Reducció del corrent reactiu en un filter híbrid de quatre fils

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Índex

• **Introducció**
• **Presentació de l’estructura de quatre fils**
• **Descripció del control**
• **Reducció de la corrent reactiva**
• **Resultats de simulació i experimental**
• **Conclusions**
INTRODUCTION

• **Main drawbacks of classic parallel APF:**
  – Need high voltage DC BUS
  – **Two options:**
    • Three leg inverters: Need split DC capacitor
    • Four leg inverters: neutral leg oversized to support k.3 harmonics

• **Hybrid APF solution:**
  – L-C Coupled APF (Hybrid Filter) ➔ Lower DC bus voltage
  – Neutral connection to negative of DC BUS ➔ Only 3 legs

• The advantages and disadvantages are presented
LC COUPLED 4 WIRE STRUCTURE

ADVANTAGES

500µF/80uH, for 400VAC,
63A filt. (smaller \(L_C\))

Lower DC voltage. (400\(V_{DC}\),
but can operate with 100\(V_{DC}\))

Lower \(C_{DC}\) and more
tolerance with DC ripple

Voltage sharing control not
required and still symmetric
\(+V_{DC}/2\) to \(−V_{DC}/2\) voltage
LC COUPLED 4 WIRE STRUCTURE

DRAWBACKS

Fixed leading current (25kvar for 63A at 400V\textsubscript{AC})

This connection requires \( V_{\text{DC}} \) control at coupling \( C_C \)
**CONTROL (1)**

- Filter is based on a current controlled Voltage Source Inverter (VSI)
- Current controller must perform three functions
  - $i_{F^*}$ is composed of three reference terms
CONTROL (2)

- **The ripple current to be cancelled** ($i_H$)
  - Load current subtracted from fundamental component
  - Fundamental component derived from active power

- **The necessary current** ($i_{CC}$) **to maintain the DC voltage of coupling capacitor at** $V_{DC}/2$
  - PI controller

- **The necessary current** ($i_{AC}$) **to cancel the mains voltage**
  \[ i_{AC}^* = V_{PH} \cdot j \cdot \omega \cdot C = V_{PH} \cdot j \cdot K_C \]
  - $i_{AC}$ reduced mains voltage partially cancelled
    - VSI voltage must be increased
    - $di/dt$ achievable is reduced
**CONTROL (3)**

![Control Diagram](image)

- **Windowed Filter 20ms**
- **PLL**
- **Zero crossing detector**
- **Fundamental Reference Generation**
- **Phase Amp**
- **Zero crossing detector**
- **Fundamental Reference Generation**

Mathematical expressions:

- \( P = \frac{1}{T} \int v \cdot i \cdot dt \)
- \( Q = \frac{1}{T} \int v \cdot i \cdot e^{-j\frac{\pi}{2}} dt \)
- \( \varphi = \tan^{-1} \frac{Q}{P} \)

Control parameters:**

- \( K_C \)
- \( i_{cc}^* \)
- \( i_{AC}^* \)
- \( i_{F}^* \)
- \( i_{H}^* \)
- \( i_x^* \)
- \( V_{DC} \)
CONTROL (3)

\[ i_{H^*} \rightarrow \frac{1}{4} \sum_{j}^{i-4} i_{Hj} \rightarrow i_{H^*} \rightarrow i_{Hj} - i_{Hj-1} \rightarrow \text{MAX} \left( \frac{\Delta i_{Hj}}{\Delta t} + \frac{\Delta i_{Hj-1}}{\Delta t} \right) \rightarrow \text{MAX} \rightarrow \frac{\Delta i_{Hj}}{\Delta t} \text{ MAX} \rightarrow 0 \div 1 \rightarrow + \rightarrow \frac{1}{K_C} \rightarrow K_C \]

\[ \frac{i_{F_{\text{RMS}}}}{\text{MAX}} \rightarrow \text{RMS} \rightarrow i_{HRMS} \rightarrow \text{RMS} \]

\[ K_C \text{ is reduced if:} \]

- Small harmonic current contents
- Small \( \text{di/dt} \)
LOAD AND MAINS CURRENTS:
Simulation of Case 2: unbalanced load

Simulated

\( I_{\text{load}} \) (soft) and \( I_{\text{mains}} \) (Bolt)

\( I_{\text{mains}} \) THD
- Without filter \( \text{THD}(I)=20.26\% \)
- With filter \( \text{THD}(I)=5.9\% \)
LOAD AND MAINS CURRENTS: Experimental Case 2: unbalanced load

Experimental $I_{\text{mains}}$ during a filter stop
10 A/div; 10ms/div
without compensation ($I_{\text{mains}}=I_{\text{load}}$) and with compensation ($I_{\text{mains}}$)

Without filter
$THD(I)=20.5\%$

With filter
$THD(I)=6.1\%$
COUPLING CAPACITORS VOLTAGE IN CASE 2

Simulated for case 2: Unbalanced load

Experimental for case 2: Unbalanced load
Simulated currents and $K_C$ evolution
Experimental currents
CONCLUSIONS

- **Main feature**: Leading current reduction in a hybrid parallel APF
- **Advantages of such improvement**:
  - The neutral current can be much higher
  - Single Capacitor Bus
  - DC bus voltage may be reduced
- **The paper presents an improvement in control method based on time domain techniques, which gives a fast response**
- **The behaviour of this improvement has been demonstrated by simulation and experimental tests.**
Thank you for your attention
REFERENCES


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Notice the great asymmetry of voltages available to inject the required current. Requires high $V_{DC}$ or very low $L_C$. 
**EQUIVALENT CIRCUIT (ONE PHASE)**

\[
V_{CC} = V_{AC} + V_{DC(CC)} = -V_X + \frac{V_{DC}}{2}
\]

- **Mains voltage** \( V_X \)
- **Neutral** \( V_N \)
- **Coupling capacitor voltage** \( V_{CC} \)
- **Filter current** \( I_F \)
- **Symmetric** +\( V_{DC}/2 \) to −\( V_{DC}/2 \) voltages

**Notes:**
- \( V_{AC} \)
- \( V_{DC} \)
- \( I_X \)
- \( L_C \)
- \( C_C \)