Closed loop control system simulation of 12 pulse rectifier for transient changes in source inductance

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Abstract-In modern high current industrial applications power electronic converters like 6 pulse and 12 pulse controlled converters are used. In a power system transient operation of generators will effect respective changes in source inductance of the total system this would in turn cause delta changes in firing angle of the converter in operation. This paper mainly focuses on the modelling of 12 pulse converter and to find the changes in firing angle of converter to evaluate range of operation for a set of source inductance and closed loop control of 12 pulse converter system through MATLAB/Simulink software. The effect of source inductance on the operation for 12 pulse converter is analysed. The different combinations of firing angles for converter is stated for which the converter can appropriately operate within a satisfied region with respect to the Application. A High Current Electro-plating application is considered which uses 12 pulse converter.

Keywords—12 pulse converter, Electro-plating application, Transfer function, MATLAB/Simulink

I.INTRODUCTION

As technology grows every day, the study of power electronics to develop the most efficient energy transformation. Power electronics is the study of designing analyzing and controlling the flow of electrical energy by providing voltages and currents in a form that is suited for user load. For a large load, a 12 pulse rectifier is commonly used in industrial field to perform better in terms of the harmonic injected to the input line supply. In normally high current application like electro-plating Industry uses the 12 pulse rectifier to have proposed current and voltage as shown in the fig 2.1. In designing the converter the main constraint which is considered is Source inductance [1]. Source Inductance one of the main element that decides the firing angle of the converter i.e. for a finite value of source inductance makes a finite firing angle change in the converter there by having an undesirable effect on converter operation. In the power system the generator connection i.e. in terms of series, parallel, adding of generator & removal of the generator makes an effective change in the source inductance reflected to the system this change in the source inductance makes a wholesome effect on the converter especially a sensitive one.

The objective of this paper is to model the 12 pulse converter and simulate the converter in MATLAB/Simulink software for different values of Source inductance. The set of source inductance values are so chosen depends on the operating range for respective application. In section I the introduction to 12 pulse converter is described in section II modelling of 12 pulse

Converter is explained in section III the simulation and results are expressed and finally in section IV conclusion.

II.MODELLING OF 12 PULSE RECTIFIER

A 12 pulse bridge is arrangement of two 6 pulse bridges at DC output side in series [3]. The phase displacement among the two AC supplies is usually 30° and is realised by using converter transformers by two different secondary windings. Typically one of the valve windings is star connected and the other is delta connected. By twelve valves linking each of the two sets of three phases to the two DC outputs, here is a phase change every 30°, and harmonics are substantially reduced [2]. For this purpose the 12 pulse system has become standard on almost all line-commutated converter DC systems.

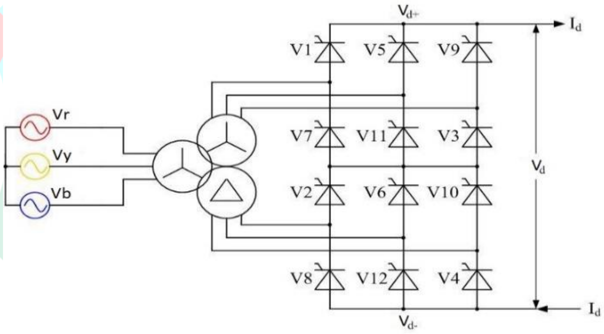

Fig 2.1: 12 pulse Converter

a) Open loop modelling

Firstly consider the Ideal case – A switch with Source Inductance as shown in the fig 2.2.

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{1+\frac{sL_S}{R_l}} \quad (1)$$

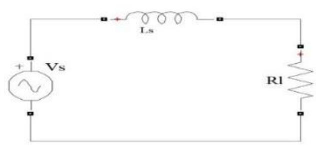

Fig 2.2: Ideal case – A switch with Source Inductance

Secondly Consider the Source Inductance & Internal resistance and also output Capacitor with Equivalent series resistor (2 valve Conduction) as shown in fig 2.3.

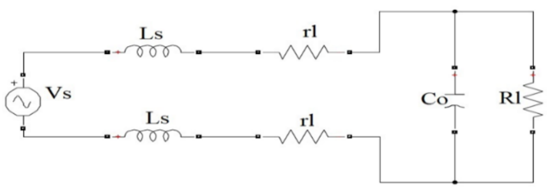

Fig 2.3: 2 valve Conduction mode

Deriving transfer function for the above circuit to get the stated equation

$$\frac{V_{out}}{V_{in}} = \frac{\frac{1}{1/_{Rl}}+\frac{1}{rc+1/_{sC}}}{sL^2+(R+rl)^2+\frac{1}{1/_{Rl}}+\frac{1}{rc+1/_{sC}}} \quad (2)$$

$$\frac{V_{out}}{V_{in}} = \frac{(C\,Rl\,rc)s+Rl}{L(Rl\,C+rc\,C)s^2+[L+C\{RRl+rlRl+Rrc+rcrl+Rlrc\}+(Rl+R+rl)\}]} \quad (3)$$

