

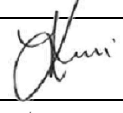

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Substations Electrical Condition Assessment

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Executive Summary

Introduction

Transnet Port Terminals Infrastructure Engineering: Electrical team has been tasked to undertake a condition assessment at the Port of East London for the Grain Elevators Substations. The idea is to ensure a safe and reliable electrical infrastructure to prevent incidents that may lead to machinery damage and/or fatalities, and to also ensure the availability of critical spares in the event of a breakdown. The assessment also aims to address the current damage of one of the substations which the switchgear has exploded.

The current electrical infrastructure is now old and with limited available spares which poses a risk of power supply to critical operations. It is a requirement by law to entirely make a substation compliant to at least the minimum enforced regulations once you attempt to undertake upgrades of plant such as switchgear.

Scope Overview

The main scope covers the condition assessment of the Port of East London for the Grain Elevators Substations 1, 2 and Junction Tower minisub,

Whereas the main mechanical scope covers the condition assessment from a mechanical building perspective of all the substations listed above.

Literature Review

This section seeks to summarise the bases for the identified findings and proposals. Substation buildings shall be of size suitable for design and working space requirements. MV and LV switchgear shall be separated with a barrier. Oil distribution transformers shall have an oil containment to avoid spillage to the environment and the substation building area. The substations must be zone classified with suitable dust resistant plant.

Medium voltage switchgear shall ensure operator safety through the application of SANS 62271 arc flash requirements. A reliable, low maintenance, and environmentally friendly MV circuit breakers are the preferred technology. For the LV switchgear; the fuse and circuit breaker technologies have contesting properties over each other, but circuit breakers have been proven and accepted to be more beneficial than fuses.

Mechanical

Modern switchgear rooms are all adequately ventilated and fitted out with air conditioning systems as well as positive pressurising systems which prevents dust particles from entering the substation from the outside due to a pressure differential which is created by having a higher pressure inside the substation than outside the substation. This pressure differential is created by pumping clean filtered air from the outside of the building into the building and having either a small ventilation wall grille with limited flow to the outside of the building or having an extraction fan which is smaller than the supply fan with its filter.

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All building spaces must be adequately ventilated in accordance with SANS 10400-O. Each substation must also be fitted with a fire detection system in compliance with SANS 10139. Substations must all be supplied and fitted with the relevant number of CO₂ type fire extinguishers together with the relevant fire signage in each substation in compliance with SANS 10400-T. It is best practice to provide a fire gas suppression system for all substations. The fire gas suppression system is however not a statutory requirement.

Site Assessment

All three substation buildings are in a generally good condition (with a few wall cracks) and space is an issue in substation 2. The transformer rooms are banded for oil containment and all rooms are full of grain dust. There is no dust extraction/ suppression system for the substation which is the suspected reason for the explosion at substation 2. All substations use old technology switchgear with spares unable on the market. It is recommended that all switchgear shall be upgraded with new modern switchboards. All the proposed upgrades or refurbishments shall be compatible with SANS 61850 for substations automation.

The positive pressurised system is non-operational which means that there is no measure of protection for the electrical switchgear against dust entering which can cause catastrophic explosion of panels. All upgrades needs to be carried out in line with SANS 10400-O, SANS 10400-T, ASHRAE HVAC design codes.

Conclusion

It is recommended that the business supports the recommendations of this report and approve funding as detailed in the resultant cost estimate.

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Definitions/Abbreviations

TPT	Transnet Port Terminals
NMD	Notified Maximum Demand
N+1	A network state where one critical component of the electrical supply system is out of service, e.g. a source transformer or supply cable. Under N+1 conditions, electrical networks are typically operated using a contingency plan where load shedding may be necessary.
PLP	Project Life Plan
MVA	Mega Volt Amperes
kV	Kilo-Volts
Plant	Includes fixtures, fittings, implements, equipment, tools and appliances, and anything which is used for any purpose in connection with such plant.
Dead	Means at or about zero potential and isolated from any live system
Earthed	Means connected to the general mass of earth in such a manner as will ensure at all times an immediate safe discharge of electrical energy.
SANS	South African National Standard
ANSI	American National Standards Institute
IEC	International Electro Technical Commission
IEEE	Institute of Electrical and Electronics Engineers
FM200	Heptafluoropropane
HVAC	Heating, Ventilation and Air Conditioning
ISO	International Organization for Standardization
ORS	Owner Requirement Specification
CAD	Computer Aided Design
PFC	Power Correction Factor
UPS	Uninterrupted Power Supply
kVA	kilo Volt Amperes
kA	kilo Amps
kW	kilo Watts
CT	Current Transformer
VT	Voltage Transformer
SCADA	Supervisory control and data acquisition

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2 Introduction/Background

Substations are key to the infrastructure of Transnet Port Terminals as they supply various equipment and machinery with the required power in order to ensure continuous operations. In order to support Transnet's vision of delivering freight reliably, a safe and reliable electrical infrastructure is required to ensure sufficient, uninterrupted and a quality power supply for the ports of Transnet. The Port of East London is supplied from the East London Municipality through the Main Substation (see annexure 1 for a complete single line network diagram)

The Port is undertaking upgrades for critical electrical plant and the TPT Engineering Department was tasked to undertake a conditional assessment of all electrical infrastructure at the grain elevator; this report focuses on substations. The assessment was focused on challenges of noncompliance with legislations and the modernized design standards. The assessment also aimed to check if the current substation equipment can continue to be utilized for over their life span. The substations at the grain elevator are the source of electricity to supply all the machinery to ensure continuous operation.

