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Arc flash mitigation techniques

Abeera Khan[1] and Muhammad Mohsin Aman[1*]

[1] Department of Electrical Engineering, NED University of Engineering and Technology, Karachi, 75290, Pakistan

(mohsinaman@neduet.edu.pk) * Corresponding author

Abstract: Arc flash is a major cause for injuries and even death of working personnel around the globe. Arc flash hazard analysis is necessary to protect the personnel against damage or fatalities related to an arc flash event. If a worker is wearing a flash suit (adequately rated or not), it does not mean that the worker can work safely anytime and anywhere. PPE do not give a worker such freedom from hazards even if it is chosen appropriately. This paper explores different mitigation techniques which would help engineers and technicians to reduce incident energy levels at electrically energized equipment during an arc flash event.

Keywords: Arc flash analysis, Incident energy, PPE.

I. INTRODUCTION AND BACKGROUND

An arc flash is an arcing fault caused by a short circuit between two energized conductors. The electrical arc that occurs between these energized conductors is with exception to the laser, the hottest known substance on earth. The arc can reach temperature up to and beyond 20,000 K, which is approximately four times as hot as the sun's surface [1][10]. Arc flash is measured in terms of incident energy (calories per square centimeters, cal/cm^2). An arc flash occurs without any warning. It causes complete damage of equipment and serious injuries or death of people. Injuries might happen from inhaled gases, blinding light, flying shrapnel, shock waves and thermal radiation during an arc flash event [2].

Insulation breakdown between two energized conductors at sufficient voltage is the cause of arc flash, which could be due to treeing, aging, loose connections, overheat and human error [10]. Distance of the person from arc flash source, the arc flash intensity and the protective equipment worn by the worker at the time when arc occurs, greatly influence the degree of injury [3]. Depending upon the magnitude of the incident energy, PPE can include Flame Resistant clothing, hardhat, hood, face shield, safety glasses, gloves, shoes etc. [2]

Various standards deal with the prevention of arc flash effects which are updated with time. According to the Occupational Safety and Health (OSH) act, employers are required to provide a safe and healthful workplace. They are also responsible to comply with every OSHA standards that are applicable. OSHA refers to their standard Code of Federal Regulations, CFR.

Employers have the responsibility to assess the workplace to find out if hazards are present, or may likely to be exist. Moreover, they must ensure that each employee uses the PPEs that could protect them adequately [4]. It is required that working personnel, exposed to the electrical shock hazards, to be qualified for the tasks that they have to perform while wearing the appropriate PPE [5]. Only insulated tools should be used when working on the energized equipment is needed [6].

Survivability from arc flash gets increased if the rating of PPE is commensurate with the hazard level [7]. The calculated incident energy at various system locations helps to select the PPE accordingly. Too little PPE leaves workers inadequately shielded and hence undesirable. Too much PPE is also undesirable because it may restrict movement and raises hazard risk related to a specific work task, or may cause other hazards such as increased heat stress.

II. MITIGATION TECHNIQUES

The appropriate PPE is a last line of defense so we must look for such working practices and engineering controls that can help the working personnel to reduce the exposure to arc flash hazards. These techniques and methods also help to minimize the chances of occurrence of arcing faults.

A. Improving work practices

An economical way to mitigate arc flash hazards is to improve work practices. De energizing the equipment before performing work is the easiest approach which is not possible every time. As a result, other ways should be considered.

Infrared analysis allow inspection of the equipment to be made without exposure to the equipment. IR windows whose working is based on the contactless IR thermography technology, help the employees to conduct IR scans with no need to remove switchgear side panels. This reduces the possibility of arc flash events, resulted due to accidental contact with live buses.

Shipping splits, compression fittings and local lugs served as pressure junctions for many electrical equipment. These connections become loose over time because of the thermal cycling and vibration. When electric current flows through such connections, it results in overheating and ultimately an Arc Flash. Industries can regulate pressure junctions and can get alerts of loose connections before they become so loose that leads to an arc flash accident, by the help of non-conducting thermal sensors known as pyrometers.

Analyzing and repairing insulation before it fails could avoid arc flash explosions. Anticipative maintenance programs help to get aware of possible insulation damage in switch gear, motors, transformers, generators and substations.

To predict the likelihood of faults before they actually occur, Partial Discharge (PD) sensing is another method. This method works by sensing high frequency discharges in insulation systems at MV and HV. It can give months of advance warning, as the sensors installed permanently, feeds an external PD relay. This enables continuous on-line monitoring without the need to remove protective covers and notifies when a problem arises in the insulation system. No additional and special PPE is needed as soon as the covers are not removed. The alerted problems can be corrected safely by de-energizing the specific piece of equipment. Currently, PD technology exists for generators, transformers, motors and switchgear [8].

B. Arc resistant switchgear

Arc resistant switchgears and equipment are being manufactured that can redirect the arc flash energy away from the worker or operator. Since the cubicle doors are the weakest part of the structure, they blow open, exposing the personnel to the tremendous heat and blast, when there is buildup of extreme pressure (due to rapid expansion of heated air) during an arc flash incident. With the duct work linked to the top of the switchgear, the heated gas and pressure wave are redirected outside the building. Arc resistant switchgear can be much effective, able to mitigate the incident energy to few cal/cm^2 provided the doors are shut and covers are placed.

