# Policy Paper on Refurbishment of Distribution Transformer (DT)

International Copper Association India

31 January 2022

Final

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# Abbreviations

The list of abbreviations used in the draft report is presented below:

| Abbreviation | Description |
|---|---|
| **$^0$C** | Degree Celsius |
| **ABR** | Average Billing Rate |
| **ACOS** | Average Cost Of Supply |
| **Al** | Aluminum |
| **ARR** | Aggregate Revenue Requirement |
| **AT&C** | Aggregate Technical and Commercial Losses |
| **BAU** | Business as Usual |
| **BEE** | Bureau of Energy Efficiency |
| **BIS** | Bureau of Indian Standards |
| **CAGR** | Compounded Annual Growth Rate |
| **CapEx** | Capital Expenditure |
| **CEA** | Central Electricity Authority |
| **CERC** | Central Electricity Regulatory Commission |
| **Cu** | Copper |
| **DISCOM** | Distribution Company |
| **DT** | Distribution Transformer |
| **ERDA** | Electrical Research and Development Association |
| **FLL** | Full Load Loss |
| **FY** | Financial Year |
| **GFA** | Gross Fixed Assets |
| **GWh** | Gigawatt hours |
| **HV** | High Voltage |
| **ICA** | International Copper Association |
| **INR** | Indian Rupees |
| **IPDS** | Integrated Power Development Scheme |
| **IS** | Indian Standards |
| **KPI** | Key Performance Indicator |
| **kVA** | kilo Volt-Ampere |
| **LV** | Low Voltage |
| **M&V** | Monitoring and Verification |
| **MPPKVVCL** | Madhya Pradesh Poorv Kshetra Vidyut Vitran Company Limited |
| **MSEDCL** | Maharashtra State Electricity Distribution Company |
| **MVA** | Million Volt-Ampere |
| **NLL** | No Load Loss |
| **O&M** | Operation and Maintenance |
| **OEM** | Original Equipment Manufacturer |
| **OpEx** | Operational Expenditure |
| **PoC** | Proof of Concept |
| **R&M** | Repair and Maintenance |
| **R-APDRP** | Accelerated Power Development and Reforms Programme |
| **RDSS** | Revamped Distribution Sector Scheme |
| **RoE** | Return on Equity |

| Abbreviation | Description |
|---|---|
| **SERC** | State Electricity Regulatory Commission |
| **TANGEDCO** | Tamil Nadu Generation and Distribution Corporation Limited |
| **TCO** | Total Cost of Ownership |
| **UDAY** | Ujwal DISCOM Assurance Yojana |

# 1. Executive Summary

Distribution Transformer (DT) play a vital role in the power distribution network of the DISCOMs. For overall DISCOM viability, it is imperative that each DT turn into a profit center. It is estimated that out of 21.73% national average AT&C losses in FY 2020, about 5.16% is contributed by Technical losses in DTs, and it can be brought down to 4.20% and below. Under prevailing operational practices of public DISCOMs, the DT's technical losses are not generally measured unless it fails and further, there is no pro-active asset management approach towards DT's repair and O&M practices.

The key operational issues that the DISCOMs experience with respect the DT asset management are

1. Deviation in technical losses in operating legacy DTs and repaired DTs reinstated into system

2. Premature failure of new and repaired DTs

To address the above dual issues (i.e., technical loss deviation and premature failure) in DT asset management, ICA India has carried out pilots on refurbishment of DT in three key utilities (i.e. Madhya Pradesh Poorv Kshetra Vidyut Vitran Company Limited (MPPKVVCL), Maharashtra State Electricity Distribution Company (MSEDCL), Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO)) in India. It is recognized that, Refurbishment of DTs resulted in helping utilities to address the deviation in technical losses from the rated specifications. DT refurbishment fundamentally involves augmentation or replacement of the active materials in a DT i.e., Core and Winding, depending on the condition, and design of the DT.

The pilot studies conducted in the utilities demonstrated that, the energy performance of DT after refurbishment is equivalent to the newly procured Cu DT at about 50% of cost, and its giving extended life to DT equivalent to that of a new transformer.

Among the installed DT capacity, the average annual failure rate of DTs in country is estimated to be about 8.54% (i.e., 0.97 million DTs) and the failure rate varies from 4% to 30% across the states in India. Out of the failed DTs, considering 70% is being repaired through conventional repair, the estimated annual technical loss from DT is about 4,664 GWh which can be brought down to 2,953 GWh (i.e. annal energy savings of 1,712 GWh). Annual energy savings of about 1,712 GWh, at the India level, results in an annual cost saving of about INR 1,059 crore.

In addition to the failed DTs, there are legacy DTs in the distribution network which operate with deviation in losses from the rated specifications. Considering 40% of operational DTs are legacy DTs, the estimated annual energy loss from the legacy DT is about 57,732 GWh.

The 57,732 GWh annual technical loss in DTs is equivalent to 5.16% of the total net input energy at pan India level. This technical loss can be reduced by refurbishing the inefficiently operating legacy DTs in the system. This would result in an annual DT technical loss of about 46,994 GWh. Refurbishment of all the inefficiently operating DTs in the Distribution network would help in realizing an annual energy savings of about 10,738 GWh (57,732 – 46,994), at India level, amounting to an annual savings of INR 6,560 crore. The expected annual energy savings of about 10,738 GWh would result in an annual emission reduction of about 8.5 Mn ton $CO_2$.

Though the annual estimated potential saving of 10,738 GWh is possible through refurbishment, the refurbishment of 100-200 kVA DTs (where failure rates and energy losses are predominantly higher), can be targeted by Bureau of Energy Efficiency (BEE) in initial Phase as these DTs are easy to access, refurbish, and monitor due to their predominant use in urban and semi-urban regions. This selective targeting will help in an estimated annual energy savings of about 3,367 GWh or annal energy cost savings of INR 2,088 crores to the utilities

Keeping these factors into consideration, the key policy recommendations for enhancing the energy efficiency of DTs in DISCOM through improvisation of asset management practices are

1. **Target DISCOMs:** All PAT notified DISCOMs, as under BEE Notification S.O.5045(E) dated 1st October 2018 , shall undertake measures to improve the energy efficiency of DTs through refurbishment and improved asset management practices.

2. **DTs to Refurbish:** All operational DTs, which are operating at a high level of deviation in technical losses, with name plate ratings ranging between 100 kVA and 200 kVA. However, DISCOM may choose to the improve the energy efficiency performance level of operating DTs with ratings less than 100 kVA.
3. **Target Performance Level for Enhancing DT's Energy Efficiency:**
    a. DTs which are procured before the date of notification of BEE's S.O. 185(E) i.e., Standards for Star Labelled Distribution Transformer dated 12th January 2009, shall have the total loss (i.e. No Load Loss (NLL) and Full Load Loss (FLL)) equivalent to or better than the prevailing energy consumptions standards for Star 1 Labelled Distribution Transformer with +10% tolerance (i.e. energy consumption standards as under BEE's notification S.O.4062(E) dated 16th Dec, 2016)
    b. DTs which are Star Labelled but having the total loss deviations on higher side from its specifications shall restore the loss level to its respective star level +10% tolerance. This includes DT's which are both within and outside the warranty period.
4. **Deviation from Target Energy Efficiency Level:**
    a. In case of deviation in annual loss from target energy efficiency level, the cost of deviated energy loss shall not be passed on to the retail consumers for the entire deviation period (i.e. period starting from completion of DT refurbishment) until the deviation is brought under the limits.
    b. In case the deviations are un-addressable, the DISCOM shall replace the DT with a minimum Star 1 level DT under prevailing energy consumption standards i.e., energy consumption standards as under BEE's notification S.O.4062(E) dated 16th Dec, 2016 and its amendments if any.
5. **Fiscal and Non-Fiscal Support:** DISCOM is allowed to utilize the financial support from applicable Central and State Scheme such as Revamped Distribution Sector Scheme to enhance its DT energy efficiency performance under the Policy. Further, BEE may provide capacity building support to DISCOM on enhancing the DT energy efficiency performance.
6. **Consequence for Non Implementation of Policy:** In case of non-implementation of the Policy, the SERC may disallow the 100% of the cost of deviated energy loss and 50% of the Repair and Maintenance (R&M) cost of all DT's.

# 2. Background

## 2.1. Context

In the value chain of electricity, India's distribution network continues to be the weakest link as most distribution utilities are making losses as result of poor infrastructure, inefficient operation, and expensive long term power purchase agreements, among others. These losses, in turn, avert them from making investments required to enhance the quality of power supply[1]. India's distribution system is fronting the issue of high Aggregate Technical & Commercial (AT&C) losses and low supply quality for a long period. Government of India has taken various steps and interventions to reduce the AT&C losses via schemes including R-APDRP, IPDS, UDAY and the recently rolled out Revamped Distribution Sector Scheme (RDSS) among others which support state governments in bringing down the AT&C losses and improving the quality of power.

While these interventions support the state distribution utilities in improving the technical and commercial performance of the Distribution Companies (DISCOMs), one of the indistinct issues that the distribution utilities continue to face is the reasonable failure rate of Distribution Transformers (DTs) and the deviation of technical losses (No Load Loss (NLL) and Full Load Loss (FLL)) from rated specifications. This results in commercial losses, reduction in supply quality and reliability to the consumers.

While the failure rate of DTs is usually tracked by the DISCOMs, the deviation in technical losses in DTs are generally not measured and monitored by the distribution utilities. Further, the total technical loss deviations are as high as about 30% from the rated specifications in DTs which are reinstated into service post conventional repair, and in legacy transformers operating inefficiently.

The key reasons for not focusing on the technical loss deviations in the DTs by utilities are[2]:

- Lack of metering and monitoring mechanism for DT to measure the losses
- Lack of emphasis on the energy efficiency of DTs after repairs.
- Absence of policy interventions at state and central level to recognize the technical losses in DTs and to tap the opportunity to bring down the AT&C losses.

Presently, there is no formal practice followed by DISCOMs to ensure that DTs are operating efficiently. Lack of monitoring systems to track the health of operational DTs or DTs which are being reinstated into network post repair, is leading to untimely failure and inefficient operations. This leads to following snags in distribution utilities

1. Increased recurring operating costs;
2. Increased revenue loss (on account of energy losses); and
3. Increased contingent capital expenditure (for replacement of failed DTs)

These problems eventually deter the technical and financial performance of DISCOMs.

## 2.2. Purpose Statement

The purpose of the policy paper is to explain how the failed DTs, post-repair and legacy transformers are operating inefficiently at higher loss levels in the distribution system and how DT refurbishment with an aim to improve operational performance would help DISCOMs in:

1. Reducing technical losses;
2. Differ Capital Expenditure (CapEx);
3. Lower Repair & Maintenance (R&M) cost;
4. Improving the reliability of the distribution network; and
5. Reduces the retail tariff of distribution

This paper makes policy recommendations to tap the potential of energy loss reduction of about **10,738 GWh per annum**[3] by increasing the energy performance of inefficient legacy and failed DTs through refurbishment.

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[1] NITI Aayog, 2021, https://www.niti.gov.in/sites/default/files/2021-08/Electricity-Distribution-Report_030821.pdf
[2] Based on primary research with select DISCOMs in India
[3] Refer to Appendix A.8 for detailed estimates on savings potential

# 3. Refurbishment of DT for Energy Performance and Reliability Improvement in Select DISCOMs of India

## 3.1. Preamble

DTs play a vital role in the power distribution network of the DISCOMs. DTs are one of the critical and high value CapEx assets for DISCOMs. For overall DISCOM viability, it is imperative that each DT must turn into a profit center. It is estimated that out of 21.73%[4] national average AT&C losses in FY 2020, about 5.16%[5] is contributed by Technical losses in DTs, and it can be brought down to 4.20%[3] and below.

Under prevailing operational practices of public DISCOMs, the DT's technical losses are not generally measured unless it fails. Further, there is no pro-active asset management approach towards DT's repair and O&M practices.

Failure rate of DTs is one of the important Key Performance Indicators (KPIs) for DISCOMs. The average failure rate at India level is relatively higher when compared to the global benchmark. In India, on average 8.54%[6] DTs fail every year and average rate of failure of aluminum wound DTs is more when compared to the copper wound DTs. In general, overloading is cited as one of the root causes of DT failure amongst various other reasons. DTs are frequently overloaded, resulting in deterioration of their operating health and its lifespan.

Any failure of the DT before the expiration of its designed lifespan (i.e., 25 years) results in an unplanned outage, production loss to economy, and in most cases substantial financial losses to both utilities and customers. Overall, it affects the reliability of the network.

Considering the current financial state of public DISCOMs, performance improvement of DTs becomes a decisive factor in protecting DISCOMs from further losses and provides opportunity to minimize overall AT&C losses.

Due to financial constraints for procuring new DTs, most public utilities operate DTs beyond their useful life by inefficiently repairing them several times. This contributes to reduced efficiency of DTs and high technical losses in the distribution system.

Realizing the need to minimize the technical losses and improving the reliability of DTs, an opportunity to be explored by DISCOMs is improving the performance of DTs through refurbishment. The DT refurbishment carried out by International Copper Association (ICA India) at select DISCOMs in India shows that, refurbishment has resulted in an enhanced performance - equivalent to Energy Efficiency Levels specified by both Bureau of Energy Efficiency (BEE) and Bureau of Indian Standards (BIS); extended life of the old DTs (equivalent to new DT); and increased reliability.

## 3.2. Issues in DT Asset Management

The key operational issues that the DISCOMs experience with respect the DT asset management are

1. Deviation in technical losses in operating legacy DTs and repaired DTs reinstated into system
2. Premature failure of new and repaired DTs

[4] PFC – Performance review of state utilities (FY 2020)
[5] Refer to Appendix A.8 for detailed Loss Estimate
[6] Refer to Appendix A.4 for failure rate details across states

### 3.2.1. Deviation in Technical Loss

The deviation in technical losses from name plate specifications are majorly due to following causes and reasons:

| | |
|---|---|
| Non Standard Repair Practices | • Lack of non standard DT repair practice results in inefficienct repair, and operational performance therafter<br>• Lack of design capabilities with repairer to achieve optimum flux density. |
| Lack of focus on Energy Efficiency post Repair of DT | • Absence of pre and post repair technical loss assessment in conventional repair, masking cost of energy inefficiency in the DT repair practices |
| Lack of DT Metering | • Absence of metering in DT results in no focus on energy efficiency |
| No Energy Performance baseline reference for Legacy DTs | • DTs procured by DISCOM prior to BEE's Standard and Labelling program for Distribution Transformer in 2009, doesn't have standard specifications for techincal losses |

Refurbishment of DTs can help utility address the deviation in technical losses from rated specifications. The details on minimization of technical losses through DT refurbishment is discussed in the section 2.4.

### 3.2.2. Premature failure of New and Repaired DTs

The major causes for premature failure in both new and repaired DTs are:

**Overloading**

- Lack of non standard DT repair practice results in inefficient repair and inefficient operation therafter

**Poor O&M Practices by DISCOM**

- Freqent overloading and poor maintenance of DT resulting in failures

**Poor procurement & contractual practices**

- Procurement without consideration of Total Cost of Ownership (TCO) (i.e. cost of energy loss, Repair & Maintenance Cost); non standard workmanship and material use due to pricing pressure; non clarity on responsibility of event of failures in Supply and Service agreement.
- Very short warranty period offered by the repairer/OEM and its acceptance by DISCOM's i.e. minimal control on performance
- No mechanism/contractual obligation for measuring the energy performance of DT post repair other than the prevailing acceptance tests

**Lack of focus/absence of a system to track Total Cost of Ownership**

- No system in place to track the TCO of DT from purchase to scrap among majority of DISCOMs. Recurring repair cost adds to retail tariff of consumers.
- Conventional repair is less expensive which is masking the total cost of ownership/operation of legacy DT

**Monitoring Mechanism**

- No monitoring mechanism is available in majority of DISCOMs to evidently identify the DT failure reasons on account of DT OEM's workmanship, design, and material used (and) on account of DISCOM's O&M
- Absence of continuous energy performance monitoring of DTs, to ascertain the quality of functioning of DT

The details on minimization of total cost of ownership through DT refurbishment, and its commercial attractiveness are discussed in the section 3.5.

### 3.2.3. Other Issues and Challenges

In addition to operational challenges (i.e., technical loss deviation and premature failure), there are regulatory and market related challenges which are resulting in an increased CapEx and recurring R&M costs of DTs among DISCOMs.

1. **Regulatory Challenges:** Approval of capex proposals (including DT) without scrutinizing effectiveness of earlier approved DT capex (i.e., whether the asset lasted to its full lifetime), dilutes the prudency in procurement by DISCOM. As a result, new capex addition results in additional fixed cost to consumers which could potentially be avoided through effective procurement.
2. **Commercials of Conventional Repair:** Conventional repair is less expensive (without factoring the cost of energy inefficiency) which is masking the total cost of ownership/operation of legacy DT.
3. **DISCOMs awareness on Refurbishment:** It is renowned that that the conventional repair is the limited and commonly adopted option that is available with DISCOM. The awareness on refurbishment of DT is in a nascent stage among public utilities in India.
4. **Prevailing Repair Ecosystem:**
    a. Basis the primary interactions with select DISCOMs in India by ICA India, it is inferred that there is an apprehension from DISCOM about relatively high cost of refurbishment of DT (without weighing the long-term commercial benefits) and its commercial attractiveness (primarily due to lack of awareness).
    b. In addition, there is an apprehension from DT repairers about the expected changes in legacy repair system/process as the current system of repair is not on the basis of outcome/performance driven.
    c. Absence of capacity/awareness with repairers/DISCOM to have transition from conventional repair to refurbishment.

## 3.3. Refurbishment of DT in Select DISCOMs in India

To address the earlier referred dual issues (i.e., technical loss deviation and premature failure) in DT asset management, ICA India has carried out pilots on refurbishment of DT in three key utilities in India. The details of DISCOMs and the size of the DT which are refurbished under the pilots are as below:

Table 1: DISCOMs where Proof of Concept studies were conducted

| Sl.No | DISCOM | Refurbished DT Size |
|---|---|---|
| **1** | Madhya Pradesh Poorv Kshetra Vidyut Vitran Company Limited (MPPKVVCL), Madhya Pradesh | 1x100 kVA and 2x200 kVA |
| **2** | Maharashtra State Electricity Distribution Company (MSEDCL), Maharashtra | 1x100 kVA |
| **3** | Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO), Tamil Nadu | 1x100 kVA |

### 3.3.1. Refurbishment of DT

Refurbishment of DT is undertaken to reduce the high technical losses to near manufacturer specification. It can be best proactively undertaken on operational high loss legacy DTs and also on failed DTs. DT Refurbishment fundamentally involves augmentation or replacement of the active materials in a DT i.e., Core and Winding, depending on the condition, and design of the DT.

