INTEGRATION OF MULTIVARIATE DISTRIBUTED ENERGY RESOURCES FOR DEMAND RESPONSE: APPLICATIONS IN THE INDIAN SCENARIOS

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ABSTRACT

India's national missions to advance demand-side management and DERs such as, the Enhanced Energy Efficiency, Smart Grid, Wind and Solar Energy, Electric Mobility, etc., provide a pathway for sustainable developments. With these national missions, India is relying on large targets of 175 GW of renewable energy generation by 2022, which comprises of 100 GW Solar, 60 GW Wind, 10 GW Biomass, and 5 GW Small Hydro and have plans for 40% of generation capacity through non-fossil sources. Integration of DERs like rooftop solar, energy storage, electric vehicles, and demand flexibility becomes important to address the challenges of supply variability and cost-effective integration. We examine fundamental aspects for the integration of multifarious—large-scale and disparate technologies—Distributed Energy Resources (DER) and Flexible Demand (e.g., demand response) applications. During peak times a distribution utility can ask for customer to reduce the demand with the help of DR program and customer can use electricity from electric vehicle using vehicle to grid technology or energy storage. The results show that for high penetration of DERs, it is important for a distribution utility to engage customers and use smart grid technologies to automate monitoring and actuation of the resources in real-time.

INTRODUCTION

Distributed Energy Resources (DERs) are said to be behind the meter energy generation/storage resources typically installed at the end consumer premises. Typical DERs considered in this paper are: Solar PV, Energy Storage and Electric Vehicles. Some of the key elements like Energy Efficiency and Demand Response contribute to grid reliability by effectively providing platform for effective integration of these DERs. Most of the consumers are connected to the distributed grid that consumes as well as produce and known as prosumers. Some of the role of DERs identified for Indian condition in this paper which are explained further are: low cost source of energy; standalone system; stand by power or backup generation and peak shaving. With support from central and state government policies like National Solar Mission, National Mission for Electric Mobility and draft Microgrid policy in place, performance improvements and cost reductions in the technology have played a major role in adoption of DERs in India. Major growth in DERs have been through implementation of both utility scale and rooftop solar PV projects. Solar PV has seen the largest adoption in recent years.

FLEXIBILITY PROVISIONS WITH DER

Presently, the grid is managed by changing the output on the generation side by changing the governor mode of operation and there is no or limited provision to change load on the demand/consumer side. With two way communication, consumers can help in managing the distribution grid by integration of Distributed Energy Resources and Demand Response applications. The following section gives overview of flexibility, which can be provided using Distributed Energy Resources. The goals and objectives of this study are:

1. Looking at application of DERs in India
2. How DERs can be integrated with DR

The State of Renewable Generation.

With national wind and solar missions driving aggressive renewable energy targets in India, India has set an ambitious target for renewable generation capacity of 175 GW by 2022 from the extant grid-tied renewable capacity of 45 GW, as show in figure 1 [1], or 15% share amid the total generation capacity of 303 GW. India's ratification of Paris Agreement, India plans to add 40% of renewable generation capacity by 2030. This would translate to about 300 GW from renewables, where majority estimates—of 210 GW—are from solar energy [2].

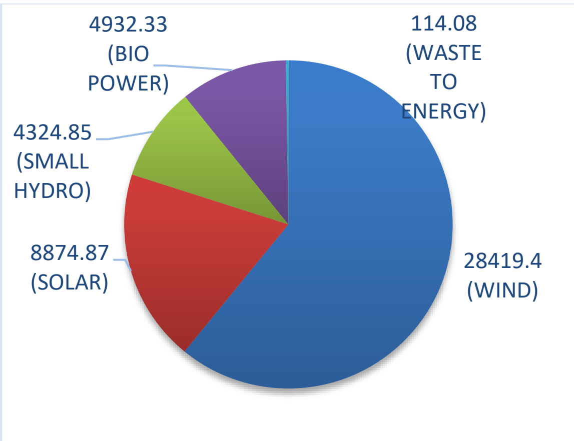

Figure 1: RE Installed Capacity in India (MNRE-November 2016)

Of the 175 GW 2022 target, 40 GW is proposed from rooftop solar photovoltaic (PV), which plays a role of DER among different residential, commercial, and industrial facilities among the various states. The current rooftop solar installations in India stand at about 1 GW. The rest of the solar PV is from grid-scale installations, which adds to the spatial and temporal generation variability and integration challenges. Commercial and industrial consumers are aggressively deploying rooftop solar PV on a large unused roof-space and, as the PV costs drop and the payback period is lessened. Utility scale tariff in India for solar PV has come down to USD 0.07/kWh in a recent projects which has already reached grid parity.

