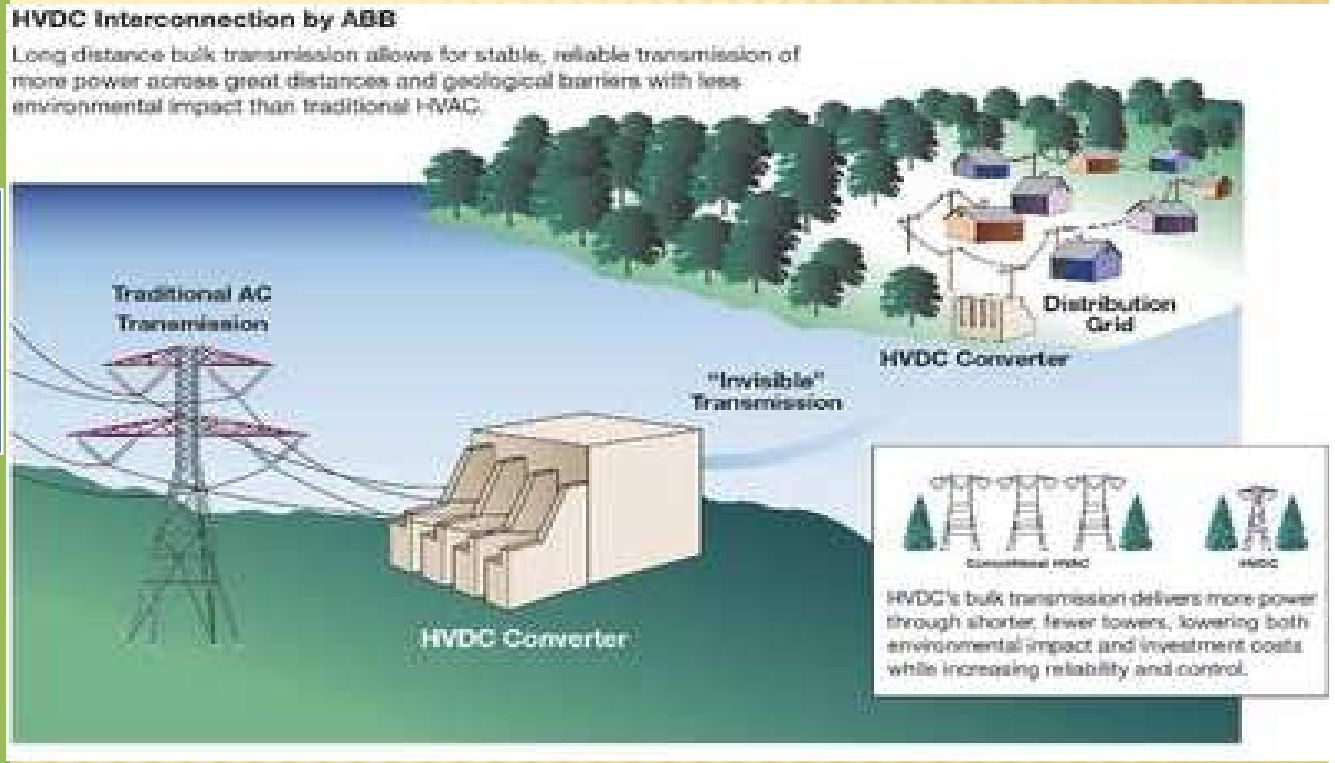
JSS ACADEMY OF TECHNICAL EDUCATION NOIDA

2011

SEMINAR REPORT

TOPIC:-

ANALYTICAL MODELLING OF HVDC TRANSMISSION SYSTEM CONVERTER USING MATLAB/SIMULINK



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ABSTRACT:-

In modern power systems network, it is essential to transmit power from one region to another region in order to meet the load demands. This can only possible by having Asynchronous power transmission between two regions operating at different frequency. This Asynchronous power transmission is called HVDC transmission.

In today electricity industry, in view of the liberalization and increased effects to conserve the environment, HVDC solutions have more desirable for the following reasons:

Environmental advantages
Economical (cheapest solution)
Asynchronous interconnections
Power flow control
Added benefits to the transmission (stability, power quality etc.)

