Introduction

The present leaflet introduces the Laboratory for Wind Turbine Testing of the Renewables Division/Wind Energy Department of Center for Renewable Energy Sources (CRES). It provides information about its scope, structure, services provided and concludes with a list of past and current projects. A few words about CRES are also provided in the following paragraphs.

CRES is the national co-ordination center for Renewable Energy Sources (RES), Rational Use of Energy (RUE) and Energy Saving (ES). It was founded in September 1987 by Presidential Decree 375/87. It is a public entity, supervised by the Ministry of Development, General Secretariat of Research and Technology, and has financial and administrative independence.

The aim of CRES is the promotion of RES/RUE/ES applications at a national and international level, taking into consideration the environmental impact, in the production and use of energy. Over the years, CRES has participated in more than 500 European and national projects. These include research and development projects, demonstration projects, projects dealing with energy information systems, feasibility studies, market research, promotional activities for the use of RES/RUE/ES.

CRES has a scientific staff of more than 150 highly experienced and specialized scientists, and engineers. CRES is composed of the following basic units:

- Strategic Planning, Programming and Control Unit
- Division of Energy Policy and Planning
- Division of Renewable Energy Sources
- Division for Energy Information Systems, Dissemination & Training
- Division of Administrative Support
- Quality Assurance Office

Brief history

The Laboratory for Wind Turbine Testing has been founded in 1997 and constitutes a quality structure operating under the Wind Energy Department of CRES. It is a founding member of the European MEASNET network of measuring institutes acting in the wind energy field. From the beginning of its establishment the LWTT was committed in developing a quality assurance system according to EN45001 which was acquired in 2000 after a thorough and successful audit from Germanischer Lloyd leading to the accreditation from the German certification authority DAP. The quality assurance system was recently (summer of 2001) updated to comply with the new ISO17025 standard and was accredited again by DAP (DAP-PL-3266.00).

Structure

The LWTT is a dynamic organization continuously considering and applying improvements in both its administrative and technical procedures. The structure of the laboratory is organized in the following units:

- ✓ The Laboratory Head
- ✓ The Quality assurance department

- ✓ The Technical Support Department
- ✓ The Wind structure and Wind Turbine Department
- ✓ The Blade Testing Facility Department

The Technical Support Department is responsible for equipment issues (purchase, maintenance, calibration, database), development and design of measuring systems, preparation and testing of complete measurement systems before and after their use in field and laboratory tests, support in the phase of measuring system installation, commissioning, dismantling. The Department has 6 members (1 electrical engineer, 2 electronics technicians, and 3 mechanical technicians).

The Wind Structure and Wind Turbine Department comprises the Operators who are responsible for the test services provided by the LWTT and issue the intermediate and final reports under the quality control of the Quality Assurance Department. For each test service type (eg power performance) there is one person (the most experienced) appointed responsible to whom any relevant unsolved matters are addressed. This person is also appointed as the LWTT's representative in the respective MEASNET expert subgroup so that there is ontime adjustement to the most recent technical developments in the subject. The Department is manned with 11 members (5 mechanical engineers, 5 electrical engineers and 1 physicist) of which 2 hold a Phd, and 3 are in the final stage of their Phd studies.

The Blade Testing Facility comprises 4 members supporting and operating the full-scale blade testing activities and test services of LWTT. The Department is manned with 2 mechanical engineers and 2 mechanical technicians.

Scope

The LWTT performs the following tests :

- Power Performance (MEASNET, IEC-61400-12)
- Power quality (MEASNET, IEC-61400-21)
- Noise measurements (source)- (MEASNET, IEC-61400-11)
- Noise measurements (receptor)- (IEA-Recommended Practices-10, ELOT-CRES/TC-81 WG-5 Draft standard)
- Load measurements (IEC-TS61400-13)
- Anemometer Calibration (MEASNET)
- Wind potential measurement and analysis
- Static full-scale blade testing
- Fatigue full-scale blade testing

The tests denoted as "MEASNET" are also covered by the corresponding MEASNET documented procedures. For the remaining tests, the MEASNET stamp is not provided because there do not yet exist technical procedures developed by the expert groups operating within the network. Furthermore, no international standards yet exist for the last three tests listed above.

The tests are performed using calibrated equipment (traced to national and international standards), according to the well-documented "Technical Procedures" and the more detailed "Guidelines" which constitute an integral part of our Quality Assurance System.

