Small Scale Generator Interface Protection Amendments

Distribution Code Consultation

11/12/2017

Contents

1. EXECUTIVE SUMMARY

This consultation is seeking views from industry regarding proposed amendments to Small Scale Generator (SSG[1]) interface protection settings. It follows the recent NIE Networks consultation *NIE Networks' Generator Interface Protection Amendment Project*[2], which proposed amendments to Large Scale Generators (LSG) which are now in force. This consultation recommended that no amendments should be made to SSG interface protection settings as the associated risk of fatality and out of phase reclosure for the proposed settings were considerably higher than LSG.

Considering the responses from the previous consultation, engagement with the Single Electricity Market (SEM) Committee, Utility Regulator (UR), Commission for Regulation of Utilities (CRU) and an updated position from System Operator Northern Ireland (SONI) regarding the required interface protection settings, NIE Networks commissioned Strathclyde University to perform additional analysis to quantify the impact of risk mitigation measures. Strathclyde University concluded that the risk mitigation measures studied offered a cumulative reduction in risk when compared to the scenario where no risk mitigation measures were employed.

It is NIE Networks' view that with the prudent approach taken in the derivation of the risk figures, combined with the risk mitigation measures and significant financial benefits[3] in amending generator interface protection settings, the proposed settings in Table 3 for SSG should be adopted. However, NIE Networks will continue to investigate measures to reduce the risk of electrocution and out-of-phase reclosure with the view to reduce the risk below the current risk level over time. For the avoidance of doubt, these changes will apply retrospectively to all SSG.

NIE Networks will accept general comments on the proposed amendments to SSG interface protection settings and in particular would welcome views on the specific questions outlined in section 5. This consultation will commence on 11/12/17 and will close on 22/01/18.

2. INTRODUCTION

2.1 Interface Protection

Interface protection is the protection employed by Distributed Generation (DG) at the point of connection to the electricity network to safeguard the electricity system from, amongst other things, electrical islanding. Electrical islanding occurs when part of the electricity system becomes disconnected from the main grid but remains energised due to the presence of connected DG: this phenomenon is shown in Figure 1. There are a number of substantial concerns associated with electrical islanding, which include but are not limited to:

- Increased risk of electrocution due to unearthed distribution system operation resulting from electrical islanding.

- Increased risk of out-of-phase reclosure of generation and the main grid, potentially causing catastrophic failure of generation and risk to human life.

Whenever an electrical island occurs, if there is a generation and demand imbalance on the island then the frequency and/or voltage magnitude on that island will fluctuate. The frequency, voltage and Rate of Change of Frequency (RoCoF) or Vector Shift (VS) elements of the G59 relay work collectively to mitigate electrical islands, albeit the RoCoF or VS element will, in general, activate first. Furthermore, generation sites with ground mounted substations generally require Neutral Voltage Displacement (NVD) relays with an operational time of 10 seconds for LV

[1] Generation >16A/phase & <5MW
[2] http://www.nienetworks.co.uk/documents/D-code/Generator-Interface-Protection-Amendment-Project_D.aspx
[3] Amendment of the RoCoF standard is envisaged to reduce SEM production costs by €13m/annum.

connected SSG to be fitted as a further safeguard to ensure that islanding does not form as a consequence of earth faults.