The HVDC Technology:

The fundamental process that occurs in an HVDC system is the conversion of electrical current from AC to DC (rectifier) at the transmitting end and from DC to AC (inverter) at the receiving end. There are three ways of achieving conversion:

- Natural Commutated Converters.
- Capacitor Commutated Converters (CCC)
- Forced Commutated Converters.

The components of an HVDC transmission system:

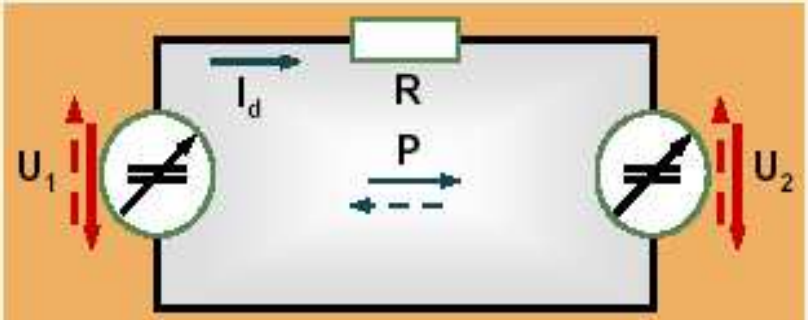
The three main elements of an HVDC system are:

- The converter station at the transmission and receiving ends.
- The transmission medium.
- The electrodes

Principles of HVDC

Simplified Block Diagram

Equivalent Circuit



Characteristics

- I_d in one direction only
- Magnitude of P or I_d controlled depending on difference in terminal voltages (U_1, U_2)
- Direction of P controlled depending on polarity of terminal voltages (U_1, U_2)

Advantages of HVDC transmission:

HVDC Transmission have many advantages over ac transmission. Some of technical and economical advantages are given below:

