# E-Hazop: A fresh approach to reviewing electrical systems

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**Abstract:**

Electrical safety and operability have never been more important, with new energy transition investments and the need to maximise availability and reliability with rising energy costs. This paper discusses a fresh approach to reviewing electrical systems for both new and existing facilities, going beyond a compliance audit and addressing issues with previous approaches. It then describes the building of an integrated solution on a common digital platform as part of a comprehensive suite of hazard studies.

Electrical hazards include loss of power to critical equipment, direct harm from electric shock or arc flash and damage to infrastructure due to switchgear and transformer fires. These may be on Electrical Generating sites, Oil & Gas, Chemical and General Manufacturing sites and are also present on many smaller operating locations. An appropriately focused and structured approach is therefore required to identify and analyse such hazards and the systems managing them. Such an approach also has a positive impact upon availability of facilities and operability.

Complex process hazards are effectively reviewed by following an appropriate HAZOP methodology. This paper describes how a similar approach has been applied to reviewing complex electrical hazards. The formal review structure is used alongside specialist electrical knowledge and experience gained across a wide range of industry sectors to bring fresh clarity, robustness and integration to the review and management of electrical distribution systems.

Human Factors is key to the understanding of electrical system hazards and as such should be part of the discussion of each aspect (each node and each guideword) throughout the review and not seen as an add-on or as separately defined activity as with other assessment approaches. To do this successfully, operational and maintenance staff need to be an integral part of the review process and be part of the team to tell the story of what does happen in practice and of foreseeable hazardous events.

**Keywords:** E-Hazop, EHAZOP, HAZOP, Electrical Hazards, Risk Assessment, Good Practice, Best Practice, Management of Change, Compliance, Audit, SAFOP, SAFAN, SYSOP, OPTAN, Human Factors.

## Introduction

Electrical safety and operability have never been more important, with energy transition investments and the need to maximise availability and reliability with rising energy costs. Historically, electrical hazards have not had a high profile across organisations (arguably a fit and forget part of the operating asset) despite having the potential to result in significant harm. Known hazards tend to be managed by following the original codes of practice but there is often no process for identifying other electrical hazards present in the original design or which arise over time. Furthermore, poor recording and communication of previously identified hazards results in a lack of awareness amongst operations and maintenance staff.

ABB E-Hazop is a fresh approach developed by ABB to identify, assess and manage electrical system hazards. It combines the learning from established Process Safety study methodologies and Process Safety Management (PSM) approaches with specialist electrical knowledge and operating experience to bring fresh clarity, robustness and integration.

Through this paper the term “ABB E-Hazop” is used to distinguish this new specific approach from other approaches that have been generally termed “EHAZOP”.

It’s clear that there are significant hazards and operability issues associated with electrical systems, but it has not always been clear how to best identify and manage these hazards, for both new and existing facilities, going beyond the standard “tick box” approach of a compliance audit. There is now also the opportunity to use new developments in recording and integrating information on digitized platforms for sustainability and ease of revision control.

This new approach is aimed at electrical hazards in the sectors of Generation, Transmission and Distribution. These may be on Electrical Generating sites, Oil & Gas, Chemical and General Manufacturing sites and are also present on many smaller operating locations, predominantly looking at High and Medium voltage systems along with their associated back-up and protective systems. It also aligns with international standard IEC 61882 “Hazard and operability studies (HAZOP studies) – Application guide” [1] and UK COMAH (Seveso) guidance [2] as well as other international good practice guidance and is intended to help organisations take a step forward with the safe and reliable operation of their electrical systems.

## Facilities have a range of hazards

When we look at facilities, we see that the hazards present tend to fall into 3 categories: personal (occupational) safety, process safety and electrical safety. Each category of hazard is important and needs to be managed appropriately if we are to truly understand and reduce the significant risks associated with operating such facilities.

## Managing Hazards

Over recent decades, significant improvements have been made with occupational safety by emphasising the need to take personal ownership and in building a culture of following safe individual practices. Unlike occupational safety hazards, which tend to be simple and result in immediate harm, process safety hazards and electrical hazards tend to be complex. The management of them involves multiple groups of people carrying out diverse activities, and if something goes wrong with this, significant harm may result, often to other parties, at a later time. To manage complex hazards, the focus needs to be on organisational practices rather than individual mindsets because incidents are not of a simple agent/victim type in their making. Different risk assessment techniques need to be used to review the multi-layered nature of managing complex hazards and different ways are required to describe tolerability as there is usually no resultant harm until it is too late.

