PCIC EUROPE

PETROLEUM & CHEMICAL INDUSTRY COMMITTEE

EUR18_13 - Our Electrical people work and switch safely and we know it...

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Tutorial – do we know…?

- Introduction
- Electrical Safety in the Oil and Gas industry
- The Basics
- Real life cases and discussion
- Lessons learned
- Do we really know…?
- Conclusions?

Introduction

- This Tutorial's objective is to to engage the audience in an interactive session on the subject of Electrical Safety in the Oil & Gas environment.
- The authors will discuss some real life examples of recent Electrical Safety incidents in the industry, and how they were handled.
- Lessons learned, as with all Industry incidents, are of utmost importance. Are these lessons learned always implemented?
- The session is not only intended for end users but also discusses design and operational issues of industrial hardware, with lessons learned for manufacturers and system designers.

- *Your active participation is appreciated!*

Introduction of authors/presenters

- Wim de Wilt

Independent Consultant Electrical Engineering Oil & Gas and renewable energy, Senior volunteer Consultant Shell Foundation – Access to Energy programme

37+ years work experience in the Oil & Gas Industry, in a wide variety of electrical engineering and management roles, worked for Shell in Europe, Middle East, Far East and USA.

Last industry role: Global Discipline Head, Electrical Engineering and Rotating Equipment, Shell International. (2004-2016).

- Paul Donnellan

Principal Technical Expert Shell Projects & Technology

25+ years in Petrochemical and Power Generation

XOM Refinery; National Power UK, Shell, NAM NL

Electrical Safety in the Oil and Gas Industry

- The Basics

Is your Site Electrical Safety system up to date and regularly audited?

Most Oil and Gas Companies have a well established Health & Safety culture, with a regulated work permit system and a set of approved Electrical Safety procedures and practices.

For (Electrical) staff in Operations and Maintenance with Electrical switching duties there must be a training and authorisation system in place in line with Country and Company regulations.

The Electrical Safety on the site is managed through the above set of procedures and associated permit system, with selected Electrical and non-Electrical staff authorised to perform switching, isolation, earthing, working on equipment, restoring power, etc.

Electrical Safety in the Oil and Gas Industry

- Safety in Design

How does the Oil and gas Industry work with Manufacturers on Electrical Safety, to what extent, and what can be improved?

Electrical installations are engineered based on the applicable International (or Country) and additional Company Electrical Engineering standards. It must be recognised that these standards have developed over time and as a consequence installed equipment will vary in safety standards.

Safety is an important component in the design of Electrical equipment, together with reliability and economics.

Company Engineering standards do include lessons learned from safety incidents, this is often seen as the real added value.

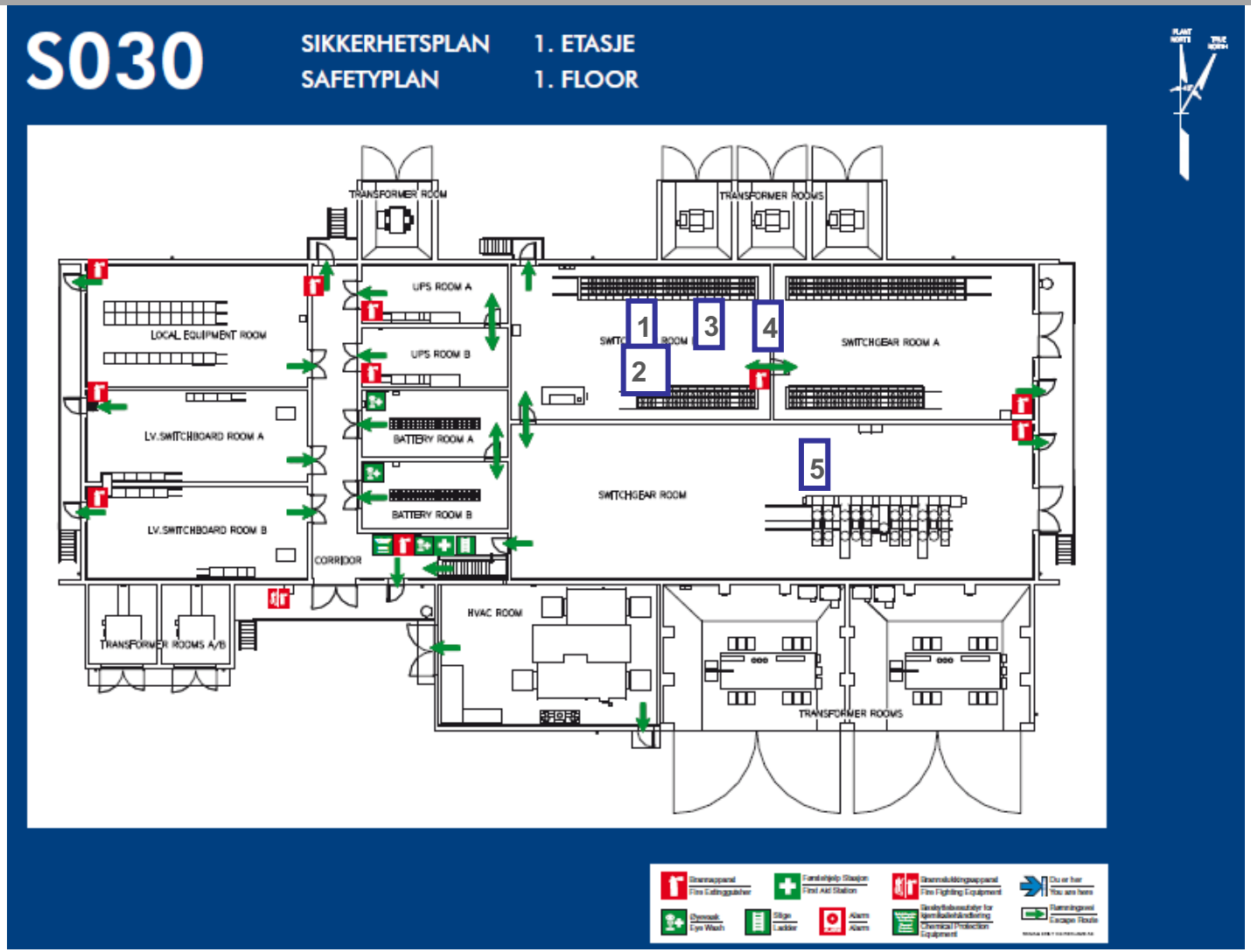
Engineering Contractors and Manufacturers of equipment are valued partners in the design and engineering process.