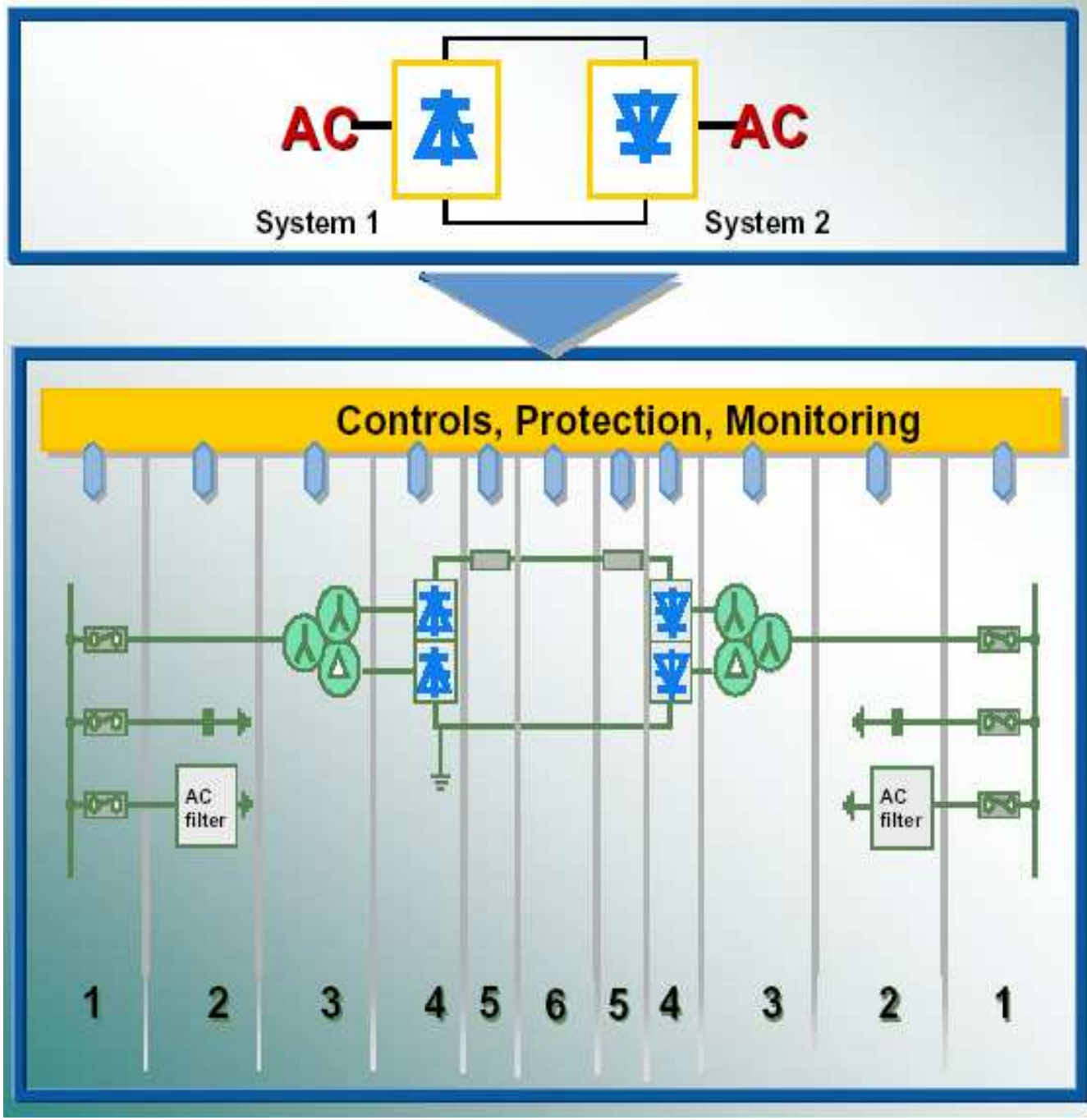
i) For transmitting bulk power over long distance say above 500km these systems are economical.
ii) During bad weather conditions, the corona loss and radio interference are lower for a HVDC line as compared to that in an ac line of the same voltage and same conductor size.
iii) Compare to ac transmission, HVDC transmission is cheaper in cost because ac system required three conductors to carry power where as HVDC transmission lines require two conductors.
iv) Right-of-way for a DC line is about 20-40 percent lesser than that for an ac line of the same power transmission capability.
v) Unlike ac transmission, HVDC transmission system does not requires any intermediate substations for compensation.
vi) The transmission losses in a HVDC transmission are lower than the ac transmission of the same power transmission capability.
vii) The towers of HVDC lines are simpler, cheaper than ac lines.
viii) No skin effect in HVDC lines, so uniform distribution of current over the section of the conductor. There is a skin effect in ac lines.
ix) Voltage regulation is better in case of DC transmission.
x) Power flow control is easy in HVDC link.
xi) High reliability.

Disadvantages of HVDC transmission:

HVDC transmission have few limitations as

i) Initial cost is high because it requires additional requirement of converters (rectifier and inverter stations), filters, reactive power compensators.
ii) Overhead capacity is low as compared to ac transmission.
iii) HVDC converter need cooling systems.
iv) HVDC converters produce harmonics both ac and dc sides which may cause interference with the audio frequency communication lines.
v) Reducing ripples from the dc output, filters requirement is more.
vi) Maintenance of insulators is more.
vii) HVDC circuit breakers is expensive.
viii) Voltage transformation is not possible in DC side and hence it is to be provided on the ac side only.

HVDC Terminal



1 AC Switchyard

2 AC Filters, Capacitor Banks

3 Converter Transformers

4 Thyristor Valves

5 Smoothing Reactor

6 DC Cable

Converter Station

Converter station consists the following equipments and as shown in fig

i. Converter unit
ii. Converter transformer
iii. Filters
iv. Reactive power
v. Smoothing reactor
vi. Switch gear

i. Converter Station:
ii. Converter transformer:

The converter transformer can have the different configurations, they are

a) Three phase, two winding transformer
b) Single phase, three winding transformer
c) Single phase, two winding transformer

The above of (a) and (b) type of transformer can be installed at the valve side & winding are stator and delta with neutral point ungrounded.