Improvements in process safety have more recently been made by improving the management of the complex hazards involved. This goes beyond just following design codes and standards. There is an expectation that hazard studies, such as HAZOP, Safety Integrity Level (SIL) determination, such as Layer of Protection Analysis (LOPA), occupied buildings risk assessments (OBRA), etc. will be carried out to a good standard thereby providing a robust means in managing such complex hazards and associated Directives such as Seveso (enacted by COMAH in the UK) are fully embraced.

So far, there has not been the same expectation of managing and reviewing the complex nature of electrical hazards, and Industry focus has subsequently remained on following design codes and standards as the primary method for determining safe systems of work.

## Electrical Hazards

Simple electrical hazards can be managed by basic universal measures such as visual checks, fuses and overload protection in much the same way as electrical hazards are managed in the home. You keep it in good condition and check it periodically. But, in a similar way to process safety hazards, more complex electrical hazards, with potential to cause significant harm, require a more complex, multi-layered means of managing them as the hazards are not obvious and many people may be involved. An appropriately focused and structured approach is therefore required to identify and analyse such hazards and the systems managing them. This needs to acknowledge that components occasionally fail, systems (both automated and procedural) do go wrong, and people do not always act in the pre-defined way.

Where the consequence of this could be significant, measures should be in place to prevent or reduce the harm and these measures should be suitably robust. Without reviewing significant electrical hazards and the systems around them, gaps will be present, and weaknesses will develop and grow. When looking at high hazard systems, the focus is predominantly on High and Medium voltage systems along with their associated back-up and protective systems.

## Potential Harm

By managing electrical hazards, the risk of harm can be reduced.

Electrical hazards have the potential to cause:

- Harm to People – for example electrocution
- Harm to the Environment – such as loss of oil from a transformer, or the fire water run-off from dealing with a transformer fire.
- Damage to Equipment – possibly from a switchroom fire

It is not only the infrequent big events that are of concern. There are far more small events occurring all the time.

- Harm to People – such as an electric shock or even a near miss
- Harm to the Environment – from oil leaks, smoke from electrical fires and increased energy usage, due to reduced efficiency.
- Damage to Equipment – may be a reduced life due to insulation breakdown resulting in increased maintenance and capital spend.

## Opportunities to Improve Availability and Operability

By understanding electrical hazards and improving how they are managed, there are opportunities to make systems more robust and resilient, thus reducing downtime and increasing availability. Making systems more stable and procedures more consistent also improves operability.

Typical availability and operability issues:

- Disruption to Operation – due to site down time or limited operation while repairs are carried out.
- Reputational Damage – following a major incident or extended outage.

- Disruption to Operation – due to an increased maintenance workload, and maintenance issues may end up taking operational focus.
- Reputational Damage – due to the facility having less than 100% availability, and a perception of poor organizational culture can develop.

### New energy generation technologies

New technologies of solar, wind, storage, etc. each bring new challenges. Each facility can learn from its own incidents and issues but carrying out a good review of the electrical system allows previous issues from across existing industry to be considered and potential issues to be identified and addressed without having to experience them. A simple example is the on/off/variable nature of many new generating technologies contrasting with the more consistent traditional technologies.

This can not only put additional strain on components but also adds complexity to management systems and processes and introduces additional potential for human error such as working on inactive but still “live” systems. Many new technology installations are in more remote locations and the systems are often distributed over large areas. This introduces an additional dimension to supervision and monitoring as well as making resolution of issues more time consuming and costly. These aspects are not addressed by just following design codes and rely upon a good review that tells the story of what is really happening and what could foreseeably occur.

Where facilities rely on an unbroken, steady power supply to operate safely and maintain continuous operation they may benefit from their electrical systems being more robust and resilient than design codes demand.

