RoCoF Modification Proposal– TSOs' Recommendations

Disclaimer: This document is intended to represent the views of EirGrid and SONI only, and their position as of 4th September 2012 on the RoCoF issue. It should not be taken as representing the views of the Joint Grid Code Working Group, the DSOs (NIE and ESB Networks), Generators, or the wider industry in Ireland and Northern Ireland.

Introduction and Context

The purpose of this document is to give some background and contextual information to assist the Regulatory Authorities as they consider the proposed Rate of Change of Frequency (RoCoF) modification and associated issues.

The Irish Government has set a target of 40% of electricity to come from renewable generation by 2020 [1]. Northern Ireland has set a similar target [2]. The vast majority of this electrical energy is expected to come from wind turbines. In order to achieve the 40% target, the instantaneous amount of wind on the system will have to far exceed 40% at times because wind is an intermittent resource. For various technical reasons, there are limits to how much wind can be accommodated on a power system. These limits will determine the level of curtailment experienced by windfarms, and have a knock-on impact on the viability and bankability of windfarm projects, and thus on the likelihood of the Government targets being achieved. The TSOs (EirGrid and SONI) launched the DS3 Programme (Delivering a Secure and Sustainable Electricity System) in 2011 in order to address these technical constraints on the maximum allowable wind penetration. The Grid Code and RoCoF Workstreams in the DS3 programme aim to specifically address the issues around the current operational limits on wind generation, and are doing so with cross-industry participation in a joint grid code working group, an industry advisory council, and through TSO-DSO meetings and bilateral discussions.

The impact of high levels of wind generation has been studied in various different ways over the past few years [3]. The "Facilitation of Renewables" (FoR) study, which was published in 2010, was a detailed technical study that considered levels of non-synchronous generation (wind and HVDC imports) up to 100% of system demand. The studies covered a variety of issues related to power system operation including fault levels, small-signal stability, frequency response, transient stability, as well as potential mitigation measures to help solve any problems encountered. It was based on an assumed 2020 network, with the technical analysis being carried out by Siemens and ECAR consultants. The final report was drafted by Ecofys, and the study was peer-reviewed [4].

The main outcome of the study was that wind levels (non-synchronous generation) up to about 75% of demand could be accommodated, but a series of mitigation measures would have to be carried out. Beyond 75% with current technology it would not be prudent to operate the power system of Ireland and Northern Ireland. One of the main mitigation measures was to address the issue of RoCoF. This issue is the current binding limitation on operating the power system past a system non-synchronous penetration (SNSP) of 50%.

The modification being sought on RoCoF is the first step in enabling the TSOs to operate the system with higher levels of wind, helping both Ireland and Northern Ireland to achieve their renewable energy targets. If approved, a series of other steps will then be required, including testing of generators and resolution of the loss-of-mains issue on the distribution networks. Improved windfarm standards will also be required in the future. But the RoCoF problem is one of the main hurdles that need to be overcome; otherwise the TSOs' policies on allowable non-synchronous penetration levels will not change.

The RoCoF Problem

The nominal system frequency is 50Hz. This is maintained by the synchronous machines on the system adjusting their power output so that supply and demand remains in balance. The rotational inertia of the machines tends to keep the frequency steady, though some fluctuation in frequency is allowed and expected. When a generator trips off the system, there is an instantaneous energy imbalance in the system. The speed of the synchronous rotating machines reduces to maintain the energy balance, resulting in a decrease in frequency. The rate of change of frequency is a measure of how rapidly the speed of the machines, and thus the system frequency, slows down. The FoR study found that for the loss of the largest generator on the system, RoCoF values in excess of 0.5Hz/s could occur.

Separately, the FoR study found that if a fault led to a voltage dip, and this voltage dip affected a cluster of windfarms, then much higher RoCoF values could be experienced. These large RoCoF values (>1 Hz/s) were due to the significant energy imbalances caused by the windfarms reducing their output for hundreds of milliseconds following such a fault clearance. This was estimated in the highest wind scenario to be up to 1400MW for a three phase fault on Tarbert-Prospect 220 kV cable. In turn, this significant energy imbalance could adversely interact with other units that were incapable of riding through RoCoF in excess of 0.5 Hz/s leading to a cascade collapse. However on this particular challenge Ecofys found that additional investigations were required.

