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GEORGIAN WIND FORECASTING PROJECT: REPORT ON REQUIRED INFRASTRUCTURE, WORKS AND COST ASSESSMENT TO INCREASE THE FORECASTING ACCURACY

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ACRONYMS

⁰C	Celsius
AEMO	Australian Energy Market Operator
AEP	Annual Energy Production
AWEFS	Australian Wind Energy Forecasting System
CAISO	California Independent System Operator
CECS	Configuration, Evaluation and Communication System
CFD	Computational Fluid Dynamics
CSV	Comma-Separated Values
DA	Day Ahead
DUID	Dispatchable Unit ID
E.S.Y.D	Greece's National Accreditation System
EnCT	Energy Community Treaty
EU	European Union
EUR	Euro
FCR	Flow Complexity Recognition
FTP	File Transfer Protocol
GFP	Georgia Wind Forecasting Project
GoG	Government of Georgia
GSE	Georgian State Electrosystem
GUI	General User Interface
hPa	Hectopascal
ID	Intraday
IEC	International Electro Technical Commission
LES	Large Eddy Simulation
LiDAR	Light Detection and Ranging
m/s	Meter / Second
MARS	Measurement and Recording System
MEASNET	International Network for Harmonised and Recognised Measurements in Wind Energy
MW	Megawatt
NEA	National Environmental Agency
NTF	Nacelle Transfer Function
NWP	Numerical Weather Production
QWF	Qartli Wind Farm
RSD	Remote Sensing Device
SCADA	Supervisory Control and Data Acquisition
SCP	Secure, Contain and Protect
sFTP	Secure File Transfer Protocol
SoDAR	Sonic Detection and Ranging
TYNDP	Ten Year Network Development Plan
USAID	United States Agency for International Development
USD	US Dollar
UTM WG S	Universal Transverse Mercator
VDRAS	Variation Doppler Radar Analysis System
VRE	Variable Renewable Energy

WPG	Wind Power Generator
WPP	Wind Power Plan

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INTRODUCTION

In October 2016, Georgia signed the Energy Community Treaty (EnCT) signaling the country's commitment to direct future energy planning and market development towards approximation with the European Union (EU). This step commits Georgia to enhance the security of energy supply by promoting the development of relevant infrastructure, increasing market integration and gradual regulatory approximation towards key elements of the EnCT, and promoting the use of renewable energy sources. In order for Georgia to meeting its strategic commitments in the energy sector, the United States Agency for International Development (USAID) is providing technical assistance and policy advice on legal, regulatory and institutional reform issues, including facilitating investment and deal structuring, engineering and environmental analyses, financial planning, and outreach, and other consulting. This technical assistance, ("USAID Energy Program") is being rendered by Deloitte Consulting LLP, under a USAID contract, AID-OAA-I-13-00018.

The objective of the USAID Energy Program is to support Georgia's efforts to facilitate increased investment in power generation capacity as a means to increase national energy security, facilitate economic growth, and enhance national security. The project will have a significant impact on energy market reform efforts of the Government of Georgia (GoG) to comply with the country's obligations under the EnCT. The investment objective will be achieved through the provision of technical assistance to a variety of stakeholders in the energy sector.

The specific goals of USAID Energy Program are to: (1) support Georgia in energy market development per Georgia's obligations under the EnCT, (2) build the capacity of the GoG and relevant institution(s) to evaluate the fiscal and long-term impacts of regulatory changes, (3) promote energy investments, primarily in variable renewable energy development, (4) to support the integration of non-hydro renewable energy into the power system, and (5) provide strategic advisory services to the GoG to increase Georgia's energy security. The outcome of this Program is to enhance Georgia's energy security through improved legal and regulatory framework and increased investments in the energy sector, especially in wind and solar, and to encourage competitive energy trade.

USAID Energy Program is tasked to provide technical assistance to the Georgian State Electrosystem in the design and implementation of a modern forecasting system that provides accurate and timely information of expected production and availability of renewable energy-based generation units. The program discussed the design with the key GoG agencies, experts representing private forecasting firms in the global renewable energy market, one wind power generator in Georgia and the developers of future projects. This work *in toto* is called the Georgia Wind Forecasting Project.

The awareness of the need for developing Variable Renewable Energy (VRE) forecasting has increased in Georgian for the last 4-5 years. Ten Year Network Development Plan approved in 2016 and subsequent years, highlighted the unmet needs of renewable energy forecasting and helped to identify research requirements and implementation strategies for VRE forecasting services.

As a result of USAID Energy Program's technical assistance to Georgian State Electrosystem (GSE), GSE has access to wind power forecasts and weather parameter prediction at 7 locations from March 2020. One of the 7 locations is a Qartli Wind Farm (QWF) with 20 Megawatt (MW) installed capacity. The remaining 6 locations represent the potential wind farms, with the prospective to be constructed and commissioned in the nearest future.

Deterministic forecast of power (MW) and meteorological parameters (Wind Speed m/s, wind direction -degrees, temperature-Celsius) is available in a Day-Ahead (DA) and Intraday (ID) format with a 36 hour ahead and 3 hours ahead of time horizon respectively. DA forecast has a granularity of 15 minutes whilst ID forecast has lower granularity-5minutes. Both DA and ID are updated hourly.

At the design phase, the Centralized Forecasting System implementation was prioritized over the delivery of forecasting services by vendors. At the same stage, the delivery of forecasting services was selected as a time and cost-effective solution for the implementation of wind power forecasting system.

Currently, UL AWS True Power, the worldwide known vendor of forecasting services and Denmark company ENFOR are employed for the delivery of forecasting services to GSE.

Forecasts are accessible for GSE at General User Interface (GUI) as the Data Handling and Visualization Tool as well as at Secure File Transfer Protocol (sFTP) server under the disposal of GSE.

The report aims to provide insights on the data set needed for the delivery of the accurate wind power forecast, covers the equipment that may be deployed for the measurement of meteorological and power parameters and includes references to the wind industry standards applicable for wind measurement. In the conclusion, the report also incorporates direction for future work.

The target audience for the report is mostly, GSE. The document explains the need for additional infrastructure, costs to comply with data exchange intervals set by vendors, and improvements required for data exchange by making it mandatory though license requirement. Improving data exchange is essential for enhanced and advanced accuracy of the forecast.

This paper is organized into 6 sections. Section 1 describes the Georgian Wind Forecasting Project (GFP) and its current state. Section. 2 incudes the forecasting data requirement. Section 3 offers the description of potential data sources required for forecasting and a list of data the quality, availability and reliability to be controlled by System Operator and Operator of Wind Farm. Section 4 refers to equipment that may be deployed for wind parameter measurement. Section 5 lists wind industry standards applicable for wind parameter measurement and lastly Section 6 offers the major conclusions and the possible future directions.

EXECUTIVE SUMMARY

Increasing the amount of wind energy is a key strategic goal of the Georgian Government. However, integrating wind energy into the national power grid is a significant technical obstacle. Wind power forecasting can play a pivotal role in facilitating the integration of wind energy. Wind power forecasts are deemed as the most crucial for determining an appropriate balance on the power system.

Highly accurate wind power forecasts will enable renewable energy to effectively increase its fraction in the energy portfolio. Accurate wind power forecasts are also essential for several reasons such as reducing the occurrence or length of curtailments (which translate to cost savings), employees' safety, and mitigating the physical impacts of extreme weather on wind power systems.

In the electricity market, wind power forecasts can also assist market participants in the application of suitable bidding strategy, unit commitment or event impact the value of the spot price. Since forecast errors are real costs in the energy market, more accurate forecasts will enable utilities and their ratepayers to save a substantial amount of money.

Forecasting can also save costs when operators need to schedule wind project maintenance and construction. Wind projects often require that turbines be taken down during the maintenance or commissioning of new turbines. This can take hours to weeks depending in part on the weather.

Without accurate forecasting information, the chances of idling a mobilized work crew and necessary equipment (such as large cranes) increases. Such associated costs can exceed US$10,000 per day. If the operator fails to take advantage of the right weather conditions for construction, operations, and maintenance, overall project costs can increase as deadlines are missed. Also, plant generation will be diminished, and resultant production revenues will be lost.

1. The Main Findings.
    - No need for specific infrastructure. There is a need for data exchange improvement
2. The Main Recommendations.
    - For forecasting data input, it is recommended to stay with nacelle based and meteorological tower based measurements that outperform Remote Sensing Device (RSD) in terms of availability;
    - A proper measurement is a primary interest of developers, therefore there is no need to ask developers change or rearrange equipment for measurement;
    - Remote Sensing Devices can't ensure 98% measurement availability in the case of Georgia. Even, the technology for wind speed measurement is not mature.

Before making data measurement and its sharing mandatory with 10 min intervals, GSE needs to resurvey the developers of wind farms.

High forecast accuracy is dependent on an optimal combination of data from Wind Farm Supervisory Control and Data Acquisition (SCADA) System, representing the lower production. Also, it is dependent on the availability of meteorological data from wind turbine, and the input from Numerical Weather Production (NWP) models conditional on the forecasting time horizon. In ideal cases, when SCADA data are both online and of high-quality, statistical and hybrid prediction models generally produce the greatest degree of forecasting accuracy.

Currently, there is only one commissioned wind farm QWF and dozens of potential wind farm locations in Georgia. QWF is the existing Wind Farm and the remaining 6 are just locations. GFP considers wind power and meteorological parameter forecast for 7 locations. Due to the progress in connection procedures, the probability of starting construction in the nearest future in those locations is high.

Wind farms from those 6 locations will be connected to GSE SCADA system prior to commissioning testing. Respectively data that is measured at the proximity of potential locations for the preciseness and accuracy of the forecast is important.

In general, there are two types of data input - Static and Dynamic that is important for the accuracy of the wind power forecasting and requested by vendors of forecasting service. Historical measurement data is considered under the Static, whereas an automatic data exchange of power and meteorological parameters measurement data with the specific data transfer intervals is considered under the Dynamic. Depending on the period, whether it is past or the present, the plant availability data can be attributed either to Static-Historical or Dynamic category of data.

Under GFP, vendors of forecasting services requested the historical observations to be provided at the same interval as the shortest forecasting increment (i.e. if 5-minute forecasts are required, historical observation data in 5-minute intervals is requested). Vendors are requesting the real-time observations to use the same interval (or shorter) as used for the shortest forecasting interval.

Due to restrictions on travel caused by the COVID-19 outbreak, the complete arrangement of automatic data exchange has been challenged. The automatic upload of measurement data to GSE sFTP server was established only for one potential location of wind farm, whilst for the 4 out of 6 locations (one is existing wind farm) the upload of the data to sFTP server is performed manually with the delay of one week and for some location up to month.

As known, Data logger - *a device that receives measurement signal from sensors, converts it to value, stores it as a data and then communicates with modem to transfer files* - needs to have updated firmware software and must be reconfigured to generate measurement files and transfer it more frequently. In most of the cases, the upgrade of firmware software and reconfiguration may be done remotely without accessing datalogger at site. Unfortunately, it was not the case for GFP.

However, despite the hurdles on data exchange, the experience gained from GFP shows that there is a minor need in the upgrade of infrastructure and mostly what is needed it's to line up the proper data exchange between data loggers, SCADA and GSE sFTP server.

Due to the increased frequency of measurement data transfer files, datalogger and modem will be active longer and consume more power compared to the mode that considers once per week or day access to the datalogger memory. This might trigger a need for upgrading the power supply equipment of meteorological towers. The estimated cost for transportation/delivery, customs clearance and installation by a local technician is it up to 400 Euro + 40%-60%.

To line up the data exchange between the data loggers of met towers and GSE sFTP, SCADA and sFTP server, with an appropriate to the commercial sensitivity of measurement data, a new server hardware, separate from the SCADA system may be deployed. The tentative budget may be up to 2500 USD.

QWF is connected to the GSE SCADA. With the accomplishment of SCADA, high frequency data exchange will be available between SCADA and GSE sFTP server.

To ensure the operability of a centralized forecasting system, the Australia Energy Market Operator and California Independent System Operator made instantaneous measurements and its transfer mandatory. Instantaneous means values are updated at least every 4-10 seconds, with 4 seconds or faster preferred. If only averages are available, the maximum 15-second average update is required.

Below is provided a list of recommendation that may be useful in overcoming the data exchange issues that remain under the GFP:

(a) Correctly calibrated and computed nacelle sourced wind speed is an accepted source of met data;
(b) Correctly calibrated and computed meteorological tower sourced wind speed from potential locations is an accepted source of met data;
(c) Light Detection and Ranging (LiDARs) will need to be able to comply to a delivery percentage of 98% in Georgia in order to be acceptable alternatives to meet masts and nacelle-based measurements;
(d) LiDARs may be used as a calibration/verification method according to IEC61400-12-1:2017 to proof correctness of met masts or nacelle sourced data signals. The complexity of flow and need in data post processing should to be considered;
(e) Radars data may be deployed for improvement of forecast however it needs to be further studied, needs a common platform for data exchange and existence of a forecasting model that is capable to utilize it;
(f) Data upload to GSE sFTP server needs to be automated;
(g) Sampling and Provision of all met and power data signals through the SCADA may be a minimum of 1-minute average based on a minimum of 12 sub-minute sample points;
(h) Sampling and Provision of all met data signals from potential locations may be a minimum of 5-10-minute average based on a minimum of 12 sub-minute sample points;
(i) As the backup of power data at the wind farm connection point under the SCADA system,

GSE may deploy power data at generation output with the same sampling intervals and data transfer intervals. Or vice versa;

(a) The capability of GSE SCADA needs to be checked and tested regarding (g), (i) and (h) should be double checked with developers of wind farms;
(b) Accurate met data should be provided by existing and potential wind farms 98% of the time;
(c) Continuous quality assessment of met data should be part of the forecasting system;
(d) Annual surveying of wind developers on performed sensor calibration should be part of the forecasting system;
(e) For existing wind farms, signals provision for each wind turbine availability, active power availability, MW set point, should be a requirement with validation by forecasters;
(f) Incorporation of announcements by wind farms on full and partial scheduled and non-scheduled outages should be entered into the wind farm SCADA system;
(g) The upgrade of met towers power supply to ensure the increased data transfer intervals should be the responsibility of wind farm developers;
(h) To line up the data exchange between the data loggers of met towers and GSE sFTP, SCADA and sFTP server appropriate to the commercial sensitivity of measurement data new server hardware, separate from the SCADA system may be deployed.

Following the present report, as a next step GSE may evaluate the capability of wind farm developers to measure data transfer and ask contractor, engaged in SCADA upgrade, to arrange automatic data upload of measurement data from SCADA to GSE sFTP server. GSE will further proceed with the Draft Amendment to Network Rules -Wind Power Forecasting Regulation that makes data measurement and data sharing to dispatch licensee mandatory.

The benefits from following the recommendations in this report can be:

- Reduced imbalance charges and penalties;
- Competitive knowledge advantage in real-time and ‘day-ahead’ energy market trading;
- More efficient project construction, operations, and maintenance planning.

1. CURRENT STATE OF WIND POWER FORECAST IN GEORGIA

For the last 4-5 years, the awareness of the need for developing VRE forecasting has increased in Georgia. Ten Year Network Development Plan (TYNDP) approved in 2016 and then in subsequent years, highlighted the unmet needs of renewable energy forecasting and helped to identify the research requirements and implementation strategies for VRE forecasting services.

As a result of the Program's Program technical assistance provided to GSE, it has access to wind power forecasts and weather parameter prediction at 7 locations from March 2020. One from 7 location it is a QWF with 20 MW installed capacity. The remaining 6 location represents potential wind farms, with the perspective to be constructed and commissioned in the nearest future.

