network in normal operation. We cannot with certainty state if this estimate is valid also today.

Based on the information gathered in this project we get the sense that unwanted tripping of wind power generators occurs but not to an extent that it would be considerably disturbing.

A recommendation is to include equipment in future projects that registers voltages and currents in order to increase the experience for the future and to improve the availability in existing plants. This becomes increasingly important as the plants become larger.

Many network owners demands computer models in order to perform system studies. With for example PSS/E models, not all details are included in the model and awareness of this is needed when doing the simulations. Depending on the purpose of the simulation, the model used needs to be adapted accordingly and the appropriate software needs to be used. There are also no guaranties that the models are correct and analysis must be done for all simulations and cooperation with the turbine manufacturer is recommended in difficult cases. It is also important to mention that the modelling of the connection and the collector grid needs to be according to what study is to be done, for example transient stability or high frequency studies put different requirement on the whole model, not just the wind turbine.

There are cases where additional models need to be developed when the wind turbine has low voltage ride through (LVRT) and short circuit studies needs to be done. This is due to that there are often difficulties in simulating short circuits with the model that includes the LVRT function.

On some special networks, like Åland and Gotland very detailed studies are required to get a clear understanding of the impact of connecting wind power. It must be emphasised that it is the owner of the wind turbine that is responsible that the requirements are fulfilled and not the wind turbine manufacturer.

4.1.2 Over voltage and earth fault

Many foreign suppliers have installed relay protection that on the medium voltage level measures phase to ground. Medium voltage networks are in Sweden high impedance grounded. This means that when there is an earth fault the two healthy phases suddenly have up to phase-to-phase voltage. This leads to that the relay trips on over voltage when there is an earth fault.

4.1.3 Under voltage

Several cases of unwanted trips when there has been voltage dips has been reported. Voltage dips are a natural occurrence in networks due to faults and since newer turbines are equipped with low voltage ride through (LVRT) this is normally not a problem. Older turbines can however have difficulties staying connected following a voltage dip since they are not equipped with LVRT functionality. There are indications that in some unique cases wind turbines trips as many times as 50 per year. This is of course also dependent on fault frequency in the connecting network.

New turbines have also problems staying connected even though they are equipped with LVRT. Power electronic failure or tripping of the wind turbine is assumed to often be related to failure of the LVRT functionality. Therefore it is very important that turbine tripping or component failure is monitored and followed up so that the underlying cause can be identified.

There are also experiences showing that despite that a wind turbine is equipped with LVRT the relay settings are to narrow not allowing the functionality of the LVRT to be used. The time delay of the relay protection should be coordinated to the most frequent faults and their tripping times in accordance with SvK 2005:2, see [2].

The relay protection on the medium voltage level often isn't coordinated with the internal protection of the wind turbine. It could be difficult to get the manufacturer to change the settings to have a situation that is satisfactory regarding tripping. The ambition is to have the internal protection trip first to have a faster restart of the turbine.

It is our assessment that most of the answers received can be sorted under what has been described above.

4.1.4 Islanding protection

Islanding is luckily a seldom occurrence but when it do occurs it is often unclear that the responsibility is shared between the producer and the network owner if it leads to damage to third party. Therefore it is in the interest of both the producer and the network owner to reach a satisfactory solution.

Protection used to avoid islanding is over- and under frequency, over- and under voltage where the under voltage protection needs to be set with a time that exceeds the demand on LVRT.

Beside these, zero sequence voltage protection can be used set sensitive with a large time delay. This protection is often mistaken for an earth fault protection relay but is in fact only a complement as stated in AMP, [1].

Some network owners state demands on relay protection that measures the frequency derivative. This could be ineffective in cases with wind turbines having converters. They control the output power and the difference is stored as kinetic energy in the turbine until the pitch control has operated. This means that there could be power balance in the island system, which then results in no change in frequency. This protection relay probably trips on faults that are meant to be within the LVRT functionality. It is very important that these protection functionalities are coordinated. Another risk using frequency derivative protection is that there could be difficulties measuring the frequency during a disturbance. This is due to that false zero crossings in the voltage could occur. Depending on how this is done and how short the tripping time is unwanted tripping could be a result.

One needs to consider that fulfilling the LVRT, see [2], which is an requirement by law, is up to the wind turbine owner but this sometimes comes in conflict with the demands of the network owner. The network owner demands can however be negotiated upon while the Grid code, [2], cannot.

