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Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE

Schlussbericht, 1. Dezember 2011

COST ACTION ES1002: WIRE

PARTIZIPATION 2011

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BFE-Vertrags- und Projektnummer: SI/500607 / SI/500607-01

Zusammenfassung

Meteotest hat im 2010 eine neue COST Action mit dem Titel „WIRE: Weather Intelligence for Renewable Energies“ lanciert. Am 10. November 2010 wurde die neue COST Action ES1002 offiziell mit einem Kickoff-Treffen in Brüssel gestartet. Inzwischen beteiligen sich 25 Europäische Länder sowie die USA, Kanada und Japan an der Aktion.

Ziel dieses Projekts ist es, der Meteotest die Teilnahme an den Projektmeetings sowie das Erstellen von spezifischen Dokumenten, welche die Schweiz betreffen zu ermöglichen.

Das erste Jahr der COST Action stand im Zeichen der Erarbeitung eines State-of-the-Art Reports. Es gelang, die grosse Anzahl der Teilnehmer zu mobilisieren und den Austausch von Informationen und Know-How zu starten.

Meteotest konnte an allen Treffen teilnehmen sowie alle geforderten Dokumente aufbereiten und einreichen. In diesem Sinn fand auch eine Vernetzung mit den Teilnehmern der Aktion statt.

Im 2011 konnte kein nationales Projekt im Bereich der COST Aktion gestartet werden. Dieser Umstand limitierte die Möglichkeiten einer aktiven Beteiligung an der COST Aktion.

Das Interesse an der COST Aktion ist nach wie vor sehr gross. Meteotest plant, weiterhin an den Meetings teilzunehmen, auch wenn die Finanzierung durch nationale Projekte nach wie vor nicht gegeben ist. Zudem sind weitere nationale Projekte geplant.

Projektziele

Die Entwicklung zu immer mehr erneuerbarer Energieproduktion stellt neue hohe Anforderungen an die Energieversorger. Dezentrale Produktionsstandorte und die wetterabhängige und damit hochvariable Stromproduktion erfordern neue Methoden zum Produktions- und Netzmanagement. Aus diesem Grund erhalten zuverlässige und genaue Vorhersagen der Wind und Sonnenenergieproduktion ein immer höheres Gewicht um das Stromnetz stabil zu halten und um am Strommarkt gute Preise erzielen zu können.

Meteotest hat deshalb im 2010 eine neue COST Action mit dem Titel „WIRE: Weather Intelligence for Renewable Energies“ lanciert. Am 10. November 2010 wurde die neue COST Action ES1002 offiziell mit einem Kickoff-Treffen in Brüssel gestartet. Inzwischen beteiligen sich 25 Europäische Länder sowie die USA, Kanada und Japan an der Aktion.

Im Fokus der COST Action steht deshalb die optimale Nutzung von Wetterinformationen für die Produktion und den Transport von Sonnen und Windenergie. Das Hauptziel der Aktion wurde im Antrag wie folgt formuliert:

“The main objective of the Action is to enhance the methodologies of forecasting wind and solar power production in the time domain of a few minutes up to several days ahead. This will be achieved by combining numerical weather models with suitable post-processing methods as well as real-time surface and remote sensing measurements. A further goal is to establish a common understanding between the relevant communities (wind and solar, meteorologists, energy engineers, grid managers) in order to optimise the technical and economic integration of these renewable energies into electricity grids and markets. Finally, this Action aims at transferring knowledge from advanced to less developed countries in this field.”

Die Teilnahme an dieser COST Action ermöglicht der Schweiz, sich auf Europäischem Niveau zu vernetzen und Zugang zum Europäischen Know-How in diesem Bereich zu erhalten.

Ziel dieses Projekts ist es, der Meteotest die Teilnahme an den Projektmeetings sowie das Erstellen von spezifischen Dokumenten, welche die Schweiz betreffen zu ermöglichen. Die Finanzierung dieser Arbeiten (Teilnahme an den Meetings, Erstellung von Präsentationen und Papers etc.) wird mit dem Beitrag des Bundesamts für Energie zumindest teilweise gedeckt.

Die Reisespesen dieser Aktivitäten werden von der COST Action direkt entschädigt. Die Arbeitszeit für die administrativen Arbeiten von Meteotest als Grant Holder (Einladungen verschicken, Entschädigungen prüfen und auszahlen etc.) sowie für den Betrieb der Webseite werden ebenfalls von der COST Action gedeckt.

Durchgeführte Arbeiten und erreichte Ergebnisse

Arbeiten

Das erste Jahr der COST Action stand im Zeichen der Erarbeitung eines State-of-the-Art Reports. Das erste Meeting im März 2011 wurde dafür verwendet, spezifische Präsentationen zum aktuellen Forschungsstand aus den verschiedenen Ländern zu geben. Zudem wurde jedes Teilnehmerland dazu angehalten, ein Poster zu den nationalen Aktivitäten zu präsentieren. Meteotest präsentierte die folgenden drei Poster (im Anhang beigefügt):

- State of the Art in Switzerland
- Swiss-WIRE: Beschreibung des geplanten nationalen Forschungsprojekts
- Wind Forecasting considering Icing

Der Bericht zum Meeting befindet sich im Anhang dieses Dokuments. Als Hauptschlussfolgerungen können die folgenden beiden Punkte festgehalten werden:

- Windvorhersagen sind schon relativ weit entwickelt und werden operationell eingesetzt. Forschungsbedarf besteht bei Rampen (starken Zu- oder Abnahmen der Windgeschwindigkeit innert weniger Stunden), in komplexem Gelände sowie unter speziellen Bedingungen wie z.B. Vereisung.
- Solarvorhersagen sind generell noch nicht sehr weit entwickelt, der Bedarf nach solchen Prognosen steigt aber wegen der stark zunehmenden installierten Kapazitäten. Hier besteht genereller Forschungsbedarf.

