OPTICAL ARC FLASH PROTECTION AND INSTALLATION EXPERIENCE - PART II

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B. WESTINGHOUSE 50DHP-1200 TESTS

The Westinghouse DHP circuit breaker tests also included nine optical arc flash relays, again configured in three groups of three relays with similar light sensitivity setting variations among the relays within a common group. Optical sensor fibers were looped through the breaker, main bus and feeder cable compartments. Radial lens sensors were located in the main bus and breaker compartments. The optical fiber sensors groups were routed in the same three distinct patterns used in the GE breaker tests.

Another optical arc flash relay with eight radial lens sensors was also tested. The radial sensors were placed in the vicinity of the arc chutes and in front of the circuit breaker.

Test Number	Average Symmetrical Current (kA)	Average Total Current (kA)
3	2.92	3.98
5	2.90	3.99
6	2.93	4.02
7	2.94	4.04
9	19.7	29.1
10	10.1	14.3
11	10.0	14.2
12	10.2	14.3
13	16.5	23.4
15	14.1	18.8

Table 4 – 4.76 kV Westinghouse DHP Breaker Tests

Fig. 6 Optical Fiber Sensor in the Breaker Compartment

Fig. 7 Failed Westinghouse DHP Breaker

Three-phase current interruption tests were performed at 4.76 kV as listed in Table 4.

During test 9, the Westinghouse DHP circuit breaker failed to interrupt the test current of 19.7 kA even though its interrupting rating at 4.76 kV is 30.3 kA. The fault was subsequently isolated by an upstream breaker. All optical fiber sensors and all optical lens sensors detected sufficient light and tripped when the Westinghouse breaker failed to interrupt the test current.

The optical fiber sensors detected sufficient light to operate the optical arc flash relay when the Background Light Reference Level Adjustment was set at the minimum setting for the 2.92 kA levels in tests 3 through 7.

The optical fiber sensors in the breaker compartment shown in Figure 6 did not detect sufficient light to operate the optical arc flash relay when the Background Light Reference Level Adjustment was set between midway and maximum for tests 10 through 13 and test 15.

The optical fiber sensor loops placed in the vicinity of the arc chutes sensed sufficient light to operate the optical arc flash relay for tests 10 through 13 and test 15. All radial lens sensors detected sufficient light to operate the optical arc flash relay in the breaker and bus compartments at all levels of current interruption.

Figure 7 shows the external damage to the circuit breaker resulting from the failed 19.7 kA interruption test.

VII. DOCUMENTED CASE STUDIES

There have been at least two documented cases to date where an arc flash event occurred in medium-voltage switchgear protected by optical arc flash relays utilizing the long fiber sensor technology.

A. CASE #1: DETROMOVICE POWER PLANT

During the morning shift at the Detromovice Power Plant in the Czech Republic on June 26, 2006, two workers were exercising a 6.3 kV breaker that had been withdrawn to its test position. Unfortunately, they forgot that the breaker was closed as they tried to rack it into the operation position. To make matters worse, they bypassed the mechanical interlocks as they forced the breaker into position. This initiated an arc that could have caused serious consequences.

Fortunately, the switchgear was equipped with dedicated optical arc flash protection utilizing long fiber sensor technology. Within 82 milliseconds, the entire substation was disconnected and a major personnel and equipment catastrophe was averted.

Eyewitnesses reported that the cubicle compartment was full of white sticky smoke from the burned plastic parts but that was the extent of the damage. Repairs consisted of cleaning the breaker and cubicle as well as replacing the breaker rosette and cubicle pins. Figure 6 shows photos taken immediately following the incident. No permanent damage to the installation or surrounding equipment was encountered and the plant was quickly returned to service thanks to the fast reaction time of the optical arc flash relaying. Most importantly, however, both workers escaped injury and possible death.

For those who may not have witnessed the after-effects of an arc flash explosion, the photos in Figure 6 may seem severe.

Fig. 8 Detromovice Power Plant 6/26/06 Arc Flash Event Photos

Actually, the opposite is true. It is not uncommon for an arc flash event to cascade down a switchgear lineup before the fault can be cleared. The fact that damage was confined to the single cell is remarkable.

Had the optical arc flash protection not been installed, the estimated direct cost of the physical damages could have been as high as $1.6 million USD. Indirect loses including extended loss of production would probably have been many times higher yet.

A similar accident at this same plant occurred in 1979 well before the installation of dedicated arc flash protection. That incident resulted in a three-day outage. Loss production and equipment damages totaled several million dollars.

B. CASE #2: KEMIRA GROW HOW PLANT

Kemira Grow How has a fertilizer plant located in Uusikaupunki, Finland. Energy consumption is 18 MVA and the plant has 7 MVA of on-site generation. Primary products are fertilizers for farms, greenhouses, gardens and forests.

In 2003, the Kemira Grow How plant narrowly avoided a major catastrophe just one day after installing optical arc flash protection based on long optical fiber sensor technology in 1965 vintage medium voltage switchgear.

The arc flash event was initiated when a disconnect switch was opened but failed to extinguish the arc. The disconnect switch that was being opened fed a long underground cable, not normally energized. Due to the capacitive no-load current in the cable, the air-disconnecting switch could not extinguish the arc. Instead, the arc progressed to the bus compartment where it evolved into a three-phase bus fault.

According to Jari Lintula, Electrical Department Manager, the accident was the result of human error.

Jari Lintula (Manager) and Pentti Laine (Technician) were working in the same room when the flash occurred. Neither was injured although both were a bit shaken.

The just-installed optical arc flash protection detected the arc flash and tripped before the switchgear could sustain any significant damage. The plant was restored to service in a few hours. Had dedicated arc flash protection not been installed, the fault clearing time would have doubled and the incident energy would have doubled as well. It is difficult to estimate the damage that might have occurred but it would most likely have been quite expensive. One day of lost production costs millions of dollars.

Arc flash protection was originally installed at this site as insurance to limit the direct and indirect damages associated with an electrical accident. The investment was paid back many times over in one day.

VIII. CONCLUSIONS

Incident energy is directly proportional to the total arcing time. Ultra-fast clearing of arc flash faults is essential in controlling arc flash hazards and minimizing incident energy levels. Even a few milliseconds improvement can shift hazard levels and PPE requirements to a lower category.

With a typical operating time of only 2.5 milliseconds, optical arc flash protection is far faster than conventional relaying schemes. Compared to the more common bus differential protection scheme, optical arc flash protection is both faster and less expensive to implement but most of all, it protects all high voltage compartments not just some of them. The availability of long fiber light sensors makes this form of protection an even more practical and cost effective form of arc flash protection.

Optical arc flash protection is ideal for equipment with vacuum or SF6 interrupters since all normal arc-interrupting flashes are contained within sealed interrupters. In air-magnetic breakers, the breaker cell design must be carefully studied to determine the best location for fiber sensor routing as well as lens sensor placement. Neither type of sensor should be located near or above the top of the arc chutes.

The optical arc protection system can be effectively applied in 15 kV/500 MVA GE MagnaBlast breakers with good security at all Background Light Reference settings.

Although the optical arc flash protection system tests involving 5 kV Westinghouse DHP breakers were inconclusive above 16.5 kA, the tests demonstrated the effectiveness in detecting an arc flash event resulting from an improperly functioning breaker attempting to interrupt fault current.