Transforming the Transformer- Active Repair Way

International Copper Association India
Copper Alliance

Improving Reliability and Efficiency of legacy Distribution Transformers

Loss Reduction | Reliability Improvement | kVA Enhancement

6th Sept 2019 Lucknow

Objectives

Legacy DTs improvement

1

Loss Reduction

Total Technical Losses reduction

2

Reliability Improvement

Reducing DT Failure rates

3

kVA Capacity Enhancement

Increasing kVA capacity of DTs to allow higher % loading

Intensity of Problem: High DT Failure rates, huge spent on R&M, and High DT Technical losses

Failure rate is the most observed KPI for DTs. DT Technical losses mostly remain undiscovered.

	All India statistics
Total DT counts	~12.5 million
Total DT MVA capacity	~2,20,000 MVA
Avg. DT Failure rate	~12-15% (6-8 lakhs DTs fail yearly)
Repair and Maintenance costs spent on DTs repair	~3,000 INR crores/ year
Avg. Total Technical losses in DTs	~3%
Avg. AT&C losses	24%

Recent trend is to sweat key assets by the utility

DT-1: 100KVA AT MPPKVVCL

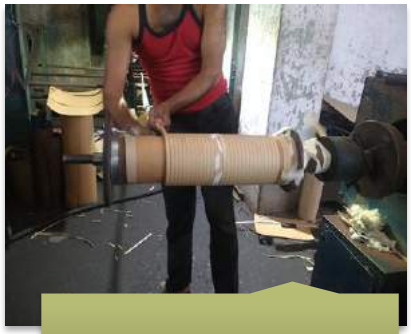
Methodology, Solution & Results, Cost Benefit Analysis

Methodology

Pre-Repair Testing, Execution and Post-Repair Testing at MTRU; Independent Testing at ERDA

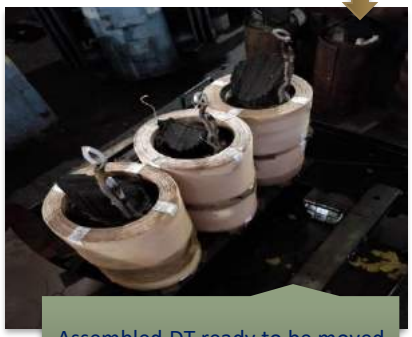
Received DT at MTRU

Pre-repair testing (open circuit and short circuit test) at MTRU with MPPKVVCL representatives



LV Winding as per design at MTRU

HV Winding as per design at MTRU



Assembled DT ready to be moved for oven drying

Oven dried DT placed in tank as final assembly

Post Repair testing with MPPKVVCL representatives

Final Active Repaired DT was sent to ERDA for validation of results

DT to be connected in the network

Monitor performance of the DT

Active Repair Solution and Results

100 kVA DT happened to be functional DT with small fix, hence full pre-repair testing could be done. Both HT and LT windings were replaced with Cu windings. Significant Full Load loss reduction.

Key Design Parameters	Unit	Utility Specs	Baseline Pre-repair (at MTRU)	% Deviation from Specs	Actual Post-repair (at ERDA)	% Change from Specs
Capacity	kVA	100	100		109*	+9%
Year of Manufacturing			2013			
LV Winding Material			DPC Al		DPC Copper	
# of LV Turns	#		76		76	0%
HV Winding Material			DPC Al		DPC Copper	
# of HV Turns	#		3,344		3,344	0%
No Load Loss	Watts	260	258	-0.7%	295	+13.6% **
Full Load Loss	Watts	1,760	2,358	+34%	1168	-33.6%
Impedance	%	4.05 – 4.95	3.84		4.21	
Total Winding Weight	Kg		46.62		192.36	

** kVA enhancement 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.*

Cost Benefit Analysis

Active Repair provides good cost economic option to Discom to upgrade legacy DTs asset with performance (measured in terms of Total Loss) equivalent to a level of EE as per IS 1180

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,779
Avg. Cost of Supply (Rs./kWh)	6.25 (as per MPPKVVCL ARR 2017-18)
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Simple Payback Period including financing charges (years)	3.18

Options for Discom		
1. Business as Usual		
INR 11K (failed DT conventional repair cost) + INR 29K (yearly energy loss)		
2. Replacement		
	Al	Cu
1 star	INR 0.96L	INR 1.45L
3 star	**INR 1.3L**	**INR 1.9L**
3. Active Repair		
plus INR 0.86L (almost new Cu DT with enhanced efficiency and high Cu salvage value)		

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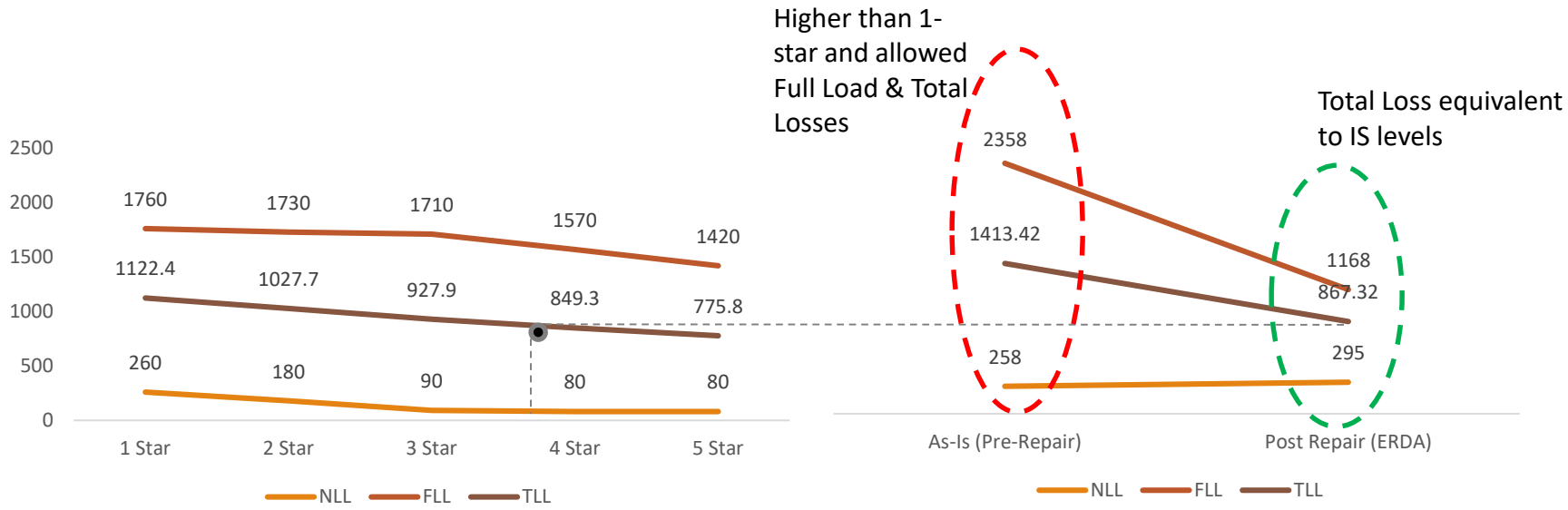
Total Units Saved (kWh/year)	4,779
Avg. Cost of Supply (Rs./kWh)	4.50 (as per MPPKVVCL ARR 2017-18)
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Simple Payback Period including financing charges (years)	3.59