Technical outline of services

a. Power Performance

The Power Performance Testing refers to the establishment of the relation between the net electrical power delivered to the grid by a single wind turbine and the reference wind speed at a suitable upstream location. The aim of the test is either to experimentally prove the theoretically derived power curve of a new wind turbine model for certification purposes or to assess the manufacturer or developer "guaranteed" power curve of a selected wind turbine in a new wind farm.

The test encompasses meteorological, operational and electrical measurements. It is conducted according to the IEC-61400-12 standard and the MEASNET Power Performance Procedure.

Normally, the test comprises two stages. In the first stage, the site calibration is performed, i.e. a measurement procedure aiming to the establishment of the relation between the wind speed measured at the reference meteorological mast and that on a temporary mast deployed at the tested wind turbine position (prior to its erection). In case this is no possible, the LWTT offers alternative solutions including the use of nacelle anemometer but preferably the installation of a mobile telescopic mast on the nacelle of the wind turbine set in a back-yaw operation with the rotor parked.

The second stage of the measurements (power curve) follows the completion of the site calibration phase. The height of the reference meteorological tower is set equal to the wind turbine hub height and the reference anemometer is top mounted. A secondary reference anemometer of the same type is also installed near the met-mast top on a side boom along with the reference wind vane. Optionally other cup anemometers may be used to provide data for the wind shear over the rotor disk. A thermometer (optionally thermohygrometer) is also deployed on the mast near the hub height. The rest of the standard meteorological equipment comprises a precipitation sensor and a barometer. The readings from the barometer, thermometer (and hygrometer if present) are combined to estimate the air density to be used for power curve normalisation purposes.

If asked by the customer more met sensors may be installed (sonic anemometer, second thermometer). Tubular meteorological towers guyed by four to eight anchors are used by LWTT for heights up to 60m. Currently there do not exist commercial solutions for higher masts of this type.

All instruments are calibrated before the start of the test. In particular the cup anemometers are calibrated in CRES wind tunnel facility according to the MEASNET Procedure for Cup Anemometer Calibration. The standard anemometer used for the power performance testing is the Vector Instruments A100K cup anemometer featuring a low distance constant and a high resolution.

The wind turbine operational parameters are provided from the sensor panel of the wind turbine using optical isolators as interfaces. The standard signal needed is the availability or status signal defining if the wind turbine is in a condition to produce power given sufficient wind speed. Only data from this mode may be used for the power performance testing. The wind turbine nacelle anemometer may be also measured if required using optical isolators. Other operational parameters optionally measured are the nacelle azimuth (yaw) position and the rotor rotational rate.

The active power delivered to the grid is measured with voltage (if necessary) and current transformers and a power transducer calibrated for a range of –50% to +200% of the wind turbine nominal power.

The data logging system used is a data logger based system (Stylitis –1 or Stylitis 40 logger) or a PC-based system using the in-house developed data acquisition software CRESDAQ. The former has the ability to store statistics on a user selected time basis (from 1 min to 1 hour) and a set sampling rate of 1 Hz. It may be operated with a solar panel-charger-battery configuration. The latter is a more flexible system providing the opportunity to store time-series of the measured parameters at up to three different sampling rates up to the kHz range. Online visual inspection of time series and power spectra are offered.

In case of GSM network availability the systems may be reviewed over a GSM modem and data downloaded. With the PC-based system SMS messages are possible to be sent at user-defined regular intervals or conditions, as well as any-time interrogation of the system.

After the completion of the measurement campaign a comprehensive test report is issued according to the aforementioned standards and procedures including the following main items:

- Description of test site and wind turbine
- Documentation of measuring system
- Log book details
- Methodology of analysis and data selection
- Calculation of acceptable sectors and site calibration coefficients
- Power performance results in graphs and tables (scatterplots) and power coefficient (raw and normalised to standard density)
- Reference meteorological conditions scatterplots and analysis
- Wind turbine operational parameters scatterplots
- AEP calculation for typical Weibull wind speed distributions
- Uncertainty assumptions and calculations for all parameters
- Verification of site calibration results
- Power performance subsets categorised eg between dry and wet periods.

Sensitivity studies of power performance on selected parameters may be conducted according to the customers' requirements (example: sensitivity to turbulence levels, wind direction variability, wind flow inclination).

