Autotransformer Connection Based Configurations

- ✓Star Connected Autotransformer
- ✓Delta Connected Autotransformer
- ✓Polygon Connected Autotransformer
- ✓Delta-Polygon Connected Autotransformer
- ✓Hexagon Connected Autotransformer
- ✓T- Connected Autotransformer

CONVENTIONAL WYE- DELTA TRANSFORMER

- ✓LARGE KVA RATING OF TRANSFORMER
- ✓MORE COST
- ✓DIFFICULT TO MAKE IDENTICAL WYE AND DELTA WINDINGS

❖MODELING AND DESIGN OF MULTIPULSE AC-DC CONVERTERS

➢Twelve-Pulse Converters Based on $+15^0$ and -15^0 Phase Shift

✓Star Connected Autotransformer

$V_a' = K_1 * V_a - K_2 * V_b$

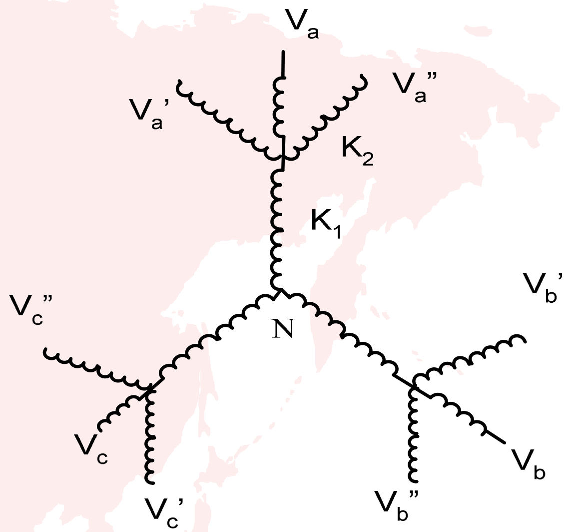
$V_a'' = K_1 * V_a - K_2 * V_c$

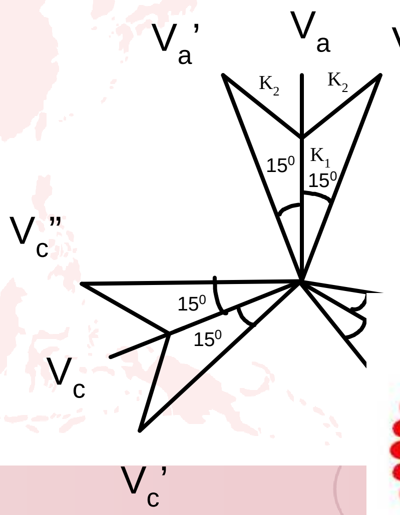
$V_a = V\angle 0^0,\ V_b = V\angle -120^0,\ V_c = V\angle 120^0$

$V_a' = V\angle +15^0,\ V_b' = V\angle -105^0,\ V_c' = V\angle 135^0$

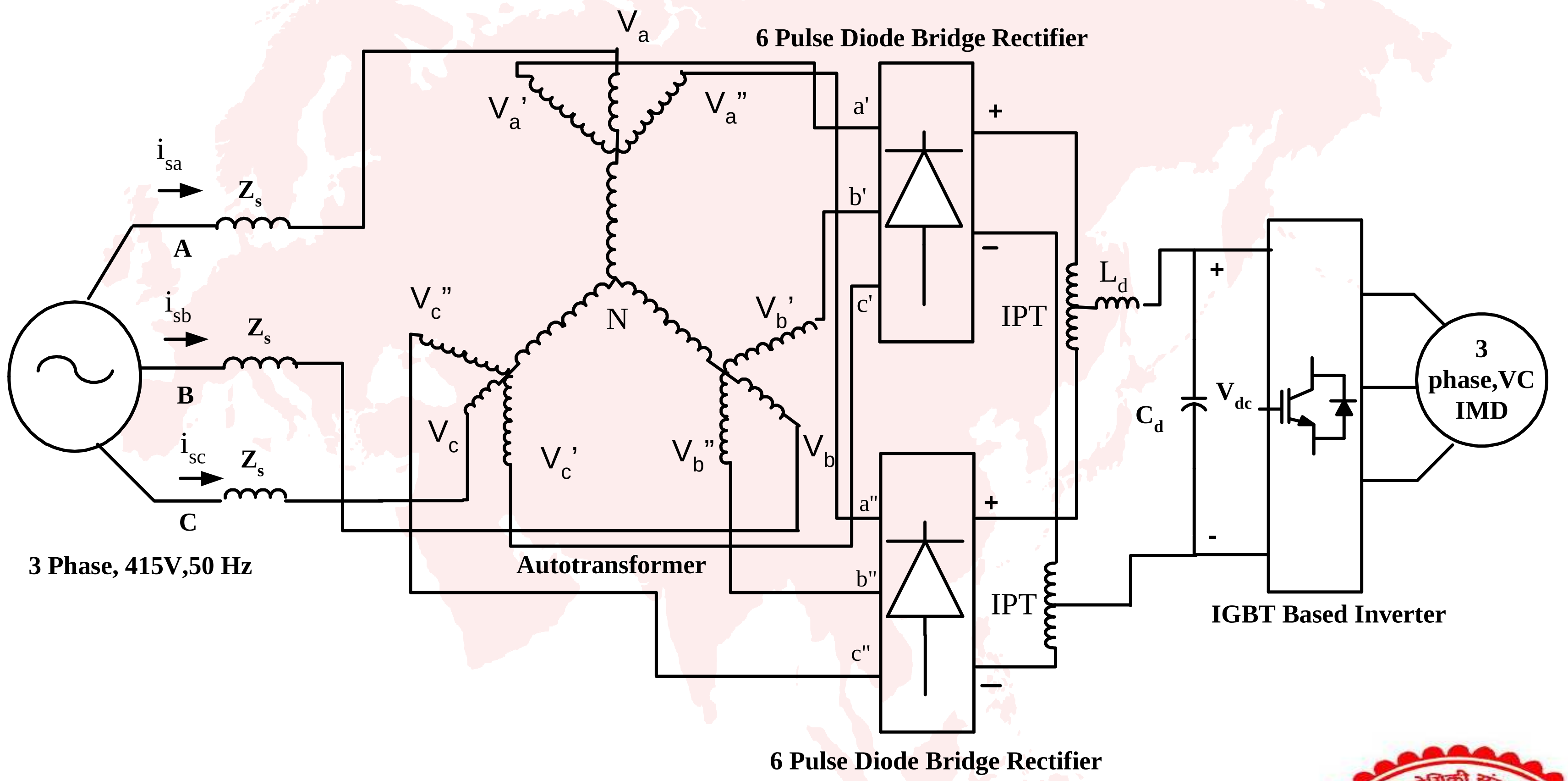
$V_a' = 0.816\ V_a - 0.298\ V_b$

$V_a'' = 0.816\ V_a - 0.298\ V_c$

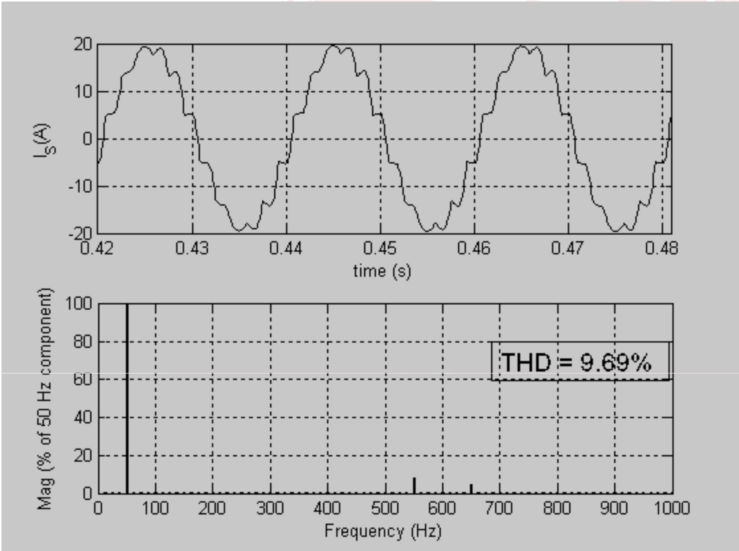


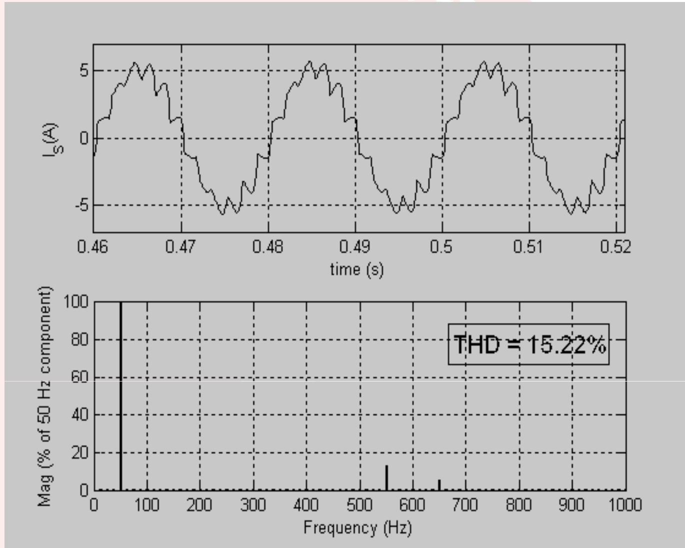


STAR Connected Autotransformer Based 12 Pulse Converter



AC MAINS CURRENT WAVEFORM AND ITS HARMONIC SPECTRUM





FULL LOAD

THD = 9.89%

Magnetics Rating = 36%

LIGHT LOAD (20%)

THD = 15.22%

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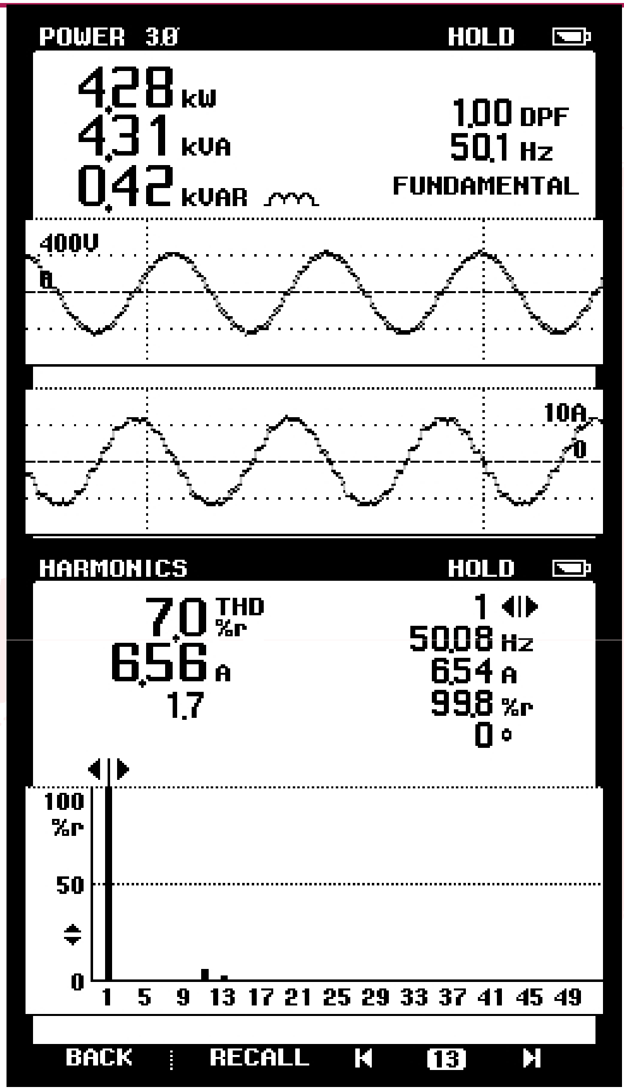
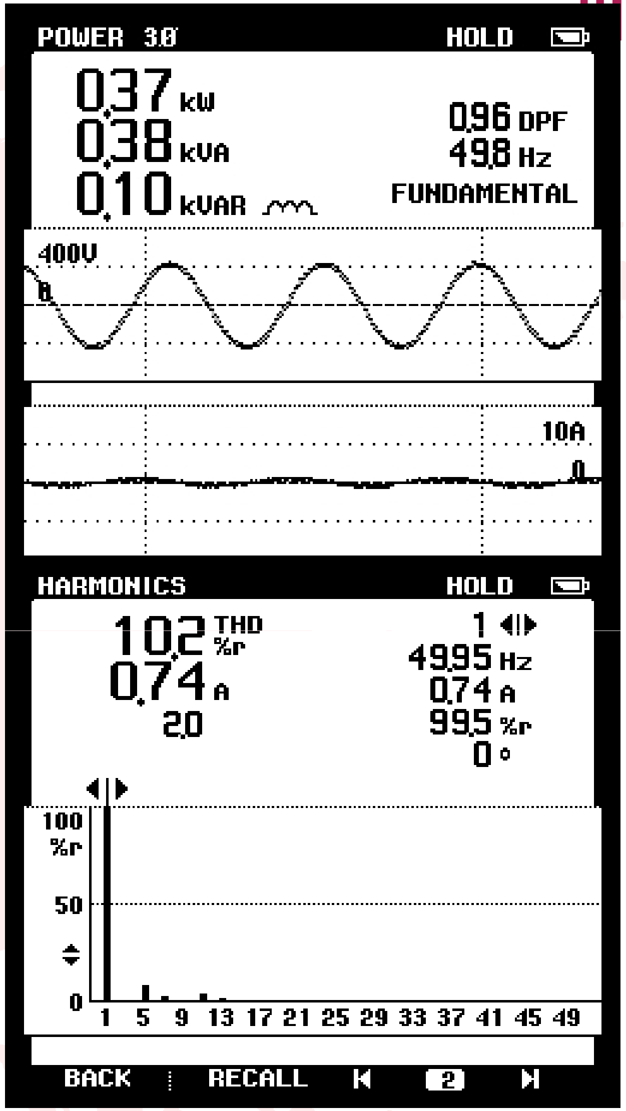
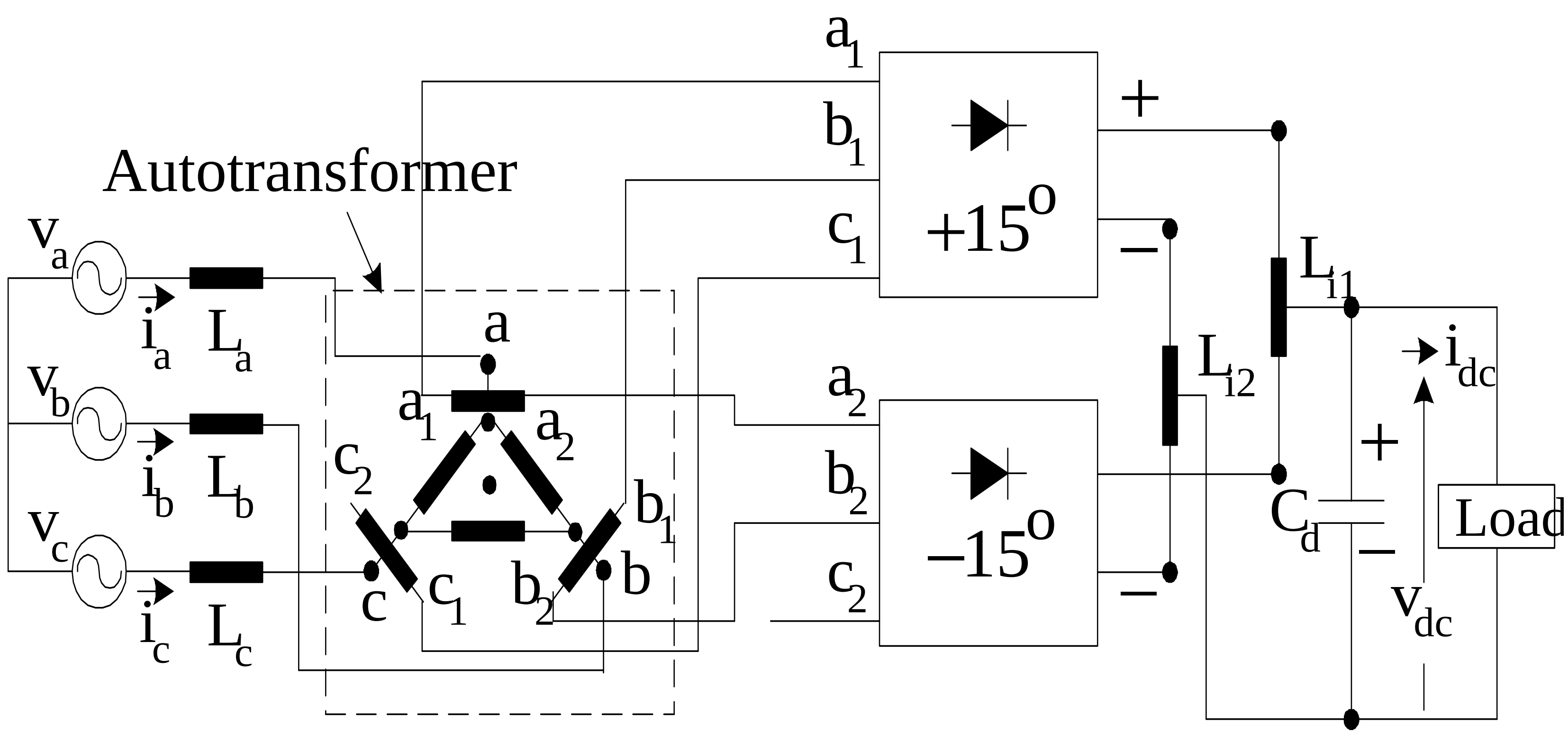


