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Load follows generation: the new paradigm for future power system control in presence of high penetration of variable renewable resources

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Mladen Kezunovic

Corresponding author :
kezunov@ece.tamu.edu
Texas A&m University, College Station, United States

Abstract

In the 130 years since the invention of the legacy electric power system concept, electrical generation has been adjusted to match electrical consumption (i.e., the "load") as it varies throughout the time of day and seasons. This "generation follows load" paradigm is a major roadblock to the large-scale incorporation of renewable energy into the national power grid since energy sources such as wind and solar provide inconsistent, variable power that cannot easily be controlled to follow consumption. As a result, today's centrally planned and controlled power system design is no longer adequate. This paper is to introduce a new control approach to enable a "load follows generation" paradigm where a flexible engineered system with distributed control at the users' sites will revolutionize the power industry. Customers will be able to generate power on-site, purchase power from a variety of sources (including each other), sell power back to the grid, select the level of the supply reliability they wish to purchase, and choose how to manage their electricity use. The resulting solution will make the electricity grid significantly more efficient and robust by facilitating extensive use of renewable energy sources and reducing end-use losses in the system. With renewable energy sources widely distributed (e.g., roof-top solar panels and wind farms), the proposed approach will allow exchange of power among utilities, market service providers, consumers, and aggregators (services representing many loads), and also allow power exchange within a customer site.

By incorporating this flexibility into their operations, utilities will be able to adjust the overall load they must serve to match available power. This "load follows generation" approach is essential to allow unhindered inclusion of low-emission renewables in the electricity grid. At the same time it makes consumers active agents in the energy exchange.

Earlier research addressed discrete aspects of the scientific challenges, but the new approach called Flexible Load Energy eXchange (FLEX) will provide the system-level, holistic approach to achieve its vision. The overarching goal is to develop the science, technology, and control system design required to enable energy exchange between the customer and other parties in the electricity energy exchange ecosystem to unlock the huge potential of renewable generation. A central impediment is the stochastic variability of renewable energy sources such as wind and solar, prompting some to question if dependence on renewable sources will ever be viable. Even when wind (which tends to produce at night) and solar (produced during the day) are combined, severe variations in generation require huge adjustments (termed "ramping" within the industry), and spinning (on-line) reserves using conventional generation. This paper explores the missing critical component of smart grid development: smart and flexible loads. In addition, power interruptions, which are often caused by generation/load imbalances or faults on end-user radial connections, will be greatly reduced in a FLEX-enabled power grid by on-site or alternate customer generation. FLEX will also enable customer participation to create new market arrangements, such as wholesale and retail options, and incentives to increase energy efficiency not previously available.