Cases

- We will discuss some real life electrical incident cases
- Emphasis will be on lessons learned to be be shared and to have a discussion.
- Cases chosen to discuss different aspects of Electrical Safety, related to People, Policies and Practices.

Case 1 – Plotplan substation gasplant

1. Revision11kV
2. Revision 22kV
3. SF6 Job
4. Coupling S120
5. 132kV



Case 1 – what happened?

- At an onshore installation, a maintenance team was working in Substation S30 with10 year revision on 11/22 kV SF6 Switchboards. 2 persons, 1 service engineer from the vendor and 1 high voltage electrician from Site Maintenance were working in the substation (*Leader for Safety*) . In the revision, gas samples were taken from the SF6 gas in the switchgear compartments.

- In one of the circuit breakers, gas was detected outside the specification. It was decided to evacuate the gas and replace it. A notification was raised and a job was planned by work preparer. Work permit was issued and Work order was attached.

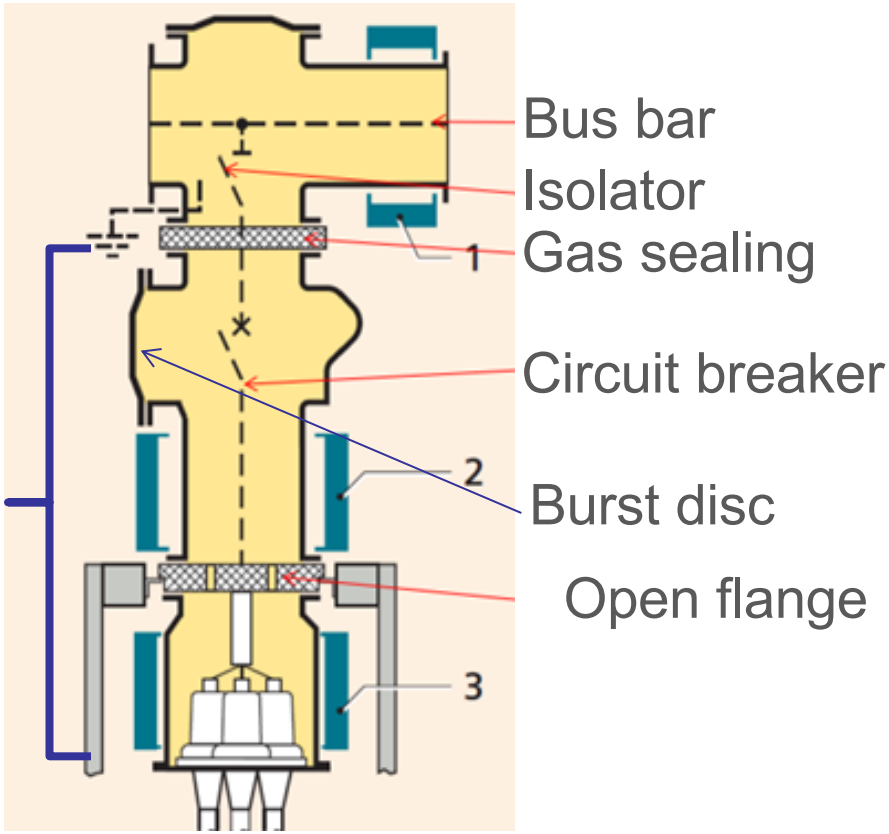
- Work permit was activated and leader was contacted to isolate the switchgear. Leader for coupling calls Leader for safety and confirms that circuit breaker is opened (Isolator to bus bar is still closed, hence there is still power on in the compartment with the gas outside the specifications). Job with evacuating the gas was started.
- After evacuation of the SF6 gas was started vendor specialist and Leader for Safety commence with the10 year revision on 11/22 kV SF6 Switchboard and Switchgear.