Options for Discom		
1. Business as Usual		
INR 11K (failed DT conventional repair cost) + INR 29K (yearly energy loss)		
2. Replacement		
	Al	Cu
1 star	INR 0.96L	INR 1.45L
3 star	**INR 1.3L**	**INR 1.9L**
3. Active Repair		
plus INR 0.86L (almost new Cu DT with enhanced efficiency and high Cu salvage value)		

Upgradation of Legacy DT

Active Repair enhances the performance of the old legacy DT to a level of Energy Efficiency stipulated as per IS 1180 specially at higher loading conditions



**Total Losses values are calculated at 70% DTR loading*

Active Repair Solution as per actual kVA

100 kVA DT was found to be approx. 86kVA based on the pre-repair test results and radiator fins calculation

Key Design Parameters	Unit	Utility Specs	Baseline Pre-repair (at MTRU)	% Deviation from Specs	Actual Post-repair (at ERDA)	% Change from baseline
Capacity	kVA	100	86*		109**	+20%
Year of Manufacturing			2013			
LV Winding Material			DPC Al		DPC Copper	
# of LV Turns	#		76		76	0%
HV Winding Material			DPC Al		DPC Copper	
# of HV Turns	#		3,344		3,344	0%
No Load Loss	Watts	260	258	-0.7%	295	+15% ***
Full Load Loss	Watts	1,760	2,358	+34%	1168	-50%
Impedance	%	4.05 – 4.95	3.84		4.21	
Total Winding Weight	Kg		46.62		192.36	

**Based on pre-repair test results and radiator fins calculation as mentioned in slide 12*
***kVA enhancement 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.*

Calculation of approximate kVA capacity/ loading of the transformer

RATED KVA	100	NO.OF PH	3	MAKE	SWASTIK
HV VOLTS	11000	HV AMPS	5.25	SR.NO.	SC/119243
LV VOLTS	433	LV AMPS	133.34	STORE ID	13-37609-9

	LENGTH		WIDTH		AV.HEIGHT	
TANK DIMENSIONS :	815	mm	325	mm	775	mm

TANK SURFACE AREA (EXCL.TOP & BOTTOM) :	1.767	SQ. METER
HEAT DISSIPATION RATE FOR TANK	500	WATTS/SQ.METER
LOSSES DISSIPATION CAPACITY OF TANK :	883.5	WATTS
TOTAL NO. OF RADIATOR BANKS IN TRANSFORMER	2	NOS.
RADIATOR SECTION USED :FIN HGT X WIDTH	500 mm X	230 mm
HEAT DISSIPATION PER FIN: at Oil Temp Rise of	45	oC
(AS PER RADIATOR DATA SHEET)	88	WATTS / FIN

RADIATOR FINS CALCULATION: (TO ASSES COOLING CAPACITY AT RATED LOAD)	RATING PLATE KVA & LOSSES AS PER P.O/SPEC.	PRE-REPAIR TEST AS PER RATING PLATE KVA	ACTUAL KVA CAPACITY OF TRF FOR PO/SPEC LOSSES	
KVA RATING:	100	100	86.41	KVA
NL LOSS	260	258	258	WATTS
FL LOSS	1760	2357	1760	WATTS
TOTAL LOSSES FOR DISSIPATION	2020	2615	2018	WATTS
DISSIPATION CAPACITY OF TANK	883.5	883.5	883.5	WATTS
DISSIPATION REQUIRED BY RADIATORS	1136.5	1731.5	1134.5	WATTS
HEAT DISSIPATION PER FIN FOR SELECTED SIZE	88	88	88	WATTS/FIN
CORRECTION FACTOR AS PER RADIATOR FIXING	0.82	0.82	0.82	-
EFFECTIVE HEAT DISSIPATION PER FIN	72.16	72.16	72.16	WATTS/FIN
THEREFORE TOTAL NO. OF FINS REQD.	15.75	24	15.73	NOS.
NO OF TOTAL FINS PROVIDED	16	16	16	NOS.

NOTE: The Load Losses at pre-repair test at Rated (100) kVA = 2357 Watt

The Load Losses by Calculation at actual(86.41) kVA = $(86.41/100)^2 \times 2357$ Watt

= 1760 Watt as per PO

CONCLUSION :

RATED KVA OF TRANSFORMER 100 KVA

APPROX.KVA AS PER PRE-REPAIR TEST RESULTS 86.41 KVA
(BASED ON LOSSES & RADIATORS)

Cost Benefit Analysis

Considering 86kVA baseline

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,779
Avg. Cost of Supply (Rs./kWh)	6.25
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Simple Payback Period including financing charges (years)	1.66

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,779
Avg. Cost of Procurement (Rs./kWh)	4.50
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Simple Payback Period including financing charges (years)	2.42

Cost Benefit Analysis

Considering salvage value of Cu

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,779
Avg. Cost of Supply (Rs./kWh)	6.25 (as per MPPKVVCL ARR 2017-18)
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Cu Salvage Value (INR)	89,006
Simple Payback Period including financing charges (years)	2

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,779
Avg. Cost of Procurement (Rs./kWh)	4.50
Total Money Saved (INR/year)	29,871
Total Cost for Active Repair (INR)	98,131
Total Cost for Conventional Repair (INR)	11,342
Incremental Cost (INR)	86,789
Cu Salvage Value (INR)	89,006
Simple Payback Period including financing charges (years)	3

ERDA Test Results (1/2)

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E-mail : erda@erda.org
Web : http://www.erda.org
Certificate No.: TC-5389

TEST REPORT Sheet : 1 of 6

NAME AND ADDRESS OF CUSTOMER	REPORT NO.: RP-1819-015362 DATE : 21.07.2018	
M/s. M.P.PASHCHIM KSHETRA VIDYUT VITARAN CO.LTD. OFFICE OF THE EXECUTIVE ENGINEER (MTRU) GPH COMPOUND,POLOGROUND, INDORE (M.P.)-452001.	CUSTOMER REF. NO.	DATE
	NO.242/EE/MTRU/18-19/ INDORE	24.05.2018
	DATE OF SAMPLE RECEIPT	DATE OF TESTING
	13.06.2018	11.07.2018 & 12.07.2018

SAMPLE DESCRIPTION
DISTRIBUTION TRANSFORMER
Manufactured by: SWASTIK COPPER P. LTD.
Rating : 100 kVA
Volts : 11000/433 V (at no-load)
Current : 5.25/133.3 Amps
Phases : 3/3 ; %Impedance : 4.5 %
Vector group : Dyn11 ; Frequency : 50 Hz
Winding : Copper
Cooling : ONAN
Losses as specified by customer :
1.Guaranteed no load loss : 260 W +(IS Tol.)
2.Guaranteed load loss at 75 °C:
1760 W +(IS Tol.)
Guaranteed maximum temperature-rise in oil/winding :45/50°C(as specified by customer)

SAMPLE IDENTIFICATION
ERDA sample code number : ERDA-00263644
Manufacturer serial no. : SC/119243
Customer: Madhya Pradesh Paschim Kshetra Vidyut Vitaran company ltd.
Year of manufacture :2013

Enclosed drawing numbers :
1) ICA/SC/100.11/02
2) ICA/SC/100.11/01

TEST DETAILS	TEST SPECIFICATION
As per sheet 2 of 6.	As per sheet 2 of 6.

