E 001
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ELECTRICAL WORKSHOP

E001 OCCUPATIONAL HEALTH AND SAFETY.

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SAFETY CLOTHING, SAFETY PROTECTION EQUIPMENTS ← P P E
PERSONAL PROTECTIVE EQUIPMENTS.

SAFE WORKING PRACTICE — (GENERAL + SPECIFIC AREA)
- CONFINED SPACE
- SAFETY COMPETENCY PRACTICE CERTIFICATES

REDUCING SAFETY HAZARDS.
- ENGINEERING DESIGN
- ELIMINATION
- REDUCTION.
- ENCLOSING.

NSW WORK COVER AUTHORITY

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PERSONAL PROTECTIVE EQUIPMENTS.

CONFINED SPACE
SAFETY COMPETENCY
PRACTICE CERTIFICATES

THORITY

SAFETY IN WORK PLACE

WORKERS

- WEAR APPROPRIATE PERSONEL PROTECTION EQUIPMENTS
- OBEY THE SAFE WORKING PROCEDURES, INSTRUCTION
- MUST NOT UNDERMINE THE SAFETY SYSTEM
- MUST NOT PERFORM ANY ACTIVITIES DANGEROUS TO HIMSELF / HERSELF (OR) OTHERS.

Employers

- must TAKE THE RESPONSIBILITY FOR DUTY OF CARE
- MUST ELIMINATE ANY UNSAFE CONDITIONS AS PRACTICABLE
- MUST INFORM AND INSTRUCT THE EMPLOYEES OF ANY UNSAFE CONDITIONS / PERFORM PREVENTIVE MAINTENANCE

STATE GOVERNMENT

- SAFETY REGULATION, LEGISLATION, ACT.

- MUST NOT USE ANY LOOSEN TOOLS.
- MUST BE CARE FUL WHILE WORKING NEAR EXPOSED CONDUCTORS.
- BEND THE KNEE TO LIFT HEAVY OBJECTS
- ALWAYS ASK FO ASSISTANCE IF WORKING ALON IS HIGH RIS

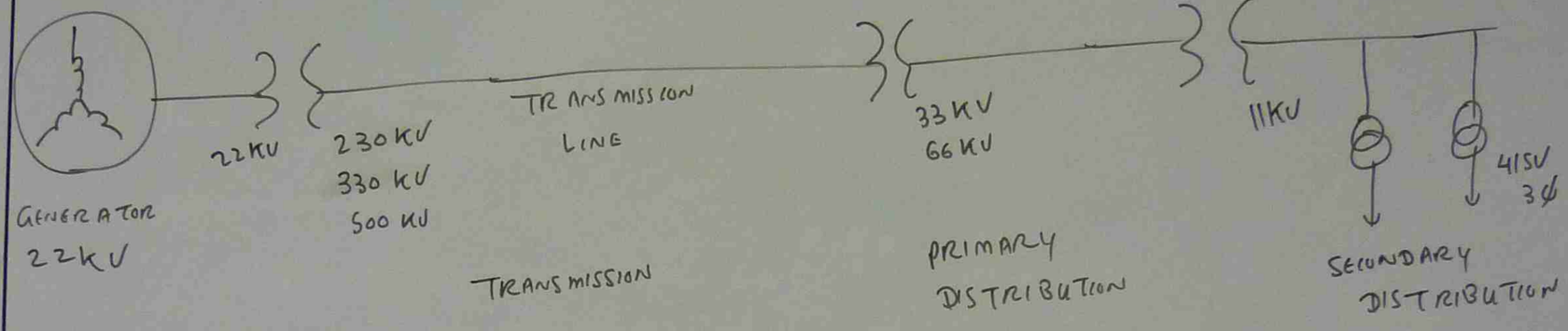
RRENT TRANSFORMER

LOAD

BATTERY

POWER LINE

- DC
- AC — STEP UP / STEP DOWN THE VOLTAGE

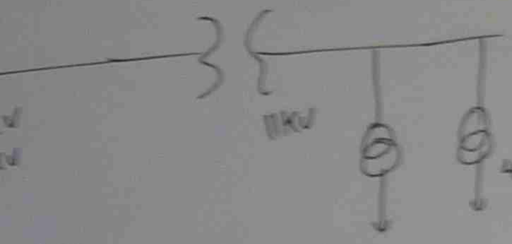


THE MAJOR ELECTRICAL ITEMS IN MOST INDUSTRIAL / COMMERCIAL PLANT

1. POWER GENERATION EQUIPMENTS
2. PRIMARY AND SECONDARY DISTRIBUTION SYSTEMS INCLUDING FEEDERS TRANSFORMERS, SWITCH GEAR, PROTECTIVE EQUIPMENTS.
3. MOTOR DRIVES, HEATERS, OVENS, ASSOCIATED WIRING AND CONTROL EQUIPMENTS.

4 LIGH
5 ELECTR
6 AUXIL
7 COM
8 SPEC
9 RO
10 VEN

DOI



INDUSTRIAL | COMMERCIAL PLANT

ION SYSTEMS INCLUDING FEEDERS
E EQUIPMENTS.

TED WIRING AND CONTROL

4. LIGHTING EQUIPMENT, LIGHTING WIRING CIRCUITS
5. ELECTRICAL AND ELECTRONIC CONTROL AND INSTRUMENTATION
6. AUXILIARY SYSTEM, FIRE ALARM ETC
7. COMMUNICATION EQUIPMENTS.
8. SPECIAL ITEMS, ELEVATOR, LIFT
9. ROADWAY, YARD LIGHTING.
10. VENTILATOR, REFRIGERATOR, AIRCONDITIONER.

D016 NETWORK SERVICE

RELIABILITY OF POWER SYSTEM

VOLTAGE MUST BE CONSTANT
FREQUENCY MUST BE CONSTANT
PHASE SEQUENCE — CORRECT
↑
POSITIVE SEQUENCE

- BASIC INDUSTRIAL COST
- MANAGEMENT (SUPERVISION / WORK SIMPLIFICATION
- LEGAL RESPONSIBILITY.

VOLTAGE VARIATION

VOLTAGE VARIATION OCCURS
- THE VOLTAGE AT THE SOU CERTAIN LIMIT
- THE VOLTAGE AT THE S TRANSFORMER
- TRANSMISSION AND DIS AND REACTANCE OF TH

G WIRING CIRCUITS

TROL AND INSTRUMENTATION

ARM ETC

LIFT ETC

GHTING.

, AIR CONDITIONER.

LCE

RELIABILITY OF POWER SYSTEM

VOLTAGE MUST BE CONSTANT
FREQUENCY MUST BE CONSTANT —
PHASE SEQUENCE — CORRECT

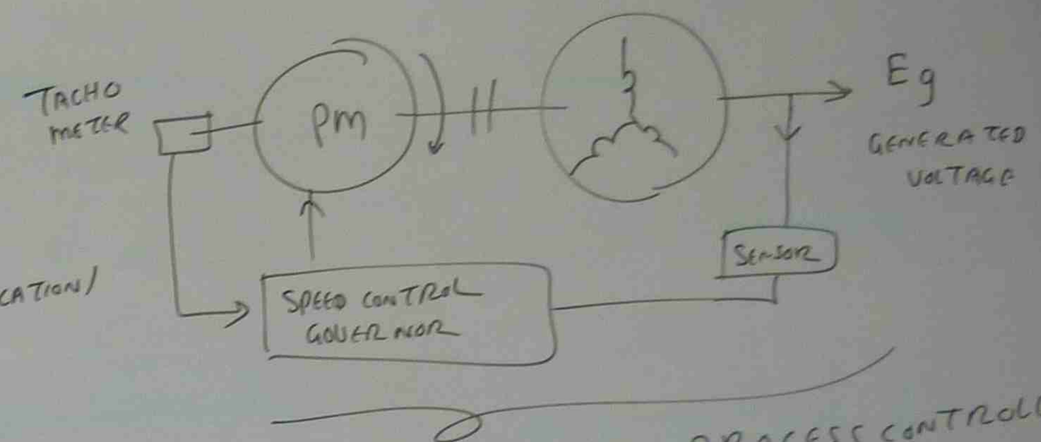
↑
POSITIVE SEQUENCE

$N_S = \frac{120f}{P}$ N_S = SYNCHRONOUS SPEED

$f = \frac{N_S \times P}{120}$ P = NO. OF POLES
f = FREQUENCY

COST

— BASIC INDUSTRIAL COST
— MANAGEMENT (SUPERVISION / WORK SIMPLIFICATION)
— LEGAL RESPONSIBILITY.



I 006 — PROCESS CONTROLLER

VOLTAGE VARIATION

VOLTAGE VARIATION OCCURS BECAUSE OF ONE (OR) MORE OF THE FOLLOWINGS.

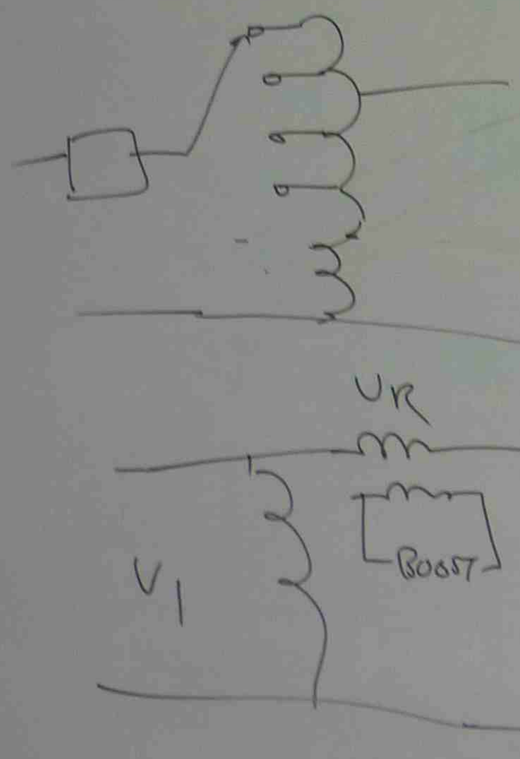
— THE VOLTAGE AT THE SOURCE MAY NOT BE CONTROLLED (OR) ONLY CONTROLLED TO A CERTAIN LIMIT
— THE VOLTAGE AT THE SECONDARY OF TRANSFORMER VARIES WITH THE LOAD ON TRANSFORMER
— TRANSMISSION AND DISTRIBUTION LINES CAUSE VOLTAGE DROPS DUE TO RESISTANCE AND REACTANCE OF THE LINES.

