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NIA ENWL013

Detection and Prevention of Formation of Islands via SCADA

Closedown report

31 July 2019

VERSION HISTORY

Version	Date	Author	Status	Comments
1	30 July 2019	Geraldine Paterson	Final	

REVIEW

Name	Role	Date
Lucy Eyquem	Innovation PMO Manager	03.07.19
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APPROVAL

Name	Role	Signature & date
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CONTENTS

GLOSSARY

Abbreviation	Term
ADMS	Advanced Distribution Management System
AVR	Automatic Voltage Regulation
DCode	Distribution Code
DG	Distributed Generation
DNO	Distribution Network Operator
DSR	Demand Side Response
EU	European Union
GB	Great Britain
IPSA	Software for power system design and operation applications
NIA	Network Innovation Allowance
NMS	Network Management System
PowerFactory	Power system software application for analysing generation, transmission, distribution and industrial systems
PV	Photo Voltaic
RoCoF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition

1 EXECUTIVE SUMMARY

1.1 Aims

This project was a proof of concept study into the use of an Advanced Distribution Management System (ADMS) to detect the presence of islands on the distribution network.

1.3 Methodology

Our project partner, WSP, carried out some modelling to understand the likelihood of a stable island forming. A desktop review was conducted into the capability of our Network Management System (NMS) to detect and automatically respond to island formation.

1.4 Outcomes

The modelling work showed that there is an increased risk of islands forming on the distribution network particularly in light of the new protection settings for generators.

1.5 Key Learning

In order to use the NMS to detect and automatically respond to island formation modifications will be required to the NMS functionality which could prove difficult due to the dynamic nature of islands.

1.6 Conclusions

The likelihood of islands forming is increasing. The current NMS functionality will highlight when a part of the network is “energised by generation” but this requires a manual response from the control engineer. Parts of the response could be made automatic by changing the NMS software. Full automation may not be possible due to complex networks and the dynamic nature of some of the islands.

2 PROJECT FUNDAMENTALS

Title	Detection and prevention of formation of islands via SCADA
Project reference	NIA_ENWL013
Funding licensee(s)	Electricity North West Limited
Project start date	Jan 2016
Project duration	2 years 6 months
Nominated project contact(s)	Geraldine Paterson

3 PROJECT BACKGROUND

The amount of generation connected to distribution networks at all voltage levels has steadily increased in recent years which has led to parts of the network where generation matches or exceeds demand at certain points on the load curve.

The requirements for grid connection of generators detailed in the European Network Code are currently undergoing modification which will allow the dynamic behaviour of generators and their protection and control facilities to change under certain fault conditions in order to preserve or to re-establish system security.

In addition to the EU Network Code changes there are proposed changes to the GB Distribution Code to alter the Rate of Change of Frequency (RoCoF) settings for generators from 0.125Hz/s to 1Hz/s. These wider settings help to stabilise the system from a national perspective.

The emergence of commercial measures such as Demand Side Response (DSR) contracts used to balance system frequency, trading positions and network constraints have also increased in recent years. These contracts can result in some quite significant changes to the demand profile of the distribution network.

The combination of altering settings or control on generators to allow them to remain connected for smaller system disturbances and the increase in demand and associated DSR will potentially lead to an increase in the risk of a generator supporting an islanded network on the local distribution system.

The problem is how to reliably and economically detect when an island has formed and to determine what steps are then appropriate to take once an island has been detected.

The project will investigate the use of SCADA and ADMS functionality to detect and then fragment islands formed on the distribution network. If the investigation proves successful a formal DCode modification could be prepared.

4 PROJECT SCOPE

The project is a proof of concept examination into the use of SCADA and ADMS as a solution to overcome the issue of island formation as a result of wider RoCoF settings.

5 OBJECTIVES

To produce a proof of concept paper and associated functional specification on the use of SCADA and ADMS to detect and fragment islands formed on the distribution network.

6 SUCCESS CRITERIA

This project will be considered a success upon production and publication of a proof of concept paper and associated functional specification on the use of SCADA and ADMS to detect and fragment islands formed on the distribution network. It is proposed that the outcomes of the project will be shared with industry experts and comments invited.

7 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

A key requirement for the formation of an islanded network is to have the generation and demand closely balanced. Modelling was carried out by our project partner WSP to investigate the likelihood of an island forming particularly in light of new protection settings adopted by the industry.

WSP was provided with the IPSA model of the Electricity North West network downstream of Heysham grid supply point. This model was transferred to PowerFactory using bespoke software developed by WSP and further improved to enable the modelling required for this project. Generation was added to the model to represent the accepted generation which will be connected to the Heysham and Lancaster grids in the near future. Each existing generator required appropriate controller models and parameters to be set including AVR and governor for synchronous machines.

