Reduction of Transformer Failures Using Amorphous Core Transformers

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Introduction

PacifiCorp Electric Operations, the company formed by the merger of Utah Power & Light and Pacific Power & Light, has a strong commitment to providing reliable, cost-effective service to its customers. Since 1989, amorphous core transformers have made up the majority of Utah Power & Light's purchases of distribution transformers, and this will continue with the merged company as long as new bids for amorphous transformers continue to provide an economic benefit.

This paper will address how a problem with distribution transformer failures led UP&L to select low loss amorphous core units as a potential solution. Also, a review will be provided of UP&L's extensive transformer monitoring and reliability studies, which convinced us of the high reliability of amorphous core transformers.

Background

PacifiCorp has a diverse range of territory, including mountainous regions, desert regions with extreme temperature swings, and diverse loading characteristics due to a mix of urban and rural areas (Figure 1). Our transformers have to operate reliably under a wide range of conditions.

Starting in 1973, Utah Power & Light began monitoring transformer failures. In 1985 a rigorous auditing procedure was established to keep track of different manufacturer's transformer failure rates (Figure 2). We found some unsatisfactorily high failure rates. For example, the 33% failure rate listed in Figure 2 is based upon a manufacturer of 3-phase pad units for whom 3 out of 9 of one year's transformers failed within a year of being installed. Other unsatisfactorily high first-year failures are

shown in Figure 2 for various transformer sizes made by different manufacturers. Naturally, we wanted to learn the cause for these failures and what could be changed to prevent them in the future. We were especially interested in whether any operating procedures at UP&L could be contributing to early failures.

We found that many of the premature failures were occurring with seasonally-loaded transformers. Examples would be transformers which are used to serve irrigation pumps. These units make up 5 to 10 percent of our total installed base of distribution transformers. Our practice had been to shut these units off during the winter, when they were not in use, to conserve no-load losses. Investigations led us to believe that the action of turning transformers off each year was creating condensation, which resulted in failures when the units were put back in service. We saw that amorphous core transformers would provide an ideal remedy for this problem. Because they have such low core losses, UP&L found that it would be economical to keep amorphous core transformers energized all year round. In addition to avoiding the failures, the manpower costs to energize and de-energize the transformers would also be eliminated.

Approval of Manufacturers of Amorphous Core Transformers

In order to evaluate amorphous core transformers, UP&L purchased 12 units from General Electric in 1987 for test purposes. In 1988 and 1989 we purchased 12 test units each from ABB and Howard Industries, respectively (Figure 3). We confirmed the losses specified in the certified test reports for each of these three

manufacturer's test units. We did teardowns to convince ourselves of the quality of each manufacturer's amorphous core transformers. We were particularly interested in how the amorphous cores were secured in the tank, and in how the manufacturers had encapsulated the cores.

These teardowns convinced us that the manufacturers were all producing high quality transformers. For example, we wanted to make sure that chips of amorphous metal would not dislodge from the core and end up in the oil or windings. We have found no chips of amorphous metal in any of the transformers. We also saw that all three manufacturers were using reliable techniques to encapsulate the cores and to attach them to the tanks in a secure fashion.

Another part of our program was to visit each of the three aforementioned transformer manufacturers to qualify their amorphous core manufacturing techniques and facilities.

As a result of the test programs we have been routinely purchasing amorphous core transformers from GE, ABB, and Howard Industries since 1990. In addition, we have changed our policy and will now accept amorphous core transformer bids from other manufacturers without having to go through test procedures or plant visits. We now consider amorphous to be interchangeable with silicon steel, and will accept amorphous bids from all manufacturers.

UP&L's Commercial Use of Amorphous Core Transformers

UP&L purchases transformers based on equivalent total owning cost, which takes into account the transformer's purchase price plus cost of losses, along with a vendor evaluation factor which depends on each vendor's product performance (Figure 4). Amorphous core transformer bids have been the most economical choice in many cases for UP&L. Since 1987, UP&L has purchased over 6,000 amorphous core transformers (Figure 5). The range of kVA sizes is from 10 kVA overhead units to 750 kVA 3-phase pad-mounts (Figure 6). From a practical point of view, our linemen have found no difference in installing the amorphous core units. Whether a transformer has an amorphous core or a silicon steel core is considered "transparent".

