A Novel PWM Scheme With Two Switching Frequencies And Wide Carrier To Improve The THD In Voltage Source Converters

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A Solution for The Grid

Existing Grid Challenges

According to the 2011 World Energy Outlook (WEO) by the International Energy Agency (IEA), the global energy demand will increase by 40% by 2035 and the global installed power generation is expected to double.

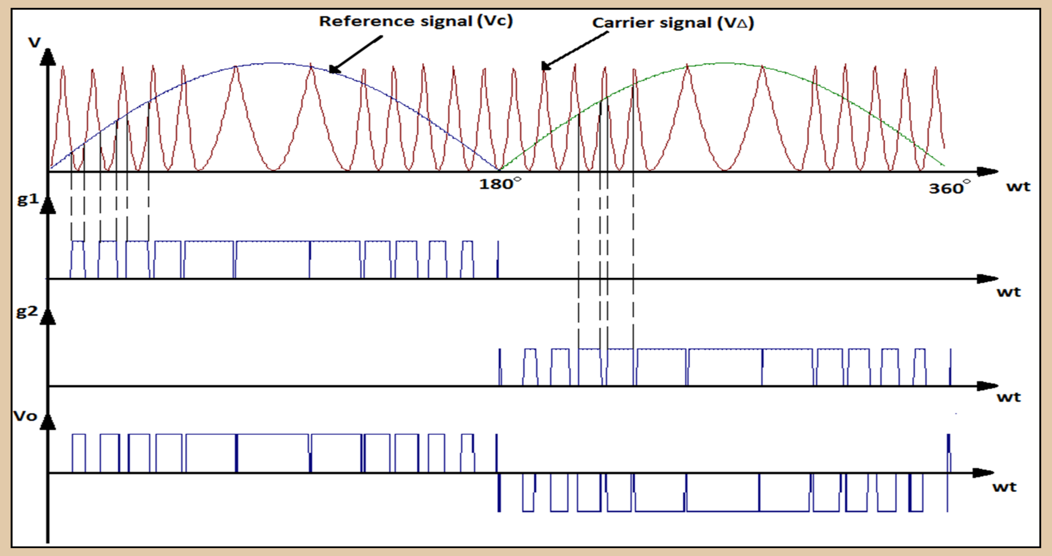
Trending Solutions

- Integrating more renewable energy sources is required to withstand the rapid increase in the demand.
- The improvement in energy conversion efficiency, from generation to the end-user, could save up to 20% in the primary energy

Power Electronics as the Solution

- Increasing the fundamental component and reducing the THD of the converters are the focal points.
- This can be achieved by developing a new Pulse Width Modulation technique.

The Concept of the VFSPWM Technique



Variable-Frequency Inverse Sinusoidal Pulse Width Modulation

- This method applied two concepts:
  1. Widening the ON state in the converters will increase the output fundamental component.
  2. The rate of change in information at the peak of the sinusoidal reference is relatively small

$$b_n = \frac{2}{T}V_{dc}\left[\int_0^{\alpha_1} sin\ n\omega t\, d(\omega t) + \int_{\alpha_1}^{\alpha_2} sin\ n\omega t\, d(\omega t) + \cdots + \int_{\alpha_m}^{\pi/2} sin\ n\omega t\, d(\omega t)\right]$$

$$= \frac{2V_{dc}}{T}\left(\frac{1 - cos\ n\alpha_1 + cos\ n\alpha_2 + \cdots + cos\ n\alpha_m}{n}\right)$$

