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Re-thinking Access and Electrification in India: From Wire to Service

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1. Synopsis and Recommendations: Add a service delivery component for defining "electrification"

"Electrification" has been a priority for India for many years, and there are ongoing plans and projects to improve access to many more households, followed by electricity for all in the coming years. Despite improvements in the threshold for village electrification (moving from any single point to 10% of homes plus common areas, etc.), the benefit of electrification is lost for citizens if there is no electricity supply during periods of need.

We propose an update to the definition of electrification that both extends the threshold for service connections and, more importantly, adds a service component of actual supply. With a focus on household demand, we propose a requirement for utilities to supply electricity during the peak household demand periods of 6 – 10 PM, and a morning block of approximately 6:30 – 8:30 AM (the latter to be determined based on actual demand in a multi-stakeholder process). Even if there is a transient shortfall, *transparency* and *predictability* are key requirements for improved load-shedding.

2. Electrification and Load-shedding

The definition of electrification is well-publicized, and statistics are available, even if these require updates given the rapid pace of deployment of new connections. Ideally, data should be granular such that we have more that state-level or utility-level data. Districts, taluks, etc. are one option, or it might be easier to do this as per electrical geographies, either operational (DISCOMs have divisions, sub-divisions, etc.) or physical (by substation, feeder, etc.).

What is entirely missing are data on outages, specifically, load-shedding (cutting off 11 kV feeders to reduce demand to match limited supply). Outages due to faults are important and worth documenting, but can be treated separately. Load-shedding is a choice, at least for where to shed load at any given instant, and is the purview of the distribution utility (DISCOM, or ESCOM).

How much and where is the load-shedding? It turns out, *no one knows*! There are typically signals or commands given by the State Load Despatch Center, based on which substations switch off feeders for load-shedding. Facing shortfalls, utilities invariably end up resorting to Scheduled Load-Shedding, in part guided by state Regulators. However, there is often flexibility in some of the directives/guidance,for example, in Karnataka, for households the Regulator has mandated supply for 11 hours of the 12 hours between 6 PM and 6 AM.

Is this being achieved? No state really knows since the actual outages are done manually and at the edge, and the data are rarely aggregated or even fed bottom-up. A second challenge is that what little is known is mostly average statistics, and not granular by time or geography.

How does one measure load-shedding? Karnataka is an outlier in that is has already installed a SCADA (Supervisory Control and Data Acquisition) system down to the 11 kV distribution feeders, owned and operated by the State TransCo/Load Despatch Center. Short of this, one would need feeder monitoring, which can be done even without a SCADA system. To help frame the size of the problem, a state like Karnataka has approximately 8,000 feeders spread over 1,400 sub-stations. Using 3-phases per feeder, we have approximately 24,000 nodes to be monitored in (near) real-time. A simple current monitor and GSM/3G wireless node, which can be placed anywhere on the LT line downstream, could be made for approximately Rs. 1,200. Thus, even for states without proper feeder metering, outage measurements can be done rather cheaply.

The good news is that if one is interested in historical (accounting or auditing) data, then measurements can be done even more cheaply since one doesn't require the same communications system.

3. Shortfalls are much higher

3.1. What is the shortfall in the Indian Power Sector?

Officially CEA shows the actual 2013-14 shortfalls as 4.2% for energy (kWh) and 4.5% as peak (GW). It turns out both numbers are systematically wrong, and understate the shortfall significantly. (Of course, while there are systematic biases in the official data, the *trend* is positive over the last few years.)

Before we even come to the fundamental error in methodology, there are other major challenges with the sources of data and assumptions at a system level.