TEST RESULTS : As per sheets from 3 of 6 to 5 of 6.
ENCLOSURE : Photographs of test sample – As per sheet 6 of 6.
TESTS WITNESSED BY : 1) Mr.Sunil Patel (E.E.,M/s.MPPKVVCL-INDORE)
2) Mr.Ashish Pandit (Project associate, M/s. International Copper Association, India)
REMARKS : 1)The transformer **conforms** to the guaranteed requirement as per above mentioned test specification for above mentioned test nos. 2 to 4.
2) Criteria limit has not been specified for test no.1.

PREPARED BY CHECKED BY APPROVED BY (Kapil J. Sharma)

Note : 1. This report relates only to the particular sample received for testing in good condition at E.R.D.A.
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3. Publication of this report requires prior permission in writing from Director, E.R.D.A.
4. Only the tests asked for by the customer have been carried out.
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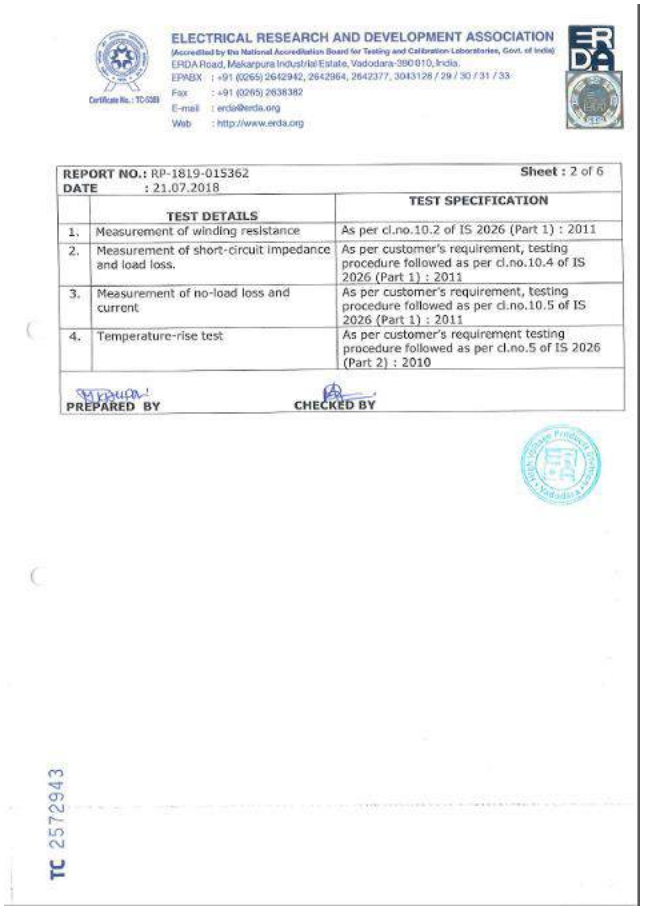

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REPORT NO.: RP-1819-015362 Sheet : 2 of 6
DATE : 21.07.2018

	TEST DETAILS	TEST SPECIFICATION
1.	Measurement of winding resistance	As per cl.no.10.2 of IS 2026 (Part 1) : 2011
2.	Measurement of short-circuit impedance and load loss.	As per customer's requirement, testing procedure followed as per cl.no.10.4 of IS 2026 (Part 1) : 2011
3.	Measurement of no-load loss and current	As per customer's requirement, testing procedure followed as per cl.no.10.5 of IS 2026 (Part 1) : 2011
4.	Temperature-rise test	As per customer's requirement testing procedure followed as per cl.no.5 of IS 2026 (Part 2) : 2010

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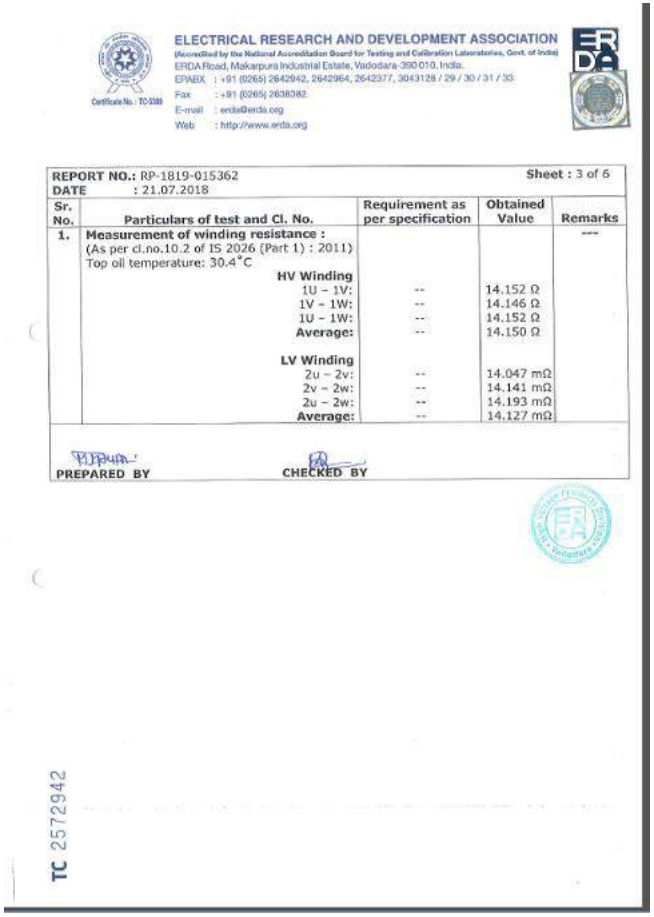
ERDA Test Results (2/2)

ERDA results were very close to measurements done at MTRU



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REPORT NO.: RP-1819-015362 Sheet : 3 of 6
DATE : 21.07.2018

Sr. No.	Particulars of test and Cl. No.	Requirement as per specification	Obtained Value	Remarks
1.	**Measurement of winding resistance :** (As per cl.no.10.2 of IS 2026 (Part 1) : 2011) Top oil temperature: 30.4°C			---
	HV Winding			
	1U - 1V:	--	14.152 Ω	
	1V - 1W:	--	14.146 Ω	
	1U - 1W:	--	14.152 Ω	
	Average:	--	14.150 Ω	
	LV Winding			
	2u - 2v:	--	14.047 mΩ	
	2v - 2w:	--	14.141 mΩ	
	2u - 2w:	--	14.193 mΩ	
	Average:	--	14.127 mΩ	

