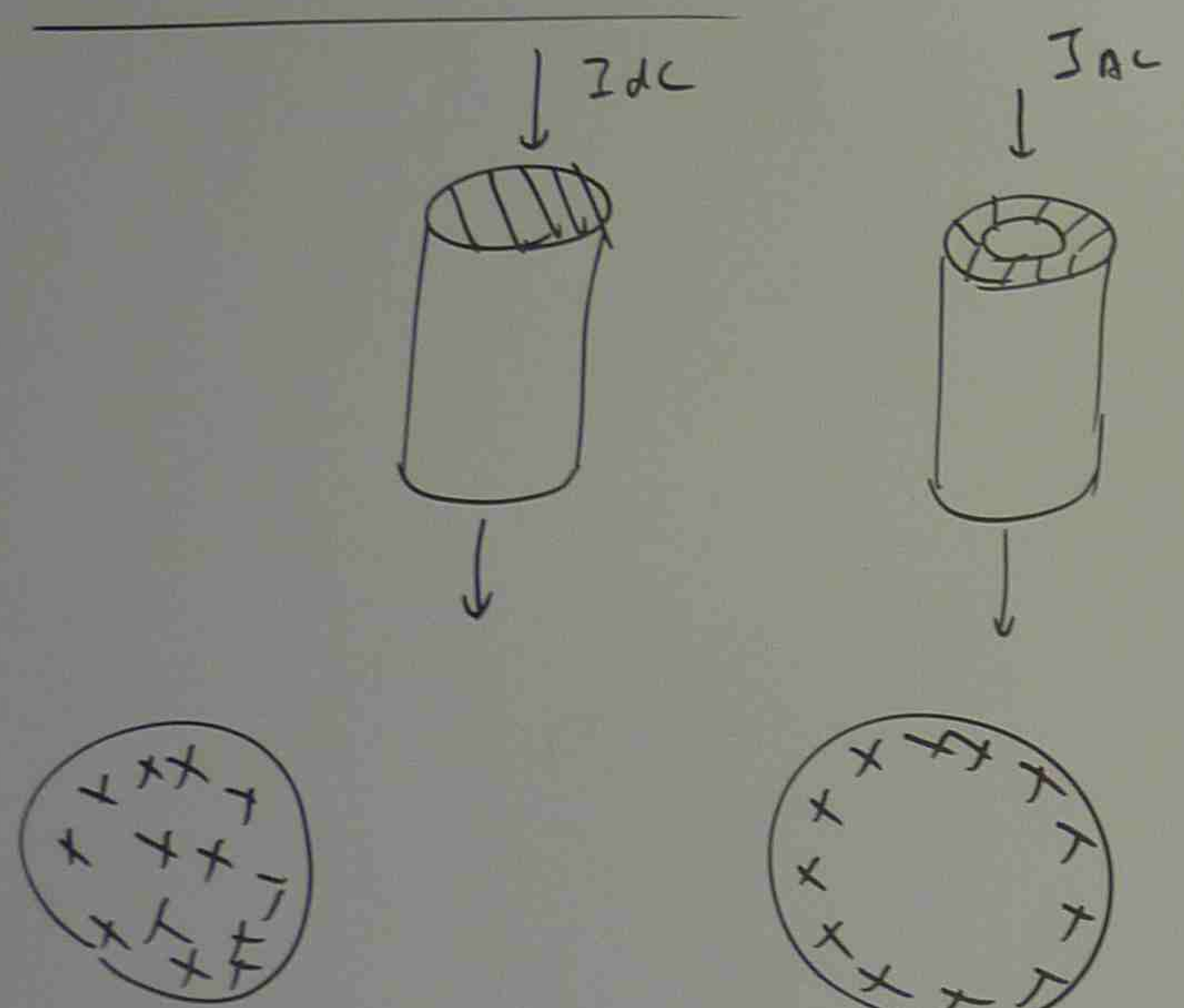
HARMONIC LOSSES IN TRANSFORMER

① SKIN EFFECT



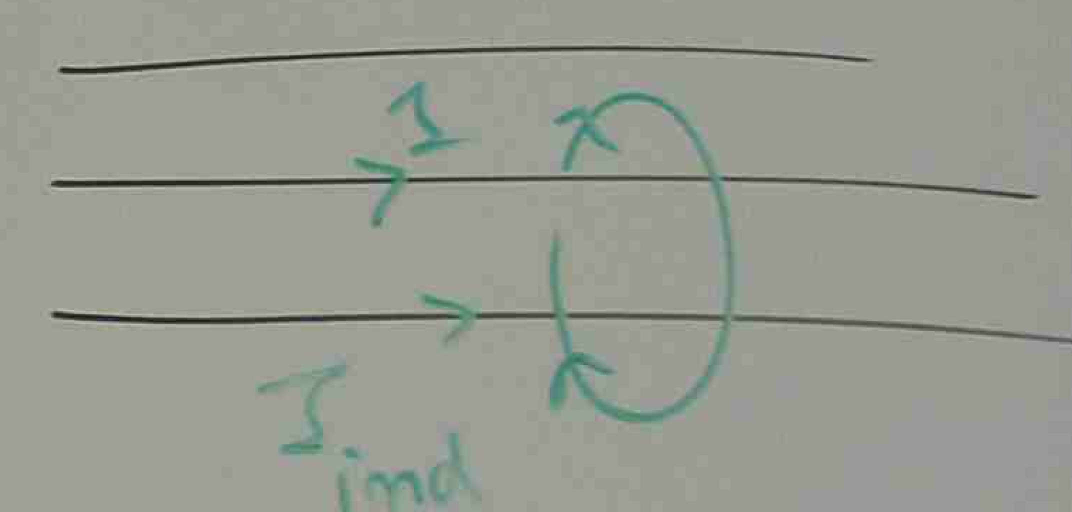
DC CURRENT   AC CURRENT

THE AC CURRENT DISTRIBUTION IS DENSE AT THE SURFACE OF CONDUCTOR CAUSING MORE POWER LOSS

② HYSTERESIS AND EDDY CURRENT LOSSES

THE HARMONIC CURRENT CAUSES HYSTERESIS AND EDDY CURRENT LOSSES IN TRANSFORMER CORE.

③ PROXIMITY EFFECT



THE AC CURRENT DISTRIBUTION WITHIN A CONDUCTOR DEPENDS ON THE CURRENT DISTRIBUTION OF NEIGHBOURING CONDUCTORS (OR) CONDUCTING PARTS.

DERATING OF SINGLE PHASE TRANSFORMER

FOR TRANSFORMERS, TWO DERATING PARAMETERS CAN BE DEFINED

- REDUCTION IN APPARENT POWER RATING
- REAL POWER CAPABILITY.

THE COST OF HARMONICS

THE COST OF HARMONICS CAN ORIGINATE EITHER IN

- THE COST FOR RUNNING THE MACHINE AT DERATED CAPACITY
- THE USE OF HARMONIC FILTERS & ASSOCIATED COST.

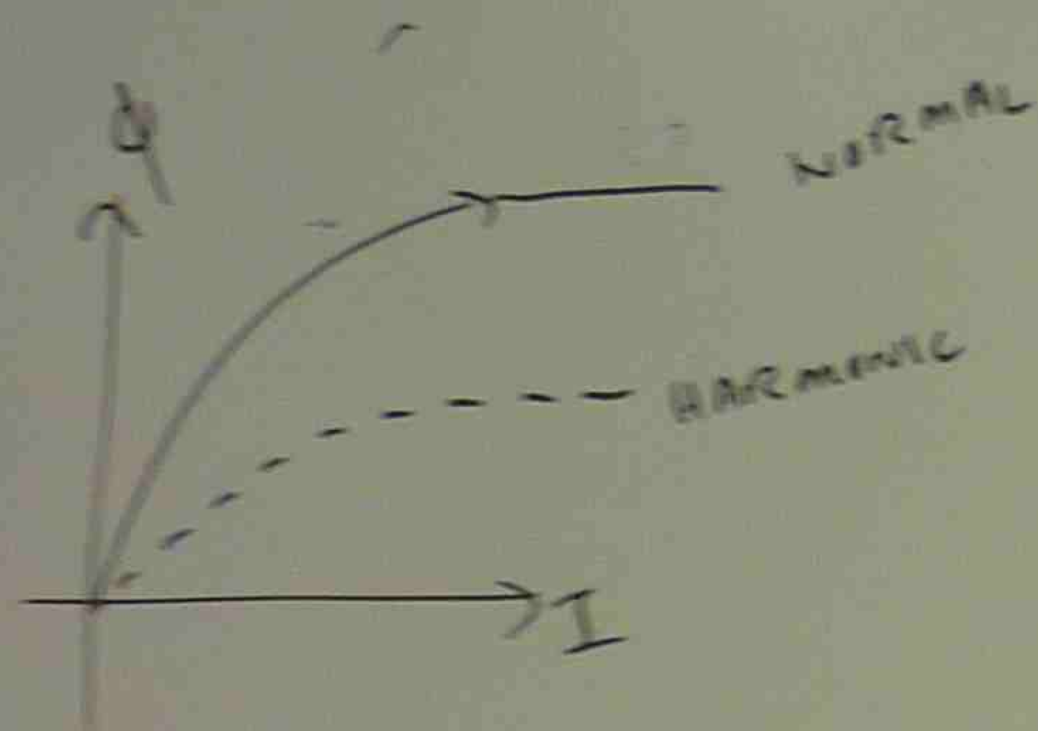
VARIOUS OPERATING MODES OF ROTATING MACHINES

- STEADY STATE OPERATION
- SHORT TERM OPERATION
- STEADY STATE WITH SHORT TERM OPERATION
- INTERMITTENT OPERATION
- STEADY STATE WITH INTERMITTENT OPERATION.

REDUCTION OF VIBRATIONS & TORQUE PULSATIONS IN ELECTRICAL MACHINES

VIBRATIONS AND TORQUE PULSATIONS GENERATE ELECTROMAGNETIC FORCES THAT MAINLY ACT ON THE END OF THE TURNS OF STATOR WINDING.

BESIDE INCREASED TEMPERATURE, VIBRATIONS AND TORQUE PULSATIONS ARE MAJOR REASONS FOR DETERIATION OF INSULATION LEVELS.

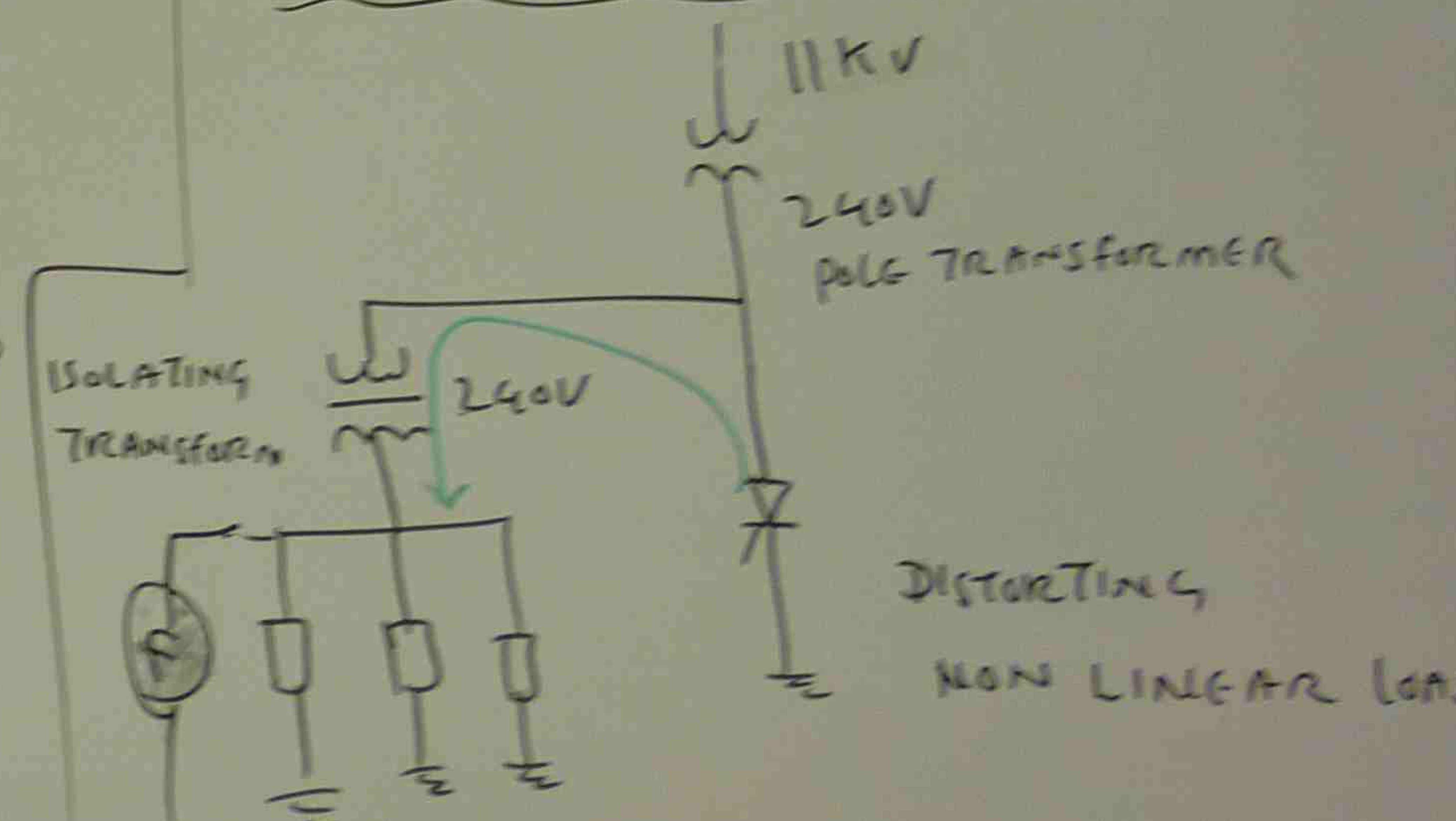


POSSIBLE IMPACTS OF POOR POWER QUALITY ON POWER TRANSFORMERS

- SATURATING TRANSFORMER CORE BY CHANGING IT'S OPERATING POINT ON NON LINEAR X–i CURVE.
- INCREASING CORE (EDDY CURRENT AND HYSTERESIS) LOSSES AND POSSIBLE TRANSFORMER FAILURE DUE TO UNEXPECTED HIGH LOSSES
- INCREASING COPPER LOSSES
- MALFUNCTIONING OF PROTECTIVE RELAYS
- REDUCTION OF EFFICIENCY
- DERATING OF TRANSFORMERS
- DECREASE OF POWER FACTOR
- GENERATION OF PARALLEL RESONANCE
- DETERIORATION OF TRANSFORMER INSULATION NEAR TERMINALS DUE TO HIGH VOLTAGE STRESSES.

