PETROLEUMSTILSYNET

Investigation report

Report	
Report title Investigation of an arc flash and fire in a switchboard room on Statfjord B	Activity number 001037054

Security grading

☑ Public	☐ Restricted	☐ Strictly confidential
☐ Not publicly available	☐ Confidential	

Involved	
Team T1	Approved by/date KMA/17 December 2020
Members of the investigation team Odd Tjelta, Linn Iren Vestly Bergh, Tom Haldorsen, Trond Jan Øglend	Investigation leader OTj

Contents

1 Summary

When replacing a circuit breaker in the drilling switchboard on Equinor's Statfjord B facility, a short circuit and arc flash occurred at 02.30 on 18 August 2020 with a consequent switchboard fire. Two people were transported to land on suspicion of inhaling harmful smoke. The Petroleum Safety Authority Norway (PSA) decided on the same day to investigate the incident.

The incident occurred in connection with replacing a defective circuit breaker in a drilling switchboard. This breaker was replaceable and withdrawable, allowing it to be changed using simple aids. After the electrician had wound the breaker some way into its garage, a flash of light was observed in and an abnormal sound heard from the switchboard. The electrician moved quickly away, and a bright flash and loud bang were heard soon afterwards. Observing a fire inside the switchboard, the electrician fought this with a CO_2 extinguisher before leaving the room.

Main power was lost as a result of the arc-flash incident in the switchboard. Combined with the fire, this added to rather confused conditions for the emergency response personnel in the initial phase. Gas was later indicated in M15, which also helped to complicate understanding of the position. It emerged from the investigation that the incident command on Statfjord B had an inadequate grasp of a position involving fire and gas detection in two switchboard rooms. Disconnection of ignition sources did not occur in one of these rooms until 40 minutes had passed, and was only partly done in the other.

Based on exposure to harmful smoke from the fire in the switchboard room, this incident could potentially have had a fatal outcome for one person. The potential for the arc flash caused by the short circuit is a serious burn injury for one person.

Personnel directly involved in the incident during extinguishing were exposed to harmful smoke and were followed up on this basis. It will not be possible to identify the development of possible latent injuries until some time after the incident.

The direct cause of the incident is very probably a conductive foreign body which caused a short circuit when inserting the circuit breaker, with a consequent arc flash and fire.

A number of underlying causes of the incident on Statfjord B have been identified by the investigation. These relate primarily to:

- technical deficiencies
- expertise and capacity

- decision-making and information-sharing processes
- roles, responsibilities and conduct of analyses
- coordination and collaboration between operator and contractor
- planning and executing the work of replacing the breaker.

The investigation has identified 11 nonconformities in relation to the incident:

1. risk management in Equinor
2. barrier management
3. lack of expertise and training
4. conducting maintenance work at night
5. inadequate information sharing and use of information systems
6. failure by Equinor to see to it that Archer complies with requirements in the HSE legislation
7. deficiencies in the maintenance programme and in improving such work
8. deficiencies in the arc-flash study and communicating necessary information
9. lack of protection against thermal effects
10. lack of protection against interruptions and of adequate selectivity between protection devices in the event of faults in the installation
11. deficiencies in handling hazard and accident situations.

2 Background information

2.1 Description of the facility and the organisation

The Statfjord field has been developed with the Statfjord A, B and C platforms. It straddles the median line between the Norwegian and UK continental shelves in the Tampen area. Statfjord B is an integrated production, drilling and quarters platform standing in 145 metres of water at the southern end of the field, and came on stream on 5 November 1982.

Statfjord B has been part of the field life extension (FLX) business area since 1 April 2020.

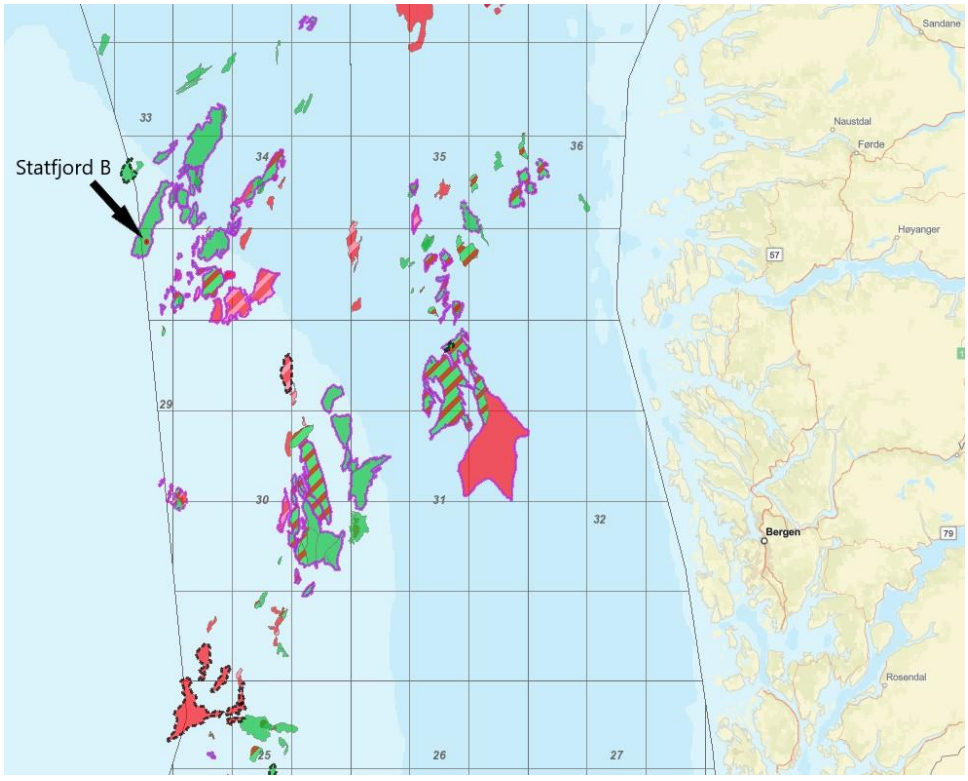

Figure 1 Map of the area. (source: Norwegian Petroleum Directorate)

Before the incident, production on Statfjord B was progressing as normal. A total of 128 people were on board. The weather was fine, with a light breeze from the north-east, an external temperature of about 15°C and a calm sea. Archer, responsible for drilling on Statfjord B, had no drilling activities under way. It was in a "phase 3" stage, with drilling halted, and was working on various maintenance jobs. Statfjord B was supplied before the incident with electricity from gas turbine generator A (NG7001A).

2.2 Definitions/abbreviations

Definitions	
Aris	Part of Equinor's formal management system, describing work processes.

Night electrician	Involved in the incident, Archer employee. On Statfjord B since January 2020
Night mechanic	Involved in the incident, Archer employee. On Statfjord B since January 2020. Not a qualified electrician.
Day electrician	Not directly involved in the incident, Archer employee, long experience from Statfjord B.
Archer apprentice	Involved in the incident, second tour on Statfjord B.
DocMap	Part of Equinor's formal management system along with Aris, for example. Contents include technical and WP requirements.
Incident energy	Thermal energy on a surface at a given distance from the source, generated by an arc flash. Normally expressed in calories per cm^2.
Arc flash	Explosive release of energy from arcing caused by an electric current through ionised air. Energy in the arc flash is converted to heat and light at temperatures up to 19 000℃. Pressure waves and toxic gases from vaporised metal can occur.
M15	Local control room with low-voltage switchboards and control cabinets. Gas detection there disconnects ignition sources in non-essential equipment (ignition source group 1A).
MIS risk	Management information system. Tool for managing and communicating major incident risk. Serious deficiencies (D and E) in Timp can be presented here.
Abbreviations	
AC	Alternating current
ART	Alarm and reaction team
AVR	Automatic voltage regulator
CCR	Central control room
DC	Direct current
DSHA	Defined situations of hazards and accidents
ESD	Emergency shutdown
FLX	Field life extension business area
HV	High voltage >1 000VAC
M1	Modification proposal dealt with in SAP
MEI	Manual electrical isolation
NCS	Norwegian continental shelf
O&M	Operations and maintenance head (production head in FLX)
OBE	Operational barrier element
OIM	Offshore installation manager
PA	Public address system
PM	Preventive maintenance
PPE	Personal protective equipment

PSA	Petroleum Safety Authority Norway
RNNP	Trends in risk level in the petroleum activity
SAP	System for maintenance administration on a facility
Timp	Technical integrity management programme
VSDS	Variable speed drives system
WO	Work order
WP	Work permit

Table 1 Definitions/abbreviations.

3 The PSA investigation

The PSA received written notification from Equinor early on Tuesday 18 August 2020 of an incident with an arc flash and subsequent smoke development in switchboard room W11 on Statfjord B. The incident caused a power outage with loss of main power and activation of gas detection in the M15 switchboard/generator control room. Two people were transported to hospital for further follow-up because of exposure to smoke. A video meeting on the incident was held at 10.00 on the same day, and the PSA decided soon afterwards to investigate.

The PSA investigation team arrived on Statfjord B at about 08.00 on Thursday 20 August 2020.

3.1 Investigation team's mandate

The following mandate was provided for the PSA investigation.

a. Clarify the incident's scope and course of events (with the aid of a systematic review which typically describes time lines and incidents).
b. Assess the actual and potential consequences
    1. Harm caused to people, material assets and the environment.
    2. The potential of the incident to harm people, material assets and the environment.
c. Assess direct and underlying causes (barriers which have failed to function).
d. Identify nonconformities and improvement points related to the regulations (and internal requirements).
e. Discuss and describe possible uncertainties/unclear points.
f. Discuss barriers which have functioned (in other words, barriers which have helped to prevent a hazard from developing into an accident, or which have reduced the consequences of an accident).
g. Assess the player's own investigation report.
h. Prepare a report and a covering letter (possibly with proposals for the use of reactions) in accordance with the template.
i. Recommend – and normally contribute to – further follow-up.

3.2 The investigation team

Name	Position	Discipline area
Odd Tjelta	Principal engineer/ investigation leader	Process integrity
Tom Haldorsen	Principal engineer	HSE management
Trond Jan Øglend	Principal engineer	Process integrity
Linn Iren Vestly Bergh	Senior adviser	Occupational health and safety

3.3 Methodology

Relevant personnel in the Archer and Equinor organisations on land and offshore have been interviewed. An inspection has been conducted on Statfjord B along with meetings and a review of relevant documents/logs. Equinor's investigation report has also been reviewed. Barriers which functioned have not been described in detail.

Documents requested and received in connection with the investigation are listed in an appendix.

3.4 FLX organisational structure

Equinor established the FLX business area in 2020 as shown in Figure 2 below.