The configuration (c) can be used on the AC side and the transformer are connected in parallel with neutral grounded.

Note: The leakage reactance of the transformer is chosen to limit the short circuit currents through any value.

The converter transformers are designed to withstand DC voltage stresses and increased eddy current losses due to harmonic currents.

iii.Filters:

Three types of filters can be used in the converter station, they are

a) AC filter
b) DC filters
c) High frequency (RF/PLC) filters

iv. Reactive power source:

Converter stations require reactive power supply that is dependent on the active Power loading [about to 60% of the active power]. Fortunately, part of this reactive power requirement is provided by AC filters. For addition of above the shunt (switched) capacitor, synchronous condensers and static Var systems are used. On the dependency of speed of control is desired.

v. Smoothing reactor:

Generally a sufficiently large series reactor is used on DC side to get the smooth DC current and also for the protection. The reactor is designed as a linear reactor and is connected on the line side, neutral side or at intermediate location.

vi. DC switch gear:

The DC switch gear is usually a modified AC equipment used to interrupt small DC currents [employed as disconnecting switches]. DC breakers or metallic return transfer breakers (MRTB) are used, if required for interruption on rated load currents.

In addition to the equipment described above, AC switch gear and associated equipment for protection and measurement are also part of the converter station.

Applications of HVDC Transmission:

On the basis of applications, HVDC transmission systems are scheduled as an alternative to extra high voltage AC transmission system for the following reasons:

i) Long distance high power transmission by overhead lines
ii) Under water transmission
iii) Transmission by underground cable
iv) Asynchronous interconnection of AC systems operating at different frequencies.
v) HVDC back to back system
vi) Multi terminal HVDC system for interconnecting them or more three phase AC system.

Analysis of HVDC Converters

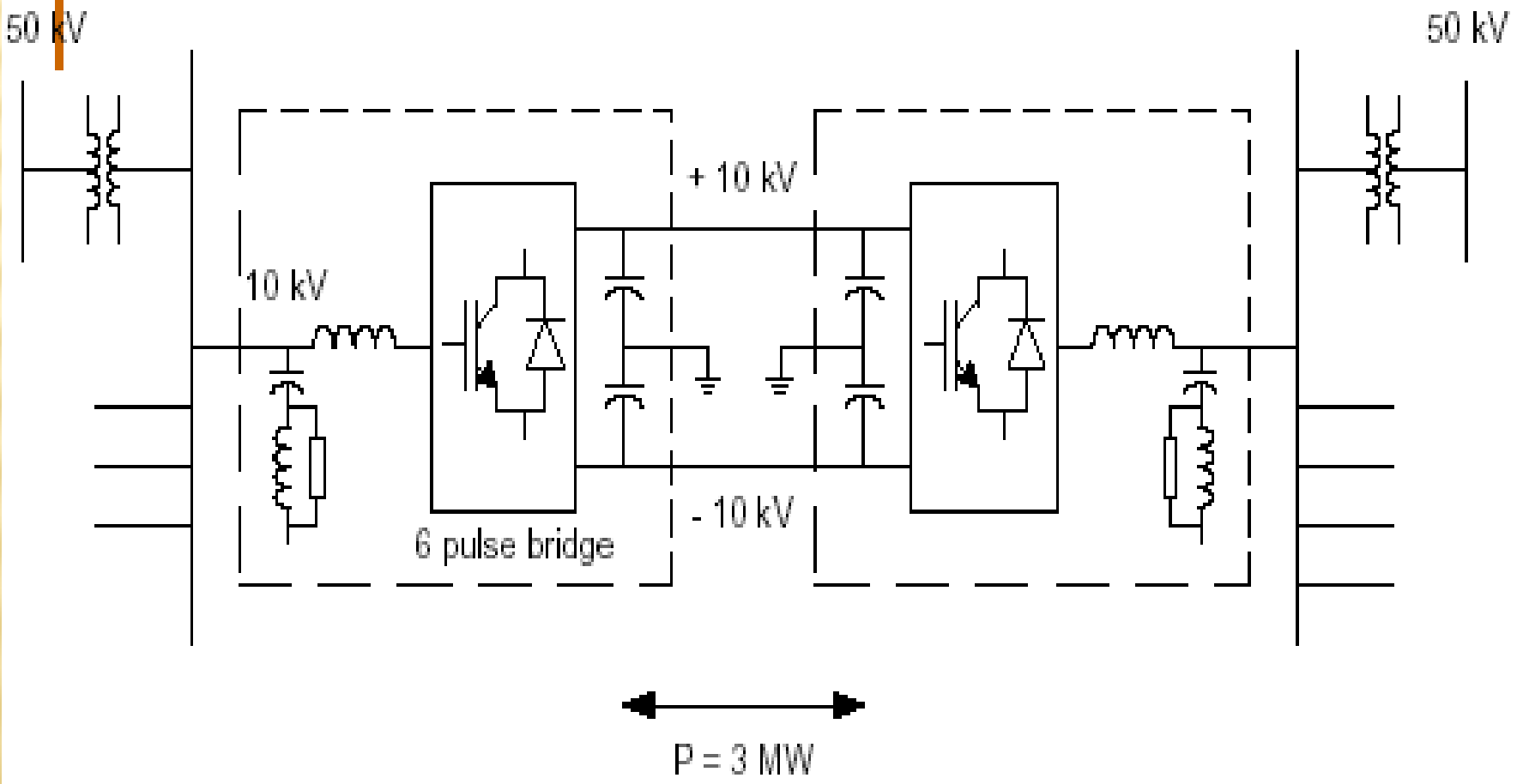
Introduction:

• HVDC converters converts AC to DC and transfer the DC power, then DC is again converted to AC by using inverter station.

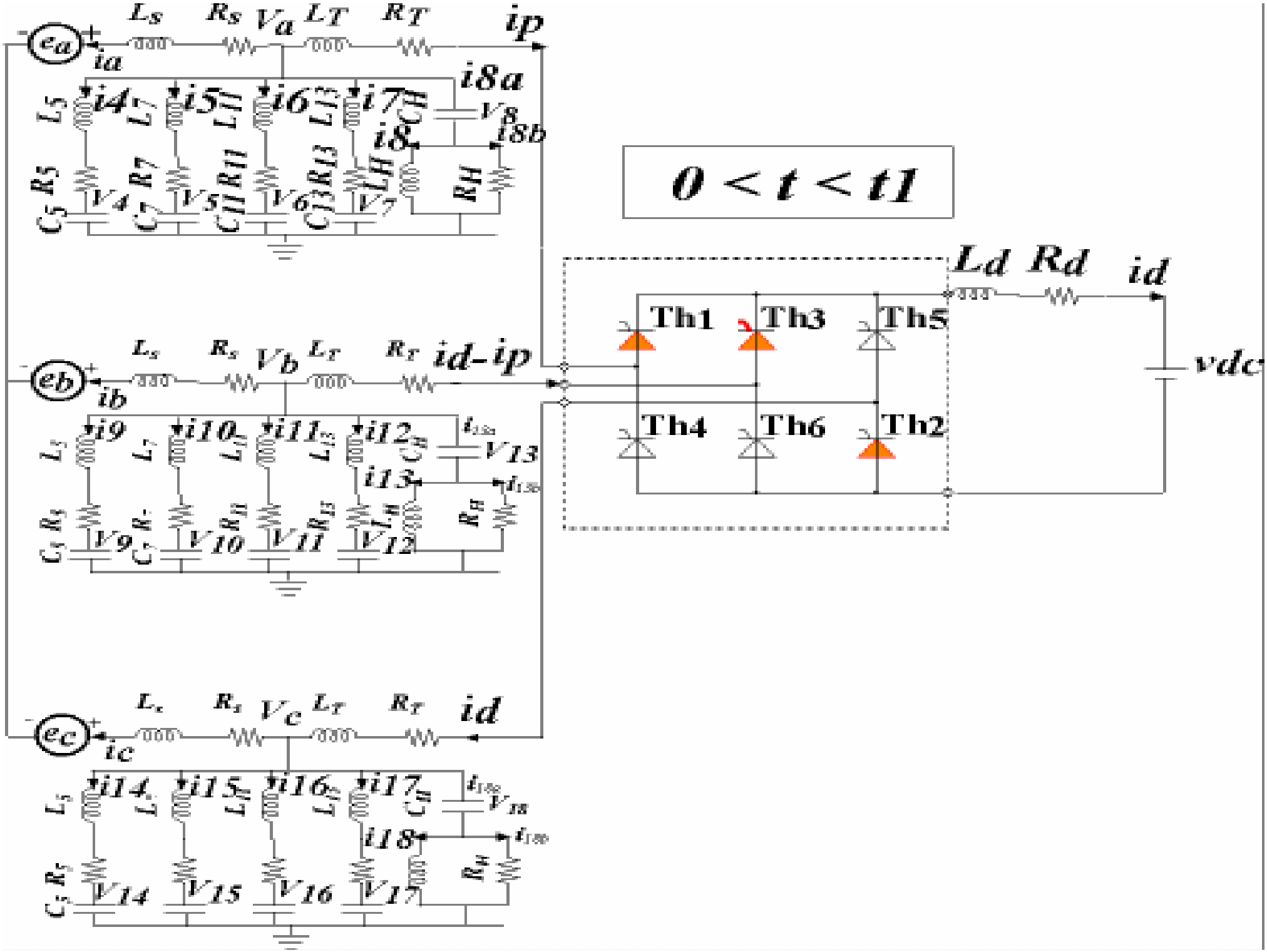
• HVDC system mainly consists of two stations, one in rectifier station which transfers from AC to DC network and other is inverter station which transfers from DC to AC network.