Full Load

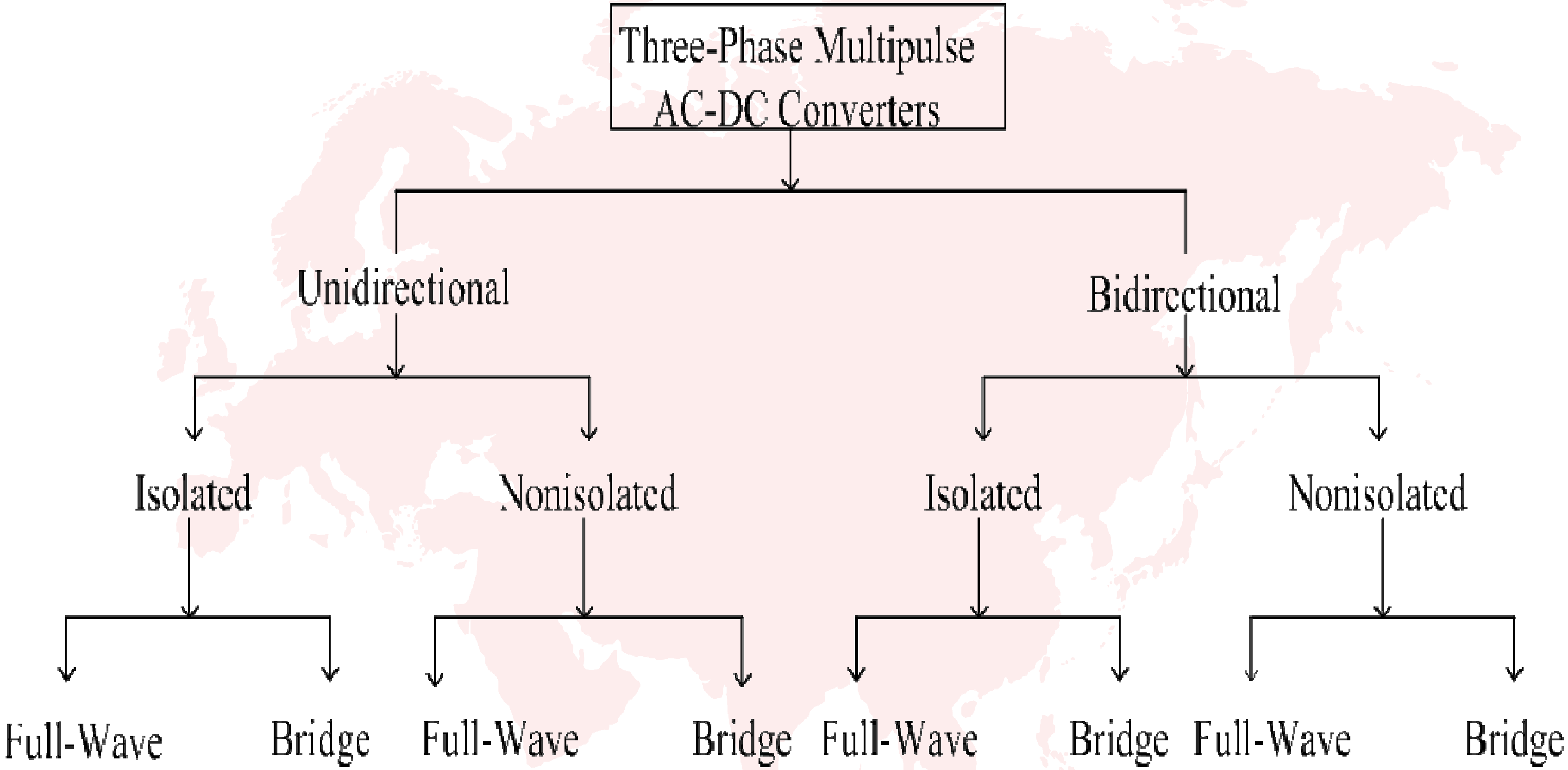


Light Load

Three-Phase Non-isolated 12-Pulse Converter.



Classification



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Shortfalls in 12-Pulse Converters

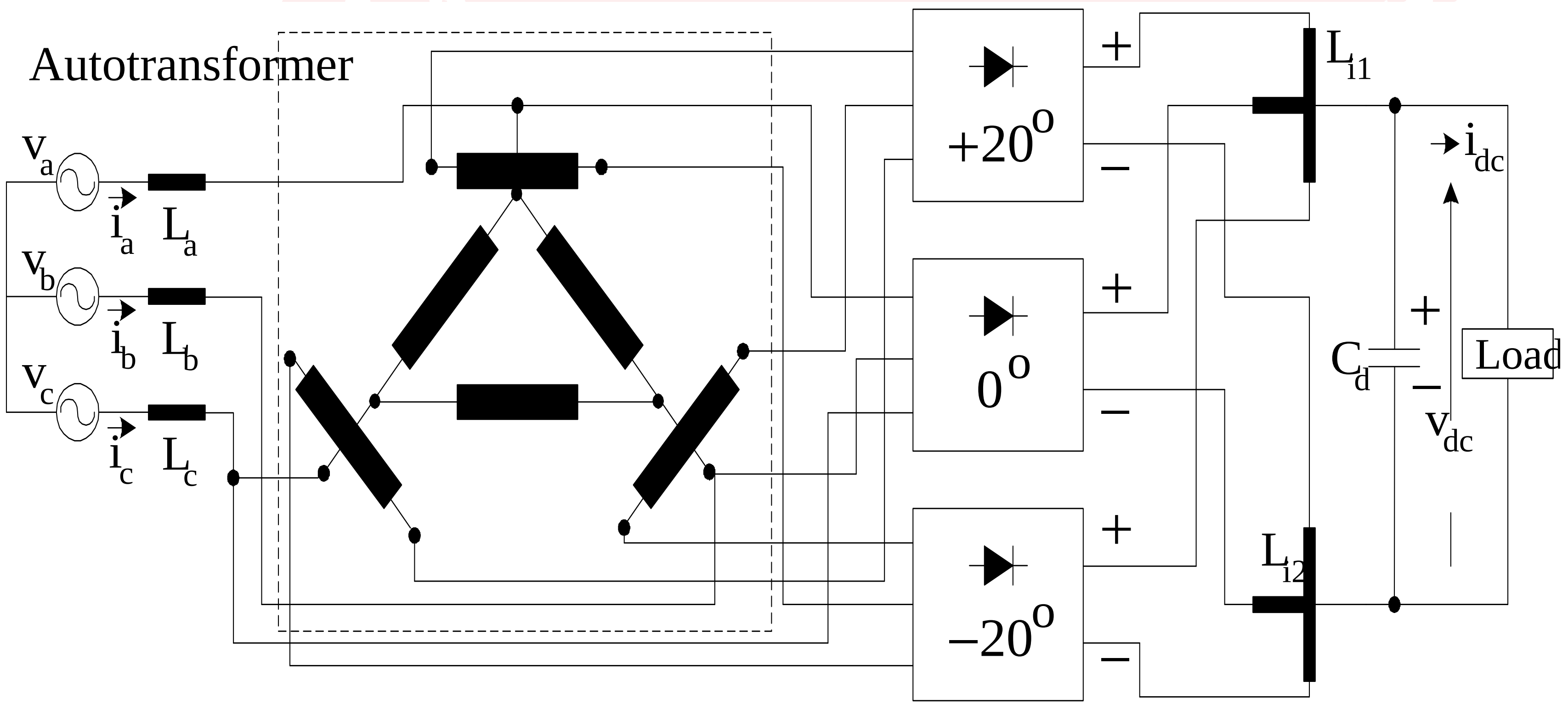
- ✓High THD of ac mains current
  - ✓ Not within IEEE Standard 519 limits

SOLUTION

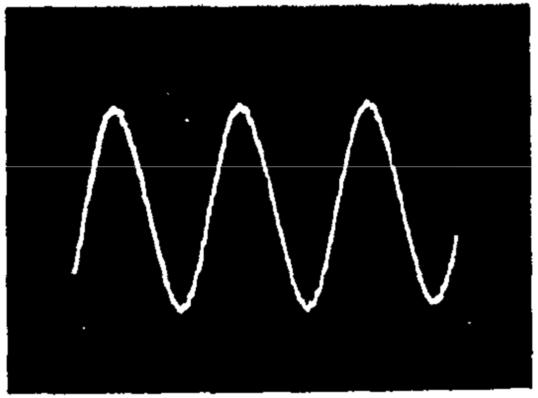
Use of 18-pulse converters

- ✓ THD of ac mains current well within IEEE Standard limits
- ✓Near unity power factor operation

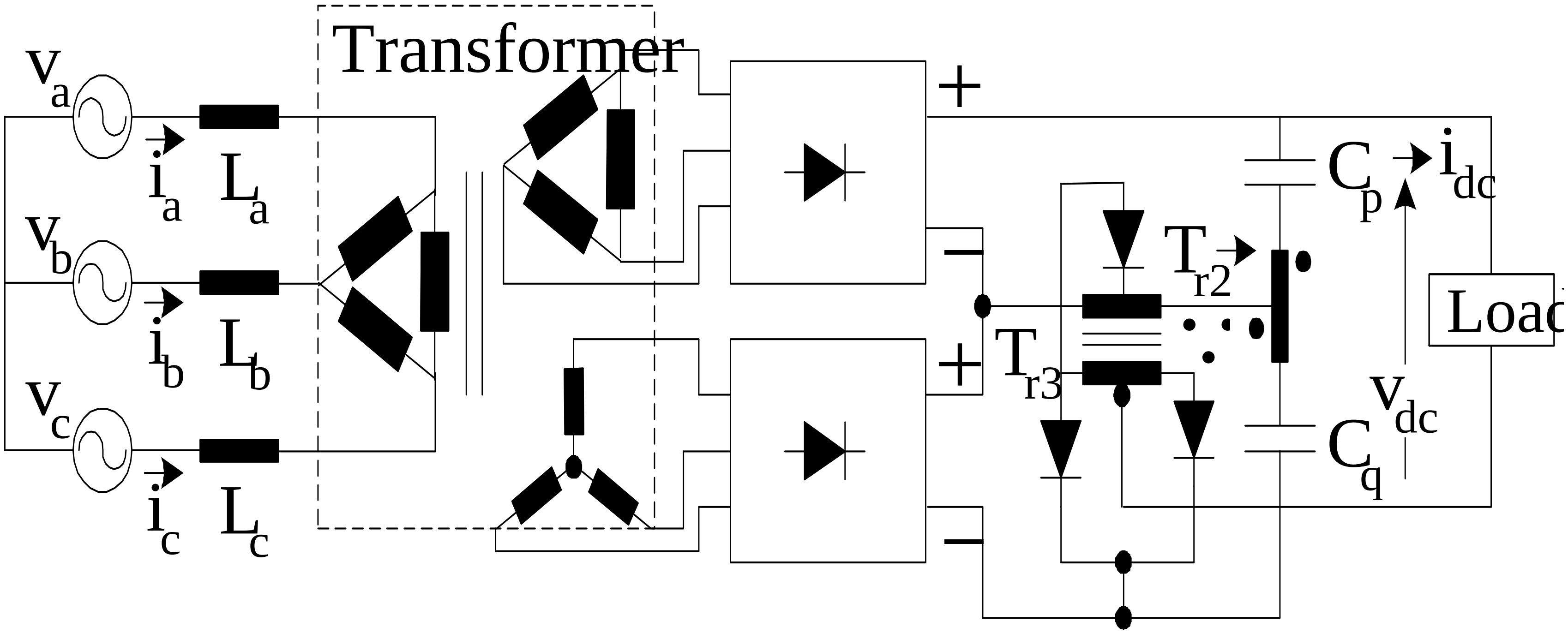
Three-Phase Unidirectional 18-Pulse Converter