Für den State-of-the-Art Report wurde jedes Teilnehmerland angehalten, eine ca. 2-seitige Zusammenfassung der Aktivitäten im Bereich der COST Aktion zu schreiben. Dieses Dokument wurde von Meteotest im November 2011 fertiggestellt. Es befindet sich im Anhang dieses Dokuments.

Es wurden für die Aktion verschiedene Frageboden erstellt, um die Bedürfnissen und Möglichkeiten der einzelnen Länder zu evaluieren (können auf der Website heruntergeladen werden):

- Fragebogen zu Wettermodellen, die in Europa eingesetzt werden. Wurde von MeteoSchweiz und Meteotest eingereicht
- Fragebogen zu verfügbaren Testdaten/Test Sites in Europa: MeteoSchweiz plant auf Ihrer Messstation in Payerne einen Vergleich von verschiedenen Strahlungsmessgeräten. Ansonsten sind in der Schweiz gegenwärtig, mangels nationalen Projekts, keine Testdaten insbesondere von Kraftwerken verfügbar. Es ist geplant mit der BKW Verhandlungen zu führen, ob die Daten der Kraftwerke von Mont Soleil/Mont Crosin trotzdem für die COST Aktion eingesetzt werden können.
- Fragebogen zu den Bedürfnissen von End Usern der Vorhersagen: Wurde an EnergiePool Schweiz AG, BKW und Swissgrid verteilt. Weitere Verteilung vorgesehen.

Meteotest baute im 2011 die Webseite der COST Action auf: www.wire2011.ch. Für die Teilnehmer der Aktion wurde ein passwortgeschützter Zugang eingerichtet (User: harry; Pwd: potter).

Meteotest nimmt ebenfalls am IEA PVPS Task 14: High Penetration of PV Systems in Electricity Grids teil.

Meetings

Meteotest nahm im 2011 an den folgenden Meetings teil:

- Working Group / Management Committee Meeting vom 22. Bis 24. März 2011 in Nizza, Frankreich. Ca. 70 Teilnehmer (CH: Meteotest, MeteoSchweiz, Minder Consulting)
- Working Group Meeting vom 14. September 2011. Ca. 50 Teilnehmer (Meteotest, MeteoSchweiz)
- Core Group Meeting vom 22. bis 23. November 2011 in Risoe, Dänemark. 10 Teilnehmer (Meteotest, MeteoSchweiz)

Nationale Projekte

Im März 2011 bzw. Mai 2011 wurde ein Gesuch für ein nationales Forschungsprojekt beim Staatssekretariat für Forschung und Bildung bzw. bei SwissElectric Research eingereicht. Im Projekt war eine Zusammenarbeit zwischen Meteotest, MeteoSchweiz sowie der Juvent SA und der EnergiePool Schweiz AG vorgesehen. Der Fokus lag auf den folgenden beiden Gebieten:

- Windvorhersage in komplexem Gelände mit spezieller Betrachtung von Rampen und Vereisung
- Flächige Solarvorhersagen für die Schweiz

Die Gesuche wurden im Juli 2011 abgelehnt, trotz guter Bewertung (SBF). Hauptkritikpunkte waren die fehlende Innovation sowie zu wenig ersichtlicher wirtschaftlicher Nutzen der Ergebnisse.

Zusätzlich wurde beim Förderfonds der BKW ein Gesuch für Kürzestfristvorhersagen der Sonnenenergien eingereicht. Im Projekt ist eine Zusammenarbeit zwischen Meteotest, Minder Energie Consulting, MeteoSchweiz sowie der Juvent SA und der EnergiePool Schweiz AG vorgesehen. Das Gesuch ist noch hängig.

Bewertung und Ausblick

Bewertung 2011

Das erste Jahr der COST Action stand im Zeichen der Erarbeitung eines State-of-the-Art Reports. Es gelang, die grosse Anzahl der Teilnehmer zu mobilisieren und den Austausch von Informationen und Know-How zu starten.

Meteotest konnte an allen Treffen teilnehmen sowie alle geforderten Dokumente aufbereiten und einreichen. In diesem Sinn fand auch eine Vernetzung mit den Teilnehmern der Aktion statt. Durch den Beitrag des BFE konnten knapp 50% der dafür angefallenen Kosten gedeckt werden.

Im 2011 konnte kein nationales Projekt im Bereich der COST Aktion gestartet werden. Dieser Umstand limitierte die Möglichkeiten einer aktiven Beteiligung an der COST Aktion.

Ausblick 2012

Im Jahr 2012 wird einerseits der State-of-the-Art Report fertiggestellt. Andererseits werden die nötigen Vorbereitungen getroffen, um geeignete Testdaten für die Modellierung zu Verfügung zu stellen um einen Vergleich der verschiedenen verfügbaren Modelle durchführen zu können. Es sind folgende Meetings geplant:

- Februar 2012: Editorial Group Meeting zur Fertigstellung des State-of-the-Art Reports
- Mai 2012: Working Group / Management Committee Meeting mit Fokus auf Remote Sensing
- Sommer 2012: WG1/WG3 Meeting zu Betriebes von Freileitungen aus meteorologischer Sicht (eventuell in Bern, hängt vom geplanten nationale Projekt ab)
- September 2012: WG1/WG2 Meeting zum Test der Strahlungsgeräte in Payerne
- November 2012: Core Group Meeting: Planung der Aktivitäten im 2013

Das Interesse an der COST Aktion ist nach wie vor sehr gross. Meteotest plant, weiterhin an den Meetings teilzunehmen, auch wenn die Finanzierung durch nationale Projekte nach wie vor nicht gegeben ist.