$$= \frac{2V_{dc}}{nT}\left[1 + \sum_{k=1}^{m} cos(n\alpha_k)\right]$$

Since $T = \frac{\pi}{2}$,then

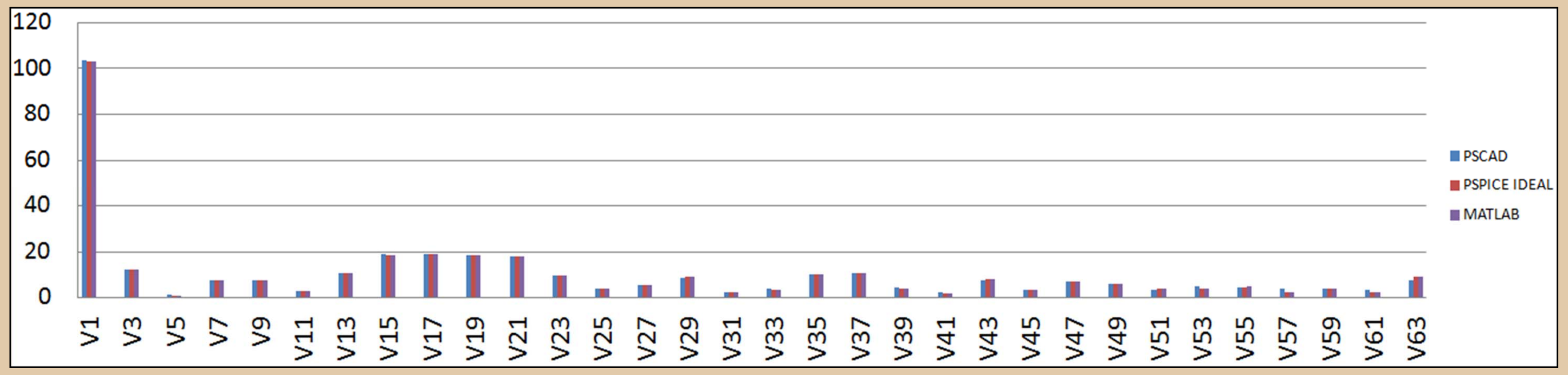
$$b_n = \frac{4V_{dc}}{n\pi}\left[1 + \sum_{k=1}^{m}(-1)^k\, cos(n\alpha_k)\right] \text{ for n=1,3,5,...}$$

The Mathematical Representation of the VFSPWM technique

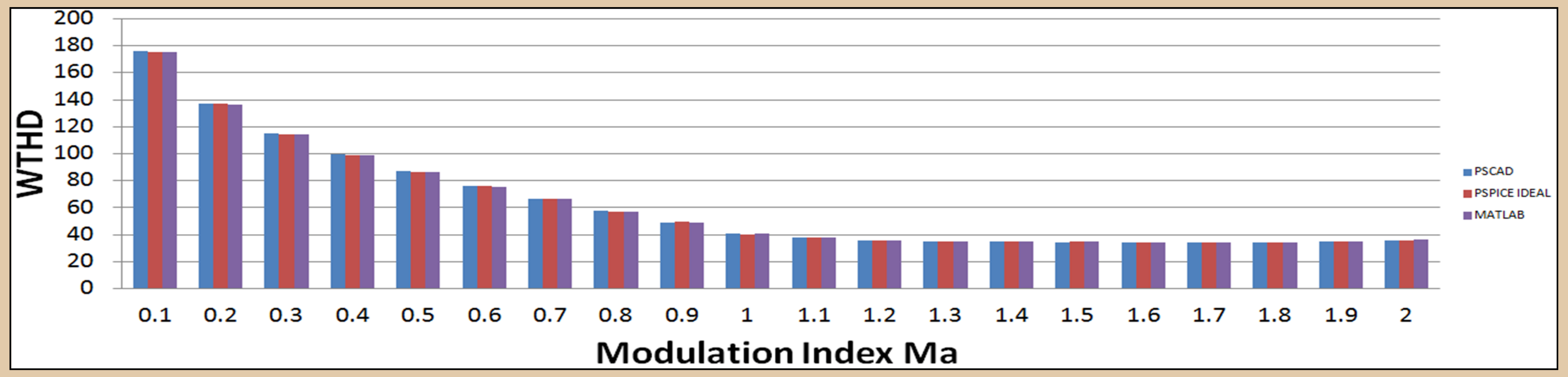
```
ang = [fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(1),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(2),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(3),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(4),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(5),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(6),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(7),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(8),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(9),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf1*(x)))-Ma*sin(x),x(10),[0 pi/3]);
     fzero( @(x)1-abs(cos(Mf2*(x)))-Ma*sin(x),x(11),[pi/3 pi/2]);
     fzero( @(x)1-abs(cos(Mf2*(x)))-Ma*sin(x),x(12),[pi/3 pi/2])]
```