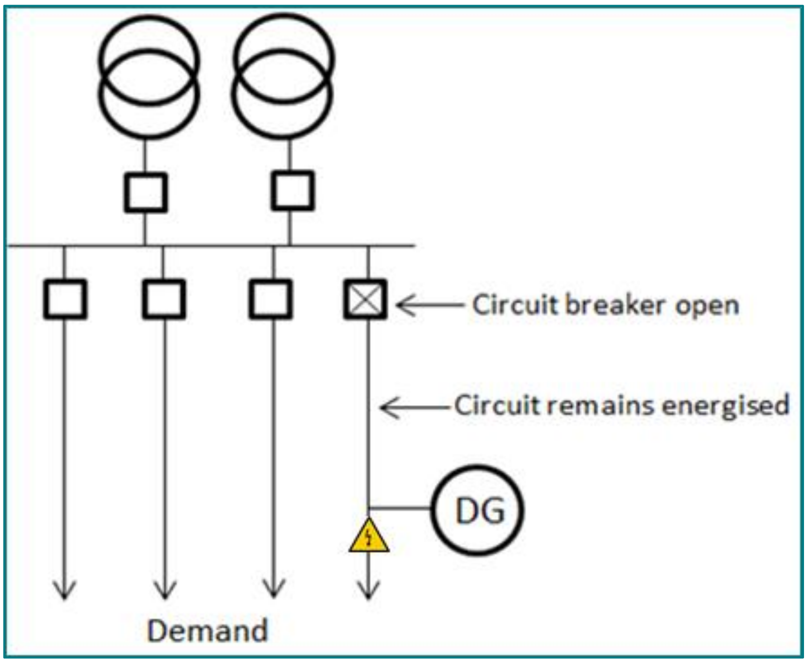

FIGURE 1

The current generator interface protection settings required by NIE Networks, commonly known as G59 protection, are shown in Table 1.

Interface Protection Element	NIE Networks' Recommended Setting	Maximum allowable setting
Over Frequency	50.5 Hz	50.5 Hz
Under Frequency	48 Hz	48 Hz
Over Voltage	1.1pu	1.1pu
Under Voltage	0.9pu	0.9pu
RoCoF	0.125 Hz/s	0.4 Hz/s
Vector Shift	6 deg	12 deg

TABLE 1

2.2 RoCoF Issue

The Facilitation of Renewables (FOR) study, 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 on the island of Ireland. The study has shown that during times of high wind generation following the loss of the single largest credible contingency, (RoCoF) values of greater than 0.5 Hz/second could be experienced on the island of Ireland power system, up to 1Hz/second, measured over a rolling 500ms.

In such a scenario the generator interface protection currently employed by Distributed Generators (DG) connected to the NIE Networks' distribution system will operate disconnecting a large quantum of generation from the system. In an already turbulent scenario this would further exacerbate system instability.

Accordingly, the main outcome of the FOR study was that System Non-Synchronous Penetration (SNSP) of up to 75% of demand could be accommodated, but a series of mitigation measures would have to be carried out. One of these measures was the need to address the issue of RoCoF.

In order to overcome this concern, and thus enable higher SNSP levels to be experienced on the system, NIE Networks was tasked by the TSO to examine the current generator interface protection requirements employed by DG to ascertain if these could be relaxed. Consequently, NIE Networks employed Strathclyde University to establish the most appropriate generator interface protection settings for DG connected to the NIE Networks' distribution system. They were also tasked with determining the impact on the various risks associated with adopting the proposed settings, most specifically the risk of electrocution and out-of-phase reclosure of generation and the electricity system.

The analysis carried out by Strathclyde University was detailed in the recent consultation, *NIE Networks' Generator Interface Protection Amendment Project*[4], where changes to LSG were proposed. In this consultation NIE Networks did not propose changes to SSG interface protection on the basis that the risk of electrocution associated with the existing SSG settings resides well within the Health and Safety Executive's (HSE's) ALARP[5] region which calls for additional mitigating measures in an attempt to reduce the perceived risks. Changes to the interface protection settings for SSG would further increase the risk of electrocution and therefore were deemed to be unjustified at that time. The risk of electrocution associated with the current SSG settings and proposed SSG settings are shown on the HSE's ALARP diagram in Figure 2.