Based on visual inspection, the grain elevator substations have been operating with equipment that have reached its life span and over. The substations still have old equipment such as oil circuit breakers, mechanical operated relays, CT's, VT's, old analogue voltmeters and ammeters. Currently, grain elevator Substation 2 is out of service due to a fault and the challenge is that there are no spares for the old technology. There are no spares where in case of a breakdown and or an emergency and the plant require spares such as; circuit breakers, vacuum current transformers, digital operating relays. One of the highest risks is that of the safety of the employees whom need to enter these substations to perform maintenance and switching.

2.1 Objective

The main objective of the conducted condition assessment is to identify design and safety conformance and inform on the necessary Electrical and Mechanical Infrastructure upgrades.

3 Scope Overview

The grain elevator has three substations namely Substation 1, Substation 2, and junction tower minisub; these are reticulated between floor levels 14, 13, 12, the basement, and the quayside. These substations were assessed mainly against the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) (OHS Act). The assessment was mainly a visual inspection exercise and excluded fault finding, sample testing and routine testing. The focus of the inspection and the report was to address the current challenges of the all electrical equipment mainly caused by grain dust and to address non-compliance, so less is highlighted about a lot of good practice that was observed.

The abovementioned substations were also visually assessed from a mechanical perspective in terms of compliance with the relevant ventilation rates and mechanism as well as the fire safety compliance. The inspection was purely of visual type and no mechanical components were assessed via non-destructive methods. The inspection focussed on the compliance to the national building regulation in terms of the requirements for ventilation and fire protection.

4 Methodology

The conducted condition assessment was focused on compliance requirements enforced by the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) (OHS Act) that is administered by the Chief Inspector of the Department of Labour. The OHS Act requires that the assessed electrical substation and installations concerned comply with the requirements of SANS 10142 and other SANS applicable normative references. Where SANS proved to be silent in addressing specific requirements for the assessment, applicable references from the International Electrotechnical Commission (IEC), the National Electrical Code (NEC), the Institute of Electrical and Electronics Engineers (IEEE) and the publications of Global Asset Protection Services (GAPS) were used to inform the findings and recommendations. The intent of the standards was also studied to appropriately assess the enforcement of the regulations. It was also important to apply a thought process of the possible risk analysis application that might have been a motivation for the installation at the time, this possibly exempted the application of other standards for the respective installation.

The assessment was primarily based on a visual inspection of the substation rooms and the housed electrical plant. Useful information such as drawings and previous maintenance records were requested and made available to the team before the assessment. Information was also taken from the maintenance personnel to understand challenges to assess and help resolve as part of the subsequent upgrades. Section 4 below discusses the theoretical bases that were useful in identifying the findings and to guide the recommendations.

5 Literature Review

5.1 Indoor Substation Arrangement

5.1.1 Floor Plan.

The OHS Act Electrical Machinery regulation which is the fundamental regulation for substation buildings, under the switch and transformer premises clause, enforces that the user shall cause enclosed premises housing switchgear and transformers to be of ample size so as to provide clear working space for operating and maintenance staff. The supplementary design SANS standards are not specific on the algorithm for arranging an indoor substation including specifying the required clear working space. Arrangement designs, which in this context refers to the layout of the plant and the substation building, are expected to vary; as long as the fundamental enforced guidelines are adhered to. It is important to mention that the functionality of the design or electrical power system solution cannot be assessed in isolation with the risks associated with personnel, property and the environment.

Typical substation arrangements are based on the National Electrical Code (NEC) guidelines that were and/or are accepted as general practice. These guidelines allows for a variety of arrangements including having all the substation components, which are the transformers and switchgear, to be in one room. In addition, the NEC code advises on the acceptable minimum working clearances for operation and maintenance staff as enforced by the OHS Act. See table 1. This information can also vary with different manufacturers based on the make of the plant. The substation room height requirement is generally necessitated by the space required between the top of the MV switchgear and the roof. In case of the internal fault, the height of the roof has a significant impact as the hot gasses can bounce of the roof of the building causing injury to the operator or possible damage to the building. The fault level is used to consider the required roof height for the possible impact.

Table 1: NEC Indoor Substation Minimum Clearances

Distance	Description
300mm	Horizontally between any item of equipment and the substation wall.
600mm	Horizontally between any two items of equipment.
1200mm	Horizontally in front of any MV switchgear.
Roof Height > 4m	For a typical panel height of 2720mm with 31.5kA internal arc fault for 1s.
Roof Height >3.5m<4m	For a typical panel height of 2720mm with 25kA internal arc fault for 1s.
Roof Height > 3m<3.5m	For a typical panel height of 2720mm with 31.5kA internal arc fault for 1s.