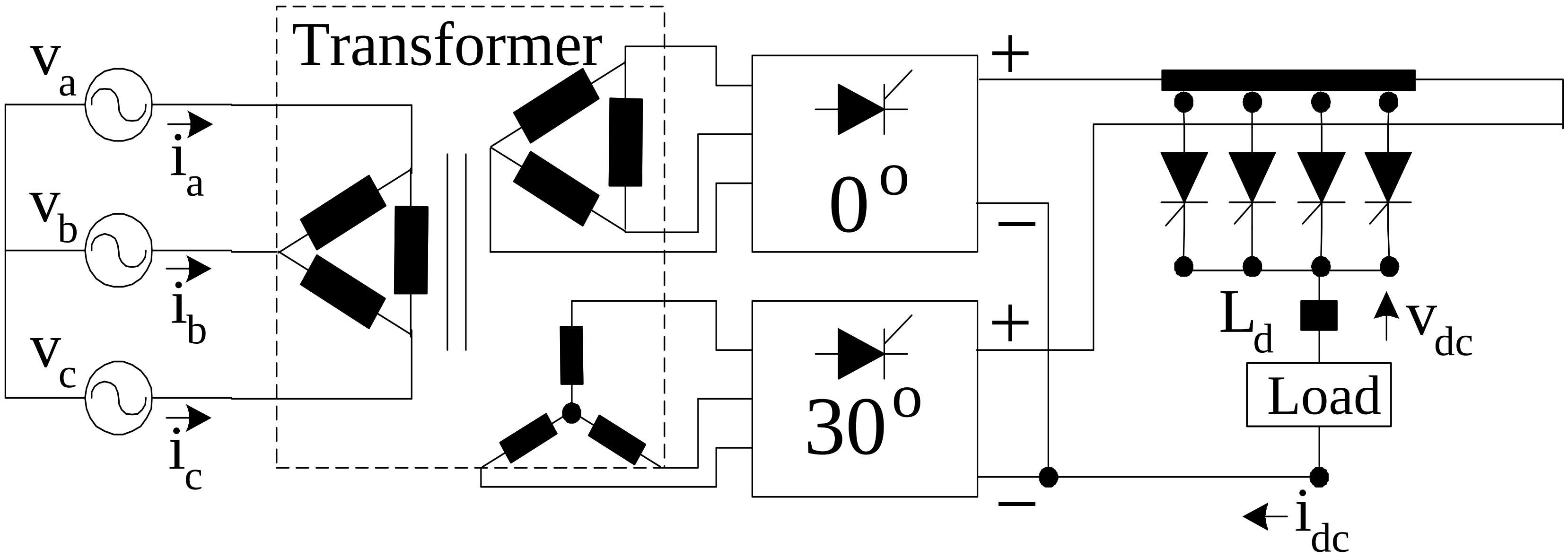
18 Pulse Converter

Harmonic Currents		
I_3	0.7%	
I_5	0.5%	
I_7	0.1%	
I_{11}	0.1%	
I_{13}	0.1%	
I_{17}	0.9%	
I_{19}	1.5%	
I_{23}	0.1%	*THD (current) = 1.97%*
I_{25}	0.1%	percentage harmonic constant = 34

24-Pulse Converter



48-Pulse Converter



MULTIPHASE CONVERTERS

➢ **CLASSIFICATION OF MULTIPHASE AC-DC CONVERTERS**

❖ **Phase Number Based Configurations**

❖ **Nine-Phase AC-DC Converters**

❖ **Fifteen-Phase AC-DC Converters**

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❖Nine-Phase AC-DC Converters

✓Delta Connected Autotransformer

Phase shift = 360^0/ Number of output phases

$V_{a1} = V_a + K_1 V_{ca} - K_2 V_{bc}$

$V_{a2} = V_a + K_1 V_{ab} + K_2 V_{bc}$

$V_a = V\angle 0^0$, $V_b = V\angle -120^0$, $V_c = V\angle 120^0$

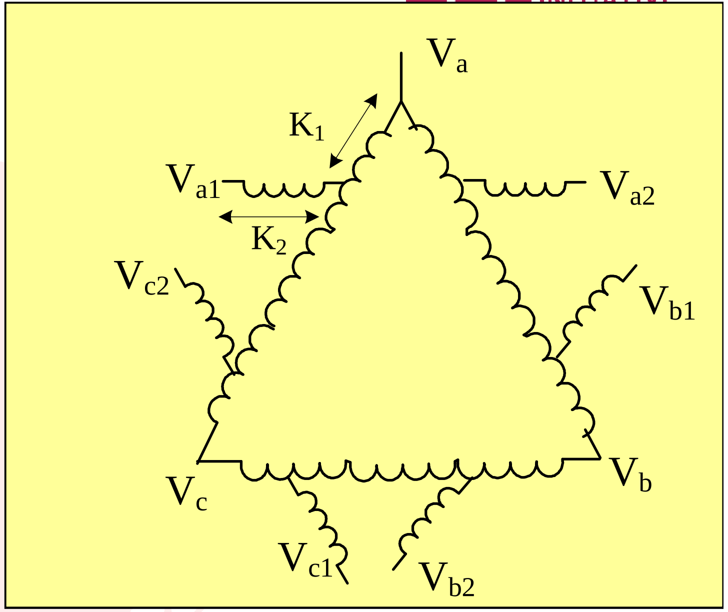
$V_{a1} = V \angle 40^0$, $V_{b1} = V\angle -80^0$, $V_{c1} = V\angle 160^0$

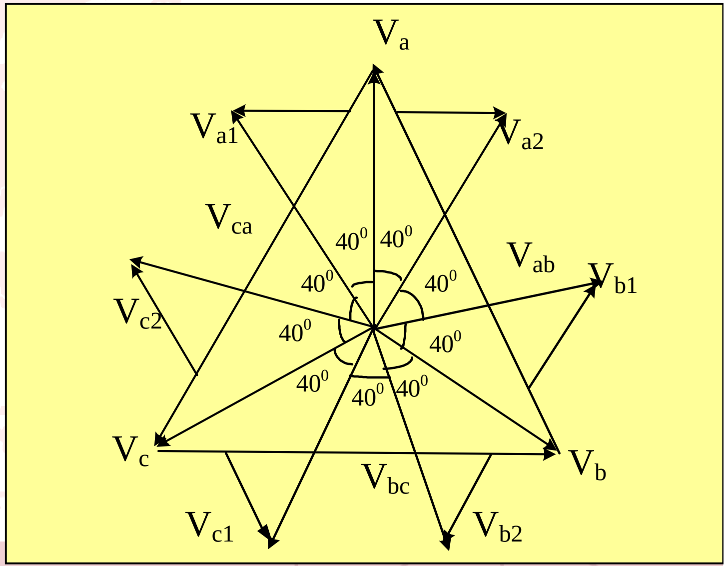
$V_{a2} = V \angle -40^0$, $V_{b2} = V\angle -160^0$, $V_{c2} = V\angle 80^0$

$K_1 = 0.156$ $K_2 = 0.293$

$V_{a1} = V_a + 0.156 V_{ca} - 0.293 V_{bc}$

$V_{a2} = V_a + 0.156 V_{ab} + 0.293 V_{bc}$





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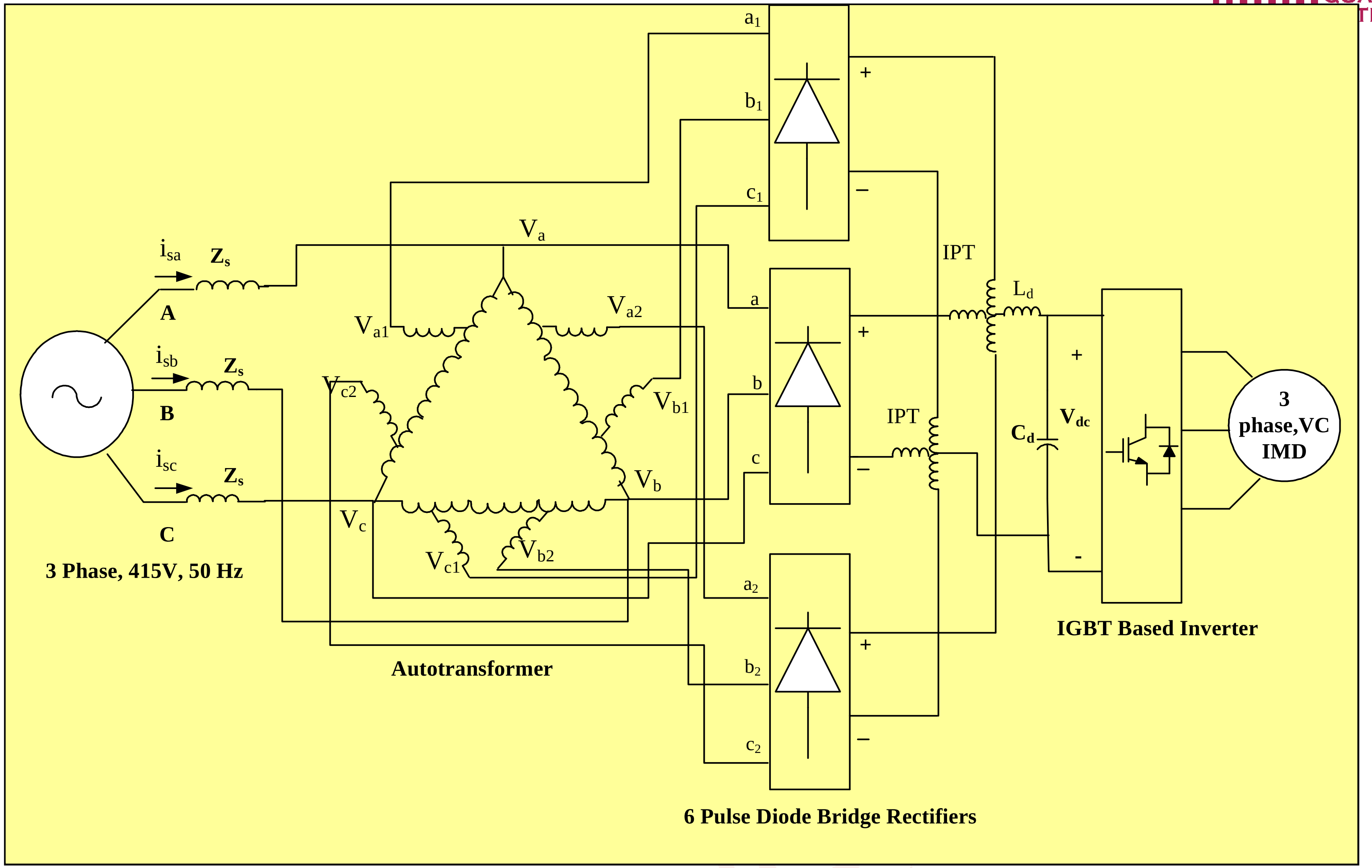
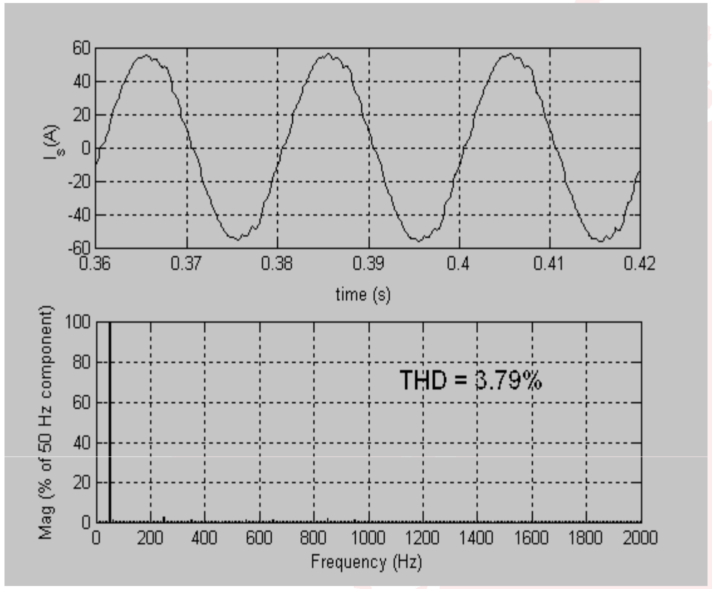
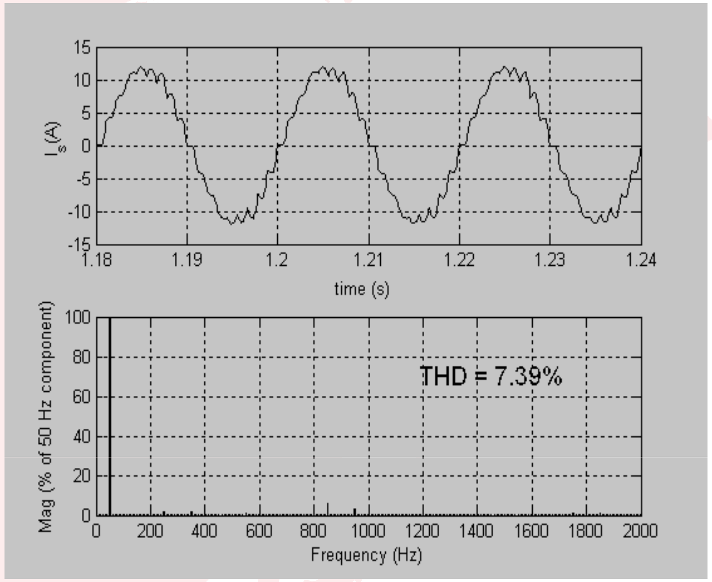