- After 10 minutes the compartment was almost empty an arc flash to earth occurred. This caused the bursting discs to fail and the switchboard room was filled with smoke. This caused the high voltage relay of the 22kV bus bar incomer to trip. This tripped 2 substations and the admin building resulting in a full production shutdown at the site.

Case 1 – Risk Assessment Matrix

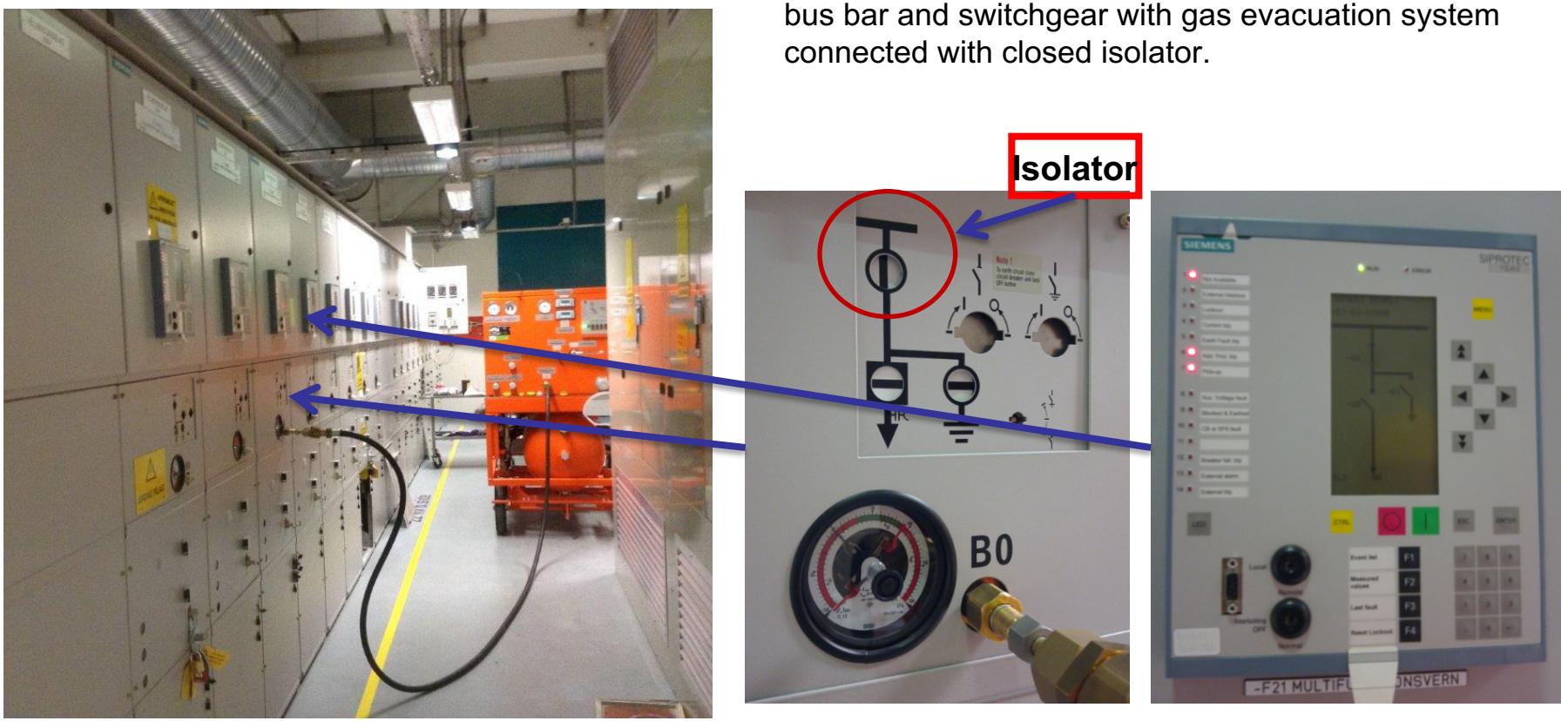
SEVERITY	CONSEQUENCES				INCREASING LIKELIHOOD				
	People	Assets	Community	Environment	A	B	C	D	E
					Never heard of in the Industry	Heard of in the Industry	Has happened in the Organisation or more than once per year in the Industry	Has happened at the Location or more than once per year in the Organisation	Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No effect					
1	Slight injury or health effect	Slight damage	Slight effect	Slight effect					
2	Minor injury or health effect	Minor damage	Minor effect	Minor effect					
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate effect					
4	PTD or up to 3 fatalities	Major damage	Major effect	Major effect					
5	More than 3 fatalities	Massive damage	Massive effect	Massive effect					

Design 22kV SF6 Switchgear (typical)



Gas evacuation system for SF6 gas

Picture taken from the front and shows involved bus bar and switchgear with gas evacuation system connected with closed isolator.

