POWER SYSTEM PROTECTION

THE PROTECTION of ELECTRICAL POWER SYSTEMS FROM FAULTS THROUGH THE ISOLATION OF FAULTY PARTS FROM THE REST of THE ELECTRICAL NETWORK.

THE OBJECTIVE of PROTECTION SCHEME IS TO KEEP THE POWER SYSTEM STABILITY BY ISOLATING ONLY THE COMPONENTS THAT ARE UNDER FAULT, WHILST LEAVING AS MUCH of THE NETWORK AS POSSIBLE STILL IN OPERATION.

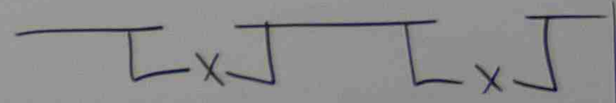
COMPONENTS of POWER SYSTEM PROTECTION SCHEME

SMALL POWER SYSTEM ⟶ FUSE

MEDIUM (OR) LARGE POWER SYSTEM ⟶ PROTECTIVE RELAY + CIRCUIT BREAKER

AUTOMATIC LINE SECTIONALIZER

AUTOMATIC SWITCH WITH A SELF CONTAINED CIRCUIT OPENING DEVICE THAT AUTOMATICALLY OPENS THE MAIN ELECTRICAL CIRCUIT AFTER SENSING AND RESPONDING TO A PRE-DETERMINED NUMBER of SUCCESSIVE MAIN CURRENT IMPULSES.



RE-CLOSER

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m FAULTS THROUGH THE ISOLATION

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EEP THE POWER SYSTEM STABILITY

ARE UNDER FAULT, WHILST

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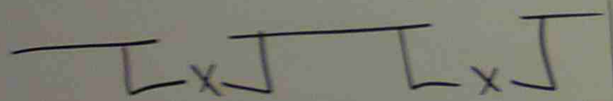
TIVE RELAY + CIRCUIT BREAKER

INED CIRCUIT OPENING DEVICE

AIN ELECTRICAL CIRCUIT AFTER

-DETERMINED NUMBER OF

ES.



RE-CLOSER

AN AUTOMATIC HIGH VOLTAGE ELECTRIC SWITCH. IT TRIES TO RE-CLOSE THE LINE FOR FOUR OR FIVE TIMES UNDER TEMPORARY FAULT CONDITION. WHEN THE FAULT IS PERMANENT, IT WILL ISOLATE THE LINE PERMANENTLY.

BIL

BASIC INSULATION LEVEL.

A REFERENCE INSULATION LEVEL THAT MEASURES THE ABILITY OF THE INSULATION TO WITHSTAND VERY HIGH VOLTAGE SURGES.

SUBSTATION EQUIPMENTS

PROTECTION

OVER CURRENT RELAY, DIFFERENTIAL RELAY

REVERSE POWER RELAY

VOLTAGE LEVEL CHANGE

STEP DOWN POWER TRANSFORMERS

EARTHING

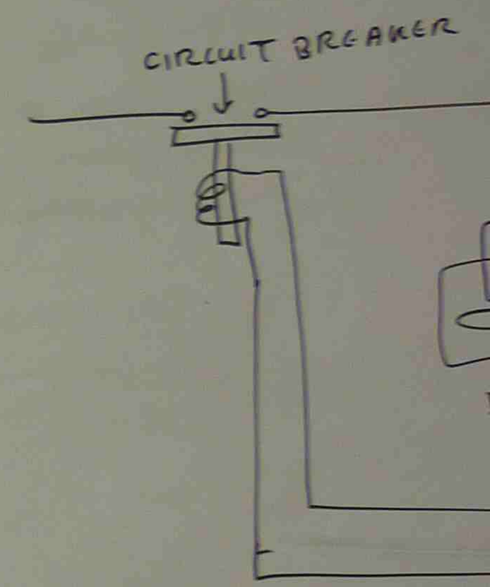
EARTHING TRANSFORMERS

POWER FACTOR IMPROVEMEN

FREE RUNNING SYNCHRONOU

POWER FACTOR OF THE WH

OVER CURRENT RELAY



RIC SWITCH. IT TRIES TO RECLOSE
TIMES UNDER TEMPORARY FAULT
PERMANENT, IT WILL ISOLATE

THAT MEASURES THE ABILITY
D VERY HIGH VOLTAGE SURGES.

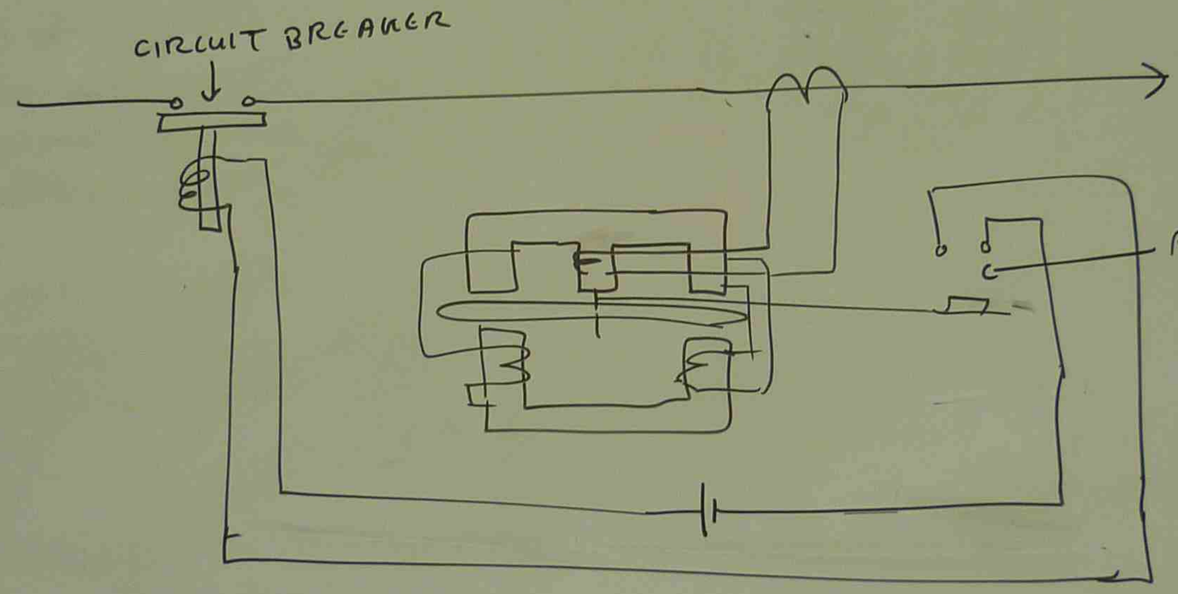
RENTIAL RELAY

RMERS

POWER FACTOR IMPROVEMENT

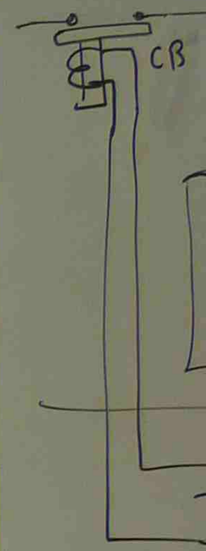
FREE RUNNING SYNCHRONOUS MOTORS TO IMPROVE THE POWER FACTOR OF THE WHOLE SYSTEM.