In the Northern Ireland Grid Code there is no specific mention of RoCoF. SONI expect conventional generation to have the capability to continue operating through RoCoF values greater than 1Hz/s. Historic RoCoF events have occurred in Northern Ireland that have been greater than 1Hz/s with no sympathetic tripping from generators. Prior to new generation being connected in Northern Ireland, SONI provide a connectee with a Minimum Functional Specification (MFS) which does include a RoCoF value of 1.5Hz/s. Since the year 2000, over 1100MW of new generation has complied with an MFS [5]. However, the current RoCoF standard in Ireland as specified in the Grid Code is 0.5Hz/s: generators are obliged to stay synchronised for RoCoF values up to this level. Thus, it is conceivable that if the system was operated such that RoCoF values in excess of 0.5Hz/s could occur, then conventional generators could cascade trip off the system, or argue that they were not designed to operate in such scenarios. It would not be prudent to operate the power system in this scenario. Therefore there is a need for generators to ensure they are capable of riding through RoCoF values in excess of 0.5Hz/s , but not exceeding 1Hz/s on the all-island system (or 2Hz/s in Northern Ireland if they underwent a system separation event).

A related problem is that the Distribution System Operators (DSO) employ or mandate protection schemes for loss-of-mains protection. These schemes aim to ensure that should a part of the distribution network become islanded from the rest of the distribution system, that there is no generation left operating on that local system, keeping it live. This is prudent and in keeping with their duties to ensure a safe network. Currently ESB Networks and NIE employ or mandate schemes that utilise under- and over-frequency relays as well as rate of change of frequency relays or vector-shift detection. The majority of embedded generators in Northern Ireland use vector-shift rather than RoCoF.

Where RoCoF settings are used for loss-of-mains and they are set at levels which can be experienced following the largest single credible contingency, then there is a risk of cascade tripping on the power system, potentially leading to a blackout.

It needs to be made clear that the proposed Grid Code modifications on RoCoF are seeking a *capability* from generators and windfarms connected to either the transmission or distribution network to ride through higher rates of change of frequency that result from loss of generation events, whereas the DSOs need to specify a RoCoF threshold (which needs to be exceeded for a set period) that allows them to protect against generation islanding on the distribution system(s). Thus, on the distribution system, distribution-connected generators may be disconnected due to relay action as a result of high RoCoF values or as a result of vector shifts. It is not the intention of the TSOs to dictate how loss-of-mains protection is implemented or what settings need to be applied – that is the DSOs role. However, the operational policies of the TSOs and the loss-of-mains protection settings applied by the DSOs will need to be co-ordinated as the levels of wind increase on the power system.

Process

Following the publication of the Facilitation of Renewables Study in April, 2010, EirGrid formally wrote to all generators in Ireland (during Quarter 4, 2010) requesting confirmation of their technical capability with regard to RoCoF. The majority of the replies indicated that the generators were Grid Code compliant, but did not specify if they could withstand RoCoF values higher than 0.5Hz/s. EirGrid subsequently wrote to the generators again in early 2011 seeking further information on the RoCoF capabilities of generators. The majority of responses did not clearly address the issue. It was decided that an alternative approach, using the Grid Code Review Panel as a forum, was required, as formal modification proposals to the Grid Code would enable generators to formally respond on their capabilities.

SONI carried out a similar exercise at the beginning of 2012. All generators that are connected to the transmission system or have a Transmission Use of System Agreement (TUOSA) were contacted for information on their RoCoF capability. The main findings were that that over 85% of connected wind generation use vector shift rather than RoCoF. The responses from conventional generators were not as comprehensive but generally stated that the RoCoF capability would be in the region that is mentioned in the Minimum Functional Specification (i.e. 1.5Hz/s). However, there were concerns on the effect of increased and more frequent high RoCoF events on the lifespan of the generators.

An initial RoCoF Grid Code modification (MPID 219) was proposed at the Ireland Grid Code Review Panel Meeting #29 on October 13, 2011. In this proposal, a change from 0.5Hz/s to 4Hz/s was suggested. At this meeting, it was suggested by EirGrid that a working group be set up to allow cross-industry participation.