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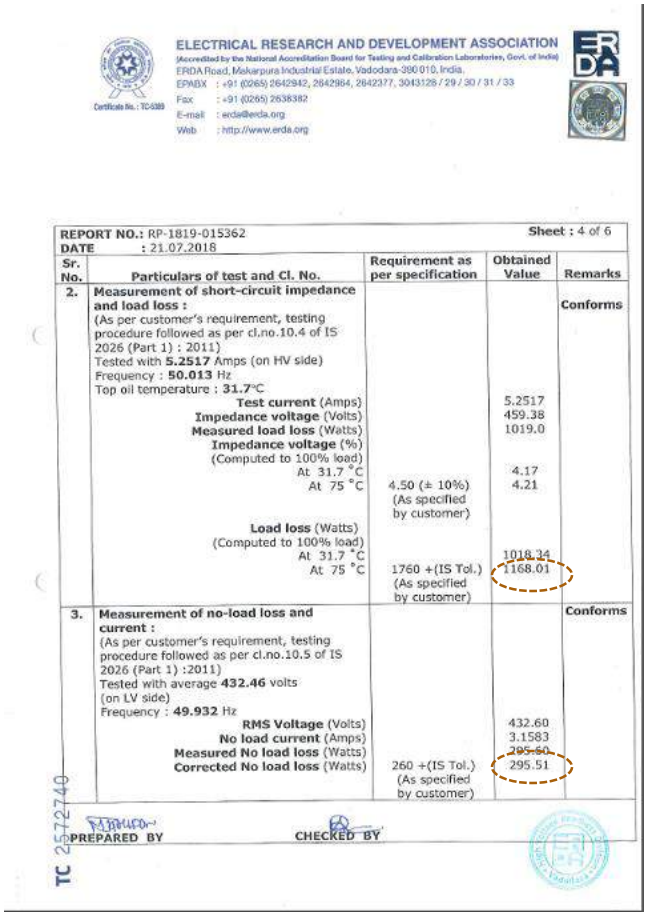

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REPORT NO.: RP-1819-015362 Sheet : 4 of 6
DATE : 21.07.2018

Sr. No.	Particulars of test and Cl. No.	Requirement as per specification	Obtained Value	Remarks
2.	**Measurement of short-circuit impedance and load loss :** (As per customer's requirement, testing procedure followed as per cl.no.10.4 of IS 2026 (Part 1) : 2011) Tested with **5.2517** Amps (on HV side) Frequency : **50.013** Hz Top oil temperature : **31.7**°C			**Conforms**
	Test current (Amps)		5.2517	
	Impedance voltage (Volts)		459.38	
	Measured load loss (Watts)		1019.0	
	Impedance voltage (%) (Computed to 100% load)			
	At 31.7 °C		4.17	
	At 75 °C	4.50 (± 10%) (As specified by customer)	4.21	
	Load loss (Watts) (Computed to 100% load)			
	At 31.7 °C		1018.34	
	At 75 °C	1760 +(IS Tol.) (As specified by customer)	1168.01	
3.	**Measurement of no-load loss and current :** (As per customer's requirement, testing procedure followed as per cl.no.10.5 of IS 2026 (Part 1) :2011) Tested with average **432.46** volts (on LV side) Frequency : **49.932** Hz			**Conforms**
	RMS Voltage (Volts)		432.60	
	No load current (Amps)		3.1583	
	Measured No load loss (Watts)		295.60	
	Corrected No load loss (Watts)	260 +(IS Tol.) (As specified by customer)	295.51	

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Losses measured at MTRU

1168

293

Scenario Analysis

Sensitivity to Avg. Cost of Supply (ACoS)

	Payback period (years)		
	0% CAGR ACoS	5% CAGR ACoS	10% CAGR ACoS
100 KVA	3.55	3.34	3.18

Sensitivity to DTR loading

	Payback period (years)			
	70% DTR Load	80% DTR Load	90% DTR Load	100 % DTR Load
100 KVA	3.18	2.39	1.84	1.50

Sensitivity to kVA Enhancement

	Payback period (years)
With kVA enhancement*	2.59
Without kVA enhancement	3.18

**Based on the ERDA results it is estimated that Active Repair of DTs also enhanced the kVA capacity to 109kVA*

DT-2: 200 KVA

Results, Cost Benefit Analysis

Active Repair Solution and Results

200 kVA DT was failed, hence full pre-repair testing cannot be done. Both HT and LT windings were replaced with Cu windings. Significant Full Load loss reduction.

Key Design Parameters	Unit	Utility Specs	Baseline Pre-repair (at MTRU)*	% Deviation from Specs	Actual Post-repair (at ERDA)	% Change from Specs
Capacity	kVA	200	200		219**	+9.5%
Year of Manufacturing			NA			
LV Winding Material			DPC Al		DPC Copper	
# of LV Turns	#		42		42	
HV Winding Material			DPC Al		DPC Copper	
# of HV Turns	#		1,848		1,848	
No Load Loss	Watts	500	561	-	567.79	+13%***
Full Load Loss	Watts	3,000	3,000	-	1729.69	-42.34%
Impedance	%	4.5 – 5.5	-		4.42	
Total Winding Weight	Kg		86.20		297.45	

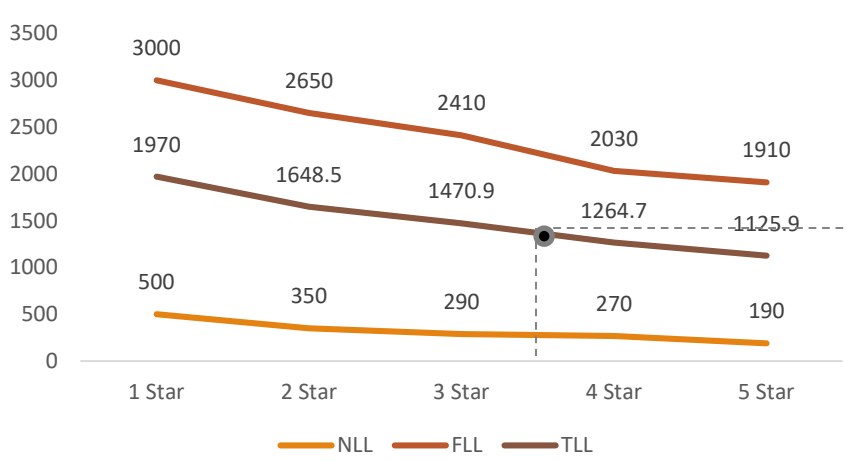
** Since it was failed DT, pre-repair Full Load loss measurement cannot be done. It is hence assumed to be same as spec value. No Load loss was estimated to be same as spec value.*

