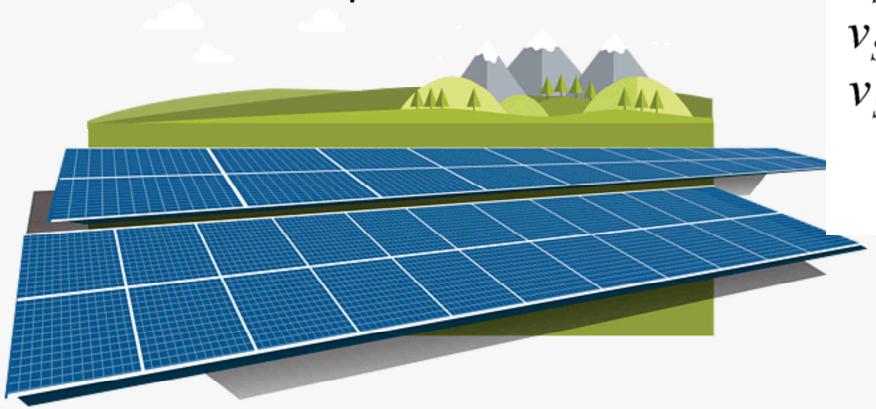
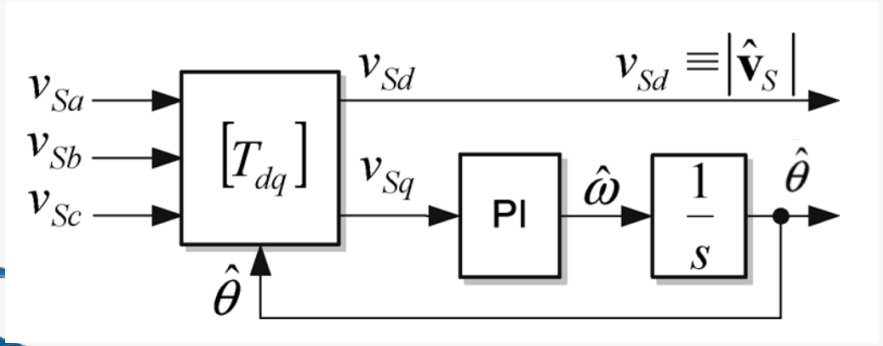
Modelagem e Controle de Sistemas Fotovoltaicos

Aula 06 – P2: Estruturas de Sincronismo com a Rede Elétrica (PLL)

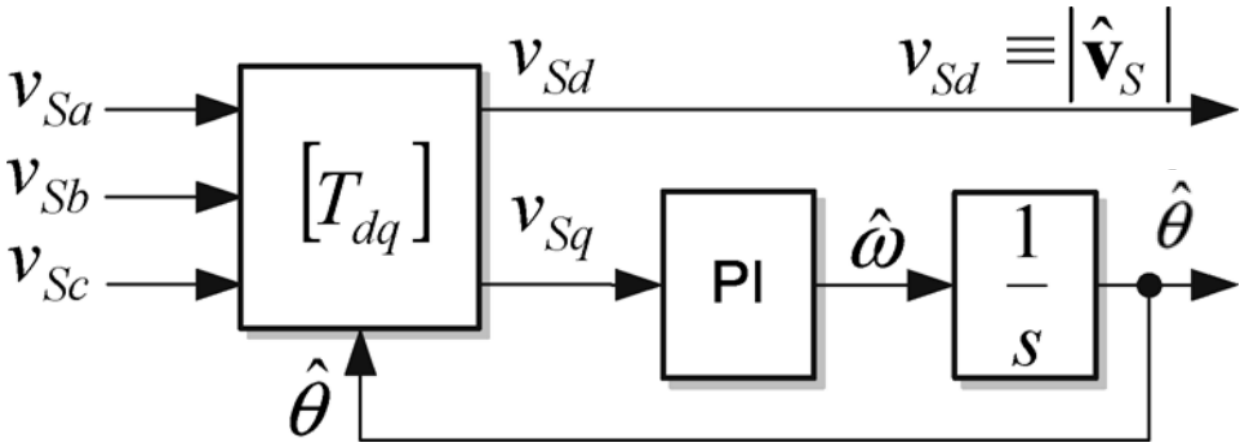
Prof. Heverton Augusto Pereira
heverton.pereira@ufv.br