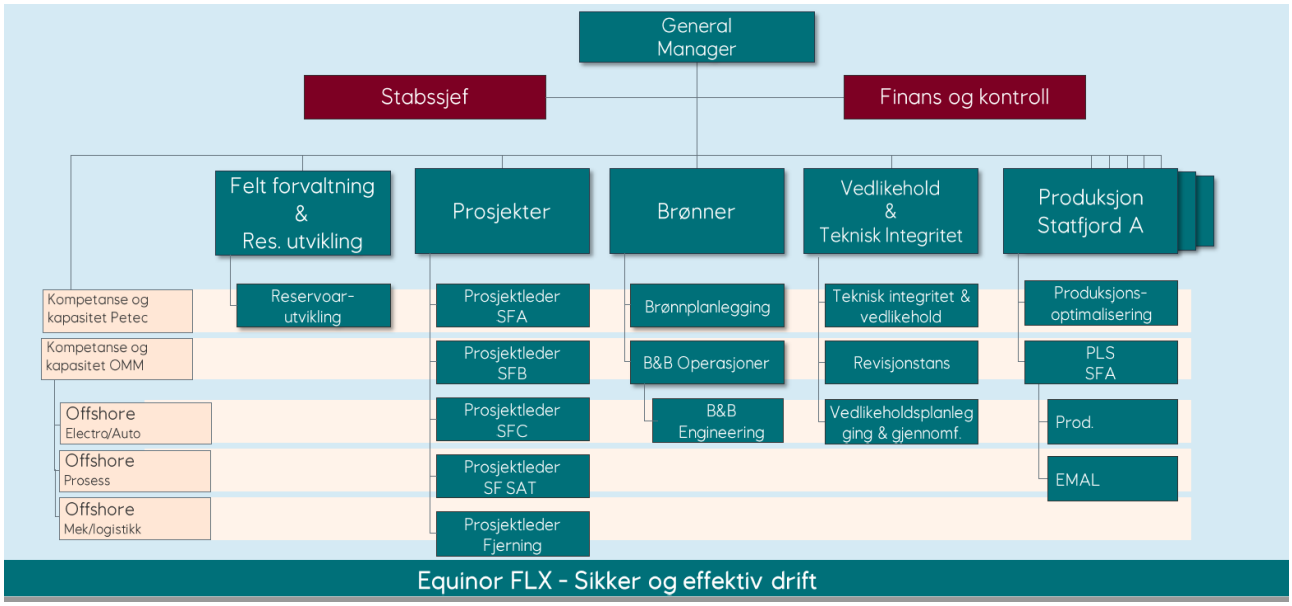

Figure 2 The FLX platform organisation on Statfjord B.

The production department has overall responsibility for safe, efficient and sustainable operation of installations and fields, including satellites, and for ensuring that all activities on the respective facilities are risk-assessed and coordinated. It is responsible for optimising production in the short and medium terms.

Integrated responsibility for technical integrity, management and execution of maintenance in the business area rests with the maintenance and technical integrity

(FLX MTI) department. Its duties include the role of responsible party for electrical installations in FLX as well as pursuing systematic improvements in maintenance and planning, and executing necessary maintenance activities.

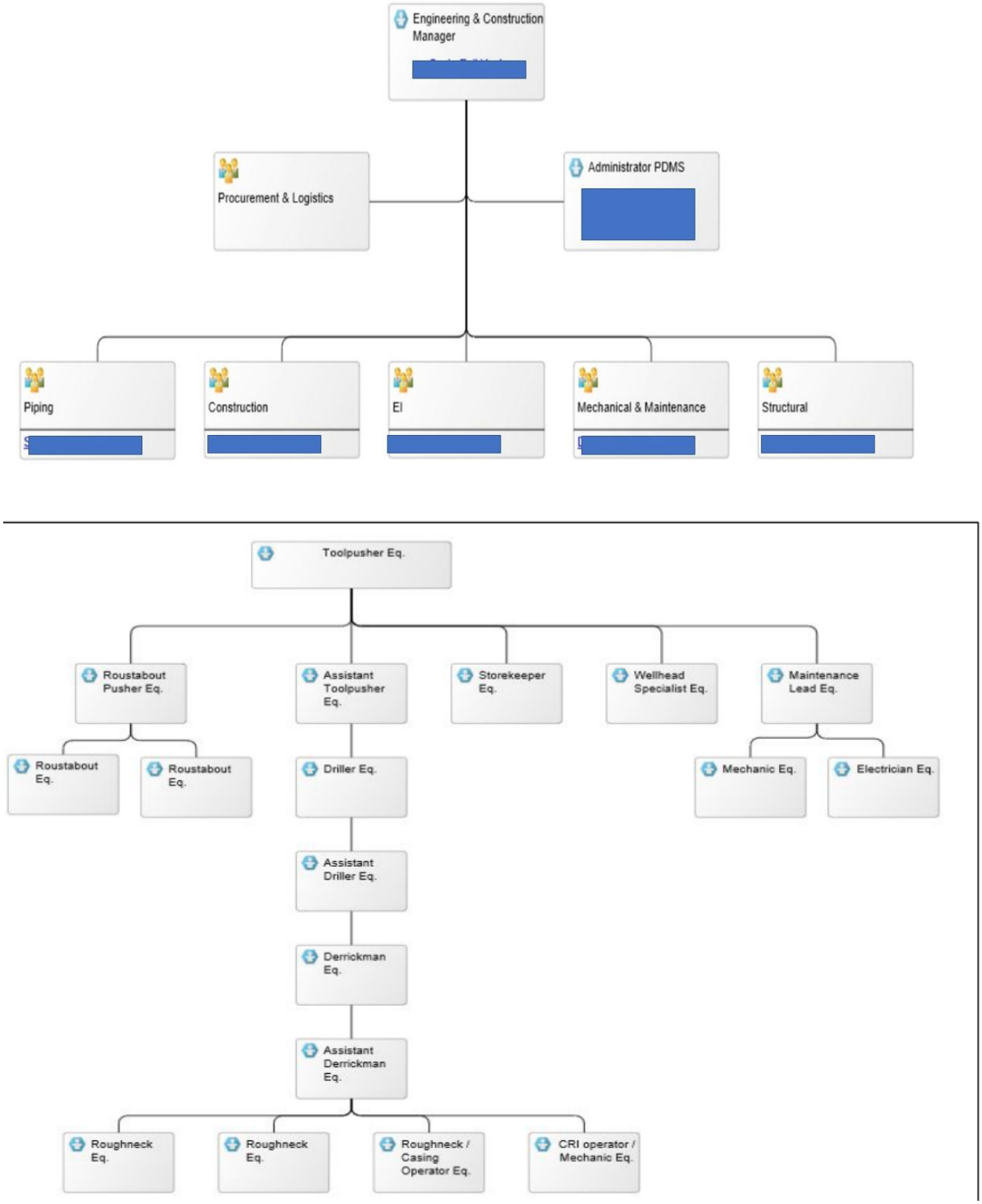

Figure 3 Organograms: Archer Statfjord B, offshore and on land.

Equinor's offshore installation manager (OIM) is responsible for the whole Statfjord B platform, while Archer is the drilling contractor. The latter thereby has area

responsibility on behalf of Equinor for the drilling module with associated electrical installations and utilities.

3.5 Equipment involved in the incident

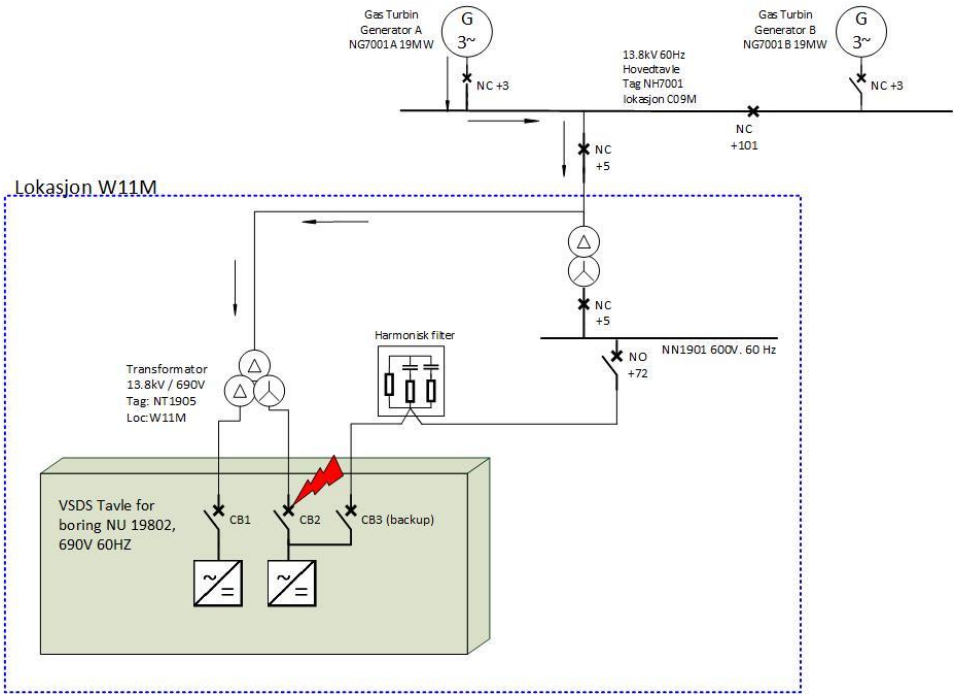

Figure 4 Simplified diagram of equipment involved in the arc-flash incident.
Key: Hovedtavle: main switchboard; Lokasjon: location; Harmonisk filter: harmonic filter; VSDS tavle for boring: VSDS drilling switchboard.

The accident occurred in an electrical switchboard for drilling (VSDS switchboard, tag NU19802) manufactured by National Oilwell Varco.

This switchboard's function is to convert incoming alternating current (AC) to direct current (DC) and distribute the latter to individual inverters. These convert DC to AC with variable frequency and voltage for regulating the speed and torque of such drilling-related machinery as drawworks, mud pumps and top drive. Alternatively, the switchboard can be supplied from switchboard NN1901A, which permits limited operation with electricity from a dedicated drilling generator.

According to its declaration of conformity, the switchboard was manufactured in April 2007 and installed on Statfjord B in 2009 as part of a drilling upgrade programme. The installation also included a Δ:Δ/Y transformer which supplies the switchboard with AC from the Statfjord B grid. This transformer is ungrounded, and the biggest significant fault currents are thereby limited to phase-phase faults or faults on the DC side of the rectifier. The switchboard has ground fault monitoring which continuously measures leakage currents to ground.

The switchboard was arc-flash tested, but failed the approved test. Compensatory measures were implemented to reduce the probability of an internal arc flash, while

hinges and door locks were replaced with more robust versions and two bolts were added to the door for the incomer field. The switchboard's short-circuit withstand rating is reportedly 70kA. Maximum continuous load for AC busbars is 5 000 A.

The switchboard is constructed in stainless steel and appears robust. The manufacturer's technical documentation states that the cabinet structure will help protect personnel from arc-flash injuries, but this presupposes that doors are closed. Insulating materials are fitted to cover all components in the switchboard which exceed 120VAC. AC busbars are insulated on both sides of the incomer breaker.

The breaker to be replaced was a withdrawable Emax E3H 32 type (690V, 3 200A, Ics= 75kA). It can be placed in three different positions:

1. separation position: main and signal contacts disconnected
2. test position: main contacts disconnected, signal contacts connected
3. operating position: main and signal contacts connected.

The position is indicated at the lower right-hand side of the breaker's front panel. A breaker can only be manoeuvred between different positions when in open position. To change from test to operating position, it is wound in with a dedicated tool. Contacts on the breaker then engage with contacts in the cassette. Neither the breaker which was removed nor the one inserted had its own tag number. No service or maintenance is registered either for the breaker which was in service or the one kept as a spare since 2006.

