Comparison of the harmonic reduction by using harmonic passive fitters and technique of intervene firing method at the pulse of the 6-pulse phase controlled converter.

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Abstract: This article introduces technique to reduce harmonic by using the 5^{th} and 7^{th} harmonic tune filter and line reactor in the comparison to the technique of intervening firing method at the pulse of the 6-pulse phase-controlled converter in every 1/6 period. The design of the technique introduced in this article is to reduce the harmonic distortion of the current and the voltage resulted from three-phase thyristor phase-controlled converter. The waveform obtained from the experiment was analyzed on the spectrum of the current, voltage and the total harmonic distortion. The double firing method causes zero vectors of output voltage and input current. Designing the mechanism of the converter based on the idea of Park Vector Theory, the number of harmonic distortion in the intervening firing method were compared to those in normal firing method.

1. INTRODUCTION

Phase control converter has been using Thyristor for the switching device that can able to be control short circuit. There are uses for height voltage system but the mainly problem of them are harmonic distortion of output voltage and so many inputs current. For solution concern harmonic distortion in old day used fitter to adjust frequency for variable inductors reactance equation capacitor reactance.

This article presently technique of intervene firing method, comparisons with normally intervening firing that use passive filter. Technique of intervene firing at the 6-pulse phase-controlled converter.

We use this technique for drive DC motor. There were from obtained from the experiment was analyzed on the spectrum of the current voltage, harmonic distortion (THD).

Design of passive harmonic filter and technique of intervene firing method.

1. Find the apparent Power (KVA) and amplitude of voltage that using for drive load.
2. And then

$$\mathbf{I} = \frac{\mathbf{S}}{\sqrt{3}\mathbf{V_p}} \qquad (1)$$

3. Compute impedance of system.

$$\mathbf{Z} = \frac{\mathbf{V_p}/\sqrt{3}}{\mathbf{I}} \quad \text{or} \quad \mathbf{Z} = \frac{\mathbf{V_p}/\sqrt{3}}{\mathbf{I}} \qquad (2)$$

4. Compute the value of line reactance and should be have 3-5% of impedances system.

$$\%\mathbf{X}_L = 3\% - 5\%(\mathbf{Z}) \qquad (3)$$

5. Compute inductance.

$$\mathbf{L} = \frac{\mathbf{X}_L}{2\pi f} \qquad (4)$$

Computing factor of the passion harmonic filter consist of

1. Define any parameter of system that use for harmonic filter.
2. Define reactance power.

$$\mathbf{Q}_{com} = k\mathbf{W}(\tan\theta_1 - \tan\theta_2) \qquad (5)$$

$\mathbf{Q}_{com}$ Reactive power $(kVAR)$
kW Real power (kW)
θ_1 angle of old power factor
θ_2 angle of new power factor

3. Analyze information harmonic current from exactly measurement or estimate and define number of filter.
4. Separate $\mathbf{Q}_{com}$ from follow the number of filter.
5. Define turning point of harmonic filter.
6. Define voltage of capacitor.

$$V_{Cr} \geq \frac{n_h^2}{n_h^2 - 1} \times V_{sys} \qquad (6)$$

V_{sys} voltage system
n_h turning value
V_{Cr} capacitor voltage

7. Define reactive power of capacitor that use.

$$Q_{Cr} = \frac{Q_{Com}}{\left[\frac{n_h^2}{n_h^2 - 1}\right] \times \left[\frac{V_{Sys}}{V_{Cr}}\right]^2} \qquad (7)$$

Q_{Com} compensation reactive power
Q_{Cr} capacitor reactive power

8. Find capacitor, inductor, and resistor.

$$X_c = \frac{V_{cr}^2}{Q_{cr} \times 10^3} \qquad (8)$$

$$C = \frac{1}{2\pi f \times X_c} \qquad (9)$$

$$L = \frac{X_c}{2\pi f \times n_h^2} \qquad (10)$$

$$R = \frac{X_L}{Q_F} \text{ ที่ } n_h^2 \qquad (11)$$

Q_F Qulity factor

9. Installation harmonic filter with system and analyze harmonic current in the path of system and inspects performance of harmonic filter.

$$I_{RMS,Li} = \sqrt{\left(I_{Fi,l} \times 1.1\right)^2 + \sum_{h=2}^{n} I_{Fi,h}^2} \qquad (12)$$