Conclusion

Our original interest in failure rate reduction with amorphous core transformers concerned the seasonally-loaded units. Amorphous core transformers have helped to reduce failures in these installations. The fact that we don't have to energize and de-energize these units every year has turned out to be a valuable added benefit, beyond the lower total owning cost of the amorphous units we have purchased. In addition to the failure rate reduction benefit, we've found an incidental reliability benefit in the fact that amorphous core units are, in general, turning out to have lower failure rates because of the greater care that transformer manufacturers are putting into their construction. With over 6,000 amorphous core units on our system, we haven't had a single failure or warrantee replacement (Figure 7). This is a remarkable achievement.

We have seen that the transformer manufacturers are putting their best people on their amorphous core transformer production lines, and are producing a high-quality product.

Now that UP&L has merged with Pacific Power & Light, forming PacifiCorp Electric Operations, we have revised our loss evaluation factor. The 1990/1991 UP&L value for core losses was $5.05 per watt. We have determined a new value of $4.82 per watt for PacifiCorp as a whole for 1992/1993. We look forward to continuing to purchase amorphous core transformers as long as they continue to provide an economic benefit.

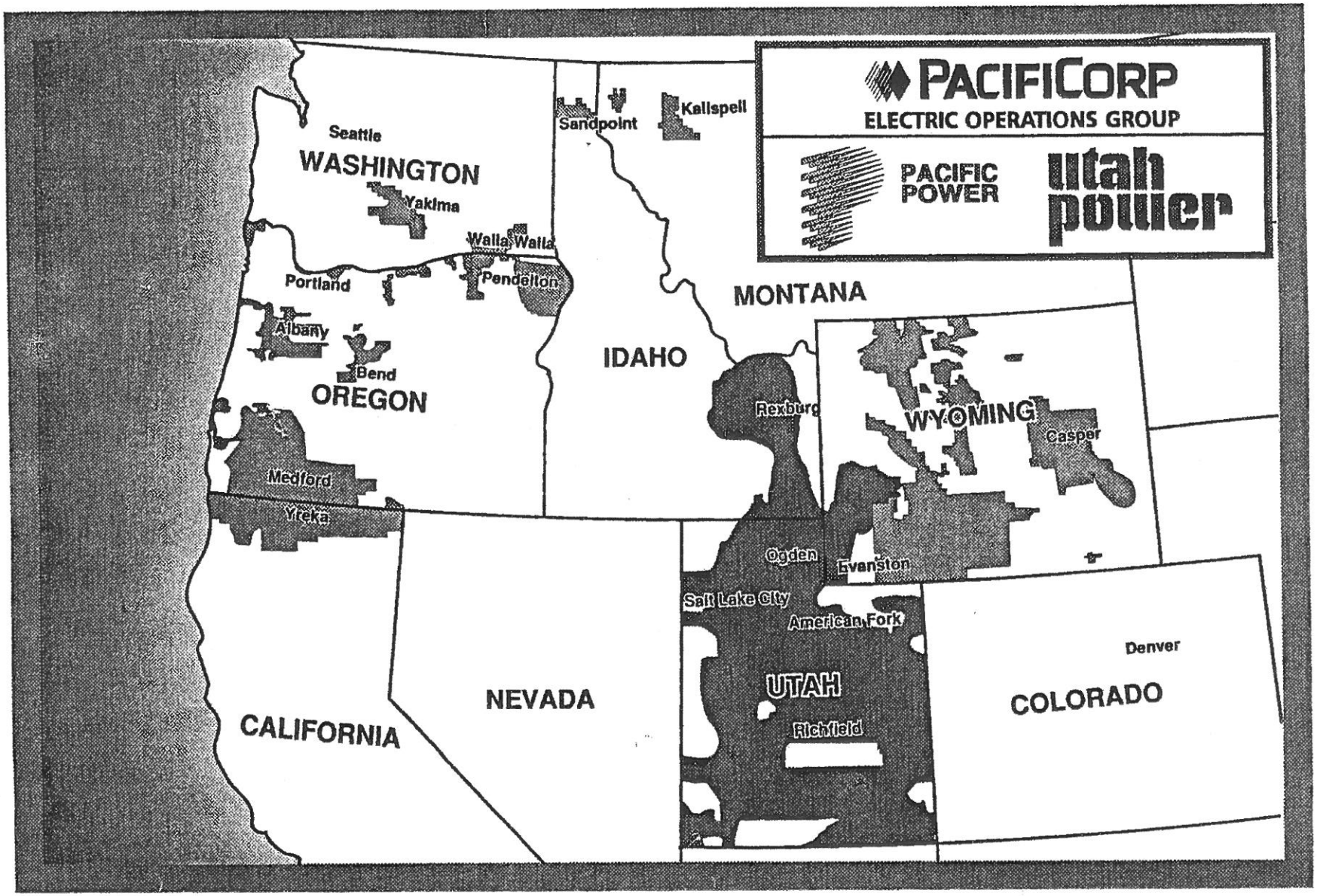
PACIFICORP
ELECTRIC OPERATIONS GROUP
PACIFIC POWER
utah power
Seattle
WASHINGTON
Yakima
Walla Walla
Portland
Pendelton
Albany
Bend
OREGON
Medford
Yreka
CALIFORNIA
Sandpoint
Kallspell
MONTANA
IDAHO
Rexburg
WYOMING
Casper
Ogden
Evanston
Salt Lake City
American Fork
UTAH
Richfield
NEVADA
Denver
COLORADO