Delta Connected 9-Phase Converter

Results



Full Load



Light Load

THD = 3.79%

THD = 7.39%

❖Fifteen-Phase AC-DC Converters

✓Star Connected Autotransformer

$$V_{a1} = K_1 V_a \angle 0^0 - K_2 V_b \angle -120^0$$

$$V_{a2} = K_3 V_a \angle 0^0 - K_4 V_b \angle -120^0$$

$$V_{a3} = K_1 V_a \angle 0^0 - K_2 V_c \angle 120^0$$

$$V_{a4} = K_3 V_a \angle 0^0 - K_4 V_c \angle 120^0$$

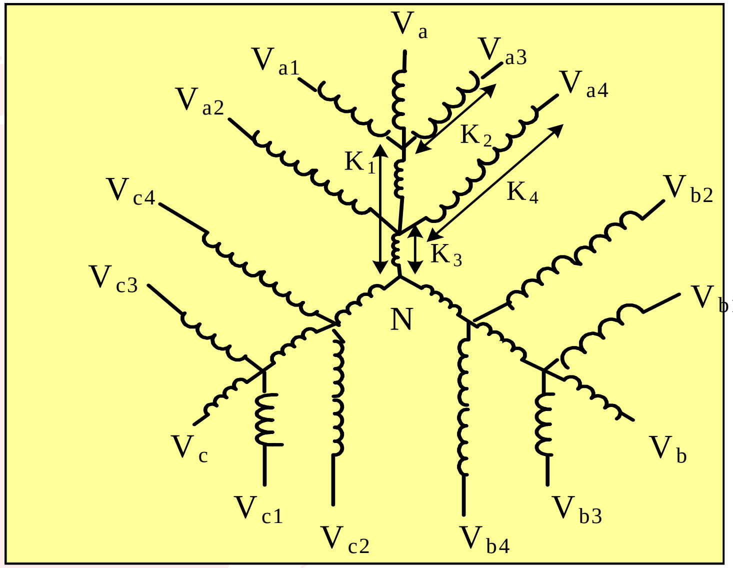
$V_a = V\angle 0^0$, $V_b = V\angle -120^0$, $V_c = V\angle 120^0$

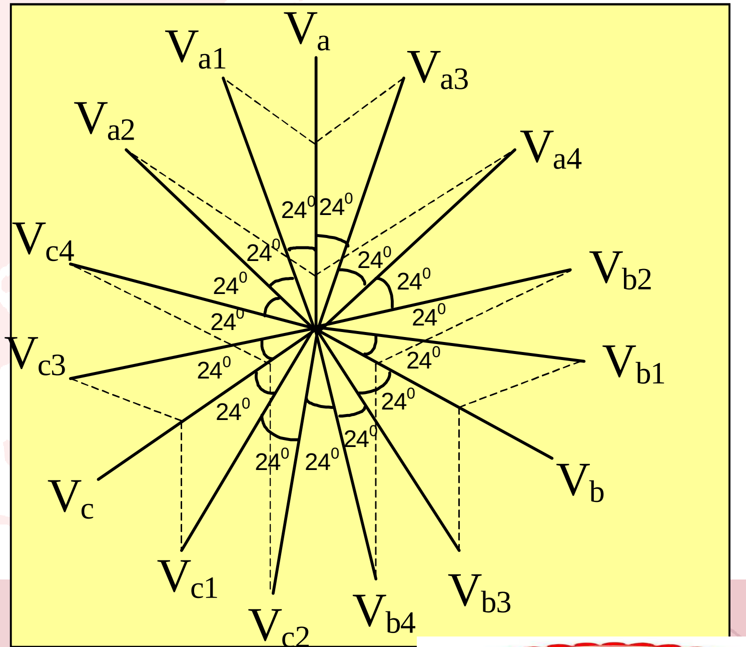
$V_{a1} = V\angle 24^0$, $V_{b1} = V\angle -96^0$, $V_{c1} = V\angle 144^0$

$V_{a2} = V\angle 48^0$, $V_{b2} = V\angle -72^0$, $V_{c2} = V\angle 168^0$

$V_{a3} = V\angle -24^0$, $V_{b3} = V\angle -144^0$, $V_{c3} = V\angle 96^0$

$V_{a4} = V\angle -48^0$, $V_{b4} = V\angle -168^0$, $V_{c4} = V\angle 72^0$





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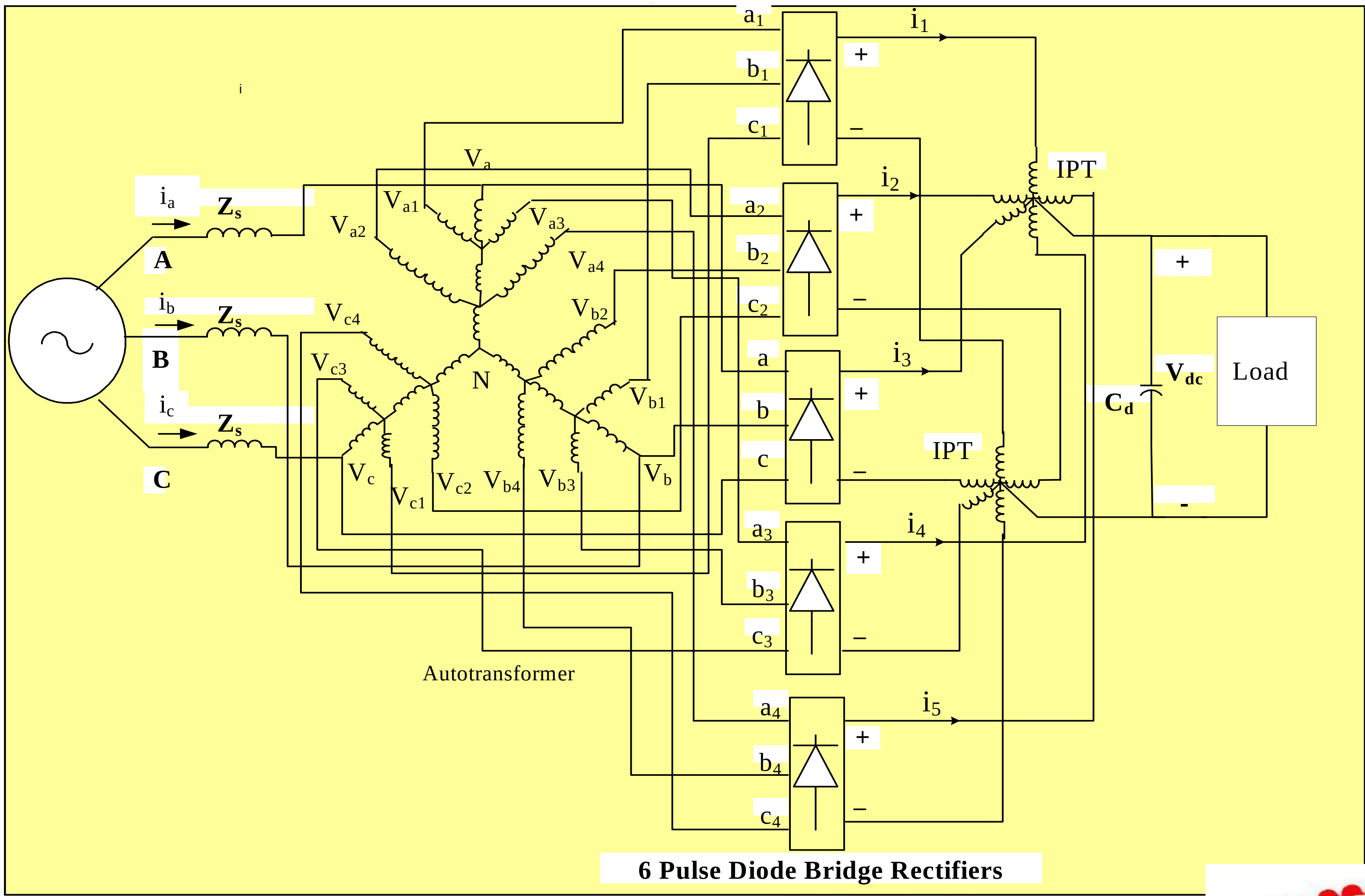
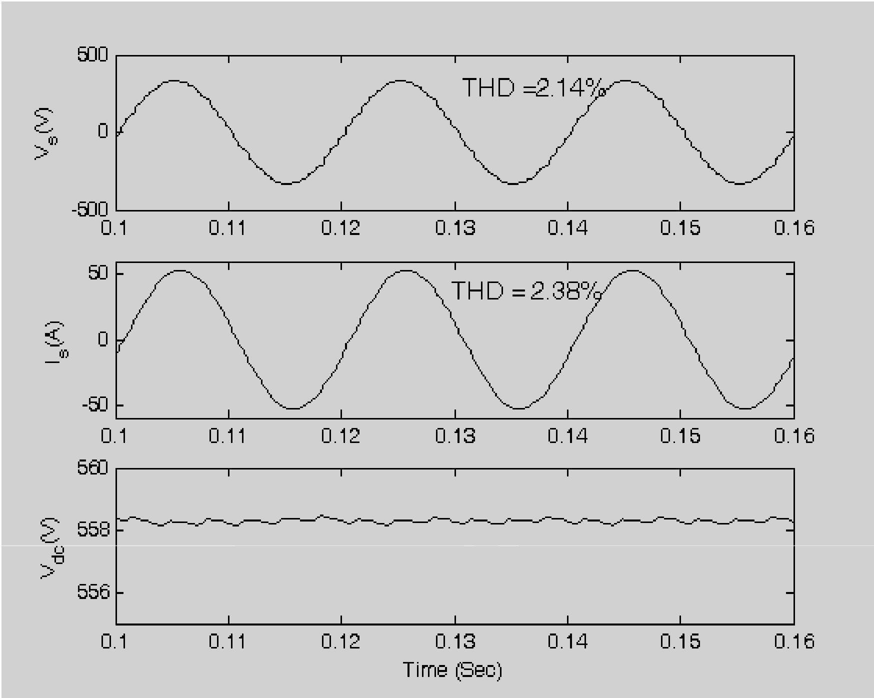
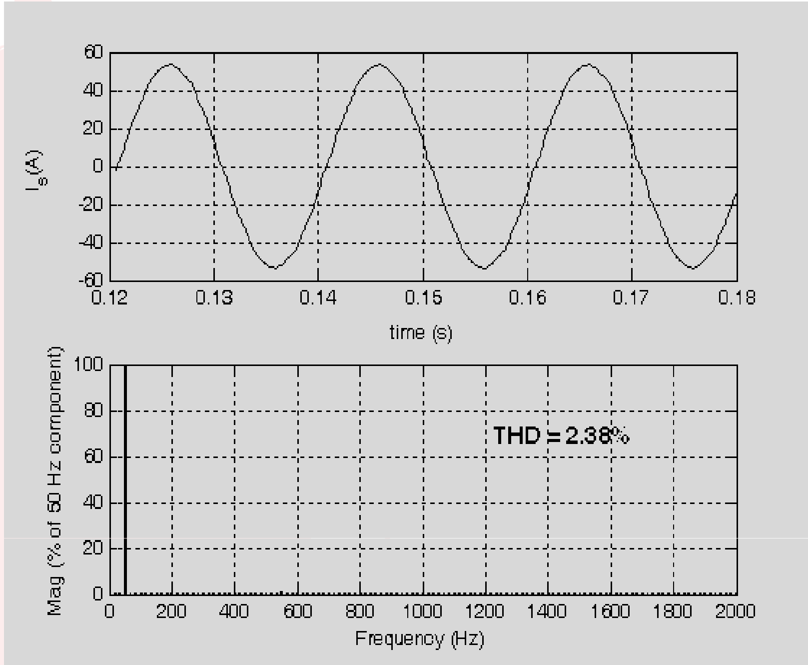