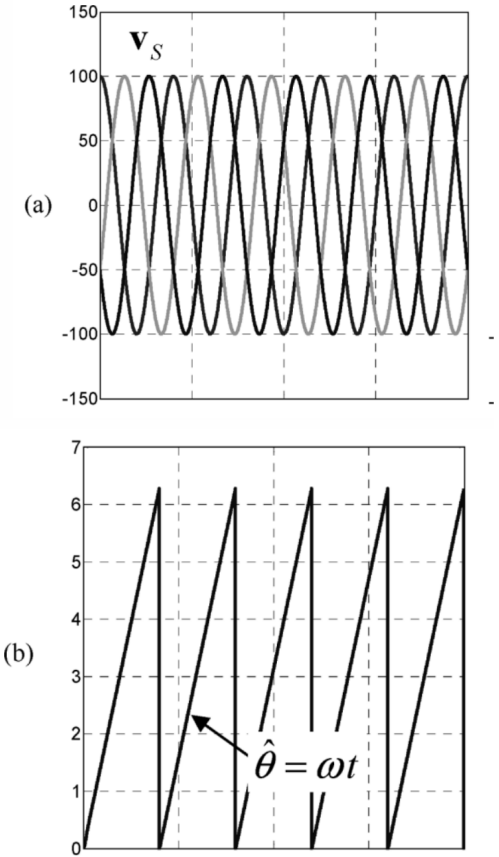
SRF-PLL – Synchronous Reference Frame

- ✓ Transformação abc-dq
- ✓ Controlador PI
- ✓ Estrutura simples
- ✓ Susceptível a distúrbios da rede como tensões desbalanceadas e componentes harmônicas



Fonte: P. Rodriguez, J. Pou, J. Bergas, J. I. Candela, R. P. Burgos, and D. Boroyevich, “Decoupled double synchronous reference frame PLL for power converters control,”IEEE Trans. Power Electron., vol. 22, no. 2, pp. 584–592, Mar. 2007.

SRF-PLL – Synchronous Reference Frame



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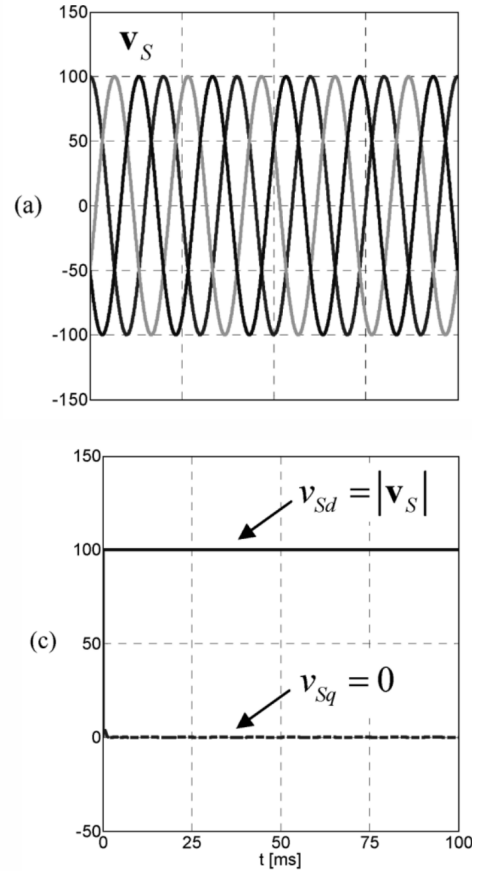

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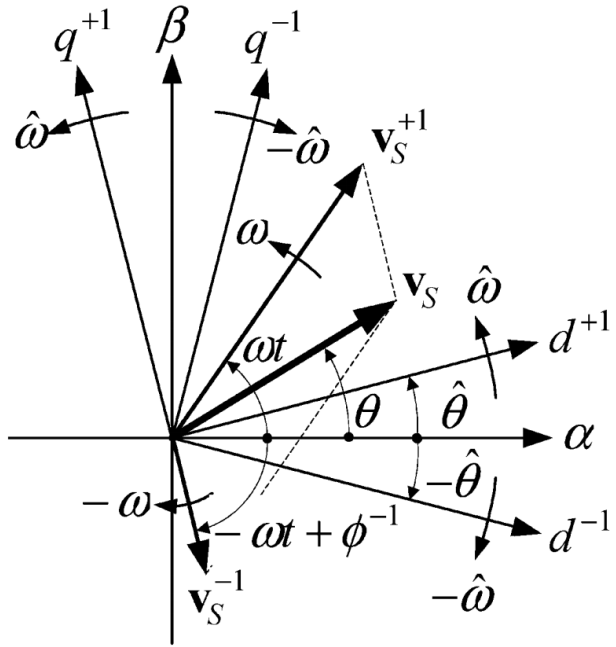
DDSRF – Decoupled Double Synchronous Reference Frame