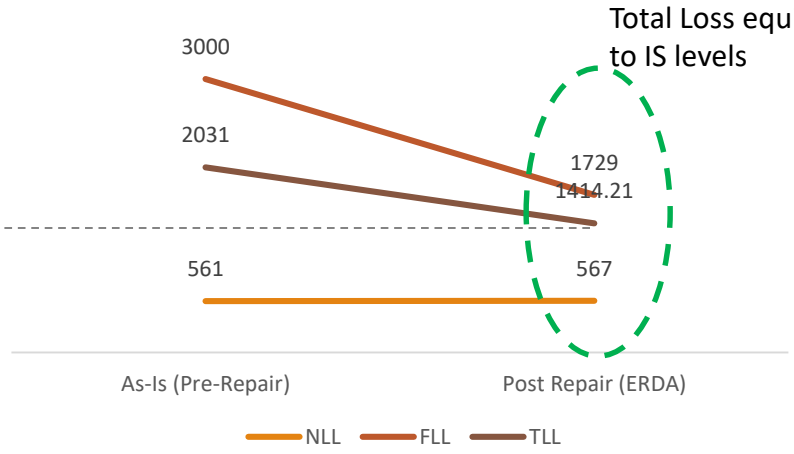
*** kVA enhancement inferred and estimated from ERDA Heat Testing results, done at standard 100% rating*

**** 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%*

Upgradation of Legacy DT

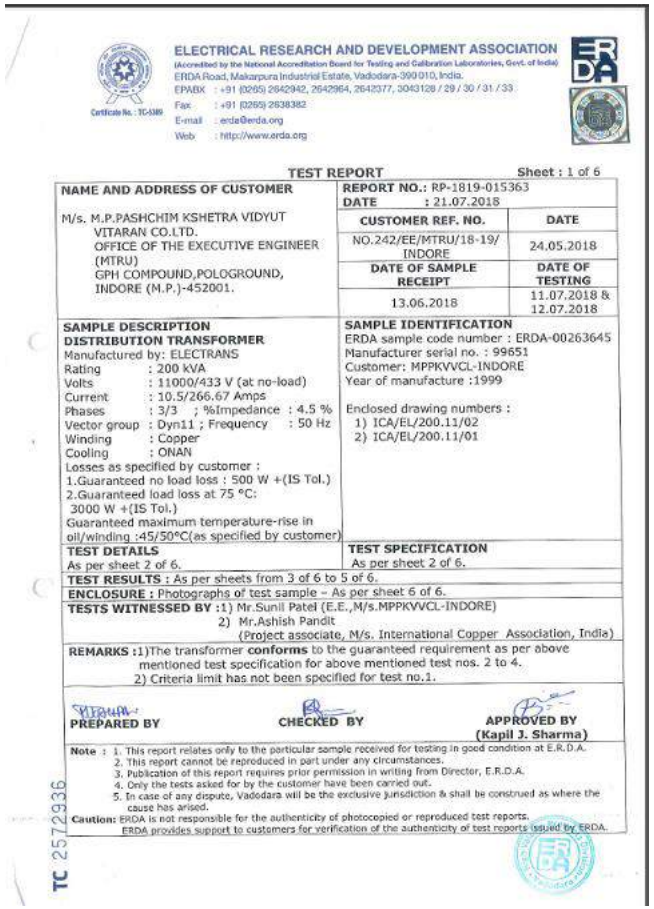
Active Repair enhances the performance of the old legacy DT to a level of Energy Efficiency stipulated as per IS 1180 specially at higher loading conditions





**Total Losses values are calculated at 70% DTR loading*

ERDA Test Results (1/2)



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TEST REPORT Sheet : 1 of 6

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	NO.242/EE/MTRU/18-19/ INDORE	24.05.2018
	DATE OF SAMPLE RECEIPT	DATE OF TESTING
	13.06.2018	11.07.2018 & 12.07.2018

SAMPLE DESCRIPTION
DISTRIBUTION TRANSFORMER
Manufactured by: ELECTRANS
Rating : 200 kVA
Volts : 11000/433 V (at no-load)
Current : 10.5/266.67 Amps
Phases : 3/3 ; %Impedance : 4.5 %
Vector group : Dyn11 ; Frequency : 50 Hz
Winding : Copper
Cooling : ONAN
Losses as specified by customer :
1.Guaranteed no load loss : 500 W +(IS Tol.)
2.Guaranteed load loss at 75 °C:
3000 W +(IS Tol.)
Guaranteed maximum temperature-rise in oil/winding :45/50°C(as specified by customer)

SAMPLE IDENTIFICATION
ERDA sample code number : ERDA-00263645
Manufacturer serial no. : 99651
Customer: MPPKVVCL-INDORE
Year of manufacture :1999

Enclosed drawing numbers :
1) ICA/EL/200.11/02
2) ICA/EL/200.11/01

TEST DETAILS
As per sheet 2 of 6.

TEST SPECIFICATION
As per sheet 2 of 6.

TEST RESULTS : As per sheets from 3 of 6 to 5 of 6.

ENCLOSURE : Photographs of test sample – As per sheet 6 of 6.

TESTS WITNESSED BY : 1) Mr.Sunil Patel (E.E.,M/s.MPPKVVCL-INDORE)
2) Mr.Ashish Pandit
(Project associate, M/s. International Copper Association, India)

REMARKS : 1)The transformer **conforms** to the guaranteed requirement as per above mentioned test specification for above mentioned test nos. 2 to 4.
2) Criteria limit has not been specified for test no.1.

PREPARED BY **CHECKED BY** **APPROVED BY** (Kapil J. Sharma)

Note :
1. This report relates only to the particular sample received for testing in good condition at E.R.D.A.
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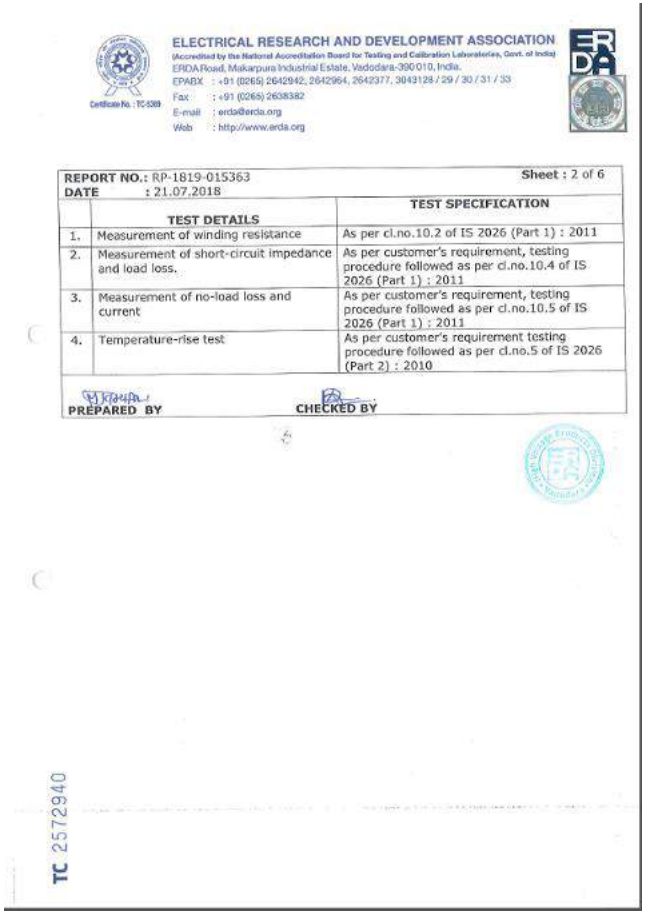

