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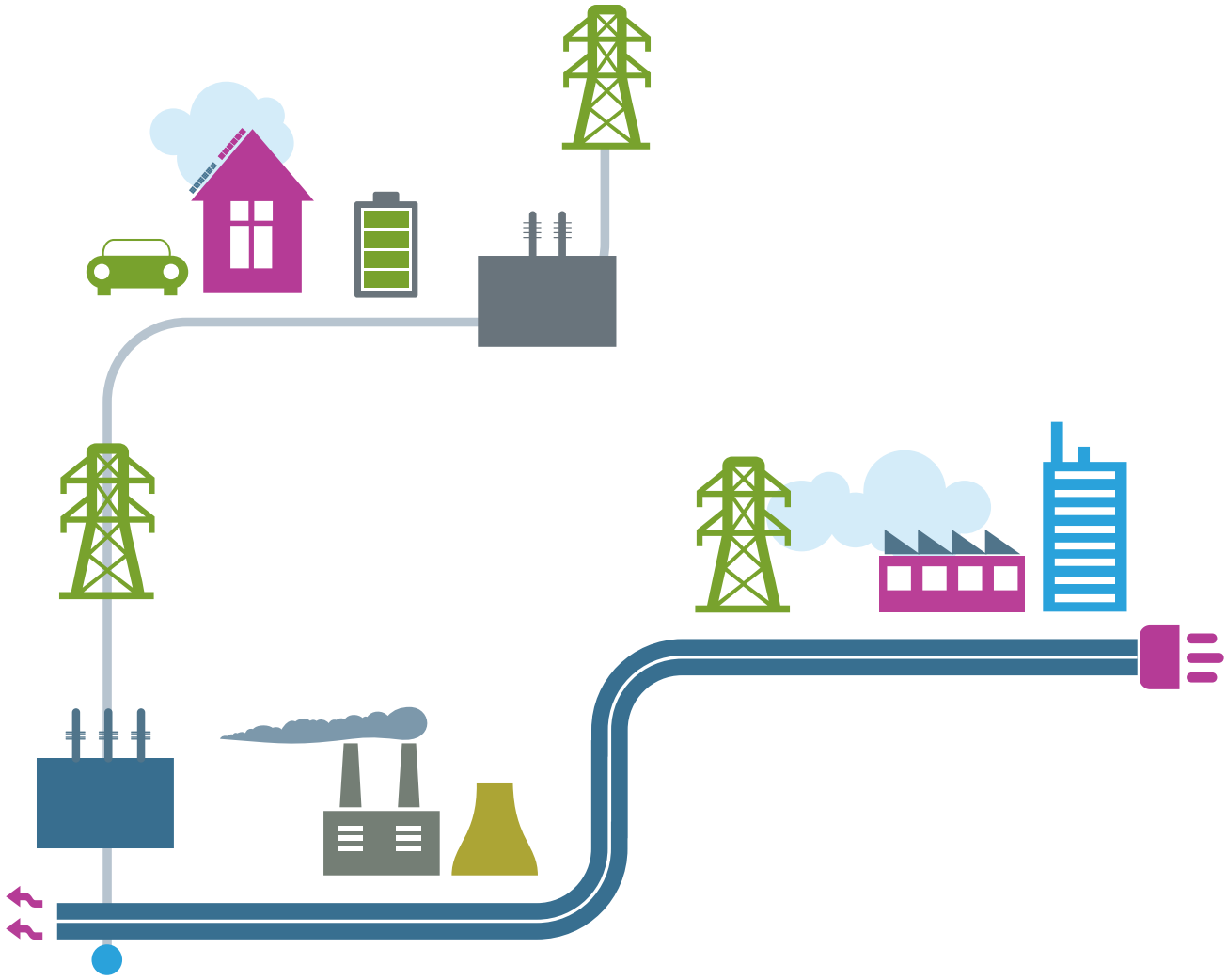
BEAMA NETWORKS – PRESSURE RISE IN SUBSTATIONS CAUSED BY ELECTRICAL FAULTS (2017)



September 2018

ABOUT BEAMA

BEAMA represents manufacturers of electrical infrastructure products and systems from transmission through distribution to the environmental systems and services in the built environment, with 200 members ranging from SMEs to large multinationals.

We work with our members to ensure their interests are well represented in the relevant political, regulatory and standardisation issues at UK, EU & international levels.

BEAMA member products provide a sustainable, safe, efficient and secure UK electrical system. We support our members in ensuring that the UK has a strong electrotechnical industry which is recognised as an essential part of modern society and brings invaluable economic, social and environmental benefits.

Our Networks Sector is made up of members with interests in network products, transformers, switchgear, communications, automation, relays, smart grid, and related safety and energy supply and control technology. As part of the networks section of BEAMA, our aim is to explore and develop opportunities, provide technical services and to foster sustainable growth in new markets.

