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CONSTRUCTION & CONTRACTING

GENERATION AND DISTRIBUTION OF ELECTRIC POWER SIMPLIFIED OVERVIEW

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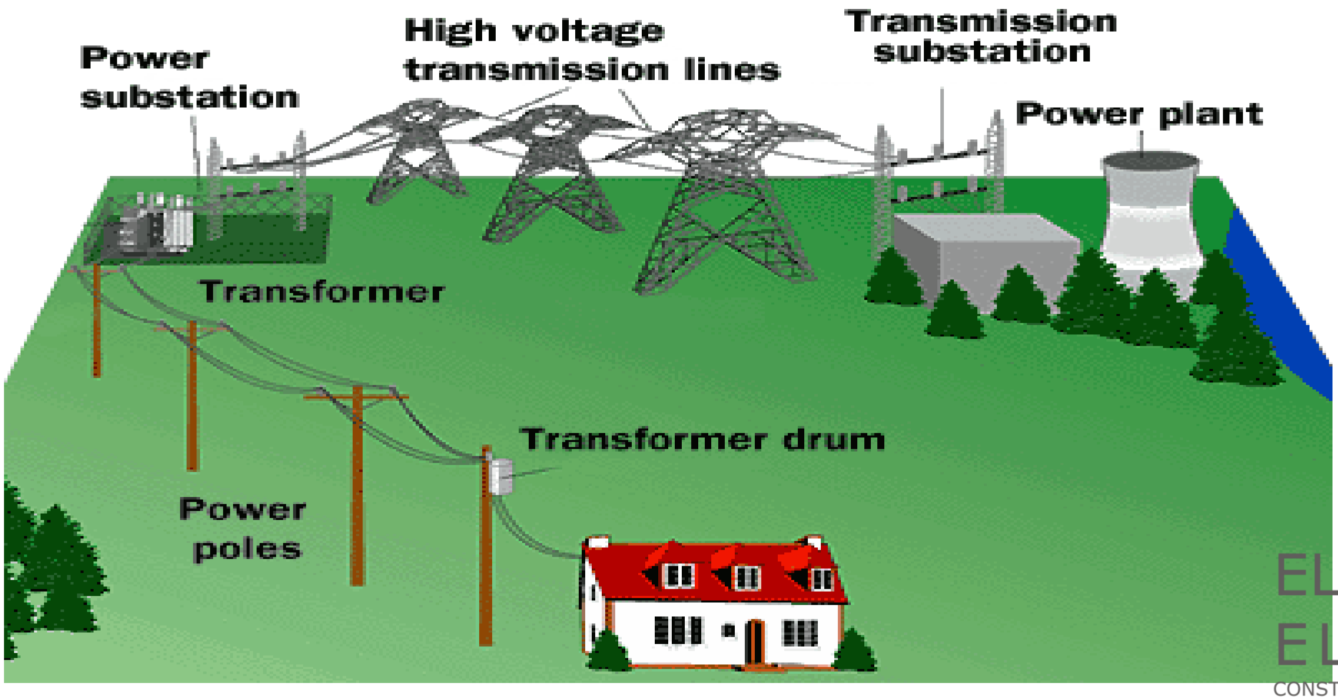
Electric power

- **Electric power**, often known as **power** or **electricity**, involves the production and delivery of electrical energy in sufficient quantities to operate domestic appliances, office equipment, industrial machinery and provide sufficient energy for both domestic and commercial lighting, heating, cooking and industrial processes.
- The following slides show briefly the journey of electrical power from the generation stage until it reaches to the end consumers.



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1- Generation of Electricity

Electricity generation is the first process in the delivery of electricity to consumers. The other three processes are electric power transmission, electricity distribution and electricity retailing.

Electricity has been generated for the purpose of powering human technologies for at least 120 years from various sources of potential energy. The first power plants were run on wood, while today we rely mainly on oil, natural gas, coal, hydroelectric and nuclear power and a small amount from hydrogen, solar energy, tidal harnesses, and wind generators.

1-1 Methods of generating electricity

Rotating turbines attached to electrical generators produce most commercially available electricity. Turbines may be driven by using steam, water, wind or other fluids as an intermediate energy carrier. The most common usage is by steam in fossil fuel power plants or nuclear power plants, and by water in hydroelectric dams. Small mobile generators are often driven by diesel engines, especially on ships, remote building sites or for emergency standby.

1-1-1 Fossil fuel power plant

- A **fossil fuel power plant(FFPP)** (also known as steam electric power plant in the US, thermal power plant in Asia, or power station in the UK) is an energy conversion center designed on a large scale for continuous operation. Just as a battery converts relatively small amounts of chemical energy into electricity for temporary or intermittent use, the FFPP converts the sun's energy stored in fossil fuels such as coal, oil, or natural gas successively into thermal energy, mechanical energy, and finally electric energy for continuous use and distribution across a wide geographic area. Each FFPP is a highly complex, custom designed system. Present construction costs (2004) run to $1300/kW, or $650 million USD for a 500 MWe unit. Multiple generating units may be built at a single site for more efficient use of land, resources, and labor.

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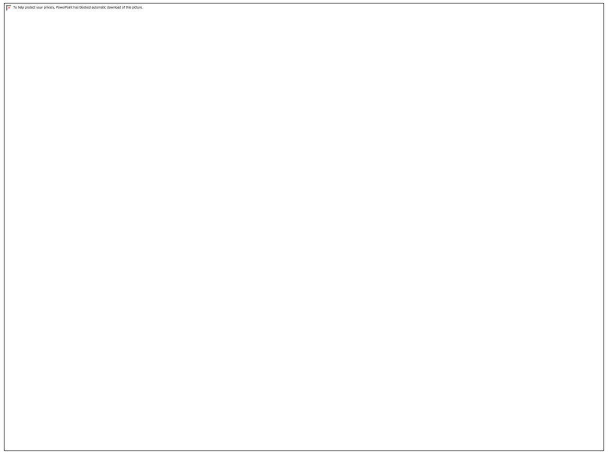
1-1-2 Nuclear power plant

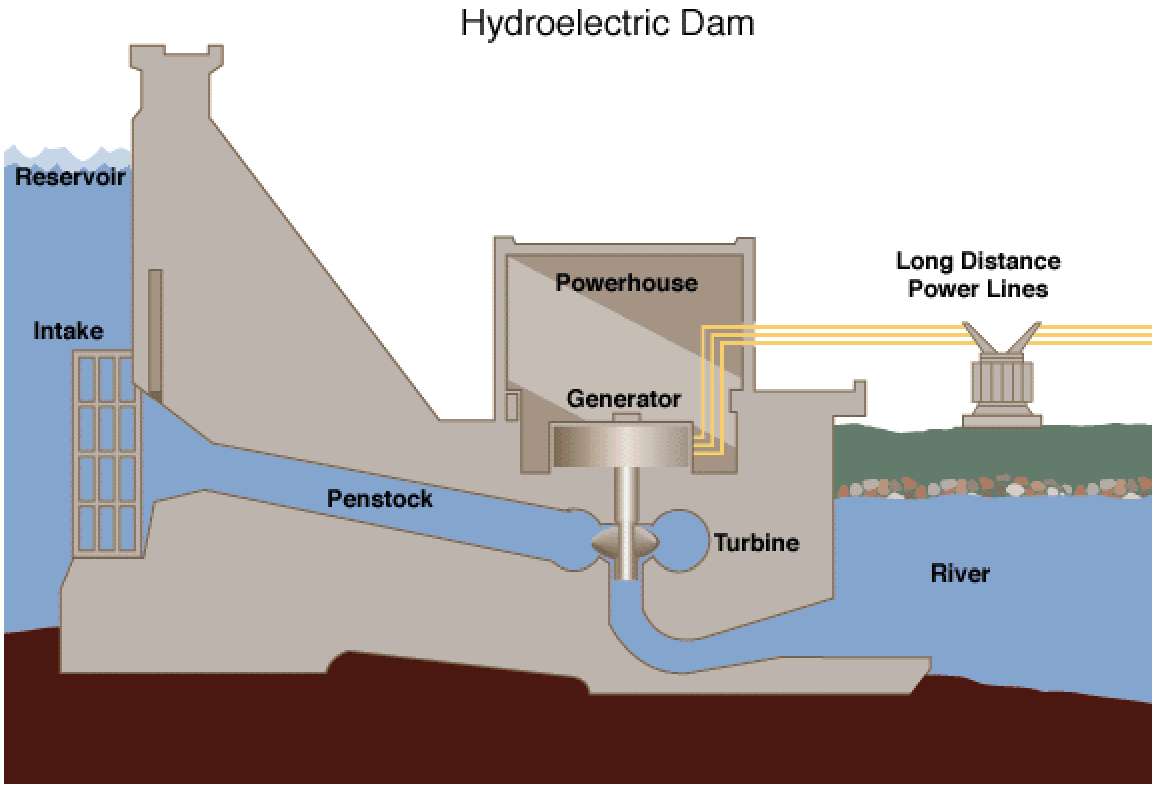
- A **nuclear power plant** (**NPP**) is a thermal power station in which the heat source is one or more nuclear reactors. Nuclear power plants are base load stations, which work best when the power output is constant. Their units range in power from about 40 MWe to almost 2000 MWe, typical of new units under construction in 2005 being in the range 600-1200 MWe.



A nuclear power plant in Cattenom, France. Most obvious in this picture are the large cooling towers. The two cylindrical buildings in the center house the nuclear reactors

1-1-3 Hydroelectricity

- **Hydroelectricity**, or **hydroelectric power**, is a form of hydropower, (i.e.,the use of energy released by water falling, flowing downhill, moving tidally, or moving in some other way) to produce electricity. Specifically, the kinetic energy of the moving water is converted to electrical energy by a water turbine driving a generator. Most hydroelectric power is currently generated from water flowing downhill, but a few tidal harnesses exist that draw power from the tide. Hydroelectric power is generated at dams or other places where water descends from a height, or coasts with a large tidal swing (such as the Bay of Fundy). Hydroelectricity is a renewable energy source, since the water that flows in rivers has come from precipitation such as rain or snow, and tides are driven by the rotation of the earth.



Hydroelectric dam in cross section

Itaipu Dam

Itaipu is a dam that includes the largest hydroelectric power plant in the world. It is situated between Brazil and Paraguay along the Paraná River.

The plant consists of 18 generator units of 700 MW (megawatts) each, allowing for a total output of 12,600 MW of power.

1-1-4 Diesel engine

- The **diesel engine** is a type of internal combustion engine in which the fuel is ignited by being suddenly exposed to the high temperature and pressure of a compressed gas containing oxygen (usually atmospheric air), rather than a separate source of ignition energy (such as a spark plug).
- The vast majority of modern heavy road vehicles (trucks), ships, long-distance locomotives, large-scale portable power generators, and most farm and mining vehicles have diesel engines.

2- Transmission of Electricity

Electric power transmission is the second process in the delivery of electricity to consumers. Electrical energy is generated by power plants and is then sold as a commodity to end consumers by retailers. The electric energy transmission and electricty ditribution networks allow the delivery of the generated electricity to consumers. The rapid industrialization in the 20th century made electrical transmission lines and grids a critical part of the economic infrastructure in most industrialized nations.

A transmission grid is made up of :
2-1 transmission circuits, and 2-2 power substations.
Energy is usually transmitted on the grid with 3-phase alternatig current (AC). The voltage level on the bulk power transmission system is typically between 115 kV and 765 kV. Energy may also be transmitted using high voltage direct current.

Electricity is usually sent over long distance through a combination of overhead power transmission lines and buried cables

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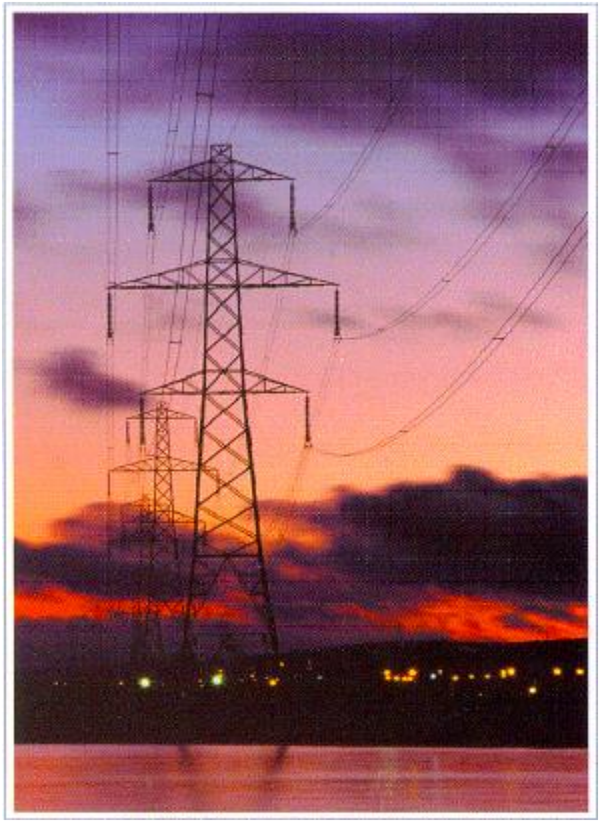
2-1-1 Over head transmission lines (OHTL)

A **transmission line** is the material meduim or structure that forms all or part of a path from one place to another for directing the transmission of energy, such as electromagnetic wave or acoustic waves. Example of transmission lines is wires.



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There are different types of over head conductors. The choice depends on the application. The following shows some of over head conductors types:

- Bare soft and hard drawn stranded

Soft drawn type is used for grounding electrical systems, while hard drawn type is used in over head distribution networks.

Copper Conductors

- All aluminium conductors

used for aerial distribute lines have relatively short spans, aerial feeders and bus bars of substations.

(A.A.C.)

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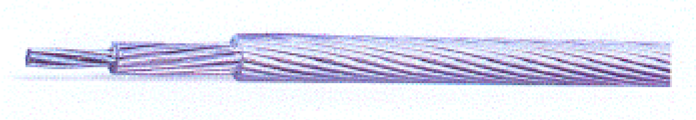
- All aluminium alloy conductors

  used for transmission and distribution networks, having relatively long spans.

(A.A.A.C.)

- Aluminium conductor steel reinforced

  used for power transmission over long distances



(A.C.S.R.)

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Conductors Comparison Between Different Types of Aluminum

(for 185 mm^2 Conductor as an example)

	AAC	AAAC	ACSR
Tensile (KN)	43.66	71.55	85.12
Weight (Kg/Km)	671.1	670.3	980.1

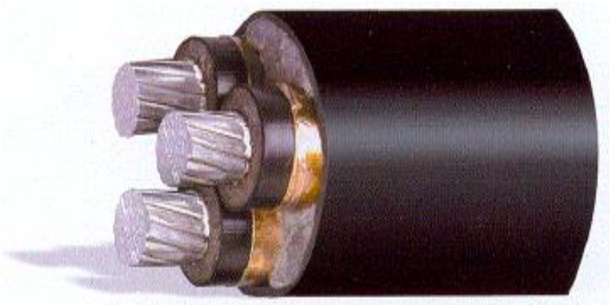
2-1-2 Cables

- **Power cable** (a type of electrical cable) is an assembly of two or more electrical conductors held together with, and typically covered with, an overall sheath. The conductors may be of the same or different sizes, each with their own insulation and possibly a bare conductor. Larger single conductor insulated cables are also called power cables in the trade. The sheath may be of metal, plastic, ceramic, shielded, sunlight-resistant, waterproof, oil-resistant, fire-retardant, flat or round, and may also contain structural supports made of high-strength materials.

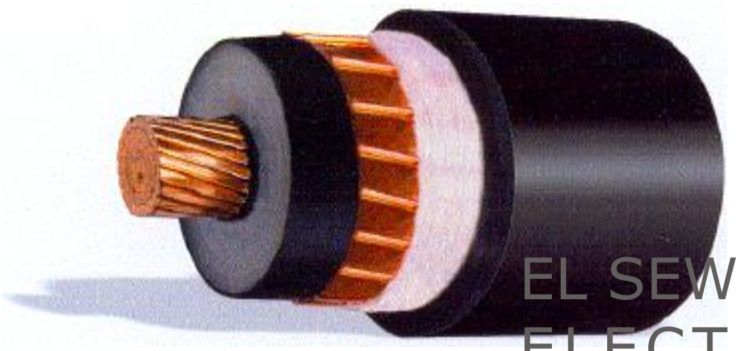
Cables are usually classified according to their operating voltage as follows:

1. Low voltage cables (up to 1kv).

2. Medium voltage cables (3kv up to 30kv).



3. High voltage cables (66kv up to 500kv).



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The strandard rated voltage of a cable is denoted by Uo/U (Um),

where

Uo : is the rated power-frequency voltage between conductor and earth or metallic screen.

U : is the rated power-frequency voltage between conductors.

Um : is the maximum continuously permissible operating voltage of a cable at time or in any part of the network.

Uo/U *(kV)*	0.6/1	1.8/3	3.6/6	6/10	8.7/15	12/20	18/30	38/66
Um *(kV)*	1.2	3.6	7.2	12	17.5	24	36	72.5

Note: Cable design for 6/10 and 18/30 kV is applicable for 6.35/11 & 19/33 kV respectively.

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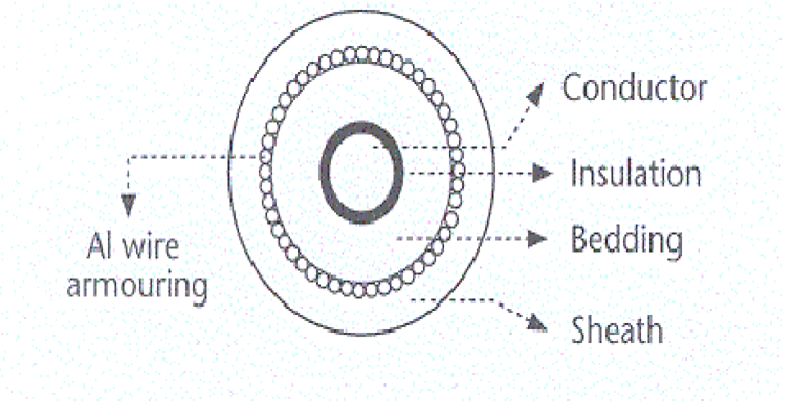
1- Cable Construction

The general construction of the cable is given below:

1. **conductor**
2. **Insulation**
3. **Assembly**
4. **Bedding**
5. **Armouring**
6. **sheath**



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Conductors

Comparison Between Copper And Aluminum

Aluminum requires larger conductor sizes to carry the same current as copper. For equivalent capacity, aluminum cable is lighter in weight and larger in diameter than copper cable.

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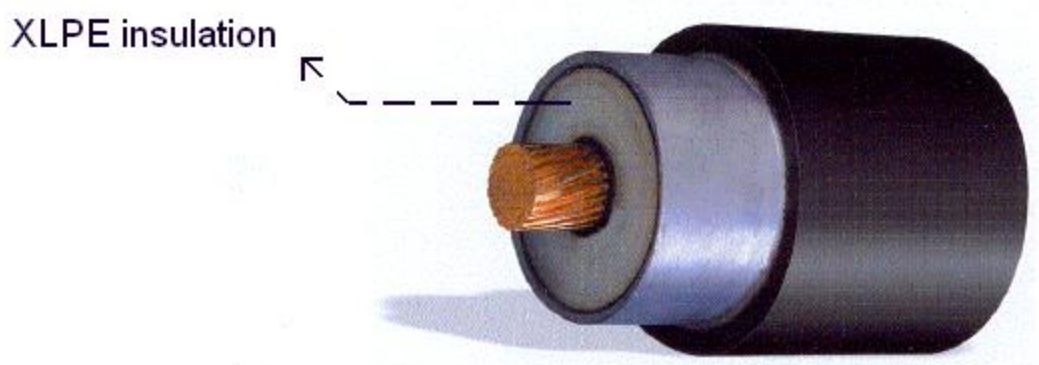
Comparison between single core and multicore cables:

For same cross sectional area, single core cables Ampacity is greater than that of multi-core cables. But from economics point of view multicore cables are preferred.

Insulation

The selection of a particular type of insulation to be used depends upon the purpose for which the cable is required and qualities of insulation to be aimed at. The following are the chief types of insulation groups that can be used:

1. Rubber
2. Polyethylene
3. Polyvinyl chloride (PVC)
4. Fibrous material
5. Silk, cotton, enamel.
6. XLPE



Armouring

Steel-Tape Armouring

A steel tape is provided over the bedding but They are not very flexible, and their use is limited where bending of the cables cannot be avoided.

Wire Armouring

It has been found that a single layer of wire Armouring provides better mechanical protection as against two layers of steel tape.

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SINGLE CONDUCTOR CABLES

PROBLEMS OF INDUCED VOLTAGES AND CURRENTS ASSOCIATED WITH THEIR USE.

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PROBLEMS OF INDUCED VOLTAGES AND CURRENTS ASSOCIATED WITH THEIR USE

The increased ampacity requirements and short-circuit capabilities of modern power systems have some problems.

It has become evident that there is a need for cable engineer to select the sheath-bonding method to fit a particular installation.

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Polymeric-Insulated Cables has a metallic Path for the fault current return.

The metallic path in the form of:

Helically applied wires or tapes .a

Solid metallic sheath .b

Combination between a and b. .c

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Bonding Methods

Solidly bonded and grounded sheaths are the simplest solution to the problem of sheath voltages.

Induced voltage will cause a circulating current to flow.

This current generates losses that appear as a heat.

These metal sheath losses reduce the amount of heat that can be assigned to the phase conductor.

Various methods of bonding may be used for the purpose of minimizing sheath losses.

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Special Bonding Methods

- The metallic sheath of a single conductor cable for a.c service acts as a secondary of a transformer.
- The current in the conductor induces a voltage in the sheath.
- The induced voltage causes current to flow in the completed circuit.
- Losses can be considered as a significance value affecting conductor ampacity.

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This problem of sheath losses becomes particularly important when large single conductor cables comprising a circuit are placed in separate ducts, or spacing between directly buried cables is increased to reduce the effects of mutual heating.