$I_{Fi,l}$ Current use in filter i at fundament frequency

$I_{Fi,h}$ Harmonic current i at harmonic filter

$I_{RMS,Li}$ Totally current that use in filter

Technique of intervening firing method

The basic modal of phase control converter, that uses for experiment show in fig.3 can able show below.

$$v_d(t) = \left[S_a(t)\ S_b(t)\ S_c(t)\right] \begin{bmatrix} v_{an}(t) \\ v_{bn}(t) \\ v_{cn}(t) \end{bmatrix} \qquad (13)$$

$$\begin{bmatrix} i_a(t) \\ i_b(t) \\ i_c(t) \end{bmatrix} = \begin{bmatrix} S_a(t) \\ S_b(t) \\ S_c(t) \end{bmatrix} i_d(t) \qquad (14)$$

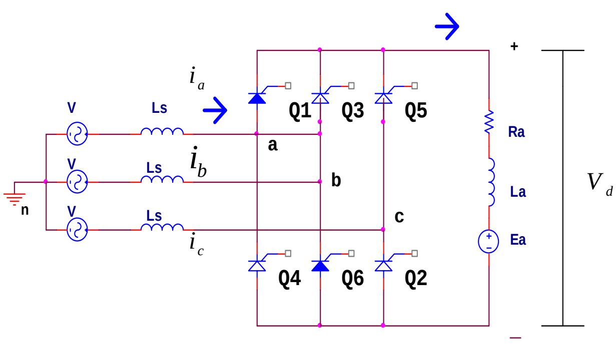

Fig.1 Three-phase thyristor control converter

Equation $S_a(t)$, $S_b(t)$ and $S_c(t)$ are switching function vector formula $s(t)$ of switching function can find like this

$$S(t) = \begin{bmatrix} S_x(t) \\ S_y(t) \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 0 & -\sqrt{3/2} & \sqrt{3/2} \\ 1 & -1/2 & -1/2 \end{bmatrix} \begin{bmatrix} S_a(t) \\ S_b(t) \\ S_c(t) \end{bmatrix} \qquad (15)$$

Input voltage

$$\begin{bmatrix} v_{an}(t) \\ v_{bn}(t) \\ v_{cn}(t) \end{bmatrix} = \begin{bmatrix} \sqrt{2}V_{an}\sin(\omega t) \\ \sqrt{2}V_{an}\sin(\omega t - 2/3\pi) \\ \sqrt{2}V_{an}\sin(\omega t - 4/3\pi) \end{bmatrix} \qquad (16)$$

Table 1 value of switching function

Conducting Switches	$S_a(t)$	$S_b(t)$	$S_c(t)$	$s(t)$
Q_5 และ Q_0	0	-1	1	S_1
Q_1 และ Q_6	1	-1	0	S_2
Q_1 และ Q_2	1	0	-1	S_3
Q_3 และ Q_2	0	1	1	S_4
Q_3 และ Q_4	-1	1	0	S_5
Q_5 และ Q_4	-1	0	1	S_6
Q_1 และ Q_4	0	0	0	S_0
Q_3 และ Q_6	0	0	0	S_0
Q_5 และ Q_2	0	0	0	S_0

Technique of intervene fining method at the pulse of the 6 pulse phase control converter in every 1/6 period. This article S_0 will be create. Consider the first 1/6 period before intervening firing of i_{G1}, at $\omega t = 0$. Thyristor Q_3, Q_4 enable a both and when there are intervening firing of i_{G1}, at $\omega t = 0$ Thyristor Q1 Trig when $v_{ab} \rangle 0$ in 1/6 period. Q_1 will be turned on and Q_3 turn off then vector of o/p. v_d and input current i_a, i_b, i_c = 0 when i_{G5} Trig and Q_5 also. When $v_{ca} \rangle 0$ in 1/6 period, Q_5 turn on and Q_1 turn off when output voltage, v_d become to v_{ca}. The sequence of Trig will be repeat. The result is value distortion in o/p voltage v_d reduction.

