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Resilience-driven Integration of Distributed Energy Resource (DER): Holistic Value Analysis

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Despite the push from local and federal governmental organizations toward the adoption of clean-energy technological solutions, electric utilities are still slow to integrate DERs. Challenges are mainly driven by the need to quantify all the potential DER values, invisible DER behind the meters, identifying incentive streams, and near-zero marginal cost of renewables.

The push to integrate distributed renewable energy resources (DRERs) is typically incentivized by the local and federal governments in the form of renewable tax-credits, net-metering, time-of-use (TOU) rates or policy mandates in an effort to decarbonize the electricity grid. There is also increasing pressure from climate activists, subsequent environmental compliance and regulatory mandates, and pressure from investors and shareholders, which can successfully reduce dependence on traditional fossil fuel-based generators. However, strategic bidding from the renewables with zero-marginal cost in the transmission sector has long suppressed the true cost of renewable energy resources, and there is an increasing concern over the impacts of DRERs in the electricity market. With increased penetration, the operators are worried about the inherent variability of the renewable energy resources, which would drive up prices with requisite peaking resources. There are concerns also on the emergency operation of the power system in the presence of DRERs.

High Global Horizontal Irradiance (GHI) results in increased penetration of solar photovoltaics (PVs), but also leading to a well-known ‘duck curve’, impacting the system reliability and introducing operational challenges. Such a phenomenon also postures a lack of preparedness across utility companies in terms of thorough integrated distribution resource planning. On the other hand, climate change and consequent frequent extreme weather events have exposed further vulnerability in our aging electricity grid. Consumers are wary of the new policies, including Public Safety Power Shutoffs (PSPS) and new emergency preparedness plans. Furthermore, increasing self-sufficiency through PVs coupled with batteries and other microturbines will make the customers less reliant on the electricity grid. Increasing penetration of data-driven operational and control devices is making our grid ‘smart’ but expected to introduce cyber vulnerabilities bringing additional cyber-risk and cyber-resilience cost. Therefore, there are increasing interests across multiple stakeholders in the power industry to quantify the values of DRERs in terms of capacity, energy, reliability, decarbonization, cyber-risk, and resiliency considering life cycle of DRER.

Uniqueness among Diversity: DRERs

DRERs is an umbrella term to include multiple technologies such as PVs, storage systems, microturbines, fuel cells, co-generation, wind generation, and demand response among many others. Due to different spatiotemporal energy distribution of renewable energy with various climatic and geographic conditions, characteristics of these technologies vary widely. The primary motive behind the increasing clean energy push was to replace the conventional generating fleet, where DRERs would supply the local electricity demand, with the excess being transported through the bulk power system (BPS). Such a system would also capture geographic and temporal diversity of solar and wind generation. With flourishing behind-the-meter (BTM) solar PV penetration, DRERs are almost synonymous with PV-Battery systems. Additionally, there has been a broader discussion over electric vehicles (EVs). While the consensus is that EVs have the potential to balance out some of the variabilities of the DRERs through vehicle-to-grid technologies, consumer adoption and quantifying value of EV services could still be a challenge. Furthermore, widescale penetration of EVs can stress the existing grid.

The utilities or the distribution operators will, therefore, be expected to thoroughly investigate the implication of DRERs integration, which will be specific to the region and provide necessary hardening to manage DRER variabilities. Furthermore, each power distribution feeder needs to be treated separately due to versatile load and generation. There has also been discussion that certain DRERs would suffer from outages during extreme events, making them unreliable during emergency operations. Therefore, over-reliance on one specific DRER would seriously impede the transition towards clean energy paradigm. However, it is imminent that during these events, the energy supply chain would be significantly crippled, and the introduction of a diverse set of DRERs, enabling the ability of the distribution grid to operate in isolation, would substantially improve the resiliency of the distribution grid.

Necessary Holistic Value Analysis of DRERs

Gone are the days when the power distribution system was typically operated as a load center. Most of the planning efforts were spent strengthening the bulk power system, and planning for the distribution grid involved reliability improvements (e.g., SAIDI, SAIFI, CAIDI). With the introduction of an active distribution grid with bidirectional flows, behind-the-meter generation, and the multitude of other DRER penetration, it can be envisaged that the distribution grid would require significant redesign along with means to enable various data flows. If the DRERs participate in bulk grid services, they are expected to remain visible to the corresponding operators directly or indirectly. Tremendous efforts would be needed to streamline the telemetry exchange in real-time to help with realizing DRER values. With uncertain generation, conventional generators need to be retrofitted to provide flexibility services. Additionally, DRERs, by virtue of their fast power electronic interfaces, would also be able to provide some of the flexibility services. However, guaranteeing resource adequacy will be an enormous challenge for expanding grid services to the transmission network, and one needs to justify the need for additional measures to integrate transmission and distribution system operation fully.