The major purpose of special sheath bonding for single conductor cables is the prevention or reduction of sheath losses.

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Any sheath bonding or grounding method must perform the following functions :

Limit sheath voltage. .1

Reduce or eliminate sheath losses. .2

Maintain a continuous sheath circuit to permit fault .3 current return.

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Conclusion:

There is no clear-cut point at which special bonding should be introduced and the extra cost of the larger conductor size cables needed for a solidly bonded system must be balanced against the cost of additional equipment and the maintenance cost arising from the grater complexity of a specially bonded systems.

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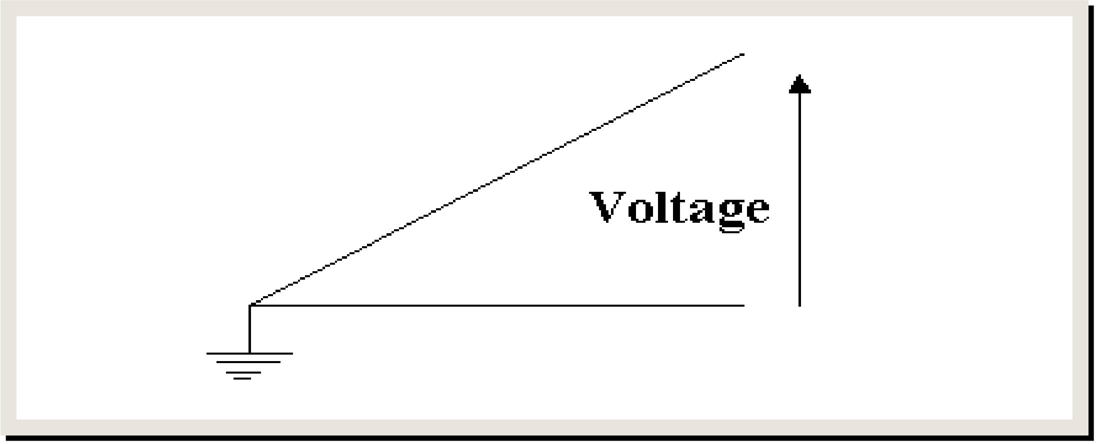
Special bonding systems

Single Point Bonding

The simplest form of single point bonding consists in arranging for the sheaths of the three cables to be connected and grounded at one point only.

At all other points a voltage will appear from sheath to ground that will be maximum at the farthest point from the ground point.



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It is recognized that this voltage will be greatly exceeded during system transients and short circuits.

Maximum sheath voltage permitted at full load varies between countries.

When the circuit length is such that the sheath voltage limitation is exceeded at one end of the circuit, this bond may be connected at some other point, for example the center of the length.

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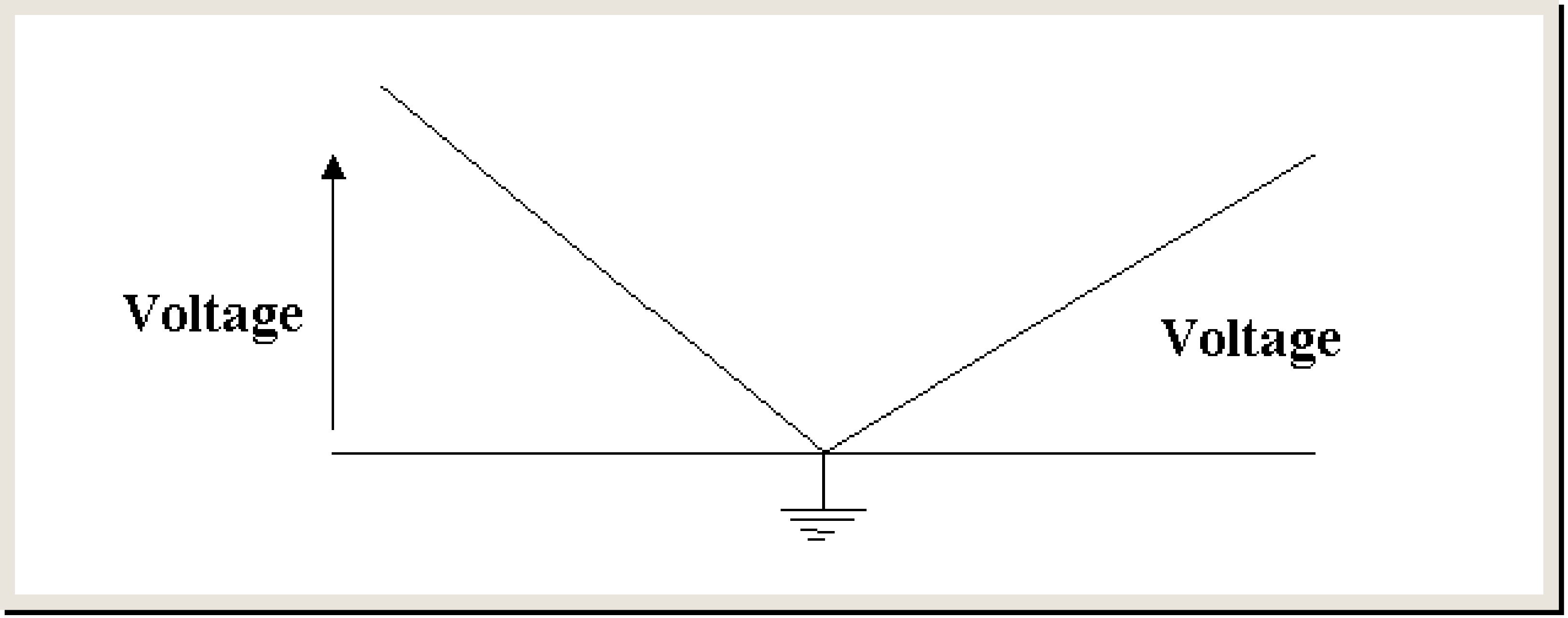
Single-Point Grounding near the center of cable run.



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Parallel Ground Continuity Conductor

During a ground fault on the power system the zero-sequence current carried by the cable conductor returns by whatever external paths are available.

Since a single-point bonded cable sheath is grounded at one position only, it cannot expect in the case of a cable fault carry any of the returning current.

A Parallel external conductor is available or is provided to serve as an alternative path and this conductor is grounded at both ends of the route. The size of the conductor must be suitable to carry the full expected fault current for the cable system.

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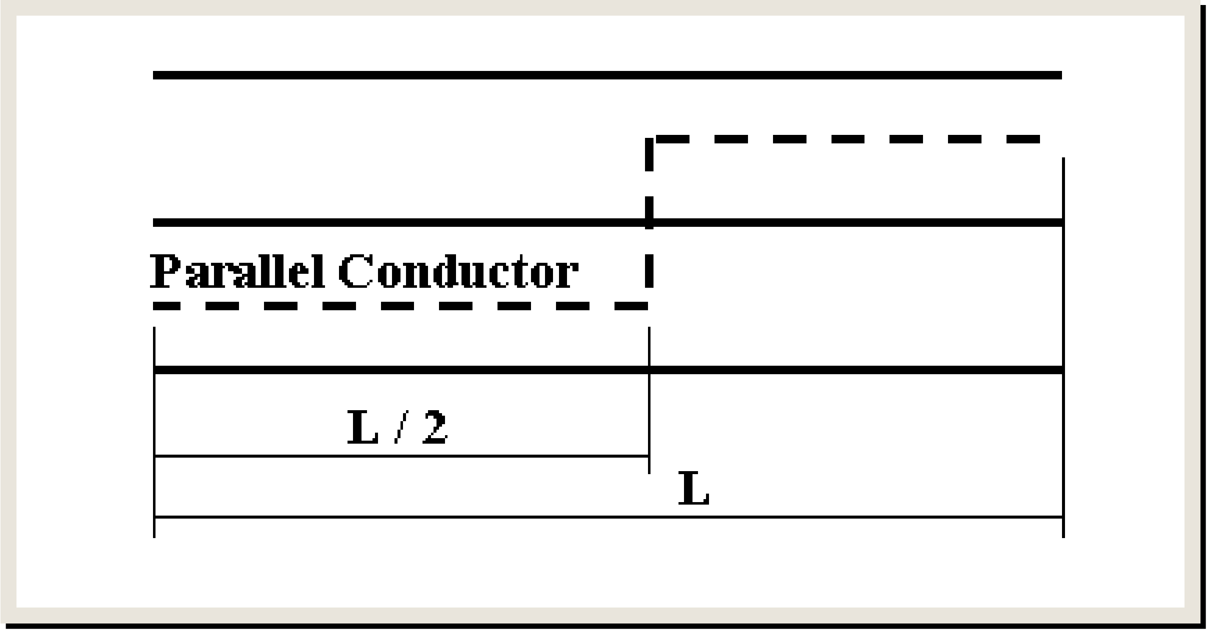
The parallel ground continuity conductor will be subject to voltage induction for power cables in the same way. To avoid circulating currents and losses in this conductor it is preferable when the power cables are not transposed, to transpose the parallel ground continuity conductor.



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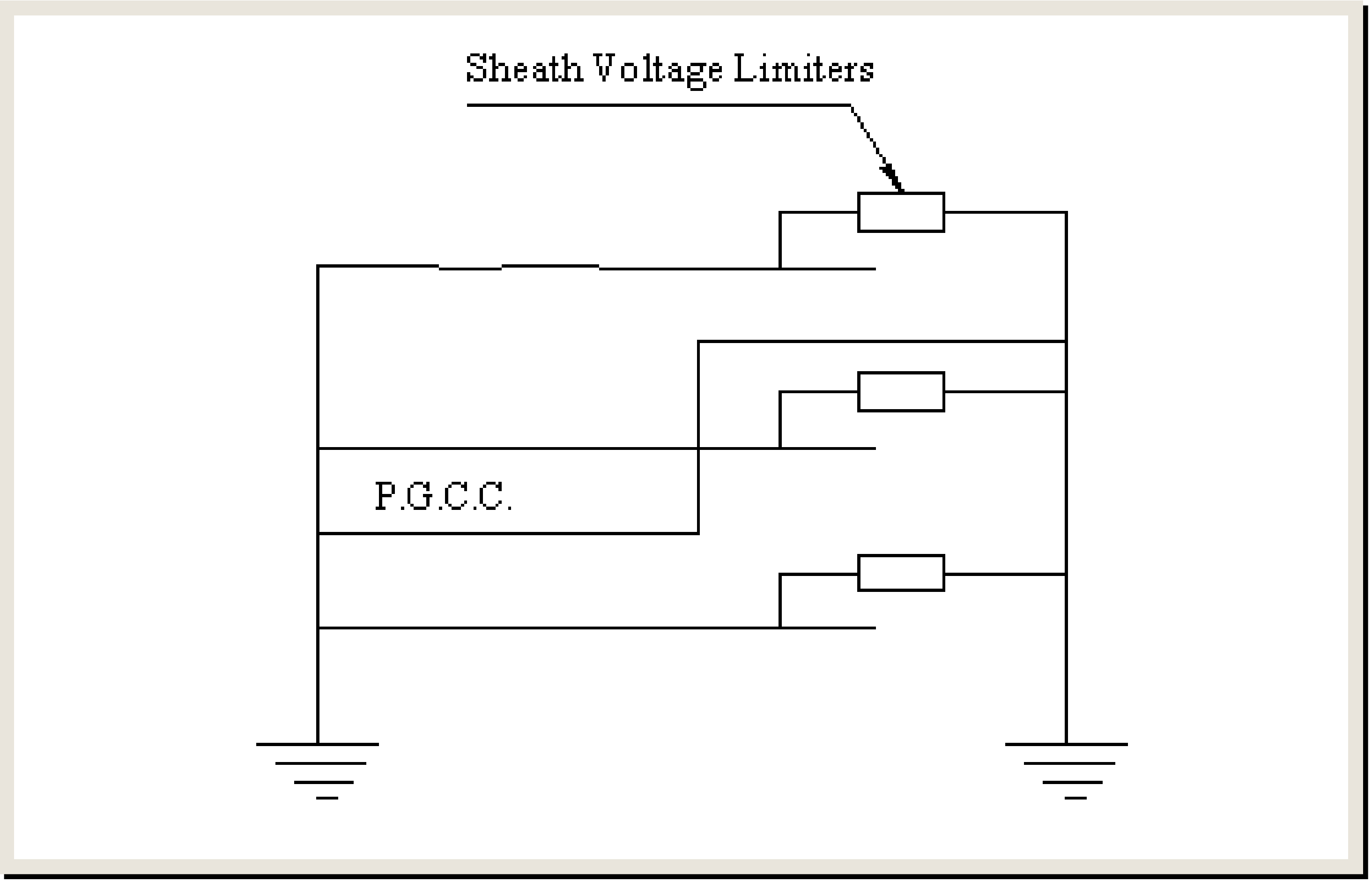
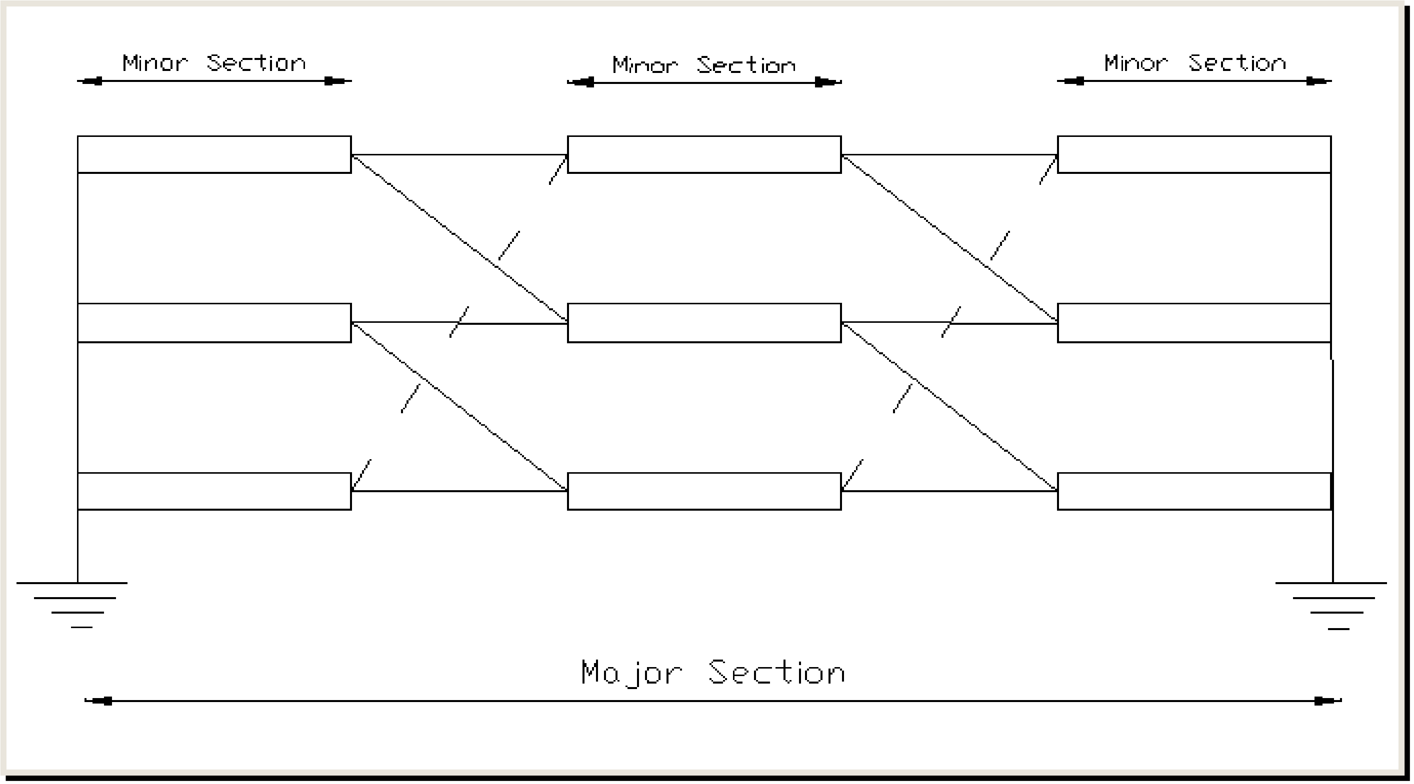
PROBLEMS OF INDUCED VOLTAGES AND CURRENTS ASSOCIATED WITH THEIR USE



PROBLEMS OF INDUCED VOLTAGES AND CURRENTS ASSOCIATED WITH THEIR USE

Cross Bonding

Cross bonding consists essentially in sectionalizing the sheaths into minor sections and cross connecting them so as to neutralize the total induced voltage in each three consecutive sections.



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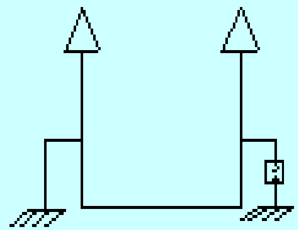
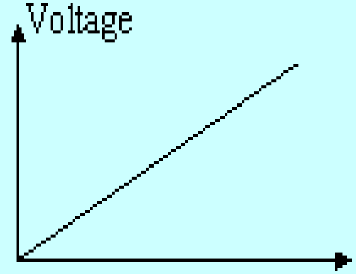
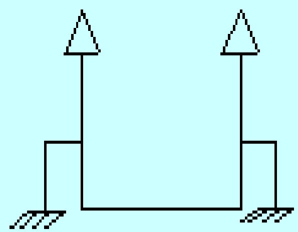
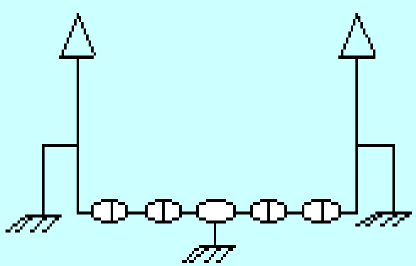
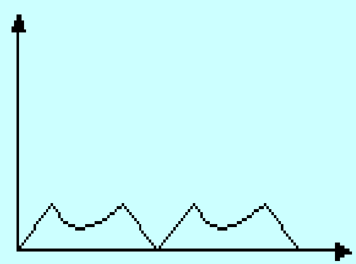
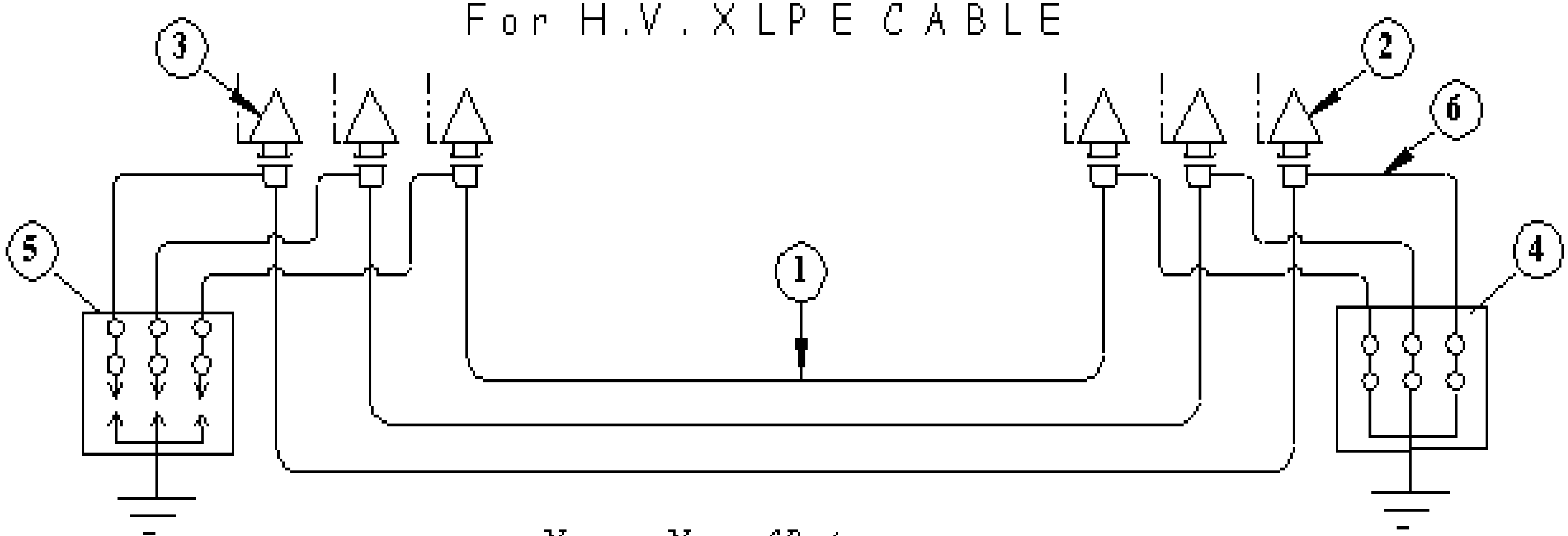
Sectionalized cross bonding can be achieved when the number of sections is divisible exactly by 3, the circuit can be arranged to consist of one or more major sections and at the ends of the circuit, the sheaths are bonded together and grounded.

Although the grounds at the junctions of major sections will generally be local ground rods.

SHEATH BONDING SYSTEM OF SINGLE CORE HV CABLES

Bonding method	Bonding method	Sheath induced voltage	Comment
Single point bonding			(1) Applicable for sheath length circuits. (2) Simple bonding system (3) Surge voltage limiter is applied on the other end
Solid bonding		None	(1) Applicable for circuits carrying small power Not suitable for large conductor size because of large sheath current loss. (2) Simple and cheap bonding system
Cross bonding			(1) Applicable for long length circuits (2) Suitable system because of small sheath current loss (3) Popular method.

