A commentary on the methodologies for estimating Transmission and Distribution loss in Indian regulatory practice

The Percentage Problem

Prayas (Energy Group)

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Discussion Paper by Prayas (Energy Group)

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March, 2019

Prayas (Energy Group)

About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non-profit organisation based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of society, in particular. Prayas (Energy Group) works on theoretical, conceptual, regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas (Energy Group) has contributed to the development of energy sector policy as part of several official committees constituted by ministries, the erstwhile Planning Commission and NITI Ayog and advisory committee of many regulatory commissions. Prayas is registered as a SIRO (Scientific and Industrial Research Organisation) with the Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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Snapshot

Transmission and Distribution (T&D) loss and Aggregate Technical and Commercial (AT&C) loss are often quoted metrics to assess the health of electricity distribution companies (DISCOMs). High losses could be due to low network investment, poor maintenance or theft. Increase in losses implies higher costs and consequently consumer tariffs. Analysis of ten large states in India show that a one percentage point (p.p.)[1] increase in distribution loss results in a Rs. 180 to 300 crore annual cost increase for DISCOMs in each state. The impact is higher for T&D loss increase.[2] Considering these impacts, regulatory commissions set targets for loss reduction. There is also a loss reduction commitment under the Ujjwal DISCOM Assurance Yojana (UDAY) and the Integrated Power Development Scheme (IPDS).Annual loss reduction targets approved by regulators and under these schemes are in the range of 0.25 p.p to 5 p.p in most states.

Loss assessment is affected by long-standing metering challenges, especially related to unmetered consumers and the lack of accurate interface metering in the T&D network. Keeping these significant issues aside, this paper highlights that the losses estimated could vary by up to 4 p.p. depending only on the methodology used for calculation. To arrive at this estimate, various methodologies for calculating percentage losses were compared using CLEAR (**C**alculating **L**oss and **E**nergy **A**ccounting in **R**egulatory practice), a spread-sheet based tool, developed by Prayas. Variation in losses in CLEAR depends only on the treatment of factors detailed below:

With rising DISCOM tariffs, large consumers have been meeting demand through alternate options such as open access or captive generators. Even though these consumers use the T&D network, the network loss is often estimated without considering such energy input and consumption. This treatment overestimates T&D loss by 2 to 4 p.p but does not affect AT&C loss.

Distribution franchisees are appointed to manage operations in the DISCOM's high loss pockets. While estimating losses, franchisees are often treated as single consumers drawing power from higher voltage levels. This is not reflective of how energy is handled as DISCOM consumers in the franchised area are also connected at lower voltage levels with high percentage losses. This treatment under-estimates T&D and AT&C loss by 1 to 4 p.p.

All short-term and renewable energy (RE) is typically assumed to be procured within the state transmission network. However, DISCOM purchase outside the state has been on the rise. Further, RE generation in the DISCOM network has been growing. Not considering this overestimates T&D loss by 0.03 to 0.1 p.p. and AT&C loss by 0.1 to 0.2 p.p.

The variation in percentage losses across methodologies is large enough to meet the annual AT&C loss reduction target specified under UDAY for 19 states. The variation could be larger if methodologies for calculating collection efficiency are also compared.

Given these wide-reaching implications, a standardised methodology for loss estimation, which accounts for energy as handled in the system is imperative. Only then will using these metrics for setting policy targets, comparing losses, and assessing progress under central government schemes hold any merit.

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[1] Percentage point or p.p.is the unit for the arithmetic difference between two percentages.

[2] Though transmission and distribution functions are handled by separate entities, this report considers T&D loss together as both increase DISCOM costs. Further, with metering challenges and estimation approaches there may be a variation in apportioning loss between the transmission and distribution network.

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List of Abbreviations

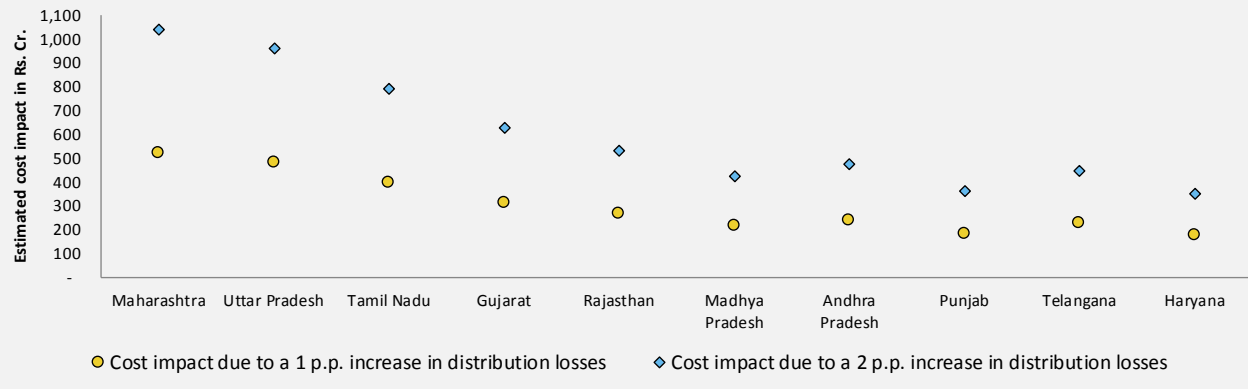
AMR	Automatic Meter Reading
AT&C	Aggregate Technical and Commercial
CEA	Central Electricity Authority
CESU	Central Electricity Supply Utility
CLEAR	Calculating Loss and Energy Accounting in Regulatory practice
DEEP	Discovery of Efficient Electricity Price
DF	Distribution Franchisee
DT	Distribution Transformer
DISCOM	Electricity Distribution Company
EHV	Extra High Voltage
ERC	Electricity Regulatory Commission
FoR	Forum of Regulators
GW	Giga Watt
HT	High Tension
IPDS	Integrated Power Development Scheme
kV	kilo Volt
kWh	kilo Watt hour
LT	Low Tension
MoP	Ministry of Power
MU	Million Units
MYT	Multi Year Tariff
p.p.	percentage point
RE	Renewable Energy
SERC	State Electricity Regulatory Commission
T&D	Transmission and Distribution
UDAY	Ujjwal DISCOM Assurance Yojana

1. Background and Context

Transmission and Distribution (T&D) loss and Aggregate Technical and Commercial (AT&C) loss are often used metrics to ascertain the health and operational efficiency of any electricity distribution company (DISCOM). The use of these metrics helps assess DISCOM performance over time, aids target setting for loss reduction and enables comparison of different DISCOMs across states.

Losses have cost impacts. As shown in Figure 1, a one percentage point (p.p.) increase in actual distribution loss alone could potentially increase the cost incurred by DISCOMs in ten states by Rs 180 to 300 crores annually.[3]

Figure 1: Indicative cost impact (Rs. Cr) due to percentage point increase in distribution loss [4]



Due to its critical impacts, State Electricity Regulatory Commissions (SERCs) regularly estimate distribution loss during the tariff determination process and also specify norms and annual loss reduction targets. This annual target in recent years has been in the range of 0.24 to 4 p.p. in most states.[5] Costs incurred due to distribution losses in excess of the norm are typically not allowed to be completely recovered from consumers to incentivise the DISCOMs to reduce such losses.[6]

The Ujjwal DISCOM Assurance Yojana (UDAY)—a bailout scheme worth Rs. 5 lakh crores aimed at ensuring financial turnaround of DISCOMs—is committed to reducing AT&C losses.[7] Under this scheme, the targeted loss is specified and reduction in losses is monitored on a division-wise basis. AT&C loss reduction is also tracked under the Integrated Power Development Scheme (IPDS), a union government programme worth Rs.32,000 crore aimed at strengthening network

[3] Percentage point or p.p. is the unit for the arithmetic difference between two percentages.

