A Suppression Method of The Low Frequency Fluctuation of The Neutral Point Potential under 3-Level SHEPWM based on 3-Order Harmonic

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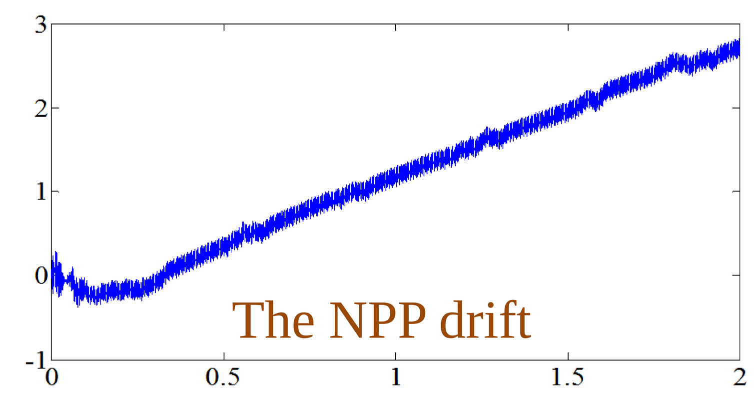
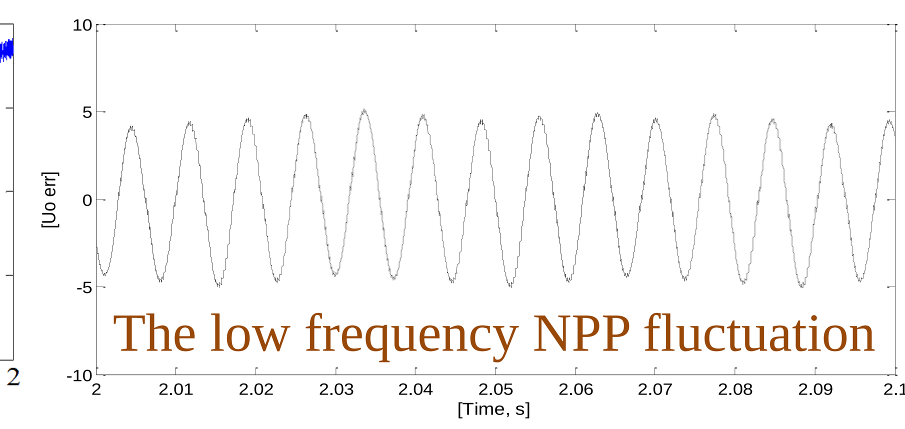
Introduction

For medium and high voltage high-power neutral-point-clamped (NPC) three-level converters, the neutral point potential (NPP) problem is a troublesome issue. Especially under selective harmonic elimination PWM (SHEPWM), the NPP problem will become more hard.