The dangers of islanding should be investigated. Many studies addressing this have been carried out but few concrete recommendations are given. Our perception is that there is a risk that third party over current protection or fuses don't trip within correct time and that personal safety and danger of material damage mostly is on third party plants and equipment. This is due to that upon islanding the short circuit power is reduced and might not be enough to lead to trip that under normal conditions would in fact lead to trip.

The question on how to detect islanding and what consequences that can result from islanding that should be prioritised are questions that should be investigated.

How sure are we that fuses and over current protection will operate during island operation with wind power?

Some network companies have made a different assessment where disconnection of earth faults has been prioritised. This is also the case for cable networks even though there are no legal requirements in Sweden to disconnect earth faults in cable networks. Depending on the system earthing and the network capacitance it could however be desirable to trip in order to avoid damaged equipment. What is important is that the zero sequence voltage protection is as according to [1], a protection against islanding and not an earth fault protection when in islanding, the settings are for these two different approaches are very different. At the moment SvK have started looking into the possibility to use wind turbines for black start. They are to be used to secure that substations have supply for the switchgear and control equipment. It is then important to consider relay protection functionality since the conditions are drastically changed when only having wind power as a source of fault current.

4.2 Power quality

While we know that harmonics with frequencies twice the switch frequency exists meaning the 90^{th} harmonic when the switch frequency is 3 kHz the requirements in IEC 614 00 – 21 only guides to state harmonics up to number 40. This means that the harmonics in question are not presented. Many network owners has noticed this and state requirements on all harmonics.

4.2.1 Harmonics

With a growing share of full power converters the focus on harmonics increases.

One reported problem was that in a case with several turbines there were occasional trips as the production reached a certain level, often the level of harmonics was high at the same time.

We must also consider that resonance can occur in different locations, even within the wind turbine. Resonance problems are difficult to deal with and they are not constant over time. Measurements with high frequency capabilities such as transient recorders are recommended from start of operation and where possible also prior to start of operation. This enables the possibility to quickly take actions and to have the possibility to notice changes. This doesn’t only apply to harmonics but other parameters as well.

Disturbances on PLC communication have been registered without finding the direct cause of it. The harmonics omitted by from example wind turbines are reaching the frequencies used by PLC.

Gotlands Energi AB has been measuring harmonics since the middle of the 1990’s in order to notice changes. In the beginning the harmonic content increased. Then requirements on wind turbines were introduced to limit the harmonics, which has proven to be successful. This is something that can be recommended for other network operators.

4.2.2 Flicker

Flicker is not a large problem with the newer technologies that are used in the most common types of wind turbines. In IEC 614 00 – 21 the flicker factor shall be stated for different network impedance phase angles. When using voltage source converters the emission of flicker can be set depending on the short circuit angle. This is today not a problem other than possibly in some specific connection.

4.3 System related issues

4.3.1 Zero sequence system and earth fault

It has been observed that voltage source converters have the property of wanting to regulate unsymmetrical voltages to symmetrical ones. This leads to that the voltage becomes symmetric but the current is unsymmetrical. This results in unsymmetrical voltage in the voltage level above. This appears when there is an unsymmetrical network that then affects the zero sequence system. Problems with primary substation transformer tripping on zero sequence protection at high wind power generation in the underlying network have been reported. For the same network there were also occasions of problem with automatic tuning of the Peterson coil due to no zero sequence voltage. This was resolved by installing current injection in the system earthing. We believe that these two problems are due to what is described above.

We don’t know which consequences this has, when does is need paying attention to? How are the earth fault protection affected by this? Could it lead to incorrect tuning of the Peterson coil resulting in that requirements of 3 and 5 kohm aren’t fulfilled? Could it lead to currents in the generator bearings?, see [3], “Frekvensomriktare – guide för elanvändare och allmänt sakkunniga inom elområdet, Elforskrapport, Stockholm, November, 2004.” for some more information regarding problems on bearings.

The issues above are recommended to be investigated further.

4.3.2 System earthing

In larger sea based wind farms the way that the system is earthed when having extensive cable networks should be looked into. The same applies to the larger land based wind farms.

In Sweden high impedance grounding is often used. There are indications that there are fewer problems abroad, where low impedance grounding is used, on transient disturbances, resonance and harmonics. This should be studied since there have been many disturbances on existing 33 kV collector grids in Sweden. If we want to introduce low impedance grounding, maximum 500 A of earth fault current, in the collector grids in Sweden the knowledge available about low impedance grounding needs to be spread. Within this field a study is proposed including a literature study.

In the installation of a wind turbine there are two demands. One from the manufacturer considering lightning according to the machine directive and one from the network considering the zero sequence system and touch voltage. It should be incorporated in the project design of each wind turbine project how these demands can be fulfilled.