- ✓ Transformação abc-αβ
- ✓ **Transformação αβ-dq**
- ✓ dq: sequência positiva



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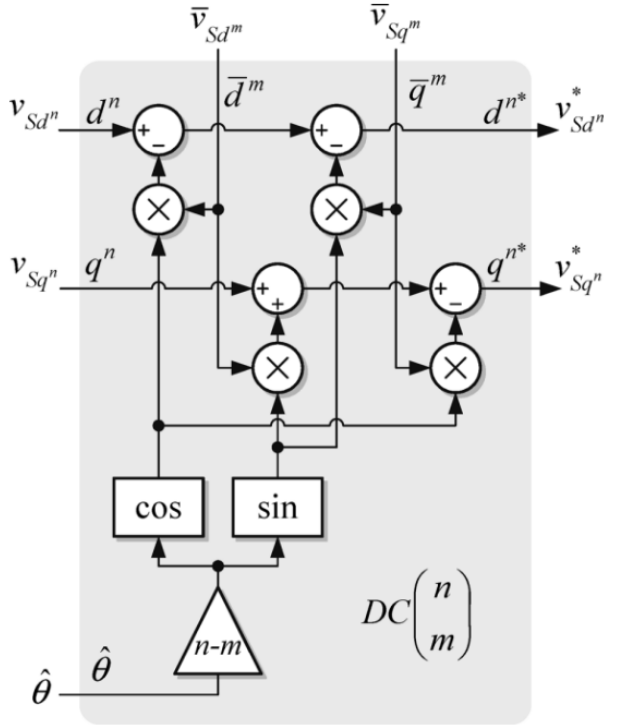
DDSRF – Decoupled Double Synchronous Reference Frame

- ✓ Desacoplamento entre sequência positiva e negativa



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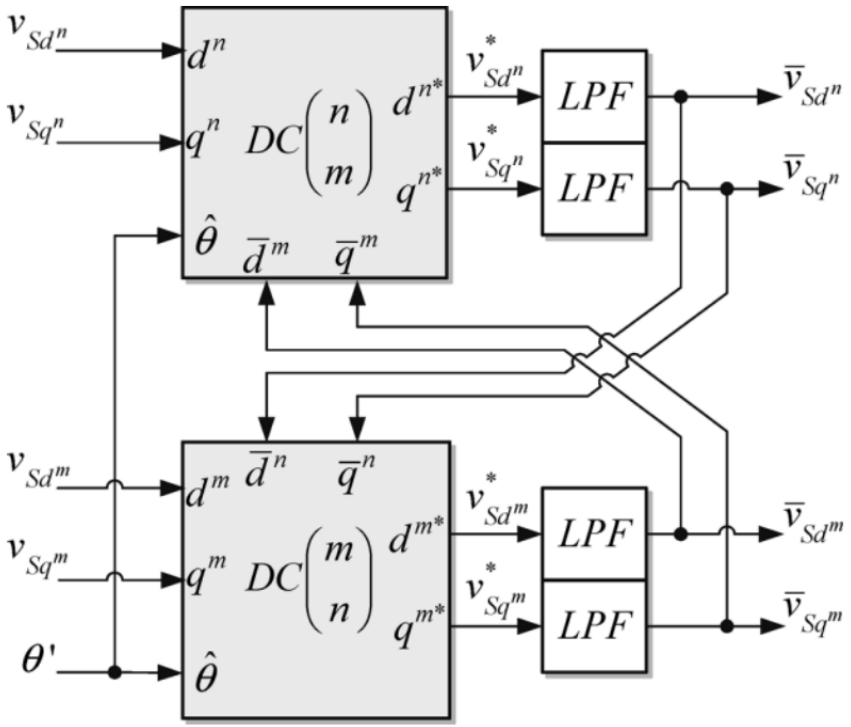
DDSRF – Decoupled Double Synchronous Reference Frame

- ✓ Desacoplamento entre sequência positiva e negativa
- ✓ Uso de filtro passa baixas