Schematic Diagram For H.V. XLPE CABLE



No.	Name of Parts
.1	H.V. XLPE POWER CABLE
2	SF6 GAS IMMERSED TERMINATION
3	OIL IMMERSED TERMINATION
4	SOLID BOND LINK BOX (3WAY)
5	LINK BOX WITH ARRESTER (3WAY)
6	SINGLE BONDING WIRE

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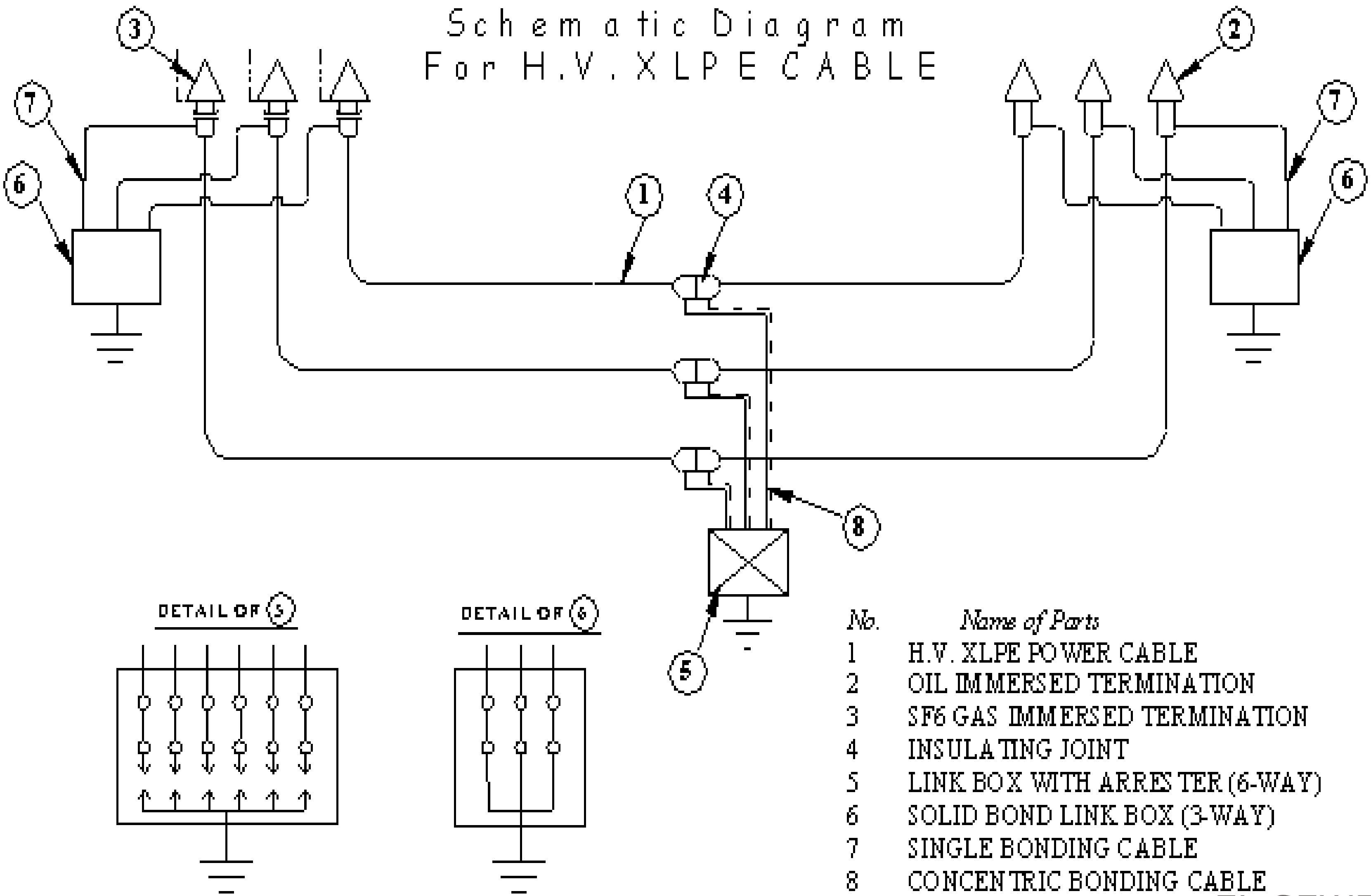
Schematic Diagram For H.V. XLPE CABLE



No.	Name of Parts
1	H.V. XLPE POWER CABLE
2	OIL IMMERSED TERMINATION
3	SF6 GAS IMMERSED TERMINATION
4	INSULATING JOINT
5	LINK BOX WITH ARRESTER (6-WAY)
6	SOLID BOND LINK BOX (3-WAY)
7	SINGLE BONDING CABLE
8	CONCENTRIC BONDING CABLE

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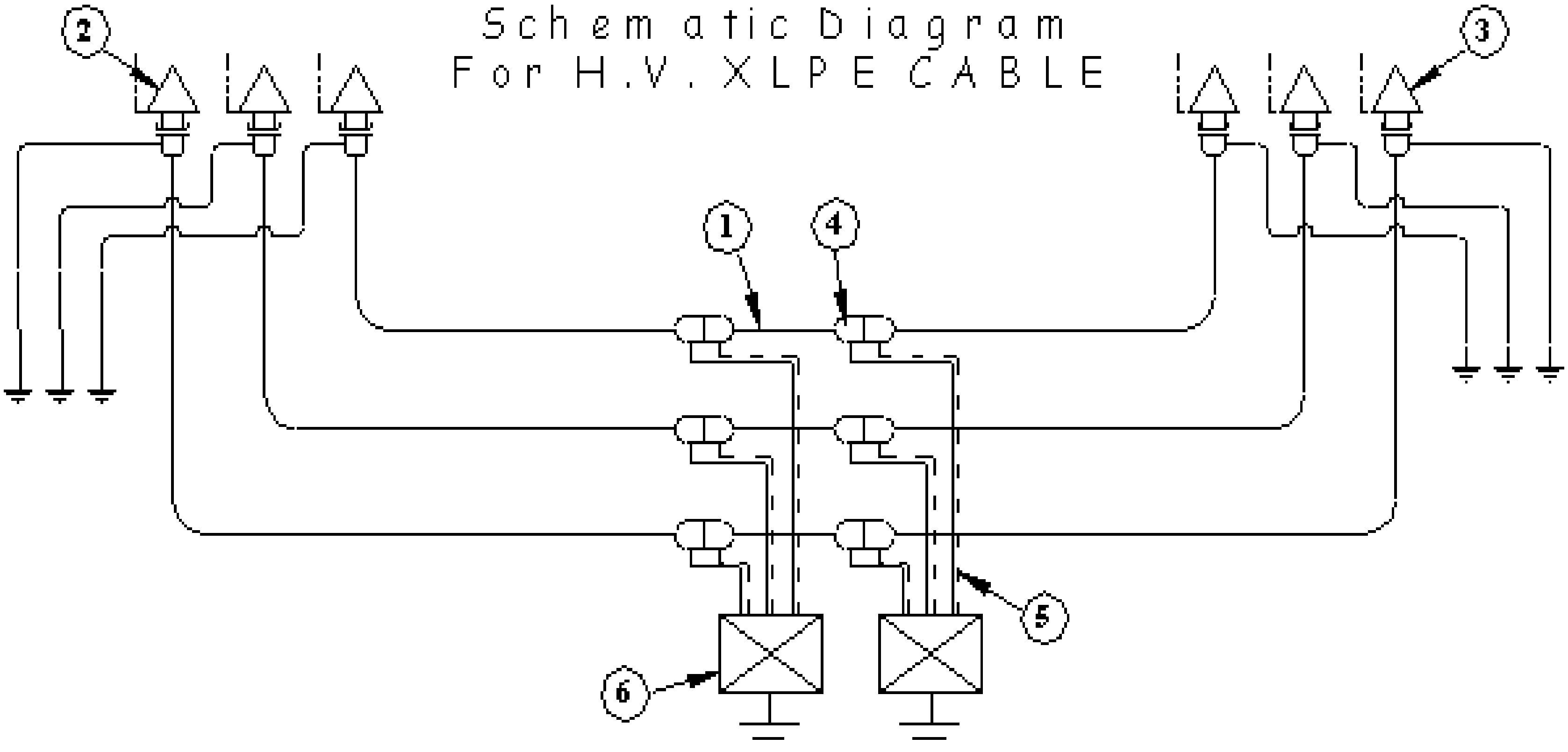
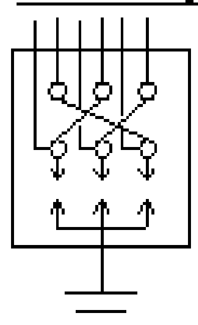
Schematic Diagram For H.V. XLPE CABLE



DETAIL OF 6



No.	*Name of Parts*
1	H.V. XLPE POWER CABLE
2	SF6 GAS IMMERSED TERMINATION
3	OIL IMMERSED TERMINATION
4	INSULATING JOINT
5	CONCENTRIC BONDING CABLE
6	CROSS BOND LINK BOX

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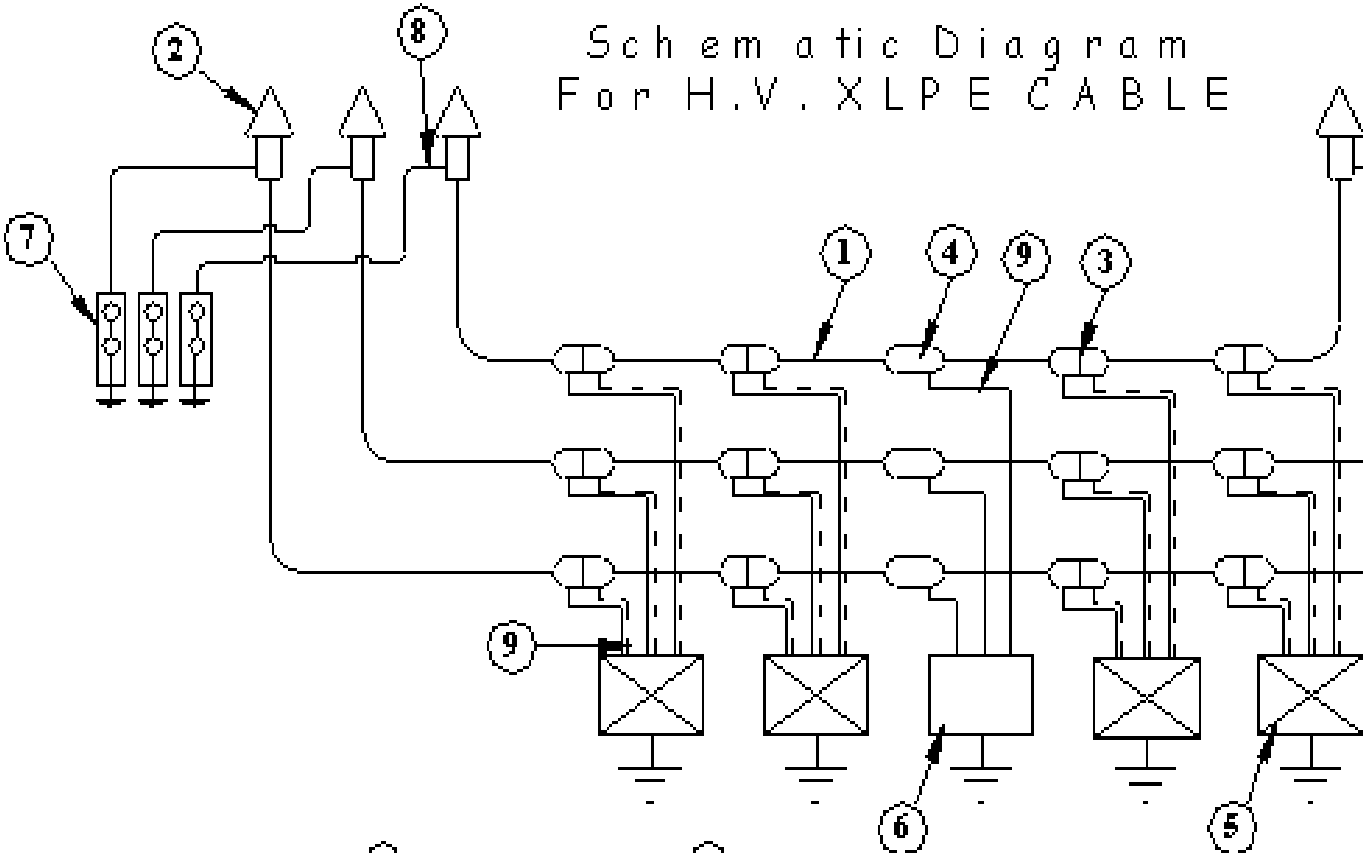
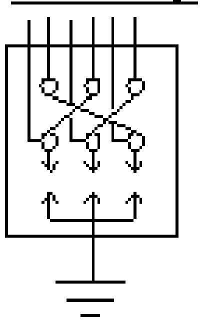
Schematic Diagram For H.V. XLPE CABLE



DETAIL OF 5



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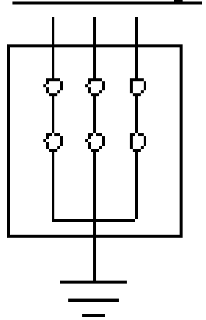

No.	Name of Parts
1	H.V. XLPE POWER CABLE
2	OUTDOOR TERMINATION
3	INSULATING JOINT
4	STRAIGHT THROUGH JOINT
5	CROSS BOND LINK BOX
6	SOLID BOND LINK BOX (3WAY)
7	SOLID BOND LINK BOX (1WAY)
8	SINGLE BONDING CABLE
9	CONCENTRIC BONDING CABLE

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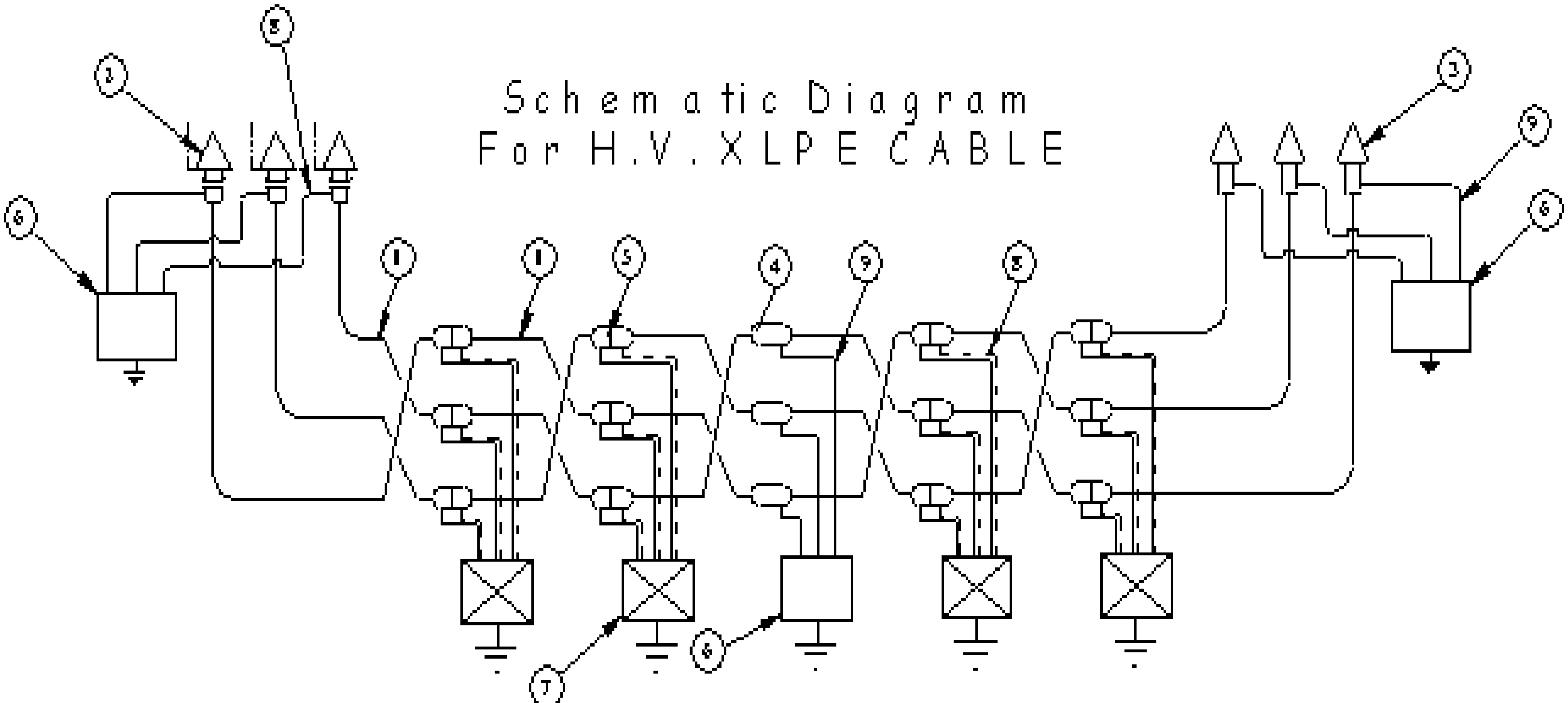
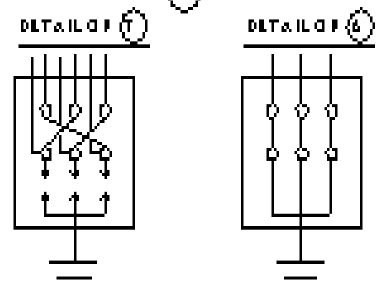
Schematic Diagram For H.V. XLPE CABLE





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3	OUTDOOR TERMINATION
4	STRAIGHT THROUGH JOINT
5	INSULATING JOINT
6	SOLID BOND LINK BOX (3 WAY)
7	CROSS BOND LINK BOX
8	CONCENTRIC BONDING CABLE
9	SINGLE BONDING CABLE

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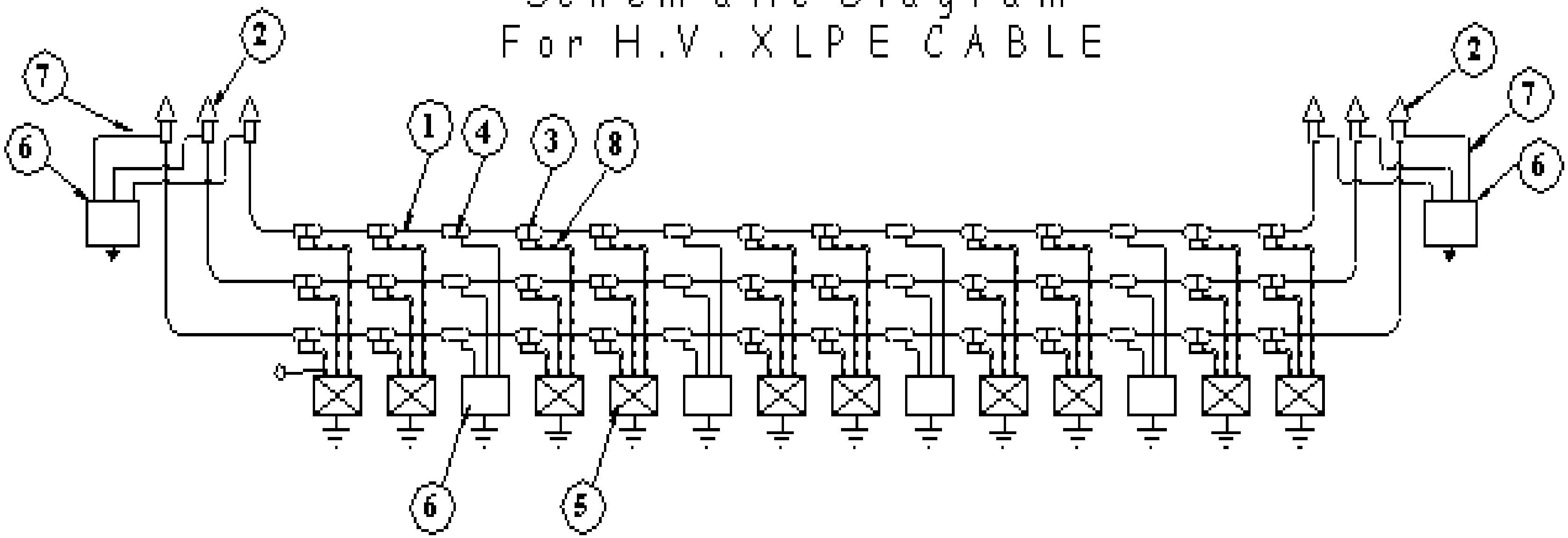
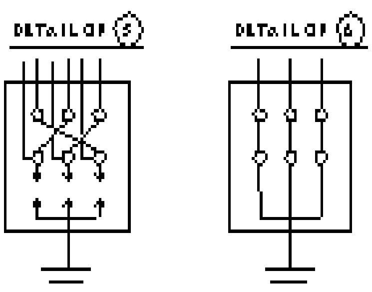
Schematic Diagram
For H.V. XLPE CABLE





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PROTECTION OF SPECIALLY BONDED CABLE SYSTEMS AGAINST SHEATH OVER VOLTAGES

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PROTECTION OF SPECIALLY BONDED CABLE SYSTEMS AGAINST SHEATH OVER VOLTAGES

In Case of Special Bonding System

Single point bonded

Cross bonding

There is a need for sheath over voltage protection (sheath voltage limiters).

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Types of Sheath Voltage Limiters (SVL)

- Spark gaps
- Surge arresters

  (Silicon carbide non-linear resistor in series with spark gap)
- Silicon carbide non-linear resistors without spark gap
- Zinc Oxide non-linear resistor ….roves more non-linear current/voltage c/c^{s} than silicon carbide; more stable when subject to frequent surges.

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2- Cables installation

Cables are usually buried approximately 750 mm deep for L.V. and slightly deeper, say 1000 mm for H.V. Covering cables a PVC ribbon close to the surface when the cable trench is backfilled. This ribbon can be distinctly coloured, market “DANGER ELECTRICITY CABLES” .

High voltage cables laying

cables laid in trefoil formatin

cables laid in flat formation

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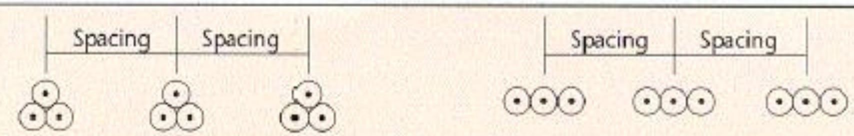
Derating factors: Each cable has its own Ampacity . But this value of Ampacity do not consider some factors like ground temperature, burial depth, trefoil or flat formation of single core cables , etc.