Figure 1: Schematic Map of Locations

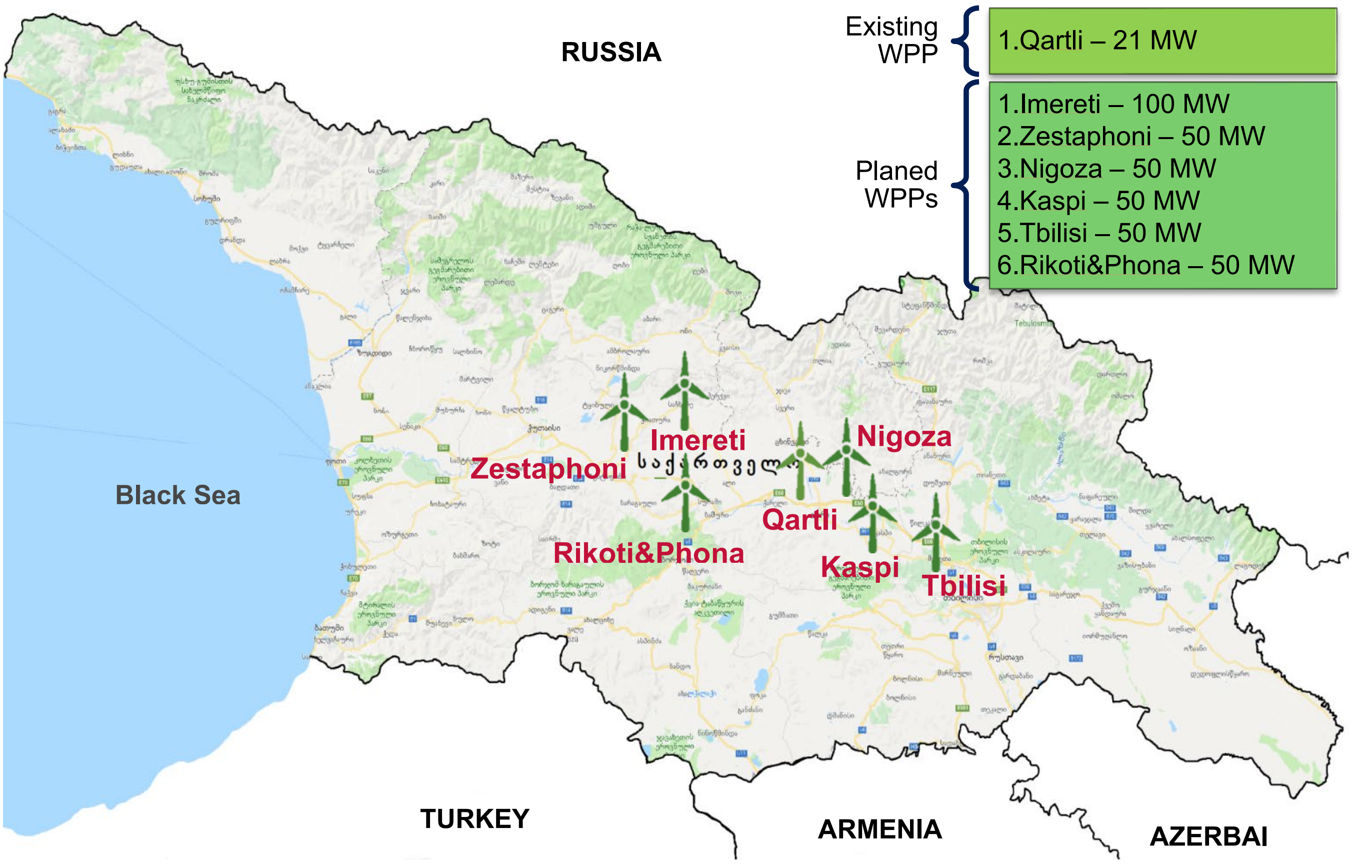

Table 1: Forecasting Specifications

Type of forecast		Time horizon	Update intervals	Granularity	Forecasted Parameters
Day Ahead (DA)	Deterministic	36 hours Ahead	Hourly	15 min	**Active Power** in MW **Wind Speed** - m/s **Wind Direction** - Degrees from true North **Temperature** -Celsius **Barometric Pressure**
Intra Day (ID)		3 hours ahead	Hourly	5 Min	

Deterministic forecast of power (MW) and meteorological parameters (Wind Speed m/s, wind direction -degrees, temperature-Celsius) are available in a DA and ID format with a 36 hour ahead and 3 hours ahead of time horizon respectively.

The DA forecast has a granularity of 15 minutes whilst ID forecast has lower granularity-5 minutes. Both DA and ID forecasts are updated hourly.

At the designing phase, the preference was given to the Centralized Forecasting System implemented through the delivery of Forecasting Services by vendors. At the same stage, the delivery of forecasting services was selected as a time and cost-effective solution for the implementation of wind power forecasting system.

Currently, UL AWS True Power the worldwide known vendor of forecasting services and Denmark company ENFOR are employed for the delivery of forecasting services to GSE.

Forecasts are accessible for GSE at GUI as Data Handling and Visualization Tool as well as at sFTP server under the disposal of GSE.

Table 2: GSE sFTP Server Data Exchange Specifications[1]

Item	Qartli 21 MW	Imereti 100 MW	Zestaphoni 50 MW	Kaspi, Tbilisi, Nigoza, Rikoti & phona, total 200 MW
Data Transfer intervals	Once a week	Once a Day	Once a Month	N/A
Data Granularity	1 min	10 min	10 min	N/A
Type of Data	• Active Power • Wind Speed • Wind Direction • Temperature	• Wind Speed • Wind Direction • Temperature • Pressure	• Wind Speed • Wind Direction • Temperature • Pressure	N/A
Upload on sFTP	○ Manual	✓ **Automatic**	○ Manual	N/A

As depicted in Table 2, power and meteorological data comes to GSE sFTP server with delays and its uploading is not automated yet for all locations. The measurement data upload close to real-time significantly improves the accuracy of the wind power forecast.

The Improvement data exchange has been challenged by travel restrictions caused by the COVID-19 outbreak. There was a need to upgrade data logger's software. Hence, the technical specialist had to arrive from abroad and visit met mast location to reprogram data loggers. As travel was restricted, the upgrade of software turned challenging.

In the case of QWF, the data has satisfactory granularity but transfer mean and intervals have plenty space for improvement. Automation and the increase in frequency of data transfer intervals pending accomplishment of SCADA upgrade project.

The measurement of meteorological data (Wind speed and direction, temperature and barometric pressure) is performed at nacelles of existing wind farm and also at Meteorological towers[2] located to the proximity of mentioned 6 locations, Before the commissioning of Wind Power Plant (WPP), main purpose of meteorological parameter measurement is the resource assessment. The measurement of power parameters is performed at the output of generators, plant transformer and at GSE substation.

Measurement data is collected at GSE sFTP server and access to the measurement data is granted to only forecasting service providers. Both power and metrological parameter measurement data is normally considered commercially sensitive and confidential. Access to the measurement data was granted to UL and ENFOR after signing a Confidentiality Agreement with GSE. Also, GSE had a Confidentiality Agreement with operators' developers of wind farms.

The automated data exchange happens between the vendors forecasting model and GSE sFTP server. The upload of forecast csv. extension files to GSE sFTP server is automated as well. In general, sFTP server is a mean of data exchange between GSE and Forecasting Vendor, GSE and Operator developer. Also, it stores measured data and forecast files as well.

Alongside the forecast files uploaded each hour to GSE sFTP server forecasts, and graphs visualizing forecasted and measured parameters are available through the vendors GUI.

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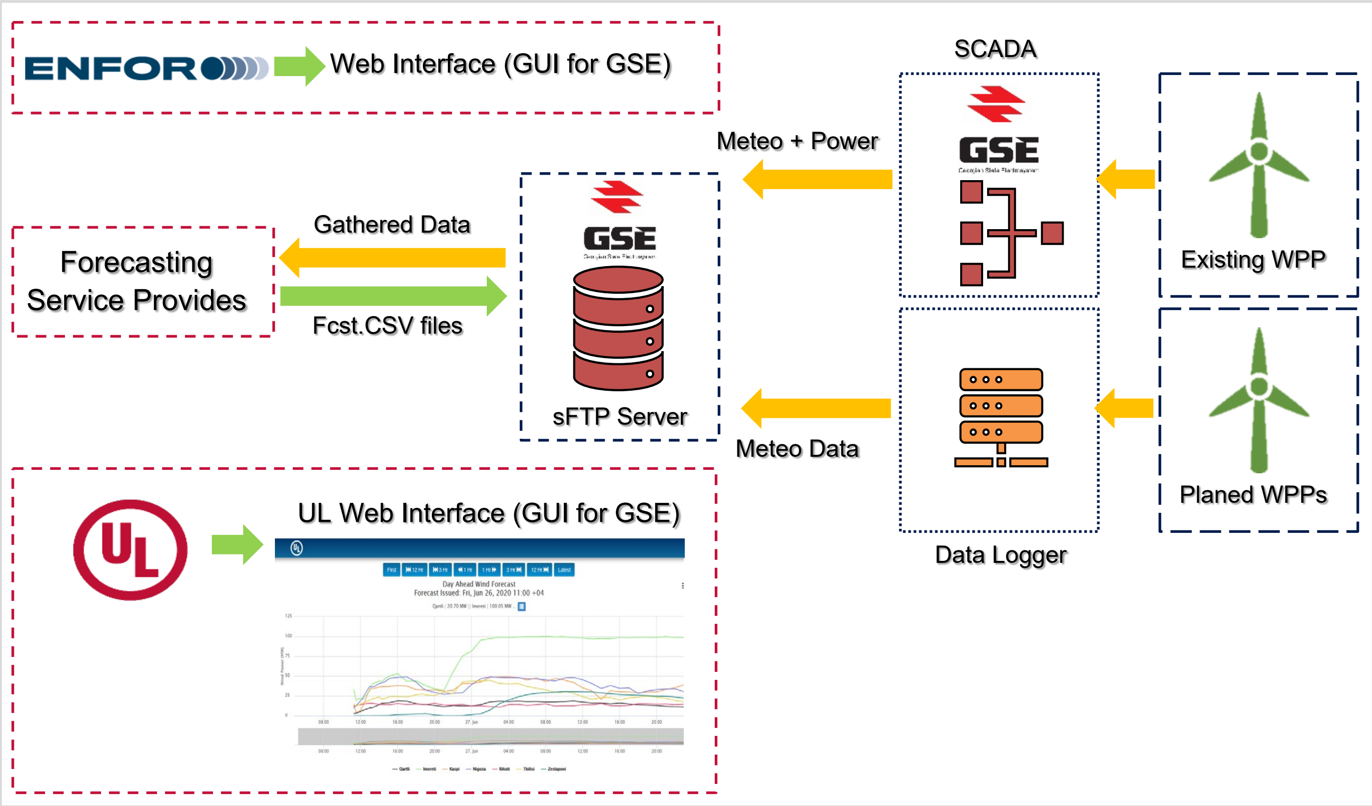
[1] GSE 5th October presentation at Gori -Wind Power Forecasting

[2] A tower used at a potential project site which has equipment attached to it which is designed to assess wind resource. Generally, a met tower will have anemometers, wind direction vanes, temperature and pressure sensors, and other measurement devices attached to it at various levels above the ground.
Source: http://www.windustry.org/resources/meteorological-tower-met-tower#:~:text=A%20tower%20used%20at%20a,designed%20to%20assess%20wind%20resource.

Figure 2: The Schematics of Data Exchange for Wind Power Forecasting[3]



[3] GSE Presentation 5th of October Gori Wind Power Forecasting

2. WIND POWER FORECASTING DATA REQUIREMENT

GEORGIA WIND POWER FORECASTING PROJECT DATA REQUIREMENT

There are two types of data inputs requested by vendors of forecasting service, which may be referred to as: “Static” data and “Dynamic” data. Static data includes information about the facility and any historical meteorological and generation observations available from each site. Dynamic data refers to meteorological and generation data that can be collected and made available to UL in real-time. A detailed listing of the requested static and dynamic data is provided below.

Vendors requested that the following static plant data be made available for each wind facility / location:

- Facility Name;
- Location - Center Point Latitude and Longitude;
- Sensor locations (latitude and longitude) and instrumentation heights;
- Turbine technology: manufacturer and model, height, number of turbines, power curve, cut in and cut out speeds;
- Rated MW capacity;
- Historical generation observation data from the plant for a period of 12-24 months prior to the start of forecasting if available, otherwise for as far back as is available;
- Historical meteorological sensor data from the equipment that will provide dynamic (real-time) meteorological data for 12-24 months prior to the start of forecasting if available, otherwise for as far back as is available.

Vendors requested the historical observations to be provided at the same interval as the shortest forecasting increment (i.e. if 5-minute forecasts are required, historical observation data in 5-minute intervals is requested).

The dynamic data, delivered in real-time, includes current observations from the facility. This data is incorporated into the forecasting system in real-time and can significantly impact the quality of short-term forecasts (predictions over the first few hours after time of forecast delivery). Vendors can forecast with no dynamic data, but optimal forecast accuracy will be achieved with the inclusion of Dynamic data.

The following summarizes the dynamic data requested from an individual wind plant:

- Real-Time MW production;
- Observed availability in MW;
- In advance - Outages, maintenance or similar (only for the site with a wind farm);
- In Advance - Curtailments or similar (only for the site with a wind farm);
- Wind speed and direction at hub height;
- Temperature;
- Pressure.

Vendors requesting the real-time observations to be used at the same interval (or shorter) as will be used for the shortest forecasting interval.

Timely receipt of representative observed generation data is particularly important to ensure high-quality short-term generation forecasts.

Plant availability is the key to developing a representative training sample for statistical models. If plant availability cannot be supplied, then all output forecasts will assume 100% plant availability.

Meteorological data helps provide insight into the current conditions on site and is also critical for use in quality controlling the generation data.

CAISO AND AEMO - DATA REQUIRED FOR FORECASTING SYSTEM

High forecast accuracy is dependent on an optimal combination of data from SCADA System, representing the lower production and also the availability of meteorological data from wind turbine, and the input from NWP models depending on the forecasting time horizon. In ideal cases, in which the SCADA data are both online and of high-quality, statistical and hybrid prediction models generally produce the greatest degree of forecast accuracy.

To ensure the operability, accuracy and reliability of the forecasting system, Australian Energy Market Operator (AEMO) and California Independent System Operator (CAISO) made the supply of static and dynamic data mandatory for wind farms. The technical specifications of wind farm, together with geographical and topographical data are considered under the static, whilst the delivery of the real-time data on instantaneous measurement of power generation and measurement of certain meteorological parameters are mandatory under the dynamic.

According to the mentioned requirements for Wind Power prediction, SCADA Instantaneous measurements are required. Instantaneous means, values updated at least every 4-10 seconds, with 4 seconds or even faster preferred. If only averages are available, maximum 15-second average update is required. The provision of historical data is preferred with the same granularity of data which is required for instantaneous measurement.

Both AEMO and CAISO set specific requirements regarding the existence of meteorological measurements and for the existence of the specific meteorological equipment. In the case of wind, the preference is given to meteorological parameters measured on nacelles of wind farm, however according to the CAISO data requirement the meteorological measurement data may derive from met tower and Remote Sensing Devices such as LiDAR and Sonic Detection and Ranging (SoDAR) located at the very proximity of wind farm.

Table 3 represents the Current Production - Meteorological and Turbine Availability Data requirement set by the AEMO to produce the forecasts through Australian Wind Energy Forecasting System (AWEFS).

Table 3: AEMO Forecasting Data Requirement[4]

1 2 3	W W W	Name DUID Region
		Wind farm Status
4 5 6	W W W	Status of the wind farm From which date is or will the wind farm be fully operational? From which date will the wind farm be first connected to the grid or energised?
		Wind farm nominal data
7 8 9	W W W	Nameplate Rating Maximum Capacity Wind Turbine Characteristic Curves for each turbine
		Wind farm location & terrain data
10 11 12 13 14 15 16 17 18 19	W W W W W W W W W W	Geographical coordinates (UTM WGS-84) Geographical coordinates Wind farm altitude Wind farm geometry Orography information Mesoscale roughness coefficient Roughness of surrounding area Met mast measuring height Met mast Geographical coordinates Air density
	Wind Farm SCADA to AEMO:	

[4] Australian Energy Market Operator Energy Conversion Model

20	W	
21	W	Wind farm active power
22	W	
23	W	Number of wind turbines available for generation data Number of wind turbines
24	W	actively generating
25	W	Local Limit Estimated Power
26	W	Wind speed data
27	W	Wind direction data Temperature data
28	W	Wind Farm Control System Set-Point Pressure or humidity data
29	W	
30	W	
31	W	SCADA data available from this wind farm
32	W	

DUID – Dispatchable Unit ID; UTM WG S – Universal Transverse Mercator.

Instantaneous measurements are required unless otherwise agreed by AEMO. Instantaneous means values are updated at least every 4-10 seconds, with 4 seconds or faster preferred. If only averages are available, the maximum 15-second average update is required.

For the AEMO, measurement of wind speed and direction from turbine nacelle anemometers are much preferred than measurements from meteorological mast(s).

CAISO, in his data requirement, goes further and sets requirement on the number of installations and the type of equipment to support an accurate power generation forecasting and the communication of such forecast, meteorological and other required data.

Apart from the meteorological data from met-towers and meteorological stations, CAISO is requesting nacelle wind speed from Wind Power Generators (WPGs) and direction from the Designated Turbine[5].

These are the CAISO required wind meteorological data points for WPG participating in CAISO markets.

Table 4: CAISO Required Meteorological Data[6]

Element	Device(s) Needed	Units	Accuracy
Wind Speed (Meter / Second)	Anemometer, wind vane and wind mast	m/s	± 2m/s
Air Temperature (Degrees Celsius)	Temperature probe & shield for ambient temp	ºC	± 1º
Barometric Pressure (hectopascals)	Barometer	hPa	± 60 hPa
Real Time Data	Metering of Power	MWs	

m / s – Meter / Second; ⁰C – Celsius; hPa – Hectopascal.