### 3.3.2. Process of DT Refurbishment

As the internal losses in a transformer is contributed through distributed magnetic flux, the pilots were focused on correcting the magnetic flux inside the transformer through winding compensation. The process adopted for refurbishment of the DT is as below:

**1. Pre Refurbishment Testing & DT Selection**

- Measurement of **No Load Loss** and **Full Load Loss** and Selection of DT based on its **No Load Loss** and **Full Load Loss.**

**2. Design Options and Finalization**

- Selection of Design Option for **Core or Windings or both** based on Loss Levels

**3. Refurbishment**

- Undertaking refurbishment on **winding or core or both** as applicable

**4. Post Refurbishment Testing**

- Measurement of **Total Loss**

**5. Reporting**

- Reporting of test results

Basis the discussion with various DT manufacturers and DT subject matter experts by ICA India, the selection of DT for refurbishment has been performed on the basis of deviation of NLL & FLL of DT from its ideal loss level or manufacturers specification.

Table 2: Scope for refurbishment based on loss deviation levels

| Case | Existing No Load Loss above Ideal Level | Existing Full Load Loss above Ideal Level | Scope for Refurbishment |
|---|---|---|---|
| **1** | <20% | <20% | No refurbishment work required |
| **2** | <20% | >20% | Winding replacement is required |
| **3** | >20% | <20% | Core material addition is required (with limited winding augmentation) |
| **4** | <20% | Between 20% & 40% | Both winding replacement and core material addition is required |
| **5** | Between 20% & 40% | >40% | Both winding replacement and core material addition is required |
| **6** | >40% | >40% | DT Replacement is required |

For case 1, where the No Load and Full Load losses are both within 20% of ideal loss levels refurbishment can help reduce the technical losses further. However, they are generally not economically viable.

For case 6, where both No Load and Full Load losses exceed 40% than the ideal loss levels, any attempts to bring down these technical losses through refurbishment may not be effective. In such a case, entire DT replacement may be a viable option.

For total losses ranging from 10% to 30% from ideal loss level, the DT refurbishment can help bring down the technical losses near to ideal loss levels or even better, which can be inferred from the results of PoC (refer section 3.4) that has been carried out.

## 3.4. Results of Proof of Concept (PoC)

During the course of baseline assessment, it is observed that, the NLL deviation in the DT varied from 12% to 82% from the specification and the FLL deviation varied from 3% to 34% from the specification. Despite significant variation, the implementation of DT refurbishment resulted in reduction in the total losses to a level which is even lower than the specification. Details of performance improvement during PoC studies is discussed below.

### 3.4.1. Madhya Pradesh Poorv Kshetra Vidyut Vitran Company Limited (MPPKVVCL)

Old DTs were randomly chosen and refurbishment was performed using multiple design options to study the impact on losses in the DTs.

#### 3.4.1.1. Design option 1: Improvement for best performance

In this design, both High Voltage (HV) and Low Voltage (LV) windings are replaced with electrolytic grade copper windings, with an aim to optimize full load losses and improve efficiency while achieving enhanced capacity. The design option was tested on two DTs (1x100 kVA, 1x200 kVA). The results are tabulated below:

Table 3: PoC results – 100 kVA DT (MPPKVVCL)

| Key Design Parameters | Unit | Specification | Baseline (As-Is) | % Deviation from Specification | Post repair results (measured at ERDA) | % Change from Baseline |
|---|---|---|---|---|---|---|
| **Capacity** | kVA | 100 | 86.46 | | 109* | +20% |
| **Year of Manufacturing** | Year | - | 2013 | | - | |
| **Flux Density** | Tesla | 1.55 | - | | - | |
| **LV Winding Material** | | - | DPC Al | | DPC Cu | |
| **No of LV Turns** | Nos | - | 76 | | 76 | 0% |
| **HV Winding Material** | | - | DPC Al | | DPC Cu | |
| **No of HV Turn** | Nos | - | 3,344 | | 3,344 | 0% |
| **No Load Loss** | Watt | 260 | 258 | -0.7% | 295 | +15%** |
| **Full Load Loss** | Watt | 1,760 | 2,358 | +34% | 1,168 | -50% |
| **Total Loss** | Watt | 2,020 | 2,616 | +29.50% | 1,463 | -44% |

*KVA enhancement is inferred and estimated from ERDA results
** The allowed tolerance for loss level as per TS-1116 for repaired transformer are: No-load loss is 15% ; Full load loss is 15%; Total loss is 10%. No Load loss could have been reduced by increasing no. of turns with trade-off of slight higher (still reduced) Full Load loss. Total Loss optimization was done.

The standard loss for BEE's Star 1 rated 100 kVA DT at 100% loading is 1,650 Watt whereas the total loss achieved through refurbishment of DT is 1,463 Watt at 100% loading.

Table 4: PoC results – 200 kVA (MPPKVVCL)

| Key Design Parameters | Unit | Specification | Baseline (As-Is) | % Deviation from Specification | Post repair results (measured at ERDA) | % Change from Baseline |
|---|---|---|---|---|---|---|
| **Capacity** | kVA | 200 | 200 | | 200 | 0% |
| **Year of Manufacturing** | Year | - | 2004 | | - | |
| **Flux Density** | Tesla | 1.55 | - | | - | |
| **LV Winding Material** | | - | DPC Al | | DPC Cu | |
| **No of LV Turns** | Nos | - | 42 | | 42 | 0% |
| **HV Winding Material** | | - | DPC Al | | DPC Cu | |
| **No of HV Turn** | Nos | - | 1848 | | 1848 | 0% |
| **No Load Loss** | Watt | 500 | 561 | +12.20% | 567.79 | +13** |
| **Full Load Loss** | Watt | 3,000 | 3,000 | - | 1,729.69 | -42.34% |
| **Total Loss** | Watt | 3,500 | 3,561 | | 2297.48 | -35.48% |

**The allowed tolerance for loss levels as per TS-1116 for repaired transformer are: No-load loss is 15% ; Full load loss is 15%; Total loss is 10%

The standard loss for BEE's Star 1 rated 200 kVA DT at 100% loading is 2,300 Watt whereas the total loss achieved through refurbishment of DT is 2,297 Watt at 100% loading.

### 3.4.1.2. Design option 2: Improvement for cost-effective capacity enhancement

In this design, HV winding is made of electrolytic grade copper & LV winding is made of aluminum, with an aim to optimize initial cost and focus on reduction of full load losses. The design option was tested on a 200 kVA DT. The results are tabulated below:

Table 5: PoC results – 200 kVA DT (MPPKVVCL)

| Key Design Parameters | Unit | Specification | Baseline (As-Is) | % Deviation from Specification | Post repair results (measured at ERDA) | % Change from Baseline |
|---|---|---|---|---|---|---|
| **Capacity** | kVA | 200 | 200 | | 200 | 0% |
| **Year of Manufacturing** | Year | - | 2004 | | - | |
| **Flux Density** | Tesla | 1.55 | - | | - | |
| **LV Winding Material** | | - | DPC Al | | DPC Al | |
| **No of LV Turns** | Nos | - | 42 | | 42 | 0% |
| **HV Winding Material** | | - | DPC Al | | DPC Cu | |
| **No of HV Turn** | Nos | - | 1848 | | 1848 | 0% |
| **Total Loss** | Watt | 3,500 | 3,850 | +10% | 3,029 | -21.32% |

## 3.4.2. Maharashtra State Electricity Distribution Company (MSEDCL)

Old DT was randomly chosen, and refurbishment was done by the way of changing both HV and LV windings to electrolytic copper and increasing the number of turns by 15% in both HV & LV winding, to study the impact on losses in the transformer. The performance has been studied for a period of 2 years post repair through Transformer Monitoring Unit (TMU) connected through energy meter. The results are tabulated as below:

Table 6: PoC results – 100 kVA DT (MSEDCL)

| Key Design Parameters | Unit | Specification | Baseline (As-Is) | % Deviation from Specification | Post repair results | % Change from Baseline |
|---|---|---|---|---|---|---|
| **Capacity** | kVA | 100 | 100 | | 109* | +9% |
| **Year of Manufacturing** | Year | - | 2004 | | | |
| **Flux Density** | Tesla | 1.55 | 1.55 | 1.55 | 1.35 | -13% |
| **LV Winding Material** | | | DPC Al | | DPC Copper | |
| **No of LV Turns** | Nos | | 75 | | 86 | +15% |
| **HV Winding Material** | | | DPC Al | | DPC Copper | |
| **No of HV Turn** | Nos | | 3,300 | | 3,784 | +15% |
| **No Load Loss** | Watt | 260 | 426 | +65% | 295 | -30.75% |
| **Full Load Loss** | Watt | 1,760 | 1,815 | +3% | 1,654 | -8.87% |
| **Total Loss** | Watt | 2,020 | 2,241 | +10.94% | 1,949 | -13% |

*KVA enhancement is inferred and estimated from ERDA results

In addition, improvement in reliability of DT due to refurbishment is discussed in Appendix A.1.

### 3.4.3. Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO)

Old DTs were randomly chosen, and refurbishment was performed by the way of changing HV winding to electrolytic copper, to study the impact on losses in DT. The results as observed pre and post repair are tabulated as below:

Table 7: PoC results – 100 kVA DT (TANGEDCO)

| Key Design Parameters | Unit | Specification | Baseline (As-Is) | % Deviation from Specification | Post repair results (measured at NABL) | % Change from Baseline |
|---|---|---|---|---|---|---|
| **Capacity** | kVA | 100 | 100 | | 108 | |
| **Year of Manufacturing** | Year | - | 2010 | - | - | |
| **Flux Density** | Tesla | 1.55 | - | - | - | |
| **LV Winding Material** | | - | DPC Al | - | DPC Al | |
| **HV Winding Material** | | - | DPC Al | - | DPC Cu | |
| **No Load Loss** | Watt | 260 | 474 | +82% | 472 | 0.42% |
| **Full Load Loss** | Watt | 1760 | 2067 | +17.44% | 1559 | -25% |
| **Total Loss** | Watt | 2020 | 2541 | +25.79% | 2031 | -20% |

### 3.4.4. Summary of PoC Studies

*Table 8: Summary of PoC Studies*

| Design Option | DISCOM | DT Rating (kVA) | Deviation in technical loss from rated specifications (in %) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-Repair Readings | | | Post-Refurbishment Reading | | |
| | | | NLL | FLL | Total Loss | NLL | FLL | Total Loss |
| 1 | TANGEDCO | 100 | +82% | +17.44% | +25.79% | +81.53% | -11.42% | +0.54% |
| | MPPKVVCL | 200 | - | - | +10% | - | - | -13.46% |
| | | **Average** | **+82%** | **+17.44%** | **+17.89%** | **+81.53%** | **-11.42%** | **-6.46%** |
| 2 | MSEDCL | 100 | +65% | +3% | +10.94% | +13.46% | -6% | -3.51% |
| | MPPKVVCL | 100 | -0.7% | +34% | +29.51% | +13.66% | -33.6% | -27.57% |
| | | **Average** | **+32.15%** | **+18.5%** | **+20.22%** | **+13.56%** | **-19.8%** | **-15.54%** |

From the above table, basis the refurbishment of 100 kVA DT[7] at MPPKVVCL, the following deviations in technical losses were considered for analysis of savings potential at India level:

*Table 9: Assumptions for deviation in technical loss from rated specifications, post refurbishment in DTs*

| Loss | Deviation in technical loss from rated specifications (in %) | |
|---|---|---|
| | Pre-Repair | Post-Repair |
| **No Load Loss[8]** | +15% | +10% |
| **Full Load Loss** | +30% | -30% |

## 3.5. Commercial Attractiveness of DT Refurbishment

PoC has demonstrated that, the energy performance of DT after refurbishment is equivalent to the newly procured Cu DT at about 50% of cost, and its giving extended life to DT equivalent to that of a new transformer. Further, the simple payback period for refurbishment investment ranges between 3.18 years and 6.26 years with an average simple payback period of 4.3 years (at 70% loading of DT). It's noted that, the simple payback period will further reduce to 1.5 years to 2.21 years at a 100% loading. Details on cost benefit analysis of PoC studies are deliberated below.

[7] PoC results of MPPKVVCL is considered as both LV & HV windings are refurbished without change in the number of turns in the coils, whereas at MSEDCL PoC number of windings has been changed
[8] Based on ICA India's primary interaction with select DISCOMs (MPPKVVCL, TANGEDCO, MSEDCL). Though NLL deviation as high as 82% was observed, conservatively it was assumed that deviation in NLL pre-repair is only +15% for analysis

### 3.5.1. Cost Benefit Analysis

Refurbishment of 100 kVA DT across DISCOMs has resulted in an average annual energy savings of about 3,000 kWh with a refurbishment cost ranging from about INR 68,000 to INR 98,000, resulting in an attractive payback period of about 3 years.

Table 10: Cost Benefit Analysis – 100 kVA DT

| S.No | Parameter | Unit | MPPKVVCL | MSEDCL | TANGEDCO |
|---|---|---|---|---|---|
| 1 | **Total Units Saved** | kWh/year | 4,779 | 1,838 | 2,198 |
| 2 | **Average Cost of Supply (ACOS)*** | INR/kWh | 6.25 | 6.03 | 5.85 |
| 3 | **Total Money Saved** | INR/Year | 29,871 | 11,083 | 12,858 |
| 4 | **Total Cost of Refurbishment** | INR | 98,131 | - | 68,930 |
| 5 | **Total Cost of Conventional Repair** | INR | 11,342 | - | 22,946 |
| 6 | **Incremental Cost (4-5)** | INR | 86,789 | - | 45,983 |
| 7 | **Simple Payback period including financing charges** | Years | 3.18 | 6.26 | 3.20 |

* Based on year the PoC study has been conducted. For MPPKVVCL, MSEDCL, TANGEDCO it is 2019, 2016 and 2019 respectively

Similarly, refurbishment of 200 kVA DT has resulted in an annual energy savings of about 4,800 kWh with a refurbishment cost of about INR 1,51,502 resulting in an attractive payback period of about 4.5 years.

Table 11: Cost Benefit Analysis – 200 kVA DT

| S.No | Parameter | Unit | MPPKVVCL |
|---|---|---|---|
| 1 | **Total Units Saved** | kWh/year | 4,858 |
| 2 | **ACOS** | INR/kWh | 6.25 |
| 3 | **Total Money Saved** | INR/Year | 30,368 |
| 4 | **Total Cost of Refurbishment** | INR | 1,51,502 |
| 5 | **Total Cost of Conventional Repair** | INR | 19,973 |
| 6 | **Incremental Cost (4-5)** | INR | 1,31,529 |
| 7 | **Simple Payback period including financing charges** | Years | 4.56 |

In Business as Usual (BAU), DISCOMs are incurring recurring cost of DT repairs along with a hidden cost of energy loss which are generally not measured and managed. As an alternate investment option, DISCOM may secure a new DT to address the issues of energy loss and recurring repair cost, however, it costs DISCOM almost 2x as compared to the cost of refurbishment without compromising on the energy efficiency performance.

Table 12: Options with DISCOMS to address failed DTs

| S.No | Scenario | 100 kVA | | 200 kVA | | Remark |
|---|---|---|---|---|---|---|
| 1 | **Business as Usual (INR) (Operational Expenditure (OpEx))** | | | | | Performance of Refurbished old legacy DT is equivalent to the performance of new Cu DT, with an enhanced efficiency and high Cu salvage value |
| | **Conventional Repair Cost** | 11,000 | | 19,000 | | |
| | **Yearly Energy Loss Cost** | 29,000 | | 30,000 | | |
| 2 | **Replacement (INR) (Capex)** | Al | Cu | Al | Cu | |
| | **1 star** | 96,000 | 1,45,000 | 1,65,000 | 2,40,000 | |
| | **3 star** | 1,30,000 | 1,90,000 | 2,10,000 | 2,80,000 | |

| S.No | Scenario | 100 kVA | 200 kVA | Remark |
|---|---|---|---|---|
| **3** | **Refurbishment (INR)** | 98,131 | 1,50,000 | |

As seen above, the incremental costs of refurbishment are reasonably less when compared to procuring a new DT, while the performance is equivalent to that of a BEE rated new DT. Also, though the refurbishment of DT is expensive option compared to conventional repair, the benefits realized from increased savings through lower energy losses will compensate for the incremental costs.

### 3.5.2. Sensitivity on DT Refurbishment Investment

The ACOS has been in increasing trend[9] among most DISCOMs in India on account of raising Average Power Purchase Cost and AT&C losses. DT loss is one of the key contributors to DISCOM's overall AT&C losses (refer section 4.4), however, the losses vary with respect to the loading condition of the DT.

It is to highlight that, the simple payback period on DT refurbishment investment improves radically with an increase in ACOS and loading condition of the DT, as shown below.

Table 13: Sensitivity of Payback period to CAGR of ACOS

| CAGR of ACOS | DT Capacity | 0% | 5% | 10% | DISCOM |
|---|---|---|---|---|---|
| **Payback Period (Years)** | 100 kVA | 3.55 | 3.34 | 3.18 | MPPKVVCL |
| | | 3.58 | 3.37 | 3.20 | TANGEDCO |
| | | 8.41 | 7.13 | 6.26 | MSEDCL |
| | 200 kVA | 5.60 | 4.95 | 4.56 | MPPKVVCL |

Table 14: Sensitivity of Payback period to average DT Loading

| Average DT Load | DT Capacity | 70% | 80% | 90% | 100% | DISCOM |
|---|---|---|---|---|---|---|
| **Payback Period (Years)** | 100 kVA | 3.18 | 2.39 | 1.84 | 1.50 | MPPKVVCL |
| | | 3.20 | 2.53 | 2.06 | 1.72 | TANGEDCO |
| | | 6.26 | 5.64 | 5.18 | - | MSEDCL |
| | 200 kVA | 4.56 | 3.47 | 2.70 | 2.21 | MPPKVVCL |

## 3.6. Impact of DT Refurbishment on Distribution Retail Tariff

### 3.6.1. Treatment of conventional cost of Repair in R&M Expenses

The conventional repair cost incurred for failure of DTs is generally covered under the R&M Expense of Distribution utilities. The expenses incurred for R&M activity carried for the Distribution network by the Distribution Utilities are booked as R&M expenses in the financial statement. However, the State Electricity Regulatory Commissions approves the "R&M expenses" for Distribution utilities on Normative Basis i.e., in percentage of approved Gross Fixed Assets (GFA). In case where R&M expenses are higher than the normative case, the DISCOM has to absorb the loss. Hence, DISCOMs are constrained to limit the R&M cost of DT, however, there is no robust system that presently captures the R&M cost at individual DT level across its operations.

### 3.6.2. Treatment of DT Refurbishment cost as Capex

The refurbishment of failed DTs with additional cost may be assumed as Capital Expenditure (Capex) during the expenditure year. The refurbishment of failed DTs will result in avoidance of requirement for additional capex for procurement of new DTs. As seen earlier, the refurbishment of DTs can be done at about 50% of actual cost of new DTs, which will result in avoidance of additional Capex to the state utilities.

