ELECTRICAL CONNECTORS

Essential Weak Links of any Electrical System

A case study at MPMKVVCL, BHOPAL

INTRODUCTION

This paper contains information about existing Electrical Equipment Connectors, here we specifically refer to POWER & DISTRIBUTION TRANSFORMER, ISOLATOR, CTs, PTs, AB Switches etc…. Connection Systems mainly for following concerns,

"TECHNICAL LOSSES, SAFETY, O&M ISSUES"

This paper will provide a better support to the Utilities in order **to introduce new available, proven connection systems and elaborate their own specifications to rationalize the test requirements and acceptance criteria** for minimizing operational issues due to terminal connections at Power & Distribution Transformer and other equipments.

If we want efficient & long term working of Transformers (any electrical equipment) and Cables connected to equipment, then connections are also have to perform in desired manner for considered long term period. Normally we pay much attentions towards Class A items like Transformers and Cables specs, and Class C items like connections/clamps are ignored and kept for last minute decision mostly.

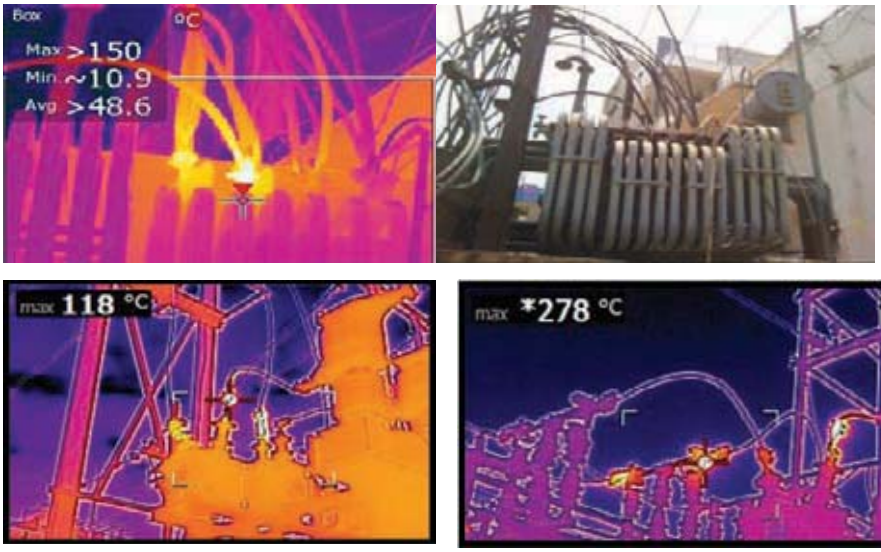
MAIN CONCERNS

Let's concentrate on Power Distribution segment where SAFETY of Transformers due to OVERHEATING, which is either ignored or unaddressed.

ISSUES @ TRANSFORMER CONNECTIONS (EXISTING)

- **O&M issues**
  (Oil Leakage, Installation Method, Operator Skill, Long Term Reliability)

Efficiency Degradation of Electrical Equipments due to **Over-Heated** Electrical Connections.



Thermo-vision Photos: Transformer, Isolators and CTs

SAFE & EFFICIENT CONNECTORS' CRITERIA	
Easy to Install (simple tools, less effort)	**Easy to Maintain, Monitor & Control** (O&M Concern)
Proven **Safety** (Fool-proof / Mistake-Proof): ZERO Accidents	Compact & Light Weight (**FOOTPRINTS : Space Constraint** - mainly in Metros)
Wide range acceptability (**Standardization** w.r.to sizes/types)	**Robust** in extreme conditions (Dust, Pollution & Moisture, Heavy Rain.)
Economical - Value for Money (Justifiable – Value Proposition)	**Reliability** (Product Life Cycle) **Retrofit** arrangement (for existing system / products)

Weight of the Connector and its Installation Method results in exerting cantilever force on the transformer bushing that results in oil leakage. The oil leakage (UNSAFE) that is observed from transformer bushings and subsequent oxidation of CONNECTIONS (DETERIORATION) are highly undesirable.

