



Report 2023

Task 25

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Design and Operation of Energy Systems with Large Amounts of Variable Generation

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Energy system impact studies are important for defining targets for wind and other variable renewable energy, and for defining future decarbonising pathways.

Task 25 is working towards commonly accepted methodologies to be applied in system impact studies for power and energy systems dominated by wind and solar energy. International collaboration is key to harvest knowledge from both practical experience and studies in different countries in the evolving power and energy systems of the future.

Task 25 started its final sixth phase of collaboration in 2021. Updating Recommended Practices for Wind/PV Integration Studies was the main effort for the Task in 2023. In addition, participants of Task 25 publish joint articles - in 2023 on flexibility, intra-hour balancing and improving market value of wind.

Task 25 brings best practices from wind integration experience, study methods, and results to member countries and a wider audience through IEA, IRENA, Global Power System Transformation (G-PST) and Energy System Integration Group (ESIG). On top of these international network stakeholders, the system operators are the main target group of Task 25, following Task 25 work directly (from Denmark, Italy, France) and as observers (Germany, Finland, Spain, Japan, Sweden, the UK).

Introduction

Task 25 work started in 2006 to tackle the differences that were seen in results from wind integration and cost of integration studies. By

analysing the multitude of studies investigating power system impacts of wind power, most differences in the results of the studies were explained and best practices for system studies were formulated. Since then, a convincing amount of experience from wind integration has emerged. Targets for wind and solar are reaching higher and higher shares of demand. The concerns regarding variable generation are shifting from costs of integration to costs of power system inflexibility. Assessing the impacts in practice means comparing costs and reliability of alternative scenarios for power and energy systems.

International collaboration remains key to learn from both experience and studies of wind integration in different countries, in the evolving

power and energy systems of the future. Task 25 is in its sixth term (2021-24). The main stakeholders are the system operators, joining Task 25 directly and as observers. IEA and IRENA have been frequent observers to Task 25 meetings, and work through other relevant international networks, Global Power System Transformation (G-PST) and Energy System Integration Group (ESIG) and ENTSO-E are closely followed.

In addition, Task 25 is active in inter-TCP collaboration: Solar Integration (PVPS TCP Task 14), and Flexibility Needs in Future (Hydro TCP Task 9; Bioenergy Task 44) are important common topics for system studies, as well as transmission planning (ISGAN WG6).

Table 1. Countries Participating in Task.

COUNTRY	INSTITUTION
Canada	NRCan; University of Victoria; University Laval
China	SGERI
Denmark	DTU Wind and Energy Systems; TSO Energinet.dk
France	EdF R&D; TSO RTE; MinesTech
Germany	Fraunhofer IEE; FfE
Ireland	UCD; SEAI; Energyreform
Italy	TSO Terna
Japan	Kyoto University; CRIEPI
Norway	NTNU; SINTEF; NVE
Netherlands	TU Delft; TNO
Portugal	LNEG ; INESC-TEC
Spain	University of Castilla La Mancha; Comillas Pontifical University
Sweden	KTH
United Kingdom	Imperial College; ORE Catapult
United States	NREL; ESIG; DoE
WindEurope	European Wind Energy Association

Progress and Achievements

Through Task meetings, an international forum has been established for member countries, including their Transmission System Operators (TSOs), to exchange knowledge of and experiences with electricity system operations with large amounts of wind and solar energy.

The two meetings in 2023 were mainly in-person, however allowed online participation. TSOs from Denmark, France, Italy, Japan and Sweden joined year 2023 meetings. The Spring meeting was hosted by Kyoto University and TEPCO in Kyoto, Japan, and the Autumn meeting by Terna in Rome, Italy. A public workshop was organised in Kyoto in conjunction with the Task meeting.

Joint articles were published on the following topics:

- A visual assessment to evaluate the diversity of flexibility sources, called a “flexibility chart”: updated and further developed into an article to illustrate as an “at-a-glance” and “easy-to-understand” graph depicting the potential of flexibility resources in a given country or area, led by

Kyoto University [1]

- Current practice on balancing the power system intra-hour was published, led by KTH: Strategies for Continuous Balancing in Future Power Systems with High Wind and Solar Shares [2]
- Improving the value of wind in markets: a peer review conference paper, led by SINTEF: Improving wind power market value with various aspects of diversification [3]
- Grand challenges Grid: listing research needs for wind power plants for grid support services needed in the future. The full article was submitted to WES journal, and main summary points were presented and published as a conference article at WISO wind and solar integration workshop: Grand challenges Grid – research needs for future grid support of wind power plants [4]