[4] The cost impact shown in Figure 1 is only due to the increase in power procurement required due to increased distribution loss. The rate considered for the additional power purchase is assumed to be at the average power purchase cost for the DISCOM.

[5] This is based on the analysis by Prayas (Energy Group) of various state tariff orders across years.

[6] As per gain and loss sharing mechanism specified in Multi Year Tariff regulations of the SERCs.

[7] Ujwal DISCOM Assurance Yojana or UDAY is a bailout scheme for DISCOMs to enable takeover of accumulated liabilities of state-owned DISCOMs by State Governments through the issuing of bonds. Under this scheme, State Governments and DISCOMs commit to a reduction in AT&C losses. The Ministry of Power tracks reduction in AT&C losses for all DISCOMs in the UDAY portal. For more information, please see: https://www.uday.gov.in/atc_india.php

infrastructure.[8] The loss reduction targets under central government programmes are in the range of 1 to 5 p.p in most states.[9]

Assessment of losses is an imperative first step before estimating loss reduction. However, the lack of accurate metering infrastructure in the T&D network and at the consumer end is a major challenge.

At the consumer level, uncertainty due to unmetered consumption still persists. In most states, agricultural consumers are unmetered and in some states such as Bihar and Uttar Pradesh a considerable portion of residential consumers are also unmetered. The consumption from unmetered connections is not measured, but estimated based on consumption norms set by the commission. These norms have been reported to be overstated in multiple states (PEG, 2018b). For example, in Uttar Pradesh, the assumed monthly consumption from a rural home is 72 kWh, which is closer to the average consumption of homes in Mumbai and Hyderabad (UPERC, 2016; Josey, 2018).[10] A similar trend has also been observed for agricultural consumption in multiple states. The methodology used for the estimation of unmetered consumption will have a significant impact on losses.[11]

There are also challenges due to poor metering infrastructure in the T&D network. As per the Forum of Regulators (FoR) Technical Committee Report on Scheduling, Accounting, Metering and Settlement of Transactions in Electricity (SAMAST) published in July 2016, only 30% of interface energy meters are read through Automatic Meter Reading (AMR) systems while for the rest, data is collected manually. Further, a survey conducted by the Technical Committee also revealed that in several locations data is either unavailable or the meter reading is erroneous (FoR, 2016).

The percentage of loss reported can also vary with the methodology used for calculation. In fact, notwithstanding metering challenges, there can be up to a 4 p.p. variation in losses simply due to the methodology used for calculation. This paper discusses the existing methodology for estimating T&D and AT&C losses in regulatory practice and shows that it does not reflect how energy is actually handled in the system due to certain assumptions. Given the variation in losses, it also advocates for a standardised methodology to be adopted across states for calculating T&D and AT&C loss.

[8] The Integrated Power Development Scheme (IPDS) is a central government capital expenditure grant scheme to ensure strengthening and metering of the sub-transmission and distribution networks in primarily urban areas across states. One of the major objectives of the scheme is to reduce AT&C losses.

[9] This is based on the analysis by Prayas (Energy Group) of Memorandums of Understanding signed by DISCOMs, State Governments and the Central Government for all states participating in UDAY.

[10] The current norm specified by the Uttar Pradesh Electricity Regulatory Commission (UPERC) for unmetered rural domestic consumers is 144 kWh/kW/month. Assuming that a typical rural domestic consumer will have a connected load of 500 watts, the norm on an average would be 72 kWh. 500 watts is the norm specified for above poverty line connections under flagship electrification programmes of the central government (MoP, 2013). This is a reasonable estimate given the fact that 15 million homes have been given connections recently (between 2011 to 2019) in Uttar Pradesh (Census, 2011; REC, 2019).

[11] For a detailed description of methodologies and practices related to the estimation of unmetered consumption, especially agricultural consumption, please see 'Understanding the Electricity, Water, Agricultural Linkages (Vol. 2): Electricity Supply Challenges' (PEG, 2018b).

It must be noted that transmission and distribution functions are handled by different companies and hence transmission and distribution losses are considered separately in regulatory practice. However this discussion paper considers them together for the following reasons:

- Both transmission and distribution losses increase power procurement costs and therefore impact DISCOM finances and consumer tariffs.
- Due to the inadequacies in metering infrastructure and the approaches adopted in various states to estimate losses, the losses apportioned between the transmission function and the distribution function may vary. However, the overall energy loss in the transmission and distribution network has financial impacts and variations and thus changes in the overall estimate needs to be considered while discussing methodologies.
- Estimating and reporting T&D losses has been a convention in the sector as it accounts for energy input and sales in the T&D network within the state and helps hold utilities accountable for reduction in losses.

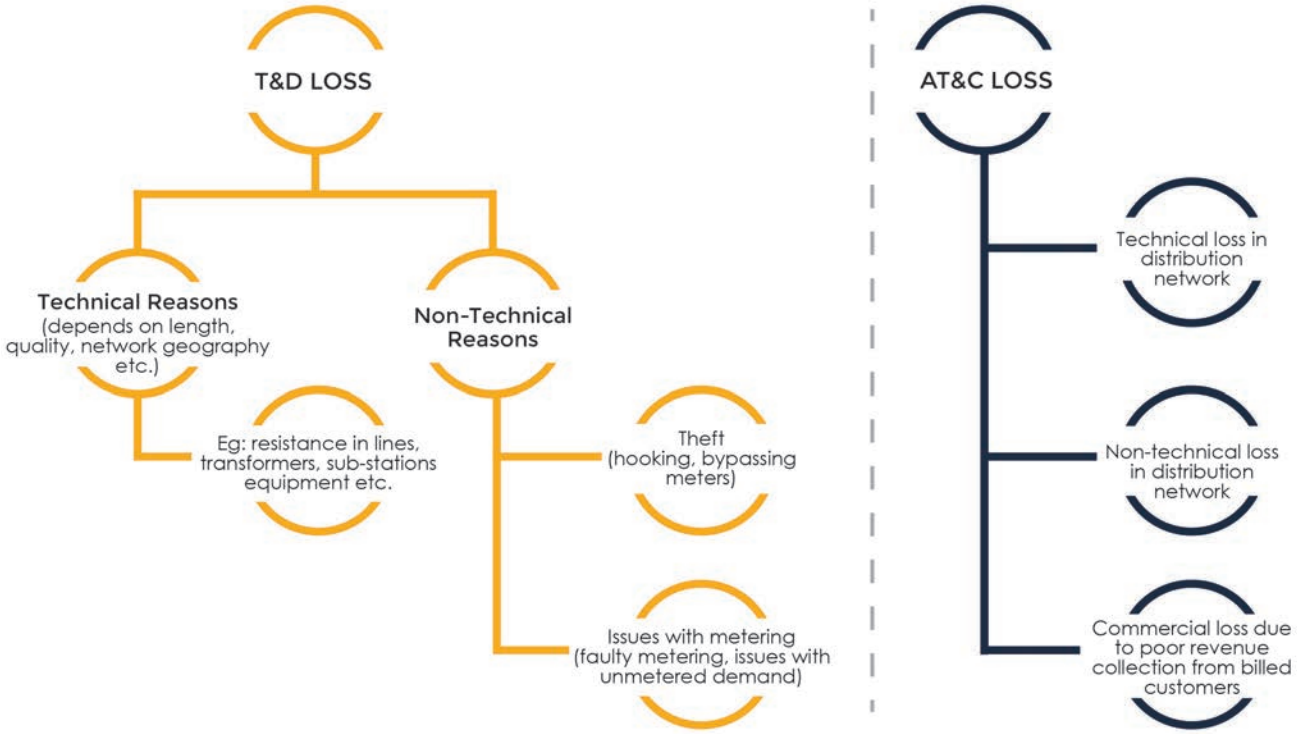
2. What are T&D losses and AT&C losses?