A wind power generator with the installed capacity of more than 5 MW, requires the installation of a minimum one meteorological tower and two meteorological stations, measuring the barometric pressure, temperature, wind speed and direction. The meteorological tower should be located on the windward side of the wind farm. One meteorological station is required to be installed at the average hub height of the wind turbines. The second meteorological station may be co-located on the primary meteorological tower and be installed approximately 30 meters below the average hub height.

Where the placement of meteorological station tower(s), in accordance with this requirement, cause a reduction in production or violation of a local, state, or federal statute, regulation or ordinance, the CAISO, in coordination with any applicable forecast service provider, will cooperate with the WPP to identify an acceptable placement of the meteorological station tower.

The use of Sonic Detection and Ranging (SoDAR)[7] and / or LiDAR[8] equipment may be an acceptable substitute for wind direction and velocity, based on the consultation and agreement with the forecast service provider and the CAISO.

The measurements for telemetry data points should be sent to the CAISO in real time (i.e., 4 seconds) from wind power generators.

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[5] Designated Turbine - A turbine designated by the CAISO, in which nacelle wind speed and generation in MW is required
[6] California Independent System Operator Business Practice Manual for Direct Telemetry
[7] SODAR – Sonic Detection and Ranging- a meteorological instrument also known as a wind profiler which measures the scattering of sound waves by atmospheric turbulence
[8] LIDAR – Light Detection and Ranging - a meteorological instrument which measures the properties of scattered light waves caused by atmospheric turbulence.

3. GEORGIA - POTENTIAL SOURCES FOR DATA FOR WIND POWER FORECASTING

Forecast models mostly need input such as meteorological observational and power measurement data, as well as data on weather parameter predictions that come from NWPs. Forecast error and accuracy vary and depend on factors that can be controlled by system or plant operators and factors that are beyond control.

Input that comes from NWP, as well as terrain characteristics, may be considered as an Uncontrollable factor for System or WPP operator, whilst under the Controllable factors may be considered:

1. The existence of required power and weather parameter measurement data;
2. Availability of the data for 98% of time – Measurement and delivery of data without the minimal interruption;
3. Data Transfer Intervals;
4. Data Quality and its reliability.

Below provided Table 5 indicates the sources of data that may be useful if deployed as an input for wind power forecasting. Supplementary to the data sources, listed in Table 5, the weather data from meteorological radars may be deployed as a supplement to those measured at Wind Farm Locations.

However, for this report, data from radars will be attributed to the Uncontrollable Factors, because:

- Those radars are under the disposal of environmental or semi military agencies, as well as under the disposal of air or marine navigation agencies – data exchange negotiations may be challenging if a common platform does not exist.
- During the study of forecasting models, the capability to utilize weather data from radars for wind and solar power forecasting were found only under the portfolio of the National Centre of Atmospheric Research[9];
- The possibility to utilize radar data is subject to separate scientific study, that may be time-consuming and requiring resources.

Table 5: Potential Sources of Data Required for Forecasting

Parameter	Source						Importance for Forecasting
	Existing Farm					*Potential Wind Farm*	
1	2	3	4	5	6	7	8
Power In MW	WPP SCADA	Electricity Meters					High
Availability	WPP SCADA						High
Plant status	WPP SCADA						High
Setpoint	WPP SCADA						High
Wind Speed	WPP SCADA	Anemometers on Nacelle +Data Logger	Ispin Anemometer on Rotor	Nacelle Mounted LiDAR Ground Based LiDAR or SoDAR	Anemometers on met towers +Data Logger	Ground Based LiDAR or SoDAR	Medium
Wind Direction	WPP SCADA	Wind Vanes on Nacelle +Data Logger	I spin Anemometer on Rotor	Nacelle Mounted LiDAR Ground Based LiDAR or SoDAR	Wind Vanes on met towers +Data Logger	Ground Based LiDAR or SoDAR	Medium
Temperature	WPP SCADA	Sensors on Nacelle or other appropriate		Nacelle Mounted LiDAR	Sensors on Met Tower +Data Logger	Ground Based LiDAR or SoDAR	Lower than Medium in non-icing conditions

[9] https://ral.ucar.edu/projects/forecasting-for-wind-energy

Parameter	Source						Importance for Forecasting
	Existing Farm					Potential Wind Farm	
1	2	3	4	5	6	7	8
		location + Data Logger		Ground Based LiDAR or SoDAR			
Barometric Pressure	WPP SCADA	Sensors on Nacelle or other appropriate location +Data Logger		Nacelle Mounted LiDAR Ground Based LiDAR or SoDAR	Sensors on Met Tower +Data Logger	Ground Based LiDAR or SoDAR	Lower than medium

THE EXISTENCE OF MEASUREMENT DATA

In Table 2 GSE sFTP server data exchange specifications, the needed power and weather parameters measurements and the measurement data are available. Above provided Table 5 includes the list of potential sources of power and weather parameters, the existence and the reliability of which affect the preciseness and accuracy of forecasting. Under Table 5 column #2, #3 and #4 indicate the measurement and data sources that exist for GFP.

In terms of 98% availability, in certain circumstances, conventional instrumentation, ultrasonic and Ispin sensors outperform the remote sensing ground-based equipment (please referrer to Section 4 RSD). For instance, the operation of the Lidar is influenced by atmospheric conditions (e.g. fog, density of particles in the air). Rain and dirt on output window also reduces the Lidar's ability to measure. If properly arranged, conventional instrumentation in most of the cases outperformers the availability of RSD.

AVAILABILITY OF THE DATA

In Table 2 GSE sFTP server data exchange specifications, the needed power and weather parameters measurements and the measurement data are available. However automatic exchange and the availability of data, its quality and high frequency of data transferring needs attention and due to the certain circumstances challenged.

The efficient way to overcome these hurdles is to set mandatory the measurement and delivery of the measured data to GSE Dispatch Licensee.

If assumed that the measurement of meteorological parameters according to the international standards and guidelines is a primary interest of wind farm operators and developers of wind farms, and the data quality control is handled by the providers of forecasting services, currently Georgia Wind Forecasting Project is primarily focused on ensuring the high frequency data transfer intervals and automation of data exchange.

There are Wind power industry-specific standards that are deployed to ensure the proper measurement (Please refer to Section 5 subparagraph Standards for Wind Measurement).

DATA TRANSFER INTERVALS

As for AEMO and CAISO the data transfer intervals are set mandatory close to real time.

AEMO - Instantaneous measurements are required unless otherwise agreed by AEMO. Instantaneous means values are updated at least every 4-10 seconds, with 4 seconds or faster preferred. If only averages are available, the maximum 15-second average update is required.

CAISO - The measurements for telemetry data points should be sent to the CAISO in real time (i.e., 4 seconds) from wind power generators.

The threshold that GFP vendors of forecasting services set for data transfer intervals, considers no more than 5 min data transfer intervals for ID forecast, whilst for DA, according to the request, it may be no more than 15 min data transfer intervals.

When GSE SCADA upgrade is completed, no more than 5 min data transfer intervals may be easily achieved because the retrieval of data through the I Level SCADA under the disposal of GSE Dispatch Licensee may have a higher frequency like once per 1 minute and less.

A bit challenging may be achieving no more than 5 min data transfer intervals for those locations where the wind parameter measurement is performed for the resource assessment purpose -i.e. potential wind farm locations.

Below are justifications based on the example of the Ammonite Meteo 40 Datalogger Manual. Ammonite is a company amongst the wind industry leader supplying equipment for wind and solar resource assessment.

JUSTIFICATION

Meteo-40 consists of two basic systems[10]: The Measurement and Recording System (MARS) and the Configuration, Evaluation and Communication System (CECS). For measuring and recording data, only MARS is needed. MARS is designed to work with minimal power consumption. It controls the analog data logger hardware, measurement channels and data storage.

CECS will be started by MARS according to the configured time schedule, e.g., to upload measurement data. After the scheduled actions have been executed, CECS turns off automatically to reduce power consumption.

For Supervisory Control and Data Acquisition System SCADA operation, CECS[11] will run permanently. This is possible by means of the CECS always active mode. Otherwise CECS is configured to run for 20 minutes, before it automatically turns off. When the time is expired and an action is still running, e.g., sending an email, the system will wait until the action is finished and will switch off afterward.

POWER SUPPLY COST ESTIMATION

In view of the above mentioned, CECS will remain activated if data transfer intervals are set to10 min for the only those locations where the weather parameters measurement are available.

This in turn means increased power consumption.

To estimate the required power consumption the Ammonite Meteo 40 power supply estimation tool has been deployed.

Assumptions:

a) Instead of 1 hour a day modem is available 24 hour a day;
b) Extra consumption during the transmission of the data is 24 times more instead indicated 20 min during the day.

Daily Consumption estimated as a 103 Watt/hour and considering the 8 days of autonomous work requirement the capacity of battery can be estimated to 50 Ampere/hour at nominal voltage 12 Volts.

Approximate cost for power supply equipment to satisfy the requirement of above provided estimation provided below:

Table 6: Power Supply Estimation

Power supply, „Advanced“ for measurement system and aviation signal lights
• 1x charge regulator Solarix PR1010
• 1x battery (VRLA-AGM) 12V, 50 Ah (maintenance free, non-spillable, incl. safety data sheet for aviation transport)
• 2x solar panel 40 Wp (2.0 m cable) incl. mast support
Total cost 390Euro.

With the delivery custom clearance and installation, the cost may be increased with 40%- 60%.

TYPE OF DATA THAT IS AVAILABLE FROM DATA LOGGERS

It is possible to request both live data and statistics over SCADA. For the statistics to be calculated, a time interval must be selected. The stat interval, usually 10 min, can have the following values:

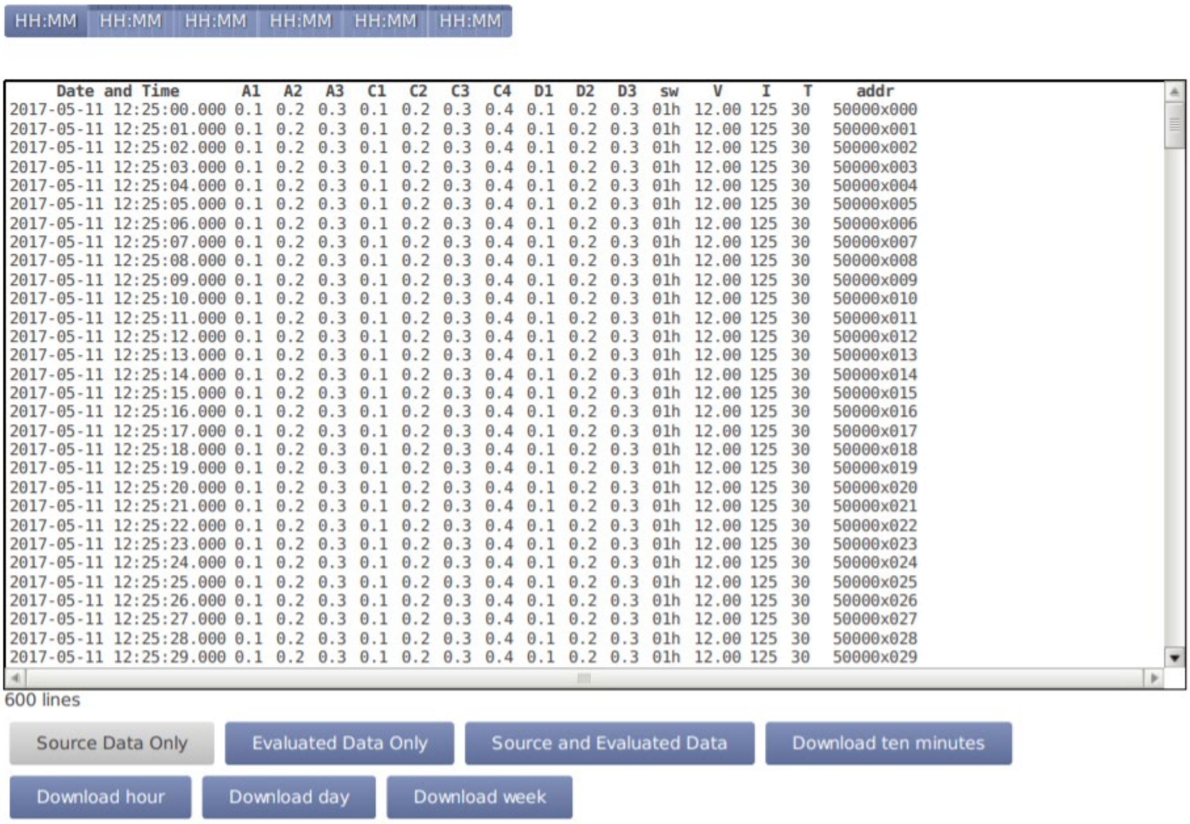
[10] Data Logger Meteo-40 1.4 The Two Systems of Meteo-40
[11] Data Logger Meteo-40 1.4.1 CECS: Switch on / off behavior

Table 7: Available Statistics Intervals of Datalogger Meteo 40

1 s	2 s	3 s	5 s	10 s	20 s	30 s
1 min	2 min	5 min	10 min	15 min	20 min	30 min
			1 h			

Also, for the download its available Source Data[12] that can be with the one second granularity as its indicated at Figure 3.

Figure 3: Statistical Intervals of Measurement Data Sored in Datalogger Memory



The source data storage is organized as a ring buffer, which means that the oldest data will be overwritten, when the storage is filled entirely. For compactness reasons data is saved in a binary format and cannot be read directly.

Comma-Separated Values (CSV) extension files with the measurement data can be uploaded to sFTP[13] server. Meteo-40 stores[14] measurement data in standard CSV format with appended information in ini file format. In almost all cases, the CSV files created by Meteo-40 are compressed using GNU gzip (http://www.gzip.org/).

Connection of Data logger and SCADA[15] may be established over RS485 (Modbus RTU) and over Ethernet (Modbus TCP/IP), whilst with the modem access (data logger connected to modem, e.g., GPRS/GSM, directional radio, satellite) Data transfer can be performed via email Secure, Contain and Protect (SCP) / File Transfer Protocol (FTP) / sFTP, AmmonitOR or manual data download via web interface).

[12] Data Logger Meteo-40 6.7 Access to Source Data
[13] Data Logger Meteo-40 User's Manual 7.6 Configuring SCP, FTP and SFTP Parameters
[14] Data Logger Meteo-40 User's Manual 6.6 The CSV File Format
[15] Data Logger Meteo-40 1.7 Communication Methods and Required Devices

DATA TRANSFER INTERVALS

Menu of Ammonite Meteo 40 datalogger allows configuring the schedule[16]. Configuring the scheduling includes defining the communication behavior during a day and selecting on which e CSV file transfer intervals and data transfer method such as sFTP, weekdays an action should be performed.

SCP / FTP / sFTP on below provided Figure 4 Indicates, when and how often CSV file(s) should be uploaded to a configured server using SCP, FTP or sFTP. If necessary, CSV files are generated automatically before upload.

Figure 4: Configuring the Schedule [17]

Action	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Start time	Duration	Quantity	Interval	Next	
Online	☒	☒	☒	☒	☒	☒	☒	12:00	00:20	1	0:00	2017-05-12 15:48	Run now
AmmonitOR	☒	☒	☒	☒	☒	☒	☒	12:00		1	0:00	2017-05-12 15:48	Run now
Email	☒	☒	☒	☒	☒	☒	☒	12:00		1	0:00	2017-05-12 15:48	Run now
FTP/SCP	☐	☐	☐	☐	☐	☐	☐	12:00		1	0:00	2017-05-12 15:48	Run now
Only generate CSV	☐	☐	☐	☐	☐	☐	☐	12:00		1	0:00	2017-05-12 15:48	Run now

Save

CSV generated by Datalogger memory may contain two types of information – measurement and statistical data. The primary point of interest for GFP is measurement data.

Under the Quantity column among the FTP / SCP raw user enters the number of actions, which should be performed during a day. After changing the Quantity to a number higher than 1, an Interval can be entered. The last action will be performed at the latest at midnight, even if the user's defined a number of actions has not been achieved.

Manual just sets the input method for the quantity- Enter the Quantity as integer, e.g., 2, 3, 4. without the indication of maximum number of communications per day. That, in the case of 5 min intervals would be equal to the 288.

However, in the CSV-file that represents statistics and that can be uploaded to the sFTP server lines can be created from 1/4 s to 1 h interval whilst the new aggregate data file in CSV format can be created from every 5 minutes to weekly.

Statistics interval[18] for files Defines over which time interval statistics are calculated, generating a new line in the CSV file. All current data that has been collected since the last generated file is considered to generate new aggregate data. Several intervals are available from 1/4 s to 1 h.

File interval Determines, how often a new aggregate data file in CSV format has to be created. Selecting Hourly, produces one file per hour that includes data from the last hour. Daily generates only one file per day, etc. Several intervals are available from every 5 minutes to weekly. The file interval is also applied to Gust data files.

