Smart Grids, Storage, and Renewables – Pillars of the Future Grid

RAHUL TONGIA[1]

Smart Grids are a complex, important topic worthy of their own book, if not books, but these have a special synergy to renewables. Most directly, Smart Grids are designed to handle variability, and enable renewable energy, amongst other functionalities of efficiency, robustness, flexibility, consumer participation, etc.

AN INDIAN SMART GRID

What are Smart Grids? There is no single technology or design, but this is a general term for the transformation of the power grid using digital communications and control to enable functionalities such as increased monitoring, resiliency, flexibility, efficiency, and enhanced renewables integration. Definitions and functionalities abound, but for India, the killer apps are likely to be different. In the West, labor costs for meter reading and connections/disconnections have been one driver, in addition to pressures due to renewable energy and electric vehicles, as well as concerns on handling the peak on aging infrastructure (especially in the US). In India, the short-term needs include reduction of losses (both technical and financial) and keeping the grid in balance (especially given shortfalls). Focusing on these applications, and viable price points, will make or break Smart Grids in India.

It's important to recognize that Smart Grids are only a means to an end, an enabling infrastructure. Instead of feeder-level load-shedding, using smart meters, one could provide all homes 50-100 watts (or 300 watts) as "lifeline" if one wished. You also don't need a Smart Grid to cut down theft, but it helps immensely. The scope for Smart Grids is vast, and one area where there is synergy with renewable energy (RE) is helping with balancing the grid, managing the load in times of shortfall of supply.

Traditional Demand Side Management (DSM) programs worked only up to a point – the classic example of a CFL bulb helped mainly because this cut down the evening peak demand, but if so-called paying (commercial and industrial, or C&I) consumers reduce their overall demand, this hurts the finances of the utilities.[2] In contrast, Demand Response is reducing demand specifically when the utility needs it, in a dynamic manner, through a pricing or a control signal. Instead of procuring peak power, the utility can pay for load reduction, effectively enabling consumers to participate in the grid, through what are termed Virtual Power Plants. This is one part of making consumers prosumers (producers-consumers), the other being distributed RE.

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[1] Portions of this chapter draw or are taken from a PlanetPolicy blog piece done by the author (http://www.brookings.edu/blogs/planetpolicy/posts/2014/05/29-smart-grids-india-tongia).

[2] This incentives problem hurts all efficiency programs, especially if utilities are in a Rate of Return (RoR) regulatory framework. A better schema focuses on service, instead of kilowatt-hours.

Probably the greatest reason Smart Grids can work in India is a willingness to change – people are frustrated with business-as-usual. The government recognizes the issue of utility losses (many billions of dollars per year), and consumers hate losing power and paying for back-up power (also to the tune of billions of dollars per year). This has an impact on GDP growth reportedly of several percent. In the U.S., to save a dollar or two per month, consumers may not get that excited or bothering changing their lifestyle (a small enough sum leading to what I have called the "Smart Grid Slice of Pizza Syndrome", i.e., ~$1/month), but in India, if you tell consumers that with modest modifications to their usage patterns, they can save Rs. 50/month (with time of day pricing), or avoid blackouts, many will jump at it. Modest? They already face extreme (involuntary) engagement with the grid – many lose power weekly if not daily, and expensive back-up power only covers part of their load.

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TABLE 1: Drivers for a Smart Grid in India

UTILITIES	CUSTOMERS	GOVERNMENT
• Reduction of T&D losses in all utilities as well as improved collection efficiency • Peak load management – multiple options from direct load control to consumer pricing incentives • Reduction in power purchase cost • Better asset management • Increased grid visibility • Self-healing grid • Renewable integration	• Expand access to electricity – "Power for All" • Improve reliability of supply to all customers – no power cuts, no more DG sets and inverters • Improve quality of supply – no more voltage stabilizers • User-friendly and transparent interface with utilities • Increased choices for consumers, including green power • "Prosumer" (producer and consumer) enablement • Options to save money by shifting loads from peak periods to off-peak periods	• Satisfied customers • Financially sound utilities • Tariff-neutral system upgrade and modernization • Reduction in emission intensity

Source: India Smart Grid Vision and Roadmap (Min. of Power, August 12, 2013)

If we see the drivers for Smart Grids in India (Table 1), we can see that there is a strong mapping to the functionalities Smart Grids enable. These are actually broad transformations, and Smart Grids aren't any specific technology or even architecture/design to enable these.

POLICY NEEDS FOR SMART GRIDS

Smart Grids are a fundamental transformation of utilities, and focusing on the Distribution Utilities, rollouts need to be in sync with a number of operational and business process changes. Beyond the well-recognized need for standardization (and standards), modularity, etc., improved Smart Grids require the below policies and efforts:

Focus on Consumers (and Utilities), their Needs, and Think Bottom-up

Too much of Indian smart grids today are top-down driven, if not vendor/consultant driven. Utilities have their hands full trying to implement the Flagship R-APDRP program, which can be considered a pre-cursor to Smart Grids. Both efforts need to synergize to avoid duplicated or wasted effort. Instead, Smart Grid sustainability comes when there is a need if not desire for them. Consumers need carrots (e.g., no more load-shedding) and not just sticks (e.g., theft detection). Consumers also should have multiple options for engagement, e,g., through mobile phones and SMSes, instead of the Internet or even fancy in-home displays for interaction.