VOLTAGE CONTROL

AUTOMATIC VOLTAGE REGULATOR

TAP CHANGER

BOOSTER TRANSFORMER

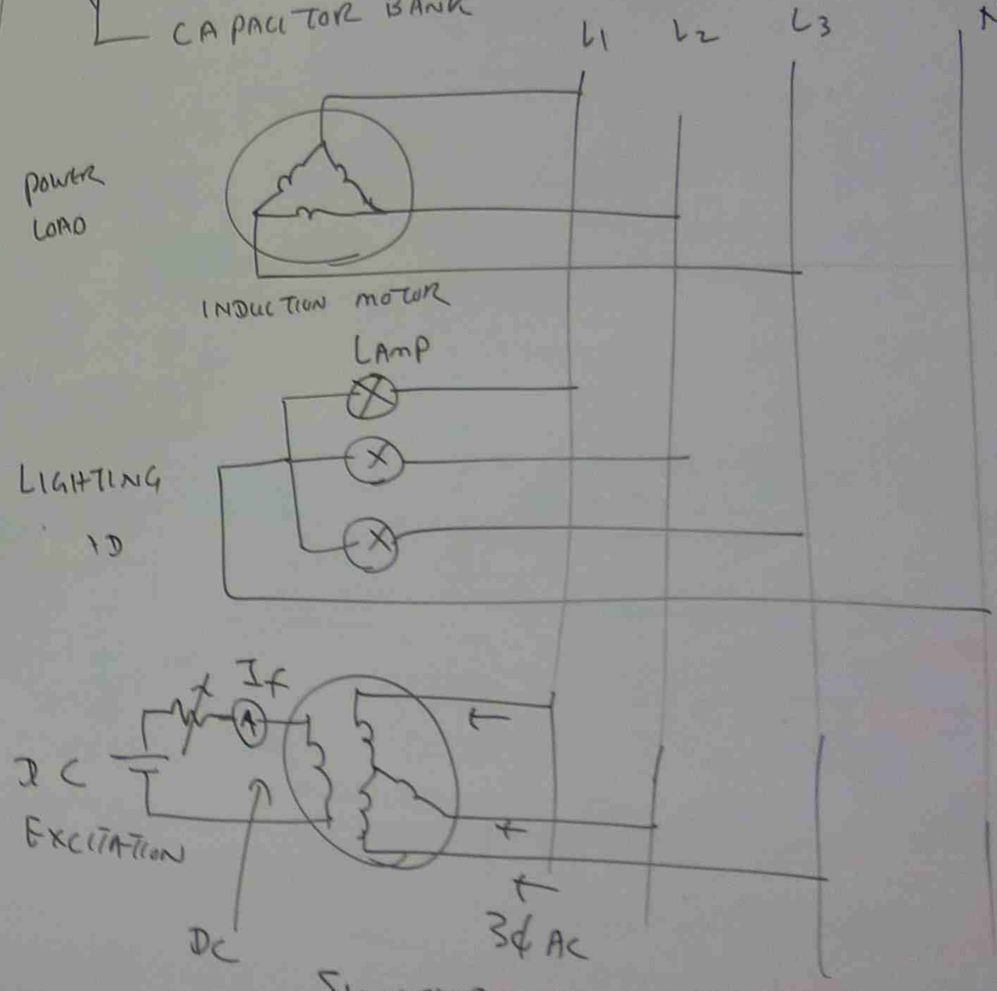


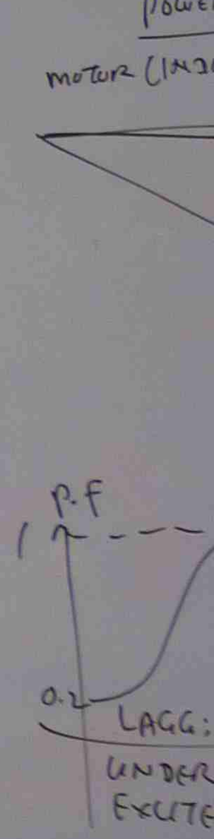
$V = V_1 \pm U_R$

LOAD CONTROL (POWER FACTOR)

- SYNCHRONOUS MOTOR
- STATIC VAR COMPENSATION SYSTEM
- CAPACITOR BANK

REACTIVE POWER FLOW CAN CHANGE THE SYSTEM VOLTA





TROL

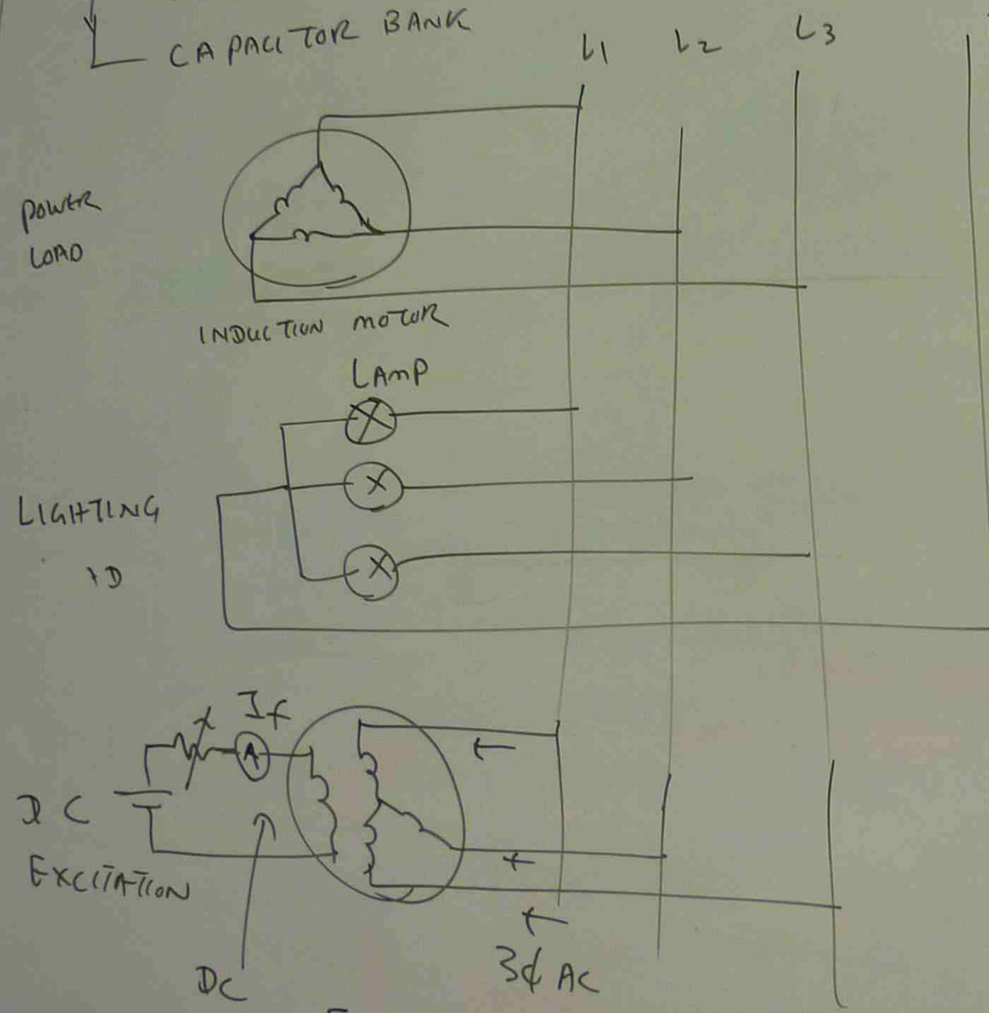
E REGULATOR

FORMER

LOAD CONTROL (POWER FACTOR)

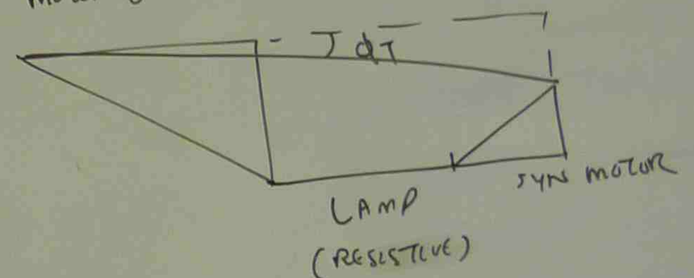
REACTIVE POWER FLOW
CAN CHANGE THE SYSTEM VOLTAGE

- SYNCHRONOUS MOTOR
- STATIC VAR COMPENSATION SYSTEM
- CAPACITOR BANK

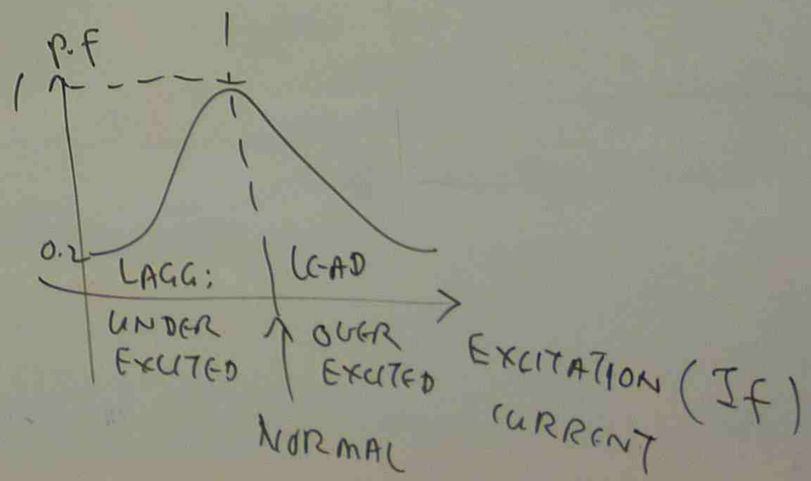


SYNCHRONOUS MOTOR

POWER TRIANGLE

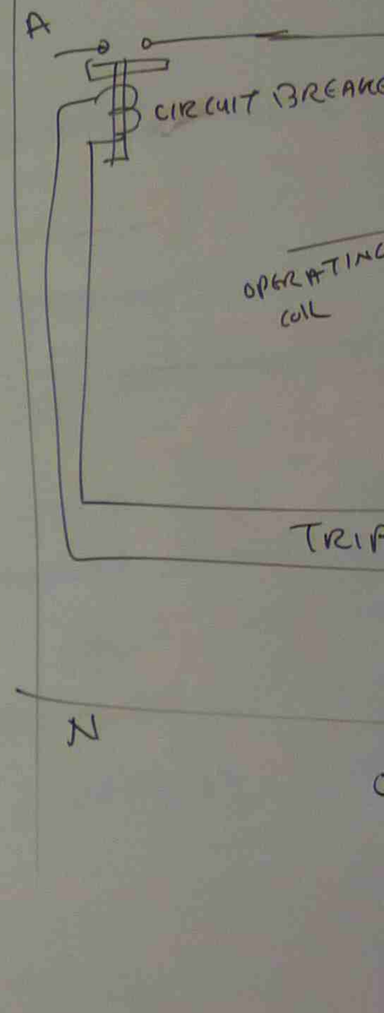


$PF = \cos\phi_T$



POWER LINE PRO

PROTECTIVE RELA
CIRCUIT BREAKER



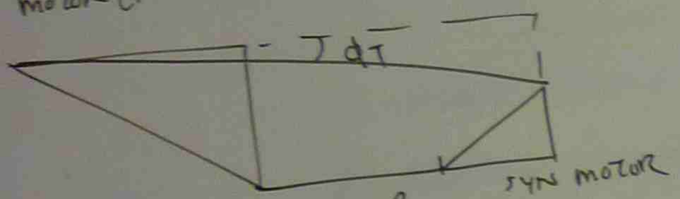
V_R

FLOW

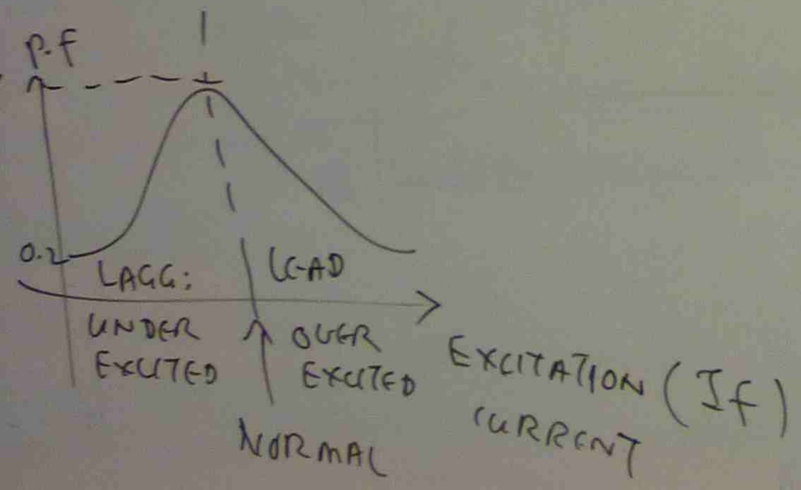
SYSTEM VOLTAGE

POWER TRIANGLE

MOTOR (INDUCTIVE)



