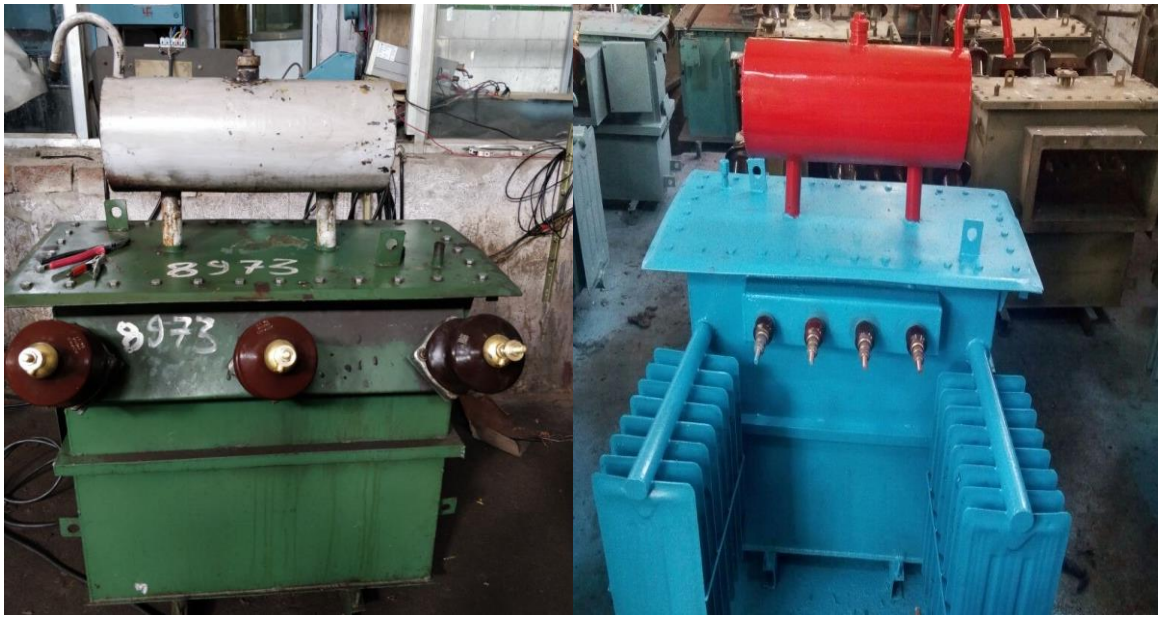
Giving new life to the legacy Distribution Transformers through Proactive repair



*Abstract— Distribution Transformer (DT) is the heart of distribution network. It is essential to monitor its health as it is one of the high CAPEX assets for DISCOMs. For overall DISCOM viability, it is important that each individual DT is turned into a profit center. It is estimated that of 24% national average AT&C losses, at least 3-4% comes from Technical losses in DTs alone, and it can be brought down to 0.5% and below. Restructured Accelerated Power Development and Reforms Programme (**R-APDRP**) has envisaged utilities to carry out an energy audit of a DT for monitoring losses (at least on a sampling basis) but unfortunately, this keeps missing the attention, add to the extent that DT technical losses are not even measured till it breaks down. And only broken-down DTs are sent for repair, and there is minimum to none pro-active approach to DT renovation, repair towards modernisation and O&M.*

This article presents a repair concept called 'Proactive Repair' using winding compensation only, with no change to the healthy core. Proactive repair was conducted in field at Madhya Pradesh Paschim Kshetra Vidyut Vitaran Company Limited (MPPKVVCL), Indore on Aluminum wound legacy DTs (100kVA and 200kVA) with high technical losses, with winding compensation carried out through copper winding replacement. Results revealed significant technical loss reduction, reliability improvement and kVA enhancement of the repaired DTs thereby breathing new life in them.

The proposed proactive repair can be developed as an easy replicable DT repair technique, and DISCOMs can selectively apply it to high technical loss-making legacy DTs that will yield shorter payback period. Existing DT repairers can be incentivized to undertake proactive repairs through performance tied improved repair contract or service level agreements (SLAs) with further extension to provide integrated DT managed services for improved reliability and life cycle management.

1. Current Scenario of Distribution Transformer Repair Practices in India

In India, DT failure rate is one of the important KPI for Indian DISCOMs. Any failure of the DT before expiration of its designed lifespan results in unplanned outage, revenue loss, unavailability of critical services and in most cases huge financial losses to both utilities and customers. Overall, it affects the KPI of the utility. The prominent reason for DT failure is cited to be winding failure on prolonged overloading. It has been observed that no factual data is collected on loading of the transformers. Overloading of the transformer goes unnoticed till the DT fails. As per DT assessment study, failing of LV and/or HV winding is reported to be one of the major types of failure occurring in DTs as compared to core damage (~2% DTs). The high DT failure rate and losses in DTs usually originates from weak practices in asset life-cycle management. These include procurement, regular O&M and repairs. Some of the practices observed are as mentioned below:

- The DT procurement often ignores life-cycle cost or the total cost of ownership as against meticulously observed in case of power transformers.