Use societal cost benefit analyses (CBA) for proving the business case of Smart Grids, instead of utility Return on Investment (ROI)

Improved if not Innovative Financing & Accounting

• Innovative doesn't mean convoluted Wall Street-type instruments, just improved granularity and accuracy. Instead of average costs, one has to account for marginal costs and time of day costs. Pricing issues are covered in more detail in other chapters of this volume.

• Use societal cost benefit analyses (CBA) for proving the business case of Smart Grids, instead of utility Return on Investment (ROI). If a Smart Grid ends load-shedding, as of now the utility doesn't benefit financially, but the consumer saves on back-up power. A ROI will not capture this, but a CBA will.

• Consumers today pay for electricity meters – can they pay for a smart meter? A modern digital meter already costs about Rs. 1,000 (almost $20), so can consumers cover the incremental estimated Rs. 1,000 for a simple smart meter? This isn't the full system cost, but the utility could cover shared infrastructure, telecoms, data center, analytics, and more. This is akin to the telecom concept of "houses with tails", where the last hop optical fiber costs are borne by the household, in exchange for a network this can simply plug in to.

Is this fair? First, if the utility buys the smart meter, ultimately it charges the consumer down the road. Second, regarding affordability, in most urban areas, the most basic of homes costs many hundreds of thousands of rupees (in Mumbai, there are single-room tenements that builders have paid Rs. one crore for). This incremental cost is a small price to pay for improved electricity.

Learn, try, Innovate, and Focus Efforts (Including Mission Mode)

If anyone says they have a perfect, ready smart grid at the Indian price point, with modularity, interoperability, security, and other important features, then either they're unaware, or trying to sell you something. Smart grids need effort, and the 14 nationally supported Pilot Projects are a step toward rollouts. Better pilots would differentiate between learning and deployment pilots. India also needs innovation to handle communications and other challenges, not to mention usability and consumer engagement needs. In-home displays are available, but most are too expensive (if not complex) today. The government is planning a National Smart Grid Mission, which can help drive both funding and policy. Every domain would love a Mission, but this needs to be one with independent authority and budget. Smart Grids aren't a drop-in solution – these are a process, not a product. Hence, the ability to engage if not mandate participation from required stakeholders will be key to success. This is especially true given the real challenges are not at the Centre but with the States, which are resource-constrained, both in skilled manpower and cash. In addition, a Smart Grid is really a fundamental transformation of the grid, and hence needs links to RE, Electric Vehicles, energy efficiency, climate change, etc., all of which already have National Missions or similar efforts.

Challenges with Smart Grids remain, including relating to the technology, especially communications. Rural areas have limited cellular (data) coverage, and urban areas are cellular congested, and RCC-type dense construction with apartments doesn't help in urban areas. Perhaps Smart Grids (and similar applications) need dedicated or additional spectrum. These are surmountable issues - probably the single biggest challenge is one of mindset. To a utility, nothing looks cheaper than load-shedding, which should be disallowed. We can and should be granular. We already differentiate consumers and tariffs. But now we can do it smartly, in a transparent, equitable, and efficient manner.

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ELECTRICITY ACT 2003 (PROPOSED) AMENDMENTS

The Government solicited comments on proposed Amendments to the Electricity Act 2003, along with a request for new suggestions. While the most striking of the amendments relates to structural separation and retail competition, there are a number of needs for enabling Smart Grids (and renewables).[3] Importantly, legislation should be about enabling stakeholders and changes, and less about specific targets or timeframes (except where required for a policy push, like the carbon reduction goals by the European Union).

The EA2003 Amendments must reflect Smart Grids, Renewables (especially by end-consumers), and storage technologies, removing generator-centric licensing norms for their use. If a consumer is capable of Demand Response, they should be treated equivalent to a Virtual Power Plant. While Demand Response is usually for larger consumers, renewables (and storage) could allow anyone to become a prosumer. In practice, due to scale and complexity reasons, many Smart Grid functionalities could be undertaken by specialized third parties, who could, for example, aggregate loads, supply, or load-reductions to the threshold required for market (or other mechanisms) participation. Such entities also need license exemptions, along with renewables based microgrids. The amendments talk of distribution (supply) licensees procuring sufficient power to avoid power cuts or load-shedding. Beyond needing teeth for such rules (penalties for non-compliance), the Act should also allow the use of innovative supply models (such as Smart Meter-based load-curtailment) to meet shortfalls. In addition, while the proposed Amendments talk of improved power quality, they do not explicitly enable about new services for achieving these, such as ancillary services

STORAGE AND ITS POLICY NEEDS

Storage is an intuitively attractive proposition, helping not only variability of supply (like with RE), but also varying demand. The main challenge has always been one of economics. Not only is there an investment required, almost all technologies also suffer from efficiency losses. Pumped hydro, where water is pumped up during off-peak periods, is the technology most commercialized and in large scale globally (and has a 79% round trip efficiency per US EIA data), but pumped hydro has found limited deployment in India. Part of this is simply the lack of economic incentives (missing Time of Day supplier pricing), but also because of lack

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[3] Portions of this sub-section draw from India Smart Grid Forum comments on the proposed EA2003 Amendments (Rahul Tongia and Reji Kumar Pillai, lead authors).