The duration of the measurement campaign is dictated by the minimum requirements set by the standards and the site wind conditions. A rough estimate for site calibration studies using two met-masts is 1-2 months and for power performance 3 weeks to 2 months.

b. Power quality

The wind turbine power quality delivered to the grid must fulfill specific requirements set by international standards and grid operators. Factors that are of importance during the continuous operation mode of the wind turbine include the flicker emission (related to wind turbulence induced fluctuations of the electrical output of the wind turbine), power peaks at specified time intervals, harmonic and interharmonic currents and current distortion levels. Flicker and voltage change factors are also measured during start-up at low and rated wind, as well as transitional situations (eg switching between generators). The hardware demands for such measurements are quite high. The IEC-61400-21 and MEASNET requirement to measure harmonics up to 9 kHz imply sampling frequencies of at least 18 kHz. The LWTT has developed the so-called Thales system for power quality measurements, a compact stand-alone system easy to install and operate. The Thales system is able to perform simultaneous current and voltage measurements on the three phases at sampling frequencies up to 51.2 kHz. The voltage transformers or sensors used as well as the current transformers are of sufficient dynamic response to capture fluctuations up to the required frequency. The six outputs of the transformers are passed through 5^{th} order Butterworth filters before sampled by the A/D card. The system also accepts a cup anemometer and wind vane input to provide the reference meteorological conditions.

The CRESDAQ software is used for configuring the data acquisition parameters : record length, sampling frequency, sensor parameters etc. The signals are observed in realtime and power spectra and time series may be re-played for inspection purposes. Flicker factors for four impedance angles and all three phases as well as harmonic levels may be automatically calculated right after the end of each record interval. The data acquisition may be programmed according to a used defined capture matrix to ensure that only data from valid sectors and wind speed, power and turbulence classes are actually recorded in the hard disk (this is mainly to save disk space, since the power quality measurements are very space consuming).

Flicker measurements are taken at 3200Hz and transients and harmonic data at 51.2 kHz.

The analysis and reporting satisfies the IEC-61400-21 and MEASNET requirements and includes the following items:

- Description of test site and wind turbine
- Documentation of measuring system
- Log book details
- Methodology of analysis and data selection
- Maximum power at 0.2 sec and 1-min.
- Scatterplots and tables of active and reactive power vs. wind speed and turbulence intensity vs. wind speed.
- Scatterplots of flicker values vs. wind speed for three phases and four grid impedance angles.
- Flicker coefficient calculations for normal operation (specified wind speed distribution) and transients.
- Harmonic and interharmonic analysis and current distortion levels
- Uncertainty assumptions for measured parameters.

The duration of the measurement campaigns is dictated by the minimum requirements set by the standards and the site wind conditions. A rough estimate for flicker measurements is 2-3 weeks (normally unattended operation) while the measurements required for the harmonic analysis and the transients are performed during a site visit of sufficient duration (~1 week) to record the appropriate data.

c. Noise measurements (source)

The acoustic emission noise measurement refers to the establishment of the relation between the emitted sound power levels (broadband, 1/3-octave band and narrowband) by a single wind turbine at the reference wind speeds of 6, 7, 8, 9 and 10 m/s. The aim of the test is either to prove the acoustic emission performance of a new wind turbine model for certification purposes or to assess the manufacturer or developer "guaranteed" acoustic performance specifications of a selected wind turbine in a new wind farm.

The test encompasses acoustical, meteorological and electrical measurements. It is conducted according to the IEC-61400-11 standard and the MEASNET Acoustic Noise Measurement Procedure.

The sound pressure levels of the emitted noise (broadband and 1/3-octave band Leq values) are measured and recorded by the real-time acoustic analyser, while in parallel the linear acoustic signal is recorded in a DAT-recorder for further analysis (narrowband).
The corresponding meteorological (wind speed and direction, temperature, barometric pressure) and electrical power output data are recorded in a data-logger or pc.
Measurements are carried out when the W/T is on operation and then immediately when the W/T is stopped, so that the background noise is measured with the same as possible meteorological conditions.

The reference position for sound pressure measurements (which will lead to the calculation of the sound power level) is at horizontal distance from the centre of the tower, equal to the altitude from the ground to the centre of the rotor plus the rotor radius, downwind from the W/T.
If asked by the customer more measurements at lateral positions and upwind from the W/T are performed, in order to investigate the directivity of the wind turbine noise emission.
Each microphone is placed at ground level on a wooden round board of a thickness of 12 mm and diameter 1 m.