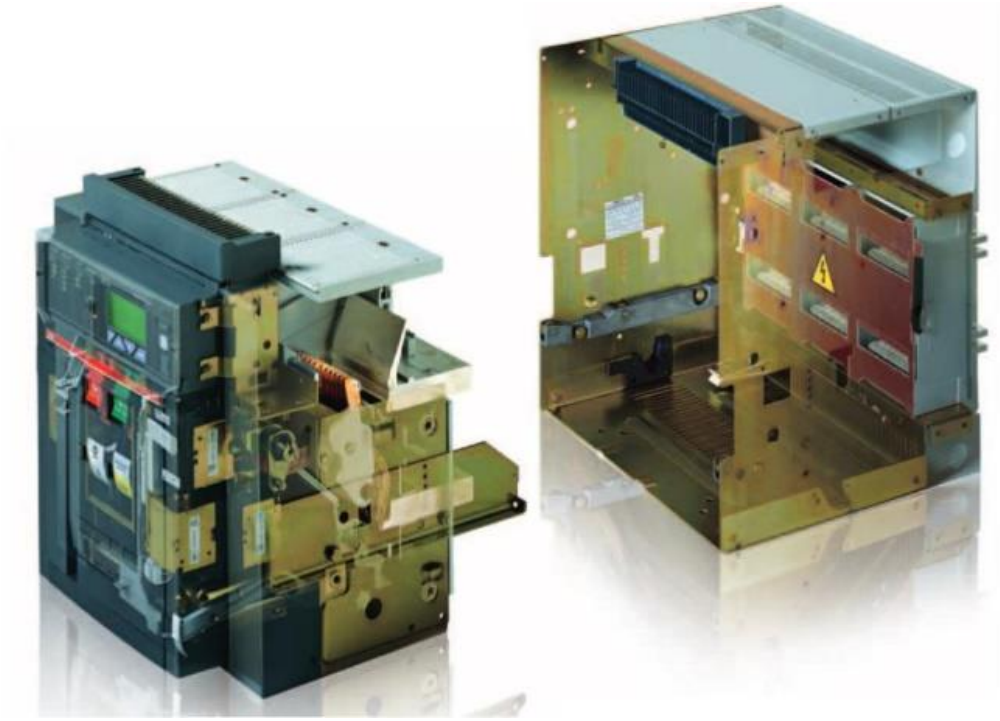

Figure 5 Photomontage ABB. E3 Circuit breaker with associated cassette.

3.6 Arc-flash study

When planning work on electrical installations, all risk factors – electrical and other hazards – must be known. Growing attention has been devoted in recent years to the dangers posed by arc flashing, on measures to reduce its consequences in electrical installations, and on equipment to protect against it. Requirements for guarding against thermal effects, including from arc flashing, are found in section 47 of the facilities regulations on electrical installations. Implementation details can be found in the IEC 61892 series. IEEE 1584™ and NFPA70E are regarded as recognised methods for arc-flash analyses and for calculating potential incident energy, as well as requirements for protective equipment. Guidelines have been issued on specifying the scope of work and delivery details for arc-flash studies in accordance with IEEE standard 1584™.

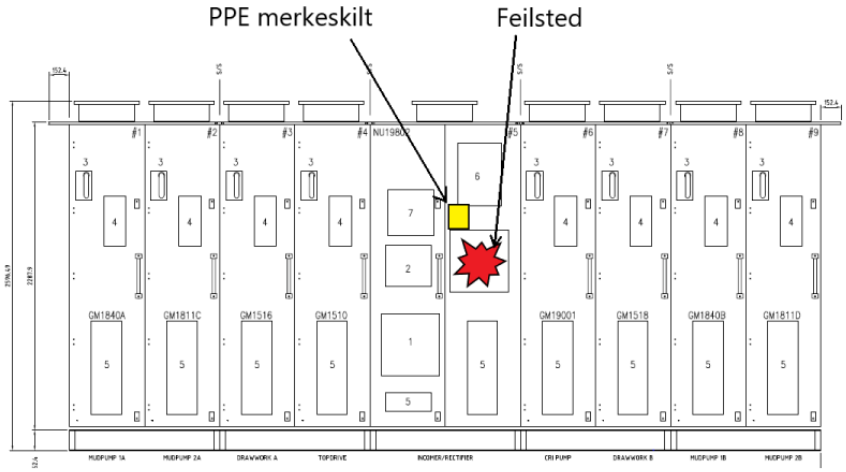

Figure 6 Overview of VSDS switchboard.
Key: PPE signage; Fault location.

3.7 Relevant incidents

Fourteen fires with a major accident potential were registered in RNNP during 2010-19. Of these, five can be said to be electrically related (smoke development in switchboard room, heat transfer in cables, short circuits in switchboards and so forth).

The PSA received notifications or reports of 29 fires in 2019. Eight of these can be said to be electrically related, but none had a major accident potential.

An overview of earlier relevant incidents in Equinor is presented below.

Date	Location	Title
17 Nov 2003	Statfjord B	Short circuit in 440V switchboard
4 Jun 2006	Statfjord B	Short circuit in switchboard NN1902, starter drawer for mixer pump GP1803A
22 Apr 2009	Sleipner	Personal injury following short circuit in emergency

		switchboard
5 Nov 2010	Kalundborg	Short circuit in switchboard when turning off motor starter
9 Jun 2011	Statfjord C	Short circuit in 440V circuit breaker during connection
25 Jul 2020	Kårstø	Arc flash during work on switchboard in T-200 Sub caused serious personal injury

Table 1 Overview of earlier relevant incidents.

3.8 Information on risk

In September 2019, Timp identified (in PS11) that arc-flash energy in electrical switchboards exceeded the acceptance criterion (graded D).

An MIS risk tool with associated measures was established on 7 November 2019 to cover the threat of production shutdown from an integrity challenge with electrical switchboards. After FLX became operational, a separate risk with measures was also established on 8 May 2020 related directly to arc-flash energy exceeding the acceptance criterion. MIS risk primarily covered risks in electrical installations where Equinor has maintenance responsibility.

4 Course of events

To establish a timeline and identify the course of events, the investigation team has utilised documentation acquired, interviews with relevant personnel and data from various Statfjord B safety systems.

4.1 The incident in brief

During the day shift on 17 August 2020, the Archer electrician had the opportunity to operate incomer breakers CB1 and CB2 in the VSDS switchboard (NU19802). Problems were then discovered when operating CB2. The day electrician informed his night counterpart at the shift change that an attempt to replace it should be made as and when appropriate. The night electrician decided to change the breaker during the following shift. He took the view that this was a routine job, since the breaker could be withdrawn completely and replaced with simple aids (elevator and winder). No work permit or isolation of the switchboard was considered necessary. Job planning continued after identifying the correct spare part and checking that the settings were the same.

Because of the breaker's shape and weight (about 60kg), the electrician decided that help was needed to move it in and out of the switchboard and asked the night mechanic to assist. After a verbal risk assessment in switchboard room W11, with the main emphasis on crush injuries, he started the job by removing the defective breaker from the switchboard. This went as planned. Before installing the new breaker, a new verbal risk assessment was carried out – this time with the emphasis on dangers associated with installing a breaker in an energised switchboard. It also emerged from interviews that the executing personnel were aware of earlier

undesirable incidents which had occurred in such operations. Once the breaker was positioned in its garage, the switchboard door was closed with handles and two bolts.

Around 02.30, the electrician began to wind the breaker over the final steps towards intervention with the energised claw contacts in the breaker cassette. The mechanic was standing at this time on the right-hand side away from the breaker. Soon afterwards, the electrician observed a flash of light and a noise described as a high-frequency transformer sound inside the switchboard. The electrician moved quickly away before a bright light flash and bang occurred, followed by a wave of heat.

The electrician saw a fire inside the switchboard and decided to fetch the CO_2 extinguisher from the neighbouring room (see Figure 7) to fight the flames. The mechanic was despatched to notify the control room by phone. After seeking to extinguish the fire through the grille in the switchboard door, the electrician quickly saw that this was having little effect. He therefore opened the door, allowing black smoke to pour out. After emptying the extinguisher, the electrician left the room. Interviews with the people involved established that this took about three-five minutes.

On the night of the incident, Statfjord B was powered by generator A (NG7001A). The VSDS switchboard (NU19802) for drilling was supplied from the 13.8kV main switchboard (NH7001) via outgoing feeder +5 and transformer NT1905 (13.8kV AC/690VAC) (NT1905). See Figure 4 for a diagram of the installation.

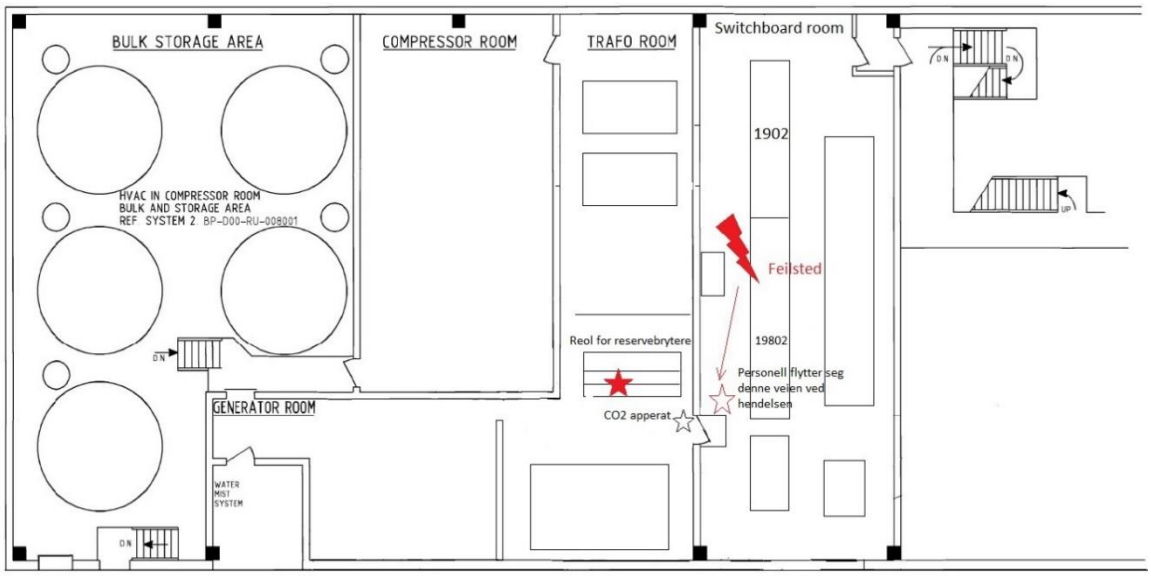

Figure 7 Simplified diagram of module W11 on Statfjord B, with relevant locations highlighted.

4.2 Arc flash and fire in chronological order

The incident occurred in connection with replacing a breaker in the VSDS switchboard. Prior and subsequent activities which could be significant, in addition to the actual incident, are presented in the table below.