So, the cable Ampacity is modified according to specified ratio.

For example, the following table shows how the single core cables formation affects the Ampacity value:



Number of circuits	Trefoil formation			Flat formation		
	Touching		Spacing = 0.15 M		Spacing = 0.30 M	
nr	Trefoil	Flat	Trefoil	Flat	Trefoil	Flat
2	0.77	0.80	0.82	0.85	0.88	0.91
3	0.66	0.69	0.73	0.76	0.80	0.83
4	0.60	0.63	0.68	0.71	0.74	0.77
5	0.56	0.59	0.64	0.67	0.72	0.75
6	0.53	0.57	0.61	0.64	0.70	0.73

Medium Voltage Cables test

A . Visual and mechanical inspection :

1- Inspect exposed sections of cables for physical damage and evidences of overheating and corona.

2- Inspect terminations and splices for evidences of overheating and corona.

3- Inspect all bolted electrical connections for high resistance using one of the following methods:

i - Use of low – resistance ohmmeter.

ii - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.

iii- Perform thermo graphic survey .

4- Inspect comparison – applied connections for correct cable match and identification.

5- Inspect for shield grounding , cable support , and termination.

6- Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.

7- Inspect fireproofing in common cable areas , if specified.

8- If cables are terminated through window –type current transformers, make an inspection to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.

Medium Voltage Cables test

B .Electrical Tests:

1- Perform a shield – continuity test on each power cable by ohmmeter method.

2- Perform an insulation – resistance test utilizing a megohmmter with a voltage output of at least 2500 volts. Individually test each conductor with all other conductors and shields grounded . Test duration shall be one minute.

3- Perform resistance measurements through all bolted connections with a low resistance ohmmeter, if applicable .

4- Perform a dc high – potential test on all cables . adhere to all precautions and limits as specified in the applicable NEMA/ICEA standard for specific cable. Perform tests in accordance with ANSI/IEEE standard 400.test procedure shall be as follows , and the results for each cable test shall be recorded as specified herein .test voltages shall not exceed 60 percent of cable manufacturer's factory test value or Maximum test voltage in the table.

Note:

1- Insure that the input voltage to the test is regulated .

2- Current – sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of equipment .

Medium Voltage Cables test

3- Record wet – and dry-bulb temperatures or relative humidity and temperature.

4- Test each section of cable individually.

5- Individually test each conductor with all other conductors grounded. ground all shields.

6- Terminations shall be adequately corona – suppressed by guard ring , field reduction sphere , or other suitable methods as necessary.

7- Insure that the maximum test voltage does not exceed the limits for terminators specified in NSI/IEEE Standards 48 or manufacturer's specifications.

8- Apply a dc high – potential test in at least five equal increments until maximum test voltage is reached . no increment shall exceed the the voltage rating of the cable .Record dc leakage current at each step after a constant stabilization time consistent with system charging current.

9- Raise the conductor to the specified maximum test voltage and hold for five minutes, Record readings of leakage current at 30 seconds and one minute intervals thereafter.

10- Reduce the conductor test potential to zero and measure residual voltage at discrete intervals.

11- Apply grounds for a time period adequate to drain all insulation stored charge.

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Medium Voltage Cables test

C .Test Values:

1- Compare bolted connection resistances to values of similar connections.

2- Bolt – torque levels shall be in accordance with manufacturer specification.

3- Microhm or millivolt drop values shall not exceed the high levels of the normal ranges as indicated in the manufacturer's published data .if manufacturer's data is not available , investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4- Shielding must exhibit continuity . investigate resistance values in excess of ten ohms per 1000 feet of cable.

5- Graphic plots may be made of leakage current versus step voltage at each increment and leakage current versus time at final test voltages.

6- The step voltage slope should be reasonably linear.

7- Capacitive and absorption current should decrease continually until steady state leakage is approached.

8- Compare test results to previously obtained results.

INSULATION-RESISTANCE TEST VOLTAGES FOR ELECTRICAL APPARATUS

Maximum Voltage Rating of Equipment	Minimum Test Voltage ,DC	Recommended Minimum Insulation Resistance in Megohms
250 volts	500 volts	25
600 volts	1,000 volts	100
5,000 volts	2,500 volts	1,000
8,000 volts	2,500 volts	2,000
15,000 volts	2,500 volts	5,000
25,000 volts	5,000 volts	20,000
35,000 volts	15,000 volts	100,000
46,000 volts	15,000 volts	100,000
69,000 volts	15,000 volts	100,000

Maximum Maintenance Test Voltages (KV,dc)

Insulation type	Rated Cable Voltage	Insulation Level	Test Voltage (Kv,dc)
EPR	25 KV	100 %	60
	25 KV	133 %	75
	28 KV	100 %	64
	35 KV	100 %	75
Polyethylene	5 KV	100 %	19
	5 KV	133 %	19
	8 KV	100 %	26
	8 KV	133 %	26
	15 KV	100 %	41
	15 KV	133 %	49
	25 KV	100 %	60
	25 KV	133 %	75
	35 KV	100 %	75

Maximum Maintenance Test Voltages (KV,dc)

Insulation Type	Rated Cable Voltage	Insulation Level	Test Voltage Kv,DC
Elastomeric	5 KV	100 %	19
Butyl and Oil Base	5 KV	133 %	19
	15 KV	100 %	41
	15 KV	133 %	49
	25 KV	100 %	60
Elastomeric	5 KV	100 %	19
EPR	5 KV	133 %	19
	8 KV	100 %	26
	8 KV	133 %	26
	15 KV	100 %	41
	15 KV	133 %	49

2-2 Substations

A **substation** is the part of an electricity transmission and distribution system where voltage is transformed from low to high and vice versa using transformers. The range of voltages in a power system varies from 110 V up to 765 kV. Transformation may take place in several stages and at several substations in sequence, starting at the generatig plant substation where the voltage is increased for transmission purposes and is then progressively reduced to the voltage required for household use.

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A typical substation will contain line termination structures, high-voltage switchgear, one or more power transformers, low voltage switchgear, surge protection, controls, and metering.

The following is a quick overview on the main components in any substation.

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2-2-1 Switchgear

The term **switchgear**, commonly used in association with the electric power system, or grid, refers to the combination of electrical disconnects and/or circuit breakers meant to isolate equipment in or near an electrical substation. Typically switchgear is located on both the high voltage, and the low voltage side of large power transformers.

Medium voltage switchgear

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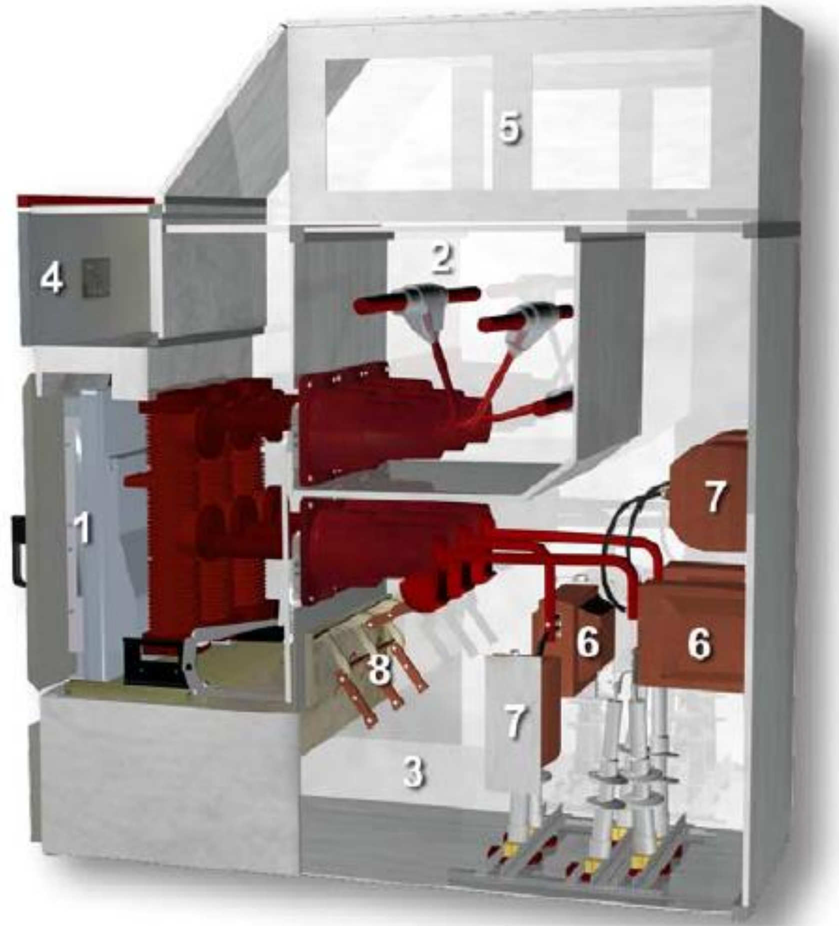
Construction

<u>**1** Circuit breaker compartment</u>
<u>**2** Bus bar compartment</u>
<u>**3** Cable compartment</u>
<u>**4** Low voltage compartment</u>
5 Arc channel
6 Current transformers
7 Voltage transformers
8 Earthing switch



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- The unit consists, as shown above, of three power compartments bus bars, cable, circuit breaker and low voltage compartment for instruments, auxiliary circuit wiring. these compartments are more clear in the following short notes:

Main bus bars compartment: The bus bar compartment houses the main bus bar system, which is connected to the circuit breaker fixed insulating contacts.

Cable compartment: Current transformers, earthing switch and surge arresters are installed in the cable compartment. Space is provided for multiple cable connections.

Low voltage compartment: All secondary equipment required for protection and control functions is located in this compartment.

Circuit-breaker compartment: The circuit-breaker compartment A fitted with the necessary guide rails accommodates the withdraw ability, this compartment can be moved between the service position and the test/disconnected position.

M.V & L.V Switchgear

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Sf6 Circuit Breaker

Sf6 circuit breaker with spring operated mechanism is excellently suitable for switching of short-circuit currents, overhead lines and cables under load and no load, transformers and generators, motors, ripple control systems and capacitors - even in parallel.

Terminals for fixed circuit-breaker.

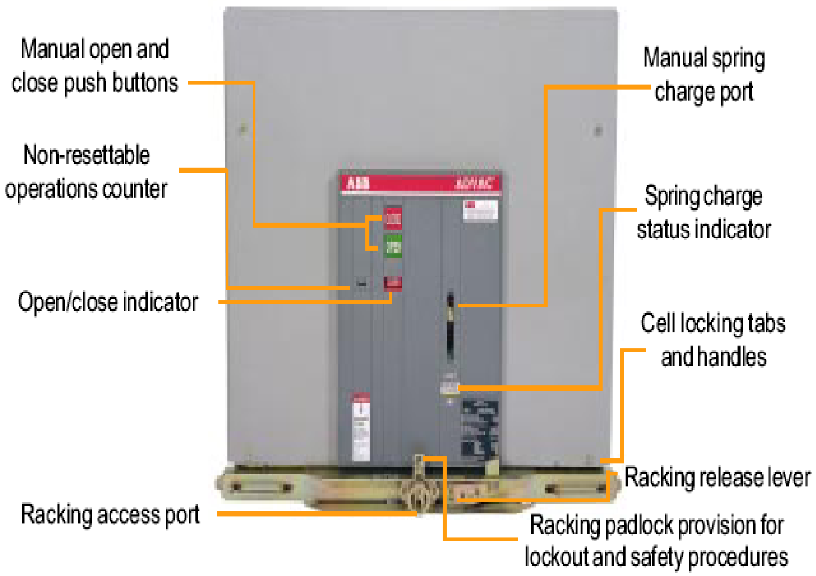
Tulip isolating contacts for withdrawable circuit-breaker.

Plier isolating contacts for withdrawable circuit-breaker.

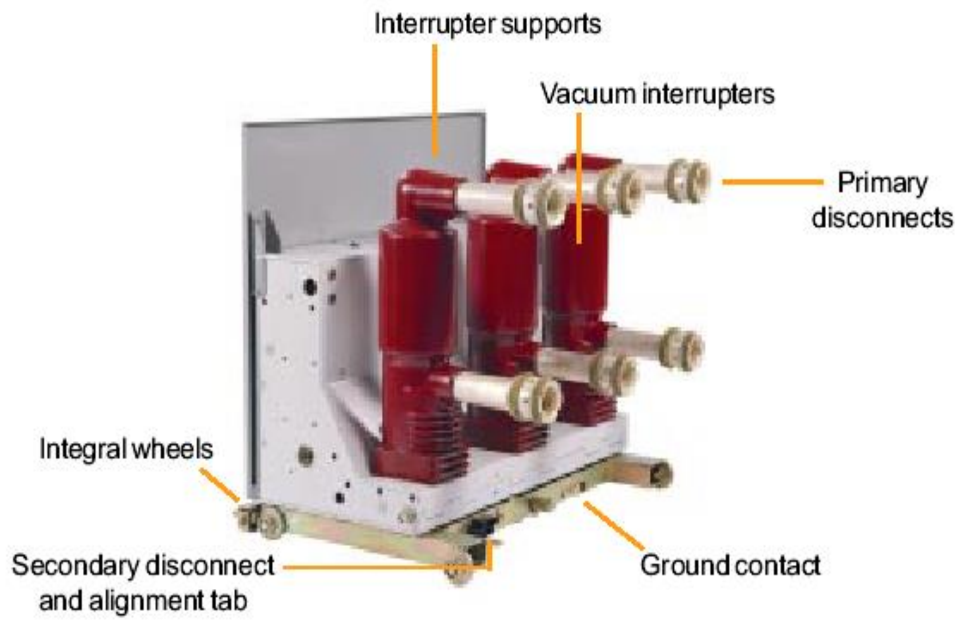
Vacuum Circuit Breakers

Universal Applications:

- Medium voltage motor starting applications
- Capacitor switching
- Mining applications where high reliability and resistance to dust and humidity are critical.



Front view of ADVAC circuit breaker



Rear view of ADVAC circuit breaker

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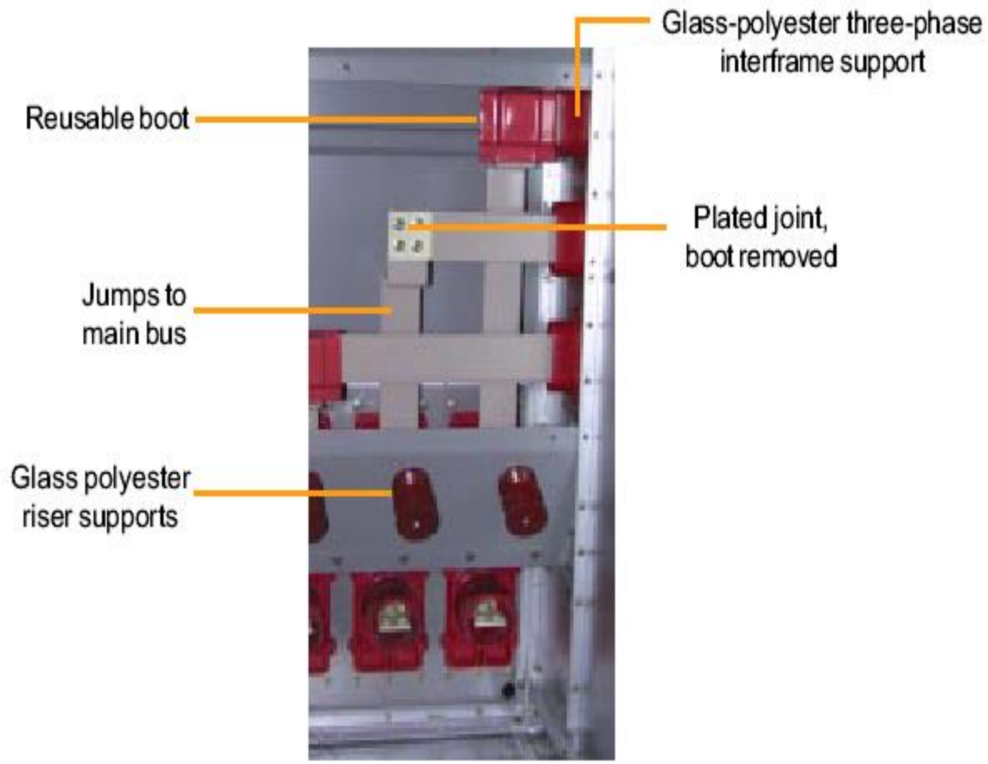
Air Disconnector Switch

They are used in secondary distribution substations for supplying lines, power transformers and ring networks.

Primary Bus System

All primary bus is 100% copper with full round edges, and is available in 1200 A, 2000 A, 3000 A and 4000 A ratings. The bus is silver-plated at joints and bolted together with a minimum of two halfinch porcelain supports are standard at 3000 A or 4000 A, and optional in other ratings.



Main Bus Compartment
(End section - Cover removed)

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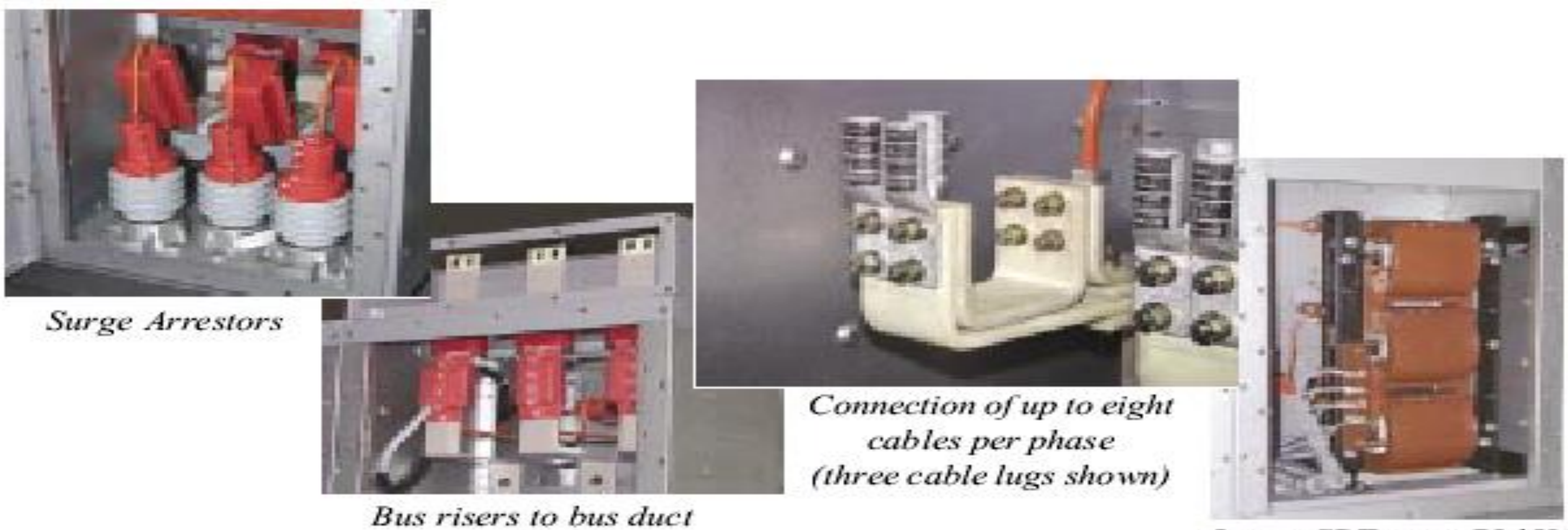
Cable Compartments

Well-designed cable compartments for both Safe Gear and Advance provide an efficient layout with ample room for stress cones and a choice of cable terminations and lug types.



Surge Arrestors

Bus risers to bus duct or roof busings

Connection of up to eight cables per phase (three cable lugs shown)

Large CPT up to 75 kVA

Various Application Designs in Cable Compartments

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Control Panel

The control panel is ideally fulfill the requirements of automated processes for more transparency and efficiency.

It comprises very modern and competitive range of contactors, soft starters, starters, proximity sensors, limit switches, manual motor starters, a wide range of electronic relays and overload relays, together with an extended program of pilot devices and Plus.

