SOLUTION FOR INTERNAL ARC FLASH HAZARDS IN AIR INSULATED SWITCHGEAR

Young-woo Jeong LS Industrial Systems. - Korea ywjeong@lsis.biz Hyun-wook Lee LS Industrial Systems. - Korea hwleea@lsis.biz Yang-seop Sin LS Industrial Systems. - Korea yssin@lsis.biz

Young-keun Kim LS Industrial Systems. – Korea youngk@lsis.biz

ABSTRACT

Conventional protection system is insufficient for an internal arc flash accident in air insulated switchgear. Because arc reaches its maximum temperature and pressure 10 to 15ms after ignition and conventional protection method requires the relay operation time, the circuit breaker operation time and time coordination. So Arc Protection System(APS) is essential for switchgear and recently this system has been gathering many interests. In this study, an APS has been developed with optimizing software tool for designing a fast earthing switch. The system consists of light sensors, arc protection relays and arc eliminator which close fast the circuits to earth. All components were tested and revealed their performances are enough to protect the switchgear from arc flash.

In the process to develop the APS, we found several essential facts and developed our own technologies to design a reliable system. We decided experimentally the optical lux level of the arc flash accident in switchgear comparing other light source. And we developed point and loop optical sensors, arc protection relays and arc eliminator. Especially exclusive algorithm for arc detection was developed and applied to arc protection relay. Finally we developed very fast calculation software for optimizing the Thomson drive in arc eliminator. Its speed is up to 10 times of the conventional finite-element method base software.

INTRODUCTION

The temperature of an electrical arc can reach up to 20,000 K and the energy of the arc is converted into heat, pressure and radiation. An electrical arc is transited into four steps compression/expansion/emission/thermal and reach its maximum pressure within 10~15ms after the ignition of the arc. So it looks like an explosion.

Generally the switchgear is essential equipment in electrical power systems and consists with a circuit breaker, busbar, current transformer, potential transformer and etc. In case of a breakdown or an accident in the switchgear, the power system is damaged by the power failure. In spite of the countermeasure, internal arc accidents in a switchgear occurred often by the mistake of an operator, dielectric breakdown of outworn equipment, an invasion of an animal and etc. A long arc flash duration can damage the apparatus in power system and induced the blackout and people around the switchgear. So NFPA(National Fire Prevention Association) in U.S. push to wear an protection clothes(gadgets) on to when a person is near to the switchgear. According to IEC standard, the switchgear must pass the internal arc test. For this reason, the manufacturers of switchgear design the strong structure to withstand high temperatures and pressures from the internal arc. However, those methods cause prices to go higher and size to bigger. Furthermore, it is impossible to protect the apparatus and person from the arc accident perfectly. Some manufacturers develop the APS that is able to minimize the loss of properties and lives by extinguishing the arc within extremely short time. In this paper, we introduce the APS developed by LS Industrial Systems.

ARC PROTECTION SYSTEM

Usually upstream relay waits 200~300 ms when short circuit accident has sensed because of the time coordination with the downstream relay. So when an internal arc flash accident is occurred in a switchgear, the protection procedure with a traditional OCR(Over Current Relay) and circuit breaker is not sufficient. By the unnecessary waiting time of 200~300 ms the switchgear and the person will be damaged severely otherwise the maximum pressure and temperature reaches within 10~15ms after the ignition.



Figure 1 Composition of Arc Protection System

The other side, when using APS in an electrical power system, arc light sensors are able to detect the light signal from an arc flash without delay. Using the light and the current from the CT(Current Transformer), an electrical arc accident will be decided by an arc protection relay or an arc module. And then an electrical arc is removed early from a CB(Circuit Breaker) or an arc eliminator.

ARC LIGHT SENSOR

A small part of the arc energy is consumed with a radiation. The arc light sensors are able to detect the light from the arc without delay.

The arc light sensors are 2 types. One of them is point sensor established in the compartment of the switchgear and the other is loop sensor established along the busbar. Both sensors, point sensor and loop sensor, detect the narrow and wide area, respectively.



Figure 2 Arc Light Sensor

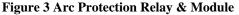
The point sensor consists with an optical fiber and a sensor cap. When arc accident occurs, sensor cap detect the light and that light signal transfer to relay(arc protection relay or arc module) by the optical fiber. The loop sensor consists with an optical fiber only, in the other words, the optical fiber itself is loop sensor. That sensor detects the light from all area in the established fiber loop.

Using the point sensor, customers are able to know the accident location, because one or two sensors are established in each compartment of the switchgear respectively. But the customers want to monitor many compartments in some switchgear, the same or more quantities are required. In this case, the loop sensors are suitable to apply. The loop sensor has a self diagnosis function checked on a regular bias to break down or not.

ARC PROTECTION RELAY

A conventional OCR(Over Current Relay) requires 1/2 ~1cycle(8.3~16.7 ms at 60 hz) to determine an accident. Therefore that is imposible to protect a power system and person from the arc flash accident.

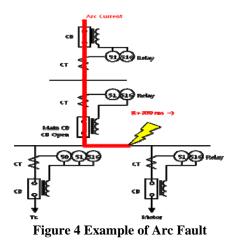




An arc protection relay monitore the arc flash accident wi thout other element and an arc module is added to a conve ntial OCR.