Time	Event	Comments
2006	Breakers in the switchboard and in store are manufactured	
2007	VSDS switchboard constructed.	
2009	Electrotechnical studies conducted in connection with upgrading the drilling facilities.	Analyses show that a fault at the incomer breaker of the VSDS switchboard would give a relatively long disconnection time and increase the threat of harm to equipment and people. The document with details regarding the incomer protection devices and connections in the AC section are missing from Equinor's archive. S0100541-PROT-0001 (BP-S0100541-PROT-0001) (AC drive lineup protection).
2009	Installation of the VSDS switchboard.	Documentation that the switchboard can tolerate a short circuit of up to three seconds is missing.
2009	The spare breaker was part of the switchboard delivery, and stored on a shelf in the room next to W11 ("squirrel store").	No preservation or further follow-up of this breaker is documented.
2009	Arc-flash calculations and PPE requirements on Ekofisk – among the first such calculations on the NCS.	This was done following a serious incident at Teesside in the UK.
2 May 2019	Equinor circulates information on arc-flash levels with associated PPE requirements for switchboards on Statfjord B.	The guidelines for the recognised method (IEEE1584) were not observed. The responsible party for electrical installations on Statfjord sent an e-mail with an overview of the PPE level for the

	The calculations are done by an Equinor trainee and verified by electrical personnel/ engineer.	various switchboards to Archer's responsible electrician and other electricians, plus Equinor's electrical discipline lead on Statfjord B and C. Offshore personnel were asked to mark switchboards with signs and to hang up a one-line form showing the PPE level.
2 May 2019	Archer's responsible electrician followed up the Equinor e-mail with e-mails to the company's electricians (e-mail address for the posts) and maintenance leader on Statfjord A, B and C. Copied to operations engineer for Statfjord B and Equinor contract manager.	Electricians were informed of risk related to work on switchboards, and instructed that no work was to be done on switchboards defined as PPE3/4. This information was issued by e-mail without any follow-up to check that relevant personnel had read and understood it. The offshore O&M leader was not included in this e-mail correspondence.
28 Jun 2019	Equinor drew up and distributed instructions to its electricians on Statfjord B restricting work on/servicing of 6kV and 440V switchboards with PPE above 40 cal/cm^2 (PPE4).	Equinor's instruction for work on switchboards with high arc-flash energy introduced a general ban on exposing busbar packages in an energised state on switchboards assessed as above PPE X (>40 cal/cm^2). Measures were also required for reducing levels or wearing suitable garments when servicing switchboards with PPE level 4. Reduction measures were required for PPE X. This instruction does not include Archer drilling switchboards with PPE > 40 cal/cm^2.
1 Sep 2019	Archer personnel on Statfjord C experienced problems getting the incomer breaker to close. A fault was also found on the spare breaker.	Statfjord C has the same switchboard and breakers. Problems had been experienced there when operating incomer breakers. This led to the active and spare breakers being sent ashore for overhauling and testing. This information did not lead to any action on Statfjord B.
Sep 2019	Timp identified	Several switchboards exceeded the

	deficiencies related to potential arc-flash energy in PS11.	acceptance criterion of 8cal/cm^2 in TR3021. An exemption (Disp) was established. See incident 27 September 2019.
27 Sep 2019	Internal exemption because of high arc-flash energy level in 440V switchboards on Statfjord B is valid until 31 December 2020.	This does not include 690V drilling switchboards (Archer's area of responsibility) which have a similar high arc-flash energy level. Equinor's internal requirement in TR3021 is that arc-flash energy in switchboards must not exceed 8cal/ cm^2. Arc-flash protection devices can be used to meet this requirement.
8 Jan 2020	Report from Archer's annual internal electrical inspection on Statfjord B on 12-15 November 2019 published. Relevant findings Equinor is responsible for dealing with: 1. PPE level on switchboards must be more clearly marked. 2. Switchboard NN1902 in W11 had incorrect PPE class on yellow warning sign: value is 8.6cal/cm^2, but should be PPE 3. 3. Arc-flash protection devices on the most vulnerable switchboards must be followed up to reduce hazards and ensure simpler operation. 4. No hearing protection was provided for the special hard hats with visor forming part of the recommended PPE to protect against arc flash.	Equinor was warned about these findings, but they were not followed up by Archer. Nor did Archer give Equinor any deadline for dealing with them. These findings were not followed up in the established follow-up system.

5 Aug 2020	Lack of information prompted a request for guidance on arc-flash risk on Statfjord C in connection with internal electrical inspection. E-mail response from Archer's responsible electrician to electricians on Statfjord A, B and C.	The Archer responsible electrician's e-mail confirmed that guidance on the arc-flash risk should have been sent out and asked all Statfjord facilities to respond with a confirmation that this had been received, made available and read.
	Actual incident 18 August 2020	
Time	**Event**	**Comments**
19.00-01.30	Started planning the job, located the spare breaker, needed help to move breaker over to elevator/switchboard, talked with night mechanic in the 21.00 break and got help from him.	Mechanic asked about a WP, but the electrician considered this a routine job which did not require one. Archer's night electrician was the authorised night-shift operations leader for the drilling electrical installations and area authority in the relevant switchboard room. A verbal risk assessment was conducted with the mechanic covering some potential hazards in the operation. No responses to an incident were discussed. Those involved did not know the history and condition of the spare breaker stored in the adjacent room.
01.30.00– 02.15.00 (unconfirmed)	Defective breaker wound out of its garage in the switchboard.	
01.30.00 – 02.15.00 (unconfirmed)	Defective breaker slid onto the elevator and moved away from the switchboard.	
02.15.00- 02.30.00 (unconfirmed)	New breaker lifted into the garage, pushed in until it stopped.	The breaker was moved back and forward a little to ensure that it was properly seated in the garage.
02.20.00- 02.30.00	Closed switchboard door and secured it by	The mechanic stood to the right of the electrician, a little away from the

(unconfirmed)	turning the handles and screwing in two bolts.	switchboard.
02.20.00-02.30.28 (unconfirmed)	Wound the breaker in for the final distance, past the test position and probably into some contact with claw contacts in the breaker garage.	Soot-free traces on the breaker's upper contact set indicate that the contacts were a few millimetres in contact with the claw contacts in the garage. The electrician reports that he first heard a high-frequency transformer noise and saw a flash of light through openings in the switchboard. The breaker was not operated in test position before being wound in. According to the manufacturer and the user manual, the breaker has a test position which permits it to be used without engaging the main contacts. But the user manual for the switchboard does not describe any such function.
02.30.28	Short circuit with sharp and sudden load increase on the turbine generator.	Electrician quickly moved away from the switchboard, mechanic was already a little distance off, the rumbling intensified followed by a powerful flash and a bang.
02.30.31	Upstream breaker in cubicle +5 in HV switchboard NH7001 which supplies drilling tripped owing to overload. Automatic voltage regulator (AVR) fault occurred on generator A.	Timing approximate because of relatively long sampling intervals on measurements in the HV switchboard and turbine generator (once per second). Load increased from 9MW to 25MW in about two seconds. The switchboard room went quiet.
02.30.32	Breaker for generator A in cubicle +3 in the HV switchboard NH7001 open (AVR fault).	Loss of main power.
02.30.33	Generator A received overspeed alarm and tripped.	This was probably a consequence of the generator suddenly losing all load.
02.30.33-02.35.28	Fire extinguishing in NU19802.	Electrician observed a fire in the switchboard and fetched the CO_2

(unconfirmed)		extinguisher from the adjacent room to try putting it out. Sent night mechanic at the same time to notify control room by phone. Tried to extinguish through grille in switchboard door, but opened the door when this was ineffective, with black smoke pouring out. Emptied CO_2 extinguisher in the switchboard and left the room. Estimates that this took about three-five minutes. Confirmed he was OK by radio during extinguishing.
02.30.33-02.35.28 (unconfirmed)	Notification of fire in W11.	Mechanic left the room to notify the control room by phone about short circuit and fire. Message received by CCR operator.
02.30	PA announcement.	CCR reported loss of main power.
02.30.48	Smoke alarm in W11.	CCR received early detection from W11-SDE-202A detector in W11 switchboard room. Followed by more smoke detectors in the room.
02.33	General alarm.	Manual activation from CCR. Deactivated at about 02.35.
02.33.10	Smoke alarm M15.	
02.34	Incident command mustered.	In the CCR and later in the emergency response centre.
02.35	Incident command centre established in M21.	Close to M15.
Abt 02.35	Archer apprentice.	Archer apprentice met electrician outside switchboard room. After a short talk, the former decided to make a simple search of the room for people. Felt around with foot, held breath and felt fine afterwards.
02.37.19	Gas detection in M15.	First one, then both detectors – high, followed by high-high alarms.
02.39.46	ESD with blowdown.	
Abt 02.40	Status meeting in response centre.	
02.40.00 (unconfirmed)	Incident command informed about incident in W11.	By the electrician exposed to smoke.
Abt 02.50	PA announcement by	Information on smoke, gas leak and loss

	OIM.	of main power.
02.50	Personnel on board (POB) check completed.	
02.50	Electrician and mechanic treated in hospital for smoke inhalation. Later flown to Haukeland Hospital by Statfjord B search and rescue (SAR) helicopter.	
Abt 03.00	SAR team entered M15.	Gas and smoke detection continued. Ignition sources in room not isolated.
03.11.12	ESD-D	Emergency generator stopped earlier, and ESD-D isolated ignition sources in the drilling area.
03.15	SAR entered W11.	Still smoke in the room
03.37	SAR helicopter took off with two patients.	People affected by smoke in W11.
03.51	PA announcement.	Personnel leave the lifeboats, position of fire in W11 clarified.
04.15	Deluge valve in drilling area opened, general alarm.	Low pressure of working air (deluge valve not connected to instrument air).
Abt 06.00	Main power restarted, normalisation. Information to everyone on board.	
21 Aug 2020	On the basis of the Statfjord B incident, Archer opened a Synergi case and distributed it to everyone in its organisation. This bans people from working on the incomer part of switchboards until the actual incident energy in these sites has been identified. Synergi also clarifies a requirement that the second person must be a skilled electrician working in	

	this discipline.	
25 Aug 2020	Technical note switchboard with new arc-flash calculation for switchboard NU19802.	A technical note was drawn up following the arc-flash incident in the 690V drilling switchboard NU19802 on Statfjord B to provide an indication of arc-flash energy at the relevant place in the switchboard (incomer breaker). This indicates very high energy levels with an arc flash, far above PPE 4 or 40 cal/cm^2.
27 Aug 2020	Equinor issued a safety alert with reference to Statfjord B and Kårstø Synergi cases. Immediate measures were that PPE against arc flash must as a minimum be used when servicing breakers with open enclosures in switchboards with arc-flash energy levels from PPE1 (1.2 cal/cm^2) and above.	

Table 2 The incident in chronological order.

5 Potential of the incident

5.1 Actual consequences

Given the damage at the site, technical calculations and the long disconnection time for the fault current, it can be concluded that substantial energy was liberated by the incident. New calculations of the incident energy at the relevant site show that this exceeds 100 cal/cm^2. That primarily reflects high short-circuit levels and long disconnection time.

Personnel directly involved during extinguishing work were exposed to harmful smoke and were followed up for this. Both were quickly discharged from hospital. On publication of this report, the investigation team is not aware that personnel involved have had acute symptoms of smoke exposure. Possible latent effects will not become apparent until some time after the incident.

A thin film of smoke was observed in the M15 turbine control room. This had no direct connection with the fire and smoke in W11, but probably occurred indirectly as a consequence of the incident because of loads on electrical equipment related to

power generation. It has not been possible to determine why hydrocarbon gas detection activated there. This was probably an error reading, which may be related to smoke in the room. The room has no internal gas sources, and gas was not indicated anywhere else on the facility.

Material damage is largely confined to a section of the VSDS switchboard, and was caused by heat from the arc flash as well as by molten metal being flung around inside. Particles of melted metal were thrown out via ventilation holes at the base of the switchboard door, but caused minor damage. The drilling plant was not in use during the incident. The process plant, imports of processed oil from Snorre B and gas exports were shut down by the power failure. No environmental damage has been identified as a result of the incident. The financial consequences of the damage are calculated to be about NOK 3 million.

5.2 Potential consequence

This incident involves two different potential consequences.

- When the electrician opened the switchboard door to fight the fire, he was exposed to smoke which could have had acute toxic effects (from such substances as carbon monoxide or cyanide) and, in the worst case, been fatal.
- Personnel used only PPE normally required for work on the facility (electrician's coverall, gloves, safety boots, hard hat and goggles). Based on the available incident energy at the relevant place in the VSDS and the failure to use extra PPE, the investigation team believes the potential of the incident under slightly different circumstances was serious burn injuries for a person.

What probably prevented a more serious course of events with the arc-flash incident was the switchboard's robustness and the closure of the door with handles and bolts before the electrician began to wind in the breaker. He was also quick to move away when he received advance warnings through small flashes of light and unusual sounds from the switchboard. The mechanic stood further away during the winding, which had been agreed in advance.

Had the correct incident energy for the site been known, the job would probably not have been tackled in the way it was. Marking the switchboard with a PPE level of 2.5 cal/cm^2 could potentially have made a negative contribution to the incident. The electrician could have been lulled by a false belief that energy in the switchboard was much lower than the actual level. According to the switchboard supplier, this should not have posed any danger for personnel if the door was closed and integrity intact up to 70kA short-circuit current. This claim is not supported by any documentation. Normally, the specified short-circuit withstand rating is applicable for up to one second. According to calculations, the maximum short-circuit current at the VSDS

switchboard should be 55kA. Photographs and the site inspection show that small holes were burnt in the switchboard.

