Reviewing Standards for Small Wind Turbines

Measurement Working Group

Data measurement activities are an essential part of small wind turbine (SWT) applications as they provide vital and necessary information regarding the electrical - environmental parameters of the installed system, thus enabling reliable and consistent monitoring and control. In addition, the historical data gathered, are of utmost importance in research activities regarding the design, performance, quality assessment testing and development of the relevant technology infrastructure.

Introduction

Measurement standards document the **professional principles and practices** the interested stakeholder parties (policy makers, manufacturers, practitioners, end-users etc.) are required to adhere to and the **level of quality and effort** expected in all measurement activities. Standards have accompanying guidelines that present recommended best practices to fulfill the goals of the standards. While currently a plethora of measurement standards, as well as guidelines regarding testing and measuring AC sources are available, **most of them mainly focus on measurements on the utility grids** (i.e IEC 62053, IEC 61039).

The lack of a coherent set of documentation regarding off-grid applications in the context of data collection and high quality measurements, raises a challenging task, especially **taking into account the particularities involved in small wind turbine applications**, (i.e. the range of frequency varies from the standard frequency, $50Hz$ or $60Hz$, and the current THD is as high as 40%)

This report, which is the outcome of the ongoing **Wind Empowerment Network Measurement Working Group** research activities, focuses on providing details on the principles and methods employed in the collection, storage and analysis of data measurements, thus **providing guidelines based on existing standards and facilitating the progress towards future standardization activities**. In this context, it further facilitates the establishment of an enabling environment for a rapid uptake of renewable energy technologies, by **contributing to the development of the necessary quality infras-**

tructure framework for small wind turbine applications with respect to the data measurement methods and resulting activities. Data measurement methodologies and activities require the **complete information flow,** (from the setup of the installation site and the wind cup installation specifications, to the data harvesting interval and the current/voltage transducers specifications) to be accurate and adhere to the respective standards in order to provide a **complete, reliable and consistent set of data** to be exploited in a **commonly accepted and reproducible way**. In this report, significant effort has been made to maintain the above mentioned structure that will **ensure every part of the data information flow will be accounted for and evaluated**.
This document is a ***mid-term report*** which incorporates the review results of the following standards and **will be constantly updated and enriched** towards the final report:

- **IEC 61400-12-1**:2005 Power performance measurements of electricity producing wind turbines
- **IEC 60688:2013** Electrical measuring transducers for converting AC and DC electrical quantities to analogue or digital signals
- **IEC 60044-1:1996** instrument transformers - Part 1: Current transformers
- **IEC 60044-2:2002** Instrument transformers - Part 2 : Inductive voltage transformers transformers

Our aim is the final report to be a complete guide to data measurement activities, therefore currently the following standards are being reviewed and this list may grow:

- **IEC 61400-12-2:2013** Power performance of electricity-producing wind turbines based on nacelle anemometry
- **IEC 61400-21:2008** Measurement and assessment of power quality characteristics of grid connected wind turbines
- **IEC 61400-25-1:2006** Communications for monitoring and control of wind power plants - Overall description of principles and models
- **IEC 61400-25-6:2011** Communications for monitoring and control of wind power plants - Logical node classes and data classes for condition monitoring
- **IEC 61869 series :** Instrument transformers

Power performance measurements of electricity producing wind turbines - IEC61400-12-1

Scope: The purpose of **IEC 61400-12.1** is to provide a uniform methodology that will ensure consistency, accuracy and reproducibility in the measurement and **analysis of power performance** of wind turbines and provides guidance in the **measurement, analysis, and reporting of power performance testing for wind turbines** of all types and sizes when connected to either the electric power network or a battery bank.

The wind turbine power performance characteristics are determined by:

- The measured power curve and
- The estimated annual energy production

A key element of power performance testing is the measurement of the wind speed and the use of **cup anemometers** has long been regarded as suitable for this kind of measurements.

The measured power curve is determined by collecting simultaneous measurements of wind speed and power output at the installation site **for a period that is long enough to establish a statistically significant database over a range of wind speeds and under varying wind and atmospheric conditions**.

A test site meeting **IEC power performance test requirements** as well as **instruments and data acquisition systems that are calibrated per the standard's requirements,** are necessary for the above to be possible. Test sites are typically selected in areas with high winds, on rural or undeveloped land and away from local settlements to avoid turbulence created by trees, buildings, or other structures. Usually large tracts of land are needed so that test sites can be developed as needed.

Test equipment for SWTs includes a meteorological mast with **anemometers** and **wind vanes** for measuring wind speed and direction. **Temperature** and **pressure** data help to provide understanding for atmospheric characteristics. A data acquisition shed, houses the data acquisition systems (DAS), turbine inverter (if appropriate), measurement equipment and computers.

Location of meteorological mast

Care should be taken in selecting the appropriate location for installing the meteorological mast. It should be located neither too close to the wind turbine, nor too far from it, since the correlation between wind speed and electric power output will be reduced. In most cases, the best location for the meteorological mast would be upwind of the turbine in the direction of the most valid wind to be expected and should be positioned at a distance from the wind turbine of between 2 and 4 times the rotor diameter D. **A distance of** $2.5 times$ **the rotor diameter** D **is recommended**. In the case of a vertical axis wind turbine, D is equivalently defined as $2\sqrt{\frac{A}{\pi}}$, where A is the swept area of the rotor, and distance is defined as $L + 0.5D$, where L is the distance between the centre of the turbine tower and the mast of an equivalent horizontal axis wind turbine.

Appropriate **arrangement of instruments on the meteorological mast is important for accurate wind turbine testing**.

More specifically:

- The anemometer should be installed in a such a way so that flow distortions, especially from mast and boom influences are minimised. Other instruments on the mast should be mounted close to hub height but in a way that interference with the anemometer is avoided. **The preferred method for mounting the anemometer, is on top of the meteorological tower with no other instruments or equipment nearby**.
- Temperature and pressure sensors should be located close to the hub height on the meteorological mast, at a minimum of $1.5m$ below the primary anemometer. The temperature sensor should be mounted in a radiation shield.
- The pressure sensor may be mounted in a weatherproof box. However, care should be taken to ensure that the box is properly vented so that pressure readings are not influenced by the pressure distribution around the box.
- **The anemometer** should be mounted on a round vertical tube, with the same outer diameter as used during calibration, which carries the cable to the anemometer inside. The **angle deviation from vertical** should be less than 2, and it is recommended to use an inclinometer.
- **The tube** should be no larger in diameter than the body of the anemometer and should support the anemometer cups at least $0,75m$ above the meteorological tower and any other flow disturbances.
- **The bracket connecting the anemometer to the vertical tube** should be compact, smooth, and symmetrical. If necessary to hold the anemometer steady, the small-diameter vertical tube may be mounted on another tube of larger diameter in order to ensure that no parts of the meteorological mast extend beyond a 1:5 cone whose vertex is at the height of the anemometer cups.
- Other instruments must be positioned at **least** $1.5m$ **below the anemometer**

cups. These instruments and their supporting brackets to a boom, may extend beyond the 1 : 5 cone.

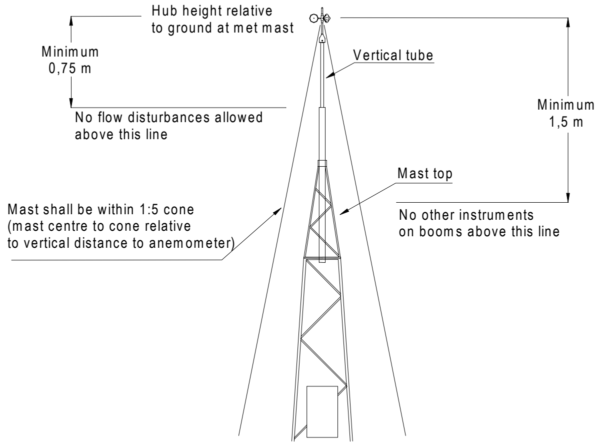

Figure 1: *Example of a top-mounted anemometer and requirements for mounting.*

Alternative methods of anemometer mounting should be considered to have increased uncertainty in wind speed measurement due to flow distortion. Relatively small distortion is obtained when two cup anemometers are top mounted side-by-side with adequate separation from the tower and each other. The anemometer cups must be mounted above the boom by a minimum of 15 times the boom diameter, but 25 times the boom diameter is recommended. The anemometers should be separated by at least $1.5m$ and no more than $2.5m$. The figure **??** shows an example of a side-by-side configuration. **The measurement sector should be restricted** so that the control cup anemometer does not affect the primary cup anemometer. The uncertainty due to flow distortion of other instruments and mast and boom must be determined.

Measurement sector

The wind turbine and the meteorological mast should not be influenced by neighbouring wind turbines. The minimum distance from the wind turbine and the meteorological mast to neighboring and operating wind turbines should be two rotor diameters D of the neighboring wind turbine or two rotor diameters of the wind turbine, if it

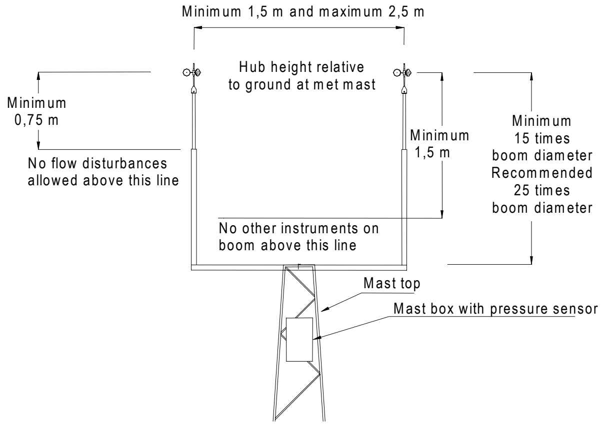

Figure 2: *Example of alternative top-mounted primary and control anemometers positioned side-by-side and wind vane and other instruments on the boom.*

has a larger diameter. No significant obstacles (e.g. buildings, trees, parked wind turbines) should exist in the measurement sector within a reasonable distance from the wind turbine and meteorological mast. **If this is unavoidable, then an obstacle model is used to predict/assess the influence of obstacles** upon the mast and the turbine position at hub height.