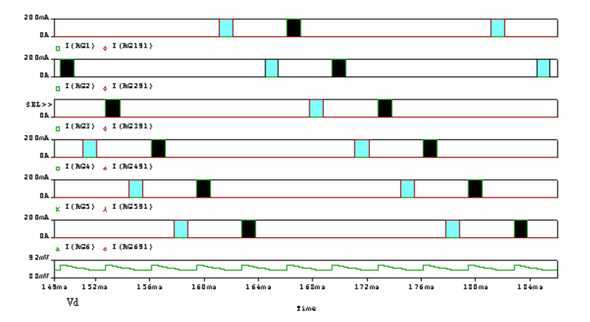

Fig 2 at $\alpha = 80^o,\ \beta = 20^o$

The value of distortion harmonic, V_d , V_{dmax} , I_a , S and V_{ripple} compute from equation below.

$$v_d(t) = v_d + \sum_{n=1}^{\infty} \sqrt{2} V_n \sin(n\omega t + \psi_n) \qquad (17)$$

$$v_{ab}(t) = \sqrt{2} V_{ab} \sin(\omega t + \frac{\pi}{6}) \qquad (18)$$

$$V_{ripple} = \sqrt{\sum_{n=1}^{\infty} V_n^2} \qquad (19)$$

$$I_a = \sqrt{\sum_{n=1}^{\infty} I_n^2} \qquad (20)$$

$$S = 3V_{an} I_a \qquad (21)$$

Result of experiment

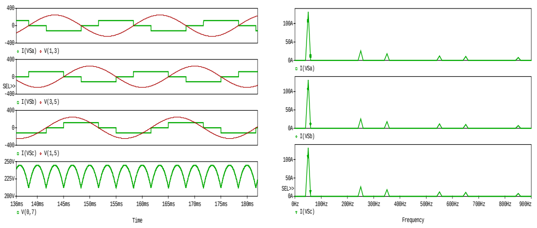

Fig 3 graph and current spectrum before take filter at $\alpha = 0^o$

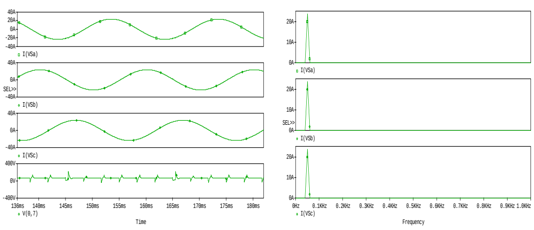

Fig 4 graph and current spectrum behind take filter at 5^{th} , 7^{th} and line reactor at $\alpha = 0^o$

Table 2 percentage of current harmonic $THD_i(\%)$ at $\alpha = 0^o, 30^o, 60^o$

Test Condition	$THD_i(\%)$		
	$\alpha = 0^o$	$\alpha = 30^o$	$\alpha = 60^o$
No Filters	24.61	27.16	27.36
Harmonic Filter $C_5 = 240\,\mu F$, $L_5 = 1.84\,mH$ $C_7 = 150\,\mu F$, $L_7 = 1.38\,mH$	2.98	4.35	4.65

The result of intervene firing

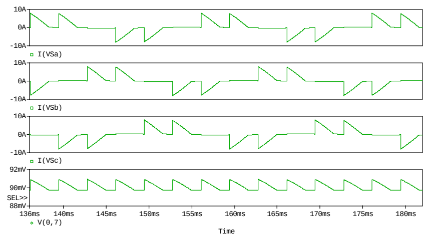

Fig 5 current graph i_a , i_b , i_c and voltage V_d at $\alpha = 80^o,\ \beta = 60^o$

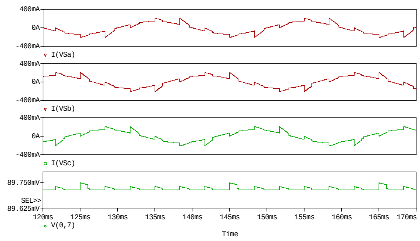

Fig 6 current graph i_a , i_b , i_c and voltage V_d at $\alpha = 120^o,\ \beta = 20^o$

Table 3 value of current harmonic $THD_i(\%)$ at $\alpha = 30^o - 120^o, \beta = 0^o - 60^o$ comparison with normally trig

Double Firing		$THD_i(\%)$	Firing	$THD_i(\%)$
α	β		α	
30	0	27.39	30	27.16
60	0	27.82	60	27.36
60	30	27.32	60	27.36
80	60	12.35	80	28.81
120	30	10.83	120	32.03
120	60	10.22	120	32.03

From fig. 3 and 4 $\alpha = 0^o, 30^o, 60^o$ harmonic filter passive can able reduction distortion harmonic but we consider THD(%) when the value of Trig's angle increase to much then input current and output voltage reduction the quality of filter reduction also.

Summarize

Reduction distortion harmonic from 6-pulse phase control converter show by to change space vector then can able make zero vector of output voltage and input current become to zero via every 1/6 period when comparison with passive harmonic filter

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