Meteotest nimmt ebenfalls am IEA PVPS Task 14: High Penetration of PV Systems in Electricity Grids teil. Meteotest unternimmt die nötigen Schritte um die beiden Forschungsprogramme besser miteinander zu vernetzen, insbesondere im Bereich der Solarvorhersagen aber auch für eine Synchronisation der ausgewählten Teststandorte. Es ist geplant, dass Vertreter der beiden Aktivitäten an den jeweiligen Meetings teilnehmen und die Aktivitäten der entsprechenden Aktion vorstellen.

In der Schweiz sind zudem die folgenden Aktivitäten geplant:

- Durchführung von Vergleichsmessungen mit diversen Strahlungsmessgeräten an der MeteoSchweiz Messstation in Payerne
- Einreichen eines Projektgesuchs im Bereich der Optimierung des Betriebes von Freileitungen aus meteorologischer Sicht beim BFE (Bereich Netze).

Anhang

Weather Intelligence for Renewable Energies
State of the Art in Switzerland

R. Cattin[1], S. Dierer[1], J.Remund[1], V. Stauch[2], B.Calpini[2], L.Vuilleumier[2] and A. Heimo[1]
[1] Meteotest, Switzerland
[2]Federal Office of Meteorology and Climatology MeteoSwiss, Zürich & Payerne, Switzerland

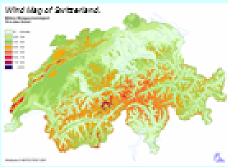
GENERAL SITUATION

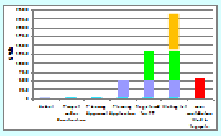
Switzerland has a high portion of renewable energy due to hydropower which meets approximately 60% of the country's electricity requirements. The portion of wind and solar energy is significantly lower: the installed capacity of wind power plants is 42 MW with an expected annual production of 74 GWh and solar power plants have an installed capacity of 95 MW with an annual production of 80 GWh. Following the general trend und pushed by a national fee-in law, both energy sources are strongly growing. The installed capacity of wind power increased by 150% in 2010 and further large projects are under development. The installed capacity of solar plants increased by 35% in 2010. For the next three years, PV installations are expected to grow about 50 – 70 MW per year.

To date, the demand for wind and solar energy forecasts in Switzerland is small due to the small contribution of those energy sources to the total power production. Still, strongly growing installed capacity increases the demand. Users of solar and wind forecasts are small utilities mainly interested in power plants in Switzerland, big utilities that are trading wind and solar power all over Europe and the Swiss organization that manages the compensation for renewable electricity fed into the grid. The energy convention currently discussed between Switzerland and the EU might create further need for wind and solar power forecasts. Additionally, utilities are interested to use weather forecasts for an optimal operation of power lines. As far as we know, forecasts currently used are mainly based on direct model output from weather forecast models, few using statistical post-processing. Thus, there is a potential to use already existing methods to improve the forecasts as well as to develop new user-optimized products.

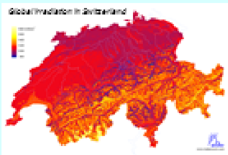
POTENTIAL AND DEVELOPMENT IN SWITZERLAND

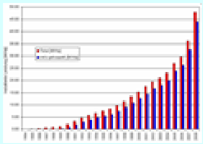
The national feed-in law generated a large growth.





Overview of wind energy projects which have been realised, planned and registered to the feed in tariff in Switzerland.

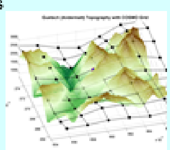




Temporal evolution of the installed capacity of solar power in Switzerland.

CHALLENGES IN SWITZERLAND

The challenges for wind and solar power forecasts in Switzerland are different from many other countries in Europe due to the very complex terrain. The horizontal grid of the numerical weather models, even if they are operated at very high resolution, is not sufficient to resolve the complex topography any the effects caused by that. Therefore, new innovative post-processing methods and optimal integration of observations are needed in order to optimize the quality of the production forecasts

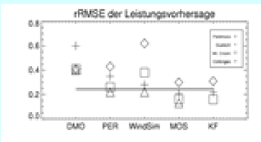


Comparison of real topography (Swisstopo 25) and COSMO-2 model grid. Courtesy of C. Hug.

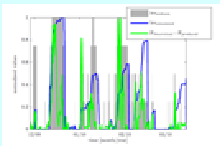
WIND ENERGY

A research project carried out by Meteotest and MeteoSwiss investigated the potential of several downscaling methods for two prediction horizons (3-6 hours and 24-48 hours) of wind power forecasts for complex terrain like in Switzerland. Direct model output of the COSMO models was compared to a dynamical downscaling approach, a linear regression and a postprocessing approach based on a Kalman filter. The results show that the statistical approaches give the most accurate forecasts for most of the locations.

Another challenge for wind energy in Switzerland is atmospheric icing. Atmospheric icing can cause power production losses or even production stops when ice accretes on the wind turbine blades. Therefore it needs to be considered when providing wind power forecasts. Several research projects were dealing with the forecast of atmospheric icing, and recently, a project focused on wind power production considering icing.



Summary results of the Swiss wind forecast project showing the performance of the power forecasts of different forecasting methods.



NWP Simulation of ice loads versus production loss of a wind turbine. The grey areas represent camera observations of icing.

