A New Control Method for Shunt Active Filters Based on Sinusoidal Signal Integrators

Ebrahim Babaei
Majid yavari
Seyed Hossieni Hossieni

Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tabriz, Iran
Contents

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Introduction

- Importance of **power quality for sensitive loads**
- **Harmonic problems in distribution systems**

- What are the solutions?

**Solutions:**
- LC filters
- Active filters
- Hybrid filters
Introduction

Challenges:

- Filter characteristics depend on the source impedance,
- The shunt filter can suffer from series resonance with the source,
- Passive filters are large
- Have constant compensation characteristic
Active filters can be divided into two groups:
- Shunt active filter
- Series active filter

Shunt active filter

Series active filter

Hybrid filter
Proposed control method

Proprietary Sinusoidal Signal Integrator (PSSI)

The transfer function of a PSSI is given by

\[ H(S) = K_p + \frac{2 \cdot K_i \cdot s}{s^2 + \omega^2} \]

\( K_p \) is the proportional gain
\( K_i \) is the integral gain
\( \omega \) is the resonance frequency

Block diagram of a PSSI
Proposed control method

- Lines currents converted to three positive, negative, and zero sequences

\[
i_a = \sqrt{2} \sum_{n=1}^{\infty} I_{1,a,n} \sin(n \omega t + \phi_{1,n}) + \sqrt{2} \sum_{n=1}^{\infty} I_{2,a,n} \sin(n \omega t + \phi_{2,n}) + \sqrt{2} \sum_{n=1}^{\infty} I_{0,a,n} \sin(n \omega t + \phi_{0,n})
\]

\[
i_b = \sqrt{2} \sum_{n=1}^{\infty} I_{1,b,n} \sin \left( n \omega t + \phi_{1,n} - \frac{2\pi}{3} \right) + \sqrt{2} \sum_{n=1}^{\infty} I_{2,b,n} \sin \left( n \omega t + \phi_{2,n} + \frac{2\pi}{3} \right) + \sqrt{2} \sum_{n=1}^{\infty} I_{0,b,n} \sin(n \omega t + \phi_{0,n})
\]

\[
i_c = \sqrt{2} \sum_{n=1}^{\infty} I_{1,c,n} \sin \left( n \omega t + \phi_{1,n} + \frac{2\pi}{3} \right) + \sqrt{2} \sum_{n=1}^{\infty} I_{2,c,n} \sin \left( n \omega t + \phi_{2,n} - \frac{2\pi}{3} \right) + \sqrt{2} \sum_{n=1}^{\infty} I_{0,c,n} \sin(n \omega t + \phi_{0,n})
\]

- Consider the following transfer functions:

\[
T_{a'} = \frac{2}{\sqrt{3}} \frac{\cos \omega \theta}{\sin \omega \theta}
\]

\[
T_{a''} = \frac{2}{\sqrt{3}} \frac{\cos \omega \theta}{\sin \omega \theta}
\]

\[
\frac{i_a}{\vdash i_v} = \frac{v_{a'}}{\bar{v}}
\]

\[
\frac{i_b}{\bar{i}} = \frac{v_{a'}}{\bar{v}}
\]

- Using the above equations, we have:

\[
i_a \sin((1)\sin((1))^{1}_{1,a} = \sqrt{33}
\]

\[
i_a \cos((1)\cos((1))^{1}_{1,a} = \sqrt{33}
\]

- Fifth order harmonics:

\[
i_{5,a} \sin((5)\sin((5))^{1}_{1,5} = \sqrt{33}
\]

\[
i_{5,a} \cos((5)\cos((5))^{1}_{1,5} = \sqrt{33}
\]
Consider the following transfer functions:

\[
T'_{dq} = \frac{1}{\sqrt{3}} \left( 2 \cos \omega + \sin \omega \right)
\]

Using the above equations, we have:

\[
\frac{I_{le}}{I_{le}}(\omega) = \sqrt{3} \left( \frac{I_{le}}{I_{le}}(\omega) \sin(\omega) + \frac{I_{le}}{I_{le}}(\omega) \cos(\omega) \right)
\]

Fifth order harmonics:

\[
\frac{I_{le}}{I_{le}}(\omega) = \sqrt{3} \left( \frac{I_{le}}{I_{le}}(\omega) \sin(6\omega) + \frac{I_{le}}{I_{le}}(\omega) \cos(6\omega) \right)
\]
Similarly, the harmonic components in positive and negative sequences can be obtained for seventh, eleventh, thirteenth, seventeenth, and nineteenth order harmonics in the rotating reference frame with $+\omega$ and $-\omega$ rotation speeds.

<table>
<thead>
<tr>
<th>Harmonic component decompose to the component of positive and negative</th>
<th>Angular Frequency Signal, after applying to the reference frame $+\omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{1,5}$</td>
<td>$4\omega$</td>
</tr>
<tr>
<td>$I_{2,5}$</td>
<td>$6\omega$</td>
</tr>
<tr>
<td>$I_{4,7}$</td>
<td>$6\omega$</td>
</tr>
<tr>
<td>$I_{2,7}$</td>
<td>$8\omega$</td>
</tr>
<tr>
<td>$I_{13,1}$</td>
<td>$10\omega$</td>
</tr>
<tr>
<td>$I_{23,1}$</td>
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<tr>
<td>$I_{13,3}$</td>
<td>$14\omega$</td>
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<tr>
<td>$I_{11,7}$</td>
<td>$16\omega$</td>
</tr>
<tr>
<td>$I_{21,7}$</td>
<td>$18\omega$</td>
</tr>
<tr>
<td>$I_{11,9}$</td>
<td>$18\omega$</td>
</tr>
<tr>
<td>$I_{21,9}$</td>
<td>$20\omega$</td>
</tr>
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</table>

<table>
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<th>Harmonic component decompose to the component of positive and negative</th>
<th>Angular Frequency Signal, after applying to the reference frame $-\omega$</th>
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</thead>
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<tr>
<td>$I_{2,5}$</td>
<td>$4\omega$</td>
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<tr>
<td>$I_{4,7}$</td>
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<td>$18\omega$</td>
</tr>
</tbody>
</table>
Proposed control method

Block diagram of proposed current control scheme
System parameters

• RMS value of the line-to-line network voltage is considered 200V.
• **The value of source inductance (L_s) is 0.15mH.**
• The value of line-side inductance (L_l) is 2.5mH.
• **The value of active filter inductance (L_f) is 0.5mH.**
• The load is considered as a thyristor controlled rectifier with 70 degrees firing angle used to feed a resistance-inductance dc load.
• **Resistance value of load is 2.5Ω** and inductance value of load is 1mH.
Simulation results of the Proposed method

THD of the line current is decreased from 28% to 1.98%

Simulation results of conventional method

THD of the line current is decreased from 28% to 3.7%
Simulation results

Proposed method

Reference method

The spectrum of line current

The spectrum of load current

The spectrum of active filter current
Conclusions

• In this paper, a new controller is proposed for shunt active filters.

• A distinctive advantageous of the proposed method over other methods is using a single rotating reference frame.

• In the proposed method, the load current harmonics can completely compensated in both positive and negative sequences.

• This results in a distinctive current THD reduction.
Thanks for your Attention