The modelling was conducted using both the existing (G59) and new (G99) generator protection settings. The results show that using G99 settings the likelihood of a stable island forming on the distribution network has increased.

Now that it is understood that islanded networks are a real possibility the project investigated whether an Advanced Distribution Management System (ADMS) has the functionality to reliably detect the island and then what actions can be taken.

Islanded operation is usually avoided due to safety concerns and issues surrounding protection coordination, and our licence obligations to operate the network within the statutory limits such as voltage, frequency and power quality. However, there are potential benefits to allowing the operation of islands. It can increase the reliability of the network and reduce supply interruptions. Critical loads can benefit from uninterrupted supply in the event of outages in the upstream utility supply. It can also assist with black start after the network has undergone a local, regional or national black out.

This research work produced a functional specification on the use of a Network Management System (NMS) to reliably detect and fragment an island.

Full details of this development work can be found in the closedown report on the Electricity North West website.

8 THE OUTCOME OF THE PROJECT

8.1 Summary of outcome

Electricity North West's network out of Heysham GSP was selected for this study. The network model was extracted from an IPSA file and converted to PowerFactory to allow for accurate modelling of protection systems, scenario management and to accelerate studies. The converted model was validated using load flow and short circuit analyses.

The modelling results showed that there is a significantly wider load range over which an island can be sustained when using G99 settings compared to G59 settings, thereby significantly increasing the risk.

Once an island is formed, a sustained island can be detected by the presence of voltage and frequency in the isolated network. The voltage and frequency must be stable and operating within the statutory limits.

An ADMS or network management system (NMS) has the functionality to detect the status of network switches and includes a tracing facility that can identify if part of a network is energised from a grid supply point. By correlating the information of switch statuses at strategic locations and the measurement of local network parameters such as voltage and frequency the detection of an island can be achieved.

If it is acceptable to be operated as an island, the network switches that are associated with the potential island network should be monitored as well as the voltage and frequency of the island network. As frequency is currently not monitored in the distribution network, deploying frequency monitoring devices at strategic locations of a distribution network that have a high probability of forming an island should be explored.

When re-connecting to the grid after the fault is cleared, unsynchronised reclosing can result in damage to network assets and customer equipment, therefore, DGs must be controlled so that voltage magnitude, phase and frequency between the island and main grid are within the limits for synchronisation.

Alternatively, if the island needs to be shut down it can be done manually and reenergised from the DNO network in stages. This is of course an economic decision which must consider CI and CML costs.

Full details of this development work can be found in the closedown report on the Electricity North West website.

8.2 Modelling an Island

The region of Electricity North West's network selected for this study was Heysham GSP, the model for which was extracted from an IPSA file and converted to PowerFactory; to allow for accurate modelling of protection systems, for ease of scenario management and to accelerate studies. The converted model was validated using load flow and short circuit analyses.

Following the conversion, additional modelling of generation and protection was required to allow for dynamic simulation. The aim of this study was to produce results which are representative of the wider GB system; therefore, the parameters and models selected were typical and not site specific.

A summary of generation and peak demand in the IPSA model is shown in Figure 1. Most of the generation within the Heysham group are individually in excess of 50MW and so subject to inter-trip in the event of loss of mains. The remaining generation is around 107% of the underlying peak demand plus losses.

Figure 1: Base case demand and generation [MW]

	All Plant	Small & Medium (<50 MW)
Synchronous	140.4	89.4
Wind	526.0	34.0
PV	9.5	9.5
Total Generation	675.9	131.4
Demand	111.5	
Losses	11.6	

Three generation scenarios were developed to demonstrate the ability to sustain an island; these are described below:

- High Export – a case which maximises the export at the 400kV transmission system interface by setting all generation to export at rated capacity.
- Low Renewables – a case with low wind and PV.
- Low Import – a case with zero real power import. All large machines (>50MW) are out of service. All wind generation is out of service but all PV was retained.

In all scenarios, the disconnection of the 132kV network from the transmission system is initiated at t=100ms. An inter-trip scheme disconnects all plant of 50 MW or more after 80ms (i.e. t=180ms) by default.

The analysis was carried out over a range of loading and a summary of the results are shown in Figure 2. The full results are in Appendix 1.

Figure 2: Load range at which an island can form

Standard	Scenario	Load Range for Island Formation (%)
G59	High Export	55 – 75
	Low Renewables	55 – 70
G99	High Export	65 – 115
	Low Renewables	45 - 90

The results show that there is a significantly wider load range over which an island can be sustained when using G99 settings thereby significantly increasing the risk.

8.3 Detecting an islanded network

Once an island is formed, a sustained island can be detected by the presence of voltage and frequency in the isolated network. The voltage and frequency must be stable and operating within the statutory limits.

