An Overview of Coordinated Control via TSO-DSO Interface for Congestion Management in Distribution Networks

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An Overview of Coordinated Control via TSO-DSO Interface for Congestion Management in Distribution Networks

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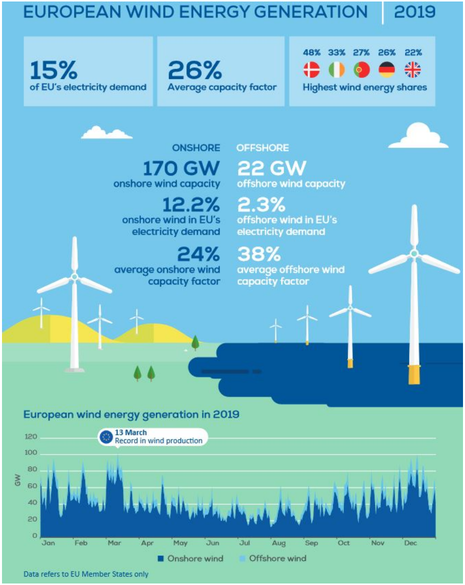
Wind Energy in Europe

As per the report [1]



- Wind energy shares a significant portion of the electricity demand.
- In Denmark, wind energy share is 48%.
- Challenges in power balancing with high share of wind energy [2].

Operation of a Modern Power System

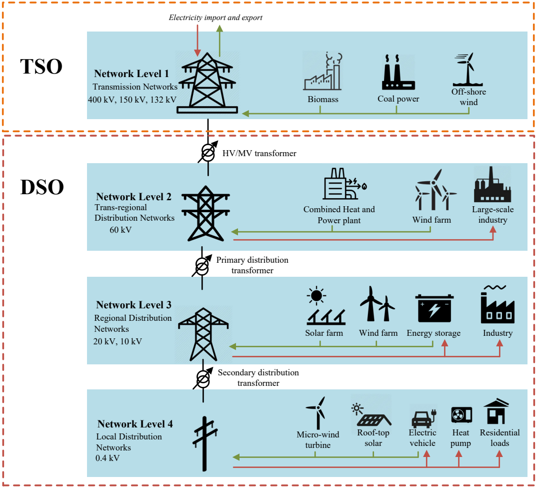


Figure 1: Layout of modern power system [3].

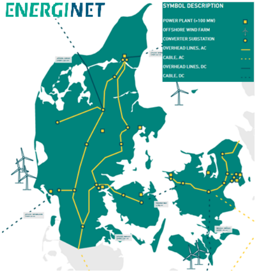
Power grids may be *"stressed"* due to varying renewable energy generation.

How DSOs can manage grid congestion?

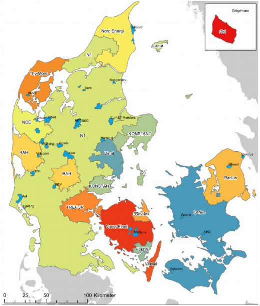
Can the TSO-DSO interface be used for congestion management?

Power System Operators

- **Transmission System Operator** - The TSO operates the transmission assets and is responsible for the power balance on the transmission system. For the example case of Denmark, it is Energinet.



- **Distribution system Operator** - The DSO operates the distribution grid, and often additionally acts as a retailer. Examples in Denmark include, e.g., DONG Energy, Syd Energi, SEAS-NV, etc.



Need for TSO-DSO Coordination

- In modern power systems, the tranmission system operator (TSO) requires ancillary services[1] by DERs such as WPPs at distribution networks.
- Ancillary services by WPPs can be used for frequency/voltage regulation [5].
- However, ancillary services provision may cause bottlenecks at distribution networks.
- The existing grid codes alone cannot address the potential problems.
- Coordination and exchange of information among the TSO, distribution system operators (DSOs) may be a solution [6, 7].

This work deals with congestion management by an advanced TSO-DSO Interface

[1] Any type of service provided by network resources (e.g., DERs) procured by the system operators to the support power system operations [4].

Advanced TSO-DSO Interface

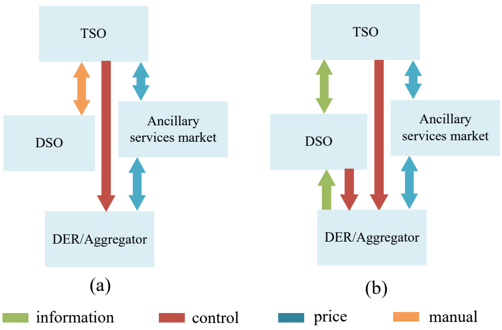


Figure 2: Interaction in (a) present scenario with manual interaction (b) improved interface involving DSO.

- At present, the communication between the operators of the TSO and DSO is on manual basis and it happens only when there is a need.
- An improved interface is proposed in [8, 6, 9] in which information exchange is done on a continuous basis between TSO and DSO.

