Mobile Trailer 1T-40.0.2 Failure
February 2, 2005

BACKROUND:

Utilities generally use a fleet of mobile auto-transformer trailers to substitute for in place sub-station transformers that have failed in service. This process, particularly in a large utility, demands that, when needed, these mobile auto-transformers be able to be transported to a given substation or risk the loss of thousands of customers from the utility grid.

In many cases, different size (MVA) mobile transformers with varying voltage requirement levels (69kV to 500kV) could be needed depending on the size and type of failed transformer at a particular substation. In many cases, a mobile auto-transformer may be stored at a given substation location, but may not be energized until needed. In other cases, where a particular substation has a mobile auto-transformer on site but it isn’t the right size, another mobile auto-transformer may be needed to be transported to that substation to provide necessary power substitution for the failed on site transformer until such time as a new transformer can be ordered, manufactured, shipped and installed on site, which may be a period of twelve to eighteen months.

Because of the importance of these units to a utility’s reserve power grid

BACKGROUND, CONT'D:

operations, mobile auto-transformer maintenance becomes very important. This paper describes a failure that occurred to one of these trailers as it was being transported under emergency conditions to a substation due to the failure of the wheel bearings on that trailer prior to reaching its proposed destination.

Mobile trailer 1T-40.0.2, containing a 40 MVA mobile single phase auto-transformer was fully overhauled between the months of March 22, 2001 and May 15, 2001 by Fleet Maintenance in Davis, CA, after which it was moved a distance of nineteen miles to the Vaca Dixon Substation where it was set on station in a de-energized condition until Wednesday, February 2, 2005. The auto-transformer was then moved a distance of eight miles from Vaca Dixon to a location along the Interstate 505 Freeway where the street side, outside-rear-front wheel bearing seized catastrophically, along with a second wheel bearing located directly inboard and a third located directly behind the second inboard bearing.

The trailer weight as stated on the original manufacturer's drawing #639136, dated 9/17/57, indicated a total gross weight of 135,888 lbs for the trailer, including the 91,000 lb transformer. Substation records indicated the weight to be 133, 280 lbs. However, the weight as measured on the Davis Service Center scales was 115,000 lbs.

INITIAL OBSERVATIONS:

The spindle and the associated wheel bearing for the outside-rear-front wheel was reviewed, at which time it was noted that the roller bearings had completely seized to the bearing assembly and the spindle associated with that bearings had been worn down to approximately ½ its original diameter, due to some sort of frictional force.

At this point, it was difficult to determine the "root cause" of the failure, since there wasn't enough of the required evidence present, at that time, to make a studied observation, however, several thoughts were provided by personnel regarding the cause of the failure from a possible bearing misalignment to a bearing grease failure or use of improper grease, to a possibility that the trailer sat on station for an extended period of time without being moved and the grease dried out on the bearing surfaces.

All available parts from all sixteen spindle assemblies (thirty two axles and wheels) were collected and turned over to TES for evaluation by the Welding and Metallurgy group.

MAINTENANCE HISTORY:

Following the overhaul of the trailer in 2001, Fleet Maintenance conducted both

MAINTENANCE HISTORY, CONT'D:

long inspections on a yearly basis and 90 day BIT inspections as required by UO Standard D-S0468 (since superseded by UO Standard S3468). Those inspections and associated time commitments by the mechanics are noted in the TEAMS database.

It is, however, difficult to determine exactly what procedures were followed by both Fleet Maintenance and Substation Personnel, since there are no records to indicate if the brake inspections were conducted as prescribed in the standard or the unit was exercised during that period of time on station, which amounted to approximately three years, eight months and eighteen days.

INITIAL FINDINGS:

The driver of the tractor trailer who picked up the unit for transport at the Vaca-Dixon Substation, noted that the tires were on the ground and partially buried in the on-site gravel, which indicates that there may have been partial loading on the tires and the wheel bearings. Drawing #639136 shows a procedure for setting the trailer on station, using jacks to get the tires completely off of the ground. He did not know whether or not the unit had been completely grounded during that timeframe, as stipulated by Instruction #3 in the Operating Instructions for the General Electric 40.0 MVA Mobile transformer, Company #1T-40.0.2, which requires that the "opposite corners of the unit be connected to the station ground grid using at least two 250 MCM copper cables, along with touch potential grading.

A garage foreman at the Davis Garage stated that he'd had occurrences, one in particular, where he had been shocked when he walked up to a Mobile Auto-Transformer (MAT). He remembered an incident at Table Mountain where they checked the voltage to ground and measured 80 volts during operation due to improper grounding. He now uses a grounding bar when he approaches an MAT.