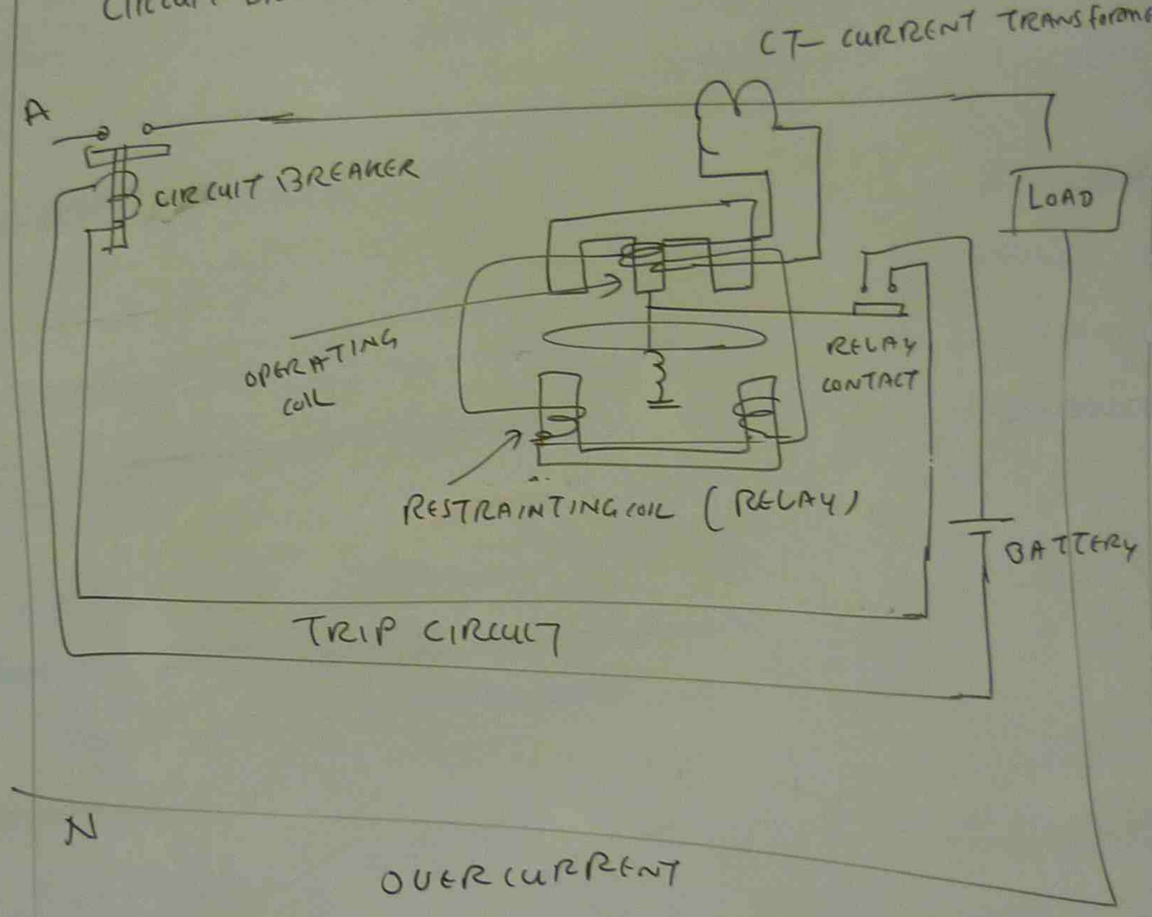
$PF = \cos\phi_T$



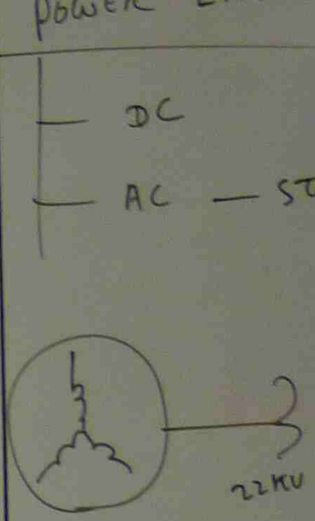
POWER LINE PROTECTION

PROTECTIVE RELAY

CIRCUIT BREAKER



POWER LINE



THE MA

1. POWER
2. PRI
   TRA
3. MOTO
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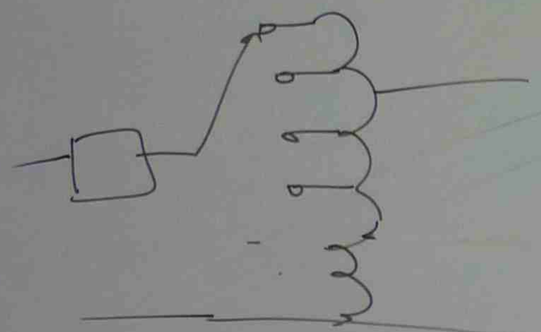
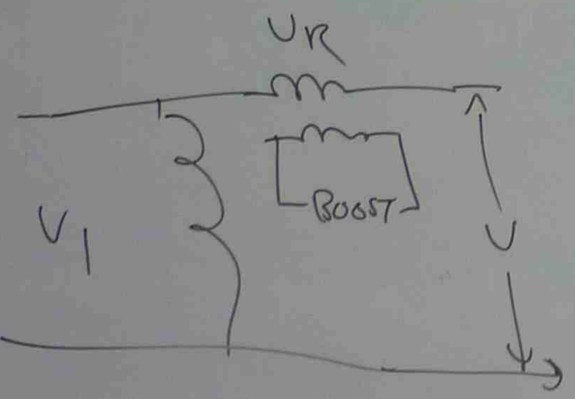
VOLTAGE CONTROL

AUTOMATIC VOLTAGE REGULATOR

TAP CHANGER

BOOSTER TRANSFORMER



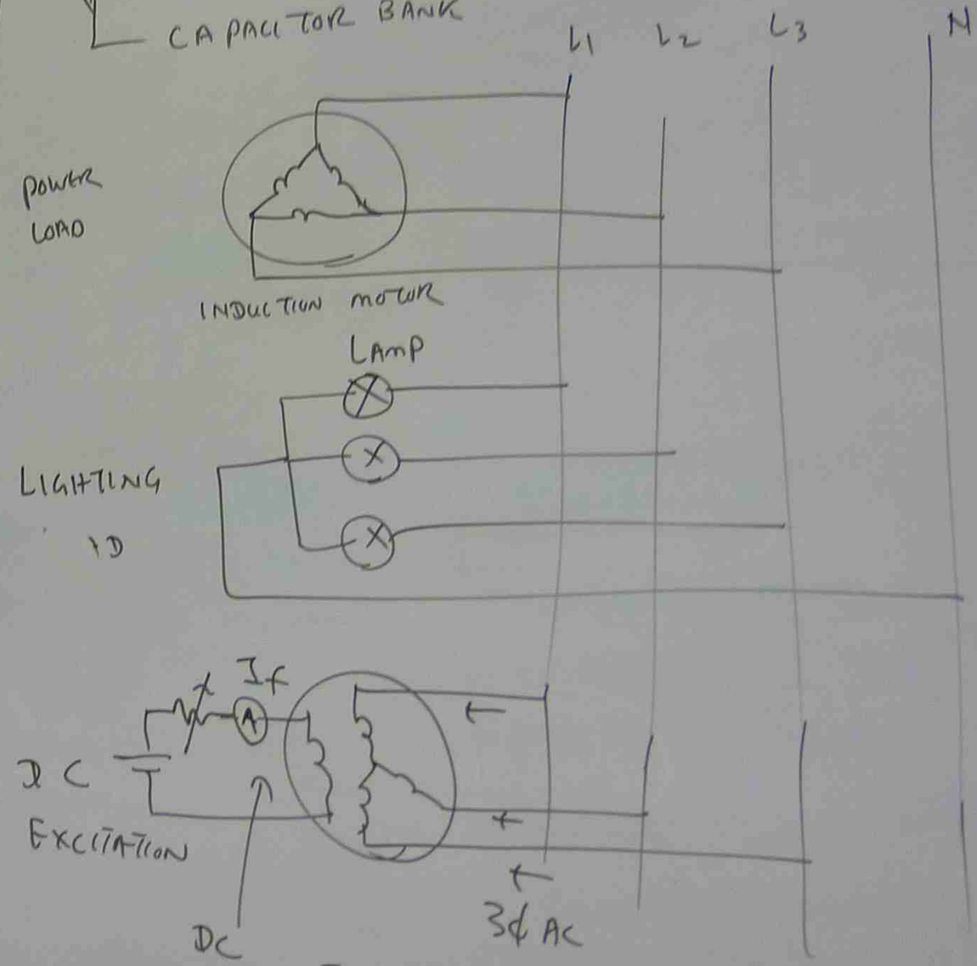


$V = V_1 \pm U_R$

LOAD CONTROL (POWER FACTOR)

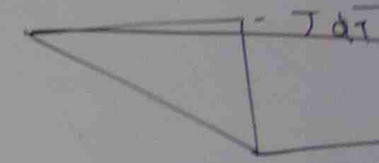
- SYNCHRONOUS MOTOR
- STATIC VAR COMPENSATION SYSTEM
- CAPACITOR BANK

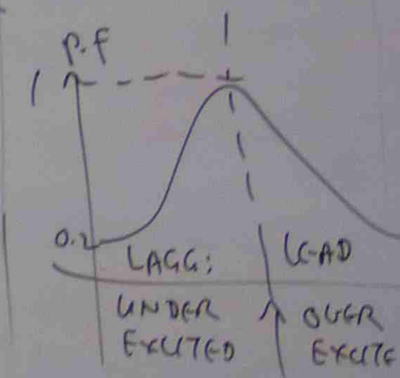
REACTIVE POWER FLOW
CAN CHANGE THE SYSTEM VOLTAGE



SYNCHRONOUS MOTOR

POWER TRIANGL



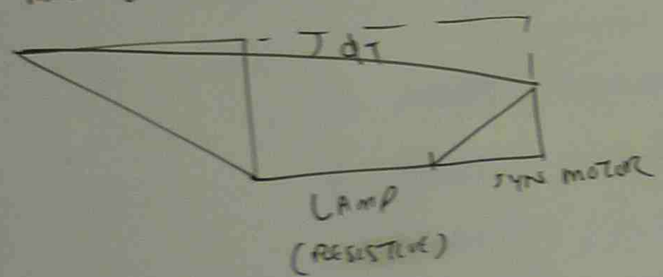


REACTIVE POWER FLOW
CAN CHANGE THE SYSTEM VOLTAGE

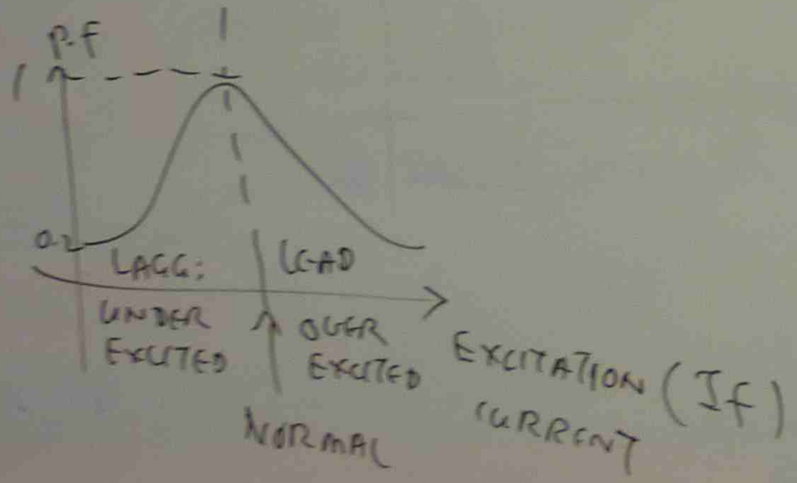
L3 N

POWER TRIANGLE

MOTOR (INDUCTIVE)