Additionally, work on joint publications to be published in 2024 was ongoing for Dynamic Line Rating in Transmission planning, and Role of sector coupling, storage, and transmission expansion in future energy

systems. The IEEE PES Magazine issue on inverter based variable generation was prepared by guest editors J. Matvosyan and H. Holttinen for publishing in March/April 2024 [5]

Task 25 is highlighting the evolving best practices for system impact studies. Recommended Practices RP16 have been updated to Edition 3, including recommendations for wind and solar dominated power systems. The main challenges are 1) power system stability due to the inverter based, non-synchronous grid interface, and 2) balancing due to the varying resources. Although both challenges already entail mitigation options, more research and demonstration are needed to determine how wind and solar power plants, including grid forming capabilities, can become the backbone of future power systems relying on renewable energy sources. For the flexibility needs of wind and solar dominated systems, storage and flexible demand may provide two cost efficient pathways in future. New electrification loads can help for both short-term balancing and for seasonal mismatch of future demand and generation.

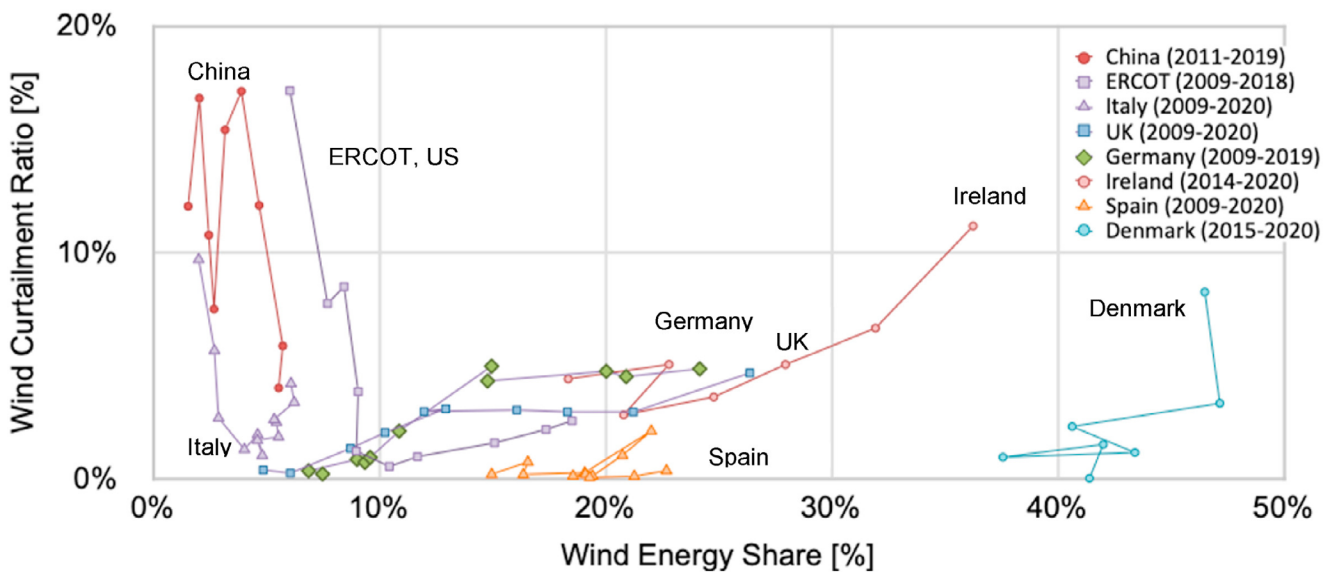


Figure 1. Trends of wind curtailment in some European countries, Texas and China. Some countries have experienced high curtailed energy initially, due to lack of transmission or inflexibilities. It is more common to see the curtailment challenge after 15-30% share of wind energy [3].

Presentations disseminating the work of Task 25 included:

- Deepwind conference Trondheim January 2023: Keynote presentation (H. Holttinen) and NTNU/Sintef presentation on diversification benefits.
- TEM109, Boulder February 2023: Grand Challenge Grid – presentation and session lead (H. Holttinen)
- Public seminar for Japanese audience in Kyoto 10th May 2023, in conjunction with Task 25 meeting, presentations from Energinet (A. Orths), UCD (D. Flynn), ESIG (D. Lew), NREL (B. Frew), VTT (J. Kiviluoma and N. Helistö)
- EEM Lappeenranta June 2023: joint paper and presentation WP Markets (T.K. Vrana)
- WISO23 Copenhagen September 2023: presentation and joint paper on Grand Challenge Grid for (H. Holttinen)

Highlights

Cross-cutting activities

Task 25 has formed links with other System Operator networks: In the current phase, the Global Power System Transformation Consortium G-PST collaboration, in particular, is highlighted. Task 25 was involved in their Inaugural Research Agenda publication and contributed to their research repository, as well as helped organise a joint workshop on future research projects.