5.1.2 SANS 10142-2 Buildings and Enclosures.

A barrier shall separate the MV and LV equipment that are installed in the same building. The MV bushing connections shall be sealed and insulated. The barrier is also important to restrict entry to the MV plant may personnel only authorised to work on LV plant wish to do so without interfering with the MV section of the substation. This design shall be enforced with careful consideration of the provision of the required escape routes. This implies that the LV section

alone when segregated from the MV section shall allow for two entry/exit points. As a general requirement, barriers such as solid walls, doors, screens (wire mesh) shall have a minimum height of 1.8m and shall ensure that no part of the body of a person can reach the dangerous zone near live part. Barrier clearances shall be in accordance with the requirements of NRS 060.

5.2 Distribution Transformers

Distribution transformers shall meet the requirements of SANS 780. The Port uses oil filled transformers which shall be, regularly as far as reasonably practicable and advised by the manufacturer, tested for polychlorinated biphenyls (PCBs) contents. Ideally the transformer shall be free of PCBs. Transformer tests are important in identifying underlying causes of resultant final events such as high temperature, excessive loading, a deficient power supply or electric faults. Common terms used to categorize the type and cause of a loss, like electrical breakdown, accidental operation, control failure, arcing, fire and electrical overload, oversimplify and do not necessarily identify the prime reason or reasons for a loss-producing event. These common terms do not readily identify system related failures that initiate such incidents [4].

Indoor oil-filled equipment shall have an oil enclosure or drain that prevents any spilt oil from reaching a part of the building that is not designed to accommodate the spill. The enclosure or drain shall be such as to satisfy the fire officer [SANS 10142-1&2].

5.3 Medium Voltage Circuit Breaker

5.3.1 Oil Circuit Breakers

Oil has been employed as an insulating and arc-extinguishing medium in majority of the existing MV switchgear at the Port of East London. It has been extensively used as the anciently adopted technology and generally has a proven record of reliability and performance. However, this technology poses a number of safety, environmental, operational and economic risks. Failure can lead to a catastrophic explosion and subsequent oil fire. The Ignition of oil often results in a rupture of the switch oil chamber, resulting in the ejection of burning oil and gas clouds, causing death or serious injury to persons and major damage to plant and buildings in the vicinity of the failed equipment.

During normal usage, the oil decomposes due to regular arc flashes during switching, leading to the oil becoming polluted by carbon particles, reducing its dielectric strength. Hence periodical maintenance and replacement is required. The familiarised alternative to oil circuit breakers are Vacuum Circuit Breakers (VCB) and gas insulated circuit breakers, using Sulphur Hexafluoride gas (SF₆).

5.3.2 SF₆ Circuit Breakers

SF₆ physical properties of very high dielectric strength (3 times more than air, high thermal interruption capabilities (10 times more than air) and high heat transfer (2 times more than air) are the reasons SF₆ has been successfully used by the Electrical industry since 1960 . SF₆ circuit breakers are also known as gas insulated circuit breakers (GICB) or gas circuit breakers (GCB). Current GCBs use a puffer method that uses the motion of the moving contact to create a puff of SF₆ gas which will help extinguish the arc. SF₆ circuit breakers have the following environmental impact and hazards:

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- Very stringent handling requirements and training.
- Displaces oxygen for breathing, leakage can cause suffocation.
- SF₆ is not an ozone-depleting gas, but one of the most powerful global warming/greenhouse gases known. It is nearly 22 200 times more effective at trapping infrared radiation than an equivalent amount of CO₂ [SANS 62271-4].
- SF₆ gas in its pure state is relatively non-toxic. However, when SF₆ gas is exposed to extreme heat, it can produce hazardous by-products which can poses severe health and safety risks [SANS 62271-4].

5.3.3 Vacuum Circuit Breakers (VCB)

The vacuum circuit breaker market continues to grow due to its simple design, low maintenance requirements, and being environmentally safe compared to SF₆ circuit breakers. The disadvantage is that they are large in size and would not be a good consideration for the space constraints at the Port of East London grain elevator substations.

5.3.4 Development of Standards for MV Switchgear Rated for Arc Protection

Switchgear standards historically considered the electrical capability of switchgear with little regard to the effects of internal arc. To achieve some degree of safety users and manufacturers have considered, measures ranging from PPE, specific operating procedures, through to remote control and arc detection systems, however these measures do not change the characteristics of the switchgear, and therefore the switchgear / switch room should still be considered a high risk area.

In 1990 the IEC 60298 "Specification for MV Switchgear" included for additional requirements for resistance against internal arc, and thereby introduced the concept of safety for operators against the effects of internal arc. Since 2003 this standard has been superseded by the IEC62271-200 standard which includes for a broader definition of metal enclosed switchgear and a clear classification of the internal arc certification. The standard makes provision for a comprehensive series of standards that will cover the full range of standards applicable to medium voltage switchgear [2].

5.4 Low Voltage Switchgear

There are two basic types of Overcurrent Protective Devices (OCPDs):

Fuse - An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

Circuit breaker - A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.

Both technologies are comparable in terms of the advantages each carry over the other. Both fuses and circuit breakers will continue to have their places in the electrical installations depending mostly on the application. Fuses offer circuit protection that is inexpensive, straightforward and fast protection. Their faster circuit protection time is perhaps their biggest benefit over circuit breakers.