$PF = \cos\phi_T$

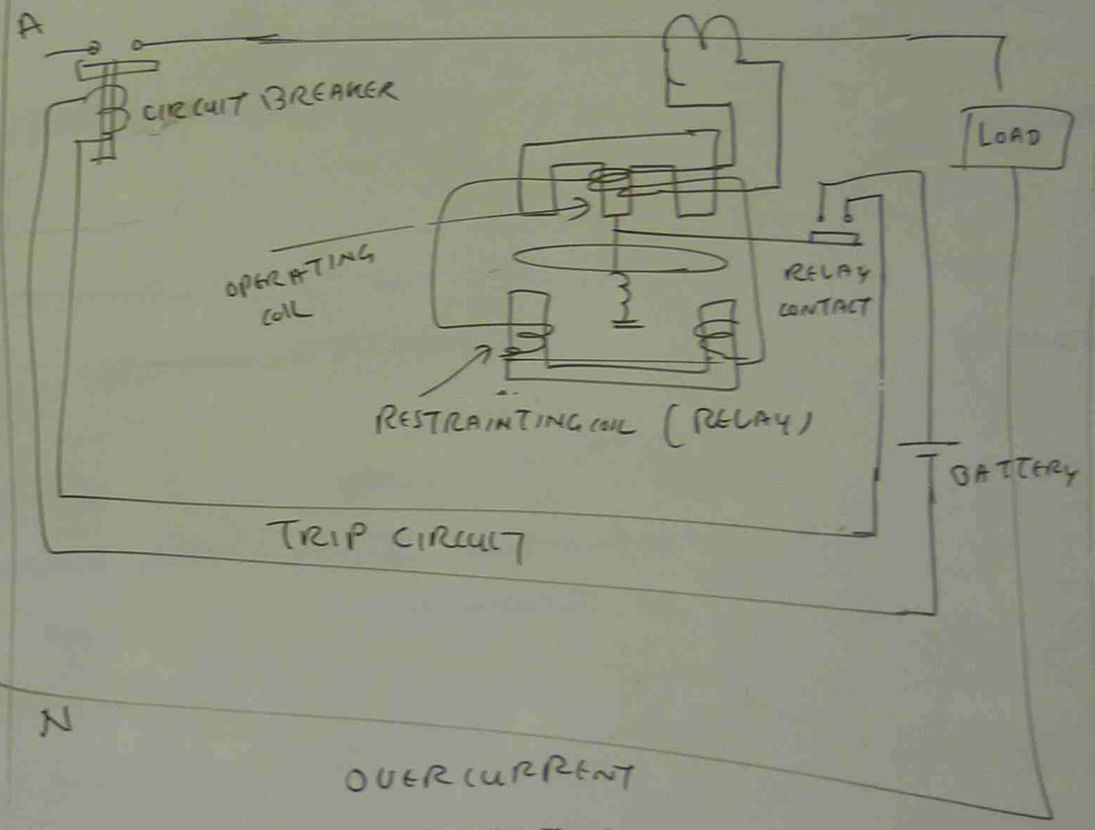


POWER LINE PROTECTION

PROTECTIVE RELAY

CIRCUIT BREAKER

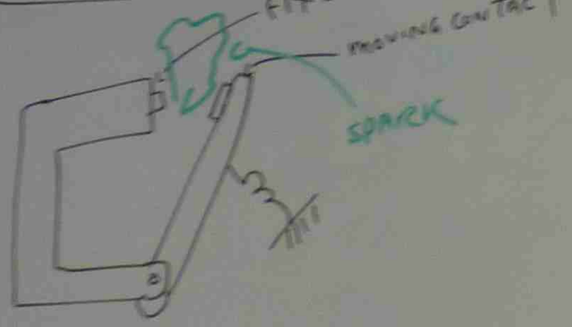
CT- CURRENT TRANSFORMER



OVERCURRENT

PROTECTION

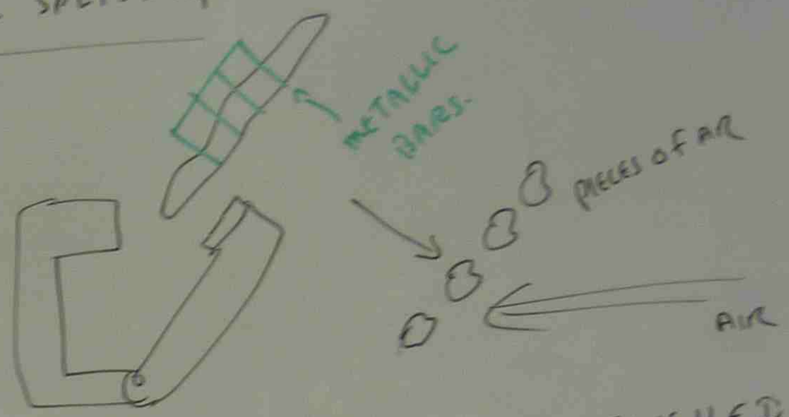
CIRCUIT BREAKER



WHEN CIRCUIT BREAKER CONTACTS ARE OPENED, IT PRODUCES THE SPARK (ELECTRIC ARC)

THE SPARK NEEDS TO BE REDUCED

ARC SPLITTING



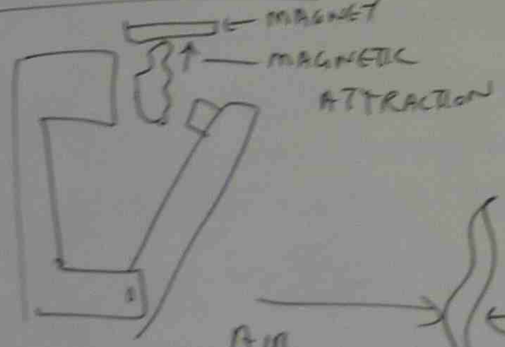
EXTINGUISHED

THE SOLID ELECTRIC ARC DC
CIRCUIT BREAKER CONTACTS IS
SPLIT AND COOLED BY NATURA
FORCE AIR (OR) OIL (OR)

↓

OIL CIRCUIT BR
(O.C.B)

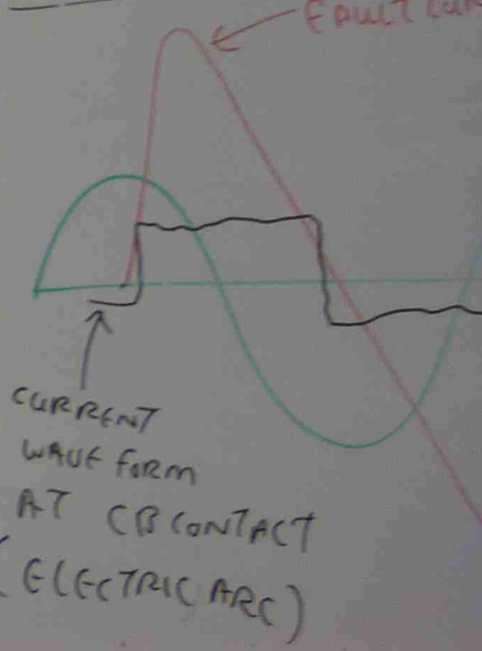
ARC LENGTHENING



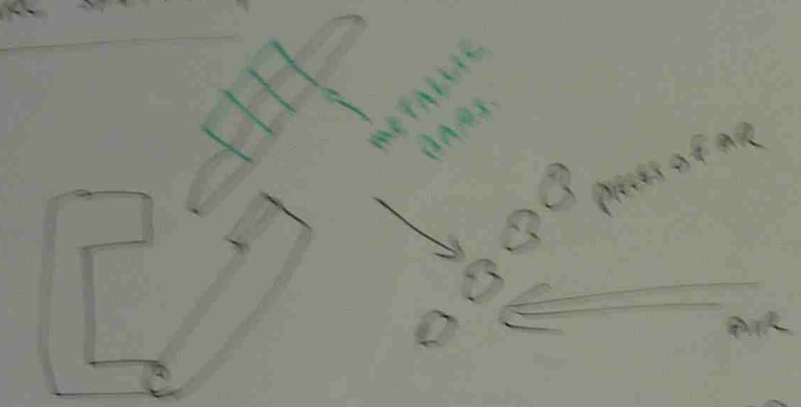
ARC COOLING

- NATURAL
- FORCED AIR – ABCB – AIR BLAST C.B
- GAS – SF6

EFFECT OF POWER SYSTEM BY ELECTRIC ARC



ARC SPLITTING

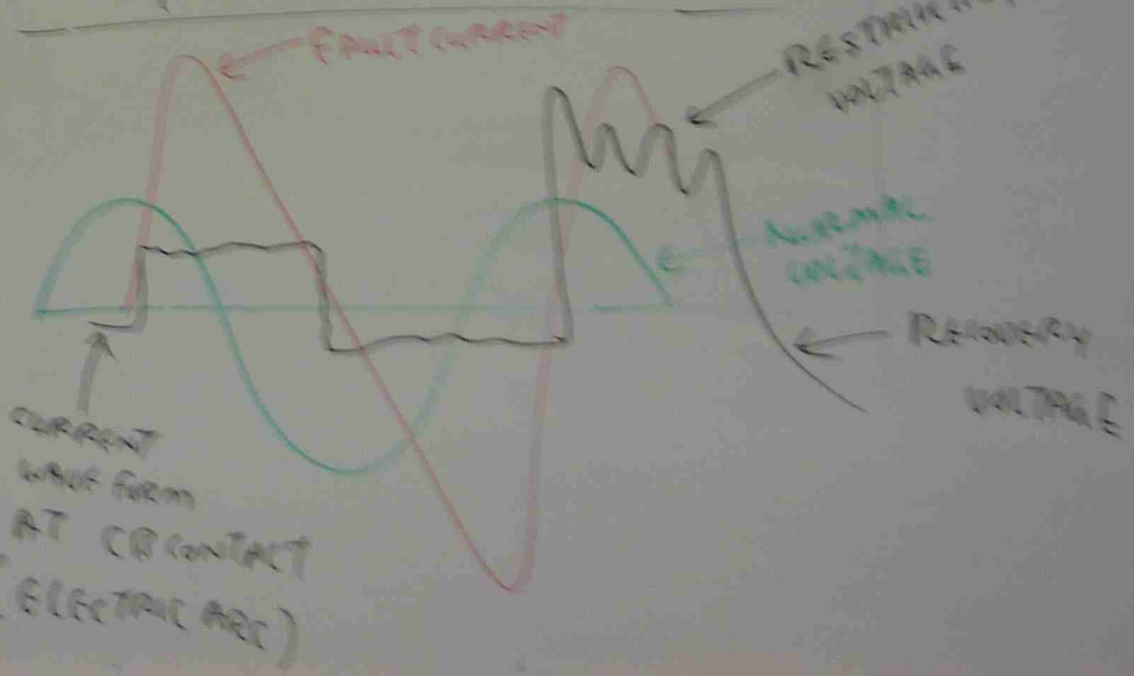


THE SOLID DIELECTRIC MEDIUM BETWEEN CIRCUIT BREAKER CONTACTS IS LEAD THEN SPLIT AND COOLED BY NATURAL AIR (OR) BLAST AIR (OR) OIL (OR) SF_6 GAS

↓

OIL CIRCUIT BREAKER (O.C.B)

EFFECT OF POWER SYSTEM VOLTAGE WAVE FORM BY ELECTRIC ARC



(1) SUBDIVIDE THE
(2) LIMIT THE
(3) SPLIT THE
COOLED

MAIN TRIP
- AUTOMA
WHEN
MUST
CLOSING
SOLEN

ARC COOLING

- NATURAL
- FORCED AIR – ABCB – AIR BLAST C.B
- GAS – SF_6

OCCURS BETWEEN

S IS LENGTHENED/

TURAL AIR (OR)

(OR) SF_6 GAS

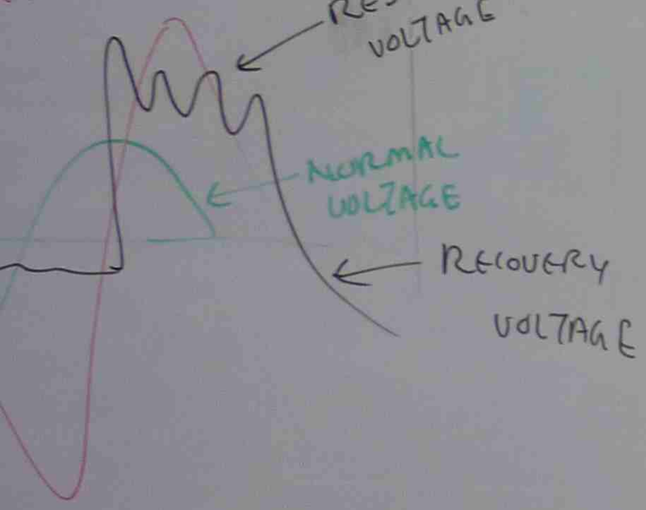
BREAKER

13)

TEM VOLTAGE WAVE FORM

RC

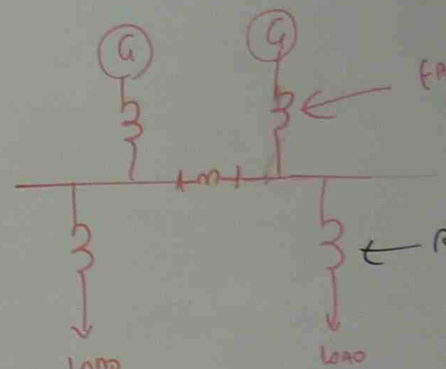
CURRENT



(1) SHORTEN THE ARCING PERIOD — QUICKER RESPONDING TO COOL THE ARC

(2) LIMIT THE ARC MAGNITUDE —— LIMITING SHORT CIRCUIT CURRENT

(3) SPLIT THE ARC & COOLED DOWN



CO-ORDINATED WITH PROTECTIVE RELAYING.