### Good and Best Practice

Good Practice describes regulations, codes and guidance which needs to be followed to satisfy the law. There is a range of Good Practice legislation and guidance relevant to electrical safety, such as COMAH [2], IEC 61882 [1], Health and safety at work act [3], Electricity at work regulations [4], Machinery Directive [5], PUWER [6], and similar around the world such as NFPA70E [7] in the US. Some of this is prescriptive in defining specific requirements, and some is goal setting including overarching statements like, “all measures necessary” and “suitable and sufficient”. Whatever form of electrical hazard assessment is used, applicable good practice must be identified, and any gaps highlighted.

We should also aim to progress the expectation of electrical safety and operability by identifying and implementing best practices that go beyond prescribed good practice. This aspect will be discussed further later in this paper.

## When to carry out a review of electrical systems

### Existing facilities

Periodically reviewing the electrical distribution system of an existing facility gives an opportunity to see how it is operating now, identify gaps to good practice, learn from previous issues, engage the current workforce (understanding hazards, safeguards, why certain activities are carried out in a particular way and valuing the perspective of operations and maintenance personnel) as well as generating a clear record to aid communication and build upon. There is always opportunity to improve, and a periodic review provides an ideal forum to identify practical and effective improvements to both hardware and procedures. This should ideally be carried on a periodic basis to maintain safe systems of work validity e.g. every 5 years. Once a baseline review has been conducted, and recorded well, subsequent reviews will be easier and quicker as the focus will be on recent experiences and changes.

### New builds and modifications

Reviewing the conceptual design of the electrical distribution system for a new facility or modification gives the opportunity to identify potential issues whilst there is time to modify the design.

Opportunities to implement inherently safe and robust systems are greatest early on in the project lifecycle. Once committed to a design, it is expensive and time consuming to make changes.

Reviewing the detailed design of an electrical installation package (new build or modification) enables the following of good practice (codes, regulations, and standards) to be reviewed and documented. It also allows further measures (best practices) that could be implemented, to be identified and evaluated to ensure that the risk is As Low As Reasonably Practicable (ALARP).

The design of the system should be reviewed along with the processes by which it is operated and maintained, as well as the people aspects (who does what and when, competence, training, etc.). The equipment may be code compliant, but the real benefit of the review is in looking at the whole system, how it integrates onsite, the way it is operated, the processes by which it is managed and the people who work with it.

The ideal approach is to carry out a review early in a project to review the high-level design (when design changes and equipment selection recommendations can be acted upon) and then revisit the review when the detail design is available (to confirm design and focus on process and people issues). This results in two smaller focussed studies at appropriate times in the project lifecycle instead of a single larger study attempting to be all embracing towards the end of the engineering phase.

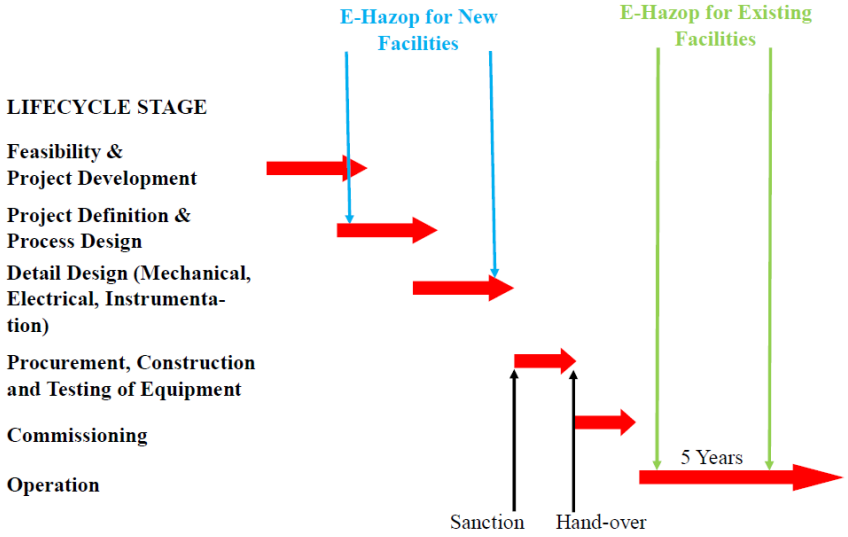


Figure 1 – Timing of E-Hazop Studies

## Issues with historical approaches

Over the years, industry has addressed the review of electrical systems in a range of ways. Three common approaches have been to use Process Safety 'HAZOP' with additional electrical guidewords, 'SAFOP' with a task orientated approach or "FMEA" to focus on component failures.

