IEA Wind Task 36 Session Topic 2: Meteorological Measurements and Instrumentation Standardization for Integration into Grid Codes: What can we learn from the WMO ?

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***Abstract*—State of the art wind power forecasting methodologies utilise, besides wind speeds from weather forecasts, on-site real-time power measurements from SCADA systems and meteorological measurements from met masts or suitable alternatives to estimate and predict wind power. The combined use of the trend of the forecast and measured meteorological variables represents the state-of-the-art method for the prediction of wind power for the next few hours, as well as high speed shut-down and critical ramping events. This explains the need for high quality measurements, even though similar considerations are applicable in the management of dispatch, i.e. ranging down to cover also lower wind speeds. Today, there are no standards or guidelines on the quality requirements for instrumentation or on the type of instrumentation itself that would help system operators to develop their grid codes. In this paper, We introduce a new topic of the second phase of IEA Wind Task 36 (2019-2021) that addresses the issues associated with the measurement, quality control and communication of data for meteorology-related energy applications. We discuss the benefits and limitation of the existing standards for the collection, maintenance and storage of data from other areas of the wind power industry and the meteorological community. We develop a list of key elements that are important to consider when developing requirements in the grid codes of the transmission system operation that deal with wind and solar generating units and how to organise access, storage and quality of data related to energy meteorology.**

I. INTRODUCTION

Meteorological measurements provide an independent measure of the wind resource and weather situation at any given time. This information can and is, as technology enhances, not only an obligation that stems from technical requirements of the system operator, but is also used to optimise operation of the wind turbines by the wind farm operators. For both the system operator and the wind farm operator, these measurements are an independent signal at the wind farm that can warn about critical weather and provide an indication on whether the wind turbines work at their expected performance level. For the transmission system operator, such measurements can additionally be used for situational awareness of the weather in the control area that may affect the transmission lines. They also provide an additional way of verifying whether the power data from a given wind farm is unreliable in situations that may be critical for grid operations

In recent years, the assimilation of meteorological measurement data from wind farms into Numerical Weather Prediction (NWP) systems has been tested by meteorological centres (e.g. [1], [2]). One of the most important findings from these experiments has been that the quality of provided data is the most essential issue to be solved in order to gain higher quality forecasts with such measurements. In fact, it has been identified that if there is no specific effort put into standardisation of methods, processes ans instrumentation for data collection from renewable energy sources (RES) in the power industry, the benefits can not be achieved [3]. A work package in the second phase of the IEA (International Energy Agency) Wind Task 36 Wind Power Forecasting [4] (2019-2021) has been created in order to provide recommendations for standards regarding measurement , collection and quality control of relevant meteorological data. The World Energy and Meteorology Council (WEMC) also created a special interest group (SIG) on ”Data exchange, access and standards” for the same reason. While WEMC's SIG also aims to evaluate and develop best practices and standards for the collection, structure and exchange of relevant data, their focus extends to ”..web-based standard, open, inter-operable platforms for the dissemination of data; funding solutions for-long-term development and maintenance of databases; and intellectual property issues”. This means that the entire community is basis for the SIG, while the IEA Wind Task 36 focus is dedicated to the end-users of variable generation resource forecasts. The IEC working group SC8A is preparing a technical report at present in order to identify areas, in which standardisation is useful and should be pursued in the near future by IEC. In this process, data collection and processing with the respective IT implementation practices are one topic that has gained some attention.

In the IEA Wind Task 36 effort, the first step has been to identify and examine already existing standards for their applicability for the purpose of real-time forecasting of the variable generation resources from wind and solar. In a next step, a review and analysis of existing requirements at end-users will be compiled in order to get an overview of the current status, overlap and differences in the industry. Once this information is collected and analysed, recommendations will be formed and aligned with work from the WEMC special interest group and the IEC SC8A.

In the next sections, the first analysis of existing standards are presented and discussed.

II. Known Standards

So far, standards for measurements and design of measurement collection in the wind energy and power industry have only been developed for the planning and commissioning phase of wind and solar parks. In these applications, meteorological measurements serve as an indicator of the wind resource and expected power output at the site of interest for the financing of a wind or solar project.

The European Wind Energy Association (EWEA) has through an EU funded project in the "Intelligent Energy - Europe" program (2007-2013) established a web site that describes the important aspects of measurement campaigns for the establishment of wind energy projects [5]. The most common parameters derived from meteorological measurements taken for this purpose are:

- Mean wind speed
- Maximum three-second gust wind speed
- True standard deviation of wind speed
- Mean wind direction
- Mean temperature

The EWEA webpage points to three parties providing recommendations on minimum technical requirements for anyone "intending to make bankable wind measurements" [5]:

- the International Electrotechnical Committee (IEC)
- the International Energy Agency (IEA)
- the International Network for Harmonised and Recognised Wind Energy Measurement (MEASNET)

The IEC 61400-12 standard [6], [7] has been drafted for "Power performance measurements of electricity producing wind turbines" and provides in Annexes A to K guidelines around the setup of meteorological measurements and the respective measurement campaigns. While the measurement procedures and the derived results are much geared towards the overall consistency of the manufacturers power curve and the prevailing wind resource, there are a number of Annexes that are relevant for the subsequent operation of the facility when real-time measurements of the wind resource at the site are typically required.