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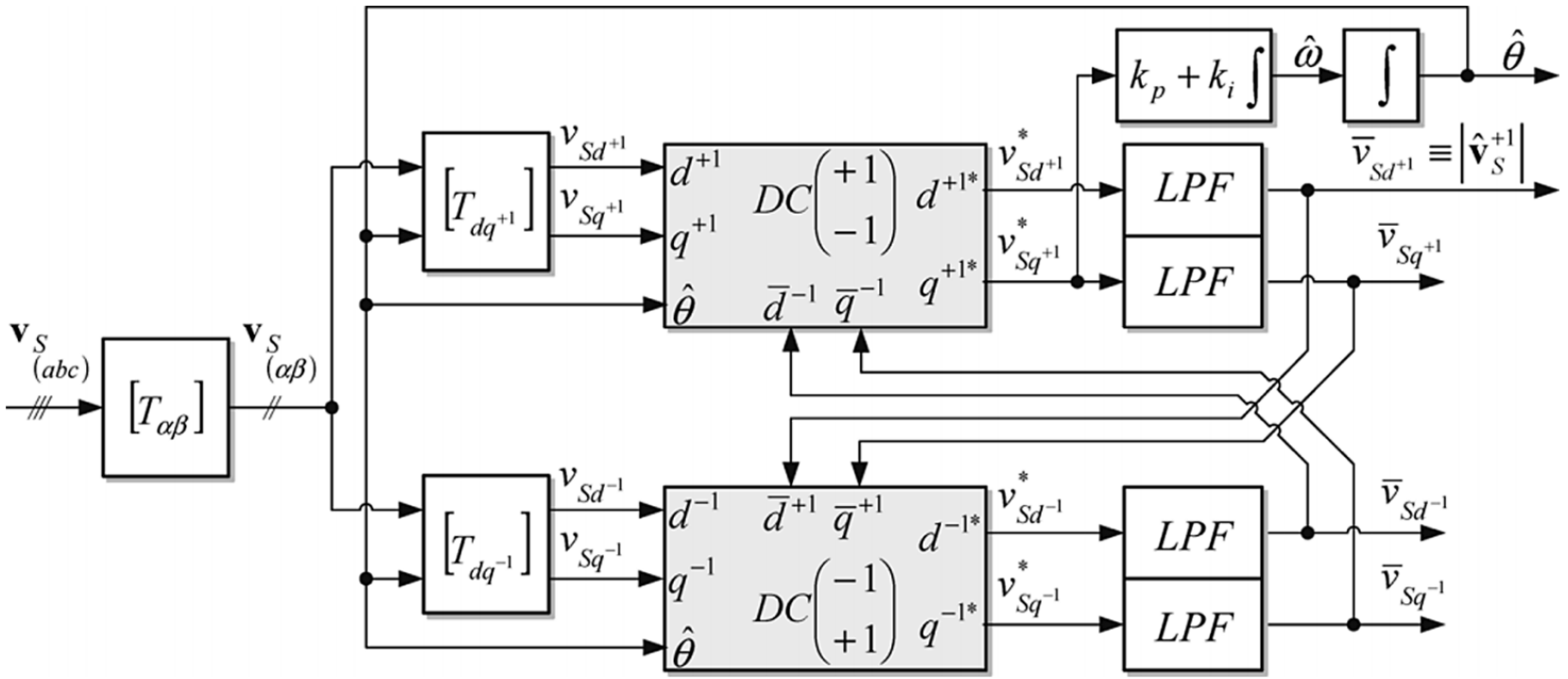

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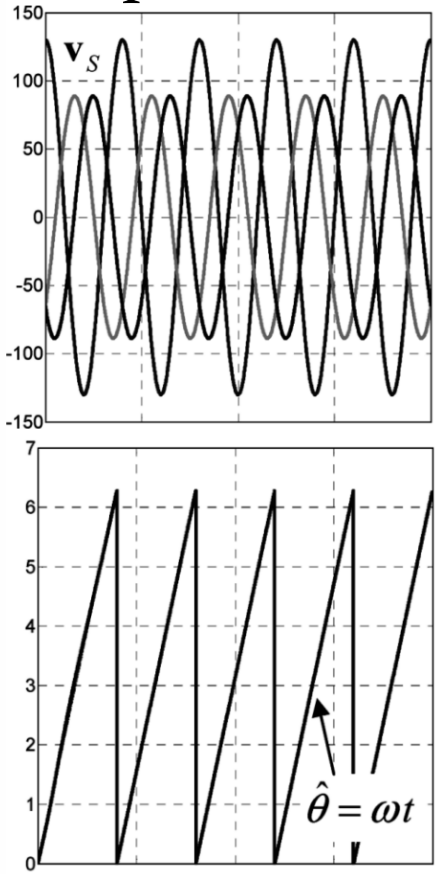

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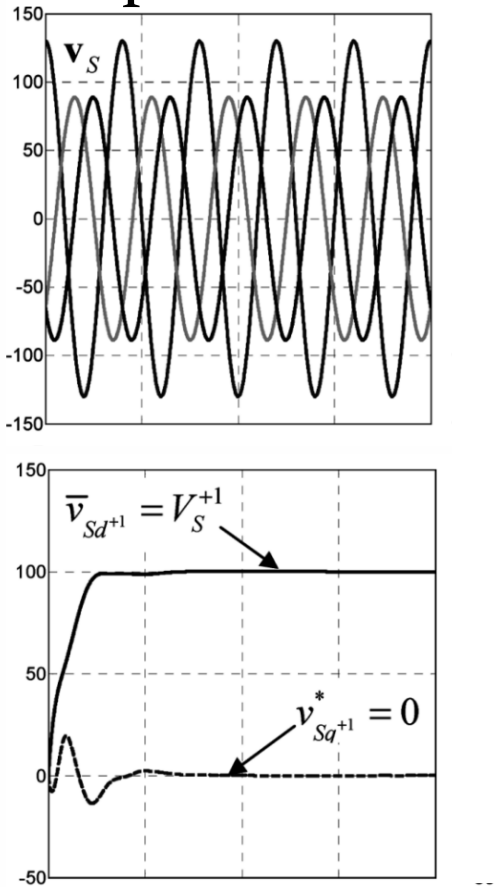