Correction factors, flow distortion, site calibration

The installation site should be **assessed for sources of wind flow distortion due to topographical variations**. The assessment should identify whether the power curve can be measured without a required site calibration.

Without a site calibration, the terrain at the site may only show minor variations from a plane, which passes both through the base of the tower of the wind turbine, and the terrain within the sectors. In addition, if the terrain characteristics are within the limits of 3% and 10% of the maximum slopes, then a flow model can be used to determine if a site calibration measurement can be avoided. **Otherwise a site calibration measurement is required**.

A site calibration **quantifies and potentially reduces the effects of terrain and obstacles on the power performance**

measurement. A **key result** of a site calibration test is a table of flow correction factors for all wind directions in the measurement sector. Another result is an **estimate of the uncertainty** of these correction factors. The test may provide information that justifies a change to the allowable measurement sector.

Concerning the site calibration, **two meteorological masts should be erected**:

- One mast **is the reference position meteorological mast, to be used also for the power performance test**. The second mast is the turbine position mast. The setup requires two anemometers, a wind vane and a data acquisition system. The reference position anemometer and the wind vane should be mounted on the meteorological mast that is also used for power performance testing and measurement. The turbine position anemometer should be mounted on a temporary mast as close as possible to the position where the turbine's hub will be, or was located. This anemometer should be within 2.5% of hub height and the mast as close as possible to the turbine tower centre-line but no more than $0.2H$ from the centre-line, where H is the turbine hub height.
- A second wind vane may be mounted on the temporary mast at the turbine position **to provide additional information on flow distortion at the site**.

Data should be collected **continuously at the same sampling rate** as for the power performance parameters data collection. Data sets should be based on $10min$ periods derived from **contiguous measured data**. **The mean, standard deviation, minimum and maximum values for each** $10min$ **period should be derived and stored**.

As a minimum, the site calibration data set should consist of $24h$ **of data for each non-excluded wind direction bin**. Each bin should have **at least** $6h$ **of data, for wind speeds above** $8m/s$ **and at least** $6h$ **of data, for wind speeds below** $8m/s$**.** Beyond these minimum requirements, the test should be monitored to indicate the convergence of data.

Environmental parameters

By the time the installation site is set up, the procedure of electrical quantities measurement of the wind turbine can then take place. To assess the performance and the operational characteristics of the wind turbine the following quantities need to be measured and evaluated according to international standards and respective guidelines:

speed

Wind speed measurements should be made with a cup anemometer. An anemometer is an instrument to measure wind speed. As such, **it is subjected to external conditions that may influence the wind speed measurement** through the operational characteristics of the instrument. Some of the most common influence parameters of cup anemometers are turbulence, air temperature, air density, and average flow inclination angle. **Anemometers being used for power performance measurements should be assessed for these influential parameters and operational uncertainties**. The uncertainty in wind speed measurement derives from **three sources**:

- The calibration of the instrument
- The operational characteristics of the anemometer and
- Flow distortion due to instrument mounting effects.

Wind direction

Wind direction should be measured with a wind vane. A wind vane used for this purpose should be mounted on the meteorological mast on a boom. The combined calibration, operation, and orientation uncertainty of the wind direction measurement should be less than 5^o. At this point, it is worth mentioning that all instruments used to measure wind speed and wind direction must have gone through the calibration process according to ISO standards and should be supported by a thorough assessment of calibration uncertainty.

Temperature and pressure

As already mentioned, **temperature and pressure sensors** should be present on the meteorological mast.

Air density ρ should be calculated on the basis of the mean wind tunnel air temperature T, relative humidity ϕ and barometric pressure B, using equation:

$$\rho = (\frac{B}{R_0} - \varphi \cdot P_w(\frac{1}{R_0} - \frac{1}{R_w}))$$

where,

B, is the barometric pressure $[P_a]$

T, is the absolute temperature $[K]$

ϕ, is the relative humidity $(0to1)$

R_0, is the gas constant of dry air $[287, 05J/kgK]$

R_w, is the gas constant of water vapour $[461, 5J/kgK]$

P_w, is the vapour pressure $[P_a]$

Electric power

At this section, the equipment requirements for measuring electrical quantities of the system are presented.

The net electric power of the wind turbine should be measured using a **power measurement device (e.g. power transducer)** and should be based on measurements of current and voltage **on each phase**. The class of the current transformers should meet the requirements of IEC 60044-1 and the class of the voltage transformers, if present, should meet the requirements of IEC 60186. They should be **class** 0.5 **or better.**

The accuracy of the power measurement device, if it is a power transducer, should meet the requirements of IEC 60688 and should be class 0.5 or better. If the power measurement device is not a power transducer then the accuracy should be **equivalent to class** 0.5 **power transducers.**

Measurement procedure

Measurement post-processing and data acquisition must be performed in a way that the collected data meet a set of clearly defined criteria to ensure that the data are of sufficient quantity and quality to accurately determine the power performance characteristics of the wind turbine. **The measurement procedure should follow a designated format so that every procedural step and test condition can be reviewed**:

- During the measurement period, the wind turbine should be in normal operation, as prescribed in the wind turbine operations manual, and the machine configuration may not be changed. **Any special maintenance actions should be noted**.
- Data should be collected continuously at **a sampling rate of** $1Hz$ **or higher**. Air temperature, air pressure, wind turbine status and precipitation, if measured, may be sampled at a slower rate, **but at least once per minute**.
- The data acquisition system should store either sampled data or statistics of data sets, based on $10min$ **periods**, as follows:
  - *mean value,*
  - *standard deviation,*
  - *maximum values and*
  - *minimum values*

In order to ensure that **only data obtained during normal operation of the turbine are used in the analysis, rejection criteria must be adopted and be clearly reported**. Data rejection criteria may include, but are not limited to, *wind speeds out of the operating range of the wind turbine, fault conditions preventing the normal operation of the turbine etc.* For the selected data sets, wind speeds should be corrected for flow distortion from site calibration and air pressure should be corrected if measured at a height other than close to hub height.

The selected data sets should be sorted using the **method of bins** procedure. The selected data sets should at least cover a wind speed range extending from $1m/s$ below cut-in, to $1.5 times$ the wind speed at 85% of the rated power of the wind turbine. Alternatively, the wind speed range should extend from $1m/s$ below cut-in, to a wind speed at which "Annual Energy Production measured" is greater than, or equal to 95% of "AEP-extrapolated". t should be clearly stated which of the two definitions has been used to determine the range of the measured power curve. The wind speed range should be divided into $0.5m/s$ contiguous bins centered on multiples of $0.5m/s$.

The database should be considered complete when it has met the following criteria:

- Each bin includes **a minimum of** $30min$ of sampled data,
- The database includes **a minimum of** $180h$ of sampled data.

In case that a single incomplete bin is missing, then that bin value can be estimated by linear interpolation from the two adjacent complete bins.

When the process of measurements, in accordance with all the above criteria is completed, then the **wind turbine power performance characteristics,** such as the power curve and the estimated annual energy production (AEP), can be derived.

Data normalization

The selected data sets should be **normalized to two reference air densities**:

- One should be the **sea level air density**, referring to ISO standard atmosphere ($1.225kg/m^3$). The other should be the average of the measured air density data at the installation site during periods of valid data collection, rounded to the nearest $0.05kg/m^3$. No air density normalization to actual average air density is needed when the actual average air density is within $1.225 \pm 0.05\ kg/m^3$.
- Alternatively, the other normalization may be carried out to a **nominal air density pre-defined for the site**. The air density may be determined from measured air temperature and air pressure according to the equation:

$$\rho_{10\,\mathrm{min}} = \frac{B_{10min}}{R_o T_{10min}}$$

$\rho_{10\mathrm{min}}$, is the derived $10min$ averaged air density

T_{10min}, is the measured absolute air temperature averaged over $10min$

B_{10min}, is the measured air pressure averaged over 10 min and R_0 is the gas constant of dry air $287,05J/(kgK)$.

For a stall-regulated wind turbine with constant pitch and constant rotational speed, data normalization should be applied to the measured power output according to the equation:

$$P_n = P_{10min} \frac{\rho_0}{\rho_{10min}}$$

P_n, is the normalized power output P_{10min}, is the measured power averaged over $10min$ ρ_0, is the reference air density.

For a wind turbine with active power control, the normalization shall be applied to the wind speed according to the equation:

$$V_n = V_{10min} \sqrt[3]{\frac{\rho_{10\,\mathrm{min}}}{\rho_{10min}}}$$

V_n, is the normalized wind speed V_{10min}, is the measured wind speed averaged over $10min$

Determination of the measured power curve

The measured power curve is determined by applying the "method of bins" for the **normalized data sets**, using 0.5 m/s bins and by calculation of the mean values of the **normalized wind speed** and **normalized power**

output for each wind speed bin according to the equations:

$$V_i = \frac{1}{N_i} \sum_{j=1}^{N_i} V_{n,i,j}$$

$$P_i = \frac{1}{N_i} \sum_{j=1}^{N_i} P_{n,i,j}$$

V_i, is the normalized and averaged wind speed in bin-i

$V_{n,i,j}$, is the normalized wind speed of data set j in bin-i

P_i, is the normalized and averaged power output in bin-i

$P_{n,i,j}$, is the normalized power output of data set j in bin-i

N_i, is the number of 10 min data sets in bin-i.