As the Refurbished DTs can be put to use in the same year, the capitalization of asset can be considered and treated as Capex by the DISCOM. The capitalization due to refurbishment during the year will have an impact on

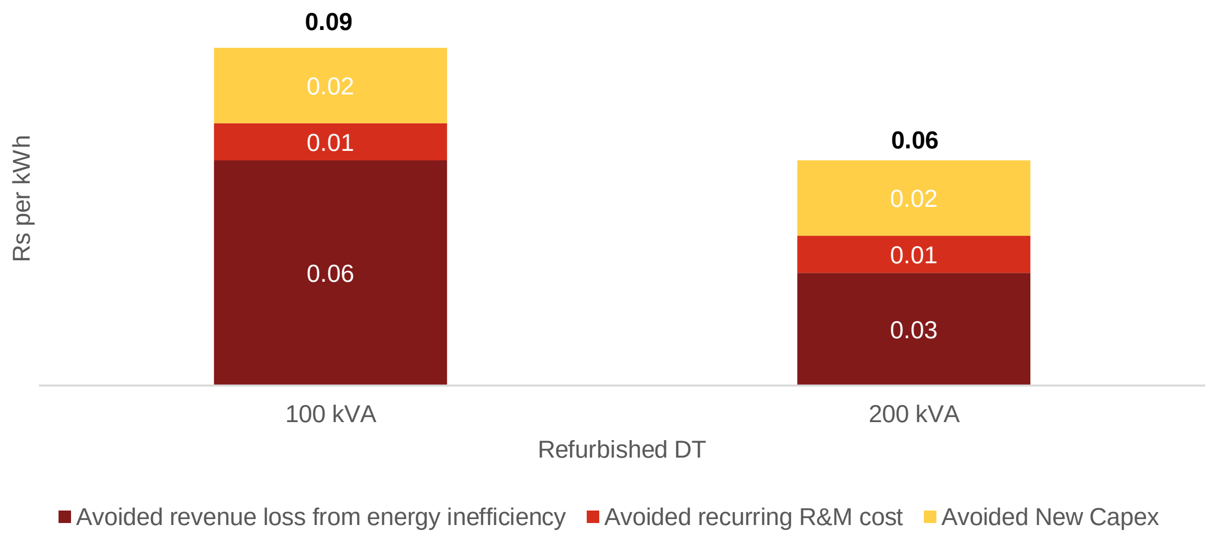
[9] https://www.statista.com/statistics/808201/india-cost-of-state-electricity-supply/

ARR components such as capitalization, additional debt, additional equity, interest on project loans, Return on Equity and Depreciation.

### 3.6.3. Impact of DT Refurbishment on Distribution Average Billing Rate

The refurbishment of DT helps utility in saving the cost towards energy inefficiency, recurring R&M cost of legacy DT's and the new capex. Basis the performance of PoC, it noted that DT refurbishment helps to reduce the Average Billing Rate (ABR) by INR. 0.06 per kWh to INR. 0.09 per kWh[10], at 70% loading of the DT.

Figure 1: Impact of DT Refurbishment on Retail Tariff




The above impact is the result of energy sale volume made through a single 100/200 kVA DT on an annual basis.

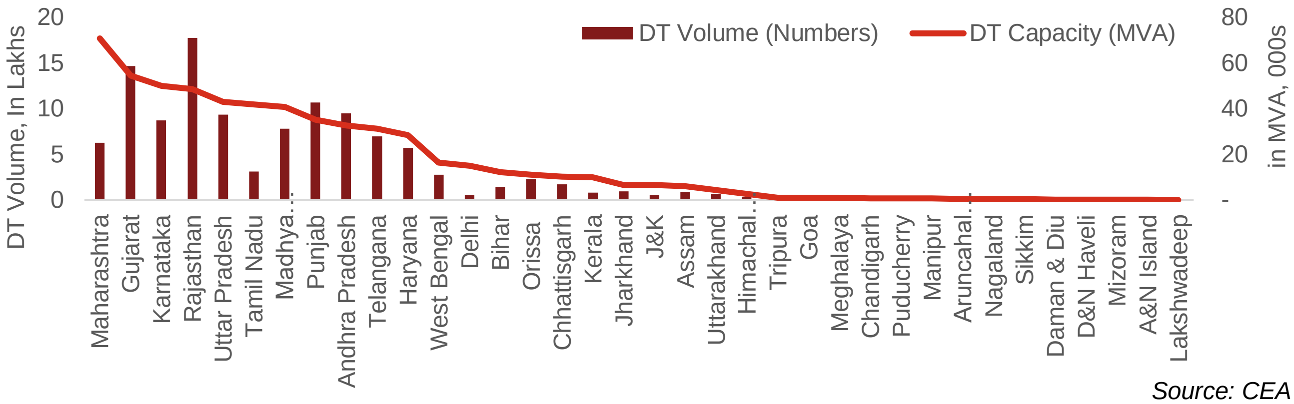
[10] Refer to Appendix A.2 for the detailed impact of refurbishment on Retail Tariff

# 4. Potential for Energy Savings and Emission reduction through Refurbishment of DT in India

## 4.1. Overview of DTs Installed in India

The volume of DTs installed in the distribution network of India as on 31st March 2019 is over 11.4 million with an aggregate capacity of 5.89 lakh MVA[11]. Majority of these DTs (volume wise (90.5%) and capacity wise (83.6%)) are concentrated in about twelve[12] Indian states which are predominantly industrial and agricultural-based economy. The details of state wise installed capacity of DTs and its volume are shown below:

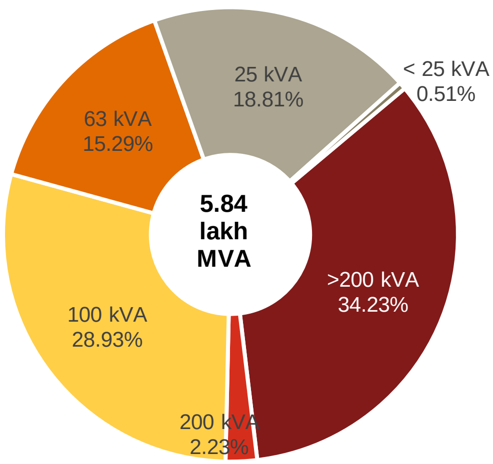
Figure 2: Installed capacity, volume-wise, capacity wise, by state




*Source: CEA*

Among the top twelve states, the Proof of Concept for DT Refurbishment has been implemented in Maharashtra, Madhya Pradesh & Tamil Nadu covering about 25% of these top states. It is expected that, the majority volume of 11.4 million population DT would be distributed among 100 kVA and 200 kVA capacity. On the basis of data collected during PoC studies at MPPKVVCL by ICA India and the public domain information on DT capacity distribution in a DISCOM at Karnataka (representing both the agriculture and industrial economy-based state), the split of installed DTs capacity at India level has been assumed as below:

Figure 3: Indicative[13] breakup of Installed DTs, by capacity (in %)



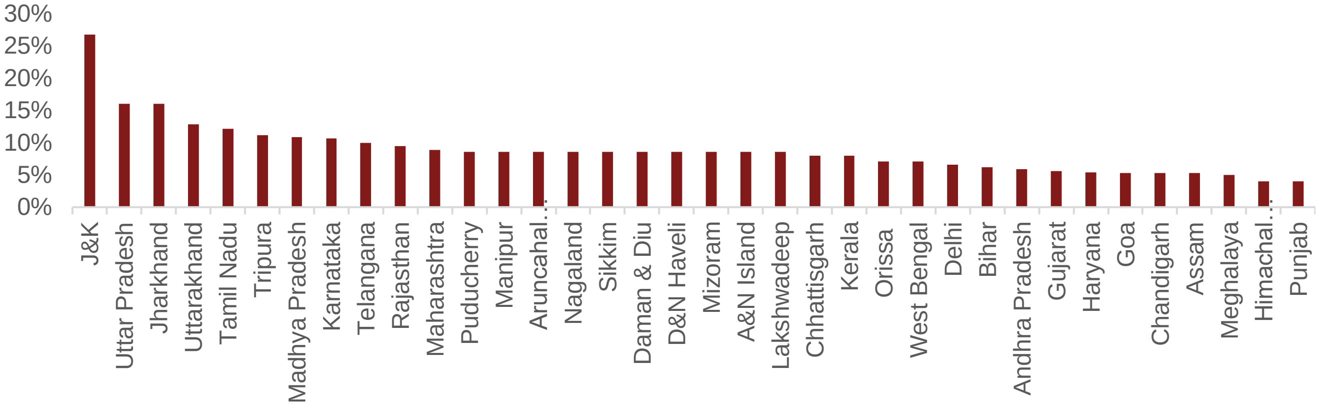

- 100 kVA to more than 200 kVA are predominantly used DTs, by capacity, in the distribution network
- < 100 KVA DTs are majorly used in rural feeders which are higher in volume and lacks the metering facility
- Similarly, 100 kVA to greater than 200 kVA DTs are predominantly installed in urban and semi-urban feeders where DTs are accessible and can be monitored

[11] All India Statistics report, 2020 - CEA
[12] Maharashtra, Gujarat, Karnataka, Rajasthan, Uttar Pradesh, Tamil Nadu, Madhya Pradesh, Punjab, Andhra Pradesh, Telangana, Haryana and West Bengal
[13] Refer to Annexure A.3 (Assumption 3) for the methodology of determining the split of DTs

## 4.2. DT failure rate in India

Among the installed DT capacity, the average annual failure rate of DTs in country is estimated to be about 8.54%[14] (i.e., 0.97 million DTs) and the failure rate varies from 4% to 30%[14] across the states in India, as detailed below:

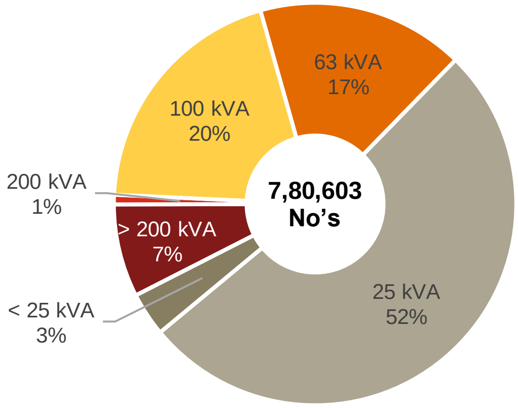
Figure 4: Failure Rate of DTs[5], by state (in %)




Higher DT failure rate results in higher R&M costs, lower reliability, loss of revenue to DISCOM and increase in tariff to the end consumers. It is expected that, about 50% of total failures are majorly in 25 kVA DTs which are majorly serving the rural feeders, where the loads are poorly metered and managed. The next notable failed volume is commonly observed in 100 kVA DTs which are prominent in urban and semi urban areas and most of these DTs are expected to be metered.

An indicative split of failed DTs in India (adjusted on the basis of capacity) has been shown below:

Figure 5: Indicative failed volume of DTs (in %)[15], by capacity




- About 7,80,603 DTs of various capacities fail every year resulting in loss of revenue, higher R&M costs and lower reliability to the distribution network
- As observed in the PoC studies, refurbishment can improve the reliability and lower the failure rates in DISCOM

## 4.3. Annual energy savings potential through refurbishment of failed DTs at Pan India Level

Out of the failed DTs (i.e. 7,80,603 no's), considering 70%[16] (i.e. 5,46,532 no's) is being repaired through conventional repair and remaining 30% DT's (i.e. 234,181 no's) are beyond repair, and needs premature replacement. The deviation in technical loss in these repaired DTs, as observed in PoC studies, are as shown below:

Table 15: Deviation in losses, from rated specifications, post conventional repair, as observed in PoC studies

| Loss | Deviation |
|---|---|
| **No-load loss** | +15% |
| **Full load loss** | +30% |

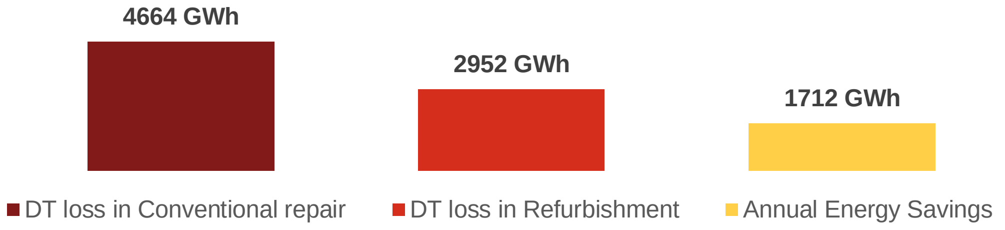
[14] Refer Appendix A.4 for the methodology of arriving at the national average DT failure rate
[15] Refer Appendix A.5 for the methodology of arriving at the split of failed DTs
[16] https://www.cstep.in/drupal/sites/default/files/2019-01/CSTEP_RR_Strategic_Roadmap_for_Implementation_of_UDAY_Scheme_Dec_2017.pdf

Table 16: Deviation in losses, from rated specifications, post refurbishment, as observed in PoC studies

| Loss | Deviation |
|---|---|
| **No-load loss** | +10% |
| **Full load loss** | -30% |

Therefore, refurbishment of failed DTs would unlock an annual energy saving potential of about 1,712 GWh as shown below.

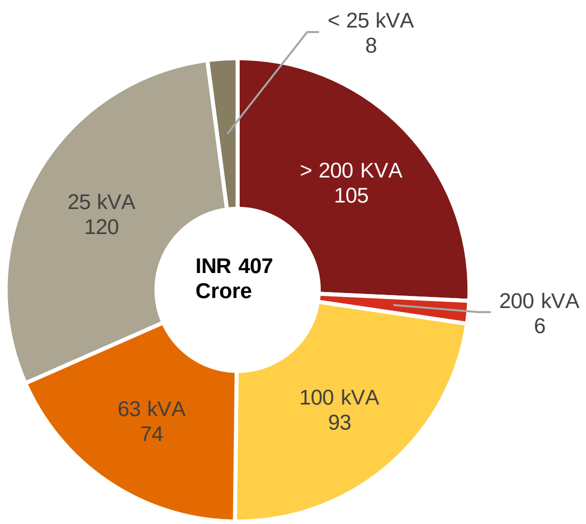
Figure 6: Indicative technical loss in DTs[17] among conventional repair and refurbishment, at India level




Annual energy savings of about 1,712 GWh, at the India level, results in an annual cost saving of about INR 1,059 crore[18].

In addition, considering the potential of refurbishment in restraining the technical losses in DTs within the specified limits as per IS 1180, some of the earlier unrepairable DTs through conventional repair can be successfully reinstated into the distribution system, thereby resulting in CAPEX savings to the DISCOMs. Conservatively, considering only 20% of the earlier unrepairable DTs (i.e., 20% of 234,181 no's), through conventional repairs, can be brought into service, the annual CAPEX savings for DISCOMS would be about INR 407 crore[19], the split of which is shown below:

Figure 7: Indicative annual CAPEX savings through refurbishment[15], by capacity (in INR crore)



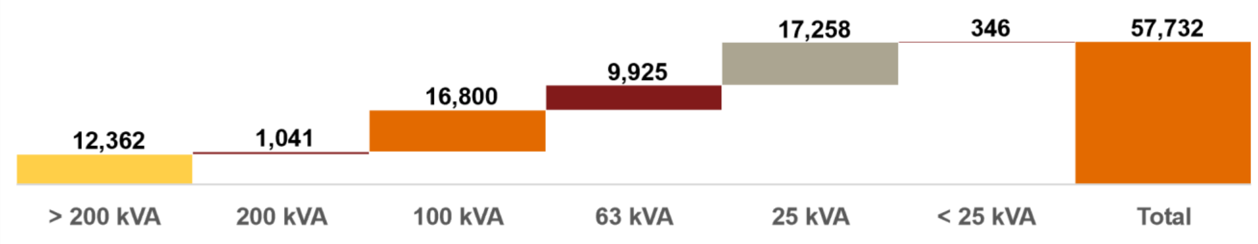

[17] Refer Appendix A.6 for the methodology of calculating savings from the refurbishment of failed DTs
[18] at ACOS of INR 6.2 per kWh
[19] Refer Appendix A.7 for detailed estimates on savings of CAPEX

## 4.4. Annual Savings Potential through refurbishment of legacy DTs at Pan India level

In addition to the failed DTs, there are legacy DTs in the distribution network which operate with deviation in losses from rated specifications as seen in the PoC studies. If these inefficiently operating DTs in the Distribution network of India are to be refurbished and reinstated into the network, the potential benefits from refurbishment, would be significant. To elucidate, at India level, the average AT&C loss is 21.73%[20] (as on 31 March 2020), out of which, basis the deviations observed in PoC studies, the contribution from DT technical loss is estimated to be 5.16%[21] which is significant. If the inefficiently operating legacy DTs are to be refurbished, the DT technical loss would reduce to 4.20%[21] leading to about 1% reduction in overall AT&C loss.

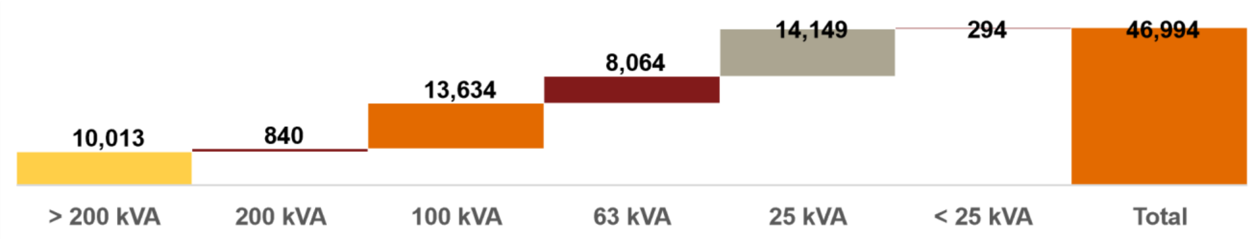
Considering that 60% of operational DTs would be relatively new and operating at least at Energy Efficiency level 1 (as specified in IS 1180), and the remaining 40% would be legacy DTs operating at deviation levels as observed in PoC studies, the estimated annual energy loss from the legacy DT is about 57,732 GWh[21].

Figure 8: Estimated existing technical losses in Installed DTs[18], by capacity (in GWh per annum)



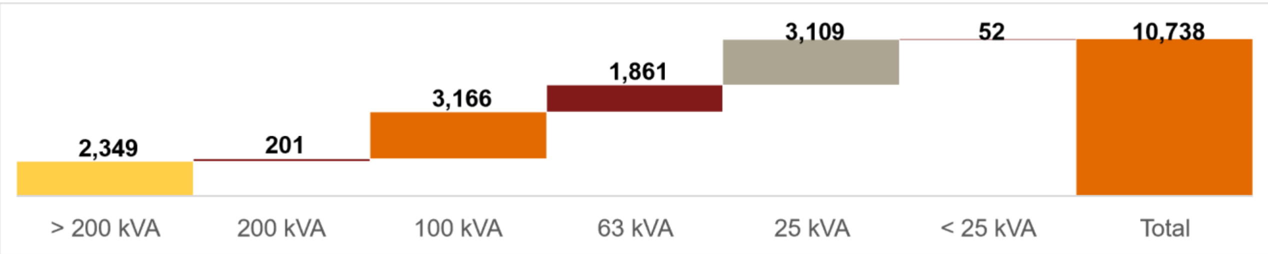

The 57,732 GWh annual technical loss in DTs is equivalent to 5.16% of the total net input energy at pan India level. This technical loss can be reduced by refurbishing the inefficiently operating legacy DTs in the system. This would result in an annual DT technical loss of about 46,994 GWh.

