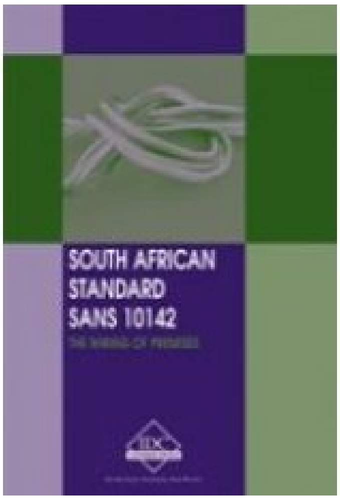
AS-E - South African Standard SANS 10142- The Wiring of Premises



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Short Description

South African Standard SANS 10142 - The Wiring of Premises is designed for electrical and instrumentation personnel, who have prior knowledge of electrical engineering this latest requirements of the standard. This manual is a must have for those working in the residential, commercial, or industrial electrical industry. Each Article of the Code is thoroughly discussed and reviewed in easy-to-understand language. This manual is designed to provide up to date information and training on the latest edition of South African Standard SANS 10142 - 'The Wiring of Premises'. Note: This manual is NOT the standard itself, it is a guide to the implementation of the standard.

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1 Distribution System Overview

This chapter gives brief information on 3-phase electrical systems and why they are used.

Different methods of generation, transmission and distribution of electricity are discussed. Different types of transformer and its connections are illustrated. Use of switching equipment and their different types are given. Circuit breakers for low voltages and for high voltages are discussed. The dangers of electricity and the need for safety in operations and maintenance is covered in detail.

Learning objectives

- Historical perspective of growth of 3-phase AC electrical system
- Generation, transmission and distribution
- Transformers
- Switching Equipment
- Circuit breakers LV and HV
- Dangerous of electricity
- Need for safety in operation and maintenance

1.1 Introduction

In distribution systems, three-phase systems are the most common; although for certain special jobs, a greater number of phases is also used. All modern generators are practically three-phase. For transmitting large amount of power, three-phase is invariable used. The reason for this is:

1. It is more efficient
2. It uses less material for given capacity
3. It costs less than single phase apparatus

For larger installations all three phases and the neutral are taken to the main distribution panel. From the three-phase main panel, both single and three-phase circuits may lead off.

This delay between 'phases' has the effect of giving constant power transfer over each cycle of the current, and also makes it possible to produce a rotating magnetic field in an electric motor. Figure 1.1 shows 3-phase connections of transmission lines.

Figure 1.1

3-phase connections

1.2 Methods of generation of electricity

At the power station, an electrical generator converts mechanical power into a set of alternating electric currents, one from each electromagnetic coil or winding of the generator.

The popular methods of power generation by conventional methods are:

- Thermal
- Hydro
- Nuclear

The alternative methods of generating electrical energy without the use of prime movers are called the non-conventional methods of power generation. For example:

- Solar cells
- Fuel cells
- Tidal power
- Wind power

As an example, at a coal-fired power plant in Laughlin, Nevada USA, owners of the plant ceased operations after declining to invest in pollution control equipment to comply with pollution regulations.

1.2.1 Electric generators

An electric generator consists of two main sections – the revolving section called the **rotor**, which is directly coupled to the steam turbine's drive shaft, and the stator, a series of wire coils, which form a cylinder around the rotor. The rotor, which is really an electro-magnet, revolves at high speed to generate electricity (alternating current) in the stator. A separate static exciter energizes the wire coils of the rotor.
A generator produces electricity. Figure 1.2 shows production of electricity.

Figure 1.2

Production of electricity

1.2.2 How electricity is made

Electricity has traditionally been generated from coal – a fossil fuel. The process to produce electricity from coal comes through stages, which are:

- Mining coal
- The boiler
- Steam turbine
- Electrical generator
- Transmission
- Impact on the environment

Mining coal

Coal is mined at open cut or underground mines, then crushed, washed and transported to power stations to be stockpiled and used as fuel.

The boiler

The pulverized coal is burned at very high temperature, converting water circulating in the boiler tubes into high-pressure steam.