Annual energy production (AEP)

- Generic AEP is estimated by applying the measured power curve to different reference wind speed frequency distributions. A Rayleigh distribution, which is identical to a Weibull distribution with a shape factor of 2, should be used as the reference wind speed frequency distribution. AEP estimations should be made for **hub height annual average wind speeds of 4, 5, 6, 7, 8, 9, 10 and 11 m/s** according to the equation:

$$AEP = N_h \sum_{i-1}^{N} [F(V_i) - F(V_{i-1})] \ldots$$
$$\ldots \left(\frac{P_{i-1} + P_i}{2} \right)$$

AEP, is the annual energy production

N_h is the number of hours in one $year 8760$

N, is the number of bins

V_i, is the normalized and averaged wind speed in bin i

P_i is the normalized and averaged power output in bin i

$F(V)$, is the Rayleigh cumulative probability distribution function for wind speed:

$$F(V) = 1 - exp \left(-\frac{\pi}{4} \left(\frac{V}{V_{\text{ave}}} \right)^2 \right)$$

V_{ave} , is the annual average wind speed at hub height

- The AEP should be calculated **in two ways, one designated "AEP-measured", the other "AEP- extrapolated"**. If the measured power curve does not include data up to cut-out wind speed, the power curve should be extrapolated from the maximum complete measured wind speed up to cut-out wind speed.
- **AEP-measured** should be obtained from the measured power curve by assuming zero power for all wind speeds above and below the range of the measured power curve.
- **AEP-extrapolated** should be obtained from the measured power curve by assuming zero power for all wind speeds below the lowest wind speed in the measured power curve and constant power for wind between the highest wind speed in the measured power curve and the cut-out wind speed. The constant power used for the extrapolated AEP should be the power value from the bin at the highest wind speed in the measured power curve.

For all AEP calculations, **the availability of the wind turbine should be set to** 100%. For given annual average wind speeds, estimations of AEP-measured should be labelled as "incomplete" when calculations show that the AEP-measured is less than 95% of the AEP-extrapolated.

Estimations of measurement uncertainty in terms of standard uncertainty of the AEP, should be reported for the AEP-measured for all given annual average wind speeds.

The uncertainties in AEP, described above, only deal with uncertainties originating from the power performance test **and do not take into account uncertainties due to other important factors relating to actual energy production for a given installation**.

Reporting format

An important part to complete the procedure is the presentation of data and processed results. The test report should contain the following information:

- A description of the test equipment,
- A description of the measurement procedure,
- Presentation of measured data,
- Presentation of measured power curve for air density at sea level,
- Presentation of measured power curve for site specific air density,
- Presentation of measured power curves collected under special operational and atmospheric conditions,
- Presentation of estimated annual energy production for air density at sea level,
- Presentation of estimated annual energy production for site specific air density,
- Presentation of measured power coefficient,
- Uncertainty of measurement,
- Deviations from the procedure.

Electrical measuring transducers - IEC 60688:2013

Scope: This International Standard is intended to specify the terminology and definitions relating to transducers whose main application is in electrical power engineering, especially for the purposes of **process control and telemetry systems.** This chapter is not an integrated report of the standard, but aims to unify the test methods used in **evaluating transducer performance** and to specify **accuracy** limits and **output values** for transducers.

This standard applies to measuring **transducers** used for converting alternating electrical quantities such as: *Current, Voltage, Active power, Reactive power, Power factor, Phase angle, Frequency,* to an **output signal**.

Within the **measuring range**, the **output signal** is a function of the measurand. An **auxiliary supply** may be needed. This standard applies:

- If the **nominal frequency** of the input(s) lies **between** $5Hz$ **and** $1500Hz$
- If a **measuring transducer is part of a system for the measurement of a non-electrical quantity**
- To transducers for use in a variety of applications, such as telemetry and process control and in one of a number of defined environments.

Class index, permissible limits of intrinsic error, auxiliary supply and reference conditions

The **class index** for a transducer is defined as shown in the table **??**:

Table 1: *Relationship between the limits of intrinsic error, expressed as a percentage of the fiducial value, and the class index*

class index	0.1	0.2	0.5	1
limits of error	±0.1%	±0.2%	±0.5%	±1%

When the transducer is under **reference conditions**, the error at any point between the upper and lower nominal values of the output signal should not exceed the limits of the intrinsic error given in table expressed as a percentage of the **fiducial value** [1] When the transducer is under reference conditions, the error at any point between the upper and lower nominal values of the output signal should not exceed the limits of the intrinsic error given in table expressed as a percentage of the fiducial value.

Some transducers that are part of the measuring equipment may need **an auxiliary supply**. This is specified in two separate categories, d.c. and a.c. supplies.

As far as the **DC supply** is concerned:

- The preferred nominal value of d.c. auxiliary supplies should be $24V$, $48V$ or $110V$.
- The battery supply may be **earthed or floating**. Suitable means should be provided in the transducer to ensure isolation between the power supply and the input/output circuits of the transducer.
- The transducer should withstand **any ripple up to a maximum of** 10% **peak to peak**, superimposed on the d.c. power supply.
- **The noise fed back** to the battery from the transducer should be limited to $100mV$ peak to peak when measured with a specified source resistance at **all frequencies up to** $100MHz$**.**

As far as the AC supply is concerned:

- The nominal values of voltage, current, frequency and auxiliary supply should be specified by the manufacturer. For auxiliary supply, voltage may be provided by a separate supply or may be derived from the measured voltage.

Requirements

The **nominal values** of voltage, current, frequency and auxiliary supply should be specified by the manufacturer.

[1]Fiducial value: is a value to which reference is made in order to specify the accuracy of a transducer. The fiducial value is the span, except for transducers having a reversible and symmetrical output signal when the fiducial value may be half the span if specified by the manufacturer.

The **nominal value of the output signal** can be obtained for any adjusted value of the measurand within a given range.

Adjustment range for transducers which can be adjusted by the user:

- for the input voltage: 80...120% of the nominal value
- for the input current: 60...130% of the nominal value.

This means that the nominal value of the output signal can be obtained for any adjusted value of the measurand within the ranges given above.

The **lower and upper nominal values of the analogue output signals** should be chosen from those given below:

- **Output current**
  - The signal (4 - 20mA) is preferred.
  - (0 - 20mA)
  - (0 - 1mA)
  - (0 - 10mA)
  - (±1 - 0mA)
  - (±10 - 0mA)
- **Compliance voltage**, for variable output load transducers having a current output, the value of the voltage appearing across the output terminals up to which the transducer complies with the requirements of this standard.
- **Output voltage**
  - (0 - 1V)
  - (0 - 10V)
  - (±1 - 0V)
  - (±10 - 0V)

The **maximum ripple content** in the output signal should not exceed twice the class index.

Before determining the **response time**, the transducer should be under reference conditions and the auxiliary circuit **should be energized for at least the pre-conditioning**

time, unless it is energized from one of the input quantities and is not separately accessible. The response time should be stated by the manufacturer and should be determined for an input step such that it would produce a change in output signal from 0% **to** 90% **of the fiducial value.** If a test for decreasing input is required, the input step should produce a change in output signal **from** 100% **to** 10% **of the fiducial value.**

The output signal should be **limited** to a maximum of twice the upper nominal value. When the measurand is not between its lower and upper nominal values, the **transducer should not, under any conditions**, for example over-current or under-voltage, produce an **output having a value between its lower and upper nominal values.**

Transducers should be capable of **withstanding**, without damage, **exposure to temperatures within the range** $40C$ **to** $+70C$.

When the transducer **is sealed to prevent unauthorized adjustment**, access to the internal circuit and to the components within the case should not be possible without destroying the seal.

Instrument transformers - IEC 60044:2003

Scope: These parts of IEC 60044 apply to new inductive voltage transformers and current transformers for use with electrical measuring instruments and electrical protective devices at frequencies from 15 Hz to 100 Hz.

Normal service conditions

- Inductive voltage transformers and current transformers that are classified in three categories as given in table ??
- The altitude does not exceed 1000 m.
- Other service conditions for indoor transformers:
  - The influence of solar radiation may be neglected.

Table 2: *Temperature categories*

Category	Minimum temperature	Maximum temperature
-5/40	5	40
-25/40	25	40
-40/40	40	40

  - The ambient air is not significantly polluted by dust, smoke, corrosive gases, vapours or salt.
  - The conditions of humidity are as follows:
    * The average value of the relative humidity, measured during a period of $24h$, does not exceed 95%
    * The average value of the water vapour pressure for a period of $24h$, does not exceed $2.2kPa$.
    * The average value of the relative humidity, for a period of one month, does not exceed 90%.
    * The average value of the water vapour pressure, for a period of one month, does not exceed $1.8kPa$.
- Other service conditions for outdoor transformers.
  - **Average value** of the ambient air temperature, measured over a period of $24h$, does not exceed $35C$.
  - **Solar radiation up to a level of** $1000W/m^2$ (on a clear day at noon) should be considered.
  - The ambient air may be polluted by dust, smoke, corrosive gases, vapours or salt.
  - **The wind pressure does not exceed** $700Pa$ (corresponding to $34m/s$ wind speed).
  - Account should be taken of the presence of condensation or precipitation.

Special service conditions

- For installation in a place where the **ambient temperature can be significantly outside the normal service condition range**, the preferred ranges of minimum and maximum temperature to be specified should be:
  - $-50C$ and $40C$ for very cold climates
  - $-5C$ and $50C$ for very hot climates.
- For installation at an **altitude higher than** $1000m$, the arcing distance under the standardized reference atmospheric conditions should be determined by multiplying the withstand voltages required at the service location by a **factor k** This factor can be calculated with the following equation:

  $$k = e^{\frac{m(H-1000)}{8150}}$$

  where, H is the altitude in metres ($m = 1$ for power-frequency and lightning impulse voltage, $m = 0,75$ for switching impulse voltage).

