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TRANSFORMERS
The Heart of Power Systems

56 Industry Conclave

86 Odisha Power Conclave

91 Young @ IEEMA, IIM

Other Stories...

Embracing Proactive Maintenance and Active Repair for Distribution Assets

Regular inspections and proactive repairs are vital for the longevity and efficient operations of distribution transformers, helping optimise costs

Just as the human heart is integral to the functioning of the body, the core and winding is the heart of a distribution transformer (DT). A DT requires consistent maintenance and inspection to ensure operational efficiency and longevity. Regular checks and preventive maintenance can help identify and address potential issues before they lead to disastrous failures.

It is imperative for skilled technicians to diagnose and address issues within a DT, sometimes necessitating rewinding or replacement. Ensuring the health of the DT through meticulous upkeep is critical for the overall system's vitality and performance.

Getting the Best out of a DT

Electricity is a key element for a country's economic growth and is directly linked with GDP and citizens' quality of life. Rapid industrialisation and urbanisation in India have led to increasing demand for power. With DTs as the heart and soul of electrical networks in the country, the power sector has been taking several initiatives to guarantee reliable 24 x 7 power supply through DTs.

That said, we have seen several cases of DT failures time and again. We need to implement a proactive asset management strategy to significantly improve performance and efficiency of DTs. The best solutions to minimise failures in DTs are proactive monitoring, timely intervention, and maintenance. Regular inspections and maintenance can significantly extend the life-cycle of DTs. This approach involves systematic planning and strategy, including standard operating practices. It not only reduces the frequency of failures and associated losses but also leads to getting the best out of a DT's expected life, which should be nothing less than 25 years.

High Losses Leading to Financial Challenges

A DT is a crucial asset for a power distribution network, playing a vital role in the economic health of distribution companies (discoms). While several discoms conduct energy audits, they often focus on aggregate technical and commercial (AT&C) losses, which are influenced by metering, billing and collection inefficiencies – largely management, rather than technical issues. In India, discoms face high AT&C losses of 15-30% across states, with technical losses estimated at about 9-12%. These figures are high as compared to other countries, converting into financial challenges.

Notably, there are about 15 million DTs in India, with 1-1.2 million breaking down annually, either due to poor asset management or low-quality repairs. Low-cost procurement policies often overlook the life-cycle cost and carbon footprint, further contributing to inefficiencies.

Transformer Losses & Their Types

Transformer losses are of two types: no-load losses, mainly due to poor core quality and repairs, and load losses, which occur in windings and increase with loading. Measuring technical losses in operational DTs is complex. Typically, only secondary side metres are used for energy auditing, but measuring technical losses requires primary side metering, which involves significant investments. Mobile setups with a standby DT can be used during shutdown periods, meeting practical challenges.

Most discoms address DT issues only on failure, focusing on getting them operational rather than reducing losses. Current repair contracts and service level agreements (SLAs) do not incentivise loss reduction. Additionally, DT repair technicians often lack knowledge of design optimisation for loss reduction, failing to follow best practices. The approach for mushrooming DT repair service is more like a cycle repair shop approach. This is also largely because repairers have no incentives to do a quality job needed for an engineering product like DT. Moreover, equipment or facility for loss measurement is also often outdated and inaccurate.

There can also be cases of mortality and premature failure for DTs. While such DTs are normally repaired instead of replaced, they require huge fresh capital investments, which have a supply shortage for public utilities.

Here, we can consider undertaking operations to extend a productive life of a failed DT (static and efficient equipment). This will help extend its productive existence in the distribution system, serving customers and promoting reliable and efficient supply.

Case Study

With above realities, challenges and the philosophy, a pilot execution on active repair of DT was conducted with the following objectives:

- There is high technical loss deviation in old legacy DTs as compared to the manufacturing specifications or guaranteed technical particulars (GTP).
- Active repair can sizeably reduce technical loss, achieving close to (or even better than) manufacturing specifications per the latest IS standard.
- Active repair with winding compensation only, including change of winding materials, allow a scalable repair technique to improve efficiency levels.
- Active repair is techno-commercially viable to discoms. They can selectively undertake active repair only for high-loss legacy DTs to derive a shorter payback period.