As recognized by the NFPA 70E, special improvements in safety is associated with this type of switchgear. Today, two types of arc resistant switchgears are being employed. In type 1, personal protection is ensured only in front of the equipment while type 2 offers protection throughout the external perimeter of the switchgear. The arc fault blast that is internal to the switchgear, in its proper closed working condition, is directed to somewhere, the working personnel may not be present through arc flaps or phelum on top.

Arc resistant switchgear is not able to mitigate the arc flash energy by itself which means that the adequate PPE is necessary when the door of switchgear is open and the breaker is not in its cell and the cable compartment covers are not used. In that case, it is no longer remains an arc resistant switchgear [8].

From the manufacturers, new designs are available to mitigate arc flash hazards. These equipment are tested to withstand internal arcing fault and to ensure that the personnel working on the electrically energized equipment or operating the switch is not exposed to the hazards.

C. Increasing the working distance

Racking in and racking out the circuit breakers is an extremely hazardous tasks to perform. There are many documented accidents that occurred while racking in/out breakers. Recently, remote breaker racking devices are being marketed by the manufacturers. The device allows the worker to stand to a side when the device racks in the breaker. At the operator’s location, the incident energy gets reduced because of increased working distance [11].

The device includes a remote control panel, having open and close switches for every circuit breaker or remotely operated actuators or switches. The breaker operation is controlled remotely by remote control unit having a 20 feet cord

The remote operation of circuit breakers or switches can be implemented in a variety of manners as it is an established mitigation technique. Switching of devices can be remotely accomplished by the use of remotely mounted push buttons, switches and HMI screens. Moreover, it can also be done by networking through SCADA systems, network-connected relays etc. The remote operating point should be located outside the flash protection boundary of the particular device being operated and is considered ideal situation.

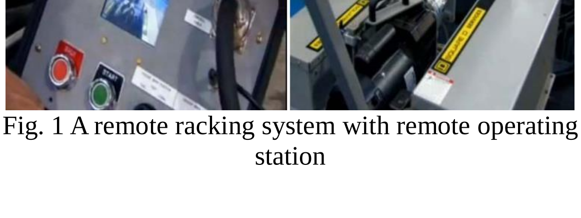

Fig. 1 A remote racking system with remote operating station

For both medium voltage and low voltage devices, large number of remote racking options exist (Fig. 1). It must be ensured that when using this solution for mitigation, the workers are still able to perform work with no hindrance. It is likely that increased working distances may cause hindrances to the personnel while working

D. Modifying the existing settings

Arc flash energy can also be limited by changing the existing protective device settings in such a way that the fault clearing time at the associated arcing fault current get decreased. When implementing this solution, care must be taken because the protective device coordination may get affected while decreasing the fault clearing time of the devices [12].

E. Zone selective interlocking

Zone selective interlocking (ZSI) is another option which can reduce the duration of arc on a bus and at the same time maintain coordination with downstream devices. Unless the main circuit breaker gets a blocking signal from a downstream protective device, it will operate quickly [11]. A main breaker for instance, may have 0.2s short time setting and considering a typical bolted fault current of 40 kA for a substation, this accounts for 17 cal/cm^2 as an incident energy at a switchgear bus. With the help of zone selective interlocking, fault on the switchgear bus can be made unseen by the downstream feeder breakers and hence main breaker could open instantaneously or in 0.05s approximately with estimated incident energy of 4 cal/cm^2 [9].

F. Ultra-fast arc flash protection

The occurrence of an arcing fault produces radiation that can be sensed by analyzing visible light. Arc flash protection based on optical sensors gives very short fault clearing time. Overcurrent condition is employed as a restraining element along with light detection (dual sensing) to avoid unnecessary and false tripping, maintaining the security of the protection system.

During arc flash event, the tripping of the breaker can be initiated by a dedicated arc flash protection relay (Fig. 2) or by a typical numerical relay that has arc flash protection feature. The relay is programmed to trip quickly if it sense a light flash originating from an arc flash event and an increase in current. Only when these two conditions are fulfilled together, the relay will generate a trip signal towards the upstream breaker. Arc flash energy is much decreased as the relay operates quickly.

Fig. 2 Arc flash detection relay

With dedicated arc flash relay, the trip signal is initiated in 7ms and within 15ms when using numerical protection relay. A relatively shorter trip time can be achieved if semiconductor output instead of conventional trip relay is employed. The arcing duration consists of time of operation of relay (7-15ms) and operating time of the breaker (50-80ms usually). In some cases, in order to resist the rise of pressure, even shorter time of clearance is required. Therefore, arc quenching devices are employed which is also tripped by the relay within 2-5ms along with the tripping of the breaker in 7ms.

Two types of sensors are used: optical fibers sensor and point sensors. Fig. 3 shows the types of sensors used. Point sensors have advantages over other type of sensor which include retrofit installation and indication of exact fault location because the point sensors are installed in every compartment to be protected. Personal point sensors can far more enhance the safety of the working personnel.

Fig. 3 Point sensor and fiber optic sensor

III. CONCLUSION

Electric arc explosions are not combustion phenomena but they are predominantly physical explosions, due to very rapid conversion of electrical energy into heat. Every year, millions of dollars are costed to the industry. Because arcing time is the most critical factor, fast optical sensor based protection methods are preferred. Combination of sensing of light and overcurrent has proved to be a very efficient method. For the most demanding cases, ultrafast arc eliminating technology is available. The safest solution is working on the equipment when de-energized and it can be implemented at any location but it is not always feasible every time. The technicians or engineers can use these methods to reduce incident energy levels. It is necessary that every location should be identified and analyzed to see which solution is most beneficial and at the same time most cost effective.

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