An ADMS or NMS has the functionality to detect the status of network switches and includes a tracing facility that can identify if part of a network is energised from a grid supply point. By correlating the information of switch statuses at strategic locations and the measurement of local network parameters such as voltage and frequency the detection of an island can be achieved.

The functionality required to use the NMS to detect and close down an island is in Appendix 2, with the associated proof of concept paper in Appendix 3.

8.4 Sustaining an islanded network

Once detected the DNO then needs to decide whether it is acceptable to sustain the island. If it is deemed unacceptable for the network to be operated as an island then an inter-tripping scheme could be employed to ensure the island is shut down. If it is acceptable the network switches that are associated with the potential island network should be monitored as well as the voltage and frequency of the island network. As frequency is currently not monitored in the distribution network, deploying frequency monitoring devices at strategic locations of a distribution network that have a high probability of forming an island should be explored.

Appropriate measures should then be employed to ensure a safe, stable and reliable operation of the islanded network. The control of the islanded network may either be local or central. There are many different schemes proposed for both local and centralised control of islanded networks. One example of local control is for all the DGs within the island to employ active and reactive power drop control schemes but this would entail contractual agreements between the DNO and DG owners to allow control of the system to be handed over to a third party.

An example of centralised control is a scheme in which one DG is designated as the slack source (master) capable of regulating the island frequency and voltage and the remaining DGs (slaves) outputting active and reactive power based on set points sent from an auxiliary control system which could be integrated with the NMS. For a centralised control scheme, the DNO is best placed to have the responsibility of forecasting the island demand and dispatching DGs.

When re-connecting to the grid after the fault is cleared, unsynchronised reclosing can result in damage to network assets and customer equipment, therefore, DGs must be controlled so that voltage magnitude, phase and frequency between the island and main grid are within the limits for synchronisation.

8.5 Closing down an islanded network

When attempting to connect two systems it is crucial to match voltage magnitude and angle; and frequency on both sides of the open circuit breaker(s) before closing. Poor synchronizing can damage generators and prime movers due to mechanical stress caused by rapid acceleration or deceleration and can cause frequency and/or power oscillations leading to instability or which could damage other equipment. These disturbances may also cause protective equipment to operate.

When the synchronising variables quantities are matched, there will be no disturbance to either network. Practically however, it is unlikely that these quantities will match exactly, but the differences can be minimised through control systems.

In an island situation embedded generation could feasibly control frequency and voltage magnitude, potentially with support from static compensation as required. Frequency could be adjusted to minimise the voltage phase angle difference over waveforms over a closing breaker and the breaker closed.

A synchroscope is a manual device which can be used to monitor quantities over an open breaker separating two systems. A needle rotates according to frequency difference (slip). A stationary needle will indicate an identical frequency with phase angle difference between two systems. Voltage magnitude over the open breaker can be monitored through voltage transformers. Such a device could exist at power plant, where generation is localised; and where governor and exciter control can be manually controlled.

Synch-check relays are automatic systems which determine if differences in synchronising variables are within defined limits and can close a breaker. If this is the case, in a future system, islands could be formed at any voltage level but they should be designed as such. The location of synchronising equipment and any associated remote communications need to be installed in advance of any island formation. Without such equipment, resynchronising islands is ill-advised.

The other option is to manually shut down the island and re-energise from the DNO network in stages. This is, of course, an economic decision which must consider CI and CML costs.

9 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

There were no modifications to the planned approach for this project.

10 PROJECT COSTS

Item	Category	Estimated Costs £k	Final Costs £k rounded	Variance
1	Project Management	50	45	-10%
2	Consultancy	150	74	-51%
	Total	**200**	**119**	**-40%**

11 LESSONS LEARNT FOR FUTURE PROJECTS

The project has demonstrated that the likelihood of islands forming is increasing and will warrant additional measures to detect and respond to the conditions. The NMS can be used to detect an island but it currently requires a manual response by a control engineer.

The functional specification produced can be developed further and used to inform changes to the NMS to allow more automatic responses.

12 PLANNED IMPLEMENTATION

The outcomes of the project cannot be directly implemented without further development. Electricity North West is currently considering whether to undertake this additional development.

13 DATA ACCESS

Electricity North West's innovation data sharing policy can be found on our website.

There is no data for this project as it was a research project using models of our network.

14 FOREGROUND IPR

There is no IPR for this project as it was a research project using models of our network.

15 FACILITATE REPLICATION

This project was a research project which produced a proof of concept and associated functional specification. There is no replication but network operators may wish to use the functional specification and apply it to their network management systems.

16 APPENDICES

Appendix 1 – “Detection, Sustainment and Close-Down of Islands”; report by WSP.

Appendix 2 – “Functional Specification on the use of SCADA and ADMS to detect and fragment islands formed on the distribution network”; specification by Electricity North West.

Appendix 3 – “Detection of Islands – A proof of concept paper”; paper by Electricity North West.