Grid State Detection

Driving the future of electric power transmission by deploying artificial intelligence

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Siemens Energy is driving the future of electric power transmission by deploying artificial intelligence

The electric power system is rapidly transforming into a constellation in which the use of power electronics-interfaced devices (PEID) is the norm. The trend is being driven by the ongoing transition to a low carbon energy system, with conventional synchronous generators being retired and replaced by renewable energy sources that are interconnected by power electronics.

These developments are transforming electrical grid systems from networks in which synchronous generators provide the services needed to maintain stability, such as rotational inertia, frequency and voltage control, into a future power system dominated by PEID with a different dynamic behavior and different possibilities for delivering such services [1].
System operators need to be prepared to cope with this new landscape. And with investments and approval processes for additional transmission capacity being hard to resolve, optimum utilization of existing capacities becomes all the more important. One prerequisite for enabling such services, however, is the ability to reliably estimate the state of power grids at any given time.

Stepping up to meet this need, Siemens Energy has developed an online state-of-the-art solution for AI-enabled grid state estimation. We anticipate that this solution will enable our customers to increase their system flexibility and control capabilities, and efficiently use the technology available to enhance the robustness and reliability of the power system.

Our state-of-the-art, AI-enabled grid state estimation solutions provide valuable information to system operators, facilitating their daily planning and decision-making in control rooms around the world.

To bring these development efforts closer to our end-customers, next steps are implementation into specific project applications. We are seeking partners to collaborate with us on customizing, validating and further developing such solution.

Grid strength assessment

Fault level calculations have been carried out for years to determine the short-circuit currents at various substations in the power transmission and distribution industry. These calculations are normally performed by steady-state simulation programs to calculate node fault level Sk" [in MVA]. A number of different established procedures describe how these calculations should be performed [2][3][4],[5].

With more and more fast-functioning voltage controlling equipment being installed (including static VAR compensators, static synchronous compensators, synchronous condensers, voltage-source converters and line-commutated converters for HVDC) and their growing impact on transmission system dynamics, it becomes increasingly important to consider nearby voltage controlling devices in fault level measurement.

To avoid the errors in fault level measurement introduced by the presence of nearby converters, Siemens Energy uses machine learning (ML) to increase accuracy and extract new valuable insights on the presence of nearby converters. Siemens Energy has introduced a more comprehensive concept, referred to below as "network strength", which captures both the fault level of the AC system as well as the impact of nearby voltage controllers. These measurements can be triggered at any point in time or on a periodic basis using Siemens Energy power electronic converters. Our research shows that the information provided by this approach based on artificial neural networks (ANN) can improve grid dynamic performance and maintain stability [6].

Rotational inertia estimation

Large-scale deployment of renewable energy installations, notably inverter-connected wind turbines and photovoltaic systems which do not provide rotational inertia, are displacing conventional synchronous generation installations and their rotating machinery. This accelerating trend will considerably reduce the power system's rotational inertia, which in turn has negative implications for frequency dynamics and power system stability.