Coordination between TSO and DSO

- At present, TSO utilizes DERs for ancillary services such as freqeuncy restoration reserve (FRR) by communicating active power setpoints to DERs.
- DSOs are not aware of the above process and a new power setpoint to DERs may cause network congestion.
- In improved TSO-DSO interface, DSOs can be involved to pre-check if the requested power setpoints by TSO donot cause overvoltages/overcurrents.
- A congestion management algorithm can be executed to alter OLTC settings and utilize reactive power capability of DERs to alleviate congestion.

Proposed TSO-DSO Interface

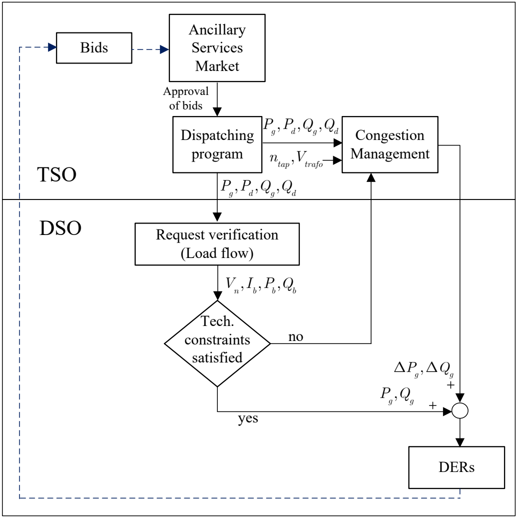


Figure 3: Flowchart illustrating the proposed TSO-DSO interface.

Details of the Algorithm

- The key idea here is the execution of a congestion management (CM) algorithm by the TSO to manage the distribution grid voltages and currents within limits.

- The DSO receives power dispatch from the TSO and checks if it will result in violations of voltages and currents limits. The CM algorithm is activated to adjust the power dispatch to DERs.

- An OPF method based on quadratic programming [10, 11] is used to calculate OLTC tap settings and reactive power setpoints of DERs.

Quadratic Programming Based OPF [10, 11]

The objective of the proposed OPF is to

Minimize the square of the change in reactive power dispatch of DERs and transformer secondary voltage

subject to the following constraints.

1. Linearized active power balance equations at all nodes of the network.
2. Linearized reactive power balance equations at all nodes of the network.
3. Voltage limits at each node of the network.
4. Current limits at each branch of the network.

Simulation Studies - TSO-DSO interface

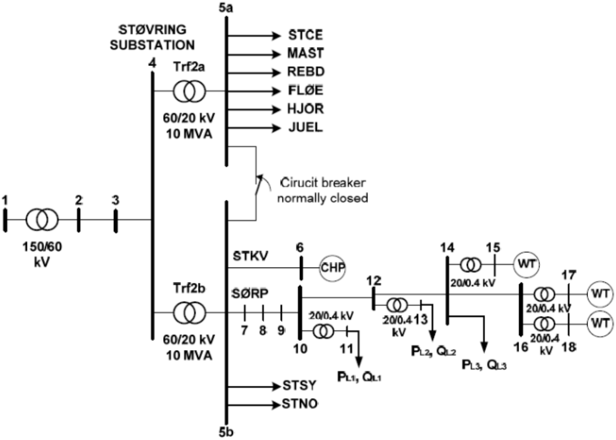


Figure 4: A representative MV network considered for simulation study [12].

Case 1 : Without Proposed TSO-DSO Interface

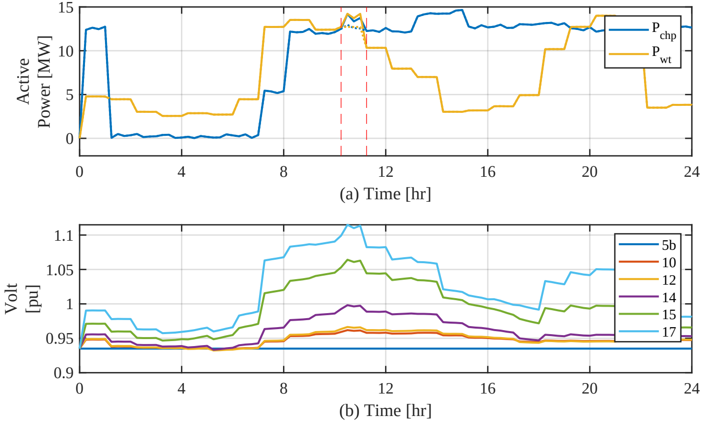


Figure 5: Case 1: Without proposed TSO-DSO interface (a) active powers of WPP and CHP in response to an hypothetical TSO request for up-regulation within the time period marked in vertical red color lines. Solid and dashed lines show the power profile with and without ancillary services, (b) voltages at MV nodes.