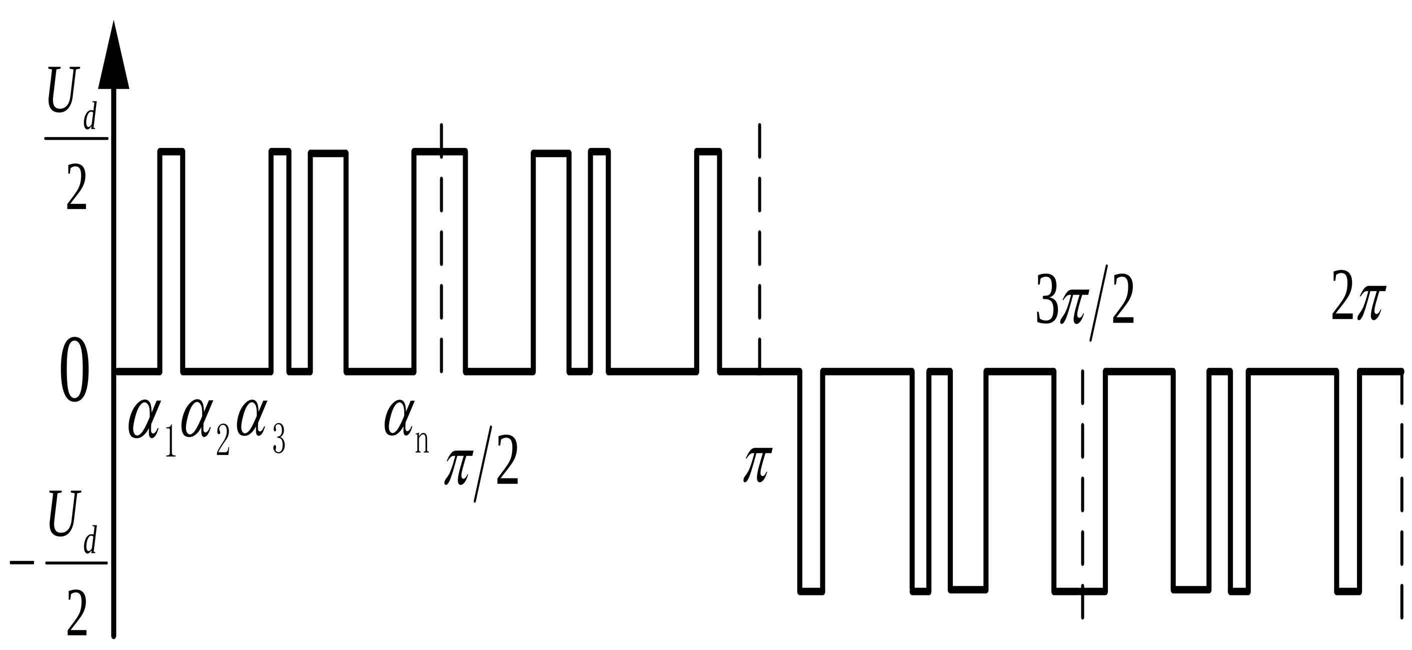
The classification of the NPP problem





The SHEPWM are the mainstream choices for high voltage high power applications.

The low frequency NPP fluctuation problem under SHEPWM is discussed.



The PWM waveform of phase *u*

$$a_n = \frac{2U_{dc}}{n\pi}\sum_{i=1}^{N}(-1)^{i+1}\cos(n\alpha_i), n=1,3,5\ldots$$

$$a_n = 0, n = 2,4,6,\ldots$$

$$b_n = 0, n = 1,2,3,\ldots$$

$$\begin{cases}|a_1| = \sum_{i=1}^{N}(-1)^{i+1}\cos(\alpha_i) = M\\ |a_n| = \sum_{i=1}^{N}(-1)^{i+1}\cos(n\alpha_i) = 0\end{cases}$$

The switching angles are usually be got via off-line calculation.

The proposed way tries to suppress the low frequency NPP fluctuation by setting the optimal k_3.

$$\begin{cases}|a_1| = \sum_{i=1}^{N}(-1)^{i+1}\cos(\alpha_i) = M\\ |a_3| = \sum_{i=1}^{N}(-1)^{i+1}\cos(3\alpha_i) = 3k_3M\\ |a_n| = \sum_{i=1}^{N}(-1)^{i+1}\cos(n\alpha_i) = 0\end{cases}$$

The relationship between 3-order harmonic component (k_3) and the NPP

The neutral point current (i_o):

$$i_o = (1-|v_u|)i_u + (1-|v_v|)i_v + (1-|v_w|)i_w = -|v_u|i_u - |v_v|i_v - |v_w|i_w$$

$$\begin{cases}v_{u1} = \frac{4}{\pi}M\sin(\theta)\\ v_{v1} = \frac{4}{\pi}M\sin(\theta-2\pi/3),\\ v_{w1} = \frac{4}{\pi}M\sin(\theta+2\pi/3)\end{cases}
\begin{cases}v_{u3} = \frac{4}{\pi}k_3M\sin(3\theta)\\ v_{v3} = \frac{4}{\pi}k_3M\sin(3\theta-2\pi)\\ v_{w3} = \frac{4}{\pi}k_3M\sin(3\theta+2\pi)\end{cases}
\begin{cases}i_u = I_m\sin(\theta-\varphi)\\ i_v = I_m\sin(\theta-2\pi/3-\varphi)\\ i_w = I_m\sin(\theta+2\pi/3-\varphi)\end{cases}$$

The voltages and currents

$$i_o = -\frac{4}{\pi}M|\sin(\theta)+k_3\sin(3\theta)|i_u - \frac{4}{\pi}M|\sin(\theta-2\pi/3)+k_3\sin(3\theta)|i_v - \frac{4}{\pi}M|\sin(\theta+2\pi/3)+k_3\sin(3\theta)|i_w$$

