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NIA Project Registration and PEA Document

Date of Submission

May 2016

Project Reference Number

NIA_NGET0183

Project Registration

Project Title

Solar PV Forecasting Phase 2

Project Reference Number

NIA_NGET0183

Project Licensee(s)

National Grid Electricity System Operator

Project Start

July 2016

Project Duration

2 years and 1 month

Nominated Project Contact(s)

Andrew Richards

Project Budget

£300,000.00

Summary

The scope of this project is both to understand the variability of solar generation and to improve solar PV generation forecasting in the medium and short term.

Analysis of solar generation will be focused on both regional and GB-aggregated solar PV generation and load factors. Historical assessment will consider 34 years with a resolution of 1 hour and above

At short timescales radar and satellite data and solar generation data driven statistical methods will be utilised to improve solar forecasts derived from NWP models, this work is distinct from, though intended to complement, prior activity that NGET have commissioned to access real time PV generation.

The variability of GB-aggregated solar generation will be assessed based on a newly derived long term dataset (described in work package 1); this will have an hourly resolution and run for at least 34 years. This data will be analysed to quantify the magnitude and frequency of a range of solar generation events.

The analysis will focus on two types of low probability events of particular interest:

- Persistent generation, where the combined solar and wind generation remains above/below a certain threshold for a prolonged period.
- Transition and ramping events, where the solar generation is rapidly changing.

Nominated Contact Email Address(es)

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Problem Being Solved

A recent, dramatic increase in installed photovoltaic generation is now impacting the electricity demand profile. This influence has

been challenging to predict and is currently leading to significant demand forecast errors. The total solar capacity in Great Britain is now in excess of 9.3 GW, and is forecast to rise to 15.7 GW by 2020. Owing to the size of the individual installations (the largest solar farm in the UK is just 48 MW) all of this capacity is embedded within the distribution networks. Currently National Grid has a simplified transfer model to convert solar irradiance into generated power. This model has not been tested against actual solar generation data because of the lack of available data.

National Grid has identified a number of opportunities to improve methods of forecasting solar PV generation in order to reduce electricity demand forecast errors. This project complements the work being done under the following NIA projects that have recently been started over the past six months:

NIA_NGET0139 – Solar PV Monitoring Phase 1.
NIA_NGET0170 - Solar PV Monitoring Phase 2.
NIA_NGET0177 – Solar PV Forecasting Phase 1.

There is also a need to consider effects of the variability of solar generation, and how it interacts with other variable generation, particularly wind, at higher penetration levels. This impacts both on design of network in planning time scales and on economic tools to manage the variability.

Method(s)

The scope and methods for the complimentary solar monitoring and forecasting projects identified above are summarised as follows: NIA_NGET0139 – Solar PV Monitoring Phase 1 and NIA_NGET0170 - Solar PV Monitoring Phase 2 are focused on developing the capability for the Electricity National Control Centre to be able to interpolate and accurately model solar output using a sample of real data from the many hundreds of thousands of solar PV installations already operating and those that may be connected to the network in the future.

NIA_NGET0177 – Solar PV Forecasting Phase 1 is being undertaken with the Met Office to test and stretch the current state of the art capabilities cloud cover forecasting (the largest single factor affecting of solar pv forecast error) at a scale that is meaningful for forecasting regional output from solar PV installations.

This project builds on the work done previously by National Grid in the context of wind forecasting by re-analysing historic weather data to model how a power system with today's capacity of solar PV would have behaved at different times of the past 3 decades to provide a context to the potential frequency of extreme events.

The project partner has developed a range of tools and approaches in previous wind power investigations. Archived data from Numerical Weather Prediction (NWP) models provides a history of atmospheric behaviour and weather forecast predictions. Satellite based Re-analysis datasets draw on NWP models to provide a 34 year, large scale representation of the atmosphere, from which atmospheric properties over Great Britain can be derived.

This project will leverage the expertise and approaches from the earlier work on wind generation. The Re-analysis datasets will be used to construct a 34 year, coherent representation of solar irradiance, wind speed and temperature over a GB grid. This data can be used to derive distributions of solar variability, solar ramping events and combined solar/wind events. These distributions will be found at different time scales, from hourly to daily, seasonally or yearly, and different geographical scales, from regional to aggregate GB. The precise finest time or spatial scale will be determined during the data-exploratory phase of the project, but is expected to be: temporally – hourly; and spatially – Grid Supply Point (GSP) group level.

This project will construct a validated solar irradiance to electrical power model suitable for being used at national or regional level. This will improve the current crude model used by National Grid, but will also avoid the unnecessarily detailed modelling that is done at solar farm level. This will both improve operational solar generation forecasts, and hence electricity demand forecasts; but also allow the construction of joint time series of demand, solar generation and wind generation which are vital for planning network requirements and balancing services requirements.

UoR has expertise in using satellite and radar data for improving short term forecasts of precipitation in between the 6 hourly Met Office weather model runs. This project will leverage this expertise to use satellite and radar information to improve solar forecasts from 1 hour to 6 hour time horizon, improving operational visibility of potential changes in the highly volatile solar generation.