SOLAR ENERGY

Solar power forecasts have been performed by Meteotest based on WRF simulations driven with GFS data. The model system was tested within the IEA SHC Task 36 for six months at different locations in the USA and for one year at 30 locations in Austria, southern Germany, Switzerland and Spain. The WRF model showed some deficiencies in simulating solar radiation in cloudy conditions. Still, it seems that the combination of weather models with statistical post-processing is a promising approach to optimized forecasts. Meteotest is a member of IEA PVPS Task 14 and IEA SHC Task 46. In Switzerland the forecast of solar energy forecast will be an important issue during the next years

Activities of MeteoSwiss in the field of statistical postprocessing of COSMO numerical weather predictions comprise an operationally implemented Kalman filter correction for wind speed, temperature and dewpoint temperature for meteorological measurement sites in Switzerland and Europe. Within the research project "Use of weather and occupancy forecasts for optimal building climate control", MeteoSwiss developed statistical methods for optimized solar radiation and temperature forecasts at building sites.

Long-term radiation monitoring has been performed at the MeteoSwiss BSRN station of Payerne since 1992 and at the GAW Baseline station of Jungfraujoch since 1998.

SWISS WIRE

Swiss Research Project on Weather Intelligence for Renewable Energies

R. Cattin[1], S. Dierer[1], V. Stauch[2], B.Calpini[2] and A. Heimo[1]
[1] Meteotest, Switzerland
[2]Federal Office of Meteorology and Climatology MeteoSwiss, Zürich & Payerne, Switzerland

INTRODUCTION

Renewable energies such as wind and solar energy will play an important, even decisive role in order to mitigate the projected consequences of climate change to our society and environment. Pushed by a national feed-in law and sinking production costs, large growth rates of wind and solar energy are expected also in Switzerland during the next years. As wind and solar energy production and transport is strongly dependent on highly variable weather processes, the importance of accurate weather forecast information for the energy industry increases significantly. For example, accurate forecasts enable to reduce the amount of balance energy and thus lead to a more cost-effective renewable energy production. In Switzerland, all these needs meet in an environment with harsh climate and complex terrain as well as a large spatial and temporal variability of the meteorological conditions. Therefore, the proposed project addresses the scientific challenge to develop suitable methodologies for providing the best possible weather information for energy production of wind and solar power plants in Switzerland. This will be achieved by the development of novel approaches for an optimal combination of numerical weather prediction (NWP) model forecasts and observations (statistical post-processing).

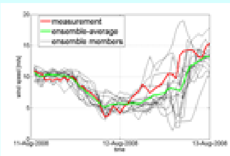
The work will be carried out in the framework of the European COST Action ES1002 WIRE (Weather Intelligence for Renewable Energy) and is a partnership between the Swiss Federal Office of Meteorology and Climatology MeteoSwiss and Meteotest, a meteorological private company in Switzerland. WIRE has the general goal of providing the best possible specific weather information for forecasting the energy production of wind and solar power plants for the next minutes up to several days ahead. It investigates the difficult relationship between the highly intermittent weather dependent power production and the energy distribution towards end users.

RESEARCH TASKS

Based on the state of knowledge and the requirements in Switzerland, the following two research tasks (RT) have been identified for this project:

RT1: Improved wind forecasting with focus on wind ramps by applying different approaches to combine multi model results

Accurate wind ramp forecasts have been identified as one of the most challenging tasks in the field of wind forecasts. In this task, a multi model ensemble consisting of COSMO-7, COSMO-2, WRF and MM5 will be set up for wind forecasts. Wind forecasts based on the ensemble median and Bayesian model averaging (BMA) will be developed. Different variations of BMA methods will be implemented and results evaluated during a test period. Additionally, forecasts of atmospheric icing, which can be a major source for wind production ramps in Switzerland, will be implemented in the forecast system.



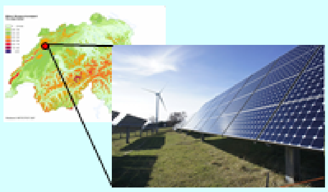
Example of a multi model wind forecast

RT2: Improved solar radiation forecasts on the COSMO grid for Switzerland and Europe:

Solar power plants are usually wide spread over an area (e.g. of roofs). Therefore, not only accurate point information about the expected incoming solar radiation is important but also precise spatially comprehensive forecasts. This way, forecasts can be aggregated to regions associated with supply points particularly relevant for grid managers to ensure grid security or balance groups to plan the energy portfolio. The goal of this task is to develop new statistical models for the correction of entire fields of COSMO radiation forecasts based on local measurements from the Swiss Meteorological Network. For this, a detailed characterization of the systematic forecast errors will be identified from historical forecast-observation pairs considering also additional model states that may explain the variability of the error. The forecasts will then be spatially corrected taking into account the spatial correlation structure of the forecast fields. The resulting forecasts will be assessed and evaluated with independent point measurements and satellite images.

TEST BED MONTSOLEIL / MONT CROSIN

The test bed Mont Soleil/Mont Crosin in the Swiss Jura will provide comprehensive observational data for statistical post-processing and intensive forecast evaluation. This site offers the unique opportunity to have a significant installed capacity of 24 MW wind and 50 kW solar power within a few square kilometers. Furthermore, the site is located in an environment which addresses many typical Swiss characteristics, e.g. complex terrain, turbulent winds, convective clouds, atmospheric icing, snow etc.



Location and image of the test bed Mont Soleil / Mont Crosin.

Within the test bed, numerous specific measurement systems such as mobile weather stations, a sub-network of radiation measurements (companion project SOPRANO) etc. will be installed in the framework of the project. Additionally, access to the operational data of the wind and solar power plant will be established and they will also be equipped with additional sensors (e.g. ice detectors).