6 Direct and underlying causes

6.1 Direct cause

The direct cause of the incident was very probably a conductive foreign body which contributed to a short circuit and arc flash as the electrician wound in the breaker. That has in turn ionised the air, which quickly developed into a three-phase short circuit/arc flash and fire. The lower contact set (phase conductors) melted/ vaporised, as did the actual cause of the fault (the foreign body). Nothing suggests that the actual breaker has been defective.

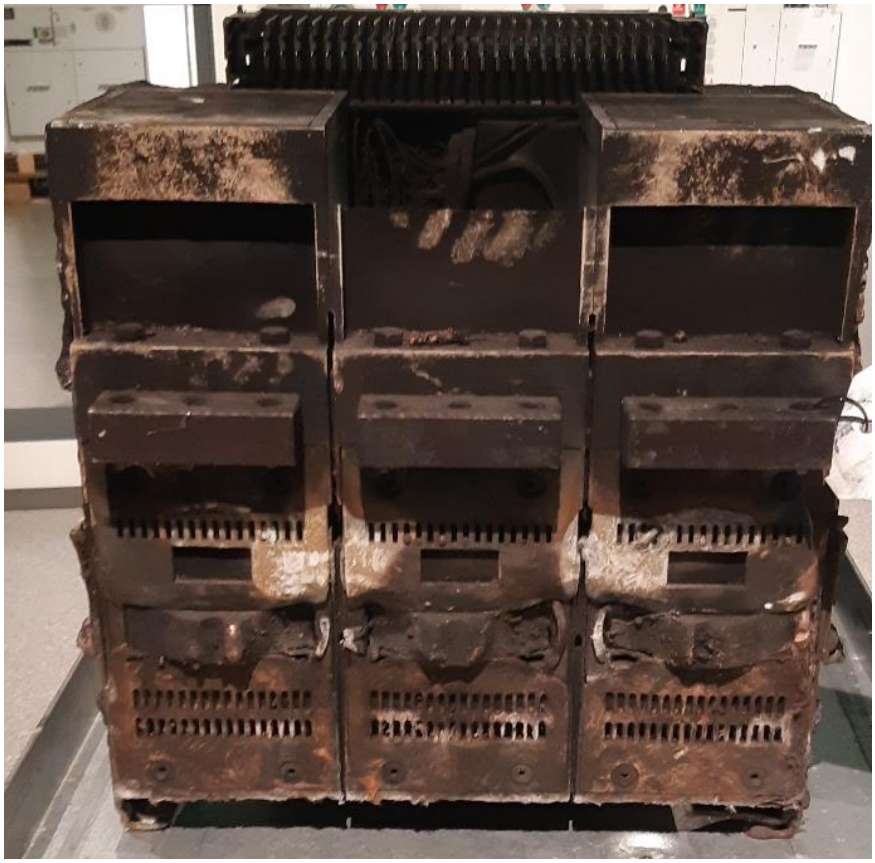

Figure 8 Damage to the lower contact set on the spare breaker.

6.2 Underlying causes

A number of underlying causes of the incident on Statfjord B have been identified by the investigation. These relate primarily to:

- technical deficiencies
- expertise and capacity
- decision-making and information-sharing processes
- roles, responsibilities and conduct of analyses

- coordination of collaboration between operator and contractor
- planning and executing the work of replacing the breaker.

6.3 Technical deficiencies

Major changes were made to the existing installation when the drilling VSDS switchboard was installed in 2009, including an expansion from one to two transformers on the same outgoing feeder from the main HV switchboard. The investigation has identified the following possible risk factors related to this change.

- The company was unable to produce information which could document the switchboard's withstand rating for an arc flash. The VSDS switchboard was not fitted with protection devices against arc flash.

- Electrotechnical analyses in 2009 showed that a fault in the incomer part of the switchboard would put it in the thermal part of the trip curve for the upstream protection device. This leads to a long disconnection time (two-three seconds) in the event of a fault.

- The specifications for the VSDS switchboard specify its short-circuit withstand rating as 70kA. The switchboard's declaration of conformity refers to section 6.7.5 of IEC 61892-3, which refers in turn to section 7.5 of IEC 60439 with regard to short-circuit protection and withstand rating. This standard assumes, unless specifically stated, that the specified short-circuit withstand rating is applicable for one second (both standards are the 1999 edition).

- It has not been documented that measures were taken after the 2009 installation to ensure that variations during faults and after fault correction did not cause power failures. The AVR should have been included in this process (see IEC 61892-2:2005 9.4.2. & 9.6.6).

The overall picture indicates that the plant already had latent deficiencies in 2009 which were not prioritised for correction. These were technical deficiencies which contributed to the incident and increased the risk of hazards when working in the installation.

6.4 Expertise and capacity

Governing documents specify requirements for training and expertise of technical personnel, including electricians and cross-trained people who can support them.

The following governing documents and recommendations are relevant with regard to expertise and training for personnel working with or close to low-voltage systems.

- Equinor's OM 105.12 (R-11712) governing document on safe work with electrical systems. Two people for work on or near low-voltage installations.

- Equinor's OM 105.12 (I-105035) governing document on safe work with electrical systems. Second person for work on or near low-voltage installations.
- Section 8.1 of Archer's annual electrical verification on Statfjord B 2019 (PD-0022264).
- Section 91 of the activities regulations on work on and operation of electrical installations. See the Norwegian regulations on safety when working in and operating electrical installations (FSE).

It emerged from interviews and document reviews that the night mechanic had not received the training needed to support work in the switchboard room. Nor had personnel on board received emergency response training for this room. The investigation revealed that Archer personnel did not muster in accordance with the alarm instructions. On the first general alarm, for example, they did not go to their muster stations but to the incident site.

The investigation found that a number of posts in Archer were occupied by new personnel. Appointed to their roles within the past year, the electrician, mechanic and onshore maintenance leader were limited in their ability to explain safety-critical decisions and guidelines adopted by the organisation. Personnel had limited knowledge of technical weaknesses and applicable nonconformities in the electrical installations. They knew, for example, little about applicable work processes, risk in the plant, the applicable safety strategy, maintenance concepts and measuring maintenance efficiency. The lack of knowledge and overview could have contributed to the adoption of incorrect priorities and decisions ahead of the incident.

Through interviews with Equinor and Archer employees, it emerged that a number of them experienced a high level of personnel turnover and an increased workload through training requirements, sickness absences and organisational changes. This meant that personnel experienced capacity challenges, which contributed in part to Archer managers being largely reactive in their follow-up of personnel and installations. The PSA team was informed, for example, that manager follow-up was largely based on individuals contacting superiors if they had a problem or needed clarification. Concern was also expressed in interviews over the possible impact of downsizing plans for Statfjord B on the opportunity to work safely and securely.

6.5 Decision-making and information-sharing processes

Equinor's governing document on organisation, management and control (OMC20) for Statfjord B allocates many critical decision processes to the land organisation.

It is unclear how safety-critical information was adequately addressed and utilised as the basis for decisions. Examples of such information which was inadequately

addressed in the decision base and communicated to relevant decision-makers are listed below.

- Safety-critical instructions for work on Statfjord B's electrical installations.
- The status of and planned work on the electrical installations.
- Implementation of the arc-flash study (prerequisites and limitations).
- Weakening in technical integrity (Timp) was not known to Archer.
- Archer's quarterly report, which included maintenance, contains no information on the electrical installations. Nor does it provide any overview of nonconformities or deficiencies in its own installations or in those maintained by Equinor.

Safety-critical information and decisions were inadequately coordinated or addressed if unintended HSE effects were to be avoided.

The investigation found pre-incident information transfer in the organisations to be inadequate. Critical information, for example, was sent by e-mail to shared mailboxes without following up whether it had been received, understood and acted on by the recipients. Nor was safety-critical information logged or communicated through established reporting and/or nonconformity systems. Another example of deficient experience transfer in Archer related to faults with corresponding breakers on Statfjord C in 2019, when similar problems were discovered and lack of maintenance identified. This information was not made known to those responsible on Statfjord B.

Equinor and Archer conducted self-evaluation of electrical installations through annual inspections. The investigation found that this process had failed to pick up deficiencies in compliance with requirements and in knowledge of the management system. Equinor had not audited the electrical installations for the past three years. It largely used the condition monitoring of technical safety (TTS) system to verify technical systems, which was inappropriate since none of the questions in this process included technical conditions related to electrical safety.

It emerged from the investigation that little was done systematically to highlight and communicate risk in the electrical installations through follow-up systems. Some relevant information on such risk could be found, for example, in Timp under PS11 (emergency power and lighting), but it was unclear how this was entrenched in the Timp process. Details of various reporting systems or of managing and executing personnel who individually had an overview of knowledge or information important for risk management were not communicated adequately across the organisation. That contributed to an inadequate shared understanding of equipment condition, inadequate risk assessments and a weakening of the decision basis.

Interviews also revealed that the safety delegate system played little role as an information channel for addressing possible working environment challenges such as

expertise and capacity. The service had reportedly received few suggestions or feedback from Statfjord B personnel in recent months. This was explained by the introduction of an arrangement in response to Covid-19 which excluded safety delegate meetings and safety walks. Meetings were replaced by circulating a presentation containing overarching "safety flashes".

6.6 Roles, responsibilities and conduct of analyses

Equinor established a new centre of expertise in 2019 as a resource to provide support for arc-flash calculations on various company facilities. It was responsible for the arc-flash study on Statfjord B.

It emerged through the investigation that understanding of roles and responsibilities related to the arc-flash study and its follow-up in the organisation was unclear. Interviews revealed inadequate involvement and communication between the unit doing the analysis on land and personnel on Statfjord B. Relevant information about the installation's design and utilisation, for example, was not acquired as part of the study. Arc-flash calculations performed by Equinor's recently established expertise centre were not verified by a third party. Information on conditions, prerequisites and boundaries in the analysis were not submitted to the target group in a nuanced and holistic manner. This meant that warning signs with information on incident energy and PPE requirements for the VSDS switchboard did not provide the correct details and could have contributed to inadequate risk understanding by the personnel involved. Had the arc-flash study involved incomer breakers, and had this information been communicated to relevant personnel offshore, the level of incident energy would have been so high that the job would probably not have been tackled in the way it was.

Work was under way to install arc-flash protection devices on other Statfjord B switchboards, but the VSDS switchboard was not included in this programme. Its inclusion had been proposed by personnel on switchboard, but the decision was taken to remove it from the scope of work.

6.7 Coordination and collaboration between operator and contractor

Archer is the drilling contractor on Statfjord B, which means it has area responsibility for the drilling module with associated electrical installations and utilities. Equinor's OIM has responsibility for the whole platform.

Statfjord B has been through several change processes in recent years, where close collaboration and new ways of working between the parties are a success criterion.

A number of observations have been made in the Statfjord B incident which touch on challenges related to coordination, collaboration and information flow between Archer and Equinor.