The active repair method primarily focuses on reliability improvement and technical loss reduction in DTs through winding compensation and any change in winding material when the core is in an acceptable condition. The core is left untouched as different makes of DTs will entail different laminate designs and cuts. It is not an easy and replicable repair method. Active repair can be carried out on both, failed and functional legacy DTs, though as a rule it will be selectively applied to high-loss DTs.

Here is a case study for undertaking active repair on a sample DT in Maharashtra:

A 100-kVA failed DT was requested from a discom. DT selection for high losses was done basis DT chronological and inventory data, including key parameters such as DT make, no-load loss, full-load loss, ageing and number of repairs already made.

The selected sample DT was tested at the repairer's lab to perform routine and type tests, including temperature rise test, to verify its condition and measure the 'as-is' no-load and full-load losses per IS 2026. As the 100 kVA was a failed DT, its no-load loss was measured by supplying rated voltage at LV winding and keeping the HV winding open per IS 2026. Its full-load loss was calculated based on an empirical formula. The test was carried out by an independent, local technical institute with calibrated metres.

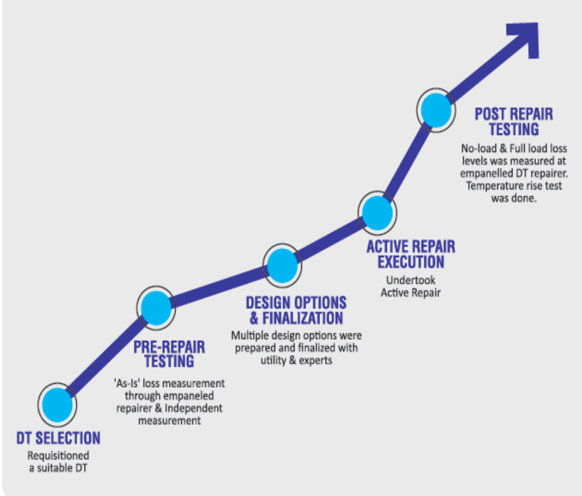
'As-is' loss level measurements for the failed 100 kVA aluminum DT were conducted. It was found that the 'as-is' no-load loss was 65% higher, while the full-load loss was 3% higher from the manufacturing specification values, which were as per the old 1-star Bureau of Energy Efficiency (BEE) rating. Post active repair, the no-load loss was reduced to 13% and full-load loss to -3% from the manufacturing specification values.

Founded on baseline measurements, different design options for the DT was worked out. Designs were prepared with both, LV and HV windings being replaced with copper windings with an increased number of turns and optimally using the window space.

Subsequently, in consultation with design experts and the discom team, the final design for active repair was chosen and the following sequence of activities was agreed to:

- Unstacking of core laminations and restacking them securely to reduce air gap between laminations.
- Placing LV and HV windings per design specifications and re-assembling.
- Moving to oven drying to eliminate moisture.
- Placing final assembly back in the tank and closing.

A step-by-step approach was adopted during the active repair execution for DT sample to ensure checks and validation at each level as shown.



After active repair execution of the DT, it was tested for post-repair loss levels by performing routine and type tests per IS 2026. Below are the active repair design interventions and pre-repair and post-repair results for the 100-kVA failed DT.

Table 1: Design and Results for Active Repair with Reference to Baseline Measurements and Utility Specs

Key Design Parameters	Utility Spec	Baseline (As-is)	Actual Post-repair Results
Capacity (kVA)	100	100	100*
Flux density (Tesla)	1.55	1.55	1.35
LV winding material	-	DPC Al	DPC Copper
LV winding number of turns, ID (mm), OD (mm)	-	75, 123, 159	86, 123, 156
HV winding material	-	DPC Al	DPC Copper
HV winding number of turns, ID (mm), OD (mm)		3300, 179, 260	3,784, 176, 241
No-load loss (W)	260	426	295
Full-load loss (W) at 134A-rated current	1,760	1,815	1,654
Total winding weight (kg)	-	57	174

The post-repair heat-run test was then taken. Temperature rise of the winding and top oil were found within permissible limits as defined in IS 2026.