In order to evaluate the transferability of the methodologies developed within this project to other sites, they will be tested at different production sites within the Swiss Balance Group for Renewable Energies. In addition, the portfolio effect of producing forecasts for production sites grouped in defined areas will be investigated leading to an improved mutual understanding of forecast providers and end users.

Furthermore, the project aims at a close collaboration with the operators of the solar and wind power plants on Mont Soleil/Mont Crosin (Mont Soleil Society, Juvent SA), the company responsible for the Swiss Balance Group for Renewable Energies (Energiepool AG) and the power line construction department of BKW.

Through this project, Switzerland will contribute to all working groups of COST Action ES1002. The companion project SOPRANO will mainly contribute to working group 2.

Wind power forecasting considering icing

Oechslin, Roger[1]; Dierer, Silke[2]; Cattin, René[2]; Georg, Mayr[1]

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[2] Meteotest, Fabrikstrasse 14, 3012 Bern, Switzerland

Motivation

The number of wind farms in cold climate regions increases, e.g. in Scandinavia, North America and the Alps. There is a considerable wind potential in cold climate regions but icing is a limiting factor. Depending on the mode of operation during icing conditions (e.g. switching off, heating of the turbines), icing affects the power production in different ways and needs to be considered in power forecasts. The aim of this study is to investigate the potential of forecasting wind power considering icing.
Investigations are based on information from two Wind Turbines (WT) that areoperating in Switzerland in a region with frequent icing. In winter 2009/2010 several icing events of different strength took place. Wind power forecasts are calculated using the Weather Research and Forecasting (WRF) model coupled with a Kalman filter (Kalman 1960) and an icing algorithm (Makkonen 2000).

Test site St.Brais

The test site St.Brais is situated in the Swiss-Jura at 1049m a.m.s.l. (Figure 1). The test site consists of two Enercon WT equipped with a blade heating system. Measurements of wind, temperature and humidity are taken at hub-height (78m) (Figure 2). Additionally two web-cams are monitoring icing on the blades and on the sonic anemometer (Figure 3).

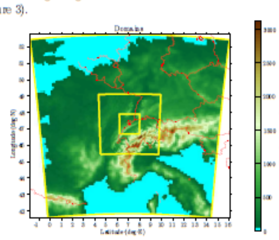

Figure 1: Terrain height in the outermost domain of the WRF simulations at 12km grid size. The nested domains at 4km and 1.3km grid size are marked by yellow trapezes. The position of the St.Brais test site is marked by a red dot.

Figure 2: Measurement equipment on the nacelle of one WT, the other WT is seen in the background.

The amount of ice is determined based on the web cam pictures on the anemometer cam and classified in the following way:

- Class 0 no ice at all
- Class 1 some parts of the structure have some ice or melting ice rests
- Class 2 ice cover along the windward side is closed
- Class 3 ice extents toward windward side and around the structure
- Class 4 structure is fully covered in ice, no metal left

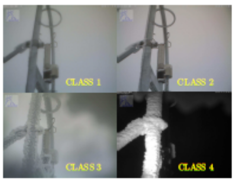

Figure 3: Examples of the icing classes. Class1(upper-left panel), Class2(upper-right panel), Class3(lower-left panel), Class4(lower-right panel)

The forecasting system

The model system consists of the numerical weather prediction model WRF delivering input for the icing algorithm (Figure 4). Power forecasts are calculated based on Kalman filter post-processed wind speed forecasts combined with a power curve. Wind power and icing forecasts will be combined by a self learning algorithm.

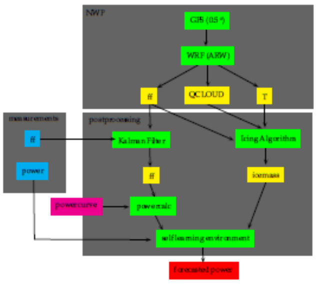

Figure 4: Schematic overview of the modeling system. The self learning has not yet been implemented.

The icing algorithm model describes the ice accretion due to in-cloud icing on a freely rotating cylindrical structure (Figure 5).

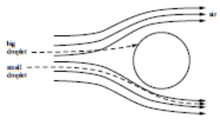

Figure 5: Schematic diagram of droplet flow around a cylinder. (Makkonen 2000)

Results

The forecasting system was used to simulate power and icing forecasts for the period from 2009-11-28 to 2010-03-15. Table 1 shows that the Kalman filter significantly reduces the biases and the RMSE. Simulations at 4km grid size are slightly better then at 1.33km grid size. The reason for that is still under investigation. When separately evaluating the forecast horizons, the results are similar throughout all the forecast horizons (Figure 6)

model resolution	forecast horizon	DMO			KF		
		Bias	MAE	RMSE	Bias	MAE	RMSE
4km	13-36h	2.18	2.88	3.76	−0.06	1.53	2.05
4km	37-60h	2.28	2.94	3.83	−0.07	1.56	2.08
1.33km	13-36h	2.59	3.17	4.12	−0.04	1.54	2.06
1.33km	37-60h	2.70	3.26	4.21	−0.05	1.58	2.10

Table 1: Bias, Mean absolute error (MAE), root mean square error (RMSE) for wind speed and time-series from 2009-11-28 to 2010-03-15. Forecasts have been verified with anemometer measurements on top of the WT.

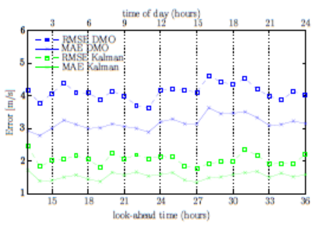

Figure 6: MAE and RMSE of wind speed for different forecast horizons in the DMO and using the Kalman filter.