OVER CURRENT RELAY



EQUIPMENT PROTECTION

DISTANCE RE



CT-
PT-

OPERATI
RESTRAI

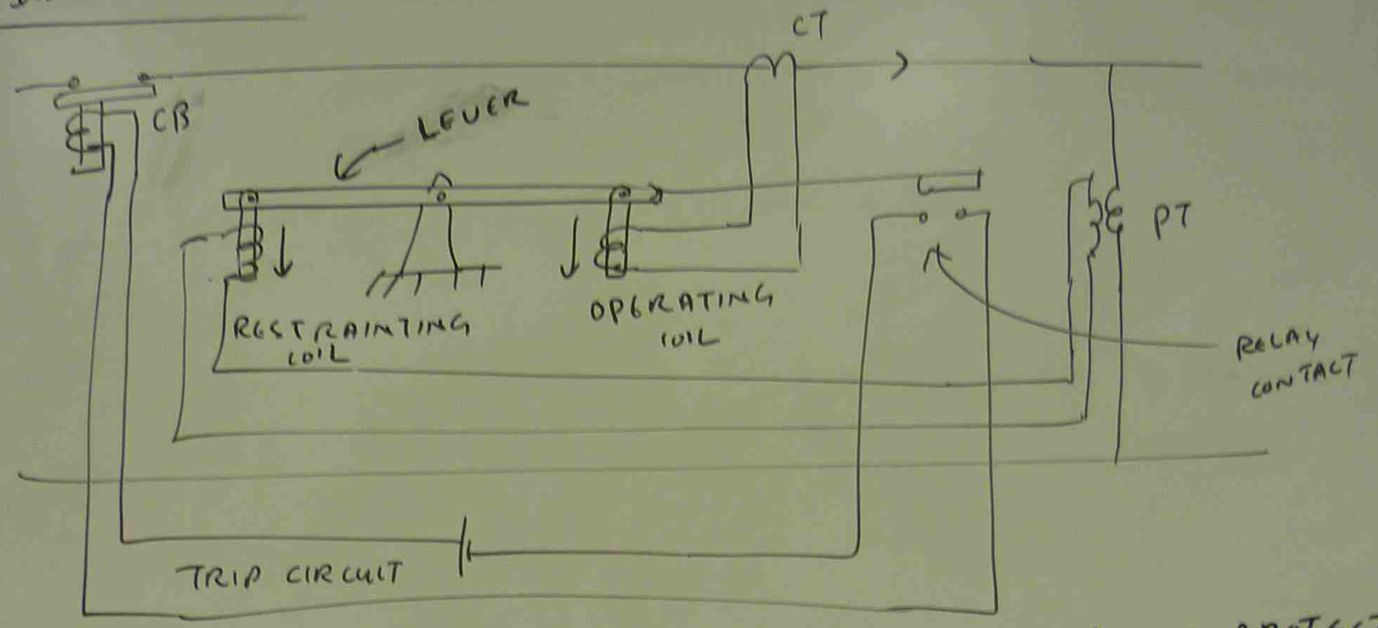
NORMA

FAULT

RELAY
CONTACT

EQUIPMENT
PROTECTION

DISTANCE RELAY



CT - CURRENT TRANSFORMER
PT - POTENTIAL TRANSFORMER

OPERATING COIL FLUX $\propto$ LINE CURRENT

RESTRAINING COIL FLUX $\propto$ LINE VOLTAGE

NORMAL — LINE VOLTAGE IS HIGH
LINE CURRENT IS LOW

$$\text{LINE IMPEDANCE} = \frac{\text{LINE VOLTAGE}}{\text{LINE CURRENT}}$$

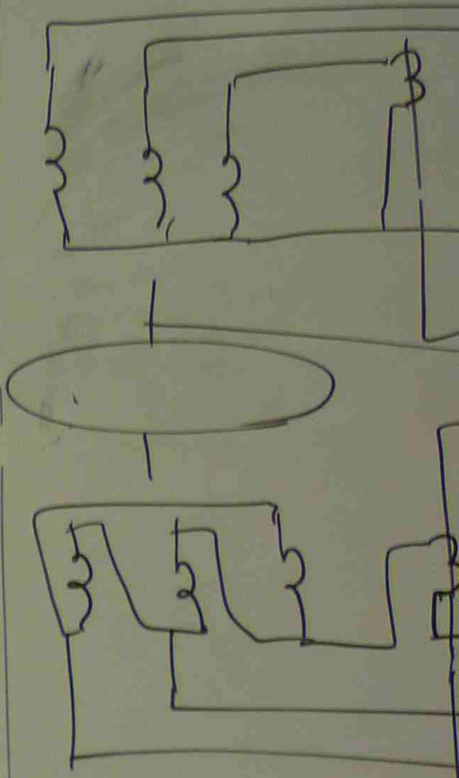
FAULT — LINE VOLTAGE IS LOW
LINE CURRENT IS HIGH