1) *Ad-hoc load shedding.* How is shortfall calculated? Load shedding is based on feeders which are switched off, leading to a limited sense of the instantaneous loss of power at a feeder level however, almost no utility aggregates these data systematically.
2) *Unknown real demand.* There is no clear sense of what the true (unrestricted) demand would be, especially if consumers knew they had uninterrupted power available.
3) *7 PM arbitrary peak.* While there is mostly an evening peak, there are variations by season as well as between states, and the shortfall at 7 PM may not be the exact peak shortfall. Equally importantly, if there is a higher shortfall at a non-peak period, that should be the basis for defining the shortfall. It is entirely possible that the shortfall during the "non-peak" is higher if there is variable supply, both due to renewables as well as due to choices made in despatch schedules, especially hydropower.
4) *No spinning reserves.* This figure of shortfall excludes any spinning reserves. The Grid Code talks of 5% reserves but that is likely too low. Spinning reserves should be at least as high as the single largest point of failure (spanning both generation plants and interconnections), likely good enough for 2-3 (most systems have planned maintenance outages). In the West, the spinning reserves are targeted at 20%, with 15% as a typical minimum
5) *Incomplete frequency correction for supply and demand*. There is incomplete capture of system response to frequency deviations. When the frequency deviates (indicating a supply-demand mismatch), load profiles also change. CEA methodologies allow for a slight load correction (for synchronous loads like motors) but they do not capture the generator response characteristics as per standardized (droop curve) characteristics. In essence, a system could suffice with an "x" increase of load, but if one were to operate the system at optimal (50 Hz) frequency, then one would need much more than "x" increase in capacity. Otherwise, existing generators have to over-work to keep the system stable, which impacts their O&M and lifespan.
6) *Artificially flat load profile.* A 4.2% average versus a 4.5% peak shortfall implies a mind-bogglingly high Plant Load Factor (PLF, aka capacity utilization factor). In no other stable system is this so high – the off peak demand is usually 30-50% lower than the peak demand, sometimes lower. The only reasons for this, even if true, would be artificial load management including feeder rostering for agricultural pumpsets which are turned on mostly at night.

Most importantly, the CEA methodology for peak doesn't take the instantaneous peak for measuring peak shortfall, but the monthly peak shortfalls along with the maximum supply and maximum demand in a given year and compares them. In some cases, this even results in different months being used, which might be acceptable in some cases, however the peak demand is seasonal, and there is organic (year-over-year) growth. This results in the last month of the year invariably having the highest capacity, though maximum demand may not correspond to this period. If one had the end of the financial year (e.g., 2011-12) coincide with the period of maximum demand in the year, after normalizing for seasonal variations then one would find a higher shortfall in capacity.

This truly needs instantaneous peak calculations, with a granularity provably finer than monthly numbers. For e.g., official data for November 2012 shows an MU (energy) deficit higher than demand (MW) deficit (!) - how is that feasible, unless the same decoupled supply and demand methods are applied?

Even without applying any sophisticated statistical analysis for seasonality or organic growth, a simple examination of monthly peak shortfalls (below) shows how the annual number is systematically low. The maximum supply is NOT the same as the month for maximum demand. In fact, there is systematic bias in each. Supply is maximum both later in the year (as more capacity comes on line) and after the monsoon, when hydropower increases and wind power is maximum. Demand decreases at the same time, decreasing further until a rebound with the new agricultural season and also the next dry period if not early summer (South India). While speculation at this point, similar improvements in granularity of using the true deficit *within* a month might raise the deficit, even before correcting for points 1-6, by several percent.

Table 1: Peak (MW) Shortfalls All-India

	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	**year 2013-14**
Peak Demand (MW)	132,122	135,561	132,790	131,102	132,040	135,155	131,286	128,405	131,271	134,854	135,918	135,650	**135,918**
Peak Availability (MW)	122,402	126,964	125,110	123,726	126,774	129,815	125,629	123,602	125,953	128,094	129,633	129,238	**129,815**
Surplus(+) / Deficit(-) (MW)	(9,720)	(8,597)	(7,680)	(7,376)	(5,266)	(5,340)	(5,657)	(4,803)	(5,318)	(6,760)	(6,285)	(6,412)	**(6,103)**
(%)	-7.4	-6.3	-5.8	-5.6	-4.0	-4.0	-4.3	-3.7	-4.1	-5.0	-4.6	-4.7	-4.5

Source: CEA 2014-15 Load Generation Balance Report

3.2. Policy implications of higher shortfall

If we agree the shortfall is higher than official numbers, so what? A cynic might argue that large shortfall is large shortfall – how large is merely academic. In reality, there are major implications of underestimating the shortfall, and it can lead to less effective or useful policies. If one truly believed that the shortfall were only some 5% and the subsequent Plan would bridge the gap (assuming successful execution) then that distracts from the fact that if the shortfall is far higher, then the Plan, even if implemented in full, will be insufficient.