- Further disadvantages associated with OLD connections include the installation practices of existing electrical connectors is not standardized and the method is complex. Installation of such electrical connectors is further affected by application of force for uncontrolled tightening force and Tightening torque.

- **Overheating or Hot Spots**
  Undesirable Temperature rise @Connections are due to high contact resistance of conventional bolted and crimped connections and dissimilar Contact Surfaces. Limitations associated with these connectors include frequent overheating of connectors that leads to failures and interruptions resulting in power loss and revenue losses.

- **Outdoor Susceptibility**
  Water and Dust Ingress, Pollution, Increasing Ambient Temperatures including heat fluctuations, Corrosion will further deteriorate contacts to increase contacts resistance drastically.

ROOT CAUSES

Electrical Contact Resistance is important parameter to assess connector quality and reliability. Three main factors which affect contact resistance values are Conduction, Oxidation factor and Pressure/Force applied while connection.

Following factors are essentially contributing towards high Contact Resistances and added to undesirable Temperature Rise

A. Raw Materials

1. Transformer windings are of Aluminium materials upto 100KVA and then after of Copper materials.
2. Transformer bushings Studs are either of Brass material or Copper material which are used for connections.
3. All cable or conductors are of Aluminium materials such as AAAC, ACSR or AAC type
4. Different Connector materials
   - **Palm Connector:** Brass
   - **Lugs:** Aluminium
   - **Bimetal Connector:** Brass + Aluminium
   - **PG Clamps:** Aluminium

   So in overall, we have "Aluminium, Aluminum Alloys" and "Copper, Copper Alloys" for Transformer electrical application.

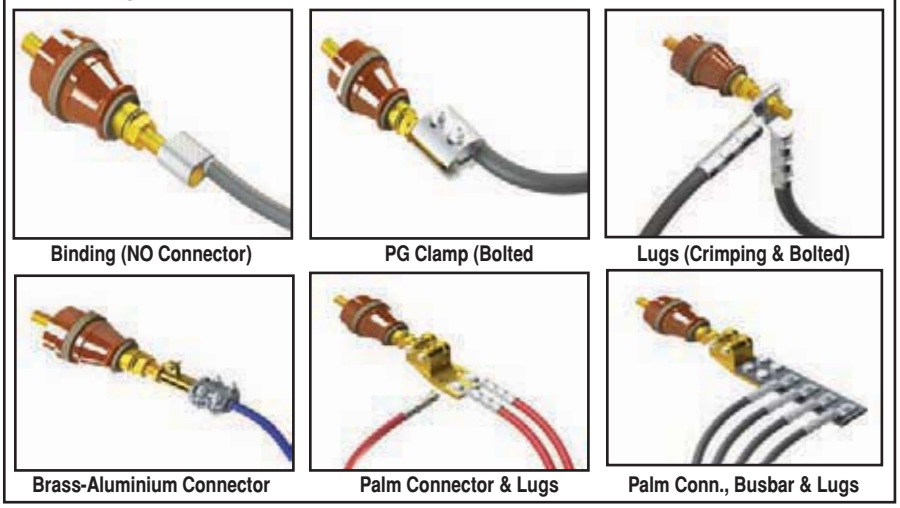
B. Connector Designs

Existing Connector Designs are not based Energy Efficient Design like maximum contact area, controlled forces criteria etc… hence these issues.

C. Manufacturing Methods

- **Sand or Gravity Die Casting:** Partial Porosity, Al Alloy & Process Limitations
- **Extrusions:** No Porosity and High Conductive Aluminium Alloys
- **Conventional Machining:** Not suitable for mass production and quality products
- **CNC Machining:** Reliability and Repeatability of consistent Manufacturing Process
- The best combination is to design connectors based on Extrusions and CNC machining.

D. Existing Connection Methods



RECOMMENDATIONS

From above four points, use of Crimped, Bolted, Brass as raw material, Casted Aluminium, Bimetal washers etc..,all are old conventional practices which need to be improvised based on current objectives of achieving 24X7 Reliable Power Supply and high Ampacity requirements.