The Joint Working Group involves participants from the TSOs, DSOs, Wind Industry and Developers, and Conventional Generators, as well as the Regulatory Authorities, from both sides of the border. A terms-of-reference document was drafted, and a call for participation was issued on January 9th, 2012. Everyone who expressed an interest in participating was invited to attend.

The first JGCWG meeting was held on February 13th, 2012.
The second JGCWG meeting was held on March 12th, 2012.
The third JGCWG meeting was held on April 16th , 2012.

The fourth JGCWG meeting was held on May 14th, 2012.
The fifth JGCWG meeting was held on July 5th, 2012.
The sixth JGCWG meeting was held on August 13th, 2012.

Two Joint Grid Code Review Panel meetings have also been held since the working group was set up. The original timeline indicated that Grid Code modifications would be developed and brought forwards to the review panels before the end of 2012.

Evolution of the RoCoF Modification

The initial RoCoF proposal of 4Hz/s, set out in October 2011, was large enough to cover loss of largest infeed and subsequent tripping of distribution-connected generation due to loss-of-mains protection operation. It also covered a significant portion of the voltage-dip induced frequency dip events simulated in the FoR study, and could have allowed an instantaneous wind penetration up to about 70% (Figure 2). Bilateral discussions with wind turbine manufacturers also indicated that 4Hz/s was the RoCoF standard for new turbines. This modification proposal was met with significant opposition by generators, who indicated that this higher RoCoF requirement would be difficult to comply with. The DSO also expressed concern that this higher standard might be difficult to align with their loss-of-mains protection requirements. Note that in this initial proposal, no time frame was specified for the measurement of RoCoF. As time went on, it became clear from studies and simulations that the measuring window over which the RoCoF is calculated was just as important as the RoCoF value itself. It also became apparent that the fault ride-through clauses of the Grid Code should always supersede the RoCoF standard, irrespective of the RoCoF value.

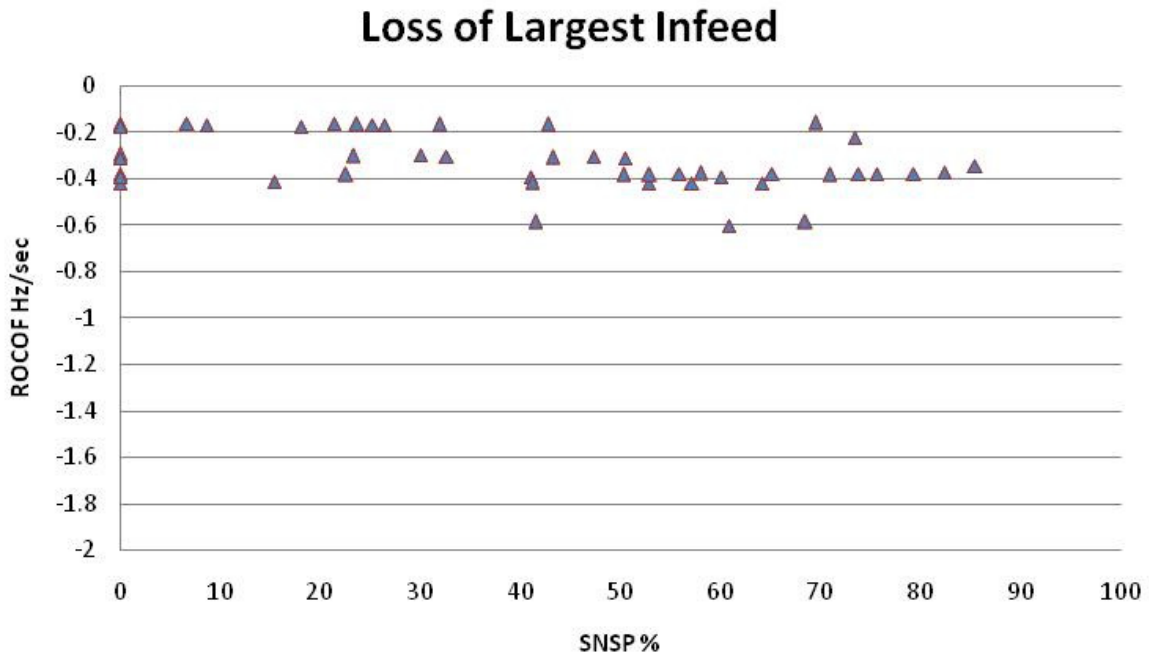

Figure 1: FoR Study Results on Loss of Largest Infeed in 2020. RoCoF magnitudes of over 0.6Hz/s are seen. The 1Hz/s modification will be sufficient to cover for the loss of a single large generator or interconnector infeed or outfeed.