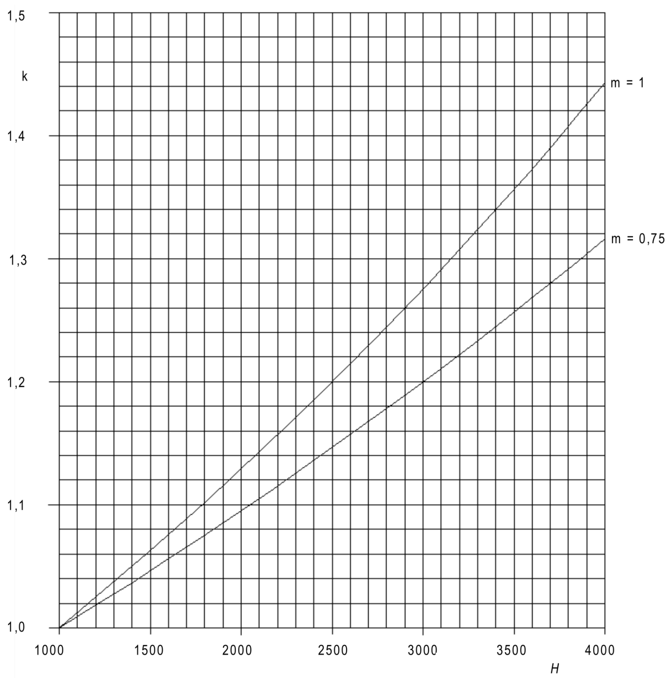

Figure 3: *Altitude correction factor*

System earthing

The considered system earthing are:

- isolated neutral system (a system where the neutral point is not intentionally connected to
- earth, except for high impedance connections for protection or measurement purposes)
- resonant earthed system (a system in which one or more neutral points are connected to earth through reactances which approximately compensate the capacitive component of a single-phase-to-earth fault current)
- earthed neutral system:
  - solidly earthed neutral system (a system whose neutral point(s) is(are) earthed directly)
  - impedance earthed neutral system (a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents).

Ratings for current transformers

- The standard values of rated **primary currents** are: <u>10</u>, 12.5, <u>15</u>, <u>20</u>, 25, <u>30</u>, 40, <u>50</u>, 60, <u>75</u> A, and their decimal multiples or fractions. **The preferred values are those underlined**.
- The standard values of rated secondary currents are: $1A$, $2A$ and $5A$, but the **preferred value is** $5A$.
- The standard values of **rated output up to 30 VA** are: $2.5VA$, $5VA$, $10VA$, $15VA$ and $30VA$. Values above $30VA$ may be selected to suit the application.

The standard value of rated continuous thermal current is the rated primary current. When a rated continuous thermal current greater than rated primary current is specified, the preferred values should be 120% to 150% and 200% of rated primary current. A rated short-time thermal current should be assigned to the transformer.

If an inductive voltage transformer or current transformer is specified for service at an altitude in excess of 1000 m and tested at an altitude below 1000 m, the limits of temperature rise given should be reduced by the following amounts for each 100 m that the altitude at the operating site exceeds 1000 m:

- Oil-immersed transformers 0.4%
- Dry-type transformers 0.5%

Communications for monitoring and control of wind power plants - 61400-25

Scope: The focus of the IEC 61400-25 series is on the communications between wind power plant components such as wind turbines and actors such as SCADA Systems. Internal communication within wind power plant components is beyond the scope of the IEC 61400-25 series. The IEC 61400-25 series addresses vendors (manufacturers, suppliers), operators, owners, planners, and designers of wind power plants as well as system integrators and utility companies operating in the wind energy market. The IEC 61400-25 series is intended to be accepted and to be used worldwide as the international standard for communications in the domain of wind power plants. The wind power plant specific information describes the crucial and common process and configuration information.

The lEC 61400-25 series is designed for a communication environment supported by a client-server model. Three areas are defined, that are modelled separately to ensure the scalability of implementations:

- wind power plant information models,
- information exchange model, and
- mapping of these two models to a standard communication profile.

The wind power plant information model and the information exchange model, viewed together, constitute an interface between client and server. In this conjunction, the wind power plant information model serves as an interpretation frame for accessible wind power plant data. The wind power plant information model is used by the server to offer the client a uniform, component-oriented view of the wind power plant data. The information exchange model reflects the whole active functionality of the server. The lEC 61400-25 series enables connectivity between a heterogeneous combination of client and servers from different manufacturers and suppliers.

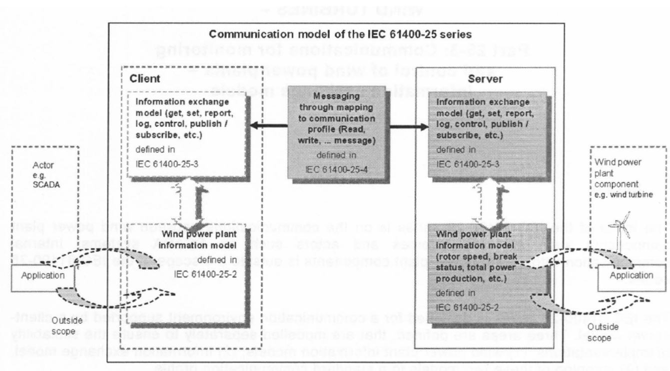

Figure 4: *Conceptual communication model of the IEC 61400-25 series*

As depicted in figure ??, the lEC 61400-25 series defines a server with the following aspects:

- information provided by a wind power plant component, for example, 'wind turbine rotor speed' or 'total power production of a certain time interval' is modelled and made available for access. The information modelled in the lEC 61400-25 series is defined in lEC 61400- 25-2.
- services to exchange values of the modelled information defined in lEC 61400-25-3.
- mapping to a communication profile, providing a protocol stack to carry the exchanged values from the modelled information (lEC 61400-25-4).

Terms and definitions

Actor: role a system plays in the context of monitoring and control, while it is not directly involved in wind power plant operation, such as Supervisory Control and Data Acquisition System (SCADA).

Communication function: used by an actor to configure, perform and monitor the information exchange with wind power plants, for example operational and management function.

Protocol stack: particular software implementation of a computer networking protocol suite. The terms are often used interchangeably. Strictly speaking, the suite is the definition of the protocols and the stack is the software implementation of them

Overall description

Wind power plant components are technical systems employed in the operation of wind power plants. They consist of various sub-components, which will not be differentiated in the following. All wind power plant components fall within the application area of the IEC 61400- 25 series.

The information modelled in the IEC 61400-25 series covers the following corresponding components:

- **wind turbine:** rotor, transmission, generator, converter, nacelle, yaw system, tower, alarm system.
- **meteorological system:** meteorological conditions of the wind power plant.
- **wind power plant management system:** wind power plant control
- **electrical system:** wind power plant grid connection

Generic requirements on communication

Wind power plants are monitored and controlled by various external actors, such as local or remote SCADA systems, local real time build-in control systems, energy dispatch centres etc. The objective of the monitoring of wind power plants is to provide the actors with information on the complete system and the installed components. This information is deemed to be an important knowledge basis for the control of wind power plants. Thus, wind power plants and external actors shall meet an essential prerequisite to be able to exchange information within the framework of monitoring and control: They shall be able to communicate with the outside world.

Typically, any wind power plant component, which needs to exchange information with other components and actors, is therefore equipped with a so-called intelligent electronic device (IED), which can send data to external receivers and receive data from external senders. A wind turbine usually possesses a wind turbine controller, which is primarily responsible for the internal monitoring and control of the wind power plant component, but also allows external monitoring and control.

Communication content

Information is the content of the communication that takes place within the framework of monitoring and control. The basic elements are raw data from the wind power plant component, which shall be processed into specified. There are five types of information that can be differentiated and are important for the monitoring and control of wind power plants:

- process information
- statistical information
- historical information
- control information
- descriptive information

Process, statistical and **historical** information provide the contents required for the monitoring and control of wind power plants; this information shall be communicated by the wind power plants. **Process information** provides information on the behaviour of certain complete systems and their components, on their current states. **Statistical information** is often useful to evaluate the operation of a wind power plant. By using **historical**

Information, it might be possible to track the operational trends in logs and reports.

Control information is intended to transmit the contents required for the control of wind power plants, such as access profiles, set points, parameters and commands; this information shall first be communicated to wind power plants by certain actors. Wind power plants shall store control information and provide this for further communication to subprocesses.

Descriptive information is the type and the accuracy of the information, as well as the time and the data description.

Communication functions

The actors communication for monitoring and controlling the wind power plants require special functions to configure, perform and monitor the information exchange with wind power plants. These functions can be divided into the following two main categories:

- **Operational functions:** are used by the actors to obtain information on wind power plants and to send control instructions to wind power plants. The operational functions include:
  - **monitoring:** operational function used for local or remote observation of a system or o process for any changes which may occur overtime. The term can also be used for observation of the behaviour of a data value or a group of data values.
  - **control:** Changing and modifying, intervening, switching, controlling, parameterisation, optimising of wind power plants.
  - **data retrieval:** collecting of wind power plant data
  - **logging:** Logging is a function intended for sequential recording of data and events in chronological order. The result of the logging is a log.
  - **reporting:** The reporting is a function intended to transfer data from a server to a client, initiated by a server application process.
- **management functions:** are required for the higher-lever management of the information exchange. They are used by actors to secure integrity of the monitoring and control process. The management functions included are as follows:
  - **user/access management:** Setting up, modifying, deleting users (administratively), assigning access rights (administratively), monitoring access.
  - **time synchronization:** Synchronisation of devices within a communication system.
  - **diagnostics (self-monitoring):** This function is used to set up and provide for self-monitoring of the communication system.
  - **system setup:** Defining how the information exchange will take place; setting, changing and receiving (retrieval) of system setup data.

Communication model

The lEC 61400-25 series defines a communication model for the monitoring and control of wind power plants, taking into account all requirements made with reference to the communication, on an abstract level. The communication model comprises three separately defined areas:

- information model
- information exchange model
- mapping of the information model and the information exchange model to standard communication profiles.

The wind power plant **information model** (see figure **??**) provides the contents required for the information exchange that takes place within the framework of the monitoring and control between client and server.