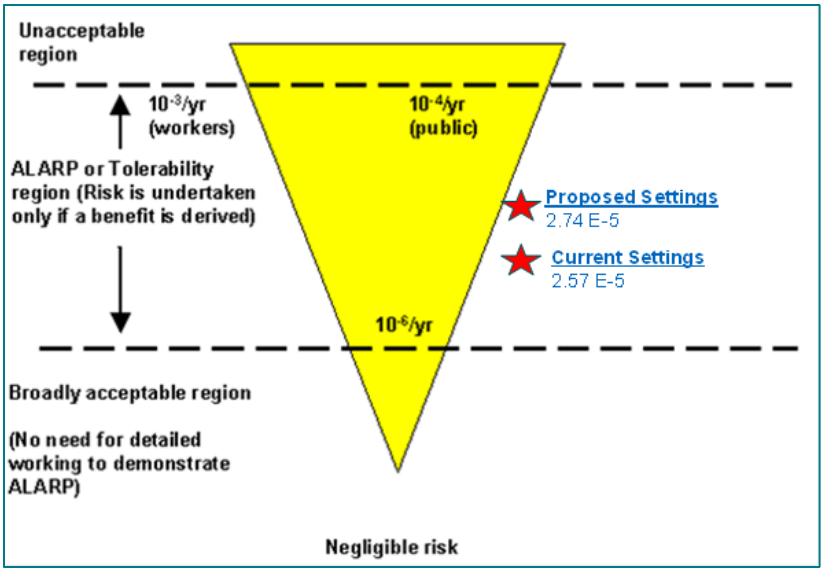

FIGURE 2

4 http://www.nienetworks.co.uk/documents/D-code/Generator-Interface-Protection-Amendment-Project_D.aspx

5 As Low As reasonably Practicable

Considering the responses from the previous NIE Networks' consultation[6], engagement with the SEM Committee, UR, CRU and an updated position from SONI regarding the required interface protection settings, NIE Networks commissioned Strathclyde University to perform additional analysis to quantify the impact of risk mitigation measures.

3. RESEARCH

3.1 Risk Mitigation

NIE Networks identified the following risk mitigation measures that could be implemented:

1. **Compliance with a 1Hz/second standard as opposed to a 2Hz/second standard.**

The initial research performed by Strathclyde University was based on a worst case RoCoF event of 2Hz/second measured over 500ms as requested by SONI. Consequently, the analysis proposed interface protection settings that would remain stable for a 2Hz/second event. In an attempt to reduce the risk of electrocution NIE Networks engaged with SONI who indicated that a setting of 1Hz/second with a 500ms delay is now acceptable for SSG in NI. This setting was subsequently approved by the UR in the recent NIE Networks consultation *NIE Networks' Generator Interface Protection Amendment Project*[7] and is currently being implemented for LSG.

2. **Reduction of NVD operating time from 10 seconds to 7 seconds for LV connected SSG.**

There is a requirement for SSG with export capability, over a particular size and connected to the system via a ground mounted transformer, to fit Neutral Voltage Displacement (NVD) protection. This protection currently has an operating time of 10 seconds. NIE Networks identified that if this operating time was reduced to 7 seconds then a reduced risk of electrocution can be achieved. 7 seconds was identified as the lowest operating time that could be accommodated without interfering with other system protection.

3.2 Results

The impact of the risk mitigation measures on risk of electrocution are shown in Figure 3. It can be seen that compliance with a 1Hz/second standard as opposed to a 2Hz/second standard offers a risk reduction moving the risk closer to the current risk level.

The risk mitigation measures also offer a small risk reduction with regards to the out-of-phase reclosure. This is demonstrated in Table 2.

It was also identified that if generators employing VS protection transferred to RoCoF protection the impact on risk would be negligible.

[6] http://www.nienetworks.co.uk/documents/D-code/Generator-Interface-Protection-Amendment-Project_D.aspx
[7] http://www.nienetworks.co.uk/documents/D-code/Generator-Interface-Protection-Amendment-Project_D.aspx