Those two types of relay determine the arc accident by an algorithm using a light signal from an arc light sensor and a current signal from a CT. When the arc accident is

determined from the algorithm, the relay transfer an operating command to CB or arc eliminator. Because of the arc protection relay has not element except the arc, operating command is transmitted within 2.5 ms. However, OCR which arc module was added to is transmitted within 15 ms on account of it has many element.



When the arc accident is occurred that location in figuir 4,a downstream CB is not able to cut off the accident current. But upstream OCR, without arc module, waits 200~300 ms because of the time coordination with the downstream relay. Therefore arc current is kept until 300 ms(time coordination + 3cycle(CB operation time)), and during that period, power apparutus is damaged.

While the arc module has been added to the OCR, it is able to determine the arc accident without time coordination by the arc flash and current sinal from the CT. In that case, damage from the arc accident is reduced.

ARC ELIMINATOR



Figure 5 Arc Eliminator

Arc fault can be confirmed by Arc Protection Relay and then trip signal will be sent within 2.5ms. However, circuit breaker can successfully cut off fault current after 3 cycles. That means this system should endure the fault current at least 3 cycles. For the sake of reducing the damage to the system, fault current should be sensed and cut off within 10~15ms before temperature and pressure reaching the maximum value. So it is impossible for normal circuit breaker to extinguish arc fault perfectly.

Arc Eliminator is a kind of high speed earth switch, which will keep required insulation level in normal state but close the switch within 3.5ms by receiving the signal

to lead arc fault current to earth point and avoid accident until upper circuit breakers acting. The specification of Arc Eliminator can be seen on table 1.

Rated Voltage	25.8 kV
Short Time Withstand Current	40 kA/1sec
Short Circuit Making	40 kA
Performance	(DC Factor : 2.6)
AC/Impulse withstand voltage	60 kV / 150 BIL
Operation Time	3.5 ms

Table 1 Specification of Arc Eliminator

As it mentioned above, arc eliminator cut down accident by making the arc fault current follow into earth prior to the action of circuit breaker. So it should have the capability to withstand pre arc and short time current. And its performance has been proved by taking short time withstands current and short time making test at PT&T high voltage test center of LS industrial systems.

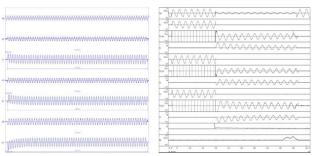


Figure 6 Short time withstand current & making test

In addition, arc eliminator is installed inside switchgear. When there isn't any abnormal phenomenon in switchgear, the high voltage electrode and earth electrode of arc eliminator always keep live, which requires arc eliminator to endure surge voltage and overvoltage from the system. And AC and Impulse withstand voltage performance also have been proved by PT&T shows satisfaction of insulation level.

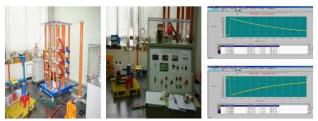


Figure 7 AC/Impulse withstand voltage test

ACTUATOR OPTIMIZATION

The operation of an arc eliminator is completed within 3.5 ms. Conventional mechanism, such as oil pressure, spring and etc., is unsuitable by reason of the characteristic of a mechanical operation.

Thomson drive applied with arc eliminator use the electromagnetic repulsion force. That is composed of an exciting coil and a moving plate having ground connection. When the current is flowing through the exciting coil, an eddy current is induced at the moving plate. For this reason, the electromagnetic repulsion force is generated between the exciting coil and the moving plate. According to repulsion force, the moving plate travels from the coil to the high voltage part.

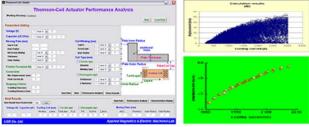


Figure 8 Optimizing Software

An optimization of the Thomson drive is very important factor to achieve the operation performance of an arc eliminator.

For the dynamic performancer analysis of the Thomson drive, time stepping finite element method(FET) combined with circuit and motional equations have been the most popular method. It is, however, very time consuming. To optimization of the arc eliminator, a novel computationally efficient analysis software is developed by transferring the problem into an equivalent circuit model considering the distribution of the eddy current in the plate. The accuracy and efficiency of the software are verified through comparison with FEM result, it has under 5 % error.

Using that software, a structure and a circuit of the arc eliminator is optimized.

CONCLUSION

It is very dangerous for human and switchgear because of the high temperature and pressure made by arc fault current. So IEC standard make specific requirement for switchgear on arc withstand test recently. In this project, not only 2 types of APS made up of arc light sensors, arc protection relay, arc module and arc eliminator are developed and tested, but the most optimizing software for Thomson Drive has also been developed. In the future, we will full fill with our company test requirement for APS on the base of our research and then to engage in IEC standard definition on arc protection device.

Acknowledgments

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP).

REFERENCES

[1] NFPA 70E, Standard for Electrical Safety in the Workplace, 2004 Edition.

[2] M. Wactor, et al., 2001, "Strategies for mitigating the effects of internal arcing faults in medium voltage metal enclosed switchgear", Transmission and Distribution Conference and Exposition, vol.1, 323-328

- [3] L. F. Santos, et al., 2006, "New Strategy to Counteract Arc Flash Hazards", Transmission and Distribution Conference and Exposition, 1-6
- [4] R. A. Wilson, et al., 2007, "Tripping with the Speed of Light: Arc Flash Protection", Protective Relay Engineers, 226-238
- [5] M. Zeller, et al., 2009, "Add trip security to arc flash detection for safety and reliability", Power Systems Conference, 1-8