4.4 Administration

The network owner needs to make sure that the connections fulfil the requirements stated to ensure operation of the network. How this is done varies, some allow the wind turbine to be connected to the network after a safety inspection and that an organisation for operation is in place. A test period is used where the producer ensures that all requirements are met, when this is done the network owner installs the meter to register the energy produced. Using this approach the producer is urged to as quickly as possible fulfil the demands. An agreement for selling the energy produced must also be in place.

4.4.1 Technical demands

Technical specifications are in part referred to standards but in some cases the network owner can specify other terms adapted for the actual network or the application. One not so familiar with wind turbine connections can feel that there should be identical requirements regardless of connection. This cannot be a goal in Sweden when our networks are spread geographically. There are however potential to reduce the total cost for connection by stating relevant demands on specific connections. This require a high level of knowledge at above all the network owner, possible solutions is often in reach in cooperation with the wind turbine manufacturers.

There is a risk that the developer wants a cheap connection with the risk of poor availability that the final owner has no insight in.

One problem for the network owners is to specify general demands that can be applied on all types of wind turbines. This results in that there is a perception that the demands are not strict. There is however several ways that safety and quality can be fulfilled in the network. It is a matter getting the connecting producers to understand and to have a dialogue on the solutions that are best for both parties.

The network owners can also state demands that are more tough or reinforce the network more than required due to that there is no experience or that reliable information in the turbines that will be connected is not available.

One large problem in that case and in many others is that the contracts are signed between the producer or the developer and the network owner. This results in that either the final owner or the wind turbine supplier is legally involved in the connection contracts.

The so-called AMP appendix, see [1], has been used as a specification on power quality and wind turbine data. It is meant to be a document in the contract to know what disturbances to consider. There are both network owners and producers that has not realised the meaning of these guaranteed values.

The tests stated in this AMP appendix is based basically on IEC 614 00 – 21 are seldom done in a good way. It is seldom stated what network the tests has been made on. According to IEC 614 00 – 21 the measurements shall be done in a network that has a short circuit power of 50 times the rated power of the connected wind turbine. If you then have a 3 MW turbine you need 150 MVA of short circuit power at the test site. Since most of the measurements are done on low voltage this requirement is then impossible to fulfil. The standard should be changed considering this.

The circuits for invoice metering have in a number of cases been carried out incorrect. This depends on lack of experience in certifying the measurement using torodial current transformers, one phase cables are used which requires that the cable shield are fed back through the current transformer to cancel its current. This is the way it is done for earth fault protection. This should be taken into consideration when educating personnel certifying the measurement.

4.4.2 Legal design

The wind turbines are often manufactured to fulfil the machine directive and is then a machine including the high voltage connection. It is then only the connecting cable and the earthing that requires qualified personnel. If the network owner performs these things there is no qualified personnel connected to the wind turbine, which is in accordance with the regulations. This often introduces problem with the network owner’s administrative rules on preliminary application and notice of completion. This leads often to unnecessary problems and are a cause of irritation, preliminary application and notice of completion is not adapted for this kind of connection and is a bit unnecessary when the connection is preceded by an investigation, offer and an order.

4.4.3 Follow up

Nothing relevant has been reported.

4.4.4 Connection contract

Many network owners state 10, 20 or 36 kV in the documentation but the actual voltage during operation is not stated in the contract. This leads to unnecessary problems like unwanted tripping that can result in large costs. There are also mistakes between the developer and the manufacturer resulting in incorrect ratio of for example the transformer that also leads to large costs.

4.4.5 Commissioning

Nothing relevant has been reported.

4.4.6 Operation

Many large wind farms with collector grids have no strategy on how the turbines and the collector grid should be run. The owners think that it is the manufacturer of the wind turbines that is responsible for the network during the time of guarantee and that they don’t need to take any responsibility. This only applies to the wind turbines but not for the collector grid. This result in a situation where the nominated person in control of the electrical installation is difficult to reach since it in practice it is just a formality. We think that the trade probably will resolve this in the near future so that operating routines are satisfactory. For example, in Sweden, many of the wind turbines are monitored from Denmark with no possibilities to reduce power, which is a requirement according to [2].

According to [2] it is required that the active and reactive power can be controlled. For this there are practical challenges that need to be addressed although it has been realized in several places.

There is a problem with large cable collector grids producing large amount of reactive power when the wind turbines are not producing, this is not always handled and is an increasing problem that needs attention. Installing reactors is one solution but other solutions might be available, it needs however to be addressed.