- Equivalent equipment was not maintained in the same way by Equinor and Archer. It emerged from the investigation that Archer was not familiar with Equinor's prevailing maintenance concept. The companies had different preventive maintenance (PM) programmes for electrical circuit breakers held in store, for example.
- Equinor had issued instructions which limited work on 440VAC switchboards with high arc-flash energy (>PPE4). This was not known to Archer personnel, even though the company was responsible for several switchboards with correspondingly high incident energies.
- Equinor knew little about the technical condition of installations maintained by Archer and vice versa.
- Information flow between the companies on plant integrity was unclear. Timp was not an Archer tool. Updated information on potential switchboard hazards was not known to Archer personnel, for example.
- When drilling was under way, Archer played the ART role in emergency response for its defined area. Between drilling campaigns, this role was transferred to Equinor. The investigation revealed that, when this incident occurred, Equinor's emergency response leadership was unaware that Archer no longer played the ART role in the response organisation. Statfjord B thereby had an incomplete response organisation during the incident.
- FLX was established as a separate business area on 1 April 2020. Knowledge in the Archer organisation of plans related to FLX was limited.
- There was little or no predictability with regard to new assignments and work transferred from Equinor to Archer. A number of jobs related to lighting, for example, were transferred to the latter. Interviewees also reported an increased workload with following up minor projects.

The investigation has revealed poor coordination of the preconditions for collaboration between operator and contractor. A lack of safety-critical information sharing, communication, cooperation and coordination contributed to differing work practices and cultures between Archer and Equinor, which in turn made a negative contribution to the incident and the emergency response follow-up.

6.8 Planning and executing the work of replacing the breaker

The need to replace the circuit breaker was identified by the day shift on 17 August 2020. It was decided that this would be done as and when appropriate, but that the job was not time-critical because drilling was halted. Archer's night electrician decided to make the replacement early on 18 August 2020.

Several conditions which show that changing breakers in the switchboard room was a risky job have been identified by the investigation. The following risks and uncertainties were not taken into account when planning and executing the work.

- Inadequate knowledge of the operation. The maintenance history shows that breakers in the VSDS switchboard had not been replaced earlier.
- Little was known by the personnel about the spare breaker's condition. It was manufactured in 2006 and had been in store on board since 2009. No maintenance/service/preservation was registered for it.
- No procedure or routine describing the job of replacing a breaker was available for use by the personnel.
- Knowledge that undesirable incidents had occurred in similar operations earlier did not lead to changes in work methods.

Despite these risks, the job was assessed as a simple routine assignment. Replacing a breaker in the switchboard room was not on the Statfjord B work plan, nor had a corrective WO or notification been established for the job. It was executed alone at night with the help of personnel who lacked electrical qualifications or the necessary training.

With the available information, understanding and background, the executing personnel regarded the job of replacing a breaker as routine. The lack of assessment and follow-up of hazards associated with replacing this breaker shows that personnel on board lacked sufficient understanding and knowledge of the actual risks involved when planning the job.

Local operative and organisational factors as well as operational parameters helped to give an insufficient basis for personnel to maintain an adequate understanding of the risks associated with the job. Examples include the following.

- Failure to communicate preconditions and limitations of the arc-flash study probably led to incorrect marking of the switchboard. This gave inaccurate details about incident energy and PPE requirements for the relevant workplace, which contributed to the failure of executing personnel to use appropriate PPE, and may have led the personnel to underestimate the hazards of the job.
- Inadequate knowledge of the breaker manual's contents. Interviews revealed that personnel knew little about this content, and that the manual was not used in planning and executing the job. Personnel were also unfamiliar with the age and maintenance status of the reserve breaker.
- Inadequate teaching and training of personnel. The night electrician had not been trained in responding to incidents in the switchboard room, and the mechanic had not had necessary and required training to support work there.
- Unclear requirements on the need for WPs. Interviews with both executing and managing personnel reveal conflicting and unclear perceptions about WP

requirements for this job (Docmap and Aris). Docmap (which is Statfjord B specific) was little known to or used by Archer personnel. That could have contributed to a lack of advance planning and risk assessment.
- Inadequate coordination of and information sharing about work practices between Archer and Equinor. Interviews reveal that executing Archer personnel on board were unfamiliar with safety-critical information or details about technical condition from Equinor. It emerged from the investigation that the companies would have done this job in different ways.
- Many choices and important assessments – on the use of WPs, for example, work methods, procedures and risk assessments – were largely left to the individual. This means that individual differences, experience and expertise had an effect on critical decisions.

Before the incident, several conditions should have called for a halt and assessment of risk. The investigation shows that several risk factors and facts were unknown to the executing personnel and thereby not part of their situational awareness and decision basis when the job was executed. Failure to use a WP and the decision to do the job alone at night were the consequences of several latent conditions in the organisation. The personnel involved were thereby poorly equipped to understand the potential risk in the planned work.

7 Emergency response

Saving life will be the first priority in an emergency. The response on Statfjord B dealt quickly with the injured and had everyone on board checked after about 25 minutes. The injured suffered not from the short circuit and arc flash, but from the consequent firefighting with a CO_2 extinguisher in the W11 switchboard room.

In addition to the injured, the emergency response had to deal with the loss of main power as well as gas (erroneous) and fire detection in W11 and M15. The most important timings in the emergency response on board are as follows.

02.30	Observation of fire in the switchboard and use of CO_2 extinguisher.	
02.30	PA announcement.	CCR reported loss of main power.
02.30	Report of fire in W11.	Second person involved called the CCR to report short circuit and fire.
02.30.48	Smoke alarm in W11.	Several smoke detectors activated in rapid sequence.
Abt 02.33	General alarm.	Manual activation in CCR. Deactivated at about 02.35.
02.33.10	Smoke alarm in M15.	Uncertain whether the smoke was

		coming from W11.
02.34	Incident command mustered.	CCR and emergency response centre.
02.35	Incident command centre established in M21.	Close to M15.
02.37.19	Gas detection in M15.	First one then both detectors, high then high-high.
02.39.46	Blowdown.	
Abt 02.40	Status meeting in emergency response centre.	
	Incident command informed of incident in W11.	By electrician exposed to smoke.
	PA announcement by OIM.	Information on smoke, gas leak and loss of main power.
02.50	POB check.	
Abt 03.00	SAR team entered M15.	Continued gas and smoke detection. Disconnection confined to ignition sources in group 1A.
03.11.12	ESD-D.	Emergency generator shut down earlier and ESD-D isolated ignition sources in the drilling area.
Abt 03.15	SAR team entered W11.	Still smoke in the room.
03.37	SAR helicopter took off from Statfjord B with two patients.	People harmed by smoke in W11.
03.51	PA announcement.	Personnel leave lifeboats, position with fire in W11 clarified.
04.15	Deluge valve in drilling area opens, general alarm.	Low pressure of working air.
	Normalisation.	
	Information to all on board.	

Table 3 Emergency response in chronological order.

7.1 CCR – information on gas detection, fire and loss of main power

In an emergency, the CCR and incident command on Statfjord B maintain an overview of the position with the aid of big screens, operator monitors, alarm logs and a dedicated overview (matrix) for fire and gas detection as well as ESD.

Loss of main power will be observed immediately with the shutdown of ventilation and lighting as well as a change to the noise level.

The CCR and incident command quickly become aware of gas and smoke detection through information available both on screens and in separate fire and gas overviews.

In dealing with gas leaks (DSHA 1), fire (DSHA 3), personal injuries (DSHA 6) and loss of main power (DSHA 17), the CCR and incident command will be assisted by dedicated action plans (in the overall emergency response plan).

Figure 9 The CCR with big screens, fire, gas and ESD overviews and operator monitors. Photograph: Equinor.

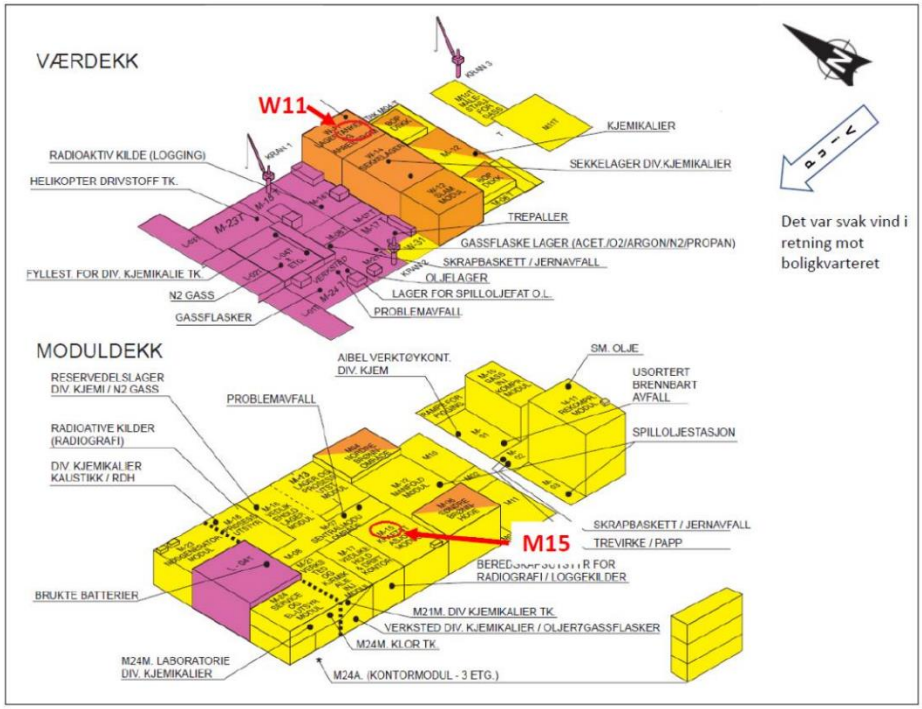

Figure 10 Overview of the relevant M15 and W11 modules (from Equinor's investigation report).

7.2 Electrical fires

The PSA commissioned an analysis in 2012 of causes and measures related to fires in electrical installations within its area of authority (offshore facilities and land plants). Carried out by Sintef, this analysis aimed to identify direct and underlying causes of such incidents and to propose countermeasures. Causes and measures were broken

down into human, technological and organisational (HTO) categories. The emergency response to these incidents was also assessed on the basis of the investigation reports. The analysis was based on 35 investigations and seven interviews.

Section 3.9 of the report describes the emergency response challenges.

- It is necessary to be aware that the fire area is under voltage. Measure: include an electrician in the firefighting team.
- Expertise on electrical fires in the response team must be strengthened.
- Trained personnel are needed who can establish control over an incident and who are familiar with the hazards in various circumstances.
- Sufficiently early disconnection of the power supply.
- Knowledge is needed about hazardous gases which might be in the fire area.
- Avoid using seawater for extinguishing to prevent corrosion damage.
- Disconnecting power on land may be more difficult because of the varying availability of electricians, particularly at night (up to an hour's response time). In contrast, electricians are always available offshore.
- Personnel act differently on fixed and floating installations. On floaters and ships, crew will concentrate on keeping the electrical system going. On fixed installations, attention will be focused on shutting down and turning off.
- The stop button must be made accessible to shut off the voltage easily.

Many of these recommendations are highly relevant for the Statfjord B incident.

7.3 Emergency response and deficient barrier functions in M15 control room

According to the alarm log, first activation of smoke and gas detectors was at 02.33.10 and 02.37.19 respectively. Blowdown of the process plant was activated at 02.39.46.

The action plan (in the emergency response plan) specifies that, in the event of DSHA 01 (oil/gas leaks) and DSFA 03 (fire), the response organisation must supplement PA announcements by assessing such moves as blowdown, firefighting, isolation of ignition sources, safety of response personnel and announcing the location of the incident command centre.

Only parts of the ignition sources were isolated during the incident. The investigation team has also been unable to see that safety of response personnel was assessed, given that gas detection, fire and ignition sources were present in M15. The following actions were taken.

- Gas on the platform was announced (over the PA system), but this information did not prompt changes to the room entry procedure. The SAR team entered M15 without all the ignition sources being disconnected.

- The incident command centre was established close to the control room where gas was detected.