As shown in Figure 2, T & D loss is essentially the energy loss in the T&D network and may be due to technical and non-technical reasons. Technical reasons are attributable to power flows through equipment in the T&D network. These depend on various factors (such as the resistance in power lines, transformers, sub-station equipment, etc.) and vary with voltage levels, network parameters and network geography. Non-technical reasons include power theft (hooking, bypassing meters) and issues with metering (defective meters, errors in meter reading, and issues with estimation of unmetered demand).

The quantum of T&D loss is linked to the total energy handled by the system, the physical characteristics of the system (network parameters, length, quality, etc.), metering efficiency and non-technical losses. It does not change with the type of consumer (industry, residential) or industry structure (type of agreements between DISCOMs and franchisees, ownership of generation assets, and the nature of contracts with open access and captive consumers).

The metric AT&C loss captures technical loss, theft and issues with metering in the distribution network in a manner similar to T&D loss. In addition, AT&C loss also captures commercial loss due to default in bill payment and inefficiency in revenue collection. This is also shown in Figure 2.

Figure 2: Components of T&D loss and AT&C loss metrics



T&D loss is measured as the difference between the active energy available and energy sold to the users of the grid. Loss on a line is measured as the difference between energy input and energy sale for final consumption. The percentage of loss over the T&D network can be calculated using the following formula:

$$\text{T\&D Loss (\%)} = \frac{\text{Energy input in network - Energy sold to all users of network}}{\text{Energy input in network}} \text{ x100}$$

Let us assume that Utility X is the only user of the grid and that the energy input and sale for this utility can be correctly measured (i.e. there are no unmetered consumers and that the transmission and distribution metering interface is accurate). If the energy input in the network is 10,000 MU and energy sales of Utility X is 9,000 MU then the percentage of losses on the network is 10%.

AT&C loss is measured as the difference between the energy available for sale in the distribution network and the energy for which payments are received by the DISCOM. As AT&C loss is only concerned with the energy loss in the distribution network, transmission losses are not accounted for. The fundamental difference between the DISCOM's distribution loss and AT&C loss is that while the former measures the difference between energy input and energy sold, the latter measures the difference between energy input and energy sales for which there is revenue realisation. Sales for which revenue is realised are essentially captured through the collection efficiency of the DISCOM. Collection efficiency is the ratio between the revenue actually received from consumers and the revenue billed as per regulated tariffs. In essence, when billing issues are minimal, the sale with revenue realisation is a product of the energy sales of the DISCOM and the collection efficiency.

The percentage of AT&C loss can be calculated using the following formula:

$$\text{AT\&C Loss (\%)} = \frac{\text{Input Energy in DISCOM network - Sales with revenue realisation}}{\text{Input Energy in DISCOM network}} \text{ x100}$$

Where Sales with revenue realisation = Sales × Collection Efficiency

$$\text{Where Collection Efficiency} = \frac{\text{Revenue received from sale of energy}}{\text{Revenue expected from sale of energy}}$$

This report focuses on the variation in the percentage of transmission as well as distribution loss calculated based on the methodology used. The energy input considered for AT&C loss calculation is the input in the distribution network for the DISCOM's use. Due to the differences across methodologies for distribution loss calculation, AT&C loss calculated can also vary.

It must also be noted that significant variation in AT&C loss calculated could also take place due to the methodology used for calculating collection efficiency. The calculation methodology prescribed by the Central Electricity Authority (CEA) accounts for revenue collected during the year along with past receivables gathered from consumers (CEA, 2017). In sharp contrast, the definition of collection efficiency on the National Power Portal managed by the Ministry of Power is only concerned with the revenue billed for the current year and explicitly excludes arrears (MoP, 2018). For a DISCOM which has had significant billing arrears in the past but has managed to increase the collection of revenue of current and past liabilities in recent years, there could be a 1 to 10 p.p variation in estimation of collection efficiencies depending on the methodology considered. The variation in AT&C loss due to collection efficiency calculation methodologies is not the focus of this discussion paper. Currently, it is not clear which methodology is used by DISCOMs to calculate collection efficiency for reporting AT&C loss.

3. How are losses estimated and reported in regulatory processes?

Before discussing how percentage losses are estimated, it is important to note key aspects regarding energy flow in the T&D network. The T&D network typically consists of lines and sub-stations. Sub-stations are known by the voltage levels present and the power handled. The transmission system is characterised by 66, 110, 132, 220, 400, 765 and 1200 kV voltage levels. Voltage levels above 66 kV are typically part of the transmission network and are also referred to as Extra High Voltage (EHV) levels. The distribution system connects to the transmission system at voltage levels of 33, 22 or 11 kV. The distribution transformer (DT) is an 11 kV sub-station and connects to the lines to supply power to consumers connected to the low tension network.[12] Losses vary with voltage levels and the estimation of percentage T&D loss would be finally based on aggregate input and sales in the considered network across voltage levels.

DISCOMs typically procure power from generators within and outside the state transmission network. The input into the distribution network would be the power procured after accounting for the applicable transmission losses. For power procurement from outside the state, this would just be the applicable intra-state and inter-state transmission losses. For power procured within the state, it is only the applicable intra-state transmission losses. The energy available for input into the distribution network is typically referred to in regulatory formats as the energy available at the Transmission<>Distribution (T<>D) periphery.