Considering Rl>>>rc, rl, & R

$$G(s) => \frac{V_{out}}{V_{in}} = \frac{Cs\,rc+1}{L\,C\,s^2+\left[\left(\frac{L}{Rl}\right)+C(R+rs+rl)\right]s+1} \quad (4)$$

b) Closed loop Modelling

The block diagram in fig 2.4 states closed loop control of 12 pulse converter and it done with help of Proportional & Integral (PI) controller and reference alpha and reference Id current is set and therefore an expected output Current is achieved as shown in the fig 2.4.

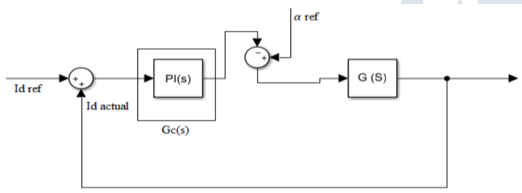

Fig 2.4: PI controller

The PI controller transfer function is given equation: -

$$G_c(s) = K_p + \frac{K_i}{s} \quad (5)$$

$$\frac{V_o(s)}{V_i(s)} = \frac{G(s)+G_c(s)}{1+G(s)+G_c(s)} \quad (6)$$

Equating the exact values i.e. equation (5) in equation (6),

$$\frac{V_o(s)}{V_i(s)} = \frac{[Cs\,rs+1](K_p+{}^{K_i}/_{s})}{s-K_pL_s\left[\frac{1}{Rl}+s(Rl+rc+rl)\right]-K_iL_s[\frac{1}{Rl}+(Rl+rc+rl)]} \quad (7)$$

In the equation (3) the K_p & K_i value are taken and the elements Cs, rc & rl is neglected

$\therefore K_p$=5 K_i=100 L_s=5.5mH Substituting above K_p & K_i values in equation (3),

$$\frac{V_o(s)}{V_i(s)} = \frac{\frac{sK_p+K_i}{s}}{s-5.5*10^{-3}(K_p+K_i)} \quad (8)$$

$$\frac{V_o(s)}{V_i(s)} = \frac{5s+100}{s^2-\frac{s105}{1000}} \quad (9)$$

$$\frac{V_o(s)}{V_i(s)} = \frac{s+\frac{100}{5}}{5s\left[\frac{s}{5}+\frac{0.105}{5}\right]} \quad (10)$$

$$\frac{V_o(s)}{V_i(s)} = \frac{s+20}{s(s+0.0191)} \quad (11)$$

The transfer function in equ.11 is with respect to 12Pulse converter & it is verified for Stability with the MATLAB software by programming approach and the polar plot is verified to state the system in acceptable region or unacceptable region for the respective application.

III.SIMULATION RESULTS OF 12 PULSE RECTIFIER

➢ Open loop simulation: The circuit diagram of 12 Pulse converter and simulation result along with output current and voltage is shown in below diagram

Table 3.1: Specifications

Sl No	mponents	Values
1	tput Voltage(V)DC	200.5
2	ut voltage(V)AC	200
3	tput Current(Amp)	41
4	quency(Hz)	50
5	tput Resistor(ohm)	10
6	urce Inductance(mH)	5

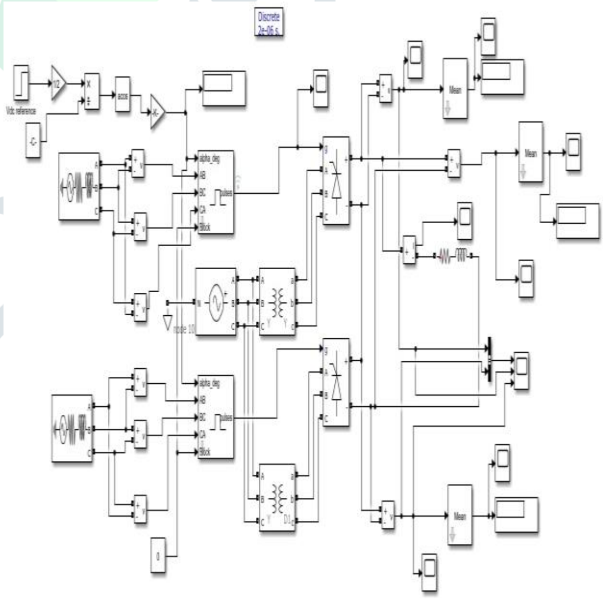

Fig 3.1: MATLAB 12 Pulse Converter (Open Loop)