MAINTAIN SYSTEM STABILITY

- AUTOMATIC RECLOSING SYSTEM.

WHEN TEMPORARY FAULT HAPPENS, THE C.B MUST RECLOSE AS SOON AS FAULT IS CLEAR.

CLOSING MECHANISM

SOLENOID, MOTOR, SPRING, FLYWHEEL.

SYSTEM VOLTAGE

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + X_L^2}}$$

LINE RESISTANCE

INDUCTIVE REACTANCE $= 2\pi fL$

VCE

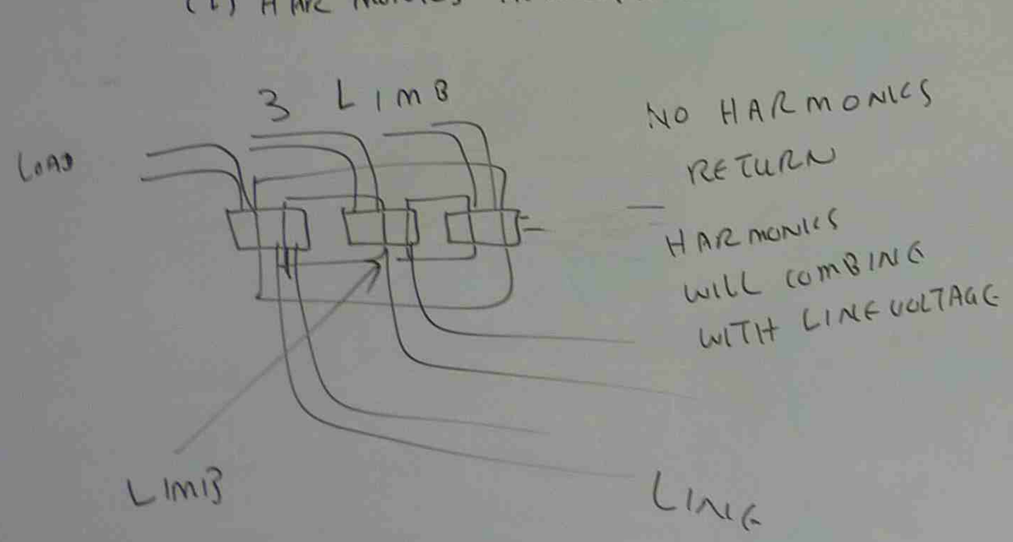
SOURCE OF ELECTRICAL INTERFERENCE

INTERFERENCE CAN CREATE VOLTAGE SURGE IN LINE.

↑ CAUSED BY

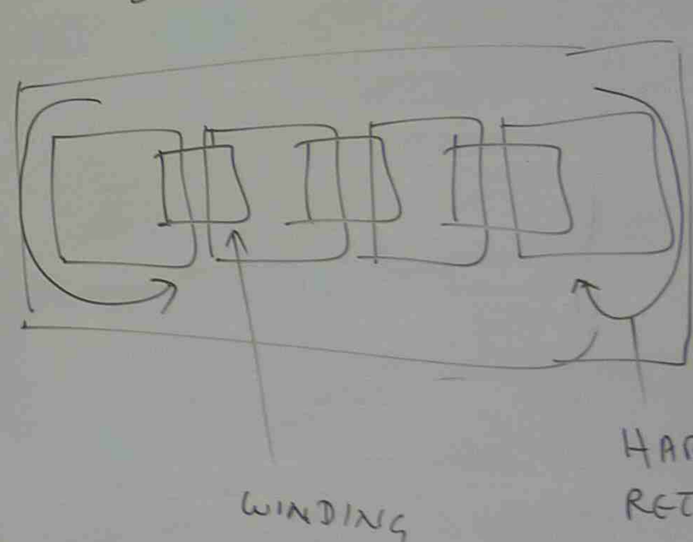
(1) LIGHTNING STRIKE

(2) HARMONICS INTERFERENCE ← SWITCHING POWER SUPPLIES CAUSE HARMONIC



NO HARMONICS RETURN

HARMONICS WILL COMBINE WITH LINE VOLTAGE



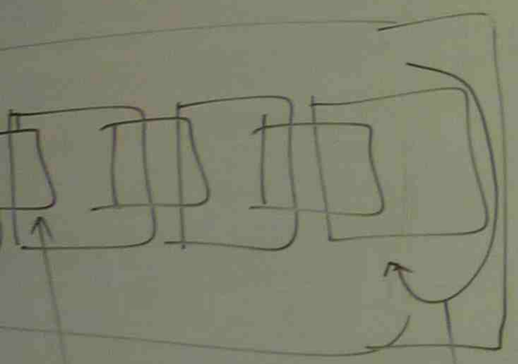
BY USING 5 LIMBS TRANSFORMER

HARMONIC CAN BE REDUCED

N LINE.

SWITCHING POWER SUPPLIES
CAUSE HARMONIC

LIM 3



WINDING

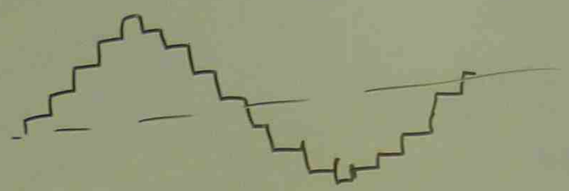
HARMONIC
RETURN PATH

G 5 LIMBS TRANSFORMER

IC CAN BE REDUCED

BY INCREASING THE SIZE OF NEUTRAL WIRE

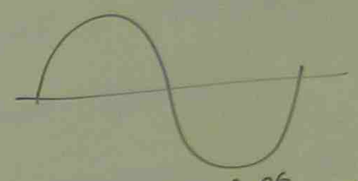
HARMONICS CAN BE REDUCED.



STEP AC

SWITCHING MODE AC

PWM - PULSE WIDTH MODULATED AC



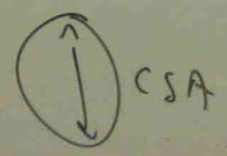
PURE SINUSOIDAL AC

GENGRATOR

(3) RADIO FREQUENCY HARMONIC

HARMONIC REDUCTION METHODS

- USE OF FIVE LIMBS TRANSFORMER
- USE OF HARMONIC FILTER
- USE OF BIGGER SIZE NEUTRAL WIRE



CSA

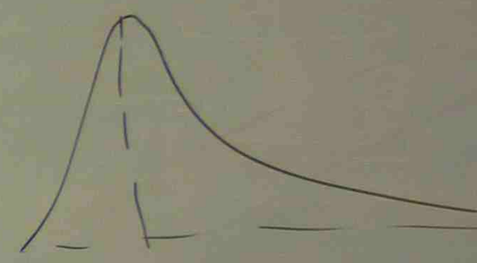
EVERY INTERFERENCE HAS

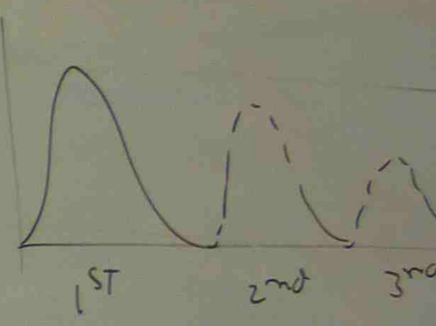
(1) SOURCE OF INTERFE

(2) VICTIM WHICH IS

(3) INTERFERENCE COUP

LIGHTNING STRIKE





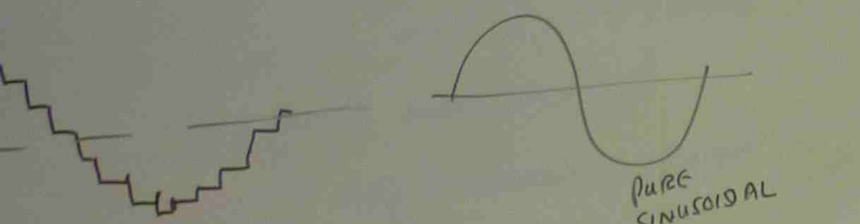
FIRST BIGGEST

SMALLER STROKES

ONE LIGHTNI

EASING THE SIZE of NEUTRAL WIRE

CAN BE REDUCED.



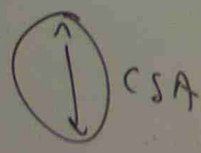
FREQUENCY HARMONIC

NIC REDUCTION METHODS

FIVE LIMBS TRANSFORMER

HARMONIC FILTER

BIGGER SIZE NEUTRAL WIRE



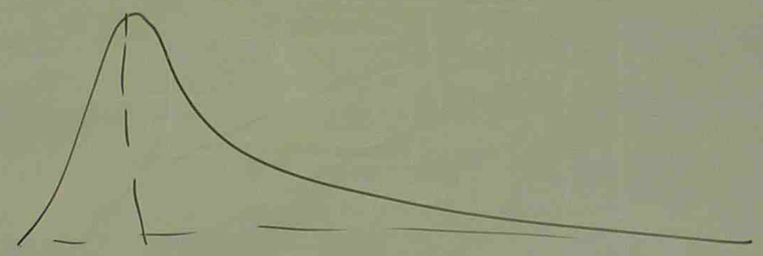
EVERY INTERFERENCE HAS THREE COMPONENTS

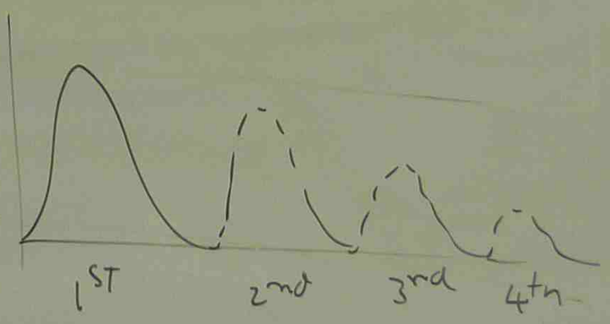
(1) SOURCE OF INTERFERENCE

(2) VICTIM WHICH IS UPSET BY INTERFERENCE

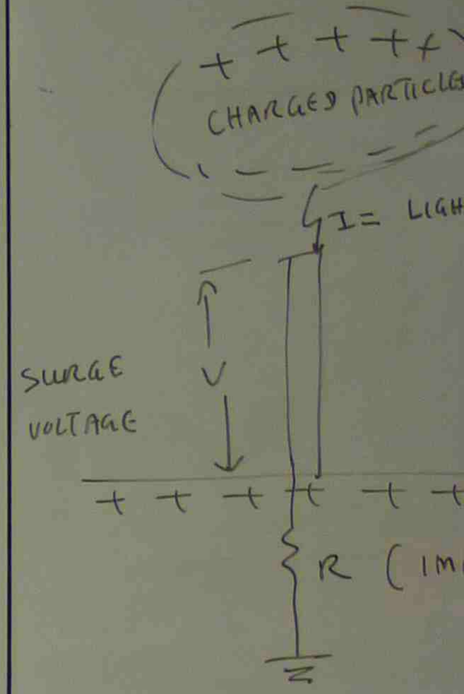
(3) INTERFERENCE COUPLING PATH

LIGHTNING STRIKE





FIRST BIGGEST STROKE + SUBSEQUENT SMALLER STROKES ARE CONTAINED IN ONE LIGHTNING STRIKE.



