ARC-FLASH HAZARD AND PROTECTION FOR ELECTRIC SWITCHBOARD AT NSRRC

Tzong-Shyan Ueng, Yung-Feng Chiu, Yu-Chih Lin, Kung-Cheng Kuo,
Chien-Kuang Kuan, NSRRC, Hsinchu, Taiwan

Abstract

During the operation of electrical equipment the arc-flash accident could damage the equipment and endanger the working personnel. In order to prevent this type of accidents from happening and to minimize the damages, a dedicated setup is being installed inside the electric switchboard for suppressing the accidents at the initial stage of arcing at NSRRC's power system. The installed device includes the arc sensor, the smoke detector, the circuit breaker and the protection relay. Further improvement on preventing the arc-flash accidents is also under study.

INTRODUCTION

An arc-flash is a sudden electric discharge through air between conductors or from a conductor to a ground due to an electric breakdown. When an arc fault occurs, the electric impedance between the connection areas is decreased as the arc temperature increases. Thus, the high energy ionization currents flow through this passage will produce very bright light and a temperature much higher than that at the surface of sun. In the usual arc-flash accident in switchboard, the transient energy can be as high as 10 MW or even higher, which results in a temperature above 4000 ^{o}K. This high temperature can liquefy or vaporize the metals used as conductors or destroy equipments. Also, any person nearby could be severely injured or even loss life.

Figure 1: An arc-flash accident took place in the capacitor bank for TLS.

An accident of arc-flash had occurred at one of the capacitor banks of power system for Taiwan Light Source before, Fig. 1. In the figure it shows that among the 3 phases of power capacitor, one phase has burst apart. It was speculated that the cause is due to the degradation of dielectric strength of insulation. During the accident the resultant high temperature damaged the capacitor and the cables nearby. A thick black smoke was also produced at that time.

DETECTION AND SUPPRESSION OF ARC-FLASH

In the current practice there are circuit breakers in every level of the power distribution system in NSRRC for the circuit protection coordination. When there are short circuits or circuit overloads, the breaker protection system will cut off the power supply as soon as possible automatically. If there is an arc-flash, it could still result in a severe damage quickly. The Utility Group has decided to add arc-flash/smoke protection relays to suppress the arc-flash accidents.

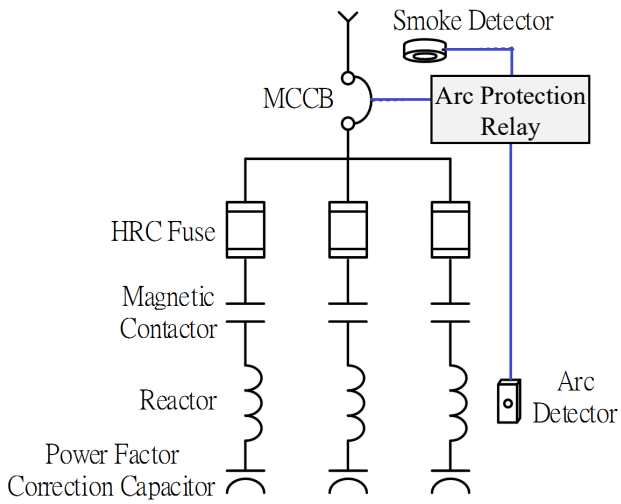

Figure 2: The one-line diagram of the arc-flash and smoke detection system for NSRRC's capacitor bank.

The capacitors used in the power system are in general susceptible to harmonics, power surge and thermal stress. Its dielectric strength of insulation materials could be degraded. In order to increase the protective capability for the power circuit, the arc-flash/smoke detection relays, Fig. 2, were installed in the power capacitor switchboards for both Taiwan Light Source and Taiwan Photon Source. As shown in Fig. 2, the basic protection devices of power capacitors are HRC fuse (High Rupturing Capacity Fuse) and MCCB breaker (Molded Case Circuit Breaker). The operational mechanism of these two devices is to detect

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and interrupt the over-current for suppressing the arc-flash accidents. And, the arc-flash/smoke protection relay is to use the mechanism of detecting the light illuminance and the smoke intensity to trigger the trip. In the configuration, the arc detector and the smoke detector are installed in the top area inside the switchboard in which the capacitor banks are installed. The arc detector installed has effective detection angle for more than 220°, detection range of 4 m and light sensitivity of 8000 lux. The installation arrangement is shown in Fig. 3.

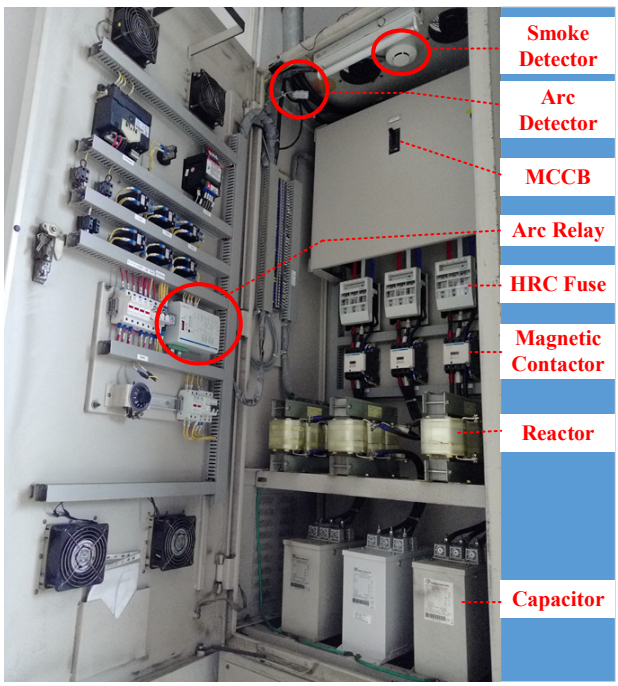

Figure 3: The installed devices in the switchboard.