The anemometer and wind vane are placed before the W/T at an altitude of at least 10 meters above the ground and at a distance greater than two and less than four times the diameter of the W/T's rotor. The acceptablee angular sector depends on the sensor's height.

The acoustical measuring system is calibrated immediately before and after each measurement, recording the signal emitted by the sound calibrator. All the other instruments are calibrated before the start of the test.

The active electrical power is measured by an electrical power analyser, or with voltage (if necessary), current transformers and a power transducer.

The data logging system used is a data logger based system (Stylitis –1 or Stylitis 40 logger) or a PC-based system using the in-house developed data acquisition software CRESDAQ.

After the completion of the measurement campaign a comprehensive test report is issued according to the aforementioned standards and procedures including the following main items:

- Description of test site and wind turbine
- Documentation of measuring system
- Methodology of analysis
- Broadband, 1/3-octave band and narrowband analysis results in graphs and tables
- Uncertainty assumptions and calculations for all parameters

If asked by the customer, other possible characteristics of noise emission can be examined (infrasound, low frequency noise, impulsivity and amplitude modulation of the broadband noise).
Dependence of the sound power levels on selected parameters may be conducted according to the customers' requirements (example: dependence on rotational rotor speed).

The duration of the on-site measurement campaign is dictated by the minimum requirements set by the standards and the site meteorological conditions. A rough estimate under ideal meteorological conditions is 3 days.

d. Noise measurements (receptor)

The acoustic immission noise measurement refers to the assessment of the sound pressure levels emitted by a single wind turbine or a group of wind turbines at a noise receptor location, for the purpose of verification of compliance with noise immission limits and of noise propagation models.

The test encompasses acoustical, meteorological and optionally electrical measurements. It is conducted according to the IEA-Recommended Practices-10, and the ELOT-CRES/TC-81 WG-5 Draft standard procedures.

The sound pressure levels of the emitted noise (broadband and 1/3-octave band Leq values) are measured and recorded by the real-time acoustic analyser, while in parallel the linear acoustic signal is recorded in a DAT-recorder for further analysis (narrowband).
The corresponding meteorological (wind speed and direction, temperature, barometric pressure, humidity) and electrical power output data are recorded in a data-logger or pc.
Measurements are carried out when the W/T is on operation and then immediately when the W/T is stopped, so that the background noise is measured with the same as possible meteorological conditions.

The microphone is placed at a height of 1.2-1.5 m or 5 m from the ground level, depending on the purpose of the measurement. When there are high levels of wind-induced noise, a calibrated secondary wind-screen can be used.

The wind speed is measured (or calculated if the power curve is used) in two positions. The first anemometer and the vane are placed before the W/T at an altitude of at least 10 meters above the ground and at a distance greater than two and less than four times the diameter of the W/T's rotor. The acceptable angular sector depends on the sensor's height. The second anemometer is placed near the microphone position at an altitude of at least 10 meters above the ground.

The acoustical measuring system is calibrated immediately before and after each measurement, recording the signal emitted by the sound calibrator. All the other instruments are calibrated before the start of the test.

The active electrical power is measured by an electrical power analyser, or with voltage (if necessary), current transformers and a power transducer.

The data logging system used is a data logger based system (Stylitis –1 or Stylitis 40 logger) or a PC-based system using the in-house developed data acquisition software CRESDAQ.

After the completion of the measurement campaign a comprehensive test report is issued according to the aforementioned standards and procedures including the following main items:

- Description of test site and wind turbine
- Documentation of measuring system
- Methodology of analysis
- Broadband, 1/3-octave band and narrowband analysis results in graphs and tables
- Uncertainty assumptions and calculations for all parameters

If asked by the customer, other possible characteristics of noise emission can be examined (infrasound, low frequency noise, impulsivity and amplitude modulation of the broadband noise).

The duration of the on-site measurement campaign is dictated by the minimum requirements set by the standards and the site meteorological conditions. A rough estimate under ideal meteorological conditions is 2 days.

e. Load measurements

Load measurements are a very crucial part of the design verification or improvement of a wind turbine model. They are typically ordered by wind turbine manufacturers to verify their new products (prototypes) and attain the required certification according to one of the IEC environmental classes (defined in terms of site annual win speed and turbulence levels).