### Process Safety HAZOP and applicability to electrical hazards

Process Safety HAZOPs do not provide complete coverage of electrical hazards as:

- HAZOP is usually based on assessment of plant Process and Instrumentation Diagrams (P&IDs) which do not display the electrical infrastructure. Where there is an attempt to include electrical distribution issues, the use of a P&ID does not ensure full coverage, nor does it show the required detail of the system.
- HAZOP guidewords are not developed to assess electrical systems robustly. For example, loss of power would be included but the detail of what would cause this would not. Similarly, electrical hazards such as arc flash and phase faults would not be identified and discussed.
- The HAZOP team often does not include people with sufficient knowledge of the electrical systems.
- The HAZOP team are rarely presented with sufficient information of the electrical aspects of the system being studied.

### SAFOP and applicability to electrical hazards

SAFOP (Electrical Systems Safe Operability Review) is an approach used to review and analyse various aspects of electrical safety and is comprised of 3 separate parts: SAFAN (Safety Analysis), SYSOP (System Security and Operability Analysis) and OPTAN (Operator Task Analysis).

SAFOP can be useful for assessing electrical systems in more detail, but experience suggests it also has a number of drawbacks as it can:

- Provide a level of confusion regarding an unclear boundary between each component of SAFOP and with other studies, such as Process Safety HAZOP, resulting in duplication and inconsistency.
- Be a time-consuming activity with a large drain on available project or operational resources.
- Be difficult for a non-specialist to engage productively in the process and appreciate the necessary interactions across the 3 differing SAFOP parts.

- Generate studies that tend not to be easily accessible and therefore don't get referred to or built upon throughout the lifecycle of the facility. Often such studies are done once then filed away.

## FMEA and applicability to electrical hazards

FMEA (Failure Mode and Effect Analysis) is a detailed technique analysing individual failures of defined components or "blocks".

FMEA can be useful for reviewing the reliability of electrical systems and their robustness to maintain operation in the event of component failures. Experience suggests it has a number of drawbacks as it can:

- Miss foreseeable "real life" scenarios as the focus is at a finer level of detail, looking at the failure of individual components.
- Miss people and process issues as the focus is on component failures
- Provide a level of uncertainty regarding the scope and bounds of the study and with how it fits with other studies, such as Process Safety HAZOP, resulting in gaps, duplication and inconsistency.
- Be a complex time-consuming activity with a large drain on available project or operational resources.

## General Observations

When looking at the management of electrical systems on existing facilities, weaknesses with previous review approaches are often apparent and typically manifest as:

- Older plants may never have been reviewed.
- Over reliance on simple compliance audits.
- A lack of learning from incidents and near misses that have occurred at the facility under review or in wider industry.
- A lack of focus on foreseeable human error.
- Poor records (inability to demonstrate safe operation).
- Fit and forget mentality - people lose sight of expected life of systems.
- Ageing and obsolescent plant.
- Electrical hazards are often managed by perceived compliance and not viewed as complex hazards.
- Changes to design and operations compromise the system
- Tightening standards are ignored, missing the opportunity to make improvements
- Loss of corporate memory through staff turnover
- There tends to be poor visibility of electrical assessments across organisations with operators and maintenance staff often being unclear of electrical hazards and the systems in place to manage them.
- Known hazards are often well managed but there is no process for identifying other hazards present in the original design or which arise over time.
- Actions from audits and reviews are often not completed
- Poor communication of hazards can result in the "basis of safety" being defeated
- Not cross linked with other site assessments resulting in duplication and lack of consistency

## Why now is the time for a fresh approach?

Electrical system incidents and issues keep happening on too frequent a basis with many events coming to light through our hazard studies and incident investigations of electric shocks and system outages. Such incidents have typically been put down to people doing something they shouldn't or that something just broke. But this does not provide an understanding of what is really going on or result in an improved approach. This used to be the case with other complex hazards, such as chemical process hazards, and over recent years, improvements have been made with their management and review, so why not with electrical systems?