Annexes D and E address the evaluation of uncertainty in measurements and the theoretical basis for determining the uncertainty of measurement. Annex F provides information about the calibration of instruments, the measurement procedures and the analysis of the data. Annexes I and J address the classification of anemometry and the assessment of the cup anemometry.

The IEA Wind Task 11 (Best Technology Information Exchange Recommended Practices) has drafted best practice guidelines that assist in implementation of wind energy projects and compliance with the requirements specified in IEC 61400-12 [8]. The recommended practices by IEA Wind Task 11 address all aspects of a wind energy project from the site assessment to the noise regulation and the general wind integration.

In their recommended practices guideline 11, wind speed measurement and use of cup anemometers are also dealt with [9]. It is in fact a best practice guide for the IEC 61400 MT 13 with updated power performance measurement standards. Guideline 15 addresses ground-based vertically-profiling remote sensing for wind resource assessment [10], especially in cold climates, complex terrain and with increasing hub heights, where met masts are expensive and planning permissions are more complicated.

The International Network for Harmonised and Recognised Wind Energy Measurement (MEASNET) published a guideline on cup anemometer calibration [11], providing information on how to calibrate cup anemometers to fulfil the IEC standards. These guidelines are useful and can be used in the operational phase of the wind integration as well to set up technical requirements for the instrumentation to be used for the real-time delivery. Additionally, the integrity of the measurement procedure is described and it is recommended that the ISO/IEC 17025 standard [12] should be followed. Here, the management and technical as well as reporting requirements for measurement campaigns are standardised.

The IEC 61400-12 standard, guidelines from MEASNET and some recommended practices from IEA Wind Tasks are applicable only in resource assessments. The US environmental protection agency (EPA) provides a Meteorological Monitoring Guidance for Regulatory modelling Applications, which is a guideline on the collection of meteorological data for use in regulatory modelling applications such as air quality. All these guidelines and standards provide recommendations for setup and maintenance of instruments, the measurement and reporting for all main meteorological variables. However, only the EPA guidelines deal with real-time usage in relation to meteorological modelling applications.

All of these guidelines and practices will be studied in more detail in the IEA Wind Task 36 phase 2 in order to compile recommendations for the real-time usage of instrumentation to be used in the real-time grid management and operation.

III. Data handling in the meteorological community (WMO)

The meteorological (and hydrological) community have established an umbrella organisation, the World Meteorological Organisation (WMO), for the provision of weather and climate information. The WMO originated from the International Meteorological Organization (IMO), which was founded in 1873 to facilitate the exchange of weather information across national borders. Established in 1950, the WMO became a specialized agency of the United Nations in 1951. The WMO facilitates free and unrestricted exchange of data and information among their members for products and services in real- or near-real time on matters relating to safety and security of society, economic welfare and the protection of the environment. It contributes to policy formulation in these areas at national and international levels. [13].

The WMO is dedicated to international cooperation and coordination and emphasises the importance of these attributes for the national meteorological services that work around the clock to provide vital weather and climate information worldwide. Their early and reliable warnings of severe weather and fluctuations in air quality as well as of climate variability and change allow decision-makers, communities and individuals to be better prepared for weather and climate events. WMO supports national meteorological and hydrological services in *meeting their international commitments in the areas of disaster risk reduction, climate change mitigation and adaptation, and sustainable development* [13]. In their programme they facilitate and promote, among others, the following core topics ([13]):

1) the establishment of networks of observational stations to provide weather, climate and water-related data;
2) the establishment and maintenance of data management centres and telecommunication systems for the provision and rapid exchange of weather, climate and water-related data;
3) the creation of standards for observation and monitoring in order to ensure adequate uniformity in the practices and procedures employed worldwide and, thereby, ascertain the homogeneity of data and statistics;
4) the coordination of research and training in meteorology and related fields.

These 4 topics can directly be transformed into the requirements for an internationally organised handling of the access and exchange of meteorological data related to energy applications. In fact, the energy meteorology would be able to take advantage of a lot of the lessons learned by the WMO in the establishment of observational networks, establishment of data management centres and the creation of standards for observational data collection, access and maintenance.