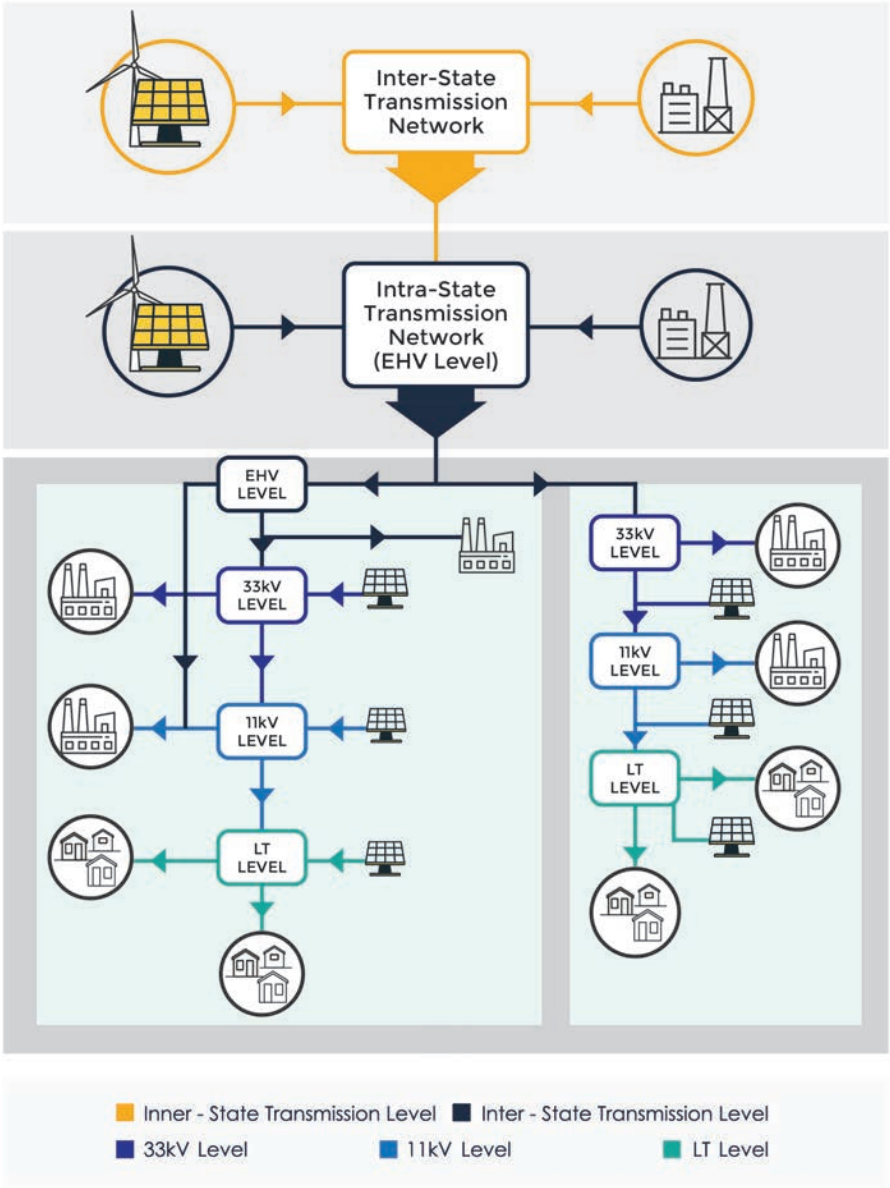
Generators, especially renewable energy (RE) generators can be embedded in the distribution network. The energy available from these generators will not be subject to transmission losses but only distribution losses based on the concerned voltage level. These should also be accounted for while calculating energy available in the system.

In the distribution network, consumers connected above 11kV—mostly large industries and commercial enterprises—are considered as High Tension (HT) consumers and the rest are considered as Low Tension (LT) consumers. Typically, losses are higher at lower voltage levels. The sales grossed up for losses at a voltage level gives the energy requirement at that voltage level. In order to estimate the energy requirement at the T<>D periphery, the sales and energy requirement at each voltage level is grossed up for losses. Some HT industrial and commercial consumers draw power at the Extra High Voltage (EHV) level itself and thus distribution losses are not applicable.

Figure 3 provides an illustrative and simplistic description of how energy is handled in the system. It shows energy inputs at the intra-state and inter-state transmission levels to meet the demand in the system. This demand can be from consumers connected at the EHV level or consumers connected at the 33 kV, 11 kV or LT level. These may be from DISCOM consumers (including those in distribution franchisee areas), and open access and captive consumers using the network at various voltage levels.

[12] For more details and a simple explanation of the system, please refer to the 3rd revised edition of 'Know You Power: A Citizen's Primer on the Electricity Sector' (PEG, 2019).

Figure 3: Voltage-wise inputs and sales



Based on an assessment of the energy flow in the system as described above, the following can be calculated:

- Ideally, the energy requirement in the system after accounting for losses and the energy available in the system should match. The difference between the energy requirement at the T<>D periphery and the energy available at the T<>D periphery gives an indicative estimate of the surplus energy for sale or the energy deficit in the system.
- The difference between the energy input in the state transmission network and the total sales is used to calculate the T&D loss. Surplus energy, if any, can also be accounted for as sales.
- The difference between the energy requirement at the T<>D periphery and the sales is used to calculate the distribution loss.
- The difference between the energy requirement at the T<>D periphery solely attributable to DISCOM sales and the sales to DISCOM consumers for which revenue has been received (a product of the sales at each voltage level and the collection efficiency) is used to calculate the percentage of AT&C loss for the DISCOM.

As discussed, this type of energy accounting is crucial and it takes place through the energy balance formats used in tariff petitions and orders before SERCs. A typical energy balance format is shown in Table 1 which shows the calculation methodologies for energy requirement, energy available and percentage losses currently used by most SERCs.

Table 1: Typical energy balance format

Particulars	Formula
Calculation of Energy Available	
Power Procured from Inter-State Sources (MU)	Inter PP
Inter-State Transmission Loss (MU)	Inter Loss
Inter-State Transmission Loss (%)	Inter P Loss= Inter Loss*100/Inter PP
Power at State Boundary (MU)	State Power =Inter PP-Inter Loss
Power Procured from Intra-State Sources (MU)	Intra PP
Intra-State Transmission Loss (MU)	Intra Loss
Intra-State Transmission Loss (%)	Intra PP loss= Intra Loss*100/(Inter PP+ State Power)
Energy Available at T<>D Periphery (MU)	E Avl= Intra PP +State Power – Intra PP Loss
Calculation of Energy Requirement	
Sales at LT Level	LT Sales
LT Level Loss (MU)	LT Loss
% of LT Level Loss (%)	% LT Loss =LT loss/ (LT sales+ LT loss)
Energy Requirement at LT level (MU)	LT Req = LT Sales +LT Loss
Sales at 11 kV Level	11 kV Sales
11 kV Level Loss	11 kV Loss
% of Loss at 11 kV Level	% 11 kV Loss =11 kV Loss/ (11 kV Sales+ 11 kV Loss+ LT Req)
Energy Requirement at 11 kV (MU)	11 kV Req = 11 kV Sales + 11 kV Loss+ LT Req
Sales at 33 kV Level	33 kV Sales
33 kV Level Loss	33 kV Loss
% of Loss at 33 kV Level	% 33 kV Loss =33 kV Loss/ (33 kV Sales+ 33 kV Loss+ 11 kV Req)
Energy Requirement at 33 kV (MU)	33 kV Req = 33 kV Sales + 33 kV Loss+ 11 kV Req
Sales at EHV Level (MU)	EHV Sales
Energy Requirement at T<>D Periphery (MU)	E Req = 33 kV Req +EHV Sales
Surplus (+)/ Deficit (-) at T<>D Periphery (MU)	S/D= E Avl – E Req
Calculation of Loss Based on Information Available in the Energy Balance Format	
T&D Loss % =(Intra Loss+ LT Loss+11 kV Loss+33 kV Loss)/(State Power +Intra PP)	
AT&C Loss % =(E req- (LT Sales+ 11 kV Sales+33 kV Sales+ EHV Sales)*Collection Efficiency)/E Req	

Table 1 is a simplified table which does not account for open access and captive inputs and does not separately account for distribution franchisee sales. Further, it does not account for generation embedded in the distribution network. Collection efficiency is not part of the energy balance table but has been shown in Table 1 only to illustrate the relationship between the energy balance format and the calculation methodology for AT&C loss.

The energy balance format used by most DISCOMs presumes that the electricity will flow more or less in a linear fashion. So electricity from 33 kV will flow to 11 kV. However, as illustrated in Figure 3, sales to consumers at 11 kV can also take place directly from 220 or 132 kV sub-stations at the EHV level. It is difficult to assess the percentage of cases where this takes place as this information is not available in the public domain. Ideally this could also be accounted for in the energy balance format, if significant.