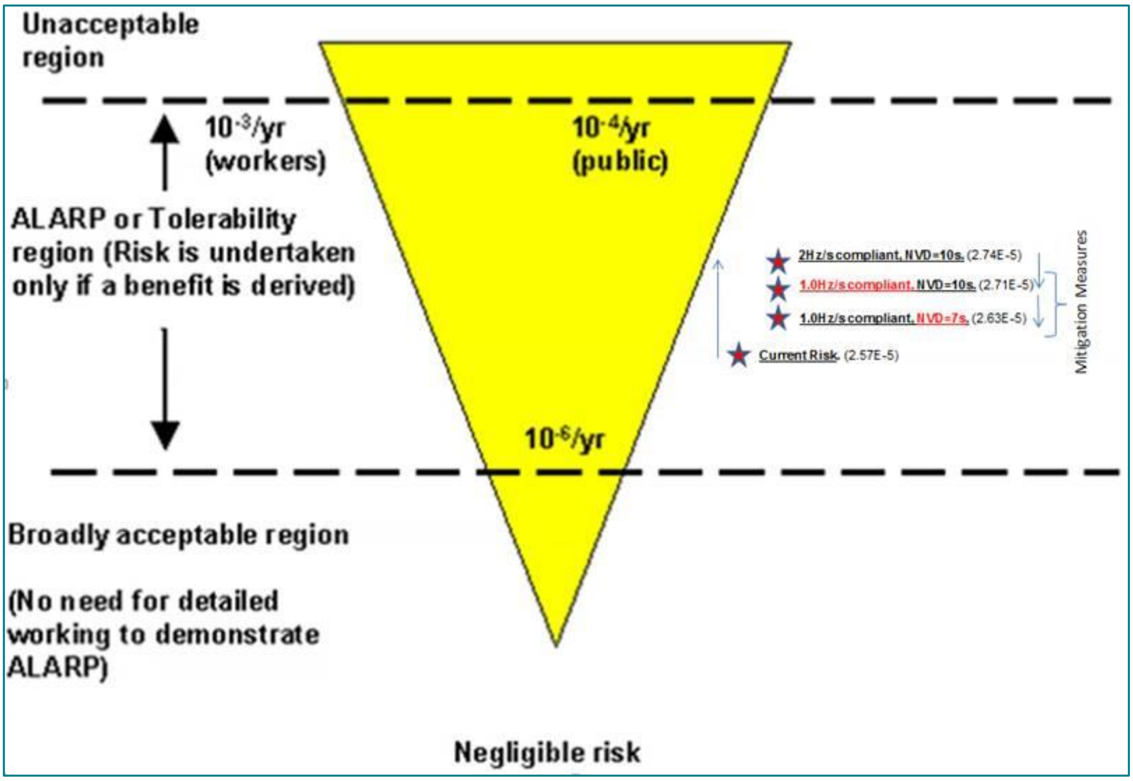

FIGURE 3

Settings	Current Settings, 10s NVD operating time	2Hz/s Compliant, 10s NVD operating time	1Hz/s Compliant, 10s NVD operating time	7s NVD operating time
Out of phase reclosures/annum	4.09E-2	4.36E-2	4.31E-2	4.30E-2

TABLE 2

4. NIE NETWORKS' POSITION

The costs and benefits associated with interface protection amendments are outlined in the recent NIE Networks' consultation: *NIE Networks' Generator Interface Protection Amendment Project*[8]. The indicative costs are included in Appendix 2 of this consultation. However, this amendment does increase the existing risk of fatality and out-of-phase reclosure of generation due to electrical islanding and should be given due consideration.

The adoption of the risk mitigation measures outlined in section 3.1 results in a risk of fatality for SSG of 2.63E-5 per annum and represents a marginal risk increase (c2%) from the current settings.

The risk mitigation measures also reduce the number of out-of-phase reclosures per annum when compared to the scenario where no risk mitigation measures are employed and represents

[8] http://www.nienetworks.co.uk/documents/D-code/Generator-Interface-Protection-Amendment-Project_D.aspx

a marginal risk increase (c5%) from the current settings. It is NIE Networks' view that with the prudent approach taken in the derivation of the risk figures, coupled with the risk mitigation measures, a risk level as low as reasonably practicable has been achieved, justifying the adoption of the proposed settings in Table 3 for SSG. However, NIE Networks will continue to investigate measures to reduce the risk of electrocution and out-of-phase reclosure with the view to reduce that risk below the current risk. For the avoidance of doubt, these changes will apply retrospectively to all SSG.

NIE Networks advise that each SSG should ensure that they are content with the risk of electrocution and out-of-phase reclosure and, if required, install additional protection to further reduce this risk. NIE Networks will provide generators with the required data, chargeable to the generator, to facilitate them in conducting their own risk assessment; guidance on performing a risk assessment is also available in the Distribution Code. These charges will be included in NIE Networks' Statement of Charges.

