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A Game Changer — Electricity Feeder Monitoring, Visualization, Analytics and Consumer Notifications: Suggestions for improvements

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1. Introduction

There are 2 schemes envisaged by the Ministry of Power related to feeder-level data, spanning monitoring, visualization, analytics, and notifications, and these are dramatic game-changers. First, online 11 kV feeder monitoring (integrating this with a National Power Portal), which instruments all distribution feeders to monitor the actual supply, and second, Urja-Mitra (an outage notification/management scheme), which aims to give consumers outage notifications via SMSes or online Apps. These may appear just to be evolutionary but are remarkable, and subtly revolutionary.

A cynic may claim these aren't directly doing much, as the actual supply position is not being changed, not to mention such issues are in the hands of the Distribution Companies (DisComs). Somewhat true, but today, we don't know the true position of power supply, and without data, we are—pardon the pun—in the dark when it comes to knowing the granular and detailed situation of load-shedding, a scourge of today's electricity system. While official statistics show the shortfall of power has improved, this is on average, and it's really the bottom-up picture, the last areas (often rural and under-developed regions) where the gap is both large and not fully known.

In this discussion note, we examine these policies in greater detail, offering suggestions for improved design to maximize cost-effectiveness and improved policy outcomes. Specifically, we focus on functionalities desired, which are linked to the policy questions and outcomes, and then tie these into the required architecture/design for the same, keeping in mind the cost-effectiveness of the schemes. This note is predominantly focused on feeder monitoring, even though there can and should be obvious links between the two.

Fundamentally, these systems must add data on the quantum of outages (load lost), with timings, instead of just capturing data on duration of outages. This requires possible tweaks to proposed communications architectures. There are additional suggestions for system design including issues of legacy equipment, scalability, and consumer interface.

2. Importance of Data and Links to Policy Objectives

It is said for policy schemes you cannot know what you cannot measure. Data should become the basis for both measuring (and visualizing) progress/milestones/compliance as well as guide optimal operations today as well as planning for the future. There are a number of impressive data portals for the power sector, from DELP (LED bulbs) to Rural Electrification (GARV portal).

While there is no dearth of data on the power sector, these have a few limitations:

1) **Availability** – Do we have all the data we need? How much today's shortfall of power?
2) **Accuracy** – Is the data reliable. Non-instrumented data (that too digitally captured and transferred, as opposed to manually read and transcribed) carries risks of gaps, inaccuracies, fudging, etc. One hidden problem with all data driven analytic systems is GIGO (Garbage In – Garbage Out).
3) **Granularity** – Do we have data with geographic (feeder- or even consumer-level) granularity or temporal granularity (time of day)? Average numbers are not sufficient, e.g., 95% supply. Is it that 5% of people never get power? Or that everyone loses 1 hour of supply every day? If so, is that at random times or at the peak demand period (evenings)? Etc.

We have shown that today's shortfall of power numbers as published by CEA are inaccurate and understate the problem.[1] CEA uses a notional peak and asks the states to report the shortfall at that time period, which suffers due to lack of instrumentation. Second, the supply and demand requirements aren't time synchronized. What is really needed is that one calculates the shortfall in (near) real-time. The proposed schemes by Government of India should address both these issues.

In a number of publications and presentations, we have suggested such feeder monitoring and analytics, worrying about the disproportionate load-shedding some areas face (especially rural),[2] in addition to the need for "electrification" itself to have an updated definition going beyond the wire to the actual *service*.[3]

While a number of attempts have been made in the past to monitor feeder supply status, some were voluntary and thus obviously limited, such as the crowd-sourced online tool powercuts.in. Other projects such as by Prayas (Electricity Supply Monitoring Initiative) focused on a multiple dozen locations to highlight the situation (expanding to hundreds of locations across India). In contrast, we had suggested that a state-level if not national program is more cost-effective, and not very expensive at all.[4] The cost is mainly a function of the number of feeders in a state, which can be in the order of 1,000 for smaller or less developed states to over 10,000 for states like Karnataka.[5]

If we consider the policy goals/needs and linkages for feeder and outage data, these include:

1) **24x7 power for all** – Meeting this target combines electrification of all households at a wire level *plus* service delivery (no load-shedding).
2) **(ending) Load-shedding** – how much is being shed, where, and when? While the goal must obviously mean zero load-shedding, an interim starting point may be *penalizing unscheduled load-shedding*. The dual of this is *monitoring compliance with load-shedding schedules*. Once the consumer notification system is in place (Urja-Mitra), one could also penalize utilities for non-notification of outages, especially scheduled outages.
3) **Knowing the quantum of shortfall** – There are two aspects to growth of power demand (with obvious overlap). First would be "organic" growth linked to GDP growth. The second would be one-off or "inorganic" growth coming from step changes in meeting 100% electrification and zero-load-shedding (the overlap comes from the fact that some amount of reduced load-shedding is already underway). Feeder monitoring can help with the second, which helps plan future supply far better.
4) **Time of Day (ToD) profiles** – Assuming we know the true (including latent) demand for power, it is vital that planning not be based on kWh (energy, or kilowatt-hours) shortfall but ToD varying shortfalls of capacity (kW). Feeder monitoring can help with these exercises

[1] R. Tongia, "Re-thinking Access and Electrification in India: From Wire to Service" Brookings India Discussion Paper 01-2014, September 2014 (http://brookings.in/wp-content/uploads/2014/09/electrification-from-wire-to-service.pdf)

[2] S. Harish and R. Tongia, "Do rural residential electricity consumers cross-subside their urban counterparts?" Brookings India Working Paper 04-2014, August 2014. http://brookings.in/wp-content/uploads/2014/09/Cross-subsidies-working-paper-August-v2.pdf

[3] R. Tongia, "Re-thinking Access and Electrification in India: From Wire to Service" Brookings India Discussion Paper 01-2014, September 2014. http://brookings.in/wp-content/uploads/2014/09/electrification-from-wire-to-service.pdf

[4] R. Tongia, Invited presentation on "Improving Power Supply and Policy through Data, Visualization, and Smart Analytics" presented at the Ministry of Power's States 8th RPM (Review and Performance Monitoring), New Delhi, August 10, 2015.

[5] Karnataka, with roughly 12,500 feeders, already has a ~full 11 kV SCADA system, the first in the country.

dramatically. Subsequently, feeder-level profiles can be overlaid with consumer level data to tease out future growth of types of demand and corresponding granularity, e.g. residential demand is most likely to grow in the morning and evening peaks.

3. Functionality and Parameters

Outages can be of two types, faults, or supply-shortfalls. Faults themselves can be localized, or upstream (affecting many lines and sets of consumers). Shortfalls can be known in advance (manifesting as scheduled load-shedding) or last-minute shortfalls (unscheduled load-shedding). The latter has differing time periods. It could be that one can see that demand is higher than envisaged, or that (say) wind speeds were lower than forecast. Or, it could be an emergency due to a failure of a generation station or transmission interconnection. Is this last one a fault? Not necessarily, since the system design should have enough buffer capacity to handle a "normal" range of failures. In the west, grid reserve margins have often been 15% if not more.

Feeder monitoring should be more than simply a binary (on/off) data point. The fact that meters are required can allow for far greater data. In addition, there is the issue of time periods, which impact the use of the data.

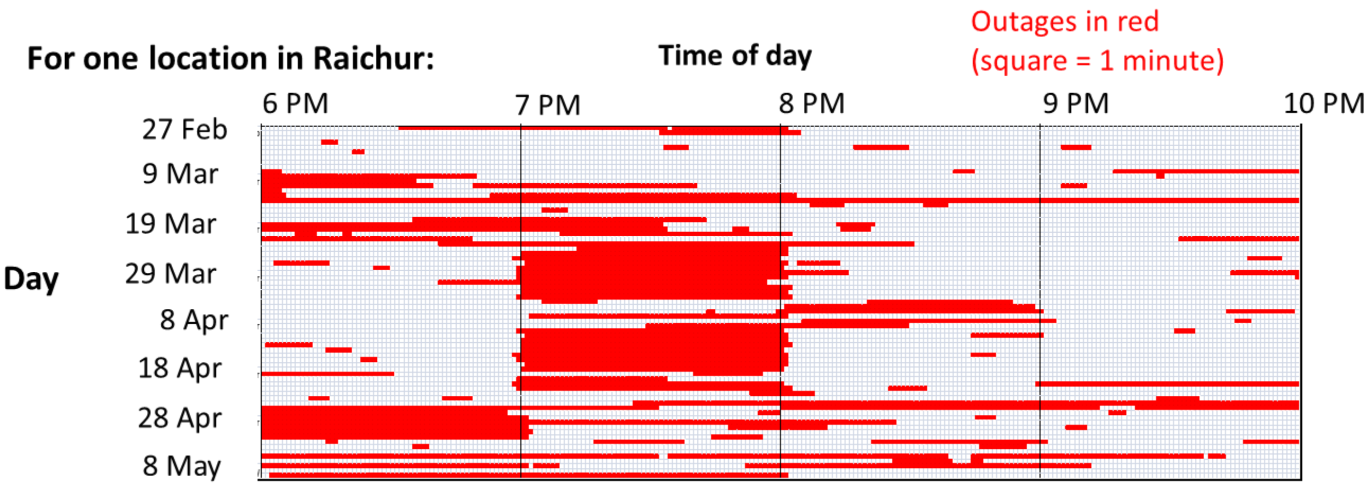
3.1. Recommendations for Adding Parameters