It is suggested that a further check of this issue be carried out, on both energized and non-energized mobiles, to determine proper grounding on both stored and active units and to determine if possible damage to other Mobile Auto-Transformers due to induced voltage could be a problem.

TES FINDINGS:

The three sets of failed bearings and wheel spindles were submitted to TES for failure analysis. In addition, sixteen bearing sets consisting of the inner and outer roller bearings from each wheel spindle were removed from the trailer and submitted for analysis. (Included in these sixteen bearing sets were the three new bearing sets installed to replace the failed bearings.)

Visual examination of the parts from the three wheels where bearing failure

TES FINDINGS, CONT'D:

occurred revealed catastrophic and complete failure of the bearings on those wheels. Figure 1, below, illustrates the extent of damage found and is representative of the five bearings that failed on the three subject wheels. Because of the extent of damage to the failed bearings, little useful information as to the cause of failure was obtained from those bearings.

Figure 1: Outer bearing from spindle #10. Rollers are welded to the inner race.

The bearings from the wheel locations without failures were visually examined to determine any additional damage to other bearings. Two types of damage were found on the bearing surfaces: faint linear frosting on the races and rollers of bearings on Spindles #10, #11, #15, and #16 (see Figure 2 below); and scattered pitting on the races of the bearings on Spindle #7.

Samples of damage found in the visual examination were analyzed in further detail using scanning electron micrography to classify the damage found visually. The results of this examination are summarized, as well, in Figure 2 showing both the damage type found and location of each bearing on the trailer. It is noteworthy that all of the bearings with arcing damage were located on the aft wheel carriage of the trailer, as were the three spindles that suffered catastrophic bearing failures. Only one spindle on the front carriage had bearing damage, which was caused by a different failure mechanism than the failures on the aft carriage.

TES FINDINGS, CONT'D:

Front of Transformer Trailer			
Spindle #1 O: No damage I: No damage	Spindle #2 O: No damage I: No damage	Spindle #3 O: No damage I: No damage	Spindle #4 O: No damage I: No damage
Spindle #5 O: No damage I: No damage	Spindle #6 O: No damage I: No damage	Spindle #7 O: **Corrosion pits** I: **Corrosion pits**	Spindle #8 O: No damage I: No damage
Spindle #9 O: **Failed bearing** I: **Failed bearing**	Spindle #10 O: **Failed bearing** I: **Arcing damage**	Spindle #11 O: No damage I: **Arcing damage**	Spindle #12 O: No damage I: No damage
Spindle #13 O: No damage I: No damage	Spindle #14 O: **Failed bearing** I: **Failed bearing**	Spindle #15 O: **Arcing damage** I: **Arcing damage**	Spindle #16 O: **Arcing damage** I: **Arcing damage**
Rear of Transformer Trailer			

Figure 2: Location and type of damage found on trailer bearings. **I** denotes the inner bearing on the spindle; **O** denotes the outer bearing on the spindle.

Figures 3 and 4 are scanning electron micrographs that show surface damage on a bearing with linear frosting damage that did not fail; this damage is representative of the damage found on the other aft carriage bearings examined.

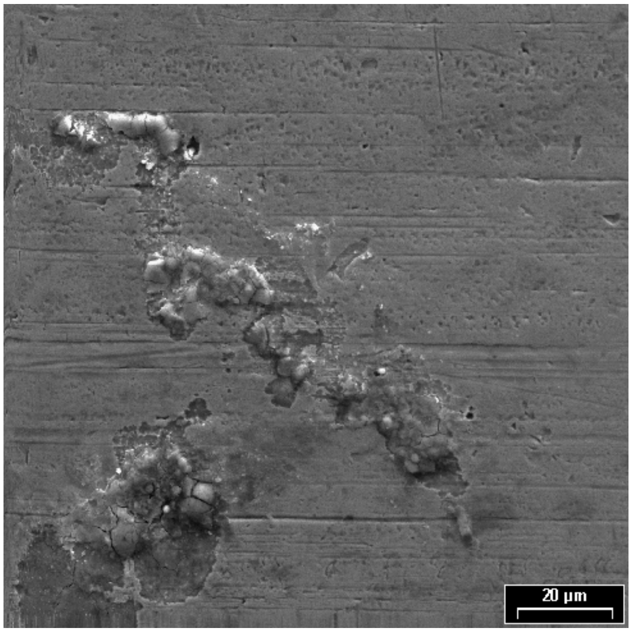

Figure 3: Scanning electron micrograph of electric discharge damage on roller from spindle #10 inner bearing.