Star Connected 15-Phase Convert

Results

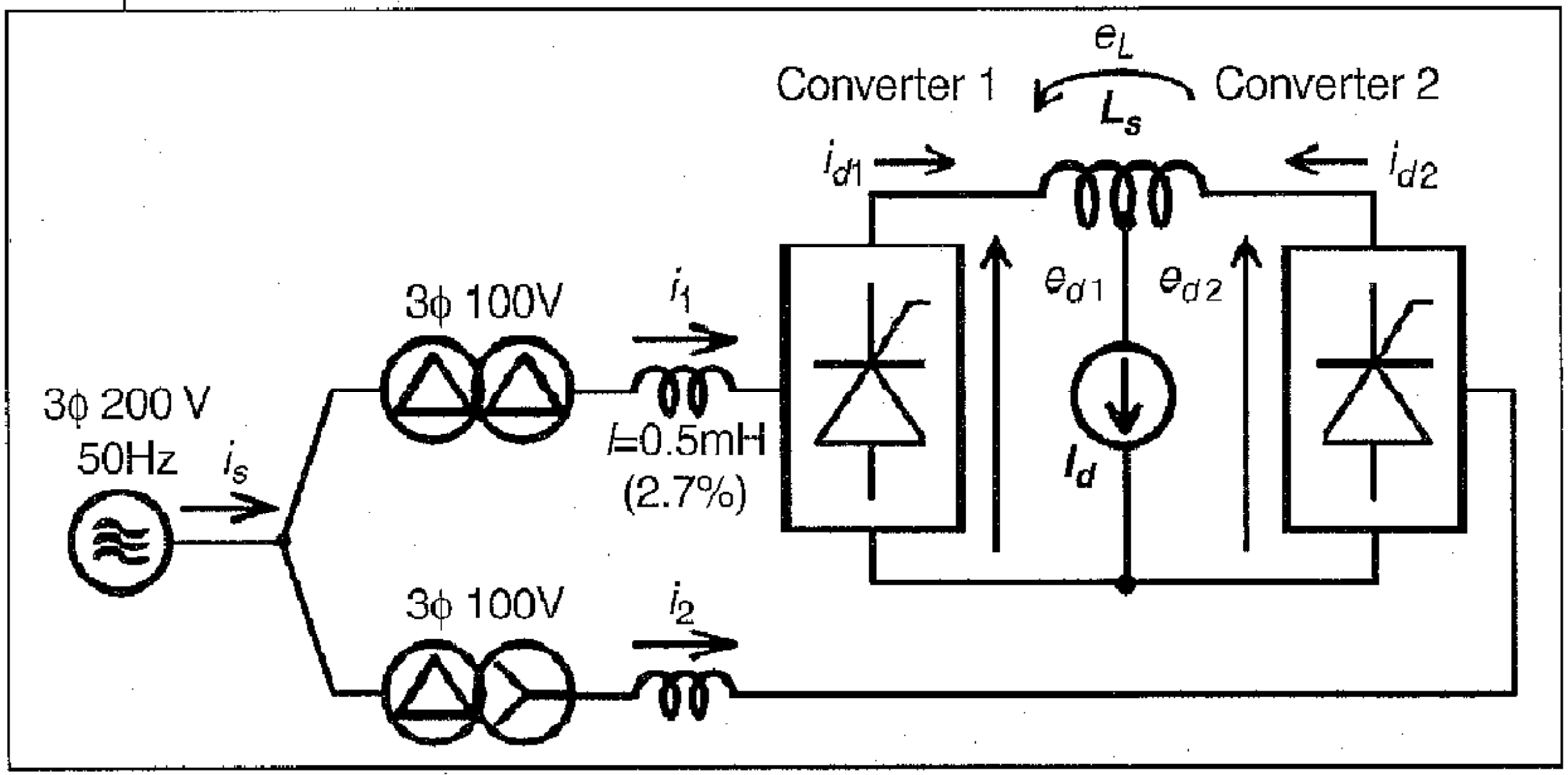




THD = 2.38%

Magnetics Rating = 76%

Controlled Multi-pulse (12 pulse)



Controlled Multi-pulse (12 pulse)

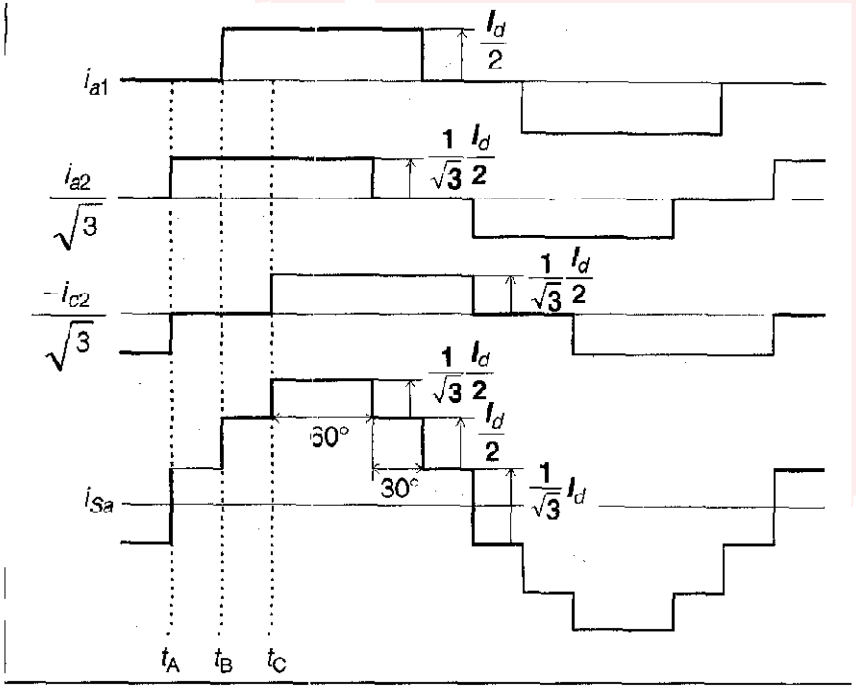
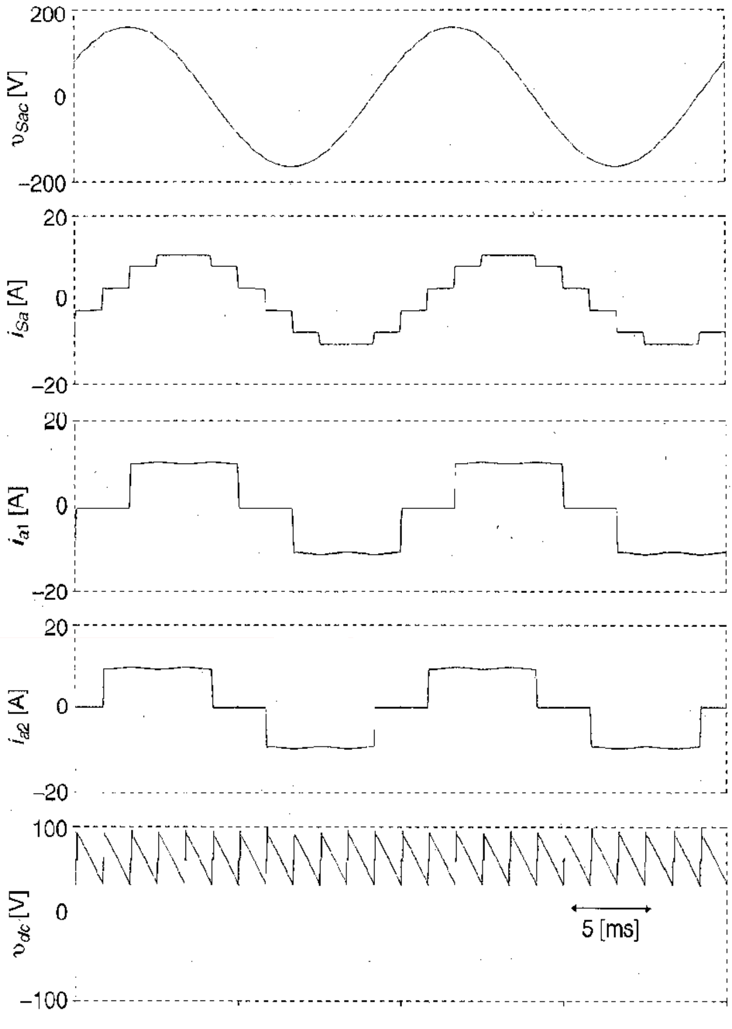


Fig. 3. Schematic explanation for ac currents.



(a)

Controlled Multi-pulse (12 pulse)

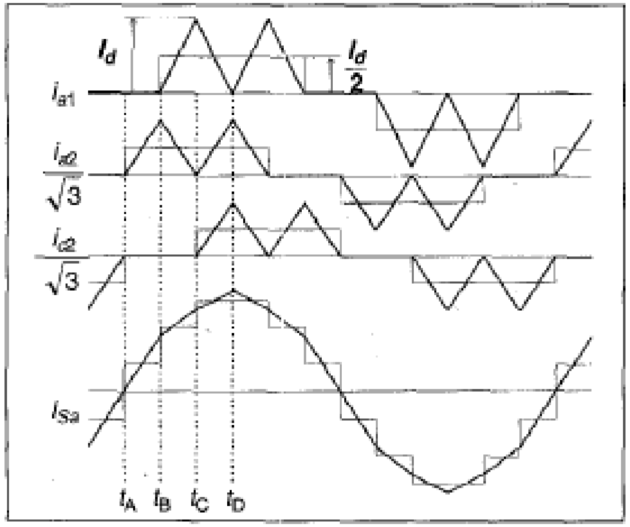


Fig. 4. Current waveforms (triangle waveform with amplitude of I_d / 2).

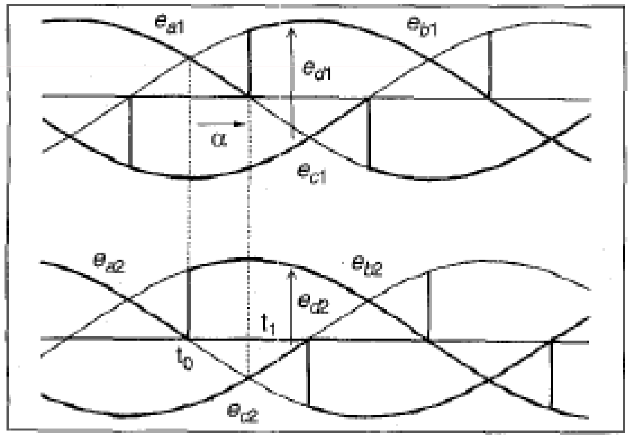


Fig. 5. Source and output dc voltage waveforms of each converter in Fig. 1.

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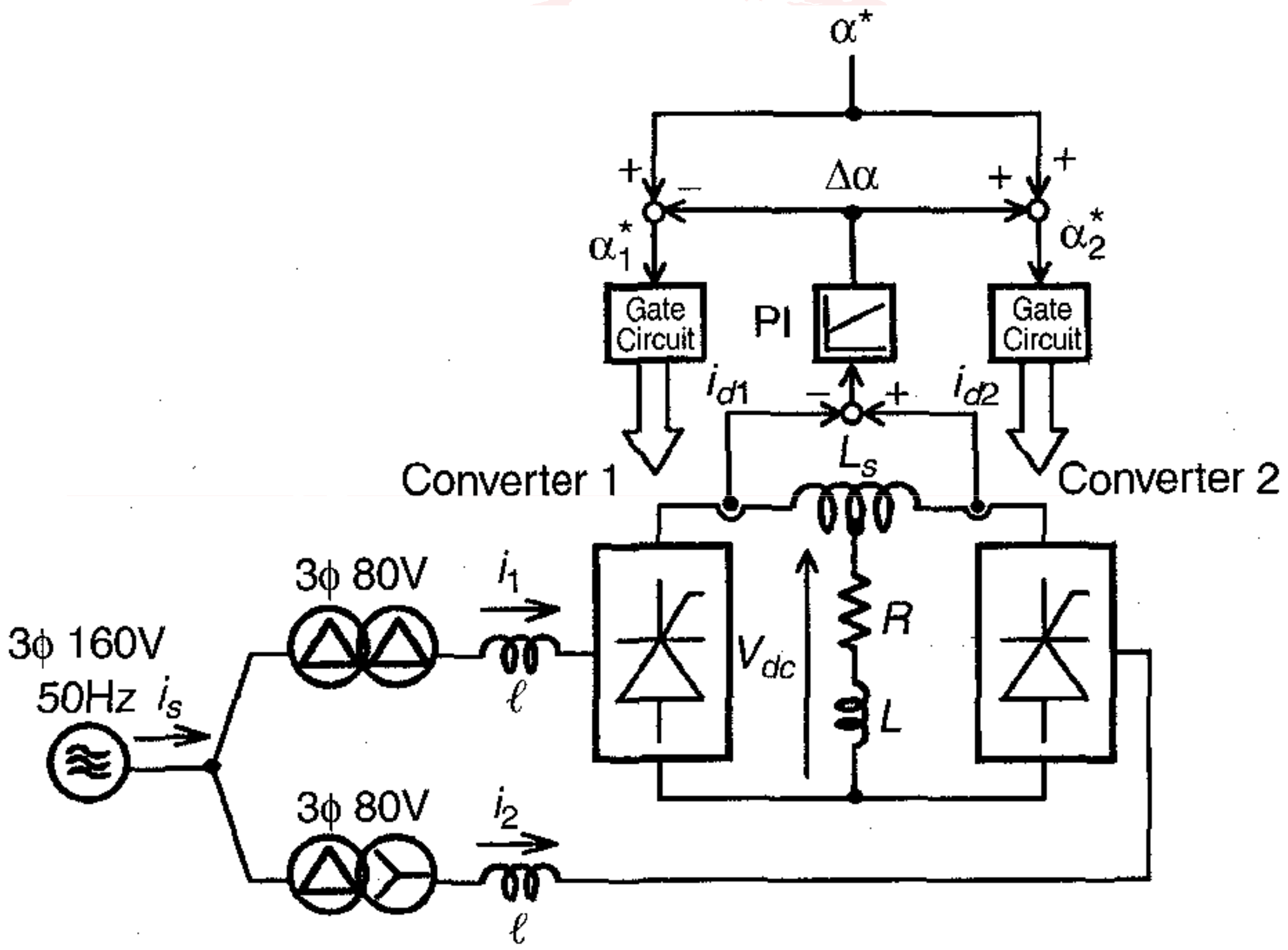
Controlled Multi-pulse (12 pulse)



Controlled Multi-pulse (12 pulse)- Simulation Results

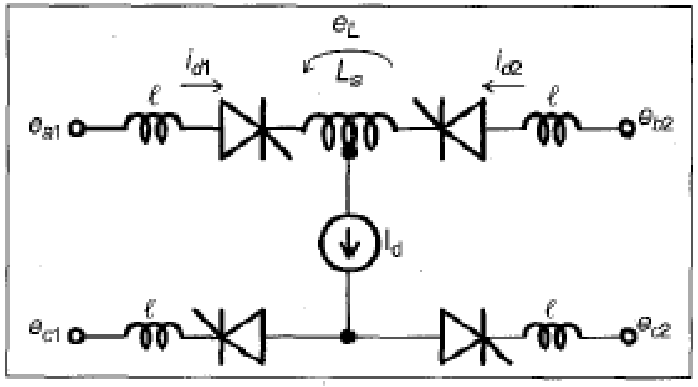


Fig. 6. Equivalent circuit between time from t_0 to t_1 for Fig. 1.