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REPORT NO.: RP-1819-015363 **Sheet :** 2 of 6
DATE : 21.07.2018

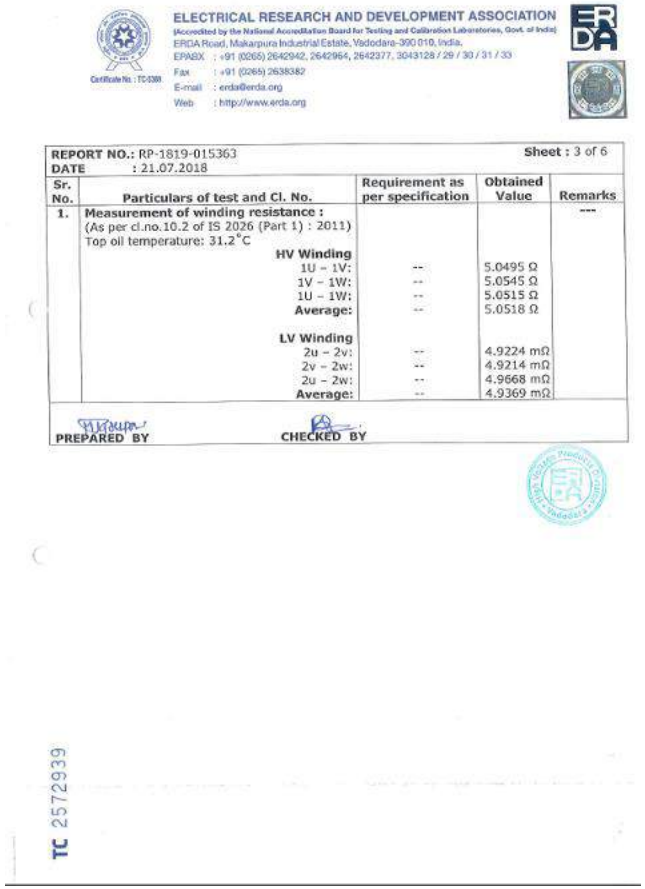
	TEST DETAILS	TEST SPECIFICATION
1.	Measurement of winding resistance	As per cl.no.10.2 of IS 2026 (Part 1) : 2011
2.	Measurement of short-circuit impedance and load loss.	As per customer's requirement, testing procedure followed as per cl.no.10.4 of IS 2026 (Part 1) : 2011
3.	Measurement of no-load loss and current	As per customer's requirement, testing procedure followed as per cl.no.10.5 of IS 2026 (Part 1) : 2011
4.	Temperature-rise test	As per customer's requirement testing procedure followed as per cl.no.5 of IS 2026 (Part 2) : 2010

PREPARED BY **CHECKED BY**

TC 2572940

ERDA Test Results (2/2)

ERDA results were very close to measurements done at MTRU



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REPORT NO.: RP-1819-015363 Sheet : 3 of 6
DATE : 21.07.2018

Sr. No.	Particulars of test and Cl. No.	Requirement as per specification	Obtained Value	Remarks
1.	**Measurement of winding resistance :** (As per cl.no.10.2 of IS 2026 (Part 1) : 2011) Top oil temperature: 31.2°C			---
	HV Winding			
	1U – 1V:	--	5.0495 Ω	
	1V – 1W:	--	5.0545 Ω	
	1U – 1W:	--	5.0515 Ω	
	Average:	--	5.0518 Ω	
	LV Winding			
	2u – 2v:	--	4.9224 mΩ	
	2v – 2w:	--	4.9214 mΩ	
	2u – 2w:	--	4.9668 mΩ	
	Average:	--	4.9369 mΩ	

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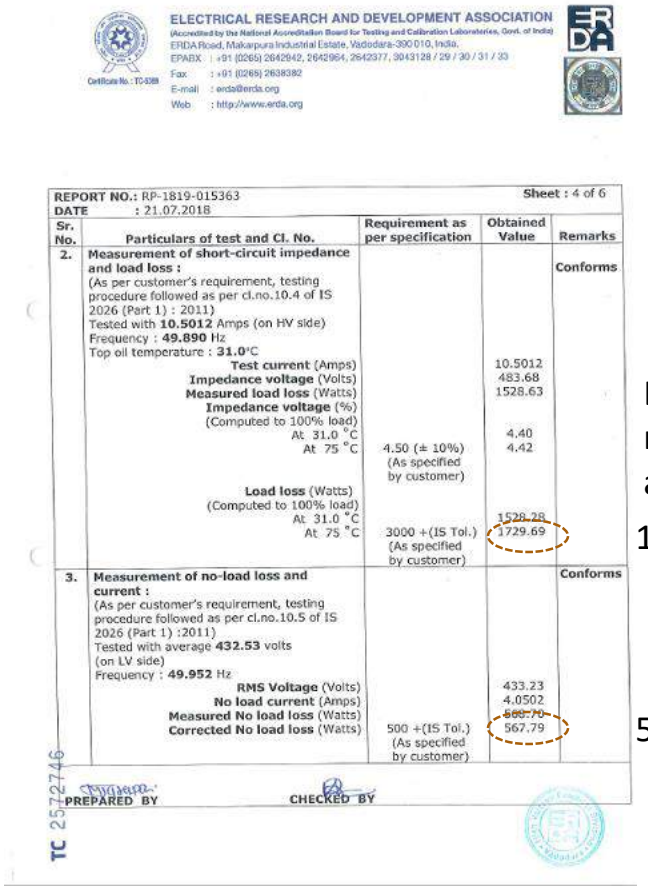

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REPORT NO.: RP-1819-015363 Sheet : 4 of 6
DATE : 21.07.2018