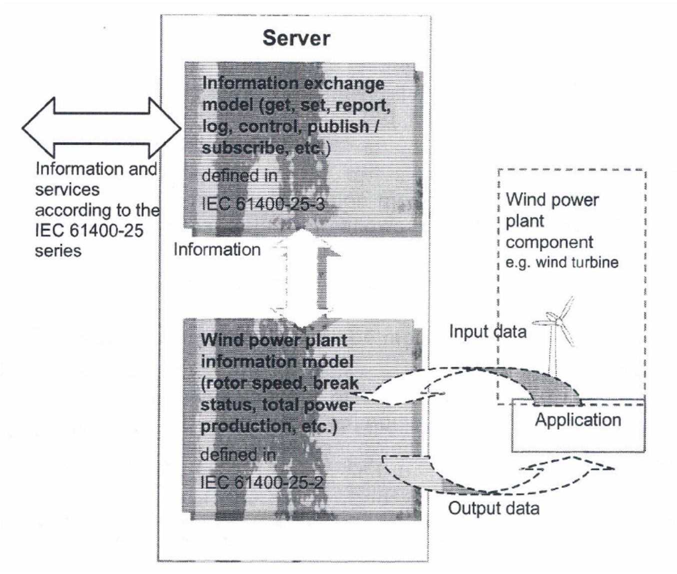

Figure 5: *Data processing by the server (conceptual)*

The IEC 61400-25 series utilises the **concept of object modelling** to represent the systems and components of a wind power plants to communicate with. This means that **all of the components in the real world are identified as objects** that have data such as analogue values, binary status, commands and set points and these objects and data are mapped into generic, logical representations of the real world components as a wind power plant information model.

Breaking a real world component down into objects to produce a model of that object involves identifying all of the data and functionality of each component object. **Each data has a name and a simple or complex type (a class)** and represents data in the device to be read or updated.

Instead of dealing with lists of numbered quantities, an **object-modelling** approach lets us organise and **define standard names for standard things**, independent of the manufacturer of the equipment. If the equipment has a shaft for which the rotational speed is available for reading, **it has the same name regardless of the vendor** of that equipment and can be **read by any client program** that knows the information model.

The **information exchange** mechanisms rely on standardised **wind power information models**. These information models and the modelling methods are the core of the lEC 61400-25 series. The lEC 61400-25 series uses the approach to model the information found in real components as depicted in the conceptual overview in figure ??. All information made available to be exchanged with other components is defined in the lEC 61400-25 series. The model provides for the wind power plant automation system an image of the real world (power system process, generator, etc.).

The lEC 61400-25 series defines the information and information exchange in a way that is independent of a **concrete implementation** (i.e., it uses abstract models). The lEC 61400-25 series also uses the concept of virtualisation. Virtualisation provides a view of those aspects of a real device that are of interest for the information exchange with other devices.

The approach is to **decompose the functions** into the smallest entities, which are used to exchange information. The granularity is given by a reasonable distributed allocation of these entities to dedicated devices (lED). These entities are called logical nodes (e.g., a virtual representation of a rotor class, with the standardised class name WROT). The **logical nodes** are modelled and defined from the conceptual application point of view. Logical nodes are collected in a logical device representing for example a complete wind turbine.

Based on their functionality, a logical node contains a list of data (e.g., rotor speed) with dedicated information. The data have a structure and a well-defined semantic (meaning in the context of wind power plant systems). The information represented by the data are exchanged by the services according to the information exchange services defined.

The logical nodes and the data contained are crucial for the information model and the information exchange services for wind turbines to reach interoperability.

The information exchange between server and client requires a uniform communication protocol on both sides. A **specific mapping** to a communication profile defines how the objects in the wind power plant information model and the functions and services defined in the information exchange model are implemented using a specific protocol stack, i.e. a complete communication protocol. IEC 61400-25-4 specifies in detail the communication protocols applied in the IEC 61400-25 series.

Wind power plant information model

For modelling purposes, information could be logical nodes, data or data attributes. Data consists of data attributes that can be, for example the value (of a measurand, state, set-point etc.), accompanying name, time, quality, accuracy, unit etc.

A wind power plant comprises different types of information. Besides source data, wind turbine controllers usually derive a huge amount of additional information (10 min averages, alarms, logs, counters, timers, etc.). This valuable information is locally stored and available for future use or analysis. In the table ??, the relations between different information categories are shown and their definition will be used in the lEC 61400-25 series.

Because all the information categories as listed in Table comprise their own formats and properties, the IEC 61400-25 series has to define a **general wind power plant information model**. The structure of this top-down view model is hierarchical and based on the modelling approach as defined in IEC 61850-7-1 Clause 6 (Modelling approach of the IEC 61850 series) where the basis are described in IEC 61850-7-2:2003, Clause 5. Hierarchical means that **different levels of common information are distinguished and grouped together** into classes. Lower level classes will automatically inherit properties as specified by upper level classes. The structure of the wind power plant information model is concisely given in figure ??. Each level will be discussed separately in more detail.

The highest level is called Logical Device (LD), which is decomposed into Logical Nodes (LN). A logical node consists of a collection of related data, called data classes (DC). Each data class **inherit a collection of properties**, as defined by a so-called **Common Data Class** (CDC) to which it is assigned. A common data class consists of a collection of data

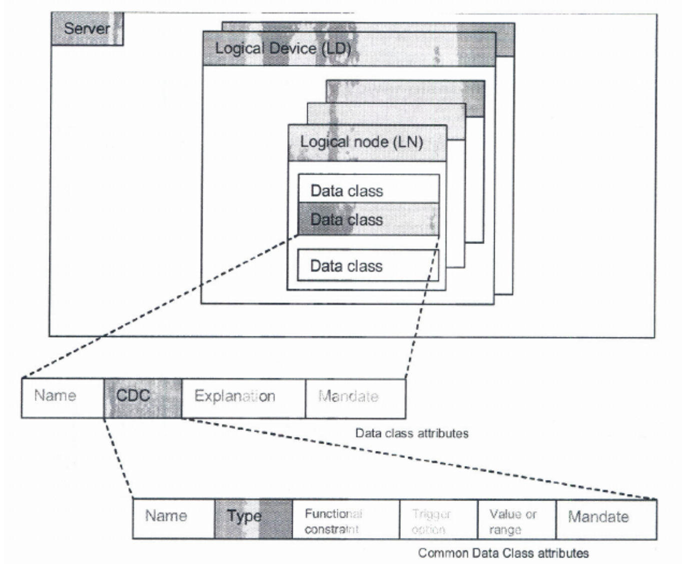

Figure 6: *Structure of wind power plant information model*

records. The most basic detail of data can be found in the type-definition of a common data class.

Wind power plant information exchange model

The primary **objective** of the wind power plant **information exchange model** defined in the IEC 61400-25-3 is to exchange information provided by the instantiated information model of the various classes, such as Logical Nodes, Data, Data Attributes or control blocks. The IEM defines a server that provides:

- an instance of the wind power plant information model, and
- required functions including the associated services (Get, Set, Control, Query, Report, etc.) which enable a client to access the instantiated information model.

The IEC 61400-25 series defines the server role only. A client issues service requests to the server, by sending request messages, and receives response messages or reports from the server.

A server provides access to its wind power plant information model instance for multiple clients, as illustrated in figure ?? . Each client

Table 3: *Wind power plant information categories*

Category	Description
Process information	
State information	Discrete information concerning the current condition or behaviour of a component or system
status alarm event	Condition of a component or system (stl/st2/ ..stn) Statement of safety intervention by for example the turbine control system State transition (status, alarm, command)
Analogue information	Continuous information concerning the current condition or behaviour of a component or system
measured data processed data Three phase data	(Sampled) value of a process quantity Measured value, which has been processed (10m-average/. ..) Measured value of a three phase electric power quantity
Control information	
Control information	Discrete information concerning the current condition or behaviour of a component or system
command set point parameter	Controllable status for system behaviour (enable/disable, activate/deactivate etc) Reference value for a process quantity Controllable value for system behaviour (adjustment)
Derived information	
Statistical information	The result of applying a statistical algorithm to a set of data.
timing data counting data characteristic data	Total time duration of a specific state Total number of occurrences of a specific event Properties of information or data observed (min, max, average, std. dev, etc.)
Historical information	Information about the time passed
log transient log report	Chronological list of events for a specific period of time Event triggered chronological list of high resolution source information for a short period of time. Periodical notification comprising the information that represent the state and data requested in the report control block.

can, independently of other clients, communicate with the server.

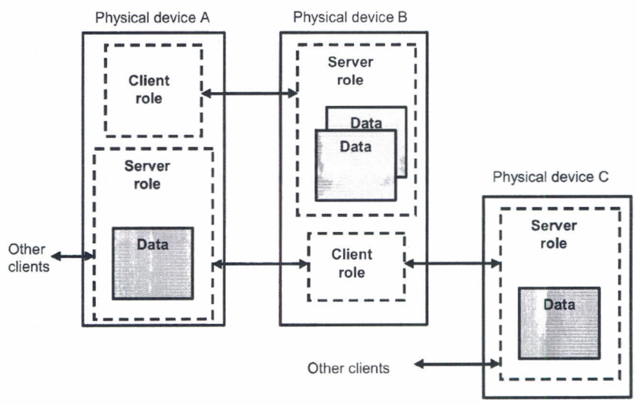

Figure 7: *Client and server role*

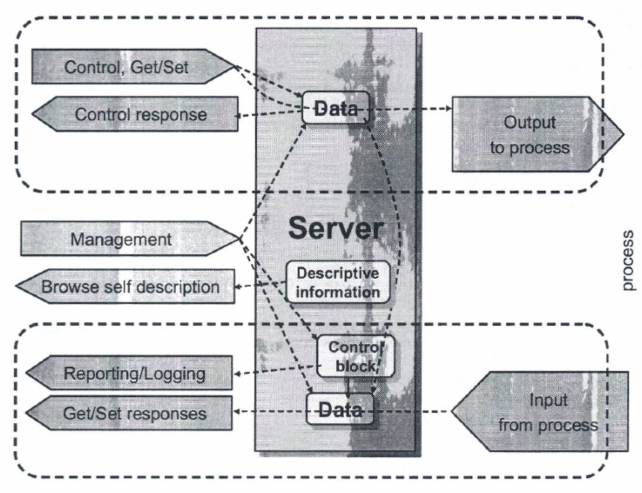

Figure 8: *IEM Service models*

The wind power plant information model in the server supports the access services as depicted in figure ??.