LINE IMPEDANCE IS LOW

$\phi_{OPERATING} > \phi_{RESTRAINING}$

LINE PROTECTION

DIFFERENTIAL RE



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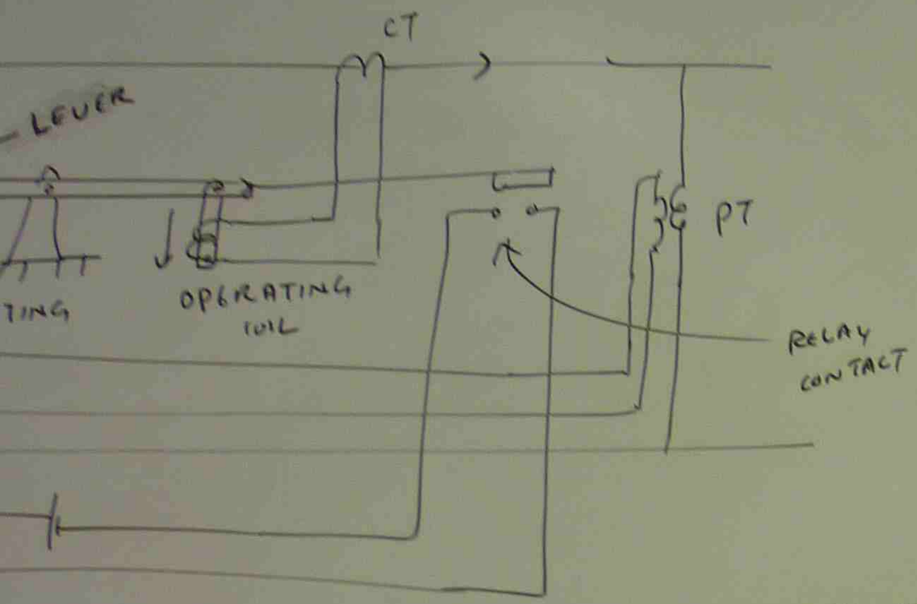
MAIN POWER TR



RANSFORMER
TRANSFORMER

∝ LINE CURRENT
∝ LINE VOLTAGE

TAGE IS HIGH
RRENT IS LOW

TAGE IS LOW
RRENT IS HIGH

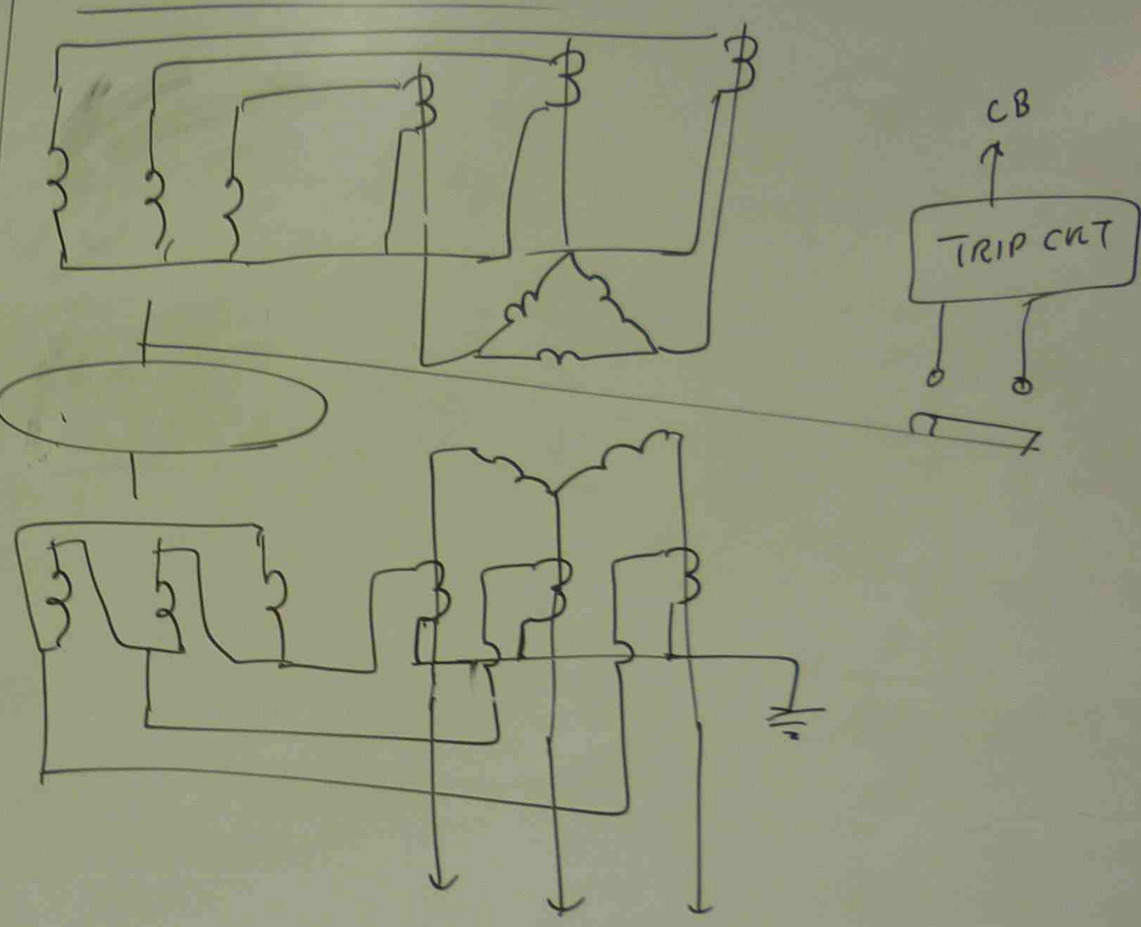
LINE PROTECTION

$$\text{LINE IMPEDANCE} = \frac{\text{LINE VOLTAGE}}{\text{LINE CURRENT}}$$

LINE IMPEDANCE IS LOW

$\phi_{OPERATING} > \phi_{RESTRAINTING}$

DIFFERENTIAL RELAY



DIFFERENTIAL PROTECTION FOR
MAIN POWER TRANSFORMER

SUPERVISING

EQUIPMENTS FOR

- TRANSMISSION LINE
ARE UTILIZED.
- DISTRIBUTIONS
(OR) WOODEN

INSULATORS

PIN INSULA
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POLE STRENGT

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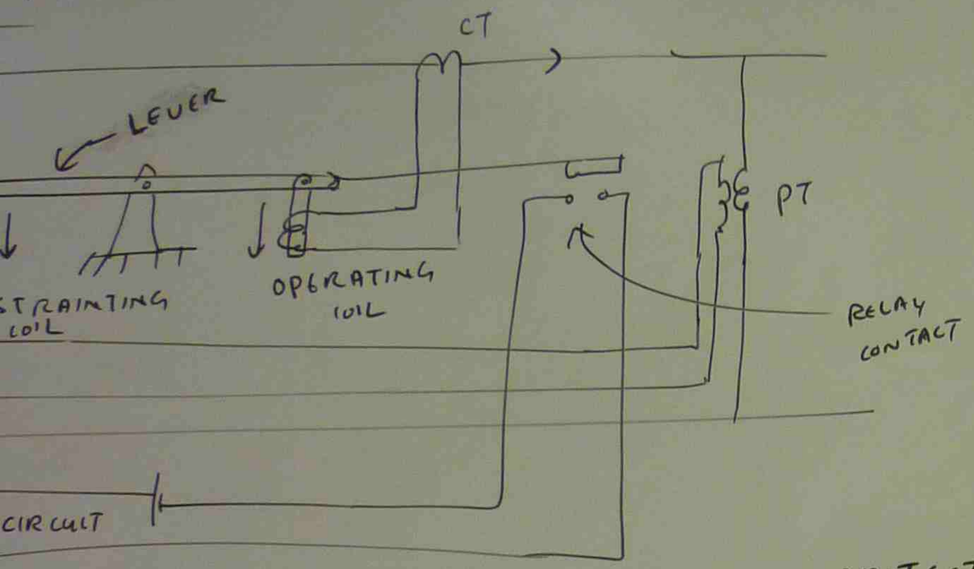