Generate partial files Generate CSV files up to the current moment, even if the file interval has not yet finished.

In the case of GFP, once per day 10 min granularity data automatic upload is available only for one location. From the remaining location where the measurement data is available, measurement data needs to be uploaded manually when received through email. As a probable reason mentioned for challenged automation of data exchange, and for decreasing the data transfer intervals, in most of cases it was mentioned problem with the remote upgrade of data logger firmware version and the need to access data logger to upgrade firmware version at location.

[16] Data Logger Meteo-40 7.2 Configuring the Communication Schedule
[17] Data Logger Meteo-40 7.2 Configuring the Communication Schedule Fig 7.1 Configuring the schedule
[18] Data Logger Meteo-40 6.3.1 Configuring Statistics and CSV files

With the consideration of above mentioned, under the frame of GFP project, it was impossible to test capability of data loggers like its described in manual to transfer 10 min granularity data with no more than 10 min data transfer intervals.

Very effective will be if GSE doublecheck and request from developers of wind farms to obtain from their service organization engaged in wind resource assessment campaign:

a) The model and version of datalogger / or Met tower Commissioning report;
b) Firmware version of datalogger;
c) Data logger manual;
d) According to manual and Real - The technical specification on the capability of datalogger to create files containing measurement information>Format of file i.e. file extension > Statistical interval > interval between the files generation;
e) According to manual and real - the minimum and maximum quantity that may be set for number of communications per day/24 hours;
f) Installed solar panels model, panel peak capacity in watt, and number of modules;
g) Deployed battery and indication of capacity in Ampere Hour;
h) Ask whether they are capable to generate each 5 minute the measurement data file with the statistical interval 1 minute or less, and set schedule for connection between the datalogger and GSE sFTP to 5 or 10 min;
i) Instruct developers on the connection to sFTP and later check their capability to follow instructions.

Whilst the above mentioned refers to the measurement data transfer intervals, the Plant availability information and its data transfer intervals still have to be discussed. What GFP project has lack from the QWF data exchange it’s a Plant Availability Data.

DATA QUALITY AND RELIABILITY

Each nacelle of QWF is equipped with two sets of sensors for the measurement of wind speed and wind direction. During the forecasting data requirement discussions with the developers of wind farms, one of the developers mentioned that each nacelle of the planned wind farm will be equipped with a complete set of meteorological sensors.

If assumed that Nacelles of wind turbines is equipped with two pair of sensors for wind speed and wind direction measurement, and is supplemented with the temperature and barometric pressure sensors, in case of proper arrangement and installation, the 98% availability of measurement can be ensured. Even, if one pair of wind speed and direction sensor (important parameter for forecasting) underperforms or malfunctions, the second one will perform the measurement of necessary parameters.

As for metering the power, if the metering at the connection point fails, as a substitute GSE may provide metering data measured at the output of the generator or vice versa. For GSE both types of measurement data may be available under the SCADA. For reliability, it would be nice to have power data metered as a back-up, at each generator output of QWF.

In the case of potential locations, Wind speed and wind direction sensors are installed on meteorological towers (see paragraph 4 Wind Measurement Equipment Fig 5 Sensor Location Schematics on Met Tower) at different heights. If one pair of sensors for wind speed and direction measurement fails, data may be supplied from the pair installed at a lower height.

Since the quality of the data is a primary interest of Operators and developers, indirectly the quality of data can be ensured as well. For wind resource assessment and wind turbine power performance testing, the most important part is to properly arrange weather parameter measurement equipment according to the industry standards (please see section 5 Wind Measurement and WPP Monitoring Standards). Another factor that affects the quality, reliability, and preciseness of the wind parameter measurement it is the periodical calibration of the sensors (see section 4. Calibration of Sensors).

The high quality and reliable measurement data come from sensors that are high quality, properly installed at specific height and location, time to time when needed calibrated and maintained.

Moreover, there is a possibility to allocate data quality controlling duty to the provider of forecasting services. The other option may be to perform the so-called Control Measurements with the deployment of RSD. However, the deployment of RSD may serve as an effective tool in revealing improper measurement but will be very ineffective during the disputes between system operator and wind farm operator if the proper measurement of the meteorological parameters is of great importance.

Here we would like to provide an example of a dispute between parties on improper metering of power. To resolve such disputes, parties apply to accredited laboratories where it can be proved whether or not the device-meter is properly measuring the power. This may be true for wind measurement equipment as well, but there is a slight difference - In Georgia. The MEASNET (International Network for Harmonized and Recognized Measurements in Wind Energy) accredited laboratories are not available here, the ones that have under the disposal Wind Tunnel - a specific installation for calibration of Wind measurement equipment.

Current arrangement of GSE (Dispatch licensee) I level SCADA element is satisfactory for receiving Power and measurement data from QWF Meteorological and Electric Component. However, GFP project lacks Plant Availability Data from the QWF data exchange.

Actually, Plant Availability data is not the measurement, it is estimated information and values that are generated by the Wind Farm SCADA. According to the existing network rules II and III level SCADA and data transmission equipment must be arranged in agreement with the GSE Dispatch licensee. During the agreement process, the future of below-listed information through the SCADA may be arranged.

If during the agreement of SCADA II and III level with wind farm operator, GSE negotiate with developer sharing the data on plant availability, this together with the approval of amendments to network rules on wind power forecasting will be efficient way for GSE to overcome the issue of sharing by wind farm the plant availability information and data

Table 8: Plant Availability Data Example

<table>
<tr><th colspan="2">AEMO Wind Power Forecasting Conversion Model
Plant Availability Data from Wind Farm SCADA</th><th>Article from existing Network Rules adopted for Georgia</th></tr>
<tr><td>Number of wind turbines available for generation data</td><td>Number of turbines available for generation. This definition is the summation of:
• Turbines operating
• Turbines available to operate, but not operating due to ambient wind conditions (very low / high wind speeds, extreme direction change)
• Turbines available to operate, but paused due to down regulation.

This definition excludes all the following cases:
• Turbines under maintenance or repair
• Turbines with a fault or damage
• Turbines not yet built
• Transmission/distribution network not available

If agreed with AEMO, turbines paused due to ambient temperature may be counted as available in this signal.</td><td rowspan="4">ARTICLE 45. OPERATIONAL COMMUNICATION BETWEEN THE DISPATCH LICENSEE, THE TRANSMISSION LICENSEE AND ELECTRICITY SYSTEM PARTICIPANTS
7. II and III Level SCADA and data transmission system shall be placed according to the following conditions(7.10.2016):
c) electricity system participants shall agree types of II and III Level SCADA and data transmission equipment with Dispatch Licensee.
d) expenses related to II and III Level SCADA and data transmission system implementation, placement and operation shall be covered by the respective participant</td></tr>
<tr><td>Number of wind turbines actively generating</td><td>Number of turbines actively generating power</td></tr>
<tr><td>Local Limit</td><td>In MW, the SCADA Local Limit for a wind farm is the lower of its plant availability and all technical limits on the capacity of its connection assets to export energy.
When implemented in AWEFS, the SCADA Local Limit is used to cap the UIGF for the wind farm in the dispatch timeframe.
The SCADA Local Limit excludes limits on a transmission network and distribution network (to ensure AEMO's compliance with clause 3.7B(c)(6) of the Rules), and may exclude other limits managed by AEMO through the central dispatch process.
Limits already communicated in the SCADA Turbines Available signal may be excluded from the SCADA Local Limit.
Manually-applied transient limits not intended to apply at the end of the next dispatch interval may be excluded from the SCADA Local Limit.
The SCADA Local Limit should not exceed the higher of the nameplate rating and the Maximum Capacity of the wind farm.</td></tr>
<tr><td>Wind Farm Control System Set-Point</td><td>MW set-point applied in the wind farm's control system to limit (down regulate) its output. At other times when no limit applies, the set-point to be set to above the wind farm's Nameplate Rating, but below 250% of it.</td></tr>
</table>

4. WIND MEASUREMENT EQUIPMENT

To minimize the uncertainty inherent in extrapolation, it is important to measure the wind speed as near as possible to the hub height of the planned wind turbine. For accurate measurement results, the International Electrical Commission (IEC) standard specifies how to locate met masts and the installation of cup anemometers, which have to be calibrated traceably before and after a measurement campaign. The difference between both calibrations should not exceed ± 0.1 m/s.[19]

In some cases, additional measurement stations might be useful. According to the IEC, wind speed, wind direction and air density must be measured for site assessment. Learn more about the equipment for wind measurement through the table provided below:

Table 9: Ammonite Standard Wind Measurement System and System Components

Simple Terrain	
Structure for sensors installation to the proximity of proposed hub height	Met Mast Installation
Measurement Data Collection and Transfer	• Meteo-40 data logger • Steel cabinet with terminal for Meteo-40 • GSM/GPRS modem with omni-directional antenna
Power Supply	• Power supply system with solar module and solar charge controller
Wind Speed	• 4x Anemometers, calibrated (Thies First Class Advanced)
Wind Direction	• 2x Wind vanes, digital (Thies First Class TMR)
Temperature and Humidity Sensor	• 1x Combined air temperature (Pt1000) and humidity sensor with weather and radiation shield
Barometric Pressure	• 1x Barometric pressure sensor
Optional to Met Mast Installation	• ZX 3001) (LiDAR) or AQ510 wind finder2) (SoDAR) including power supply system
Complex Terrain	
Structure for sensors installation to the proximity of proposed hub height	Met Mast Installation
Measurement Data Collection and Transfer	• Meteo-40 data logger • Steel cabinet with terminal for Meteo-40 • GSM/GPRS modem with omni-directional antenna
Power Supply	• Power supply system with solar module and solar charge controller
Wind Speed	• 6x Anemometer (Thies First Class Advanced)
Wind Direction	• 3x Wind vane, digital (Thies First Class TMR)
Wind Speed and Wind Direction	• 1x 3D Ultrasonic anemometer or propeller anemometer
Temperature and Humidity Sensor	• 1x Combined air temperature (Pt100) and humidity sensor with weather and radiation shield • 1x Temperature (Pt100) sensor with weather and radiation shield
Barometric Pressure	• 1x Barometric pressure sensor
Additional to Met-mast installation	• ZX 300 (LiDAR) or AQ510 wind finder (SoDAR) including power supply system

WIND MEASUREMENT SYSTEM COST

The supply of standard compliant meteorological mast including the installation may cost up to $100000 -except the taxes.

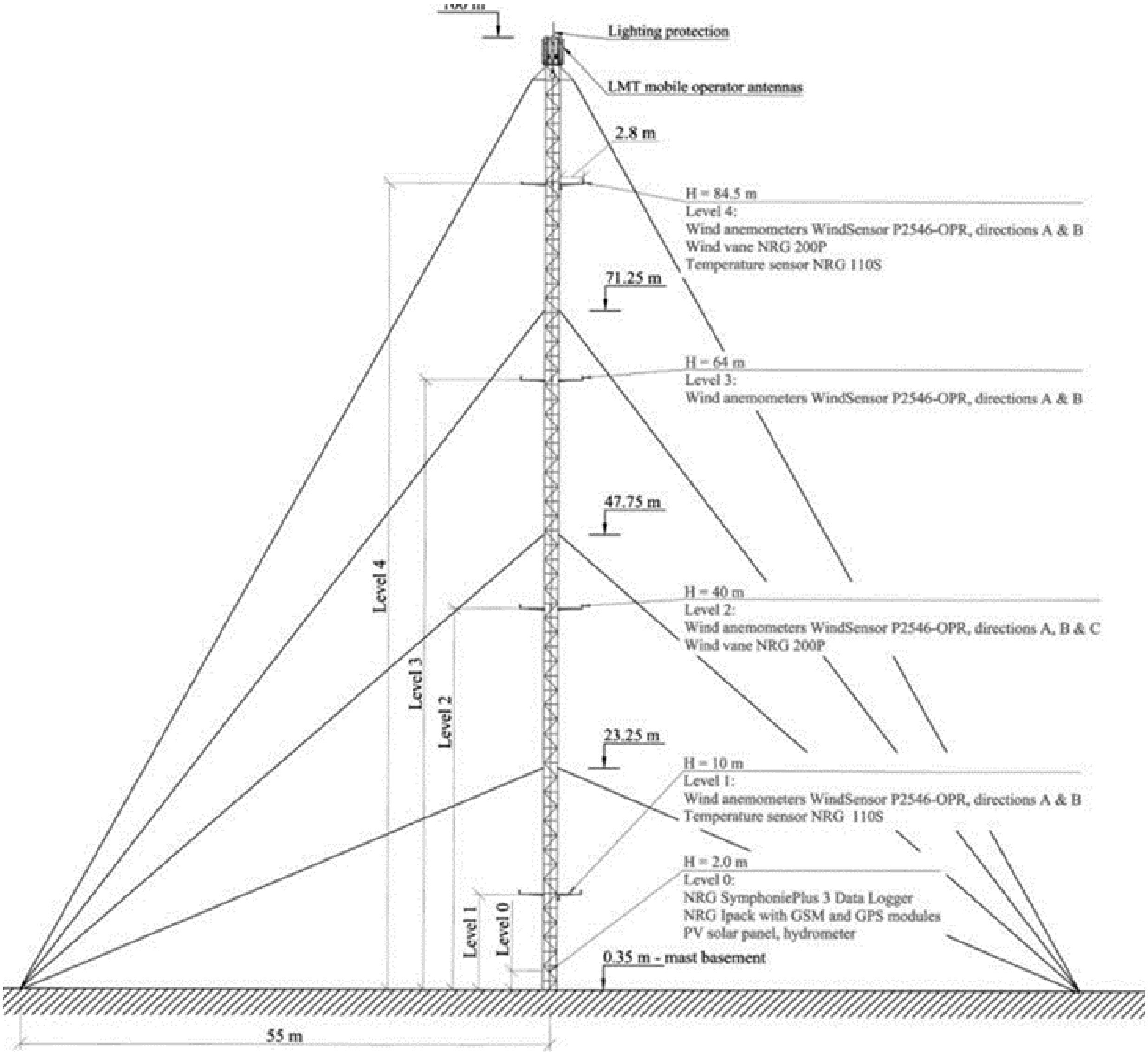
Table 10: Meteorological Tower Cost

Met Mast	Supply only (EUR)	Supply & Supervision (EUR)	Supply & Install (EUR)
80m	39.078	48.601	62.603
100m	46.068	56.422	71.095
120m	55.822	67.005	86.251
140m	67.330	79.343	100.161

[19] ammonit.com/images/stories/download-pdfs/MeasurementSystems/EN_PS_Ammonit_WindResourceAssessment.pdf

Below on Figure 5 it’s a schematics on placement of metrological sensors and the Symphonie PLUS3 measuring complex on the triangular lattice masts with 100 m height located in Ventspils, Pāvilosta and Ainaži regions, where five levels correspond to reference heights of 2, 10, 40, 64 and 84.5 m.

Figure 5: Placement of Metrological Sensors on Met Mast



If already supplied, the assembly of meteorological mast and installation of met sensors will need from 5 to 7 days and it’s a very optimistic estimation. However, if met mast components and sensors are not delivered, the delivery of all components and its installation may take up to a month.

Furthermore, considering the numbers in Table 11 Met mast installation costs is up to €30000. Based on assumption that in Georgia it will cost 6 times less, the cost for each installation may be €5000.

Beyond the met mast installation cost, one proposing wind measurement campaign must consider the cost of sensors, as well as calibration and installation cost. Below provided table represents sensor price without the installation cost.

Table 11: Illustrative Cost of Wind Measurement Equipment

Price (USD)	Type of Equipment and Standard compliance
828.00	Cup Anemometer
1,184.77	Wind Vane + Calibration
457.95	Communication -Data Transfer
5,798.00	Ultrasonic 3D anemometer + Calibration
1,98.00	Barometric Pressure measurement sensor +Calibration

Price (USD)	Type of Equipment and Standard compliance
899.00	Temperature and Humidity Sensor +Calibration
2,052.51	Data Logger
496.58	Housing for Measurement Equipment
496.58	Lockable metal shelter box / control cabinet and assembly
684.00	Power Supply System
457.95	Communication -Data Transfer

ISPIN TECHNOLOGY

The ISpin Technologies are promising. It can provide accurate and precise wind measurements on each of the turbines in a wind farm independently from the site and the wake conditions.

This method may allow the measurement of power curves on all turbines in a wind farm by adapting or even enhancing the methods described in IEC 61400-12-2 to the iSpin capabilities and to measure and monitor the performance on each of the wind turbines in the wind farm at any time during the life time. It helps to make them comparable to each other, as well as to other reference measurements (met masts, lidar, warranted power curves) and over time to detect changes in the performance. For the first time, this would enable to manage the performance of all turbines in a wind farm actively, detect underperformance as early as possible, conduct counter measures and re-establish performance[20].