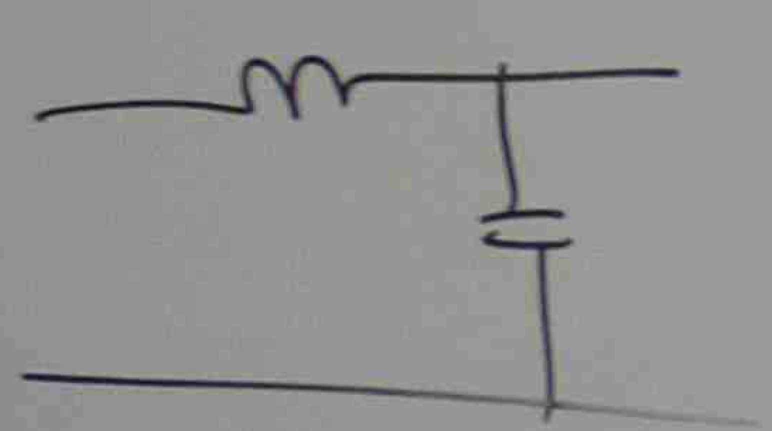
HARMONIC FILTERING

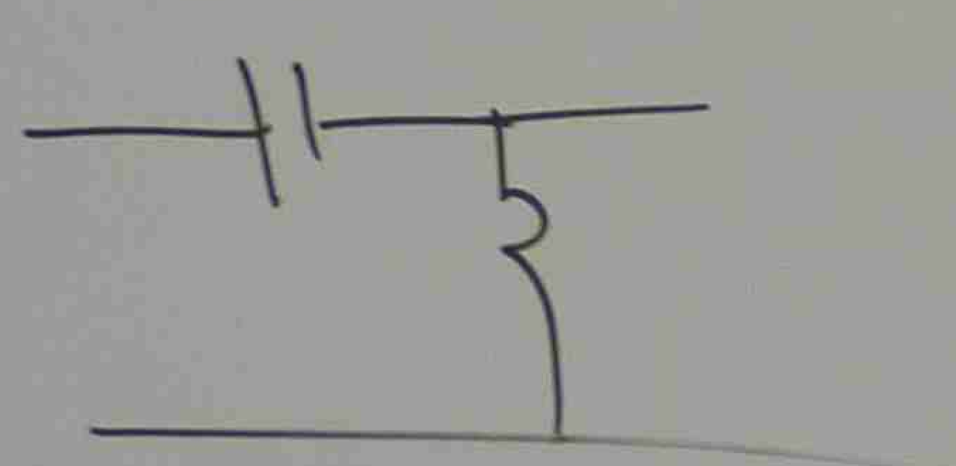
USE OF ISOLATION TRANSFORMER

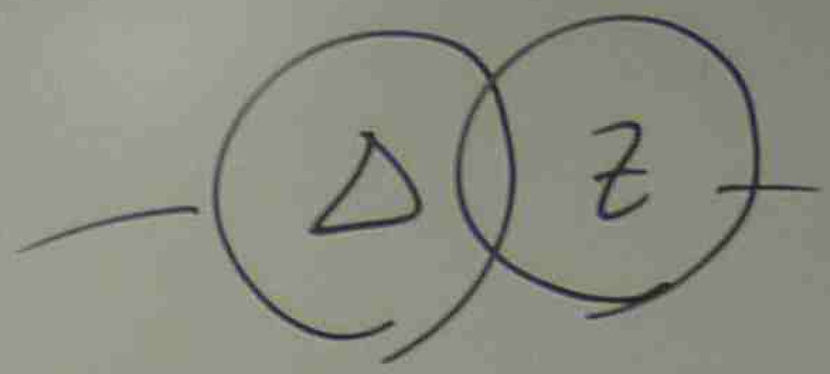


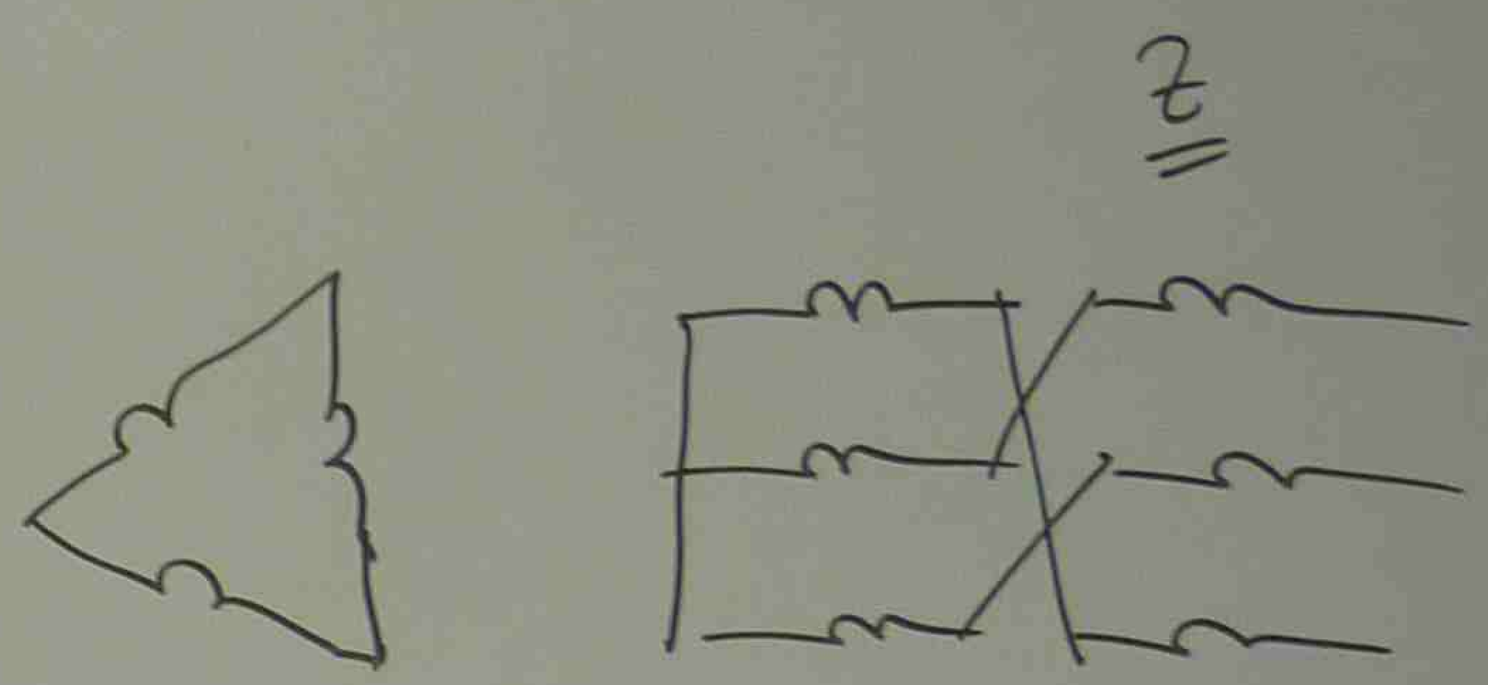
HARMONIC FILTER

- INTERACTION WITH POWER SYSTEM
- FORMING PARALLEL RESONANCE CIRCUIT WITH SYSTEM OF IMPEDANCE
- CHANGING CHARACTERISTICS DUE TO FILTER PARAMETER VARIATION
- UNSATISFACTORY PERFORMANCE UNDER VARIATION OF NON LINEAR LOAD PARAMETERS.
- COMPENSATING A LIMITED NUMBER OF HARMONIC
- NOT CONSIDERING THE POWER QUALITY OF THE ENTIRE SYSTEM
- CREATING PARALLEL RESONANCE.









ZIG ZAG

Δ/Z TRANSFORMER CAN REDUCE THE HARMONIC

INTERACTION OF HARMONICS WITH CAPACITORS

MIS APPLICATION OF POWER CAPACITORS IN TODAY'S MODERN AND COMPLICATED INDUSTRIAL DISTRIBUTION SYSTEM COULD HAVE THE NEGATIVE IMPACT ON BOTH OF THE CUSTOMERS AND UTILITY EQUIPMENTS.

- AMPLICATION AND PROPAGATION OF HARMONICS RESULTING IN EQUIPMENT OVER HEATING AS WELL AS FAILURES OF CAPACITOR BANKS THEMSELVES.
- UNBALANCED SYSTEM CONDITIONS WHICH MAY CAUSE MAL OPERATION OF RELAYS.
- DUE TO CAPACITOR SWITCHING, RUSH CURRENTS AND TRANSIENT OVER VOLTAGES.
- VOLTAGE INCREASE OCCURS DUE TO TRANSIENT OSCILLATION OF CAPACITOR BANK
- SOURCE FREQUENCY CAN COME CLOSE TO SERIES RESONANT FREQUENCY, ABSORBING MAXIMUM POWER.

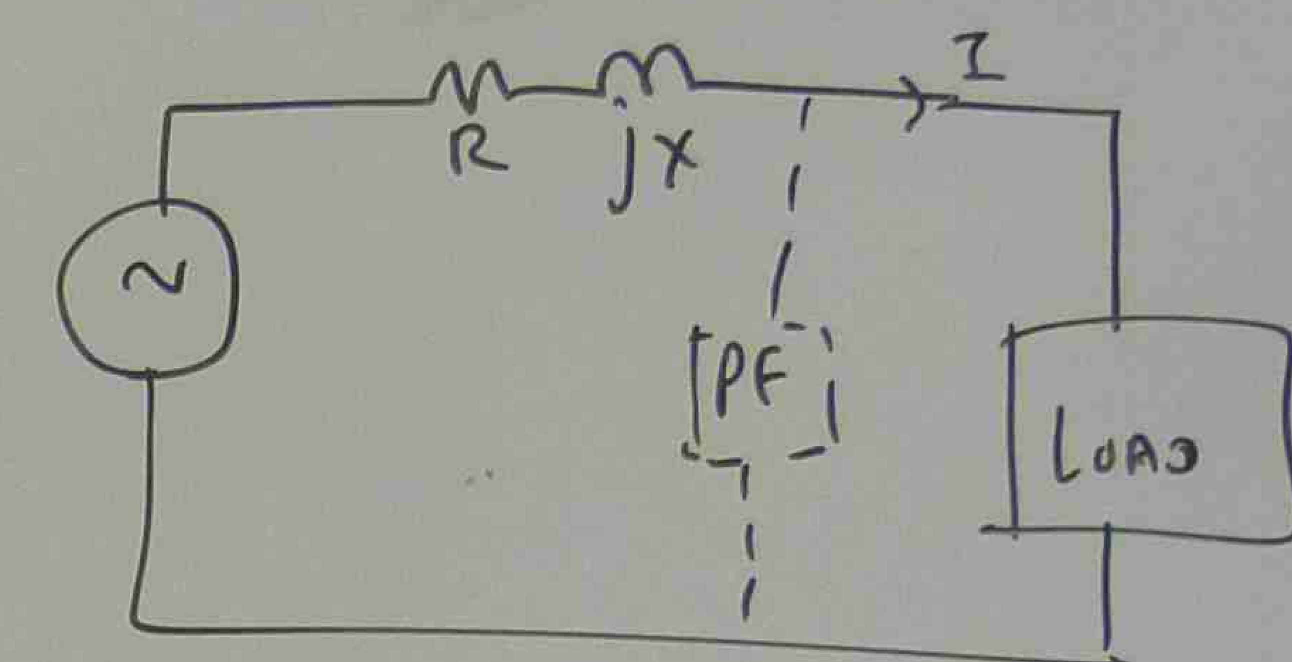
SOLUTIONS TO

- DE TUNE THE CIR
  CAPACITOR BANK
- SWITCH LARGE
  ONE SECTION OF
- USE OVER VOLTA
- APPLY SURGE AR
  LOCATIONS WHERE
- CONVERT LOW VOL
  BANKS TO HAR
- USE PROPERLY
  - INSTALL
  - USE TRANSIE

SOLUTIONS TO VOLTAGE INCREASE

- DETUNE THE CIRCUIT BY CHANGING CAPACITOR BANK SIZE.
- SWITCH LARGE BANKS IN MORE THAN ONE SECTION OF THE SYSTEM
- USE OVER VOLTAGE CONTROL METHOD.
- APPLY SURGE ARRESTERS AT THE LOCATIONS WHERE OVER VOLTAGE OCCURS
- CONVERT LOW VOLTAGE PF CORRECTION BANKS TO HARMONIC FILTER.
- USE PROPERLY TUNED FILTER
- INSTALL ISOLATION TRANSFORMER
- USE TRANSIENT SURGE SUPPRESSORS.

REACTIVE POWER COMPENSATION



$P + jQ$

P = ACTIVE POWER (kW)

jQ = REACTIVE POWER (kVAR)

R = LINE RESISTANCE

jX = LINE INDUCTIVE REACTANCE

PF - POWER FACTOR CORRECTION CAPACITOR

- IMPROVED VOLTAGE PROFILE
- REDUCE POWER SYSTEM LOSSES
- RELEASED POWER SYSTEM CAPACITY
- INCREASED PLANT RATING

ROLE OF FILTERS IN POWER SYSTEM

HARMONIC CAN CAUSE INSULATION FAIL, FLASH OVER, BLACK OUT ETC.

THE SOLUTION TO THE PROBLEM IS TO INSTALL A HARMONIC FILTER FOR EACH NON LINEAR LOAD, CONNECTED TO POWER SYSTEM.

FILTERS CAN ONLY COMPENSATE HARMONIC CURRENTS / HARMONIC VOLTAGE AT INSTALLED BUS. THEY DO NOT CONSIDER THE POWER QUALITY OF THE OTHER BUSES.

TYPES OF NON LINEAR LOADS

- CURRENT SOURCE (CURRENT FED) LOAD → (THYRISTOR | RECTIFIER)
- VOLTAGE SOURCE (VOLTAGE FED) LOAD → (AC MOTOR DRIVE POWER SUPPLY)
- COMBINATION OF CURRENT AND VOLTAGE SOURCE → (VARIABLE FREQUENCY FED AC MOTOR)
  (CSI FED AC MOTOR DRIVE)

VS

FILTE
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CLASS

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T ETC.