The Joint Working Group held its first meeting in February 2012. At this meeting, the TSOs had indicated that a RoCoF value in the range 1-2Hz/s would be sought. As a result of the meetings, the conventional generators and windfarms were able to give some clarity as to what their RoCoF capability was, or what studies might need to be done to find out the capability. The wind industry indicated that all windfarms could operate up to 1Hz/s, and many of them could operate at 2-4Hz/s. The conventional generators indicated that significant work would need to be done by the OEMs to determine an exact value of RoCoF capability. Concern was expressed about the impact of high RoCoF values on plant lifetime due to additional stresses on the shafts, particularly at 2Hz/s and above.

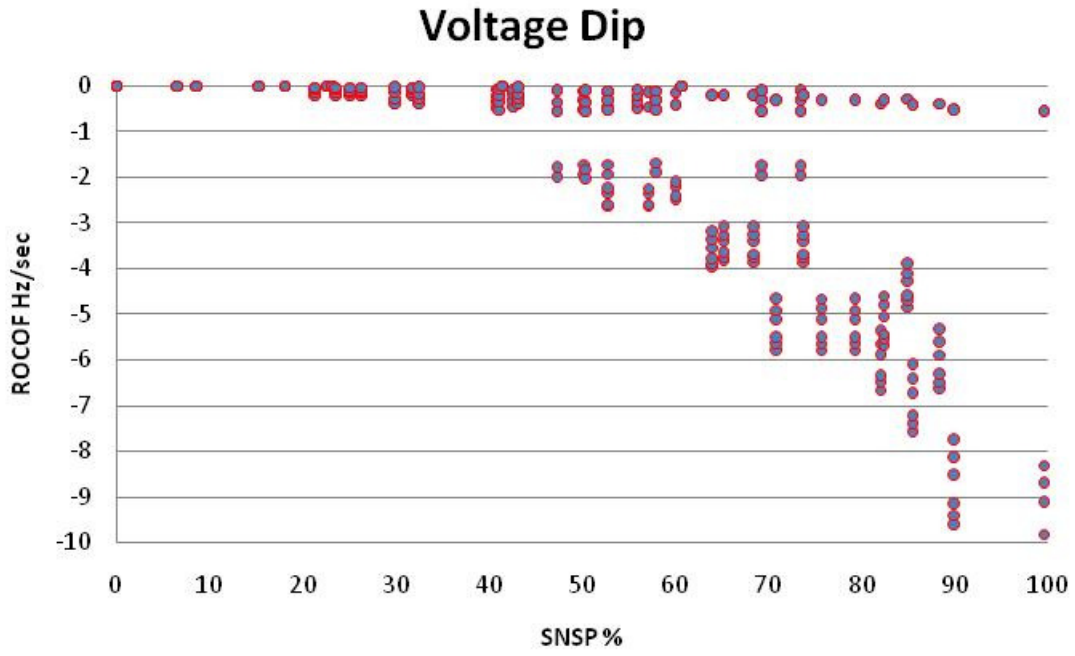

Figure 2 FoR Study Results on Voltage-Induced Frequency Dips in 2020: The initial proposal of 4Hz/s would have allowed SNSP levels up to 65-70%. The current proposal of 1Hz/s in Ireland means that this issue must be dealt with through better windfarm standards.

One area of concern to the generators was the precise value of RoCoF being sought, as the TSOs position had evolved since the initial Grid Code proposal. Given that the wind industry had given assurances that 1Hz/s would cover all windfarms, the TSOs undertook to carry out studies to give a value of RoCoF that would only cover loss of largest infeed or outfeed. EirGrid determined that a value of 1Hz/s would be sufficient to cover for the loss of the East-West interconnector exporting 500MW. This value also assumes that the voltage-dip induced RoCoF values would be addressed through better windfarm standards, and that the loss of mains issue would be dealt with separately: a RoCoF standard of 1Hz/s only addresses one aspect of the problem. However, given the continuing impact of the 50% SNSP limit on wind curtailment, it was felt that 1Hz/s was a pragmatic and readily achievable standard that would enable the TSOs to increase the SNSP limit.