- To reduce overheating, High Ampacity Connectors with TR (< 20^{O}C) above ambient (instead of <= 45^{O}C) and other stringent changes in specifications are to be done.
- Connectors are our Weakest Link as of now and can be big opportunity for REDUCE Losses and to INCREASE system reliability. Loss at each connection has potential to save, if energy efficient connectors are deployed and commissioned in mass.
- Along with "Energy Efficient Transformers" we need INNOVATIVE "Energy Efficient Connectors" which are clearly more efficient (than defined) & suitable for O&M need till last miles.
- Standardization of Cables and Connectors are key

CUSTOMIZATIONS WORK & CASE STUDY RESULTS FOR NEW CONNECTORS

- We have come up with INNOVATIVE designs which are applied for PATENTs and these products will act as Power Loss Reducer thus named as TUSKER Terminals which are O&M Friendly & will build Energy Efficient & Reliable system for long term.
- Temperature Rise (above ambient) results are less than 20^{O}C and showing no major changes in resistance values.
- These new connectors are available for Threaded Studs, Plain Dia. Studs, Flat Busbars & IPS Al Tubes.

(TUSKER Terminals for M12, M20, M30, M40, M48 Studs)

"Annual Potential Savings per Transformer"	45386	Transformer Population Nos
Approx Savings/year from Transformers in Crores	6.8	1500

Additional Tangible Benefits

1. Failure due to
   - Oil leakages
   - Cables/Connections Overheating
   - PH-PH and PH-Earth Faults
2. Revenue Loss due to Shut down
3. Maintenance Cost
   - No Crimping
   - No Hydraulics tool and its maintainance
4. Safety
   - Complete insulation by Insulation Cover

Contact Resistance Measurements in micro-ohms

Details	KV	BEFORE			AFTER		
		R	Y	B	R	Y	B
8MVA, 33/11KV POWER TRANSFORMER	33	680	297	504	5	6	6
	11	910	4440	681	4	29	4
33KV ISOLATOR	33	790	640	730	25	16	18
11KV CURRENT TRANSFORMER	11	810	294	520	9	16	17
Sum of all contact resistance values	33	3641			76		
	11	7655			79		

VALUE PROPOSITION for Power Transformer 8MVA, 33/11KV

Details	Units	11KV		33KV	
		BEFORE	AFTER	BEFORE	AFTER
Transformer Current Rating (as per Voltages)	Amp	420	420	140	140
Avg Current in the connector (Per circuit, 80% of X'mer Load)	Amp	336	336	112	112
"Average Contact Resistance at Cable Connections at ambient temperature of 35^{0}C "	Micro Ohms	7,655	79	3,641	76
Average Contact Resistance at Cable Connections at 70^{0}C for existing connection & at 45^{0}C for Tusker Terminals	Micro Ohms	8,804	82	4,188	79
Energy Loss per circuit / year in kWh/Yr	KWH	8,703	81	460	9
Technical loss per annum/per transformer (A) - INR 5/Unit	INR	43,515	405	2,300	45
i) Revenue loss @shutdown/maintenance/ breakdowns	INR	28,800	0	0	0
ii) Manpower cost for regular maintenace twice in a year	INR	1,200	0	0	0
Indirect loss in Rs per annum / transformer (B) = i + ii	-	30,000	0	0	0
Total loss in Rs per annum/per transformer - A (B not taken)	INR	43,536	407	2,301	44
Total loss in Rs in 10 years /per transformer - A	INR	435,364	4,074	23,008	435
Potential Energy Savings per Month	INR	3,594		188	
Potential Energy Savings per Annum from total 12 connectors at Power Transformer, Isolator & CT	INR	45,386	"Based on Power Savings Payback < 1 year"		

Safe, Reliable, Energy Efficient Solution: TUSKER TERMINALs

CONCLUSION

On real-time testing, we have observed there is great potential of Power savings (minimization of Heat Losses) based on I2R calculation on 8MVA Power Transformer. Resistance have been improved from three digits to single digits and thus reducing TR during life cycle of Equipments and Cables.

This directly increases Efficiency and Reliability of whole Electrical System, also more beneficial indirectly in long run by reducing your Maintenance Failures. This leads to increase in Revenue by reduction of replacement CAPEX & OPEX..

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