LV substations power distribution business is shifting from fuse technology to circuit breakers mainly because of reliability reasons which implies less down time. The melting operating mechanism of a fuse is a one-way process, the fusible link can no longer carry current and must be replaced. Which results in down time. Stocking spare fuses can help keep potential system downtime to a minimum but can mean that a substantial inventory of spare fuses must be maintained. A circuit breaker, on the other hand, clears faults from the system through opening of a set of contacts. As long as the circuit breaker does not sustain damage in the process of clearing the overcurrent, the contacts can be reclosed, and the circuit re-energized by manually closing the circuit breaker. A circuit breaker should always be inspected after a high fault, and testing may also be wise, particularly if any damage or stress is seen when the circuit breaker is inspected, to ensure that the device will function properly. In many cases, and particularly if the circuit breaker is properly applied within its ratings, the circuit can be re-energized after only minimal downtime. Technology behind circuit breakers continue to increase in line with Morden design standards including substation automation requirements to SANS 61850. To motivate for the required LV switchgear upgrades to utilise circuit breakers, the following list outlines substantial advantages circuit breakers have over fuses [3]:

- Circuit breakers are dead front. Fuses have exposed live parts.
- Circuit breakers can be tested for proper operation. To truly test a fuse, it would need to be destroyed in the process. It is a sacrificial device.
- A fuse does not offer magnetic and electronic trip unit feature protection, only thermal. The dual trip-curve feature of a circuit breaker makes them unique compared to fuses.
- A circuit breaker can be used as an ON/OFF switch.
- A blown fuse can be easily replaced with the wrong size, or even jerry-rigged (using a wire or small copper bar to replace the fuse) creating a safety issue.
- Start-up tripping is an issue with fuses (need to oversize the fuse for inrush current). Fuses can require larger wiring to compensate for inrush current.
- A circuit breaker can provide ground fault protection, a fuse cannot.
- Fuses “age” and degrade over time which can cause nuisance tripping.
- Single phasing on three-phase loads does not happen with a three-pole circuit breaker. All circuits trip at once. Using individual fuses for a three-phase power can result in single phasing and equipment damage.

5.5 Hazard Classification of areas

Hazardous locations are areas where fire or explosion hazards may exist due to the presence of flammable gasses/vapours, flammable liquids, combustible dust or ignitable fibres. The type of hazard is defined as an “explosion hazard” in Class 1 and 2 locations and a “fire hazard” in class 3 locations. Materials do not need to be in a gaseous state for an explosion.

Area classification describes the hazardous materials that are, or may be, present in a given area and the probability that they are present. This information is then used to select the right equipment for a given area and to ensure safe installation.

The National Fire Protection Assn. (NFPA) (American Standard) publishes the primary standards for classification of areas that are dust hazardous. Similar standards are available in Europe

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under the International Electro-technical Commission (IEC). In South Africa, hazardous areas are classified according to ATEX (see diagrams below)

NFPA 499 explains the U.S. system for classifying hazardous areas, which is based on three classifications: class, division and group. Hazardous areas are initially broken down by the general type — or class — of material involved.

- Class I materials include gases and vapours,
- Class II includes dusts
- Class III includes fibres.

The standards further classify the degree of the hazard by Division 1 or Division 2 definitions. A Division 1 area is where hazardous dust clouds or layers will be present on a regular basis. In a Division 2 area, hazardous dust clouds or layers will only be present due to a malfunction or failure of handling equipment. Additional factors often considered when determining area classification are the potential quantity of combustible dust present and the adequacy of dust removal systems. These factors could result in an unclassified area.

Hazardous dust areas must also be considered with respect to two other principles. First, the potential for existing dust to be airborne in an enclosed area must be considered along with the potential presence of an ignition source. The primary means of managing this risk is to use dust ignition proof or dust-tight equipment. Second, one must consider dust layers that can accumulate in excess of 0.794mm on electrical or mechanical equipment that could potentially interfere with the dissipation of heat and allow the layer of material to reach ignition temperature. Grain dust is particularly dangerous in this regard due to a phenomenon known as carbonization. A layer of grain dust exposed to air and alternating periods of high and low temperatures will chemically decompose over time and form a cake-like layer on the equipment. The ignition temperature of carbonized grain is significantly lower than the ignition temperature of a cloud of grain dust — approximately 250°C compared to 390°C, respectively.

US HAZARD CODES COMPARED TO ATEX HAZARD ZONES

GASES & VAPOURS					DUSTS				FIBRES		
US		ATEX			US		ATEX		US		ATEX
Class I	Class I	Zone	Zone	Zone	Class II	Class II	Zone	Zone	Class III	Class III	Zone
Div 1	Div 2	0	1	2	Div 1	Div 2	20	21	Div 1	Div 2	22
GROUP A		II C			GROUP E		No Groups		No Groups		No Groups
Acetylene		Acetylene / Hydrogen			Conductive Dusts				Textiles / Woods		All Materials
GROUP B		II B			GROUP F						
Hydrogen		Ethylene			Non conductive dusts						
GROUP C		II A									
Ethylene		Propane									
GROUP D											
Propane											

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ATEX		COMPARABLE HAZARD CODES FOR ATEX & US	US	
zone	0	explosive gas / air mixture is continuously present	class I	div 1
zone	1	explosive gas / air mixture is likely to occur in normal operations	class I	div 1
zone	2	explosive gas / air mixture is not likely to occur	class I	div 2
zone	20	explosive dust atmosphere continuously present	class II	div 1
zone	21	explosive dust atmosphere occasionally present in normal operations	class II	div 2
zone	22	explosive dust atmosphere unlikely to occur	class III	

GASES AND VAPOURS : THERE ARE THREE ZONES FOR GASES AND VAPOURS

ZONE 0	Flammable atmosphere highly likely to be present - may be present for long periods or even continuously.
ZONE 1	Flammable atmosphere possible but unlikely to be present for long periods.
ZONE 2	Flammable atmosphere unlikely to be present except for short periods of time - typically as a result of a process fault condition.

