1 Background

Sometimes lost behind the attention given to multi-megawatt wind farms, the market for autonomous electrical systems using small wind turbines is becoming an increasing attractive business. However, in spite of the maturity reached on the development of the wind technology for grid-connected power plants, the state of the art of wind autonomous systems is far away from technological maturity and economical competitiveness. Average costs for current wind stand-alone installations vary from $3500 to 10000 US per installed kW, which contrasts with $1000-1300 per installed kW corresponding to grid-connected installations. If we just talk about the cost of the wind turbine itself, the specific cost (cost per kilowatt) varies from $1500-5000 for stand-alone machines contrasted with $675 for grid-connected ones.

In relation to the performance analysis for both kinds of systems, we find values of average specific energy produced for stand-alone around 0.15 kW/m² whereas the average value for grid-connected systems is 0.5kW/m². This is mainly due because grid-connected systems are used in higher wind speeds sites, but also shows that there is a wide range for improving the present technology for stand-alone wind turbines.

The technology for stand-alone wind systems, and more specifically for the wind turbines, is clearly different from the one used in grid-connected systems. These differences affect all of the subsystems, mainly the control and electrical system, but also the design of the rotor of the wind turbines. Small Wind Turbines (SWT) existing in the market are machines that have developed in a nearly “hand-crafted” way, with maturity that is far from the one corresponding to the wind turbines for grid-connection.

There is a lack of standards and guidelines applied to wind-powered autonomous systems, as well as to wind turbines that are not grid-connected. In particular the wind energy community needs a standard method for determining the power performance characteristics of turbines that are not connected to the grid. Such an effort is currently underway in the International Electrotechnical Commission (IEC). See www.iec.ch or directly http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=E&wwwprog=dirwg.p&ctnum=1914. The TC88/MT12 group of the IEC is revising the IEC standard, IEC 61400-12, “Power performance testing.” Although most of the revisions to IEC61400-12 are concerned with grid-connected wind turbines, an Annex has been proposed that addresses testing of small turbines that are not connected to the grid.

Many of the researchers and test engineers whose contributions led to the Annex are concerned that the proposed methods are not well founded in scientific and practical experience. This feeling persists even though several programs have been concluded in the United States and Europe in which testing issues were investigated. This symposium addressed these issues and to identified appropriate follow-on activities.
2 Summary
The meeting was a successful sharing of information by sixteen participants from twelve organizations representing seven countries. The meeting covered three main topic areas:

1. Recent findings on methods to measure power performance of non-grid connected wind turbines,
2. Present activities being conducted by other participants
3. Feedback on current proposal for the IEC standard

The most salient points in each topic area are summarized below from the organizers’ perspective (which may not represent the views of other participants). Overall the meeting was very instructive on a technical basis and useful by providing contacts for future cooperative research. It was especially important to obtain concurrence from the participants that the proposed Annex to IEC 61400-12 (the international standard for power performance testing of wind turbines) should be recommended for approval.

The group decided to communicate future developments this area through an email group of limited size with the potential to convene another meeting if appropriate. See also paragraph 4 Continuation below.

3 Discussion

3.1 Recent findings on measurement of the power performance of non-grid connected wind turbines

3.1.1 Jan Pierik, ECN, the Nederlands
Pierik reported on the PEMSWECS project. They found:

1. if voltage variations of the battery bank are less than 30%, they may have a large effect on some parts of the power curve but do not have a large effect on AEP (annual energy production)
2. sampling rates of at least 2 hz (vs current requirement of 0.5 hz in grid connected turbines) should be used
3. preaveraging should be 30 sec for turbines with rotor diameters less than 6 m and 30 sec for rotors less than 10 meters
4. battery voltage should be allowed to vary over wide ranges of SOC and then the data should be binned to show the effect of voltage variations.
5. voltage variations can be obtained using a voltage regulator and so batteries do not need to be part of the experimental set up.
6. raw data should be saved

3.1.2 Felix Avia, Ciemat, Spain
Avia reported on the methods that Ciemat plans to use for testing:

1. since shorter preaveraging time increases data scatter in the power versus wind speed curve and indicates lower AEP for low wind speed sites, 10-minute preaveraging should be used.
2. wind speed range should be from 0 to 14 m/s
3. no normalization should be done for air density
3.1.3 Brad Cochrane, CERMAK PETERKA PETERSEN, Inc., USA
Cochran reported on an analytical study that he conducted concerning the influence that wind turbulence has on kinetic energy. He found that when using a 10-minute pre-averaging time, the variation in kinetic energy between two test sites could vary by as much as 23% for the same mean wind speed. This effect is more important for small wind turbines because they are closer to the ground and are likely to be placed in more varied locals, thus, exposed to winds of higher turbulence. For certain turbines this effect may be offset by a decrease in turbine efficiency with high turbulence levels, however, each turbine will react differently. In addition, a shorter averaging time, such a 1-minute, was shown to reduce the deviation in kinetic energy between to sites with different wind turbulence. Therefore, to produce repeatable power production curves, power should be shown as a function of turbulence intensity and, perhaps, standardized power curves should be based on a specified, limited range of turbulence intensity.

3.1.4 Hal Link, NREL, USA
Link reported on work at NREL where they have quantified the effect of different preaveraging intervals on the power performance of three wind turbines

1. Longer preaveraging flattens power curves. This leads to higher indicated power levels at low wind speeds and lower indicated power levels at high wind speeds for most turbines.
2. Longer preaveraging indicates higher AEP at low wind speed sites and lower AEP at high wind speed sites. The difference is usually small compared to the uncertainty in AEP calculations

3.2 Present activities being conducted by other participants

3.2.1 Ignacio Cruz Cruz, CIEMAT, Spain
CIEMAT is embarking on a strong program to test small wind turbines and to investigate wind diesel systems.

