Agenda

Tuesday, April 9th, 2024 (9:00-12:30 CEST) DTU Risø Campus, Building 112		
Zoom Meeting Link: https://us02web.zoom.us/j/86774105304?pwd=OTdPcG5NZUxFbDlaaERxdmd0VTJrQT09 Meeting ID: 867 7410 5304, Code: 334525		
8:45 – 09:15	Registration	
09:15 – 09:45	Welcome and organizational information:	J. Remund, TM of IEA PVPS T16 Adam Jensen, DTU
09:45 – 10:30	General input • State of team & work • Meeting outlook	TM
10:30 – 11:00	Coffee break	
11:00 – 11:30	Short introduction of state and work of Subtasks 1-4	M. Sengupta P. Blanc E. Lorenz J. Remund
11:30 – 12:30	Subtask 1 (Part 1)	M. Sengupta & S. Wilbert
12:30 – 13:30	Lunch	

Tuesday, April 9th, 2024 (13:30-17:30 CEST) DTU Risø Campus, Building 112		
Zoom Meeting Link: https://us02web.zoom.us/j/86278511477?pwd=M2phUUJ6b0gwK2V2aTJMRXpWRXhoZz09 Meeting-ID: 862 7851 1477, Code: 231127		
13:30 – 14:00	Subtask 1 (Part 2)	M. Sengupta & S. Wilbert
14:00 – 15:30	Subtask 2	P. Blanc & L. Menard
15:30 – 16:00	Coffee brea	
16:00 – 17:30	Subtask 3	E. Lorenz

Forecasts of wind and clouds are important inputs for the control and value of renewable power plants. The forecasts on a time resolution of minutes or seconds are typically data driven, looking at upstream plants, all-sky images of clouds or direct measurements of wind by lidars. Therefore, to facilitate the dissemination of information about minute scale forecasting products, skill, applications, issues, and best practices to members of the electric energy community, we invite you to a Minute Scale Forecasting workshop with the goal of gathering information about methods used to produce the forecasts, the current state-of-the-art skill and uncertainty in forecasting for variables on high temporal resolution, current and planned research activities intended to improve the current level of skill, types of public and private sector operational forecasting products, the range of minute scale applications in the energy community and the quantified or perceived value obtained from those applications, the sensitivity of user's application performance to variations in forecast skill, and the unmet minute-scale forecasting-related needs or desires of the energy user community.

The workshop takes place as the collaboration of the International Energy Agency's (IEA) Wind Task 51, entitled "Forecasting for the Weather Driven Energy System", IEA Wind Task 52 Lidars, IEA Wind Task 50 Hybrid Power Plants, IEA Wind Task 44 Wind Farm Flow Control and IEA Photovoltaic Power Systems Programme (PVPS) Task 16 Solar Resource.

The venue is Risø, Denmark, on the campus of the Technical University of Denmark (https://www.dtu.dk/om-dtu/kontakt-og-besoeg/find-vej/dtu_risoe_campus).

Zoom Link for the entire workshop:

https://dtudk.zoom.us/j/4540565095?pwd=Q1BJSXR0ZkM3SlhRSTZKdStDdTlpQT09

Password: C1c3r0

Agenda

Wednesday, April 10, 2024 DTU Risø Campus, Building 112	
Zoom Link for the entire workshop: https://dtudk.zoom.us/j/4540565095?pwd=Q1BJSXR0ZkM3SlhRSTZKdStDdTlpQT09 Password: C1c3r0	
9:00 am – 9:45 am	Martin Lørup Stensdal MNU@energinet.dk Challenges and where we see the greatest benefit from accurate high-resolution forecasts
9:45 am – 10:05 am	Methieu David mathieu.david@univ-reunion.fr Probabilistic solar forecasts as a binary event using sky camera
9:45 am – 10:30 am	Elliot Simon ellsim@dtu.dk
10:30 am – 10:45 am	Networking Break
Methods of Minute Scale Forecasts and their Uncertainty (10:45 am – 12:15 pm) Chair: Aeishwarya Baviskar	
15 min + 7 min Q&A	Rodrigo Amaro e Silva rodrigo.amaro_e_silva@minesparis.psl.eu **Title**: Spatio-temporal solar forecasting **Abstract**: Often the minute-scale is perceived as being reserved to models based on high resolution imagery, either from sky imagers or from new generation satellites, since these cover the spatio-temporal nature of cloud advection. This talk will describe an approach which aims to do the same thing but by using data from a network of spatially-distributed sensors, be it pyranometers (solar radiation) or PV systems (power generation) and, if time allows, what could be the context that would enable the implied sharing of data in today's data-competitive world.