Zone 0 is the most DANGEROUS zone. It has the highest probability of a flammable atmosphere presence. Equipment for this zone must be very well protected against providing a source of ignition and have legal certification of this protection.

DUSTS - THERE ARE THREE ZONES FOR DUSTS:

ZONE 20	Dust cloud likely to be present continuously or for long periods.
ZONE 21	Dust cloud likely to be present occasionally in normal operation.
ZONE 22	Dust cloud unlikely to occur in normal operation, but if it does, will only exist for a short period.

5.6 The Elements and Prevention of a Dust Explosion

Elements that are needed for a Fire (the familiar "Fire Triangle"):

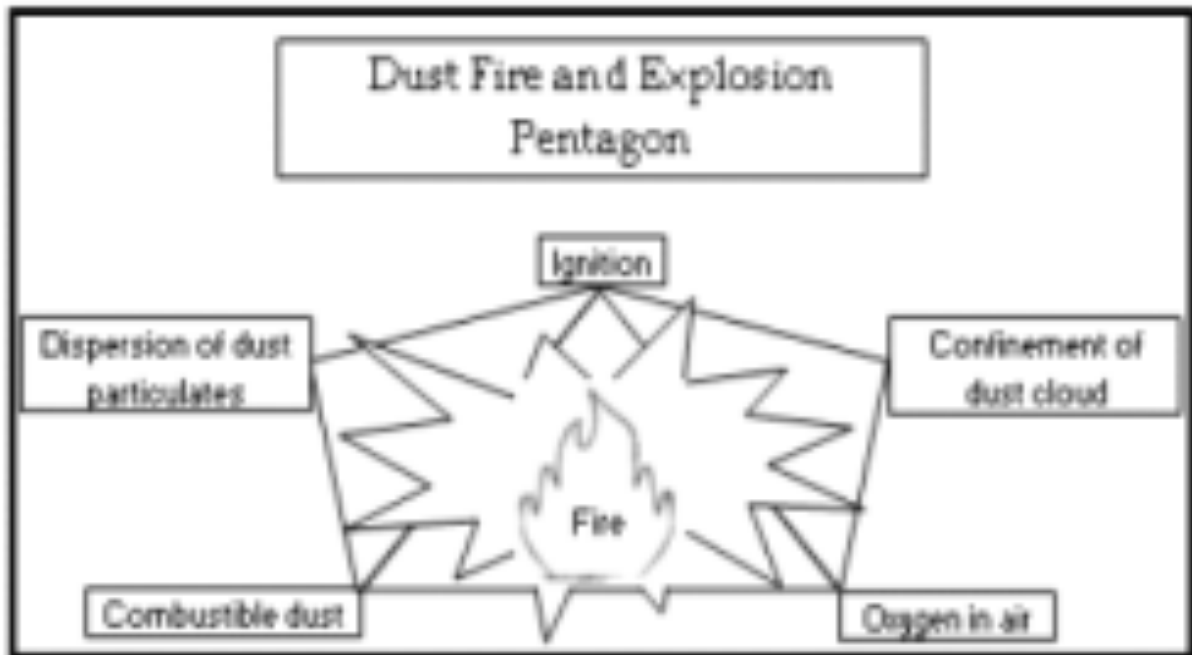
- Combustible dust (fuel)
- Ignition source (heat); and
- Oxygen in air (oxidizer)

Additional Elements Needed for a Combustible Dust Explosion:

- Dispersion of dust particles in sufficient quantity and concentration
- Confinement of the dust cloud.

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The addition of the latter two elements to the fire triangle creates what is known as the “explosion pentagon” (see Figure 1). If a dust cloud (diffused fuel) is ignited within a confined or semi-confined vessel, area, or building, it burns very rapidly and may explode. The safety of employees is threatened by the ensuing fires, additional explosions, flying debris, and collapsing building components.



An initial (primary) explosion in an area where fugitive dust has accumulated may shake loose more accumulated dust or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust.

If one of the elements of the explosion pentagon is missing, a catastrophic explosion will not occur. Two of the elements in the explosion pentagon are difficult to eliminate: oxygen (within air), and confinement of the dust cloud (within processes or buildings). However, the other three elements of the pentagon can be controlled to a significant extent.

This knowledge is a good start to formulating a prevention strategy, and the next step is to understand the two areas (dust control and ignition control) in a grain handling facility that pose the greatest danger and what can be done about them.

5.7 Dust control

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, contains comprehensive guidance on the control of dusts to prevent explosions.