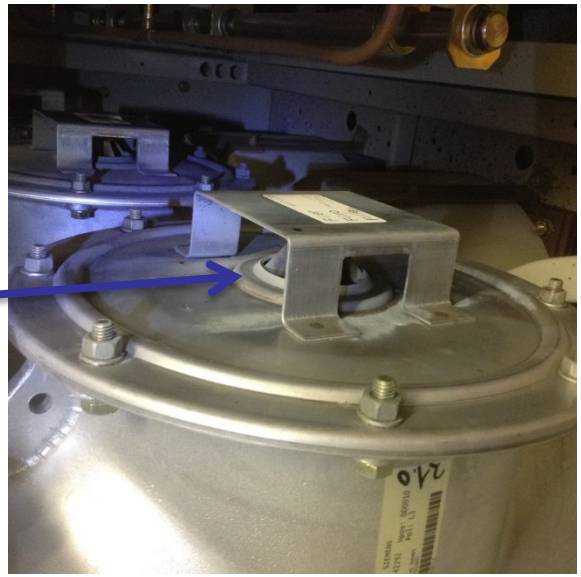


Compartment with arc flash and pressure build up

- Picture taken from behind and shows compartment with circuit breaker involved in arc flash.

Bursting disc to prevent pressure build up in case of SF6 leakage/failure

- Picture taken from behind and shows ruptured burst disc in the circuit breaker compartment and shows the involved bus bar and switchgear.



Example of normal lock out/Tag out high voltage

- Leader for switching make switching plan
- Leader for safety carries out Lock out /Tag out and tests that equipment is “dead” (no voltage present)
- Personnel carrying out the job, put on its own padlock and verifies/ensures that equipment is dead.

RAM4 + and TRC INCIDENT- KEY FOCUS AREAS

- What controls were applicable?
  - PTW, Manufacturer Procedure for work and procedure for electrical isolation.
- What was in place and what was missing and why ?
  - In place:
    - Procedure for electrical isolation, known and understood
    - Trained electrician in high voltage work
    - Good work package and PTW, Manufacturers' procedure and electrical isolation identified in PTW and Work package
    - Specialist contractor to do specialist job (competent person)
  - Not in place or Missing:
    - Not following instructions in PTW
    - Not using Manufacturers' procedure and isolation Procedure.
    - Presence and quality of worksite (individual worker) **SUPERVISION**. Specialist worker followed up of Site trained technician. Competent on equipment in use
    - Quality of **TOOL BOX TALKS** for the work team and identification of hazards and controls involved in the incident. Good towards how to handle an incident with SF6 gas. But haven't foreseen the outcome of this incident.
    - The **ROLE of LEADERSHIP** in contributing to the unsafe work environment. Ensure that people understands and reads work packages and all mitigation actions required

Case 1 – Learnings and discussion

- *Discussion: what are your leanings from this case?

- Key learnings (from incident report)
- Implement/reinstate obligatory table tops for electrical work, minimum 1 each quarter in the electrical discipline:

1. Focus especially on jobs requiring electrical isolation.
2. Identify electrical work which requires electrical isolation.
3. Roles and responsibilities according to Safety Rules and Operations
4. Leader for safety shall work on max 1 job (as per Company procedures)
5. Carry out quiz for electrical isolation.
6. Work orders to be updated to include start up meeting with specialist contractor if job is complex. Applicable for all disciplines

Case 2

Case 2 – Situation and background

An electrical arc flash incident occurred at a Central Power Plant (CPP).

The station manager and his team of electrical technicians observed a hissing sound at the low voltage (LV) switch gear panel (1000A aged LV switchgear) located in the CPP control room. While responding to arrest the situation, a decision was made to open the LV panel cubicle.

Once the cubicle was opened, there was an electrical arc flash/explosion which resulted in various degrees of burn injuries to four personnel within the immediate vicinity. Three of the injured persons were treated in the clinic and discharged same day while the fourth person was transferred to the Specialist Burn hospital for further treatment.