- Tendering process is more on standard bidding philosophy (accepting lowest bid) rather than performance-based contract.
- DTs normally fail much before completion of its service life (20-25 years) impacting the cost of capital deployed to service customers. Part of the reason for such high failure rate is overloading, absence of Condition based/Preventive monitoring, protection and Routine/Periodic maintenance
- The repair practice follows a passive approach to attend the DT when it fails. The focus is merely to get the DT back into the service, rather than availing the opportunity to completely renovate with eye for preventing energy loss and improving asset health.
- Current practice is to measure the losses in the DT post repair only, leaving no scope for further improvement. Also, the current repair contract and defined Service Level Agreements (SLAs) do not encourage technical loss reduction.
- The DT repairer's staff is adept in routine repair practices and do not consider design optimization for loss reduction or enhancing reliability. This at times lead to adoption of sub optimal practices.
- The equipment used for losses measurement or estimation are not well kept as needed to be maintained in laboratory environment, calibrated and updated for accuracy.

2. About the study

The study focuses on developing a mass replicable proactive approach to undertaking repairs (hereinafter mentioned as Proactive Repair) of DTs in service and bring down the technical losses. Proactive repair of DTs is a method that primarily focus on technical loss reduction in DTs through winding compensation, including any change in winding material. The core, if not beyond a certain level of degradation, is left unchanged as different makes of DTs will require different laminates design and cuts and that would not be an easy and replicable repair methodology. Proactive repair can be carried on both the breakdown as well as functional legacy DTs, though usually it shall be selectively applied to high loss DTs.

The study was carried out at Madhya Pradesh Paschim Kshetra Vidyut Vitaran Company Limited (MPPKVVCL), Indore on 100kVA and 200kVA DTs. In this paper we will focus on case study for 200kVA DT. Various tests like Open Circuit & Short Circuit test were carried out under the supervision of MPPKVVCL representative at Major Transformer Repairing Unit (MTRU) and technical loss reduction was validated by ERDA.

3. Proactive Repair Methodology

Below is a stepwise approach that was adopted for undertaking active repair on two sample DTs:

DT selection	Pre Repair testing	Design Options & Finalization	Proactive Repair Execution	Post Repair Testing	Reporting
- Requisitioned failed DTs from Repair Centre for study	- Loss levels were measured at MTRU in presence of MPPKVVCL representatives	- Multiple design options were prepared - Final Design Option was reviewed & approved with MPPKVVCL team	- Undertook Proactive repair based on finalized design	- Loss levels were measured at MTRU in presence of MPPKVVCL representatives - The results were also validated by ERDA by conduction loss and impedance measurement test and temperature rise test	-Test results were recorded & reported to MPPKVVCL
					

4. Pilot Results

Case 1:200 kVA failed DT: After Proactive Repair, it was observed that total loss reduced by 40% (compared to spec + allowed deviation values). Post repair results in comparison with baseline measurements and manufacturing specifications are shown in Table-1 below.

Key Design Parameters	Unit	Specification	Baseline (As-Is)	Actual Post repair results (measured at MTRU)	Actual Post repair results (measured at ERDA)
Capacity	kVA	200	200	200	200
Year of Manufacturing		-	2004	-	-
Flux Density	Tesla	1.55	-	-	-
LV Winding Material		-	DPC Al	DPC Cu	DPC Cu
# of LV Turns	#	-	42	42	42
HV Winding Material		-	DPC Al	DPC Cu	DPC Cu
# of HV Turns	#	-	1848	1848	1848
Total Loss	Watt	3000	3850	2319	2297
Impedance	%	4.5	-	4.36	4.42
Total Winding Weight	kg	-	86.19	297.45	297.45

Table 1. Design and Results for proactive repair with reference to the baseline measurements and utility specs

The DT loading was assumed to be 70% with average cost of supply of Rs. 6.25 /kWh and 10% inflation YoY. Proactive repair yields a sum total savings of 4858 kWh/year compared to baseline losses, and simple payback of around 3.5 years. The payback period further improves with increase in DT loading or cost of supply. As it was a failed DT, its kVA capacity was assumed to be same as the name plate rating of 200 kVA. However, based on the post repair test by ERDA it was observed that the kVA capacity was enhanced by 9.5% (219kVA) after the proactive repair, which can allow DT taking up more load with higher reliability. Additionally, this overhauled and upgraded DT can give full new life cycle similar to any new DT.