Energy Storage Systems

To integrate such high penetration of renewables into the grid, effectively, several actions (inter alia) have to be taken such as bringing flexibility in the conventional generation, frequency control, maintaining generation reserves and introduction of ancillary services. Energy storage is one of the effective technologies that can be used as DER. There are various types of energy storage technologies, which exist but majorly batteries may be preferred for the use of DERs as batteries can be easily installed at the consumer premise and even at the utility scale. Rapidly growing generation capacity will need large scale deployment of energy storage for transmission decongestion, protecting processing plants from grid frequency and voltage drop triggered outages.

Electric Vehicles

When cluster of Electric Vehicles (EVs) are connected to the grid, the electric vehicle batteries could provide a wide range of valuable grid services, from demand response and voltage regulation to distribution-level services. Electric utility companies can use smart grid infrastructure along with new and innovative tariff structures like Time of Use tariff to tap the potential. This will mean influencing, with increasing precision, where and when EVs are charged through a combination of partnerships, incentives, and market structures. By virtue of being a flexible load, EVs can be used both to absorb renewable energy that might otherwise be curtailed during periods of high output and low demand, and to respond to real-time fluctuations in renewable output and system ramping needs, thus reducing the need for flexible gas generation [3]. V1G and V2G are two commonly used terminologies wherein, V1G is referred to as transfer of electricity from grid to vehicle which, with the help of smart chargers can act as an enabling factor for Demand Response (DR) by charging during the off peak hour using real time communication when the load and price of electricity is low; V2G is referred to as transfer of electricity from vehicle back to the grid wherein, EV act as Distributed Energy Resource which can supply electricity when needed in order to reduce the peak demand on the grid.

Demand Flexibility

India has conducted large-scale demonstrations for automated demand response (AutoDR) to leverage flexibility from behind-the-meter loads. For example, a demonstration was conducted by Delhi’s distribution utility, Tata Power Delhi Distribution Limited (TPDDL), to automate DR for over 145 commercial and industrial customers. Studies have shown success and: (1) identified and characterized each consumer sector’s load duration curve and aggregated power demand; [4] (2) characterized AutoDR system, including advanced metering infrastructure, data analytics, smart meters, and standards; [5] and (3) estimated the potential of DR for customers in the state of Delhi.[6] The compendium of the study findings have shown that demand flexibility can play a key role in addressing India’s electricity reliability, aggressive integration of renewable generation, and enabling the distribution utilities to leverage demand response (DR), as a price arbitrage against volatile wholesale electricity prices and supply variability. Some of the major States in India with highest Grid connected solar installed projects are given in table 1

Table 1: Grid Connected Solar Power Projects

S.No.	State	MW (31-10-16)
1	Tamil Nadu	1555
2	Rajasthan	1301
3	Gujarat	1138
4	Andhra Pradesh	968
5	Telangana	963
6	Madhya Pradesh	811
	Cumulative in India	**8727**

ANALYSIS OF ELECTRICITY MARKETS FOR DER APPLICATIONS

Presently, States in India have issued time of day tariff which are usually fixed for a period of 6 months or 1 year but are not on the real time basis. As mentioned above, State Electricity Regulatory Commission’s in India issue tariff well in advance generally 1 year in advance which gives incentives to commercial and industrial consumers for shifting their load from peak period to off peak period. The concept of demand response in this case cannot be applied as there is no real time communication between utility and consumers.

In future scenario, distribution utility will send the demand response request and consumer can curtail the load or shift the load from peak hours to off peak hours.

To address this challenge, we evaluate India’s national missions, extrapolates distributed generation targets at macro- and micro-levels, and proposes electricity market structure to enable widespread DER deployment and market mechanisms for utilities to provide DR services, as a distribution system operator (DSO). A simplified version of this proposed solution is shown in figure 1 and figure 2 below.