Figure 7 shows that the simulated ice mass captures the icing events quite well. The duration of the icing events is simulated well. There is a slight tendency to simulate the melting too late. One event is simulated in March when no icing occurs in reality. There the WRF model simulated boundary layer clouds at the test site, however the web-cam images proved that to be wrong.

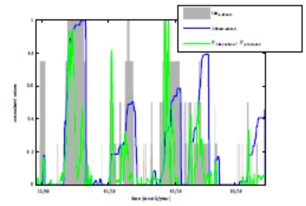

Figure 7: Simulated ice load (blue), ice mass from the web cam images (grey) and the difference between the theoretical power (power value relating to the measured wind speed in the WT's power curve) and the produced power (green). All values are normalized with their maximum.

In ice free situations the simulated power agrees well with the produced power (Figure 8). The time intervals with ice lodad simulated by the icing algorithm and the produced power going down to zero because ice was sensed by the WT agree well. The temporal correlation is rather good, however the melting processes are not captured well in the icing algorithm.

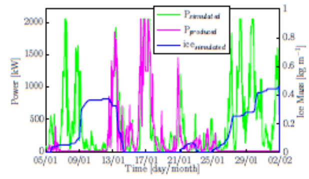

Figure 8: Produced power (red), simulated power (green) and simulated ice load (blue). The heating system was switched off during the time shown. This allows to study an undisturbed behavior of ice accretion and melting.

Conclusions and outlook

- Both the icing algorithm and the Kalman filter show very promising results regarding the power forecast and icing forecast, respectively.
- For the wind forecast, a WRF model resolution of 4km was sufficient and even better than the 1.33km. For the icing algorithm, the only difference was in the simulated ice mass. Since there are no quantitative ice mass measurements available, the difference in quality could not be evaluated.
- The challenge remains to couple the routines to get a final power forecast. This task is complicated, when a heating system is in use.
- Melting is a bit too slow in the model. This might be an effect of missing melting processes in the icing algorithm. Thus, it would be interesting to see, whether further melting processes could be successfully added to the icing algorithm.

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Acknowledgments

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COST Action ES1002 « WIRE »
« State of the Art » Workshop
22-23.4.2011, Sofia Antipolis, France

Organizer: Ecole des Mines – ParisTech (G. Kariniotakis & Ph. Blanc)
Participation: 24 countries, 70 participants
Agenda: see Annex 1
Presentations:

- 6 keynote papers
- 11 specialized papers
- ~ 20 national “State-of-the-Art” posters
- ~ 20 specialized posters

Results

The COST Action ES1002 “WIRE” “State-of-the-Art” Workshop took place in the beautiful landscape of the University areal of Sofia Antipolis, France, about 20 kilometers from the town of Juan-les-Pins, and was perfectly organized by the local staff headed by Ph. Blanc and G. Kariniotakis.

The **first part of the Workshop** was used to introduce the Action’s goals with presentations of the planned activities of each Working Group by the respective Chairs (work plans).

- WG 1 (Georges Kariniotakis)

The objectives of WG 1 were presented. One of the conclusions was that the actual wind forecasting technology is quite mature while the solar power forecasting technology is at an earlier stage. Short term forecasting (short term?) has a top research priority in the EU (e.g. TPWind). Front end research (SafeWind, Anemos.plus and Pegasus) were mentioned as well.

The WG1 objectives were summarized as follows:

- modeling techniques
- inputs in terms of NWP, realtime observations
- output (predicted variables, uncertainties, risks)
- critical assessment of past and present R&D

The overall work plan consists of three phases spread over four years.

- WG 2 (Foeke Kuik)

WG2 task overview was provided and 4 concrete action items were defined:

- assess the state of the art of observation technologies
- inventory of available test sites
- define which observations are required for WG 1 activity
- set-up of a database and make it available for WG 1.
-

A milestone survey was shown with data and deadlines. Possible sites and criteria for testing were discussed. Several campaigns may be organized in which observations and measurements are used for the forecasts.

The need for intercomparisons of already operational methods of observation in particular for solar power plants was identified. MeteoSwiss Payerne offered to coordinate and organize such field experiments against reference (climate) sensors.

WG 1 and 2 will require good communication and coordination and may organize common meetings during the COST Action period.

- WG 3 (Gregor Giebel)

The participation to the WG3 was well established with business-oriented research teams. However, the communication of the available information and knowledge is closely related to copyrights and energy producer core interests, thus giving a somewhat reduced opportunity to a fully transparent reporting. .

Building a bridge between the meteorological and the industrial communities is one of the goals of the Action and will be very challenging.

The **second part of the workshop** was dedicated to oral presentations (17), "national" posters describing the "State-of-the-Art" of the developments in each member country (~20) and more specialized posters about specific projects (~20). The posters were displayed around the meeting and coffee rooms and could be visited during 2 dedicated poster sessions allowing the participants to get acquainted and discuss freely.