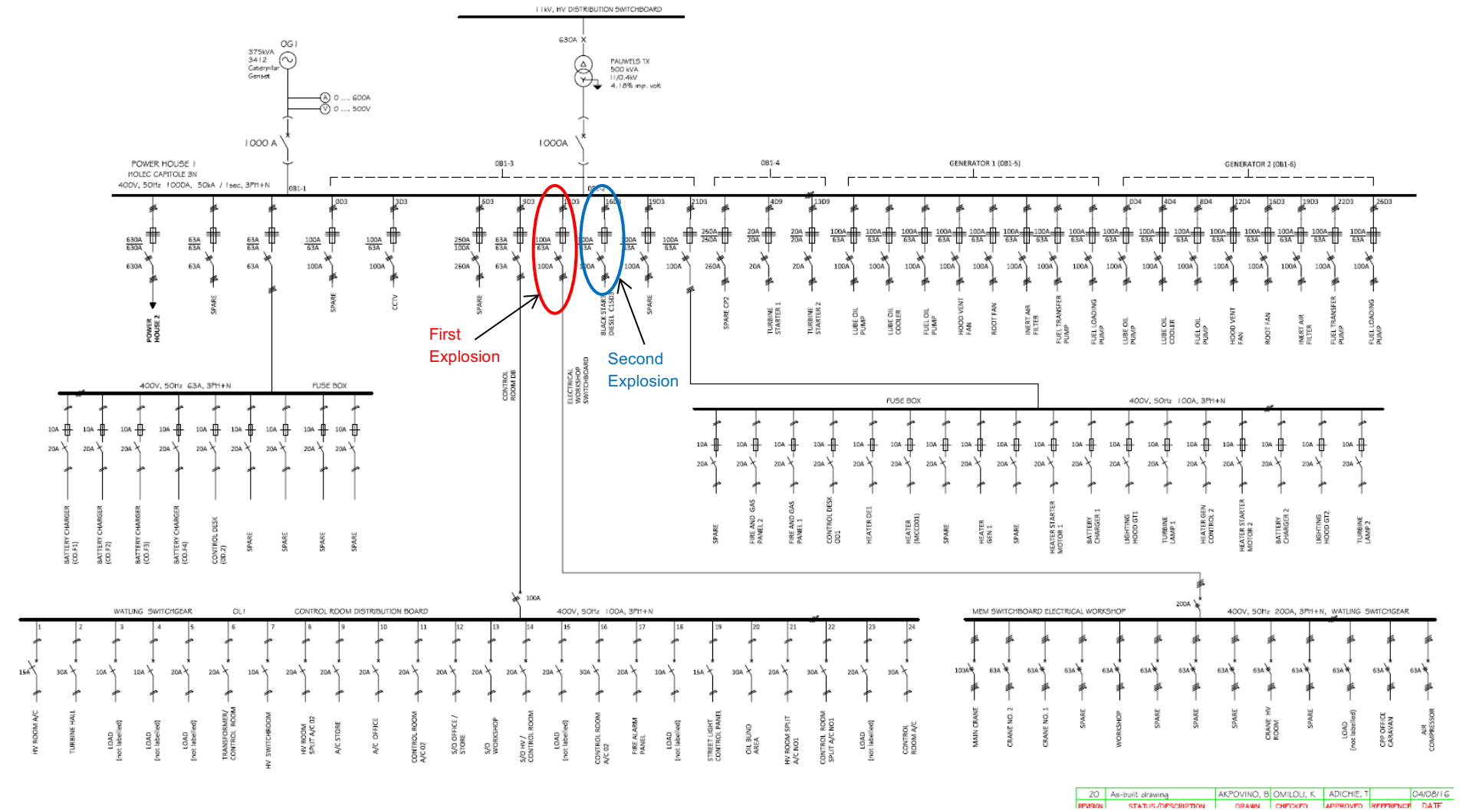
An attempt to restart the plant shortly after led to a second explosion on a cubicle above the first one on the same switchboard.

Case 2- Key Dates

The Station CPP supplies electrical power to all of the assets in the area previously operated. This includes the Main Office Area (MOA), the local residential estate and the adjacent Industrial Area (IA).

- 1983: Station CPP (4 x 2.8 MW capacity) was commissioned.
- 2009: There was a proposal to upgrade the switchboards at the CPP and substations but this was not progressed.
- 2012: Asset earmarked for divestment.
- 2013: Principal company moved out of the area along with its staff operating CPP and handed over operations and maintenance to a contractor.
- 2013: New party indicated interest to purchase plant.
- July 4th 2016 : New party signed SPA (Sale and Purchase Agreement).
- July 11th 2016 : Incident occurred.
- Sept 2016 : Full asset handover completed.

Case 2 - Station CPP LV Switchboard SLD



Case 2- LV Switchboard Specification/Description

Installed 1000A rated Low Voltage Switchboard IP41, 50KA /1s (Estimated age 34 years)

- ❑Outgoing Feeders c/w with HRC fuses and Motor Control compartment for Auxiliary Motors.
- ❑Space heater only installed in the main breaker for the switchgear and not in the individual cubicles.