R = SURGE IMPED

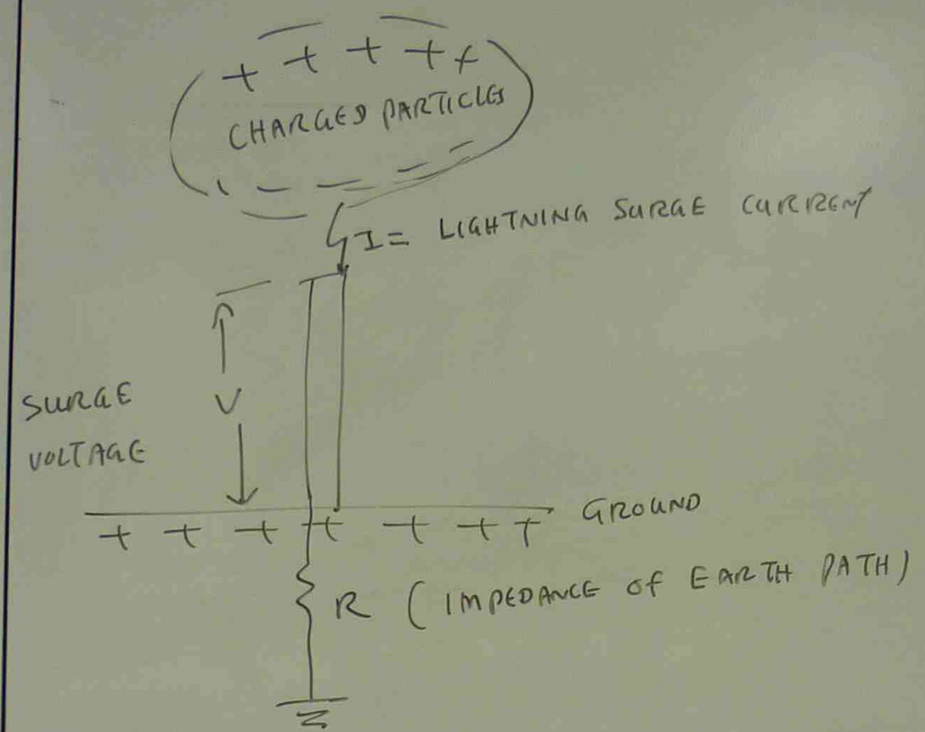
PEAK LIGHTNING = VOLTAGE

THREE COMPONENTS

ENCE

PSET BY INTERFERENCE

NG PATH



R = SURGE IMPEDANCE IS TYPICALLY 300Ω

$$\text{PEAK LIGHTNING VOLTAGE} = \frac{\text{SURGE IMPEDANCE}}{2} \times \text{LIGHTNING CURRENT}$$

$$= \frac{300}{2} \times 10\text{KA}$$

$$= 150 \times 10\text{KA} = 1500\text{KV}$$

LIGHTNING SURGE VOLTAGE.

TO WITHSTAND THE LIGHTNING STRIKE

(1) APPROPRIATE GROUNDING

(2) BIL (BASIC IMPACT INSULATION

MUST BE APPLIED.

IDEALLY, THE DIRECT STRIKE TO

LINE AND OTHER FACILITIES CAN

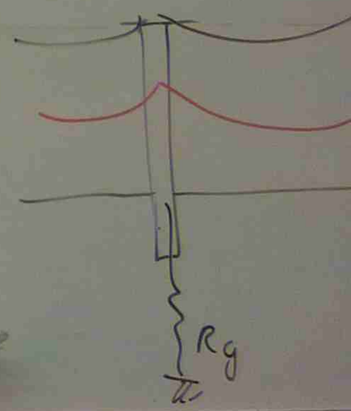
— SHIELDING THE OVER HEA

USING OVER HEAD EART

— SHIELDING THE BUILDING

LIGHTNING MAST

— BURYING POWER TRA



th

20KG + SUBSEQUENT

RE CONTAINED IN

STRIKE.

G SURGE CURRENT

GROUND

E OF EARTH PATH)

IS TYPICALLY 300Ω

= IMPEDANCE × LIGHTNING CURRENT

2

00 × 10KA

2

50 X 10KA = 1500KV

LIGHTNING SURGE VOLTAGE.

TO WITHSTAND THE LIGHTNING STRIKE

(1) APPROPRIATE GROUNDING

(2) BIL (BASIC IMPACT INSULATION LEVEL)

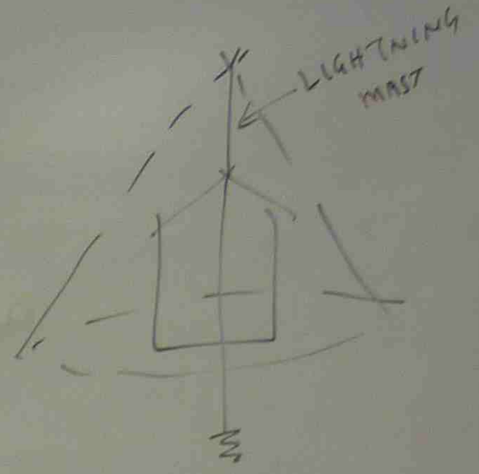
MUST BE APPLIED.

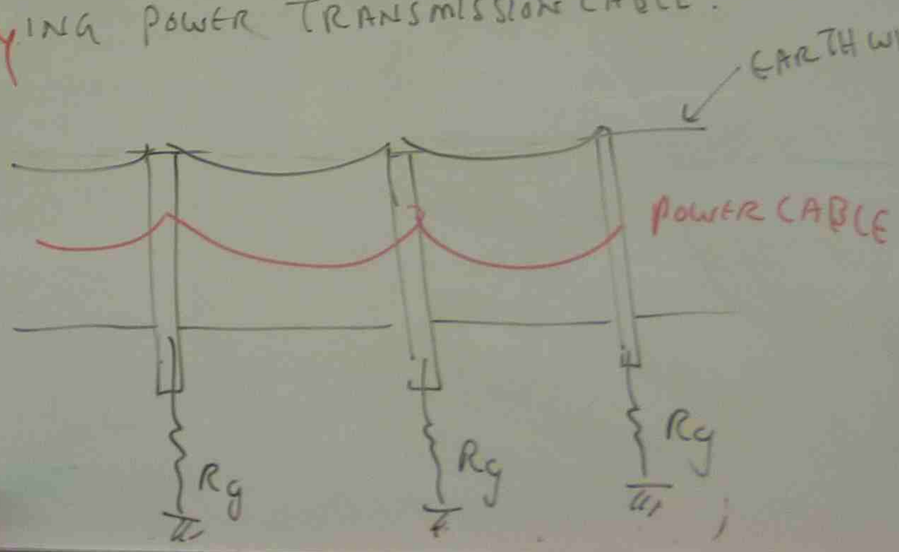
IDEALLY, THE DIRECT STRIKE TO POWER LINE AND OTHER FACILITIES CAN BE AVOIDED BY

— SHIELDING THE OVER HEAD POWER CABLE USING OVER HEAD EARTH WIRE

— SHIELDING THE BUILDING USING TALL LIGHTNING MAST

— BURYING POWER TRANSMISSION CABLE.





WHEN THE LIGHTNING
A BUILDING, THE FLA
VOLTAGE CAN SPREAD
BUILDINGS.

STRIKE

INSULATION LEVEL)

TRIKE TO POWER

IES CAN BE AVOIDED BY

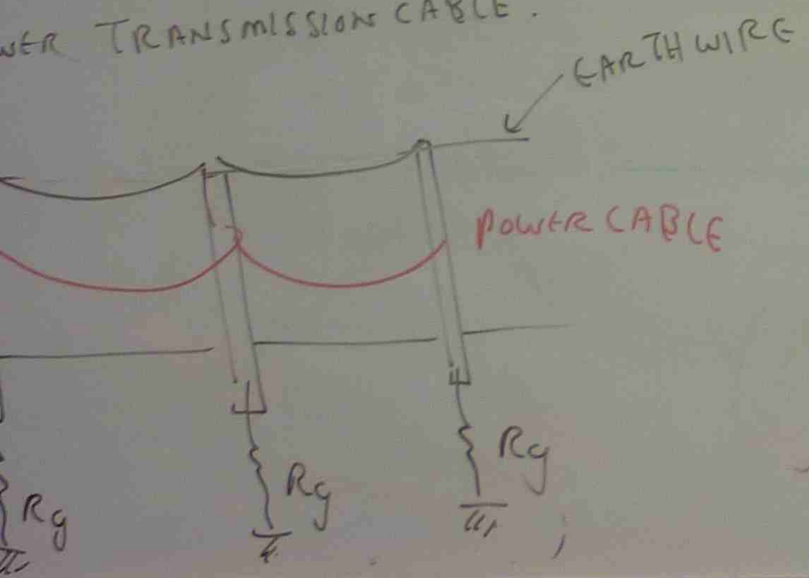
OVER HEAD POWER CABLE

AD EARTH WIRE

BUILDING USING TALL

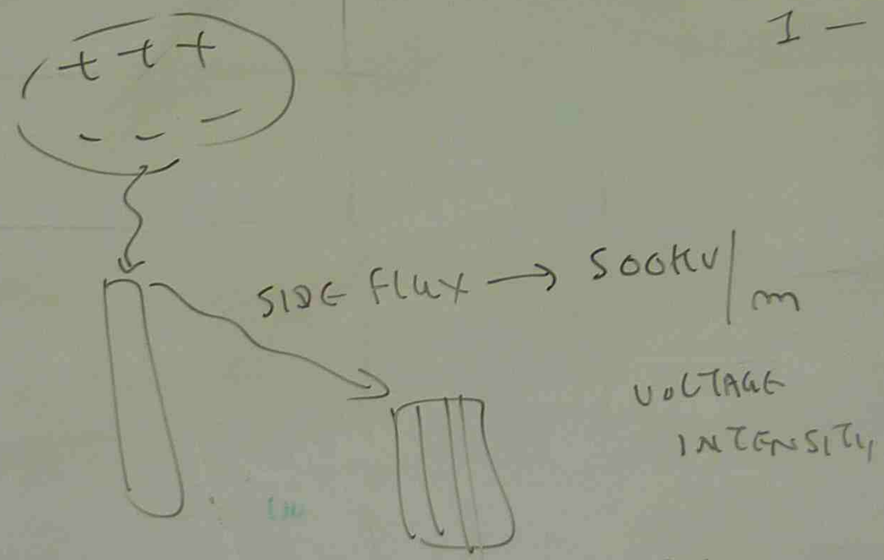
AST

WER TRANSMISSION CABLE.



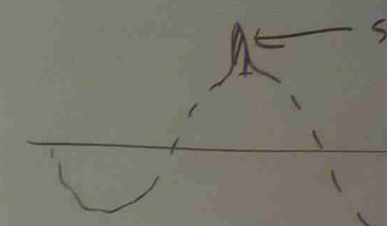
PROTECTION LEVEL	AVERAGE DISTANCE
I	10 m
II	15 m
III	20 m
IV	25 m

I — MUST BE PROTECTED UP TO 500KV/m



WHEN THE LIGHTNING STRIKES A BUILDING, THE FLASH-OVER VOLTAGE CAN SPREAD TO ADJACENT BUILDINGS.