This also obscures the true need for meeting the peak demand, which is specialized peaking power, and not power by itself. Instead of focusing on 20 GW of baseline capacity, the nation may be better served by 10 GW of baseload and 10 GW of peaking capacity, with a prioritization of the latter over the former (using past history as a guide, i.e., targets are unlikely to be achieved).

3.3. A slice of real data on load-shedding - Karnataka

Drawing from a study by Santosh Harish and Rahul Tongia,[1] we analyze SCADA[2] data for all the BESCOM (Karnataka) feeders over multiple days across 3 seasons.

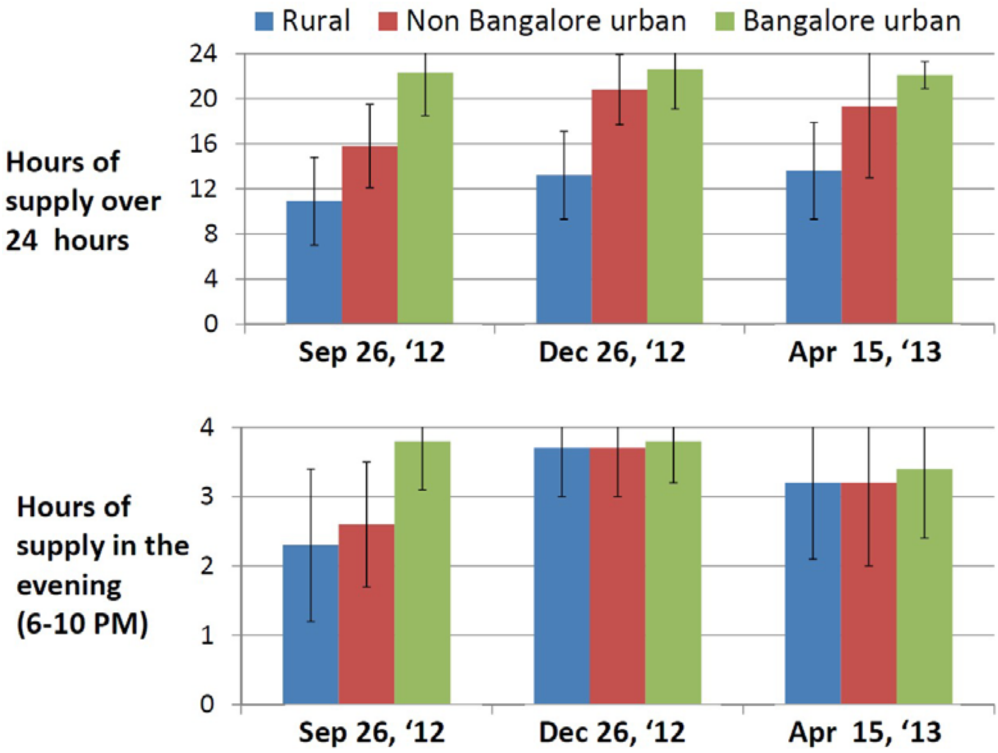

Figure 1: Actual Supply on 11kV feeders in BESCOM

We find the actual supply was measurably lower than officially targeted, let alone large variances across the feeders (see error bars). In addition, in some cases, the actual shed (calculated bottom-up) can be higher than reported.

If there were a SCADA or other feeder measurement system in place, one could quantify the actual load shed with high granularity.

[1] "Do rural residential electricity consumers cross-subside their urban counterparts? Exploring the inequity in supply in the Indian power sector", Santosh Harish and Rahul Tongia, Brookings India Working Paper 04-2014, August 2014.
[2] Karnataka is the only state in India with a ~full 11 kV distribution feeder level monitoring via its Supervisory Control and Data Acquisition (SCADA) system. No other state can properly quantify the instantaneous load-shedding on rural feeders. Under R-APDRP, urban areas can undertake such monitoring.