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MOTOR DRIVE POWER

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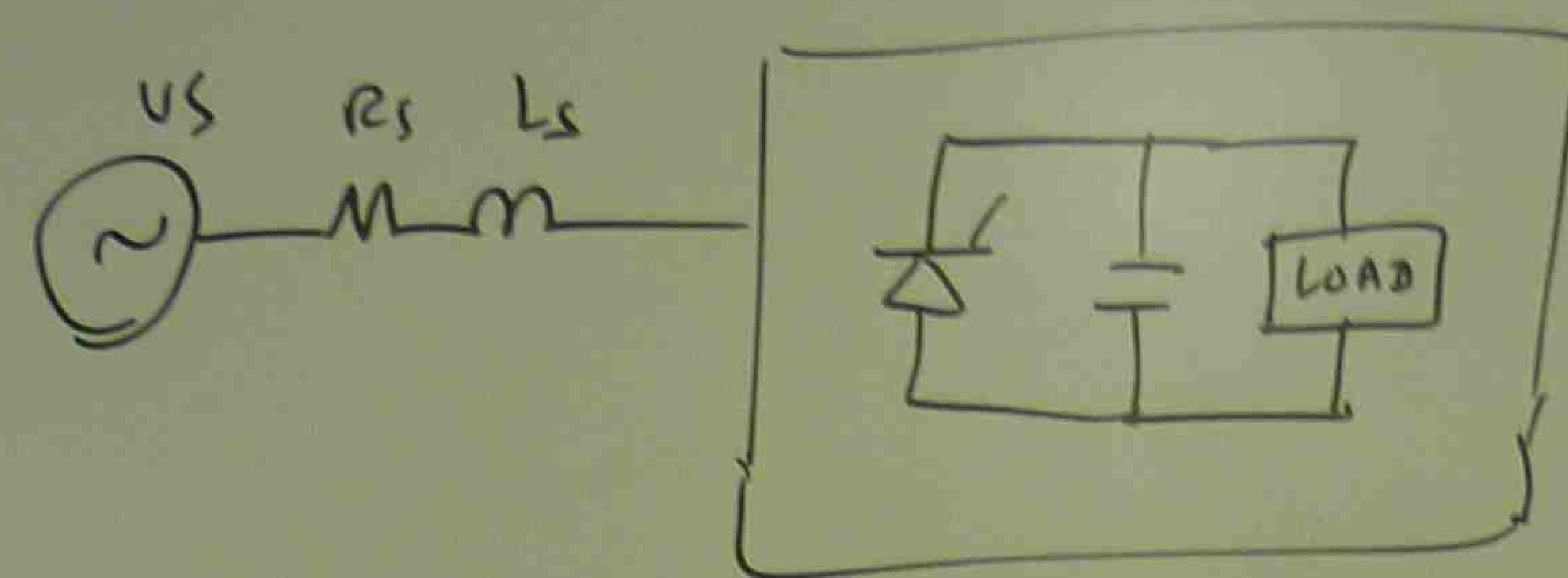
(VARIABLE FREQUENCY

AC MOTOR)

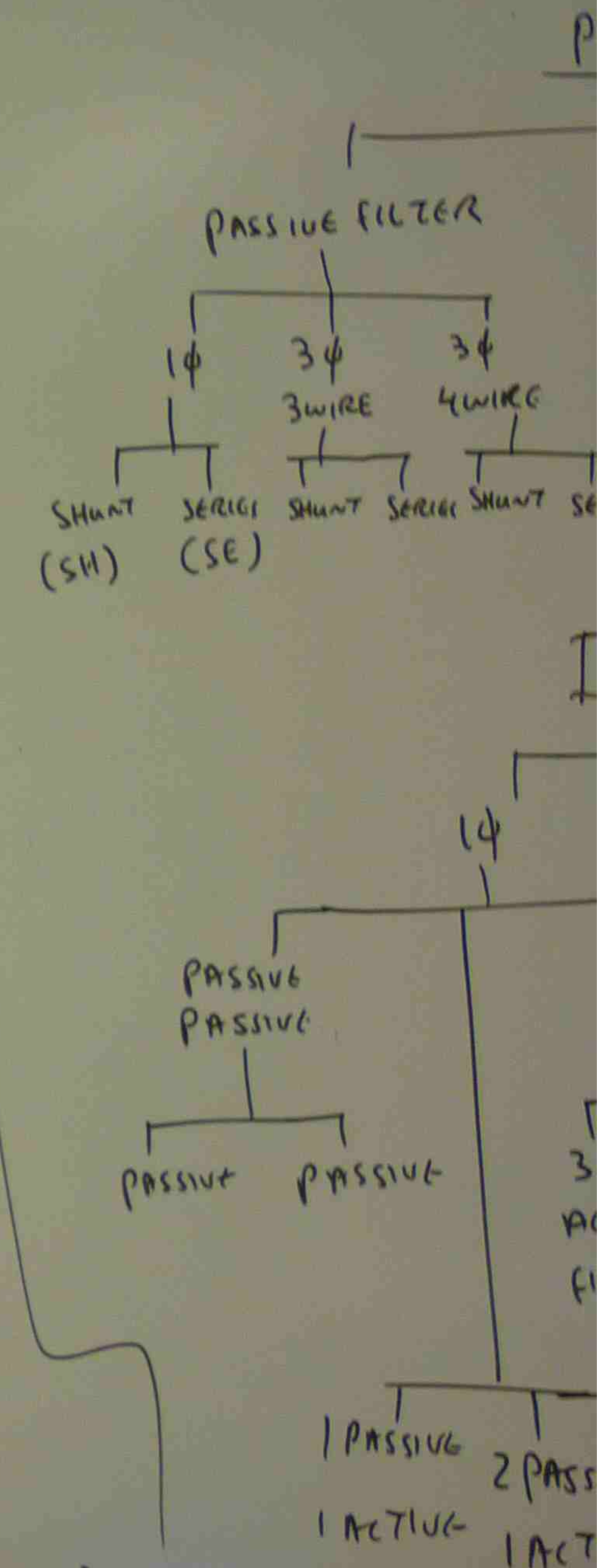
FED AC MOTOR DRIVE)



FILTERS ARE USUALLY INSTALLED AT THE POINT OF DISTORTION

CLASSIFICATION

- NUMBER AND TYPES OF ELEMENTS
- TOPOLOGY (SHUNT CONNECTED, SERIES CONNECTED, COMBINED)
- SUPPLY SYSTEM (SINGLE PHASE, 3ϕ 3WIRE, 3ϕ 4WIRE)
- TYPE OF NON LINEAR LOAD (CURRENT SOURCE, VOLTAGE SOURCE LOAD)
- POWER RATING
- COMPENSATED VARIABLE (HARMONIC CURRENT, HARMONIC VOLTAGE, REACTIVE POWER, PHASE BALANCING)



THE POINT OF

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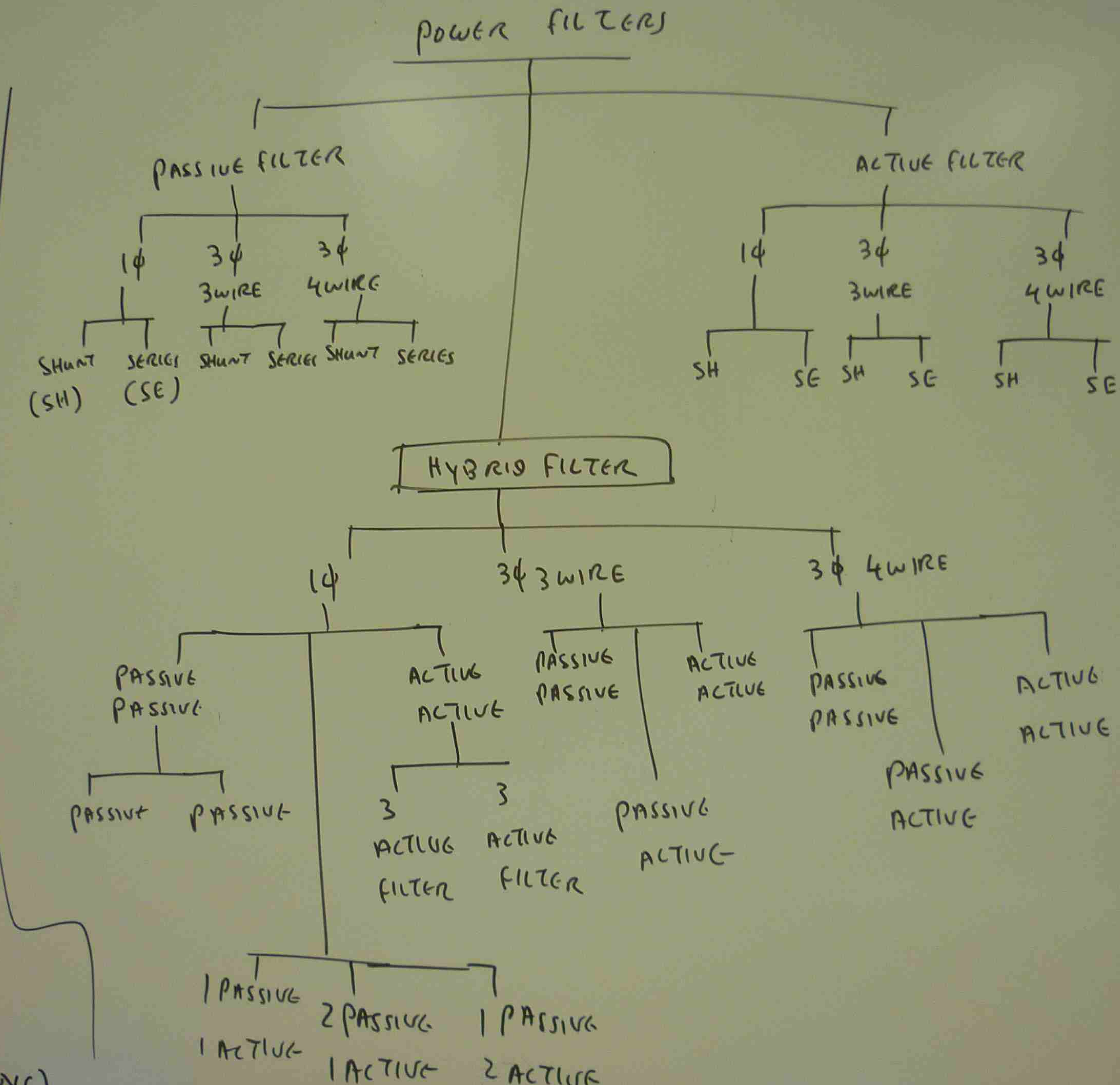
LTAGE SOURCE LOAD)

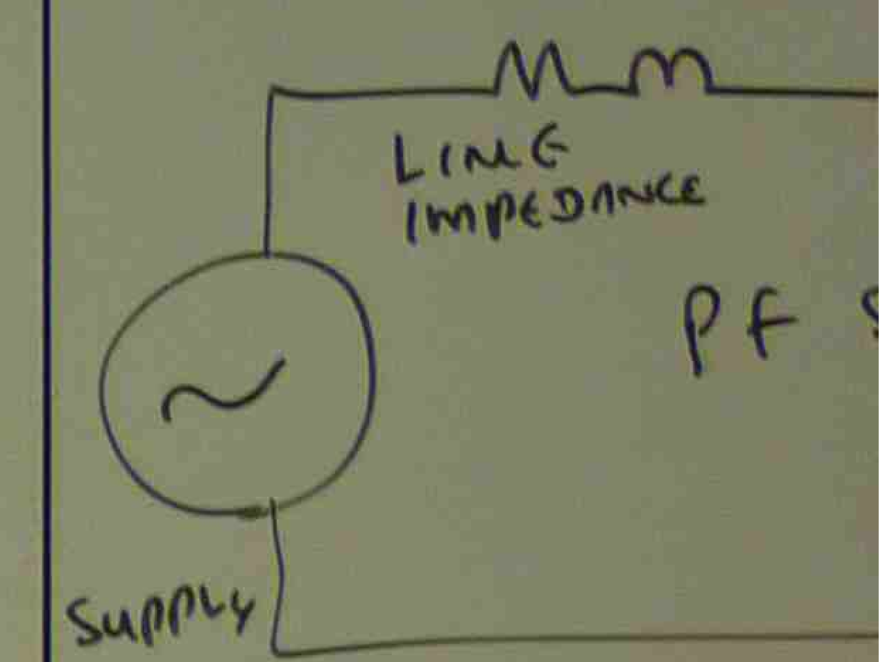
MONIC CURRENT,

MONIC VOLTAGE

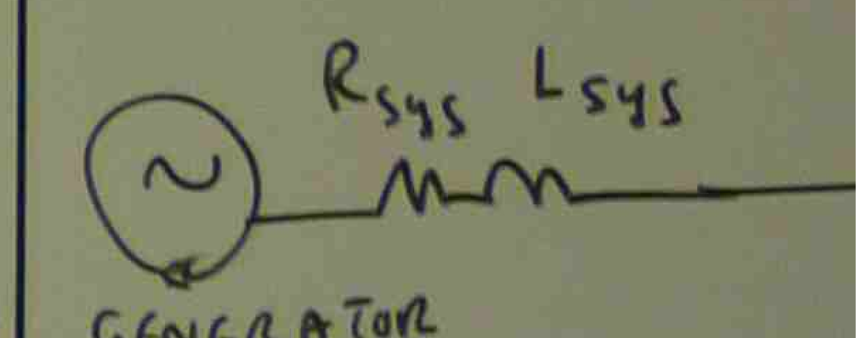
CTIVE POWER, PHASE BALANCING)