Cost-benefit analysis is one such framework that offers a holistic analysis encompassing various merits and challenges of DRER adoption from the system point of view. At the cost-benefit level, we observe multiple tiers of DRERs interaction: (i) direct interaction with the end users through BTM generation, (ii) utilities interaction through power distribution network, (iii) DRER interaction at the local electricity market ISO/RTO level, and (iv) capturing geographic diversity of DRERs across multiple ISOs/RTOs at the national level. Analyzing each of these aspects would clearly identify different infrastructures, architectures, and associated costs of accommodation:

Tier A – Customer Interaction: BTM generation is the direct implication of federal and state government renewable push, push to electrify vehicular technologies, having the capability to directly impact end users' life through reduced GHG emissions, enabling energy security, and making the customers resilient to events beyond their premises. As with any other investment, BTM comes with negative externalities, such as 'duck curve', and positive externalities, such as economic development and well-being of the society, environmental justice for the low-income community, improved public health, and reduced dependency on the bulk grid. Increasing adoption has also materialized into reduced investment costs for DRERs. The risks include policy uncertainty, declining power quality, increased price volatility, outages and operational risk with the failure of DRERs.

Tier B – Utility Interaction: The consensus that increasing DRER penetration would come with benefits, such as deferral of capacity expansion, and increasing hosting capacity, is no longer valid for certain utilities. An inadequate plan for increased penetration has resulted in multiple operational challenges, which may require significant investment in utility infrastructure. DRERs may lead the protection mechanism to become more complex, and utilities would lose revenue for being not able to sell energy. There is an increasing concern about compensating BTM generators more than the avoided cost with the current incentive rate and the ways to recover the cost of infrastructure. Letting customers directly participate in the wholesale market comes with significant reliability concerns, and the needed retrofitting makes utility operations expensive. There are challenges associated with BTM generation prediction accuracy. However, it can be expected that with DRER diversification, some of the reliability concerns would disappear. Increasing operational needs with a multitude of DRERs would necessitate increasing data flow and subsequent investment in communication infrastructure and mitigating cyber vulnerabilities. As indicated earlier, with the lack of preparedness for climate change, customers are growing to distrust utilities, which could hurt the utility consumer base, a negative externality. Alternatively, utilities will be better suited against widescale power outages, and utilities can equip themselves to provide microgrids-as-a-service (MaaS). Utilities could recoup the lost revenue through providing infrastructure-as-a-service. Furthermore, utilities would provide connectivity among multiple microgrids, improving overall resiliency.

Tier C – ISO/RTO Interaction: While the recent FERC order 2222 has paved the way toward DRER participation in the wholesale electricity market, the participation is still limited by DRER aggregators with large enough capacity. In future, it can be expected that there will be multiple avenues through which DRERs would participate in the wholesale market. Notably, facilitation of market participation comes with a significant cost to ISOs/RTOs, and associated modeling challenges, which get distributed following aggregated participation. However, the framework for market participation by the aggregators without violating reliability and the operational standard of the utilities is yet to be developed. Furthermore, facilitation of market participation would come with increased telemetry requirements and associated data complexity, increasing infrastructure investment costs. Again, given that most of the participating DRERs within an aggregator will be based on renewable energy resources with near zero marginal cost, it is not quite imperative that the market would generate appropriate price signals. Furthermore, DRERs value is in additional services, such as, long-term voltage support, frequency support, black-start support, etc., and introduces diversity in energy production.

Tier D – National-level Interactions: While coordination among multiple ISOs is expected to manage regional volatilities, political self-interests would make cross-border DRER energy flow implementation difficult. This is often coupled with uneven policy incentives for renewables across the border. Nevertheless, the irregular incentives are expected to introduce generation diversity across the electricity grid, which might positively help the bulk grid operation. Given that most transmission networks were designed with conventional generation in mind, the cross-border renewable flow comes up with price tags for increased transmission infrastructure requirements.

Holistic Value for DRERs

The discussed value streams help us understand possible ways DRERs would impact our society. It is also imminent that each of the DRER technologies brings in its unique externalities. All of these factors must be suitably included to provide the DRERs with a level-playing field. The costs of DRERs need to be appropriated through suitable policy measures considering all of the positive and negative externalities. To identify the pricing methodology of DRERs of negligible marginal costs, we need to reexamine these interactions to identify some of the common threads in which DRERs can recover their investment and operational costs, and associated discussions will be provided in the subsequent article.

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