Barrier function	Technical barrier elements	Operational and organisational barrier elements
Detection (gas and fire)	Gas – erroneous detection. Fire – correct detection.	
Ignition source disconnection	Not all potential ignition sources automatically disconnected in M15.	Manual ESD-E not activated.
Firefighting	No automatic extinguishing methods available in M15.	Fire team entered M15 without all electrical equipment being disconnected (no MEI button for the room).
Safeguarding of response personnel.		Command centre established close to M15, where gas was detected after a few minutes. Fire team entered M21 (10 people in all were there for a time).

Table 4 Barrier functions.

7.4 Emergency response to fire in switchboard room W11

According to the alarm log, the first smoke detector was activated in W11 at 02.30.48, followed by a number of other detectors.

The SAR team first entered M15, which was close to the command centre in M21, before moving into W11. This lies in the drilling area. Only one smoke and two gas detectors had been activated in M15, while a number of smoke detectors were activated in W11. That was also the room which had been occupied by people exposed to smoke. The SAR team had access to an action plan in M15, but none was available for W11. Interviewees have reported that a diagram and plan had been drawn up for entering the room. Archer has its own ART which would normally assist in a drilling-related emergency. This team was not operational at night because no drilling was under way on Statfjord B. Although Archer had informed Statoil of this as early as 12 August 2020, nobody in the emergency response organisation was aware of the change. The SAR team received help from Archer's day electrician to deal with the position in W11.

In both M15 and W11, the SAR team quickly established with the aid of a thermal camera that no fires were burning in either room. The team ventilated the rooms, and the W11 switchboard room was cordoned off at a location for follow-up of the incident.

Barrier function	Technical barrier elements	Operational and organisational barrier elements
Detection (fire)	Correct detection.	
Ignition source disconnection (electrical isolation)	No automatic disconnection of potential ignition sources in W11.	Manual ESD-D activated at 03.11, about 41 minutes after fire reported in the room
Firefighting	No automatic extinguishing methods in W11.	CO_2 extinguisher used by the electrician after the short circuit. Caused smoke damage. Fire team entered W11 later and confirmed that nothing was burning.

Table 5 Barrier functions which functioned or had deficiencies in W11.

7.5 Assessment of and lessons from emergency response

Emergency response efforts were characterised by a lack of understanding of the position. The CCR and the incident command speedily appreciated that gas and fire had been detected, but this information was not used to disconnect all ignition sources quickly in M15 before personnel entered the room. Disconnection of ignition sources did not occur in switchboard room W11 until 40 minutes had passed.

The response team on Statfjord B dealt quickly with the injured and had control over everyone on board after about 18 minutes.

Assessing and learning lessons from the response will relate to handling the consequential damage from the power outage (DSHA 17), gas (erroneous) and fire detection in switchboard room W11 and turbine control room M15. Response work had no effect on the consequences of the incident. The fire in W11 had already been extinguished by the electrician at the start of the response.

The incident command has action plans for DSHAs 1 and 3 (gas and fire detection). These were only partly observed. This and other incidents (such as the well control incident of 15 October 2016 on *Songa Endurance* and the gas leak of 5 March 2020 on Gullfaks B) show that these plans are not observed either wholly or in part (perhaps on the basis of education and experience). A correct response based on the action plans must therefore be followed up by training and education.

To assist the SAR team on Statfjord B, an incident plan had been drawn up for the areas which were Equinor's responsibility, but not for those where Archer was responsible. As with the action plans, a correct response by the SAR team based on the incident plans must therefore be followed up by training and education.

Operational parameters (factors influencing risk) for the response organisation on Statfjord B were not optimal on the night, and – as mentioned above – it had to handle four DSHAs.

- Training in responding to incidents takes place during daytime.
- The power outage meant that parts of the ventilation system shut down, and the incident command which mustered in the CCR experienced both a high differential pressure on the entrance door and ventilation dampers closing with vibration/noise.
- Part of the incident command mustered first in the CCR to secure information on the position before the first meeting started in the response centre. Little time is then available (about five-six minutes) to grasp the position before the command must decide on and prioritise response measures.
- Incidents occurred in two rooms – switchboard room W11 (Archer's area of responsibility) and turbine control room M15 (Equinor's area of responsibility). Emergency response roles were not clarified ahead of the incident. Equinor was supposed to take over response duties in Archer's switchboard room W11 at night.

The investigation showed that education and training with operational and organisational barrier elements as well as in response activities are important for rapidly limiting damage and inconveniences in cases where gas and fire are detected on Statfjord B.

8 Regulations

The 2010 application for extending Statfjord B's producing life states that Statfjord complies with the applicable HSE regulations, where section 82 of the facilities regulations on entry into force provides opportunities to apply technical requirements set by earlier regulations in the regulatory areas of health, working environment and safety. Advantage was taken of this opportunity for Statfjord, thereby utilising technical requirements in force when its facilities were designed. In connection with conversions in the Statfjord late life (SFLL) project, a dedicated strategy was developed which specified that this work was of a scope which triggered requirements pursuant to the 2002 HSE regulations.

A major conversion of the drilling installations occurred in 2009. Installed as part of this work, the electrical drilling switchboard is regulated by the 2009 facilities regulations pursuant to section 82, paragraph 4 of these regulations.

9 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: this category embraces observations where the PSA has identified breaches of the regulations.
- Improvement points: these relate to observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

9.1 Risk management in Equinor

Nonconformity

The responsible party has failed to choose technical, operational and organisational solutions which reduce the probability of damage, faults hazards and accidents. Risk management and understanding of electrical safety in the plant were inadequate and deficiencies occurred in handling the emergency response.

Grounds

Risk management in Equinor is extensive, with many work processes, and is often illustrated by the figure below. See also the PSA's comments on this in its report on the audit of Equinor's risk and barrier management – PSA reference 2020/796.

Figure 11 Illustration of Equinor's risk management.

The investigation has determined that deficiencies exist in risk management and understanding of electrical safety.

- The MIS risk overview highlighted and prescribed measures for changing 6kV switchboards and installing arc-flash protection devices in 440V and 13.8kV switchboards, but did not include the VSDS switchboard or the 600V drilling switchboard (NN-101A) in Archer's area of responsibility. See section 6.6.

Similarly, Equinor's nonconformity handling has not been established for switchboards where Archer is responsible for maintaining. See nonconformity 9.6.

- Lack of protection against thermal effects in the electrical installations. See nonconformity 9.9.
- Technical deficiencies in the installations. See section 6.3.
- Follow-up of integrity in the technical plant, see section 6.5 on decision-making and information-sharing processes.
- Planning of work. See nonconformity 9.8. The analysis of the arc-flash level in the installations was not communicated and presented in a way which ensured that relevant users received the necessary information for planning and executing the activities in a secure manner.

The investigation shows that good emergency response depends on good barrier elements which can identify conditions, reduce opportunities for the development of errors, hazards and accidents, and limit possible damage and downsides. Operational and organisational barrier elements will also be important for limiting potential damage and inconveniences. This is illustrated in the figure below, where handling of emergency response is on the extreme right.

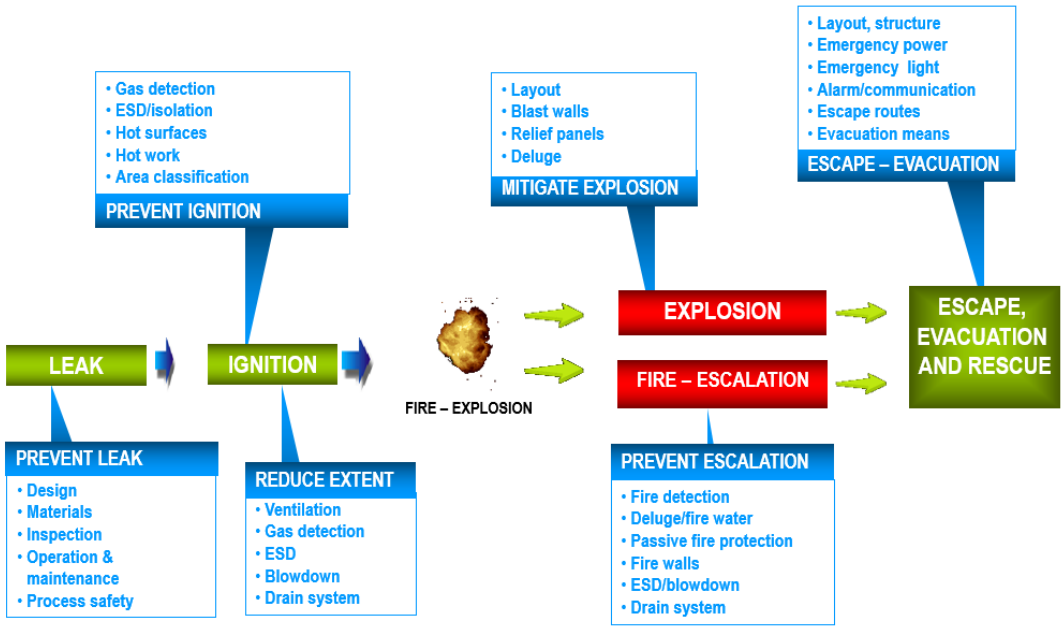

Figure 12 Barrier functions for responding to a hydrocarbon leak.

The investigation has exposed risk management deficiencies related to emergency response. See nonconformity 9.11 and nonconformities in barrier management with deficiencies in strategies and principles for the barrier functions:

- detection, with probable error in gas detection (uncertainty over gas detection in M15), see chapter 11

- confirmed gas in M15 did not trigger full ignition source disconnection, nor does the safety strategy for Statfjord B describe this response
- the response organisation did not disconnect all ignition sources manually (but this was described as an operational barrier element in the safety strategy for PS6 ignition source control)
- command centre established close to M15, where gas was detected a few minutes later
- SAR team entered a room where gas was detected and not all ignition sources had been disconnected.

Requirement
Section 4 of the management regulations on risk reduction.

9.2 Barrier management

Nonconformity
Deficiencies existed in the strategies and principles for function of the barriers.

Grounds
a) Deficiencies in the description of risk conditions in the safety strategy

The barrier (safety) strategy describes the results of analyses, assessments and consequent decisions taken on the need for risk-reduction measures. Section 5.3.6 in the Statfjord safety strategy on PS6 ignition source control provides a good and extensive description of the strategy for disconnecting such sources. The following, for example, is specified for group 2 sources, located in mechanically ventilated unclassified areas/rooms: "If gas is present in such rooms, it has very probably entered via a ventilation inlet. The position is then serious, and potential ignition sources must be disconnected in these rooms. Rooms with doors, hatches or sluices into or close to classified areas have gas detection installed. A system must therefore be in place for disconnecting potential ignition sources in such rooms, either through selective disconnection or by initiating an ESD-E on confirmed gas detection."

The M15 control room had two gas detectors which were not described in the area-specific description (section 5.4.4 in the safety strategy). The cause and effect diagram for M15 shows only partial disconnection of ignition sources in the room.

b) Deficiencies in following up operational and organisational barrier elements

The investigation found that the incident command knew little about ignition source isolation with ESD E and D. See sections 7.3 and 7.4. Section 5.3.6 in the safety strategy on PS6 ignition source control describes ESD E and D as operational barrier elements (OBEs). No training was given in these OBEs.

c) Insufficiently robust air supply to the deluge valve in the drilling area

The deluge valve in the drilling area is connected to working air. The other deluge valves in Statfjord B's fire water system are connected to instrument air and were not activated during the incident.

Requirement
Section 5 of the management regulations on barriers.

9.3 Lack of expertise and training

Nonconformity
Archer had not ensured that its personnel possessed the expertise required to carry out activities in accordance with the HSE legislation, including the handling of hazard and accident situations.

Grounds
The mechanic who helped to change the breaker had not received the necessary training. He was not a skilled electrician and lacked the necessary and required training to assist work on electrical installations.

