ELECTRICAL FLASHOVER HAZARDS AND SAFETY MEASURES REFERENCE TO DESIGN AND MAINTENANCE

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Intrduction:

In a large power plant Electrical system covering voltage right from 110volt to 400kv distributed in a complex network. The systems are designed and installed as per the standards available where safety are in place, for example : phase clearance, ground clearance,size of conductor/ protective devices, fencing of equipments, general precautions since last three decades, particularly in India.There appreciable improvement in understanding the systems by the operation and maintenance personnel on these issues in the recent years due to implementation of quality systems. The systems are being operated efficiently and reliably ,has been enhanced to a satisfactory level. But it is really a matter of concern that despite improved design, installation and maintenance practices, the product do not address the hazards associated when a maintenance worker accidently create arcing faults. Electrical flashover is a common kind of accident that really disturbs smooth running of a system. Many workers injured and killed every year while working on energised equipements. It is seen sometimes the confidence of the worker is shattered, however the experience must be the strength and support to creating a safe working environment. Through this write up, it is attempted to analyse to bring out the HOW part of the dangerous ARC fault instead of general safety measures which are being complied with every with in every system of power plants. Based on the study and analysis of arc faults, few suggestions with reference to design, maintenance to safe working practices given to minimise Electrical hazards which may help to improving safety management.

What is an Arc Flash and Hazards Associated with:

Generally flashover in an electrical system takes place when phase conductors are short circuited causing phase to phase, single phase to ground or 3 phase short circuit faults. During flashover, very high energy is released in a very short time. Metal conductors vaporize and air in the vicinity get ionized generating large amount of thermal energy resulting in severe burn to the worker who is directly exposed to the fault. Arcing involves very high temperature in the order of 20000°C and copper exp0ands 67000 times by volume when solid copper conductor melts and vaporizes during flashover. Vaporization of metal, ionization of air results high pressure blast, throwing molten metal in radial directions. Other risks of flash over fault include:

- Shock hazards due to touching the energized conductors.
- Arc blast causes:
  Flying out of debris & molten metal
  The worker who is at work may be knocked off due to pressure wave
  Intense bright light due to arc plasma can cause temporary or permanent
  Blindness to the working personnel
  Explosion / blast sound may cause damage to lungs and ear drum
  Heat leads to fire hazard

Arc Flash Study & Analysis:

One of the Arc flash analysis studies conducted by IEEE members described below for better apperception of flashover hazard.

TEST: I

It is a case of flashover in a 480 volt, 22KA (symmetrical) MCC with 640Amp (1600A frame size) ACB as incomer and the breaker has Short Time Delay of 12 cycles (0.2 second) while a worker is working on a energized system. For analysis purpose a similar situation has been created. The test arrangement involves mannequins which are used to simulate personnel working on the equipment. Measuring devices are placed on the mannequins at