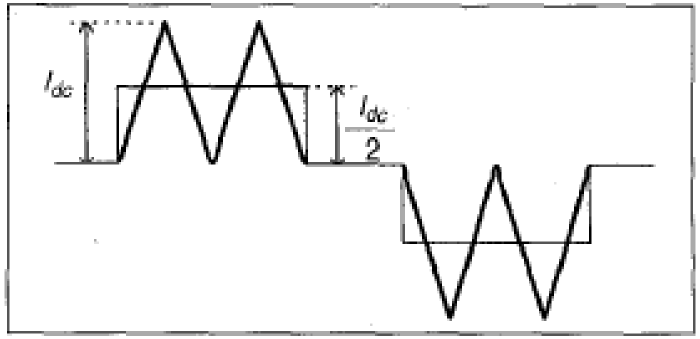
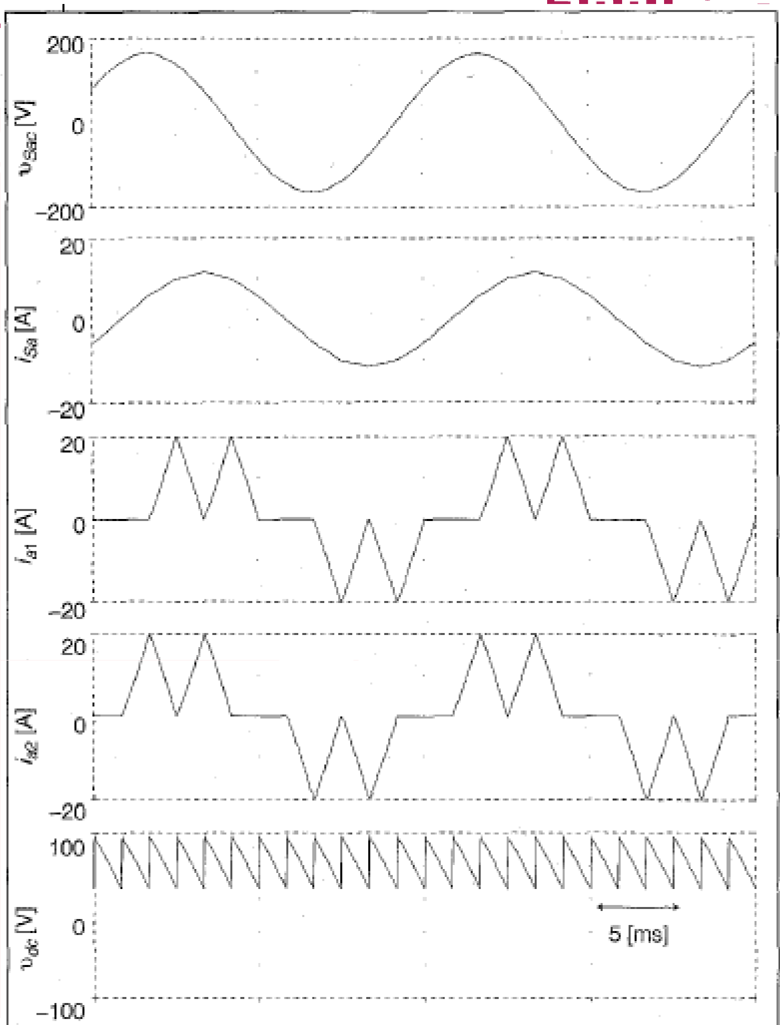


Fig. 7. Input ac current waveform of each converter.



(a)

Controlled Multi-pulse (12 pulse)- Experimental Results

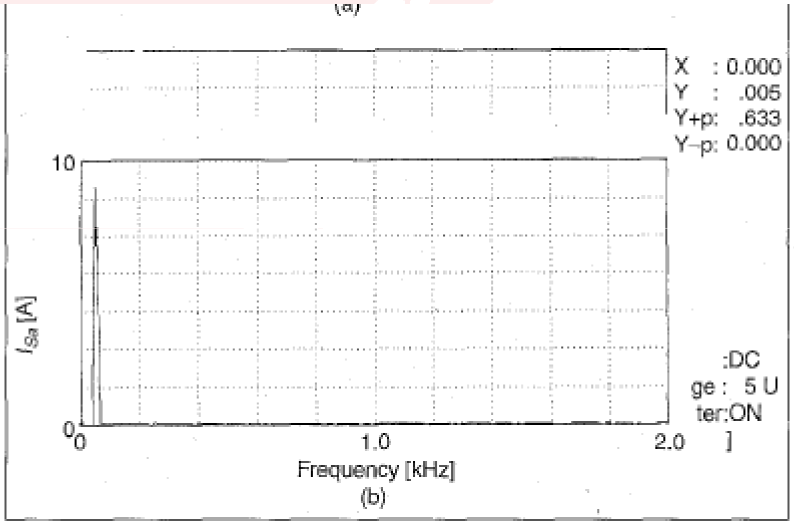


Fig. 12. Experimental results for Fig. 11. (a) Experimental waveforms. (b) Harmonic spectra of i_{Sa}.

Controlled Multi-pulse HVDC Application

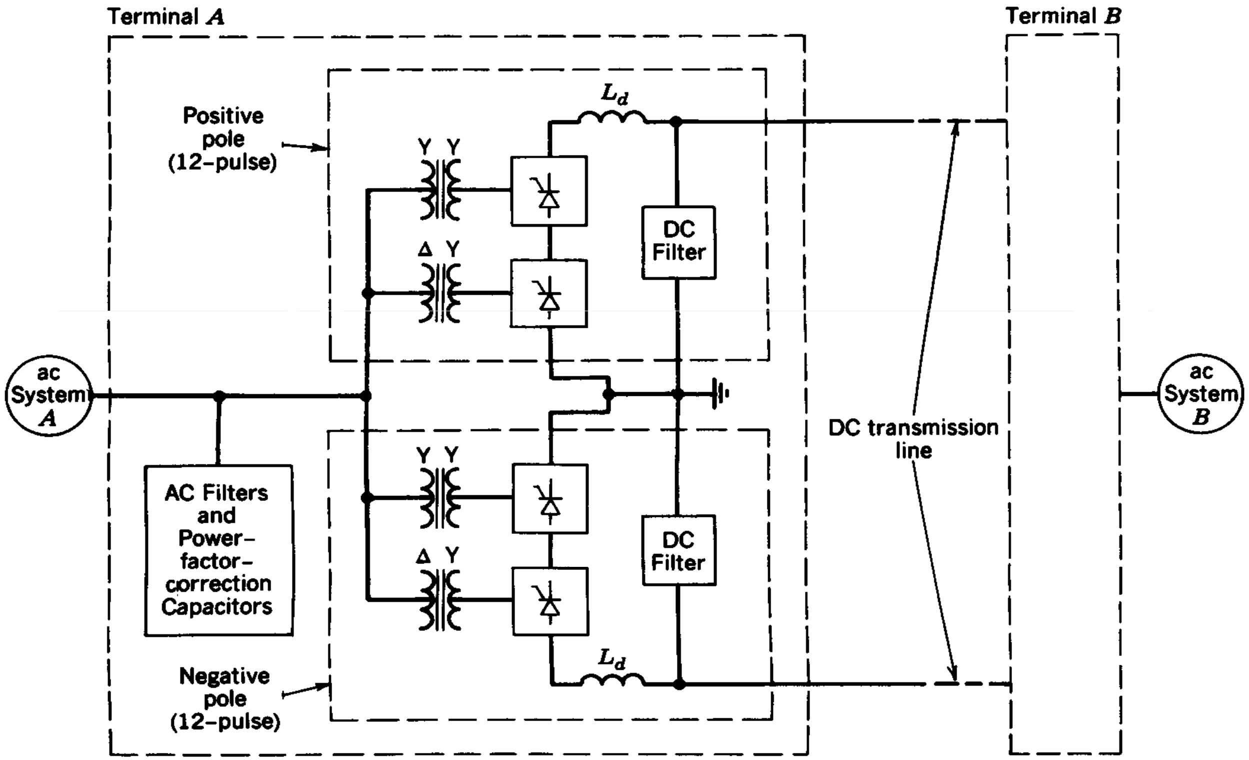


Figure 17-1 A typical HVDC transmission system.

Controlled Multi-pulse HVDC Application

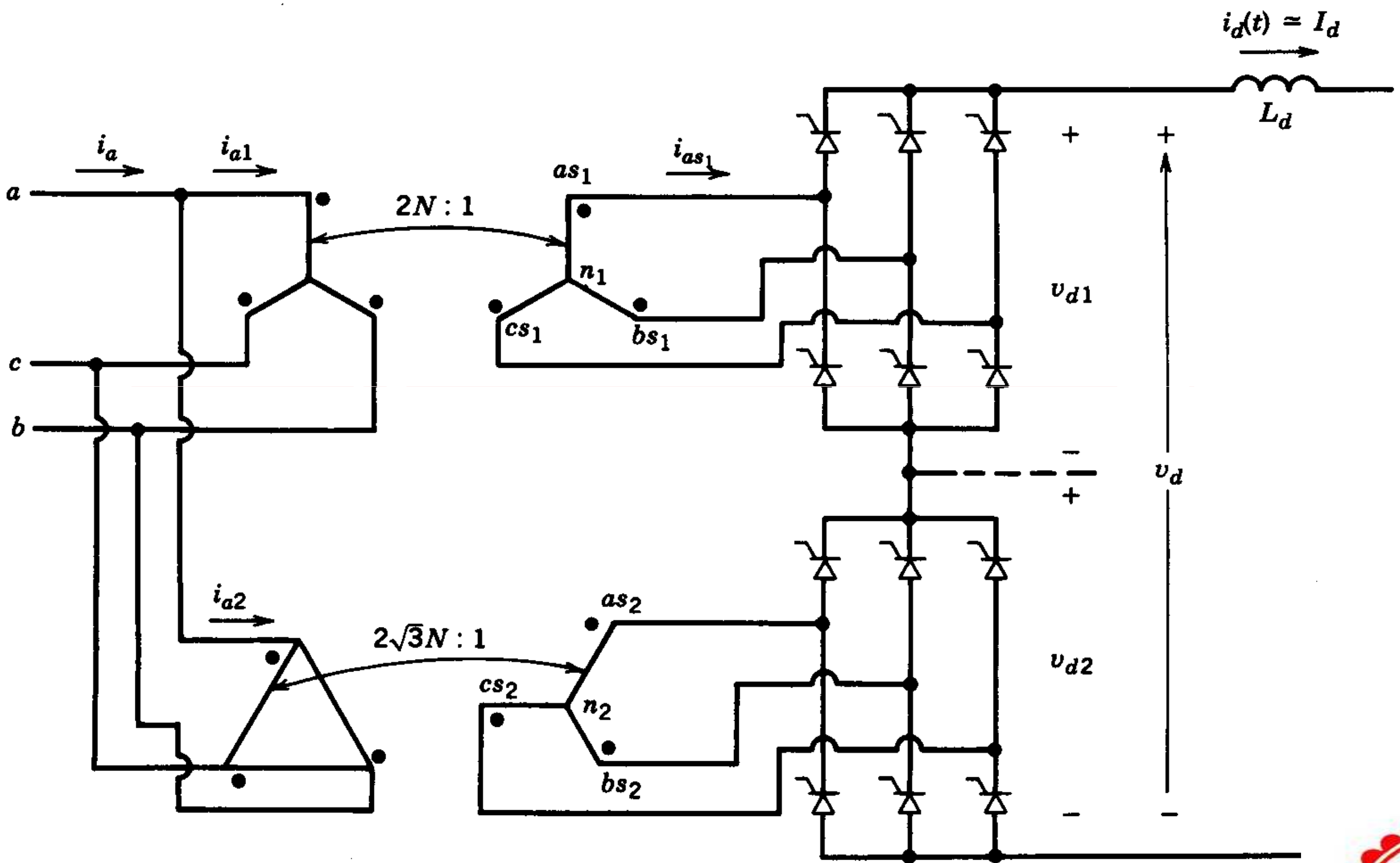


Figure 17-2 Twelve-pulse converter arrangement.