The focus of the server is to provide data that make up the wind power plant information model. The data attributes contain the values used for the information exchange. The IEM provides services for:

- control of external operational devices or internal device functions
- monitoring of both process and processed data, and
- management of devices as well as retrieving the wind power plant information model.

The wind power plant information model data instances contained in the server can be accessed by the services Get, Set, Control for immediate action (return information, set values to data, control device or function).

Reporting and logging provide the means to autonomously and spontaneously send information from the server to the client issued by a server-internal event (reporting) or to store this information in the server for later retrieval (logging).

The set of basic services that **the communications interface uses to accomplish the information exchange between the outside world and various components of the real world device** are referred to as the Abstract Communication Service Interface (ACSI). The basic methodology of these services is described in detail in IEC 61850-7-1 and 61850-7-2.

Service modelling convention

The services are generally defined by:

- a set of rules for the definition of messages so that receivers can unambiguously understand messages sent from a peer,
- the service request parameters as well as results and errors that may be returned to the service caller, and
- an agreed-on action to be executed by the service (which may or may not have an impact on process).

All services are based **on three message primitives: request, positive response and negative response**. The request primitive is used by the client to issue a service call to the server and the response primitives allow the server to return information to the client. A positive response primitive indicates that the service agreed-on action was or will be executed whereas a negative response indicates the action failed to execute or will not be executed. A message primitive may have a number of parameters, called results and errors in case of response primitives.

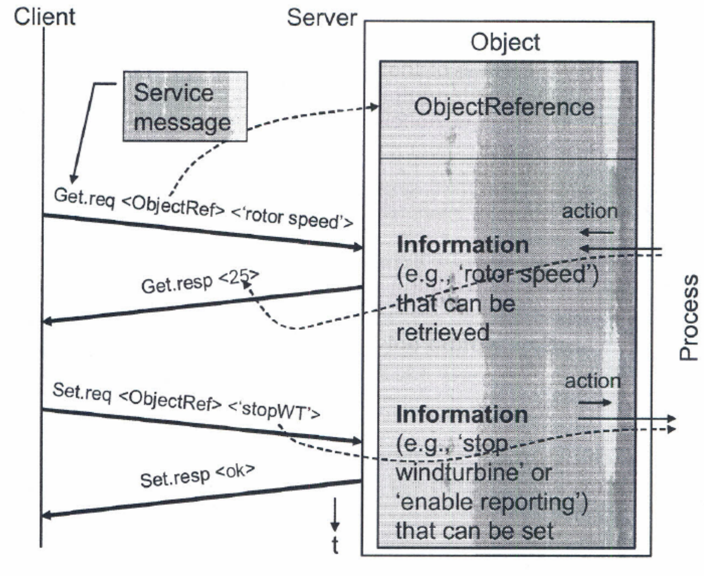

Figure 9: *EM Service models*

Mapping to communication protocols

The **specific communication service mapping (SCSM)** defines how the services and the models (server, logical devices, logical nodes, data, data sets, report controls, log controls, setting groups, etc.) are mapped to specific communication stacks, i.e. to a complete profile. The mappings and the used application layer define the syntax (concrete encoding) for the data exchanged over the network.

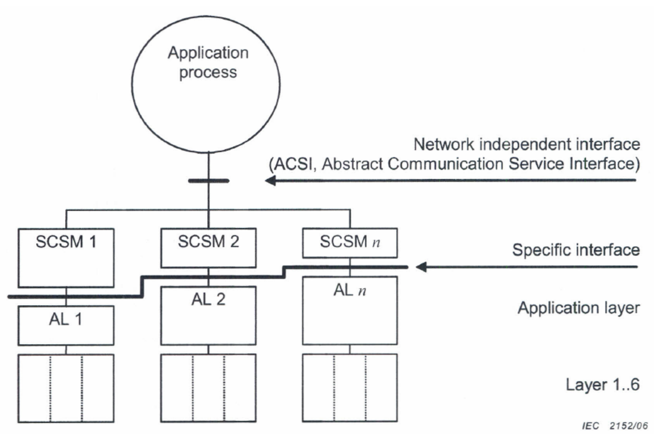

Figure 10: *ACSI mapping to communication stacks/profiles*

According to figure ??, the SCSM maps the abstract communication services, objects and parameters to the specific application layers. These application layers provide the concrete coding. Depending on the technology of the communication network, these mappings may have different complexities, and some ACSI services may not be supported in all mappings but where a service is provided in a mapping, that service shall be equivalent in its meaning to the same service in the benchmark mapping. An application layer may use one or more stacks (layer 1 to 6).

Architecture of the mappings: Multiple mappings may be supported by the IEC 61400-25 series. The conceptual architecture of the mappings is shown in figure ??.

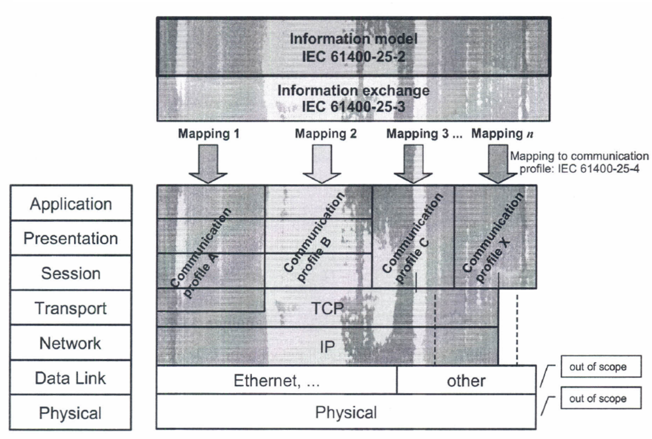

Figure 11: *Communication profiles*

The information models and the information exchange models need to be mapped to appropriate protocols. Mapping requirements are defined in IEC 61400-25-4. The protocols TCP and IP shall be the basic lower layer protocols provided by all mappings. Specific data link and physical layers are beyond the scope of the IEC 61400-25 series.

Communications for monitoring and control of wind power plants - Information models (61400-25-2)

Scope: IEC 61400-25-2 specifies the information model of devices and functions related to wind power plant applications. In particular, it specifies the compatible logical node names, and data names for communication between wind power plant components.This includes the relationship between logical devices, logical nodes and data. The names defined in the IEC 61400-25 series are used to build the hierarchical object references applied for communicating with components in wind power plants.

Overview of logical node classes

The basic **information** of a wind turbine has been **standardized**. Each component member of the system devices (wind turbine, control centre, meteorological system etc.) has been modelled in a data structure called **logical node**. A logical node is a data holder that can hold different types of information related to that component. The different data types include status, measurements, control information and settings.

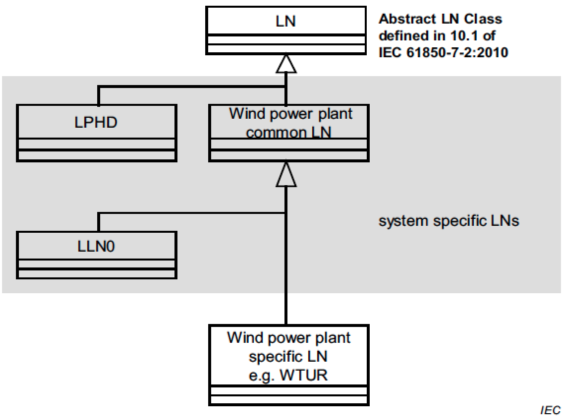

Figure 12: *Relationship of logical nodes*

The following two groups of common logical node classes are defined:

- system specific logical nodes,
- wind power plant specific logical nodes.

System specific logical nodes shall include all common information for physical hosting devices and wind power independent information. Wind power specific logical nodes shall inherit at least all mandatory information of system logical nodes.

All logical node classes defined in this part of the 61400-25 series inherit their structure from the abstract logical node class (*GenLogicalNode*) defined in 10.1 of IEC 61850-7:2010.

Table 4: *System specific logical nodes*

LN classes	Description	M/O
LLN0	Logical Node Zero	M
LPHD	Physical Device Information	M

The system specific logical node classes listed in table **??** are all mandatory. The logical node zero (LLN0) represents common information of the logical device, and the logical node physical device (LPHD) represents common information of the physical devices hosting the logical device.

Table 5: *Wind power plant general logical nodes*

LN classes	Description	M/O
WTUR	Wind turbine general information	O
WPPD	Wind power plant general information	O
WALM	Alarm information	O
WMET	Meteorological information	O
WAPC	Active power control information	O
WRPC	Reactive power control information	O
WSLG	State log information	O
WALG	Analogue log information	O
WREP	Report information	O
WAVL	Availability information	O
LTIM	Time management	O

Wind power plant information shall be classified in wind power plant specific logical nodes. In principle, classification of wind power plant information in different logical nodes is an arbitrary process and the modelling method offers flexibility. From the viewpoint of standardisation it is preferable that all wind power plant information will be build unambiguously and in asimilar way. A wind power plant consists of several components, including one or more wind turbines, which may be modelled as individual devices. Table ?? shows the wind power plant general information breakdown into logical nodes which are common to a complete wind power plant.