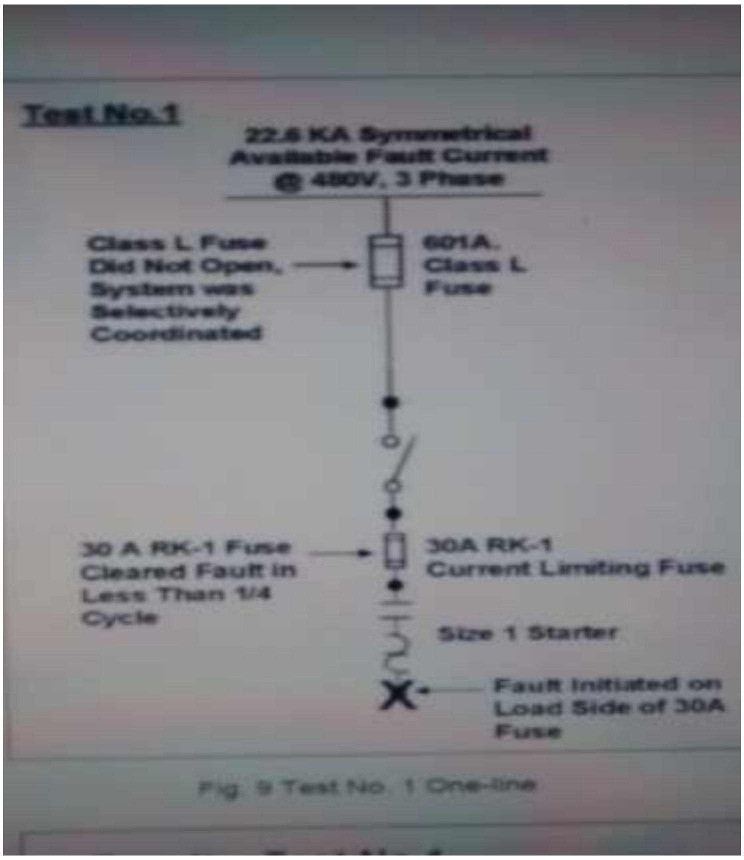

Fig. 9 Test No. 1 One-line

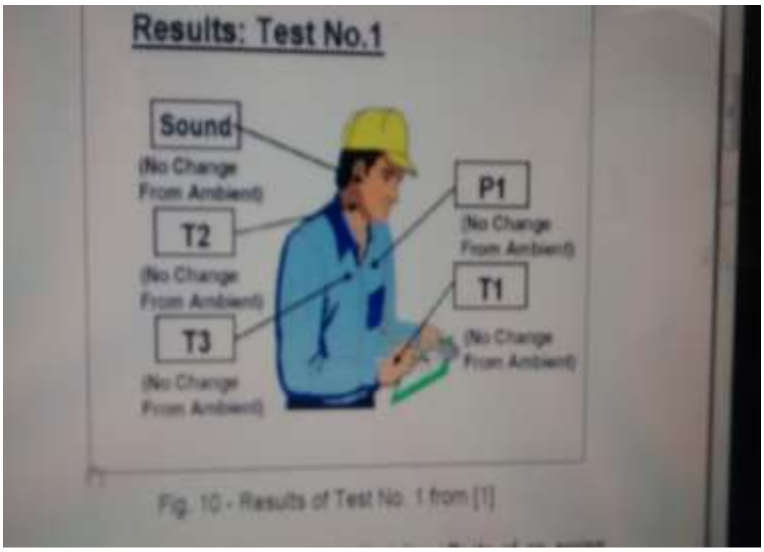

Fig. 10 - Results of Test No. 1 from [1]

various locations as well as other points in the test cell to determine temperature, the sound decibels and pressure. The test is simulated at a 480 volt MCC on a motor started feeder with test station set to operate at 6 cycles (0.1 second).

The fault is initiated on line side of 30A fuses that are protecting the motor branch circuit. The test simulation is similar to a worker causing a fault in the feeder on line side of the branch circuit. In the process the fedder over current protective device is required to act. On simulating the fault the Robot working on the equipment found totally engulfed in the arc flash / blast. The 2nd robot at the lower right (a co-worker) several feet from the equipment is away from the arc remains unaffected.

At the end of the test simulation the temperature, pressure & decibel of blast / flash measure as recorded in the measuring devices to know the extent of damage caused to the workmen.

The results show:

- Pressure exerted on the mannequin (workman) (P1) : 2160lbs/sqft.
- If the exposure of the upper body is 3 squre feet, the blast would exert
- Above 6000 pounds on the chest of the worker, that can violently throw
- Him bacward as a consequence the worker might suffer damage to his lungs.

The temperature recrorded from devices at Hand & neck (T1 & T2) = 225°C causing serious burn on neck & hand.
Temperature below shirt on the chest (T3) = 50°C, would not have burnt the skin.
As per National Fire Protection Association (NFPA) standards:
Exposure to temperature >90°C for 0.1sec – Leads to total destruction of tissue of skin which is an incurable burn injury of skin
Exposure to Temp <80°C for 0.1 sec – is a. Just curable burn.
Threshold pressure that can cause damange to the ear drum with 400 milli seconds exposure duration : 720 lb/sqft.
Threshold pressure that can cause damage to lungs with 400 milli seconds exposure duration: 2160 lbs/sqft.

TEST: II

Similarly in another test on the same feeder fault is initiated on load side after 30Amp fuses. Available short circuit current is 22000 Amp same as above. But in this test the fault was cleared by 30 Amps fuses with in 1⁄4 cycle (0.004 sec).

The results shown:

Sound	- No change from ambient
Temp at neck and hand	- No change from ambient
Pressure on chest	- No change from ambient
Temp on chest	- No change from ambient

From these tests it is evident that the size, current rating of over current device & location of fault can affect degree of risk to the worker. In addition the situation also illustrates the need for suitable / adequate PPE while working on energized system.

Safe Working Distance to Reduce Flash Injury:

With the knowledge of severe injury affect of an arc flash to the working personnel, it is essential to know how to work safely on an energised feeder. At what distance away from the source it is safe to work? It is the Arc Energy responsible for burn injury. Corresponding to the temperate / Time threshold for curable and incurable burns, Arc energy is given in the table below taking a safe distance of 3 feet from the source.

The fourmulae as per NFPA 70E(5) Standards for calculation fo Safe working Distance are given below:

$D_c=(2.65 \text{ X } MVA_{bf} x t)^{1/2}$ Where , D_c-Distance in ft for a just curable burn

$D_f=(1.96 \text{ X } MVA_{bf} x t)^{1/2}$ D_f -Distance in ft for a incurable burn

MVA_{bf} :Three phase MVA at the point of short circuit

$=1.732$ X Line Voltage X Short Circuit Current X 10^{-6}

t: time of exposure in seconds

TABLE: 1

Distance from source	Threshold temperature	Duration of exposure (short time delay for o/c device	Arc energy required: 1.732 X V X Isc X 10	Extent of injury
3 ft	Above 96°C	0.1 sec	23 MVA	Incurable burn injury
3 ft	Less than <80°C	0.1 sec	17 MVA	Just Incurable burn injury

Generally in practice the worker remain close to the panel much less than 3 feet while working on an energized Low Voltage switchgear module. This gives an idea that for safe working close to panel, safe distance should be reduced or adequate PPE to be used. If we take three phase short circuit Amp = 2200A, Voltage=440V, Time for cleaning fault = 0.1 sec.