Controlled Multi-pulse HVDC Application

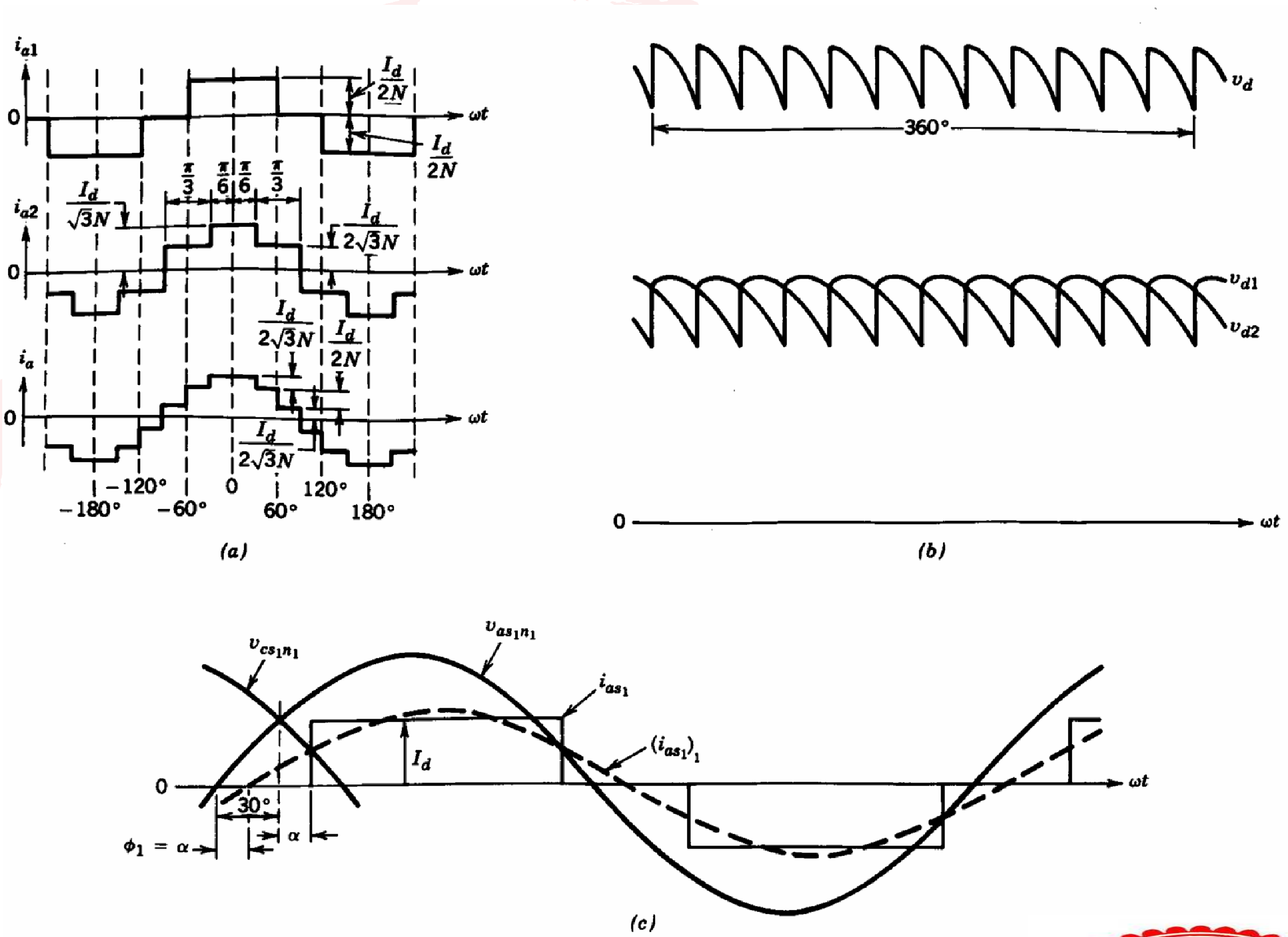


Figure 17-3 Idealized waveforms assuming $L_s = 0$.

Controlled Multi-pulse HVDC Application: inverter mode of operation

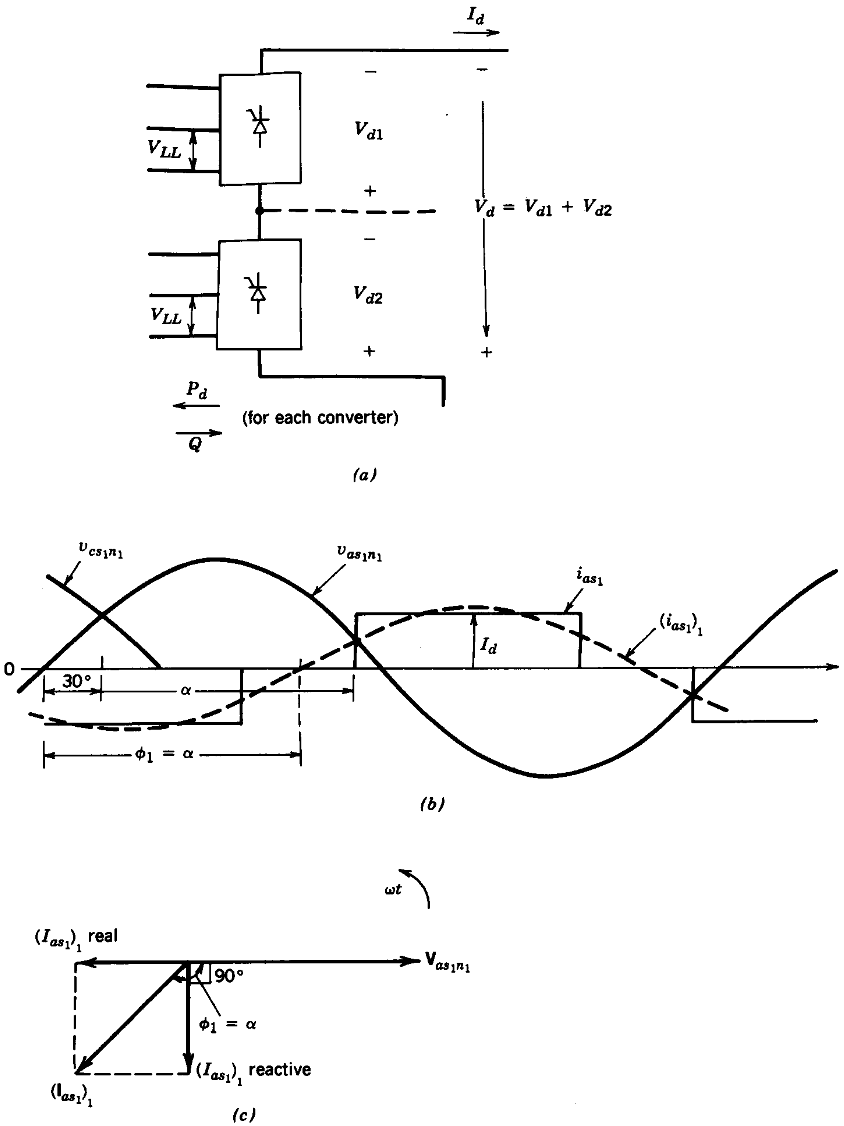
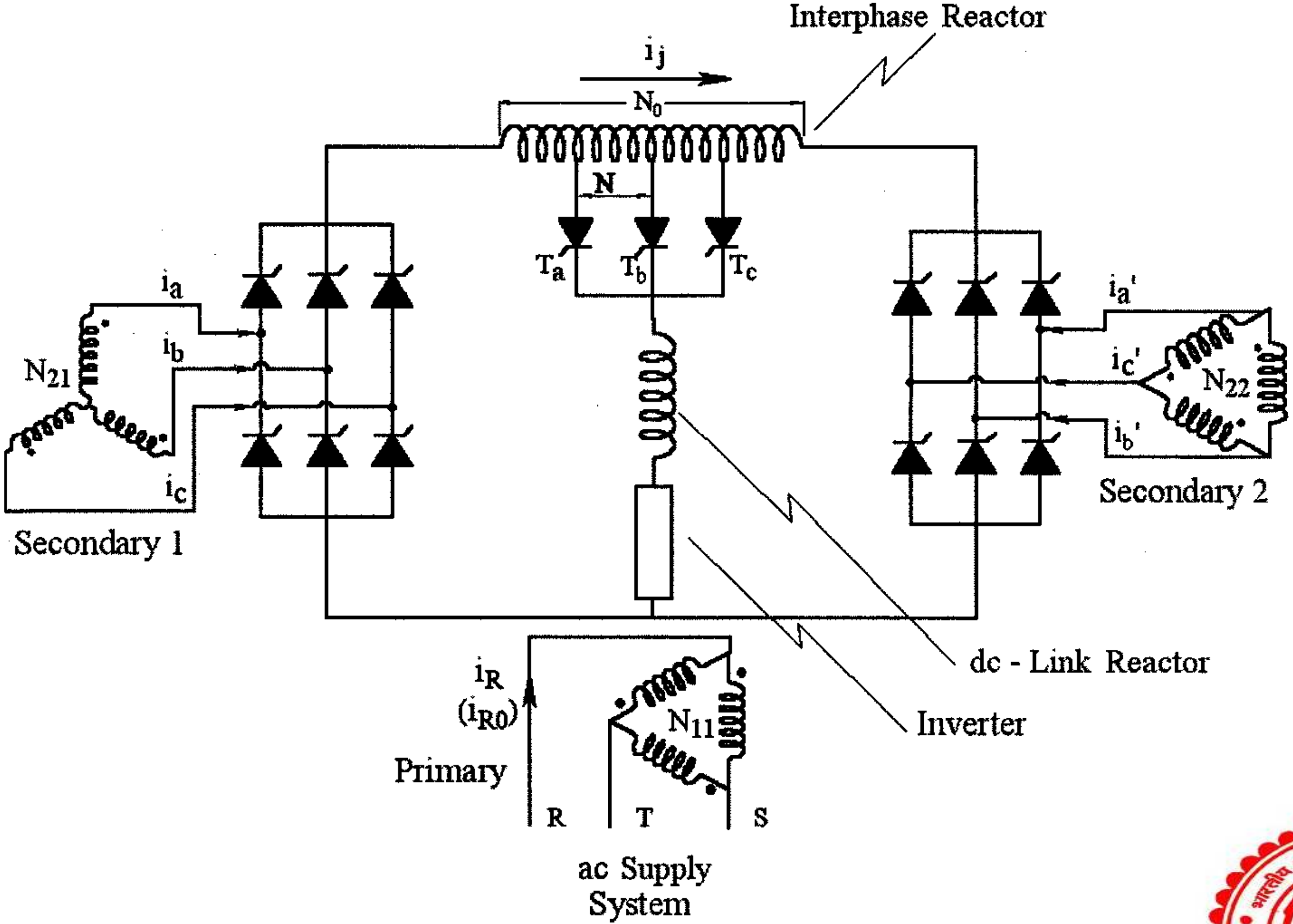


Figure 17-4 Inverter mode of operating (assuming $L_s = 0$).

Controlled Multi-pulse (36 pulse)



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Selection Criterion of IPQC

- Number of phases in AC mains (Single-Phase, Three-Phase)
- Required level of power quality in input (permitted PF, CF, THD)
- Type of output DC voltage (constant, variable, etc.)
- Power-flow (unidirectional and bi-directional)
- Number of quadrants (one, two or four)
- Nature of DC output (isolated, non-isolated)
- Requirement of DC output (buck, boost and buck-boost)
- Required level of power quality in DC output (voltage ripple, voltage regulation, sag and swell)
- Type of DC loads (linear, nonlinear, etc.)

Selection Criterion of IPQC

- Cost
- Size
- Weight
- Efficiency
- Noise level (EMI, RFI, etc.)
- Rating (W, kW, MW, etc.)
- Reliability
- Number of DC outputs
- Environment (ambient temperature, altitude, pollution level, humidity, types of cooling, etc.)

Conclusion

- Power Quality Definitions are familiarised
- Effects of PQ Problems
- Causes of PQ problems
- Mitigation of PQ Problems by

•Power Filters for Retrofit Applications

•Multi-pulse AC-DC converters

•IPQC for Single Phase and Three Phase, Isolated and Non Isolated category.

Power Factor Correction in Lighting System

INTRODUCTION

- Light sources, which are used for indoor commercial, industrial, institutional and parking applications, are fluorescent/ discharge type.

- The low and high pressure discharge lamps have better efficiency of electrical energy conversion into light (i.e. lumens/watt)

Importance of Ballast

- All discharge lamps require a ballast to regulate the flow of power through the lamp.

It provides :

- A high initial voltage to initiate the discharge.
- Limit the current to sustain discharge.

Efficiency improvement in fluorescent lamp-ballast system

Ways to improve the efficiency of a fluorescent lamp-ballast system are

- Reduce the ballast losses.
- Operate the lamp at high frequency.
- Reduce losses in the lamp electrodes.

Power Quality Issues in Lighting System

- Total harmonic distortion
- Power factor
- Crest factor
- Electro-magnetic Interference (EMI)
- Output voltage regulation
- Low ripple in the output voltage

Utility Issues

- Due to poor Power Factor

  Ineffective use of the Volt-amp ratings of utility equipment such as

  - Transformers
  - Distribution lines
  - Generators

- Due to harmonic components
  - Interference with communication and control signals.
  - Overheating of the neutral line
  - Over voltage due to resonance conditions.
  - Overheating of the distribution transformer and distribution lines.

Power Factor Correction

In case of high frequency Electronic Ballast high power factor (HPF) can be achieved by

- Passive power factor correction (PFC) technique.
- Active power factor correction (PFC) technique.
- Hybrid power factor correction (PFC) technique

Advantages of passive PFC Technique

- Easy to implement.
- No control is required.
- Robust and reliable.
- Do not generate Electro-magnetic Interference (EMI).

Disadvantages of passive PFC Technique

- Large size of the reactive elements.
- May not be able to contain the harmonics within the specified limits (the agency requirements are different for different power levels).
- Poor power factor compared with active schemes.
- Not cost effective.

Advantages of active PFC Technique:

- Lower harmonic content in the input current compared to the passive techniques.
- Near unity power factor (0.99) is possible to achieve with the Total Harmonic Distortion (THD) as low as 3-5%.
- For higher power levels active PFC techniques will result in size, weight and cost benefits over passive PFC techniques.

Disadvantages of active PFC Technique

- Electro-magnetic Interference (EMI) present at high frequency, hence EMI filter is required.
- Control is required.
- Diode reverse recovery loss problem.

Advantages of Hybrid PFC Technique

- Reduced EMI
- Increased switching frequency.
- Size and weight reduction.
- Improved efficiency.

Disadvantages of Hybrid PFC Technique

- Control is complex.
- Not cost effective.

High power factor can achieved using two power processing stages.

- Pre-regulator or power factor correction (PFC) Stage.
- High frequency inverter Stage which drives the lamp.