This paper was produced in coordination with the BEAMA Principal Products Section which has membership from the following organisations:

BACKGROUND

Members of BEAMA's Principle Products Management Committee requested that BEAMA in coordination with membership produce a technical paper on the subject of pressure rise in substations caused by internal electrical faults.

This paper aims to set out and clarify the reasons that this occurs, provide guidance to customers, highlight controls available, overview mitigative measures, provide details on relevant regulations and links to further reading on this subject. Further support and expertise is available from the manufacturers of network products.

Compliance

It is essential that customers, designers and installers of electricity networks products ensure compliance with relevant regulations and legislation. It is the duty of the customer, designers and installers to ensure these are appropriately considered and complied with. From a manufacturer perspective, the manufacturer will ensure product compliance prior to delivery of the product as well as providing appropriate recommendations and expert advice at the request of the customer or as part of product delivery.

Standards

It is essential that customers, designers and other relevant parties ensure compliance with safety policies, construction standards and regulations, technology and operation standards, as well as any other relevant standards, regulation or policies.

Substation Pressure Rise

Pressure rise in substations can occur as a result of electrical faults on electrical plant. Because of the high levels of fault current and relatively high voltages typically associated with electric power distribution systems, these faults carry high levels of energy, releasing a great deal of heat and pressure into the immediate environment.[1] It should be noted that these occurrences are extremely rare, however they should be appropriately prepared for.

Overpressure is internal pressure over and above the normal atmospheric pressure (1.03125bar) caused by an electrical fault. The resulting arc super-heats the gas, air or oil in the switchgear compartment causing a rapid expansion in volume and propagating a pressure wave travelling at approximately the speed of sound (340m/s).[2]

In modern switchgear products, an internal overpressure will result in the operation of a pressure relief device fitted to the product by the manufacturer, these are designed to vent in a directional manner. The release of the internal pressure into a building containing the switchgear can result in a pressure rise within the substation. This will need to be considered by the building designer.

Safety by design and other mitigation measures are more proactively encouraged than those that rely on training and personal protective equipment in protecting personnel. If uncontrolled, the heat and pressure released as result of an electrical fault can cause significant damage to adjacent equipment and enclosures, presenting a further hazard to the immediate external environment.

A number of factors can contribute to pressure rise incidents, human interaction and management can play a vital role in preventing these occurrences. There is evidence to suggest that these events can occur close to maintenance activity or other electrical work on the equipment.[3]

Mitigation Measures

Personnel Safety

While PPE, administrative controls, and warnings are required for every facility and make up essential parts of electrical safety policies and practices, in practice these are the least effective mitigation strategy as they provide no guarantee of personnel safety due to the heat and pressure encountered. However, these can be the difference between a survivable injury and death.[4]

Engineering controls and technologies are available and provide the opportunity to engineer systems to minimise risk internally and externally, primarily to personnel and to the substation structure. These mitigations help to ensure that any impacts are mitigated to the greatest extent possible.

Substation Structure

Building overpressure release is a method to mitigate against the impacts of arc flash and substation pressure rise. Building overpressure release serves to minimise structural damage and manage risk to the external area immediately surrounding the substation. These systems work via the inclusion of sacrificial roof panels or non-essential structural elements and/or venting systems that are designed to take the pressure caused by an incident and release it in a controlled way, maintaining the structure of the substation.

[1] Arc Flash Mitigation, Anthony Parsons, Schneider Electric (2013)

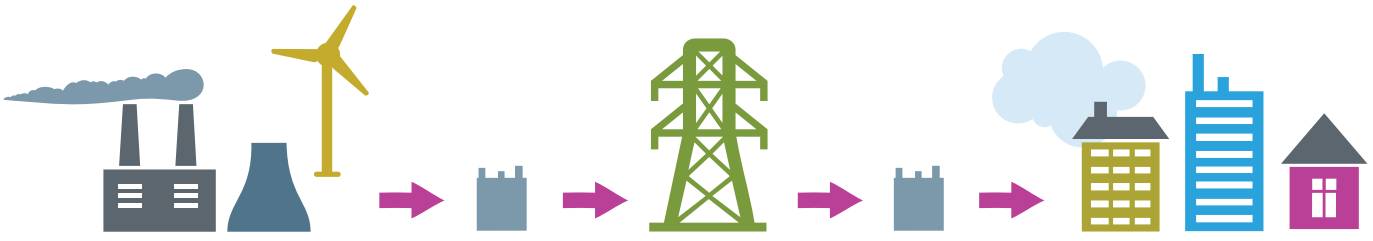
[2] UK Power Networks Engineering Design Standard (EDS) 07-0111 Substation Overpressure (2015)