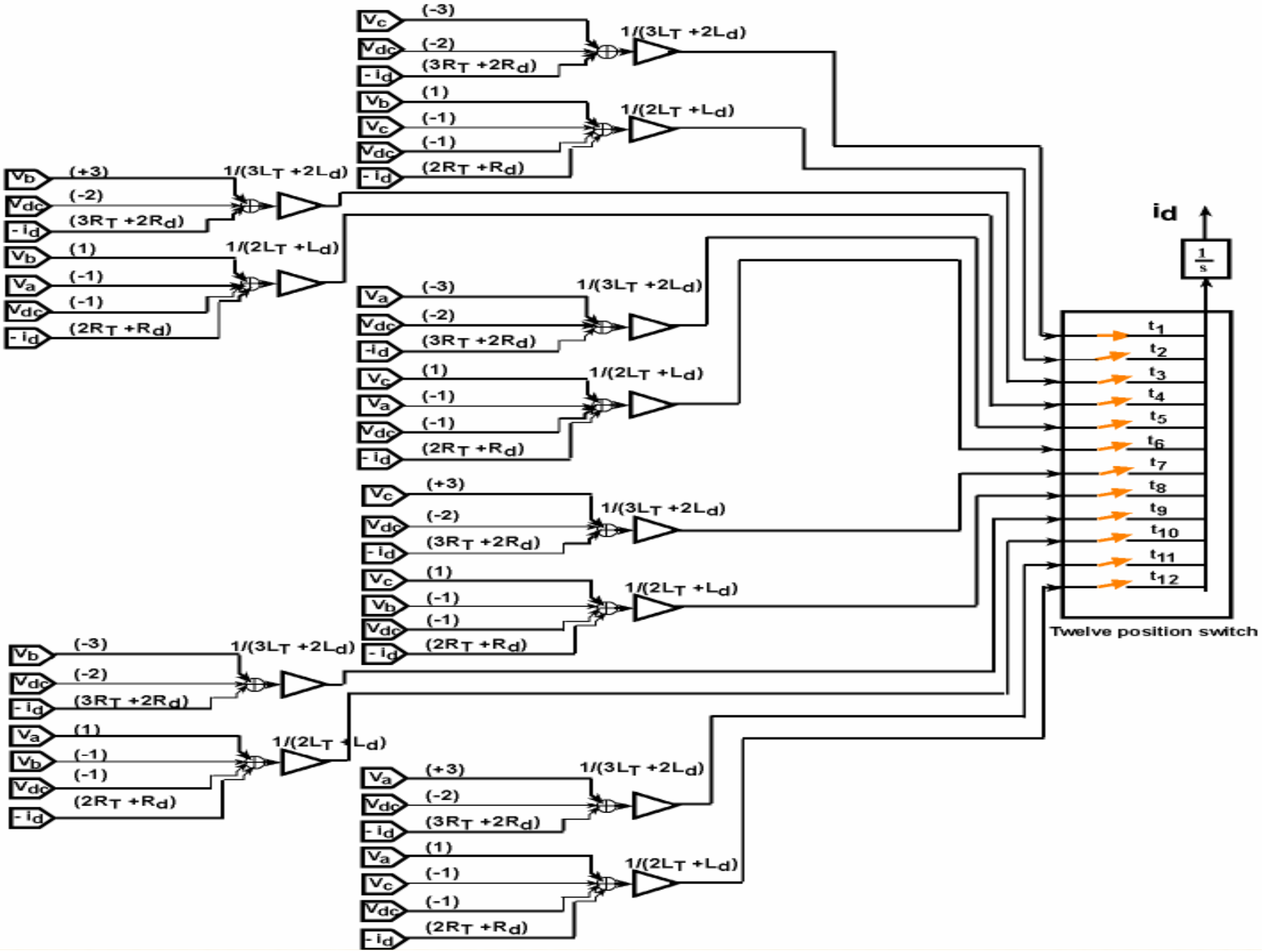
• For all HVDC converters twelve pulse bridge converters are used. Same converter can act as both rectifier as well as an inverter depending on the firing angle ‘α’.