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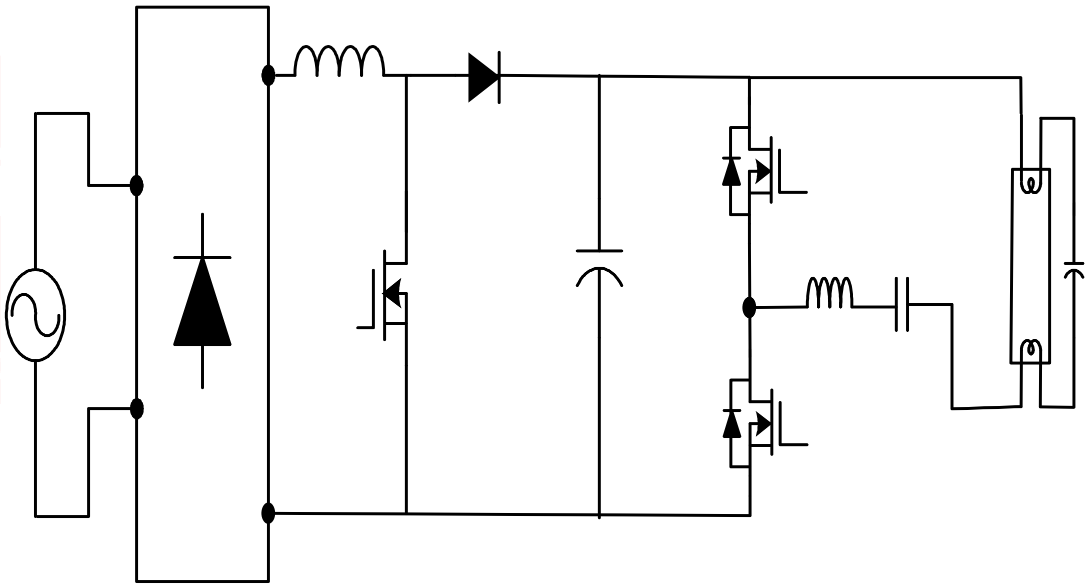
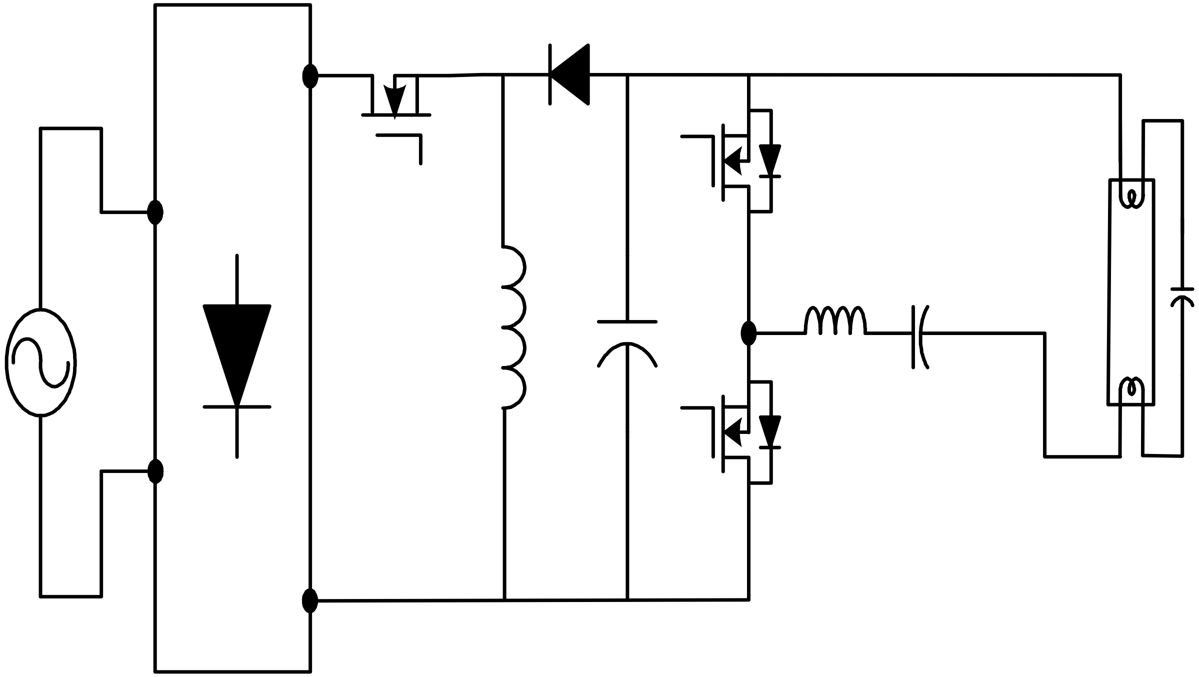
Topologies for power factor Improvement in Electronic ballast



Boost Converter with Half Bridge Series Resonant Parallel loaded Inverter

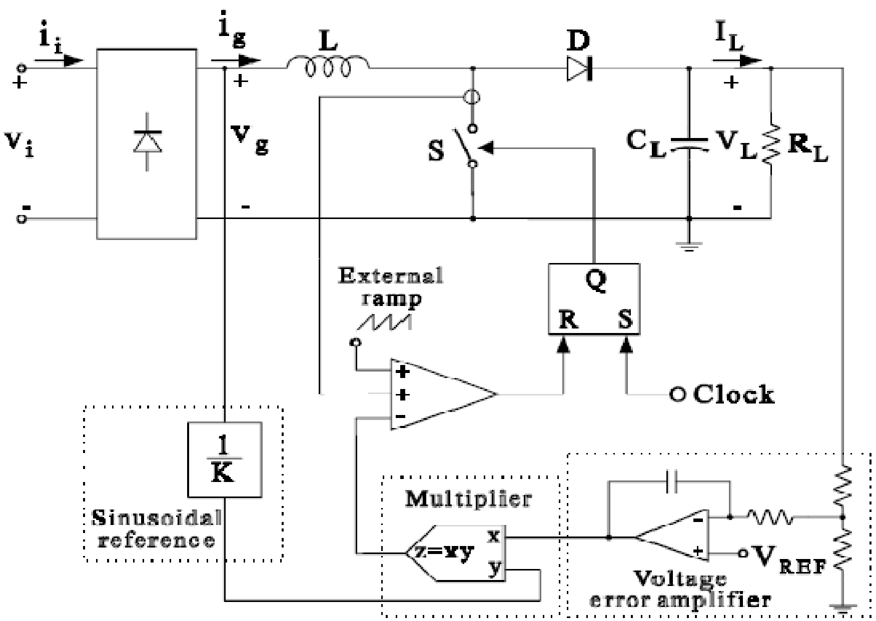


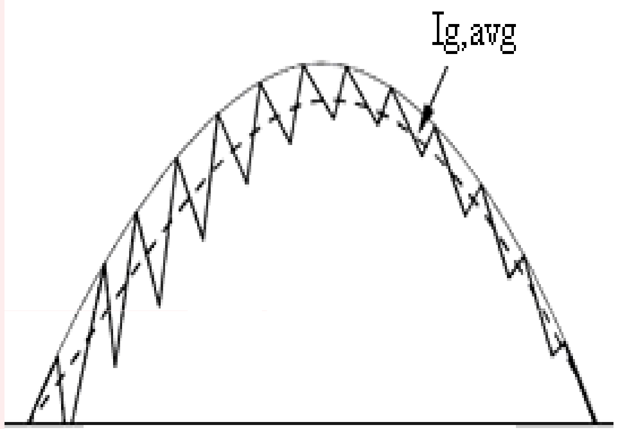
Buck-Boost Converter with Half Bridge Series Resonant Parallel loaded Inverter

Different Control Methods for PFC Converter

- Peak current mode control
- Average current mode control
- Charge control
- Hysteresis current control (HCC)

Different Control Methods for PFC Converter

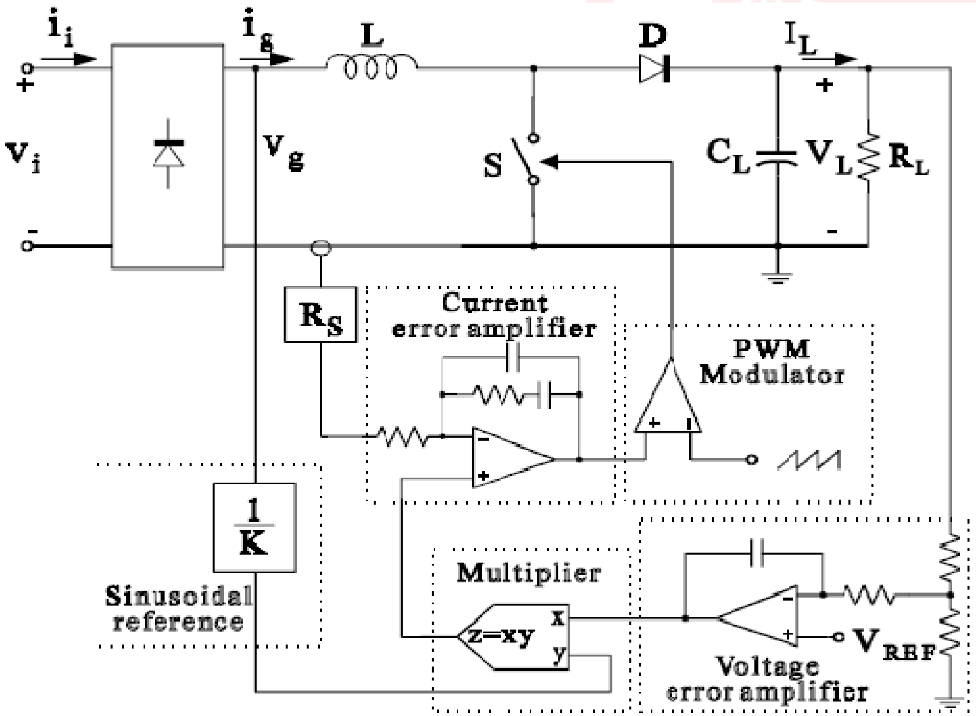


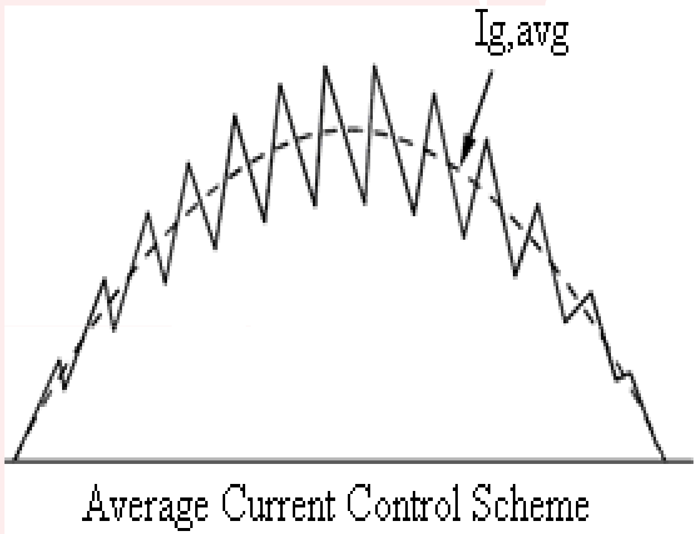


Peak Current Control Scheme

Peak current mode control

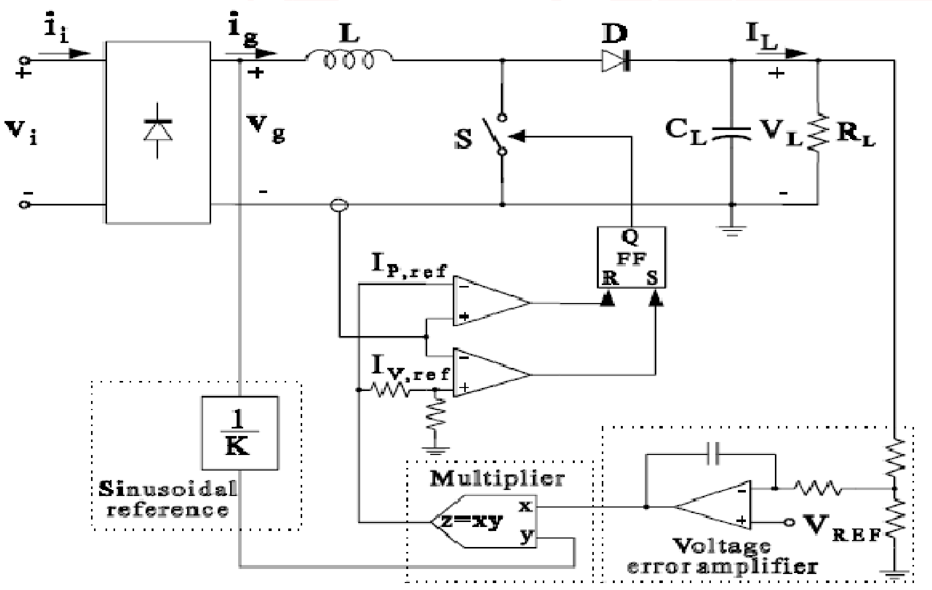
Different Control Methods for PFC Converter

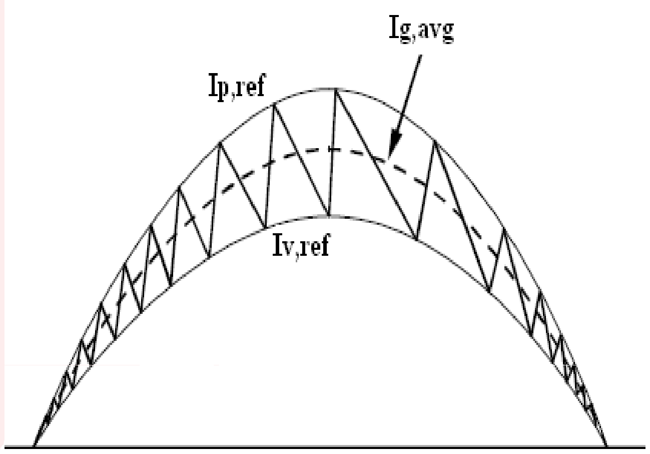




Average current mode control

Different Control Methods for PFC Converter





Hysteresis Control Scheme

Hysteresis current mode control

Conclusion

In lighting system **Input Power Factor** can be corrected using DC to DC converter and its proper control

References

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THANK YOU