Figure 9: Estimated Technical loss in Installed DTs, if legacy transformers are refurbished & reinstated[18], by capacity (in GWh per annum)




Refurbishment of all the inefficiently operating DTs in the Distribution network would help in realizing an annual energy savings of about 10,738 GWh (57,732 – 46,994), at India level, amounting to an annual savings of INR 6,560 crore[22]. The expected annual energy savings of about 10,738 GWh would result in an annual emission reduction of about 8.5 Mn ton $CO_2$[23]

Figure 10: Estimated annual energy savings through Refurbishment, by capacity (in GWh)




[20] PFC – Performance review of state utilities (FY 2020)
[21] Refer to Appendix A.8 for methodology on the calculation of potential savings from the refurbishment of legacy DTs
[22] at ACOS of INR 6.2 per kWh
[23] At an emission ratio of 0.79 tCO2/MWh

Though the annual estimated potential saving of 10,738 GWh is possible through refurbishment, the refurbishment of 100-200 kVA DTs where failure rates and energy losses are predominantly higher, can be targeted in Phase 1 as these DTs are easy to access, refurbish, and monitor due to their use predominantly in urban and semi-urban regions. This selective targeting will help in an estimated annual energy savings of about 3,367 GWh or annal energy cost savings of INR 2,088 crores to the utilities.

Similarly, though refurbishment of 25 kVA segment has shown an estimated savings potential of 3,109 GWh, its higher volume, lack of access, and monitoring may increase the complexity in implementing refurbishment in Phase 1. Hence, this segment of DT may be pursued as a part of Phase 2 implementation.

Also, DTs rated > 200 kVA are subjected to constant loading and have lower chances of failure, and refurbishment may not have a significant effect on improving reliability. However, refurbishment of this segment could potentially help in the reduction of DT technical loss by 2,349 GWh. Hence, this segment of DTs can be pursued along with other segments in later phases.

Also, within these segments, at India level, Standards and Labelling Program by BEE was notified in 2009. DTs procured by DISCOMs prior to these standards are still operational in the Distribution network and are non-labelled. These non-labelled legacy DTs operate at loss levels higher than the current BEE standards for losses. These non-labelled Legacy DTs may be the first priority of DT population that need refurbishment in order to realize larger energy and cost savings.

Further, DTs procured between 2009 & 2016 (i.e., before BEE's new specifications, came into effect after 31$^{st}$ December 2016) might have undergone conventional repair over the years and may be operating at loss levels higher than the label specifications. These DTs can be the second priority area for refurbishment.

Apart from the above, those DTs which are procured post 2016 (i.e., relatively newer DTs) but operating at higher loss levels can be refurbished subsequently. Keeping these factors into consideration, the policy recommendations for implementing the DT refurbishment is discussed in the section 5.

# 5. Policy Recommendations – Refurbishment of DT for Enhanced Energy Efficiency and Asset Management

Considering an estimated annual energy saving potential of 3,367 GWh from 100 to 200 kVA segments of DTs, which are deployed majorly in urban and semi-urban areas across states in India, refurbishment of DTs (i.e., improved DT asset management) offers an opportunity to DISCOM to reduce and manage its technical loss and improve the reliability of the distribution network.

The proposed policy recommendations for enhancing the energy efficiency of DTs in DISCOM through improvisation of asset management practices are as below:

## 5.1. Objective

The objectives of the Policy are

1. To minimize deviation in technical losses in operating legacy DTs and repaired DTs (both Star Labelled and Non-Star Labelled)
2. To improve reliability of the legacy DTs in service; and reduce premature failure of new and repaired DTs

## 5.2. Target DISCOMs

### 5.2.1. Mandatory

All PAT notified DISCOMs, as under BEE Notification S.O.5045(E) dated 1st October, 2018[24], shall undertake measures to improve the energy efficiency of DTs through refurbishment and improved asset management practices.

### 5.2.2. Voluntary

Beyond the above points, DISCOMs which are keen to enhance the energy efficiency level of its DT fleet shall undertake refurbishment of DTs as per the Policy.

## 5.3. Targeted DT Segment

DISCOM shall enhance the energy efficiency performance level of all operational DTs, which are operating at a high level of deviation in technical losses, with name plate ratings ranging between 100 kVA and 200 kVA. However, DISCOM may choose to the improve the energy efficiency performance level of operating DTs with ratings less than 100 kVA, subject to fulfillment of provisions of this Policy.

[24] https://beeindia.gov.in/sites/default/files/Gazatte%20Notification%20-%20Revision%20in%20targets%20-%20PAT%20DISCOM.pdf

## 5.4. Target Level for Enhancing DT's Energy Efficiency

DISCOM shall improve the energy efficiency performance level of its DTs as below from its baseline energy efficiency level.

### 5.4.1. Non-Star Labelled DTs

DTs which are procured before the date of notification of BEE's S.O. 185(E) i.e., Standards for Star Labelled Distribution Transformer dated 12th January 2009, shall have the total loss (i.e. No Load Loss (NLL) and Full Load Loss (FLL)) equivalent to or better than the prevailing energy consumptions standards for Star 1 Labelled Distribution Transformer with +10% tolerance (i.e. energy consumption standards as under BEE's notification S.O.4062(E) dated 16th Dec, 2016[25]).

### 5.4.2. Star Labelled DTs

DTs which are Star Labelled but having the total loss deviations on higher side from its specifications shall restore the loss level to its respective star level +10% tolerance. This includes DT's which are both within and outside the warranty period.

## 5.5. Policy Period

DISCOM shall enhance the energy efficiency level of its legacy DTs as per the target level within below stipulated timelines.

| Sl.No | Period of DT Purchase | Timeline for Enhancing DT's Energy Efficiency Level |
|---|---|---|
| **1** | Before 1st Jan 2009 | Within 3 years from the date of Notification of the Policy |
| **2** | Between 1st Jan 2009 and 31st Dec 2015 | Within 5 years from the date of Notification of the Policy |
| **3** | After 1st Jan 2016 | After 7 years of service or within 1 year from the date of identification of deviation in losses based on periodic monitoring of DISCOM. |

## 5.6. Baseline Setting and Implementation Plan by DISCOM

a. DISCOM shall identify the volume of targeted DTs to be refurbished and it shall submit the details of targeted DTs to State Designated Agency (SDA) within 6 (six) months from the date of notification of the Policy.

b. DISCOM shall complete the baseline assessment /audit of existing total loss (No-Load Loss and Full Load Loss) of targeted DTs within 1.5 years from the date of notification of the policy.

c. DISCOM shall select the targeted DTs for enhancing its energy efficiency level based on its technical loss deviation from the specifications (in case of Star Labelled DT) or prevailing BEE's energy consumptions standards for Star 1 Labelled Distribution Transformer (in case of Non-Star Labelled DT).

Table 17: Scope for refurbishment based on loss deviation levels

| Sl.No | Existing Total Loss Deviation | Remark |
|---|---|---|
| **1** | <10% | No intervention required |
| **2** | 10% to 40% | Energy Efficiency of DT to be improved, focusing on refurbishment. |
| **5** | >40% | DISCOM shall replace the DT |

d. The baseline energy efficiency level of targeted DTs shall be submitted to BEE within 4 (four) months from the date of baseline measurements along with necessary documents such as reports, certificates etc., duly signed by empowered designated authority (i.e. Chairman & Managing Director/ Managing Director) of the DISCOM.

e. DISCOM shall also submit the implementation plan for enhancing the energy efficiency level of targeted DTs to BEE within 2 months from the date of baseline measurements.

f. Before the commencement of implementation activity by DISCOM, BEE may conduct random verification of baseline measurements on sampling basis furnished by DISCOM through Accredited Energy Auditor

[25] https://beeindia.gov.in/sites/default/files/DTnoti.pdf Pg 19/47

Firms/Companies. During baseline verification, if the baseline total loss of DT is found to be less than verified/actual total loss (beyond the tolerance variation of [5]%), the baseline loss of all targeted DT's in the sample lot as identified by DISCOM shall be adjusted (i.e. increased) to the level of deviation (beyond [5]% tolerance) as found during random verification.

Table 18: Illustration for Baseline adjustment

| DT | Baseline Measurement by DISCOM | Measurement during Random Verification by BEE | Variation | Allowable Tolerance (%) | Remark |
|---|---|---|---|---|---|
| **1** | Total Loss:1780 W | Total Loss: 1850 W | +3.9% | [5%] | Within the tolerance limit. Baseline value is acceptable. |
| **2** | Total Loss:1800 W | Total Loss: 1840 W | +2.22% | [5%] | Within the tolerance limit. Baseline value is acceptable. |
| **nth** | Total Loss:1750 W | Total Loss: 1860 W | +6.29% | [5%] | Not within tolerance limit. Baseline value of all targeted DT's to be increased by 1.29% (i.e. 6.29% - 5%) |

g. Random verification of baseline measurements shall be carried out jointly with DISCOM official(s) with grade not less than Assistant Executive Engineer (AEE) to evade any ambiguity in the measurements.

h. Measurement of Total Loss shall be carried out as per [IS 2026 / IS 1180] and its subsequent amendments.

## 5.7. Implementation by DISCOM

a. DISCOM shall enhance the energy efficiency level of its DTs to the target level as per the timelines of the Policy and it may carry out the implementation in phases.

b. DISCOM may enhance its energy efficiency level by its own facilities (major repair center) or through outsourcing to its registered repair vendors.

c. On completion of enhancement of energy efficiency level of targeted DT's, DISCOM shall furnish the supporting documents demonstrating the achievement of targeted energy efficiency level.

d. DISCOM may account the resultant energy savings under the PAT scheme.

## 5.8. Monitoring and Verification (M&V)

a. DISCOM shall install the smart meter having AMR facility or covered under AMI, while enhancing the energy efficiency level of the DTs as per Ministry of Power notification F.No.23/35/2019-R&R dated 17 Aug 2021[26] and as per Central Electricity Authority (Installation and Operation of Meters) Regulations, 2019 and its amendments.

b. DT metered data on power, energy, loading, etc., may preferably be made available on real time basis through platforms (such as website, mobile app etc.).

c. Post implementation of DT refurbishment and enhanced asset management practice by DISCOM, the monitoring period for the enhanced energy efficiency of DT shall be for minimum [3] (three) years with a quarterly reporting to [BEE].

d. DISCOM shall maintain the record on annual loss level of refurbished or enhanced energy efficient DT with respect to its annual average loading.

[26] https://powermin.gov.in/sites/default/files/webform/notices/Notification_regarding_timelines_for_the_replacement_of_existing_meteRS_with_smart_meteRS_0_0.pdf

e. At the end of 1st year, an independent verification by the accredited energy auditor appointed by [BEE] shall be carried out to verify the annual loss level of the DT with respect to its annual average loading, basis the untampered recorded meter data.

f. In case of deviation in annual load loss level (on higher side) from the target level,

    i. **For Non-Star Labelled DT:** DISCOM shall restore the loss level of DTs to its target energy efficiency level either under refurbishment warranty or at its own cost.

    ii. **For Star Labelled DT within warranty period:** Either DISCOM or Original Equipment Manufacturer (OEM) shall restore the loss level of DTs to its respective star level +10% tolerance at its own cost.

    iii. **For Star Labelled DT outside warranty period:** DISCOM shall restore the loss level of DTs to its respective star level +10% tolerance at its own cost.

g. To improve the reliability of DT, the current and temperature measurements of DT on random basis shall not exceed the limit for DT loading beyond the name plate rating as under IS2026:2009 and its amendments if any.

h. DISCOM shall perform continuous condition monitoring of DT, and in case of loading violation more than [10] times in a month (i.e., violation in current and temperature readings), then, any subsequent event of DT failure shall be considered as accountability of DISCOM and its negligence to mitigate such overloading event.

## 5.9. Deviation from Target Energy Efficiency Level and Current & Temperature Tolerance

**a.** In case of deviation in annual loss from target energy efficiency level, the cost of deviated energy loss shall not be passed on to the retail consumers for the entire deviation period (i.e. period starting from completion of DT refurbishment) until the deviation is brought under the limits. SERC shall safeguard that such costs are not passed on to the retail consumers.

Table 19: Illustration for estimation of cost of deviated energy loss

| Annual Loss Level at Annual Average Loading (A) | Target Energy Efficiency Level (adjusted to annual average loading) (B) | Deviation (C = A-B) | Annual Energy Loss, kWh (D) | Cost of Deviated Energy Loss, INR (E = D x ACOS) |
|---|---|---|---|---|
| **1,650 W (Total Loss)** | **1,000 W (Total Loss)** | **650 W** | **650W x 8,000 HRS. of operation/1000 = 5,200 kWh** | **INR 31,200** (5,200 kWh x INR 6 per kWh) |
| **INR 31,200 shall not be allowed to pass on to the consumers** | | | | |

b. In case the deviations are un-addressable, the DISCOM shall replace the DT with a minimum Star 1 level DT under prevailing energy consumption standards i.e., energy consumption standards as under BEE's notification S.O.4062(E) dated 16th Dec, 2016 and its amendments if any.

c. In case of failure of DT with violations on loading i.e., current and temperature, the cost of such failure (including Repair & Maintenance Cost or Replacement Cost) shall not be allowed to pass on to the retail consumer. SERC shall safeguard that such costs are not passed on to the retail consumers.

## 5.10. Procurement

a. DISCOMs may have minimum warranty period of [3] (three) years with OEM's and/or Repairers, in case of procurement of new DT or repairer services.

b. In case of repairing or refurbishment, the loss level of DT during post repair test shall be within the target energy efficiency level.

## 5.11. Fiscal and Non-Fiscal Support

a. DISCOM is allowed to utilize the financial support from applicable Central and State Scheme such as Revamped Distribution Sector Scheme to enhance its DT energy efficiency performance under the Policy.

b. BEE may provide capacity building support to DISCOM on enhancing the DT energy efficiency performance.

## 5.12. Consequence for Non-Implementation

a. In case of non-implementation of the Policy, the SERC may disallow the [100%] of the cost of deviated energy loss and [50%] of the Repair and Maintenance (R&M) cost of all DT's.

b. Where no baseline activity is carried out by the DISCOM, SERC may arrive the cost of deviated energy loss with its assumptions to disallow such costs.

## 5.13. Administration of the Policy

### 5.13.1. Nodal Agency

a. Bureau of Energy Efficiency (BEE) is nodal agency for implementation of the Policy.

b. BEE shall co-ordinate with DISCOM and State Designated Agency (SDA) to administer and monitor the Policy as envisaged under EC Act 2001.

### 5.13.2. State Designated Agency (SDA)

a. State Designated Agency shall be any agency of state government which will be identified by BEE.

b. Role of SDA is to facilitate and monitor DISCOMs in implementing the Policy.

# 6. Way Forward

## 6.1. Implementation of Policy

BEE may deliberate the Policy Paper with Ministry of Power and implement the same.

## 6.2. Capacity Building

Refurbishment of DT is a cost-effective measure to reduce the technical loss in the distribution network. DT Refurbishment initiative can help utilities to reduce their technical loss and power purchases cost thereby lowering its overall cost of operations.

The capacity building and other support (i.e. fiscal) is essential for the DISCOMs to implement DT Refurbishment in their respective areas. In this context, Bureau of Energy Efficiency may launch a programme for capacity building of DISCOMs. This shall help in capacity building of DISCOMs in below areas to promote energy efficiency in distribution network in their respective states.

- Technical know-how on refurbishment of DT's
- Bid Process Management for DT Refurbishment
- M&V of refurbished DT performance

The objective of the capacity building programme shall be to implement the DT Refurbishment action plan in the DISCOM's areas. The following activities may be initiated by BEE under the programme.

- Selection of beneficiary DISCOMs under the Program
- Signing of Tripartite Memorandum of Understanding (MoU) between BEE, selected DISCOMs and respective SDAs.
- Engaging Project Management Consultants (PMCs) for undertaking activities under "Capacity Building of DISCOMs" program for the selected DISCOMs
- Providing Manpower Support to selected DISCOM for facilitation of DT Refurbishment related activities.

# Appendix A

## A.1. Improved Reliability due to DT Refurbishment

The PoC carried out in 100kVA DT of MSEDCL has resulted in below functionality which demonstrates the reliability of refurbished DT at various operating conditions (loading and temperature).