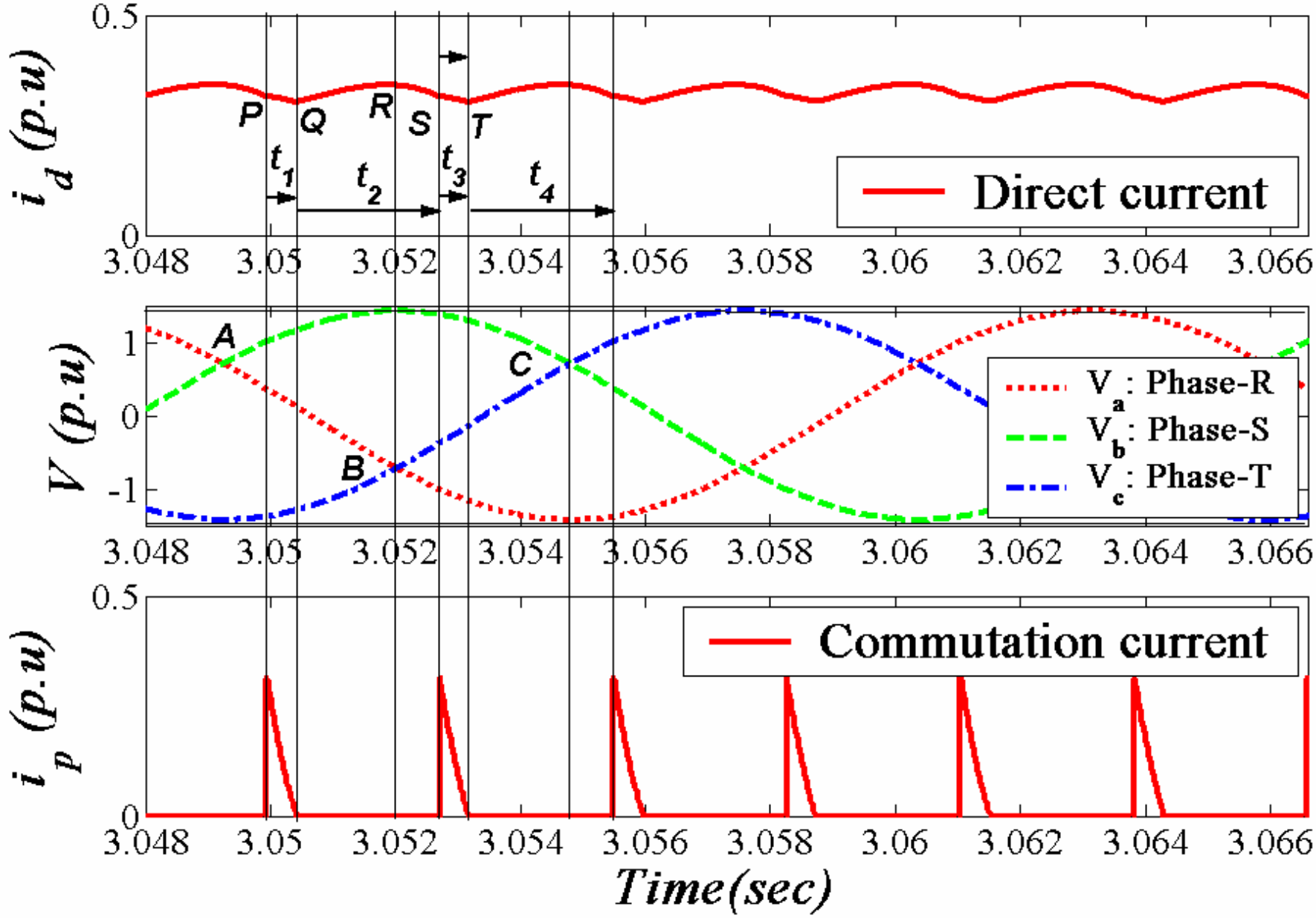
Advanced HVDC Transmission



With this in view, simple analytical model using Matlab/Simulink has been developed in this work to investigate the steady state operation of the 6 pulse single bridge HVDC transmission system converter. The model is based on dividing each cycle of the 60 Hz system into twelve intervals out of which six intervals are communication intervals with three valves conducting. The system performance for each of the 12 interval has been captured using differential equations applicable for particular interval. These equations have then been converted into integral from followed by Laplace representation to develop the 6 pulse HVDC model I Matlab/ simulink.


0 < t < t1
Th1
Th3
Th5
Th4
Th6
Th2
Ld
Rd
id
vdc
ip
id-ip
ea
eb
ec
ia
ib
ic


Vc
(-3)
Vdc
(-2)
- id
(3RT +2Rd)
1/(3LT +2Ld)
Vb
(1)
Vc
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
Vb
(+3)
Vdc
(-2)
- id
(3RT +2Rd)
1/(3LT +2Ld)
Vb
(1)
Va
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
Va
(-3)
Vdc
(-2)
-id
(3RT +2Rd)
1/(3LT +2Ld)
Vc
(1)
Va
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