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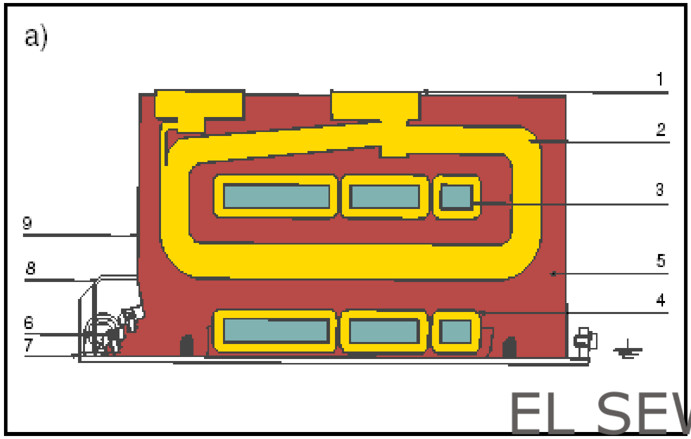
Current Transformer

1. medium voltage terminals
2. primary winding
3. magnetic circuit
4. secondary winding
5. epoxy body
6. secondary outlets
7. base plate
8. cover of secondary terminals, used for outlet sealing
9. nameplate



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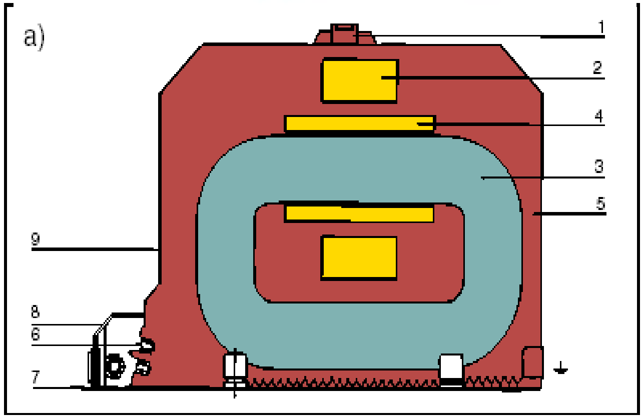
Voltage Transformer

1. medium voltage terminals
2. primary coil
3. magnetic circuit
4. secondary winding
5. epoxy body
6. secondary outlets
7. base plate
8. cover of secondary terminals, used for outlet sealing
9. nameplate



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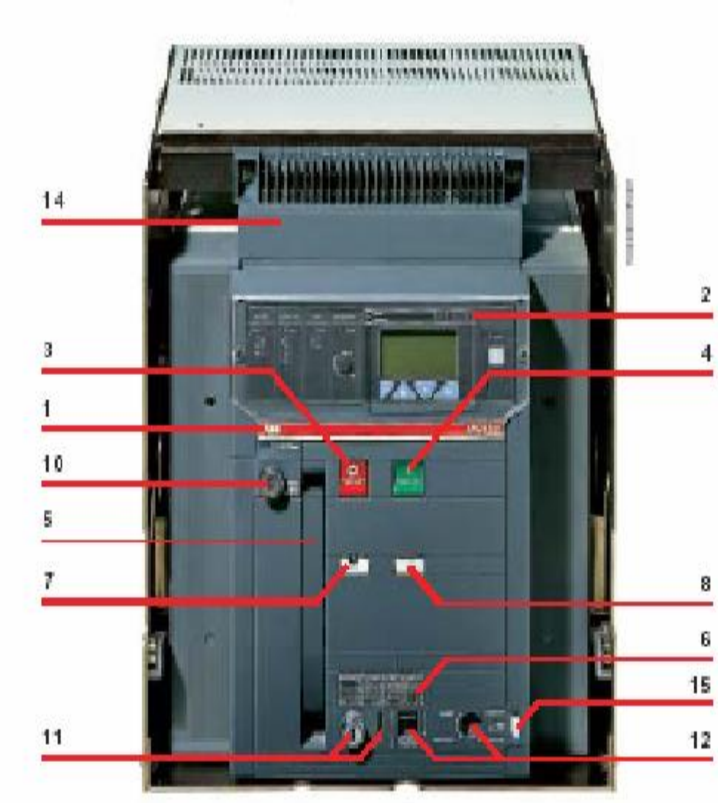
Low voltage Air Circuit-Breakers

1-Trademark and size of circuit breaker
2-release
3-Pushbutton for manual opening
4-Pushbutton for manual closing
5-Lever to manually charge closing springs
6-Electrical rating plate
7-Mechanical device to signal circuit-breaker open “O” and closed “I”
8- Signal for springs charged or discharged
9- Mechanical signaling of over current releases tripped
10- Key lock in open position
11- Key lock and padlock in racked in/ racked-out position .
12- Racking-in/out device .
13- Terminal box .
14- Sliding contacts .
15- Circuit-breaker position indicator.



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Molded Case Circuit Breakers

- Its entire range covers the current ratings between 15 A to 2500 A and interrupting ratings, at 480 V AC, which can reach150kA.

- **Universal Applications:**

– circuit breakers for power distribution (fitted with thermo magnetic or electronic trip units).

– circuit breakers with adjustable magnetic only trip units for motor protection.

– molded case switches for use as isolators or switching devices for lines, bus bars or parts of a plant .

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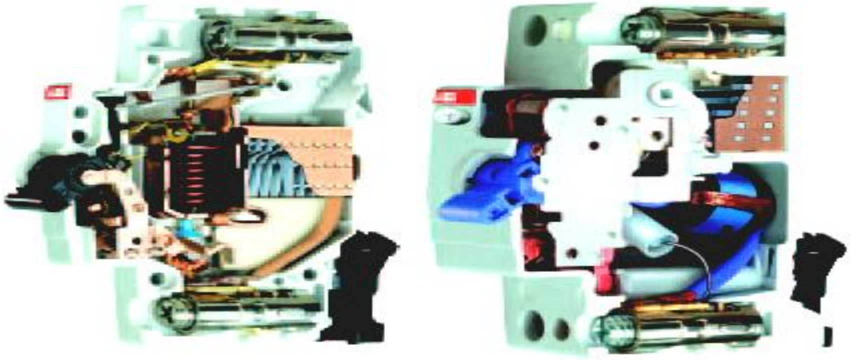
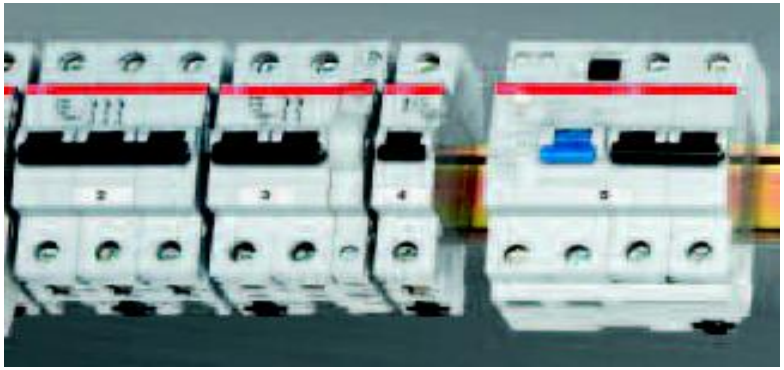
Miniature Circuit Breaker

This range of miniature circuit is suitable for all applications in residential, commercial and industrial installations.





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2-2-2 Power Transformers :

It located in substations to step up or step down the voltage. Typically it is used in power plants to step the voltage up to be transmitted. while it is used in substations to step down the voltage to be distributed.

100 MVA, 220 / 66 kV Power Transformer

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2-2-3 Current & voltage Transformers (CT’s & VT’s):

The CT’s and VT’s are used to sense the current and voltage respectively. They are the main measuring instruments in any substation.


current transformers


voltage transformers

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2-2-4 Surge Arresters:

Overvoltages are one of the most undesired phenomena for any power system. The overvoltages are due to some reasons like lightning or switching.

Surge Arrestors are used to protect the system from such severe dangers.

Polymer-housed arresters

Porcelain-housed arresters

Polymer arrester

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3- Distribution of Electricity

With the ever-increasing need to dispatch electric energy to growing loads, existing distribution systems grow and expand. As well, new networks are constructed in the new developing residential, industrial and agricultural areas. Thus, large investments are spent to construct a distribution system, such that in typical power systems, 40% of the investments are spent in the distribution system which is double the investment in the transmission system (20%) and as much as the investment in the generation plants (40%). In addition, the consumers are now progressively interested in power quality and an uninterrupted supply, i.e. a reliable distribution system is required. Therefore, system engineers in the Power Utilities progressively give every care to the distribution system operation and maintenance.

The Main Parts of distribution system are Distribution Transformers and Outdoor Distribution Transformers (Kiosks)

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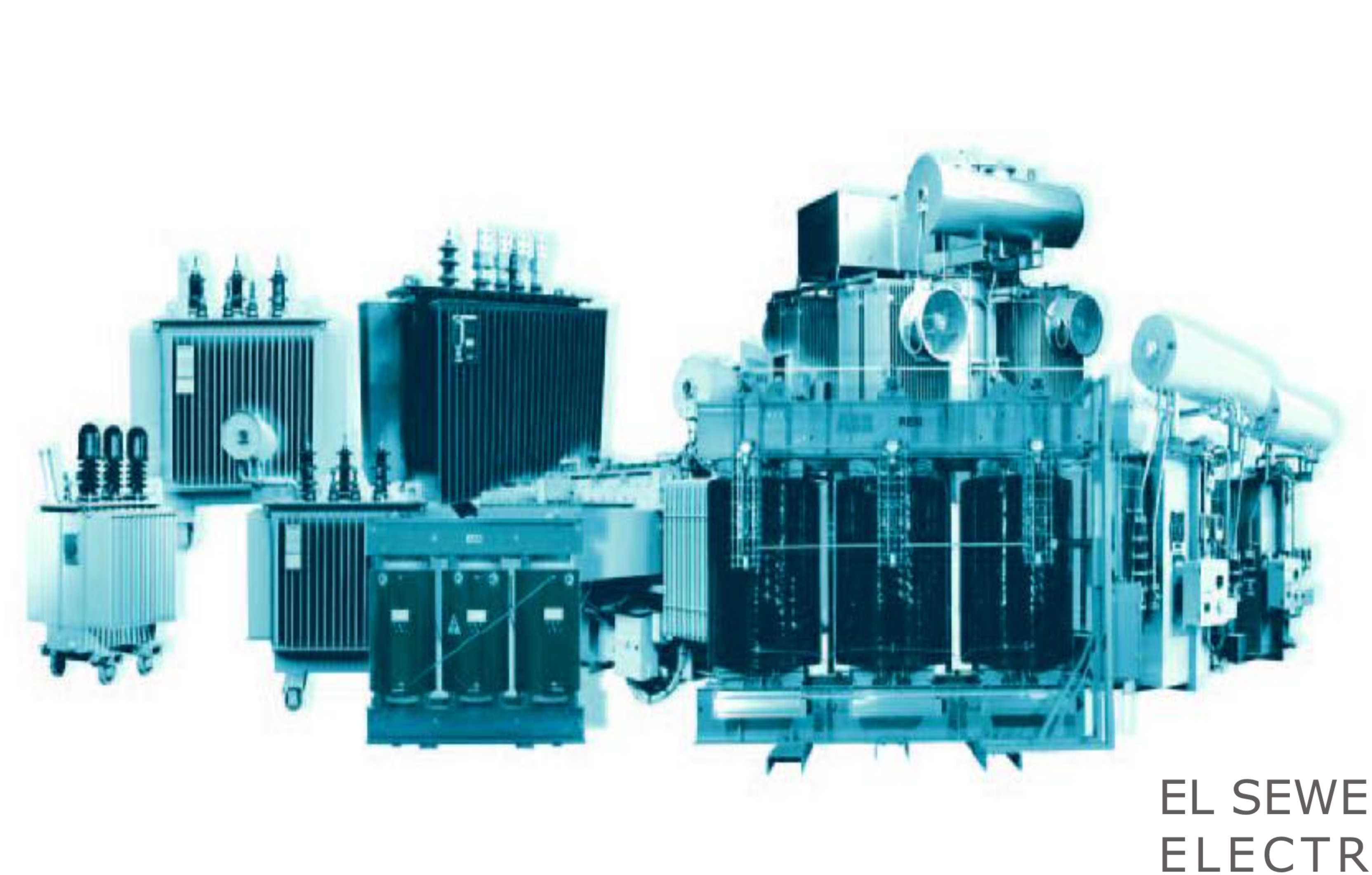
3-1 Distribution Transformers



Specification Of Distribution Transformers

In selecting and committing a new transformer, the following Parameters must be specified.

1-Rating

2-Frequency

3-Tapping on both sides of the transformer

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Main Parts of Distribution Transformers

1- Iron Core

2- Windings

Low Voltage Windings

High Voltage Windings

3- Tank

4- Oil Expansion Conservator

5- Terminals

6- Tap Changer

7- Cooling Oil

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Classification of Distribution Transformers

According To The Method of Insulating And Cooling .

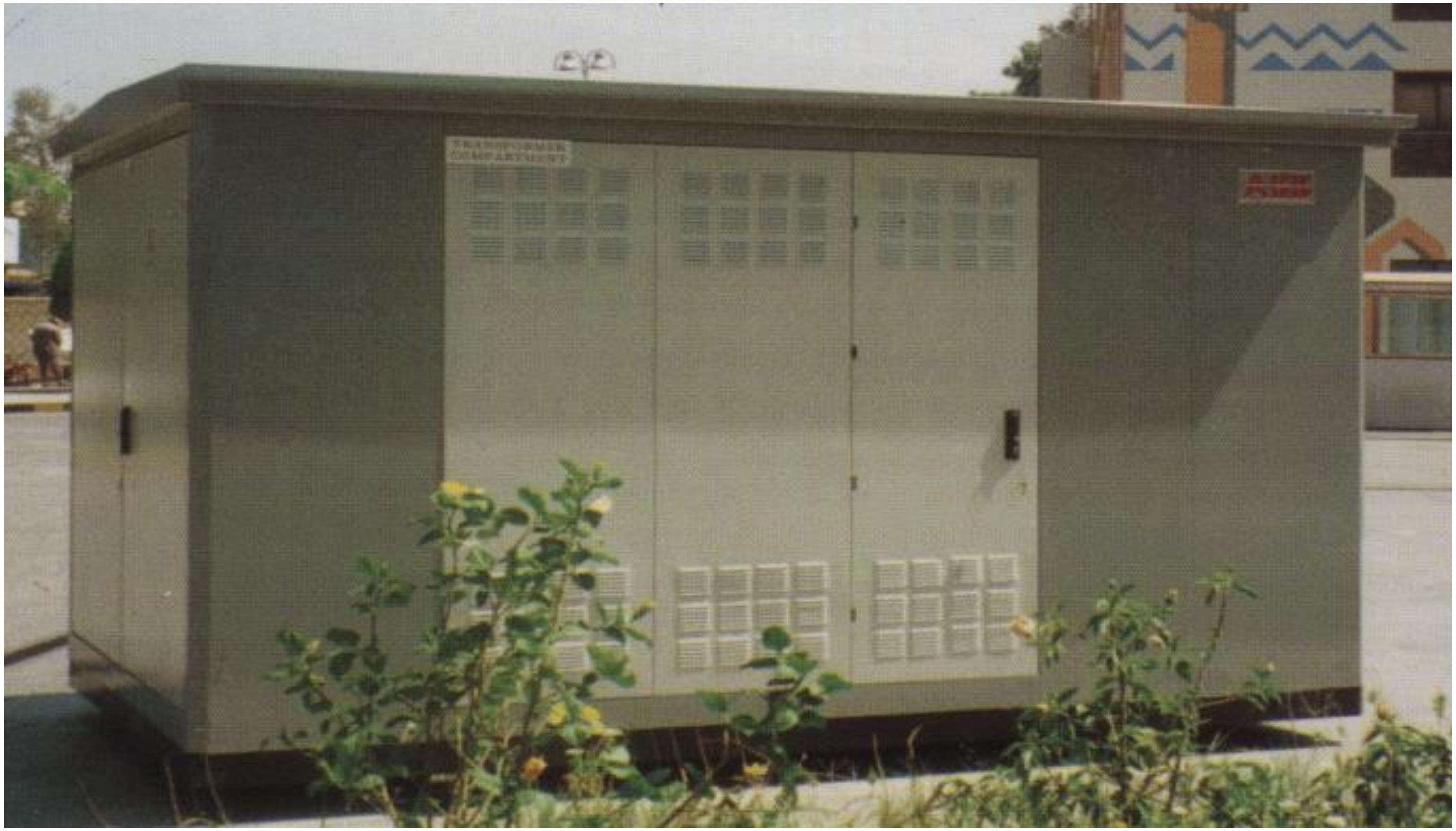
Fluid immersed transformer:

Oil has a dual function; the first is to insulate between turns with each other as well between the turns and the core. While the second function is cooling.

Dry type transformer :

Cooling takes place by means of air circulation through the turns under normal air pressure .

3-2 Outdoor Distribution Transformers (Kiosks)



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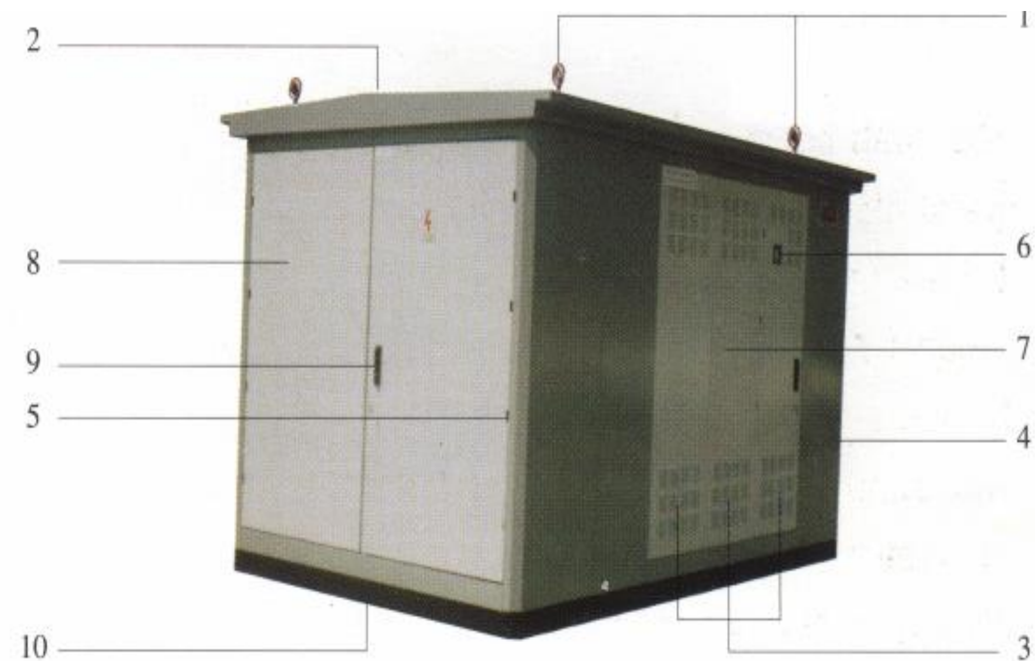
General Description Of Outdoor Distribution Transformers (Kiosks)

1-Roof mounted lifting eyes
2-Double roof with neutral ventilation
3-Ventilation louvers
4-MV compartment door
5-Heavy-duty door hinges
6-Earth fault indicator
7-Transformer compartment door
8-LV compartment door
9-Opening handle
10-Base for Kiosk



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Dimensions of The Distribution Transformers (Kiosks)

Kiosk Description	(H) Height	(W) Width	(L) Length	Weight without Transformer
Rating up to 500 KVA Voltage 12 KV	2050 mm	1680 mm	3200mm	= 2.4 ton
Rating up to 1000 KVA Voltage 12 KV	2370 mm	2000 mm	4110mm	= 3 ton

So, the location of the kiosk should be selected such that the transportation & installation and maintenance are easily done.

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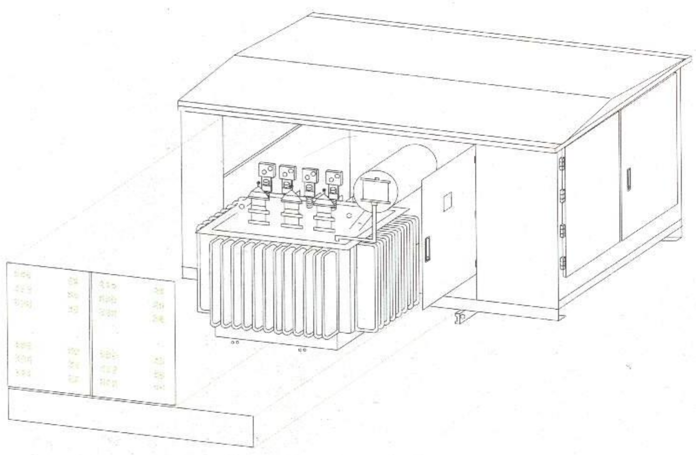
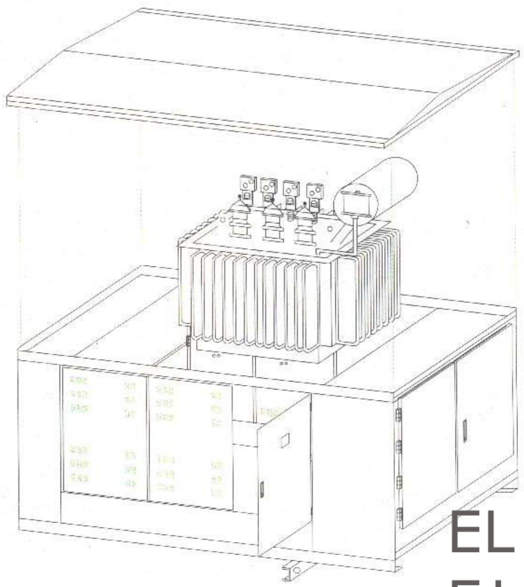
Transformer Compartment

The transformer is connected to the LV distribution board via copper bus bars or cables based on the transformer capacity, and to the MV equipment via XLPE screened cables, each of the XLPE cables is equipped with two cable end box for three single phase connection .





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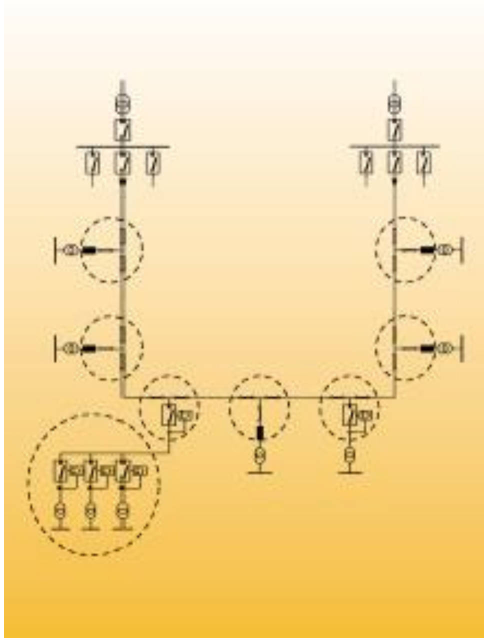
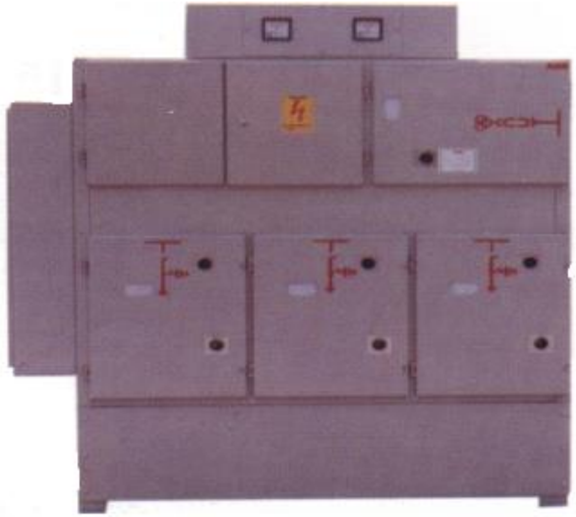
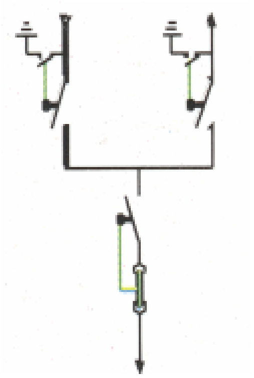
Medium Voltage Compartment

It comprises a Ring Main Unit (RMU) including up to three load break switches and one automatic fused load break switch for transformer . All circuit arrangement may be provided with earth fault indicators .