5. Post Repair Monitoring

Post Proactive Repair metering was done on both sides of the DTs (both 100 kVA and 200 kVA) with DISCOM team. The metering will help monitor the performance of Proactive Repaired DTs.

Figure 1. Metering on Proactive Repaired 200 kVA DT

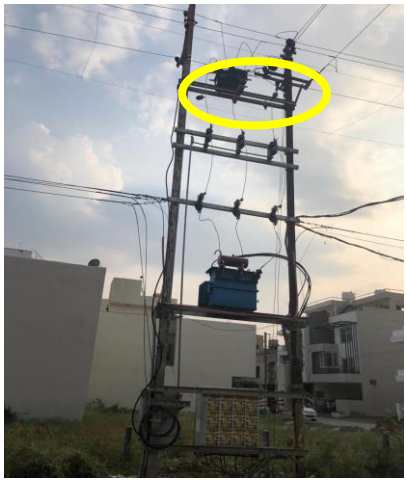


Figure 2. Metering on Proactive Repaired 200 kVA DT

6. Applicability to broader Utility

MPPKVVCL has total 2,48,611 DTs in service in two regions - Indore and Ujjain. Annually, ~20k DTs are procured across different capacities based on the field demands. The AT&C losses is around 29% as per performance indicator of MPPKVVCL (Ref: UDAY Portal). Base on the estimation of loss deviations of Discom data and representing at MPPKVVCL level, it is observed that DTs contribute ~5% of technical losses at overall utility level, resulting in ~1302.92 MU loss (assuming avg. cost of power supply as 6.25 kWh/unit).

	Scenario 1 (if DTs perform as per specs)	Scenario 2 (if DTs are at acceptable loss levels)	Scenario 3 (if losses are high deviated from spec)	Scenario 4 (if DTs Proactive Repaired)
%loading	50%	50%	50%	50%
%deviation of No-load loss	0%	15%	15%	+10%
%deviation of Full load loss	0%	15%	30%	-30%
Estimated total losses (MUs/year)	1,048	1,206	1,302	896
% Total losses with respect to energy input	4.51%	5.19%	**5.61%**	**3.86%**
Total DT technical losses (Cr.)	655.59	753.93	814.32	560.10

Assumptions		
Total Transformers	#	2,25,296
Avg. Loading	%	50%
Avg. Cost of power supply	kWh/unit	6.25
Total revenue of MPPKVVCL (as per ARR 2017-18)	Cr.	11,364
Energy Input (as per ARR 2017-18)	MU/year	23,242

If 5% technical loss can be brought down to 3% (based on best performing utility's standard) through effective & Proactive DT repair & maintenance, it can save nearly INR 254 Cr. per year (approx. 3.83% of Avg. revenue). Even if 71% of MVA capacity (less than 200kVA) is Proactive Repaired it can save nearly 180 Cr./year.

7. Conclusion

As power distribution systems continues to grow in size and complexity, technical loss reduction will form greater priority. Added with the efficiency drive the utilities are looking at reliable supply to consumers. Proactive repair with only winding compensation provides an opportunity for sizeable technical loss reduction at reduced costs over replacement with new DT incurring heavy CAPEX. In addition, the reliability improvement assures of lesser downtime. The proactive repair case demonstrated significant deviation of total losses from the specification values, and that proactive repair offers business case for sizable loss reduction.

Leveraging the breakdown repair window opportunity for legacy DTs, proactive repair can be applied to selective high losses DTs that can yield attractive payback period. It can also be applied to selective functional DTs based on loss data if tracked well from previous conventional repairs. It is evident that along with technical loss reduction repair additional benefits is brought-in in the form increased kVA capacity, higher reliability (i.e. reduced failure rate) and increased asset life with copper. To make this a viable option, DISCOMs can develop new business models and contracting for DT repairing that encourage performance tied SLAs, including technical loss reduction and possibly some combination of managed services around DTs for effective life cycle asset management.

8. References

[1] Government of India, Ministry of Power, Central Electricity Authority, New Delhi- Power Sector, April 2017

[2] "Innovative Business Model for Refurbishment of Distribution Transformers" by Idam infrastructure Advisory Pvt. Ltd, 8th Annual Conference on "Power Distribution in India" Issues & Challenges; Strategies & Solutions

[3] "Reduction of losses" by Electrical India, July 5, 2016

[4] "Determination of Capitalization Values for No Load Loss and Load Loss in Distribution Transformers" by W.D.A.S. Wijayapala, S.R.K. Gamage and H.M.S.L.G. Bandara, ol. XLIX, No. 03, pp. [11-20], 2016, The Institution of Engineers, Sri Lanka

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