Steam turbine

The steam produced by the boiler is injected at very high pressure into the turbine, spinning the fan-like blades mounted along the main drive shaft. This shaft continues like an axle from one end of the turbine to the other.

Hydroelectric generation

The principle of electricity generation is same in both hydro and thermal (steam) power stations. In a thermal station high-pressure steam produced drives horizontal turbines; water drives vertical turbines in a hydro station.

The generator produces alternating current (AC), which, after being increased in voltage via a transformer, is passed through a switchyard into the electricity grid.

1.3 Transmission of electricity

Generators output at a voltage that ranges from hundreds of volts to 30,000 volts. At the power station, transformers ‘step-up’ this voltage to one more suitable for transmission.

Transmission is done between the power plant and a substation near a populated area. Transmission normally takes place at high voltage (110 kV or above). Today, transmission-level voltages are usually considered to be 110 kV and above. Lower voltages such as 66 kV and 33 kV are usually considered sub-transmission voltages but are occasionally used on long lines with light loads. Voltages less than 33 kV are usually used for distribution. Voltages above 230 kV are considered extra high voltage (HV) and require different designs compared to equipment used at lower voltages.The power lost is proportional to the resistance and inversely proportional to the square of voltage.

DC systems require relatively costly conversion equipment which may be economically justified for particular projects. Single phase AC is used only for distribution to end users since it is not usable for large polyphase induction motors.

At the generating plants the energy is produced at a relatively low voltage (LV) of up to 30 kV then stepped up by the power station transformer to a higher voltage (138 kV to 765 kV AC, ± 250-500 kV DC, varying by country) for transmission over long distances to grid exit points (substations).

Transmitting electricity at high voltage (HV) reduces the fraction of energy lost to Joule heating. However, at extremely high voltages, more than 2000 kV between conductor and ground, corona discharge losses are so large that they can offset the lower resistance loss in the line conductors.

Electrical power is always partially lost by transmission. This applies to short distances such as between components on a printed circuit board as well as to cross country high voltage (HV) lines. The major component of power loss is due to ohmic losses in the conductors and is equal to the product of the resistance of the wire and the square of the current:

$P_{loss} = RI^2$

For a system which delivers a power, *P*, at unity power factor at a particular voltage, *V,* the current flowing through the cables is given by

Thus, the power lost in the lines,

Therefore, the power lost is proportional to the resistance and inversely proportional to the square of the voltage. A higher transmission voltage reduces the current and thus the power lost during transmission.

In addition, a low resistance is desirable in the cable. While copper cable could be used, aluminum alloy is preferred due to its much better conductivity to weight ratio making it lighter to support, as well as its lower cost. The aluminum is normally mechanically supported on a steel core.

1.4 Electrical distribution

Electricity distribution is the penultimate stage in the delivery (before retail) of electricity to end users. It is generally considered to include medium-voltage (less than 50 kV) power lines, electrical substations and pole-mounted transformers, low-voltage (less than 1000 V) distribution wiring and sometimes electricity meters.

Distribution networks are typically of two types,

- radial or

- interconnected

A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical of long rural lines with isolated load areas. An interconnected network is generally found in more urban areas and will have multiple connections to other points of supply.

Long feeders experience voltage drop requiring capacitors or voltage regulators to be installed, and the phase physical relationship to be interchanged.

Virtually all public electricity supplies are AC today. Users of large amounts of DC power such as some electric railways, telephone exchanges and industrial processes such as aluminum smelting either operate their own or have adjacent dedicated generating equipment, or use rectifiers to derive DC from the public AC supply.

Figure 1.3 shows the distribution of 3-phase electricity.

Figure 1.3

Distribution of electricity 3-phase connections

1.4.1 Modern distribution systems

The modern distribution system begins as the primary circuit leaves the sub-station and ends as the secondary service enters the customers meter socket. A variety of methods, materials, and equipment are used among the various utility companies , but the end result is similar. First, the energy leaves the sub-station in a primary circuit, usually with all three phases.

The most common type of primary is known as a wye configuration (so named because of the shape of a "Y".) The wye configuration includes 3 phases (represented by the three outer parts of the "Y") and a neutral (represented by the center of the ‘Y’.) The neutral is grounded both at the substation and at every power pole.