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Low Voltage Compartment

The main incoming apparatus is usually molded case automatic air circuit breaker , complete with overload and short circuit protection with rating up to 3200A.

The incoming unit is equipped with voltmeter and selector switch, 3 ammeters, 3 signal lamps and space for optional K.W.H meter.

The outgoing feeders is provided with the following components:

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Molded Case Circuit Breakers

As an example for the capacity of the 500 KVA kiosk, the number of the outgoing feeders With molded case circuit breakers (MCCB) may be one of the following :

-Nine frame size 160A,200A or 250A MCCB.

-Six frame size 400A MCCB .

-Four frame size 630A MCCB .

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Fused Load Break Switches

For the same example of
the 500KVA kiosk, the number
of the outgoing feeders
using fused load break
switches (SF) may be
one of the following

-Nine with (SF) 160A up to 250A.

- Six (SF) up to 400A .
- Four (SF) up to 630A .

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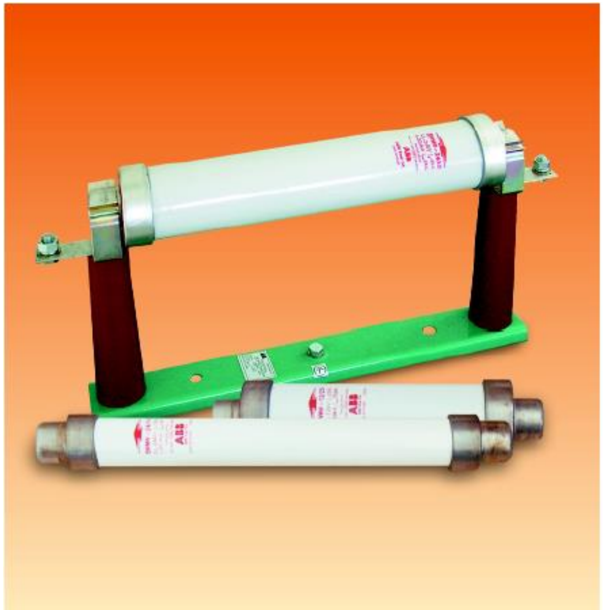
HRC fuses

For the same example of the 500KVA kiosk, the number of the outgoing feeders with high rupturing capacity fuses may be one of the Following :

- Four H.R.C. fuses up to 630A .
- Six H.R.C. fuses up to 250A .



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Power Factor Correction

AC power flow has the three components: real power (P), measured in watts (W); apparent power (S), measured in volt-amperes (VA); and reactive power (Q), measured in reactive volt-amperes (VAR).

The power factor of an AC electric power system is defined as the ratio of the real power to the apparent power

By definition, the power factor is a dimensionless number between 0 and 1. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load.

CONTENTS:-

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1.2 Plant And Appliances Required Reactive Current

1.3 The Power Factor

1.4 Practical Values of Power Factor

2- WHY IMPROVE THE POWER FACTOR

2.1 Reduction in the Cost Electricity

2.2 Technical and Economical Optimization

2.2.1 Reduction of Cable Size

2.2.2 Reduction of losses(P, Kw) in cables

2.2.3 Reduction of Voltage Drop

2.2.4 Increase in Available Power

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3- HOW TO IMPROVE THE PF.

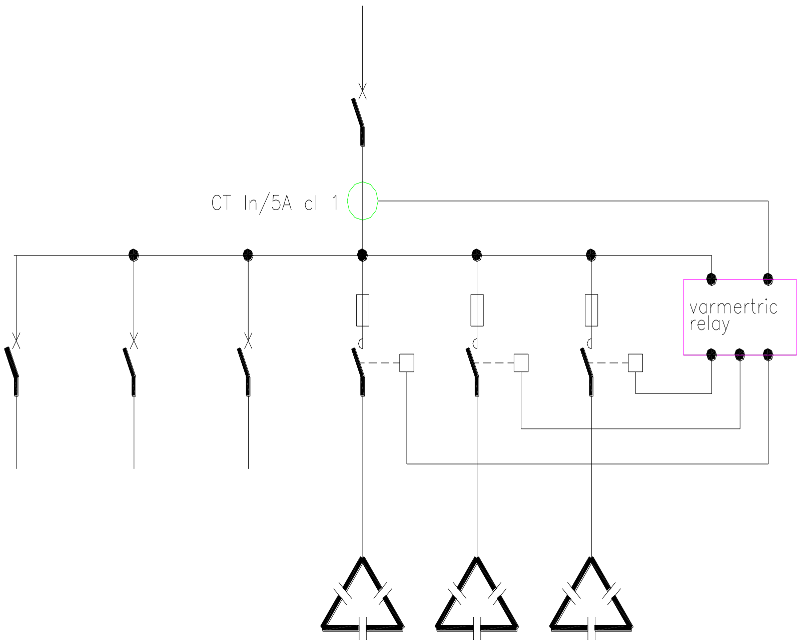
COMPENSATION AT L.V. IS PROVIDED BY

1- FIXED VALUES CAPACITOR

2- AUTOMATIC CAPACITOR BANKS

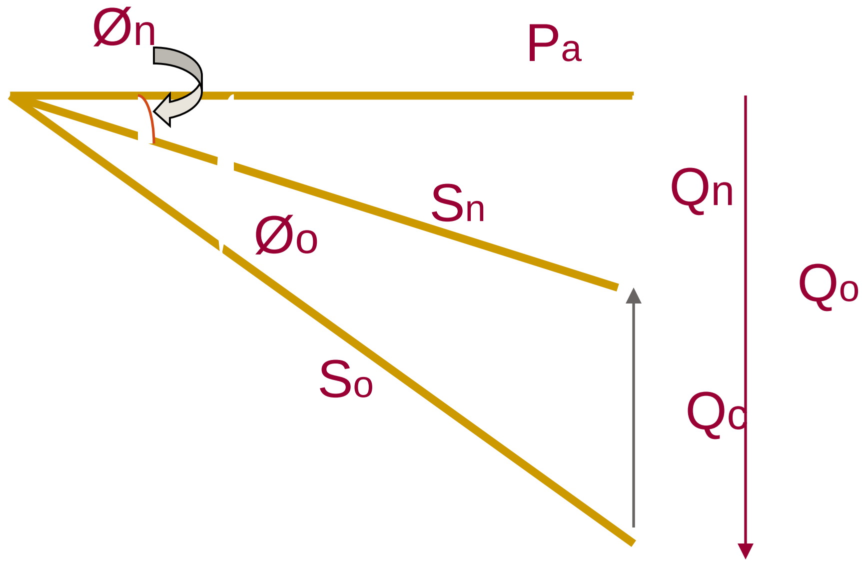
AUTOMATIC COMPENSATION PF.

- A bank of capacitors is divided into a number of section.
- Each of which is controlled by a contactor.
- A control relay monitors the power factor of the controlled circuit(s) and is arranged to close and open appropriate contactors to maintain a reasonably constant system power factor (within the tolerance imposed by the size of each step of compensation).



The principle of automatic–compensation control

4- CALCULATION THE REACTIVE POWER TO BE INSTALLED



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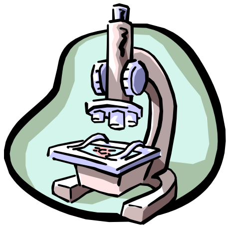
CALCULATION TABLE FOR Kvar TO BE INSTALLED

Calculation table for kvar to be installed

before compensation		capacitor power in kvar to be installed per load kW, to reach the power factor (cos φ) or the tg φ at a given value													
		tg φ	**0.75**	**0.59**	**0.48**	**0.46**	**0.43**	**0.40**	**0.36**	**0.33**	**0.29**	**0.25**	**0.20**	**0.14**	**0.08**
tg φ	**cos φ**	**cosφ**	**0.80**	**0.86**	**0.90**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.96**	**0.97**	**0.98**	**0.99**	**1**
1.33	0.60		0.584	0.733	0.849	0.878	0.905	0.939	0.971	1.005	1.043	1.083	1.131	1.192	1.334
1.30	0.61		0.549	0.699	0.815	0.843	0.870	0.904	0.936	0.970	1.008	1.048	1.096	1.157	1.299
1.27	0.62		0.515	0.665	0.781	0.809	0.836	0.870	0.902	0.936	0.974	1.014	1.062	1.123	1.265
1,23	0.63		0.483	0.633	0.749	0.777	0.804	0.838	0.870	0.904	0.942	0.982	1.030	1.091	1.233
1.20	0.64		0.450	0.601	0.716	0.744	0.771	0.805	0.837	0.871	0.909	0.949	0.997	1.058	1.200
1.17	0.65		0.419	0.569	0.685	0.713	0.740	0.774	0.806	0.840	0.878	0.918	0.966	1.007	1.169
1.14	0.66		0.388	0.538	0.654	0.682	0.709	0.743	0.775	0.809	0.847	0.887	0.935	0.996	1.138
1.11	0.67		0.358	0.508	0.624	0.652	0.679	0.713	0.745	0.779	0.817	0.857	0.905	0.966	1.108
1.08	0.68		0.329	0.478	0.595	0.623	0.650	0.684	0.716	0.750	0.788	0.828	0.876	0.937	1.079
1.05	0.69		0.299	0.449	0.565	0.593	0.620	0.654	0.686	0.720	0.758	0.798	0.840	0.907	1.049
1.02	0.70		0.270	0.420	0.536	0.536	0.563	0.597	0.629	0.663	0.701	0.741	0.783	0.850	0.992
0.96	0.72		0.213	0.364	0.479	0.507	0.534	0.568	0.600	0.634	0.672	0.712	0.754	0.821	0.963
0.94	0.73		0.186	0.336	0.452	0.480	0.507	0.541	0.573	0.607	0.645	0.685	0.727	0.794	0.936
0.91	0.74		0.159	0.309	0.425	0.453	0.480	0.514	0.546	0.580	0.618	0.658	0.700	0.767	0.909
0.88	0.75		0.132	0.282	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.740	0.882
0.86	0.76		0.105	0.255	0.371	0.399	0.426	0.460	0.492	0.526	0.564	0.604	0.652	0.713	0.855
0.83	0.77		0.079	0.229	0.345	0.373	0.400	0.434	0.466	0.500	0.538	0.578	0.620	0.687	0.829
0.80	0.78		0.053	0.202	0.319	0.347	0.374	0.408	0.440	0.474	0.512	0.552	0.594	0.661	0.803
0.78	0.79		0.026	0.176	0.292	0.320	0.347	0.381	0.413	0.447	0.485	0.525	0.567	0.634	0.776
0.75	0.80			0.150	0.266	0.294	0.321	0.355	0.387	0.421	0.459	0.499	0.541	0.608	0.750
0.72	0.81			0.124	0.240	0.268	0.295	0.329	0.361	0.395	0.433	0.473	0.515	0.582	0.724
0.70	0.82			0.098	0.214	0.242	0.269	0.303	0.335	0.369	0.407	0.447	0.489	0.556	0.698
0.67	0.83			0.072	0.188	0.216	0.243	0.277	0.309	0.343	0.381	0.421	0.463	0.530	0.672
0.65	0.84			0.046	0.162	0.190	0.217	0.251	0.283	0.317	0.355	0.395	0.437	0.504	0.645
0.62	0.85			0.020	0.136	0.164	0.191	0.225	0.257	0.291	0.329	0.369	0.417	0.478	0.620
0.59	0.86				0.109	0.140	0.167	0.198	0.230	0.264	0.301	0.343	0.390	0.450	0.593
0.57	0.87				0.083	0.114	0.141	0.172	0.204	0.238	0.275	0.317	0.364	0.424	0.567
0.54	0.88				0.054	0.085	0.112	0.143	0.175	0.209	0.246	0.288	0.335	0.395	0.538
0.51	0.89				0.028	0.059	0.086	0.117	0.149	0.183	0.230	0.262	0.309	0.369	0.512
0.48	0.90					0.031	0.058	0.089	0.121	0.155	0.192	0.234	0.281	0.341	0.484

5- WHERE TO INSTALL CORRECTION CAPACITORS



4.1 GLOBAL COMPENSATION

4.2 COMENSATION BY SECTOR

4.3 INDIVIDUAL COMPENSATION

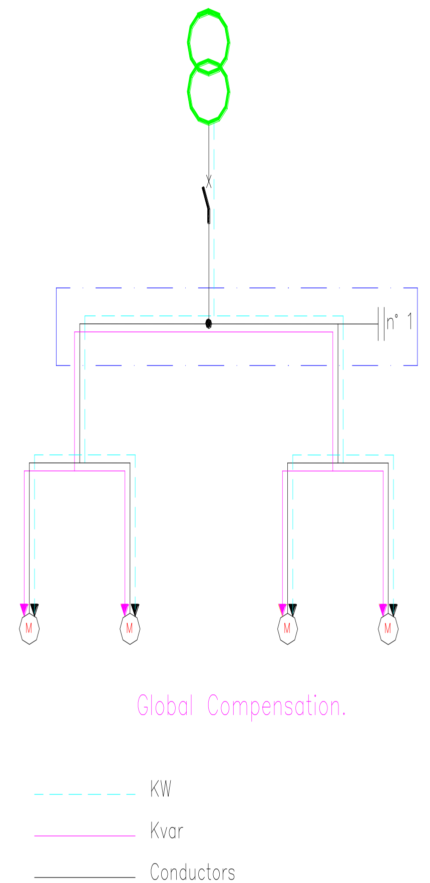
5.1 GLOBAL COMPENSATION

Principles:-

Capacitors bank is Connected to the busbars

of the main dist. Panel, and remains in service

during the period of the normal load.



Advantages:-

- *Reduce the Tariff Penalties*
- *Reduce the Apparent Power KVA*
- *Relieves the supply transformer, which is then able to accept more load if necessary.*

Comments:-

Significant reactive currents no longer exist in the installation

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5.2 COMPENSATION BY SECTOR

Principles:-

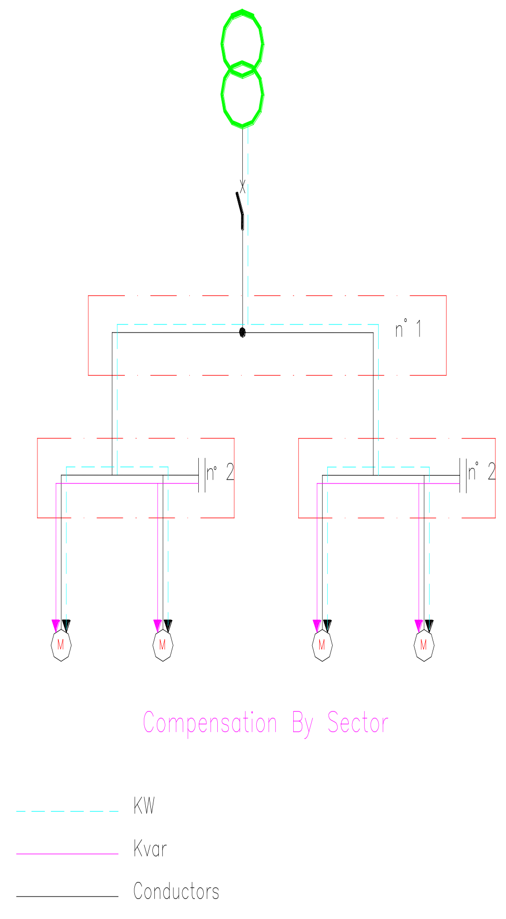
Capacitors banks are Connected to busbars of each local dist. board, and remains in service during the period of the normal load.

Advantages:-

- Reduce the Tariff Penalties
- Reduce the Apparent Power KVA
- Losses in the same cables will be reduced.
- relieves the supply transformer, which is then able to accept more load if necessary.

Comments:-

- Reactive current still flows in all cables downstream of the local dist. Boards



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5.3 INDIVIDUAL COMPENSATION

Principles:-

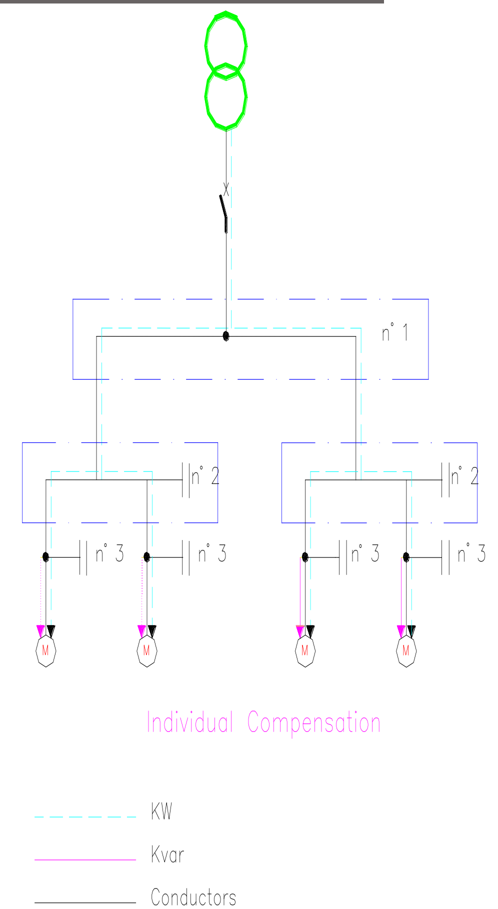
Capacitors Are Connected Directly to The Terminals of Inductive Plant.

Advantages:-

- Reduce the Tariff Penalties
- Reduce the Apparent Power KVA
- Reduce the Size of All Cables

Comments:-

- Significant reactive currents no longer exist in the installation



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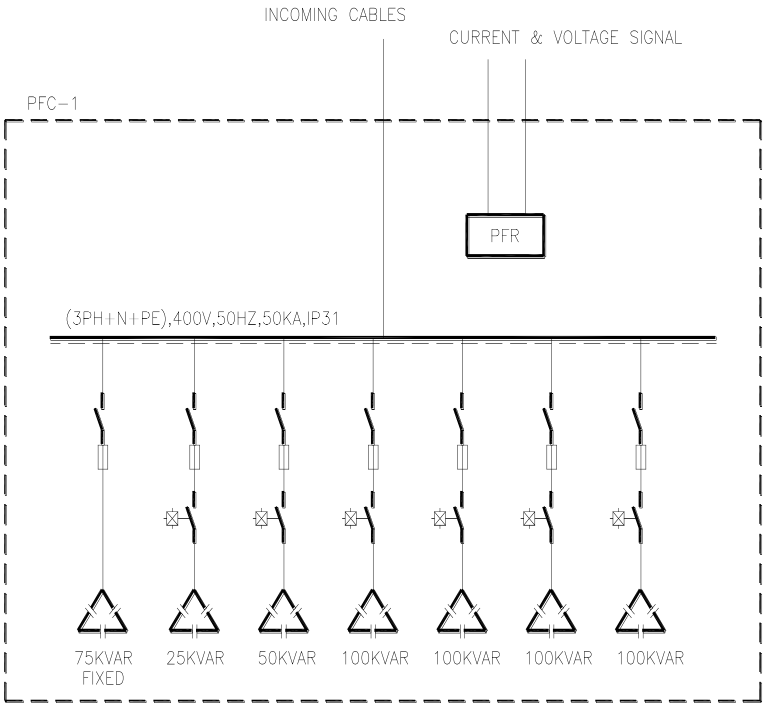
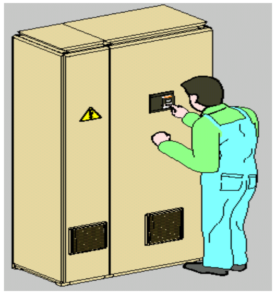
6- EXAMPLE FOR 6th STEPS PFCP



550 KVAR POWER FACTOR CORRECTION



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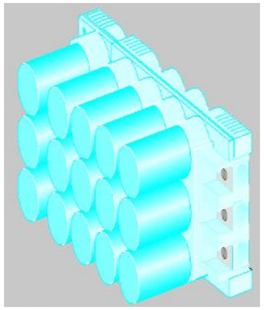
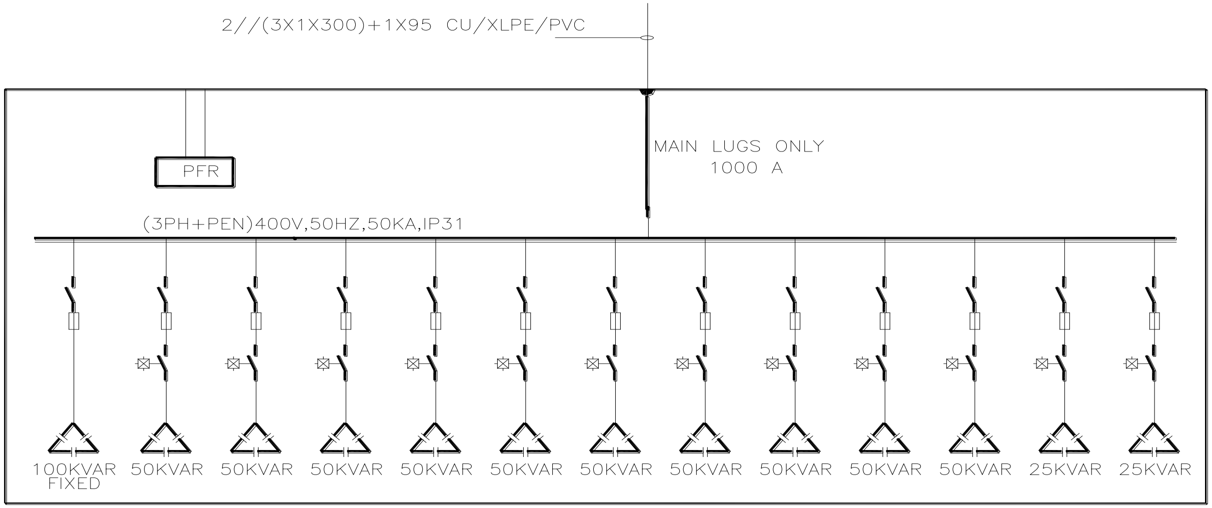
7- EXAMPLE FOR 12th STEPS PFCP





CAPACITORS RATED VOLTAGE SHOULD BE 440V. THE REQUIRED KVAR SHOULD BE ACHIEVED AT THE SYSTEM RATED VOLTAGE 400V

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8- PF CONTROLLER FOR 6th STEP

Connection

The controller is unaffected by phase rotation direction and connection direction of the current transformer (CT).