The below section adds suggestions for the proposed schemes based on best known information. There are several sets of data required for maximum functionality and value, which don't require much additional cost but only appropriate design:

1) *Phase data* – a feeder, especially rural, isn't just on/off, but can be rostered. We need data per phase.
2) *Momentary interruptions* – These are typically transient faults, and not captured within SAIDI/SAIFI. However, these impact consumers, and also can help guide operations on where to undertake tree management and even consider auto-recloser technologies.

   Recommend capturing data required for MAIFI calculations.

   See below for a data logger from several months in 2013 in one rural area in Karnataka, showing a number of short outages, which would not be captured even in 15 minute readings.



Source: R. Tongia and S. Harish (2014)

3) *Quantum of Outage* – Duration of outages isn't sufficient, the quantum of power lost is important for both proper load profiling as well as understanding shortfalls with time of day granularity. These will be critical for future power procurement planning, i.e., whether to add solar vs. coal vs. peakers vs. storage, etc.

   Given the fact we already have meters, we should design the system to capture such data. Not that simple supply on/off with timestamps can even be learned from a mobile phone plugged into a consumer socket on a feeder!

   We cannot know directly the quantum of load lost but the system should capture the load at time of outage, and also time of recovery. Such a system can capture the same information for both small/transient faults as well as longer outages like load-shedding. *However, as we shall see, there are design and communication implications of the same.*

4) *Adding ToD equivalents to "Hours of supply"* – In the table showing the draft reporting format, there is "Hours of supply" listed as a parameter. Assuming this is a daily reporting, and we fix the issue of phases/rostering of supply, we still need to distinguish *when* the supply was given, i.e., peak vs. off-peak. If someone says 20 hours of supply, but gives zero during 6 PM to 10 PM, that is the worst for citizens.

   One should create buckets of ToD, viz., morning peak, daytime, evening peak, and night (which can vary over time by consensus or by utility). The mandate should be 100% supply during morning and evening peaks as a start, as we move towards true 24x7x365 uninterrupted supply.

5) *Tagging reasons for outages* – Specifically, if there were an outage, one should be able to tag and upload why there was an outage, ranging from:
   a. Scheduled load-shedding
   b. Un-scheduled load-shedding
   c. Local fault
   d. Higher (system) fault

3.2. Time Periods Matter for Functionality

There are 3 sets of time periods to consider:

1) Measurement (how often any parameter is measured by the meter/monitoring device)
2) Storage (at meter/modem/concentrator as applicable)
3) Uploading (to the cloud/server/portal as applicable)

The current proposed *measurement* time periods are very long. These not only don't give sufficient data for operational needs and planning purposes, these completely don't allow for momentary outages or other transients. Given the fact that R-APDRP is based on 15 minutes, that should be a minimum granularity for most measurements, excluding momentary captures.

It is also unclear how/why there are distinctions made for "instantaneous" and "load profile" in the manner listed. Both can be captured at the same time period of, say, 5 minutes or 15 minutes. If one chooses a data concentrator unit (DCU) architecture (see subsequent section), it may be easier to have shorter term uploading more frequently than once per day.

How does one capture momentary outages? A DCU architecture allows one to poll a meter every minute, but only store (and forward) data if there is an outage. (If there is an outage, it stores the last reading as load served the previous minute; reverse occurs on recovery).

This intelligence is easy to put into a DCU, but hard to do on a per meter/modem pairing. Any chosen architecture should be such that we do NOT need to send 1-minute data to the cloud – only when there is an outage/event should those data points be uploaded, else we have the regular 5/15 minute data captured.