Matlab Implementation

Model Validation using Matlab/Simulink and PSPICE OrCAD



VFSPWM Spectrum - ma = 0:9, $m_{f\text{-}low}$ = 3 and $m_{f\text{-}high}$ = 9



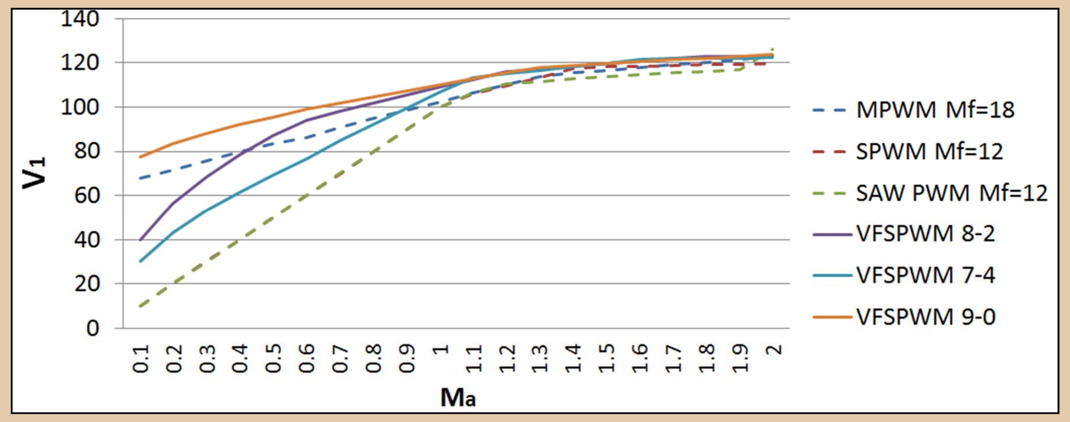
VFSPWM WTHD vs Modulation Index Ma

- To ensure the validity of the PSCAD/EMTDC model, a mathematical representation was developed in Matlab and in PSPICE OrCAD.
- The WTHD and the first 63 harmonics of the inverter output signal were compared in both simulation packages to the PSCAD model as shown in the figures to the left.

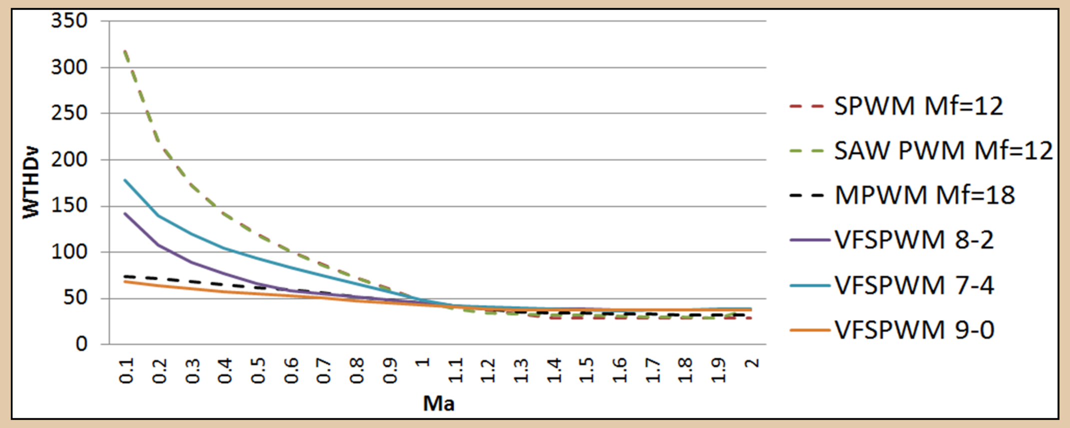
Performance Evaluation

The comparison in this section shows the result of the fundamental component and the WTHD vs the modulation index. The SPWM technique is the reference (benchmark) method because this technology is the most commonly used in the industry. The modulation techniques are evaluated based upon the converter switching frequency and the switching stress.