ENT TRANSFORMER
TIAL TRANSFORMER

FLUX ∝ LINE CURRENT
COIL FLUX ∝ LINE VOLTAGE

NE VOLTAGE IS HIGH
INE CURRENT IS LOW

NE VOLTAGE IS LOW
NE CURRENT IS HIGH

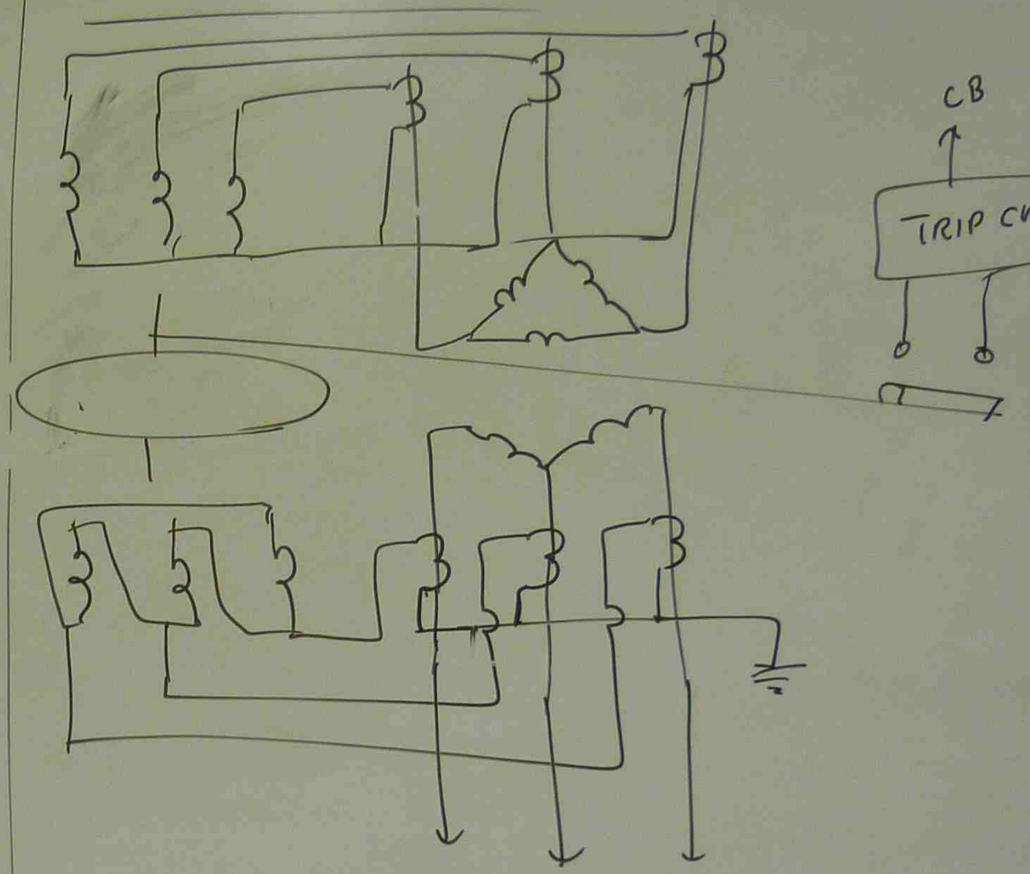
LINE PROTECTION

$$\text{LINE IMPEDANCE} = \frac{\text{LINE VOLTAGE}}{\text{LINE CURRENT}}$$

LINE IMPEDANCE IS LOW

$\phi_{OPERATING} > \phi_{RESTRAINTING}$

DIFFERENTIAL RELAY



DIFFERENTIAL PROTECTION FOR MAIN POWER TRANSFORMER

SUPERVISING TRI

EQUIPMENTS FOR L

- TRANSMISSION LINES ARE UTILIZED.
- DISTRIBUTIONS LIN

(OR) WOODEN POL

INSULATORS

PIN INSULAT
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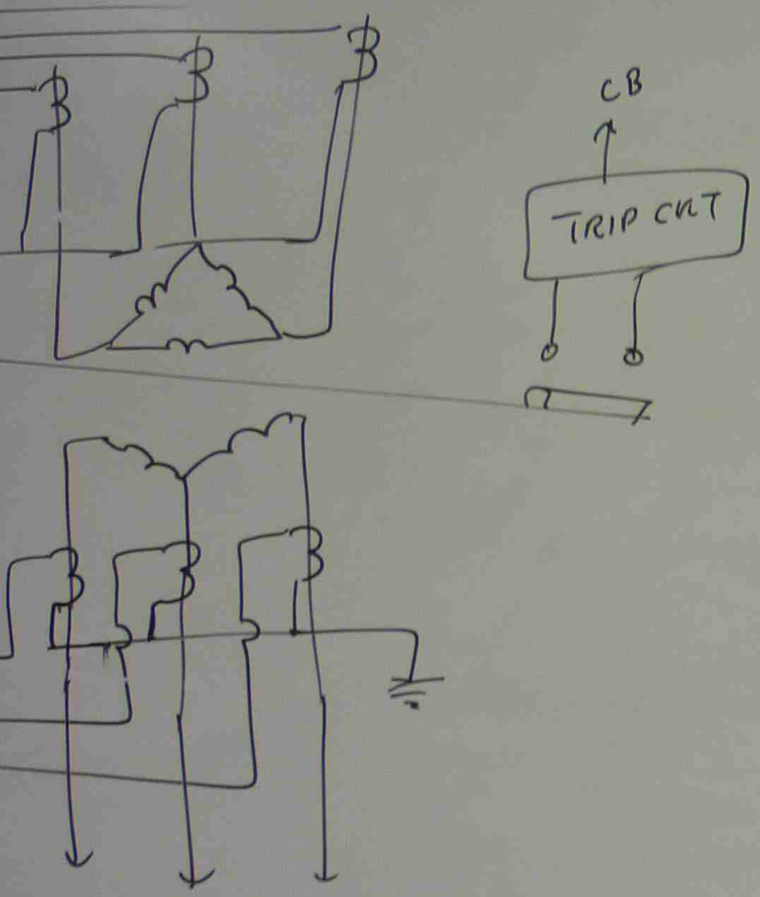
POLE STRENGTH