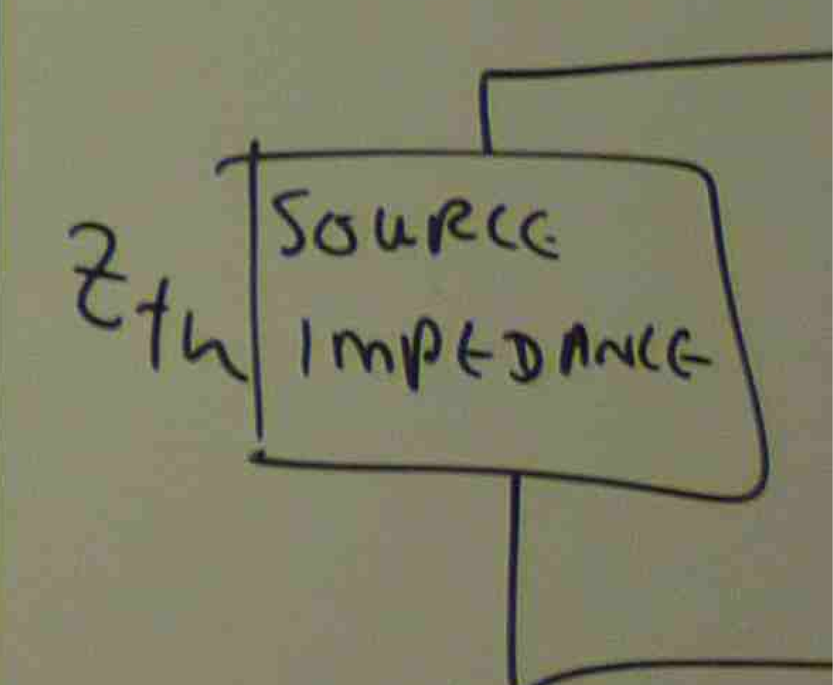


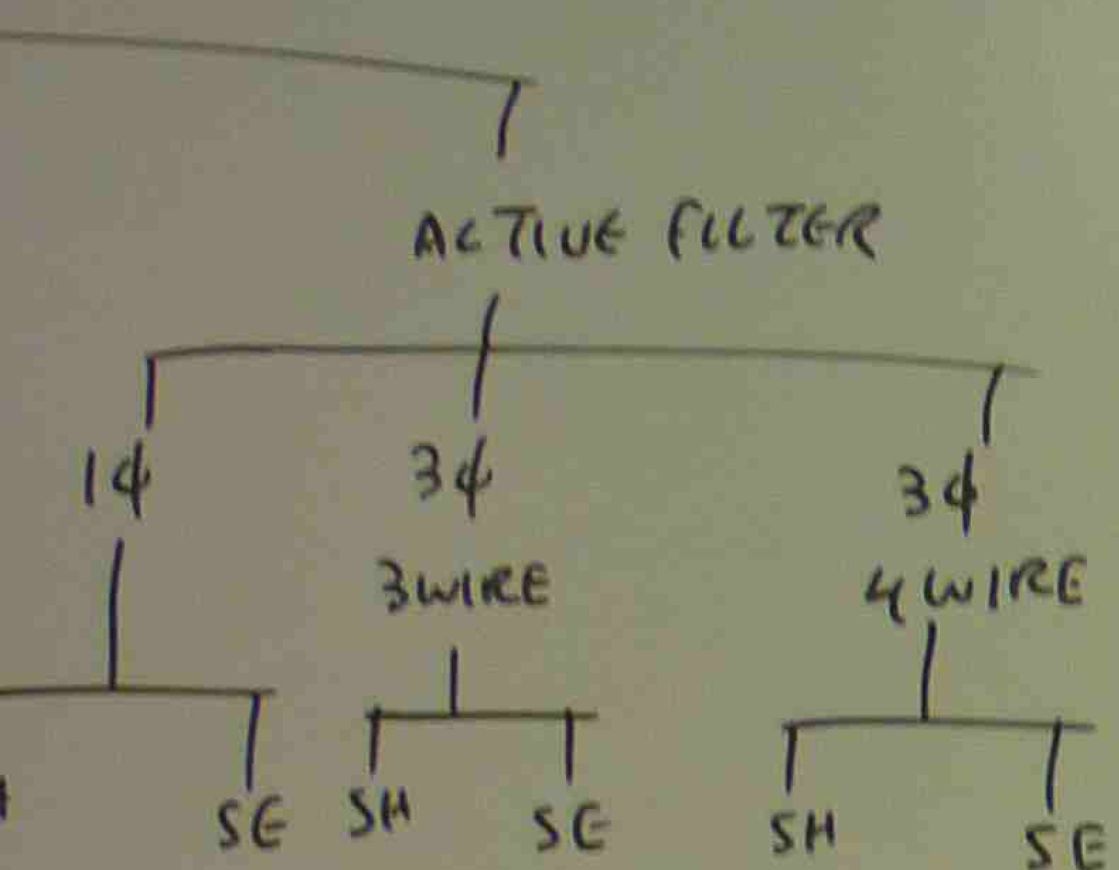
HYBRID FILTE

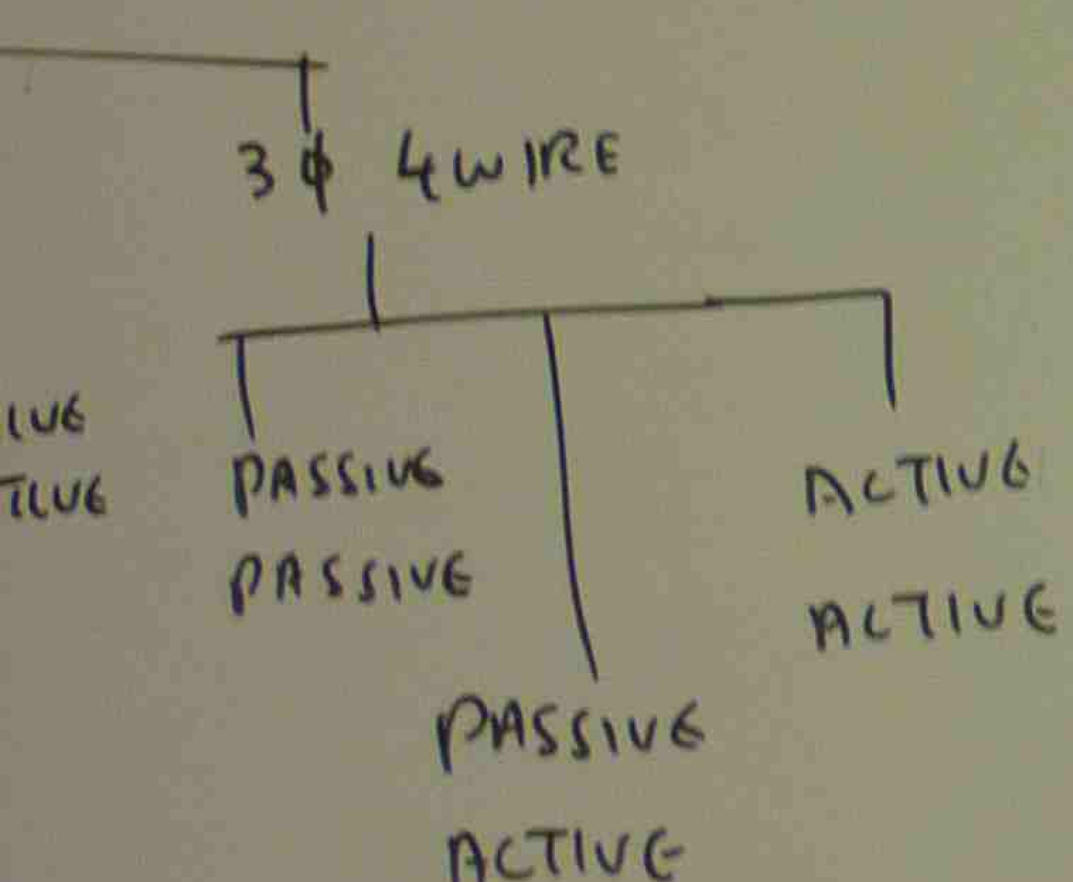


PF- PAS

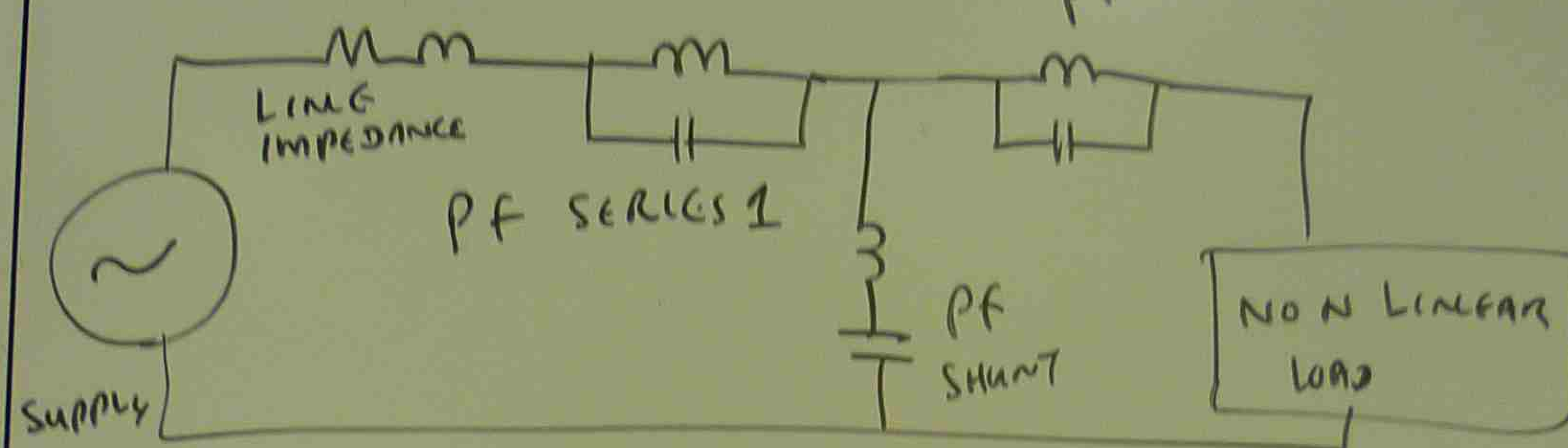




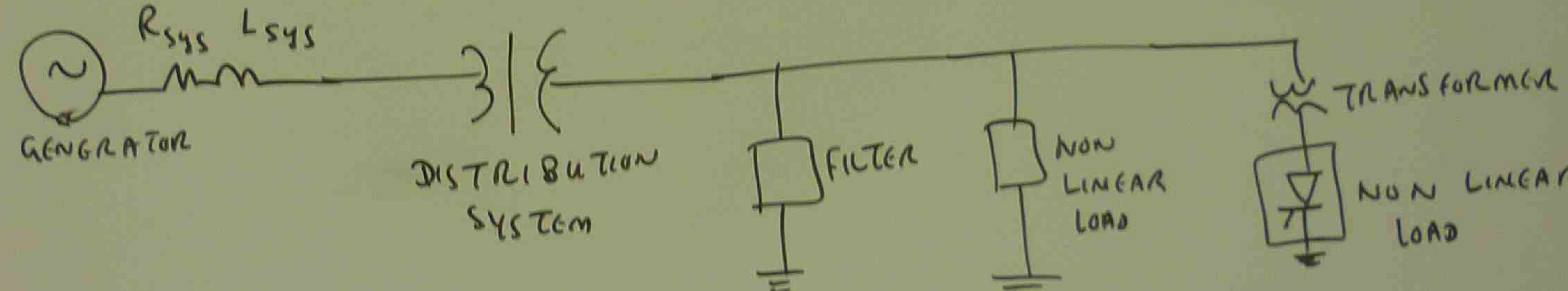


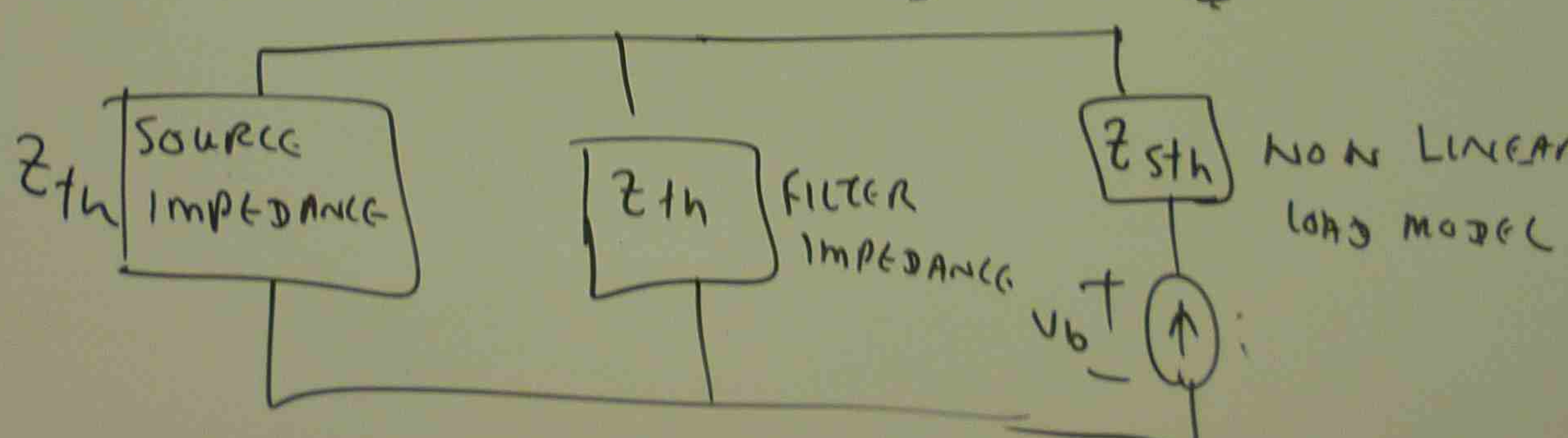


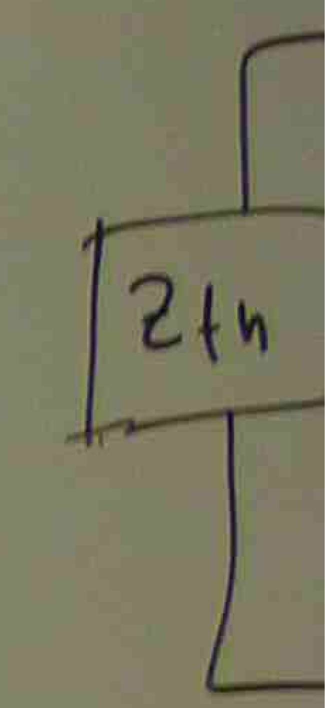
HYBRID FILTER



PF - PASSIVE FILTER







LIMITAT

- ROBUST, EC
- CAN BE
- FAST RE
- DO NOT
- P.F COR
  (POWER FAC

LIMIT

- FIXED COMPE
- LIMIT TO FE
- VARIATION
- STEPLESS C

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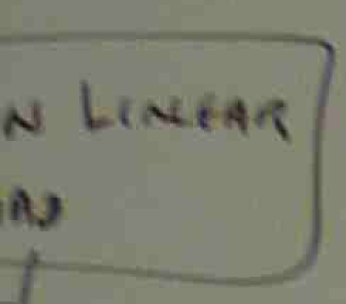
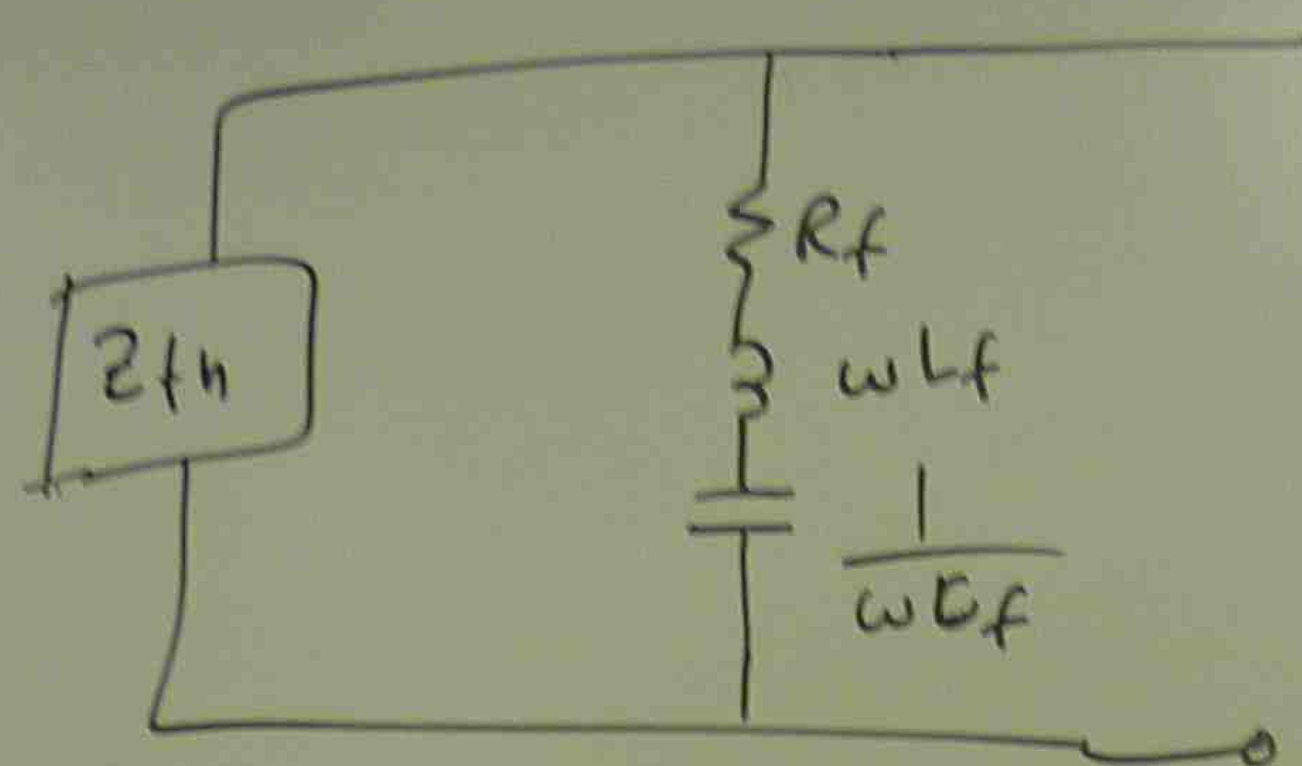
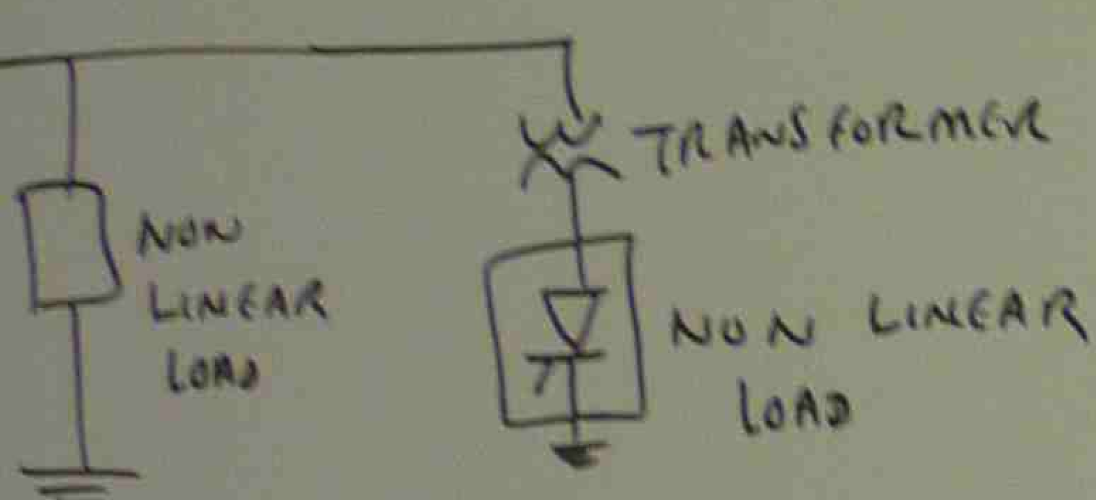