Some valuable information could be gathered from these presentations and posters:

- The WMO/CIMO has acknowledged that meteorological measurements dedicated to renewable energies may represent a specific challenge in the future and that some existing guidelines as described in the CIMO Guide should be adapted for this emerging domain.
- NCAR, USA, is fully involved in the business of forecasting for renewable energies production through its Xcel project for wind energy prediction. Close collaboration with the COST Action will be supported by both sides.
- Very short-term and short term solar forecasting of solar energy production remains very challenging. In the former domain, the use of dedicated radiation measurements and cloud tracking algorithms must be further investigated. For the latter aspects, the solar energy community could benefit from the more "mature" technologies used for the wind energy.
- The most recent developments in wind energy production forecasts are convincing. Problems remain to be solved for wind ramps and complex terrain. On the level of integration in the electricity grid, more work needs to be done and new, adapted solutions will have to be developed, especially in case of a higher penetration of renewable energies in Europe. The impressive results obtained from the ANEMOS.PLUS project show the right direction
- So far there is no renewable energy (wind and solar) regulatory agency in Europe: one of the visions of the present COST Action suggests building up bridges toward the foundation of a better standardized and coordinated renewable energy European framework - in a similar manner as the results of a former COST initiative led to the foundation of ECMWF in Reading, UK.
- Many specific R&D activities are – or will be - performed in the different European countries on the modeling and post-processing levels as well as on the integration of wind and solar energy in the electrical grid. This shows that there is an increasing demand and motivation in this field and that a higher level of collaboration between meteorology and industry is more than ever necessary: this aspect is obvious when considering the impressive number of national activities as presented in the "national State-of-the-Art" posters.

The extended abstracts of all presentations and posters will be available on the Action's website and will be used for the preparation of the "State-of-the-Art" report due to be published at the end of 2011, beginning of 2012. Most of the presentations and posters are available in the restricted area of the website.

The **third part of the Workshop** was dedicated to separate short Working Group meetings (mostly for administrative and organizational matters) followed by a plenary session where the goals and roadmap of the Action was discussed.

From the Action's organizational point of view, a majority of MC and WG members wished to participate to the activities of all WGs or, at least, to be informed about the progress and work done in other WGs. During the final plenary discussion (as well as during the first Kick Off meeting in Brussels), it was pointed out that future WGs meetings should not overlap and that participants willing to participate in all WGs could be able to attend meetings in all WGs. This shows that the goal described in the MoU to build bridges between the meteorological and the commercial/industrial communities corresponds to a real need at the present state of development of renewable energies in Europe: this openly expressed conviction reflects the participants' commitment to the Action and their high motivation.

Lessons learned

- Wind energy production forecast is today more "mature" than solar energy production forecasts.
- Wind energy production forecast is presently well established in a few countries in Europe, but needs a broader distribution in countries less advanced in the field of renewable energies.
- Domains such as very short time and ramps predictions, forecasts in complex terrains and special conditions such as icing on structures have to be further investigated.
- Solar energy production forecasts need further R&D efforts, in particular for very short time predictions. In particular, the challenging "cloud tracking" problematic needs to be further addressed by combining ground-based (including remote sensing) and satellite observations with high resolution numerical weather models coupled with specific, to be developed post-processing algorithms.
- Higher penetration of the intermittent renewable energies in the electricity grids will be challenging, both for the wind and solar productions. A European approach will be necessary in this domain.

Conclusion

The "State-of-the-Art" workshop which took place in n Sofia Antipolis only 4 month after the kick-off of the COST Action ES1002 "WIRE" was a success:

- Most of the active Action's members had the opportunity to get acquainted and to learn about the numerous European activities in this domain.
- The present state of development of the forecasting methods were described and discussed within a very motivated and friendly atmosphere.
- The achievements and weaknesses of the present knowledge for both wind and solar energy production forecasting were fairly well highlighted, together with the strengths and weaknesses of the emerging relationship with the production and distributions main actors.
- The presence of leading actors from both the solar and the wind forecast communities was unique and described as exciting by several participants.

With 70 participants from 24 countries in Europe (and contributions from USA and Japan), the COST Action ES1002 has attracted more than expected contributions from the different partners; it may be considered as a key component of the R&D strategy in the renewable energy sector for many countries in Europe.

With this first important activity, the COST Action ES1002 had an excellent start and is now on the right track to deliver a major contribution to the wind and solar energy forecasting community and to the collaboration with the power production and distribution operators.

SWITZERLAND

Switzerland's renewable energy potential

Extending across the north and south side of the Alps, Switzerland encompasses a great diversity of landscapes and climates on a limited area of 41'285 square kilometers. The population is about 7.9 million. The more mountainous southern half of the country is far less populated than the northern half.
In 2010, the total energy consumption of Switzerland was 253 TWh which was the highest value ever. 24% or 60 TWh of this consumption was electrical energy. The total production of electrical energy in 2010 was 66 TWh 38% of which were produced by nuclear power plants. Switzerland has a considerably high portion of renewable energy production due to its hydro power production which accounted for 56.5% of the country's electricity production in 2010. 0.7% of the total electricity production originated from new renewable energies. 37 GWh were produced by wind energy and 83 GWh by photovoltaic systems1. At the end of 2010, the installed capacity was 42 MW for wind energy and 111 MWp for solar energy.

Table I: Estimated development of renewable electricity production in Switzerland[2,3].

	Effective Electricity Production [TWh] 2010	**Estimated Electricity Production [TWh][3] 2020**	**Estimated Electricity Production [TWh][2] 2035**	**Estimated Electricity Production [TWh][2] 2050**
Hydropower	37.500	45.340	47.990	47.570
Biomass	1.138	1.642	2.176	3.833
Wind energy	0.037	0.535	2.929	4.000
Solar energy	0.083	0.535	2.929	10.397
Geothermal	0.000	0.276	1.084	4.378

In 2011, the Swiss government decided the nuclear phase-out, i.e. not to build any new nuclear power plants and to successively take the existing nuclear power plants off the grid by 2034. According to the Swiss energy strategy the missing nuclear energy production will be compensated through four pillars: Increased energy efficiency, additional hydro power plants, higher use of new renewable energy sources, and possibly new gas power plants (including CHP).
The growth of new renewable energies will be pushed by simplified planning procedures and a national feed-in law which actually exists since 2007. Table 1 shows the effective electricity production in 2010 and the estimated electricity production until 20502.
The numerous pump hydro plants in the Swiss mountains already act as a "battery for Switzerland" and will presumably play an important role as a “battery for Europe" in the future.