The following are some of its recommendations:

- Minimize the escape of dust from process equipment or ventilation systems;
- Use dust collection systems and filters;
- Utilize surfaces that minimize dust accumulation and facilitate cleaning;
- Provide access to all hidden areas to permit inspection;
- Inspect for dust residues in open and hidden areas, at regular intervals;
- Clean dust residues at regular intervals;
- Use cleaning methods that do not generate dust clouds, if ignition sources are present;
- Only use vacuum cleaners approved for dust collection;
- Locate relief valves away from dust hazard areas; and
- Develop and implement a hazardous dust inspection, testing, housekeeping, and control program.

5.8 Ignition control

NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, also contains comprehensive guidance on the control of ignition sources to prevent explosions.

The following are some of its recommendations:

- Use appropriate electrical equipment and wiring methods;
- Control static electricity, including bonding of equipment to ground;
- Control smoking, open flames, and sparks;
- Control mechanical sparks and friction;
- Use separator devices to remove foreign materials capable of igniting combustibles from process materials;
- Separate heated surfaces from dusts;
- Separate heating systems from dusts;
- Adequately maintain all the above equipment.

The use of proper electrical equipment in hazardous locations is crucial to eliminating a common ignition source.

6 Site assessment

6.1 Detailed Site Assessment Focus

6.1.1 Substation Plant

- Existing MV and LV switchgear:
 - Arrangement.
 - Ratings.
 - Technology.
 - Age.
 - Condition, i.e. possible oil leaks, corrosion, switching mechanism, indicators, etc.
 - Terminations.
 - Maintenance history.
 - Availability of drawings and service manuals.
 - General Safety and Compliance to SANS 62271 and SANS 10142 requirements.

6.1.2 Transformers

- Ratings.
- Insulating liquid and containment.
- Oil Sample testing history and report.
- Oil level and visual condition.
- Compliance to SANS 780 and 555 requirements.
- Terminations.
- Type of protection.

6.1.3 Cable Management

- Cable identification.
- Cable condition.
- Cable Sizes, where possible.

6.1.4 General

- Electrical lighting and power.
- Battery Terminal Unit size and condition.
- Doors opening outwards.
- Signage and Labelling.
- Plant and Equipment position.
- Trench covers.
- Availability and accuracy of Asbuilt layouts.
- Earthing and Lightning Protection, only visual lightning protection and testing reports.
- Building Structure Integrity

6.1.5 Mechanical

- Positive pressure ducting system
- Door grilles
- Fire extinguishers
- Fire signage

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6.2 Grain Elevator Substations

6.2.1 General Layout

6.2.1.1 The grain elevator is currently fed from three substations (i.e. Grain Elevator Substation 1, 2 and junction tower MS). All three substations are connected in a ring type arrangement via 150mm² paper insulated (PILC) cable and fed from the Main Substation. All three substations contain oil circuit breakers and oil cooled transformers. Substation 1 is located at the basement, substation 2 is located at the 12th floor, and junction tower MS is located at the quayside. The transformers are located adjacent to the MV switchgear room.

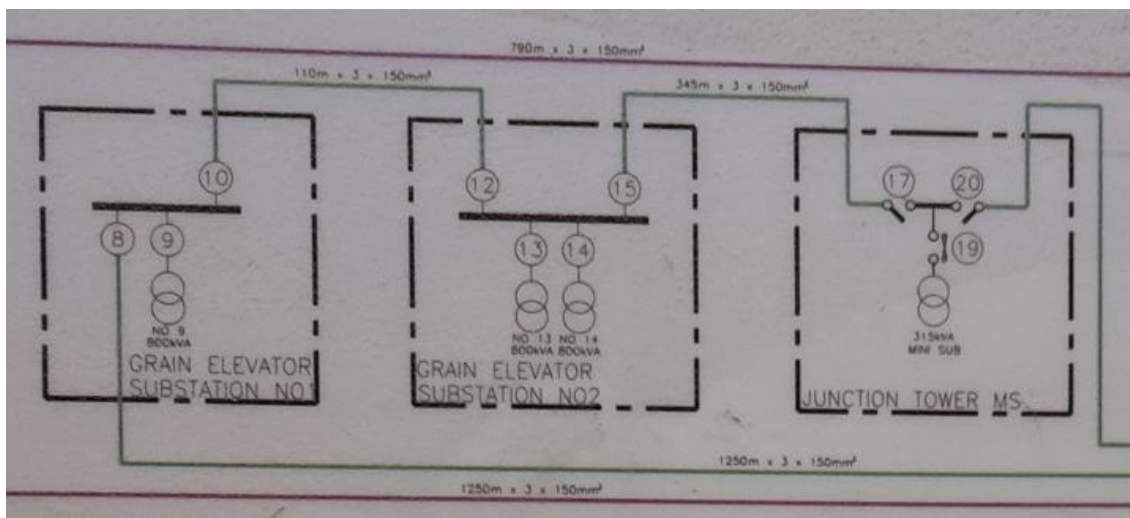


Figure 1 Port of East London Grain Elevator Substations Switching diagram

6.2.2 Findings

6.2.2.1 Room layout

6.2.2.1.1 Substation 1:

- There is enough working space as informed by the NEC recommendations discussed in above section 4.1.
- Racking space in front of the MV panels is within the recommended NEC standards.
- The general electrical lighting and power condition of the substation does need some refurbishment.
- The lighting is all fluorescent fittings which are in working condition but no emergency lighting.
- The substation room height requirements are generally necessitated by the space required between the top of the MV switchgear and the roof. In case of the internal fault, the height of the roof has significant impact as the hot gasses can bounce off the roof of the building causing injury to the operator or possible damage to the building. The height of this substation acceptable as mentioned in section 4.1 above.
- The substation floor is covered in fine grain dust which indicates that grain duct enters the substation through the existing door louvers.
- No fire extinguishers and fire signage in substation