New technology enables a digitized and integrated approach to hazard studies, so now is the time to harness the software applications available to provide a more holistic and maintainable approach to managing hazard and risk.

Electrical safety and operability have never been more important, with energy transition investments moving at a pace and the need to maximise availability and reliability with the advent of rising energy costs, electrical system readiness is fast becoming an operational priority.

## Designing a new approach: ABB E-Hazop

In order to design a fresh approach to electrical system reviews, a list of desired features was identified that the new methodology would aim to encompass.

**Features similar to a HAZOP:**

- Effective technique for analysing complex hazards
- Build on 50 years of development and improvements to HAZOP approach
- Many people from high hazard facilities are familiar with approach
- Robust and focused guidewords
- Consider Human Factors for each Hazardous Event

**Complementary to Hazop without overlapping:**

- Can be used as an extension to HAZOP
- Does not confuse and contradict other site hazard assessments
- Part of common approach to complex hazards
- Risk Ranking on same matrix as HAZOP

**Identifies good and best practices:**

- Goes beyond an audit
- Identifies good practice and gaps to it
- Identifies potential further improvements utilising industry expertise
- Prioritised recommendations

**Enables improvement of new plant design:**

- An early review gives opportunity for more inherently safer approaches to be identified and implemented
- Identifies safety critical operational and maintenance tasks so they can be given more focus to result in better design and operating procedures
- Learn from incidents elsewhere to avoid repeating them
- Make cost-effective design improvements
- Opportunity for more sustainable design

**Facilitates either remote or on-site delivery:**

- Design for remote delivery from the start
- Eliminate the requirement to travel so minimises cost and is more sustainable
- Flexible timing to minimise disruption of site operation as review meeting do not need to be a continuous block of full days
- Promote consistency by enabling common team members across studies of multiple sites within an organisation

**Provides a robust record:**

- Demonstration of pro-active approach and existing hazard management

- Clear communication of hazards and safeguards to workforce
- Reference for MOCs
- Common digital platform

This list of criteria was then used as the basis for developing a new E-Hazop approach.

## Learning from other studies of complex systems

### Progressive improvements to HAZOP

To learn from the assessment of other complex hazards, we can look at the improvements that have been made to HAZOP.

ICI developed HAZOP in the sixties, and it was adopted by industry in the 70s. Through the 80s variations were made to better suit assessment of existing facilities. The development of HAZOP has continued over time and although the basis of HAZOP has remained unchanged, a good HAZOP now looks very different to earlier versions, even those from 10 to 15 years ago.

Industry has moved on from the stunted approach of describing potential hazardous, causes, consequences and safeguards with only one or two words, thus telling us nothing of the true scenario. Practioners now have a longer discussion and use more words to tell a clear and simple story. This process also adopts the challenge set out by the HSE following the Buncefield incident in answering the 3 key questions posed during that time, namely:

1. Do we understand what can go wrong?
2. Do we know what our systems are to prevent this happening?
3. Do we have information to assure us they are working effectively?

Essentially those participating in hazard studies need to describe what can go wrong (step by step, through to the ultimate harm), what the systems are that prevent the hazardous event and describe the measures (such as periodic testing, inspection and maintenance) that assure us they will work effectively when called upon.

HAZOP studies now link with other studies (such as LOPA, critical task analysis, COMAH Safety Reports, etc.) and are being recorded on common digital platforms. Hazardous events are then plotted on a single risk matrix for the site to communicate the risk profile. This also enables a prioritised list of site recommendations to be generated.

HAZOP studies now understand that each hazard scenario tends to involve aspects of Plant (physical equipment), Process (the systems by which we use the physical equipment) and People (those who implement the systems). It's not an inevitable, random event when something fails. We can make the operation more robust by having good processes carried out by competent people.

Expectations are now to not only identify actions that will be carried out but also measures for further improvement which could be carried out, along with justification of measures not being implemented, in order to reduce the risk to As Low As Reasonably Practicable (ALARP).

### Human Factors is part of everything

Human Factors is a key aspect with electrical safety and deserves a special mention. Electrical incidents due to someone taking an incorrect course of action have all too often resulted in investigations concluding that the person was at fault and a restating of the "follow the rules" mantra. Similar incidents inevitably continue to happen. This traditional approach does not uncover the true cause and misses the opportunity to learn. Human error is not a random event of someone doing something incorrectly.