LIMITATION OF PASSIVE FILTERS

- ROBUST, ECONOMICAL
- CAN BE IMPLEMENTED FOR LARGE MVARS
- FAST RESPONSE
- DO NOT CONTRIBUTE SHORT CIRCUIT CURRENT
- P.F CORRECTION
  (POWER FACTOR)

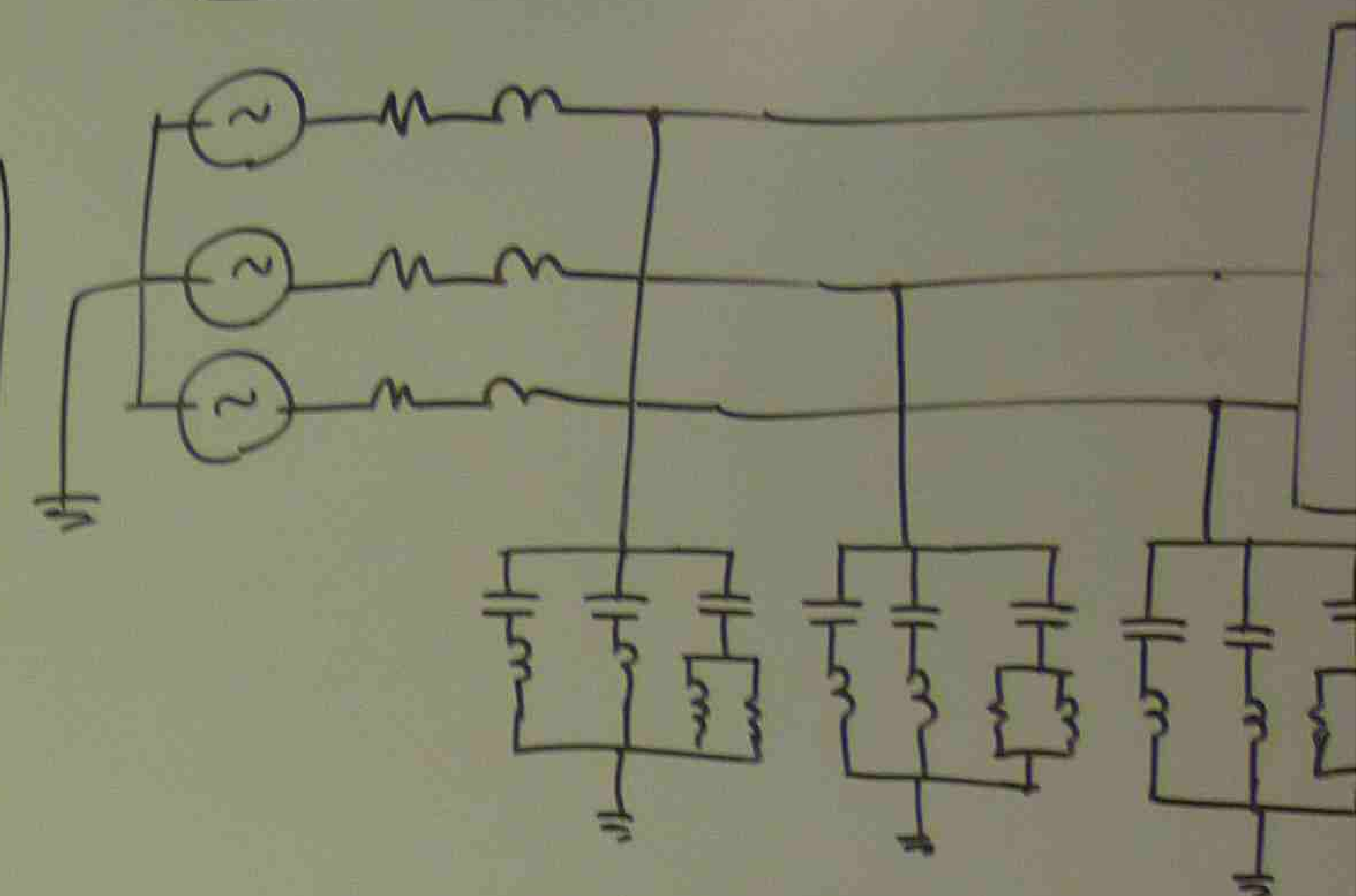


NON LINEAR LOAD MODEL

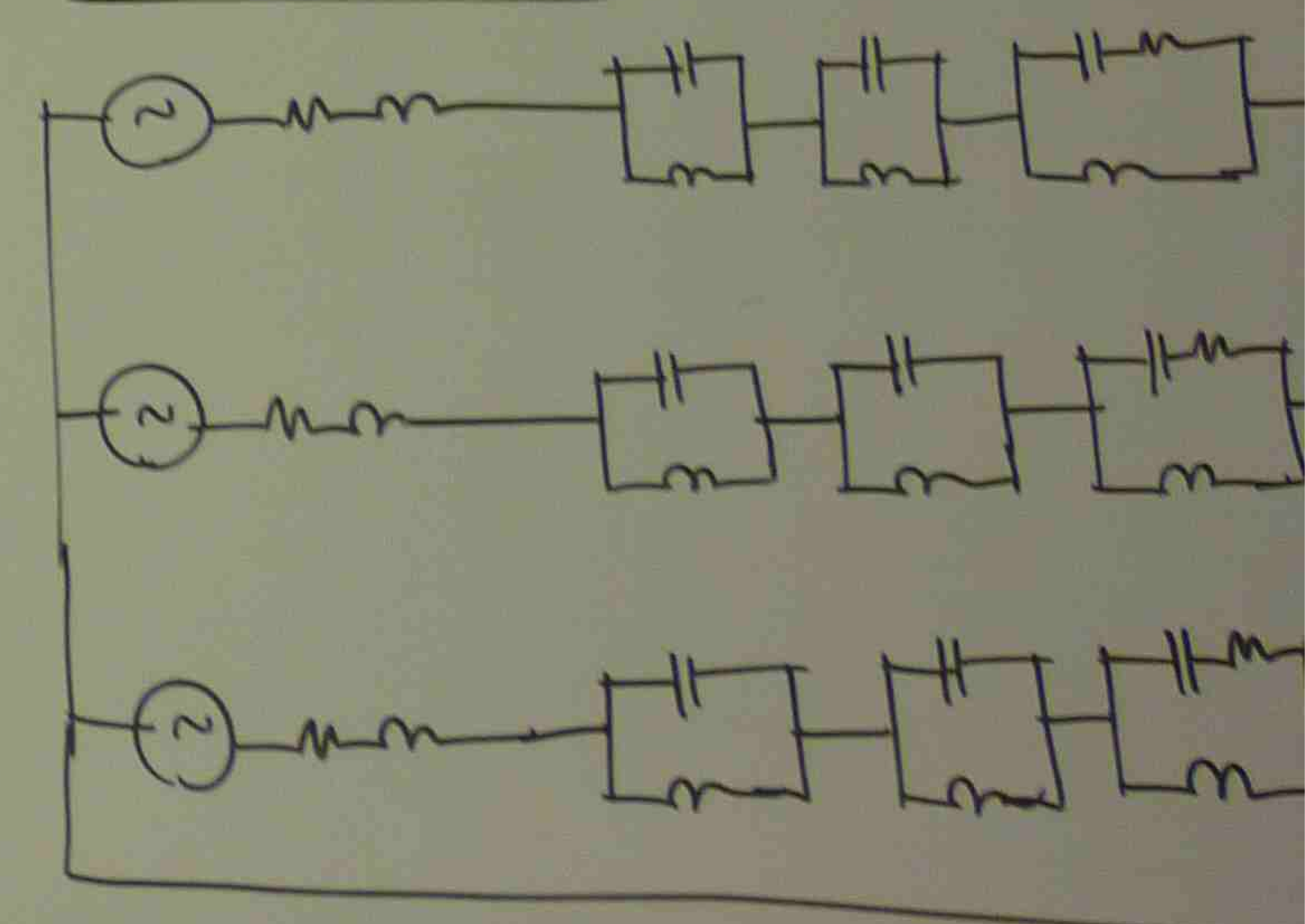
LIMIT

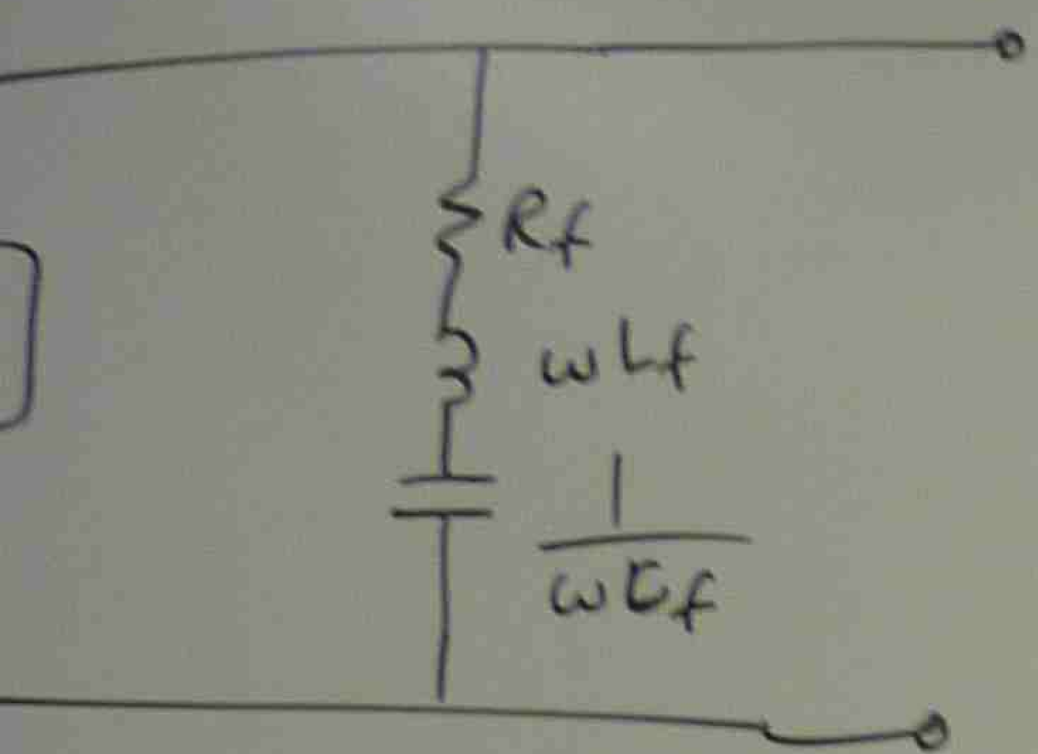
- FIXED COMPENSATION FOR HARMONICS
- LIMIT TO FEW ORDER OF HARMONICS
- VARIATION
- STEPLESS CONTROL

SHUNT FILTER



SERIES FILTER





ON OF PASSIVE FILTERS

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PLEMENTED FOR LARGE MVARS
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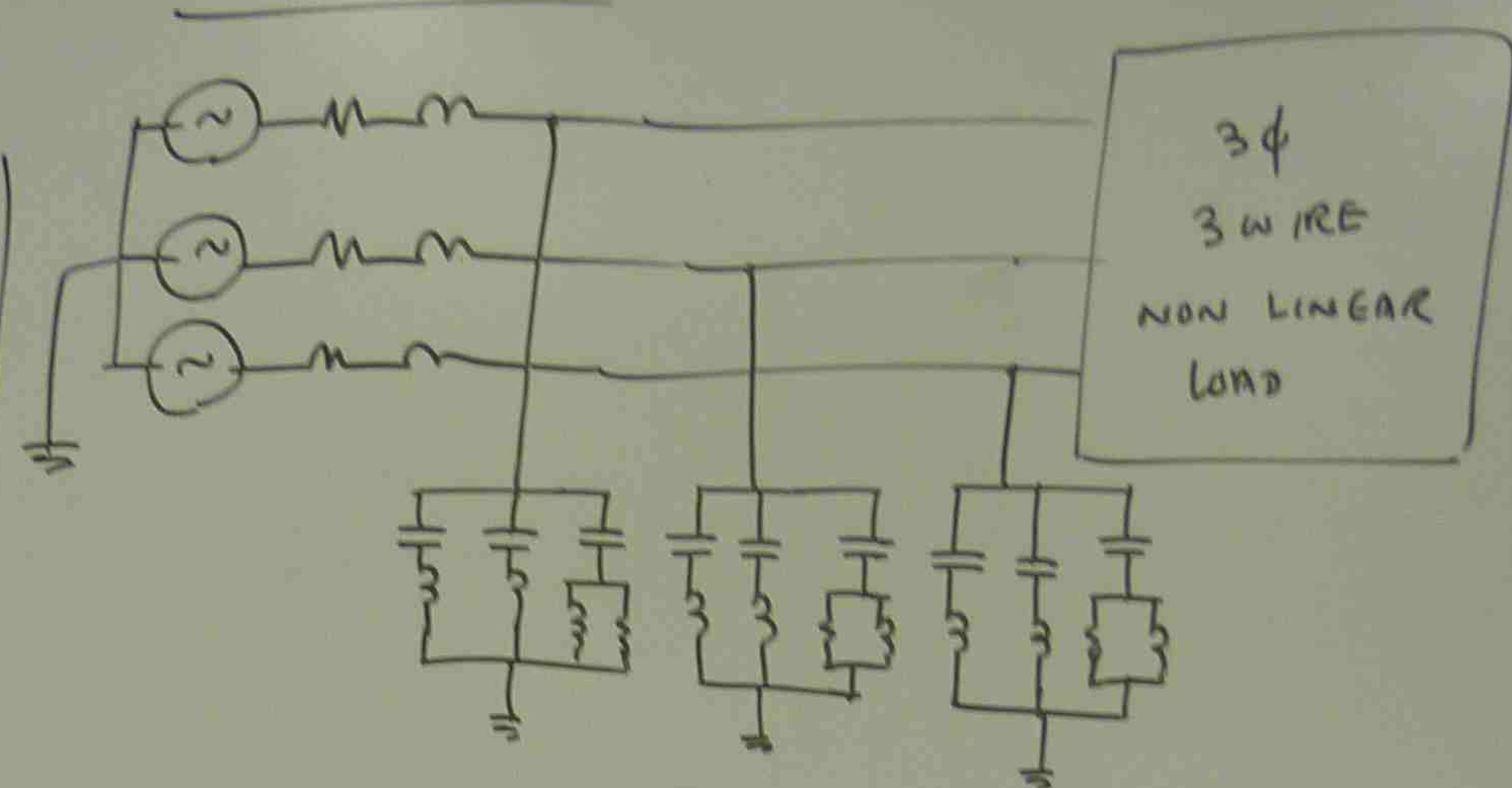
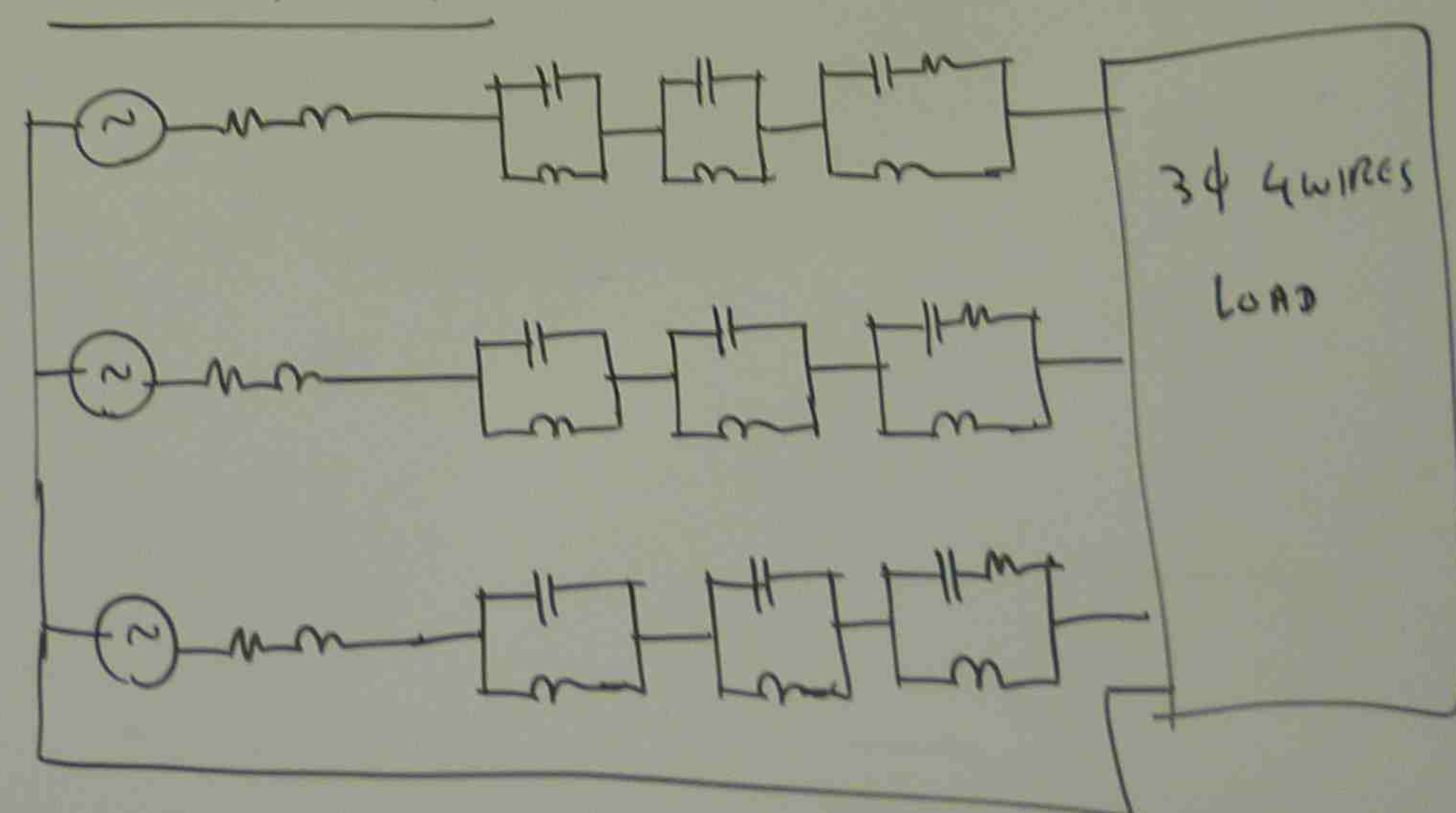
ATION FOR HARMONICS
ORDER OF HARMONICS