15 min + 7 min Q&A	Jorge Lezaca Jorge.Lezaca@dlr.de **Title:** Benefit of an All Sky Imager Network for Satellite-Based Solar Irradiance Forecasts **Abstract :** Regional satellite-based irradiance forecast can be improved through the use of blending methods with local ground observations. This blending procedure decreases in general the statistical error of the satellite forecast, specially for the locations where the ground observations are placed. In this study we investigate the benefit that an all-sky-imager (ASI) network regional forecast has on a blending procedure with the satellite-based forecast. This benefit is also compared with the one obtained with the blending of the satellite-based forecast with ground observation point forecast based on solar irradiometers. A discussion on the validity and advantages and disadvantages of of each of the blending methods will be shown.
15 min + 7 min Q&A	Andreas Boschert Andreas.Boschert@th-rosenheim.de **Title:** Enhancing PV Forecasting through Sky Imaging and Irradiance Analysis **Abstract:** HELIOS3, 4: Predictive Spatial Analytics for Solar Energy Grid Integration: Enhancing Reliability and Efficiency«. We aim to install four All-Sky Imagers (ASI-16/51) and one ceilometer (SkyVue8 LIDAR by Campbell Scientific, Inc.) at a PV test site of one of our cooperation partners to develop PV forecasts with a high spatial and temporal resolution. Several preliminary studies have already been carried out (see Figure 2). In my presentation, I will discuss spatio-temporal solar radiation (focusing on ramps and extreme events) and sky-camera networks for solar forecasting. I would especially like to present our latest research project »HELIOS«
15 min + 7 min Q&A	Nils Straub nils.straub@ise.fraunhofer.de **Title**: High resolution solar irradiance forecasting using All Sky Imagers and machine learning **Abstract**:

	High shares of variable energy sources such as photovoltaics (PV) make balancing network load and generation increasingly challenging. Electricity grids with high PV-penetration benefit from the consideration of intraminute and intra-hour variabilities via nowcasts (shortest-term forecasts). In this study we present a novel all-sky imager (ASI) nowcasting system which is benchmarked against a satellite nowcasting system and persistence. Nowcasts of our novel ASI method, satellite method and persistence are subsequently combined to a hybrid model with improved accuracy. ASI systems exploit sky images from fisheye cameras to analyze sky conditions, predict upcoming cloud situations and derive irradiance nowcasts from these. Our ASI method uses a novel machine-learning (ML) based approach that makes direct use of pixel values and other image features. It exhibits a significantly lower root mean square error (RMSE) than the satellite-based method up to LT ≤ 11min ahead and a lower mean absolute error (MAE) throughout the entire interval. The hybrid model brings about an RMSE improvement score of 5−13% over the respective optimal individual method." (Straub et al. 2024 10.1016/j.solener.2024.112319)
12:15 –13:15	Lunch
Applications of minute scale forecasts for control, ramps, and extreme events (13:15 pm – 14:45 pm) Chair: Jie Yan	
20 min + 10 min Q&A	Ndamulelo Mararakanye Ndamulelo.Mararakanye@Eirgrid.com **Title:** Extreme wind and solar ramping events in All-Island of Ireland power system
20 min + 10 min Q&A	Corina, Möhrlen com@weprog.com **Title:** On the benefits and challenges of high-resolution ensemble forecasts for minute-scale ramping applications
20 min + 10 min Q&A	Jon Olauson Jon.Olauson@svk.se **Title**: Reducing power system imbalance forecast errors using short-term wind (and solar) power forecasts