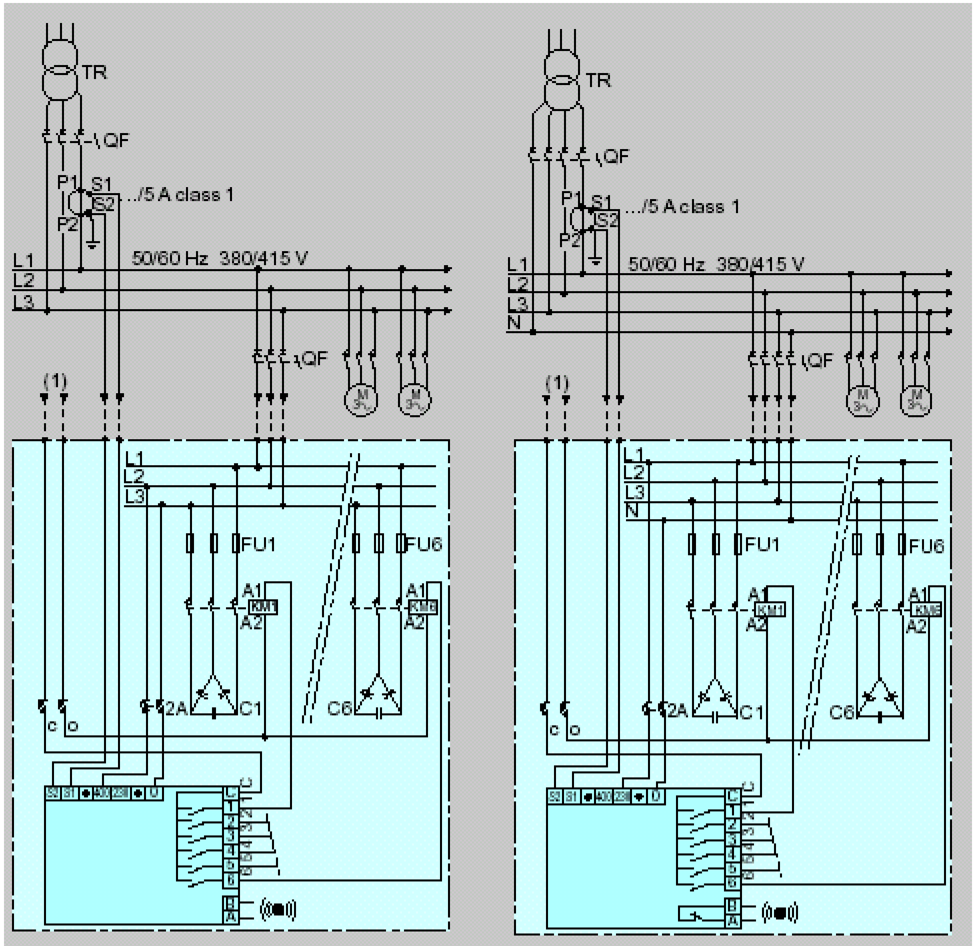
It can be connected in two ways, namely:

- **LL connection type**
  Voltage is measured between two phases. Current is measured on a phase other than the two phases previously used.
- **LN connection type**
  Voltage is measured between a phase and the neutral. Current is measured from the same phase.

Caution: the type of connection used must be consistent with the controller configuration.

On a network with voltage other than 220/240 V or 380/415 V, use a transformer to supply the controller voltage inputs.

Caution: the transformer used must only induce minimum phase shift.



Wiring diagram (LL)
e.g.380/415 V network

Wiring diagram (LN)
e.g.380/415 V network

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9- PF CONTROLLER FOR 12th STEP

Connection

Normal configuration ensures that the controller is not affected by phase rotation direction and connection direction of the current transformer (CT).

The controller can be connected in two ways, namely :

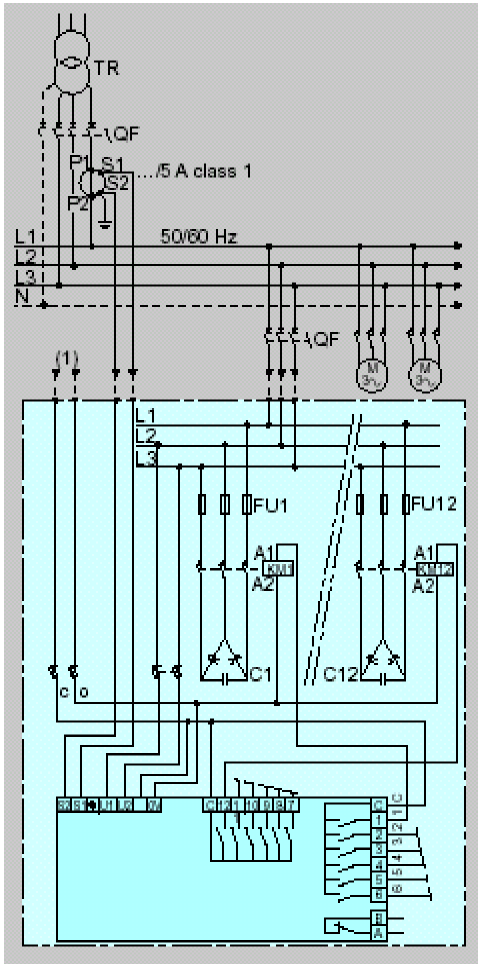
- **LL connection type**
  Voltage is measured between two phases. Current is measured on a phase other than the two phases previously used.
- **LN connection type**
  Voltage is measured between a phase and the neutral. Current is measured from the same phase.

Caution : the type of connection used must be consistent with the controller configuration.

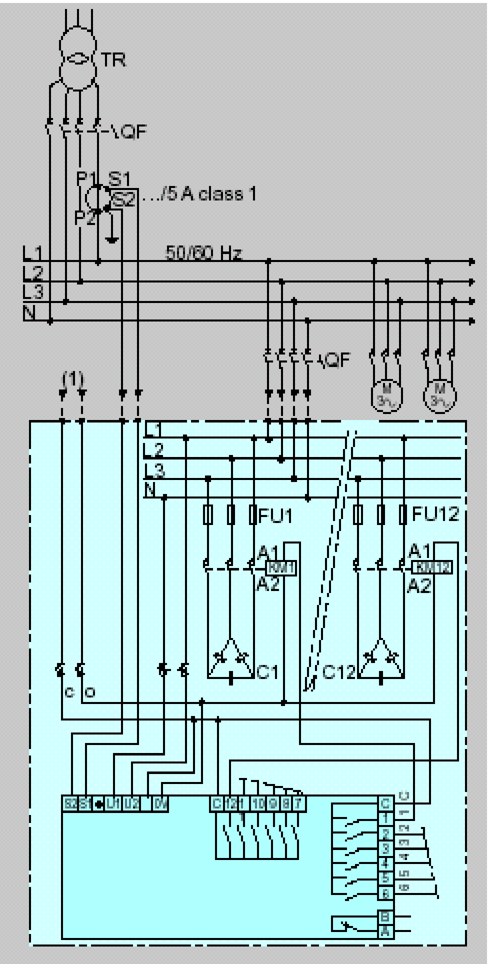
On a network with voltage less than 110 V or greater than 415 V, use a transformer to supply the controller measurement voltage inputs.

Caution : the transformer used must only induce minimum phase shift.

Caution: in operation, 4 quadrants (generator application, RC12 type only), **automatic detection of phase rotation direction must be de-activated.** (to be performed in the configuration mode). **In this particular case, CT connection direction and phase rotation direction must therefore be respected.**



Wiring diagram (LL)
e.g.380/415 V network



Wiring diagram (LN)
e.g.380/415 V network

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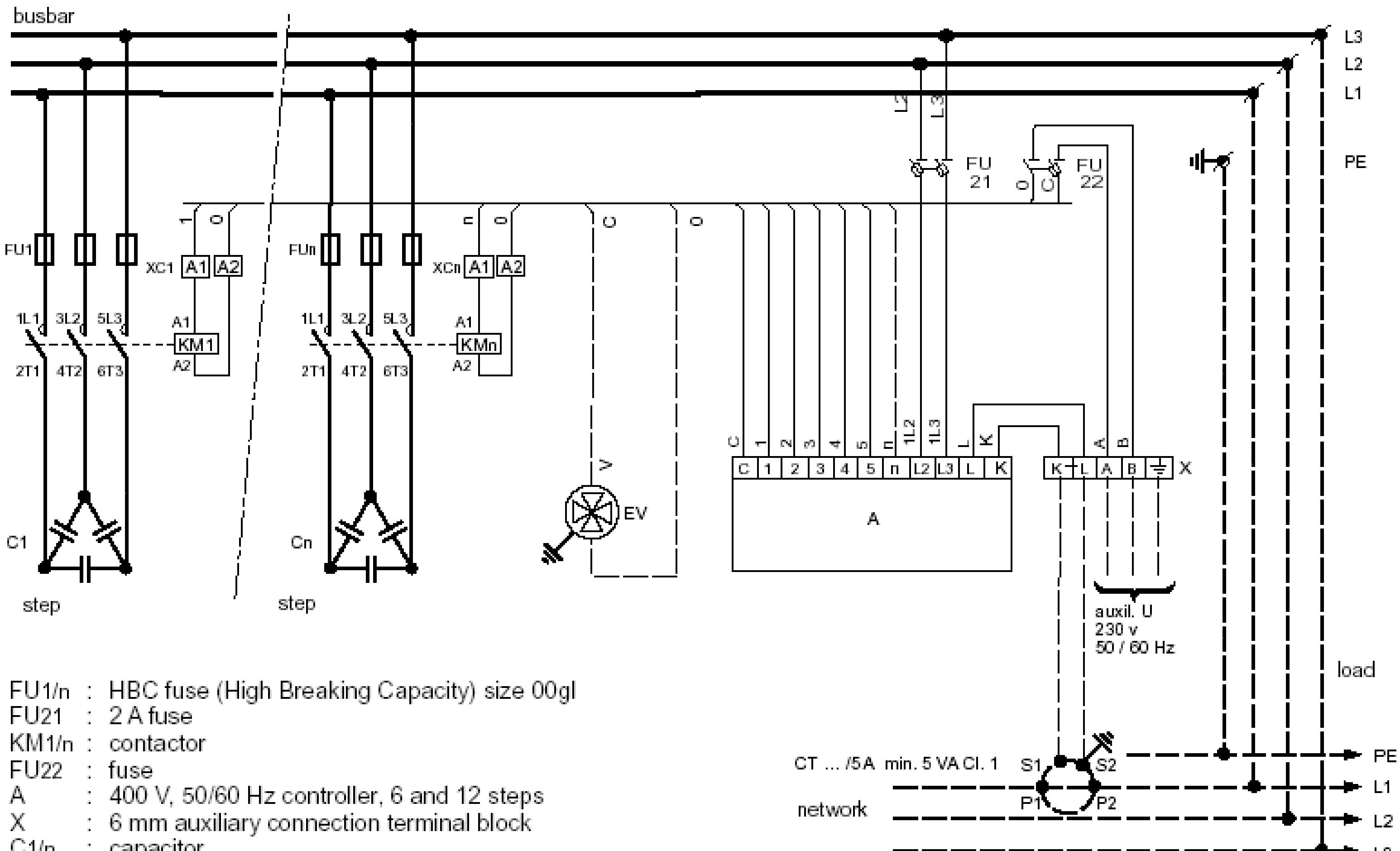
10- STANDARD DIAGRAM FOR PF CONTROLLER FOR 6th & 12th STEPS

Standard diagram



FU1/n : HBC fuse (High Breaking Capacity) size 00gl
FU21 : 2 A fuse
KM1/n : contactor
FU22 : fuse
A : 400 V, 50/60 Hz controller, 6 and 12 steps
X : 6 mm auxiliary connection terminal block
C1/n : capacitor
XC1/n : module control terminal block
EV : fan

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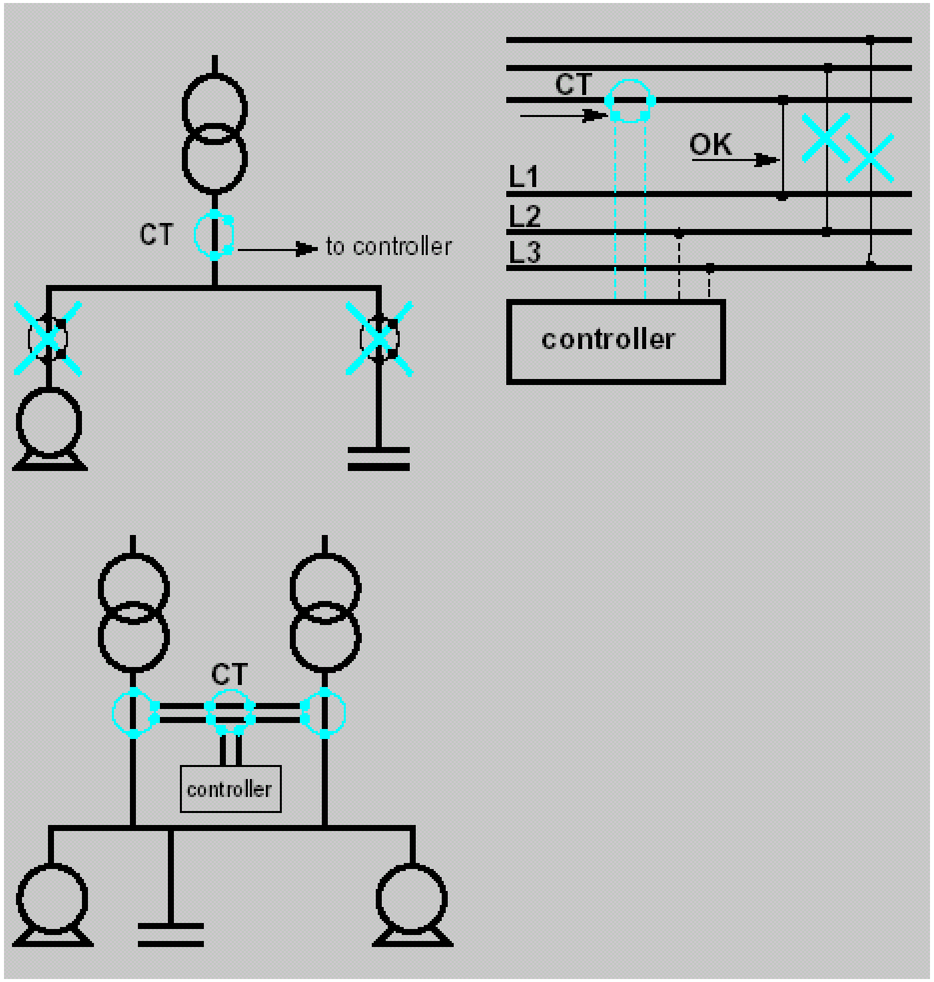
11- INSTALLATION RECOMMENDATIONS

Installation recommendations

- The CT current transformer must be installed upstream of the installation requiring compensation.
- We recommend that you place the controller voltage information between L2 and L3, to oblige the contractor to position the CT on phase L1.
- Design the capacitor bank wiring diagram so that the time required for capacitor discharging (50 sec minimum) is respected, in particular in event of contactor auxiliary voltage loss.
- Case of an installation equipped with two or more supply transformers: a summing CT must then be provided which will take all installation consumption into account.
- Case of an installation equipped with a generator set :
  a contact will be used to disconnect the bank in event of operation on the generator set.
  The best means is to use it to cut the power supply to the power factor controller.



12- FACTORY TEST

The verifications and tests

Perform all the compulsory inspections and tests and in particular the three routine tests defined in standard IEC 439-1
They complete the type tests that must have been carried out beforehand by the manufacturer.

Standard IEC 439-1 defines 10 tests for electrical switchboards :
- *7 type tests*
- *3 routine tests.*

The 7 type tests must be performed in the laboratory and test platforms on cubicles, according to the real operating configurations: complete cubicles, consisting of standard components and equipped with Varplus capacitors. Compliance with assembly instructions and performance of the 3 routine tests then ensure that the switchboard is tested and complies with standards.

1st routine test :

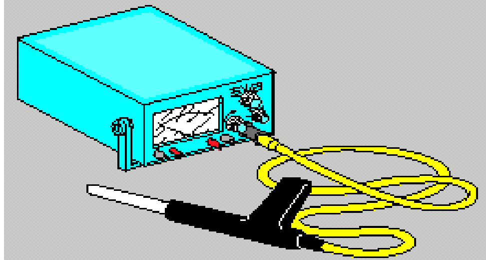
insulation monitoring

Dielectric test
All the devices must be connected, except for those that would not withstand the test voltage (disconnect the controller).

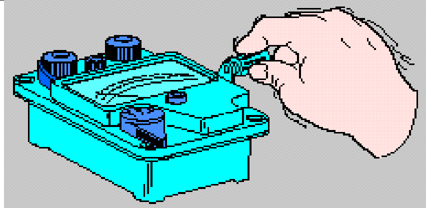
For switchboards with a voltage rating up to 660 V, apply a test voltage of 2500 V – 50 Hz for 1 minute, between all the live parts and the interconnected frames of the assembly.

NB : due to capacitor presence, the test must be performed between the 3 short-circuited phases and the earth.

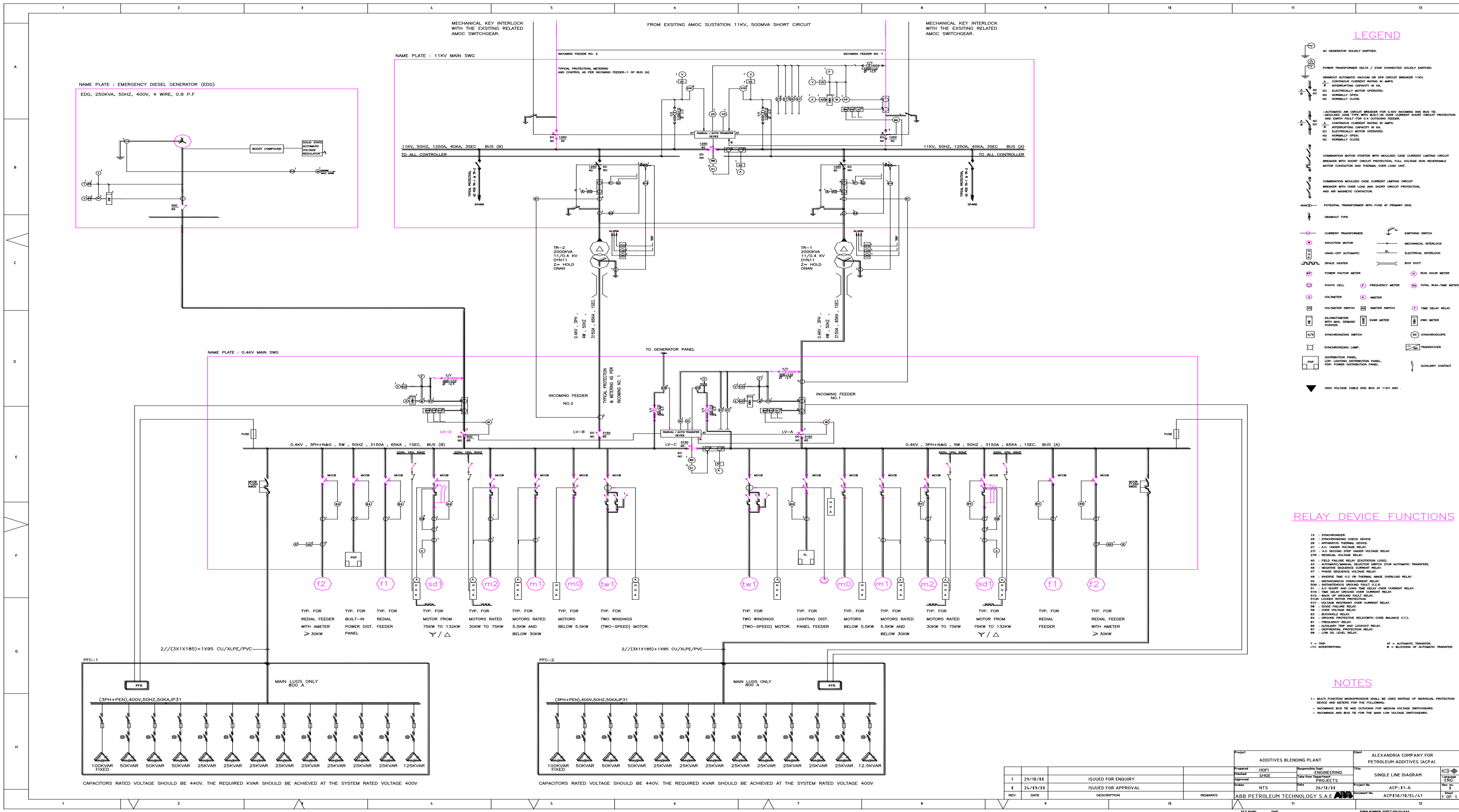
The tests are satisfactory if there is no puncturing or arcing between the various parts tested.



Another solution
If the switchboard does not undergo dielectric testing, insulation must be measured using an insulation measurement instrument at a voltage of at least 500 V (DC).
The minimum insulation resistance value must be equal to 1000 ohms/V.



13- S.L.D FOR ACPA Co.