The other type of primary configuration is known as delta, this method is older and less common. Delta has only 3 phases and no neutral. In delta there is only a single voltage, between two phases (phase to phase), while in wye there are two voltages, between two phases and between a phase and neutral (phase to neutral). Wye primary is safer because if one phase becomes grounded, i.e. makes connection to the ground through a person, tree, or other object, it should trip out the fused cutout similar to a household circuit breaker tripping. In delta, if a phase makes connection to ground it will continue to function normally.

1.5 Transformers

A transformer is a device that transforms voltage from one level to another. They are widely used in power systems. With the help of transformers, it is possible to transmit power at an economical transmission voltage and to utilize power at an economically effective voltage.

1.5.1 The ideal transformer

The following assumptions are made in the case of an ideal transformer:

- No loss or gain of energy takes place
- Winding have no ohm resistances
- The flux produced is confined to the core of the transformer, which links fully both the windings, i.e. there is no flux leakage
- There are no I^2R losses and core losses
- The permeability of the core is high so that the magnetizing current required to produce the flux and to establish it in the core is negligible
- Eddy current and hysteresis losses are negligible

1.5.2 Types of transformers

Transformers can be classified in various ways:

- By the type of construction:
- *Core type:*Windings surround a considerable part of the core
- *Shell type:*Core surrounds a considerable portion of the windings
- By cooling type:
- *Oil filled self-cooled:*Small and medium sized distribution transformers
- *Oil filled water-cooled:*High voltage (HV) transmission line outdoor transformers
- *Air blast type:*Low voltage (LV) transformers
- By application:
- *Power transformer:*These are large transformers used to change voltage levels and current levels as per requirement. Power transformers are usually used in either a distribution or a transmission line
- *Potential transformer:*These are precision voltage step-down transformers

used along with low range voltmeters to measure high voltages

- *Current transformer:* These transformers are used for the measurement of current where the current carrying conductor is treated as a primary transformer. This transformer isolates the instrument from high voltage (HV) line, as well as step down the current in a known ratio
- *Isolation transformer:* These are used to isolate two different circuits without changing the voltage level or current level

Here are a few important points about transformers:

- Used to transfer energy from one AC circuit to another
- Frequency remains the same in both the circuits
- No ideal transformer exists
- Also used in metering applications (current transformer i.e. CT, potential transformers, i.e. PT)
- Used for isolation of two different circuits (isolation transformers)
- Transformer power is expressed in VA (Volt amperes)
- Transformer polarity is indicated by using dots. If primary and secondary windings have dots at the top and bottom positions or vice versa in diagrams then it means that the phases are in an inverse relationship

1.5.3 3-phase transformers

Previously, it was common practice to use three single-phase transformers in place of a single 3-phase transformer. However, the consequent evolution of the 3-phase transformer proved space saving and economical as well.

A 3-phase transformer is a combination of three single-phase transformers with three primary and three secondary windings mounted on a core having three legs. Commonly used 3-phases are:

- 3-phase three wire (Delta)
- 3-phase four wire (Star)

Delta connection

Generally, the Delta 3-wire system is used for an unbalanced load system. The 3-phase voltages remain constant regardless of load imbalance (see Figure 1.4).

Figure 1.4

3- phase transformer delta connection on primary side

The relationship between line and phase voltages is:

$V_L = V_{ph}$

where

V_L Line voltage

V_{ph} Phase voltage

The relationship between line and phase currents is:

I_L = Ö3 I_{ph}

where

I_L Line current

I_{ph} Phase current

3-Phase 4-wire star connections

The star type of construction allows a minimum number of turns per phase (since phase voltage is 1/Ö3 of line voltage), so it is the most economical method. Each winding at one end is connected to a common end, like a neutral point; therefore, on the whole there are four wires.

This connection works satisfactorily only if the load is balanced. With unbalanced load to the neutral, the neutral point will drift causing unequal phase voltages (see Figure 1.5).