Load measurements are delicate calling for high-skill and competence of the staff involved from the preparation and design of the measurement system up to the analysis and final reporting. The loads are indirectly measured through the application of strain gages on the wind turbine main load-carrying components: the blade, shaft and tower. Strain gages are typically applied on two blades for measuring the root bending moment components, on the main shaft for measuring both bending and torque, on the tower top and bottom for measuring bending moment components in two perpendicular directions and on the tower top to measure torsion. Upon the customer’s request, measurements may be conducted on the high-speed shaft on intermediate tower heights; also nacelle accelerations in different directions and locations may be measured. The measurements on the rotating parts of the wind turbine are done with the aid of telemetry systems using inductive or RF coupling with the stationary part (nacelle) to transmit power and data.

The strain gages measure local strain levels and are deployed at carefully selected locations to avoid stress concentration regions. They are organised in full Wheatstone bridges configured to measure one type of loading (bending, torsion, axial force). Their calibration is the most essential part of the measurement campaign because the results rely on it. The load calibration campaign is performed in weak-to-calm winds to avoid aerodynamic loading effects. It is based on applying known forces (from the ground or crane) on the blade, nacelle and \or tower. The bridge response to the known forcing is recording and the linear coefficients are established for transforming the voltage output to load levels. The zero-load levels are defined through slow rotor and nacelle revolutions in weak winds.

The load measurements are linked to reference meteorological conditions, in principle wind speed and turbulence intensity, but also wind shear, flow inclination, turbulence length scale or other wind structure parameters. Therefore, a reference meteorological mast equal to the wind turbine hub-height is used equipped with at least one anemometer, wind vane, thermometer and barometer. Optional sensors are anemometers and wind vanes at several heights, additional thermometer for measuring near-surface atmospheric stability, hygrometer, precipitation sensor, ultrasonic anemometer.

The load measurements also comprise electrical power measurement, grid-status signals, nacelle position, rotor azimuth and rotational rate, pitch angle measurement.

The data acquisition system is based on a PC running the CRESDAQ software enabling continuous data acquiring and storage using a double buffer technique. Up to three different sampling rates are possible. Typically, the met sensors and yaw position are measured at 1 Hz, the electrical power and RPM at 8 Hz and the load parameters at 32 Hz to capture the dynamic effects of the wind turbine operation. All data points are stored in binary files and daily statistics files are also provided. Graphic presentation of any signal is possible, as well as real-time review of recorded time series and power spectra evaluation.

The test follows the IEC-TS61400-13 document, a very demanding one with respect to data requirements. Sufficient data over the whole operational range of the wind turbine are collected at different turbulence levels. Measurement load cases corresponding to design load cases are defined and measured (triggered or not): normal starts, stops at low and high winds, emergency shut down, grid losses, off-yaw operation, maintenance position, fault events etc.

The report provides typical time series for every type of event and mode of operation, scatterplots of meteorological, operational and load parameters, evaluation of main system eigenfrequencies, presentation of power and fatigue spectra, azimuth load variation, equivalent load scatterplots vs. wind speed and turbulence intensity, estimation, mean and equivalent load curves, calculation of composed lifetime fatigue spectra for prescribed duty cycles and different turbulence levels. Thorough uncertainty analysis is also offered.

A load measurement campaign is typically concluded and a final report issued in 4 months, also depending on un-controlled parameters (weather etc.)

f. Anemometer Calibration

In principle, it may sound easy to install an anemometer and measure its signal output either for wind potential measurements or for reference incident wind measurements used in power performance, power quality, load and noise measurements. Cup anemometers are the standard sensors used in the wind energy field; because of the high sensitivity of wind turbine power curve to wind speed, the latter is required to be measured to the highest possible accuracy. The accuracy is improved when a valid anemometer calibration has been performed and all the recommendations of good practice in anemometer mounting have been closely followed.

The procedure for cup anemometer calibration adopted within MEASNET allows for a calibration uncertainty better than 0.5%. CRES anemometer calibration is now performed in the institute's own wind tunnel facility in the wind speed range 4 m/s to 16 m/s (for wind energy applications). It is a low turbulence, open loop wind tunnel; the measuring section used for the calibrations is 0.8x0.8m. The reference velocity of the wind tunnel is taken from a differential Pitot tube. The pressure, temperature, humidity and anemometer outputs are sampled and stored at 1 Hz, for a duration of 30 sec at each calibration point. The calibration certificate is automatically produced at completion of the calibration sequence. It includes the calibration data, the reference ambient conditions, the transfer function and the uncertainty results.