Table 6: *Logical nodes for modelling a wind turbine*

LN classes	Description	M/O
WTUR	General information	M
WROT	Rotor information	M
WTRM	Transmission information	O
WGEN	Generator information	M
WCNV	Converter information	O
WTRF	Transformer information	O
WNAC	Nacelle information	M
WYAW	Yawing information	M
WTOW	Tower information	O
WALM	Alarm information	M
WMET	Meteorological information	O
WSLG	State log information	O
WALG	Analogue log information	O
WREP	Report information	O
WAVL	Availability information	O
LTIM	Time management	O

Table ?? shows the breakdown of o wind turbine into logical nodes to be used. Each model of a wind turbine shall include the mandatory logical nodes listed in table ??. Despite the fact that some logical nodes are optional for use, it is recommended in the IEC 61400-25 series to deviate as little as possible from the logical nodes as proposed in table ?? that follows.

Table ?? shows the wind power plant device specific information for non wind turbine devices break down into logical nodes.

As shown in the tables, information is mainly modelled by a set of LN classes, which are classified by physical turbine decomposition. A useful practical exception involves alarm information; all alarms shall be collected in a separate logical node.

Table 7: *Logical nodes for modelling a non-turbine device*

LN classes	Description	M/O
WPPD	Wind power plant general information	O
WALM	Alarm information	O
WMET	Meteorological information	O
WAPC	Active power control information	O
WRPC	Reactive power control information	O
WSLG	State log information	O
WALG	Analogue log information	O
WREP	Report information	O
WAVL	Availability information	O
LTIM	Time management	O

Besides common information for all turbines, most information will, in practise, be determined by the turbine concept, the manufacturer, the site and the state of the art of turbine technology. For this reason, as a modeling guideline, the data class attribute names representing the specific information in the wind power plant specific logical nodes are focussed on the most prevailing modern wind turbine concept, namely 3-bladed, variable speed, active pitch and gearbox transmission. In case of additional information originated by other wind turbine systems or components, new data classes or specialised data classes to existing LNs could be defined. Additional user-specific LNs could also be defined.

Standardised names for logical node classes are written in capital letters. Data names of the first level in the hierarchy start with a capital letter, and attribute names and data names of the second and lower levels in the hierarchy with a small letter.

Use of logical node classes

The logical node classes defined in this part of the standard and those referenced from other standards, have to be instantiated in real systems. Figure ?? depicts an example of a real wind turbine that uses several instances of logical nodes.

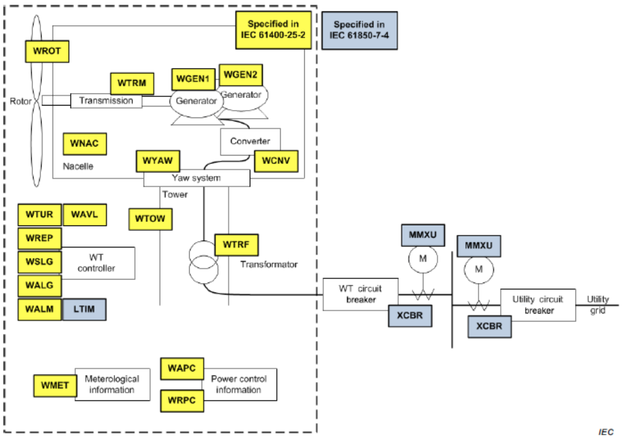

Figure 13: *Use of instances of logical nodes*

Extensions of the information model

The information model described in this document can be extended with additional logical nodes and data for a particular implementation. **If a different topology is applied or more sensors are used for monitoring purposes, the user is free to assign relevant information to additional data names. Any data can be added to any logical node.**

Basic concepts of common data classes

Shared properties of a group of data classes (of data defined in LNs) are defined in a common data class (CDC). A data class inherits all information as specified in its accompanying common data class attributes. Based on the wind power plant information requirements, a set of specific common data classes for wind power plants have been specified.

The following groups of common data classes are defined.

- Wind power plant specific common data classes:
  - Setpoint Value (SPV),
  - Status Value(STV),
  - Alarm (ALM),
  - Command (CMD),
  - Event counting (CTE),
  - State timing (TMS),
  - Alarm set status (AST).
- Common data classes inherited from IEC 61850-7-3:
  - Single point status (SPS),
  - Integer status (INS),
  - Integer status setting (ING),
  - Object reference setting (ORG),
  - Enumerated status (ENS),
  - Binary counter reading (BCR),
  - Measured value (MV),
  - Phase to ground (neutral) related measured values of a 3 phase system (WYE),
  - Phase to phase related measured values of a three phase system (WYE),
  - Controllable single point (SPC),
  - Controllable integer status (ENC),
  - Controllable enumerated status (ENC),
  - Controllable analogue process value (APC),
  - Enumerated status setting (ENG),
  - Logical node name plate (LPL).
- Common data classes inherited from IEC 61850-7-3 and specialised:

– Device name plate (DPL) $\rightarrow WDPL$.

Structure of common data classes

The abbreviated names of wind power plant specific common data classes are in capitals, short (3 characters is recommended) and shall be unique.

Inside a common data class, the information of a certain data class is modelled unambiguously by a table notation as shown in table ??.

For the sake of convenience, all common data class attributes are divided into categories. A common data class has attributes of the types that are explained briefly in table ??.

Communications for monitoring and control of wind power plants - Information exchange models (61400-25-3)

Scope This part of IEC 61400-25 provides the information exchange models that can be applied by a client and a server to access the content and structure of the wind power plant information model defined in IEC 61400-25-2. Also, gives an overview of the information exchange models for operational functions and management functions.

Information exchange models overview

The information exchange models provide services for communication functions that are grouped as follows:

- Operational functions,
- Management functions.

An instance of the wind power plant information model of a wind power plant shall be accessed by instances of the information exchange models listed in table ??. The first two columns enumerate the functional groups and their information exchange models, which are summarily described in the third column. The fourth and fifth columns identify which data kinds and transfer principles are applicable for each information exchange model. The last column indicates the ASCI service models used for the corresponding information exchange models.

Operational functions

The information exchange models for operational functions are as follows:

- association and authorisation model,
- control model,
- monitoring, reporting and logging model.

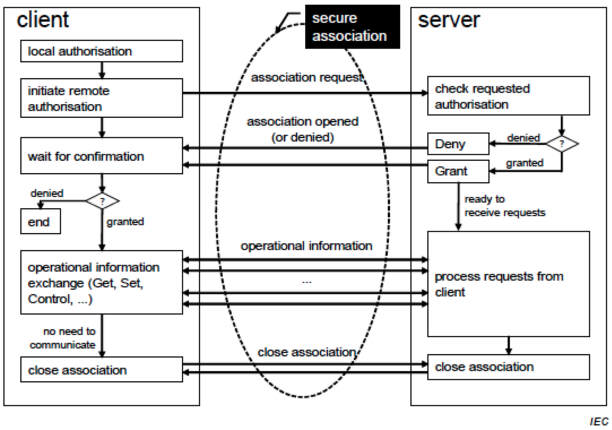

Figure 14: *Association and authorisation model (conceptual)*

The requirements to be fulfilled by an association between a client and a server are as follows:

- **authentication**: determining the identity of the user/client,
- **authorisation and access control**: ensure that the entity has the proper access rights
- **integrity**: messages and the computer infrastructure are protected against unauthorised modification or destruction,
- **confidentiality**: objects of the wind power plant information model are protected and only disclosed to appropriate users/clients,
- **non-repudiation**: preventing a user/client involved in a data exchange from denying that is participated in the exchange, prevention of denial of device: preventing a client/server from blocking access to authorised users

Table 8: *General table structure of a common data class (CDC)*

Data attribute name	Type	FC	TrgOp	Explanation and Value / Range	M/O
SubDataObject					
cdc attr. name	common data class				
DataAttribute					
Status					
cdc attr. name	attr type	fc		description and range	
Measured attributes					
cdc attr. name	attr type	fc		description and range	
Statistical information					
cdc attr. name	attr type	fc		description and range	
Historical information					
cdc attr. name	attr type	fc		description and range	
cdc attr. name	attr typeA	fc		description and range	
cdc attr. name	attr typeB	fc		description and range	
cdc attr. name	attr typeC	fc		description and range	
cdc attr. name	attr typeD	fc		description and range	
Status/measured attributes and control mirror					
cdc attr. name	attr type	fc		description and range	
Configuration, description and extension					
cdc attr. name	attr type	fc		description and range	

Control model: Defines the information exchange model for operating commands. The control model can only be applied to control objects and it is used to change the status of a device or to change the value of a set point or a parameter. the conceptual mechanism of the control model is shown in figure ??.

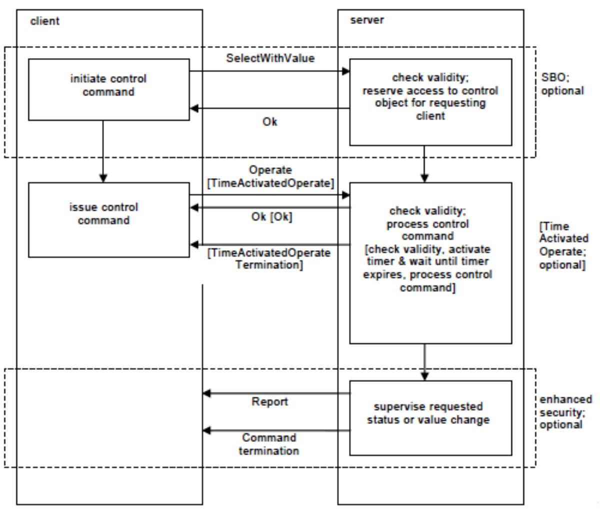

Figure 15: *Control model*

Monitoring, reporting and logging model: The models comprise three independent information retrieval methods:

- Values can be retrieved on demand by a client. This is commonly known as get or Read; the response will be transmitted immediately.
- Values can be reported to the client, following a publisher/subscriber reporting model. The server is configured (locally or by means of a service) to transmit values spontaneously or periodically. The client receives messages whenever trigger conditions are met at the server. The publisher/subscriber model may buffer events in case the communication link is down transmit all buffered events in sequence once the link is operating again, in case of a buffered report. In case of an unbuffered report, the delivery of events, in the case of a communication link failure is not guaranteed.
- Values can be logged at the device. The

Table 9: *Common data class attributes*

Data class attribute	**Description**
Data attribute name	Mnemonic abbreviation of the common data class attribute record
Type	Basic (for example INT, BOOLEAN) or composed data type definition
Functional constraint	Label to build groups for efficient information exchange. The list of functional constraints shall be as defined in IEC 61850-7-2:2010 Examples: ST Status information MX Measurands SP Setting SV Substitution CF Configuration DC Description OR Operate received BL Blocking EX Extended definition
Trigger option	Conditional notification that a state or value change has occurred dchg: data change, qchg: quality change, dupd: data update
Explanation/ Range	Description and range of an attribute record
Mandate	M: Mandatory, O: Optional, Conditional

logging model allows buffering and delivery of events in correct sequence. Logging values from multiple sources of data my be logged and each source can be configured independently of other sources. The client can query the log for entries between two timestamps or for all entries after a certain entry.