4. Step 1: Need a wire to have service

The target of electrification by wire is a useful goal, and this can now be pushed to a higher number than 10% of homes.

One could either have a flat target for defining a village as electrified, or have a moving target, tightening over time. If flat, then it would make sense to have at least the majority of homes connected to qualify as electrified. Thus, the target could be 50% electrified. In fact, 60% may be a better target since this then crosses the realm of “average numbers” into true positive territory.

Why not 100%? First, it would obviously take a very long time. Second, why a home doesn’t have a connection isn’t just a failure of the suppliers (utility) but could be economic or another reason. At the very least, the option for the availability of a connection must be there, and then one could argue that it’s a market decision as to whether they home opts for a connection or not. On the other hand, given the enormous public good aspect of electricity service, there is a rationale for subsidized connections.

Keeping in mind such issues, an alternative option is to take today’s 10% as a base for electrification, and increase it by, say, 5% per annum, such that in 8 years, one reaches the 50% target (or 10 years for 60%). Any village qualifying under such norms remains “electrified” but others become “partially electrified.” This latter term may be preferable than a binary (black-and-white) electrified vs. not-electrified. To be even partially electrified, 10% or some other threshold should remain.

Note that these numbers are not set in stone – there should be deliberation on these, and the annual increase, for example, can be made more aggressive. In addition, more than just measures for statistics sake, progress by states towards electrification should be rewarded by increasing access to grants/funds/etc.

The other issue with electrification norms is segmentation of homes, e.g., above versus below poverty line (APL/BPL). If one left connectivity to market forces, then it is feasible that APL would have higher electrification than BPL homes. This is compounded by non-market institutional/social constraints (e.g., BPL homes may be clustered remotely), making things worse. Thus, there is a rationale for separate metrics and targets for BPL instead of overall homes. On the other hand, mandated/free connectivity for BPL homes leaves those who are just outside the ambit (either due to recognition/paperwork reasons or being just over the threshold) worse off.

Due to this, it may be worthwhile to institute a new metric and support mechanism for homes. First, the total target metric for homes electrified in a village (e.g., 30% in a given year) must be met by both the total and BPL homes (with a small 1% or 2% variance allowed due to any random nature of connections). What this means is that if BPL homes are truly lagging due to economic reasons, as they cross the threshold, the APL homes should be even better connected, raising the number overall. Second, in case there is a lag for BPL homes or the overall target, BPL homes can be the ones targeted for priority connectivity, through economic support mechanisms or other means.

5. Step 2: Service is key

As well appreciated, having a wire is not sufficient if there is not power on the line, especially during periods of high demand. Load-shedding is highly regressive, with the poorest both lacking the means to utilize expensive alternatives or paying much higher for back-up alternatives such as kerosene. It is high time we demanded supply on the wire as a component of *electricity service*.

5.1. Manage existing shortfalls better: transparency and predictability

While ending load-shedding may take time, especially since increasing supply (adding generation) takes time, managing shortfalls in a fairer and more transparent manner is important.

All utilities must have strict schedules for load-shedding, well-advertised in advance, and unscheduled load-shedding must be severely restricted to unforeseen emergencies only (and not simply lack of procurement). While possible amendments to the Electricity Act to this effect may be required, allowing penalization for violations, there can be regulatory or statutory notifications as well to start the process.

All utilities must be required to report the below measures in a phased manner;

- As a bare minimum, per month, report on the total load-shedding in terms of hours-feeders. Utilities must also report on the average load-shed per feeder across the utility, as well as standard deviation.
- If acceptable to the state, add in granularity such as per district, taluk, etc. Rural vs. Urban etc.
- Gradually, move towards a per feeder reporting of load-shedding. This will require some level of instrumentation as reporting may be nominal, and not reflect the ground reality. Such data will help optimize and manage outages better.

Maharashtra has instituted feeder classification for load-shedding priorities. This is a useful step, but still doesn't publicly tell which feeders are classified as what, and how often they get called for shedding. Other challenges still remain as discussed in Section 5.3.