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DSOGI-PLL – Dual Second Order Generalized Integrator

- ✓ Princípios básicos: transformação abc-abc⁺

$$\mathbf{v}_{abc}^{+} = \begin{bmatrix} v_a^{+} & v_b^{+} & v_c^{+} \end{bmatrix}^T = \begin{bmatrix} T_+ \end{bmatrix} \mathbf{v}_{abc},$$

$$\begin{bmatrix} T_+ \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & a^2 & a \\ a & 1 & a^2 \\ a^2 & a & 1 \end{bmatrix}, \quad a = e^{-j\frac{2\pi}{3}}.$$

- ✓ Princípios básicos: transformação abc-αβ

$$\mathbf{v}_{\alpha\beta} = \begin{bmatrix} v_\alpha & v_\beta \end{bmatrix}^T = \begin{bmatrix} T_{\alpha\beta} \end{bmatrix} \mathbf{v}_{abc},$$

$$\begin{bmatrix} T_{\alpha\beta} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}.$$

Fonte: P. Rodríguez;, R. Teodorescu; I. Candela; A.V. Timbus, M. Liserre and F. Blaabjerg. New Positive-sequence Voltage Detector for Grid Synchronization of Power Converters under Faulty Grid Conditions," Power Electronics Specialists Conference, 2006. PESC '06. 37th IEEE, 2006, pp. 1-7.

DSOGI-PLL – Dual Second Order Generalized Integrator

- ✓ Princípios básicos: transformação abc-$\alpha\beta^{+}$

$$\mathbf{v}^{+}_{\alpha\beta} = \left[T_{\alpha\beta}\right]\mathbf{v}^{+}_{abc} = \left[T_{\alpha\beta}\right]\left[T_{+}\right]\mathbf{v}_{abc}$$

$$= \left[T_{\alpha\beta}\right]\left[T_{+}\right]\left[T_{\alpha\beta}\right]^{-1}\mathbf{v}_{\alpha\beta} = \frac{1}{2}\begin{bmatrix} 1 & -q \\ q & 1 \end{bmatrix}\mathbf{v}_{\alpha\beta}, \quad q = e^{-j\frac{\pi}{2}},$$

Fonte: P. Rodríguez;, R. Teodorescu; I. Candela; A.V. Timbus, M. Liserre and F. Blaabjerg. New Positive-sequence Voltage Detector for Grid Synchronization of Power Converters under Faulty Grid Conditions," Power Electronics Specialists Conference, 2006. PESC '06. 37th IEEE, 2006, pp. 1-7.

DSOGI-PLL – Dual Second Order Generalized Integrator

- ✓ Problema durante variações de frequência

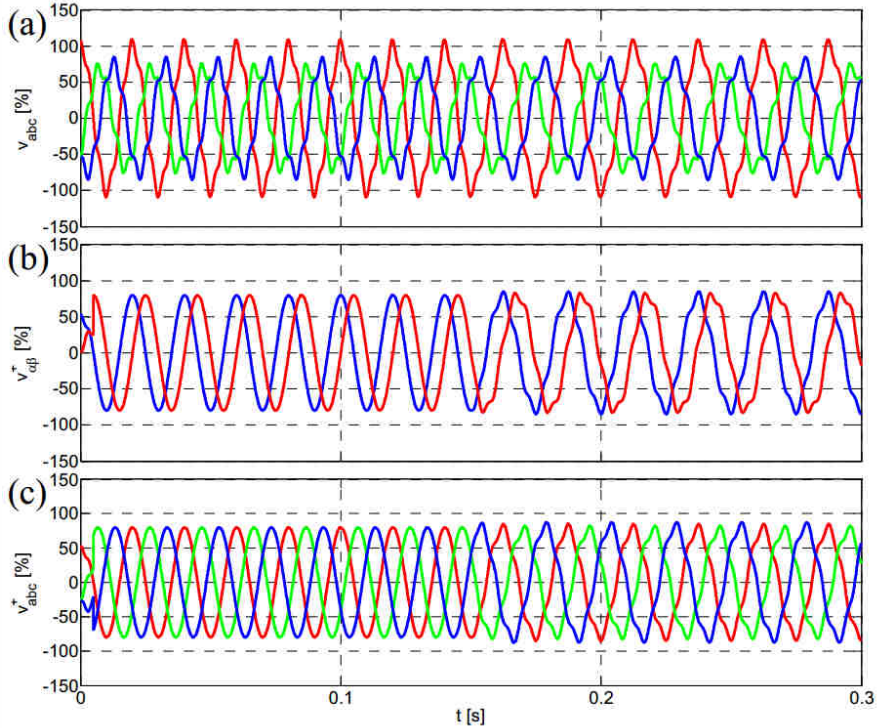
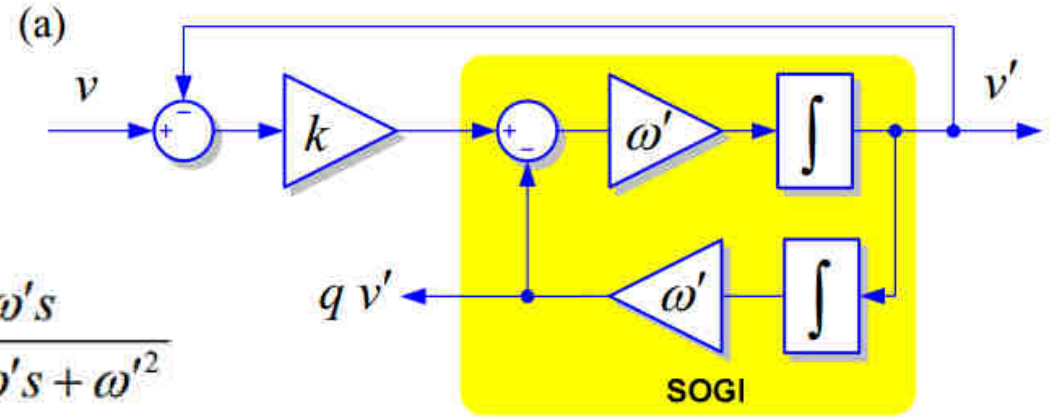