Turbine performance monitoring and detection of over- and under-performers require accurate and precise data - the more accurate and precise data allows for better turbine monitoring and concurrent optimization. Using the iSpin Guardian reports, the owner of wind farm may identify wind turbine over- and under-performers.

Table 12: Capability of Nacelle Anemometer and Spinner Anemometer iSpin[21]

Quantity	Conventional nacelle anemometry	iSpin
Wind speed	NTF sensitive to different inflow condition	NTF shows robustness even in wake
Turbulence intensity	No possibility to measure	Key capability of iSpin
Flow inclination	No possibility to measure	Key capability of iSpin
Yaw misalignment	Indirect measurement, very sensitive to measurement position	Key capability of iSpin
Shear	No possibility to measure	Evaluation ongoing
Veer	No possibility to measure	Evaluation ongoing

The cost of one set of ISpin Anemometer may be up to 11 times less to the cost of met mast installation.

LIDAR AND SODAR

REMOTE SENSING DEVICES FOR CONTROL MEASUREMENT

An alternative to mast-mounted anemometry is ground-based remote sensing systems. Two systems have found some acceptance in the wind energy sector: SoDAR and LiDAR – CAISO and AESO accepts the use of both SoDAR and LiDAR if it negotiated with the forecasting service provider.

Wind sensing remote devices is considered a promising technology for high quality wind measurements required for various applications such as hub height wind resource assessment, power curve measurements and advanced, real-time, forward-looking turbine control.

Both the Sodar (Sound Detection and Ranging) and the Lidar (Light Detection and Ranging) use remote sensing techniques based respectively on sound and light emission, in combination with the

[20] A Practical Approach for Wind Park Performance Warranties https://www.ispin-ptp.com/wp-content/uploads/2017/08/AWEA_Offshore_Windpower_2018_Poster_A_practical_Approach_for_Wind_Park_Performance_Warrantie.pdf
[21] https://www.romowind.com/en/ispin-guardian-approach

Doppler effect. The signal emitted by the Sodar is scattered by temperature fluctuations while the signal emitted by a LiDAR is scattered by aerosols.

Figure 6: Ground Based Remote Sensing Devices for Wind Measurement

ZX300 LiDAR[22] Windcube V2 Leosphere AQ510 / AQSystems / SoDAR

RSD has a potential to replace met masts but is limited by some constraints. One of the drawbacks of a SoDAR is its dependency on temperature fluctuations which in turn means that a device is at a disadvantage under neutral atmospheric conditions, which are related to high wind speed situations[23]. Since the SoDAR is an acoustic system, the presence of noise sources can influence the SoDAR's function. The source of noise could be not only rain but any other noise, for example from animals that can have an adverse effect. A particularly critical issue is the increased background noise due to high wind speeds.[24] The signal-to-noise ratio of the SoDAR is also known by declining in height, resulting in a reduced number of valid signal returns. Thus, a measured profile is difficult to interpret as the profile might be based on a different number of measurements for each height.

Sodars make some noise, they cannot operate if the ambient acoustic noise is too high , their precision is slightly lower than the precision of the best LiDAR, they cannot operate very close to large obstacles while the LiDAR can[25].The main advantage of Sodar over the LiDAR may be the lower price, weight and energy consumption. The price of Sodar may range from 1/3 to ½ of the price of the LiDAR. The primary advantage of Doppler LiDAR is its unique capability to remotely measure atmospheric winds with a relatively higher resolutions compared to SoDARs.

Furthermore, Inherently, LiDAR can remotely measure the wind speeds aloft with much higher accuracy than a SoDAR. This is due to the nature of light, which propagates ~ 1 million times faster than a sound pulse, and because a lidar's antenna aperture size compared to the wavelength, i.e. "lens diameter-to-wavelength ratio" in a lidar is about 1000 times bigger than practically obtainable with a SoDAR. This results in superior beam control and also in much higher data sampling rates[26].

For the measurement of wind parameters also its available nacelle mounted LiDARs. Theoretically, every LiDAR can be mounted in that way. However, the space and requirements on top of the wind turbine are very different to the ground. Hence, there are few commercially available instruments on the market at present, the "Wind Iris LiDAR" from Renewable-NRG and ZePHIR LiDAR. Those are a horizontally mounted LiDAR at the nacelle that looks towards the wind eye and has the same characteristics as the iSpin ultra-sonic anemometers. Nacelle based LiDARs typically mounted at the back of the nacelle like the classical cup anemometer. Because it is mounted at the nacelle and is measuring the wind in a conus towards the wind eye.

The operation of the LiDAR is influenced by atmospheric conditions (e.g. fog, density of particles in the air). Lack of particles influences its response, sometimes prohibiting measurement while fog can

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[22] https://www.zxlidars.com/
[23] CHAPTER 2 Wind resource and site assessment Wiebke Langreder Wind & Site, Suzlon Energy, Århus, Denmark. https://www.witpress.com/Secure/elibrary/papers/9781845642051/9781845642051002FU1.pdf
[24] Antoniou, I., Jørgensen, H.E., Bradley, S.G., von Hunerbein, S., Cutler, N., Kindler, D., de Noord, M. & Warmbier, G., The profi ler inter-comparison experiment (PIE). Proc. of European Wind Energy Conf. , London, UK, 2004.
[25] http://www.remtechinc.com/sites/default/files/inline-files/FAQ_Corrected3_0.pdf
[26] https://backend.orbit.dtu.dk/ws/portalfiles/portal/55501125/Remote_Sensing_for_Wind_Energy.pdf

severely attenuate the light beam before it reaches the measurement height. Rain also reduces the LiDAR's ability to measure, as scattering from the falling droplets can result in errors in the wind speed, particularly its vertical components. The LiDAR, being an optical instrument, is also susceptible to influences from the presence of dirt on the output window; hence there is a need for a robust cleaning device of the LiDAR window. Nevertheless, there are studies indicating 100 % availability of LiDAR during the measurement campaign[27].

In contrast to the very small measurement volume of a cup anemometer, both remote sensing devices measure large volumes, which change with height. Both types require significantly more power than a cup anemometer making the use of a generator necessary (for the majority of models) if no grid is available.

Depending on the use case, complex flow can have the effect, reflected in the differences between measurements made at a point (e.g., by a cup anemometer), and data derived from a volumetric measurement made using a wind lidar. This difference is not an error or an uncertainty, as the devices use different measurement processes and are not directly comparable in such conditions. This difference can potentially be mitigated by using appropriate measurement campaign design, data processing, and/or supporting models.[28]

There are indications that errors of 5–10% (and in some studies more[29]) in the mean speed are not uncommon. [30] The dependence of wind power on wind speed makes such errors unacceptable for wind energy applications. The solution for controlling uncertainty is to correct the remote sensing data for the inhomogeneities with the utilization of Computational Fluid Dynamic and Large eddy simulation (LES) models. Those models have been intensively researched as methods for correcting remotely sensed winds, the required corrections are generally second order (< 6%), and influenced primarily by terrain at the measurement site. However, the performance of model corrections is case dependent, which may be the result of insufficiently specified terrain complexity.

Accuracy - Accuracy refers to the agreement between a measurement and the true or correct value.

Precision - Precision refers to the repeatability of measurement. It does not require us to know the correct or true value.

Error - Error refers to the disagreement between a measurement and the true or accepted value.

Uncertainty - Uncertainty of a measured value is an interval around that value such that any repetition of the measurement will produce a new result that lies within this interval.[31]

Overall Wind measurements with LiDAR or SoDAR can be subject to data gaps of other nature than in the case of the application of measurement masts. These can arise from e.g.:

- Precipitation (especially SoDAR data is mostly invalid or inaccurate at rain). Vertical wind speed measurements also affect LiDAR devices;
- Fog (LiDAR can often not measure in fog);
- Decreasing data availability with measurement height;
- Internal data filters;
- Atmospheric stability (the availability of SoDAR data often decreases at neutral atmosphere due to lacking air temperature gradient);
- Too low aerosol content (can appear at LiDAR measurements, e.g. at clear weather at high altitudes);
- Too high ambient noise or fixed echoes in the case of SoDAR measurements;
- Outage of power supply;
- The maximum horizontal range of LiDARs will decease during sunny days[32];

[27] ZephIR DM achieved a 100% availability of both system and data during the performance verification. https://www.zxlidars.com/dnv-gl-verifies-nacelle-mounted-zephir-lidar-wind-measurements/ .
[28] IEA Task 32 : The Wind LIDAR Community https://community.ieawind.org/task32/glossary/complex-terrain
[29] Wind speed errors for LIDARs and SODARs in complex terrain 2008 ``Wind speed errors peak at a height relevant to wind turbines and can be typically 20%``. https://iopscience.iop.org/article/10.1088/1755-1315/1/1/012061/pdf
[30] Lidar performance in complex terrain modelled by WAsP engineering Bingöl, Ferhat; Mann, Jakob; Foussekis, Dimitri Published in: EWEC 2009 Proceedings online https://backend.orbit.dtu.dk/ws/portalfiles/portal/3744984/2009_41.pdf
[31] Bellevue College B. Accuracy vs. Precision, and Error vs. Uncertainty https://www.bellevuecollege.edu/physics/resources/measure-sigfigsintro/b-acc-prec-unc/
[32] MDPI A Review of Progress and Applications of Pulsed Doppler Wind LiDARs https://www.mdpi.com/2072-4292/11/21/2522/htm

- Scan patterns and retrieval methods[33];
- Site or platform conditions[34];
- Influences of electromagnetic radiation (e.g., by mobile radio or cellular phone networks);
- Outage of power supply;
- Sensitivity to modelling and data input.

Met mast installation outperforms RSD in the availability of measurement. However, met mast deployment for short period measurement has some disadvantages which are overweighting the RSDs ones if deployed for the same purpose.

Wind turbine wake effects distorting the flow inside the wind farm, in combination with the terrain patterns may be challenging for the installation of met mast in a proximity of wind farm according to the IEC 61400-12. Moreover, due to the cost of met mast and sensors, transportation, calibration and installation cost, and the time required for the permitting, calibration of sensors and installation, the deployment of hub height met mast for a short time period (like for a month) to check the preciseness and reliability of meteorological parameters on nacelles of the wind turbines or another mast, is not cost and time effective solution.

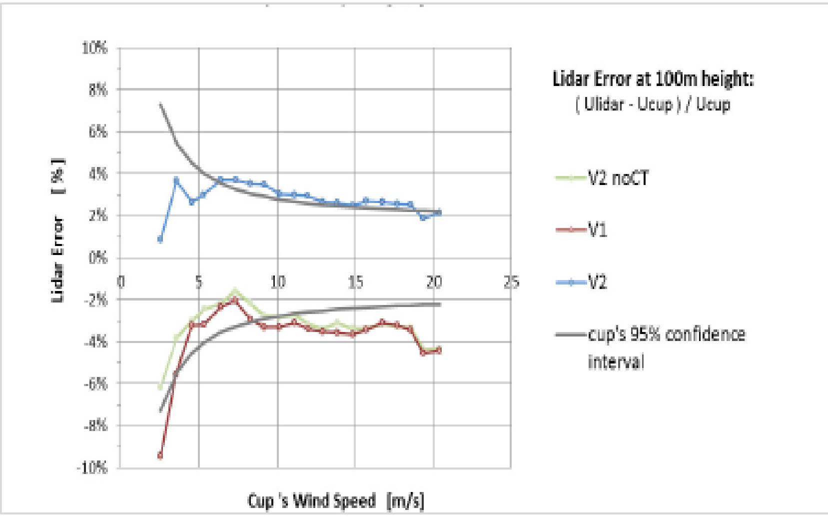
USAID Energy Program surveyed two potential suppliers for the cost and applicability of Lidar for the control measurement considering the same 7 location selected for the forecasting services.

Computational Fluid Dynamics (CFD) software deployment will either require the involvement of GSE personnel in data processing or incur cost on GSE for data processing, whilst for some locations with the Flow Complexity Recognition (FCR) module, the terrain and flow complexity will be recognized automatically and 10-minute average wind speed and wind direction will be corrected automatically.

However even after the flow modelling and measurement correction some error may remain. As an example, below provided Wind Cube LiDAR measurement results from test site which is characterized as a moderately complex terrain.

Figure 7: CRES, Greece, 2010 Site Overview

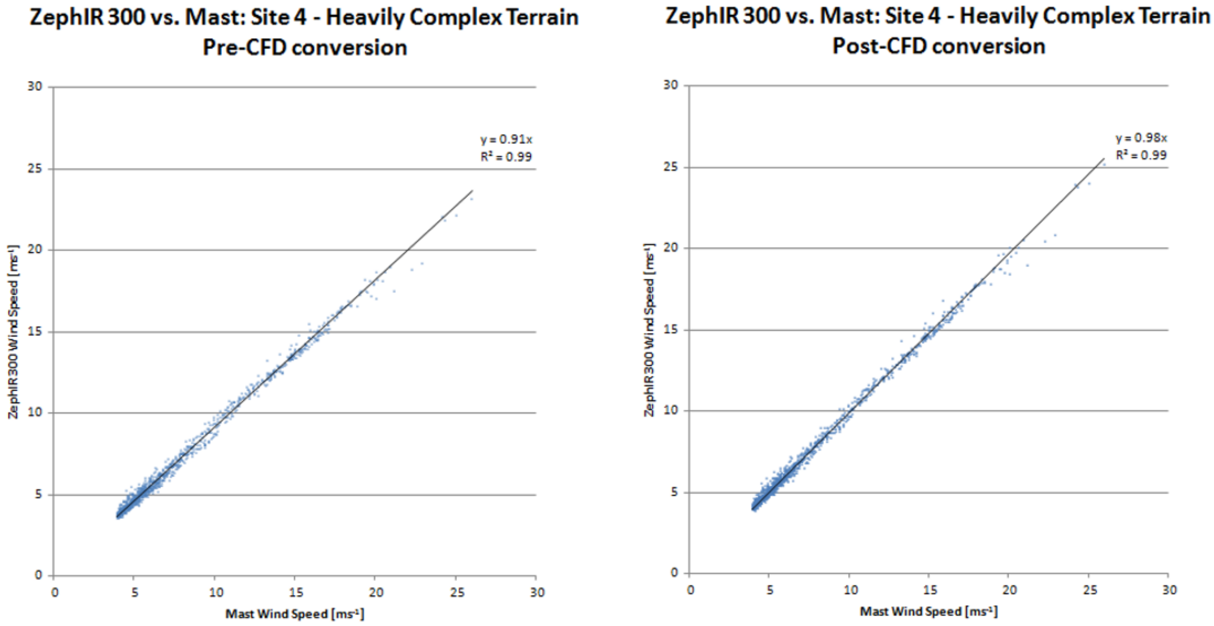
Figure 8: Uncertainty of Cup Compared to FCR Measurements (v2 noCT), and Standard Windcube Measurements (v1, v2) Bias at 100m



ZX300 LiDAR is not supplemented with the module similar to the Wind Cube's FCR. However, postprocessing of the measurement data is usually performed with the utilization of CFD software like MeteoDyn. As indicated in the feedback of potential ZX300 supplier applying CFD conversion to data from RSD in complex terrain improves the agreement between wind speed measurements from RSD and masts. The limit to the application of this methodology should only be governed by the ability of the numerical model to accurately predict the flow characteristics at the site in question.

[33] MDPI A Review of Progress and Applications of Pulsed Doppler Wind LiDARs https://www.mdpi.com/2072-4292/11/21/2522/htm
[34] MDPI A Review of Progress and Applications of Pulsed Doppler Wind LiDARs https://www.mdpi.com/2072-4292/11/21/2522/htm

Figure 9: Mast Data Versus ZephIR300 Measurements Before and After Conversion (Site 4 – Highly complex)



The deployment of LiDAR is the feasible solution to perform control measurement, however if deployed, the owner should be aware that due to the complexity of the terrain and the presence of complex flow on potential wind farm locations, at some extent uncertainties in the measurement will occur comparative to the conventional anemometry point measurements performed at met masts.

According to technical capabilities LiDAR is the feasible solution for wind speed and direction measurement in terms of cost and time effectiveness.

CALIBRATION OF SENSORS

Each wind turbine is equipped with meteorological sensors. In the case of Georgia and probably in the case of modern turbine delivery, most of the turbines are equipped with a complete set of meteorological sensors measuring at least wind speed and direction, temperature and barometric pressure. In addition, to the proximity of wind farms permanent met towers are installed to independently measure wind data and other weather parameters, but this may be optional, depending on the decision of the WPP owner. At the wind farms, the meteorological data measured at nacelles and met mast are collected and recorded by the wind warm SCADA system.

Meteorological sensors will derive to of WPP pre-calibrated. Those devices in most of the cases are maintenance free, supplemented by at list one-year warranty from the supplier[35]. LiDAR equipment will come to WPP owner with up to 36-Month warranty.