System Separation

An issue that surfaced during the discussions of the RoCoF standard was system separation. The Ireland and Northern Ireland systems are only connected with two main tie-lines, and two phase-shifting transformers at 110kV. A credible contingency could trip these lines, leading to system separation. As a result of this SONI undertook to carry out analysis to understand what levels of RoCoF could potentially occur. The studies were presented at the fifth Joint Grid Code Working Group meeting. The main findings from the studies indicated that under current operating scenarios, a single fault which separates the Ireland and Northern Ireland power systems could cause a RoCoF in excess of 2Hz/s in Northern Ireland. It was decided that while system separation remains credible, Northern Ireland would seek a Grid Code modification and operate to a temporary standard of 2Hz/s. If the interconnection between the two parts of the island becomes stronger through the planned North-South

interconnector, then an all-island value of 1Hz/s would apply. (The FOR study assumed this new North-South interconnector was in place.)

RoCoF Measurement and Definition

The exact definition of RoCoF was also discussed at the working group meetings. The Irish Grid Code only mentions 0.5Hz/s, but does not mention any time frame over which this is measured. Simulations carried out by EirGrid showed that the RoCoF values are closely related to the window over which they are measured. Thus a RoCoF value calculated using a measuring window of 1ms, could be far greater than a value calculated using 100ms or 500ms as the relevant time frame, as illustrated in Figure 1. In the discussions at the working group, the TSOs' argued that high RoCoF values that occur due to faults should be covered under the fault ride through clauses of the Grid Code. There is no evidence of any conventional generator tripping off due to a voltage dip. The TSOs' position is that 500ms is an appropriate time frame to calculate RoCoF, as it usually takes this length of time for the generators to return to a coherent state. If a shorter measuring window was used, then the TSOs would be forced to seek a higher RoCoF standard.

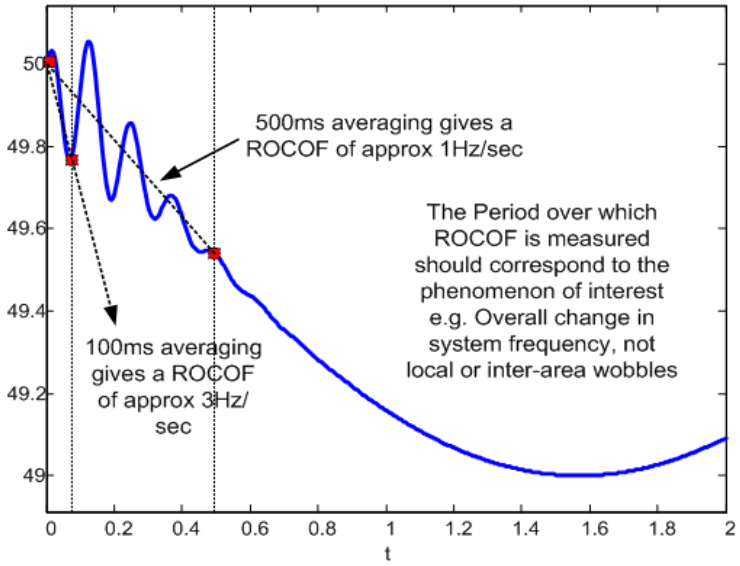

Figure 3 Illustration of frequency change and the effect of using different measuring windows

Deliverables

The main deliverables on RoCoF as a result of the DS3 programme and the Joint Grid Code Working Group include:

- Working Group Position Paper on RoCoF
- Review of Historical RoCoF incidents and International Review
- TSO Position on Testing of RoCoF
- RoCoF modification proposal for Grid Code Review Panels
- Supporting documentation for modification
- TSOs' Position on Retrospection

- Summary of Studies on Rate of Change of Frequency events on the All-Island System

Summary and TSOs' Opinion

The work done to date by the Joint Grid Code Working Group is summarized in the Working Group's Position Paper on RoCoF. That paper sets out the positions of the conventional generators, the wind industry, and the DSOs with regard to RoCoF. Here, we give the TSOs' opinion on the various matters that have been discussed, and the TSOs' recommendations to the Regulatory Authorities.