Sr. No.	Particulars of test and Cl. No.	Requirement as per specification	Obtained Value	Remarks
2.	**Measurement of short-circuit impedance and load loss :** (As per customer's requirement, testing procedure followed as per cl.no.10.4 of IS 2026 (Part 1) : 2011) Tested with **10.5012** Amps (on HV side) Frequency : **49.890** Hz Top oil temperature : **31.0**°C			**Conforms**
	Test current (Amps)		10.5012	
	Impedance voltage (Volts)		483.68	
	Measured load loss (Watts)		1528.63	
	Impedance voltage (%) (Computed to 100% load)			
	At 31.0 °C		4.40	
	At 75 °C	4.50 (± 10%) (As specified by customer)	4.42	
	Load loss (Watts) (Computed to 100% load)			
	At 31.0 °C		1528.28	
	At 75 °C	3000 +(IS Tol.) (As specified by customer)	1729.69	
3.	**Measurement of no-load loss and current :** (As per customer's requirement, testing procedure followed as per cl.no.10.5 of IS 2026 (Part 1) :2011) Tested with average **432.53** volts (on LV side) Frequency : **49.952** Hz			**Conforms**
	RMS Voltage (Volts)		433.23	
	No load current (Amps)		4.0502	
	Measured No load loss (Watts)		560.70	
	Corrected No load loss (Watts)	500 +(IS Tol.) (As specified by customer)	567.79	

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Losses measured at MTRU

1758

561

Cost Benefit Analysis

Active Repair provides good cost economic option to Discom to upgrade legacy DTs asset with performance (measured in terms of Total Loss) better than 3-star new DT

Cost Benefit Analysis	
Total Units Saved (kWh/year)	4,858
Avg. cost of supply	6.25 (as per MPPKVVCL ARR 2017-18)
Total Money Saved (INR/year)	30,368
Total Cost for Active Repair (INR)	151,502
Total Cost for Conventional Repair (INR)	19,973
Incremental Cost	131,529
Payback Period including financing charges (years)	4.56

Options for Discom		
1. Business as Usual		
INR 19K (failed DT conventional repair cost) + INR 30K (yearly energy loss)		
2. Replacement		
	Al	Cu
1 star	INR 1.65L	INR 2.4L
3 star	**INR 2.1L**	**INR 2.8L**
3. Active Repair		
plus INR 1.5L (almost new Cu DT with enhanced efficiency and high Cu salvage value)		

Scenario Analysis

Sensitivity to CAGR of Avg. Cost of Supply (ACoS)

	Payback period (years)		
	0% CAGR ACoS	5% CAGR ACoS	10% CAGR ACoS
200 KVA	5.60	4.95	4.56

Sensitivity to DTR loading

	Payback period (years)			
	70% DTR Load	80% DTR Load	90% DTR Load	100% DTR Load
200 KVA	4.56	3.47	2.70	2.21

Sensitivity to kVA Enhancement

	Payback period (years)
With kVA enhancement	3.55
Without kVA enhancement	4.56

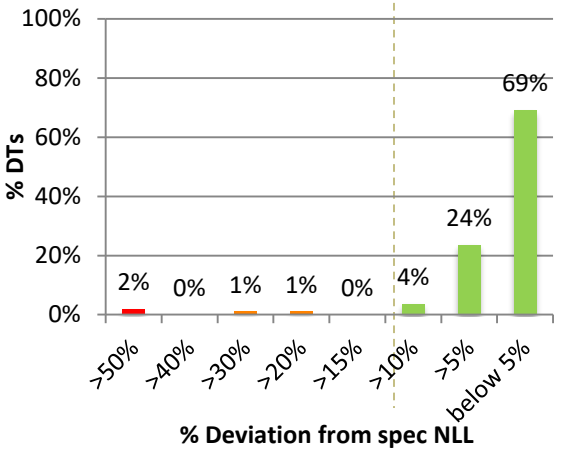
**Based on the ERDA results it is estimated that Active Repair of DTs also enhanced the kVA capacity to 219kVA*

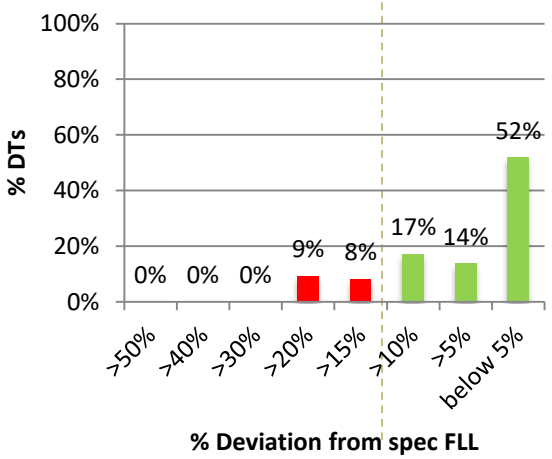
APPLICABILITY TO BROADER MPPKVVCL

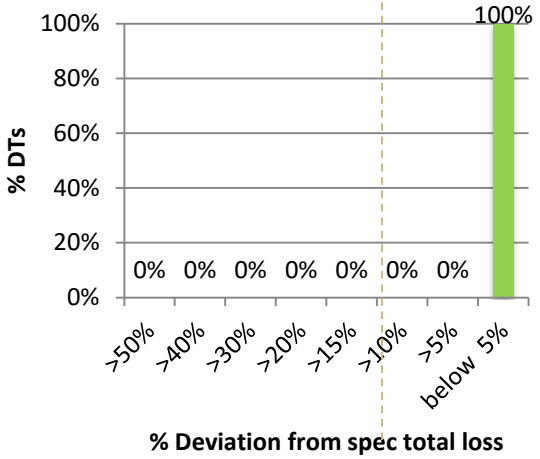
Legacy DTs with greater than allowed loss levels are existing. Full load losses seem to be higher concern than No load losses.

Based on sample repair data for 146 DTs from MTRU - 110 nos. of 100kVA DTs and 36 nos. of 200kVA DTs