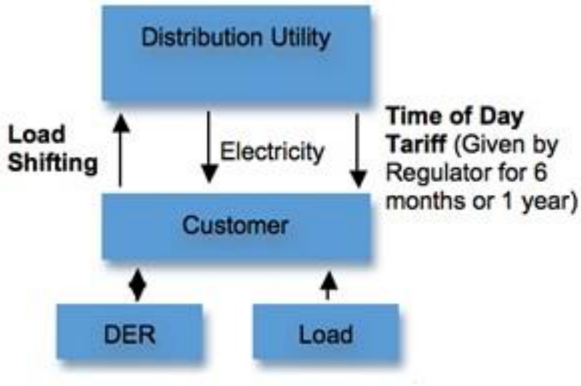

Figure 2: Present Scenario

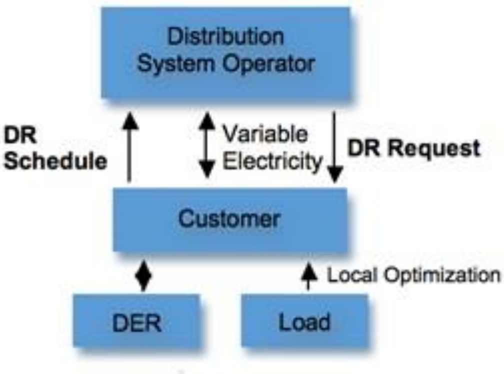

Figure 3: Future Scenario

APPLICATIONS OF DER

Some of the application of DERs identified for Indian condition in this paper which are explained below are:

Low Cost Source of Energy

With cost of solar PV system and energy storage coming down, the low Levelized Cost of Energy (LCOE) will help end consumers to reduce utility bill by generating some or all the required power. Diesel, dual-fuel, and natural gas engines are the least expensive to purchase, but emissions and maintenance costs should be considered when the number of operating hours is high. As per the Central Advisory Committee (CAC) of CERC, it is estimated that, in 2014 approximately 90,000 MW power is generated through diesel generators during power cuts. It is further estimated to grow by 5,000 to 8,000 MW [7] every year which is not good with respect to environmental concerns. Hybrid systems—such as PV or wind with batteries—are more expensive but work over a broader range of fuel costs and applications than single technologies. With ToU in place, electric vehicles can be used to store energy when the cost of energy is low and can be used for own consumption or for selling it back to the grid when the cost of energy is high thereby saving the cost.

Off-Grid Microgrid Systems

A DER in this application will run around the clock and constantly match its output to the demand. Therefore, high efficiency is required to minimize fuel costs and emissions. DERs will works as a standalone system in case of Microgrids which could offer a very good off grid solution to ~18000 un-electrified villages in India or Microgrids can act as good standalone systems for critical loads such as Military base, Hospitals etc. PV, wind turbines, and hybrid systems are beneficial in areas without adequate supplies of fossil fuels or where environmental permitting is difficult, and in off-grid applications where grid extensions are very expensive as is the case in many places in India. Particularly in remote, off-grid areas, the cost of operating and maintaining diesel generators is significant. The cost of transporting and storing fuel, combined with the potential for fuel spills and subsequent clean up, can make hybrid renewable energy systems much more life-cycle cost-effective than diesel generators alone. Places like Andaman and Nicobar are mostly dependant on diesel generators but are now moving towards cleaner mode of generation.

Stand By Power or Backup Generation

Fossil fuel-based diesel generator standby power are widely used by the Indian consumers to mitigate load shedding or scheduled or unscheduled brownouts. Diesel generators are the choice of onsite power generation due to least expensive and accessible technology option. However, this option can present environmental challenges and increase oil imports. In 2016-17, India had national level energy deficit of 0.07% [8], which is due to either non-availability of power or availability of power at a higher price. The uninterrupted power supply (UPS) systems are well suited to applications where outages last less than about 15-minutes. Batteries can handle applications of a few kW for outages of about 1 to 2 hours. India drafted with ancillary services regulations for demand response in 2015 where these DERs can play an important role in creating the ancillary services market. Here, the DERs act like large-scale batteries to store power during off peak hour or even store excess renewable energy there by reducing the need for transmission infrastructure and supplying electricity back to the grid during peak hour. India is already entering into pilot phase with National Thermal Power Corporation (NTPC) floating most promising of these pilots inviting bids for 625 MW of Solar PV with storage, in Andhra Pradesh with storage component of 100 MWh in November 2016. [9]