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The capacitors are mainly used to improve the power factor, below some types of capacitor banks.

Enclosed Switched Bank

Pole-mounted Capacitor Bank

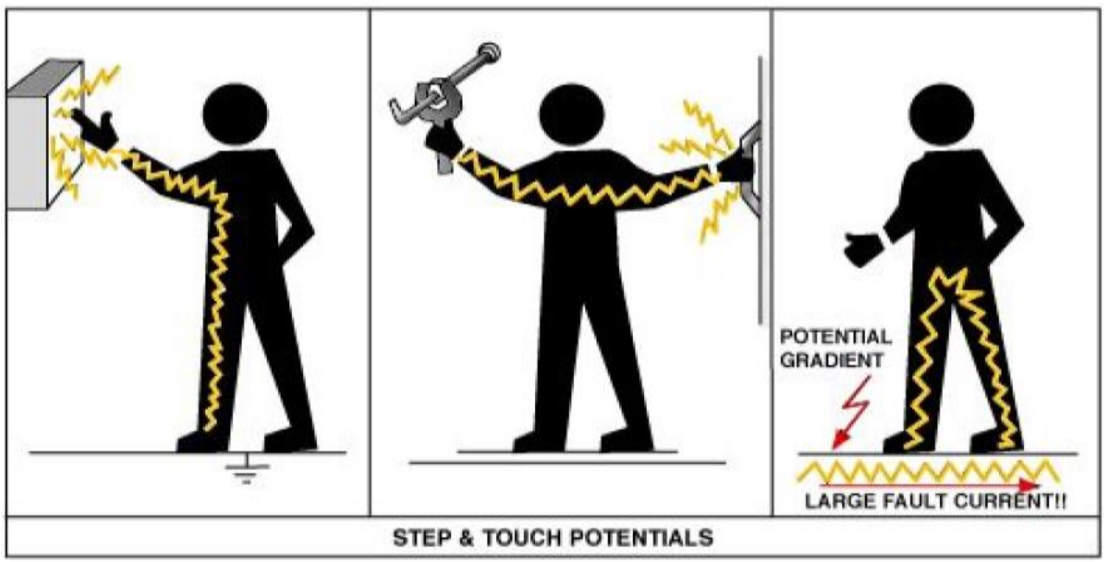
400 Mvar shunt bank for reactive compensation

Earthing Systems

In electricity supply systems, an earthing system defines the electrical potential of the conductors relative to that of the Earth's conductive surface. The choice of earthing system has implications for the safety and electromagnetic compatibility of the power supply.

A *protective earth* (PE) connection ensures that all exposed conductive surfaces are at the same electrical potential as the surface of the Earth, to avoid the risk of electrical shock if a person touches a device in which an insulation fault has occurred. It also ensures that in the cause of an insulation fault, a high fault current flows, which will trigger an overcurrent protection device (fuse, MCB) that disconnects the power supply.

A functional earth connection serves a purpose other than providing protection against electrical shock. In contrast to a protective earth connection, a functional earth connection may carry a current during the normal operation of a device. Functional earth connections may be required by devices such as surge suppression and electromagnetic-compatibility filters, some types of antennas and various measurement instruments. Generally the protective earth is also used as a functional earth though this requires care in some situations.



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Electrical System Earthing

Electrical systems shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

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The importance of the earthing system choice

a- Supply Continuity and System selectivity.

b- Over a voltage Dangers.

c- Arcing.

d- Protection earthing possibility: that include.

-The Equipment grounding

-Lighting protection grounding

-Electrostatic protection grounding

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Types of earthing

There are five basic types of earthing arrangements embodied in the systems identified by TN-C, TN-S, TN-C-S, TT and IT and these are shown in figures .

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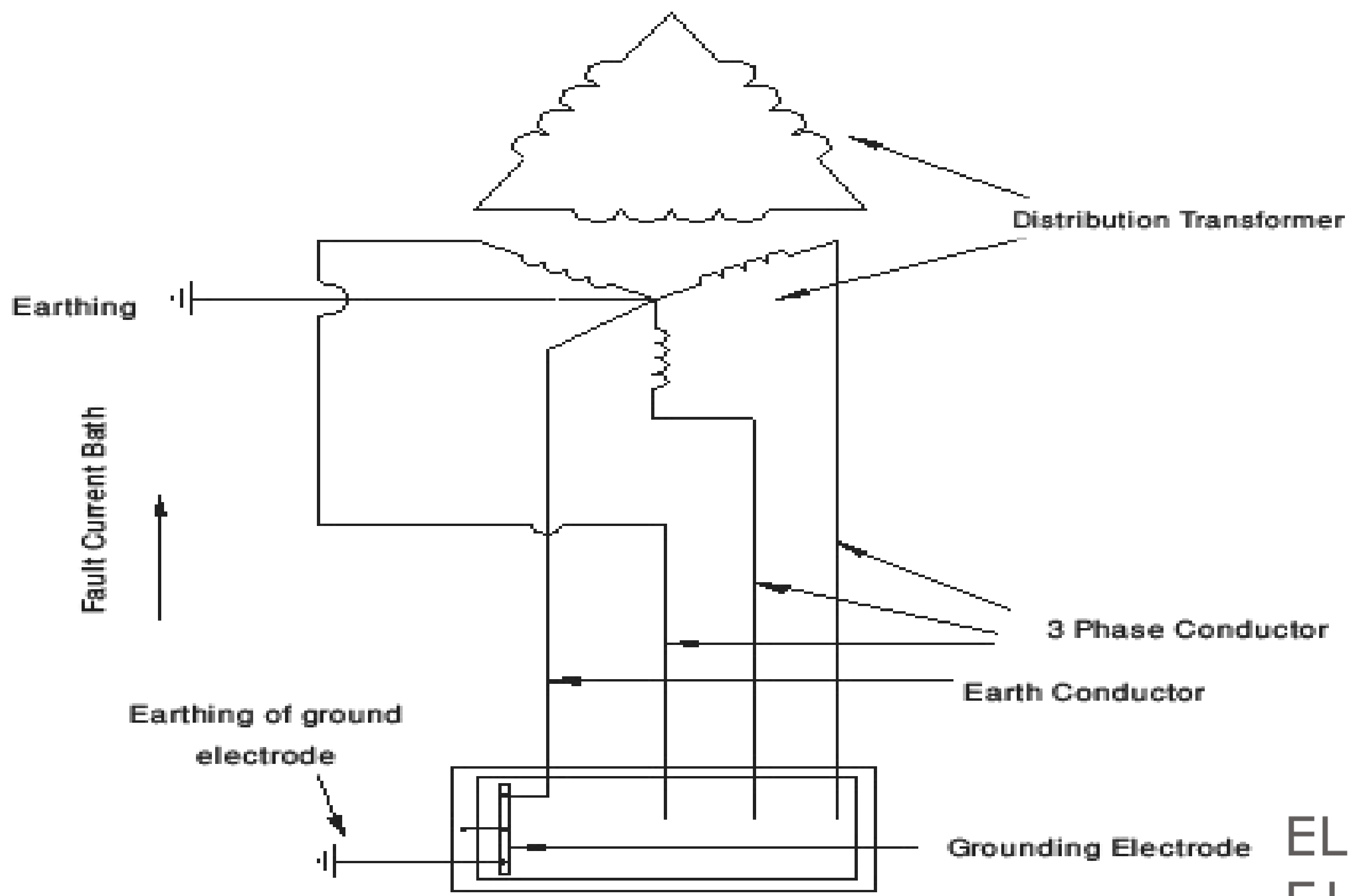
Electrical System Earthing



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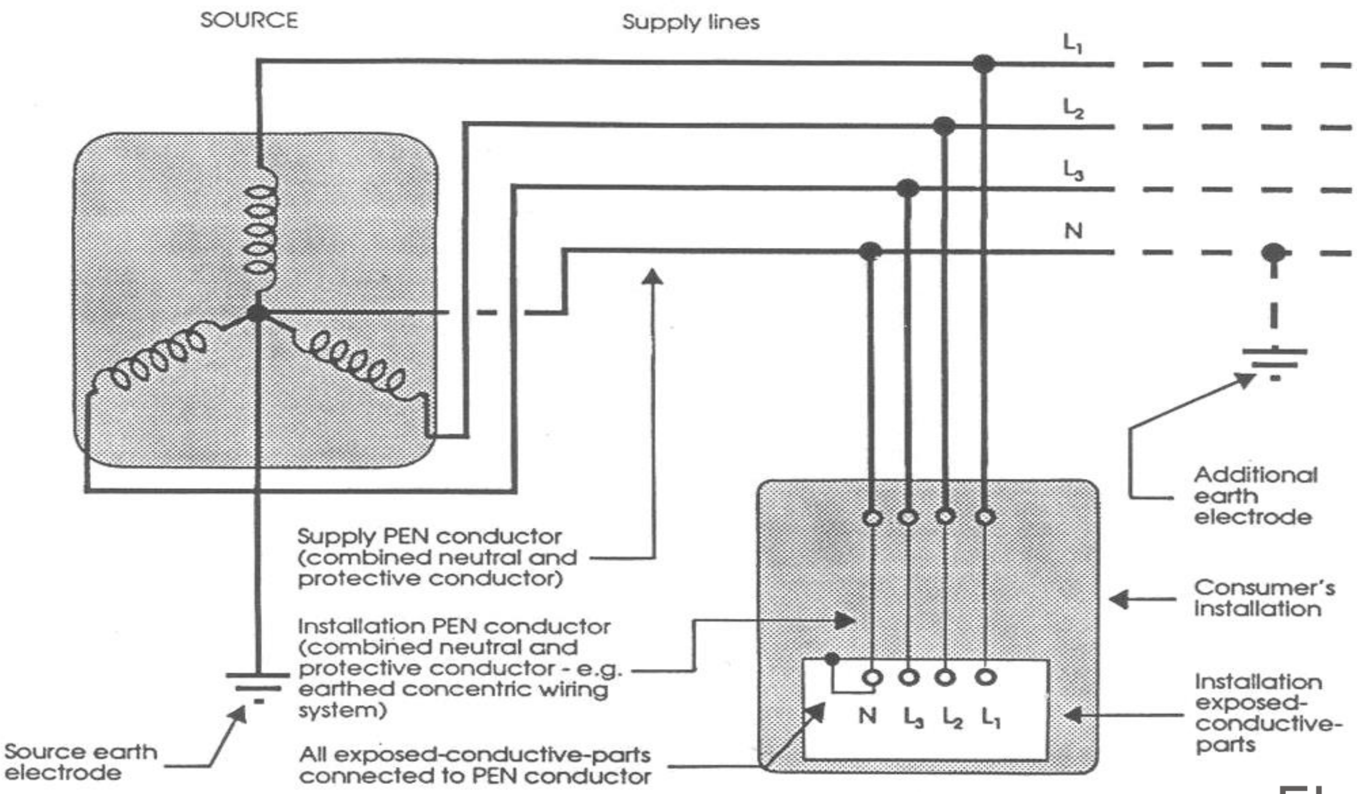
I-In the TN-C system



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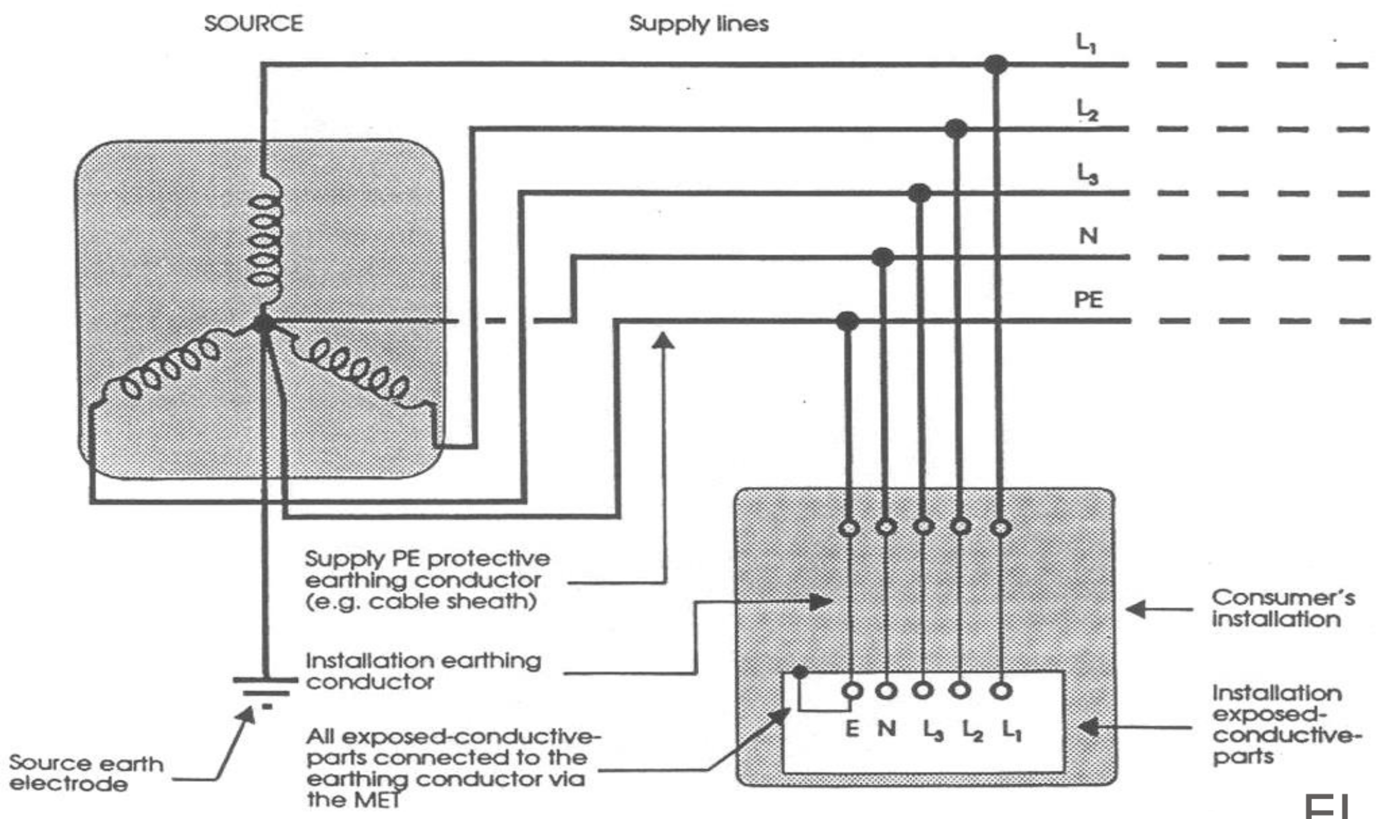
II- In the TN-S system



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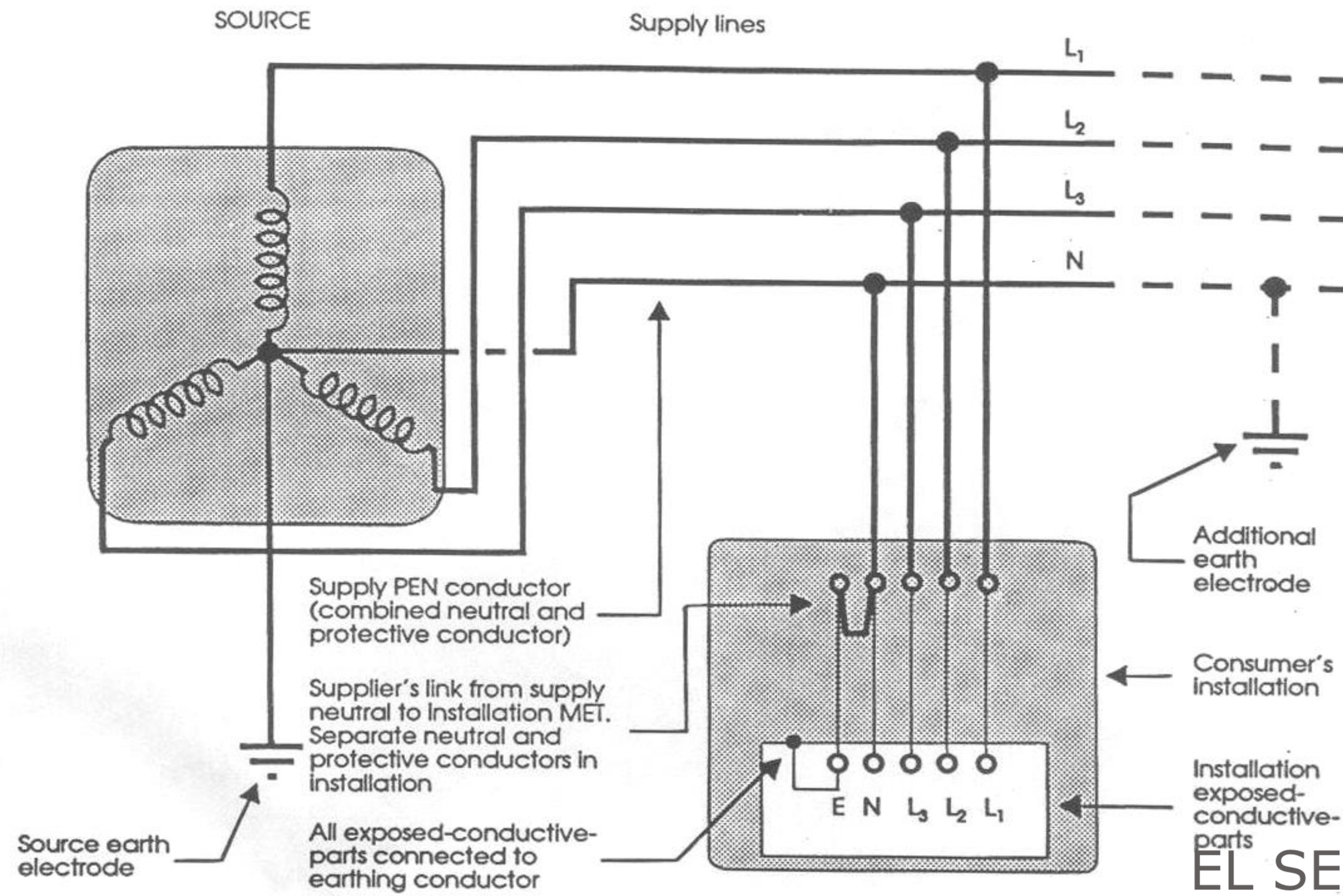
III- In the TN-C-S system



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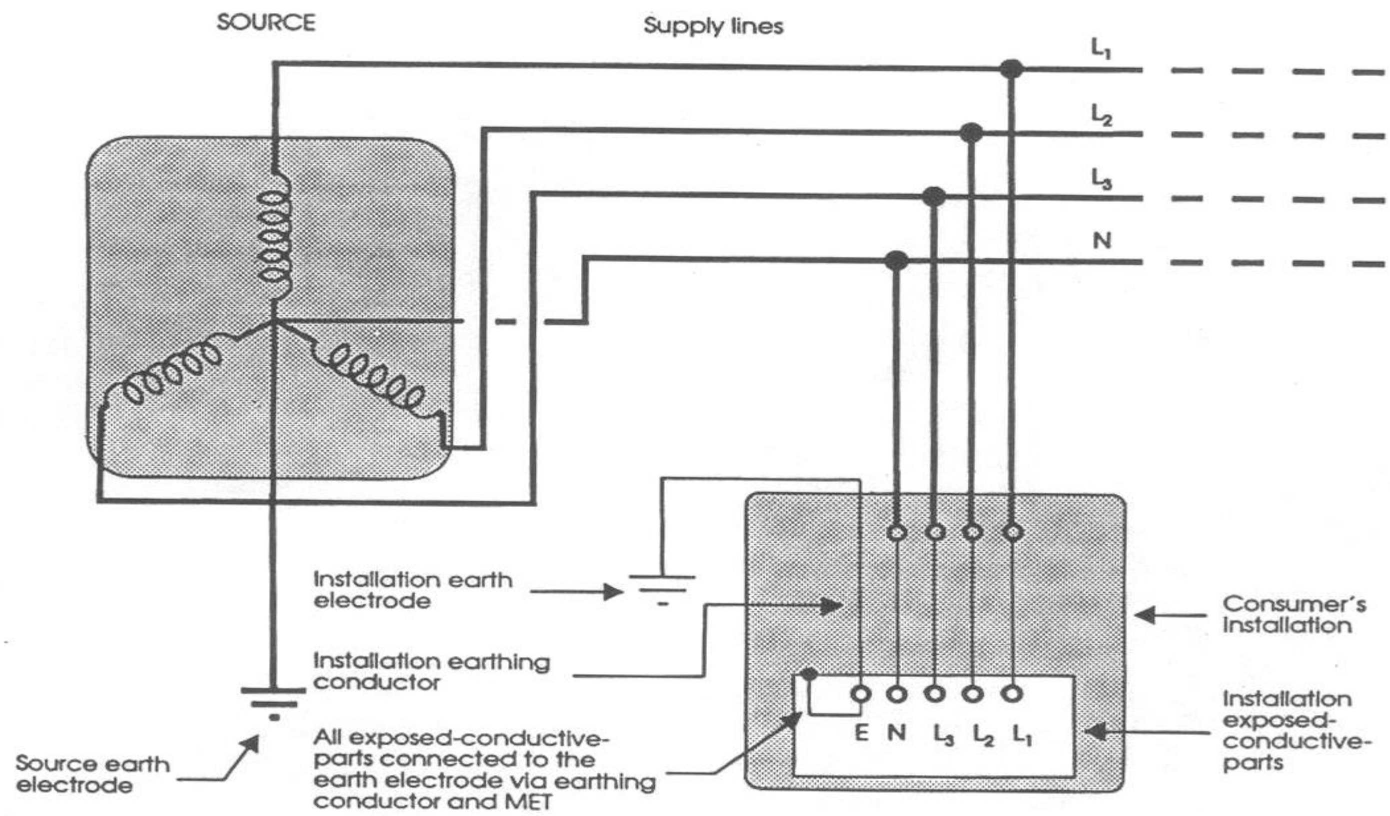
IV- In the TT system



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V- In the IT systems