In an IEA Wind TASK 36 workshop at the International Conference on Energy Meteorology (ICEM) 2019 [14], the question on the need for best practices or standards for energy meteorology data was posed. The answers from the participants directly indicated that data exchanges, access and standards need to be organised globally and preferably from a international organisation such as the WMO. The following specific comments, which again can be directly related to the program and organisational activities of the WMO, were emphasised by participants in the workshop:

1) Today there is much chaos when data from wind farms is collected There is a need for organising principles or structures
2) Meteorological instrumentation can improve power output and thereby compensate the costs for investment and maintenance of instruments
3) Industry needs scalability
4) Calibration needed in regular time intervals
5) Maintenance important for data quality
6) Need for best practices or standards
7) Need for an organisation to merge all groups around the world; WMO?

In summary, there is broad consensus among experts that there is a need for an international organisation that dedicates it's work force towards the facilitation of international collaboration and coordination of data related to energy meteorology.

IV. Review of Data Requirements in jurisdictions with significant amounts of Wind and Solar Power

In order to review the data requirements for system operators, we have selected a number of system operators with significant amounts of wind and solar power feeding into their grid. We compared the requirements for the integration of wind and solar energy into the electrical grid regarding meta- or standing data, equipment and meteorological variables to be delivered by met instruments installed at the generation facilities. It can not be considered a complete review, because we limited the comparison to 11 system operators in North America and in Europe, where information was accessible and where the amount of wind and solar power feed-in to the grid has reached a significant amount.

The selected system operators and their respective technical requirements were:

- **AESO**: Alberta Electric System Operator in Calgary, Alberta, Canada [15]
- **BPA**: Bonneville Power Administration in Portland, Oregon, USA [16]
- **CAISO**: California Independent System Operator, Folsom, CA, USA [17], [18]
- **ERCOT**: Electricity Council of Texas in Austin, Texas, USA [19]
- **NYISO**: New York Independent System Operator in Rensselaer,NY,USA [20]
- **PJM**: PJM Interconnection LLC, Independent System Operator in Valley Forge, PA, USA [21]
- **HECO**: Hawaiian Electric Company, Maoui, Hawaii [22]
- **50Hertz**: 50Hertz Transmission in Berlin, Germany. [23]
- **EIRGRID GROUP**: Irish transmission system operators Eirgrid, Dublin, Republic of Ireland and SONI, Belfast, Northern Ireland. [24], [25]
- **LitGrid**: in Vilnius, Lithuania [26]

It was found that all system operators that require meteorological data from wind ands olar generation facilities use a similar formulation in their technical requirement guides. The requirements in all cases have a time frequency of delivery under 1 hour (between 2s in the PJM control area and 15min in the Hawaiian control area of HECO) and a threshold name plate capacity of 1-30MW, above which delivery of meteorological data is required.

The variables to be collected are in all cases wind speed and direction at hub height or nacelle, temperature and pressure (except for LitGrid). In some cases ambient humidity and dew point temperature at 2m height are required for half of these TSOs. In one case (AESO) an ice-up signal is required.

Two of the TSOs require standing geo-data from every wind turbine (CAISO, BPA) and one also requires wind farm layout information (NYISO). This requirement is related to the fact that NYISO, in their latest update from June 2016, encourages the wind plant operators to collect and send data "..from as many points at the Wind Plant as are available. Ideally, the minimum amount of data would be provided from a stand-alone meteorological tower(s) and augmented with additional sensor data from the turbines." [20]. This may be related to the fact that NYISO allows data to be collected from a turbine mounted equipment, if no stand-alone tower exists. However, it is a required to obtain approval if any measurement unit is exchanged or decommissioned.

All system operators except LitGrid ask for wind measurements from a met mast at hub height or equivalent instrumentation. In the LitGrid control area, wind farms have to deliver wind speed, wind direction and temperature from at least 2 corners of the wind farm to ensure that measurements are not contaminated by wake effects.

The benefit of this strategy is increased amounts of measurement sources and significantly lower costs for the wind farms. The drawbacks of nacelle wind measurements are the uncertainty regarding yaw misalignment and corresponding wake effects.

The following Table I provides an overview of the requirements of the 8 selected system operators for comparison.

table

What is characteristic for all system operators is that the the wind and solar parks delivery frequency of observational data, including meteorological data, where required, is relatively high. In some cases on 1-minute frequencies. The frequency of data delivery is mostly dependent on the market structure, especially where RES (Renewable Energy Resources) are also traded in the short-term markets, but also, because wind speed measurements are increasingly used for dispatch and to shorten curtailment times.

