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Introduction

An authorised person closed an 11kV Oil Circuit Breaker (OCB) on to a fault at a main substation. The OCB exploded and the force of the blast blew off the substation doors, seriously damaging the building. The authorised person broke his right arm, when the door behind which he was standing was blown open. The fire that followed destroyed all the equipment within the substation. This paper looks at the incident, the cause and the actions to be taken to prevent a recurrence of a similar incident.

Sequence of Events

An authorised person had to close an 11kV OCB, feeding a mini-substation (MSS) at a main substation, after it had tripped on a fault.

A risk assessment was conducted, as required by the company rules and regulations and the authorised person decided to eliminate the risk of injury by performing remote switching of the circuit breaker.

The OCB was not equipped with electrical closing, but it did have the facility to operate remotely, by tying a lanyard onto the mechanical closing lever and pulling it from outside the substation. As an added precaution, the authorised person decided to wear a flash suit. This was not a requirement, in terms of the company's safety rules and operating regulations, as the authorised person was standing outside the substation. Another electrician, who was present, stood further away, as he was not wearing a flash suit.

The authorised person stood behind the substation door (which was unbolted at the top and bottom) for further protection, not by the open door looking into the substation. The OCB exploded, probably due to mechanism failure, seriously damaging the structure of the building. The explosion that followed blew off the main central doors of the substation, through a metal link fence, ending up about 20 metres away. The authorised person broke his right arm, when the door behind which he was standing was blown open, however, he was saved from further injury, as he was not in line with the blast and did not feel the full force of the explosion. The fire that followed destroyed all the equipment within the substation.

Cause of Incident

The cable that was feeding the MSS from the OCB in the main substation faulted. The electromechanical relay protecting the cable did not flag, to indicate what the fault was. No cause was found for the breaker to trip, so it was decided to close the breaker. However, the fault was still on the cable, the breaker mechanically failed, which led to the circuit breaker exploding. The resultant fire spread to the rest of the circuit breakers, causing the destruction of substation equipment and extensive damage to the substation building.

Root Cause

The Medium Voltage (MV) contacts inside the OCB did not latch or unlatch correctly, in time to prevent extended arcing and subsequent oil vaporisation. This led to a violent explosion, splitting the circuit breaker tank, releasing the oil. The resulting force caused the destruction of all equipment inside the substation.

Contributing Factors

- The age of the OCB.
- The original fault caused the electromechanical relay to operate, but the relay did not flag, indicating the original cause of the trip prior to the incident occurring.
- The risk assessment only took into account the danger of arc flash. The result of the power, released by the blast of the OCB exploding, was not considered.

Conclusions

The OCB was closed onto a fault, the electromechanical relay sent a trip signal to the circuit breaker, but it failed to trip, probably due to lack of maintenance. Because the breaker was an OCB, it was more susceptible to fire and explosion.

Action

- All existing circuit breakers to be fitted with remote operating devices, to facilitate operation from outside a substation building, at a safe distance.
- All general risk assessments must be reviewed, especially where OCBs are presently used, to include strategies to mitigate the risk of explosions. Controls must be put in place and applied. Procedures to be revised accordingly and all operating staff (authorised persons) trained on them.
- Regular maintenance to be carried out on all switchgear, a maintenance schedule compiled and complied with.
- Old OCBs to be replaced with new Vacuum Circuit Breakers (VCBs) or Sulphur Hexafluoride (SF6) breakers. A replacement schedule to be compiled and monitored.
- All circuit breakers to be trip tested once a year. It is recommend that timing tests are carried out at the same time.
- Relays to be secondary injected and calibrated every two years.
- A mini-risk assessment (Take 5) must be carried out at the work site, over and above the existing general risk assessment, as the risk changes at each work site, although the task remains the same.
- Medium/High Voltage (MV/HV) operating training must be conducted and reviewed every two years (refresher courses conducted).
- Full flash suits must be worn when racking in or out of the circuit breaker, spring charging and any other local operations, including tests for zero potential and live electrical phasing.

- Flash suits to be worn during all MV/HV switching operations. Personnel to stand away from any open door and in such a position that they cannot be injured by the blast from an explosion or from doors being blown open.
- Arc flash calculations to be conducted and an arc flash matrix compiled and applied to each circuit breaker.
- Batteries and battery chargers to be maintained and calibrated.
- Batteries to be load tested on entry into substation, if load test facilities exist.

General

The question is - how many times can you close a circuit breaker after a fault? There is no definitive answer to this question, as there are so many variables:

1. How old is the breaker?
2. When was the breaker last maintained?
3. How many times has the breaker operated since the last maintenance was carried out?
4. How many times has the breaker tripped on fault since the last maintenance was carried out?
5. What protection scheme is installed on the circuit breaker and when was it last tested?
6. What is the insulating medium?
7. If it is an OCB, what is the condition of the oil?
8. You should always consider what can go wrong and what will be the consequences. In this situation, what is happening inside the oil in the circuit breaker tank? The insulating properties of the oil are reduced after a fault current passes through it and the flash point of the oil is reduced.

Codes of Practice (COPs) should be drawn up with the above in mind when planning the maintenance schedule. It is a misconception, that, if the circuit breaker or MSS is vacuum or SF6, an explosion will not occur during operation. In fact, if the integrity of the SF6 or vacuum is lost, the operator is opening/closing the circuit breaker/MSS in air and a flashover could ensue. For instance, when operating with SF6 filled equipment, the authorised person must always check the SF6 gas level on the gas pressure gauge (if one exists). This should always be in the green zone. If it is in the red zone, then the unit should be completely isolated from all sources of supply, operated and the supply switched back on.

The Occupational Health and Safety Act (OHSAct) requires that a Hazard Identification and Risk Assessment (HIRA) be conducted to identify the dangers of each task. A COP should be in place for all tasks to be performed and thereafter, mitigate the risk before resorting to Personal Protective Equipment (PPE).

The flash suit provides protection for arc flash only and will give the operator very little physical protection against the force of a blast; therefore, remote tripping must always be the first option, before resorting to PPE. When looking at flash suits, it is important that the correct type and cal rating is selected (a low voltage flash suit, for example, is not suitable for use on Medium or High Voltage).

All other staff in, or working in the vicinity, should move away to a reasonable distance whilst operating is being carried out. It is also important to call the relevant Control Centre when entering substations, so that they do not operate switchgear remotely, via Supervisory Control And Data Acquisitions (SCADA), whilst the operator is in the substation.

Arc flash calculations could be carried out and the maximum fault current and heat generated can be worked out (with the circuit breaker door open or closed). Once the distances have been calculated, an arc flash matrix can be compiled, listing the required PPE and the safe distances to be away from the equipment. Nowadays, circuit breakers can be designed to have arc spaces in the switchgear, so that the breaker must be opened, closed, racked in or racked out with the door closed and any explosion contained in the chamber. Protection systems have also become more sophisticated and faster, however, the clearance time is still dependent on the actual circuit breaker tripping time.

Abbreviations Used

COP	Code of Practice
HIRA	Hazard Identification and Risk Assessment
HV	High Voltage
MSS	Mini-Substation
MV	Medium Voltage
OCB	Oil Circuit Breaker.
OHSAct	Occupational Health and Safety Act
PPE	Personal Protective Equipment
SCADA	Supervisory Control And Data Acquisition
SF6 Gas	Sulphur Hexaflouride Gas
VCB	Vacuum Circuit Breaker

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