Until now there are 38 sets of arc-flash/smoke protection relay units installed inside the switchboards for the capacitor banks in NSRRC. A general logic diagram of the protection unit is shown in Fig. 4. As shown in the figure, 1 smoke detector and 1 arc-flash sensor were connected to the control units. If any of the detectors senses the smoke or arc-flash, the corresponding warning light will be turned on automatically and the trip alarm will send the trip command to the Trip Unit simultaneously, then, the fault current is interrupted by the MCCB right away.

PERSONAL PROTECTIVE EQUIPMENT CONSIDERATION

Even the arc-flash accident can cause severe damage to the electric device and people working nearby, there are no official documents about its protection provided by Taiwan government at this moment. Now, only a limited numbers of personal protective equipment (PPE) are available in our facility. Thus, IEEE 1584 [1] and NFPA 70E [2] which have detailed descriptions and suggestions in this area are used as reference by us to prepare the PPE for protecting against arc-flash hazards. With IEEE 1584 the arc-flash protection boundary distance and the arc-flash incident energy can be calculated. From its result the arc-flash mitigation solution can be studied. Then, one can refer to the PPE categories specified in NFPA 70E to acquire appropriate PPE. In the power system of NSRRC most of the switchboards on-site have voltages under 600 V. Using the formula given by R. L. Doughty, et al. [2] for an arc in a cubic box which has 20 inches on each side and open on one end, one can calculate the thermal energy an arc fault would release to determine the PPE one might need for the arc-flash protection.

$$E_{MB} = 1038.7 D_B^{-1.4738} t_A [0.0093F^2 - 0.3453F + 5.9675]$$

where: E_{MB} = indent energy, cal/cm^2
D_B = distance from arc electrodes, inches
t_A = arc duration, seconds
F = bolted fault short circuit current, kA

In general, the distance of worker from the prospective arc for the work to be performed is about 24 inch, the escape time of the switchgear without an arc-flash relay is about 0.3 seconds, and the bolted fault short circuit current was estimated about 25 kA. From the about equation one obtains E_{MB} =9.07 cal/cm^2. Referring to the PPE categories described in NFPA 70E Standard 2015, Table 130.7(C)(16), the personal protective equipment should meet the minimum requirement of category 2.

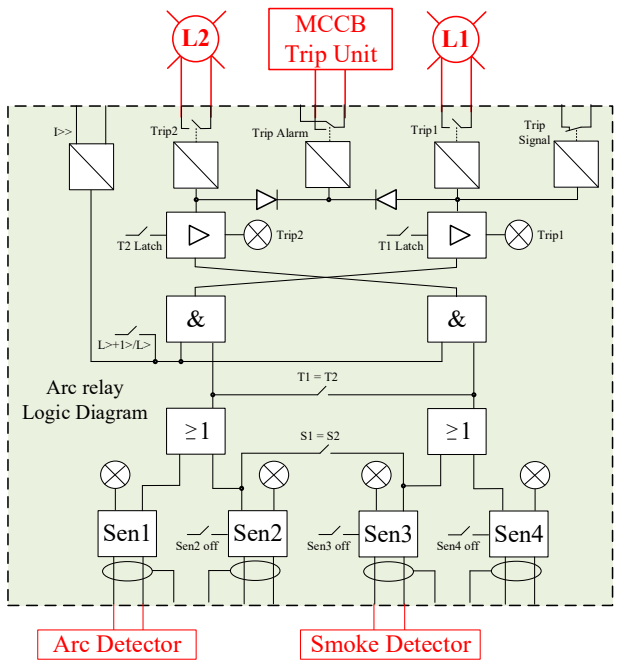

Figure 4: A logic diagram of arc-flash and smoke protection unit.

CONCLUSION

At present, the arc-flash/smoke detection systems have been installed in about 90% of the switchboards for capacitor banks. Others will also be installed in the

coming years. For the switchboards in which gas circuit breakers and vacuum circuit breakers are installed, the installation of arc-flash/smoke detection systems in these area are already planned, too. More of the enhanced protection measures are also planned in order to increase its performance. They are:

1. Setting up the interlock between the arc-flash/smoke detection system and the gas automatic fire extinguishing equipment. When the arc-flash and smoke are detected by the arc-flash/smoke detection system, besides the MCCB trip automatically, the gas fire extinguisher on-site can also activated automatically and simultaneously to suppress the fire.
2. In order to increase the reliability of the arc-flash/smoke detection system, it will be interlocked with the existing over-current relay. If both the current is over the trip rating and the arc-flash/smoke detection relay is activated, then, the breaker will be tripped.
3. Adding more arc-flash sensors and smoke sensors to each switchboard to enhance the protection capability.
4. Using the guidelines in IEEE 1584 and NFPA 70E to identify and assess arc-flash hazards for all the power system. Ensure all potential arc-flash hazards are properly labelled to inform the technician and any people nearby.
5. Acquiring proper grade of PPE according to the recommendation of PPE category.

REFERENCES

[1] IEEE Std 1584-2002, “IEEE Guide for Performing Arc-Flash Hazard Calculations”, 2002.

[2] NFPA 70E, “Standard for Electrical Safety in the Workplace”, 2015 Edition.

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