V. Discussion and Outlook

Considering our societal development on data collection and usage we can expect that the energy sector is no different and that the transition towards more sustainable and climate friendly generation will lead to a significantly higher amount of data collection over the next decade. In the electrical grid, smart metering will become widespread and provide the possibility to get an improved near-real-time estimate of both the generation and consumption on a grid system. There is a trend in many countries with sustainability and climate change programs that households will increasingly become both a consumer and a generator and use storage to become more self-sufficient. In summary, we can expect a transition phase with many challenges for governments, policy makers, engineers and scientists in order to set the correct incentives and develop the tools necessary to handle the vast amounts of data being collected to the benefit of a more efficient, economic and sustainable energy sector.

There are however a number of barriers and limitations that need consideration in order to succeed in making use of the new forms and types of data available. Some of these are obvious and others have inter-dependencies, where consequences of no-action are not clearly visible. In the previous section we have shown the substantial similarities but yet notable differences among the requirement lists of various system operators with significant amounts of wind and solar power on their grid. But, common to all is that each of them had to go through a somewhat arduous development phase of setting a grid code standard due to a lack of existing guidelines, recommended practices or standards.

In the previously cited IEA Wind TASK 36 workshop at the ICEM 2019 [14] this topic was extensively discussed. One of the questions addressed was, "Which types of measurements are needed for the management, marketing and balancing of the power in the market and grid operation?" There was broad consensus in the community that the answer to this question requires answers to a number of other questions that are interlinked to this questions. These questions include:

- Why do we need a specific measurement?
- What does the measurement represent?
- what are the limitations of a specific measurement
- what is the redundancy requirements of specific measurements
- how can reliance on single measurements be avoided
- how can the benefit of having multiple types of instrumentation be realised

The last point in fact revealed the barrier of not having standards for instrumentation, quality, reliability and suitability of data that is well known from the wind resource assessment area with respect to the generation of bankable data as well as the meteorological society, where it has been practised over many decades to incorporate many different types of measurements into the data assimilation of the models. Even though there is always some resistance against standards, it is also well known that standards are a necessity in order for business models to be developed and for technologies to mature. Without that, the scaling up of technology is not possible. In summary, the main barriers and limiting factors identified in the workshop are related to a lack of standards in following areas:

- data collection formats and storage
- instrumentation setup and maintenance
- quality control of instrumentation and data
- access rights of data

These barriers needs to be broken down in order to enable a reliable and economically efficient operation of grid systems with large amounts of renewable energy generation these barriers need to be broken down.

The IEA Wind Task 36 [4] has identified this topic as a high-priority area and is collaborating with other initiatives in various aspects of the development chain of standards for the discussed topics, such as the IEC SC8A Working Group on Forecasting for Renewables, the WEMC special interest group on Data, the IEA PVPS solar systems Task force group.

In the next 3 years, the IEA Wind Task 36 expert team plans to develop a recommended practices guideline for system operators, balance responsible parties (BRP) and market management companies in order assist them in setting requirements according to internationally agreed standardised practices and thereby enable the development of efficient technology development and implementation into operation. There will be held bi-annual meetings and workshops to discuss and disseminate the results in the various stages of this development. Interested parties can follow the task on the web page ieawindforecasting.dk and by signing up to the tasks newsletter or actively participate in the task.

Conditions			Standing Data		Equipment		Met variables to be delivered								
System Operator	threshold [MW]	frequency [sec]	geodata per wind farm	geodata per turbine	met mast	nacelle	other	ws	wd	T2m	PS	DP	HUM	other	location agl.
AESO (CAN)	5	60	1	0	1	0	0	1	1	1	1	1	1	iceup	hub/2m
BPA (USA)	20	60	1	1	1	1	1	1	1	1	1	0	1	0	hub/2m
CAISO (USA)	1/5	4	1	1	1-2	1	0.5	1	1	1	1	0	0	0	hub(+10m)/2m
ERCOT (USA)	1	300	1	0	1	0	0	1	1	1	1	0	0	0	hub/2m
NYISO (USA)	1	30	1	0	1	0.5	0.5	1	1	1	1	1	1	0	hub/2m
PJM (USA)	10/100	10/2	1	0	1	0	0	1	1	1	1	0	0.5	0	hub/2m
HECO (USA)	all	900	1	0	1	0	1	1	1	1	1	0	0	0	hub+windNET
50Hertz (GER)	n/a	n/a	1	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EIRGRID (IRL)	10	900	1	0	1	0	0	1	1	1	1	1	1	0	hub/2m
LITG (LIT)	20	300	1	0	0	2	0	1	1	1	0	0	0	0	nacelle
POWRGRID (IN)	10	900	1	0	1	0	0	1	1	1	1	1	1	0	hub/2m

TABLE I: Summary of technical requirements in a number of control areas/jurisdictions. Abbreviations for the variables are ws=wind speed, wd=wind direction, T2m=temperature at 2m, ps=surface pressure,dp=dew point temperature,hum=humidity, frequency=deliver frequency, threshold= threshold nameplate capacity of the wind farm, where the rules are applicable.

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