NIE Networks also advise that, in order to meet the TSOs objectives of keeping generation connected to the system during system faults, each SSG will be required to take action to ensure that any internal generator protection employed should not operate to disconnect the power station from the system ahead of the operation of:

- The proposed under/over voltage and under/over frequency protection requirements in Table 3 and;
- The proposed 1Hz/second (measured over a rolling 500ms) RoCoF standard.

Respecting the TSOs preference, it is NIE Networks view that VS protection shall no longer be allowed and RoCoF must be used. This change has a negligible impact on the results.

Protection Function	Existing Settings	Proposed Settings	
		Setting	Time Delay
U/V stage 1	0.9pu	0.85pu	3.0s
U/V stage 2	N/A	0.6pu	2.0s
O/V	1.1pu	1.1pu	0.5s
U/F	48Hz	48Hz	0.5s
O/F	50.5Hz	52Hz	1.0s
LoM (RoCoF)	0.125 – 0 .4Hz/s	1.0Hz/s	0.5s
LoM (Vector Shift)	6 – 12deg	N/A	

TABLE 3

4.1 Distribution Code Changes

This consultation proposes the changes required to the Distribution Code to incorporate the new generator interface protection settings. The proposed changes are included in redline format in Appendix 1 of this paper. A summary of the key changes are highlighted below:

- CC7.11 amendment to the table detailing the protection settings applicable to all Power Stations >16Amps/phase.

- CC7.11.3 amendment to require generators >16Amps/phase and <5MW connected to the system on or after 1st March 2018 to apply settings as per CC7.11

- CC7.11.5 new paragraph requiring generators >16Amps/phase and <5MW connected to the system prior to 1st March 2018 to have settings applied as per CC7.11 by 30th September 2019

5. CONSULTATION QUESTIONS

NIE Networks are seeking views from industry on the proposed amendments to SSG interface protection settings. When preparing your response to the following questions we would ask that the following points are taken into consideration:

- The proposed SSG interface protection settings will apply to all existing connected and new SSG sites. Any SSG site that has not made the appropriate settings changes by the required date would be deemed non-compliant with the Distribution Code.

- Each SSG will be responsible for applying and testing the new interface protection settings and returning the required certification to NIE Networks.

- The proposed generator interface protection settings will facilitate a system RoCoF standard of 1Hz/s measured over 500ms, which will apply at all existing connected and new SSG sites.

- Each SSG will be required to take action to ensure that any internal generator protection employed should not operate to disconnect the generator from the system ahead of the operation of the proposed under/over voltage and under/over frequency protection requirements in Table 3 and the proposed 1Hz/second (measured over a rolling 500ms) RoCoF standard.

- An earlier public consultation concluded in a UR decision that all costs associated with interface protection setting changes should be borne by the individual generator. Large Scale generators have already borne the costs associated with changes required to accommodate the new RoCoF standard.

1. Do you have any particular views or comments on the proposed SSG interface protection settings as outlined in Section 4 of this paper?

2. Do you have any comments on the proposed timescales to have these settings applied?

3. Do you have any particular views or comments on the proposed amendments to the Distribution Code as set out in Appendix 1?

4. Do you have a view on who should pay for the costs of these proposed amendments – the individual generators or the wider customer base?

5. Do you have any concerns, technical or otherwise, about the ability of your generating plant to continue to operate following the application of the SSG interface protection settings as proposed in section 4 which will facilitate a system RoCoF standard of 1Hz/s measured over 500ms?

   If yes, please give as much detail/evidence as possible so your concerns can be considered appropriately.

6. Do you have any views or suggestions on additional measures that could be put in place in order to assist generators in completing the necessary interface protection settings changes at SSG sites within the required timescales?

7. Any other comments?

6. NEXT STEPS

This consultation will commence on **11/12/17** and will close on **22/01/18**. During this period stakeholders are invited to express a view on any aspect of the proposed SSG interface protection amendments. Responses should be received **by 17:00 on 22/01/18** and should be addressed to:

Carl Hashim
Secretary, Distribution Code Review Panel
Northern Ireland Electricity
120 Malone Road
Belfast
BT9 5HT
Tel: 02890689145
E-mail: carl.hashim@nienetworks.co.uk

During the consultation period, should any stakeholder have any specific queries on any aspect of this document they should contact Carl Hashim as set out above.