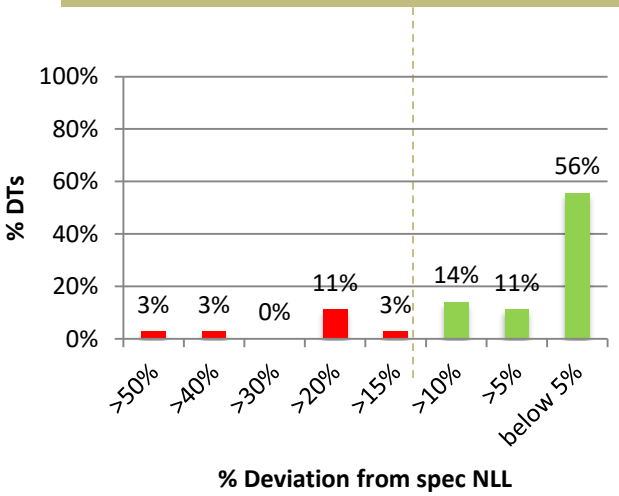
100kVA DTs

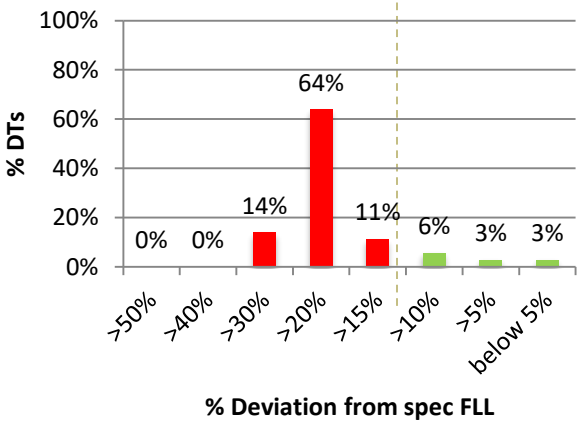


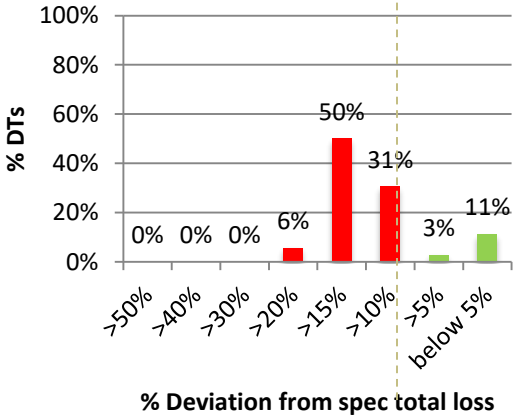




200kVA DTs







Applicability to broader MPPKVVCL

Likely current scenario

	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 Active 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

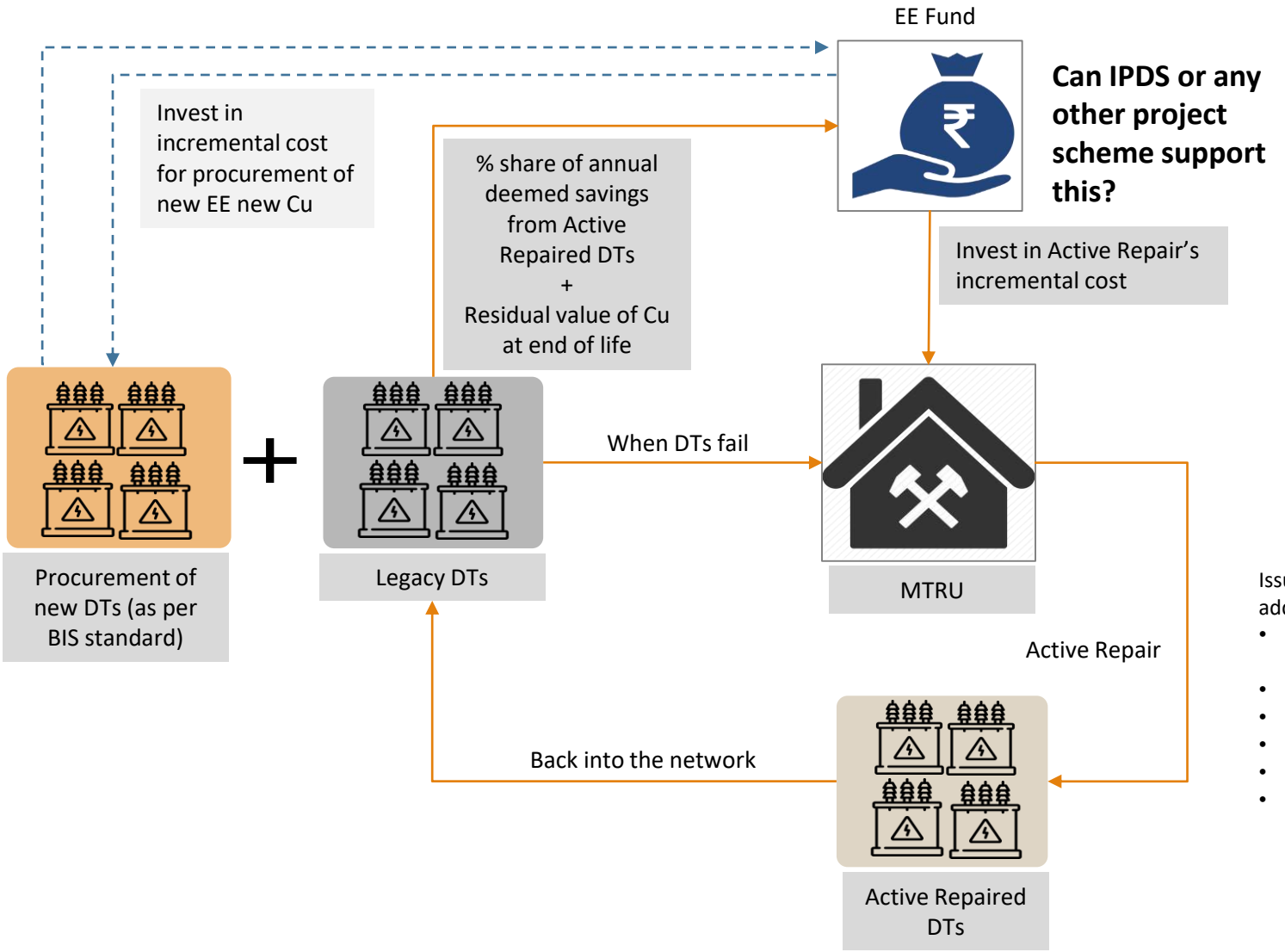
INR 254 cr. x 71%* = 180 cr./year savings

* 71% of MVA capacity is less than equal to 200 kVA DTs, that can be Active Repaired with Cu windings

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

Capacity (KVA)	No. of transformers	MVA Capacity	MVA Capacity (%)
Below 25	16,449	164	1%
25	93,364	2,334	14%
63	36,934	2,327	14%
100	59,858	5,986	37%
200	3738	748	5%
Above 200	14,953	4,710	29%
TOTAL	**2,25,296**	**16,269**	**100%**

Potential Business Model



Issues that need to be addressed

- Standardization of Active Repair solution
- Skill set
- Material Procurement
- Inhouse vs outsource
- Test capability
- Design support

OBSERVATIONS AND NEXT STEPS

Key Observations

- Active repair of DTs reduces total losses. If no. of turns can be increased, then even No load losses can be reduced. There is design trade-off between balancing No load and Full load losses.

	100 KVA	200 KVA
NLL	+13%	+12%
FLL	-34%	-42%
TL	-28%	-34%

Compared to spec values

	100 KVA	200 KVA
NLL	-1%	-1%
FLL	-42%	-50%
TL	-34%	-40%

Compared to allowed tolerance for repaired transformer

- **2 to 5 years payback period** for Active Repair investment
- Active Repair can upgrade the performance of the old legacy DT to higher than 3-star performance (measured in terms of Total Losses)

Next Steps

- **Possibility for (hybrid) Active Repair:** One can consider a hybrid active repair experiment with only HT winding with Cu and LT with Al.

- **PoC DT Monitoring**: Discom need to support monitoring DTs by placing both side meters to see performance of the Active Repaired DTs.

- **Integrating the concept with IPDS**: Consider this concept under IPDS or any other scheme (for a zone/circle) which will help Discom reduce loss trajectory as mandated by government and also help capacity enhancement of in house facilities.

THANK YOU!

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