Table 2: Post-Repair Heat-run Test Results

	Permissible Limits	Results Obtained
Winding temperature rise	550 C	45.40 C
Top oil temperature rise	500 C	380 C

Finally, cost-benefit analysis was carried out basis factual data points obtained from the supporting discom. The DT loading was understood to be 70% with an average cost of supply of ₹6.03/kWh and 10% annual inflation. Active repair defers a total savings of 1,838 kWh per year compared to baseline losses, and a simple yet efficient payback is observed. The payback period further improves with an increase in DT loading or the cost of supply.

As it was a failed DT, its kVA capacity was assumed to be the same as the nameplate rating of 100 kVA. However, based on the post-repair temperature rise test, the kVA capacity was observed as enhanced by 9% after active repair, which can allow the copper wound DT to take up more load with higher reliability. Additionally, this refurbished and upgraded DT can give a new life-cycle like any new DT.

The active repair case demonstrates momentous divergence of no-load and full-load losses from specification values, highlighting that active repair offers a business case for considerable loss reduction. Leveraging the breakdown repair window opportunity for legacy DTs, active repair can be applied to selective DTs with high losses and can help yield an attractive payback period. Additional benefits of active repair come in the form of increased kVA capacity, higher reliability (reduced failure rate), and increased asset life. Active repair provides an alternative solution to bring energy efficiency to DTs at reduced costs compared to fresh replacements. A mixed approach of applying active repair on selective old high-loss DTs and undertaking replacement of very high losses and dilapidated DTs can maintain overall cost balance, and hence, low impact on electricity tariffs to end-customers.

Repairing mechanics will be important stakeholders to shape and scale-up active repair and its benefits to discoms. They can design new performance-tied DT repair contracts to incentivise repairers to undertake active repair on the right selected batch. Such managed services contracts across the life-cycle of the DT and can potentially create better economies of scale and economies of scope for the provider, with better-integrated value proposition to discoms.

Currently, the pilot DT has been in service for past six years and has been performing much better than general expectations; for instance, it sustained an ambient temperature of as high as 47.14° in May 2018. This active repaired DT has served as a living example of new energy efficiency enhancement solutions for such legacy DTs. Adopting such methods may help in achieving and maintaining optimum energy procurement and utilisation throughout the organisation, which may help in minimising energy costs and mitigating environmental effects.

This DT was monitored initially for three years for energy delivery through a Cloud-based system showing aggregate data into one, centralised view. It provides access to both, real-time and historical energy use, with analytics to help one understand trends.

Conclusion

Regular inspections and proactive repairs are vital for the longevity and efficient operations of DTs. Embracing proactive maintenance and active repair ensures high performance, reduces failures, and lowers operational costs. This strategy not only enhances the electrical network's reliability but also supports economic growth and stability of power discoms. Similar pilot studies have been successfully executed in Madhya Pradesh and Tamil Nadu, demonstrating the potential for this approach to be widespread and scalable.

Discoms can undertake such active repair of DT actions under the programmatic approach that should be qualified as renovation and modernisation (R&M) expenses under the regulatory regime. Electricity regulators should consider such expenses to be allowed as a passthrough for annual revenue requirement through the tariff base. This concept of R&M is much popular for transmission and generation assets. It is time that R&M expenses for distribution assets are part of the tariff policy.

As power distribution systems grow in size and complexity, active repair with winding compensation offers a cost-effective solution for significant technical loss reduction compared to replacing old DTs with new ones that are fresh capex-driven. Discoms can develop new business models and contracting strategies for DT repairs that promote performance-tied SLAs, including technical loss reduction. Additionally, incorporating managed services around DTs can lead to more efficient life-cycle asset management. By adopting these approaches, discoms can achieve greater efficiency and reliability in their power distribution networks, ultimately benefiting both, the utility and its consumers.

Pictures courtesy

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