Conversion of Single Phase to Three Phase AC Drive System Using Parallel Rectifiers

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ABSTRACT: This paper is a single phase to three phase AC drive system composed of two parallel single phase rectifiers, three phase inverter, and an induction motor. The main advantage of the paper is to reduce the rectifier switch currents, the harmonic distortion at the converter input side, improvements on the fault tolerance characteristics and an induction Motor run at any loaded conditions. Even with increase in the number of switches, the total energy loss of the system lower than the conventional system. The model of the system is derived and it shown that the reduction of circulating current is an improvement objective of the system design. It required output voltage for inverter using PWM technique. This paper is a single phase to three phase drive system composed of two parallel single phase rectifiers using MAT LAB Simulink model.

Keywords:- Power converter, Parallel Rectifier, Induction Motor, Boost Regulator.

1. INTRODUCTION

Several solution have been proposed when the objective is to supply a three phase motors from a single phase mains. It is quite common to have only a single phase power grid in residential, commercial, industrial, agriculture and mainly in rural areas, while the adjustable speed drives may request a three phase power grid. Single- phase to three-phase ac-dc-ac conversion usually employs a full bridge topology which implies in ten power switches as shown in fig .1. This converter is denoted here as conventional topology.

Parallel converters have been used to improve the power capability, reliability, efficiency, and redundancy. Parallel converter technique can be employed to improve the performance of active filters, uninterruptible power supplies, fault tolerance of doubly fed induction generators, and three phase drives. Usually the operation of converters in parallel requires a transformer for isolation. However, weight, size, and cost associated with the transformer may make such a solution undesirable. When an isolation transformer is not used, the reduction of circulating currents among different converter stages is an improvement objective in the system. In this paper, a single–phase to three–phase drive system composed of two parallel single –phase rectifiers and a three- phase inverter is proposed as shown in fig .1 .The proposed system is conceived to operate where the single- phase utility grid is the unique option available. Compared to the conventional topology, the proposed system permits to reduce the rectifier switch currents; the total harmonic distortion (THD) of the grid current with same switching frequency (or) the switching frequency with same THD of the grid current; and to increase the fault tolerance characteristics. In addition, the losses of the proposed system may be lower than that of the conventional counterpart. Therefore mentioned benefits justify the initial investment of the proposed system, due to the increase of number of switches.

2. SINGLE PHASE PARALLEL RECTIFIER

Parallel rectifier means two single phase fully controlled rectifier are connected in parallel. In this rectifier circuit eight SCR are used and current divided into two rectifier circuit, so the device switching loss is less. The main advantage of the project to reduce the rectifier switch currents, the harmonic distortion at the converter input side and improvements on the fault tolerance characteristics. Even with increase in the number of switches, the total energy loss of the system lower than the conventional system. The model of the system is derived and it shown that the reduction of circulating current is an improvement objective of the system design.

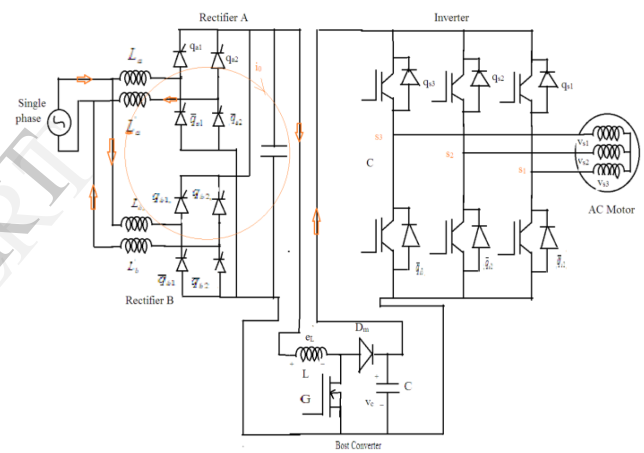


Fig.1 Proposed Single Phase to three Phase AC Motor Drive System

In this project mainly selected controlled rectifier using SCR .The specific reason for controlled rectifier circuit are not allowed the load current hence circulating current may be less but uncontrolled rectifier using diode are allowed the return current (or) circulating current ,so harmonics distortion to be created. Conclude that the PWM techniques are introduced in this project to reduce harmonics distortion and improve the power factor. Uses of Parallel Converter: Power Capability, Reliability, Efficiency, Redundancy.