	Abstract: A new balancing model is being implemented in the Nordic countries. The transmission system operators will produce power system imbalance forecasts which are used to procure frequency restoration reserves (mFRR) every 15min with a lead time of around 30min. The increased penetration of wind and solar power could potentially lead to large imbalances, these are important to forecast so they can be handled with mFRR rather than faster reserves closer to operational time. Analyses show that forecast errors could be reduced substantially with good short-term wind power forecasts. To that end, Uppsala University and Svenska Kraftnät have employed two industrial PhD students. The main focus will be wind power forecasting using e.g. SCADA, remote sensing (satellites) and machine learning.
14:45 – 15:00	Networking Break
15:00 – 16:30	Open Space for Discussion
18:30 pm	Informal Dinner Gathering (self-paid) Cost: Approx. 45€ (for one organized dinner on April 10th in Roskilde)

Thursday, April 11, 2024 DTU Risø Campus, Building 112	
Data Driven Solar Forecasting (9:00 am – 10:30 am) Chair: Andreas Kazantzidis	
15 min + 7 min Q&A	Yann Fabel yann.fabel@dlr.de Title: Leveraging Generative Models for Enhanced Solar Irradiance Ramp Detection Abstract: Short-term variations in PV power are an increasingly important challenge for solar energy integration. By anticipating sudden changes in irradiance caused by passing clouds, all-sky imager-based solar nowcasting can help address this challenge. However, the utility of nowcasting systems is highly dependent on the quality of the forecast. While recent data-driven models have

	shown great potential in standard forecast metrics such as RMSE and forecast skill, they tend to produce smoothed forecast curves and may not be well suited to detect ramps. An alternative approach is to forecast cloud motion and irradiance separately. Here, we show that by using generative video prediction to create future sky conditions, ramps can be predicted more accurately.
15 min + 7 min Q&A	Rafael Carrillo Rafael.carrillo@csem.ch **Title**: Graph machine learning for short-term PV forecasting **Abstract:** State-of-the-art approaches for photovoltaic (PV) power forecasting combine numerical weather predictions, satellite images and ground measurements with physical or machine learning models. A current limitation of these approaches is that precise high spatial and temporal resolution require a high computational and storage load. To overcome these limitations, CSEM has developed an approach to PV forecasting based on graph neural networks (GNN) that uses past measurements from a ground-based sensing network distributed in the region of interest. GNNs exploit the spatio-temporal relations of the data to improve the forecast accuracy and resolution. In this talk, I will review recent advances on graph machine learning for PV production forecasting developed at CSEM and compare them to state-of-the-art methods in PV forecasting for the six hours ahead forecasting horizon.
15 min + 7 min Q&A	Erling W. Eriksen ErlingWeen.Eriksen@ife.no **Title:** Evaluation of the impact of local sensing data and feature extraction techniques on high frequency intra-hour irradiance forecasting **Abstract:** An investigation and evaluation of feature extraction and modelling methodologies for intra-hour forecasting using two All Sky Imagers (ASI) for a 22.6 kW PV System owned and operated by the Institute of Energy technology, Kjeller, Norway. Several feature extraction methods were applied, along with different machine learning forecasting techniques on the 1 Hz irradiance and 0.1 Hz image data to investigate the flow of information from data to prediction. From the ASI images, a Cloud Motion Vector (CMV), cloud segmentation and Cloud Base Height (CBH) was extracted, constituting a set of exogenous features for irradiance forecasting. These features were

	used to construct an initial baseline model, a two-layer LSTM network with a vector output, which achieved an Mean Sqwuared Error (MSE) Skill Score (SS) exceeding 0.3 against a simple persistance model.
15 min + 7 min Q&A	Angela Meyer angela.meyer@tudelft.nl
10:30 am – 10:45	Networking Break

Data Driven Wind Forecasting (10:45 – 11:30) Chair: Andreas Rott	
20 min + 10 min Q&A	Robin Conseil robin.conseil@vaisala.com **Tittle:** Measuring the unpredictable. **Abstract:** Sudden wind regime changes in speed or direction are difficult to predict and can severely affect the operation of renewable power plants. Using the Vaisala WindCube Scan ability to measure the incoming wind up to a distance of 10/15km, threats can be detected 5 to 15minutes in advance. Two ongoing case studies will be presented: - Wind ramps detection in a wind farm to ensure grid stability. - Protection of heliostats against wind gusts in a solar power plant. Heliostats take up to a few minutes to move into the stowed position, whereas wind speed can increase almost instantaneously.
20 min + 10 min Q&A	Jie Yan yanjie@ncepu.edu.cn **Title:** AI based weather prediction for wind power forecasting **Abstract**: The accuracy of wind power forecasting is critically dependent on the quality of weather prediction. However, current wind power prediction mainly relies on Numerical Weather Prediction-NWP, which suffer from drawbacks such as extended computation times and poor timeliness. Additionally, NWP typically relies on the solution of partial differential equations that encapsulate physical principles, often without incorporating details of the wind farm's internal flow dynamics. Therefore, we propose an AI-based weather prediction method for wind power forecasting, which integrates