The calibration facility participates in the regular round robin tests within MEASNET ensuring a high quality of calibration results.

So far, only cup anemometers are calibrated. Calibration points are taken at regular steps in both ascending and descending wind tunnel flow.

The calibrated anemometers are returned to the customer within a few days from receipt under normal flow rate of item delivery by the customers.

g. Wind Potential measurements & analysis

Wind potential measurements are indispensable for the planning and successful operation of good wind farm projects. The available wind power is very sensitive to the wind speed (a cube relation exists) and a careful selection of the measurement location from experienced personnel is required. The LWTT has a strong experience of site selection, installation, maintenance and analysis related to the wind potential. Amongst others, this experience is proven by the Greek Wind Atlas produced by LWTT under the auspices of a national project co-funded by the EU. To meet its goals, LWTT deployed and operated 100 stations spread all over the greek mainland and islands for a period of one year. The measurement results have been utilised for scaling and adjusting the wind flow predictions provided by the in-house developed three-dimensional boundary layer model for the whole of the greek territory at a grid detail of 150m.

The wind measurements are offered in a variety of alternative solutions matched to the customers' requirements in terms of flexibility, cost and time limits. Guyed tubular towers from 10m to 60m height may be deployed. For a preliminary assessment of a prospect site wind potential a 10m mast is a cost effective solution which may be upgraded to larger heights if there is indication of good wind potential. Mast re-location to other sites is also possible in case of unfavourable indications.

The minimum duration of a wind potential measurement campaign is typically one year in order to account for the seasonal dependence of wind speed. However, wind energy investors are often under pressure to have an as early-as-possible indication for the viability of a wind farm development of a target site. In this case, there exists the possibility to use long-term measurements from an existing met station of LWTT and apply the Measure-Correlate-Predict (MCP) technique. MCP implies the parallel measurement for a 2-3 month period at the selected site and a neighbouring reference station. A wind speed and direction dependent correlation matrix is established and the long-term measurements are then used to extrapolate to the estimated annual wind speed distribution. The estimation is offered with uncertainty margins. The MCP technique may be applied for micrositing purposes within the area of a potential wind farm: one mast is used as a reference and 10m-mast mobile masts may be deployed in successive mode at selected locations within the selected area.

The result analysis and presentation includes a variety of comprehensive graphs and tables provided by the in-house developed WindRose software. It is an Excel-Visual Basic application providing overall statistics, diurnal and monthly wind patterns, windrose diagrams per month for mean and maximum wind speeds, Weibull scale and shape parameters in total and sectorwise, turbulence dependence on wind speed and direction, expected AEP of selected wind turbine types, capacity factors, power density, calm frequency of occurrence etc. The test report also provides a thorough site description and an uncertainty estimation. It should be realised, though, that the final result is only representative of the time interval of the recordings and may not be extended to past or future site conditions to the natural interannual variability of wind and meteorological conditions.

The measurement system used comprises a Stylitis data logger system (model 40) featuring a 10bit analog-to-digital conversion and 3 counter, 4 analogue channels. The data storage is either in flash PCMCIA cards or in the data logger memory offering capacities of up to several months. The data-logger has a low consumption offering long autonomy. A solar-panel-charger-battery configuration is typically adopted. Through the use of GSM modem, data may be downloaded whenever desired enabling early detection of sensor failure. The data-logger overall status and configuration are also accessible in this configuration.

The wind sensors used for wind potential measurements are the Vector Instruments A100K cup anemometers and W200P wind vane or the Max#40 cup anemometer and 200P wind vane. The cup anemometers are calibrated in CRES wind tunnel facility according to the MEASNET Procedure for Cup Anemometer Calibration.

Future activities

In addition to the services developed and offered by LWTT over the past years, new skills and services are under development or planned for the near-future. These include wind forecasting tools for wind farm power production planning in the liberated electricity market, wind farm evaluation in relation to contract energy guarantees and an enrichment of the "permanent" measurement network of wind stations over Greek.

The LWTT inside MEASNET

As already mentioned the LWTT is a founding member of MEASNET along with ECN (Netherlands), CIEMAT (Spain), DEWI (Germany), Risoe (Denmark) and Windtest KWK

(Germany). NEL from the United Kingdom was also a founding member but has withdrawn.