3. SYSTEM MODELING OF PARALLEL RECTIFIER

The system is composed of grid, input inductors (L_a, $L_{a'}$ L_b and $L_{b'}$), and rectifiers (A and B) Capacitor bank at the dc link, inverter, and induction machine. Rectifiers A and B are constituted of qa1, qa1', qa2, and qa2' and qb1, qb1', qb2, and qa2' respectively. The inverter is constituted of switches qs1, qs1', qs2, qs2', qs3, and qs3', the conduction state of the switches is represented by variable S_{qa1} to $S_{qs3,}$ where S_q=1 indicates a closed switches while S_q= 0 indicates an open switch. The input inductor La, La' (Rectifier A) and the input inductor Lb, Lb' Rectifier B). The capacitor bank at the Dc link inverter & induction motor. Here inductors connected in series act as filter. qa1, qa1' are first arm of the rectifier "A" & qa2, qa2' are second arm of the rectifier A". qb1, qb1' are first arm of the rectifier "B" & qb2, qb2' are second arm of the rectifier B.

System model

The input inductors = $L_a, L_a^{'}$ rectifier A inductors $L_{b,} L_b^{'}$ rectifier B inductors. The indicates a &b rectifier A & B.The capacitor bank at the dc link inverter & induction motor connected in series act as a filter circuit $[q_{a1,} \overline{q}_{a1}]$ First arm of the rectifier "A"$[q_{a2,} \overline{q}_{a2}]$ Second arm of the rectifier "A"$[q_{b1,} \overline{q}_{b1}]$ First arm of the rectifier "B"$[q_{b2,} \overline{q}_{b2}]$ Second arm of the rectifier "B"

Inverter side using 6 switches

$[q_{s1,} \overline{q}_{s2}]$ Inverter first arm $[q_{s2,} \overline{q}_{s2}]$ Inverter second arm $[q_{s3,} \overline{q}_{s3}]$ Inverter third arm Switching states represented by ON and OFF S_q=1 indicates a closed switching states S_q=0 indicates a open switching states Following equation can be derived for the front end of the rectifier

$v_{a10} - v_{a20}$ = Grid voltage – voltage drop of the first arm– Voltage drop of the second arm

$$v_{a10} - v_{a20} = e_g - i_a r_a - L di_a / dt - r_a^{'} i_a^{'} - l_a^{'} di_a^{'} / dt$$

Where p= d\dt

$$= e_g - (r_a + l_a p) i_a - (r_a^{'} + l_a^{'} p) i_a^{'} \quad (1)$$

$$v_{b10} - v_{b20} = e_g - (r_b + l_b p) i_b - (r_b^{'} + l_b^{'} p) i_b^{'} \quad (2)$$

This equation from rectifier B

$$v_{a10} - v_{b10} = (r_b + l_b p) i_b - (r_a + l_a p) i_a \quad (3)$$

$$v_{a20} - v_{b20} = (r_a^{'} + l_a^{'} p) i_a^{'} - (r_b^{'} + l_b^{'} p) i_b^{'} \quad (4)$$

Here r, l represents resistance & inductance

$$\mathbf{i_g = i_a + i_b = i_{a'} + i_{b'}} \quad (5)$$

Grid current equal to the sum of rectifier current A & B Circulating current i0 can be defined from i_a and $i_{a'}$ (or) i_b and $i_{b'}$

$$i_0 = i_a - i_{a'} = - i_b + i_{b'} \quad (6)$$

Introducing circulating current i_0 in equation (1), (2), & (3)

$$v_a = e_g - (r_a + l_a p) i_a - (r_a' + l_a' p)(i_a - i_0)$$

$$V_a = e_g - (r_a + l_a p) i_a - (r_a' i_a + l_a' p i_a - r_a' i_0 - l_a' p i_0)$$

$$V_a = e_g - (r_a + r_a' + l_a p + l_a' p) i_a + (r_a' + l_a' p) i_0 \quad (7)$$

Similar expression for vb

$$V_b = e_g - (r_b + r_b' + l_b p + l_b' p) i_a + (r_b' + l_b' p) i_0 \quad (8)$$

Where $i_a' = i_a - i_0$

$$V_{a10} - V_{a20} = V_a , \quad (9)$$

$$V_{b10} - V_{b20} = V_b \quad (10)$$

Adding equation (3) & (4) find out values of circulating voltage v_0

$$V_0 = -(r_a - r_a' + (l_a - l_a') p) i_a + (r_b - r_b' + (l_b - l_b') p) i_b - (r_a' + r_b' + (l_a' + l_b') p) i_0 \quad (11)$$

$$v_0 = v_{a10} + v_{a20} - v_{b10} - v_{b2o} \quad (12)$$

Therefore V_a & V_b from rectifier A & and rectifier B. V_0 from rectifier A & B are to regulate currents i_a ,ib and io respectively. Reference current $i_a^* \& i_b^* = i_g^* / 2$ Reference circulating current $i_0^* = 0$ In order to both facilitate the control and share equally current, voltage, and power between the rectifiers, the four inductors should be equal $r_g' = r_a = r_a' = r_b = r_b'$