The activity will be structured in three work packages, aligned to the objectives described below.

WP1. Determine characteristics of variability of solar irradiance and its correlations with other meteorological variables
In order to understand the characteristics of solar PV generation, particularly high impact low probability events, we need to understand variability of atmospheric solar irradiance, and how it interacts with other meteorological variables, particularly wind speed and

temperature. Observations for solar irradiation are not available at many of the Met Office weather stations that now exist, or have only recently been recorded. In addition, there are a limited number of Met Office weather stations located close to the solar PV installations.

This work package will use state of the art meteorological models and datasets to construct a joint time series of solar irradiance, wind speed and temperature. It will use this time series to derive statistical characteristics, particularly variability, ramping and persistence of the renewable resource at different timescales

- Use state-of-the-art meteorological datasets to generate a long term joint time-series (34 years) of solar irradiance, wind speed, temperature at finest achievable resolution, but no less than 3-hourly and regionally.
- Validate the time series against observed data where available to assess to what extent the time series is capturing the full range of extremes.
- Quantify the magnitude and frequency of a range solar irradiance events, particularly variability, ramping and persistence, and their joint occurrence with other rare meteorological events

DELIVERABLE: NGET will be provided with a 34-year joint time-series of synthetic regional and GB solar irradiation, wind speed and temperature and an accompanying report. This will provide details of the variability in solar irradiance over a range of time and spatial scales; including decadal, annual, seasonal and daily, as well as the correlation of wind and solar variables.

WP2. Develop an appropriate transfer model from solar irradiance to solar power generation, and apply it to the time series from WP1 to determine characteristics of solar PV generation

This work package will develop the transfer model that will be at the heart of National Grid's solar power forecasting, improving the current model in use. It will apply this model to the synthetic time series in WP1 to assess the characteristics of solar PV generation variability, and its correlations to wind generation and to synthetic demand time series.

- Develop improved transfer models to convert solar irradiance into generated solar PV power and validate these against metered output solar power, improving medium term (6 hours – 2 weeks) solar PV generation forecasting.
- Provide a joint time series of solar and wind load factors together with synthetic transmission demand.
- Provide statistical characteristics of the relevant power (MW) and load factor variables, both on their own and jointly.
- Provide a concise library of extreme events for use in National Grid scenario modelling

DELIVERABLE: A synthetic joint time series of solar and wind load factors at regional and aggregate GB level, together with transmission demand at National level and an accompanying report. This will provide details of the variability in solar PV load factors over a range of time and spatial scales, correlation with wind load factors and demand, and a library of interesting and extreme events.

WP3. Assess the feasible improvements in short term (1-6 hours) solar generation forecasts.

At short lead times, solar forecast errors could be reduced by making use of current observations other than Met Office solar irradiance observations. State of the art remote sensing data, satellite and radar, and new model products can be used to provide a better near real time spatial distribution of clouds and movement of frontal systems. Near-real time output estimates of solar generation can be blended with NWP forecasts. This work package will assess and develop statistical techniques for utilising this data feed. Both techniques can then be utilised in adapting the Met Office numerical weather prediction systems in between model runs. This work package will assess these data sources to improve short term solar PV generation forecasts in 1 – 6 hour time horizon.

- Use radar and satellite based remote sensing data options (e.g. radar) to improve NWP short term solar PV irradiance and generation forecasts
- Use near-real time data feeds of solar PV generation to develop statistical models to improve short term solar PV generation forecasts

DELIVERABLE: A report summarising the improvements in short term solar generation forecasting that can be achieved using radar and satellite data sources, and from using near real time solar PV generation data feeds.

Scope

The scope of this project is both to understand the variability of solar generation and to improve solar PV generation forecasting in the medium and short term.

Analysis of solar generation will be focused on both regional and GB-aggregated solar PV generation and load factors. Historical assessment will consider 34 years with a resolution of 1 hour and above

At short timescales radar and satellite data and solar generation data driven statistical methods will be utilised to improve solar forecasts derived from NWP models, this work is distinct from, though intended to complement, prior activity that NGET have commissioned to access real time PV generation.

The variability of GB-aggregated solar generation will be assessed based on a newly derived long term dataset (described in work package 1); this will have an hourly resolution and run for at least 34 years. This data will be analysed to quantify the magnitude and frequency of a range of solar generation events.

The analysis will focus on two types of low probability events of particular interest:

- Persistent generation, where the combined solar and wind generation remains above/below a certain threshold for a prolonged period.
- Transition and ramping events, where the solar generation is rapidly changing.

Objective(s)

The purpose of this project is

- To derive datasets and specific knowledge of characteristics of solar PV generation in terms of variability, ramping and persistence, and the joint characteristics of how the solar resource interacts with the wind resource, that will inform planning decisions and procurement of balancing services within NGET.
- To develop new models for converting solar irradiance into generated solar PV power. This will improve the accuracy of both solar generation and transmission demand forecasts and hence expenditure on constraint management and reserves.
- To improve short term solar generation forecasts

The objectives of this project can be considered in the following specific areas.