Figure 1.5

Three phase 4-wire transformer star connection

The relationship between line and phase voltages is:

$\mathbf{V_L = Ö3\ V_{ph}}$

where

V_L Line voltage

V_{ph} Phase voltage

And the relationship between line and phase currents is:

$\mathbf{I_L = I_{ph}}$

where

I_L Line current

I_{ph} Phase current

For the output power of a transformer in kW, we use:

where

V_L Line voltage

I_L Line current

Cos f power factor

Possible combinations of star and delta

The primary and secondary windings of three single-phase transformers or a 3-phase transformer can be connected in the following ways:

- Primary in delta – secondary in delta
- Primary in delta – secondary in star
- Primary in star – secondary in star
- Primary in star – secondary in delta

Figure 1.6 shows the various types of connections of 3-phase transformers. On the primary side, V is the line voltage and I the line current. The secondary sideline voltages and currents are determined by considering the ratio of the number of turns per phase

(a = N1/N2) and the type of connection.

Table 1.1 gives a quick view of primary line voltages and line currents and secondary phase voltages and currents.

The power delivered by the transformer in the ideal condition irrespective of the type of connection = ?3.$V_{L.}$ I_L assuming cosf = 1.

Figure 1.6

Types of connections for 3-phase transformers

Table 1.1

View of primary line voltages and line currents and secondary phase voltages and currents

Connection	**Line Voltage**	**Line Current**	**Phase Voltage**	**Phase Current**
(a) Delta-Delta				
Primary Delta	V	I	V	I / 1.732
Secondary Delta	V/a	Ia	V/ a	Ia / 1.732
(b) Delta-Star				
Primary Delta	V	I	V	I / 1.732
Secondary Star	1.732V/a	Ia / 1.732	V/a	Ia / 1.732
(c) Star-Star				
Primary Star	V	I	V / 1.732	I
Secondary Star	V/a	Ia	V / 1.732 a	Ia
(d) Star-Delta				
Primary Star	V	I	V / 1.732	I
Secondary Delta	V/ 1.732 a	1.732 Ia	V / 1.732 a	Ia

1.6 Switching

Switching is an operation intended to switch on or off or vary the supply of electrical energy to all or part of an installation for normal operating purposes, for

example a contactor. Table 1.2 shows different switching methods.

Table 1.2

Different switching methods and its purpose

Provision	Purpose	For
Switching off for mechanical maintenance	To enable non-electrical work to be carried out on switched circuit safely	Non-electrical skilled p
Emergency switching	To rapidly cut off electrical energy to remove any unexpected hazards	Anyone
Functional switching	To enable proper functioning and control of current using equipment	Installation user

1.6.1 Switching Equipment

We will now take a look at some of the switching equipment you may come across.

Elementary switching devices

- **Disconnector (**or isolator): This switch is a manually operated, lockable, two-position device (open/closed) which provides safe isolation of a circuit when locked in the open position. A disconnector is not designed to make or to break current and no rated values for these functions are given in standards. It must, however, be capable of withstanding the passage of short-circuit currents and is assigned a rated short time withstand capability, generally for 1 second, unless otherwise agreed between user and manufacturer.
- **Load-breaking switch**: This control switch is generally operated manually (but is sometimes provided with electrical tripping for operator convenience) and is a non-automatic two-position device (open/closed). It is used to close and open loaded circuits under normal unfaulted circuit

conditions. Consequently it does not provide any protection for the circuit it controls. See Figures 1.7 and 1.8.

Figure 1.7

Symbol of disconnector

Figure 1.8

Symbol of load breaking switch

- **Contactor:**The contactor is a solenoid-operated switching device. Contactors are designed to carry out numerous close/open cycles and are commonly controlled remotely by on-off push buttons.
- **Discontactor:**A contactor equipped with a thermal-type relay for protection against overloading defines a ‘discontactor’. Discontactors are used extensively for remote push-button control of lighting circuits, etc., and may also be considered as an essential element in a motor controller. The discontactor is not the equivalent of a circuit breaker; since its short-circuited current breaking capability is limited. For short-circuit protection therefore, it is necessary to include either fuses or a circuit breaker in series with, and upstream of, the discontactor contacts. See Figures 1.9 and 1.10.