Post refurbishment, 100kVA DT was reinstated into the distribution network and performance was monitored, the results from monitoring are as below:

### A. Consumption Pattern

From the data available during the monitoring period, it was observed that the refurbished DT was able to handle overloading, due to kVA enhancement from refurbishment. The details are as below:

#### 1. Maximum Monthly Consumption

It was observed that there is a decreasing trend in consumption in the months from July to October.. Also, there was an increasing trend in consumption observed from December to June. Maximum consumption was noticed in May month Detailed Loading is shown below:

Figure 11: Refurbished DT monthly loading (kWH), during the monitoring period (MSEDCL)

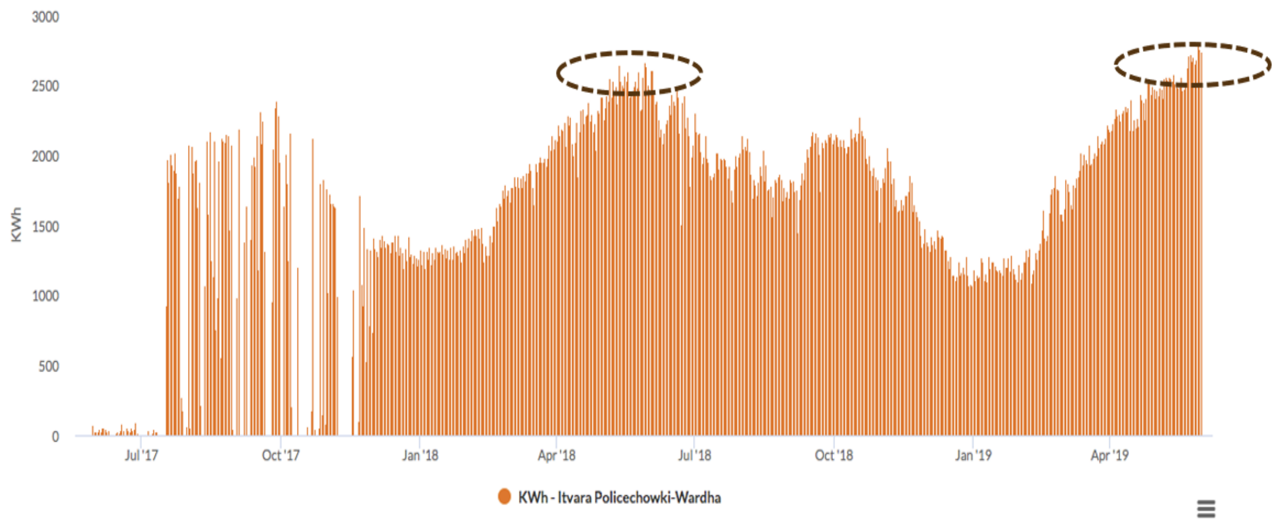



Table 20: Refurbished DT Maximum monthly loading (kWh), during the monitoring period (MSEDCL)

| Month | May 2018 | May 2019 |
|---|---|---|
| Consumption (kWh) | 2666 | 2789 |

#### 2. kVA loading on DT

Due to the enhancement of capacity from refurbishment, 100 kVA transformer was able to handle about upto 135.85 kVA load without any failure. Detailed Loading is shown below:

*Figure 12: Refurbished DT kVA loading, during monitoring period (MSEDCL)*

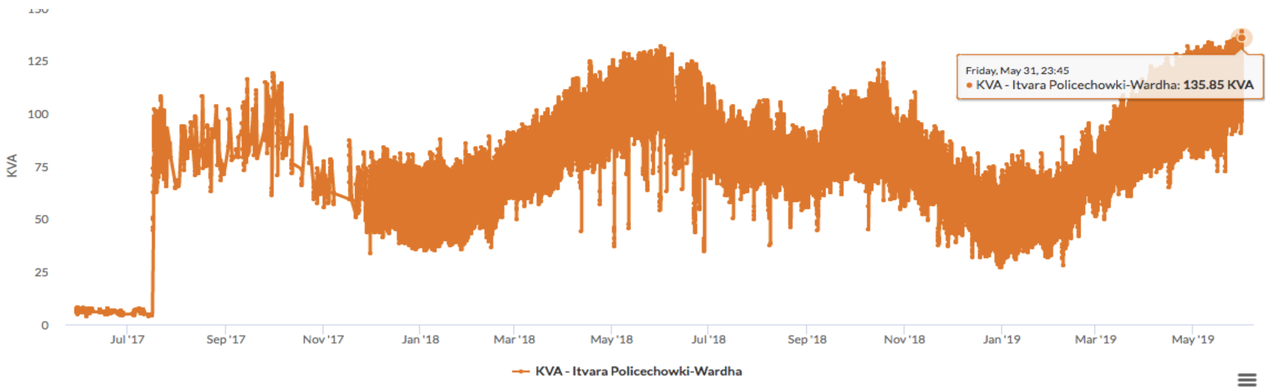



Table 21: Refurbished DT monthly average kVA loading, during the monitoring period (MSEDCL)

| 2017 | | | | | | 2018 | | | | | | | | | | | | 2019 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| 62 | 84 | 93 | 89 | 64 | 57 | 55 | 63 | 81 | 96 | 107 | 99 | 84 | 79 | 83 | 87 | 72 | 53 | 50 | 61 | 82 | 100 | 110 |

## 3. Average kW loading on DT

Due to the enhancement of capacity from refurbishment, 100 kVA transformer was able to handle a kW load as high as 116.26 without failure at 0.98 power factor at an ambient temperature $40^0$ C. Detailed Loading is shown below:

Figure 13: Refurbished DT kW loading, during monitoring period (MSEDCL)

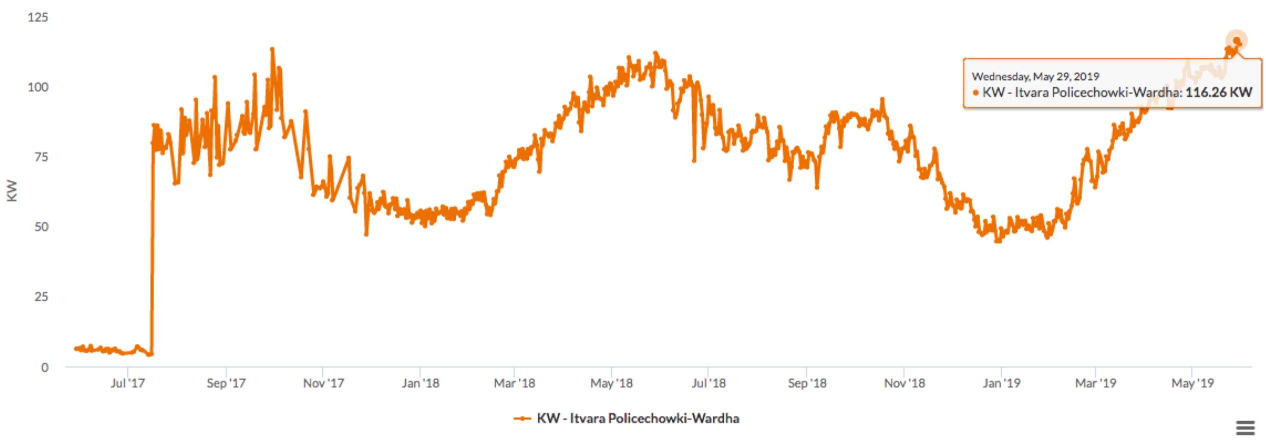


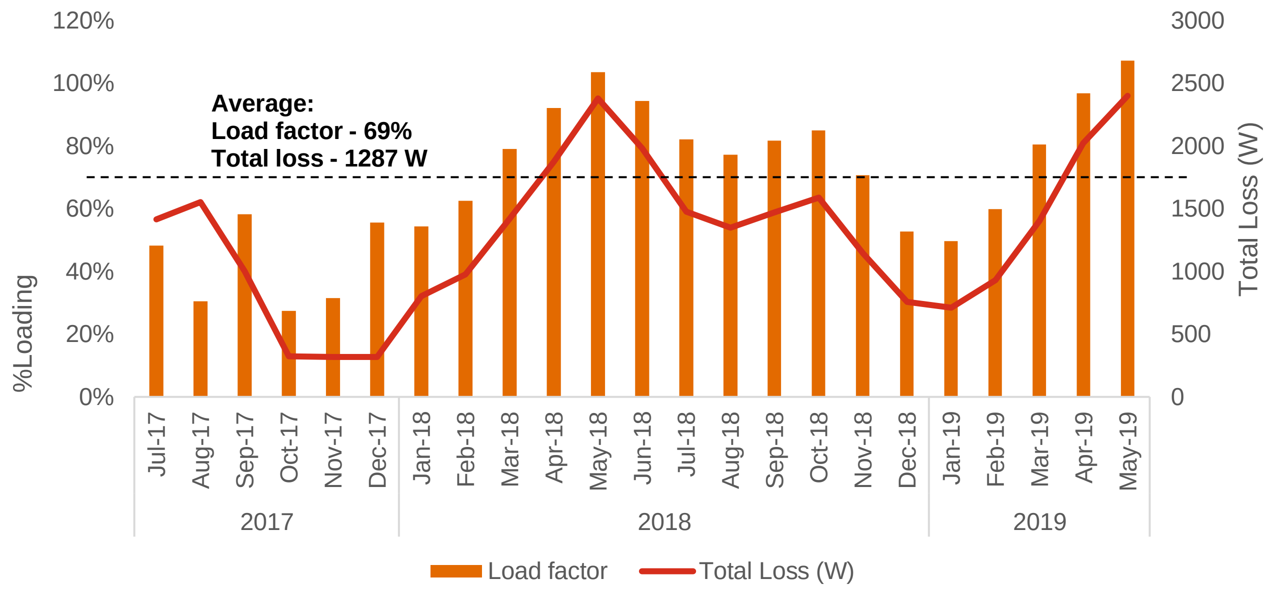

Table 22: Refurbished DT average monthly kW loading, during the monitoring period (MSEDCL)

| 2017 | | | | | | 2018 | | | | | | | | | | | | 2019 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| 82 | 86 | 87 | 93 | 66 | 58 | 54 | 62 | 78 | 89 | 103 | 97 | 83 | 78 | 78 | 88 | 74 | 58 | 49 | 59 | 78 | 96 | 106 |

## B. Load Factor & Total Technical loss

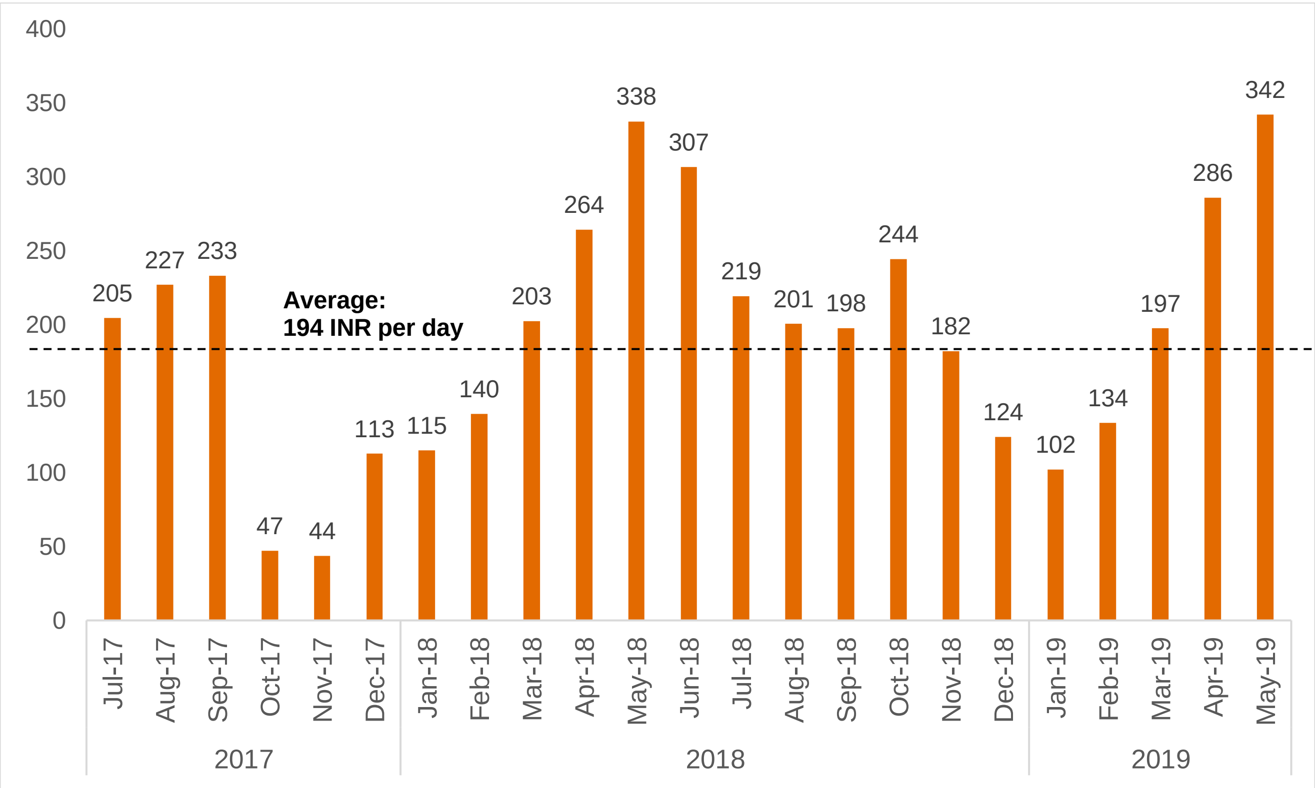
Over the period of monitoring, the average load factor was observed to be 69% with an average loss of 1,287 W, a significant reduction from the pre-repair baseline loss of 2,241 W. This lowered technical loss will lower the average lifetime operating temperature of the DT, which helps in extending the life of the DT and improving reliability. The DT post-repair hasn't failed during the monitoring period of 2 years, whereas it used to fail every year previously. The Loading and loss profile of DT during the monitoring period is shown below:

Figure 14: Loading and technical losses in refurbished DT, during monitoring period (MSEDCL)




Also, Post repair, revenue loss due to technical losses reduced by 40% due to better operational performance from refurbishment. The Average loss (INR per day) are captured in the figure below:

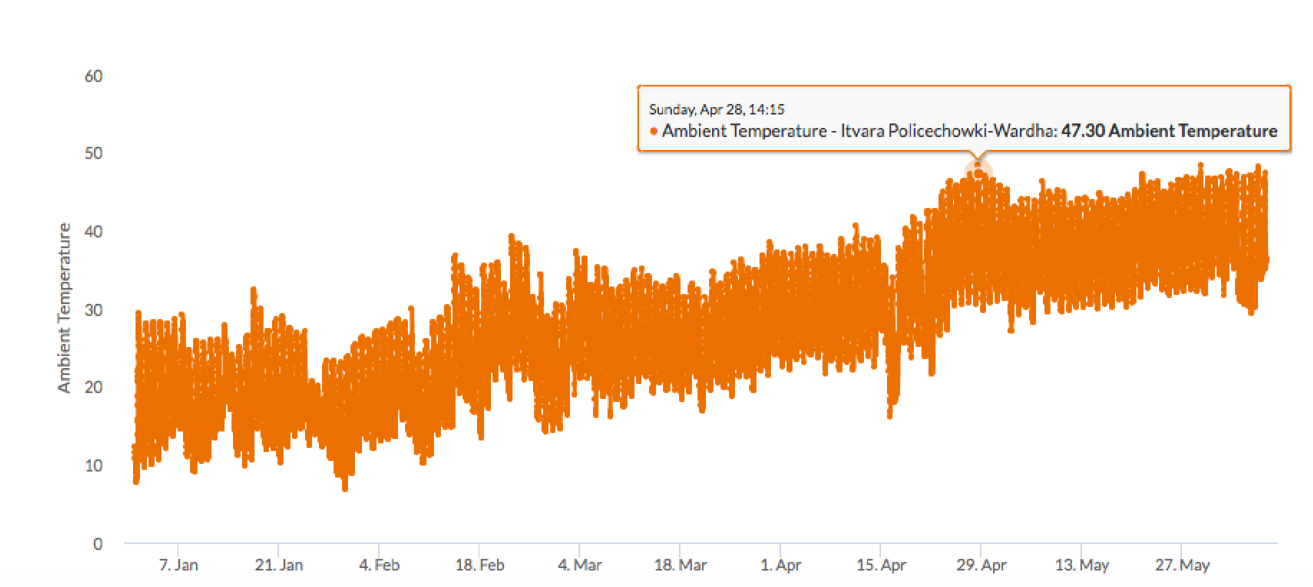
Figure 15: Average daily technical loss (INR per day) in refurbished DT, during monitoring period (MSEDCL)



### C. Temperature Profile

The temperature profile of the refurbished DT over the monitored period of 2 years shows that it has sustained an ambient temperature as high as $47^{0}$ C. Detailed temperature profile is shown below:

Figure 16: Temperature profile of refurbished DT, during monitoring period (MSEDCL)




Above results has sturdily demonstrated that the DT refurbishment has resulted in an increase in reliability with respect to change in operating conditions.

# A.2. Impact of DT Refurbishment on Average Billing Rate (ABR)

The inputs that are considered for assessing the impact of DT Refurbishment on ABR are as below

Table 23: Assumptions for assessment of Refurbishment of DTs

| Sr.No. | Particulars | Unit | Details |
|---|---|---|---|
| **1** | Units Saved for Each DT | kWh/year | 4,779 |
| **2** | No of DTs | Nos | 1 |
| **3** | Total Units Saved (A) | kWh/year/DT | 4,779 |
| **4** | ACOS (B) | INR /kWh | 6.78 |
| **5** | Total amount saved (C=A*B) | INR/year | 32,402 |
| **6** | Total Cost for Active Repair | INR | 98,131 |
| **7** | Total Cost for Conventional Repair | INR | 11,342 |
| **8** | Incremental Cost | INR | 86,789 |
| **9** | Initial Cost of DT | INR | 165,000 |

The cost of the new DTs to be replaced by DISCOM after DT failure are considered as per the energy efficiency rating shown in table below,

Table 24: Cost of DTs as per the ratings

| Sr.No. | Particulars | Unit | Cost per DT | |
|---|---|---|---|---|
| **1** | Type of DT | | Al | Cu |
| **2** | 1 star | INR | 165000 | 240000 |
| **3** | 3 star | INR | 210000 | 280000 |

## I. Impact of Technical loss and Recurring Repair Cost on ABR

### a. 100 kVA DT

The Conventional Repair is a repair of the DTs in as usual scenario, where DTs get repaired for frequent intervals (every 3 years or less), without improvement in energy efficiency and useful life.

The technical loss in DTs of 100kVA capacity assumed as 4,779 units per year (basis the PoC).

Table 25: Revenue loss due to Conventional Repair of DTs

| Sr.No. | ParticulaRS | Unit | Results for 1 Year | Results for 25 Years (cumulative) |
|---|---|---|---|---|
| **1** | Total Units loss | (kWh/year) | 4,779[27] | 109,917 |
| **2** | ACOS | INR /kWh | 6.78 | 6.78 |
| **3** | Revenue loss due to technical loss | INR | 32,402 | 745,237 |
| **4** | Total Cost for R&M | INR | 11,342 | 90,736 |
| **5** | Total (Revenue loss + R&M) to be bearded by the Discoms | INR | 43,744 | 835,973 |

Basis the above, the impact of revenue loss and cost of R&M on ABR is as below:

[27] Assumed to be starting from 3rd year onwards after the 1st repair.

Table 26: Per unit Revenue loss w.r.t saleable Units due to Revenue Loss and Recurring Repair of DTs

| Sr.No. | Particulars | Unit | Results for (A) | | Saleable Energy (kWh) * (B) | | Loss in INR Per kWh sales (A/B) | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 Year | 25 Years | 1 Year | 25 Years | 1 Year | 25 Years |
| 1 | Total Units loss | kWh/ year | 4,779[28] | 109,917 | 490,560 | 12,264,000 | 0.97% | 0.90% |
| 2 | Avg. cost of supply | INR/ kWh | 6.78 | 6.78 | 490,560 | 12,264,000 | | |
| 3 | Total Revenue loss | INR | 32,402 | 745,237 | 490,560 | 12,264,000 | 0.07 | 0.06 |
| 4 | Total Cost of R&M | INR | 11,342 | 90,736 | 490,560 | 12,264,000 | 0.02 | 0.01 |
| 5 | Total (Revenue loss + R&M) to be bear by the DISCOM | INR | 43,744 | 835,973 | 490,560 | 12,264,000 | 0.09 | 0.07 |

*At 70% loading

The impact of revenue loss and R&M cost on ABR with a service life of 100 kVA DT for 25 years is INR 0.06 per kWh and INR 0.01 per kWh (totaling INR 0.07 per kWh) which is avoidable with DT refurbishment by saving 4,779 kWh of energy annually and avoiding recurring R&M cost.

### b. 200 kVA DT

The technical loss in DTs of 200kVA capacity assumed as 4,858 units per year (basis the PoC).