Stakeholders wishing to respond anonymously should state so in their response.

Following the end of the consultation period and receipt of responses from consultees, NIE Networks will send a report to the Utility Regulator on the outcome of the consultation which will include written representations from all electricity stakeholders responses received during the consultation process.

APPENDIX 1

Connection Conditions

7.11 Suitable **Protection** arrangements and settings will depend upon the particular **Generator**'s installation and the requirements of the **Distribution System**. These individual requirements must be ascertained in discussions with the **DNO**. To achieve the objectives above, the **Protection** must include the detection of:

a. Over Voltage (O/V)
b. Under Voltage (U/V)
c. Over **Frequency** (O/F)
d. Under **Frequency** (U/F)
e. Loss of Mains (LoM)

Protection Function	All Power Stations >16Amps/phase ~~≥5MW~~	
	Setting	Time Delay
U/V stage 1	0.85pu[$]	3.0s
U/V stage 2	0.6pu[$]	2.0s
O/V	1.1pu[$]	0.5s
U/F	48Hz	0.5s
O/F	52Hz[#]	1.0s
LoM(RoCoF)¥	1.0Hz/s	0.5s[∝]

Note: ∝ The required protection requirement is expressed in Hertz per second (Hz/s). The time delay should begin when the measured rate exceeds the threshold expressed in Hz/s and be reset if it falls below that threshold. The relay must not trip unless the measured rate remains above the threshold expressed in Hz/s continuously for 500ms. Setting the number of cycles on the relay used to calculate the RoCoF is not an acceptable implementation of the time delay since the relay would trip in less than 500ms if the rate was significantly higher than the threshold.

¥ RoCoF – Rate of Change of Frequency

$ Base unit is defined as the nominal voltage at the **Connection Point.** This applies to phase-phase and phase-neutral voltages.

A default setting of 52Hz will apply unless a lower setting is requested by the **DNO**.

7.11.1 For each of the protection functions, the CB opening should occur with no inherent time delay following a protection trip operation from the relay.

7.11.2 All **Power Stations** with an output ≥5MW and connected to the **System** on or after 1st October 2017 must apply **Protection** settings as per paragraph CC7.11. For the avoidance of doubt, **Power Stations** with an output ≥5MW and connected on or after 1st October 2017 shall not employ vector shift as a LoM technique.

7.11.3 ~~All **Power Stations** ≥16Amps/phase and <5MW connected to the **System** shall maintain the protection settings as outlined in their **Connection Agreement.**~~

All **Power Stations** with an output >16Amps/phase and <5MW and connected to the **System** on or after 1st March 2018 must apply **Protection** settings as per paragraph CC7.11. For the avoidance of doubt, **Power Stations** with an output >16Amps/phase and <5MW and connected on or after 1st March 2018 shall not employ vector shift as a LoM technique.

7.11.4 **All Power Stations** ≥5MW connected to the system prior to 1st October 2017 shall ensure that the **Protection** settings as per paragraph CC7.11 are applied by 31st December 2017. For the avoidance of doubt, Power Stations with an output ≥5MW and connected to the **System** prior to 1st October 2017 shall not employ vector shift as a LoM technique.

7.11.5 **All Power Stations** >16Amps/phase and <5MW connected to the system prior to 1st March 2018 shall ensure that the **Protection** settings as per paragraph CC7.11 are applied by 30th September 2019. For the avoidance of doubt, Power Stations with an output >16Amps/phase and <5MW and connected to the **System** prior to 1st January 2018 shall not employ vector shift as a LoM technique

7.11.6 For the avoidance of doubt, the requirements of paragraph CC7.11 shall take precedence in any conflict arising between this **Distribution Code** and Engineering Recommendation G59/1/NI

7.11.7 In line with HSENI recommendations, all **Generators** should review and update relevant risk assessments to take account of the risks associated with islanding, with particular emphasis on out of phase re-closure, when adhering to the requirements of paragraph CC7.11. Further information on this is included in Appendix 4.