Fig. 1. PSC output when grid frequency changes (ω=40Hz, ω'=50Hz).

Fonte: P. Rodríguez;, R. Teodorescu; I. Candela; A.V. Timbus, M. Liserre and F. Blaabjerg. New Positive-sequence Voltage Detector for Grid Synchronization of Power Converters under Faulty Grid Conditions," Power Electronics Specialists Conference, 2006. PESC '06. 37th IEEE, 2006, pp. 1-7.

DSOGI-PLL – Dual Second Order Generalized Integrator

- ✓ SOGI – pode ser usada para gerar sinais em quadratura



$$D(s) = \frac{v'}{v}(s) = \frac{k\omega' s}{s^2 + k\omega' s + \omega'^2}$$

$$Q(s) = \frac{qv'}{v}(s) = \frac{k\omega'^2}{s^2 + k\omega' s + \omega'^2}$$

Fonte: P. Rodríguez;, R. Teodorescu; I. Candela; A.V. Timbus, M. Liserre and F. Blaabjerg. New Positive-sequence Voltage Detector for Grid Synchronization of Power Converters under Faulty Grid Conditions," Power Electronics Specialists Conference, 2006. PESC '06. 37th IEEE, 2006, pp. 1-7.

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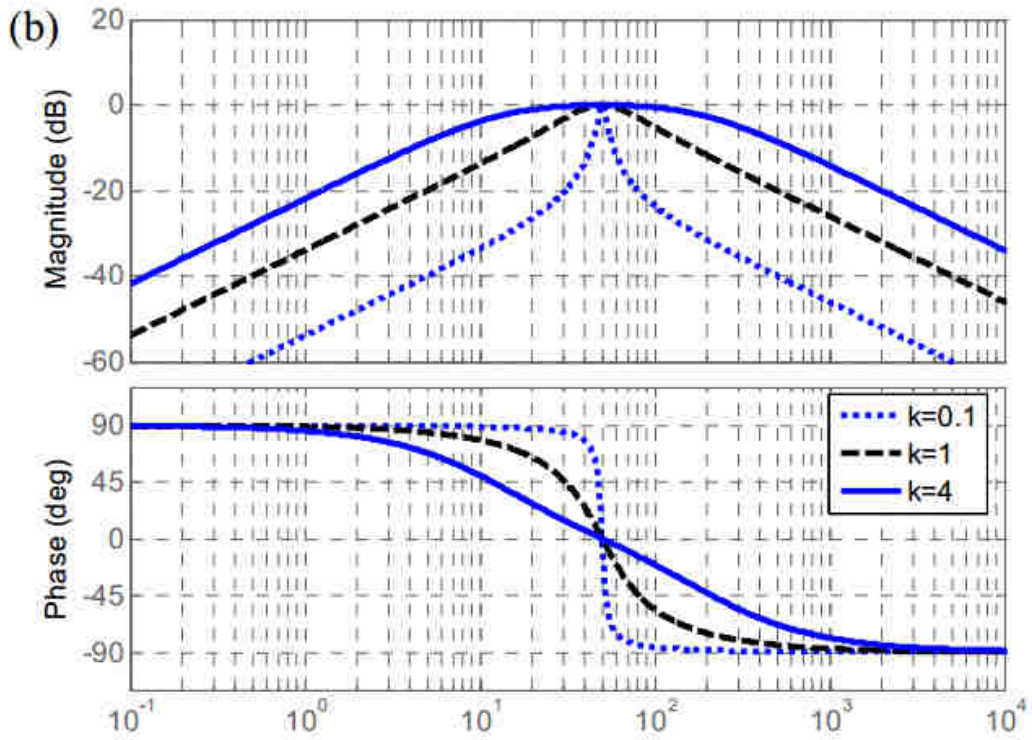