SWITCHING TRANS



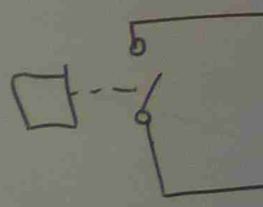
SWITCHING →

IMPACTS of TRANS

DISRUPTION OF NOR

DEGRADING OF

DAMAGE TO EQU



LIGHTNING MAST

PROTECTION LEVEL	AVERAGE DISTANCE
I	10 m
II	15 m
III	20 m
IV	25 m

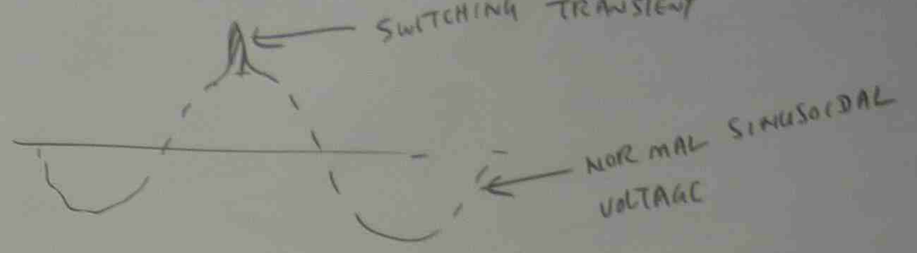
I — MUST BE PROTECTED UP TO 500KV/m

SIDE FLUX → 500KV/m

VOLTAGE INTENSITY

HEN THE LIGHTNING STRIKES BUILDING, THE FLASH-OVER OLTAGE CAN SPREAD TO ADJACENT BUILDINGS.

SWITCHING TRANSIENT VOLTAGE

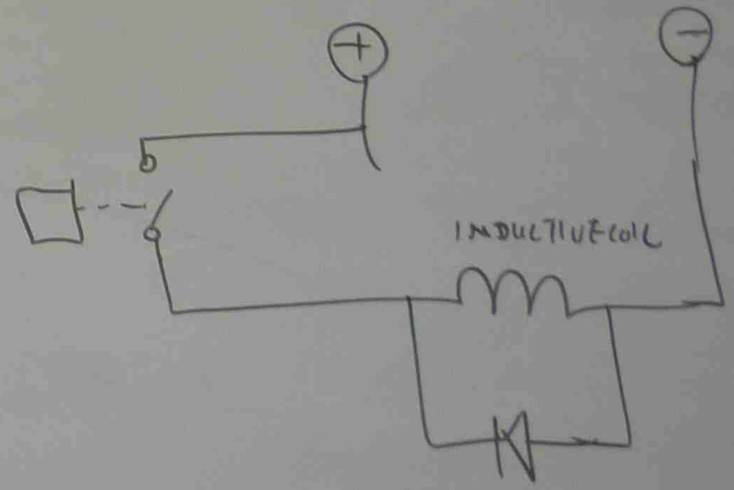


SWITCHING → 200 → 300% of NORMAL VOLTAGE ARE COMMON.

IMPACTS of TRANSIENT OVER VOLTAGE

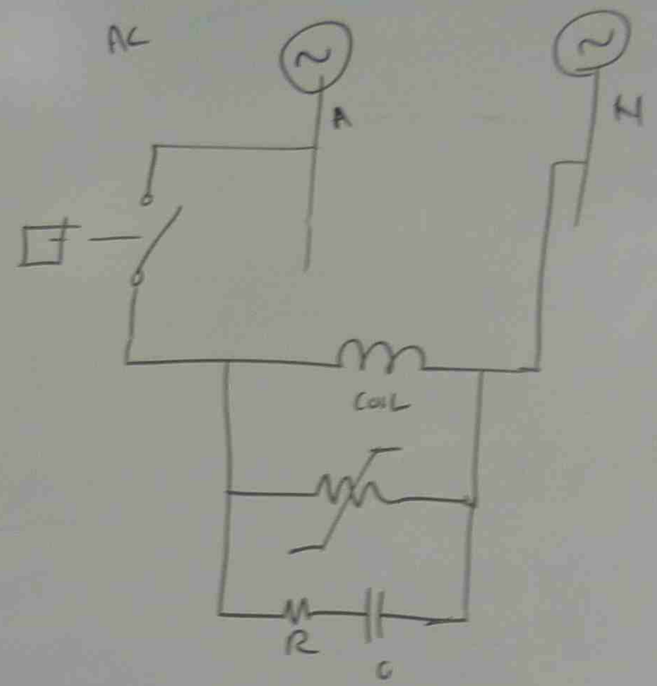
DISRUPTION of NORMAL OPERATION
DEGRADING OF COMPONENTS
DAMAGE TO EQUIPMENTS.

TRANSIENT SUPPRESSION TECHNIQUE



FREE WHEELING DIODE

17908
+
17794



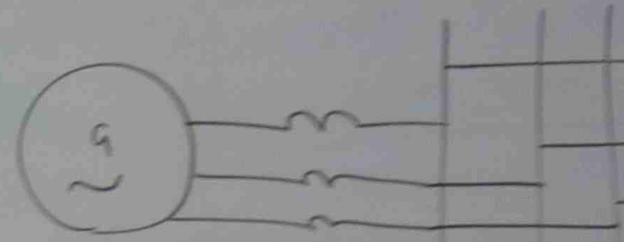
SUPPRESSION TECHNIQUE
FOR AC CONTROL CIRCUITS.

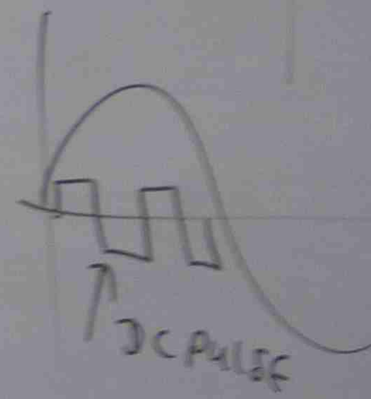
POWER SYSTEM FAULTS

CAUSED BY PHASE TO PHASE INSULATION FAILURE
(OR)
PHASE TO EARTH INSULATION FAILURE.

SOURCE OF HARMONIC

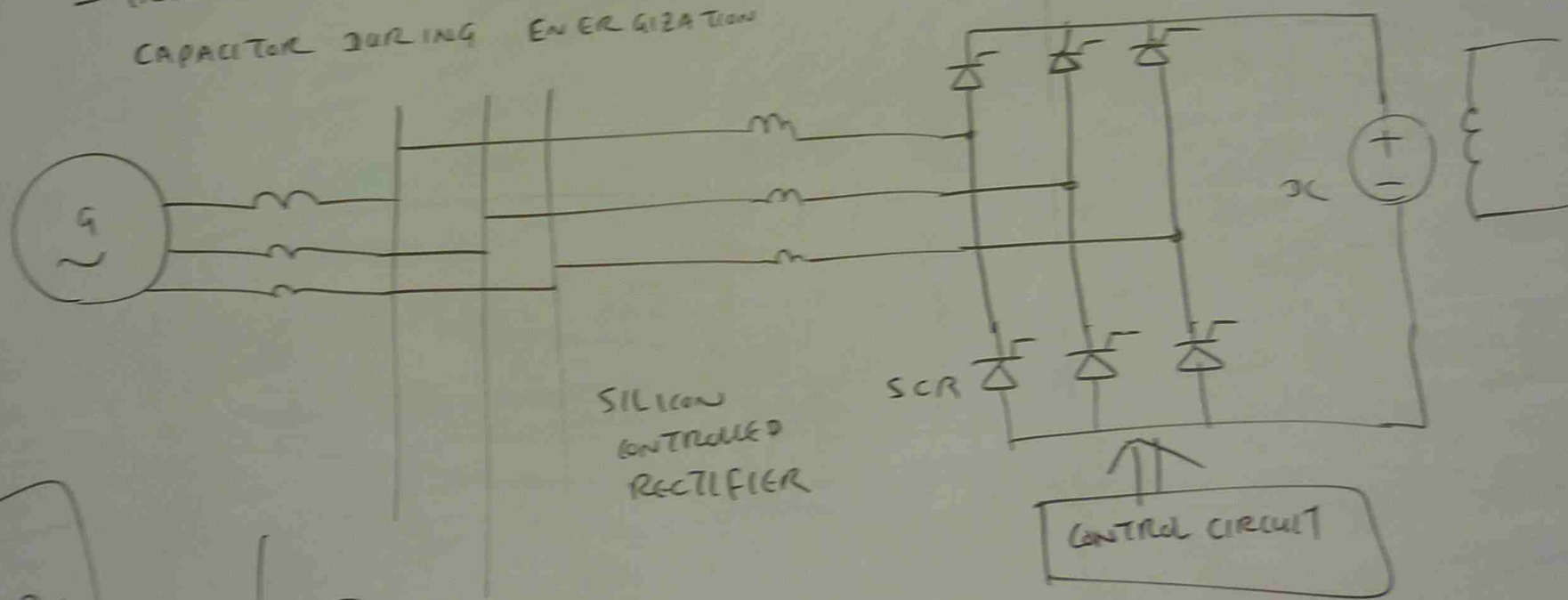
- POWER ELECTRONIC CONVERTER
- INDUSTRIAL CONVERTER SY
- TRANSIENT HARMONIC P
CAPACITOR DURING EN

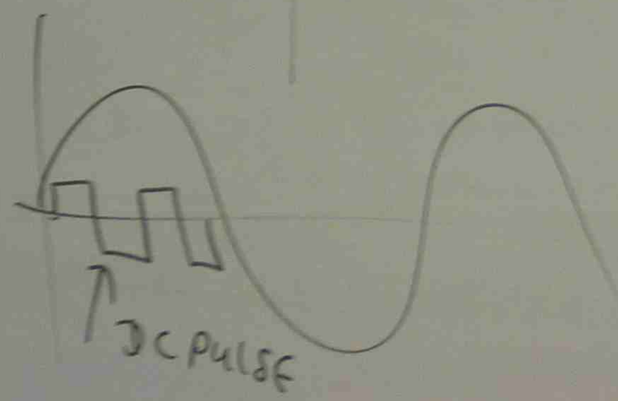




SOURCE OF HARMONIC

- POWER ELECTRONIC CONVERTER FOR MOTOR SPEED CONTROL
- INDUSTRIAL CONVERTER SYSTEM
- TRANSIENT HARMONIC PRODUCED BY TRANSFORMER CAPACITOR DURING ENERGIZATION





MICRO

CIRCUITS.

FAULTS

PHASE INSULATION FAILURE
(OR)
EARTH INSULATION FAILURE

PULSE NUM

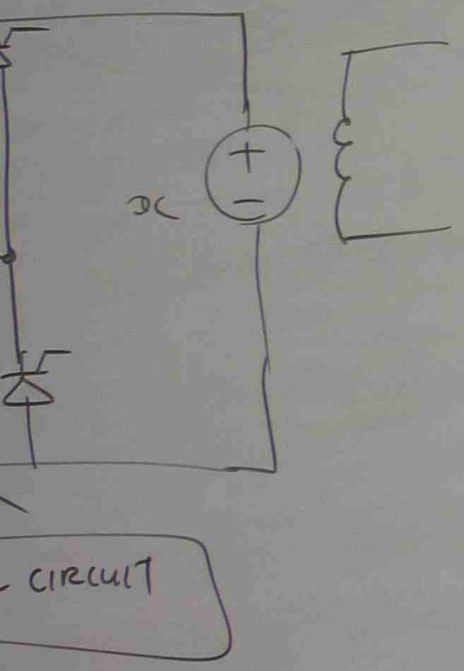
NUMBER OF
OF RECTI F

$n =$

$f_n =$

$f_n = n^{th}$

$f_1 =$ FUN



PULSE NUMBER

NUMBER OF DC PULSES PRODUCED AT THE OUTPUT OF RECTIFIER DURING 1 CYCLE OF SUPPLY VOLTAGE

$$n = kp \pm 1$$

n = ORDER OF HARMONIC

$2^{nd} \rightarrow 2$

$3^{rd} \rightarrow 3$

k = INTEGER 1, 2, 3 - -

p = PULSE NUMBER OF CONVERTER

$$f_n = (kp \pm 1) f_1$$

f_n = n^{th} HARMONIC FREQUENCY

f_1 = FUNDAMENTAL FREQUENCY

CONVERTER CONNECTION	PULSE NUMBER	HARMONIC ORDER
1ϕ Full WAVE	2	3, 5, 7, 9, 11
3ϕ ½ WAVE	3	2, 4, 5, 7, 8
3ϕ FULL WAVE	6	5, 7, 11, 13 17, 19
DOUBLE 3ϕ Full WAVE ONE SHIFTED BY 30°	12	11, 13, 23 25