The action people take is influenced by a combination of individual, organisational and job factors, as described in HSG48 [8]. As such, we need to understand the full picture of these influencing factors around major hazards. In a similar way, many hazard identification and assessment approaches have tagged "Human Error" on to a list of guidewords for it to be considered as an isolated cause.

People usually try to do the right thing. They may work on the wrong equipment as it is not clearly marked. They may think equipment is isolated due to poor communication. They may take the same approach as they did elsewhere as they thought it was a similar situation. They may perceive some deviations from procedure as "the right thing" as it's the only way to get the job done. To effectively include human factors in an assessment, we need to tell the story of how hazardous events may arise and within the story for any of the guidewords there may be human error. To do this, we need the people who work on these electrical systems in the study, fully engaged with it, and willing to talk openly.

The aim is to identify foreseeable error with significant consequences and put measures in place to make it less likely.

## ABB E-Hazop in practice

Typically the study is led by a competent and approved Hazard Study Leader with support from an Electrical Specialist Engineer and Technical Scribe.

The study team also comprises personnel from the facility including:

- Operations/Maintenance representative who work with the system day-to-day,
- Electrical Engineer who is familiar with the detail design,
- Site Management/Safety Manager representative who is familiar with the broader site issues and consequences of failures.

The E-Hazop is recorded on a digital platform software application which is used as a common platform for all complex hazard studies including HAZOP and LOPA.

The study starts with a kick-off meeting to clearly define the scope and identify previous relevant work such as HAZOPs, LOPAs, audits, incident reports, etc. An overview of site operation is discussed along with general issues including local regulations, safe systems of work, competency and training.

The ABB E-Hazop approach is similar to conventional HAZOP by defining the scope and nodes using drawings. The difference is that this is marked up on a single line diagram alongside a site layout diagram, instead of on a P&ID. The design intent of each node is described.

A long list of vague guidewords has been avoided and instead a concise list of guidewords has been developed, based on deviations from design intent, with a clearly defined structure behind them.

| Guideword (Deviation from intent) | Definition of guideword | Aspects to consider | Sub Aspects | Examples |
|---|---|---|---|---|
| **Over current** | Current higher than design | Overload | Using more than the design power | Total system power (total from the load list) exceeds equipment rating e.g. feeder breaker |
| | | | | Simultaneous start of high-power equipment |
| | | | Generator | Supplying more than the design rate of power (voltage/current/power factor) |
| | | | | Voltage control fault including,<br>Controller fault<br>Operator error - entering incorrect setpoint value |
| | | Short circuit | Bridging across live equipment | Deterioration of equipment, including insulation e.g. loose connection on a power supply terminal |
| | | | | Water ingress |
| | | | | Tools, cladding, materials and other items bridging across live equipment |
| | | | Internal phase fault | Phase conductor touching another phase conductor due to insulation failure |
| | | | External phase fault | Supply phase imbalance |

Table 1 - Example of detailed structure behind each guideword

Potential hazardous events are identified by the team; describing cause, consequence, harm (safety, environmental, financial, reputational) and operational issues along with existing safeguards that prevent this from happening (or limit the consequences). Each potential hazard is plotted on a common risk matrix to produce a site risk profile. Recommendations are identified where there are gaps to good practice (codes, regulations and guidance) and where there is opportunity to implement best practices. A prioritised recommendation list is generated at the end of the study and included in the report. Recommendations are pragmatic, focussed and can form the basis of an ALARP demonstration (justification that the risk of a significant hazard has been reduced to As Low as Reasonably Practicable).

Recording the E-Hazop on the software application tool allows for integration with other site studies and provides a solid foundation which can be built upon with further studies and periodic revalidations throughout the lifecycle of the facility. Other site studies such as HAZOP and LOPA can be recorded on the same database and linked.

## Gaps in Good Practice and Opportunities for Best Practice

For each Hazardous Event, any ‘Good Practice’ in place is recorded along with recommendations to address any gaps.