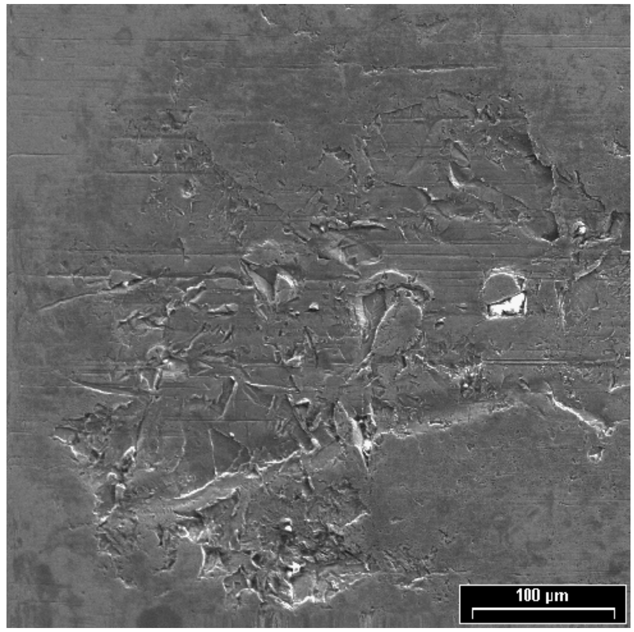

Figure 4: Scanning electron micrograph of spalling on roller from spindle #10 inner bearing.

The melting, pitting, and surface oxidation seen in Figure 3 is characteristic of arcing damage produced by low voltage electric discharge through the bearing. A potential difference of as little as two volts is known to cause this type of damage. Once damage to the bearing roller and race surface is initiated by electric discharge, the damage expands during operation by forming fatigue cracks in the surfaces that result in spalling of small particles from the bearing surface that expands the damage area, Figure 4. The wear debris produced by local spalling migrates to other areas of the bearing, spreading damage throughout the bearing. Once this damage mechanism has initiated, total bearing failure can occur in a very short period of time in heavily loaded bearings. It is likely that arcing damage from potential discharge across the bearings on Spindles #9, #10 and #14 also initiated the failures at those locations.

Substation Electric and TES Principal Grounding Engineers, completed a follow up inspection of the newly repaired 1T-40.0.2 mobile auto-transformer upon its return to the Vaca Dixon Substation on April 28, 2005, with the following observations.

TES FINDINGS, CONT'D:

The trailer had been placed in exactly the same location in the substation as before the bearing failures and it is assumed was grounded using the same procedure, as before.

At the time of the inspection, the above noted personnel noted that neither the front nor the rear wheel assemblies were adequately bonded/connected to the transformer frame support. This lack of connection is consistent with the observations of the other mobile units (at Tesla Sub) and would eventually lead to the failure mode noted above in this report.

What could not be explained by is why the front wheel assembly bearings were not damaged by the leakage current. However, the trailer has been rebuilt since then and conditions are not exactly like before the failure. It should also be noted that the front carriage assembly had an improved grounding path to the substation grid, then did the rear carriage assembly.

<u>The root cause for the aforementioned failure remained as improper bonding of all trailer parts to the grounding connection due to these observations.</u>

CONCLUSIONS AND RECOMMENDATIONS:

A review of the Monthly Mobile Inspection Forms used by Substation personnel indicated a possible problem regarding corrective actions noted during those inspections. Following an earlier overhaul, completed on May 15, 2001, the first Monthly Mobile Inspection Form was filed on 4/2/02. Many issues were indicated from month to month, from pumps not wired, to no wheel chocks, to rotten control cables, etc.

As the months progressed, new issues were reported and older issues weren't listed anymore, but there was no entry regarding any corrective actions being taken to alleviate those issues. Continued review of those documents revealed issues that were consistent in their reference, but not in their correction, such as no wheel chocks, no lightning arrestor discharge counters and separately; boxes, DC power cable on order, hydraulic jack on repair and most recently, Atmoseal pump leaking.

It is suggested that Substation and Fleet personnel review the current specification governing both Fleet and Sub-Station responsibilities to verify that all issues are covered; up to and including maximum weights that can be handled safely by Fleet Personnel for trailer overhaul and when/where those overhauls can be done. It may also be necessary to look at coordination of the overhaul activities to be done by Fleet Personnel and obtaining the necessary equipment and location to aid in the overhauls.

CONCLUSIONS AND RECOMMENDATIONS, CONT'D:

It is also recommended that there needs to be a complete grounding study of the auto transformer trailers currently in company Substation yards to verify that proper grounding of each trailer type is accomplished when the trailers are being stored and/or when they're in service. These studies should include a determination of the feasibility of applying grounding connections between the transformer, transformer pad and trailer dollies on each mobile auto-transformer unit. These requirements may also have to be stipulated in future orders for auto-transformers from company suppliers.

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