Table 27: Revenue loss due to Conventional Repair of DTs

| Sr.No. | Particulars | Unit | Results for | |
|---|---|---|---|---|
| | | | 1 Year | 25 Years (cumulative) |
| 1 | Total Units loss | (kWh/year) | 4,858[29] | 111,734 |
| 2 | Avg. cost of supply | INR/kWh | 6.78 | 6.78 |
| 3 | Revenue loss due to technical loss | INR | 32,937 | 757,557 |
| 4 | Total Cost for R&M | INR | 19,973 | 159,784 |
| 5 | Total (Revenue loss + R&M) to be bear by the Discoms | INR | 52,910 | 917,341 |

Basis the above, the impact of revenue loss and cost of R&M on ABR is as below

Table 28: Per unit Revenue loss w.r.t saleable Units due to Revenue Loss and Recurring Repair of DTs

| Sr.No. | Particulars | Unit | Results for (A) | | Saleable Energy (kWh) * (B) | | Loss in INR Per kWh sales (A/B) | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 Year | 25 Years | 1 Year | 25 Years | 1 Year | 25 Years |
| 1 | Total Units loss | kWh/ year | 4,858[30] | 111,734 | 9,81,120 | 24,528,000 | 0.50% | 0.46% |
| 2 | Avg. cost of supply | INR/ kWh | 6.78 | 6.78 | 9,81,120 | 24,528,000 | | |
| 3 | Total Revenue loss | INR | 32,937 | 757,557 | 9,81,120 | 24,528,000 | 0.03 | 0.03 |
| 4 | Total Cost for R&M | INR | 19,973 | 159,784 | 9,81,120 | 24,528,000 | 0.02 | 0.01 |
| 5 | Total (Revenue loss + R&M) to be bear by the DISCOM | INR | 52,910 | 917,341 | 9,81,120 | 24,528,000 | 0.05 | 0.04 |

*At 70% loading

The impact of revenue loss and R&M cost on ABR with a service life of 200 kVA DT for 25 years is INR 0.03 per kWh and INR 0.01 per kWh (totaling INR 0.04 per kWh) which is avoidable with DT refurbishment through saving of 4,858 kWh of energy annually and avoiding the recurring R&M cost.

[28] Assumed to be starting from 3rd year onwards after the 1st repair.
[29] Assumed to be starting from 3rd year onwards after the 1st repair.
[30] Assumed to be starting from 3rd year onwards after the 1st repair.

## II. Impact of Avoided Capex on ABR through DT Refurbishment

### a. 100 kVA DT

The refurbishment of failure DTs with an additional cost is assumed as Capex during the year and this additional capitalization during the year will have impact on ARR component and tariff. Details on inputs and calculation considered for arriving the impact of avoided capex on ABR through DT refurbishment are shown below:

Table 29: ARR Components – 100 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| **1** | Capital Expenditure | INR Crore | 0.0098 |
| **2** | Capitalization of Expenditure | INR Crore | 0.0098 |
| **3** | 70% of Debt | INR Crore | 0.0069 |
| **4** | 30% of Equity | INR Crore | 0.0029 |

Table 30: Impact on Interest on Project Loans – 100 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| **1** | Debt Addition due to Refurbishment of DT | INR Crore | 0.01 |
| **2** | Average debt | INR Crore | 0.0034 |
| **3** | Rate of interest (%)- (SBI MCLR for One year) | % | 7.00% |
| **4** | Interest on Project Loans | INR Crore | 0.0002 |

Table 31: Impact on ROE – 100 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| **1** | Equity addition due to Refurbishment of DT | INR Crore | 0.0029 |
| **2** | Average Equity | INR Crore | 0.0015 |
| **3** | RoE @ 16% | INR Crore | 0.0002 |

Table 32: Impact on Depreciation – 100 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| **1** | Add: Addition due to Refurbishment of DT | INR Crore | 0.01 |
| **2** | Rate of Depreciation | % | 5.28% |
| **3** | Depreciation | INR Crore | 0.001 |

The impact on ABR due to additional capex or avoided Capex[31] is INR 0.02 per kWh for 100kVA DT and the details are as below

Table 33: Impact on ABR due to refurbishment – 100 kVA DT

| S.No. | | Parameter | Unit | Value |
|---|---|---|---|---|
| **1** | | **Impact on Components of ARR** | INR Crore | |
| | **a** | Interest on Project Loans | RS. Crore | 0.0002 |
| | **b** | RoE @ 16% | INR Crore | 0.0002 |
| | **c** | Depreciation | INR Crore | 0.0005 |
| | **d** | **Total** | **INR Crore** | **0.0010** |
| **2** | | **Sales** | **MU** | **0.4906** |
| **3** | | **Impact on ABR due to Refurbishment of DT (1d/2)** | **INR/kWh** | **0.0203** |

[31] Cost of DT refurbishment is about 50% of the cost of new DT (basis the PoC)

### b. 200 kVA DT

The refurbishment of failure DTs with an additional cost is assumed as Capital Expenditure (Capex) during the year and this additional capitalization during the year will have impact on ARR component and tariff.

Details on inputs and calculation considered for arriving the impact of avoided capex on ABR through DT refurbishment are shown below.

Table 34: ARR components – 200 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Capital Expenditure | INR Crore | 0.0152 |
| 2 | Capitalization of Expenditure | INR Crore | 0.0152 |
| 3 | 70% of Debt | INR Crore | 0.0106 |
| 4 | 30% of Equity | INR Crore | 0.0045 |

Table 35: Impact on Interest on Project Loans – 200 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Debt Addition due to Refurbishment of DT | INR Crore | 0.01 |
| 2 | Average debt | INR Crore | 0.01 |
| 3 | Rate of interest (%)- (SBI MCLR for One year) | % | 7.00% |
| 4 | Interest on Project Loans | INR Crore | 0.0004 |

Table 36: Impact on RoE – 200 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Equity addition due to Refurbishment of DT | INR Crore | 0.0045 |
| 2 | Average Equity | INR Crore | 0.0023 |
| 3 | RoE @ 16% | INR Crore | 0.0004 |

Table 37: Impact on Depreciation – 200 kVA DT

| S.No. | Parameter | Unit | Value |
|---|---|---|---|
| 1 | Add: Addition due to Refurbishment of DT | INR Crore | 0.015 |
| 2 | Rate of Depreciation | % | 5.28% |
| 3 | Depreciation | INR Crore | 0.001 |

The impact on ABR due to additional capex or avoided Capex[32] is RS. 0.016 per kWh for 100kVA DT and the details are as below

Table 38: Impact on ABR due to refurbishment – 200 kVA DT

| S.No. | | Parameter | Unit | Value |
|---|---|---|---|---|
| 1 | | **Impact on Components of ARR** | INR Crore | |
| | **a** | Interest on Project Loans | INR Crore | 0.0004 |
| | **b** | RoE @ 16% | INR Crore | 0.0004 |
| | **c** | Depreciation | INR Crore | 0.0008 |
| | **d** | **Total** | INR Crore | **0.0015** |
| 2 | | **Sales** | **MU** | **0.9811** |
| 3 | | **Impact on ABR due to Refurbishment of DT (1d/2)** | **INR/kWH** | **0.016** |

[32] Cost of DT refurbishment is about 50% of the cost of new DT (basis the PoC)

# A.3. Assumptions for estimation of savings potential due to refurbishment

Based on secondary research and analysis, following assumptions were made:

1. For states with no failure rate information, failure rate has been approximated from peer states with similar DT profile.
2. Conservatively, for states with no available peers, national average failure rate has been used as proxy for state's failure rate.
3. Based on the available data on split of DT volume, by capacity, for Madhya Pradesh[33]) and Karnataka[34] an average of capacity split has been calculated. As Madhya Pradesh is an agricultural based economy and Karnataka is an Industrial economy, the average split calculated using the data of these two states may be representative of transformer split for the remaining states & UTs

Table 39: Assumed split of Installed DTs, by capacity, based on % of MVA capacity installed

| Capacity | >200 kVA | 200 kVA | 100 kVA | 63 kVA | 25 kVA | <25 kVA |
|---|---|---|---|---|---|---|
| **% of installed MVA** | 34.23% | 2.23% | 28.93% | 15.29% | 18.81% | 0.51% |

4. Average size of transformers over 200 kVA, and below 25 kVA has been considered as 315 kVA and 10 kVA respectively based on Proof of Concept (PoC) studies.
5. Though the failed DTs can be unrated/rated as per old BEE standards/New BEE standards, conservatively it was assumed that, failed DTs are rated and are rated at least 1 star, as per BEE Standards & Labelling (S&L) program (valid up to 31st December 2016). This is because the chance of failure would increase with age and unrated DTs will have technical losses higher than BEE specifications
6. Based on the results of PoC studies, the average deviation in losses from technical specifications of star 1 rated DT (as per BEE S&L program, valid up to 31st December 2016) in an inefficiently operating legacy DTs & conventionally repaired DTs, post-conventional repair, had been assumed as below:

Table 40: Deviation in technical losses from rated loss levels, in DTs post conventional repair / Legacy DTs operating inefficiently

| Loss | Deviation |
|---|---|
| **No-load loss** | +15% |
| **Full load loss** | +30% |

7. Based on PoC studies, the average deviation in losses from technical specifications of star 1 rated DT (as per BEE S&L program, valid up to 31st December 2016) in refurbished legacy DTS, and refurbished failed DTs had been assumed as below:

Table 41: Deviation in technical losses from rated loss levels, in refurbished DTs

| Loss | Deviation |
|---|---|
| **No-load loss** | +10% |
| **Full load loss** | -30% |

8. From secondary research[35], it is assumed conservatively that
   - 70% of the failed DTs are repairable
   - 30% of the failed DTs are beyond repair as per conventional repair practices and they are replaced

[33] Source: PoC studies by ICA in MPPKVVCL
[34] Source: BESCOM
[35] https://www.cstep.in/drupal/sites/default/files/2019-01/CSTEP_RR_Strategic_Roadmap_for_Implementation_of_UDAY_Scheme_Dec_2017.pdf

9. Though it is likely that Legacy DTs form a higher percentage of installed DT capacity, because the rated life of a DT is more than 25 years, conservatively, it is assumed that:
    - 60% of operational DTs in the distribution network are new, operate as per IS 1180 (Energy Efficiency Level 1)
    - 40% of operational DTs are legacy DTs, operate at deviation levels as specified in Appendix A.3
10. Out of the 30% failed DTs that were unrepairable conventionally, it is assumed 20% can be refurbished on a conservative basis.
11. From PoC studies, average load on DT was considered as 70%
12. In order to arrive at CAPEX savings, the following prices for new DTs has been used:

Table 42: Assumed prices of new AL star 1 rated DT

| Capacity (kVA) | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA |
|---|---|---|---|---|---|---|
| **Price (RS)** | 3,00,000 | 1,80,000 | 1,00,000 | 95,000 | 49,680 | 51,500 |

Source: Indiamart

# A.4. DT Failure Rate

Table 43: DT failure rates, by state

| State | Failure Rate | DT Volume | Failed Volume | Source |
|---|---|---|---|---|
| **Maharashtra** | **8.85%** | **6,26,248** | **55,423** | https://powermin.gov.in/sites/default/files/uploads/Maharashtra_Final_Report_27022016.pdf |
| **Gujarat** | **5.62%** | **14,62,702** | **82,241** | |
| **DGVCL** | 4.94% | | | https://powerline.net.in/2019/03/27/dgvcl/#:~:text=Further%2C%20the%20distribution%20transformer%20(DT,per%20cent%20in%202017%2D18. |
| **PGVCL** | 8.55% | | | https://www.mgvcl.com/Upload/circulaRS/GERC%20Tariff%20Order%20dated%2031%2003%202020%20for%20MGVCL.pdf |
| **MGVCL** | 3.42% | | | https://www.mgvcl.com/Upload/circulaRS/GERC%20Tariff%20Order%20dated%2031%2003%202020%20for%20MGVCL.pdf |
| **UGVCL** | 5.58% | | | http://www.ugvcl.com/UGVCL%20wins%20Semi-Finalist%20SKOCH%20Order%20of%20Merit%20Award.pdf |
| **Karnataka** | **10.68%** | **8,70,320** | **92,933** | |
| **BESCOM** | 6.96% | | | https://bescom.karnataka.gov.in/page/Departments+of+Corporate+Office/Operations/Transformer+Details/en |
| **GESCOM** | 13.21% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **HESCOM** | 11.68% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **MESCOM** | 11.61% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **MCSCL** | 9.93% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Rajasthan** | **9.45%** | **17,74,819** | **1,67,721** | |
| **AVVNL** | 9.18% | | | https://powerline.net.in/2019/02/05/avvnl/ |
| **JDVVNL** | 9.87% | | | https://cag.gov.in/uploads/download_audit_report/2019/Chapter_3_Compliance_Audit_Observations_relating_to_Power_Sector_Undertakings_of_Report_No_3_of_2019_Public_Sector_Undertakings_Government_of_Rajasthan.pdf |
| **JVVNL** | 9.30% | | | https://cag.gov.in/uploads/download_audit_report/2019/Chapter_3_Compliance_Audit_Observations_relating_to_Power_Sector_Undertakings_of_Report_No_3_of_2019_Public_Sector_Undertakings_Government_of_Rajasthan.pdf |
| **Uttar Pradesh** | **16.05%** | **9,35,944** | **1,50,238** | |
| **DVVNL** | 18.38% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **KESCO** | 12.13% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **MVVNL** | 21.60% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **PaVVNL** | 10.00% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **PuVVNL** | 18.15% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Madhya Pradesh** | **10.85%** | **7,78,552** | **84,499** | |

| State | Failure Rate | DT Volume | Failed Volume | Source |
|---|---|---|---|---|
| **MPMaKVVCL** | 10.90% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **MPPaKVVCL** | 8.17% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **MPPoKVVCL** | 13.49% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Punjab** | **4%** | **10,67,021** | **42,681** | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Andhra Pradesh** | **5.88%** | **9,50,341** | **55,833** | |
| **APEPDCL** | 6.43% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **APSPDCL** | 5.32% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Telangana** | **10%** | **6,99,292** | **69,930** | https://telanganatoday.com/transformer-failures-down-in-telangana |
| **Haryana** | **5.37%** | **5,68,979** | **30,569** | |
| **DHBVNL** | 5.55% | | | https://herc.gov.in/WriteReadData/OrdeRS/O20210330a.pdf |
| **UHBVNL** | 5.20% | | | https://herc.gov.in/WriteReadData/OrdeRS/O20210330a.pdf |
| **West Bengal** | **7.04%** | **2,75,914** | **19,425** | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Bihar** | **6.23%** | **1,46,073** | **9,094** | |
| **NBPDCL** | 6% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **SBPDCL** | 6.45% | | | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Chhattisgarh** | **8%** | **1,68,277** | **13,463** | https://powermin.gov.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_chhattisgarh.pdf |
| **J&K** | **26.79%** | **52,708** | **14,121** | https://powermin.gov.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_jammu_and_kashmir.pdf |
| **Assam** | **5.28%** | **84,702** | **4,473** | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Uttarakhand** | **12.80%** | **69,256** | **8,865** | https://cag.gov.in/uploads/old_reports/state/Uttarakhand/2008/Civil/Civil_Uttarakhand_2008/chap_7.pdf |
| **Himachal Pradesh** | **4.04%** | **31,360** | **1,267** | https://cag.gov.in/uploads/old_reports/union/union_performance/2006_2007/Civil_%20Performance_Audits/Report_no_16/min_power.pdf |
| **Tripura** | **11.19%** | **14,632** | **1,638** | https://terc.tripura.gov.in/sites/default/files/Annual_Report_2018-19.pdf |
| **Goa** | **5.30%** | **6,302** | **335** | https://cag.gov.in/uploads/old_reports/union/union_performance/2006_2007/Civil_%20Performance_Audits/Report_no_16/min_power.pdf |
| **Meghalaya** | **5%** | **10,237** | **512** | https://smartpowerindia.org/knowledge/#PUBLICATIONS |
| **Chandigarh** | **5.29%** | **2,200** | **117** | https://powermin.gov.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_Chndigarh.pdf |
| **Total** | | **1,05,95,879** | **9,05,378** | |

Note:

- State's DT failure rate has been approximated as the average of failure rates of respective state DISCOMs (for example, failure rate of Bihar is assumed as simple average of failure rates of its DISCOMs NBPDCL and SBPDCL)
- Failure rates of these states has been used in conjunction with the DT volume, to calculate the failed volume

Based on the failure rate available, the national average failure rate has been calculated as (9,05,378 / 1,05,95,879) = 8.54%

Basis, the national average of 8.54% and assumptions 1 & 2 (Appendix A.3), failure rate of the remaining states has been approximated as below:

Table 44: Assumed DT failure rates, by state

| State | Failure Rate | Remark |
|---|---|---|
| **Tamil Nadu** | **12.12%** | Approximated as the average of failure rates of Rajasthan, UP & MP |
| **Orissa** | **7.11%** | Approximated as the average of failure rates of Bihar & Chhatisgarh |
| **Kerala** | **8.00%** | Approximated as the average of failure rates of Chhatisgarh |
| **Jharkhand** | **16.04%** | Approximated as the average of failure rates of Assam & J&K |
| **Puducherry** | **8.54%** | Approximated as the National Average Failure Rate |
| **Manipur** | **8.54%** | |
| **Aruncahal Pradesh** | **8.54%** | |
| **Nagaland** | **8.54%** | |
| **Sikkim** | **8.54%** | |
| **Daman & Diu** | **8.54%** | |
| **D&N Haveli** | **8.54%** | |
| **Mizoram** | **8.54%** | |
| **A&N Island** | **8.54%** | |
| **Lakshwadeep** | **8.54%** | |

# A.5. State wise Volume of Failed DTs, by capacity

Basis assumption 3 (Appendix A.3), failed volume of DTs has been approximated as below:

Table 45: Volume of failed DTs, state wise, by capacity

| State | Installed Capacity | | Transformer Split | | | | | | | Failure Rate | Failed Transformers | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | kVA | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total | % | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total |
| **Chandigarh** | 2200 | 733987 | 798 | 82 | 2124 | 1782 | 5522 | 375 | 10683 | 5.29% | 43 | 5 | 113 | 95 | 293 | 20 | 569 |
| **Delhi** | 55907 | 14893839 | 16183 | 1664 | 43091 | 36149 | 112044 | 7597 | 216728 | 6.63% | 1074 | 111 | 2859 | 2398 | 7432 | 504 | 14378 |
| **Haryana** | 568979 | 28287569 | 30736 | 3161 | 81842 | 68657 | 212803 | 14428 | 411627 | 5.37% | 1652 | 170 | 4397 | 3689 | 11433 | 776 | 22117 |
| **Himachal Pradesh** | 31360 | 2750234 | 2989 | 308 | 7957 | 6676 | 20690 | 1403 | 40023 | 4.04% | 121 | 13 | 322 | 270 | 836 | 57 | 1619 |
| **J&K** | 52708 | 6674515 | 7253 | 746 | 19311 | 16200 | 50212 | 3405 | 97127 | 26.79% | 1944 | 200 | 5174 | 4340 | 13452 | 913 | 26023 |
| **Punjab** | 1067021 | 35075690 | 38112 | 3919 | 101481 | 85133 | 263868 | 17890 | 510403 | 4.00% | 1525 | 157 | 4060 | 3406 | 10555 | 716 | 20419 |
| **Rajasthan** | 1774819 | 48526314 | 52726 | 5421 | 140397 | 117779 | 365055 | 24750 | 706128 | 9.45% | 4983 | 513 | 13268 | 11131 | 34498 | 2339 | 66732 |
| **Uttar Pradesh** | 935944 | 42924244 | 46640 | 4796 | 124189 | 104182 | 322911 | 21893 | 624611 | 16.05% | 7487 | 770 | 19935 | 16724 | 51834 | 3515 | 100265 |
| **Uttarakhand** | 69256 | 4319357 | 4694 | 483 | 12497 | 10484 | 32494 | 2203 | 62855 | 12.80% | 601 | 62 | 1600 | 1342 | 4160 | 282 | 8047 |
| **Chhattisgarh** | 168277 | 10359486 | 11257 | 1158 | 29973 | 25144 | 77933 | 5284 | 150749 | 8.00% | 901 | 93 | 2398 | 2012 | 6235 | 423 | 12062 |
| **Gujarat** | 1462702 | 54405089 | 59114 | 6078 | 157405 | 132047 | 409280 | 27748 | 791672 | 5.62% | 3324 | 342 | 8851 | 7425 | 23012 | 1561 | 44515 |
| **Madhya Pradesh** | 778552 | 40688599 | 44210 | 4546 | 117721 | 98756 | 306093 | 20752 | 592078 | 10.85% | 4799 | 494 | 12777 | 10719 | 33222 | 2253 | 64264 |
| **Maharashtra** | 626248 | 70706514 | 76826 | 7899 | 204568 | 171612 | 531912 | 36062 | 1028879 | 8.85% | 6800 | 700 | 18105 | 15188 | 47075 | 3192 | 91060 |
| **Daman & Diu** | 924 | 256290 | 279 | 29 | 742 | 623 | 1929 | 131 | 3733 | 8.54% | 24 | 3 | 64 | 54 | 165 | 12 | 322 |
| **D&N Haveli** | 1109 | 222850 | 243 | 25 | 645 | 541 | 1677 | 114 | 3245 | 8.54% | 21 | 3 | 56 | 47 | 144 | 10 | 281 |
| **Goa** | 6302 | 1015011 | 1103 | 114 | 2937 | 2464 | 7636 | 518 | 14772 | 5.30% | 59 | 7 | 156 | 131 | 405 | 28 | 786 |
| **Andhra Pradesh** | 950341 | 32561403 | 35380 | 3638 | 94207 | 79030 | 244954 | 16607 | 473816 | 5.88% | 2079 | 214 | 5535 | 4644 | 14392 | 976 | 27840 |
| **Telangana** | 699292 | 31229540 | 33933 | 3489 | 90354 | 75798 | 234934 | 15928 | 454436 | 10.00% | 3394 | 349 | 9036 | 7580 | 23494 | 1593 | 45446 |
| **Karnataka** | 870320 | 50070950 | 54405 | 5594 | 144866 | 121528 | 376675 | 25538 | 728606 | 10.68% | 5810 | 598 | 15469 | 12977 | 40222 | 2727 | 77803 |
| **Kerala** | 80630 | 9941820 | 10803 | 1111 | 28764 | 24130 | 74791 | 5071 | 144670 | 8.00% | 865 | 89 | 2302 | 1931 | 5984 | 406 | 11577 |
| **Tamil Nadu** | 309507 | 41707618 | 45318 | 4660 | 120669 | 101229 | 313759 | 21272 | 606907 | 12.12% | 5492 | 565 | 14624 | 12268 | 38023 | 2578 | 73550 |
| **Puducherry** | 2655 | 617946 | 672 | 70 | 1788 | 1500 | 4649 | 316 | 8995 | 8.54% | 58 | 6 | 153 | 129 | 398 | 28 | 772 |

| State | Installed Capacity | | Transformer Split | | | | | | | Failure Rate | Failed Transformers | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | kVA | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total | % | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total |
| **Lakshwadeep** | 113 | 17101 | 19 | 2 | 50 | 42 | 129 | 9 | 251 | 8.54% | 2 | 1 | 5 | 4 | 12 | 1 | 25 |
| **Bihar** | 146073 | 12170277 | 13224 | 1360 | 35211 | 29539 | 91555 | 6208 | 177097 | 6.23% | 824 | 85 | 2192 | 1839 | 5700 | 387 | 11027 |
| **Jharkhand** | 95638 | 6688789 | 7268 | 748 | 19352 | 16235 | 50319 | 3412 | 97334 | 16.04% | 1166 | 120 | 3104 | 2604 | 8069 | 548 | 15611 |
| **Orissa** | 229780 | 11040920 | 11997 | 1234 | 31944 | 26798 | 83059 | 5632 | 160664 | 7.11% | 854 | 88 | 2273 | 1907 | 5908 | 401 | 11431 |
| **West Bengal** | 275914 | 16248966 | 17656 | 1816 | 47012 | 39438 | 122238 | 8288 | 236448 | 7.04% | 1243 | 128 | 3310 | 2777 | 8606 | 584 | 16648 |
| **Sikkim** | 2466 | 297207 | 323 | 34 | 860 | 722 | 2236 | 152 | 4327 | 8.54% | 28 | 3 | 74 | 62 | 192 | 13 | 372 |
| **A&N Island** | 1067 | 179306 | 195 | 21 | 519 | 436 | 1349 | 92 | 2612 | 8.54% | 17 | 2 | 45 | 38 | 116 | 8 | 226 |
| **Aruncahal Pradesh** | 8892 | 448648 | 488 | 51 | 1299 | 1089 | 3376 | 229 | 6532 | 8.54% | 42 | 5 | 111 | 94 | 289 | 20 | 561 |
| **Assam** | 84702 | 5929169 | 6443 | 663 | 17155 | 14391 | 44605 | 3024 | 86281 | 5.28% | 341 | 36 | 906 | 760 | 2356 | 160 | 4559 |
| **Manipur** | 6352 | 578543 | 629 | 65 | 1674 | 1405 | 4353 | 296 | 8422 | 8.54% | 54 | 6 | 144 | 121 | 372 | 26 | 723 |
| **Meghalaya** | 10237 | 856984 | 932 | 96 | 2480 | 2080 | 6447 | 438 | 12473 | 5.00% | 47 | 5 | 124 | 104 | 323 | 22 | 625 |
| **Mizoram** | 1942 | 216500 | 236 | 25 | 627 | 526 | 1629 | 111 | 3154 | 8.54% | 21 | 3 | 54 | 45 | 140 | 10 | 273 |
| **Nagaland** | 3626 | 327391 | 356 | 37 | 948 | 795 | 2463 | 167 | 4766 | 8.54% | 31 | 4 | 82 | 68 | 211 | 15 | 411 |
| **Tripura** | 14632 | 1100302 | 1196 | 123 | 3184 | 2671 | 8278 | 562 | 16014 | 11.19% | 134 | 14 | 357 | 299 | 927 | 63 | 1794 |
| | | | | | | | | | | **Total** | 58300 | 6013 | 155202 | 130201 | 403513 | 27374 | 7,80,603 |

# A.6. Annual Energy and Cost Savings through Refurbishment of failed DT's

Technical loss in DTs has been calculated as sum of NLL and load loss i.e., (NLL+ (% Loading)^$^2$ x FLL). Difference in technical losses, if failed DTs are repaired: 1) Conventionally, 2) Refurbished is annual savings because of refurbishment. Basis assumptions (Appendix A.3) and failure rate data (Appendix A.4, Appendix A.5), DT technical loss in case of conventional repair and in case of refurbishment has been calculated and the difference of technical losses in both the cases, is the savings from refurbishment.

Table 46: Annual Energy & Cost Savings, by state, through refurbishment of failed DTs

| State | No of Repairable DTs, by Capacity (in nos) | | | | | | Technical losses in case of conventional repair (MU), by capacity | | | | | | Technical losses in case of refurbishment (MU), by capacity | | | | | | Annual Saving | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >200 | 200 | 100 | 63 | 25 | <25 | >200 | 200 | 100 | 63 | 25 | <25 | >200 | 200 | 100 | 63 | 25 | <25 | MU | INR (Crore) |
| **Chandigarh** | 31 | 4 | 80 | 67 | 206 | 14 | 0.77 | 0.08 | 1.00 | 0.58 | 1.02 | 0.02 | 0.48 | 0.05 | 0.62 | 0.37 | 0.66 | 0.01 | 1.27 | 0.47 |
| **Delhi** | 752 | 78 | 2002 | 1679 | 5203 | 353 | 18.58 | 1.58 | 24.91 | 14.63 | 25.71 | 0.51 | 11.68 | 0.98 | 15.60 | 9.16 | 16.59 | 0.36 | 31.55 | 23.41 |
| **Haryana** | 1157 | 119 | 3078 | 2583 | 8004 | 544 | 28.59 | 2.41 | 38.29 | 22.50 | 39.56 | 0.79 | 17.97 | 1.50 | 23.99 | 14.09 | 25.51 | 0.56 | 48.52 | 27.27 |
| **Himachal Pradesh** | 85 | 10 | 226 | 189 | 586 | 40 | 2.10 | 0.20 | 2.81 | 1.65 | 2.90 | 0.06 | 1.32 | 0.13 | 1.76 | 1.03 | 1.87 | 0.04 | 3.57 | 1.80 |
| **J&K** | 1361 | 140 | 3622 | 3038 | 9417 | 640 | 33.63 | 2.83 | 45.06 | 26.47 | 46.54 | 0.93 | 21.13 | 1.77 | 28.23 | 16.58 | 30.02 | 0.66 | 57.08 | 23.86 |
| **Punjab** | 1068 | 110 | 2842 | 2385 | 7389 | 502 | 26.39 | 2.23 | 35.36 | 20.78 | 36.52 | 0.73 | 16.58 | 1.39 | 22.15 | 13.01 | 23.55 | 0.51 | 44.80 | 27.19 |
| **Rajasthan** | 3489 | 360 | 9288 | 7792 | 24149 | 1638 | 86.21 | 7.29 | 115.55 | 67.89 | 119.35 | 2.38 | 54.18 | 4.54 | 72.39 | 42.52 | 76.98 | 1.68 | 146.38 | 99.69 |
| **Uttar Pradesh** | 5241 | 539 | 13955 | 11707 | 36284 | 2461 | 129.50 | 10.91 | 173.60 | 101.99 | 179.32 | 3.58 | 81.38 | 6.80 | 108.76 | 63.88 | 115.66 | 2.52 | 219.91 | 140.30 |
| **Uttarakhand** | 421 | 44 | 1120 | 940 | 2912 | 198 | 10.40 | 0.89 | 13.93 | 8.19 | 14.39 | 0.29 | 6.54 | 0.55 | 8.73 | 5.13 | 9.28 | 0.20 | 17.66 | 8.72 |
| **Chhattisgarh** | 631 | 66 | 1679 | 1409 | 4365 | 297 | 15.59 | 1.34 | 20.89 | 12.28 | 21.57 | 0.43 | 9.80 | 0.83 | 13.09 | 7.69 | 13.91 | 0.30 | 26.47 | 13.18 |
| **Gujarat** | 2327 | 240 | 6196 | 5198 | 16109 | 1093 | 57.50 | 4.86 | 77.08 | 45.29 | 79.61 | 1.59 | 36.13 | 3.03 | 48.29 | 28.36 | 51.35 | 1.12 | 97.64 | 53.02 |
| **Madhya Pradesh** | 3360 | 346 | 8944 | 7504 | 23256 | 1578 | 83.02 | 7.00 | 111.27 | 65.38 | 114.93 | 2.30 | 52.17 | 4.36 | 69.71 | 40.94 | 74.13 | 1.62 | 140.96 | 81.33 |
| **Maharashtra** | 4760 | 490 | 12674 | 10632 | 32953 | 2235 | 117.61 | 9.92 | 157.67 | 92.63 | 162.86 | 3.25 | 73.91 | 6.18 | 98.78 | 58.01 | 105.04 | 2.29 | 199.73 | 136.41 |
| **Daman & Diu** | 17 | 3 | 45 | 38 | 116 | 9 | 0.42 | 0.06 | 0.56 | 0.33 | 0.57 | 0.01 | 0.26 | 0.04 | 0.35 | 0.21 | 0.37 | 0.01 | 0.72 | 0.29 |
| **D&N Haveli** | 15 | 3 | 40 | 33 | 101 | 7 | 0.37 | 0.06 | 0.50 | 0.29 | 0.50 | 0.01 | 0.23 | 0.04 | 0.31 | 0.18 | 0.32 | 0.01 | 0.63 | 0.32 |
| **Goa** | 42 | 5 | 110 | 92 | 284 | 20 | 1.04 | 0.10 | 1.37 | 0.80 | 1.40 | 0.03 | 0.65 | 0.06 | 0.86 | 0.50 | 0.91 | 0.02 | 1.74 | 0.83 |
| **Andhra Pradesh** | 1456 | 150 | 3875 | 3251 | 10075 | 684 | 35.98 | 3.04 | 48.21 | 28.32 | 49.79 | 1.00 | 22.61 | 1.89 | 30.20 | 17.74 | 32.11 | 0.70 | 61.07 | 36.77 |
| **Telangana** | 2376 | 245 | 6326 | 5306 | 16446 | 1116 | 58.71 | 4.96 | 78.70 | 46.23 | 81.28 | 1.62 | 36.89 | 3.09 | 49.30 | 28.95 | 52.42 | 1.14 | 99.69 | 63.90 |

| State | No of Repairable DTs, by Capacity (in nos) | | | | | | Technical losses in case of conventional repair (MU), by capacity | | | | | | Technical losses in case of refurbishment (MU), by capacity | | | | | | Annual Saving | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >200 | 200 | 100 | 63 | 25 | <25 | >200 | 200 | 100 | 63 | 25 | <25 | >200 | 200 | 100 | 63 | 25 | <25 | MU | INR (Crore) |
| **Karnataka** | 4067 | 419 | 10829 | 9084 | 28156 | 1909 | 100.49 | 8.48 | 134.72 | 79.14 | 139.15 | 2.78 | 63.15 | 5.28 | 84.40 | 49.57 | 89.75 | 1.96 | 170.65 | 112.46 |
| **Kerala** | 606 | 63 | 1612 | 1352 | 4189 | 285 | 14.97 | 1.28 | 20.05 | 11.78 | 20.70 | 0.41 | 9.41 | 0.79 | 12.56 | 7.38 | 13.35 | 0.29 | 25.41 | 14.31 |
| **Tamil Nadu** | 3845 | 396 | 10237 | 8588 | 26617 | 1805 | 95.00 | 8.02 | 127.35 | 74.82 | 131.54 | 2.63 | 59.70 | 4.99 | 79.78 | 46.86 | 84.84 | 1.85 | 161.33 | 109.06 |
| **Puducherry** | 41 | 5 | 108 | 91 | 279 | 20 | 1.01 | 0.10 | 1.34 | 0.79 | 1.38 | 0.03 | 0.64 | 0.06 | 0.84 | 0.50 | 0.89 | 0.02 | 1.71 | 0.99 |
| **Lakshwadeep** | 2 | 1 | 4 | 3 | 9 | 1 | 0.05 | 0.02 | 0.05 | 0.03 | 0.04 | 0.00 | 0.03 | 0.01 | 0.03 | 0.02 | 0.03 | 0.00 | 0.07 | 0.16 |
| **Bihar** | 577 | 60 | 1535 | 1288 | 3990 | 271 | 14.26 | 1.21 | 19.10 | 11.22 | 19.72 | 0.39 | 8.96 | 0.76 | 11.96 | 7.03 | 12.72 | 0.28 | 24.20 | 15.15 |
| **DVC** | 44 | 5 | 116 | 97 | 299 | 21 | 1.09 | 0.10 | 1.44 | 0.85 | 1.48 | 0.03 | 0.68 | 0.06 | 0.90 | 0.53 | 0.95 | 0.02 | 1.83 | 0.00 |
| **Jharkhand** | 817 | 84 | 2173 | 1823 | 5649 | 384 | 20.19 | 1.70 | 27.03 | 15.88 | 27.92 | 0.56 | 12.69 | 1.06 | 16.94 | 9.95 | 18.01 | 0.39 | 34.25 | 21.68 |
| **Orissa** | 598 | 62 | 1592 | 1335 | 4136 | 281 | 14.78 | 1.25 | 19.80 | 11.63 | 20.44 | 0.41 | 9.29 | 0.78 | 12.41 | 7.28 | 13.18 | 0.29 | 25.08 | 11.99 |
| **West Bengal** | 871 | 90 | 2317 | 1944 | 6025 | 409 | 21.52 | 1.82 | 28.82 | 16.94 | 29.78 | 0.60 | 13.52 | 1.14 | 18.06 | 10.61 | 19.21 | 0.42 | 36.53 | 21.26 |
| **Sikkim** | 20 | 3 | 52 | 44 | 135 | 10 | 0.49 | 0.06 | 0.65 | 0.38 | 0.67 | 0.01 | 0.31 | 0.04 | 0.41 | 0.24 | 0.43 | 0.01 | 0.83 | 0.35 |
| **A&N Island** | 12 | 2 | 32 | 27 | 82 | 6 | 0.30 | 0.04 | 0.40 | 0.24 | 0.41 | 0.01 | 0.19 | 0.03 | 0.25 | 0.15 | 0.26 | 0.01 | 0.51 | 1.25 |
| **Aruncahal Pradesh** | 30 | 4 | 78 | 66 | 203 | 14 | 0.74 | 0.08 | 0.97 | 0.58 | 1.00 | 0.02 | 0.47 | 0.05 | 0.61 | 0.36 | 0.65 | 0.01 | 1.25 | 1.00 |
| **Assam** | 239 | 26 | 635 | 532 | 1650 | 112 | 5.91 | 0.53 | 7.90 | 4.63 | 8.15 | 0.16 | 3.71 | 0.33 | 4.95 | 2.90 | 5.26 | 0.11 | 10.02 | 5.88 |
| **Manipur** | 38 | 5 | 101 | 85 | 261 | 19 | 0.94 | 0.10 | 1.26 | 0.74 | 1.29 | 0.03 | 0.59 | 0.06 | 0.79 | 0.46 | 0.83 | 0.02 | 1.60 | 1.04 |
| **Meghalaya** | 33 | 4 | 87 | 73 | 227 | 16 | 0.82 | 0.08 | 1.08 | 0.64 | 1.12 | 0.02 | 0.51 | 0.05 | 0.68 | 0.40 | 0.72 | 0.02 | 1.38 | 0.79 |
| **Mizoram** | 15 | 3 | 38 | 32 | 98 | 7 | 0.37 | 0.06 | 0.47 | 0.28 | 0.48 | 0.01 | 0.23 | 0.04 | 0.30 | 0.17 | 0.31 | 0.01 | 0.62 | 0.38 |
| **Nagaland** | 22 | 3 | 58 | 48 | 148 | 11 | 0.54 | 0.06 | 0.72 | 0.42 | 0.73 | 0.02 | 0.34 | 0.04 | 0.45 | 0.26 | 0.47 | 0.01 | 0.92 | 0.69 |
| **Tripura** | 94 | 10 | 250 | 210 | 649 | 45 | 2.32 | 0.20 | 3.11 | 1.83 | 3.21 | 0.07 | 1.46 | 0.13 | 1.95 | 1.15 | 2.07 | 0.05 | 3.94 | 1.92 |