The safe distance for a curable burn

$DC=(2.65 \text{ X } MVA_{bf} xt = (2.65 \text{ X } \sqrt{3} X22000X40X10^{-6}X0.1)^{1/2}=(4.44)^{1/2}=2.107$ft.

From the analysis it is learnt that:

By decreasing short time delay in the Breaker, the exposure time is low and the flash boundary reduces. This suggests to doubly sure the exact / safe delay to be provided to quick clearance of fault.

Incident Energy and use of PPE to Reduce Risk:

It is evident that the extent of burn depends on the duration of exposure explaining the incident energy of the flash. The incident energy of an arc flash is defined as the amount of flash energy per unit area expressed in Calorie / Sqcm received on a surface located at a working distance away from

flash. The working distance is an arm length about 2 feet in case of LT system & higher with increase in voltage.
The threshold value of incident energy to cause 2nd degree burn is about 1.2 cal/cm2 for a 480volt 40KA lasting for 6 cycles (0.1sec). Table 2 below shows the incident energy and burn level.

TABLE : 2

Incident Energy	Degree of burn
1.2 cal/cm2	2nd deg burn to bare skin
4 cal/cm2	Ignites a cotton shirt
8 cal/cm2	3rd deg burn to bare skin

With a background of arc flash hazard & safe distance from arc for safety, it gives a fair idea that suitable protective gears are mandatory for working on a live electrical system.

As per the national electrical code (NEC) the PPE requirements divided in to six risk categories and various Personal Protective Equipments and class use are given tables below:

TABLE : 3

Glove Class	Voltage Rating
00	2.5KV
0	5.0KV
1	10KV
2	20KV
3	30KV
4	40KV

Gloves for different voltage

TABLE : 4

PPE Class	Incident Energy Range (cal / cm2)	Min. PPE rating (cal/cm2)	Clothing description
0	0-2	N/A	Untreated cotton
1	>2 upto 5	5	FR shirt & pants
2	>5 upto 8	8	FR underwear + FR shirts & pants
3	>8 upto 25	25	Cotton underwear + FR shirt & pants
4	>25 upto 40	40	Cotton underwear + FR shirt & pant FR coverall
5	>40 upto 100	100	Cotton underclothing + FR shirt, pants, + multi-layer switching suit

Rating of PPE. Class of PPE, Required Clothing

Conclusion as Suggestion for Safety:

Some Design related Safety measures

1. The bus bars in the switchgear, MCC & panel boards need to be insulated which reduces ARC fault and also helps self extinction of arc fire.
2. Current limiting over current protective devices such as fuses and current limiting circuit breakers may be used.
3. Limit the current rating size of main and branch feeders as for as possible.
4. Do not use MCC with many feeders when requirment is less.
5. Split large load single distribution board to different independent sections to limit fault current.
6. For high capacity LT motor feeders dual element fuses can be used. For example for a 100HP motor feeder in place of 225A fuse, 175Amp dual element fuse can be used. Under fault condition 175A fuse will let through less energy than 225 fuse.
7. Use of Residual earth leakage circuit breakers in low voltage circuits particularly in welding supply soucres.

Safety Measures Related to Maintenace Practices

1. Preparation of detailed work plant by considering all possible eventualities to fulfill safety needs at any point of time, before taking up job.
2. Anticipate the unexpected results. So breeak each tak to small steps, understand that plans can change, make sure every body involved working according to plan.
3. Use procedure as tools. Like tools make sure the procedures are also maintained.
4. Identify the hazard, Consider potential hazards that may be unrelated to electrical energy.
5. Assess peoples ability. Any person assigned a task associated with electrical system must be qualified and trained for the job in hand. He must be able to identify electrical hazard.
6. There are mechanical jobs involved in electrical systems, those are to be viewed in Electrical energy angle while being handled under supervision.

Providing an Electrically Safe Working Condition:

1. Use right tools for the job. Verify the tool is in good orking condition. Ex. Using screw driver in place of fuse puller invites an accident.
2. Isolate the equipment. Keep doors closed, keep barricades in place, cover the live parts, put the equipment in a safe working condition prior performing maintenace.
3. Protect the persons. Use proper PPE, this may include, safety shoe. Gloves of suitable voltage rating, safety goggles, Helments, flame resistant clothing.
4. Minimize hazard: Be sure of shutting down every possible energy souce in case of a hazard.
5. Audit these prinicples. A principle is something believed in enough to ensure will to do. Review these principle often, add to them as needed.

References:

1. Mr. Time Crnko and Mr. Steve Dyrnes, Member IEEE, Article on “Arcing Flash / blast review tih safety suggestion for design and maintenance”
2. Maintenance world.com : Electrical safety basics – Cooper Bussmann “Maintenance Management and reliability articles by maintenance world”.
3. Mr. Rober Fuhr, IEEE Senior member, Mr. Viet Tran “Arc flash hazards – the basics”.