Variability of solar irradiance and its correlations with other meteorological variables

As part of work package 1, NGET will be provided with a 34-year time-series of synthetic GB-aggregated solar irradiance, wind speed and temperature and an accompanying report. This will provide details of the variability in solar irradiance and frequency and duration of extreme and unusual events over a range of time scales; including decadal, annual and seasonal. In addition it will highlight the frequency and magnitude of ramping events. This will allow current events to be placed in historical context and enable a better insight of the potential impacts of solar PV generation on the power system. The data also could be used in combination with data provided in a previous NIA project (NIA_NGET0016: UK-wide wind power resource: Extremes and variability), to consider extreme events associated with combined wind and solar generation. This information could be harnessed for operational planning or for investigating future energy scenarios.

Develop improved transfer model for solar power generation; determine characteristics of solar generation and interaction with wind generation and demand variability

The objective of work package 2 is to provide NGET with improved models for converting solar irradiance into solar generation power. This will improve the solar generation forecasts and the transmission demand forecasts. Using the results from Work Package 1 a joint time series of solar load factors, wind load factors and demand at regional and aggregated GB levels will be provided. A report will be presented detailing statistical characteristics, both individually and jointly of the renewable resources, focussing on variability, ramping and persistence. A library of extreme or difficult events on the transmission network will be included.

Assess the possible improvements in short term solar radiation forecasts

On completion of work package 3, a report will be presented to NGET detailing the use of remote sensing techniques and statistical techniques driven by near-real time solar generation data in improving short term solar forecasts.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

This project will provide knowledge that; (1) enables a better insight of the potential impacts of solar PV generation on the power system, at planning time scales and also for assessing tools needed within balancing services (2) improves medium and short term solar generation forecasts and hence demand forecasts. This activity will contribute to cost reduction in an area of high strategic significance. However, the full attribution of constraint and balancing costs is highly complex, rendering any estimate of direct cost benefit misleading at best. Success of this project will be evidenced by availability of solar generation information within the operational planning process. This information can be aligned to three main objectives; (1) Greater awareness and use across NGET of impact of solar generation variability and its interaction with wind generation and demand variability for use in network and

commercial planning [WP 1 and 2] (2) Improved medium term solar generation forecasting for use in operational and commercial decision making [WP 2] (3) Improvements in short term solar radiation forecasts to improve operational decision making [WP 3].

Project Partners and External Funding

n/a

Potential for New Learning

It is expected that the project will help deliver improved accuracy of GB electricity demand forecasts during daylight hours. It will enable more accurate assessment of renewable generation impacts on the transmission system. It will aid in the planning of balancing services required to manage the system with higher renewable penetration.

Scale of Project

The project will be limited in scale to lab-based studies and site investigation.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The project is being undertaken in Reading.

Revenue Allowed for the RIIO Settlement

None.

Indicative Total NIA Project Expenditure

The indicative total NIA project expenditure is £300,000

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

This project will reduce the demand forecast error that results from solar PV generation. The subsequent reduction in system balancing costs will lead to significant savings to the Industry, National Grid and the consumers. This project will add further value along with the other NIA projects which are currently running to help address other areas for better monitoring and forecasting solar PV thus reducing current errors in the forecasts. It will aid in the planning and costing of new balancing services required to manage the transmission system with higher renewable penetration. The project will also assist the EMR modelling team assess the impact of increased renewable penetration and consequent required market reforms.

Please provide a calculation of the expected benefits the Solution

If this project leads to a 10% improvement in solar PV forecasting, we can expect a contribution to saving in reserve holding in the order of £2.6 million annually.

Please provide an estimate of how replicable the Method is across GB

The research learning will be freely available.

Please provide an outline of the costs of rolling out the Method across GB.

No perceived additional costs.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

- A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).
- A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)
- A specific novel operational practice directly related to the operation of the Network Licensees system

- A specific novel commercial arrangement

RIIO-2 Projects

- A specific piece of new equipment (including monitoring, control and communications systems and software)
- A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven
- A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)
- A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology
- A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution
- A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Learning gained from the various work packages will be disseminated through papers and relevant documents published by Reading University's Meteorology Department and disseminated through the National Grid Innovation Strategy website. A technical workshop will also be organised to disseminate the learnings.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

The challenge of better forecasting for Solar PV thus helping us to better manage our reserve levels and energy demand. It will also help National Grid better manage risks.

- Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

- Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

Work has been carried out to ensure no similar projects are in progress or planned by a thorough search of the Smarter Networks Portal. The project will use the outputs from other NIA funded projects, particularly Solar PV Monitoring Phase 2 (NIA_NGET0170), where the output from the aggregated GB Solar PV output will be used to validate the PV forecast model in WP2. It will also use results from the Wind Forecasting NIA project NIA_NGET0016.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

n/a

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

n/a

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

n/a

This project has been approved by a senior member of staff

Yes