APPENDIX 4

GUIDANCE ON RISK ASSESSMENT WHEN USING ROCOF LOM PROTECTION

1 This procedure aims to provide guidance on assessing the risks to a **Generator's Plant** and equipment where a **Power Station** is considering the effect of applying higher interface **Protection** settings. Information provided by the **DNO** in relation to this appendix 4 may be at the expense of the **Generator.**

1.1 The guidance in this appendix 4 relates to a new activity. Early experience may suggest there are more efficient or effective ways of assessing the risk. The **DNO** and **Generators** will be free to adapt this procedure to achieve the **Generators'** ends.

1.2 When a **Generator** wishes to carry out a risk assessment the **DNO** will be able to provide an estimate of the net (i.e. taking into account as appropriate other Generation on that part of the network) potential trapped load. This can be in the form of a yearly profile, and possibly in the form of a load duration curve. It is possible that an island may form at more than one automatic switching point on the **DNO's** network and the **DNO** will be able to provide a profile or estimate of a profile for each. This will enable a quick assessment to be made as to the whether the mismatch between load and generation is so gross as to obviate further study. It is for the **Generator** to determine what a gross mismatch is depending on the **Generating Unit's** response to a change in real or reactive power. The **Generator** should be aware that the trapped load on a network can change over time, due to the connection or disconnection of load and or Generation and network topology changes; hence the trapped load assessment may need to be carried out periodically.

1.3 **DNOs** will also be able to provide indicative fault rates for their network that lead to the tripping of the automatic switching points in paragraph 1.2 above.

1.4 **DNOs** will also be able to provide the automatic switching times employed by any auto-reclose switchgear employed at switching points identified in paragraph 1.2.

1.5 **DNOs** will provide the information above and any other relevant information reasonably required within a reasonable time when requested by the **Generator**.

1.6 A key influence on the stability of any power island will be the short term, i.e. second by second, variation of the trapped load. The **DNO** will be able to provide either a generic variability of the load with typically 1s resolution data points, or at the **Generator's** expense will be able to measure actual load variability for the network in question for some representative operating conditions.

1.7 Armed with the above information the **Generator** will be able to commission appropriate modelling to simulate the stability of the **Generator's Plant** when subject to an islanding condition and hence assess the risks associated with an out-of-phase re-closure incident. Where the Generator considers these risks to be too high, sensitivity analysis should enable them to identify the effectiveness of various remedial actions.

APPENDIX 2

NIE Networks anticipate that, upon request, all required generators will have the capability, and desire, to change the settings in their existing G59 relays to those proposed within this document. This scenario is referred to as the "Expected Scenario". However, it is possible that some relays may not be able to be amended to the recommended settings and therefore require a new relay to be fitted; to reflect this scenario a "Worst Case Scenario" contingency has been included which assumes that 50% of LSG and SSG require a new interface protection relay to be fitted. It is not the intention of this piece of work to amend G83 protection settings; therefore G83 generators have not been considered in this analysis. Following engagement with industry the unit costs for amending generator interface protection settings were determined and the total implementation costs were calculated; the results of which are shown below.

	Unit Cost		Quantity	"Expected Scenario" Costs	"Worst Case Scenario" Costs	Comments
	Settings Change Only	New Relay Required				
11.04kW – 200kW (G59 connected only)	£450	£1050	322	£144900	£241500	Assumed that generator will be LV connected. Assumed that NVD is not required.
200kW – 750kW (Export Capability)	£450	£2050	389	£175050	£486250	Assumed that generator will be LV connected. Assumed that NVD is required.
200kW – 750kW (Non - Export Capability)	£450	£1050	83	£37350	£62250	Assumed that generator will be LV connected. Assumed that NVD is not required.
750kW – 5MW (Export Capability)	£950	£2550	28	£26600	£49000	Assumed that generator will be HV connected. Assumed that NVD is required. NIE Networks witness testing required.
750kW – 5MW (Non-Export Capability)	£950	£1550	43	£40850	£53750	Assumed that generator will be HV connected. Assumed that NVD is not required. NIE Networks witness testing required.
>5MW (Export Capability)	£2000	£13500	37	£74000	£286750	Assumed that generator will be 33kV connected. More expensive relay utilised. Assumed that NVD is required. NIE Networks witness testing required
Totals			902	£498,750	£1,179,500	[9]

[9] Costs accurate as per Q3 2016