- **Vintage Switchboard has some characteristics that make it different from modern MCC's:**

❑No Internal Arc Containment (IAC)

❑No cable compartment

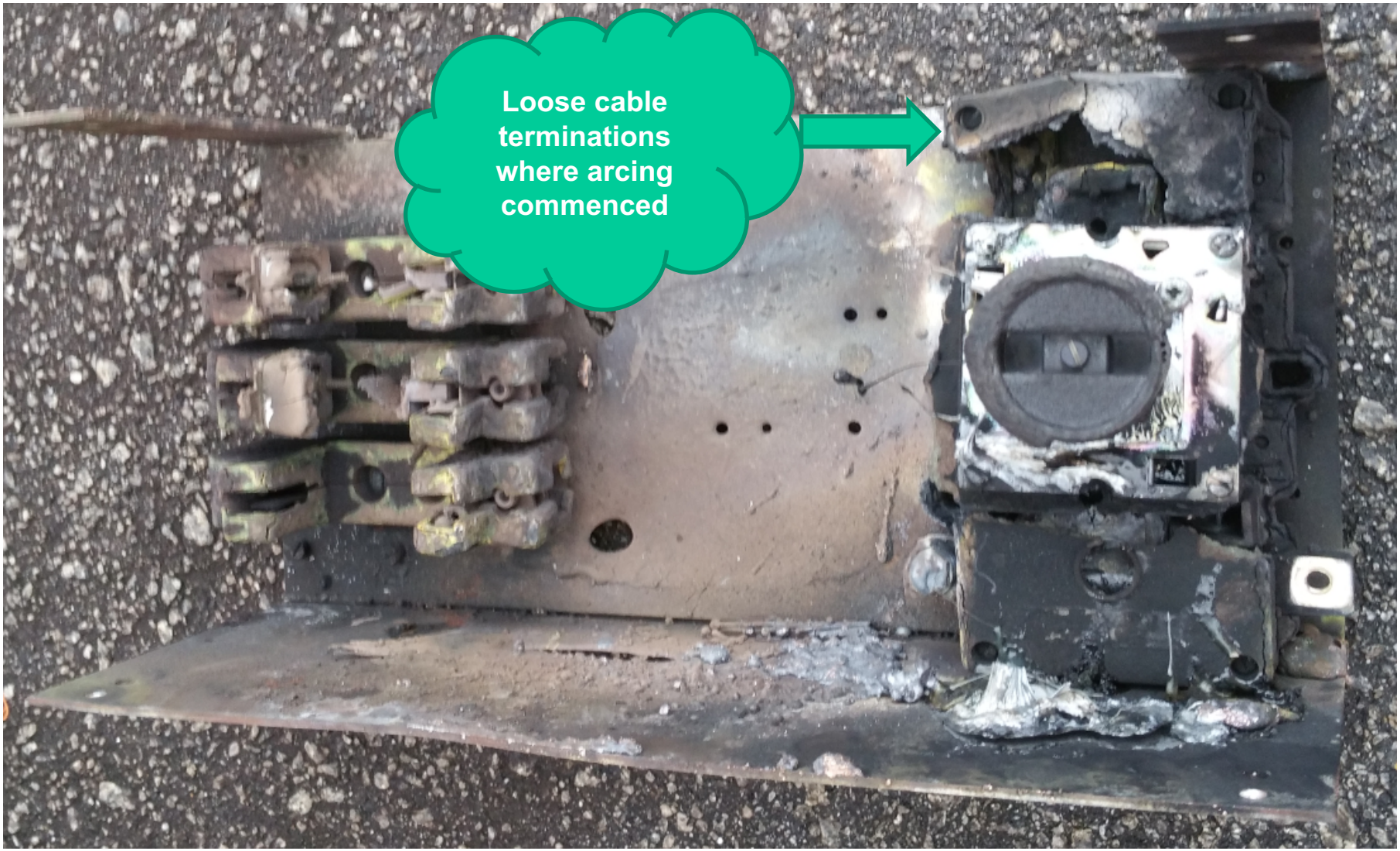
❑No isolator switch for motor circuits (only a double pole switch in control circuit), hence no mechanical interlock when opening the door of a motor compartment! The only interlock is a door switch in the contactor coil circuit. When you open the door, the contactor drops off.

❑Switchboard Incomers are usually load break switches, not providing protection. First protection to act will be the breaker upstream of the incomer.

Power Plant role play indicating positions before explosion

Note that these are not the actual persons involved in the incident.

Loose Terminal



Cover for vertical busbars burnt

Burnt vertical busbars and disconnected outgoing feeders

Case 2 - Key Findings

Switchgear & Isolation	▪ Arcing and burning commenced from loose cable connections to control switch for the first impacted panel ▪ In preparation for opening and inspection, crew personnel turned off the feeder isolator switch. This is normal practice for inspection. However, hissing sound was still heard, though damped, after turning off the feeder isolator switch. ▪ Turning off the switch and opening of the panel caused a short circuit of the phases within the connections already weakened by heat from the arcing. This led to further/rapid rise in temperature, melting of the copper bus bars and the discharge of flash and hot molten metals that impacted on the IPs. ▪ The protective devices (a circuit breaker on the LV transformer incomer to the switchboard and a circuit breaker on the HV side of the transformer) did not detect the short circuit. The plant was shutdown by pushing the station ESD button ▪ Switchgear is not arc flash compliant design; it was manufactured before the IEC standard regulations on arc flash protection. ▪ There was a high reluctance to switch off system upstream because isolation point is tied to the turbine auxiliaries and would lead to a shutdown down of the entire power plant.