I_3 = 3rd HARMONIC CURRENT

I_2 = 2nd HARMONIC CURRENT

$$I_{RMS} = \sqrt{I_2^2 + I_3^2 + I_5^2 + - - -}$$

COUP

COUPLING CAPACITANCE

$X_C = \frac{1}{2\pi}$

$I = \frac{E}{X_C}$

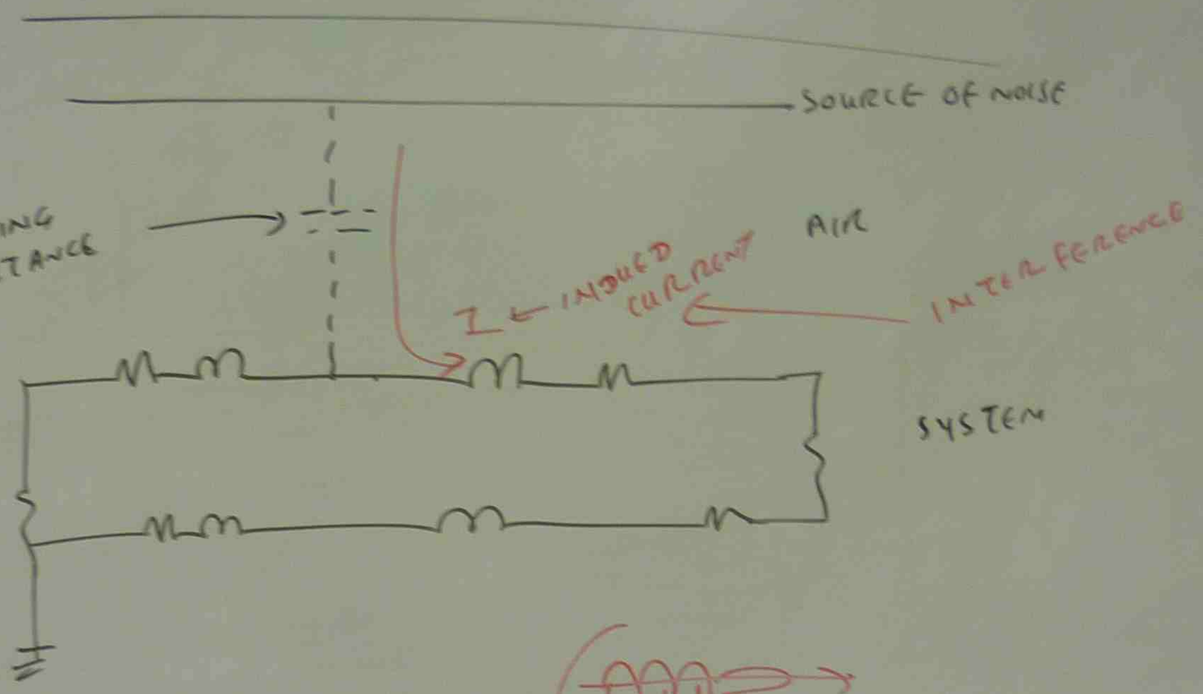
...TER ...TION	PULSE NUMBER	HARMONIC ORDER
...L	2	3, 5, 7, 9, 11
...WAVE	3	3, 4, 5, 7, 8
...WAVE	6	5, 7, 11, 13 17, 19
...U ...TED	12	11, 13, 23 25

3rd HARMONIC CURRENT

2nd HARMONIC CURRENT

$I_3^2 + I_5^2 + \cdots$

COUPLING OF INTERFERENCE INTO ELECTRICAL SYSTEM

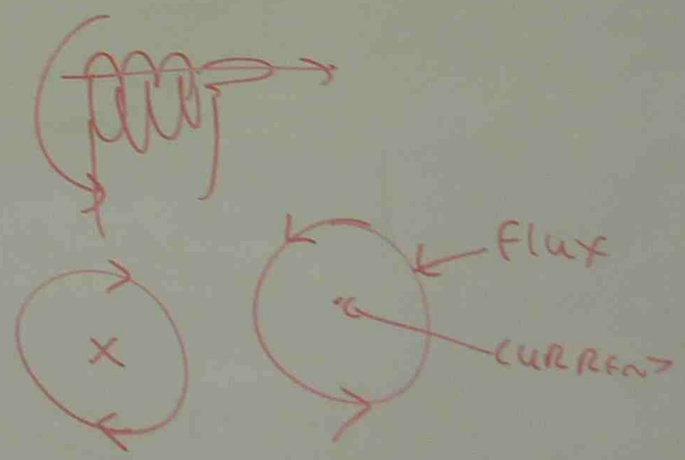


$$X_c = \frac{1}{2\pi f c}$$

$$I = \frac{E}{X_c}$$

$$X_c = \frac{0.14}{f c}$$

(kF)



THE WAVE LENGTH OF TH...
THAN 20 TIMES THE ...
UNDER CONSIDERATION.

FREQUENCY	W...
50 Hz	
10 KHz	
1 MHz	
10 MHz	3

REDUCTION OF INTE...

- USE TWISTED PAI...
- SHIELDING
- GROUNDING For...

DISTRIBUTION SY...

ECTRICAL SYSTEM

ICE OF NOISE

INTERFERENCE

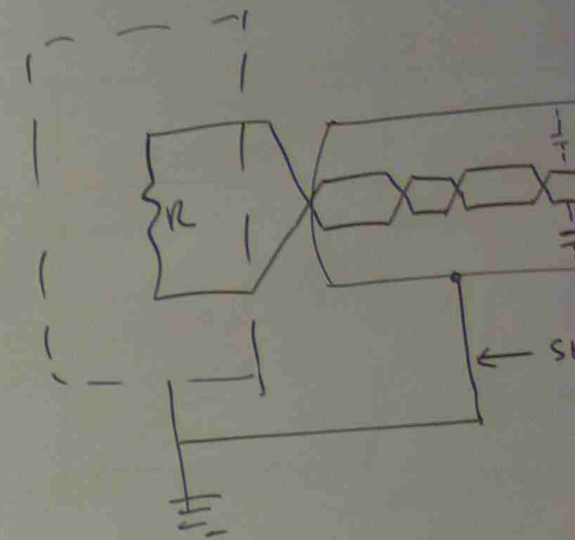
SYSTEM

THE WAVE LENGTH OF THE DISTURBANCE FIELD IS LONGER THAN 20 TIMES THE LENGTH OF THE CONDUCTOR UNDER CONSIDERATION.

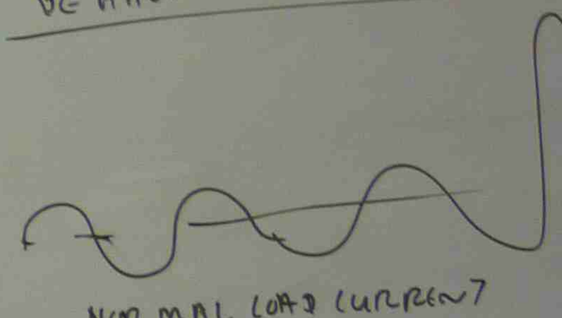
FREQUENCY	WAVE LENGTH	LENGTH OF CONDUCTOR
50 HZ	6000 Km	300 Km
10 KHZ	30 Km	1.5 Km
1 MHZ	300 m	15 m
10 MHZ	30 m	1.5 m

REDUCTION OF INTERFERENCE

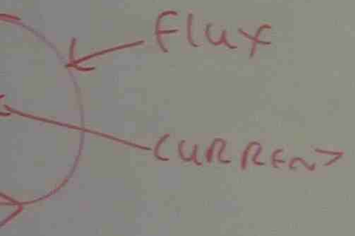
- USE TWISTED PAIR WIRE
- SHIELDING
- GROUNDING FOR CONTROL CIRCUITS IN DISTRIBUTION SYSTEM.



BEHAVIOUR OF FAULT CURR



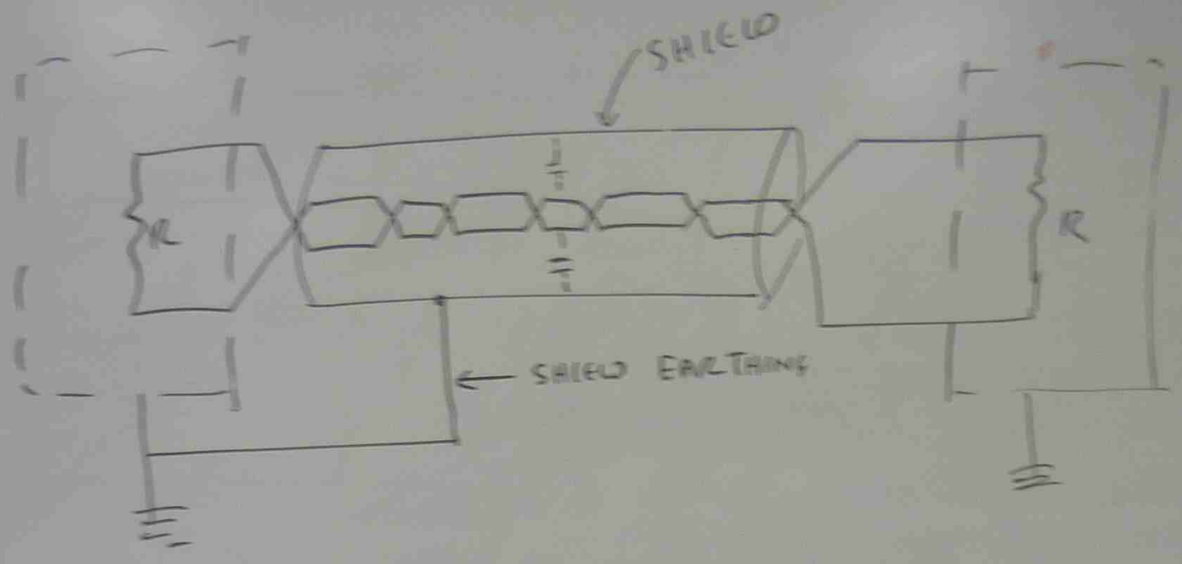
NORMAL LOAD CURRENT



IS LONGER

CTOR

H OF CONDUCTOR



E= 300V

C= 1μF

f_1 = 6 MHz

f_2 = 60 MHz

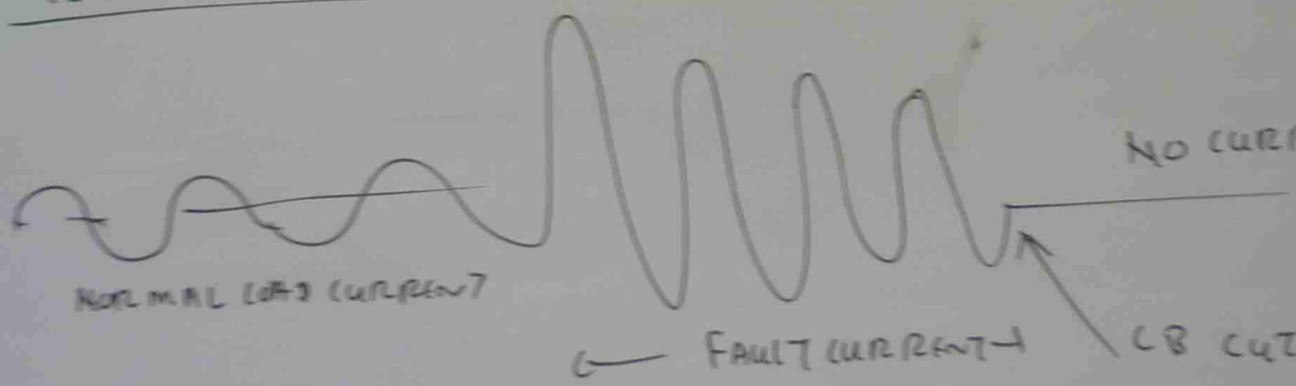
$$X_{c_1} = \frac{1}{2 \times 3.1416 \times 6 \times 10^6 \times 1 \times 10^{-6}}$$

$$= \frac{1}{6.28 \times 6}$$

$$= 0.026$$

$$I = \frac{300}{0.026} = 11.5\,kA$$

BEHAVIOUR OF FAULT CURRENT



CAUSES ELECTROMAGNETIC INTERFERENCE.

VCE