However, each measurement device after a certain period of operation will need calibration. For certain sectors, such as the wind energy the one to which we refer, there is a specific answer to this question, as standards have been set up and need to be followed. According to IEC 61400-12-1, the anemometers used for wind potential measurements must be calibrated[36] right before and after the measurement period. In addition, according to E.S.Y.D. (Greece's National Accreditation System) anemometers must be calibrated at least once a year[37].

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[35] THIES CLIMA General Conditions for Sale https://www.thiesclima.com/en/dnl/Thies-General-Conditions-of-Sale.238.pdf

[36] **Calibration**: Control of measurement magnitudes correction for anemometers without the intervention in the measurement system, or the determination of the systematic display deviation in relation to the real value of the measuring magnitude.
Calibration certificate: document with the technical properties of the device according to the national organization of measurement.
Calibration interval: to perform correct measurements, devices must be calibrated at regular intervals. This period of time is called calibration interval. Internal between calibrations should be between 1 and 3 years. https://www.industrial-needs.com/technical-data/link/calibration-certification-anemometers.htm

[37] International Wind Engineering https://www.windengineering.gr/articles/anemometer-calibration-frequency

To ensure the correctness of calibration procedure, an interested party shall obtain a wind tunnel calibration (for each anemometer / rotor pair) according to IEC61400-12-1 or IEA 11 by a MEASNET certified laboratory for the windspeed range of interest for the application.

The Highest quality calibrations are ensured when calibrating in wind tunnels that have been accredited by MEASNET. MEASNET members participate regularly in a round robin test to guarantee interchangeability of the results, which has increased the quality of the calibration significantly. It should be kept in mind that even calibrations according to the highest standard bear an uncertainty of around 1–2%.[38]

The 4-16 m/s speed range is normally specified for applications in the wind power industry[39]. MEASNET calibrations certificates are only valid for 12 months after the anemometer has been installed on a mast/tower (i.e. "installed in the field"), assuming the anemometer has been stored in "good conditions" and is installed within a "reasonable period" of the actual calibration test date.

In the case of RSD, as an example, LiDAR after a 36-month period requires maintenance and it will be refurbished and will also need recalibration.

The danger behind an un-calibrated anemometer is the incorrect conduction of a measurement or the increased uncertainty of the measurement. Sometimes the main but not correct factor in deciding whether or not to calibrate an anemometer is the cost of the calibration itself. Yet, considering the importance of accurate and precise measurement, the cost of an incorrect measurement is much higher compared to the calibration cost.

RADARS

Data derived from meteorological radars can be utilized as an input for the forecasting system. There is an example for such an approach - Variation Doppler Radar Analysis System (VDRAS) is used to provide predictors related to the wind field and the input for VDRAS is data derived from the radars, surface meteorological stations and different mesoscale NWPs.

VDRAS is a 4-D variational assimilation system[40] that produces frequently updated (on the order of 10 minutes) analyses using Doppler radar, surface observations, and mesoscale model background (Sun and Crook 2001). The mesoscale model is used to represent motion in the atmosphere, and velocities and reflectivity from single or multiple Doppler radars as well as surface observations to produce the VDRAS analyses.

The purpose of the use of meteorological radars is to make forecasts and warnings of 0-4 hour and short-term weather forecasts. Estimates can only be made with radars for the next few hours, as the range of coverage of the radar is limited due to the beam geometry and the globality of the globe, and the movement of air masses which is about 50 km / h (faster in winter and slower in summer).

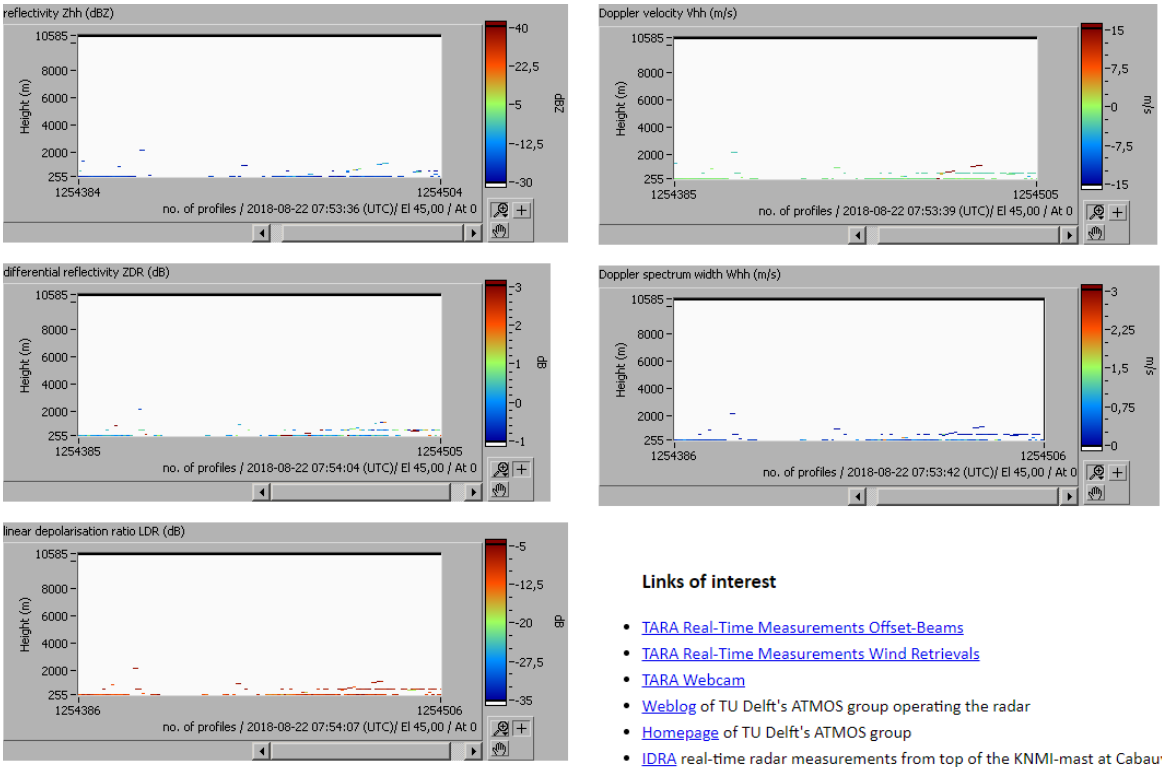
Below is provided an example of TARA project radar derived data visualization which could be publicly accessed.

[38] CHAPTER 2 Wind resource and site assessment https://www.witpress.com/Secure/elibrary/papers/9781845642051/9781845642051002FU1.pdf

[39] Vector Instruments Obtaining the highest accuracy wind speed measurements https://www.windspeed.co.uk/ws/index.php?option=faq&task=viewfaq&artid=18&Itemid=5

[40] Using Winds From The 4-D Variational Doppler Radar Analysis System (Vdras) To Nowcast Convection In Taiwan Amanda R. S. Anderson*, James W. Wilson, Tracy J. Emerson, Zhuming Ying, Juanzhen Sun, Rita D. Roberts National Center for Atmospheric Research, Boulder, Colorado

Figure 10: Near-Realtime Measurements of TARA[41]



Currently there is an operational practice of NEA to utilize data derived from radars under the disposal of Delta[42], Sakaeronavigatsia[43] and Turkey Meteorological Service[44] for the prediction of heavy rainfalls. Below provided Figure 11 and Figure 12 represent the approximate location of operational radars and at some represent the extent planned radars.

Figure 11: The Coverage Area of Radar Operated in Turkey[45]

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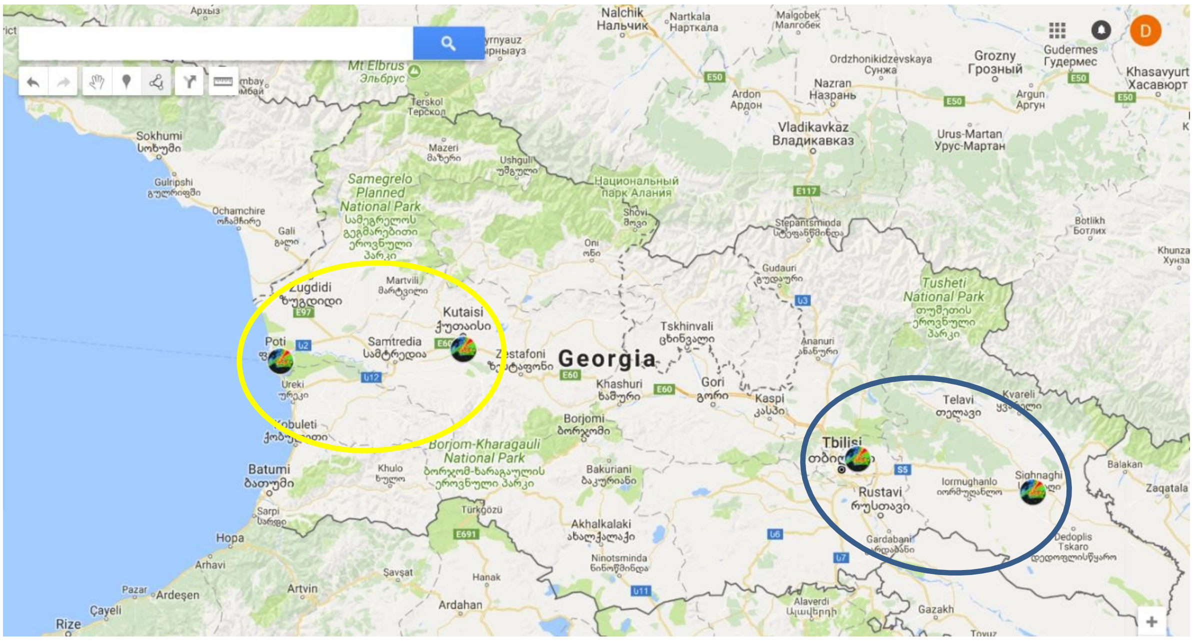
[41] http://ftp.tudelft.nl/TUDelft/irctr-rse/tara/index.html
[42] http://www.delta.gov.ge/
[43] http://airnav.ge/
[44] https://www.mgm.gov.tr/sondurum/radar.aspx?rG=anm&rR=00&rU=ppi#sfB
[45] https://www.mgm.gov.tr/sondurum/radar.aspx?rG=anm&rR=00&rU=ppi#sfB

Figure 12: Meteorological Radars in Georgia



Saqaeronavigatsia has renovated radar near Senaki, whereas with the support of USAID, NEA currently has radar near Kutaisi[46]. In general, Georgia has 4 operational radars and data derived from Turkey Meteorological Service Radar.

The existence of data derived from 5 operational radars, together with the data derived from the meteorological network of Georgia, would provide necessary input for VDRAS system which could be utilized for both solar and wind power forecasting in time horizon less than 3-4 hours with the update frequency 15 minutes.

[46] https://www.interpressnews.ge/ka/article/622392-garemos-erovnul-saagentos-amerikis-sheertebulma-shtatebma-sachukrad-tanamedrove-meteorologiuri-radari-gadasca/

5. WIND MEASUREMENT AND WIND POWER PLANT MONITORING STANDARDS

STANDARDS FOR MEASUREMENT OF WIND

Below provided three guidance documents prescribing proper measurement of wind parameters by conventional instrumentation mounted on met towers either for wind resource assessment or for wind turbine performance assessment.

If a wind parameter is measured for the wind turbine performance and resource assessment according to those guidelines, then generated measurement data can be deployed as input for forecasting as well.

- **IEC61400-12-1**;
- **MEASNET V2**;
- **FGW TR6**;
- **IEC61400-12-1**.

The most important standard is IEC 61400-12-1, which specifies the correct set up of a met mast including booms as well as its positioning, alignment, and type. It describes the quality of sensors installed on the mast to check accuracy and reliability. It defines a set of criteria regarding data quantity and quality. The IEC standard has been updated to meet the latest requirements in wind energy assessment.

Please note: The IEC 61400-12-1 standard 2005-year edition doesn't include any paragraph indicating the applicability of remote sensing devices such as LiDAR and SoDAR.

MEASNET – EVALUATION OF WIND CONDITIONS VERSION 2 – 2016

The "Evaluation of site-specific wind conditions" procedure has been agreed by MEASNET, which is a network of measurement institutes. The procedure describes the process of site assessment including data collection, evaluation and interpretation. It refers to IEC 61400-12-1 with the focus on data quality, plausibility, and integrity.

Please Note: Those are regulations from t2016 and already 4 years have passed from publication. Unfortunately, we do not have access to the IEC relevant standards to provide any updated information.

FGW TR6 – TECHNICAL GUIDELINES FOR WIND TURBINES

FGW TR6 Part 6 – Determination of Wind Potential and Energy Yield is a guideline document developed by the FGW Expert Committee on Wind Potential in Germany and describes acceptable methods to determine the wind potential and energy yield at wind turbine sites. Under FGW TR6, it is considered acceptable to develop wind projects, in Germany, based solely upon wind data gathered by RSDs. FGW TR6 also treats both SoDAR and LiDAR devices equally. This guideline is mainly applied in Germany.

Known as TR6, the German guideline recommends the use of standalone Lidar either in simple or complex terrain for wind resource assessment projects and sets out some rules regarding the measuring range and data availability. According to TR6, measurements need to be performed at a distance of 2/3 of the supposed turbine hub-height and register very good availability. It was demonstrated that the Windcube is entirely compliant with those requirements as it measures at high distances (up to 200+ meters) and register very good availability (+80%).

Based on this evidence, the TR6 guideline agrees that the device can entirely replace a met mast in simple and complex terrains. For the latter, as the wind flow could induce errors in Lidar wind speed reconstruction algorithm, an embedded flow correction model such as FCR (Flow Complexity Recognition) is required, fully validated by TR6.[47]

[47] Wind Cube V2 Specification Delivered to UEP under the performed survey

Please Note: Unfortunately, we don't have access to the TR6 guideline for the resource assessment to provide any updated information apart from the above provided one.

RSD APPLICABILITY FOR WIND SPEED MEASUREMENT ACCORDING TO THE SECTOR STANDARD

Below provided three guidance documents are a major step forward for the greater acceptance of both SoDAR and LiDAR RSDs and they are already significantly changing the way that many wind power projects are being developed.

IEC61400-12-1

IEC 61400-12-1 specifies a procedure for an IEC compliant measurement of the power performance characteristics of a wind turbine connected to the power network. For the first time, the use of ground based RSDs, ie SoDARs and LiDARs, is permitted when used in combination with a short-met mast. Both SoDARs and LiDARs are treated equally under the new version.

Ultrasonic anemometers and remote sensing devices are accepted for site assessment under certain conditions. Additionally, data integrity, quality and filtering are the main subjects in the standard (see also MEASNET).

Please note: The IEC 61400-12-1 standard 2005-year edition doesn't include any paragraph indicating the applicability of remote sensing devices such as LiDAR and SoDAR.

MEASNET V2

Released in April 2016, MEASNET - Evaluation of Site-Specific Wind Conditions Version 2 (MV2) is a procedure agreed upon by MEASNET members which defines good methodologies for accurately assessing the wind conditions at a location in full compliance with IEC61400-1. According to IEC61400-1 the site-specific conditions can be broken down into four conditions.

1) wind conditions;
2) environmental conditions;
3) soil conditions; and
4) electrical conditions.

According to MV2 both SoDAR and LiDAR based RSDs have now reached a stage where, under appropriate conditions, they can be used to assess wind conditions either supplemental with met masts or stand-alone as an alternative to met masts. MMV2 also treats both SoDAR and LiDAR devices equally.

MESNET Guideline mentions The IEC 61400-12-1, Ed. 2. IEC restricts the application of Remote Sensing Devices to simple terrain (simple terrain according to Annex B of IEC 61400-12-1.[48]

Where:

- IEC 61400-12-1 Ed.2 - International Electrotechnical Commission Standard- IEC61400-12-1 Ed. 2 Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines, 2nd Ed., CDV July 2015;
- RSD - Remote Sensing Devices such as LiDAR (Wind Cube & ZX LiDAR);
- Annex B – Annex B of IEC 61400-12-1 Ed.2;
- Complex Terrain - Complex terrain can be specifically identified using the definitions for turbine locations given in IEC 61400-12-1 (2005), and from the terrain types used in the European Wind Atlas;[49]
  IEA Task 32: The wind lidar community – Complex Terrain defined as terrain that modifies the flow of wind over and around it. This gives rise to a phenomena known as "complex flow", which is the presence of highly variable wind fields;[50]

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[48] Evaluation of Site-Specific Wind Conditions Version 2 April 2016 MEASNET Measuring Network of Wind Energy Institutes
[49] MEASNET Evaluation of Site-Specific Wind Conditions Version 2 April 2016 paragraph C4. Application of RSD in Complex Terrain
[50] IEA Task 32 : The wind lidar community – Glossary Complex Terrain https://community.ieawind.org/task32/glossary/complex-terrain

- Complex Flow - In a meteorological context, a complex flow is defined as a flow that shows strong spatial and temporal variability. This is also called heterogeneous flow;[51]
- Example of Simple and Complex Terrain (Annex 1).[52]

According to the same guideline (MEASNET), contrary to IEC 61400-12-1, Ed. 2, the application of remote sensing for wind resource assessment is acceptable in non-simple terrain if, at least one measurement mast exists on the site.[53.]