Wind energy

The main wind potential areas in Switzerland are located in the Jura Mountains. Here, average annual wind speeds up to 7.5 m/s can be found. A good overview can be seen under www.wind-data.ch. Other favorable areas are at the end of the Rhone valley near Martigny and on Alpine passes. However, there are some technical and social obstacles for wind energy development in Switzerland. Difficult access, remote grids, turbulences and atmospheric icing are technical challenges. Social acceptance, especially regarding visibility and noise exposure are frequently discussed items in the densely populated country.
Wind energy production forecasts are not yet very widely used in Switzerland mainly due to the currently limited installed capacity. However, with increased installed capacity, wind energy production forecasts will become more important especially for actors on the energy spot market. Furthermore, in areas with weak grids (typically in the Jura Mountains), these forecasts might become important in order to maintain the grid stability. An additional challenge for wind power forecasts is the inclusion of atmospheric icing as this can directly affect the energy production. Today, most end users rely on forecasts of wind speed and wind direction and convert these values to energy production internally.
A research project investigated the potential of several downscaling methods for wind power forecasts for complex terrain like in Switzerland. Direct model output of the numerical weather prediction model COSMO was compared to a dynamical downscaling approach, a post-processing approach based on linear regression and a post-processing approach based on a Kalman filter. The results show that the statistical approaches give the most accurate forecasts for most of the locations.

1 Numbers from "Schweizerische Gesamtenergiestatistik 2010"

2 Confirmed by "Energiezukunft Schweiz" study by ETHZ

3 From "Energieszenarien für die Schweiz bis 2050", Zwischenbericht II, 18. Mai 2011, Szenario "neue Energiepolitik", Angebotsvariante 2, Variante C&E

Solar Energy

Switzerland has a good potential for the production of solar energy. According to the Swiss Federal Office of Energy[4], up to 20% of the electricity production could be covered by PV electricity production. As there will be many small solar energy systems installed on roofs, the main challenge for the grid is expected to be on the lowest grid voltage levels which are currently not designed for electricity transport in both directions. Solar plants in open areas are currently not in the focus.

Solar energy production forecasts are not yet very widely used in Switzerland, mainly due to the currently limited installed capacity. However, they will become more and more important in Switzerland in the near future. Main challenges are the complex terrain as well as snow cover and situations with fog in the low lands. Today, most end users rely on regionally aggregated forecasts of global radiation and convert these values to energy production internally.

Grid Management

Due to the increasing electricity demand, the existing power line capacities in Switzerland arrive more and more at their limits, while projects for new power lines often face fierce resistance. Therefore, it has become important to exactly know the capacity limits of a given power line under the current meteorological conditions. The maximum current that a cable can carry without damage is assessed in Switzerland by static rating i.e. by ratings for three different maximum air temperatures: +10°C in winter time, +40°C in summer time and +20°C in transition time periods during spring and autumn. The winter limit is exceeded regularly while the summer limit is rather conservative, leaving unused capacities. In general, there is room for optimization through a more dynamic thermal rating considering the actual weather conditions (temperature, wind, radiation). Today, forecasts of the maximum air temperature for the next five days for different climatic regions in Switzerland are used in the grid management.

Atmospheric icing on power lines is an important issue in the Jura Mountains and on the large transport lines across the Alps. Some of the power lines through the Alps are heated in critical cases through a short circuit procedure. However, this procedure makes it necessary to turn down the power line for a couple of hours which is very relevant for the grid management and the North-South energy transport.

Energy Efficiency

Energy efficiency can be improved by developing weather forecasting tuned for the management of energy consumption e.g. for heating, cooling and lightning in buildings, where predictive control approaches are developed that make use of weather forecasts and optimize the allocation of resources in the building control system. Heating in buildings represents about 80% of the Swiss fossil fuel consumption in the household, industrial and service sector. A recent project studying potential gains in introducing weather forecasts in the control of indoor climate in buildings (OptiControl) showed the high importance of the quality of the short term forecast (first few hours and days) and particularly for the incident solar radiation on differently oriented facades.

Planned and proposed national R&D

1) A national project for assessing the possibilities of dynamic thermal power line rating as well as the influence of atmospheric icing in Switzerland will most likely start in 2012. At given pilot power lines, meteorological measurements as well as measurements of conductor temperature will be carried out. The main goal is to better understand the correlation between meteorology and conductor performance and to set up short term high-resolution forecasts of conductor temperature and atmospheric icing.

2) A performance evaluation for irradiation sensors used in the Solar Energy field will be carried out at the Baseline Surface Radiation Network (BSRN) Payerne. The goal is to compare “standard” instruments for measuring (DNI) to high quality radiation monitoring instruments. This will allow to estimate the performance of such instruments and to verify whether they meet the requirements of the solar energy sector.

3) A project proposal for very short term solar energy forecasts (+1-6h) based on quasi real-time radiation measurements and satellite data as well as wind fields from a numerical weather model has been proposed to a national utility.

4) A proposal for a National Research Program called "MeteoEnergy" plans to cover the meteorological and climatological aspects of energy production, transport and consumption. If accepted, this program will allow for launching a number of research and demonstration projects in this field.

[4] http://www.bfe.admin.ch/themen/00490/00497/index.html?lang=de