Generators

The TSOs understand the concerns of the conventional generators with operating the system with lower inertia, and the potential impact on plant-life as well as the fear of catastrophic plant failure. However, the TSOs have not seen any evidence, theoretical or otherwise, to suggest that higher RoCoF values should materially affect their plant:

- The TSOs note that some generators do not have concerns about catastrophic plant failure, but do have concerns about the impact of higher RoCoF values on plant life as a result of small amounts of damage accumulating over time.
- The TSO has not seen any evidence, either from past events in Ireland and Northern Ireland, or from other island systems internationally, that high RoCoF values cause catastrophic plant failure or lead to cascade tripping of generators, though this is based on a limited number of events.
- The TSOs accept that the current and the planned amount of non-synchronous generation in Ireland and Northern Ireland far exceeds that of other power systems around the world, and so it is unlikely that other systems have encountered the RoCoF issues that are being faced here.
- The detailed dynamic models supplied to the TSOs by the generators do not show any tripping of the machines during high RoCoF events, although these models do not model auxiliary equipment. The TSOs would be willing to use even more detailed models if the generators feel this would help in understanding the issues – but these models would need to be supplied by the generators, with appropriate explanations of the physical characteristics of the plant being modelled.
- During significant voltage dips, which are a common occurrence on every power system, instantaneous or short-duration RoCoF values well in excess of 1Hz/s can be experienced by machines. The forces experienced on the machine shaft during these events are more severe than during a loss-of-generation event, and do not cause catastrophic plant failure or cascade tripping of plant [6]. However, it should be noted that any damage done to machines by transient events is cumulative in nature.
- A review of the literature on grid-induced torsional vibrations in generators indicates that short duration/instantaneous RoCoF values up to 50Hz/s are not uncommon, and do not cause catastrophic plant failure [7]. There is evidence that sub-synchronous resonance phenomena can excite torsional modes in machines, resulting in shaft failure [8], but this is not currently an issue in Ireland or Northern Ireland to the TSOs knowledge.
- Generators are designed to withstand normal system events, such as load rejections, synchronization events, and switching events where the step change in active power

from the machine is less than 0.5pu [6]. The TSOs believe that RoCoF events fall into this category of relatively infrequent system events.

Nevertheless, given the concerns expressed by some generators about possible catastrophic failure of their plant, the TSOs will not operate at higher non-synchronous penetration levels until these fears have been allayed to the TSOs' satisfaction.

DSOs

On the issue of loss-of-mains protection and RoCoF relays, the TSOs understand and acknowledge that each DSO has a licensed obligation to ensure the safe and secure operation of the distribution systems. The TSOs will not operate the power system in a way that would adversely affect the security standards of the DSOs.

- It is the TSOs belief that the existing loss-of-mains protection could be altered, either by settings changes, or moving to alternative protection philosophies, to help resolve the loss-of-mains issue, while maintaining adequate protection against the islanding of generation on the distribution system.
- The TSOs acknowledge that in cases where load and generation are balanced in an island, it is already difficult to provide adequate loss-of-mains protection. In general protection employed on the distribution networks includes under- and over-frequency elements, and under- and over-voltage elements, as well as loss-of-mains protection. Work is required to understand and determine the appropriate settings throughout the distribution protection schemes that can adequately detect loss-of-mains in balanced islands. This may require an assessment of the probability of such balanced islands occurring.
- There exist other anti-islanding protection philosophies and network designs which could be explored, although there may be a cost associated with this.
- It is the TSOs' understanding that RoCoF protection for anti-islanding is not widely used, apart from Ireland, UK, Belgium, and Denmark. In Belgium and Denmark, the typical settings of RoCoF relays are in excess of 1Hz/s [9]. However, there may be different standards and policies on electrical islands and earthing in those countries, and in countries that don't use RoCoF protection. In Great Britain, the standard setting for RoCoF protection is 0.125Hz/s.
- RoCoF relays, if not set correctly, can be responsible for unnecessary trips, and there is evidence that they have been responsible for some spurious trippings of windfarms in Ireland in the past.
- Distribution-connected generation in Northern Ireland generally use vector shift rather than RoCoF. It is predominantly the earliest wind farms that still use RoCoF and there has also been evidence that some generators have changed from RoCoF to vector shift protection.
- Research carried out on loss-of-mains protection has indicated that vector-shift relays can be prone to nuisance tripping if not set correctly, and so it should not be inferred that vector-shift relays are any better or any worse than RoCoF relays.