WIND FORCE
CONDUCTOR,

L RELAY



PROTECTION FOR
TRANSFORMER

SUPERVISING TRIP SIGNAL TRAVELS OVER TELECOM: LINE

EQUIPMENTS FOR LINE CONSTRUCTION

- TRANSMISSION LINES (132 KV, 230 KV, 330 KV, 500 KV), STEEL TOWERS ARE UTILIZED.
- DISTRIBUTIONS LINES (66 KV, 33 KV, 11 KV, 415 V), CONCRETE POLE (OR) WOODEN POLE (OR) STEEL POLES ARE UTILIZED.

INSULATORS

PIN INSULATOR (415 V)

DIS INSULATOR (11 KV, 33 KV)

INSULATOR STRING (TRANSMISSION LEVEL VOLTAGE 132 KV, 230 KV, 330 KV, 500 KV)

POLE STRENGTH

WIND FORCE, CONDUCTOR WEIGHT, TENSIONS IN CONDUCTOR, LINE DEVIATION.

DISTRIBUTION TRANSFORME

ANY TRANSFORMER RATED INCLUSIVE WITH A PRIMARY GREATER. A TRANSFORMER RELATIVELY SMALL AMOUN IT IS USED AT THE END O DELIVERY SYSTEM. OFTE

UNDER GROUND TRANSFORM

IN BUILDINGS CONSISTING MONO BLOCK STRUCTURE UNDER GROUND INSTALLA DIFFERENT TYPES OF E CONFIGURATIONS.

ERUSING TRIP SIGNAL TRAVELS OVER TELECOM: LINE

PMENTS FOR LINE CONSTRUCTION

ISSION LINES (132 KV, 230 KV, 330 KV, 500 KV), STEEL TOWERS
ILIZED.
21 BUTTON LINES (66 KV, 33 KV, 11 KV, 415 V), CONCRETE POLE
WOODEN POLE (OR) STEEL POLES ARE UTILIZED.

TORS

INSULATOR (415 V)
INSULATOR (11 KV, 33 KV)
LATOR STRING (TRANSMISSION LEVEL VOLTAGE
132 KV, 230 KV, 330 KV, 500 KV)

STRENGTH

ND FORCE, CONDUCTOR WEIGHT, TENSION IN
NDUCTOR, LINE DEVIATION.

DISTRIBUTION TRANSFORMER

ANY TRANSFORMER RATED BETWEEN 3 AND 500 KVA INCLUSIVE WITH A PRIMARY VOLTAGE OF 0.6 KV OR GREATER. A TRANSFORMER USED TO SUPPLY RELATIVELY SMALL AMOUNT OF POWER TO RESIDENCES. IT IS USED AT THE END OF ELECTRICAL UTILITY'S DELIVERY SYSTEM. OFTEN MOUNTED ON POLE.

UNDER GROUND TRANSFORMER

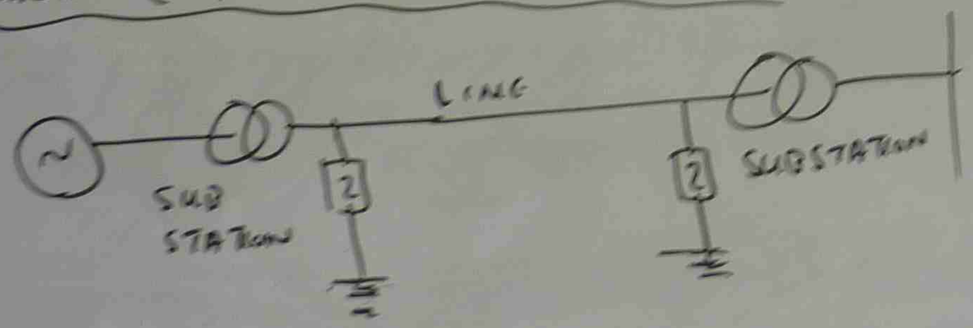
IN BUILDINGS CONSISTING OF A REINFORCED CONCRETE MONO BLOCK STRUCTURE ENCLOSURE, DESIGNED FOR UNDER GROUND INSTALLATION, WHICH CAN HOUSE DIFFERENT TYPES OF ELECTRICAL DISTRIBUTION CONFIGURATIONS.

RATING

HT (HIGH TENSION) SUBSTATION MEANS IF SUBSTATION IS SUPPLYING POWER TO ANOTHER SUBSTATION IS CALLED H.T SUBSTATION (500 KV, 330 KV, 230 KV, 132 KV, 66 KV)

LT (LOW TENSION) SUBSTATION MEANS IF SUBSTATION IS SUPPLYING POWER TO DOMESTIC AND INDUSTRIAL USAGE (66 KV, 33 KV, 11 KV, 415 V)

SURGE (OR) LIGHTNING ARRESTER



SURGE ARRESTER (OR) LIGHTNING ARRESTER DISCHARGE THE OVER VOLTAGE SURGES TO EARTH AND PROTECT THE EQUIPMENT INSULATION FROM SWITCHING SURGES AND LIGHTNING SURGES. IN A SUBSTATION, SURGE ARRESTER IS LOCATED AT THE STARTING OF THE SUBSTATION

APPLYING POWER TO ANOTHER

230KV, 230KV, 132KV, 66KV)

IS SUPPLYING POWER TO

11KV, 415V)

DISCHARGE THE OVER VOLTAGE

PMENT INSULATION FROM

ES. IN A SUBSTATION, SURGE

NG OF THE SUBSTATION

AS SEEN FROM INCOMING TRANSMISSION LINE AND IS THE FIRST EQUIPMENT of SUBSTATION.

SUBSTATION EQUIPMENTS (ECONOMIC ASPECT)

REVENUE METER

THE FUNDAMENTAL FUNCTIONS of A REVENUE METER ARE TO PROVIDE MEASUREMENTS THAT ARE WITHIN INDUSTRY ACCEPTED LIMITS FOR ACCURACY OVER A DEFINED RANGE OF OPERATING CONDITIONS AND TO PROVIDE ADEQUATE PROTECTION AGAINST UNAUTHORIZED ALTERATION OF THESE MEASURED QUANTITIES.