TROL

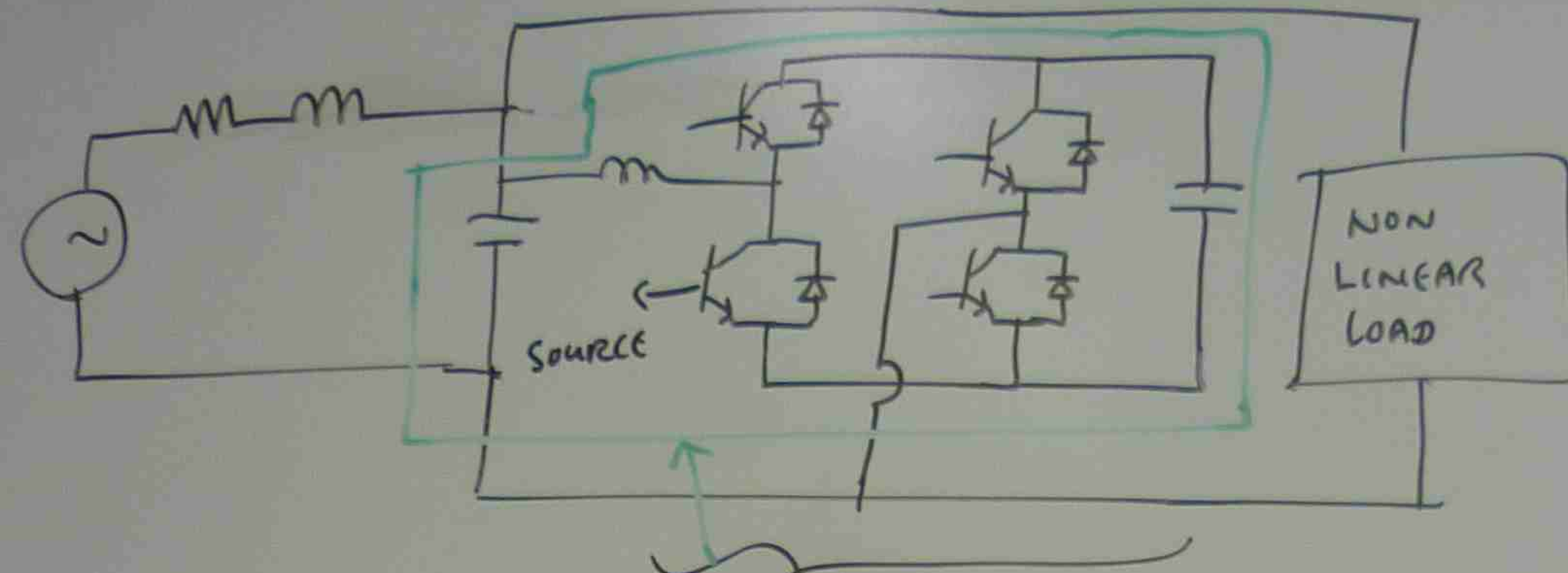
SHUNT FILTER



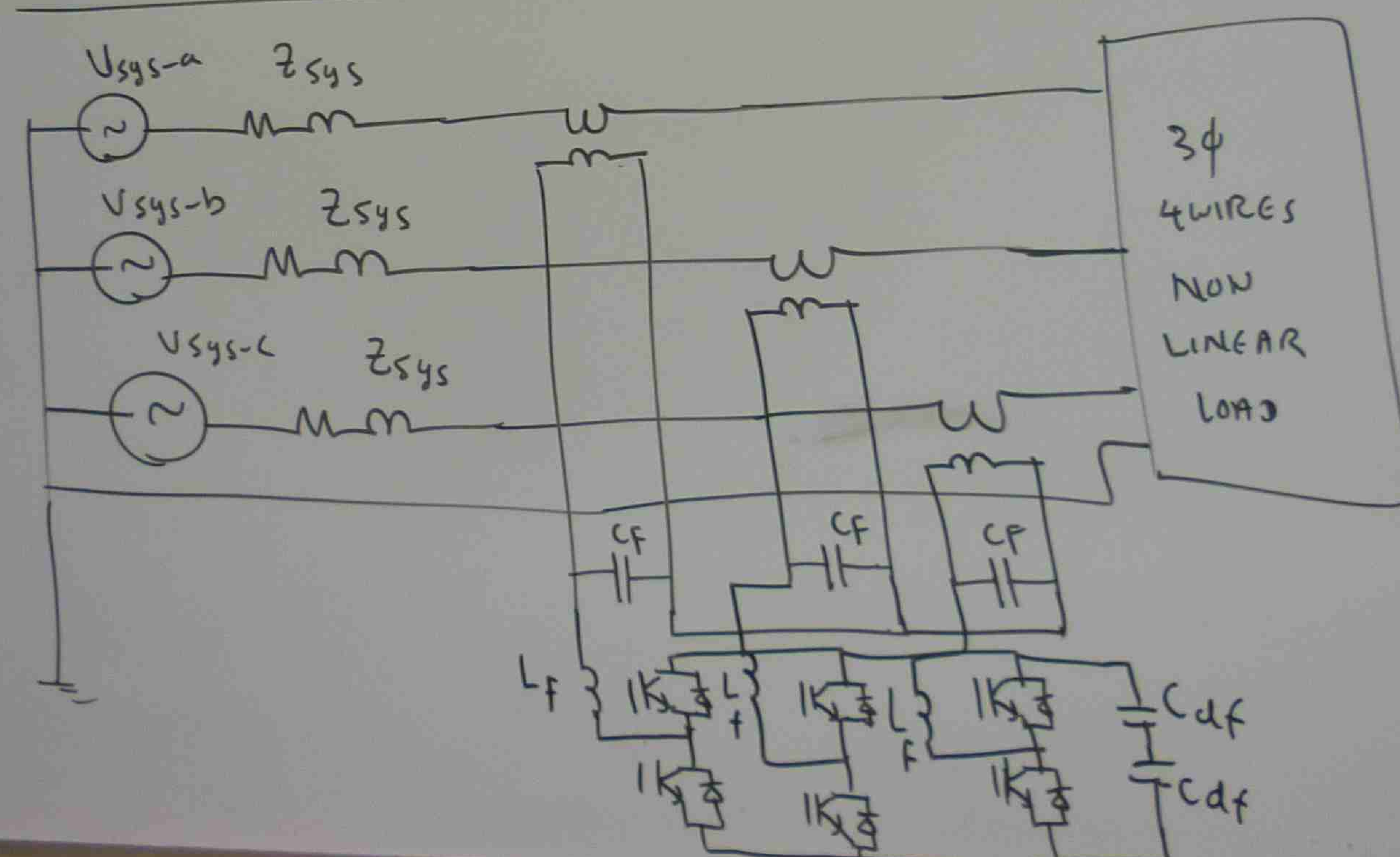
SERIES FILTER



ACTIVE FILTER



APPLICATION OF ACTIVE FILTERS IN 3ϕ POWER SYSTEM



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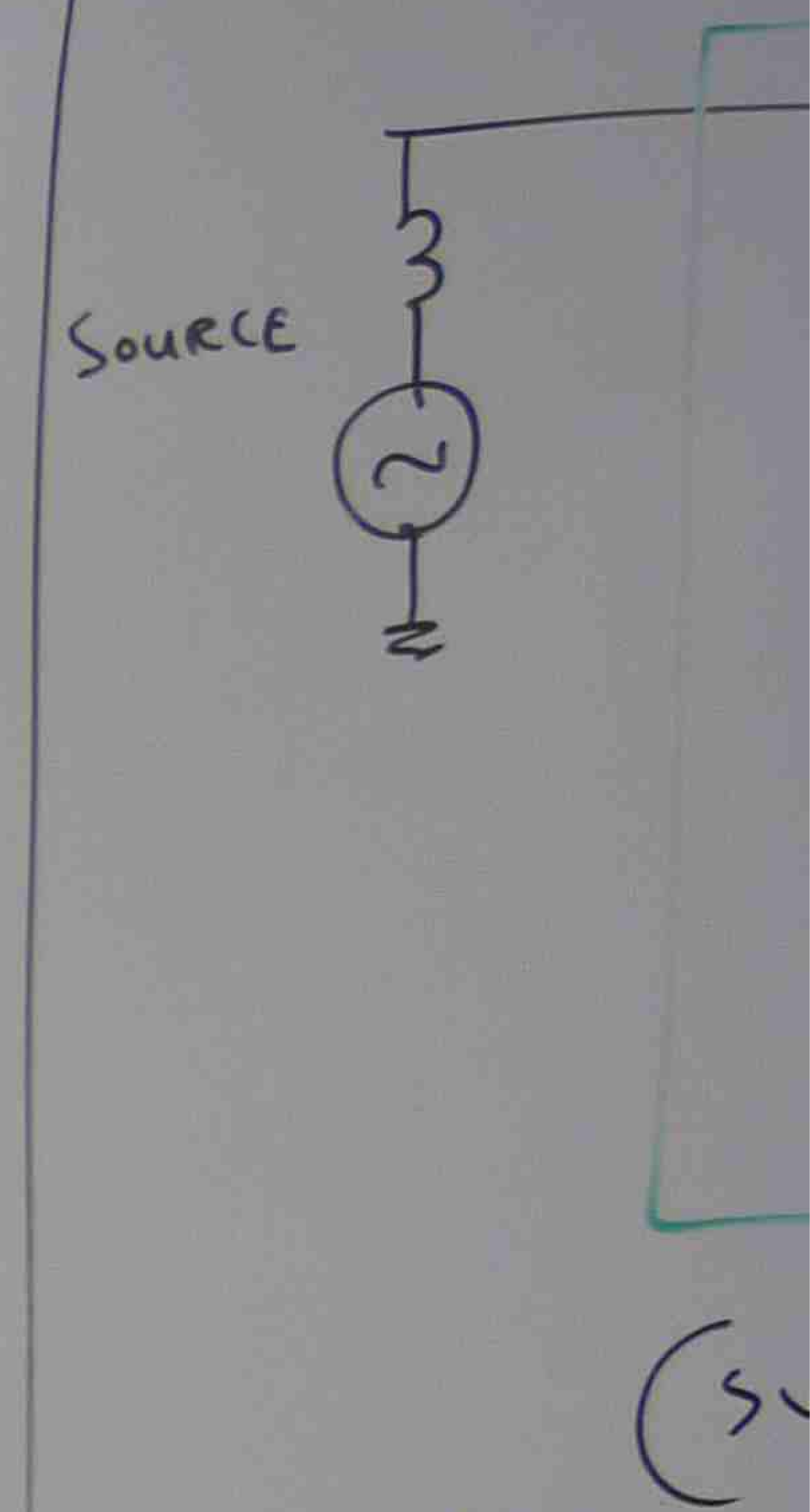