Figure 1.9

Symbol of bistable remote control switch

Figure 1.10

Symbol for contactor

1.7 Circuit breakers

A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage (HV) circuits feeding an entire city.

The circuit breaker is the only item of switchgear capable of simultaneously satisfying all the basic functions necessary in an electrical installation. It can provide a wide range of other functions, for example: indication (on-off - tripped on fault); under voltage tripping; remote control, etc. These features make a circuit breaker the basic unit of switchgear for any electrical installation. Table 1.3 shows circuit breakers functions.

Table 1.3

Circuit breaker function

Function	**Possible condition**	
Isolation		Y
Control:	Functional	Y
	Emergency switching	Y
	Switching off for mechanical maintenance	Y
Protection:	Overload	Y
	Short circuit	Y
	Insulation fault	(With differential curre
	Under voltage	(With undervoltage trip

1.7.1 Types of circuit breakers

Just like transformers, circuit breakers too can be classified in various ways.

Depending on operation

- **Magnetic circuit breakers:**implemented using a solenoid (electromagnet) whose pulling force increases with the current. The circuit breaker's contacts are held closed by a latch and, as the current in the solenoid increases beyond the rating of the circuit breaker, the solenoid's pull releases the latch which then allows the contacts to open by spring action.

- **Thermal breakers:**use a bimetallic strip, which heats and bends with increased current, and is similarly arranged to release the latch. This type is commonly used with motor control circuits. Thermal breakers often have a compensation element to reduce the effect of ambient temperature on the device rating.
- **Thermomagnetic circuit breakers:**which are the type found in most distribution boards, incorporate both techniques with the electromagnet responding instantaneously to large surges in current (short circuits) and the bimetallic strip responding to less extreme but longer-term overcurrent conditions.

Depending on voltage

- Low voltage (LV) (less than 1000 V) can be either

1. **MCB (Miniature Circuit Breaker**)—rated current not more than 100A.Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers are in this category.
2. **MCCB (Moulded Case Circuit Breaker)—**rated current up to 1000 A Thermal or thermal-magnetic operation. Trip current may be adjustable.

Many designs of LV circuit-breakers feature a short-circuit current limitation capability, whereby the current is reduced and prevented from reaching its (otherwise) maximum peak value .The current- limitation performance of these CBs is presented in the form of graphs, typified by that shown in Figure 1.11.

Figure 1.11

Performance curves of a typical LV current-limiting circuit breaker

- High voltage (HV) circuit breakers: Electric power systems require the breaking of higher currents at higher voltages. Examples of high-voltage AC circuit breakers are:

1. **Vacuum circuitbreaker** —With rated current up to 3000 A, voltages up to about 35,000V.Vacuum circuit breakers tend to have longer life than air circuit breakers. These breakers interrupt the current by creating and

extinguishing the arc in a vacuum container. These can only be practically applied for voltages up to about 35,000 V, which corresponds roughly to the medium-voltage range of power systems. Vacuum circuit breakers tend to have longer life expectancies between overhaul than do air circuit breakers.

1. **Air circuit breaker** — Rated current up to 10,000 A. Often used for main power distribution in large industrial plant. Trip characteristics are often fully adjustable including configurable trip thresholds and delays. Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.

H V breakers can also be classified by the medium used to extinguish the arc:

- Oil-filled (dead tank and live tank)
- Oil-filled, minimum oil volume
- Air blast
- Sulfur hexafluoride

High voltage (HV) breakers are routinely available up to 765 kV AC.

1.7.2 Selection of a circuit breaker

The choice of a CB is made in terms of:

- Electrical characteristics of the installation for which the CB is intended
- Its eventual environment: ambient temperature, in a kiosk or switchboard enclosure, climatic conditions, etc.
- Short-circuit current breaking and making requirements.
- Operational specifications: discriminative tripping, requirements (or not) for remote control and indication and related auxiliary contacts, auxiliary tripping coils, connection
- Installation regulations; in particular: protection of persons.
- Load characteristics, such as motors, fluorescent lighting, LV/LV transformers.
- The rated current of a circuit breaker is defined for operation at a given ambient temperature, in general: type CBs,b 30°C for domestic-type CBs,b 40°C for industrial-type CBs.