$$-1/3 < k_3 < 1$$

$$i_o = i_{o1} + i_{o3}$$

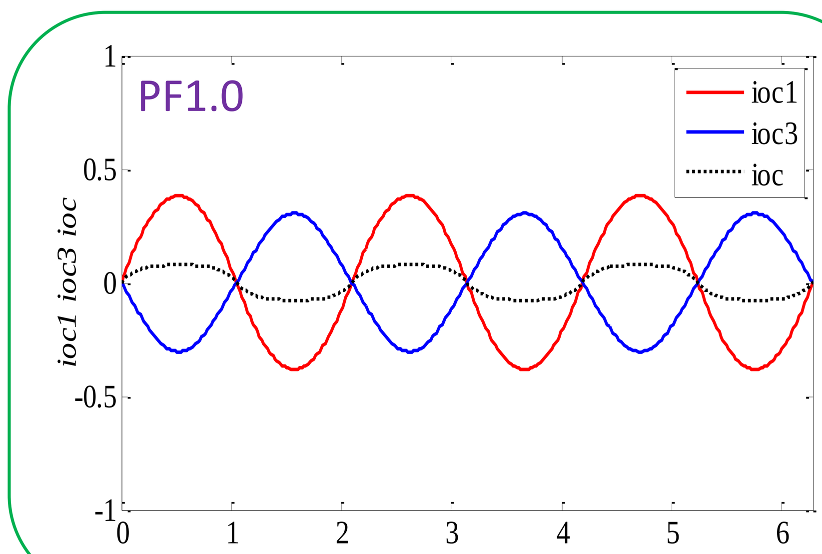
$$\begin{cases}i_{o1} = \frac{4MI_m}{\pi}\left[\frac{(-1)^r}{2}\cos(\varphi)+\cos\left(2\theta-\frac{2\pi}{3}-\varphi+\frac{\pi}{3}r\right)\right]\\ i_{o3} = \frac{4MI_m}{\pi}\left[2k_3\sin(3\theta)\sin\left(\theta-\frac{\pi}{3}-\varphi-\frac{\pi}{3}r\right)\right]\end{cases}$$

$$r = 1,2,3,4,5,6$$

$$\begin{cases}s(i_{o1}) = \int_0^{\pi/3} i_{o1} = \frac{4MI_m}{\pi}\left(\frac{\sqrt{3}}{2}-\frac{\pi}{6}\right)\\ s(i_{o3}) = \int_0^{\pi/3} i_{o3} = -\frac{4MI_m}{\pi}\left(\frac{3\sqrt{3}}{4}k_3\right)\end{cases}$$

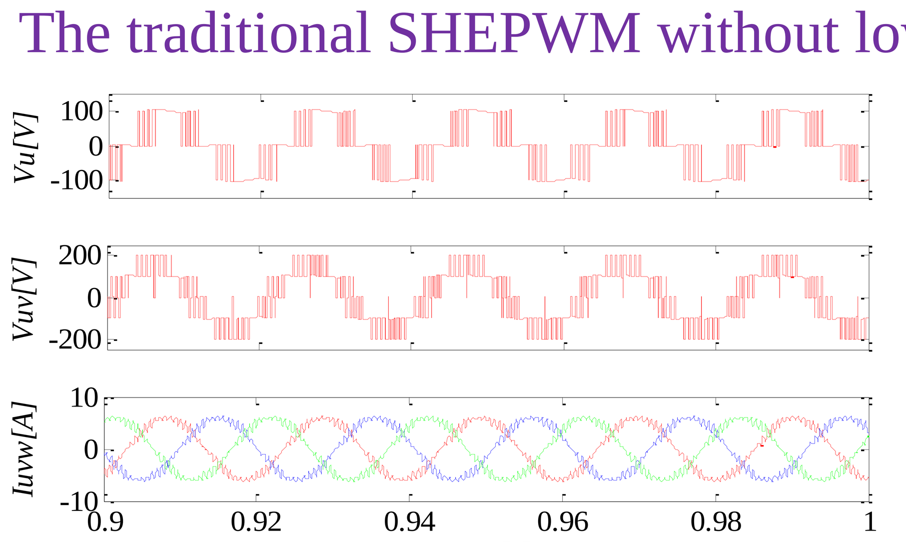
$$\begin{cases}s(i_{o1}) = s(i_{o3})\\ k_3 = 0.2636\end{cases}$$