5.2. Mandate minimum service for selected time periods

To be meaningfully electrified, there must be electricity service delivered on the wire for periods of household need. For rural areas, this is very time sensitive, starting with the evening period when lighting is required.

The first need would be meaningful measurements per utility on what is the granular shortfall to meet 100% household supply during the peak household demand periods (ostensibly, 6 – 10 PM and roughly 6:30 – 8:30 AM).

Second, there must be a target for service provision on the feeders. This links to the point about transparency and measurements (Section 5.1). The exact target number will take some time and deliberation to calculate, with the best number(s) depending on state of the grid (supply versus demand true picture).

Per village or chosen unit (neighborhood, taluk, etc.), the load-shedding per feeder in any given month should be less than a target figure, say, 1% or 2%, (excluding, again, the 10 or so emergencies in a year), then it is "functionally electrified". To scope the issue, if we assume a utility has 4,000 feeders, of which some 2,000 are rural, then 98% being functionally electrified still leaves 40 feeders of slack, which could be special cases worthy of special effort. On the majority, 1% or 2% slack by hours means half or one hour of load-shedding per week, respectively, just during the peak 6 hours (4 evening plus 2 morning). Still not ideal but likely feasible as a target.

For urban areas which are likely to have multiple feeders, instead of an average number, the same criteria will apply to every feeder serving the area. Such a system can help handle the challenge of *averaging*. 1 hour load-shedding allowed per week isn't an aggressive target *on average*. But that likely means some periods of better, and some periods of worse. Over time, say within 2 years, the period of averaging can be tightened down to weekly.

5.3. Then differentiate by types of consumers (a la Smart Grid)

The first value of measurements is for operations, and the second will be for dissemination. A problem with a simple classification scheme for feeder grading for order of load-shedding based on losses and collection, is that it still remains a blunt sword. All consumers in the feeder are treated the same. Why should one user suffer if his/her neighbours are bad? Second, the same feeders are shed more (or less) for any given ranking (grading). It is entirely unclear what the dynamics of feeder grading are and how much this has incentivized loss reduction.

A much more equitable if not efficient system for controlling supply is at the per consumer level. With a Smart Meter (a subset of a Smart Grid) one can control (limit) the supply to any individual consumer as required. While the intent isn't to enshrine load-shedding as an operational choice, as and when required, there can be transparent, fair, and efficient differentiation of consumers. Everyone can be guaranteed 24/7 supply for at least a threshold level (lifeline supply) and those willing to pay more can be given more. Clearly, anyone using back-up power is willing to pay a premium for periods of shortfall.

This type of a solution obviates the problems experienced with the so-called "Pune model" of express feeders, where all the users in a feeder were asked to pay a small reliability surcharge (reported at 42 ps/kWh?) in return for being load-shed last if at all. The initial focus was on industrial users, and feeders were made as small as possible. There were two problems. One, all consumers in the feeder were treated the same, and if someone didn't want to pay, either they were given a free ride, or the entire feeder suffered. Second, people questioned the validity of such differentiation.

6. Policy Discussion

There can be no denying a link between supply shortfalls and additional (wire) electrification. Utilities are cash-strapped, and the newest (small) consumers are both a financial burden as well as a drain on limited supply (generation). The end goal must be meaningful electrification, and, as soon as possible, no load-shedding. At the very least, during periods of maximum social benefit, i.e., the morning and evening peaks.

6.1. Thought Experiment: the missing homes don't take much supply

If we take all the rural and urban homes without a wire, and add in the homes that are likely load-shed (estimated) at any given instance, we may find some 130 million homes under consideration. If each of them were to be given a lifeline level of service equal to 100 W, even adding technical losses, this doesn't require more than 15 GW of centralized grid supply. This is not an enormous quantum of generation capacity. The challenge is not supply but supply management. First, how do we ensure that one gives a lifeline to everyone, instead of other users using up a (proportional) larger share? Second, even for the new connections, how do we know we are only adding 100 W of load? With a simple meter, we cannot. This is an additional driver for a Smart Grid, which now finds interesting value not just in urban areas but even rural areas.