POWER FACTOR

THE RELATIONSHIP BETWEEN WORKING (ACTIVE) POWER AND TOTAL POWER CONSUMED (APPARENT POWER).

DEMAND CONTROL

MAXIMUM DEMAND CONTROL.

ELECTRONIC METERING

POWER & ENERGY

PROTECTIVE

AIR CIRCUIT BREAKER (ACB)

AIR BL CIRCUI BREAKE (ABCB

AIR CIRCUIT BREAKER

- COMPRISE ONE (OR)
- WHEN THE ELECTRIC IT IS EXTINGUIS

IF OIL IS UTILIZED

IMPORTANT FACTORS

POLARITY, BUSHI

NE AND IS THE FIRST

ASPECT)

REVENUE METER ARE
ARE WITHIN INDUSTRY
ER A DEFINED RANGE
PROVIDE ADEQUATE
ALTERATION OF THESE

KING (ACTIVE) POWER
(APPARENT POWER).

OL.

ELECTRONIC METERING

POWER & ENERGY METER

PROTECTIVE SWITCH GEARS

- AIR CIRCUIT BREAKER (ACB)
- AIR BLAST CIRCUIT BREAKER (ABCB)
- OIL CIRCUIT BREAKER (OCB)
- VACUUM CIRCUIT BREAKER
- SF6 CIRCUIT BREAKER

AIR CIRCUIT BREAKER

- COMPRISE ONE (OR) MORE FIXED CONTACTS AND MOVING CONTACTS.
- WHEN THE ELECTRIC ARC OCCURS BETWEEN FIXED AND MOVING CONTACTS, IT IS EXTINGUISHED WITH AIR

IF OIL IS UTILIZED TO COOL THE ARC, IT WILL BE OIL CIRCUIT BREAKER

IMPORTANT FACTORS

POLARITY, BUSHING) OIL (TRANSFORMER INSULATING OIL), COOLING

IONISING PROCES

RADIATION (OR) ION
WHICH ARE OF SHO

THE ELECTRIC ARC
EXTINGUISHED A
THE CIRCUIT BREA

ARC INTERRUP

(1) HIGH RESISTANCE

ARC RESISTANCE

(2) LOW RESISTA

IONISING PROCESS

RADIATION (OR) IONIZING CONSISTS of PARTICLES OR ELECTROMAGNETIC WAVES WHICH ARE OF SHORT WAVE LENGTHS.

THE ELECTRIC ARC NEEDS TO BE ELONGATED, CUT, SPLIT AND EXTINGUISHED AFTER SOLID ARC BECOMES SPLIT ARC PARTICLES.

THE CIRCUIT BREAKER MUST POSSESS SUCH FUNCTIONS.

$$R = \frac{\rho L}{A}$$

ARC INTERRUPTION

(1) HIGH RESISTANCE METHOD → ARC RESISTANCE IS MADE TO INCREASE WITH TIME SO THAT THE CURRENT BECOME INSUFFICIENT TO MAINTAIN THE ARC.

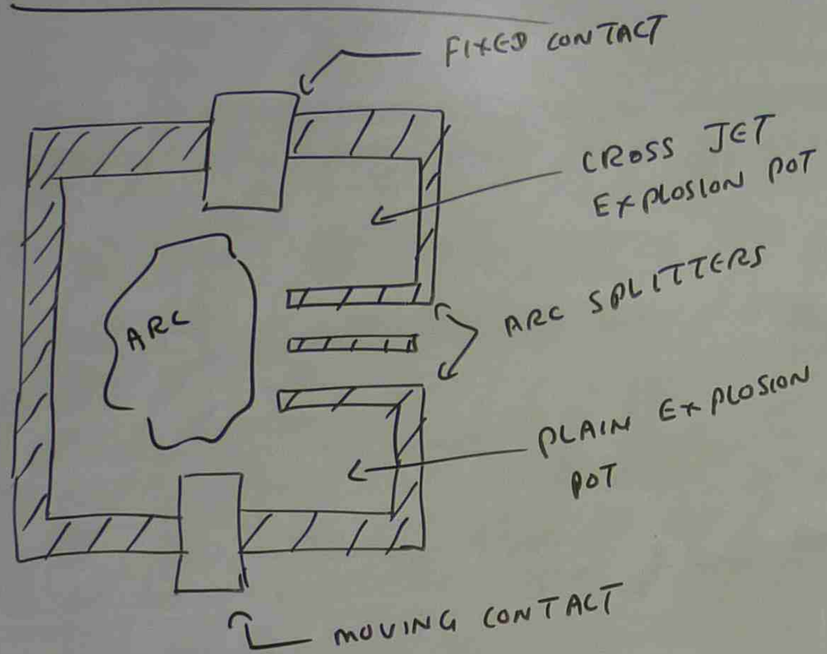
ARC RESISTANCE CAN BE INCREASED BY (i) LENGTHENING THE ARC
(ii) COOLING THE ARC
(iii) REDUCING THE CROSS SECTION OF THE ARC
(iv) SPLITTING THE ARC.

(2) LOW RESISTANCE METHOD — USED FOR AC CIRCUIT ONLY.

DE IONISATION CAN BE ACHIEVED BY

(i) LENGTHENING THE GAP
(ii) HIGH PRESSURE
(iii) COOLING
(iv) BLAST EFFECT.

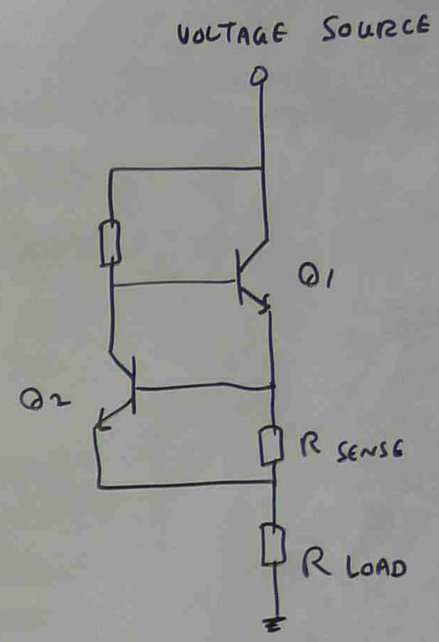
OIL CIRCUIT BREAKER



WHEN FIXED CONTACT AND MOVING CONTACT ARE SEPARATED, THE ELECTRIC ARC OCCURS.