6.2.2.1.2 Substation 2:

- There is not enough working space for MV and LV as informed by the NEC recommendations discussed in above section 4.1. Racking space in front of the MV panels is less than the recommended as per NEC standards.
- The general electrical lighting and power condition of the substation does need some refurbishment.
- The lighting is all fluorescent fittings which are in working condition but no emergency lighting.
- The substation room height requirements are generally necessitated by the space required between the top of the MV switchgear and the roof. In case of the internal fault, the height of the roof has significant impact as the hot gasses can bounce off the roof of the building causing injury to the operator or possible damage to the building. The height of this substation acceptable as mentioned in section 4.1 above.
- The substation floor is covered in fine grain dust which indicates that grain duct enters the substation through the existing door louvers.
- No fire extinguishers and fire signage in substation

6.2.2.1.3 Junction Tower MS:

- The minisub is located at the quayside and is good a and working conditions.

6.2.2.2 Design and Technology Compliance

6.2.2.2.1 Substation 1:

- For installations with oil Filled transformers, SANS 10142-2 requires that adequate provision shall be made for containing oil in case of leakages or spillages. Figure 2 shows an installation without an oil containment with some evidence of experienced leakages. The spill oil can also gain access to cable trenches which is in addition not acceptable, see *Figure 2*.
- The type of switchgear employed in this substation is that of an oil insulated switchgear, which is no longer available in the industry and maybe posing a challenge in getting spares when required. Protection relays utilised in the substation are no longer available for spares leading to retrofitting that could lead to a series of protection errors due to compatibility of the new retrofitted relays with the up/downstream protection relays as seen on *Figure 3*.
- The racking procedure for this type of switchgear may lead to poor contact which may cause internal arcing that may be harmful to the maintenance personnel when racking/operating the circuit breakers. See *Figure 3*. There is no record of switchgear type provision of internal arc protection system and arc quenching making them non-compliant with IEC 62271.
- All MV reticulation are of paper insulation and because of the grain dust the insulation has badly been affected which is a risk for more flash overs.
- There are no found records for routine tests and checks for the transformers.
- The LV board is an old type and it is made of fuses. The cable entry is bottom and cable management is that of trenching. Voltmeters and Ammeters are operational which makes an ease of analysing the day to day actual voltage and current demand. The LV board is fed from Transformer 2 and Transformer 1. The LV switchgear makes

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- use of the fuse technology, which is not recommended as per the reasons discussed in Section 4.1.
- The positive pressurising ducted system is non-operational and the door grilles allows fine grain dust through which contaminates the electrical panel and causes a big risk in terms of dust explosions.



Figure 2 Distribution transformer with no oil containment provision



Figure 3 Medium Voltage Oil Insulated Switchgear

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6.2.2.2.2 Substation 2:

- For installations with oil Filled transformers, SANS 10142-2 requires that adequate provision shall be made for containing oil in case of leakages or spillages. There is no oil containment for this substation. There is excess grain dust in the transformer room because the rooms are not dust protected.
- The type of switchgear employed in this substation is that of an oil insulated switchgear, which is no longer available in the industry and maybe posing a challenge in getting spares when required. Protection relays utilised in the substation are no longer available for spares leading to retrofitting that could lead to a series of protection errors due to compatibility of the new retrofitted relays with the up/downstream protection relays as seen on Figure 3.
- The racking procedure for this type of switchgear may lead to poor contact which may cause internal arcing that may be harmful to the maintenance personnel when racking/operating the circuit breakers. See Figure 3. There is no record of switchgear type provision of internal arc protection system and arc quenching making them non-compliant with IEC 62271
- Over and above the usage of old technology, this substation is out of service because of MV circuit breakers 12, 13, 14, and 15 located at the 12th floor have exploded due to a fault, see *Figure 4*. By visual inspection it is suspected that the switchgear has exploded due to excess dust in the substation. Since these circuit breakers are out of service, MV incomers are connected directly to the transformers 13 and 14 which means that there is no transformer protection.
- All MV reticulation are of paper insulation and because of the grain dust the insulation has badly been affected which is a risk for more flash overs.
- There are no found records for routine tests and checks for the transformers.
- The LV board is an old type and it is made of fuses, see *Figure 5*. The LV supply is of the busbar system which is not best practice. Voltmeters and Ammeters are operational which makes an ease of analysing the day to day actual voltage and current demand. The LV board is fed from Transformer 2 and Transformer 1. The LV switchgear makes use of the fuse technology, which is not recommended as per the reasons discussed in Section 4.1.
- The substation uses very old and obsolete power factor correction equipment, see *Figure 6*.
- There are very old and obsolete resistance starters for bucket elevators, fans and chain elevators, are fed from oil circuit breakers in the LV distribution room. These units regularly burn out under load and replacement banks are not of the same resistance, see *Figure 7*.
- The positive pressurising ducted system is non-operational and the door grilles allows fine grain dust through which contaminates the electrical panel and causes a big risk in terms of dust explosions.