- SENSOR
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FUNCTION

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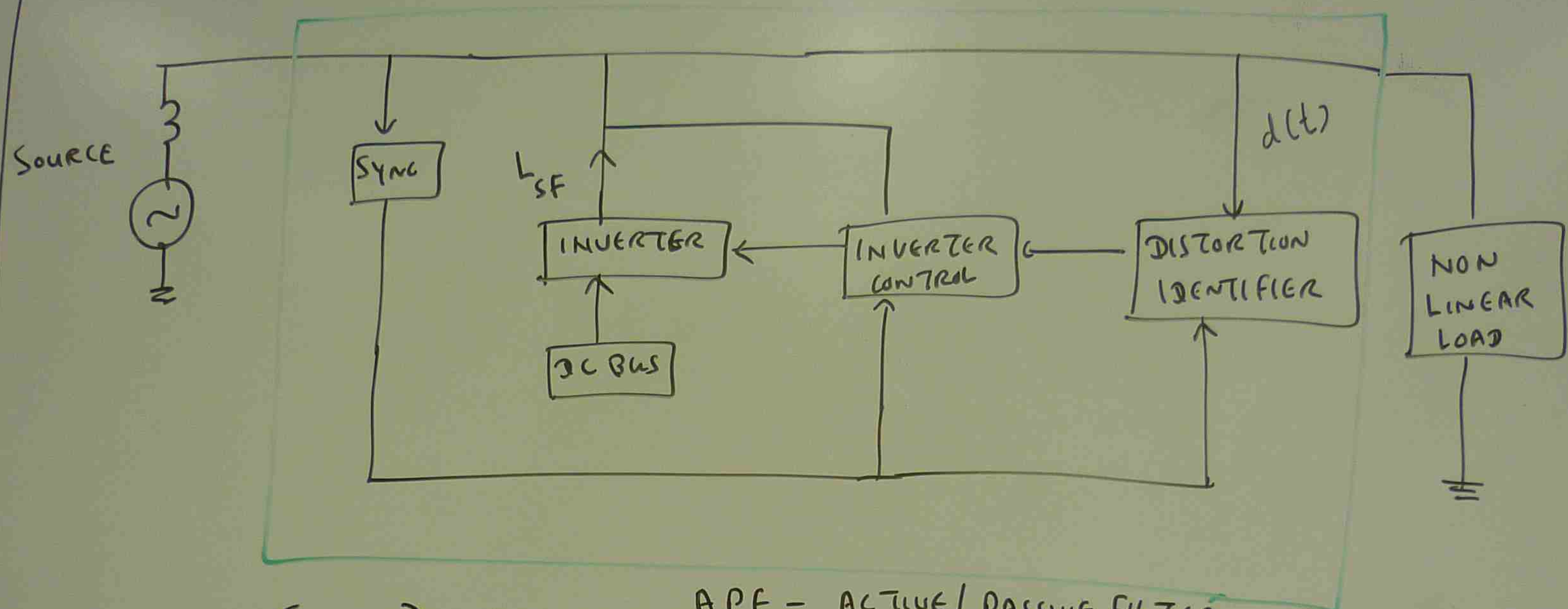
BLOCK DIAGRAM OF ACTIVE FILTER



APF - ACTIVE / PASSIVE FILTER

(SYNC)

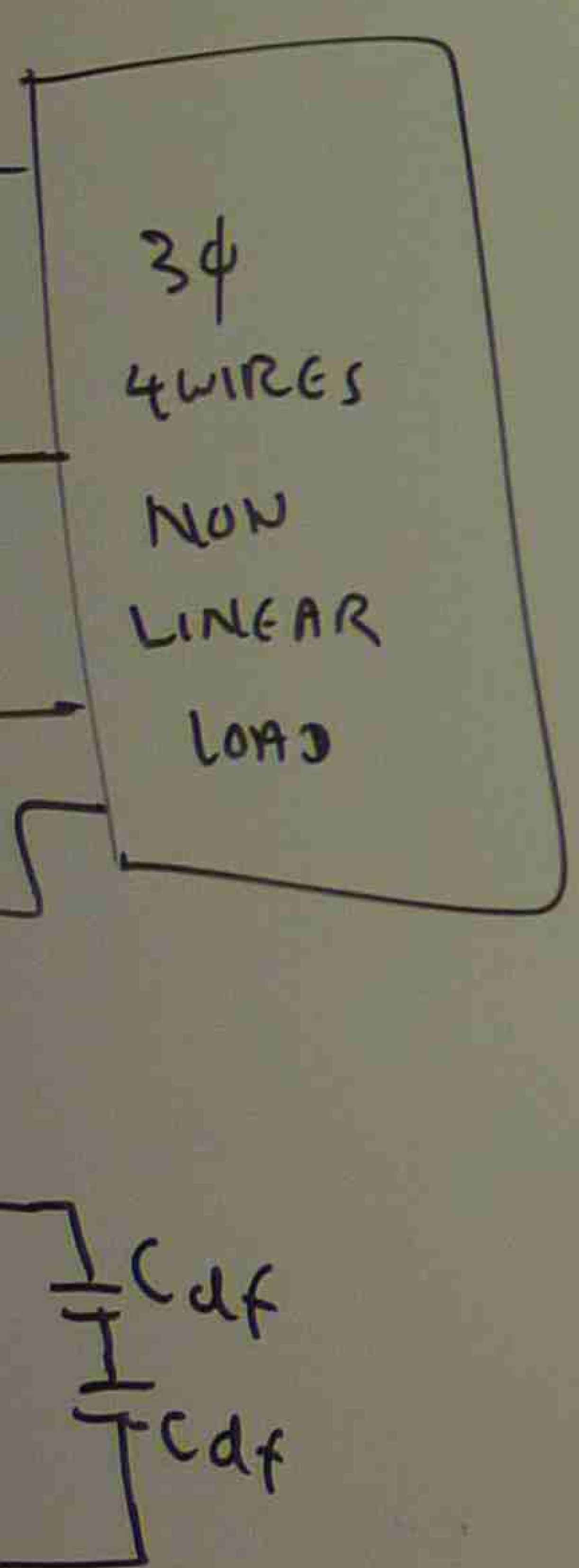
- SENSOR TRANSFORMER → MEASURE WAVEFORM AND INJECT COMPENSATION
- DISTORTION IDENTIFIER → SIGNAL PROCESSING
- INVERTER - ACTIVE FILTERING
- INVERTER / CONTROLLER → CURRENT CONTROL LOOP

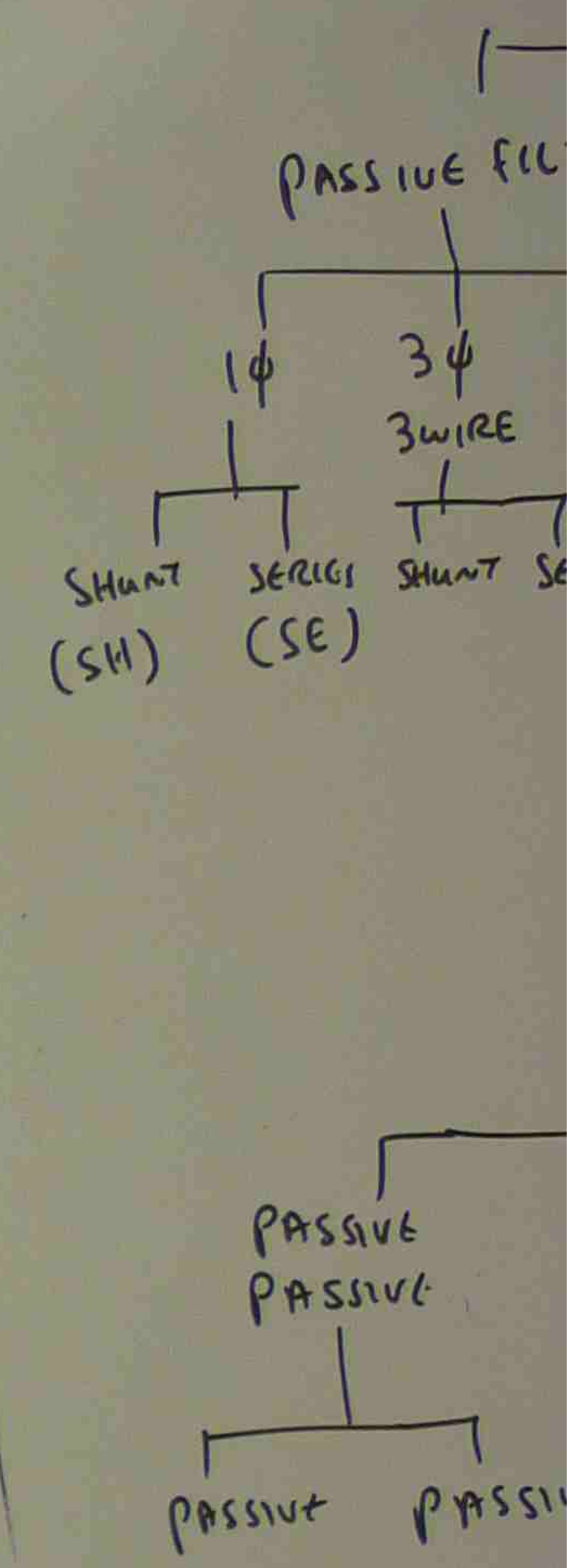
FUNCTION

- WAVEFORM COMPENSATION
- INSTANTANEOUS POWER COMPENSATION

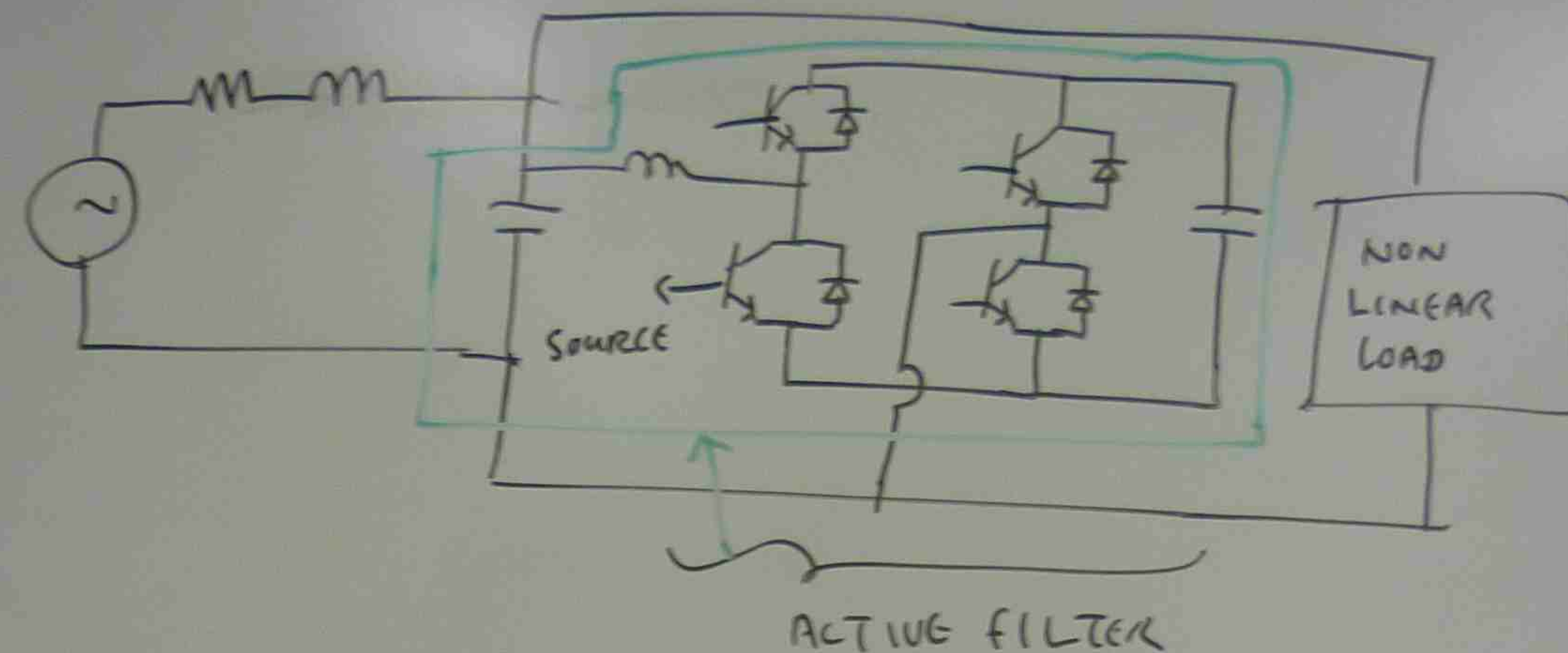
IMPEDANCE SYNTHESIS.

...VER SYSTEM





ACTIVE FILTER



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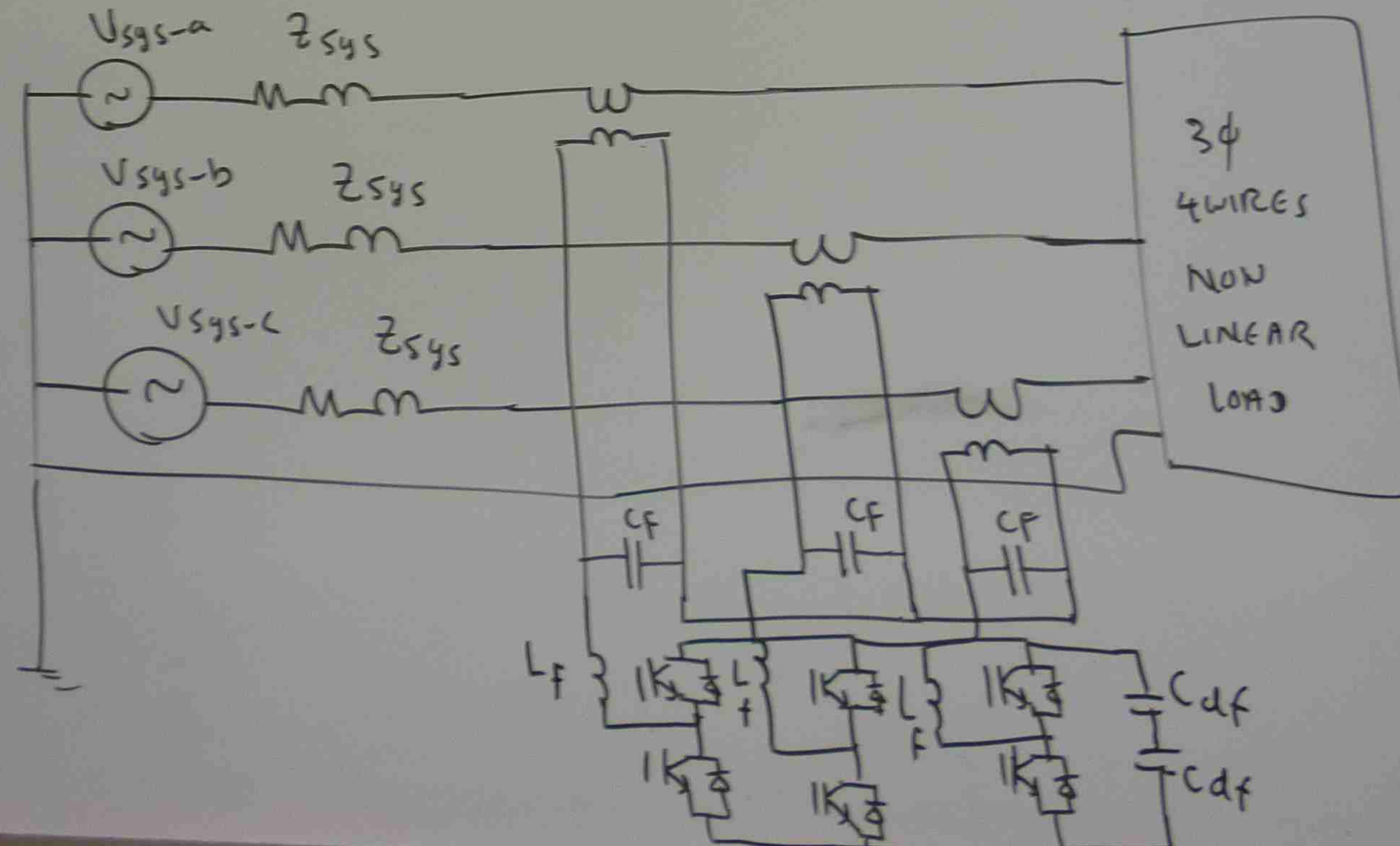