Case 2 - Key Findings

Leadership Visibility	▪ Ongoing divestment reduced visibility and leadership oversight of the plant and gave room for a weak safety culture.
	▪ Key asset management improvement programmes MIE and OI have not been initiated at the Edjeba plant.
	▪ 2013 Assurance findings not tracked although Corporate Utilities tracks assurance findings in FIM
PPE	▪ It is required to wear PPE before entering the control room(PPE zone) but 3 of the injured persons did not wear their coveralls at the time.
Hazard Identification/ Risk Assessment	▪ Notwithstanding the gravity of the first explosion, the necessary electrical integrity checks on the switchboard were also not carried out and this led to the second explosion.
	▪ After the first explosion, the switchgear was not properly reinstated- a blower was used to clean the cubicle instead of a vacuum and the Insulation Resistance (“Megger”) testing was not performed. The particles dispersed by the blower caused tracking in the adjacent cubicle and resulted in the second arc flash event.
Loose Termination	▪ Inspection of the switchboard by the investigation team revealed various degrees of tightness of the cable terminations on the fuse bases and control switches in the switchboard.
Maintenance	▪ Since commencement of divestment programme, asset has fallen behind on critical maintenance activities that were previously executed routinely

Questions for Electrical Personnel, Operations Staff & Asset Managers overseeing Electrical installations.

- Are you aware of the operating instructions and type of switchgear in your location?

- How do you know that the switchgear in your location is arc compliant or not? If it is not arc compliant, do you understand the mitigations in place including the right PPE you need to operate the unit?

- How do you ensure that routine and preventive maintenance is performed on the switchgear including checking for loose connections, verification of protection settings etc.?

- How do you recognize change in situations or operating conditions and do you feel empowered to shut down even when you are not sure?

- How do you ensure that electrical systems are certified dead before start of work?

Case 2: Lessons Learned

- * Discussion: Special operating instructions on older types, non arc resistant switchgear? Your lessons learned?

- Never assume that routine practice would suffice for all scenarios including emergencies; its is important recognize the risk introduced and act appropriately when there is change in normal operating conditions
- When site or operating conditions become or are perceived unsafe, never hesitate to shut down the operation.
- Preventive maintenance on the switchgear including checks for loose connections and Insulation Resistance Tests is critical to assure integrity of the unit.
- Cleaning of dust and debris accumulated on switchgear during Preventive Maintenance is necessary to prevent tracking and consequently arcing
- It is important to understand the operating instructions for specific types of switchgear and electric power systems. Instructions should be prepared as a local ESOP for the specific plant or facility.

Case 2 - Conclusion

- Incident was preventable
- Delayed completion of divestment of the CPP reduced management oversight and visibility.
- Poor maintenance of the switchboard led to loose terminals that arced. This subsequently led to burning and explosion of the switchgear
- Lack of competence was demonstrated.
- Availability and the use of Personal protective equipment as a last but essential defence cannot be overemphasized as it would have mitigated the severity of injuries received by the personnel

Case 3 – A FATAL INCIDENT

ELECTRICAL FOREMAN SUSTAINED FATAL 10kV ELECTRICAL SHOCK

On 3rd July 2017 planned work activities for soft start switch installation were being performed in electrical switchgear room of Modular pump station #2 at the Central Processing Facility (CPF).
The electrical work party encountered difficulties installing bolts connecting the switch to bus bars.

The foreman made decision to execute the activity himself. Regardless of PTW requirements, TBT discussions, physical signs/ barriers and a colleague's warning (verbal intervention) the foreman proceeded to unbolt an adjacent panel door containing 10,000 volts energized bus bars.

Whilst party members were locating the tool required for completion of the bolting activity the Electric foreman opened the panel door and came into contact with the live busbar with his left hand and received a **fatal electric shock**.