The LWTT is actively involved in the every MEASNET life by participating with its representatives in all the expert groups set within the network. The Head of the Laboratory currently holds one of the two Vice Presidents positions in the MEASNET Council of Members, with the responsibility of organizing the technical work performed within the expert groups.

LWTT successfully participates in all the regular (once per year for every test type) round robin tests aiming to guarantee, maintain and improve the inter-consistency of results provided by the participating institutes. The round robin tests comprise test report evaluation and analysis of a test data set provided by one participant. The results are compared and conclusions drawn on the homogeneity of the interpretation of the dataset and the analysis software. Each application is considered successful if it satisfies pre-defined quantitative deviations from the ensemble mean result of all institutes. Such procedures are applied for power performance, power quality, noise emission from wind turbines at the source, and anemometer calibration.

LWTT scientific staff is also involved in the preparation and update of the MEASNET measurement procedures.

More details about MEASNET may be found at www.measnet.org or www.measnet.com.

Quality in LWTT

The long experience, participation in national and international expert groups formulating and updating the IEC standards and technical specifications, the MEASNET Round Robin Activities, the software verification procedures incorporated in the LWTT's Quality Assurance System, the involvement in national and EU funded research projects all contribute to the high-quality services delivered to the customer by LWTT. There is continuous effort for the update of measurement procedures, software tools, technical guidelines and equipment upgrade to meet the high demands of the standards, the wind turbine industry, the wind farm developers and owners.

List of Projects- Customers

Since its foundation, the LWTT has seen a constantly increasing number of services undertaken in Greece and abroad. The mean annual growth rate of the turnover has been while the last two years the turnover nearly doubles every year. LWTT's customers come from Greece, Spain, Italy, Germany & France. Here follows a list of projects and customers of LWTT.

- Power performance, load, power quality and noise measurements for the certification of MADE Tecnologias Renovables prototype wind turbines AE61-1320 kW, AE52 – 800 kW , AE56 – 800 kW, AE59 – 800 kW in Spain.
- Load measurements for the certification of Gamesa Eolica prototype wind turbines G52 – 850 kW (2 versions), G58-850 kW, G80-2MW, G80-1.5MW in Spain.
- Noise measurements on G52-850 kW in LaPlana, Zaragoza

- Wind potential measurements and Power performance of NEG-MICON 750 kW in Sicily, Italy for ENEL-Erga.
- Load measurements and power performance of HMZ Windmaster 300 kW in Evia, Greece for design verification purposes for BIOKAT SA.
- Power Performance of NEG-MICON 750 kW in Evia for Greek Interwind SA
- Power Performance of Nordex N50, 800 kW and NEG-MICON 900 kW in Thrace Prefecture, Greece for International Parks of Thrace SA.
- Wind potential monitoring and analysis in eastern Turkey for Red Gmbh, Germany.
- Noise measurements at a receptor point for PPC, Greece (for court hearings)
- Power performance measurements of Enercon E40 and E26 wind turbines in Evia, Greece for Enercon Hellas.
- Power quality, power performance, load measurements in CRES Wind Turbine Test Station in Attiki (Enercon, Vestas, NEG-MICON, Wincon, AOC50, greek prototype wind turbine).
- Continuous wind monitoring with a permanent 100m-met mast in CRES Wind Turbine Test Station in Attiki
- Wind potential measurements in Greece for WRE, EnergieKontor Hellas, Ktistor, EΛTEX, Eoliki Repower
- Anemometer Calibration (Energie Di Midi, Terna Energeiaki, Symmetron, Enallaktiki Energeiaki, Scientific Enterprises SA, M Torres, Viking, Ktistor, Gamesa Energeiaki Hellas, Wind Engineering Hellas)
- Blade tests

Facts from LWTT turnover

Through its life the LWTT has issued more than 100 test reports for customers from Greece and abroad, for public authorities, wind farm developers and owners, measuring institutes and companies, wind turbine manufacturers. The annual turnover is shown in Graph 1. The number of contracts per year, the service distribution indicate a remarkable increase of activity, along with securing that all available services are actually exercised every year, maintaining a high level of readiness in every technical and scientific field of our scope. With the expected grow of Greek wind market a reinforcement of the greek share of our turnover is foreseen at least in absolute units. For the time being, the most significant proportion of the annual turnover comes from activities across the national borders.

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