Demand Flexibility Services

Balancing services are necessary to ensure the continuous equilibrium of demand and supply in the system. Balancing energy is needed in two ways. Upward regulation requires an increase of generation or a reduction of demand. Downward regulation reduces generation or increases demand. DER systems can generate power during the times when purchasing energy from the utility can be very expensive. These include peak demand hours, when time-of-use rates are in effect, and hours when utilities are capacity-constrained. Presently, in 2016-17 Distribution Utilities in India often have to purchase electricity at a higher price during the peak hours which results either in financial loss to distribution utility or load sheading which is a loss for consumer. PV systems, energy storage and electric vehicles can provide peak shaving in facilities where the greatest requirement for energy occurs when the solar resource is at its highest intensity, such as for air-conditioning load and other load. For these applications, DER have excellent load-matching characteristics. Diesel Generators are likely to be preferable for applications which require lower run times which can be brought online by the distribution utility or consumer as and when required but should not be preferred due to environmental constraints.

INTEGRATION OF DEMAND RESPONSE WITH DISTRIBUTED ENERGY RESOURCES

Demand Response (DR) is not a new concept but with Distributed Energy Resources coming into picture, DR plays an important role in balancing the grid. The smart grid enables DR programs so that a utility can shape the electricity load by turning down thermostats or air conditioners, for example, or stopping and starting EV charging as needed. A smart grid solution that integrates EV load management with other DR load controls allows a utility to fully optimize the demand side of the electricity equation to manage electricity supply requirements. This type of demand response could be done through an aggregator that controls the charging of hundreds or thousands of vehicles, tapering off charging when the grid operator signals that demand is high, and paying customers for the right to manage their charging—while guaranteeing that vehicles will be adequately charged when they need it. [10]

CONCLUSIONS AND RECOMMENDATIONS

The study described the integration needs of customer-side DER and how distribution utility needs to communicate with customer on a real time basis and use smart grid technologies and market mechanisms to automate the management of DER and DR services for the future electric grid scenario. The deployment of Distributed Energy Resources (DERs) is growing as is the impact on electric utility distribution networks. While DERs are increasing renewable energy with their multitude of benefits, Smart Grid will be enabler for deployment and integration of DERs. The utilities can be empowered to incorporate new power sources, purchased or generated; improve demand management; and add storage capability in order to maintain a healthy margin between load and capacity.

Information and Communication Technologies

Communications will help in monitoring and controlling the intermittent and variable generation resources on real time basis, which helps utility to schedule its power requirement on the real time basis. Communications & IT would be vital for the functioning of the electric vehicle charging infrastructure as information regarding charging of the electric vehicles would have to be sent to the utility for billing purposes and scheduling of power. Moreover, Communication and IT infrastructure are helpful in monitoring and controlling the power flow in high voltage, medium voltage and low voltage lines up to the end consumer for efficient transmission and distribution of electricity. Hence choosing a reliable and secure communications technology is a necessary requirement in order to operate in real time. A utility needs to choose communication infrastructure which can be used for other purposes like EVSE, Demand Response, Solar generation etc., and utility will not have to install different infrastructure for each and every technology.

Smart Meters & Automated Metering Infrastructure

Having a back-end AMI system capable of supporting EVSE meters allows a utility to break out EV charging seamlessly bill for EV charging at a separate rate. AMI integration also makes it easy for utilities to track and report EV charging usage for greenhouse gas credits. In addition, utilities can use AMI data to predict local reliability issues. For example, prior to installing an EVSE, a utility can compare the peak electric demand of all houses on a single transformer, add the EVSE demand, and determine whether the transformer will need to be replaced or upgraded.

Smart Charging

It is clear that even low levels of EV adoption in India can have a significant impact on a utility and its network. Implementing Smart grid technology will help utilities manage this impact by enabling smarter charging with smart chargers. Electric vehicles will act as an asset for utilities to interact with. Utilities should manipulate charging so that EVs can draw power during peak time while also ensuring the customer has a full battery when needed as charging can take place during off peak hour. By providing intelligent monitoring and communications capabilities to an electricity network, a smart grid gives utilities much greater control over all aspects of operations, from generation and distribution to metering and billing. As a result, utilities can carefully manage when and how EV charging occurs, collect EV-specific meter data, apply specific rates for EV charging, implement DR programs, engage consumers with information on EV charging status and bill impacts.

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