The energy balance formats and the level of information provided varies from state to state. For example, the electricity regulatory commissions (ERCs) in Gujarat, Rajasthan and Haryana report the losses, sales and energy inputs at the intra-state transmission and distribution level only, without a voltage-wise separation for distribution level parameters or separate reporting of inter-state transmission losses (GERC, 2018; RERC, 2018b; HERC, 2018). The Madhya Pradesh ERC provides similar details and also a disaggregated inter-state transmission loss for eastern and western regions (MPERC, 2018). The Karnataka ERC only reports distribution losses as a percentage and the energy available at the transmission periphery (KERC, 2018). The Tamil Nadu ERC does not segregate inputs and sales at all and reports T&D losses together (TNERC, 2017).The Odisha ERC provides a loss statement with distribution loss, collection efficiency and AT&C loss reported but there is no energy balance format in the order (OERC, 2017).

The energy balance formats reported by the Maharashtra and Bihar ERCs are quite detailed and report almost all information shown in Table 1, but do not provide voltage-wise segregation of sales (MERC, 2016; BERC, 2018). In contrast, the ERC in Andhra Pradesh reports voltage-wise sales and loss parameters, but the transmission losses are not segregated (APERC, 2018).

Not only are methodologies different but the use of terminology also varies across states. For example, the Bihar ERC, in the tariff order for FY19, refers to the same percentage of loss estimate as T&D loss, AT&C loss and distribution losses in different sections which makes it difficult to assess the methodology used and the significance of the metric (BERC, 2018).

The variations in level of information provided, methodologies adopted and terminologies used, make a strong case for standard formats and a uniform methodology. However, adoption of standard formats should also consider factors beyond those shown in Table 1. This is discussed in detail in Section 4.

4. Need to change methodology used for percentage loss estimation

In the last two decades, many structural changes have taken place in the sector which need to be accounted for while calculating percentage losses. For one, DISCOMs are not the only users of the T&D network, especially with the large increase in the numbers of open access and captive users of the grid. Second, many DISCOMs are appointing distribution franchisees to manage operations and networks in certain areas. The treatment of franchisee areas while estimating percentage losses for the DISCOM needs to be looked into while accounting energy handled by the system. Third, more and more power procurement is taking place from sources outside the state and this is true for short-term procurement as well. At the same time, generation from RE sources embedded in the distribution network is also increasing. The current energy balance format is not suited to account for this change as it considers all RE and short-term procurement to take place at the intra-state level. These changes and their potential impacts are described in greater detail below:

4.1 Increase in open access and off-site captive consumption

With the average cost of supply for most DISCOMs at Rs 7/kWh, many HT consumers —who have been traditionally cross-subsidising those who paying less than the cost of supply— find it lucrative to meet their demand through open access or captive generators.[13] In many states, the quantum of open access sales is as high as 20% of DISCOM's HT sales. Further, captive consumption is higher than 10% of total DISCOM sales in many states (PEG, 2018a).

Energy balance formats typically capture DISCOM sales alone. The format does not account for open access and off-site captive[14] sales and the energy input into the T&D network to meet this demand. The Maharashtra ERC comes closest to being an exception in this regard as it considers energy wheeled and sales to open access consumers while estimating T&D loss but the ERC does not include off-site captive consumption (MERC, 2016).

T&D loss is often calculated as a ratio of the loss observed in the system and the energy input to meet the DISCOM demand. Not accounting for inputs for open access and captive consumption underestimates the energy input in the system and therefore overestimates the T&D loss percentage calculated. As AT&C loss is only concerned with the sales and energy input attributable to the DISCOM, there is no change in the metric.

4.2 Increase in distribution franchisees

Distribution Franchisees (DFs) are typically appointed by the DISCOMs in order to manage billing, collection and capital expenditure in high AT&C loss pockets of the DISCOM. The first distribution franchisee was appointed in 2007 in Bhiwandi, Maharashtra. Since then there has been a proliferation of franchisees across DISCOMs. In fact, fourteen of twenty divisions of the Central Electricity Supply Utility (CESU) in Odisha are managed by franchisees.[15] The consumers in areas managed by franchisees are consumers of the DISCOMs. Thus, the sales and losses in

[13] Open access consumers refer to consumers of the DISCOM who, with the help of non-discriminatory access to the transmission and distribution network obtain power supply from generators or traders while incurring charges for use of the network and other applicable charges.

[14] When the generation and consumption of captive power do not take place in the same site, necessitating the use of the T&D network to wheel power from the captive power plant to the captive consumer.

[15] Central Electricity Supply Utility (CESU) is a DISCOM responsible for power supply to nine districts in Odisha.

the franchisee area at various voltage levels should also be accounted for in a similar fashion as DISCOM sales in the energy balance format.

Many SERCs and DISCOMs treat distribution franchisees like a bulk consumer drawing power at the EHV level or 33 kV level. For example, the Bihar ERC considered input to franchisees at 33 kV level as sales to franchisee areas. Thus, the distribution losses at lower voltage levels are not applicable even though many consumers are connected at lower voltage levels (BERC, 2018, p. 79). The Jaipur DISCOM treats input to distribution franchisees (which includes losses) as sales while estimating total DISCOM sales. Percentage losses are applied on this sales estimate to determine the energy requirement (RERC, 2018a, p. 40; JVVNL, 2017, p. 11).

Contractually, energy input for the franchisee takes place at a higher voltage level. As consumers in franchisee areas are still consumers of the DISCOM, the relatively higher percentage loss at the lower voltage levels where sales takes place should also be considered in the energy balance format. This practice is followed by DISCOMs in Madhya Pradesh (MPPMCL, 2016, p. 5). The absence of this type of accounting is akin to those losses being considered as sales at the 33kV or EHV level, which would under-estimate T&D loss and AT&C loss percentage. In fact with such a system, it is quite possible for a DISCOM to show a dramatic reduction in distribution losses in regulatory filings simply by appointing franchisees in multiple circles.

4.3 Rise in inter-state procurement of short-term power and renewable energy

Power procurement from short-term and renewable energy (RE) sources can occur both outside and within the state. The energy balance formats used in many states consider all power from these sources to be within the state transmission network. This could be because short-term and RE power procurement was insignificant in the past and was mostly intra-state. However, with the operationalisation of the Discovery of Efficient Electricity Price (DEEP) platform to facilitate short-term bilateral trade, increased sale and purchase of unrequisitioned power across the country, and the rising trade volumes on power exchanges, intra-state short-term power procurement has increased and will continue to do so in the future. Similarly, the rise in inter-state RE procurement is also likely to increase with the national commitment to adding 175 GW of RE by FY22 (PEG, 2017). Considering power from these sources solely as inputs at the EHV level over-estimates input and loss at the intra-state transmission level. Thus, it will impact calculation of T&D loss but not that of AT&C loss.

4.4 Increase in renewable energy generation in the distribution network

Wind and solar projects may be embedded within the distribution network and supply power to DISCOMs. Further, there has been a substantial increase in RE based captive projects and rooftop solar PV projects being installed by consumers due to high DISCOM tariffs and enabling provisions such as net metering. Given the cost-competitiveness of this generation option, it is also used to provide day-time power supply to farmers. Going forward, the extent of such generation embedded in the distribution network will only increase.

Energy balance formats need to capture input due to generation embedded in the distribution network (which could be for open access, captive consumers or DISCOM use) and only apply the voltage level percentage loss applicable within the distribution network. Currently, input for open access and captive power are not considered and the RE input for the DISCOM is considered only at the EHV level which could lead to a variation in both T&D and AT&C losses.