4. Architectural Issues and Design Choices

As we have seen, time periods matter for functionality. While a good design is agnostic to communications details (i.e., one could use different technologies to meet a functionality, as per standards), there are fundamental functionality (not to mention cost) issues that intersect. While a meter can measure status almost continuously, along with load, all such data doesn't need to be upload continuously (that would be expensive).

4.1. Communications

Putting a meter on a feeder is only one part of the puzzle. This meter needs to communicate upwards (to the cloud, portal, etc.). There are 2 sets of architectures available, one with a modem per meter (feeder), and another where something else handles the data. A concentrator (data concentrator unit, or DCU) can help both compile data locally as well as offer local intelligence, plus the ability to have multiple digital inputs/outputs as required. In the future, as feeders grow, the incremental cost per feeder is much lower. In addition, one could even add additional nodes or ports for data uploading once suitable infrastructure is in place, e.g., breaker or transformer monitoring.

Instead of just a single communications mode, one could have, say, Ethernet ports to take advantage of any available network or SCADA WAN, in addition to which many substations have or might have optical fibers reaching them (today available in Mumbai/Delhi, but soon in more areas under the National Optical Fibre Network, NOFN).

Having a single DCU means much less modems talking upwards than 8-10 per substation (equal to the number of feeders). This reduces not just the capex slightly, but saves on OpEx and maintenance and points of failure.[6] These devices are also much easier to harden and ensure long life/performance.

We suggest that both options be available (with or without a DCU) as per the choice of the DisCom. Our experience indicates DCU model is cheaper, robust, and also scalable. Much more importantly, it can more easily facilitate proper measurements of outages such as intensity of outage and not just duration. Else, one would need far more intelligent meters + modems per feeder.

Comparison of DCUs with feeder-meter pairs (based on discussions with a state LDC)

	Feature	Intelligent modem	DCU	Remarks
1	Connectivity to meters	Single meter	Multiple meters upto 32 meters (as of now)	
2	Input Ports	Single RS232 serial port	RS232 and multiple RS 485 ports	
3	Devices that can be connected	Single device (Energy meter)	Any device including Energy meters communicating to RS485 port	
4	Requirement at a typical sub-station	8-10 or above	Single DCU	
5	Spares management	High inventory	Lesser inventory	
6	Wiring required between Energy meter to Modem/DCU	Max of 2 meters	Max of 15 meters	
7	Technology providers	DCU and modem vendors are the same	DCU and modem vendors are the same	
8.	Cost per unit (*indicative, per Karnataka utilities)	Approx. Rs. 5,000 to 8,000	Approx. Rs.50,000 to 60,000 (perhaps lower in volume)	Hardened modems with more intelligence may be more expensive
9	Cost per substation assuming average of 10 feeders	Rs. 50,000 to Rs. 80,000 PLUS SIMS capex and opex	Approx Rs. 50,000 to 60,000	
10	Operations/Maintenance	Higher	Lower (less points of failure); Multiple uplinking options possible (redundancy)	

4.2. Urban vs. Rural feeders, and legacy issues (existing meters)

We understand that from a financing and central management perspective, rural and urban feeders are treated differently, e.g., with support from REC vs. PFC. However, from a functional and architectural design level, these should be the same or functionally the same. If one has a DCU architecture, the same DCU can talk to meters on any feeder (pure urban, pure rural, or mixed use).

It does not make sense to have separate architectures or even MDM (meter data management) systems for rural versus urban feeders, unless technically there is no other option.

It is appropriate to use existing meters where available *IF* they can provide the desired functionality, which includes more granular data (e.g., momentary outages and 5 minute data) as well as load at start and end of outage. If R-APDRP modems cannot offer these, they may need to be upgraded. Hence, a common system may be both cost-effective and robust.

It is worth mentioning that while there are a number of feeder meters in the field, even digital ones with communications ports, the practical challenges in pulling data off these in real-time (or near real-time) are non-trivial.

How can existing feeder meters provide the right data, especially if we want to measure transient outages or intensity of outages (load lost)? We may either need new meters, and/or a DCU. It's possible that with older meters, a DCU will help since the meters can be polled periodically. Else, all data would have to be uploaded for even figuring out when there was a transient event. But if we're talking about 1 minute data for transients, then it makes more sense to handle that locally instead of in the cloud, esp. for "normal" status data. Even the act of figuring out what is "normal" versus not requires measurements at a fine granularity. One option is to create a loss of supply as an event, but even this requires a battery and more logic at the meter.