Figure 1.12

A typical LV current-limiting circuit breaker

1.8 Electrical hazards

Hazards from electrical equipment can be any of the following:

Primary hazards

- Electric shock and associated effects
- Fire

Secondary Hazards

- Internal organ damage due to passage of electricity through body
- Burns on skin at point of contact
- Injuries by electric shock combined with fall
- Temperature hazards due to high temperature during operation
- Arc flash causing external burns and injuries by explosive expansion of air due to the arc.

Table 1.4 shows the safety hazards posed by electrical equipments commonly used in electrical generation and distribution systems and substations.

Table 1.4

Types of equipment and hazards associated with it

Type of Equipment	**Hazards**
Generation equipment	Electric shock, arc flash, mechanical ha
Transformers	Electric shock, arc flash, fire hazard
Overhead transmission/distribution lines	Electric shock, arc flash, fall from heigh
Cables	Electric shock, arc flash, fire hazard
Bus ducts	Electric shock, arc flash, thermal hazar
Distribution equipment	Electric shock, arc flash, thermal hazar hazard
Motive equipment	Electric shock, arc flash, thermal hazar mechanical hazards
Heating equipment	Electric shock, arc flash, thermal hazar
Lighting equipment	Electric shock, arc flash, thermal hazar heights
Uninterruptible power supplies with battery	Electric shock, arc flash, hazards from liquids and explosive gases

1.8.1 Hazardous conditions

Direct contact: Contact with exposed current carrying parts

- Maintenance process - need to open up enclosure
- Defective/damaged enclosure or insulation materials
- Unsafe design
- Maintenance people are more at risk

Indirect Contact: Contact with energized conductive parts

- Electric/Ground faults
- Leaking out of electricity
- All users are at risk

1.9 Electrical accidents and safety measures

We will briefly discuss in this section why electrical accidents happen and how we can avoid them. These points will be elaborated in subsequent chapters in further detail. Electrical accidents happen mostly as a result of the following:

- Failure to isolate or inadequate or insecure isolation of live parts (60%)
- Poor maintenance and faulty equipment (30%)
- Insufficient information about the system being worked on
- Carelessness and lack of safety procedures

Isolation measures and work on/near live equipment

Isolating normally live equipment before starting any work on it can improve safety substantially in any system. We must however bear in mind that there are certain kinds of equipment where live work is possible and certain kinds of activities where work in the vicinity of exposed live parts is unavoidable. But such work must be carried out according to well laid safety procedures.

Eliminate faults to improve safety

The other major cause of accidents is faulty equipment (which can include both poorly designed or improperly operating equipment). Unless safety is built into the design of the equipment, it can result in accidents and injury. Similarly, improperly maintained equipment too can result in failures and thereby cause accidents.

Improved knowledge level

Operating personnel with insufficient knowledge, lack of familiarity with equipment and system can also result in unsafe situations. Absence of proper operational safety procedures and violations of existing procedures can both result in accidents.

1.9.1 Safety measures

The following are some general safety measures, which should be adopted to reduce the possibility of accidents in electrical equipment.

Technical measures

- Safe design/installation of plant and equipment as per applicable codes and regulations
- Posting clear warning signs at points of hazard
- Use of equipment/sensors to warn incipient problems with automated hazard containment measures

Accident prevention measures

- Safe operating and maintenance practices established through documented procedures and instructions
- Proper periodic inspection and prompt repairs
- Use of personal safety equipment mandated in safety procedures
- Avoiding live or hot work except as mandated in the relevant codes of practice and carried on using the stipulated procedures and precautionary measures.

Organizational measures

- Creating an organizational safety structure to handle safety issues, lapses and accidents
- Documenting the procedures required to operate and maintain different electrical installations in a work place, reviewing them vis-à-vis the various applicable regulations and updating them to keep these procedures in step with regulatory changes
- Appropriate knowledge on the part of workers by proper structured training
- Establishing the requirements for levels of competence for operating electrical equipment, carrying out or supervising the issue of work-permits

to work on equipment and for normalization of system after completion of work and carrying out or supervising maintenance work on equipment on which a permit-to-work has been issued.