Case 3 - Incident details

Cable compartment door

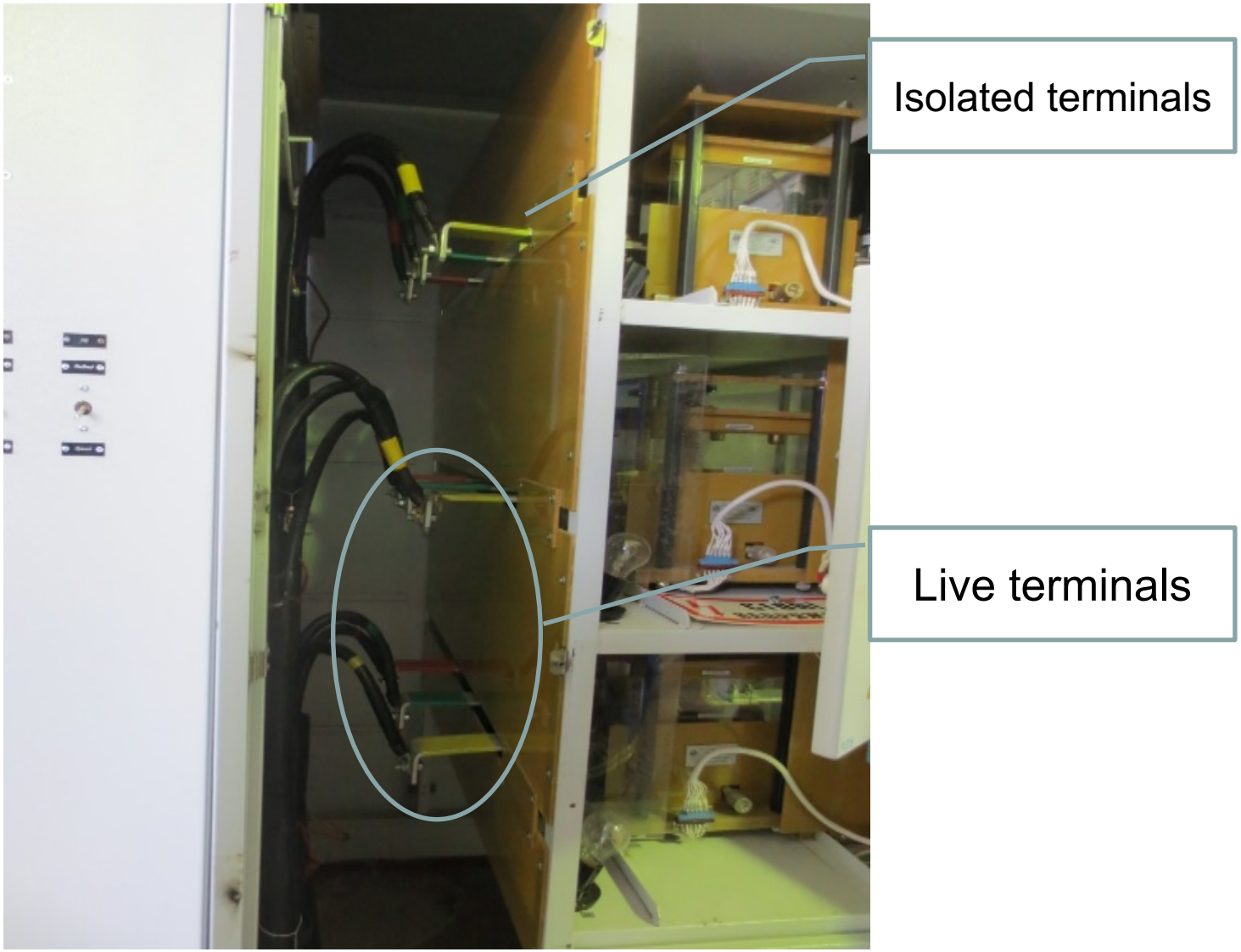
Work area

Case 3 - Incident details

Bolted connection difficult to reach

Case 3 - Incident details

Case 3 - Incident details



Case 3 – Root causes

- Complacency and Risk Normalization by Foreman during decision making and actions
- Hierarchy Based Intervention Culture Barriers (Strength of intervention from colleague)
- Failure to perform Dynamic Risk Assessment (Foreman made own decision to become involved in work execution when conditions changed disregarding the PTW requirements);
- Unintentional behavioral conditioning influencing staff to disregard personal safety

Case 3 – Lessons learned

- Discussion – hierarchy issues and complacent behavior, what can you do?
- Prior to commence work on electrical installation, ensure that all power sources are isolated (performed the necessary shutdown and isolations), apply specified PPE and insulated tools
- When **ANY** conditions change in the workplace - **STOP and NEVER** continue an activity without an **APPROPRIATE and THOROUGH** reassessment the risks and gaining the **APPROVAL** to allow it to be performed safely!

- "Don't ignore" – **INTERVENE** if you observe unsafe actions of your colleague, this could save a life!

- Anything else?

In Summary

- After discussions today – are there any thoughts about your Electrical Safety systems in place?
- Do you know that your people are equipped with the right training tools, will they speak up when they don't feel safe?
- State of equipment, is there a need for special instructions for switchgear and other equipment which is not to today's' standards?
- Knowledge and behaviors of vendors' service engineers, do they work on live equipment?
- Are we really incorporating safety into design?
- Any other thoughts?

The End

- Thank you!

- And….. Do share these learnings at your Company's site or workshop and with commissioning and maintenance staff!