THE ELECTRIC ARC IS SPLITTED BY ARC SPLITTERS AND EXTINGUISHED BY OIL.

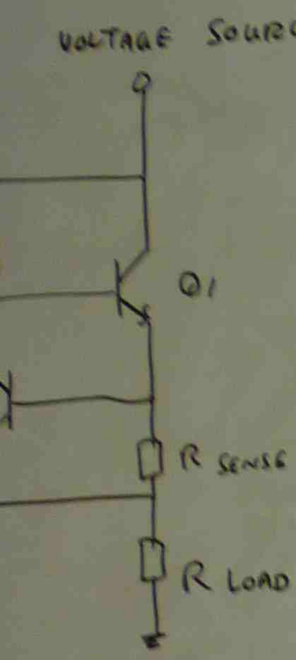
DIAGRAM of CURRENT LIMITING FUSE



MONITORING AND CONTROL INSTRUMENTS

- SMOKE DETECTOR
- HEATING REGULATORS
- THERMOSTATS
- MEASURING, WEIGHING (OR) ADJUSTING APPLIANCES FOR HOUSE HOLD (OR) AS LABORATORY EQUIPMENT
- OTHER MONITORING AND CONTROL INSTRUMENTS USED IN INDUSTRIAL INSTALLATIONS

ENT LIMITING FUSE



CONTROL INSTRUMENTS

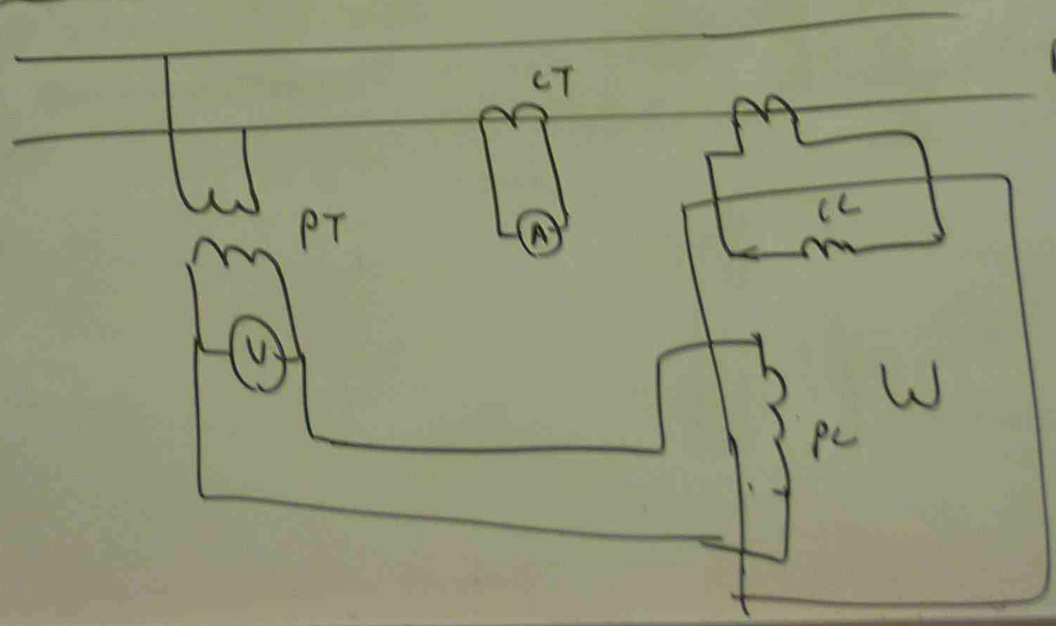
CTOR
GULATORS
TS
WEIGHING (OR) ADJUSTING
FOR HOUSE HOLD (OR) AS
EQUIPMENT
ITORING AND CONTROL INSTRUMENTS
NDUSTRIAL INSTALLATIONS

(E.g CONTROL PANELS)

VOLTAGE REGULATOR

IT IS AN ELECTRICAL REGULATOR DESIGNED TO AUTOMATICALLY MAINTAIN A CONSTANT VOLTAGE LEVEL. A VOLTAGE REGULATOR MAY BE A SIMPLE FEED FORWARD DESIGN (OR) MAY INCLUDE NEGATIVE FEED BACK CONTROL LOOPS.
ELECTRONIC VOLTAGE REGULATORS ARE UTILIZED TO PROVIDE THE STABLE DC VOLTAGE FOR COMPUTERS, PROCESSORS & OTHER ELEMENTS.

INSTRUMENT TRANSFORMERS



CC - CURRENT COIL
PC - POTENTIAL COIL

INSTRUMENT TRANSF

TO PROVIDE (i)
(ii)

OPERATION

AIR BREAK CIRCUIT

THE ARC IS E
AND 150 ms
TRIPPED.

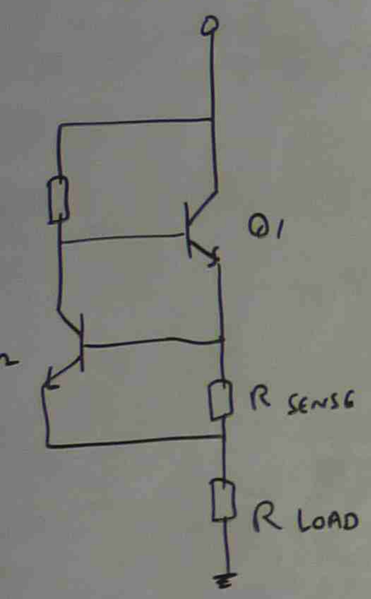
OIL CIRCUIT BR

DURING OF A

VACUUM INT

IT PROVIDES S
ELECTRONICALLY
PROTECTION IN
CONSTRUCTION.