In order to assess the possible variation in percentage losses based on how these factors are considered, various accounting methodologies are compared in this discussion paper, which are described in detail in Section 5.

5. About Calculating Loss and Energy Accounting in Regulatory practice (CLEAR)

To compare the impact of various methodologies, Prayas (Energy Group) built a simple, spreadsheet-based energy accounting and T&D loss calculator called CLEAR (**C**alculating **L**oss and **E**nergy **A**ccounting in **R**egulatory practice). In CLEAR, treatment of energy input and sales is similar to the energy balance table format used by SERCs. Just like in Table 1, CLEAR provides for the estimation of the energy available and energy requirement. However, there are some fundamental differences in the structure of CLEAR and the energy balance format in Table 1, due to the factors described in Section 4.

- CLEAR can account for input and losses due to open access and off-site captive consumption.
- CLEAR can account for generation and input of energy at the 33 kV, 11 kV and LT level. Losses are based on the assumptions made for sale of this energy at each voltage level.
- The energy requirement and energy available is not strictly calculated at the T<>D periphery but is adjusted for inputs due to embedded generation in the distribution network.
- CLEAR provides for treatment of Distribution Franchisees as a single consumer connected at the EHV level, and can also account for franchisees sales based on the point of connection of each consumer.
- As shown in Table 1, CLEAR can also estimate AT&C loss for the DISCOM under various methodologies for a given collection efficiency percentage.

The inputs the user has to specify in CLEAR are detailed in Table 2.

Table 2: Inputs to be specified by the user in CLEAR

Energy Requirement	Energy Available
Sales segregated at the LT, 11 kV, 33 kV and EHV level.	Inter-state and intra-state procurement of power from: - Long/ medium, short-term conventional sources - RE sources
Sales in areas managed by distribution franchisees	Generation embedded in distribution network
Consumption by open access and off-site captive consumers.[16]	Input to meet open access and off-site captive demand
Percentage losses at the LT, 11 kV and 33 kV level.	Percentage of transmission loss (inter-state, intra-state)

[16] In the current version of CLEAR the consumption and input at each voltage level for open access and off-site captive consumers is assumed to be in the same proportion. This can be modified with more information about the same.

Based on the user inputs, CLEAR estimates T&D and AT&C loss using five methodologies as discussed in Table 3.

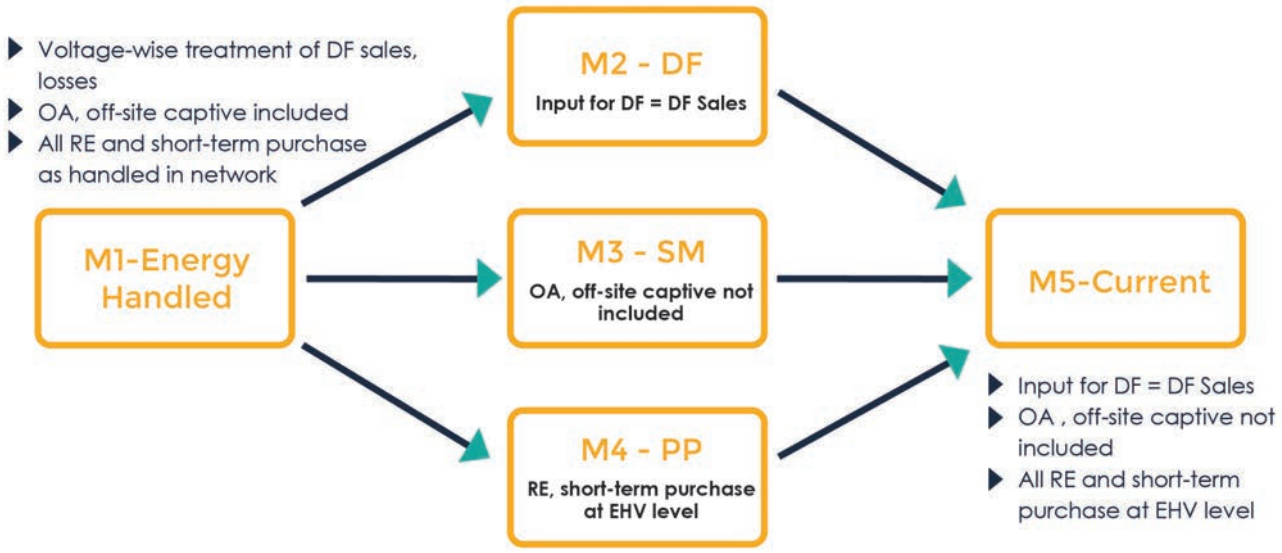
Table 3: Description of methodologies

Methodology 1 **('M1-Energy Handled')**: Energy input and consumption as handled in network
Energy Requirement: Energy delivered to end consumer (i.e. energy metered (or estimated) at consumer meter / point of interconnection) is considered as the **energy requirement**. This includes sales to DISCOM consumers, distribution franchisees and consumption by open access and off-site captive consumers. **Energy Available:** Power procurement from all sources are accounted for, based on whether they are within the state or outside it with applicable losses. Energy input from inter-state and intra-state sources to meet requirement for open access and off-site captive consumers is also considered. Further any input in the distribution network for DISCOM, open access or off-site captive consumers is also taken into account.
Methodology 2 **('M2-DF'):** Input to Distribution Franchisee treated as DISCOM sales to DFs
Variation in treatment from 'M1-Energy Handled': In **energy requirement**, the energy input for distribution franchisees at the EHV level is treated as sales to franchisees.
Methodology 3 **('M3-SM'):** Open access and off-site captive not accounted for
Variation in treatment from 'M1-Energy Handled': Open access and off-site captive consumption not considered in the **energy requirement** and input to meet open access and off-site captive demand not considered in **energy available**.
Methodology 4 **('M4-PP'):** All RE and short-term power purchase assumed to be within state
Variation in treatment from 'M1-Energy Handled': All RE and short-term procurement is assumed to be at the EHV level in the **energy requirement**.
Methodology 5 **('M5-Current'):** Current practice in many states
Variation in treatment from 'M1-Energy Handled': In **energy requirement**, the treatment of distribution franchisee sales is the same as **'M2-DF'** and the treatment of open access and off-site captive consumption is the same as **'M3-SM'**. The **energy available** is the same as **'M4-PP'.**

The description of the methodologies in Table 3 and the summary in Figure 4 make it clear that **'M1-Energy Handled'** approximates the energy input and losses based on how energy is actually handled in the system, and that **'M5-Current'** closely resembles the energy balance format currently used in many states as described in Section 4. Methodologies **'M2-DF', 'M3-SM'** and **'M4-PP'** help establish the extent of variation due to one particular assumption in the calculation methodology.

The variation in assumptions across methodologies is also summarised in Figure 4.

Figure 4: Summary of methodologies in CLEAR



Depending on the user inputs, there might be some surplus energy or deficit due to a mismatch between energy available and energy requirement, which will remain the same across methodologies.

A lot of the information required for CLEAR may not be available in a consistent manner for states but the user can also make assumptions or modify inputs accordingly. Besides the disaggregation provided in CLEAR, several other factors can also be accounted for. Examples include voltage-wise disaggregation of transmission losses, voltage-wise break-up of captive and open access sales and inputs, and capturing instances of inputs from the EHV level directly to the 22 kV or 11 kV level as shown in Figure 3. With data availability, the energy balance format and CLEAR can be modified to account for energy handled in a more accurate fashion.