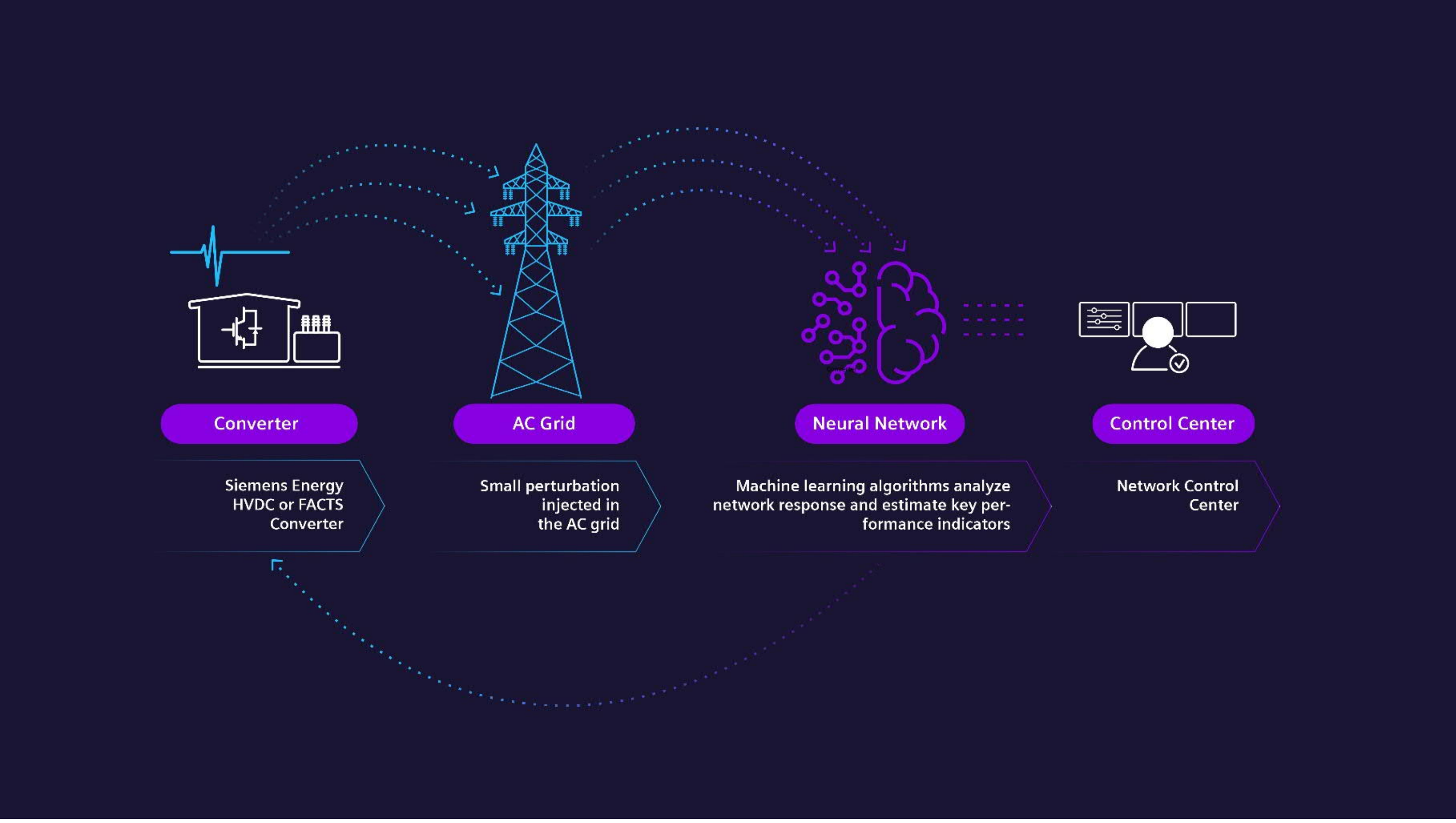
Siemens Energy is introducing a system for rotational inertia measurement using power electronic converters which can be periodically activated to deliver this vital information to system operators.

The developed method uses a known perturbation injected by the converter, then the network's frequency reaction to the perturbation is analyzed to obtain the network state estimation.

This state-of-the-art estimation method uses machine learning to deliver an accurate estimation of the power system's rotational inertia that considers real power system features such as generator controller actions, load-frequency dependence and power system oscillation modes.

Harmonic impedance measurement

The expanding installation of high voltage cables as well as PEID at the generation, transmission and load levels is rapidly changing the harmonic behavior of the power system. Hence, the task of measuring the harmonic impedance from different nodes in a power system is becoming an increasingly important one.



Grid state estimation: providing key performance indicators for managing transmission grids

Even with adequate documentation and knowledge of the harmonic characteristics of the equipment connected to the AC network, the complexity and dynamic nature of the power system makes it extremely difficult to accurately calculate the harmonic impedance of the network at any given moment. Online measurement is an elegant solution as it requires no prior knowledge of the network and no information concerning loads. By performing several measurements over time, the impedance changes can be tracked.

The gathered information can be used in harmonic penetration studies and passive filter design, and to improve the operation of active filters. Furthermore, with the increasing amount of PEID in the power system, online grid impedance measurement increasingly facilitates the analysis of controller interactions and system stability in real time.

Siemens Energy is introducing a system for harmonic impedance measurement using power electronic converters which can be used to deliver this vital information to system operators.

Conclusions

Accurate, on-demand measurement of network strength, rotational inertia and harmonic impedance is an important tool for improving planning in the transmission system operation business. Periodical input of this information based on measurements carried out in the transmission network will allow system operators to utilize the full potential of the existing transmission network.

The power transmission industry worldwide faces technological challenges today on an unprecedented scale. Siemens Energy's state-of-the-art solutions for grid state estimation can help customers meet and master these challenges by providing valuable on-demand information to support their daily activities.

References

[1] CIGRE C2/B4.38 JWG Capabilities and requirements definition for power electronics-based technology for secure and efficient system operation and control. November 2020.

[2] International Standard IEC 60909, Short-circuit current in three-phase a.c. systems, July 2001.

[3] ANSI/IEEE Std. C37.5-1979, IEEE Guide for Calculation of Fault Currents for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis.

[4] J. R. Dunki-Jacobs, B. P. Lam, and R. P. Stratford, "A comparison of ANSI-based and dynamically rigorous short-circuit current calculation procedures," IEEE Trans. Ind. Applicat., vol. 24, pp. 1180–1194, Nov./Dec. 1988.

[5] G. Knight and H. Sieling, "Comparison of ANSI and IEC 909 short-circuit current calculation procedures," IEEE Trans. Ind. Applicat., vol. 29, pp. 625–630, May/June 1993.

[6] A. J. Hernandez M, J. Lottes, D. Abhay and M. Steger, "Artificial Neural Network-Based Online Network Strength Estimation," 2018 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe), Sarajevo, 2018, pp. 1-6.

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