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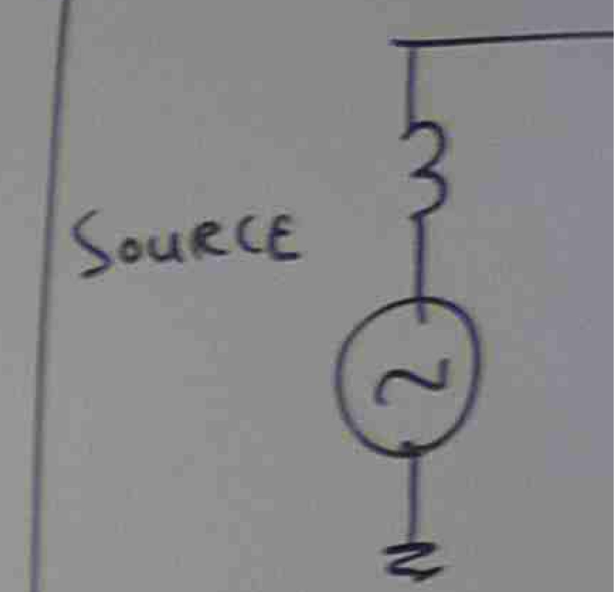

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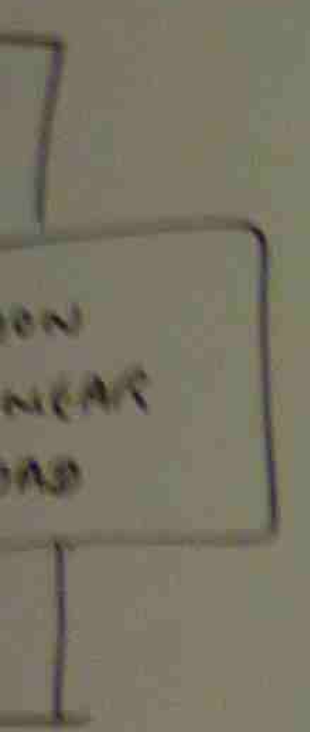
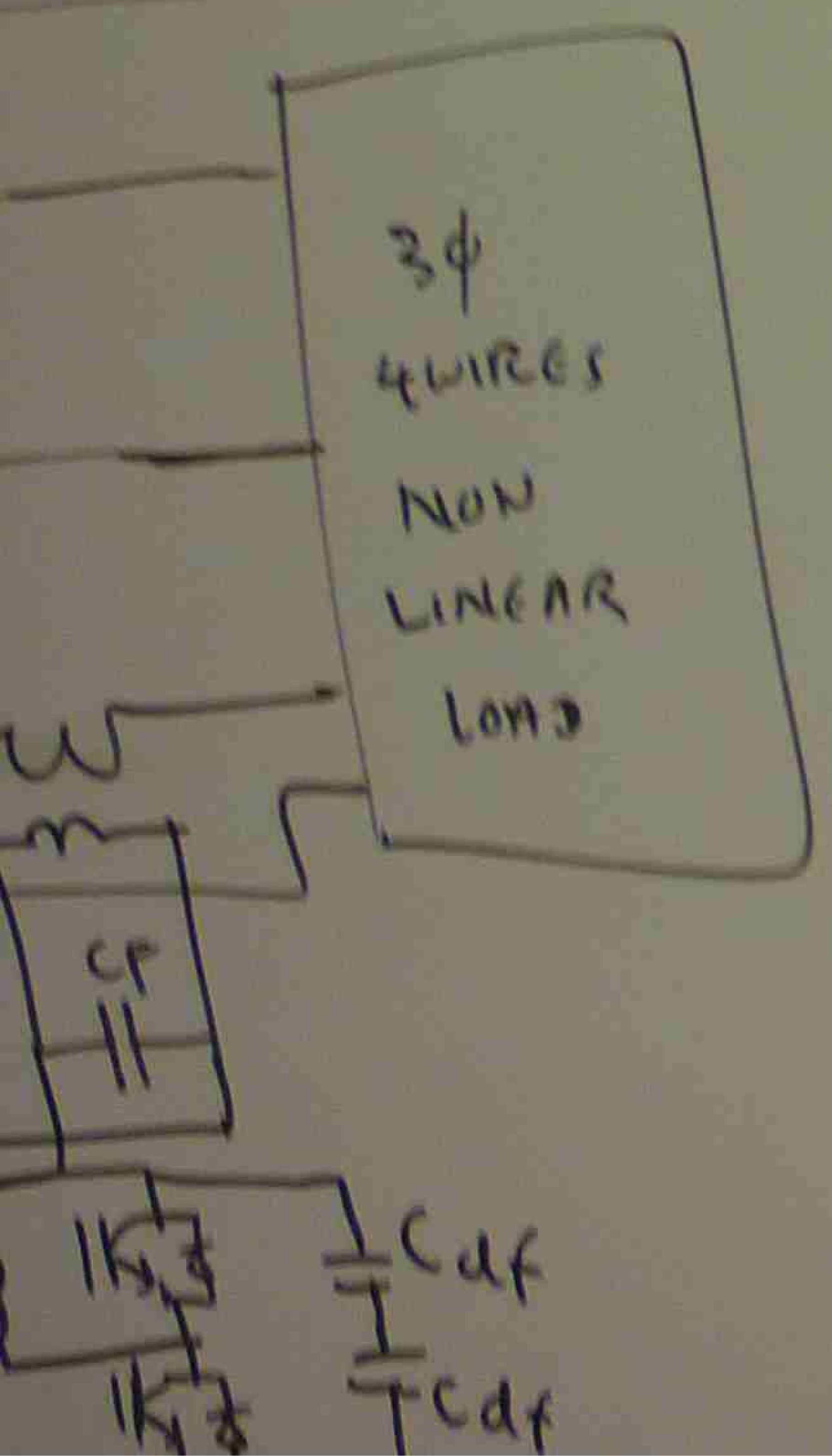
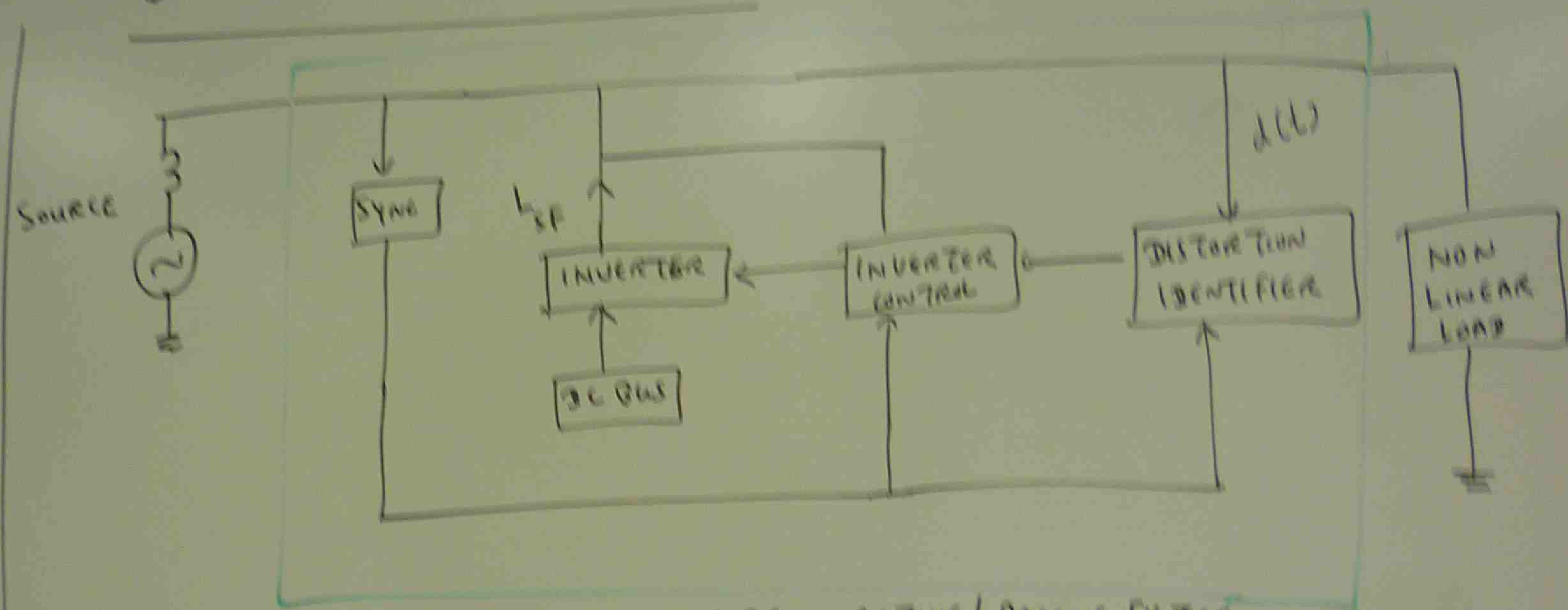


3φ POWER SYSTEM



BLOCK DIAGRAM OF ACTIVE FILTER



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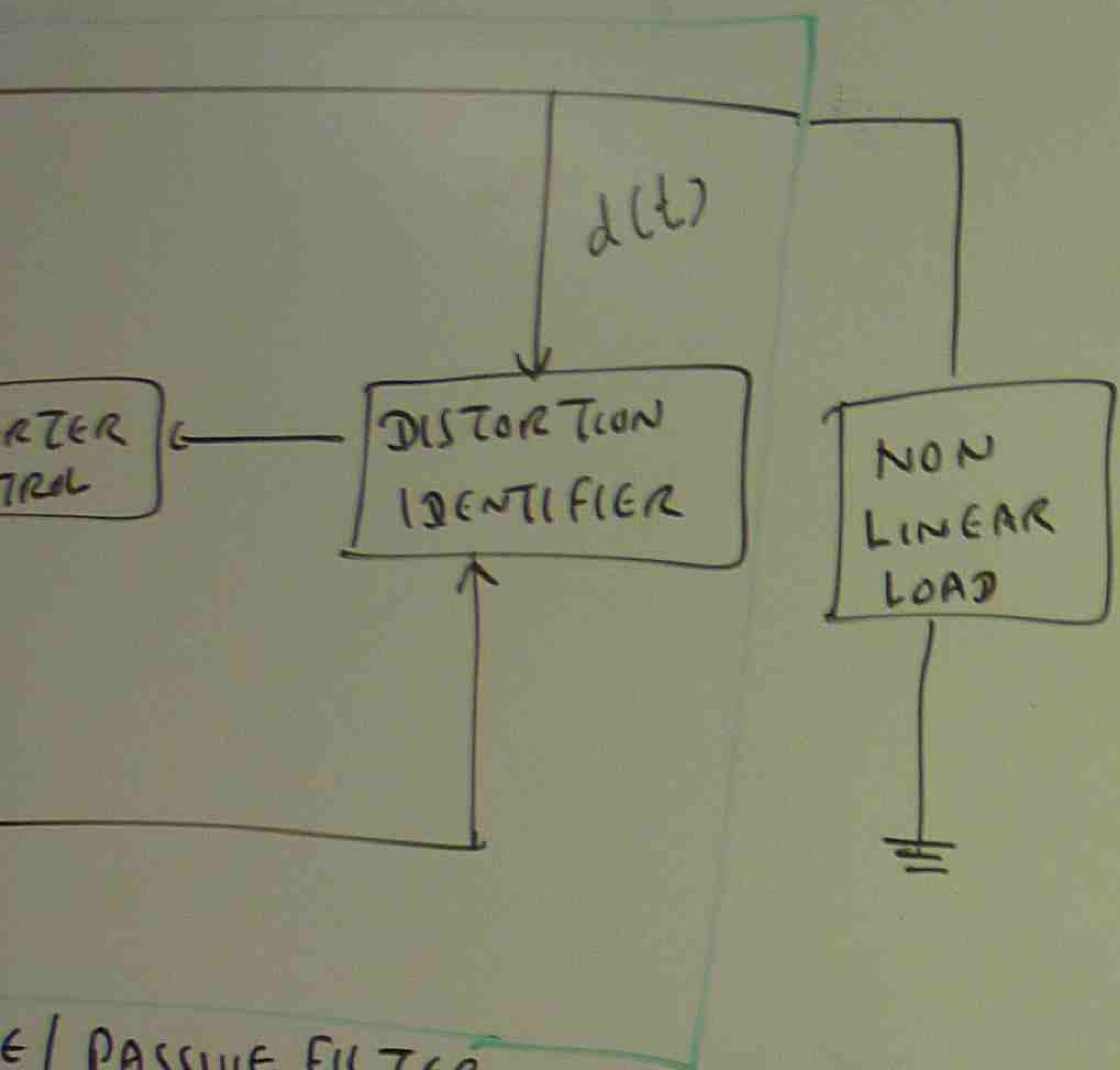
- DISTORTION IDENTIFIER → SIGNAL PROCESSING
- INVERTER - ACTIVE FILTERING
- INVERTER / CONTROLLER → CURRENT CONTROL LOOP

IMPEDANCE SYNTHESIS.

FUNCTION

- WAVEFORM COMPENSATION
- INSTANTANEOUS POWER COMPENSATION



E/ PASSIVE FILTER

E WAVEFORM AND INJECT
ATION

L PROCESSING

CONTROL LOOP

EDANCE SYNTHESIS.

RELIABILITY IMPROVEMENT

- FAST INTERRUPTING SWITCHES & FAULT CURRENT LIMITERS
  - IMPROVE RELIABILITY → APPLIED NETWORK SECURITY
    - RISK ANALYSIS
    - CURRENT & FUTURE TECHNICAL CONCEPT
    - DATA COMMUNICATION
- REDUCTION OF VOLTAGE SAG DURING SHORT CIRCUIT
- IMPROVEMENT OF POWER SYSTEM STABILITY
- REDUCTION OF MAXIMUM OCCURING MECHANICAL & ELECTRICAL TORQUE OF A GENERATOR
- EASEMENT OF THE INTERRUPTING BURDEN ON CIRCUIT BREAKER BY LIMITING FAULT CURRENT TO A DESIRABLE LEVEL.

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FAULT CURRENT LIMITERS

→ APPLIED NETWORK SECURITY

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TYPES OF EMERGENCIES

- FAILURE OF A MAJOR POWER SYSTEM COMPONENTS
- SIMULTANEOUS FAILURE OF MORE THAN ONE COMPONENT / AT DIFFERENT LOCATIONS
- OUTAGE OF POWER SYSTEM WITH IN AN ENTIRE REGION.
- DISRUPTION OF SENSING (OR) COMMUNICATION NETWORK.

- WHAT CAN BE DONE TO PREPARE THE POWER SYSTEM PRIOR TO EMERGENCY?
- WHAT SHOULD BE DONE DURING THE FAILURE?
- WHAT WILL BE DONE AFTER THE FAILURE OCCURS?
- WHAT STRATEGIES ARE TO BE USED FOR EFFICIENCY IMPROVEMENT?

- EDUCATIONAL ASPECT.

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2 CONT

DIFFERENT

SOLUTION APPROACH

1. TECHNIQUES THAT HAVE BEEN USED TO CONTROL THE COMMUNICATION NETWORK
   - TO PROVIDE EACH POWER SOURCE WITH THE INTELLIGENCE TO KEEP TRACK OF ITS LOCAL ENVIRONMENT.
   - HOW NETWORK CAN BE CONFIGURED TO IMPROVE RELIABILITY
   - HOW LOADS CAN BE SUPPLIED FROM MULTIPLE SOURCES
   - NETWORK IS HIGH DEGREE OF INDEPENDENCE AND CONTROL ITSELF

2. CONTROL AND INFORMATION PROCESSING.

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