IEA and IRENA are joining Task 25 meetings with presentations of ongoing work, and Task 25 has made reviews of their publications regarding system integration.

Collaboration with IEA PVPS Task 14 has continued when updating Recommended Practices for Wind/PV Integration Studies (RP 16 Ed 3), started for the previous Ed 2 in 2018 [6], which was also published as an

IEA TCP PVPS report in 2019.

In 2023, Task 25 had other IEA TCP contacts regarding the value of flexibility of different technologies (Hydro and Biomass), as well as transmission planning under uncertainty (ISGAN).

More recent Tasks of other TCPs can benefit from the knowledge Task 25 has accumulated, and there are more benefits of collaboration between Tasks and TCPs as we go forward in tackling the wider challenge of variable generation in future decarbonised energy systems.

Outcomes and Significance

Energy system impact studies are important for defining targets for wind and other variable sources of renewable energy, but also for defining future decarbonising pathways. Task 25 is working towards commonly accepted standard methodologies to be applied in system impact studies for wind and solar dominated power and energy systems.

Power and energy systems dominated by wind and solar are foreseen to still have challenges for system operators. Task 25 brings best practices from wind integration experience, study methods and results to member countries. There are opportunities when new electrification loads are integrated in a flexible way and the capabilities of wind and solar power plants are fully exploited.

Next Steps

Year 2024 will see the publication of several Task 25 joint articles – Grand Challenge Grid to Wind Energy Science, Dynamic Line Rating and energy sector coupling benefits.

A Recommended Practices update is in the review process (Summer 2024), including a review webinar on the 3rd of July. Fact sheets are being updated.

Two meetings for 2024 are planned:

April 2024 in Dublin, Ireland hosted by SEAI, and an Autumn meeting in Victoria, Canada, end of October, hosted by University of Victoria and NRCan.

References

[1] Yasuda, Y., Carlini, E.M., Estanqueiro, A., Eriksen, P. B., Flynn, D., Herre, L.F., Hodge, B.-M., Holttinen, H., Koivisto, M.J., Gómez-Lazaro, E., Martín Martínez, S., Menemenlis, N., Morales-España G., Pellingier, C., Ramos, A., Smith, J.C., Vrana, T.K. (2023) Flexibility chart 2.0: An accessible visual tool to evaluate flexibility resources in power systems, *Renewable and Sustainable Energy Reviews*, Vol 174, 113116. doi: [10.1016/j.rser.2022.113116](https://doi.org/10.1016/j.rser.2022.113116)

[2] Vrana, T.K., Svendsen, H.G., Korpas, M., Couto, A., Estanqueiro, A., Flynn, D., Holttinen, H., Hartel, P., Koivisto, M., Lantz, E., Frew, B. (2023). Improving wind power market value with various aspects of diversification. 2023 19th International Conference on the European Energy Market (EEM), Lappeenranta, Finland, 2023. doi: [10.1109/EEM58374.2023.10161990](https://doi.org/10.1109/EEM58374.2023.10161990)

[3] Nordström, H., Söder, L., Flynn, D., Matevosyan, J., Kiviluoma, J., Holttinen, H., Vrana, T.K., van der Welle, A., Morales-España, G., Pudjianto, D., et al. (2023). Strategies for Continuous Balancing in Future Power Systems with High Wind and Solar Shares. *Energies*, 16(14), 5249. doi: [10.3390/en16145249](https://doi.org/10.3390/en16145249)

[4] Holttinen, H. et al. (2024). Grand challenges Grid – research needs for future grid support of wind power plant. Wind and solar integration workshop, Copenhagen 27-29 September 2024. *Energynautics*.

[5] H. Holttinen et al., “System Impact Studies for Near 100% Renewable Energy Systems Dominated by Inverter Based Variable Generation,” in *IEEE Transactions on Power Systems*, vol. 37, no. 4, pp. 3249-3258, July 2022, doi: [10.1109/TPWRS.2020.3034924](https://doi.org/10.1109/TPWRS.2020.3034924)

[6] Holttinen, H. et al. (2018). Recommendations for Wind and Solar Integration Studies. RP16 Edition 2. Available at:
<https://community.ieawind.org/publications/rp>

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