The final reports from the DSOs will give more clarity on the next steps in relation to these matters.

Windfarms

The windfarm developers and representatives have indicated that all wind turbines on the island can handle RoCoF values of at least 1Hz/s, and in some cases up to 4Hz/s. Nevertheless, the TSOs would like to see some evidence of these capabilities, whether through type-tests, or frequency injections on the different turbine types.

TSOs' Opinion

The TSOs believe that the proposed RoCoF standard of 1Hz/s measured over 500ms at the generator's connection point is a pragmatic standard that can be achieved by all plant. The TSO's believe that while system separation still remains a threat, Northern Ireland will need to have a RoCoF standard of 2Hz/s until there are additional tie-lines between Ireland and Northern Ireland.

The TSOs are unaware of any theoretical reason why there should be an issue moving to 1Hz/s as a RoCoF capability of generators and windfarms.

The TSOs believe that the loss-of-mains issue may be resolved by adjusting settings and time delays on RoCoF relays, while maintaining adequate protection of the distribution system, but there remain significant challenges to be overcome.

It is the TSOs understanding that there are alternative protection/design philosophies that could be explored for loss-of-mains protection instead of RoCoF relays or vector shift.

The TSOs expect that the reviews being carried out by ESB Networks and NIE into loss-of-mains protection will provide further clarity on many of the issues raised here.

The TSOs re-emphasise that increasing the RoCoF capability to 1Hz/s only addresses one aspect of the problem. Far higher standards with respect to dynamic active and reactive response will still be required from windfarms in order to operate at the highest SNSP levels. In particular, the voltage dip induced frequency dip issue needs to be addressed.

The modification to the RoCoF Grid Code standard is a key enabler to allow more wind generation on the system. The TSOs are recommending that the proposed modification on RoCoF be approved without delay.

Next Steps

Testing and Retrospection

The TSOs will be seeking compliance of any new RoCoF standard by all connected generators and windfarms on the transmission and distribution systems. If a subset of plant is not compliant, then this could lead to a cascade failure of plant and a blackout. An alternative is that non-compliant plant may not be dispatched for security reasons, though this would

significantly complicate the operation of the power system. The TSOs will need to satisfy themselves of the ability of plant to ride-through higher RoCoF events. Generators will be required to submit a combination of documentary evidence from the OEMs and carry out frequency injection tests to simulate the impact of the event on the plant's control system and auxiliary equipment. The TSOs accept that such tests would not simulate the same forces on the shaft that would be experienced in a real event. The level of testing required will depend on the quality of the information provided by the generators.

Decision Support Tools

There are various decision support tools currently in use in the National Control Centre (NCC) and the Castlereagh House Control Centre (CHCC). These include a wind forecast tool, a contingency analysis tool, a wind dispatch tool, as well as an optimal reactive dispatch tool, and the wind security assessment tool (WSAT). All of these tools are used to inform decisions made by the control engineers. The TSOs are continually striving to make the tools better, or add new decision support processes, as system operation becomes more complex.

The Wind Security Assessment Tool (WSAT) has been in use in the National Control Centre since late 2010. It provides a near real-time assessment of voltage stability and transient stability of the Irish power system. Its main function is to help the control engineers assess the stability of the network as wind and load increase, helping the engineers to take pre-emptive action against certain events, such as voltage collapse or generator instability.

EirGrid and SONI are currently upgrading WSAT to be an all-island tool, for use both in NCC and CHCC as a decision support tool, incorporating the full dynamic model of Northern Ireland as well as Ireland. This will give a better representation of the dynamic behaviour of the system, particularly with regard to North-South flows, and the behaviour in remote areas such as Donegal, which is strongly dependent on the status of the phase-shifting transformer ties to Northern Ireland.