Table 3.2: Simulation Results

SL NO	rameters	tual value	nulated lue
α=42.2			
1.	tput Voltage	0.5 Volt	9.7 Volt
2.	tput Current	Amp	2 Amp

NO	rameters	tual value	nulated
K_p=5 K_i=100			
1.	tput Voltage	228.21	8.5
2.	tput Current	ference 50Amp ning of K_p&K_i to reach ference current value for ies values of Source luctance	Amp > Ls H Amp > Ls H Amp > Ls mH

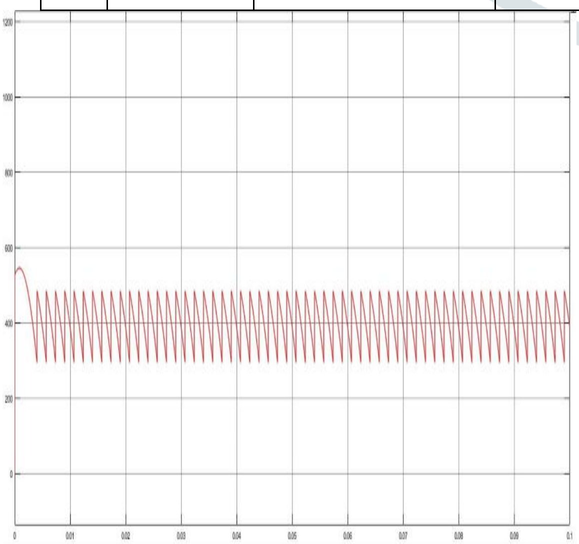

Fig 3.2: Output Voltage Waveform of 12 pulse converter

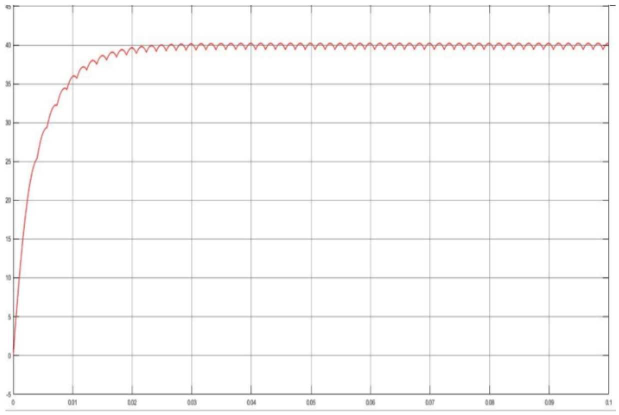

Fig 3.3: Output Current Waveform of 12 pulse converter

- Closed loop Simulation

The circuit show in fig3.1 is 12 pulse converter MATLAB diagram with close loop control using PI controller. The specification of converter in which it is simulated is tabulated below. The two 6 pulse converter are connected in series and thus the output voltages are additive and PI controller maintains the output current within the limits as given in the reference as shown in the fig 3.4.

The below shown tabular column Table 3.3 gives the closed loop results of the 12 pulse converter with respect to change in the Source inductance.