3.2.2 Ermen Llobet, Ecotecnia, Spain
Ecotecnia is interested in developing small turbines and will begin by developing several electrical conversion devices.

3.2.3 Sanders Mertens, Delft University of Technology, The Netherlands
University of Delft is investigating wind turbines installed on roofs as this is a configuration that is frequently requested in the Nederlands. Initial work using models indicates that vertical axis turbines would be superior to HAWTs in many cases due to the inclined flow typical of wind flow over flat roofs.

3.2.4 Dunia Mentado Rodríguez & Penélope Ramírez Gonzáles, Technical Institute of Canary Islands, Spain
Researchers on the Canary Islands are developing a test facility for small wind turbines. They have a very windy site with average winds of 11.9 m/s in July. In cooperation with CIEMAT, they will investigate the effect of air density on furling wind turbines.
3.2.5 Francis Pelletier, École de technologie Supérieure, Canada
Researchers in Quebec, Canada, are preparing to test wind turbines on a roof-mounted facility. They have developed instrumentation and will soon conduct a site calibration test to characterize flow over the roof.

3.3 Comments on IEC standard
Hal Link gave a presentation of some items for discussion on the present version of the IEC standard. The version discussed was the draft of 11 March, 2002. The items for discussion are included in the introductory note in chapter 1 in the beginning of the document. Eighteen of the 19 items in the annex were discussed.

3.3.1 Scope
Felix proposed that the standard is only valid for wind turbines not connected to the grid. But on the other hand it can be the situation that the system also is connected to the grid with some electrical equipment. Cochran noted that there might be a need for a standard for small wind turbines connected to the grid. The participants agreed that the annex should address only non-grid connected wind turbines. Special provisions for small turbines that are connected to the grid should be incorporated into the main body of the standard.

3.3.2 Item 1. Definition of the turbine system
Accepted as written.

3.3.3 Item 2. Minimum turbine and anemometer height of 10 meters
Accepted as written.

3.3.4 Item 3. Load requirements
Some participants felt that no batteries were necessary or, at least they did not need to be as large as would normally be used because the voltage regulator should prevent any current from flowing to the battery. A small battery or other device might be needed to maintain load voltage when the turbine is below cut-in and not producing any power. It was agreed that the first sentence should be softened to permit a smaller battery bank than would normally be used for purposes of power performance testing.

3.3.5 Item 4. Location of the battery bank
No strong feelings were aired. Acceptable percentage voltage drop could be a possible way to handle this. Another possibility is to specify the cable length.

3.3.6 Item 5. Requirements for the voltage regulation device
Accepted as written.

3.3.7 Item 6. Location of meteorological mast/tower
Accepted as written.
3.3.8 Item 7. Position to measure power output
Pierik noted that some turbines are equipped with dump load systems. He felt that it is appropriated to measure power before the dump load when the voltage is allowed to vary and the voltage protection system is set low enough that significant power is consumed by the dump load instead of being used to charge batteries or power external loads. It was agreed, since this procedure requires that voltage be regulated within tight limits and that the voltage protection device be adjusted to a high enough setting to eliminate powering the dump load, that the proposed text was acceptable.

3.3.9 Item 8. Requirements for air density measurements
Accepted as written.

3.3.10 Item 9. Requirement for monitoring wind turbine status
Accepted as written.

3.3.11 Item 10. Allowance for adjusting the charge controller (voltage protection device)
Accepted as written.

3.3.12 Item 11. Pre-averaging time 1-minute
Avia is in favor of 10 minute averaging. However he and other participants concurred that 1-minute pre-averaging was acceptable for this standard.

3.3.13 Item 12. Data set based 1-minute periods
Not specifically discussed because this requirement is a function of the preaveraging time whose discussion is noted above.

3.3.14 Item 13. Rules for a complete database
Avia proposed, and the participants agreed that the standard should include the following provisions:

a) All wind bins between 0 and 14 m/s shall be complete, and
b) The complete wind speed range should include characterization of turbine performance when the turbine is furled.

3.3.15 Item 14. Data normalization
Two possible methods are power normalization, which shifts the power curve in a vertical direction and wind speed normalization, which shifts the power curve in a horizontal direction. Avia proposed that neither method should be performed since neither has been validated for small wind turbines. Other participants shared this concern. There was weak support expressed for normalizing only the energy production.

3.3.16 Item 15. Provision for no specification of cut out wind speed
Accepted as written.
3.3.17 Item 16. Reporting requirements
Arribas de Paz noted that the text did not explain how multiple power curves should be presented when data are obtained at three battery bank voltages. He proposed that a single power curve should be presented with the variations due to battery bank voltage differences shown as part of the uncertainty bands.

3.3.18 Item 17. Reporting requirement for annual energy production at 5 m/s sites
Accepted as written.

3.3.19 Item 18. Battery bank voltage settings
Accepted as written

3.3.20 Summary
Overall the group felt that the standard should go forward even though there were several points on which no consensus was reached. It was the group’s opinion that it was better to have an imperfect, yet common method, than to continue with the present situation where no consistent method is being used. The standard can always be modified if better methods are demonstrated.

4 Continuation
It was concluded that quite extensive work is conducted within the IEC MT12 subgroup on non grid connected wind turbines. However, there is still a need to exchange information and discuss different topics with a broader group of people. This can be achieved through a news server on Internet or an email list operated by a moderator.

The latter approach was considered to be a useful way to continue the discussion. Hal Link and Felix Avia were assigned the task to find a moderator and to draw up the objectives and practical thing around such an email discussion network.