4.5 Other problem areas

Switchgear placed in towers of the wind turbine shall fulfil Swedish regulations on electrical safety that is not always the case. It has been proven that it is difficult to get manufacturers to realize that there are other regulations than for example in Germany. Within this area progress is being made.

Currents in the generator bearings can have multiple causes and should be looked into in more detail. We have mentioned unbalance as one cause but there are other possible solutions and causes.

We also need to consider circulating currents that can affect corrosion in steel and armour. This is related to the earthing and how this is carried out.

5 Suggested studies

In this section we specifically state the studies we suggest to be performed based on the information collected in this project.

5.1 Detection of islanding

The situation on islanding is not fully clear how it is to be handled. It can result in both personnel injuries and material damage and deserves attention, see 4.1.4 for description of problems that can arise. We therefore suggest that this is investigated. The goal is to find secure methods to detect islanding which then can be terminated.

5.2 Zero sequence voltage and VSC

Reported problems where unwanted disconnection of lines or complete bus bars are likely caused by initial unbalance in the network together with the characteristics of the voltage source converters, VSC, used in wind turbines. See 4.3.1 for further description. Within this area two studies are recommended:

1. the impact on zero sequence voltage and automatic tuning of the Peterson coil for:
    a. distribution networks
    b. collector networks

   we don't know if there are differences that require these to be studied separately but they have different conditions that might result in differences.
2. the impact on currents in generator bearings

5.3 System earthing

Problems with harmonics and transient disturbances that really cannot be explained are indicated to be less frequent in other countries where low impedance grounding is used. Growing number of 33 kV collector grids in Sweden means that problems could arise and we therefore suggest that it is investigated what impact the system earthing has on these problems and what is the best approach to avoid them. See 4.3.2 for further description. The study should cover the following issues:

1. investigate if the type of system earthing used is one of the reason for the problems described
2. what options regarding system earthing for these collector grids are available that is a technical good solution?
3. how can these options be realised in Sweden considering the machine directive and the Swedish regulations on electrical safety?

6 References

[1] AMP, Anslutning av mindre produktionsanläggningar till elnätet, Svensk Energi.

[2] "Affärsverket svenska kraftnäts föreskrifter och allmänna råd om driftsäkerhetsteknisk utformning av produktionsanläggningar", SvKFS 2005:2, Utkom från trycket 9 december 2005.

[3] Frekvensomriktare – guide för elanvändare och allmänt sakkunniga inom elområdet, Elforskrapport, Stockholm, November, 2004.

Appendix A

Stockholm 2010-02-02

Dear Sir or Madam!

Vindforsk III has started a project to make an inventory of problems of electrical nature that are, or assumingly are, related to the connection of wind power.

Vindforsk III is a co-financed research programme that provides funding for basic and applied research about wind power. The Swedish Energy Agency is financing 50 percent of the costs within the programme and energy companies and other companies with connection to wind power finance the other half.

The major part of this inventory is planned to be carried out through this questionnaire. We are sending it to a selection of persons that we believe has experiences to share within this field and it is our hope that you have the possibility to take some time to answer this questionnaire.

The problems we are interested in do not need to have been resolved or have been established that it exists due to connection of wind power.

Please describe each problem as detailed as possible including conditions as network topology, voltage levels, the extent of wind power installed and the type of wind turbines.

We would like to contact you in case there is a need to clarify and complement on the information you provide, either through email, phone or arrange a meeting.

The answered questionnaires will be compiled with a description of problems reported and if available also their cause and solution.

On the next page we have written some possible areas where problem could occur, this can be used as a support for your thoughts.

Questions that may arise can be put through either Christer Liljegren chl@cleps.se +46 498-27 43 16 or Daniel Wall daniel.wall@vattenfall.com +46 8-739 72 54 to where you also send your answers.

Yours Sincerely,

Christer Liljegren CLEPS AB and Daniel Wall Vattenfall Research & Development

Areas that can be used as a support for considering what problems you have or has had. Problems that don't fit into any of the areas below are still of interest.

A. Relay protection

1. Over current
2. Over voltage
3. Under voltage
4. Earth fault
5. Islanding protection
6. Selectivity

B. Power quality

1. Harmonics
2. Flicker

C. System related issued

1. Fault currents
2. Zero sequence system, phenomena in the system like zero sequence voltage or similar
3. System earthing, coordination earthing wind turbine and connecting grid

D. Administration

1. Technical demands
2. Legal design
3. Follow up
4. Coordination with other kind of generation
5. Connection contract
6. Commissioning
7. Operation

E. Other problem areas

1. Problems that aren't covered by the above

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