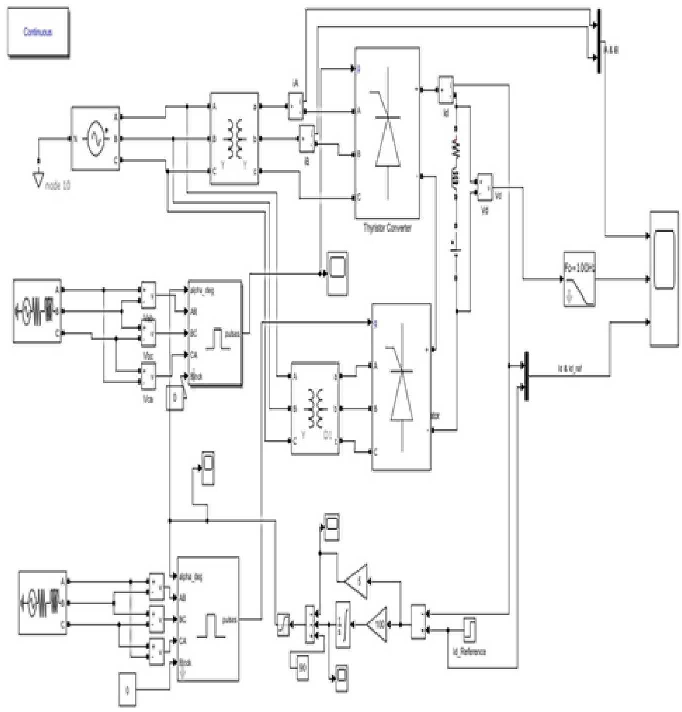

Fig 3.4: Closed loop circuit of 12Pulse converter

Table 3.3: Simulation results closed loop

Output Waveform When Ls=1mH, 5mH & 22mH is shown below

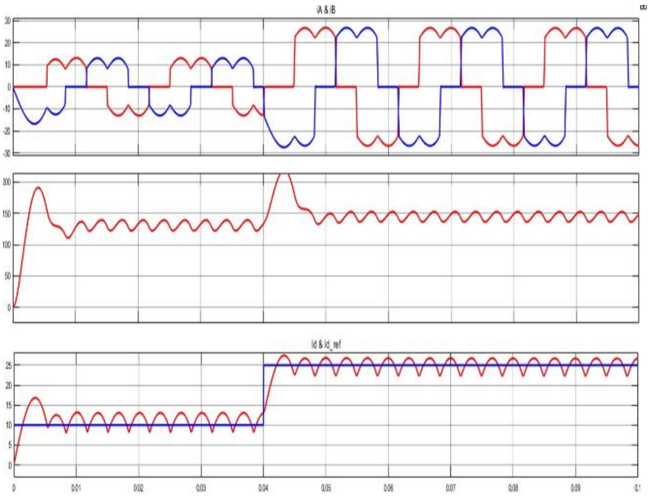

Fig 3.5: Output Waveform of 12 pulse converter Closed loop for Ls=1mH

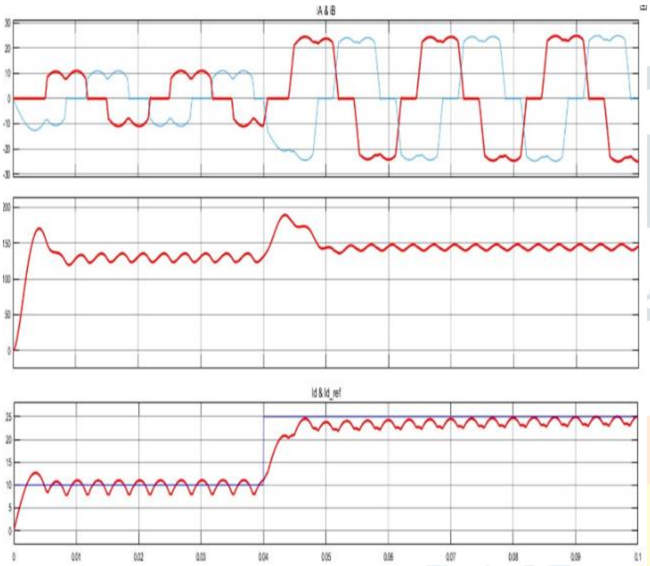

Fig 3.6: Output Waveform of 12 pulse converter Closed loop for Ls=5mH

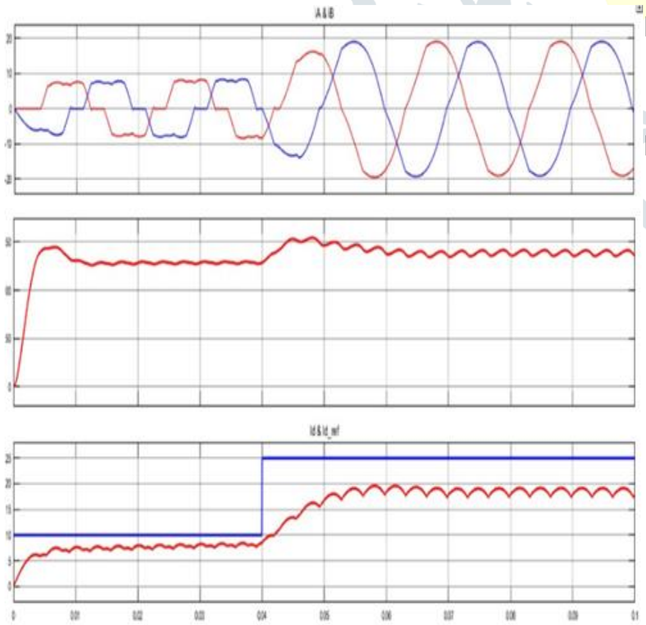

Fig 3.7: Output Waveform of 12 pulse converter Closed loop for Ls=22Mh

From the graphs fig.3.5, 3.6 & 3.7 it is clear to state that for chosen application the acceptable source inductance value should be 5mH-22mH because the output current is well inside the reference value for 5mH and 22mH but for 1mH it's above the reference value causing changes in the firing angle that effects the converter operation to shift from acceptable operation region.

IV. CONCLUSION

In this paper, Modelling of 12 Pulse Rectifier is carried out and simulation is also done by using MATLAB software tool. The effect of source inductance on the operation for 12 pulse converter is analysed and Set of Values of Source Inductance is stated for the Converter in which it operates well. Simulation results prove that the proposed Analysis can be implemented for 12 Pulse Rectifier to have stabilized operation while transient change in input Source Inductance.

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