CLEAR is available on Prayas (Energy Group)'s website. It is hoped that policy makers, regulators, consumers and researchers find it useful to better understand energy accounting practices. CLEAR can be downloaded from: http://www.prayaspune.org/peg/publications/item/407.

6. Using CLEAR for DISCOM A

To understand variations in loss percentage due to changes in methodology, let us consider the case of DISCOM A. The inputs specified in CLEAR for DISCOM Aare detailed in Table 4.

Table 4: Overview of DISCOM A[17]

Energy Related Assumptions (MU)	MU	%	Changes in methodologies
Power Purchase for DISCOM (incl. DF)	**1,06,108**	**100%**	
Long/Medium Term non-RE Purchase	**95,593**	**90%**	Same across methodologies.
Inter-state	36,326	38%	
Intra-state / EHV level	59,267	62%	
Short Term Purchase	**1,300**	**1%**	Same assumption in 'M1-Energy Handled', 'M2-DF' and 'M3-SM'. All short-term inputs assumed to be at EHV level in 'M4-PP' and 'M5-Current'.
Inter-state	520	40%	
Intra-state / EHV level	780	60%	
RE Purchase	**9,215**	**9%**	Same assumption in 'M1-Energy Handled', 'M2-DF' and 'M3-SM'. All RE inputs assumed at EHV level in 'M4-PP' and 'M5-Current'.
Inter-state	922	10%	
Intra-state / EHV level	6,174	67%	
33 kV level	922	10%	
11 kV level	737	8%	
LT level	461	5%	
Total Sales to DISCOM Consumers	**73,241**	**100%**	Same across methodologies.
Intra-state / EHV level	451	1%	
33 kV level	4,780	7%	
11 kV level	10,081	14%	
LT level	57,929	79%	
Sales to Consumers in DF Area	**4,100**	**100%**	Sales along with voltage-wise losses in 'M1-Energy Handled', 'M3-SM' and 'M4-PP'. Energy requirement by DFs assumed to be sales to DFs at EHV level in 'M2-DF' and 'M5-Current'.
Intra-state / EHV level	0	0%	
33 kV level	246	6%	
11 kV level	574	14%	
LT level	3,280	80%	
Input for Open Access and Off-site Captive	**10,659**	**100%**	Considered based on energy requirement and voltage-wise sales in 'M1-Energy Handled', 'M2-DF' and 'M4-PP'. Not considered in 'M3-SM'and 'M5-Current'.
Inter-state	3,105	29%	
Intra-state / EHV level	3,770	36%	
33 kV level	2,739	26%	
11 kV level	1,046	10%	
LT level	0	0%	
Total Sales Migration (SM)	**9,900**	**100%**	Sales migration due to open access and off-site captive grossed up for losses and accounted for in 'M1-Energy Handled', 'M2-DF' and 'M4-PP'. Sales migration not considered for energy balance in 'M3-SM' and 'M5-Current'.
Open Access (OA) sales	6,400		
Off-site Captive sales	3,500		
Voltage-wise Sales Migration	**9,900**	**100%**	
Intra-state / EHV level	4,950	50%	
33 kV level	2,970	30%	
11 kV level	1,980	20%	
LT level	0	0%	
Collection Efficiency (%)	90%		Same across methodologies.

[17] All numbers are rounded off to the nearest whole number in this table.

DISCOM A is located in a highly industrialised, large state with high levels of electrification and has significant RE power purchase. There is substantial sales migration from DISCOM A due to captive and open access options. The DISCOM also has a few distribution franchisees. In order to estimate variation in AT&C loss due to changes in methodology, it is assumed that DISCOM A has an overall collection efficiency of 90%. Note that in CLEAR, the collection efficiency considered is based on the revenue received from franchisees and not the revenue actually collected by franchisees in the franchisee area.

Table 5 shows the voltage-wise loss considered for DISCOM A.

Table 5: Voltage-wise percentage of HT and LT level losses for DISCOM A

Voltage level	DISCOM A
Inter-State	2.86%
Intra-State / EHV level	3.49%
33 kV	6.02%
11 kV	8.03%
LT level	15.12%

7. Discussion and results

Table 6 captures the percentage losses calculated with discussed methodologies for DISCOM A.

Table 6: Loss percentage estimated using methodologies in CLEAR

Methodology	T&D Loss		AT&C Loss	
	%	Variation from M1	%	Variation from M1
'M1-Energy Handled': Energy as handled in network	**24.53%**		**31.38%**	
'M2-DF': Input to Distribution Franchisee (DF) at EHV level considered as sales	**23.42%**	Under-estimation by 1.11 p.p.	**30.24%**	Under-estimation by 1.14 p.p.
'M3-SM': Open access and off-site captive consumption not accounted for	**26.36%**	Over-estimation by 1.83 p.p.	**31.38%**	No change
'M4-PP': All RE, short-term purchase at EHV level	**24.56%**	Over-estimation by 0.03 p.p.	**31.46%**	Over-estimation by 0.08 p.p.
'M5-Current': Current practice in many states	**25.16%**	Over-estimation by 0.63 p.p.	**30.31%**	Under-estimation by 1.07 p.p.

The table clearly indicates that there is a deviation of -1.11 to 1.83 p.p. in T&D loss and -1.14 to 0.08 p.p deviation in AT&C loss calculated using the various methodologies as compared to 'M1-Energy Handled'.

Some key observations include:

- For DISCOM A where sales to DFs is about 5% of total DISCOM sales, treating DFs as EHV level consumers results in T&D losses being under-estimated by 1.11 p.p.

- The consumption by open access and off-site captive consumers is about 9,900 MUs for DISCOM A which is as high as 14% of DISCOM A's sales. It is assumed that 36% of the generation to meet the demand of such consumers takes place within the distribution network. When this consumption and the energy input required for open access and off-site captive consumers are not considered, T&D loss is over-estimated by 1.83 p.p. but there is no change in the AT&C loss.

- In DISCOM A, about 1% of the total power procurement is short-term and 40% of this power is procured outside the state. Similarly, RE procurement is about 9% of the DISCOM's energy consumption, of which 10% is procured outside the state and 23% is generated within the distribution network. If all short-term and RE procurement for the DISCOM is assumed to take place at the EHV level, it will result in a 0.03 p.p. over-estimation of T&D losses and a 0.08 over-estimation of AT&C loss as compared to 'M1-Energy Handled'.

- The cumulative impact of considering DF input as sales, not accounting for open access and captive consumption and assuming all short-term, RE procurement to take place at the EHV level results in an over-estimation of T&D loss by 0.63 p.p. However, these assumptions result

in an under-estimation of AT&C loss by 1.07 p.p. The stark difference in the percentage point variation between AT&C and T&D losses in this methodology can be due to assumptions for open access and captive consumption which are only considered for T&D loss calculation.