Figure 1

UTAH POWER
MAXIMUM TRANSFORMER FAILURE RATES - BY MANUFACTURER*

	1973/85	1986	1987	1988	1989	1990
SINGLE-PHASE POLE	3.3%	1.8%	7.2%	7.1%	1.8%	0%
SINGLE-PHASE PAD	7.2%	2.3%	2.7%	3.3%	1.7%	0%
THREE-PHASE PAD	33.0%	4.7%	3.3%	3.4%	0%	0%

* NOT AUDITED

Figure 2

UTAH POWER
AMORPHOUS CORE TRANSFORMER APPROVED MANUFACTURER HISTORY

1987	1988	1989	1990	1991	1992[2]
G.E.[1]	G.E.[1] WESTINGHOUSE[1]	G.E. WESTINGHOUSE[1] HOWARD[1]	G.E. ABB HOWARD	G.E. ABB HOWARD	ALL

1. TEST ONLY
2. PACIFIC POWER / UTAH POWER

Figure 3

UTAH POWER
TRANSFORMER BID
EVALUATION METHOD

An Evaluation Factor (Ef) will be determined from the suppliers evaluation and applied to the manufacturer bid price. An Equivalent Total Owning Cost (ETOC) will be calculated from the bid price, the present value of losses and the Ef as shown below. The ETOC will determine bid awards.

ETOC = BID PRICE x Ef + K1 x NL + K2 x FL

where:

ETOC = Equivalent Total Owning Cost
BID PRICE = Supplier quoted bid price in dollars
Ef = Evaluation Factor from supplier evaluation
K1 = Loss Cost Multiplier for No Load Losses in $/watt ($5.05 ≤ 50kva, $3.88 > 50kva)
K2 = Loss Cost Multiplier for Full Load Losses in $/watt ($1.40)
NL = No Load Losses at 20° C in watts
FL = Full Load Losses at 85° C in watts

Figure 4

UTAH POWER
AMORPHOUS CORE TRANSFORMER
PURCHASE HISTORY

	1987	1988	1989	1990	1991
	12	20	1783	1833	2500*
TOTAL:	3300	3400	3500	3500	3500*
PERCENT:	.4	.6	50.9	52.3	71.4

* ESTIMATE

Figure 5

UTAH POWER
AMORPHOUS CORE TRANSFORMER
SIZES PURCHASED

SINGLE PHASE OVER-HEAD / KVA	SINGLE PHASE PADS / KVA	THREE PHASE PADS / KVA
10	25	225
25	50	300
37.5		500
50		750
75		
100		

Figure 6

UTAH POWER
TRANSFORMER WARRANTEE
REPLACEMENT RATES *

	1986	1987	1988	1989	1990
SINGLE-PHASE POLE	1.3%	3.1%	1.9%	.4%	0%
SINGLE-PHASE PAD	.8%	.8%	.8%	.3%	0%
THREE-PHASE PAD	1.0%	1.1%	1.1%	0%	0%

* NOT AUDITED

Figure 7