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Resilience-driven Integration of Distributed Energy Resource (DER): Coordinating DER Services for Value

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*In the article, "**Resilience-driven Integration of Distributed Energy Resource (DER): Holistic Value Analysis**", incentives to realize DER's value streams were analyzed for a tiered level of grid integration. Through suitable mechanisms, DERs can also provide resiliency services alongside reliability, ancillary services, and carbon-credits, helping DER operators recoup the DER investment costs while enriching the bulk power grid operations. If valued appropriately through suitable policy mandates, in the long run, DERs could compete with or possibly replace conventional generators through a market-based mechanism.*

With the increasing penetration of distributed renewable energy resources (DRERs) of minuscule capacity, the power distribution system operational architecture also needs to be more resilient and distributed, and decentralized architecture is increasingly being considered. The benefits of DRERs will not be limited to clean energy resource provision. Inverter-based resources (IBRs) driven DRERs, can provide grid services, such as long-term voltage and frequency support, including flexibility services, to the bulk-power system. In the event of catastrophic grid failures, the resource-rich DRER-based microgrids would remain as load-serving pockets, possibly providing the entire grid's black-start capability. Additionally, individual DRERs within a microgrid may have the grid-forming capacity to help the system to operate like a synchronized grid. The improved DRER operational architecture would further improve the resiliency of the bulk grid. However, the DRER operators need to ensure revenue sufficiency before they actively contribute to this endeavor, and there needs to be a mechanism for them to participate in the bulk electricity market.

DRERs: Wholesale Electricity Market Participation?

With traditional price insensitive load demand assumption, electricity markets are heavily regulated to protect the consumer's interest. The electricity market can be conceptually categorized into energy only and capacity market while guaranteeing resource sufficiency. In the energy-only market with merit-order dispatch, day-to-day market operations are expected to cover the variable cost of electricity, with the fixed cost to be recovered through scarcity pricing. However, the scarcity prices in the energy-only market are heavily regulated – to protect the customer interests – ultimately resulting in out-of-the-market capacity payment for the generators. There are markets where capacities are separately auctioned, capacities are separately paid, or adequate capacity is ensured through the reserve market, guaranteeing generators' availability if the network is in distress.

As discussed, most DRERs have close to zero marginal cost, and due to their inherent variability, their participation in the capacity market will be limited. Therefore, the immediate question will be, "what would be the pricing model for the DRERs?" DRERs can continue to bid at the lowest possible level to get cleared; however, especially in the renewable-rich electricity market, it would significantly hurt their investment cost recovery, which essentially questions the necessity of the wholesale market. If the DRERs bid as their willingness to pay, the question is, "will it provide a suitable price signal for all possible operating conditions?". Using the market mechanism to generate a long-term price signal for the generators invokes the conundrum of "pricing human life," primarily because of the criticality of electricity. In some cases, the consensus is on halting the electricity market altogether in the outbreak of a disaster and emergency action plans in place.

The solution, of course, would be to follow the middle ground. And in this regard, recently, there has been a lot of momentum on quantifying various other benefits DRERs in developing various market products to capture their intrinsic operational value. We need to look at the challenges of the future grid with the increasing integration of renewables (both infrastructural and operational) and climate change priorities, which would help us identify suitable policies for developing these market products. Discussed DRER interactions across multiple tiers and associated externalities would help us identify these newer policies, allowing us to suitably monetize the uncaptured externalities. These listed (non-exhaustive) market products would not only facilitate DRERs cost recovery but also become a staple for the grid with high penetration of renewables.

(A) Value of Flexibility: DRERs market participation would enable demand response, ultimately generating end users' interruptible rate and the system's overall reliability requirements. The energy value may not be the proper term for most renewables with zero marginal cost; instead, the individual willingness-to-pay function is expected to accurately capture the consumption component within an unperceivable tolerance level while providing flexibility. While a body of research encapsulates how individual devices will be controlled to provide flexibility, privacy concerns exist. End-users (typically residential ones) are typically slow-moving. Therefore, it can be envisaged that automated hierarchical controllers will take care of the controlling part.

(B) Value of Reliability: If the DRERs are expected to respond in such a way that hurts their comfort level or the bottom line, the associated component of willingness to pay could be classified as the cost of reliability. Traditionally, reliability events are identified by outages, as determined by one of the popular 1-in-10 resource adequacy standards. In a similar line, following outages within the distribution system, if suitably designed, DRERs could still satisfy some of the local loads. Furthermore, if allowed to participate in the wholesale market, given fast power-electronic controllers, the DRERs can provide some of the bulk-power system's slow- and fast-reserve requirements.

(C) Value of Resiliency: As a society, we rely on multiple critical infrastructures, and the electricity infrastructure is at the center of all of them, providing energy-related services. The ability of the humanity goes through tremendous shock if any of these critical infrastructures are severely damaged. We need to adapt and transform ourselves to ride through these shocks, typically defined as resilience. Notably, outages will be expected when these disasters are in progress, but on a much larger scale with the ability to significantly impact human lives. Typically, these events used to be a once-in-a-lifetime. Still, with

climate change, these events are now a frequent occurrence. As discussed, given the scope and size of the event, the value of lost load (VOLL)-based scarcity pricing would be unwise to use, and researchers are increasingly leaning towards insurance-based mechanisms. In addition to DRER resource-rich distribution grid providing microgrid-as-a-service (MaaS) to the end-users, the network can provide some of the resiliency services as ancillary services to the bulk grid, which is reported next.

(D) Value of Ancillary Services: DRERs, although of minuscule capacity, if appropriately remunerated, can participate in both short- and long-term voltage control, long-term voltage support for the transmission network, and the DRER-rich microgrids can provide the black-start capability, operate the system as an islanded network of microgrids.

(E) Value of Carbon Credits: DRERs are not carbon-free. Carbon credits are one of the mechanisms that capture some of the externalities of renewable penetration, facilitating one-to-one comparison with their conventional counterpart. Notably, carbon credits will have to be separated from the energy component, which could be simultaneously traded in parallel. Given loads and generation in an electricity grid need to be satisfied all the time, and renewables may not be available all the time, the possibility of carbon credits storage has to be considered. If the prices are designed well with due consideration of all the externalities, the inefficient ones would automatically be phased out in the long run due to their competitiveness.

The Value of DRER Services: The path forward

With the increasing penetration of DRERs, it is imminent that the electricity network architecture, planning, operations, market mechanisms, and emergency operations should undergo a significant evolution to become more resilient. As the infrastructures are cross-coupled, it may not be wise to look at each infrastructural aspect separately; instead, a service-oriented viewpoint would be more realistic. We need to look at the challenges the future grid would face both in terms of climate change and with the increasing integration of renewables in terms of DRERs to identify suitable policies for developing market products and services. These newer products and services would indirectly help DRERs to operate in a level-playing field with conventional generators while appropriately identifying their suitable prices. Given the diverse need of society and traditionally unaccounted externalities, end-users need to be increasingly involved in the decision-making and participate in the electricity market operation. While extreme events are getting more frequent, despite variability, we can fight against climate change and enable energy security and equity while making our society more resilient, with DRERs at the centerpiece.

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