WSAT is currently used to assess the transient stability and voltage stability of the power system, but is not currently used for frequency stability assessment or estimation of RoCoF values. WSAT will undergo ongoing validation against real-life events as they arise, and it is expected that by end of 2014, it will have been satisfactorily validated for use in frequency stability assessment.

Should the RoCoF Grid Code modification be approved and the other RoCoF issues resolved to the TSOs' satisfaction, the SNSP policy is expected to increase. WSAT will be used in a key supporting role during that process. Any change to SNSP policy will be on a trial basis initially. When several months have elapsed without any system issues, and assuming WSAT does not flag any stability issues, the trial SNSP policy will then become permanent, upon approval by the Managers of Power System Control and the EirGrid Group Director of Operations. This process has been outlined in the DS3 Overview Document [10]

Impact of Grid Code Changes

If the proposed Grid Code modifications are approved by the Regulatory Authorities, then the next steps are as follows:

- Generators would confirm that they could comply with the new standards

- Generators that could not comply would need to seek derogations, and supply strong evidence as to the reason why they could not comply with the new standard
- As part of the implementation process there is a recognition that some changes may be required to the Distribution Codes.
- Depending on the responses from the generators and the DSOs, the TSOs would review the SNSP policy at 6-monthly intervals

As RoCoF is a systemic issue, the SNSP policy cannot be changed until all generators (or a very substantial subset of them) have indicated that they can comply with the new standard, and the loss-of-mains issue is resolved to the DSOs and TSOs satisfaction.

Expected Frequency of High RoCoF Events

Faults and generator trippings occur randomly by nature, and so cannot be predicted in advance. Nevertheless, based on historical data, the approximate number of high RoCoF events can be estimated. There were 15 frequency events in 2011 where the frequency dipped below 49.5Hz, although there has only been one such event in 2012. There is expected to be between 2000 and 2500 hours per year in 2020 where the SNSP exceeds 50%. Based on this, one would expect less than five events in any given year with a RoCoF value in excess of 0.5Hz/s, should the operational policy on SNSP change in the future.

The number of faults on the power system varies from year to year, but there are roughly 30 short-circuit type faults on the Irish transmission system each year (and a correspondingly lower figure on the Northern Ireland transmission system due to its size). The average breakdown of faults on the Irish transmission system according to voltage level is shown in the table, where the balance to 100% is made up from transformer and capacitor bank faults.

Period	Voltage level	3-phase %	2-phase %	1-phase %
24 years (to end 2010)	**400 kV**	10.05	10.12	55.27
29 years(to end 2010)	**220 kV**	11.11	7.80	65.86
29 years(to end 2010)	**110 kV**	40.96	18.09	33.41

Assuming an even geographical distribution of faults, one would expect roughly 10 short-circuit type faults along the western region of the country where most of the windfarms are located. Of these, there would be on average three 3-phase faults on the 110kV system affecting windfarms every year. It is unlikely that there would be more than one three-phase fault on the 220kV system in any one year. Given the capacity factor of wind of about 30%, one would only expect about one significant transmission system fault per year affecting windfarms. There may of course be many more localised faults on the distribution systems.

Thus, the conclusion from a rough analysis of historical fault levels and generator trippings is that on the all-island transmission system, there would be approximately five events per year that could see high RoCoF values, and approximately one event per year where a voltage dip is severe enough to affect the output from windfarms. There is no reason to expect the historical fault rate to change in the future.

Conclusions

Issues related to rate of change of frequency are currently limiting the allowable instantaneous penetration of wind on the Ireland and Northern Ireland power system, and are having a knock-on effect on the viability of wind projects and on Government renewable targets. The TSOs have tried to resolve the RoCoF issue within the powers granted to them by the Grid Codes, and have done so in an open and transparent way. The TSOs do not believe there are any theoretical reasons why plant would not be capable of operating at the higher RoCoF values being proposed. Therefore, notwithstanding the concerns that have been raised by industry, the TSOs strongly recommend that the Regulatory Authorities approve the Grid Code modifications on rate of change of frequency as a necessary first step in solving this problem.

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