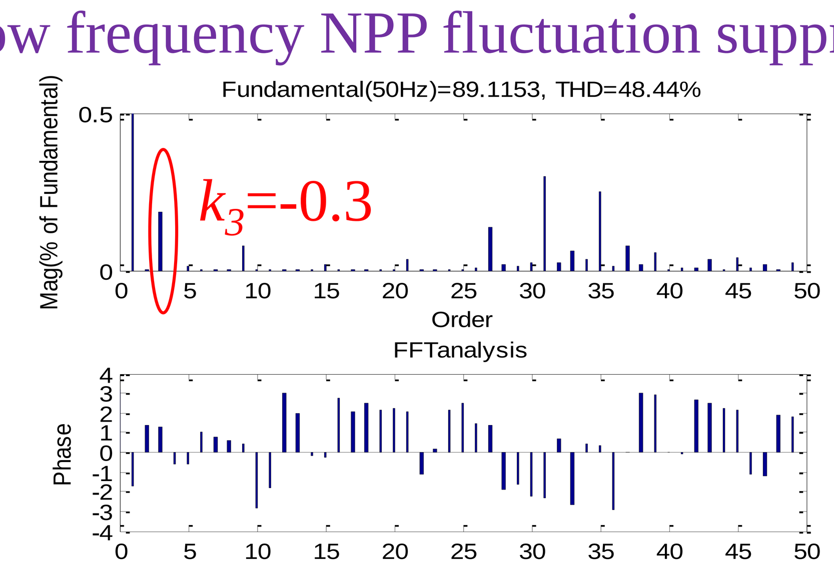
The optimal k_3

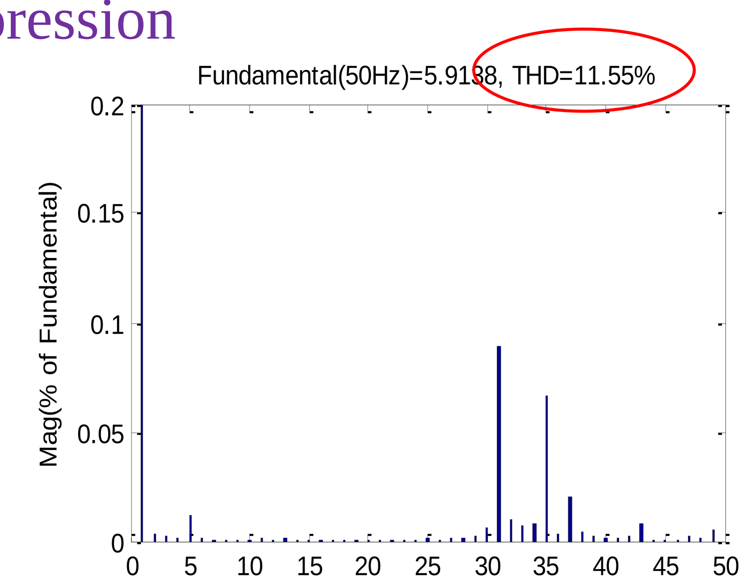


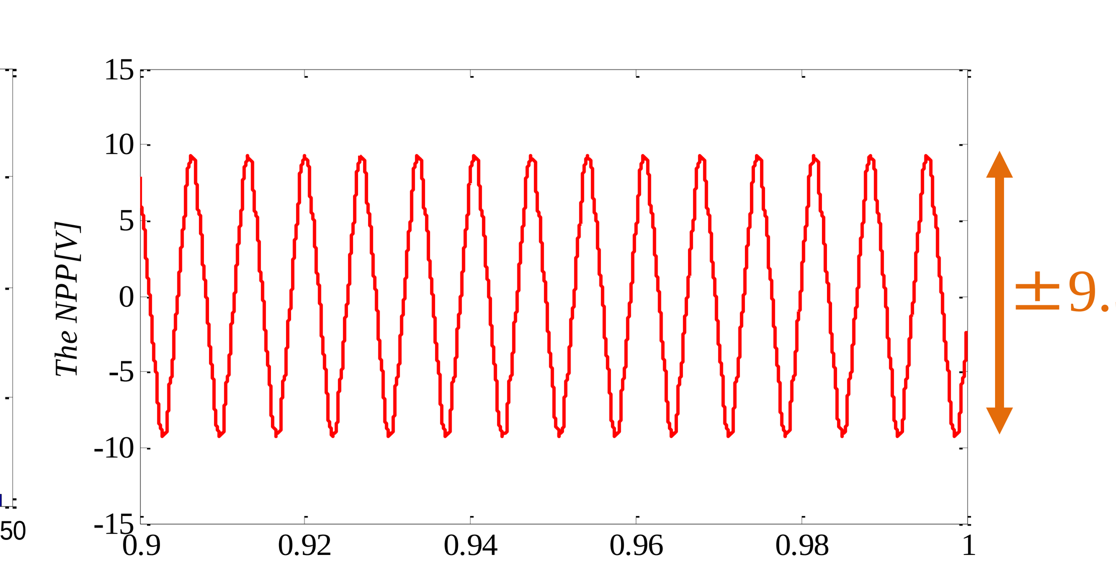
The simulation results

The traditional SHEPWM without low frequency NPP fluctuation suppression









The proposed SHEPWM method