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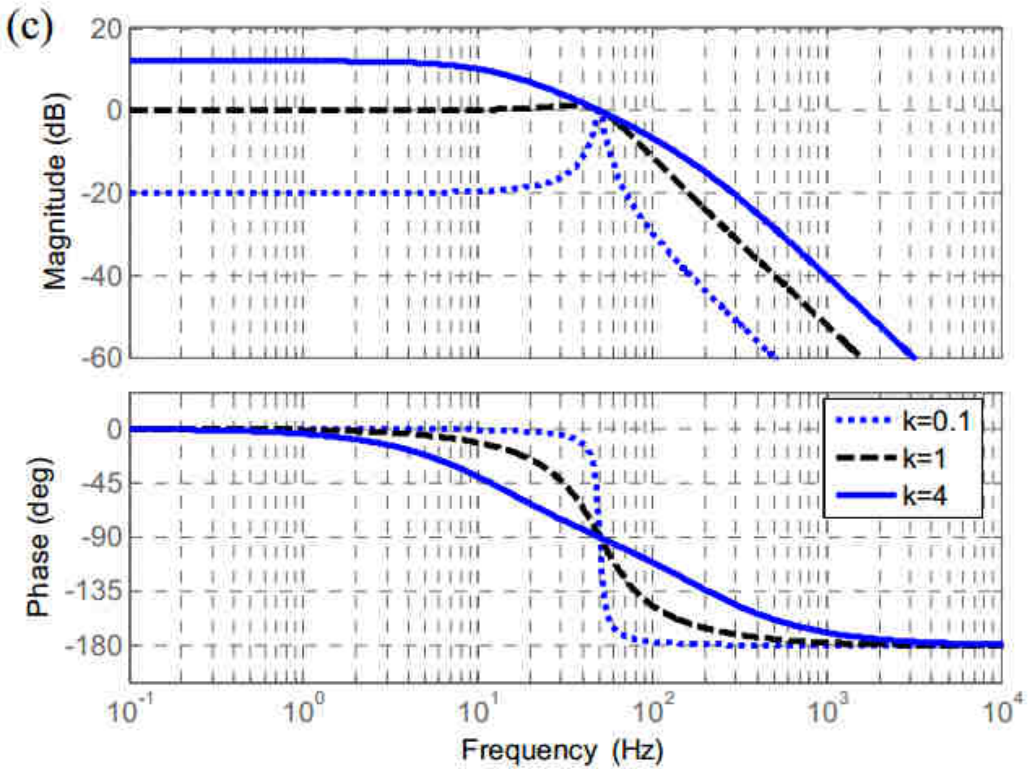

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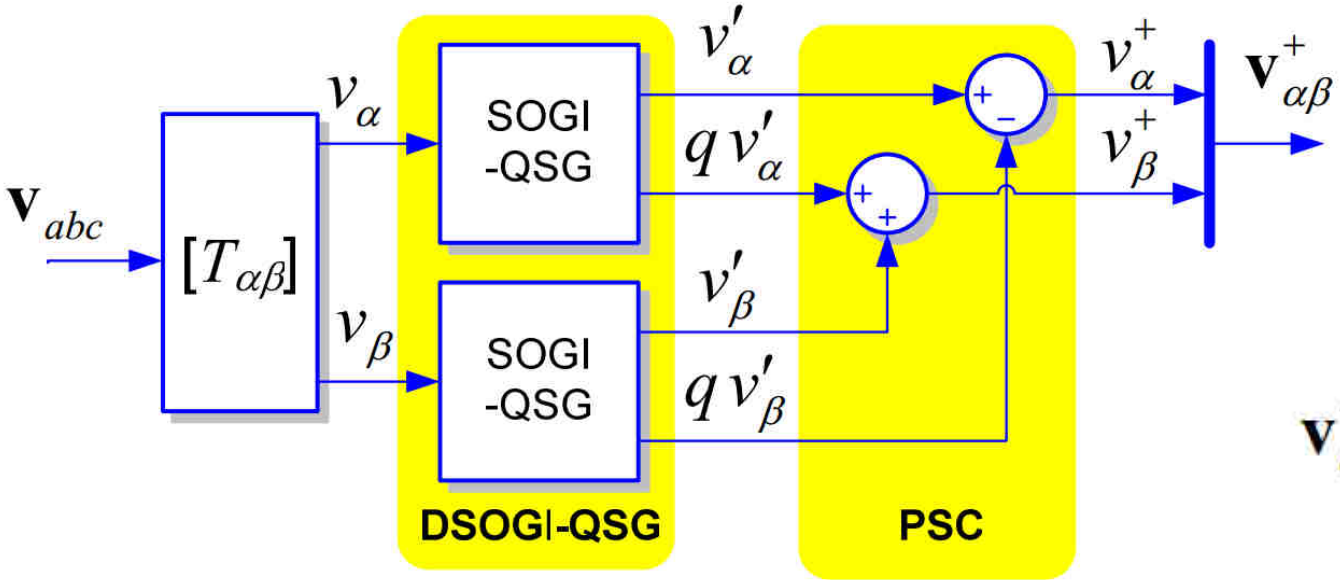