Vc
(+3)
Vdc
(-2)
- id
(3RT +2Rd)
1/(3LT +2Ld)
Vc
(1)
Vb
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
Vb
(-3)
Vdc
(-2)
- id
(3RT +2Rd)
1/(3LT +2Ld)
Va
(1)
Vb
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
Va
(+3)
Vdc
(-2)
- id
(3RT +2Rd)
1/(3LT +2Ld)
Va
(1)
Vc
(-1)
Vdc
(-1)
- id
(2RT +Rd)
1/(2LT +Ld)
id
1
s
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
t11
t12
Twelve position switch


0.5
0
i_d (p.u)
P
Q
R
S
T
t_1
t_2
t_3
t_4
Direct current
3.048
3.05
3.052
3.054
3.056
3.058
3.06
3.062
3.064
3.066
1
0
-1
V (p.u)
A
B
C
V_a : Phase-R
V_b : Phase-S
V_c : Phase-T
i_p (p.u)
Commutation current
Time(sec)

CONCLUSION

The model results are very useful in getting deeper understanding of
(1) root cause for ripple in rectifier direct current
(2) valve currents in different intervals of each time period and the
(3) Importance of tuned and high pass filters in extracting the unwanted harmonics .

This contribution can be very useful for HVDC system operation and maintenance personnel who can investigate different operating conditions for HVDC converter system using the model to optimize the system performance.