Further same guideline states that The RSD can be used as stand-alone device in flat terrain but shall not be the only measurement device in a complex site.[54]

FGW TR6

Known as TR6, the German guideline recommends the use of standalone Lidar either in simple or complex terrain for wind resource assessment projects and sets out some rules regarding the measuring range and data availability. According to TR6, measurements need to be performed at a distance of 2/3 of the supposed turbine hub-height and register very good availability. It was demonstrated that the Windcube is entirely compliant with those requirements as it measures at high a distance (up to 200+ meters) and registers very good availability (+80%).

Based on this evidence, the TR6 guideline agrees that the device can entirely replace a met mast in simple and complex terrains. For the latter, as the wind flow could induce errors in Lidar wind speed reconstruction algorithm, an embedded flow correction model such as FCR (Flow Complexity Recognition) is required and fully validated by TR6.[55]

Please Note: Unfortunately, we don’t have access to the TR6 guideline for the resource assessment to provide any updated information instead provided above.

IEC61400-12-1:2017, MEASNET V2 & FGW TR6 RSD COMPLIANCE

All three guideline documents are very similar in their treatment of RSD’s from the perspective of ensuring that the data collected will be fully accepted on either a supplemental or stand-alone basis. All three guideline documents treat both SoDAR and LiDAR devices equally, the key factors being that any RSD used must meet all of the specified requirements and that the defined processes for the specific application are strictly adhered.

Copies of all three guidelines documents can be purchased from various publishing organizations or downloaded from the internet.

Please Note: MEASNET V2 2016 and IEC6100-12-1 edition of 2005 which is withdrawn is available for this report.

VERIFICATION / MONITORING OF WIND TURBINE POWER PERFORMANCE

Due to the current absence of a sole, international standard exclusively focusing on wind measurements meant for energy yield prognoses only, the Best Practices for wind resource assessments do refer to several standards accepted by banks that each touch part of the requirements should be respected.

1. IEC 61400-12-1; Power performance measurements of electricity producing wind turbines, December 2005;
2. IEC 61400-12-1 Ed.2; Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines; March 2017;
3. IEC 61400-12-2: Wind turbines - Part 12- 2: Power performance of electricity producing wind turbines based on nacelle anemometry, March 2013;

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[51] NREL Remote Sensing of Complex Flows by Doppler Wind Lidar: Issues and Preliminary Recommendations Technical Report NREL/TP-5000-64634 December 2015
[52] MEASNET Evaluation of Site-Specific Wind Conditions Version 2 April 2016 Measuring Network of Wind Energy Institutes - List of figures
[53] MEASNET Evaluation of Site-Specific Wind Conditions Version 2 April 2016 Measuring Network of Wind Energy Institutes
[54] MEASNET Evaluation of Site-Specific Wind Conditions Version 2 April 2016 C8. Stand-Alone Application of RSD
[55] Wind Cube V2 Specification Delivered to UEP under the performed survey

4. FGW Technical Guideline for Wind Turbines, Part 6 Rev. 10: Determination of Wind Potential and Energy Production, October 2017;
5. MEASNET Power Performance Measurement Procedure Version 5, December 2009;
6. MEASNET Evaluation of Site-Specific Wind Conditions Version 2, April 2016;
7. MEASNET Cup Anemometer Calibration Procedure Version 2, October 2009.

Above is provided a list of standards, the owner of wind farm may refer in case of wind turbine performance test. Turbine performance may be tested at two stages of Wind Turbine lifetime.

The first stage its commissioning stage. At this stage the manufacturer / supplier of wind turbine aims to prove the compliance of actual power curve parameters to the one indicated in technical specification, contract or procurement order and then issue warranty. At second stage the performance of turbine is monitored to reveal under and over performers.

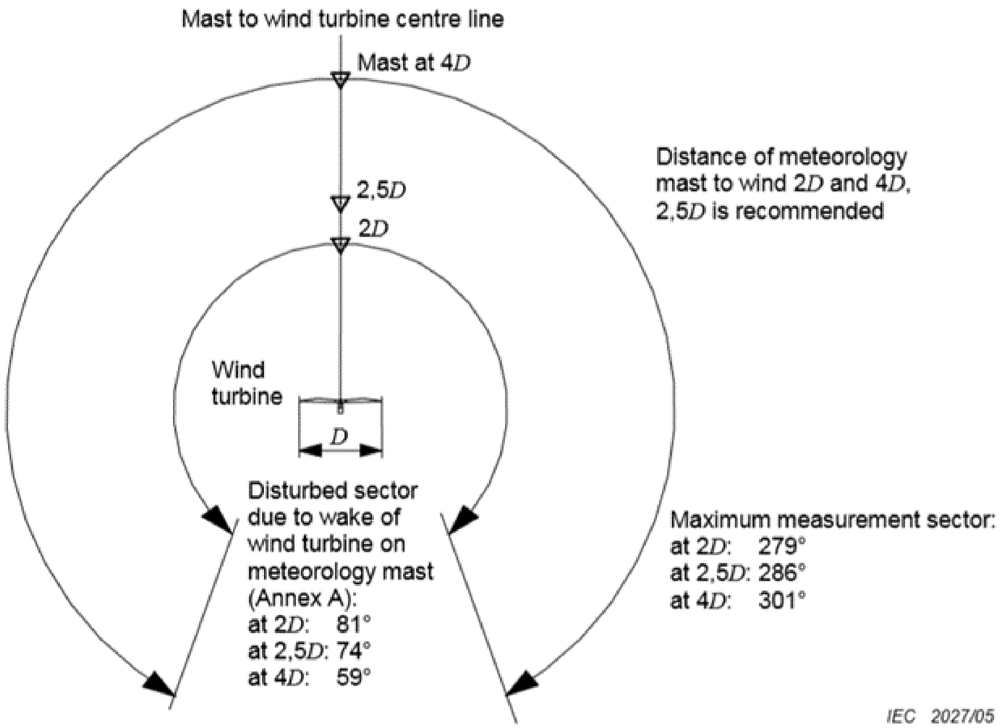
The complexity and variability of the wind resource, which is the input parameter to the energy conversion equation, has difficulties, therefore can only determine the performance of wind turbines by means of power curve evaluations for few, selected wind turbines. This may be done:

a. with the deployment of met mast according to the IEC 61400-12-1 Ed1 and Ed2;
b. in combination with a wind met mast or a RSD such as ground based lidar according to IEC 61400-12-1 and only in particular terrain complying with the requirements of the standard d) nacelle based anemometry measurements; and
c. May be utilized nacelle-based LiDAR;
d. May be utilized I Spin Technology.

IEC61400-12-1 PERFORMANCE MEASUREMENT – DEPLOYMENT OF MET MAST

After the wind farm is built, the power performance of each wind turbine must be verified according to IEC61400-12-1. IEC 61400-12-1[56] specifies meteorological tower placement between two and four rotor diameters upwind of the test turbine.

Figure 13: Requirements as to Distance of the Meteorological Mast and Maximum Allowed Measurement Sectors



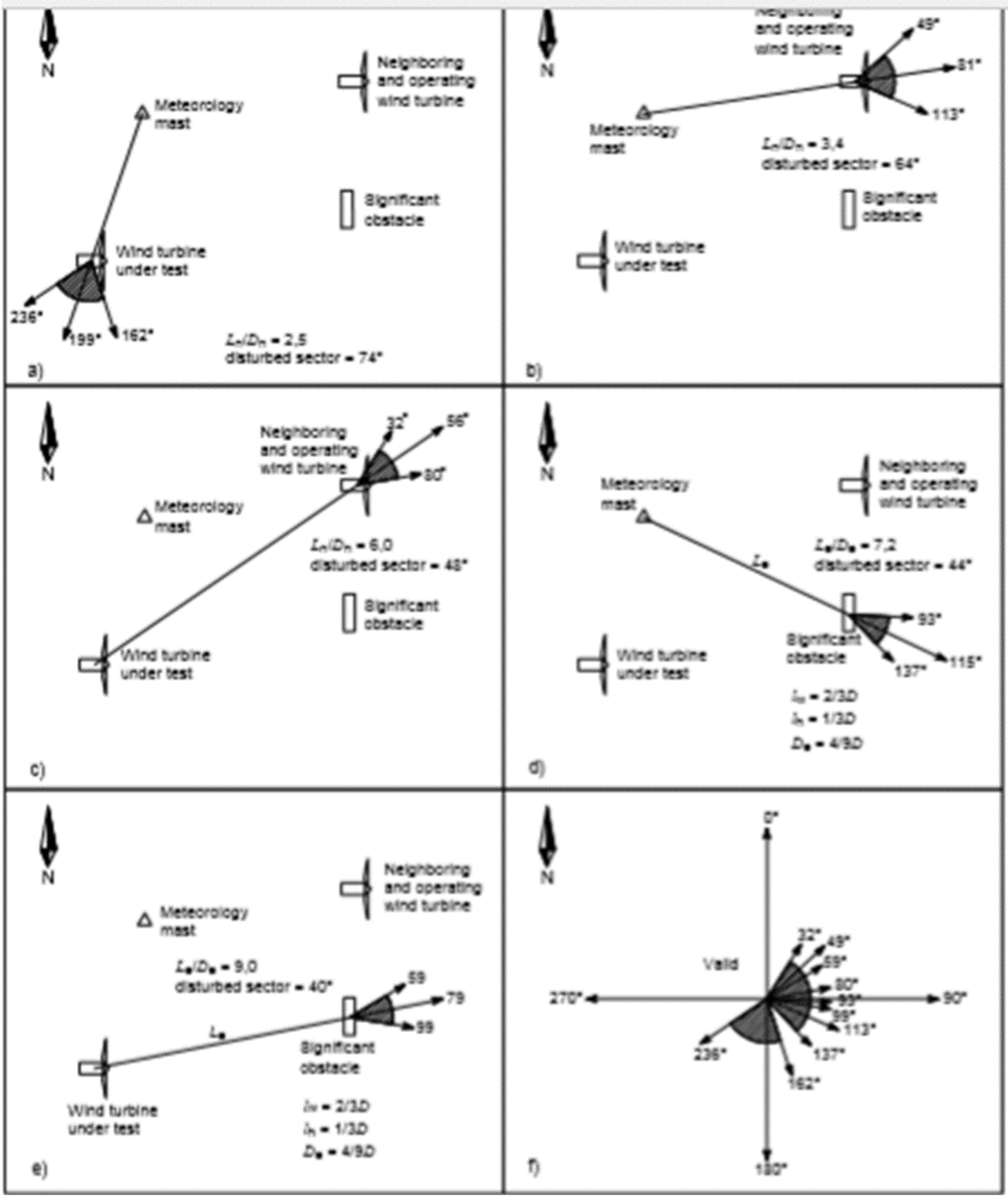
[56] IEC 61400-12-1:2005 withdrawn updated in 2017 and available at cost

However, use of an upwind meteorological tower can be difficult at some sites. In some cases, complex terrain near the turbine may make placement of an upwind tower impossible. In addition, purchase and erection of a meteorological tower can be expensive (up to 150k €), particularly as the hub height of large turbines increases.

Also, according to the same standard, the wind turbine under test and the meteorological mast shall not be influenced by neighboring wind turbines. If a neighboring turbine is operated at any time during the power performance test, its wake shall be determined and accounted for as described in the relevant annex of standard. If the turbine is stopped at all times during the power performance test, it shall be considered as an obstacle.

Below provided figure depicts sectors which shall be excluded during the performance test of turbine.

Figure 14: An Example of Sectors to Exclude Due to Wakes of the Wind Turbine Under Test, a Neighbouring and Operating Wind Turbine and a Significant Obstacle

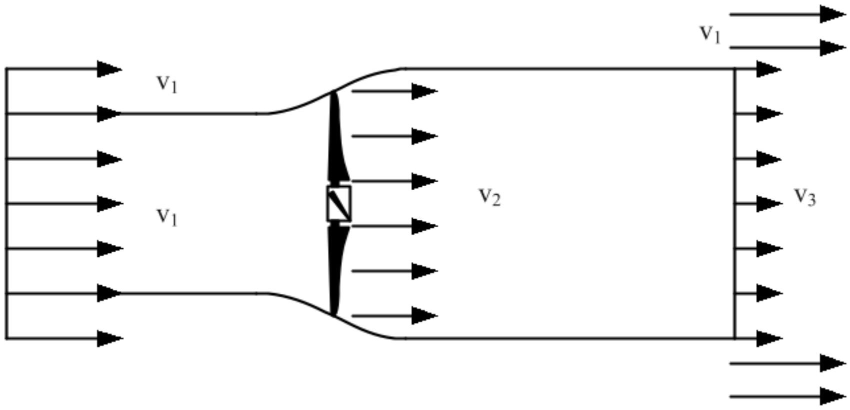


Note. The updated version of 61400-12-1 ed2. 2017 may contain different guidelines and instructions for the location of met mast and calibration of sensors.

IEC 61400-12-2[57] PERFORMANCE OF TURBINES BASED ON NACELLE ANEMOMETRY

Nacelle based wind speed measurement, performed by conventional anemometer, may be considered as not meaningful and trustworthy, but quite often is the only source of information for the input quantity "wind" in relation to the output quantity "power". Due to their position behind the rotor, the conventional nacelle anemometers are unfortunately very sensitive to changes in the flow conditions compared to those of the free inflow sector at the prototype site. Flow conditions differing from those at the prototype site, caused by environmental or wake effects, will lead to different inflow passing the rotor and nacelle structure and finally reaching the nacelle anemometer. Furthermore, those sensors are not able to measure the turbulence intensity (the variation of the wind speed) and the inflow angles, which are affecting the power characteristics as well as the fatigue loads.

Figure 15: Airflow Through and Ideal Bets Wind Turbine [58]



IEC 61400-12-2 Edition 1.0 provides a uniform methodology of measurement, analysis, and reporting of power performance characteristics for individual wind turbines utilizing nacelle-anemometry methods. The intent of this standard is that the methods described in this standard may be utilized when the requirements set forth in IEC 61400-12-1:2005 are not feasible.

This procedure describes how to characterize a wind turbine's power performance characteristics in terms of a measured power curve and the estimated Annual Energy Production (AEP) based on nacelle-anemometry. Furthermore, standard provides methods for determining and applying appropriate corrections in case if nacelle anemometer measurement is impacted by the turbulence created by the blades. However, it must be noted that these corrections inherently increase the measurement uncertainty compared to a properly configured test conducted in accordance with IEC 61400-12-1:2005. The procedure also provides guidance on determination of measurement uncertainty including the assessment of uncertainty sources and recommendations for combining them into uncertainties in reported power and AEP.[59]

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[57] IEC 61400-12-2 Edition 1.0 https://www.vde-verlag.de/iec-standards/223895/iec-61400-12-2-2013-cor1-2016.html
[58] https://www.springer.com/gp/book/9783642229374
[59] https://www.vde-verlag.de/iec-normen/preview-pdf/info_iec61400-12-2%7Bed1.0%7Db.pdf

6. REVIEW SUMMARY

Wind Power Forecast models generally need an input of meteorological observational and power measurement data, as well as data on weather parameter predictions that come from NWPs. Forecast error and accuracy depend and vary based on the factors that can be controlled by System or Plant operators and factors that are beyond the control.

NWP Input and terrain characteristics may be considered as an uncontrollable factor for System or Plant operator, whereas the followings can be considered under the Controllable factors:

1. The existence of power and weather parameter measurement data, required for forecasting;
2. Availability of the data for 98.5% of the time – Measurement and delivery of data without interruption;
3. Data Transfer Intervals;
4. Data Quality and its reliability.

Controllable - for this report means that in case the data input for forecasting models is not satisfactory with the deployment of new regulations or deployment of new infrastructure or equipment, a System or Plant Operator can improve data input and make it compatible with the specifications set by vendors of forecasting services. This, in turn, will contribute to increased preciseness and accuracy of forecasting models.

In the case of Georgia, power and meteorological parameters that are measured at the existing wind farms and potential wind farm locations may be attributed to the controllable factors. However, for this report, data from radars will be attributed to the Uncontrollable Factors. This is due to the fact that:

- Those radars are under the disposal of environmental or semi military agencies, as well as under the disposal of air or marine navigation agencies – data exchange negotiations may be challenging if the common platform does not exist;
- During the study of forecasting models, the capability to utilize weather data from radars for wind and solar power forecasting were found only under the portfolio of the United States of America National Centre of Atmospheric Research;[60]
- The possibility to utilize radar data its subject of separate scientific study, which may be time and resource consuming.