[3] Practical approaches to Mitigating Arc Flash exposure in Europe, by Hans Picard, Jan Verstraten and Rien Luchtenberg (2014)

[4] Arc Flash Mitigation, by Anthony Parsons, Schneider Electric (2013)

Controls – Design Stage Examples

CONTROL	OVERVIEW
Substation Design	This could be a combination of over pressure controls and supporting technology included at the specification and design stage. This is the ideal time to engineer and include controls to mitigate against an internal electrical fault. Discussion between the customer, civil contractor and the product manufacturer should take place to ensure that well designed control measures are implemented.
Roof and Pressure Relief Venting	Pressure relief systems include roof and side venting and the design of sacrificial and non-essential substation elements such as walls or roofs. This should be planned for and considered at the design stage in order that substations elements can be designed to fail in a controlled way and without risks to personnel either in close proximity or adjacent buildings. In instances where the substation relies heavily on wall elements for structural support, stability engineered independent support structures can be designed so that they support the full weight of the roof, these should be considered in tandem with over pressure release systems and/or venting to reduce the risk of substation damage as far as reasonably practicable.
Arc Resistant Switchgear	Arc resistant switchgear is designed to direct gases to exhaust chambers or vents. These vents will open under pressure situations and expel gases from the exhaust and out through the venting system in a safe way. Under normal operating conditions the switchgear will be open to allow air to flow, however in a fault condition specially designed openings will close shut very quickly to prevent the exit of hot gases. Other characteristics of this switchgear can include thicker wall construction to minimise the potential for burn through. In addition to these circuit breakers and specialist fuses can be installed to provide an even greater level of mitigation and control.
Relay System Design	Incorporation of arc flash detection into the protection system can significantly reduce the energy released by tripping surrounding circuit breakers to isolate the faulted section in as little as 1ms. Arc flash can be combined with overcurrent protection to identify the faulted section where the flash can cause tripping of adjacent circuit breakers.
Current Limiting Fuses	Current limiting fuses are primarily used to protect transformers, switchgear and other loads. Design and installation of these fuses can significantly reduce the arc energy released during a fault situation limiting potential exposure to personnel and damage to the structure and external locations.



Controls – Retrofit Examples

CONTROL	OVERVIEW
Electronically Tripped Breakers	In most cases, the basic overcurrent protection provided by standard thermal-magnetic circuit breakers will meet the requirements of the electrical system design. In some cases, however, basic overcurrent protection might not be enough. Electronic trip circuit breakers can provide the additional features needed in those cases. Reasons to use electronic trip circuit breakers include • enhanced coordination capabilities • integral ground-fault detection • communication capabilities • future growth potential[5]
Zone-selective Interlocking	Interlocking Zones and selective interlocking, also called zone restraint, is a system designed to reduce the stress on electrical distribution equipment during short-circuit or ground-fault conditions.

Design Responsibilities and Process

When designing a power system and associated housing such as the substation, it is essential to consider engineering controls, compliance with relevant legislation, regulation and standards and appropriate product selection. Having awareness of and understanding of risks and giving consideration to appropriate controls at the design stage will ensure that safety can be more effectively designed into a system. Whilst it is possible to retrospectively integrate controls, this approach is less effective than including for appropriate controls and design features at the design stage.

When considering issues or safety concerns that could perceivably be caused by electrical faults when designing a system and prior to construction, this will leave open a greater specification of products. It is important to understand and consider safety policies that may be in place within the customer business and in terms of network operation. Consideration of these can help to tailor and appropriately define performance requirements, for example what are acceptable control parameters, energy levels or specific product performance requirements. In terms of retrospective action, this can often be limited by the existing design and as such can be expensive to implement controls to the required performance level post commissioning, factors that can affect this may include substation space, installed products and location in addition to other factors.

Summary

Engineering controls can be a very effective measure in mitigating against substation pressure rise incidence and the associated impacts, ultimately enhancing safety for personnel. To ensure maximum effectiveness of any mitigation measures, incidence and impact should be considered at the design phase. Mitigation against electrical faults represent a solid investment from a safety and operational perspective. There are various known causes of faults leading to substation pressure rise and these should be managed and the potential for them to occur should be minimised as much as possible, either through engineering controls or specifically designed systems to mitigate the impacts of such occurrences.

Some BEAMA members offer Computational Fluid Dynamics (CFD) modelling, to calculate the pressure rise potential in substations, usually this is available at cost or in some cases service level agreements may cover this.

Further Information

For further information on the content included in this paper, please contact the manufacturer of your products or the electricity network operator for your local area.

[5] Electronic Trip Circuit Breaker Basics Circuit Breaker Application Guide, by Schneider (2012)

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