Switching Frequency



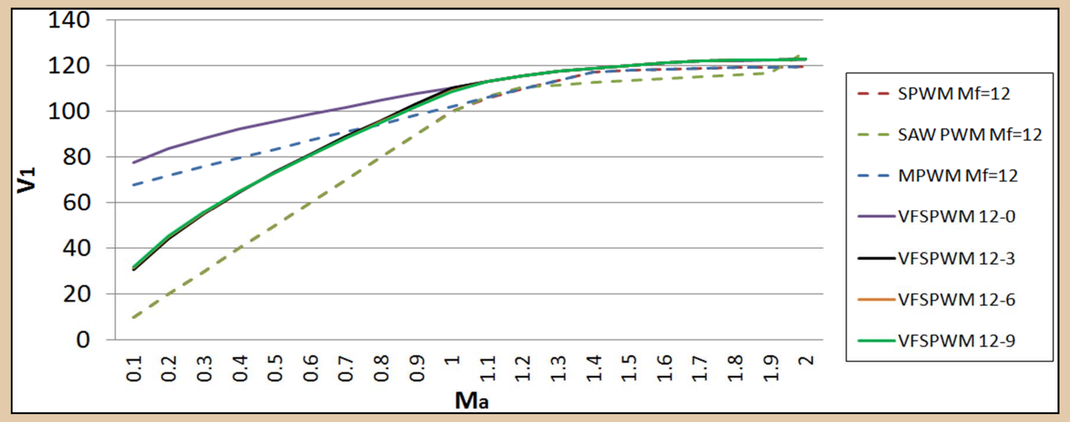
V1 vs Ma, M_f=12 with the same switching per cycle



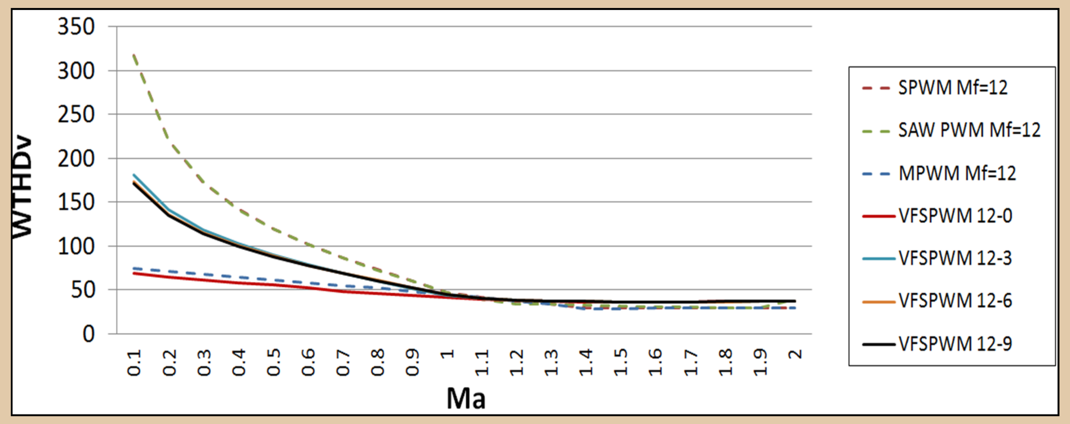
Voltage WTHD of the modulation techniques with the same switching

- To evaluate the new modulation technique, one way to do the comparison with the SPWM is by checking the fundamental component and the WTHD for the modulation techniques while the switching frequency is the same; hence switching losses.

Switching Stress, dv/dt



V1 vs Ma, M_f=12 with the same stress



Voltage WTHD of the modulation techniques with the same stress

- This test examines the modulation techniques with the same stress, dv/dt. It satisfies the fact that the number of pulses during the high slope interval is the same compared to standard PWM strategies.
- This result is expected because the inverter output does not rely on the lower harmonics.