Any ‘Best Practice’ in place is also recorded along with recommendations for further improvement. The identification of potential best practices is enhanced when the review team includes an external electrical systems specialist with broad industry experience across multiple operating organisations.

Many of the best practices are viewed by insurance companies as risk reducing measures and their implementation may therefore result in lower insurance premiums.

| Hazardous Event | Good Practice | Best Practice |
|---|---|---|
| High-Voltage insipient insulation failure | Periodic insulation resistance checks | On-line (continuous) partial discharge tests. This would provide early warning of any potential insulation failures as the equipment ages. |
| Power Transformer fire | Mineral oil with Dissolved Gas Analysis | Fire safe oil |
| Switchroom fire | Heat and smoke detection | High speed smoke detection |
| Overheating of terminal connections | Periodic visual inspection | Install infra-red viewing windows at vulnerable connections. |

Table 2 - Examples of good and best practices

## Integrating into a suite of site studies

The ABB E-Hazop approach developed can be used in isolation or as an extension to other hazard studies e.g. HAZOP, to allow hazards associated with electrical supply systems to be given detailed consideration. Typical systems of interest include generation, transformers, supply to critical equipment, back-up power supply (generator, batteries), switchgear and breakers, etc. The Process Safety and Occupational Safety aspects of the facility may have been reviewed, but E-Hazop ensures that significant electrical hazards are reviewed to an appropriate level to enable complete and consistent management of risk across a facility. Furthermore, where electrical system hazards are identified as leading to hazardous events already identified in a HAZOP a linking reference is made so the full sequence of events is recorded, and the hazardous event is not listed multiple times.

Where electrical system issues (such as loss of power) are identified as causes of significant events in a HAZOP, this can prompt an E-Hazop to review the electrical system in more detail and link to the original HAZOP.

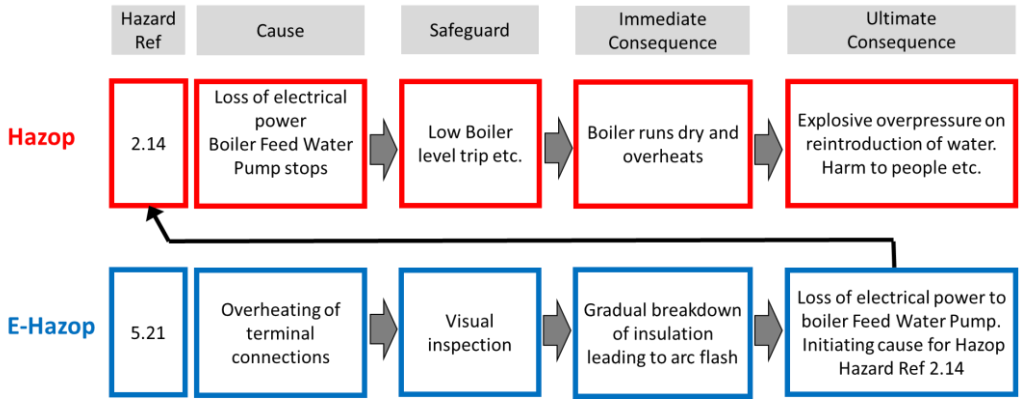


Figure 2 - E-Hazop linking with HAZOP

### Live (evergreen) assessment

By clearly and consistently recording hazards and safeguards, the E-Hazop record can easily be referred to during the management of Change (MOC) process when implementing changes. The proposed change can then be effectively assessed, and the change noted in the record. The system can be reviewed periodically, and the changes since the previous review discussed together, and the record revised. When combined with a similar approach for process safety, this maintains a current and complete risk assessment for the facility.

## Going forward

In summary, improving Electrical Safety and Operability across industry to harness the current electrical system evolution in renewables and improved electrical infrastructure will require:

- A focus on electrical systems across a more diverse range of industry sectors
- Inclusion of electrical systems into an integrated hazard review suite

- Involvement of operators and maintenance staff as study team members to tell a simple and clear story to address the real human factors issues and make incidents less likely

This will provide a demonstration of pro-active hazard management and can be referenced as an information source for regulatory compliance such as COMAH [2].

ABB E-Hazop gives the opportunity to integrate the review of electrical systems into a hazard review suite to maintain consistency and provide a solid foundation on which future review studies can build.

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