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TECHNICAL REPORT

colour inside

Renewable energy power forecasting technology

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RENEWABLE ENERGY POWER FORECASTING TECHNOLOGY

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
8A/71/DTR	8A/73/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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INTRODUCTION

The purpose of this IEC Technical Report (TR) is to describe common practices and the state of the art for renewable energy power forecasting, which includes general data requirements, methods for renewable energy power forecasting and forecast error evaluation.

Various stakeholders, including transmission system operators, transmission system owners, utilities, renewable energy generation plant developers, academic units, research institutions, certifying bodies and standardization groups, require a common understanding of renewable energy power forecasting methods, data and evaluation techniques so they can incorporate them in their operations.

Renewable energy power forecasting finds a broad application in many areas of electrical engineering related to design, analysis, market trading, and optimisation of the power system. Among others, forecasting could be as an input to the operation and management of the renewable energy generation plants and can improve the economic efficiency and reliability of the power system.

Renewable energy power forecasting is increasingly important in multi-stakeholder systems where renewable plant manufacturers, renewable energy generation plant developers and operators, as well as the power system operators, need to have a common understanding about the capabilities and methods associated with renewable energy power forecasting.

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RENEWABLE ENERGY POWER FORECASTING TECHNOLOGY

1 Scope

This Technical Report, which is informative in its nature, describes common practices and state of the art for renewable energy power forecasting technology, including general data demands, renewable energy power forecasting methods and forecasting error evaluation. For the purposes of this document, renewable energy refers to variable renewable energy, which mainly comprises wind power and photovoltaic (PV) power – these are the focus of the document. Other variable renewable energies, like concentrating solar power, wave power and tidal power, etc., are not presented in this document, since their capacity is small, while hydro power forecasting is a significantly different field, and so not covered here.

The objects of renewable energy power forecasting can be wind turbines, or a wind farm, or a region with lots of wind farms (respectively PV systems, PV power stations and regions with high PV penetration). This document focuses on providing technical guidance concerning forecasting technologies of multiple spatial and temporal scales, probabilistic forecasting, and ramp event forecasting for wind power and PV power.

This document outlines the basic aspects of renewable energy power forecasting technology. This is the first IEC document related to renewable energy power forecasting. The contents of this document will find an application in the following potential areas:

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- support the development and future research for renewable energy power forecasting technology, by showing current state of the art;
- evaluation of the forecasting performance during the design and operation of renewable energy power forecasting system;
- provide information for benchmarking renewable forecasting technologies, including methods used, data required and evaluation techniques.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61400-12-2, *Wind turbines – Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
accumulation method
wind power forecasting method for wind farm clusters that directly accumulates the forecasting results of each wind farm output

3.1.2
combination approaches, pl.
approaches usually used to describe the forecasting models which combine physical approaches with statistical approaches

3.1.3
data assimilation
assimilation combining recent observation data with the background (prior) forecast in real time, to adjust forecast model trajectories and update the background field

Note 1 to entry: In numerical weather prediction (NWP), this helps the weather forecast become more accurate.

3.1.4
day ahead power forecasting
timescale used in forecasting, which is from the current time to the next 24 hours to 72 hours

3.1.5
days to week ahead power forecasting
timescale used in forecasting, which is from the day ahead to the week ahead

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3.1.6
deterministic forecasting
kind of forecasting method that can output deterministic results

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3.1.7
deterministic forecasting evaluation
evaluation of the specific forecasting value at a certain moment in the future

3.1.8
distributed PV power forecasting
a method to forecast the total power output of distributed PVs in a certain region

3.1.9
ensemble forecasting
NWP method which produces a set of forecasts instead of making a single forecast

Note 1 to entry: This set of forecasts aims to give an indication of the range of possible future states of the atmosphere.

3.1.10
event forecasting evaluation
evaluation of the forecasting results of specific events

Note 1 to entry: For example wind or solar ramp events.

3.1.11
horizon
length of the forecast look-ahead time

3.1.12
minutes and hours ahead power forecasting
type of forecasting which is in minute scale (up to 15 min) or ultra-short-term (15 min to 6 h or 8 h)

3.1.13
nonparametric modelling
distribution-free without any assumptions of the distribution type

Note 1 to entry: It directly calculates the quantile or distribution function of the unknown random variable by means of data analysis methods.

3.1.14
numerical weather prediction
NWP
method to predict weather which numerically solves the basic equations of atmospheric motion based on the most recent observations that best represent the current atmospheric conditions

3.1.15
parameterization schemes
methods to capture the quantitative physical characteristics of radiative, convective and diffusive processes in the atmosphere and at the interface between the atmosphere and the surface.

Note 1 to entry: These processes are often determined by relatively small spatial scales, and are used in NWP models.

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3.1.16
parametric modelling
model to use a predetermined distribution type describing the probability density function (PDF) of the unknown random variable

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3.1.17
persistence forecasting
a method to use the measured power value at the current moment as the forecasted power at the future time

3.1.18
physical approaches
mathematical and physical models which are used to describe the physical factors

3.1.19
power forecasting of renewable plant clusters
the forecasting of the overall output of wind or solar PV clusters

3.1.20
probabilistic forecasting
a kind of forecasting methods that focuses on the uncertainty of power output

Note 1 to entry: Including wind power probabilistic forecasting and PV power probabilistic forecasting. The forecasting results could be the PDF, cumulative distribution function (CDF) of the random variable of power or the prediction intervals at certain probability levels.

3.1.21
probabilistic forecasting evaluation
evaluation of the forecasting results of the uncertainty of power output

3.1.22
ramp events, pl.
significant changes of power output in a short period

Note 1 to entry: These may refer specifically to those events not caused by the expected change due to the expected change in output of solar PV. Such events are prone to cause frequency fluctuation and power quality deterioration, potentially impacting the reliable operation of the power grid.

3.1.23
ramp magnitude
variation of power output in the observation period

3.1.24
ramp rate
variation rate of wind power in the observation period

3.1.25
resolution
spatial or temporal scales at which forecasts are made, measured in kilometers (spatial) or minutes/hours

3.1.26
statistical approach
mathematical model which is used to describe the relationship between historical NWP data, weather data and historical power output of a wind farm or a PV power station

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3.1.27
statistical upscaling method
establishment of an upscaling model with part of a set of points to estimate the total

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Note 1 to entry: It is the total regional power output estimated from a subset of wind farms or PV stations.

3.1.28
stochastic process for forecast development
stochastic process/model to incorporate random variation

Note 1 to entry: Usually based on fluctuations observed in historical data for a selected period using standard time-series techniques. The use of solely historical data is the main difference compared to probabilistic processes/models, which apply variations generated from some type of perturbation of the prediction process.

3.1.29
wake effect
phenomenon of wind speed decreasing after wind turbines extract power from the wind

3.2 Abbreviated terms

AE	analog ensemble
ANN	artificial neural network
AR	autoregressive
ARMA	autoregressive moving average
BPNN	back propagation neural network
BS	Brier score
BSS	Brier skill score
CART	classification and regression tree
CDF	cumulative distribution function
CFD	computational fluid dynamics