Case 2 : With Proposed TSO-DSO Interface

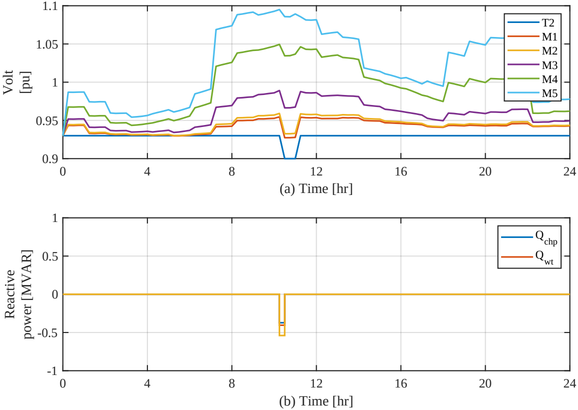


Figure 6: Case 2: With proposed TSO-DSO interface (a) voltages at MV nodes (b) additional reactive powers of DERs requested by the DSO (c) updated reactive powers of DERs.

Observations

- In case 1, the node voltages are above the limit of 1.1 pu, as the expected voltages due to calculated power dispatch are not computed and no preventive measures were taken.
- In case 2, before the power setpoints are communicated to DERs, overvoltages are estimated by the DSO and the CM algorithm is activated.
- The CM algorithm computes the OLTC tap setting and Q setpoints for DERs to prevent overvoltages.
- As a result in case 2, the node voltages are maintained within the limit of 1.1 pu.
- The proposed method is advantageous compared to local volt/var control because the network congestion are pre-checked and the voltage violations are prevented.

Conclusions

- High share of wind energy in a power system may cause network congestion during peak power production.
- An advanced TSO-DSO interface is proposed wherein, a congestion management algorithm is utilized to prevent overvoltages during the utilization of DERs for ancillary services.
- The proposed method can be implemented practically provided the technical regulations and communication infrastructure are updated suitably.
- The proposed ideology can be extended to large active loads such as electric heating systems for provision of ancillary services.

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DSOGRI
Dependable SOlutions for Intelligent Electricity Distribution GRIds

References I

[1] I. Komusanac, G. Brindley, and D. Fraile, “Wind energy in Europe in 2019,” Tech. Rep., 2020. [Online]. Available: https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2019.pdf

[2] P.-F. Bach, “Towards 50% wind electricity in Denmark: Dilemmas and challenges,” *Eur. Phys. J. Plus*, vol. 131, no. 5, p. 161, 2016.

[3] K. Nainar, “Hierarchical distributed control of active electric power distribution grids,” Ph.D. dissertation, Aalborg University, 2019.

[4] EURELECTRIC, “Ancillary services - Unbundling electricity products – an emerging market,” Tech. Rep., 2003.

[5] P. Palensky and D. Dietrich, “Demand side management: Demand response, intelligent energy systems, and smart loads,” *IEEE Trans. Ind. Informatics*, vol. 7, no. 3, pp. 381–388, 2011.

[6] P. Michael, R. Carsten, N. Christer, D. Ellen, and P. Seamus, “System operation emphasizing DSO -TSO interaction and coordination,” in *Cigre Jt. Work. Gr.*, no. August, 2018.

[7] F. Pilo, F. Silvestro, G. Mauri, J. Taylor, B. Bak-Jensen, M. Braun, and E. Kampf, “Control and Automation Systems at the TSO-DSO interface: A survey on the actual functionalities and DSO requirements,” in *Cigre WG C6.25, Dublin*, 2017, pp. 1–10.

[8] K. Nainar, B. R. Pokhrel, J. R. Pillai, B. Bak-Jensen, A. Jensen, T. Helth, J. Andreasen, and K. H. B. Frederiksen, “Advanced TSO-DSO Interface for Provision of Ancillary Services by DER in Distribution Networks,” in *Cigre symbosium 2019, Aalborg*, Aalborg, 2019, p. 3.

[9] H. Gerard, V. Energyville, E. Rivero, V. Energyville, D. Six, and V. Energyville, “Basic schemes for TSO-DSO coordination and ancillary services provision,” SmartNet, Tech. Rep., 2016.

[10] K. Nainar, B. R. Pokhrel, J. R. Pillai, and B. Bak-Jensen, “Utilization of Battery Storage for Flexible Power Management in Active Distribution Networks,” in *IEEE Power Energy Soc. Gen. Meet.*, Portland, OR, 2018.

[11] K. Nainar, J. R. Pillai, B. Bak-Jensen, and J. W. Simpson-Porco, “Predictive control of flexible resources for demand response in active distribution networks,” *IEEE Trans. Power Syst.*, vol. 34, no. 4, pp. 2957–2969, 2019.

[12] M. Altin, X. Han, A. D. Hansen, R. Løvenstein Olsen, N. A. Cutululis, and F. Iov, “Technical Feasibility of Ancillary Services provided by ReGen Plants,” DTU Wind Energy, Tech. Rep., 2018.