	large-scale spatial features of the global field and micro-scale wind speed transmission features of wind farms, to achieve turbine-level wind speed prediction. Compared to three commercial NWP results, The proposed method can reduce the prediction error of wind speed by 0.72%-18.11% (0.02 m/s -0.62 m/s) and can better capture the detailed fluctuation features of wind speed.
20 min + 10 min Q&A	Janna Kristina Seifert janna.kristina.seifert@uni-oldenburg.de **Title**: Prediction of ramp events using lidar-based minute-scale power forecast **Abstract:** With the growing share of renewable energies in today's energy system, the balancing of supply and demand becomes increasingly challenging. Of particular importance is the accurate prediction of ramp events, that can cause strong gradients in the feed-in of offshore wind farms, enhanced also by the low geographical dispersion of high-capacity offshore wind farms. We will present the characteristics of power ramps measured in a small offshore wind farm and the capability of lidar-based minute-scale power forecasts to predict such ramp events. We generated power forecasts for one year of measurements with forecast horizons up to 30 minutes. We show that during ramp events lidar-based forecasts can outperform persistence for lead times of 5 to 19 minutes and the rmse skill score reaches values up to 20 %.

----- End of Public Workshop. ------

Thursday, April 11, 2024 DTU Risø Campus, Building 112	
13:30 – 17:00	Common Meeting between IEA Wind Task 51 and IEA PVPS Task 16 (Task members only) Chair: J. Remund / G. Giebel Common topics 1. Probabilistic forecasting in PV and Wind (60 min) - Solar (P. Lauret) - Decision making and gaming (C. Möhrlen) 2. Data availability and QC (60 min) Gap filling (P. Blanc) Measurements for forecasting (S. Wilbert) Uncertainty quantifications in PV and wind (X) Solar Res. Handbook and IEA Wind Recommended Practice (60 min) - Solar (M. Sengupta) - Wind (J. Zack)

Friday, April 12, 2024 DTU Risø Campus, Building 112	
Zoom Link: https://us02web.zoom.us/j/88917729907?pwd=VElwWG9YbjUrZXo3cFdIUll3U3pYQT09 Meeting-ID: 889 1772 9907, Code: 274210	
9:00 – 10:30	Common Meeting between IEA Wind Task 51 and IEA PVPS Task 16 (Task members only) Chair: J. Remund / G. Giebel Common topics (continued) 3. Introduction to Task specific work (60 min) Firm Power (R. Perez) Data sharing and privacy climate change and extremes (K. Nielsen and X) Discussion and future collaborative work (30 min) - Update of IEA Wind RP - Use and requirements for measurements - Verification and Validation - more topics

	- schedule
11:00-11:45	Task 16 (HH Koch), wrapping up Subtask 4 • Handbook Version 4.0 Workshops, Webinar
11:45 – 12:15	Task 16, 5 min walk from HH Koch, potential tour to PV test field at Risø Conclusions of the meeting Meetings 2024 / 2025
12:30 – 13:30	Task 51 (Niels Bohr), wrapping up End of the meeting / Lunch
13:30 – 14:30	Site visit at PV test park (at Risø campus)

Practical Information:

Venue: DTU Risø Campus
Frederiksborgvej 399
4000 Roskilde

https://www.dtu.dk/english/about/campuses/dtu-risoe-campus
Google Maps: M3VW+2X Roskilde

How to get to the venue:
-Train from Copenhagen Central Station to Roskilde.
- Bus from Roskilde to Risø campus
Bus 600S (Behind the Roskilde Station)
Bus 216 (Infront of the Roskilde Station, every hour)
The total travel takes around 1 hour.

Tickets for public transport can be bought at the Journey Planner (Rejseplanen), or mobile apps such as DOT, or DSB.
It is often not possible to pay with card or cash on buses.
Tickets can also be bought at the train stations.
The Copenhagen central station is locally known as 'København H'.