Such designs can also improve the incentive of utilities to improve service and supply in rural areas, something they are hesitant to push for as it hurts their cash flow. In many cases, they use official methodologies of "high losses" to justify reduced supply, both financial as well as technical. It is worth pointing out that the technical losses to rural homes are actually very low, since the non-3-phase supply is a fraction of 3-phase (agriculture-centric) supply. During the evening peak of 6-10 PM, one can minimize pumping loads through rostering, feeder separation, etc.

6.2. Paying for the improved electricity service

One of the goals of regulated electricity services has to make utilities viable, with tariffs reflecting a cost-to-serve and reasonable returns for the utility. This includes a planned phase-out of cross-subsidies across consumer categories. Unfortunately, this is taking time.

It turns out that there is enormous money on the table to pay for additional supply when we factor in consumer alternatives (back-up energy), let alone opportunity costs and human development failures. The money spent by end-users on back-up power, and by the masses for kerosene-based back-up (lighting) is substantial and can likely pay for any additional generation, at least for a lifeline level of supply (lighting-centric). Per NSSO, roughly 85% of rural homes use kerosene for back-up or primary lighting. For 3 liters, each household pays approximately 45 rupees/month. Plus, taxpayers (central government) subsidizes the kerosene by another ~75-100 rupees/month (varies with price). Compared to this, for the lifeline level of supply for all rural homes equal to their load-shedding, the cost of peak procured electricity is only a few rupees per month!

6.3. Policy Synergies – Data, and Time of Day (ToD) Pricing

There are several additional policy actions that would synergize with meaningful electrification, i.e., electricity *service* provision to all. The first is instrumentation and better data, with high granularity. R-ADPRP is a step towards this, and it can easily tell outage levels at a Distribution Transformer (DT) level for areas of coverage. Of course, in the present avatar, it mainly covers urban areas.

The second synergy would be for the start of time of day pricing. While it has been offered for bulk consumers in most states, it is mostly a voluntary offering or one with limited offtake. Moreover, each state has different times, tariffs, options, etc. which don't necessarily coincide with the grid conditions. While residential consumer time of day will take time, and requires substantial investment in newer meters, the first step can be time of day (ToD) pricing for procurement of supply from generators. Most contracts today are bilateral kWh (energy) based, without any capacity and ToD components. Availability Based Tariff (ABT), which only applies to central generation, has a frequency-based component through Unscheduled Interchange (UI) charges, but this is not a true ToD tariff.

7. Recommendations Summary

7.1. Gather data on present wire and service levels

Each utility should gather data on

- Electrification (wire) availability by village or other unit level (including taluk, feeder, etc.)
- Quantification of load-shedding in hours and MW/MWh per feeder and unit level (village, taluk, etc.)
- Quantification of shortfall in MW and MWh for supplying all homes with supply during household per periods (evening 6-10 PM and morning 6:30-8:30 PM)

7.2. Start with transparency and predictability

- Utilities must announce a strict schedule for load-shedding with high granularity
- Unscheduled load-shedding must be monitored, limited, and even penalized
- Increase the granularity and transparency of load-shedding down to feeder level in (near) time

7.3. Define Electrification to cover *wire* and *service*, with timeframes

Need both wire and service based metrics to be met to qualify as electrified.
(Below numbers are a start – exact targets can be refined post deliberation.)

Wire based definitions of electrification:

- 10% of homes covered in Year 0, increasing by 5% every year (to reach 50% in 8 years)
- BPL homes covered must be at least within 2% of overall number; specialized focus for such homes to meet any overall shortfall

Service based definitions of electrification:

- All the feeders serving a given unit can have a maximum load-shed (excluding upto, say, 10 emergency events in a year, utility-level[3]) of 1% or 2% during the peak household demand periods of 6-10 PM and 6:30-8:30 AM (exact times can be deliberated, and may even have a seasonal component, especially for the morning)

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[3] Any emergencies must be grid level (e.g., unplanned failure of a transmission line or generator) and should be declared by a Transmission Operator, if not Independent System Operator (ISO). Necessarily, this will impact the entire utility or at least a large section of it, and not just a feeder.