The area authority in the switchboard room was not trained to tackle a fire there.

Requirements
Section 21 of the activities regulations on competence
Section 91 of the activities regulations on work on and operation of electrical installations, see the guidelines to section 91, see section 7 on overall planning in the regulations on safety when working in and operating electrical installations

9.4 Conducting maintenance work at night

Nonconformity
The maintenance work was conducted at night even though this was not necessary for maintaining production or activities directly related to drilling and well operations.

Grounds
The breaker was replaced on the night shift, with the accident happening at 02.30. Doing this job was not time-critical because drilling was shut down. Production was under way on Statfjord B when the incident occurred. Carrying out the work at night did not accord with provisions on permissible night work.

Requirement
Section 43 of the framework regulations on night work

9.5 Inadequate information sharing and use of information systems

Nonconformity

Deficiencies in communicating information required for planning and executing activities in a prudent manner. No information and communication systems were established which met the need to acquire, process and communicate data and information, internally on the facility or externally.

Grounds

- It emerged from interviews that critical information was communicated by e-mail to shared mailboxes without following up whether the information had been received, understood and acted on by the recipients.
- Safety-critical information was not logged or communicated through established reporting/nonconformity systems.

Requirement

Section 15 of the management regulations on information

9.6 Failure by Equinor to see to it that Archer complies with requirements in the HSE legislation

Nonconformity

Equinor has failed to see to it that Archer complies with requirements specified in the HSE legislation.

Grounds

As the responsible operator for Statfjord B, Equinor is required to follow up all management system elements, both its own and those of others, and ensure that they function as intended and that the requirements in the HSE legislation are complied with. This follow up must help to identify technical, operational and organisational deficiencies, faults and deficiencies.

Examples of inadequate follow up include the following.

- An internal nonconformity was established for switchboards where Equinor has maintenance responsibility (exemption 181758). No equivalent internal nonconformity was established for drilling switchboards where Archer is responsible for maintenance. That applies to switchboards with an incident energy of 8cal/cm^2, which are found in both drilling and production.
- Archer's maintenance performance differs from Equinor's practice for electrical equipment. Nor are their PM programmes coordinated. The investigation could not establish whether measures were implemented to ensure that Equinor has adequate follow-up of Archer's maintenance programme (see section 6.7).

Following an audit of electrical installations and technical safety on Grane in 2017, the PSA gave an improvement point to Statoil/Equinor concerning the lack of training for mechanics who assisted work in and operation of electrical installations. The response then was that practice would be changed so that personnel assisting work on electrical installations would either be skilled electricians or have the necessary documented training.

Requirements
Section 21, paragraph 2 of the management regulations on follow-up
Section 18 of the framework regulations on qualification and follow-up of other participants

9.7 Deficiencies in the maintenance programme and in improving such work

Nonconformity
Archer has failed to meet its responsibility to ensure that maintenance accords with the HSE requirements. The maintenance programme is deficient with regard to activities for monitoring performance and technical condition, which ensure that failure modes – either developing or actual – are identified and corrected.

Grounds
The investigation shows that Archer's maintenance system and follow-up are deficient in the following respects.

- The quarterly technical report from Archer failed to include information on the electrical installations.
- Archer was unable to explain how maintenance data are used for improvement work. A system to analyse and follow up maintenance efficiency was also missing.
- It emerged from interviews that Archer lacks an adequate overview of deficiencies/nonconformities. Approved nonconformities were not included in Archer's reporting, and the company had no separate nonconformity register.
- Archer could not present failure mode analyses for the choice of maintenance activities.
- The status of technical condition and possible deficiencies were not included in the maintenance programme.
- The six-monthly PM programme for inspection of tools used for live working on electrical installations is inadequately described. It says nothing about how a check is to be conducted or the acceptance criterion which PM programmes should describe.

Requirements
Section 47 of the activities regulations on maintenance programme

Section 49 of the activities regulations on maintenance effectiveness
Section 23 of the management regulations on continuous improvement

9.8 Deficiencies in the arc-flash study and communicating necessary information

Nonconformity
The analysis of the arc-flash level in the installations on Statfjord B was not conducted in accordance with the chosen method. This work and its results were not communicated and presented in a way which ensured that relevant users had the information needed to plan and execute activities in a safe manner.

Grounds
The guidelines for specifying and conducting arc-flash calculations in accordance with the method applied were issued in 2014. These define a recommended minimum for conducting detailed arc-flash analyses on the basis of IEEE 1584™. The Equinor analysis did not cover all the equipment where maintenance or inspection were likely to be carried out while energised. Nor had relevant information about the specific electrical installation been obtained from its user (Archer).

Results from the arc-flash study were communicated to relevant personnel via an e-mail address belonging to posts on board. It could not be documented that relevant personnel on every shift had received and read this information. The information communicated about the analysis results lacked important details on conditions, assumptions and limitations underlying the work. Arc-flash marking of the VSDS switchboard was misleading and did not reflect the incident energy for the relevant location.

Roles and responsibilities in the process of carrying out the arc-flash study and communicating its results were unclear.

Requirements
Section 15 of the management regulations on information
Section 15 of the management regulations on general requirements for analyses

9.9 Lack of protection against thermal effects

Nonconformity
The responsible party has not chosen technical solutions which reduce the probability of damage, faults, hazards and accidents. Insufficient protection was provided against thermal effects in the electrical installations.

Grounds
When the arc-flash incident occurred in VSDS switchboard NU19802, two-three seconds passed before the upstream protection device disconnected power to the VSDS switchboard. This protection device is placed in the 13.8kV main switchboard, and originally supplied a single transformer. That was changed when upgrading the drilling installation in 2009, and the outgoing feeder now supplies two transformers in parallel.

According to electrotechnical studies from the upgrading project, a fault in the VSDS incomer section will lead to a fault current in the thermal part of the discharge curve for the upstream protection device. That in turn will give a relatively long disconnection time and increase the threat of harm to personnel and equipment, and of fire. Documentation for the switchboard does not indicate what the short-circuit withstand rating is for three seconds. It is therefore unclear whether the switchboard is suitable for the available loads in the installation.

No arc-flash protection device was installed in the switchboard at the time of the incident. Had this been in place, it could have disconnected the fault at an earlier point of time and reduced the damage. Work was under way to install such protection on other Statfjord B switchboards, but did not include the VSDS switchboard. Including the latter was proposed by personnel on board, but removed from the scope of work.

Requirements
Section 4, paragraph 1 of the management regulations on risk reduction
Section 46, litera b of the facilities regulations (2009 version) on electrical installations, including guidelines

9.10 Lack of protection against interruptions and of adequate selectivity between protection devices in the event of faults in the installation

Nonconformity
Selective disconnection of faults has not been ensured when making changes to the electrical installations. Suitable protection devices has not been used to guard against faults, hazards and accidents caused by voltage regulator faults, for example.

Grounds
The incident in VSDS switchboard NU19802 did not cause selective disconnection of the consumer causing the fault current. The fault also resulted in disconnection of generator A and error messages for the AVR, which led in turn to loss of main power.

Requirement
Section 46 of the facilities regulations (2009 version) on electrical installations, including guidelines, see IEC 61892-2 (2005) 9.4.2

9.11 Deficiencies in handling hazard and accident situations

Nonconformity
The necessary measures were not implemented as quickly as possible in the hazard and accident situation on Statfjord B.

Grounds
After the short circuit in the W11 switchboard cabinet, the night electrician observed a fire inside the switchboard and fetched the CO_2 extinguisher from the neighbouring room in an attempt to douse the flames. He tried this through the grille in the switchboard door but, when it had little effect, opened the door. Black smoke then poured out. The electrician emptied the CO_2 extinguisher into the switchboard and left the room. The people involved in W11 suffered from smoke inhalation.

Archer's senior toolpusher informed Equinor's lead operations and drilling supervisors by e-mail on 10 August 2020 about changes to Archer's ART role. Equinor was asked to take over the ART function at night in the drilling area from 12 August 2020. This information had not reached the night emergency response organisation on 18 August 2020, which tried repeatedly but fruitlessly to contact the drilling ART since smoke was present in one of Archer's switchboard rooms.

According to the Statfjord B action plan for gas leaks and fires (DSHAs 1 and 3), isolating ignition sources and announcing the incident command centre should be assessed. This was not done. The command centre was established close to M15, where gas was detected after a few minutes. Nor can the investigation team see that the safety of response personnel was adequately assessed. This is based on the fact that gas had been detected in a room where not all ignition sources were disconnected and where fire had been detected. Information on this was given on the platform (over the PA system) but did not lead to changes in behaviour when entering this room. The SAR team entered it without all ignition sources being disconnected. Ignition sources in switchboard room W11 were disconnected after about 40 minutes, and the room was then entered.

A general alarm was activated from the CCR. It was deactivated after a few minutes without being followed up by a PA announcement. That created confusion among personnel. Archer personnel did not muster in accordance with the alarm instruction.

It emerged from interviews that a local response plan had been prepared for the M15 control room but not for switchboard room W11 in the drilling area. However, a plan for entering W11 was drawn up before entry.

The investigation found that the emergency response organisation knew little about ignition source isolation at ESD levels E and D.

Requirements
Section 77 of the activities regulations on handling hazard and accident situations
Section 6 of the management regulations on management of HSE

10 Barriers which have functioned

Technical barrier elements which have functioned as intended:

- emergency power started
- fire detection functioned, with detection of smoke in switchboard room W11 and in control room M15
- the ESD system functioned, with ESD 2 and blowdown, while ESD-D activated and disconnected ignition sources in the drilling module
- personnel exposed to smoke in switchboard room W11 were examined on board and transported to hospital.

11 Discussion of uncertainties

Gas detection by several detectors in the M15 control room in connection with the incident is a source of uncertainty. It has not been possible to find a source for this gas. The investigation team has not pursued this issue any further.

It has not been possible to determine the identity of the foreign body or how it caused the short circuit. The high temperatures during the incident have helped to vaporise the foreign body.

Whether the people concerned will develop long-term conditions (physical or mental) as a result of the incident and exposure to harmful smoke is uncertain. It will therefore be important that their need for further follow-up, and for possible periodic targeted health checks, is assessed by competent medical personnel.

12 Assessment of the player's investigation report

Equinor investigated the incident, and its report was submitted to the PSA on 11 November 2020. The incident is classified by the company as a Red 2 level of seriousness because of the smoke exposure. The PSA's potential is set to serious personal injury.

Recommended measures highlighted by Equinor include:

- enhance knowledge of servicing and replacing circuit breakers
- improve safety barriers to prevent injury/damage

- ensure that the arc-flash values are correct and correctly marked
- clarify requirements related to work on breakers and the use of two people
- ensure correct maintenance of breakers
- ensure that the ART is functioning in the drilling area when no drilling is taking place.

The PSA considers that observations in this report coincide by and large with its own findings, but give less attention to important underlying causes related to human and organisational conditions – such as technical deficiencies, operator-contractor relations, decision processes and information flow.

Equinor's report emphasises that the response organisation functioned well and that ignition sources were automatically disconnected early in the incident. Through interviews and documents received, however, the investigation team has registered that not all ignition sources were not disconnected. Nor did the response organisation disconnect all sources manually in M15 before the SAR team entered the room. See also nonconformity 9.11 above.

Equinor's investigation has not commented on the actions of the Archer personnel who were at work that night.

The PSA would question Equinor's assessment of issues related to conflicts of interest when establishing its investigation team to go offshore. One of its members had played a key role in carrying out the arc-flash study for Statfjord B.

13 Appendices

Appendix A: Documents utilised in the investigation (separate document)

Appendix B: Overview of personnel interviewed (separate document)

Appendix C: HTO analysis of electrical incident (see Norwegian report)