- Creating and enforcing a system for certification of personnel in accordance with the competence levels demanded by their duties.
- Create and encourage safety awareness among the workforce

We will discuss these measures in detail in the ensuing chapters.

1.10 Periodic inspection and maintenance

The objective of periodic inspection and maintenance is to determine whether an installation is in a satisfactory condition for continued service. Periodic inspection should comprise careful scrutiny of the installation without dismantling or with partial dismantling as per the scope decided by a competent person based on availability of records and the condition of the installation. Inspection will generally be along the lines followed for initial verification. The following aspects need to be carefully examined:

1. Safety of persons/livestock against electrical hazards
2. Protection against damage that can arise from a defect in the installation

- Confirmation that the installation has no defects that impair safety

1. Identification of any defects/non-compliance with Regulations in the installation which may give rise to danger
2. To ensure protection of property from fire and heat.

The person carrying out the work should give a Periodic Inspection report together with the schedule of inspection and the schedule of tests to the person ordering inspection. The record of defects/damage/non-compliance with regulations, etc. should be included in this report. The person carrying out the inspection will record the recommendation regarding the next appropriate date of inspection.

Circumstances, which require a periodic inspection and test can include:

- Test and inspection is due
- Insurance
- Mortgage
- Licensing reasons
- Change of use

- Change of ownership
- After additions and alterations
- After damage
- Change of loading
- To assess compliance with current regulations

General areas of inspection should be:

- Safety
- Wear and tear
- Corrosion
- Damage
- Overloading
- Age
- External influence
- Suitability
- Effectiveness

Safety measures for inspection:

1. Inspection should be carried out with supply disconnected, as it may be necessary to gain access to wiring enclosure, etc. and hence with large installations it will probably need considerable liaison with client to arrange convenient times for interruption of supplies to various parts of installations.
2. While testing protective conductors, these must not be disconnected unless the supply is isolated. This is important for main equipotential bonding conductors which need to be disconnected to allow for measurement.

Follow up measures

The defects revealed by periodic inspection reports should be attended to without delay to avoid unsafe situations. Apart from defect resolution, the following actions are also needed:

1. A planned schedule of preventive maintenance should be drawn up based on manufacturer's recommendation/code of practices and implemented rigorously. This will avoid too many defects from showing up during inspection.
2. Measures for condition based preventive maintenance may be adopted to attend to incipient problems and resolving the defects in early stages.

Examples: monitoring of oil parameters (online dissolved gas monitoring) in large transformers, hot-spot detection in indoor switchgear using infrared detectors, incipient arc fault detection through photoelectric sensors, etc.

While planned preventive maintenance is done according to a fixed schedule using a recommended list of maintenance works, condition based maintenance is pro-active and relies on early warning of problems. Even though this practice is well established in specific segments of mechanical machinery (such as vibration signature analysis in high speed machines), the applications in the electrical field are gradually becoming popular. The main benefit is need-based maintenance and preventing major unforeseen failures, both of which have major cost implications.

1.11 Summary

In 3-phase distribution systems, three circuit conductors carry three alternating currents (of the same frequency). This is a common method of electric power transmission. This system uses less conductor material to transmit electric power.

There are different methods available for power generation. Conventional methods are hydraulic, steam and diesel generation; non-conventional methods are nuclear, solar and wind power. Electric power is normally generated at 11-25kV in a power station.

A transformer is a device that transforms voltage from one level to another. With the help of transformers, it is possible to transmit power at an economical transmission voltage and to utilize power at an economically effective voltage. There are different types of transformer available depending on cooling type, construction and application.

Circuit breakers can provide a wide range of other functions, for example: indication (on-off - tripped on fault); under voltage tripping; and remote control. There are low voltage (LV) circuit breakers and high voltage (HV) circuit breakers available.

Electrical system hazards can be classified as primary i.e. electric shock and burns, and secondary hazards i.e. arc flash or internal organ damage. Safety precautions need to be taken whilst working on electrical systems. Electrical systems should be inspected periodically to avoid accidents. The objective of periodic inspection and maintenance is to determine whether an installation is in a satisfactory condition for continued service.