CURRENT LIMITING FUSE



AND CONTROL INSTRUMENTS

ETECTOR
REGULATORS
STATS
G, WEIGHING (OR) ADJUSTING
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(E.g CONTROL PANELS)

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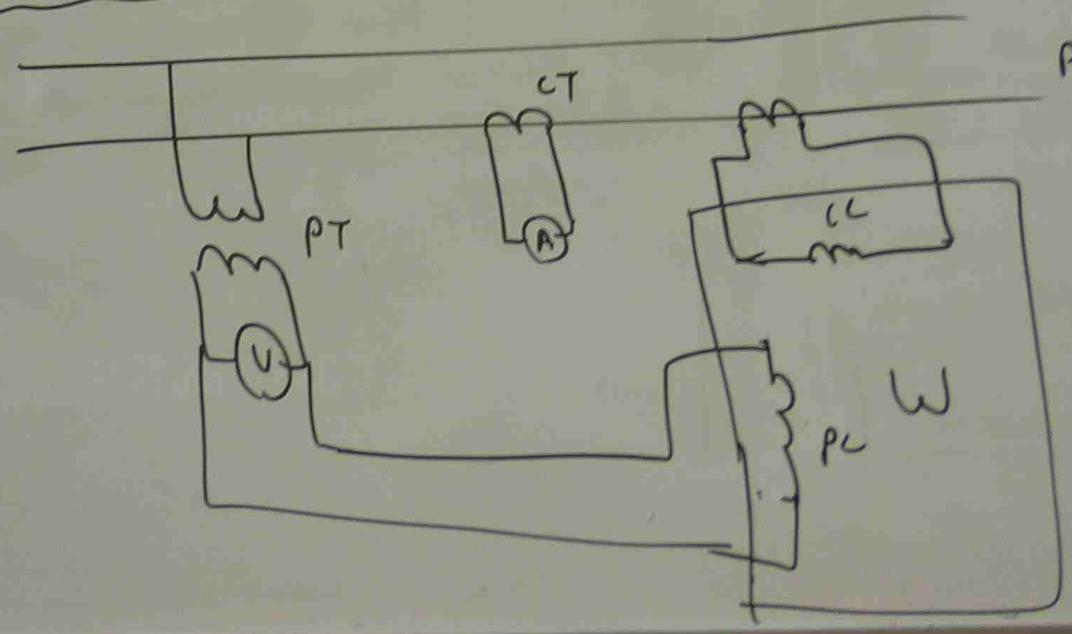

CC - CURRENT COIL
PC - POTENTIAL COIL

INSTRUMENT TR
TO PROVIDE

OPERA

AIR BREAK CI
THE ARC
AND ISO
TRIPPED.

OIL CIRCUI
DURING O

VACUUM
IT PROVIDE
ELECTRONICA
PROTECTION
CONSTRUCT

INSTRUMENT TRANSFORMERS ARE USED IN POWER SYSTEM

TO PROVIDE (i) REDUCED VOLTAGE FOR VOLTMETER
(ii) REDUCED CURRENT FOR AM METER.

OPERATION SPEEDS of CIRCUIT BREAKERS

AIR BREAK CIRCUIT BREAKER

THE ARC IS EXTINGUISHED BETWEEN 30 ms AND 150 ms AFTER THE MECHANISM HAS BEEN TRIPPED.

OIL CIRCUIT BREAKER

DURING OF ARCING IS 0.02 TO 0.05 SEC.

VACUUM INTERRUPTER

IT PROVIDES SINGLE (OR) 3 PHASE.
ELECTRONICALLY CONTROLLED OVER CURRENT PROTECTION IN A DEAD FRONT, SUBMERSIBLE CONSTRUCTION.

THE NEED FOR ELECTRICAL PROTECTION

THE PROTECTION of A POWER SYSTEM DETECTS THE ABNORMAL CONDITIONS, LOCALIZES THE FAULTS AND PROMPTLY REMOVE THE FAULTY EQUIPMENTS FROM SERVICE.

ESTIMATION of OPERATION SPEED of PROTECTION EQUIPMENTS, DETERMINATION of POSSIBLE ELECTRICAL FAULT LEVEL AND PROVIDING THE APPROPRIATE SIZE of CIRCUIT BREAKER + RELAY PROTECTION SYSTEM ARE THE IMPORTANT ASPECTS of POWER SYSTEM PROTECTION.

OVERVIEW OF ELECTRICAL FAULTS

ELECTRICAL FAULTS USUALLY OCCUR DUE TO BREAK DOWN of THE INSULATION MEDIA BETWEEN LIVE CONDUCTORS (OR) A LIVE CONDUCTOR AND EARTH.

THE BREAK DOWN MAY BE CAUSED BY ANY ONE (OR) MORE of SEVERAL FACTORS : MECHANICAL DAMAGE, OVER HEATING, VOLTAGE SURGE, IONIZING AIR, DETERIORATING INSULATION MEDIA.

ELECTRIC POWER UTILITIES ARE FACED WITH AGING INFRASTRUCTURE, INCREASING RISK of BLACK OUTS AND BLOWN OUTS CAUSING UN PLANNED MAINTENANCE AND SECURITY THREATS.

THE INFRED CAMERAS ARE UTILIZED TO CHECK THE SITUATION OF THE INSULATION of ELECTRICAL MACHINES AND EQUIPMENTS SO THAT THE PREVENTIVE MAINTENANCE CAN BE DONE BEFORE THE EQUIPMENTS ARE TOTALLY BROKEN DOWN.

PROTECTION SYSTEM

— PILOT WIRE PROTECTION SYSTEM
— MICROWAVE RELAYING
— WIDE AREA MONITORING AND CONTROL SYSTEM

EMERGENCY OPERATION FUNCTION IS TO PROVIDE THE COMMUNICATION SERVICES PERMITTING AN OPERATOR TO TAKE THE FOLLOWING ACTIONS IN RESPONSE TO A FAULT IN THE POWER SYSTEM

ORMAL CONDITIONS,
AULTY EQUIPMENTS

UIPMENTS,
UEL AND
BREAKER +
ASPECTS of

BREAK DOWN OF
CTORS (OR) A LINE

SE (OR) MORE of
R HEATING, VOLTAGE
ETEORIATING

— LOCATE THE FA
— VERIFY THAT
CLEAR THE FA
— SHED LOAD T
of UN AFFE
— MANUALLY
— DISPATCH
— CAPTURE F
THE CAUSE

N FRASTRUCTURE, INCREASING
UN PLANNED MAINTENANCE

THE SITUATION OF
EQUIPMENTS SO THAT
ORE THE EQUIPMENTS

TEM
ROVIDE THE COMMUNICATION
TAKE THE FOLLOWING
THE POWER SYSTEM

- LOCATE THE FAULT
- VERIFY THAT PROTECTION HAS OPERATED CORRECTLY TO CLEAR THE FAULT
- SHED LOAD TO ENSURE THAT FAULT DOES NOT CAUSE AN OVER LOAD OF UN AFFECTED LINES
- MANUALLY RE-ROUTE POWER TO RESTORE SERVICE TO CONSUMERS
- DISPATCH CREWS AND EMERGENCY TEAM TO FIX THE FAULT.
- CAPTURE FAULT RECORDINGS SO ENGINEERS CAN LATER ANALYZE THE CAUSE OF THE FAULT.