The reporting and logging models include:

- a Data Set class (DS), for referencing groups of data to be logged or reported,
- a Control Block class, for controlling the dynamic behaviour of the information logging or reporting, and
- a Log class, for definition of log storage.

The conceptual information exchange models for monitoring, reporting and logging are shown in figure **??**.

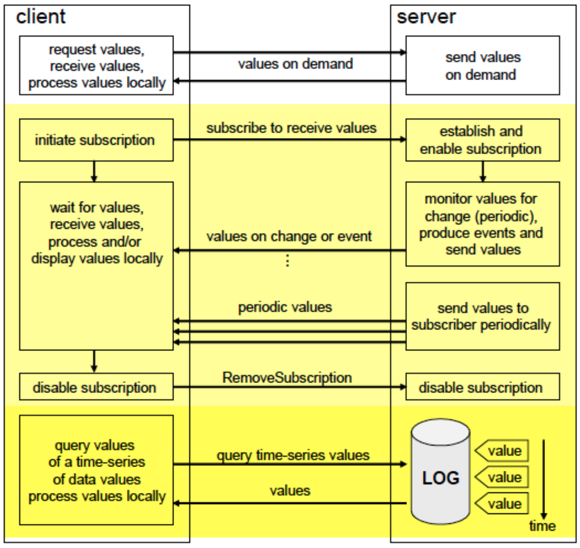

Figure 16: *Monitoring, reporting and logging model*

Management functions

The management functions are used to set-up or evolve a system. The system configuration and maintenance include the setting and changing of configuration data and the retrieval of configuration from the system. The management function models described are as follows:

- user management/access security model,
- setup model,
- time synchronisation model,
- diagnostic model.

The ASCI for wind power plant information models

The information exchanges models create an overview of the models required to be compliant with the IEC 61400-25 series. The basic information exchange models are depicted in Figure, illustrating the various components of the ASCI services. This figure ?? is used to provide a narrative description of how a typical device interacts with the outside world using these services. The normative definition of the details of the ASCI models and services are defined in IEC 61850-7-2.

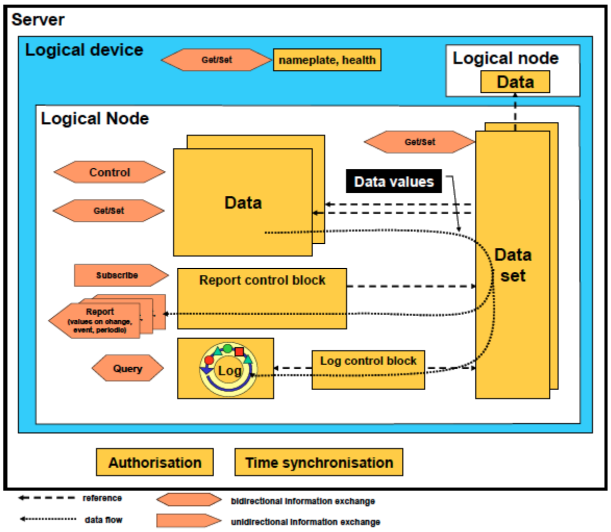

Figure 17: *Conceptual information exchange model for a wind power plant*

Services of association and authorisation

The application association model consists of provisions on how the communication between the various types of devices is achieved. The model comprises:

- class definitions of associations, and
- access control concepts.

The application association model defines the services provided for managing associations between client and server (two-party application association).

The access control model provides the capability to restrict the access of a specific client to class instances, class instance attributes, and ASCI services acting upon class instances of a specific server.

Services of ReportControlBlockClass

A report control block provides the mechanism for spontaneously reporting data values on specific criteria. The behaviour of a report control block is determined by the values of its attributes. the report control block references an instance of a data set. The attributes of an instance of a report control block can be set or retrieved.

In addition to reporting, the BRCB (BUFFERED REPORT CONTROL BLOCK) provides the functionality to prevent loss of events even if the communication is temporarily interrupted. With the URBC (UNBUFFERED REPORT CONTROL BLOCK) events will be lost in case of communication interruption.

The buffered and unbuffered reporting starts with the configuration of the report control blocks. The basic buffered reporting mechanism is shown in figure ??. The reporting starts with setting the enable buffer attribute to TRUE; setting to FALSE stops the reporting.

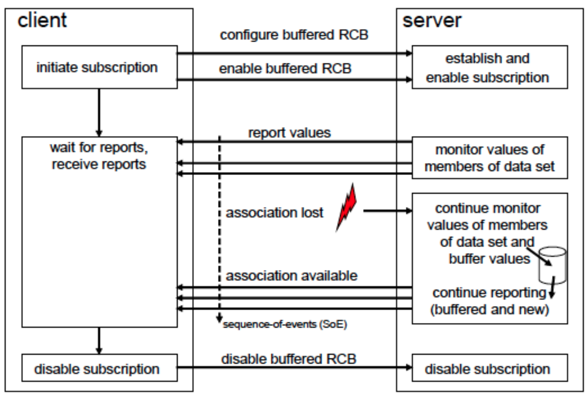

Figure 18: *Buffered report control*

The specific characteristic of the buffered report control block is that it continues buffering the event data as they occur according to the enabled trigger options in case of, for example, a communication loss. The reporting process continues as soon as the communication is available again. The buffered report control block guarantees the sequence-of-events (SoE) up to some practical limits (for example, buffer size and maximum interruption time).

Services of LogControlBlockClass and LogClass

Figure ?? shows an example of a log and three log control blocks. The first step is to configure and enable log control blocks. After enabling the association with that server may be closed. The log entries are stored into the log as they arrive for inclusion into the log. The logs are stored in time sequence order. This allows retrieval of a sequence-of-events (SoE) list.

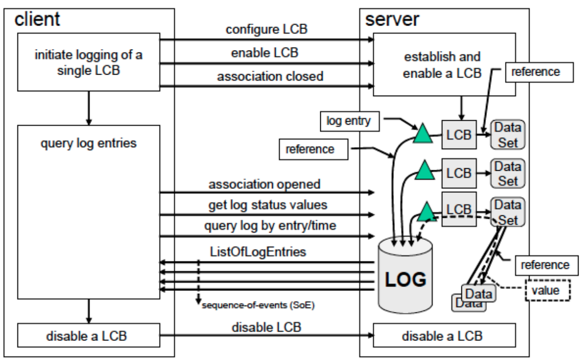

Figure 19: *Log control block*

The different log control blocks allow storage of information from different data sets into a log instance. Each log control block is independent of the other control blocks.

Conclusions

This **report** attempts to provide a consistent documentation regarding the internationally defined methodology and guidelines as far as the power performance measurement of small wind turbine applications are concerned, along with the respective ones for the evaluation of the accuracy limits and output values for the transducers related to electrical power engineering, in the context of the abovementioned applications. Standards concerning voltage and currents transformers used with electrical measuring instruments are also reviewed and presented. Furthermore the information models as well as the information exchange models regarding monitoring and control applications of wind power plants are examined. The methodology followed at this report ensures that the every part of the information flow described and evaluated, adhere to the respective standards and relevant methodologies. Having a holistic view of the standards and guidelines available, future standardisation activities are facilitated and a concise yet consistent framework is formulated, carrying forward the ongoing and future data loggers development efforts, both within the Wind Empowerment, but also for any interested organisation or individual aiming at providing robust, reliable and IEC compliant data monitoring and logging services or/and applications.

Table 10: *Information exchange models*

Functional group	**information exchange model**	**Short description**	**Information categories**	**Transfer principles**	**ASCI service models**
Operational	Authorisation	Authorisation and restriction of access to operational and management functions	Short text messages	Data transfer on demand Command transfer	ASSOCIATION
	Control	Control of operational devices	Setpoints Commands Parameters	Command transfer Set point transfer Parameters transfer	CONTROL
	Monitoring	Monitoring of current data and change of data of operational devices	Measured data Processed data Status Alarms Events Timer Counter Setpoints Parameters Time Series Data	Periodic data transfer Data transfer on demand Event driven data transfer	LOGICAL-DEVICE LOGICAL-NODE DATA DATA-SET BUFFERED-REPORT-CONTROL UNBUFFERED-REPORT-CONTROL LOG LOG-CONTROL
Reporting and logging	Trigger controlled continuous scanning and recording of values and events	Histories Reports Statistics Curves Trends Events Short text messages			
Management	Diagnostics	Self-monitoring of devices	*Monitoring, and reporting and logging information categories apply*		
	User and access management	Setting up users, access rights and monitoring access		System specific	
	Setup	Device configuration management		System specific	
	Time synchronisation	Synchronisation of device clocks		SCSM specific	