Rural transformer failure

Application Note

Power Quality **Case Study**

Measuring tools: Fluke 43B Power Quality Analyzer

Operator: Utility electrical engineer

Features used: Current waveform, harmonic spectrum and THD

Problem description

This case history involves the investigation of a utility transformer failure that occurred in a rural area surrounded mostly by farmland and open space. The failure occurred in a location where power quality problems are rare.

Fig. 1 shows a one-line diagram of the system. The failed transformer was at the end of a medium voltage utility feeder. The transformer secondary was configured as a 120/208 V, 3-phase, 4-wire system. The load consisted of three end-users: a small apartment complex, a dairy farm and a golf course clubhouse.

The engineer began his investigation by checking for reports of problems with other transformers connected to the same feeder. This bit of research didn't turn anything up, so he concluded the problem was probably related to the secondary loads. His next step was to question the end-users.

The farm owner said his milk processing equipment was running when the transformer failed. He also said nothing unusual had occurred prior to the failure, and his equipment continued to work normally after the transformer was replaced.

The apartment manager recalled that things were quiet at his facility on the evening the failure occurred. His apartment dwellers were home, cooking dinner and watching TV. Nothing unusual had occurred.

The golf course superintendent said the club had sponsored a large tournament on the day the transformer failed. The club had rented several battery powered golf carts to supplement their normal fleet. Operators plugged all of these in for recharging at the end of the tournament. About an hour after that, a fuse blew in the clubhouse's main service panel. The superintendent replaced the fuse, and not long after that the power went out — this time, due to a failed transformer.

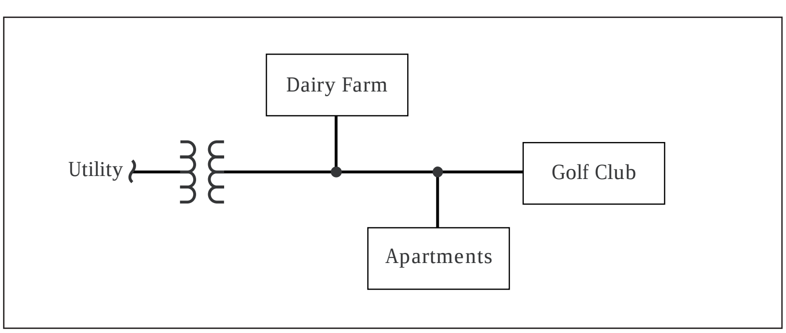

Fig. 1 Connections to the rural power transformer

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Measurements

The engineer asked to have a golf cart set up for charging, so he could record the harmonic spectrum and waveform of the battery charger current. The results are shown in Fig. 2 and Fig. 3.

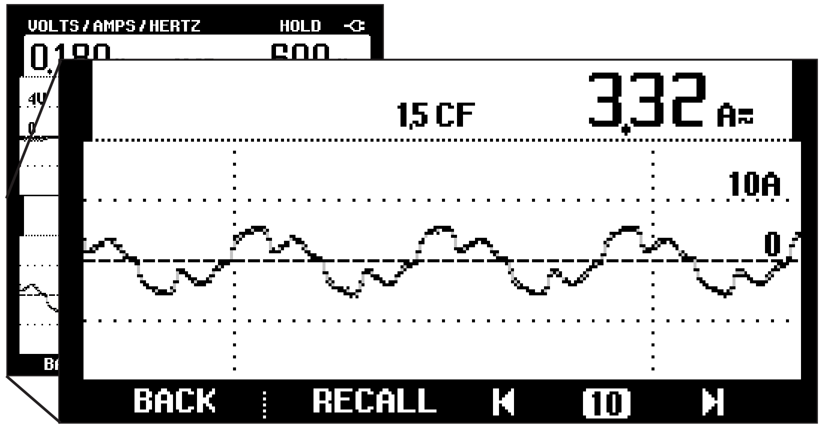

Fig. 2 Golf cart battery charger current waveform

Theory and analysis

Battery chargers are invariably non-linear loads that generate harmonic currents, due to the action of diodes or other semi-conductors that convert ac to dc. The waveform shown in Fig. 2 is typical of a transformer coupled diode rectifier. The Fluke 43B showed the total harmonic distortion (THD) of the golf cart charger current to be 37 %. Values above 20 % would be dangerously high, given the estimated size of the charger load in relation to the total transformer load.

When harmonic currents are flowing in a transformer, the result is extra heat in the windings and core laminations. Losses from high-frequency eddy currents constitute the primary cause of this extra heat. Some additional harmonic heating is due to skin effect, where the effective cross-section of a conductor is reduced at high harmonic frequencies. The amount of harmonic heating a transformer can tolerate is inversely proportional to the total secondary load. A heavily loaded transformer can overheat and fail if a large portion of the load current contains harmonics.

In the case of the rural transformer, three end-users contributed to the total load and all three experienced peak loads at the same time. The timing of the blown fuse and the ultimate failure indicated that the sudden addition of the large battery charger load caused the transformer to overheat.

Normally, the golf cart charger loads were staggered throughout the day. People plugged in the chargers at the conclusion of each round of golf. The tournament situation was unusual, because it replaced this staggered load pattern with a simultaneous load pattern. Operators plugged in all the charger units in the normal fleet plus those from the rental units, at about the same time. The sudden battery charger load coincided with the peak load from the apartment complex. Residential peak loads occur around dinnertime when people are using electric ranges, refrigerators, dishwashers, and TV sets.

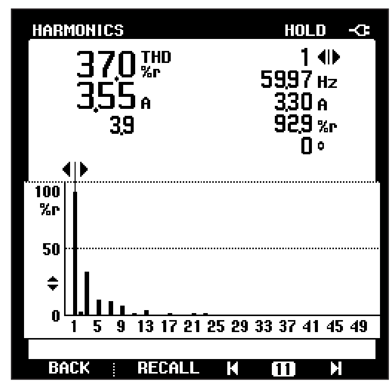

Fig. 3 Harmonic spectrum of battery charger current

Solution

To prevent failures, the golf club supervisor agreed to use careful load management. He would restrict the total number of chargers connected at any one time, and avoid the use of chargers between 5 and 7 p.m.

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