$l_g' = l_a = l_a' = l_b = l_b'$

The model equation (7) – (9) can be submitted to model given by,

$$V_a + \frac{V_0}{2} = e_g - \left[r_g' + r_g' + (l_g' + l_g') p \right] i_a - (r_g' + l_g' p)$$

$$V_a + \frac{V_0}{2} = e_g - \left[2r_g' + 2l_g' p \right] i_a - 0$$

$$V_a + \frac{V_0}{2} = e_g - 2\left[r_g' + l_g' p \right] i_a \quad (13)$$

Similar expression for V_b

$$V_b - \frac{V_0}{2} = e_g - 2\left[r_g' + l_g' p \right] i_b \quad (14)$$

$$V_0 = -\left[r_g' + r_g' + (l_g' + l_g') p \right] i_0 - \left[r_g' - r_g' + (l_g + l_g') p \right] \times 0 + \left[r_g' + r_g' + (l_g' + l_g') p \right] \times 0$$

$$V_0 = -\left[2r_g' + 2l_g' p \right] i_0$$

$$V_0 = -2\left[r_g' + l_g' p \right] i_0 \quad (15)$$

Additionally, the equation for $i_a', i_b' and i_g'$ can be written

$$V_a - \frac{V_0}{2} = e_g - 2\left[r_g' + l_g' p \right] i_a' \quad (16)$$

$$V_b + \frac{V_0}{2} = e_g - 2\left[r_g' + l_g' p \right] i_b' \quad (17)$$

$$V_{ab} = e_g - \left[r_g' + l_g' p \right] i_g \quad (18)$$

We are using four identical inductors; the circulating current can be reduced to zero.

$$V_0 = V_{a10} + V_{a20} - V_{b10} - V_{b20} = 0 \quad (19)$$

When i_0=0 $i_a = i_a'$ $i_b = i_b'$ the system model (7) - (9) is reduced to

$$V_a = e_g - 2\left[r_g' + l_g' p \right] i_a' \quad (20)$$

$$V_b = e_g - 2\left[r_g' + l_g' p \right] i_b' \quad (21)$$

4. BOOST REGULATOR

Boost regulator means output voltage is greater than the input voltage. A boost regulator using power MOSFET (or) IGBT shown in fig 4.1. The circuit operation can be divided into two modes.

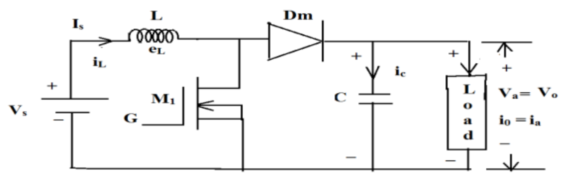


Fig 4.1 Circuit diagram of Boost Converter

Mode: 1

Mode 1 begins when transistor M1 is switched ON at t=0. The input current, which rises, flows through inductor L and MOSFET.

Mode: 2

Mode 2 begins when transistor M1 is switched OFF at t= t_1 . The current that was flowing through the transistor (MOSFET) would now flow through L, C, diode (D_m), & load .The input current, which falls, until transistor. M1 is turn ON again in the next cycle. Assuming that the inductor current raises linearly from I_1 to I_2 in time t_1

$$V_s = L(I_2 - I_1 / t_1) = L\Delta I / t_1$$

$$t_1 = L\Delta I / V_s \qquad (22)$$

And the inductor current falls linearly from I_2 to I_1 in time t_2

$$V_s - V_a = -L\Delta I / t_2$$

$$t_2 = \Delta IL / (V_a - V_s) \qquad (23)$$

Where $\Delta I = I_2 - I_1$ is the peak to peak ripple current of inductor L from equation (22) & (23)