Under the GFP project, the measurements at the proximity of existing and potential wind farm locations are active at least for 5 locations. Vendors of forecasting services can provide wind power and weather prediction without the observational data, however, for the preciseness and accuracy of the forecast measurement data, its availability, data transfer intervals, quality and reliability have great importance.

The availability of measurement devices and data transfer equipment must be ensured 98. % of the time per year by the owners of wind farms. Usually it is the requirement of System Operators - “The legal owner of a wind or solar aggregated generating facility must ensure that its meteorological data collection equipment and related devices including its data transfer equipment is designed and maintained with an availability of 98.0%”.[61]

In terms of measurement availability, the conventional instrumentation mounted on the nacelle of the wind turbine or at a meteorological tower located at the proximity of potential wind farm location, outperforms RSD such as LiDAR and SoDAR. LiDAR and SoDAR measurement are vulnerable to external factors and when affected this data must be excluded from the measurement. Overall Wind measurements with LiDAR or SoDAR can be subject to data gaps of other nature than in the case of the application of measurement masts.

RSD can be deployed for short measurement campaigns. For such campaigns, it is a cost and time effective solution compared to met mast installation. However, to be utilized for forecasting the data that derives from LiDAR has to be post processed and measurement at one location without the processing can’t be correlated to other locations.

If agreed with the vendor of forecasting services CAISO accepts RSD as the permanent mean of wind parameter measurement. However, the climate of Georgia and especially the climate in remote areas

[60] https://ral.ucar.edu/projects/forecasting-for-wind-energy
[61] AESO Complete Set of ISO Rules

where the wind farm construction is proposed, may not be favorable in terms of reliable measurement as it may be in the state of California.

Nacelle base measurement for existing wind farm and data that comes from met masts at the proximity of wind farm location is a most reliable source of data that can ensure the 98% availability of measurement and in case of proper data transfer arrangement may ensure the 98% availability of measurement and data transfer equipment.

As for AEMO and CAISO, the data transfer intervals are set mandatory close to real time. CAISO - the measurements for telemetry data points should be sent to the CAISO in real time (i.e., 4 seconds) from wind power generators. AEMO - Instantaneous measurements are required unless otherwise agreed by AEMO. Instantaneous means values are updated at least every 4-10 seconds, with 4 seconds or faster preferred. If only averages are available, the maximum 15-second average update is required. AEMO requests the same interval for the plant availability data.

We don't know if the same frequency is available under the GSE SCADA for the plant availability information, power and meteorological parameters measurement and its transfer that is requested by AEMO and CAISO. Under a GFP for QWF, measurement files are with a 1-minute statistical interval i.e. the average. Compared to the AEMO requirement on maximum 15-second average update, GSE has room for improvement. Knowing in advance the practice of other operators makes possible to consider the same intervals in the future for newly constructed wind farms.

GSE can impact the proper arrangement of SCADA element at both GSE and Wind Farm side. According to the existing Network Rules[62] I level SCADA arrangement is a responsibility of GSE - Dispatch licensee, whereas operator of the wind farm is responsible for the arrangement of II and III level SCADA. II and III level SCADA arrangement must be agreed with GSE.

The accomplishment of the current upgrade work of GSE, SCADA may eliminate issue related to the automatic upload of QWF measurement data to GSE sFTP server. However, for the potential wind farm locations, to comply data requirement and its data transfer frequency (5 min statistical interval and transfer interval) the upgrade of dataloggers firmware software, changing statistical intervals and file generation intervals as well as upgrade of power supply may be needed.

For example, Menu of Ammonite Meteo 40 datalogger allows configuring the schedule[63]. Configuring the scheduling includes defining the communication behaviour of datalogger during a day, selecting CSV file transfer intervals and data transfer method such as sFTP.

Manual just sets the input method for the quantity- Enter the Quantity as integer, e.g., 2, 3, 4. without the indication of maximum number of communications per day. That, in the case of 5 min intervals would be equal to the 288.

However, in the CSV-file that represents statistics and that can be uploaded to the sFTP server, the lines can be created from 1/4 s to 1 h interval whilst the new aggregate data file in CSV format can be created from every 5 minutes to weekly.

Considering the above provided capabilities of Ammonite Meteo 40 data logger, every 5 minutes can be created CSV file with the measurement data that has statistical interval from 1/4 s to 1 h. Respectively for GFP forecasting with the 10 min data transfer interval may be available 5 min aggregated 2 CSV files with the measurement statistical intervals 1 min.

For needs assessment of additional power supply, Ammonite Power Supply estimation tool was deployed. It was estimated power consumption and the needed capacity of the battery and solar modules. It seems that 400Euro +40%-60% of cost for delivery, customs clearance, and installation may be needed for the upgrade of met tower power supply with the new equipment - if needed and if the installation will be performed by the local specialist.

Under the GFP project gained experience shows that what is written in manuals and guidelines may not work well in practice if GPRS connection is week. For instance, the configuration of datalogger may be performed remotely and via accessing data logger at the installation site. In the case of GFP, access was needed to update firmware version of datalogger and to configure it to transfer data file with a high frequency.

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[62] Netwrk Rules Article 45 Operational Rules

[63] Data Logger Meteo-40 7.2 Configuring the Communication Schedule

It would be helpful If GSE double-checks and requests developers of wind farms to obtain the following info from their service organization engaged in wind resource assessment campaign:

a) The model and version of datalogger / or Met Tower Commissioning report;
b) Firmware version of datalogger;
c) Data logger manual;
d) According to manual and Real - The technical specification on capability of datalogger to create files containing measurement information > Format of file i.e. file extension > Statistical interval > interval between the files generation;
e) According to manual and Real – the minimum and maximum quantity that may be set for number of communications per day/24 hours;
f) Installed solar panels model, panel peak capacity in watt, and number of modules;
g) Deployed battery and indication of capacity in Ampere Hour;
h) Ask if they are capable to generate each 5 minute the measurement data file with the statistical interval 1 minute or less, and set schedule for connection between the datalogger and GSE sFTP to 5 or 10 min;
i) Instruct developers on the connection to sFTP and later evaluate their capability to follow instructions.

Also, GSE needs to ask company engaged in SCADA upgrade project to arrange automatic data exchange between the GSE sFTP server and SCADA.

For wind resource assessment and wind turbine power performance testing, the most important is to properly arrange weather parameter measurement equipment according to the industry standard (please see section 5 Wind Measurement and WPP Monitoring Standards).

Another factor that affects the quality, reliability, and preciseness of the wind parameter measurement it is the periodical calibration of the sensors (see section 4. Calibration of Sensors). According to the IEC 61400-12-1, the anemometers used for wind potential measurements must be calibrated right before and after the measurement period. In addition, according to E.S.Y.D. (Greece's the National Accreditation System) anemometers must be calibrated at least once per year.

There is a possibility to allocate data quality controlling duty to provider of forecasting services. This was done under the GFP, however with the delays in data delivery this may be ineffective.

Another option may be to perform the so-called Control Measurements with the deployment of Remote Sensing Devices. However, the deployment of RSD may serve, at some extent, as an effective tool in revealing improper measurement but may be ineffective during the disputes between system operator and wind farm operator if the proper measurement of the meteorological parameters are important.

Here we would like to provide an example of dispute between parties on improper metering of power. Usually to resolve such disputes, parties apply to accredited laboratories to check if the device-meter is properly measuring the power. This may be true for wind measurement equipment as well but there is a slight difference -In Georgia. MEASNET accredited laboratories are not available here, the ones that have under the disposal Wind Tunnel a specific installation for calibration of Wind measurement equipment.

In case of the existing contract extension or signing a new one with vendors of forecasting services, If GSE similarly to the GFP, allocates duty of data quality control to the providers of forecasting services, it may be most cost and time efficient for GSE to control the measurement data quality.

As the quality and reliability of the measurement is a primary interest of the operators / developers of wind farms, during next couple of years GSE needs just survey operators and developers of wind farms for the calibration of sensors devoted for the measurement of meteorological parameters.

The survey results and data quality reports delivered by vendors of forecasting services will be good basis for GSE to justify if the mandatory calibration of sensors and LiDAR deployment for the control measurement are needed as a next step for the forecast accuracy improvement.

The efficient way to overcome the above provided hurdles on measurement and data exchange is to set a mandatory measurement and delivery of the data to GSE Dispatch licensee 98% of the time at any stage of the wind farms lifetime. Here the experience of AESO, CAISO and AEMO can be considered.

7. SUMMARY OF RECOMMENDATIONS

(a) Correctly calibrated and computed nacelle sourced wind speed is an accepted source of met data
(b) Correctly calibrated and computed meteorological tower sourced wind speed from potential locations is an accepted source of met data
(c) LiDARs will need to comply with a delivery percentage of 98.5% in Georgia, to be acceptable alternatives to met masts and nacelle-based measurements
(d) LiDARs may be used as a calibration/verification method according to IEC61400-12-1:2017 to proof correctness of met masts or nacelle sourced data signals. The complexity of a flow and a need for data post processing should be considered.
(e) Radars data may be deployed for the improvement of forecast however, it needs analysis and the existence of forecasting model that is capable to utilize it.
(f) Data upload to GSE sFTP server should be automated.
(g) Sampling and Provision of all met and power data signals through the SCADA may be a minimum of 1-minute average based on a minimum of 12 sub-minute sample points
(h) Sampling and Provision of all met data signals from potential locations may be a minimum of 5-10-minute average based on a minimum of 12 sub-minute sample points
(i) As a backup of power data at the wind farm connection point under SCADA system, GSE may deploy power data at generation output with the same sampling intervals and data transfer intervals or the vice versa.
(j) The capability of GSE SCADA should be checked and tested on (g), and (h) should be double checked with developers of wind farms.
(k) Accurate met data should be provided by the existing and potential wind farms 98% of the time
(l) Continuous quality assessment of met data should be part of the forecasting system
(m) Annual surveying of wind developers on performed sensor calibration should be a part of the forecasting system
(n) For the existing wind farms, the forecasters should ensure the availability of wind turbine, active power, set point and signal point as a requirement with the validations
(o) Incorporation of announcements by wind farms on full and partial scheduled and non-scheduled outages should be entered into the wind Farm SCADA system
(p) The upgrade of the met towers power supply to ensure the increased data transfer intervals should be the responsibility of wind farm developers.
(q) To line up the data exchange between the data loggers of met towers and GSE sFTP, SCADA and sFTP server appropriate to the commercial sensitivity of measurement data, new server hardware, separate from the SCADA system, may be deployed.

Following the present report, as a next step GSE may evaluate the capability of wind farm developers to measure data transfer and ask contractor, engaged in SCADA upgrade, to arrange automatic data upload of measurement data from SCADA to GSE sFTP server.

GSE will further proceed with the Draft Amendment to Network Rules -Wind Power Forecasting Regulation that makes data measurement and data sharing to Dispatch licensee mandatory.

ANNEX 1: METEO-40 DATA LOGGER – COMMUNICATION METHODS

Meteo-40 Data Logger – Communication & Data Transfer

Communication Methods and Required Devices

Meteo-40 data loggers offer various methods for data transfer and communication. All available methods are commonly used as well as easy to handle and to configure. Additional devices are necessary to set up the connections, e.g. W-LAN USB stick or modem.

Accessing the Meteo-40 web interface via tunnel server

Meteo-40 can be connected directly to a tunnel server to obtain a unique subdomain. This way the GSM modem can be equipped with a standard SIM card with dynamic IP address. The tunnel server manages the subdomains. Users access the Meteo-40 web interface (when online) by entering its subdomain, e.g. https://Dxxxxxx.tunnel.ammonit.com

Method \ Action	Configuration	Software Update	Automatic Data Transfer	Manual Data Transfer	Access via Tunnel Server	Required Devices	Recommended Application	Comment
Meteo-40 (Stand-alone)	no • only a few settings can be changed	no	no	no	no		Only testing purposes.	
USB memory stick	no	no	no	yes • Download on pre-configured USB memory stick	no	Pre-configured USB memory stick 	Backup download.	Manual data download on pre-configured USB memory stick.
LAN	yes	yes • Internet access required	yes • Email • FTP/SCP • AmmonitOR	yes • Download via web interface	yes • Internet access required		Preferred method for configuration and software update.	The easiest method for initial configuration and software updates. A DHCP server in your LAN is recommended.
W-LAN	yes	no	no	yes • Download via web interface	no	USB W-LAN stick 	Maintenance on site.	USB W-LAN stick has to be configured in the web interface prior to the usage on site.
Ethernet (point-to-point)	yes	no	no	yes • Download via web interface	no		Backup access.	PC and data logger have to be configured.
USB (A/B)	yes	no	no	yes • Download via web interface	no	USB A/B cable and driver file 	Backup access.	For Windows™ PCs a driver file is required. It can be downloaded from the Ammonit website.
Modem (GSM / Radio Directional / Satellite)	yes	yes • Internet access required	yes • Email • FTP/SCP • AmmonitOR	yes • Download via web interface	yes	Modem 	Remote access during a measurement campaign.	Thanks to the tunnel server design a standard SIM card can be used in a GSM modem. Tunnel server manages IP addresses. SIM card with static IP address is not necessary.
SCADA over RS485 (Modbus RTU)	no	no	yes • Modbus protocol	yes	no		SCADA	Modbus register map has to be configured.
SCADA over Ethernet (Modbus TCP/IP)	no	no	yes • Modbus protocol	yes	no		SCADA	Modbus register map has to be configured.

ANNEX 2: METEO-40 DATA LOGGER – INCREASED POWER CONSUMPTION ESTIMATION

Ammonit

Meteo-40 Power Consumption

Calculation of a Solar supply + dimensioning of the battery
Attention, this calculation is based on general and experienced values. Regional differences are taken into account, if local mean radiation Intensity of worst month will be selected

Voltage [V]:	12.00

	Calculation of the Consumption	Consumption in A	Qty	Duration in Sec.	Interval in Sec.	average duration		average-Consumption in mA	[%]
Logger	Continuous Consumption [A] Of the logger (all channels active)	0.0295	1		permanent	24.0	h/day	0.0295	25%
Logger	Consumption of Linux operating time without MARS	0.0450	1			0.5	h/day	0.0009	1%
Logger	Consumption of Linux bootprocess	0.1400	1			0.008	h/day	0.0000	0%
Logger	Consumption Solar-Regulator	0.0040	1		permanent	24.0	h/day	0.0040	3%
Sensors	Consumption Anemometer	0.0004	4		permanent	24.0	h/day	0.0016	1%
Sensors	Consumption Wind vane	0.0001	2		permanent	24.0	h/day	0.0002	0%
Sensors	Alternative: Consumption Wind vane TMR 10-Bit	0.0025	2		permanent	24.0	h/day	0.0050	4%
Sensors	Consumption Thermometer+Hygrometer	0.0020	1		permanent	24	h/day	0.0020	2%
Sensors	Alternative: Thermometer+Hygrometer RS485 Modbus RTU	0.0070			permanent	24	h/day	0.0000	0%
Sensors	Consumption Barometer	0.0040	1	3	permanent	24	h/day	0.0040	3%
Modem	More Consumption during Modem availibility	0.7200	1			1	h/day	0.0300	26%
Modem	Extra consumption during the transmission of datas	4.8000	1			0.2	h/day	0.0400	34%
RS485	SCADA	0.0500	0			24	h/day	0.0000	0%

Average current consumption [A]	0.1173
Effective Power [W]	1.4074
Day consumption [Wh]	33.7778
Power Consumption [W] Including SC and PR	4.3305
Day consumption [Wh] including Safety Coefficient and PR	103.93

SC safety coefficient [%]	200%
PR (Performance Ratio)	0.65

0.1173

Dimensioning of the Solar-Panel					
Correspond to the North latitude: see map on table „Mean irradiation Europe"	54°	52°	50°	46°	40°
Mean daily radiation Intensity in December [Wh/(m².day)], by a panel angle of 60°	1000	1200	1500	2000	3000
Equivalent Number of hours per day with 1000W/m2 (with STC sun irradiance)	1	1.2	1.5	2	3
Requested power of the Solar Panel in Watt	104	87	69	52	35
Ammonit recommends this Solar Panel with [W]	70	50	50	30	30

Dimensioning of the battery			
Day requirement without Reserve [Wh]		33.7778	Wh
Day requirement including 100%-Reserve [Wh]		67.56	Wh
Requested number of days of autonomy		8	days
Total requested power in Wh		540.45	Wh
Required Amper hours including 100% Reserve		45.04	Ah
chosen 1	Akku with [Ah]	70	Ah

System-dimensioning detail | PV Estimation (Europe+Africa) | Mean

USAID Energy Program
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Address: 29 I. Chavchavadze Ave.,0179, Tbilisi, Georgia
Phone: +(995) 595 062505
E-mail: info@uep.ge