We are told that even R-APDRP *feeder meters* aren't DLMS standards compliant (unlike DT meters). Thus, one has to critically ask two questions from such older feeder meters: (1) What functionalities can these offer? (2) How has been their communications performance?

4.3. Other Communications suggestions

Where modems are to be used (directly with a meter or otherwise, like with a DCU), these should not be spec'ed as GPRS, but rather 3G or even 4G as available. These are backwards compatible down through Edge to GPRS. GPRS is NOT capable of push, so is the least preferred option.

5. Other suggestions

1) **Enable finer granularity and more data:** While the National Power Portal (NPP) might only want limited or aggregated data, the utility itself may find enormous value to greater granularity data or even new parameters. The architecture of measurement (as opposed to uploading or analytics) should be designed to allow finer granularity measurements, even if all of these aren't immediately utilized. Analytics can always smooth out or average finer granularity.

   Information overload remains a serious challenge, and thus ignoring or omitting certainly data isn't the solution, rather proper design to tease out relevant, summarizing, and aggregating data, plus detailed data where insightful. It is a truism that it's really complex to make something simple.

   There should be a mechanism to add new parameters for metrology/data gathering from a utility perspective, even if not mandated in the National Power Portal. This simply requires appropriate XML schemas and options to add fields as desired.

2) **Consumer Access:** We should consider more options for consumers to access their data. If we expand the vision of IT and transparency and empowerment, consumers want to know

not just an alert for outages but also historical data on quality of supply. This is before we consider options that are per-consumers, e.g., seeing billing data and history, like through a "Green Button" standard.[7] We can start with HT consumers, who should be willing to pay the entire cost of seeing their metering data (nearly) real-time. Fundamentally, lack of money should not be a bottleneck for something as important as feeder or consumer data access.

Regulators may even allow a nominal charge per consumer for this to cover the incremental operating costs (a good model for nationwide change, with the Center providing one-time or time-limited support to get things started).

One last point for policy discussion is the norms under which consumers and others (third parties) do an do not have access to power sector data. Who owns the data? Who has rights to it? How can we ensure privacy? Etc. With the inevitable growth of smart meters, at the very least a thief can know if someone is home or not. There are far more subtle and complex implications of consumer power data. Having a database of mobile numbers linked to electricity consumers (required for Urja-Mitra) raises not just issues of creating the database but also privacy and security, especially individually identifiable data (IID).

3) **Phase 2 of the plans – integrating feeder operations with consumer data:** After the basic functionality is achieved, utilities should combine consumer data (mix, billing, units, etc.) with loading data to better understand ToD and granular load profiles, plus dynamics. Dynamics include seasonality plus growth, not to mention the impact of specific interventions and policies like DSM programs, LED bulb programs, demand response, etc.

6. Discussion

These schemes are a bold step en-route to 24x7 power for all. With a little design effort/tweaks, these can do far more than capture outage basic data (like duration) but also enable granular load profiling.[8]

In 2014, when we had shared some of our studies on load-shedding, and suggested instrumentation and visualization as important tools for both compliance and equity reasons, I asked the Chairman of a state's Electricity Regulatory Commission whether they could consider supporting if not mandating such a scheme. After all, would it not perhaps embarrass the utilities? The answer was telling, "Perhaps it's high time they got embarrassed."

It's not as if states don't want to end load-shedding. They simply haven't been able to, not only because of financial constraints but also because of incomplete information. Knowing there is a two hour load-shed isn't enough for proper planning as knowing the time and other characteristics of shortfalls, which then enables better procurement. If the peak truly is in the evening, then neither solar power nor new coal plants are the answer. The better answer is a portfolio approach combining all the different options of supply adding in peaking generators plus storage plus demand response (controlling the loads). Having data would help shed light on not merely what is happening today, but also what needs to be done in the future.

[7] The name comes from a button utilities can place on their website to allow consumers to access their own data in a standardized format. More than 1/3 if not closer to 1/2 of US consumers have this, and this such programs are also used in many other countries.

[8] . In fact, analytics can do far more, e.g., rapid measurements after rostering phases can even indicate the level of phase converters used on pumpsets, but one needs to design for such measurements.