**Summary**

| | |
|---|---|
| **Total repairable DTs** | **5,46,532** |
| **Technical loss if DTs are repaired conventionally (MU)** | 4,664 |
| **Technical loss if DTs are refurbished (MU)** | 2,952 |
| **Annual Savings due to refurbishment (MU)** | **1,712** |

# A.7. Annual Capex avoidance due to DT Refurbishment

Refurbishment can help contain the technical loss in DTs post-repair and so can help in restoring a few DTs that were not repairable through conventional repair because of excessive technical loss. For analysis purposes, it was assumed that 20% of earlier unrepairable DTs can be refurbished and basis the price assumptions (Appendix A.3), the following results were obtained by using the below formula:

(Number of Failed DTs x 30%) = DTs not repairable conventionally (A)

A x 20% = Non repairable DTs conventionally that can be refurbished (B)

B x Price of new DT = CapEx savings (C)

Table 47: CAPEX avoidance due to DT refurbishment, by state (in INR)

| State | C. CAPEX Savings (Crore INR) | | | | | | |
|---|---|---|---|---|---|---|---|
| | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total |
| **Chandigarh** | 0.09 | 0.00 | 0.07 | 0.06 | 0.09 | 0.01 | 0.31 |
| **Delhi** | 1.92 | 0.13 | 1.72 | 1.37 | 2.22 | 0.15 | 7.50 |
| **Haryana** | 2.97 | 0.18 | 2.64 | 2.10 | 3.41 | 0.24 | 11.54 |
| **Himachal Pradesh** | 0.21 | 0.02 | 0.19 | 0.15 | 0.25 | 0.02 | 0.83 |
| **J&K** | 3.51 | 0.22 | 3.10 | 2.47 | 4.01 | 0.28 | 13.59 |
| **Punjab** | 2.76 | 0.16 | 2.44 | 1.94 | 3.14 | 0.22 | 10.67 |
| **Rajasthan** | 8.97 | 0.56 | 7.96 | 6.35 | 10.28 | 0.72 | 34.84 |
| **Uttar Pradesh** | 13.47 | 0.83 | 11.96 | 9.53 | 15.45 | 1.09 | 52.32 |
| **Uttarakhand** | 1.08 | 0.07 | 0.96 | 0.77 | 1.24 | 0.09 | 4.21 |
| **Chhattisgarh** | 1.62 | 0.11 | 1.44 | 1.15 | 1.86 | 0.13 | 6.30 |
| **Gujarat** | 5.97 | 0.38 | 5.31 | 4.24 | 6.86 | 0.48 | 23.24 |
| **Madhya Pradesh** | 8.64 | 0.54 | 7.67 | 6.11 | 9.90 | 0.70 | 33.55 |
| **Maharashtra** | 12.24 | 0.76 | 10.86 | 8.65 | 14.03 | 0.99 | 47.53 |
| **Daman & Diu** | 0.03 | 0.00 | 0.04 | 0.03 | 0.05 | 0.01 | 0.15 |
| **D&N Haveli** | 0.03 | 0.00 | 0.03 | 0.03 | 0.04 | 0.01 | 0.14 |
| **Goa** | 0.12 | 0.00 | 0.09 | 0.08 | 0.12 | 0.01 | 0.42 |
| **Central Sector (WR)** | 0.12 | 0.00 | 0.11 | 0.09 | 0.14 | 0.01 | 0.47 |
| **Andhra Pradesh** | 3.75 | 0.23 | 3.32 | 2.65 | 4.29 | 0.30 | 14.55 |
| **Telangana** | 6.12 | 0.38 | 5.42 | 4.32 | 7.00 | 0.49 | 23.74 |
| **Karnataka** | 10.47 | 0.65 | 9.28 | 7.40 | 11.99 | 0.84 | 40.63 |
| **Kerala** | 1.56 | 0.09 | 1.38 | 1.10 | 1.78 | 0.12 | 6.04 |
| **Tamil Nadu** | 9.90 | 0.61 | 8.77 | 6.99 | 11.33 | 0.80 | 38.40 |
| **Puducherry** | 0.09 | 0.00 | 0.09 | 0.08 | 0.12 | 0.01 | 0.39 |
| **Lakshwadeep** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Central Sector (SR)** | 0.12 | 0.00 | 0.11 | 0.09 | 0.14 | 0.01 | 0.46 |
| **Bihar** | 1.47 | 0.09 | 1.32 | 1.05 | 1.70 | 0.12 | 5.74 |
| **DVC** | 0.12 | 0.00 | 0.10 | 0.08 | 0.13 | 0.01 | 0.44 |
| **Jharkhand** | 2.10 | 0.13 | 1.86 | 1.48 | 2.40 | 0.17 | 8.14 |
| **Orissa** | 1.53 | 0.09 | 1.36 | 1.08 | 1.76 | 0.12 | 5.95 |
| **West Bengal** | 2.25 | 0.14 | 1.99 | 1.59 | 2.56 | 0.18 | 8.71 |
| **Sikkim** | 0.06 | 0.00 | 0.04 | 0.04 | 0.06 | 0.01 | 0.20 |
| **A&N Island** | 0.03 | 0.00 | 0.03 | 0.02 | 0.03 | 0.00 | 0.11 |
| **Central Sector (ER)** | 0.24 | 0.02 | 0.22 | 0.18 | 0.28 | 0.02 | 0.96 |
| **Aruncahal Pradesh** | 0.09 | 0.00 | 0.07 | 0.06 | 0.08 | 0.01 | 0.31 |
| **Assam** | 0.60 | 0.04 | 0.54 | 0.44 | 0.70 | 0.05 | 2.36 |
| **Manipur** | 0.09 | 0.00 | 0.09 | 0.07 | 0.11 | 0.01 | 0.37 |
| **Meghalaya** | 0.09 | 0.00 | 0.07 | 0.06 | 0.09 | 0.01 | 0.32 |
| **Mizoram** | 0.03 | 0.00 | 0.03 | 0.03 | 0.04 | 0.01 | 0.13 |
| **Nagaland** | 0.06 | 0.00 | 0.05 | 0.04 | 0.06 | 0.01 | 0.22 |
| **Tripura** | 0.24 | 0.02 | 0.21 | 0.17 | 0.28 | 0.02 | 0.94 |
| **Total** | 104.94 | 6.44 | 93.10 | 74.22 | 120.28 | 8.48 | **407.46** |

## A.8. Annual savings with refurbishment of inefficiently operating legacy DTs

New BEE S&L standards came into force post-December 31, 2016, and so it is likely that DTs commissioned into the distribution network prior to this date are operating at technical loss levels which are higher than new BEE S&L standards. To capture this, it is assumed that all the new DTs operate at loss levels as per EEL 1 rated DT as per IS 1180 Part 1. Also, as observed in PoC studies, Legacy DTs are assumed to operate at deviations as specified in Appendix A.3 (assumption 6), and post refurbishment, legacy DTs will operate at deviation levels as specified in Appendix A.3 (assumption 7).

Though it is likely that Legacy DTs form a higher percentage of installed DT capacity because the rated life of a DT is 25 years, conservatively it is assumed that of the operational DTs, 60% are new DTs and 40% are legacy DTs. With these premises, analysis has been carried out at an average DT loading of 70% and the results are as below:

Table 48: Annual Savings through refurbishment of inefficiently operating Legacy DTs, by state

| State | A. Current Annual total technical loss (MU) | | | | | | | B. Annual total technical loss post repair of legacy DTs(MU) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total |
| **Chandigarh** | 15.4 | 1.3 | 20.9 | 12.4 | 21.5 | 0.4 | 72.0 | 12.5 | 1.0 | 17.0 | 10.1 | 17.6 | 0.4 | 58.6 |
| **Delhi** | 312.7 | 26.3 | 425.0 | 251.1 | 436.6 | 8.8 | 1460.4 | 253.3 | 21.2 | 344.9 | 204.0 | 357.9 | 7.4 | 1188.8 |
| **Haryana** | 593.9 | 50.0 | 807.1 | 476.9 | 829.2 | 16.6 | 2773.7 | 481.0 | 40.4 | 655.0 | 387.4 | 679.8 | 14.1 | 2257.8 |
| **Himachal Pradesh** | 57.8 | 4.9 | 78.5 | 46.4 | 80.6 | 1.6 | 269.7 | 46.8 | 3.9 | 63.7 | 37.7 | 66.1 | 1.4 | 219.5 |
| **J&K** | 140.1 | 11.8 | 190.4 | 112.5 | 195.6 | 3.9 | 654.5 | 113.5 | 9.5 | 154.6 | 91.4 | 160.4 | 3.3 | 532.8 |
| **Punjab** | 736.4 | 62.0 | 1000.8 | 591.3 | 1028.1 | 20.6 | 3439.3 | 596.5 | 50.0 | 812.2 | 480.4 | 842.9 | 17.5 | 2799.6 |
| **Rajasthan** | 1018.8 | 85.8 | 1384.6 | 818.0 | 1422.4 | 28.5 | 4758.1 | 825.2 | 69.2 | 1123.7 | 664.6 | 1166.2 | 24.3 | 3873.1 |
| **Uttar Pradesh** | 901.2 | 75.9 | 1224.8 | 723.6 | 1258.2 | 25.2 | 4208.8 | 730.0 | 61.2 | 993.9 | 587.9 | 1031.5 | 21.5 | 3426.0 |
| **Uttarakhand** | 90.7 | 7.6 | 123.2 | 72.8 | 126.6 | 2.5 | 423.6 | 73.5 | 6.2 | 100.0 | 59.2 | 103.8 | 2.2 | 344.8 |
| **Central Sector (NR)** | 21.2 | 1.8 | 28.8 | 17.0 | 29.6 | 0.6 | 99.1 | 17.2 | 1.4 | 23.4 | 13.8 | 24.3 | 0.5 | 80.7 |
| **Chhattisgarh** | 217.5 | 18.3 | 295.6 | 174.6 | 303.7 | 6.1 | 1015.8 | 176.2 | 14.8 | 239.9 | 141.9 | 249.0 | 5.2 | 826.9 |
| **Gujarat** | 1142.3 | 96.1 | 1552.3 | 917.1 | 1594.7 | 32.0 | 5334.5 | 925.2 | 77.6 | 1259.8 | 745.2 | 1307.5 | 27.2 | 4342.4 |
| **Madhya Pradesh** | 854.3 | 71.9 | 1161.0 | 685.9 | 1192.6 | 23.9 | 3989.6 | 691.9 | 58.0 | 942.2 | 557.3 | 977.8 | 20.3 | 3247.6 |
| **Maharashtra** | 1484.5 | 125.0 | 2017.5 | 1191.9 | 2072.5 | 41.5 | 6932.9 | 1202.4 | 100.8 | 1637.2 | 968.4 | 1699.2 | 35.3 | 5643.4 |
| **Daman & Diu** | 5.4 | 0.5 | 7.3 | 4.3 | 7.5 | 0.2 | 25.2 | 4.4 | 0.4 | 5.9 | 3.5 | 6.2 | 0.1 | 20.5 |
| **D&N Haveli** | 4.7 | 0.4 | 6.4 | 3.8 | 6.5 | 0.1 | 21.9 | 3.8 | 0.3 | 5.2 | 3.1 | 5.4 | 0.1 | 17.8 |
| **Goa** | 21.3 | 1.8 | 29.0 | 17.1 | 29.8 | 0.6 | 99.5 | 17.3 | 1.5 | 23.5 | 13.9 | 24.4 | 0.5 | 81.0 |
| **Central Sector (WR)** | 15.8 | 1.3 | 21.5 | 12.7 | 22.1 | 0.4 | 73.9 | 12.8 | 1.1 | 17.5 | 10.3 | 18.1 | 0.4 | 60.2 |
| **Andhra Pradesh** | 683.7 | 57.5 | 929.1 | 548.9 | 954.4 | 19.1 | 3192.7 | 553.7 | 46.4 | 754.0 | 446.0 | 782.5 | 16.3 | 2598.9 |
| **Telangana** | 655.7 | 55.2 | 891.1 | 526.5 | 915.4 | 18.3 | 3062.1 | 531.1 | 44.5 | 723.1 | 427.7 | 750.5 | 15.6 | 2492.6 |
| **Karnataka** | 1051.3 | 88.5 | 1428.7 | 844.1 | 1467.7 | 29.4 | 4909.6 | 851.5 | 71.4 | 1159.4 | 685.8 | 1203.3 | 25.0 | 3996.4 |
| **Kerala** | 208.7 | 17.6 | 283.7 | 167.6 | 291.4 | 5.8 | 974.8 | 169.1 | 14.2 | 230.2 | 136.2 | 238.9 | 5.0 | 793.5 |
| **Tamil Nadu** | 875.7 | 73.7 | 1190.0 | 703.1 | 1222.5 | 24.5 | 4089.5 | 709.3 | 59.5 | 965.8 | 571.2 | 1002.3 | 20.8 | 3328.9 |
| **Puducherry** | 13.0 | 1.1 | 17.6 | 10.4 | 18.1 | 0.4 | 60.6 | 10.5 | 0.9 | 14.3 | 8.5 | 14.9 | 0.3 | 49.3 |
| **Lakshwadeep** | 0.4 | 0.0 | 0.5 | 0.3 | 0.5 | 0.0 | 1.7 | 0.3 | 0.0 | 0.4 | 0.2 | 0.4 | 0.0 | 1.4 |

| State | A. Current Annual total technical loss (MU) | | | | | | | B. Annual total technical loss post repair of legacy DTs(MU) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total | >200 kVA | 200kVA | 100kVA | 63kVA | 25kVA | <25kVA | Total |
| **Central Sector (SR)** | 15.3 | 1.3 | 20.8 | 12.3 | 21.4 | 0.4 | 71.5 | 12.4 | 1.0 | 16.9 | 10.0 | 17.5 | 0.4 | 58.2 |
| **Bihar** | 255.5 | 21.5 | 347.3 | 205.2 | 356.7 | 7.2 | 1193.3 | 207.0 | 17.4 | 281.8 | 166.7 | 292.5 | 6.1 | 971.4 |
| **DVC** | 14.0 | 1.2 | 19.0 | 11.2 | 19.5 | 0.4 | 65.1 | 11.3 | 1.0 | 15.4 | 9.1 | 16.0 | 0.3 | 53.0 |
| **Jharkhand** | 140.4 | 11.8 | 190.9 | 112.8 | 196.1 | 3.9 | 655.9 | 113.8 | 9.5 | 154.9 | 91.6 | 160.7 | 3.3 | 533.9 |
| **Orissa** | 231.8 | 19.5 | 315.0 | 186.1 | 323.6 | 6.5 | 1082.6 | 187.8 | 15.8 | 255.7 | 151.2 | 265.3 | 5.5 | 881.3 |
| **West Bengal** | 341.2 | 28.7 | 463.6 | 273.9 | 476.3 | 9.5 | 1593.3 | 276.3 | 23.2 | 376.3 | 222.6 | 390.5 | 8.1 | 1296.9 |
| **Sikkim** | 6.2 | 0.5 | 8.5 | 5.0 | 8.7 | 0.2 | 29.2 | 5.1 | 0.4 | 6.9 | 4.1 | 7.1 | 0.1 | 23.7 |
| **A&N Island** | 3.8 | 0.3 | 5.1 | 3.0 | 5.3 | 0.1 | 17.6 | 3.1 | 0.3 | 4.2 | 2.5 | 4.3 | 0.1 | 14.3 |
| **Central Sector (ER)** | 31.2 | 2.6 | 42.5 | 25.1 | 43.6 | 0.9 | 145.9 | 25.3 | 2.1 | 34.5 | 20.4 | 35.8 | 0.7 | 118.8 |
| **Aruncahal Pradesh** | 9.4 | 0.8 | 12.8 | 7.6 | 13.2 | 0.3 | 44.0 | 7.6 | 0.7 | 10.4 | 6.1 | 10.8 | 0.2 | 35.8 |
| **Assam** | 124.5 | 10.5 | 169.2 | 100.0 | 173.8 | 3.5 | 581.4 | 100.8 | 8.5 | 137.3 | 81.2 | 142.5 | 3.0 | 473.3 |
| **Manipur** | 12.2 | 1.0 | 16.5 | 9.8 | 17.0 | 0.3 | 56.8 | 9.8 | 0.8 | 13.4 | 7.9 | 13.9 | 0.3 | 46.2 |
| **Meghalaya** | 18.0 | 1.5 | 24.5 | 14.4 | 25.1 | 0.5 | 84.1 | 14.6 | 1.2 | 19.8 | 11.7 | 20.6 | 0.4 | 68.4 |
| **Mizoram** | 4.6 | 0.4 | 6.2 | 3.7 | 6.3 | 0.1 | 21.3 | 3.7 | 0.3 | 5.0 | 3.0 | 5.2 | 0.1 | 17.3 |
| **Nagaland** | 6.9 | 0.6 | 9.3 | 5.5 | 9.6 | 0.2 | 32.1 | 5.6 | 0.5 | 7.6 | 4.5 | 7.9 | 0.2 | 26.1 |
| **Tripura** | 23.1 | 1.9 | 31.4 | 18.6 | 32.3 | 0.6 | 107.9 | 18.7 | 1.6 | 25.5 | 15.1 | 26.4 | 0.6 | 87.8 |
| **Central Sector (NER)** | 1.3 | 0.1 | 1.8 | 1.0 | 1.8 | 0.0 | 6.0 | 1.0 | 0.1 | 1.4 | 0.8 | 1.5 | 0.0 | 4.9 |
| **Total** | 12362 | 1041 | 16800 | 9925 | 17258 | 346 | 57732 | 10013 | 840 | 13634 | 8064 | 14149 | 294 | 46994 |
| **Summary** | | | | | | | | | | | | | | |
| **Capacity (kVA)** | | | | | | | | **>200** | **200** | **100** | **63** | **25** | **<25** | **Total** |
| **C. Savings in Technical Loss (MU) (A-B)** | | | | | | | | **2,349** | **201** | **3,166** | **1,861** | **3,108** | **51.7** | **10,738** |

# Adding Value…