$$\Delta I = V_s t_1 / L = (V_a - V_s) t_2 / L \qquad (24)$$

Sub suiting duty cycle k= t_1/T

t_1 =k T & t_2 = (1-k) T yields the average output voltage

$V_a = V_s T/t_2 = V_s T/(1-k) T$

$V_a = V_s /(1-k)$

$(1-k) = V_s/ V_a \qquad (25)$

Sub suiting k=t_1/T (duty cycle) into equation (4) yields

$k_1 = t_1 f$ where 1/T =f

$(1- \quad t_1 f) V_a = V_s$

$V_a - V_a t_1 f = V_s$

$V_a t_1 f = V_a - V_s$

$Gt_1 = V_a - V_s / V_a f \qquad (26)$

Assuming lossless circuit $V_s I_s = V_a I_a$

$V_s = V_a (1-k)$

$V_s I_s = V_s I_a / (1-k)$

The average input current is

$I_s = V_s I_a/ V_s(1-k) = I_a / (1-k)$

$I_s = I_a/ (1-k) \qquad (27)$

The switching period T can be found from

$T = 1/f = t_1 + t_2 =$

$$\Delta IL / V_s + \Delta IL / (V_a - V_s) = (\Delta IL(V_a - V_s) + \Delta ILV_s)/(V_s(V_a - V_s))$$

$$T = \Delta ILV_a / V_s(V_s - V_s) \qquad (28)$$

And this gives the peak to peak ripple current

$$T = 1/f = \Delta ILV_a / V_s(V_s - V_s)$$

$$f = V_s(V_a - V_s) / \Delta ILV_a$$

$$\Delta I = V_s(V_a - V_s) / fLV_a \qquad (29)$$

$1\text{-}k = V_s/V_a$

$k = 1\text{-} (V_s/V_a) = (V_a - V_s)/ V_a$

$$\Delta I = V_s k / fL \qquad (30)$$

When the transistor is ON, the capacitor supplies the load current for $t_1 = t_2$. The average capacitor current during time t_1 is $I_c = I_a$ and the peak to peak ripple voltage of the capacitor is

$$\Delta V_c = V_c = V_c(t=0)$$

$$= 1/C\int_0^{t1} I_c dt = 1/C\int_0^{t1} I_a = 1/C[I_a . t]_0^{t1}$$

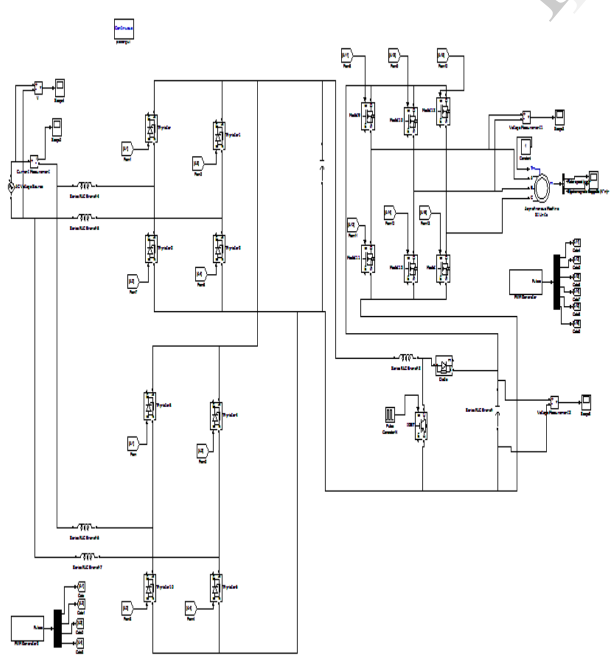
$$\Delta V_c = I_a t_1 / C \qquad (31)$$

Sub suiting $t_1 = (V_a - V_s)/V_a f$ from equation (5)

$$\Delta V_c = I_a (V_a - V_s)/V_a fC$$

$$\Delta V_c = I_a k / fC \qquad (32)$$

5. MATLAB/SIMULINK FOR THREE PHASE DRIVE SYSTEM (WITH BOOST CONVERTER)



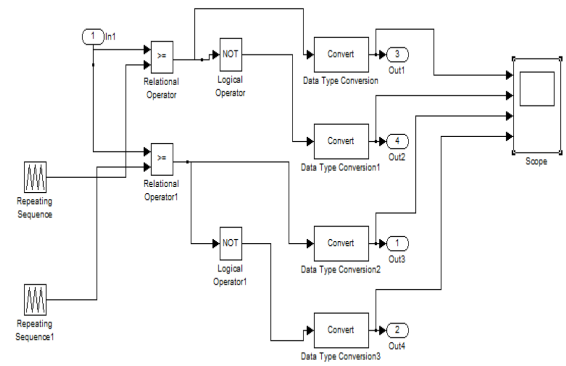


Fig 5.1 Simulation of the proposed system and the PWM technique

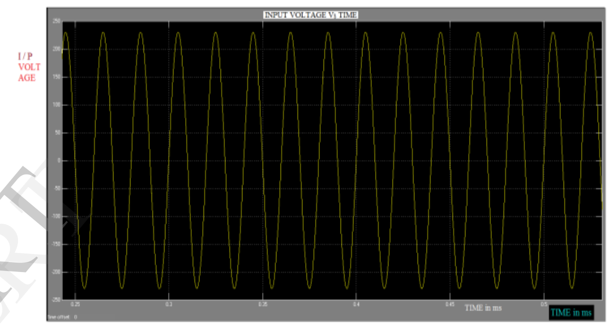


Fig 5.2 Input Voltage (Grid Voltage- E_g)

