

## SOLUTION FOR INTERNAL ARC FLASH HAZARDS IN AIR INSULATED SWITCHGEAR

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### 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

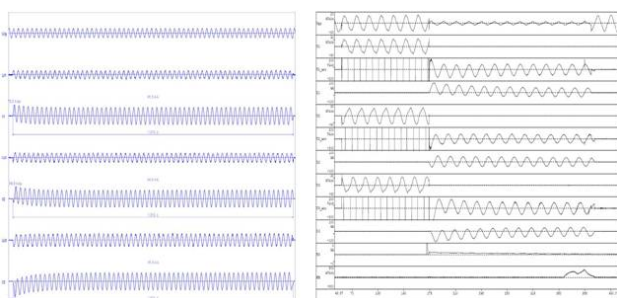


to lead arc fault current to earth point and avoid accident until upper circuit breakers acting. The specification of Arc Eliminator can be seen on table 1.

**Table 1 Specification of Arc Eliminator**

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

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.

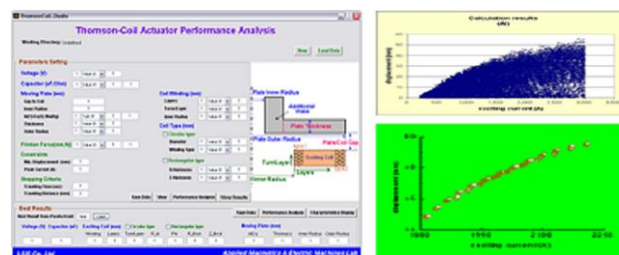


**Figure 7 AC/Impulse withstand voltage test**

**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 performance 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**

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