[4] Central Electricity Authority. (2013). Large Scale Grid Integration of Renewable Energy Source - Way Forward.

of planning and the dual nature of dams for water control as well, which limits how and when water is to be released. Worse, per CEA calculations, almost half the constructed pumped hydro systems aren't working in pumped mode, mostly due to lack of construction of the tail hydro pool (which stores enough water below to lift back up).[4]

New storage technologies (especially advanced batteries) are on the horizon, and these are likely to have increasing impact on grid operations. If one had a very cheap electricity storage solution, it would profoundly affect RE integration into the grid. Realistically, barring R&D breakthroughs, improvements are expected and steady, but will take some time to compete with peaker technologies.

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There is evidence that storage economics are driven not (just) by energy arbitrage by time of day (or season) but the ability to ramp up/down rapidly, i.e., ancillary services markets. Opening these up will allow storage technologies greater viability, at which point a storage device should be allowed to participate in both sets of markets (ancillary as well as responding to time-based shortfalls, viz., demand response). Much of the effort on batteries is driven by the push for electric vehicles (EVs), where the price differential per kilometer vis-à-vis petroleum is staggering. But the grid doesn't need the energy density like a car does, and so specialized and/or cheaper battery solutions are likely to emerge.

To help the growth of energy storage technologies, policy support includes:[5]

- Pricing incentives, including Time of Day pricing
- The start of ancillary services in the grid
- R&D support, from basic research to pilot deployments
- Regulatory ability for storage technologies to enable prosumer participation

THE FUTURE GRID AND SMART/ STORAGE SYNERGIES

The traditional grid was based on keeping up supply to meet demand (with reserve margins). Renewables make this harder. In the future, instead of supply matching demand, a Smart Grid can enable demand to also match (varying) supply, at least in part. How this is achieved is a work in progress.

India already had significant load management through the use of phase-wise rostering of supply for irrigation pumpsets in rural areas – 3 phase supply is meant to be given only during off-peak periods, including the night. Unfortunately, such load-flattening cannot continue, in part because at some point, pumpset use will approach saturation (not to mention they must become more efficient), while overall demand will grow. Today's relatively flat demand profiles will have greater and greater peak/off-peak gaps, pushing not only Time of Day pricing but even Smart Grids.

As a thought experiment, if we take all the homes that don't have electricity (either at a wire level or at meaningful supply levels), and we give them minimum lifeline supply of, say, 100 watts, the total extra capacity we'd need even from the centralized grid, with technical losses, would only be on the order of 15 GW of capacity. This is less than India has added in a single year. The catch is we have no means today of either limiting usage to 100 watts or of ensuring supply goes to such users (electricity flows like water based on voltage differentials, so new capacity is shared across the grid based on physics). Smart Grid technologies now exist to en-

[5] *More details on storage and its policy needs can be found in reports by the India Energy Storage Alliance (IESA), prepared for the Ministry of New and Renewable Energy (MNRE).*

able such curtailment through smart meters. The alternative of using distributed renewables holds promise mainly for remote locations far from the grid, or where the load is limited, such as for lighting. The flip side, which might yet materialize, is that as new "lifeline" users grow their demand, RE supply costs will fall even further, changing the dynamics of the grid. This might drive microgrids in many regions.

Renewables create grid management challenges (see Chapter 2), but new technologies can help manage such issues better. A not-so-well known fact is that the grid is mostly constrained not by the physics of the wires overloading (thermal limits) but by stability limits. Smart grid monitoring technologies such as Wide Area Measurement Systems (WAMS) on transmission lines, which can help measure the stability of the grid in real time, can reduce the risks of grid collapses, and even allow the grid to be used more efficiently (higher loading).

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A lower hanging fruit might be something as simple as Dynamic Line Rating (DLR), which has particular relevance for wind power generation and should be started across high-wind regions of India at the least. Most transmission lines have a rating based on their conductor, and this is often a conservative rating. DLR, with measurements, makes the loading limit not only dynamic, it factors in things like wind-speed. The higher the wind, the more current the line can carry safely without overheating, which is precisely when wind turbines would pump out more power.

A combination of short-term, medium-term, and long-term focused efforts will be the path ahead for Smart Grid projects in India. Smart grids have been described as a work in progress, a journey, with different utilities worldwide at different levels of implementation. If these are tough to get right in developed regions, do Smart Grids make sense for India, which is still struggling to keep the lights on (and provide access)? Smart Grids can and should look different in different places, and an Indian Smart Grid becomes not only an option but, likely, an inevitable transformation of the grid. Why? Because business-as-usual just will not meet India's aspirations in terms of speed, economics, equity and sustainability.