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Figure 4 MV Switchgear exploded and out of service



Figure 5 Old LV switchgear of fuse technology and working space

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Figure 6 Old and Obsolete Power Factor Correction



Figure 7 Old and Obsolete Resistor Starters technology

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6.2.2.2.3 Junction Tower MS:

- No issues have been noted for this minisub

6.2.3 Recommendations

6.2.3.1 Room Layout

6.2.3.1.1 Substation 1:

- Racking space in front of the MV panels is within the recommended NEC standards.
- The general electrical lighting and power condition of the substation does need some refurbishment and upgrade to conform to safety South African Standards.

6.2.3.1.2 Substation 2:

- The installation of new and modern technology switchgear will eliminate the space constraint issues for this substation. Modern MV and LV switch is very compact and much smaller in size.
- The general electrical lighting and power condition of the substation does need some refurbishment and upgrade to conform to safety South African Standards.

6.2.3.2 Design and Technology Compliance

6.2.3.2.1 Substation 1 and Substation 2:

- Supply and install gas insulated (GIS) Medium Voltage switchgear and match the existing VCB specification. The GIS shall incorporate for overload and earth fault protection in accordance to OHS Act of 1993, IEC62271-200, and SANS 10142-2. This MV panel shall be equipped with arc detection and quenching system, circuit breaker failure protection. This is the latest trend in the safety standard which has been the introduction of the IEC 62271-200 standard. See above section 4.1 for literature review on GIS.
- Supply and install differential relays and other protection relays upstream to the latest digital models and carry out protection grading on the new installed relays.
- The transformer room shall be designed and constructed with ventilation and bund walls around for oil containment requirements in accordance with OHS Act 1993 Safety regulation and SANS 10142-1&2 and the fire design requirements.
- A barrier shall be fitted to separate the MV and LV plant. See section 4.1.2. The rearrangement shall be such that a minimal disruption to the reticulation system is achieved to help avoid cable joints.
- All LV switchgear to be upgraded to Moulded Case Circuit Breaker (MCCB) and Miniature Circuit Breaker (MCB) and incorporate overload and earth fault protection in accordance to SANS 10142-1.
- Upgrade battery charger panel and batteries to 110 Volt (Ni-Cd type, maintenance free batteries), equal or similar approved to Alcad Vantex battery with 20years services life.
- Upgrade differential relays and other protection relays upstream to the latest digital models and carry out protection grading on the new installed relays.
- Upgrade fire protection system to new technology to be in line with the latest fire compliance and latest regulation requirements.
- At a later stage an upgrade substation lighting to latest energy efficient technology and lux levels and uniformity to meet the standards of SANS 10114-1 Interior lighting Part 1: Artificial lighting of interiors

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- The transformers (oil) have no labels showing the latest testing. Routine tests are advised by the investigation team.
- Install new three core XLPE cables to the grain elevator substations due to the deteriorated PILC cables.
- Installation of new power factor correction.
- Sort out the environmental operation of the switchgear which means the substation must get positively pressurized and install with filter fans and dehumidifiers so that the environment of the substation can become conducive to the switchgear installed. Sealing the substation is also recommended to prevent sea water mist and dust from entering the substation. Heat shrink the busbars including the terminations and all nuts and bolts on the switchgear.
- All switchgear compartments to be fitted with Anti-condensation heaters as they prevent humidity amongst other advantages. The substation is not climatically controlled.
- Testing of the earthing and bonding systems.
- Include a thermography analysis as part of the routine tests to detect abnormal temperatures or changes in temperature that may indicate problems in their incipient stages. Serious failures and outages may be avoided when problems can be identified and remedied early. Early detection permits more effective maintenance planning and scheduled outages.
- As part of the refurbishments, the contractor shall redo the floor finishes of all the substations and paint the walls as required.'
- Undertake a new power system protection and load flow study to complement the recommended substation upgrades.
- The positive pressurising ducted system with its intake and filter box needs to be cleaned internally, pressure tested and reinstated.
- The supply fan and filter at supply needs to be replaced.
- Fire extinguishers and fire signage to be mounted on walls in substation
- Fire gas suppression systems to be installed as best practice (not statutory requirement).

7 Conclusion

A conditional assessment for Grain Elevator substations was conducted by the Electrical and Mechanical Engineering team from TPT. This report mainly discusses the findings and recommendations to comply with the requirements of the enforced regulations for substations. Designs of building modifications, switchgear and reticulation system are required to precede the proposed supply and installations as upgrades. A cost estimate was derived from the recommendations and included as part of this report in *Annexure 1*. There were no apparent structural and civil engineering problems noted and allowance has not been made on the budget.

The Investigation team commends that the business supports and approve funding to undertake the required upgrades.

8 References

1. *Richard Blakeley, August 2012, Oil Circuit Breaker Retrofit and Switchgear Safety Solutions.*
2. *Bryan Johnson, 2013, Development of Standards for MV Switchgear Rated for Arc Protection.*
3. *Tony Parsons, 02/2007, A comparison of Circuit Breakers and Fuses for low Voltage Applications*
4. *GAPS Guidelines 5.9.0.2, Transformer Failures.*



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9 Annexure 1: Electrical Cost Estimate