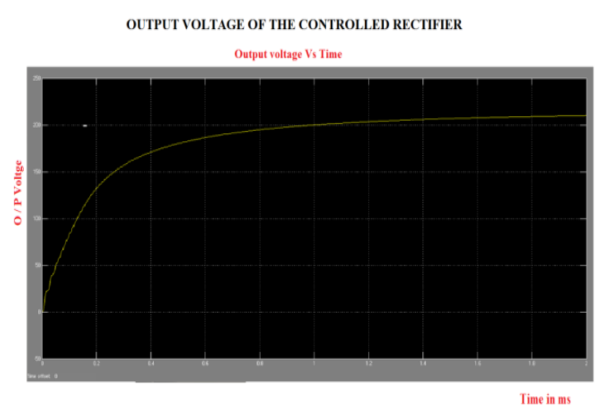
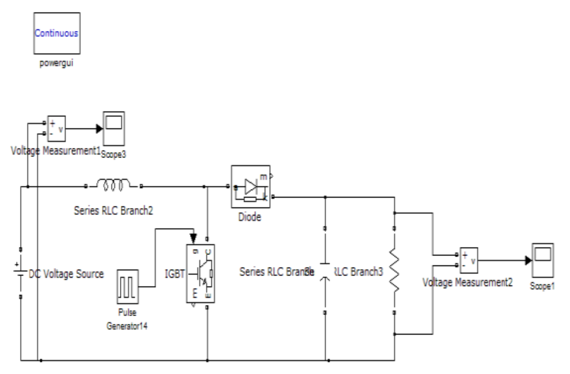


Fig 5.3 Output Voltage of the Controlled Rectifier



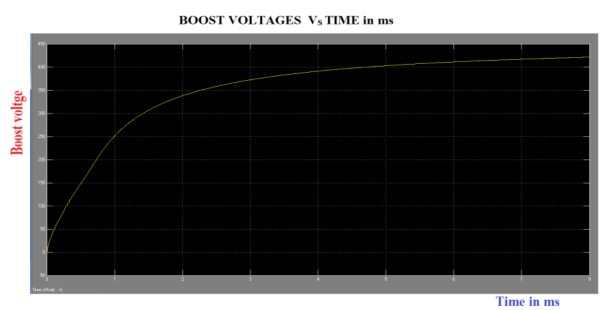


Fig 5.4 Output Voltage of the Boost Converter

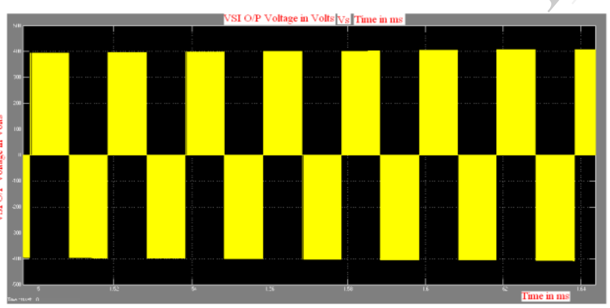


Fig 5.5 Output Voltage of the VSI Inverter

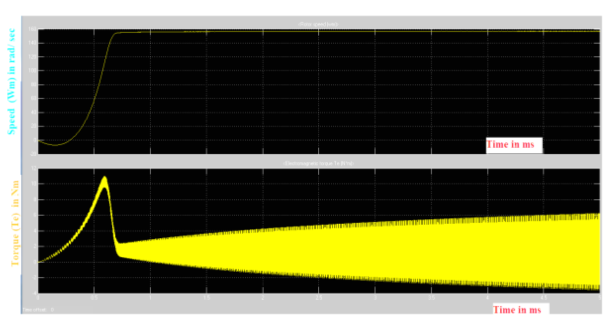


Fig 5.6 Torque, Speed Characteristics

6. CONCLUSION

A single phase to three phase drive system composed of two parallel single phase rectifiers, a three phase inverter and an induction motor was included. This project combines two parallel rectifiers without use of transformer. The compared to the conventional topology, the proposed system permits to reduce the rectifier switch currents, the THD of the grid current with same switching frequency and increases fault tolerance characteristics. Thus the losses of the system may be lower than that of the conventional part.

7. REFERENCES

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