The trends highlighted in this discussion paper, namely proliferation of distribution franchisees, increase in open access and off-site captive consumption and higher procurement from short-term and RE sources outside the state will only become more pronounced in the future. In fact, some DISCOMs are already more affected by these trends than others. In this context, it is important to understand how the variation in percentage loss due to the methodology adopted will be impacted when these trends become significant. To assess the impact of such changes, assumptions were made about possible changes in DISCOM A under four scenarios which are described below:

- **Scenario A:** Instead of sales to DFs accounting for 5% of DISCOMs sales, it is assumed to be as high as 20% of DISCOM A's sales (which is assumed to remain the same as in Table 5).
- **Scenario B:** 50% of the HT sales of DISCOM A is assumed to have migrated to open access and captive generators, resulting in a jump in sales migration quantum to about 17,500 MUs from 9,900 MUs.
- **Scenario C:** Assuming total power procurement remains the same, RE procurement from all voltage levels increases to 20% of DISCOM A's total consumption. Short-term purchase is assumed to be about 10% of total procurement.
- **Scenario D:** Assuming changes in Scenario A, B, C together for DISCOM A.

Some observations based on the results in the scenarios are given below:

- In Scenario A**,** when all the sales are considered to be at the EHV level, the T&D loss is under-estimated by 4.21 p.p. and the AT&C loss is under-estimated by 4.32 p.p.

- In Scenario B, when the quantum of open access and off-site captive consumption increases by 70% due to sales migration in DISCOM A, there is an over-estimation of T&D loss by 3.46 p.p. with no change in the calculated AT&C loss.

- In Scenario C, the quantum of RE and short-term purchase increases by 20% of DISCOM consumption and 10% of DISCOMs power purchase respectively. In this scenario, the over-estimation of T&D loss and AT&C loss is relatively lower by 0.12 p.p. and 0.18 p.p. respectively. The variation in AT&C loss can be attributed only to the increase in procurement of power from generators connected to the distribution network from 2,120 MUs to 4,666 MUs.

- Scenario D shows that the cumulative impacts lead to a 3.39 p.p. under-estimation of AT&C loss if the loss is not calculated based on energy handled ('M1-Energy Handled') but using the current practice in many states ('M5-Current'). The under-estimation of T&D loss in 'M5-Current', as compared to 'M1-Energy Handled' is 0.62 p.p. This is because the variations due to assumptions for sales migration make a difference to the T&D loss value but not change the AT&C loss percentage.

Table 7 summarises the variation between 'M1-Energy Handled' and relevant methodologies where changes specific to the assumptions in the scenario are made.

Table 7: Changes in percentage losses under various scenarios

Methodology	T&D Loss		AT&C Loss	
	%	Variation from M1	%	Variation from M1
Scenario A: DF Scenario				
'M1-Energy Handled': Energy as handled in network	24.56		31.41	
'M2-DF': Input to DF at EHV level considered as sales	20.35	**Under-estimation by 4.21 p.p.**	27.09	**Under-estimation by 4.32 p.p.**
'M5-Current': Current practice in many states	21.76	Under-estimation by 2.79 p.p.	27.15	Under-estimation by 4.25 p.p.
Scenario B:SM Scenario				
'M1-Energy Handled': Energy as handled in network	24.04		32.45	
'M3-SM': Open access and off-site captive consumption not accounted for	27.50	**Over-estimation by 3.46 p.p.**	32.45	No change
'M5-Current': Current practice in many states	26.18	Over-estimation by 2.14 p.p.	31.28	Under-estimation by 1.17 p.p.
Scenario C: Power purchase scenario				
'M1-Energy Handled': Energy as handled in network	24.37		31.28	
'M4-PP': All RE, short-term purchase at EHV level	24.49	Over-estimation by 0.12 p.p.	31.46	**Over-estimation by 0.18 p.p.**
'M5-Current': Current practice in many states	25.08	Over-estimation by 0.71 p.p.	30.31	Under-estimation by 0.97 p.p.
Scenario D: Cumulative scenario				
'M1-Energy Handled': Energy as handled in network	24.16		32.26	
'M5-Current': Current practice in many states	23.54	Under-estimation by 0.62 p.p.	28.87	Under-estimation by 3.39 p.p.

The variation in T&D loss and AT&C loss is most stark with sales migration and change in DF sales. This also indicates that the changes in methodology to account for emerging trends are most relevant for states like Bihar and Odisha which have a high number of distribution franchisees and for states like Rajasthan, Gujarat and Maharashtra which have significant open access and off-site captive consumption.

As discussed, under these scenarios, the variation can be between about -4 to 0.2 p.p. for AT&C loss. This is significant as the targets specified in the UDAY MoUs signed by the Union and State Governments specify an annual reduction of AT&C loss by less than 4 p.p. per year for 19 out of the 31 states.[18] Further, the variation in T&D loss in these scenarios falls in the range of -4 to 3.5 p.p. which is much higher than the annual percentage loss reduction target specified by SERCs in many states (like Maharashtra, Tamil Nadu, Punjab, Andhra Pradesh and Kerala), and is also comparable to the annual percentage loss reduction target in some states (like Madhya Pradesh and Haryana).

Comparing progress under these targets becomes challenging without a standardised, widely accepted methodology for loss estimation. In order to ensure that a standard and commonly agreed upon methodology is adopted:

- FoR should suggest a uniform methodology, based on public consultation and deliberations with DISCOMs, SERCs and the Ministry of Power.
- The suggested methodology can be adopted by the State ERCs. Based on this methodology, the State ERCs can re-estimate T&D losses and prescribe loss reduction trajectories in the MYT regulations.
- The same methodology can also be adopted by the Ministry of Power and the Power Finance Corporation while calculating and reporting AT&C loss.

Without such steps, comparing and tracking loss metrics may not be meaningful.

[18] As per UDAY MoUs, states which require more than 4 p.p. reduction in losses to meet their targets include Arunachal Pradesh, Bihar, Jammu & Kashmir, Jharkhand, Manipur, Meghalaya, Nagaland, Sikkim, Telangana and Tripura.

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http://www.prayaspune.org/peg/publications/item/365

Many Sparks but Little Light: The Rhetoric and Practice of Electricity Sector Reforms in India (2017)
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Webinars by Prayas (Energy Group) on select issues

Many Sparks, Little Light
www.prayaspune.org/peg/webinar/many-sparks-but-little-light.html

Electricity Distribution Companies in India: Preparing for an Uncertain Future
www.prayaspune.org/peg/webinar/electricity-discoms-preparing-for-an-uncertain-future.html

Solar Agriculture Feeders
www.prayaspune.org/peg/webinar/solar-agriculture-feeders.html

Understanding the Electricity, Water and Agriculture Linkages
www.prayaspune.org/peg/webinar/understanding-the-electricity-water-agriculture-linkages.html

Transmission and Distribution loss (T&D) and Aggregate Technical and Commercial (AT&C) loss are both crucial metrics used to assess the health of the power sector.

Not considering challenges due to poor interface and consumer metering, there are significant variations in loss estimates depending on the methodology used for calculating losses.

The estimation methodologies used in many states do not consider energy as handled by the system, especially to account for the following recent trends:

- Energy required to meet open access and off-site captive demand
- Treatment of sale to consumers in distribution franchisee areas
- Energy input in the inter-state transmission network as well as the distribution network due to renewable energy generators, net metered consumers, etc.

Using a spread-sheet based tool, developed by Prayas (Energy Group) called Calculating Loss and Energy Accounting in Regulatory practice (CLEAR), this paper, by comparing methodologies shows that there could potentially be a variation in losses calculated up to 4 percentage points.

Such stark variations call for a disaggregated and standardised approach to estimating T&D losses. Only then will efforts such as fixing trajectories for loss reduction in the regulatory process, comparing performance of DISCOMs across years and across states, and charting the progress of programmes like UDAY and IPDS that use these metrics be meaningful.

CLEAR can be downloaded by scanning the QR code below.

Prayas (Energy Group)