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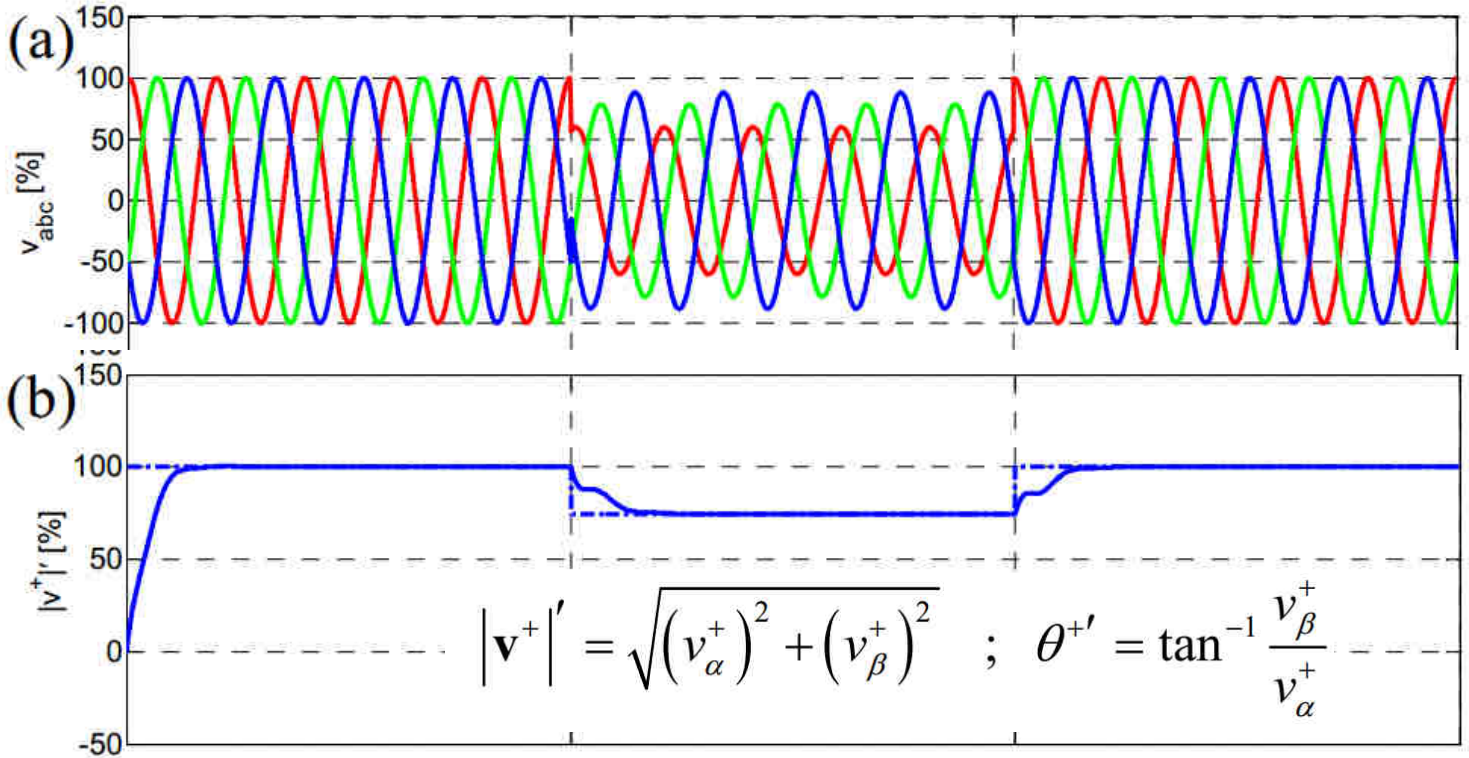

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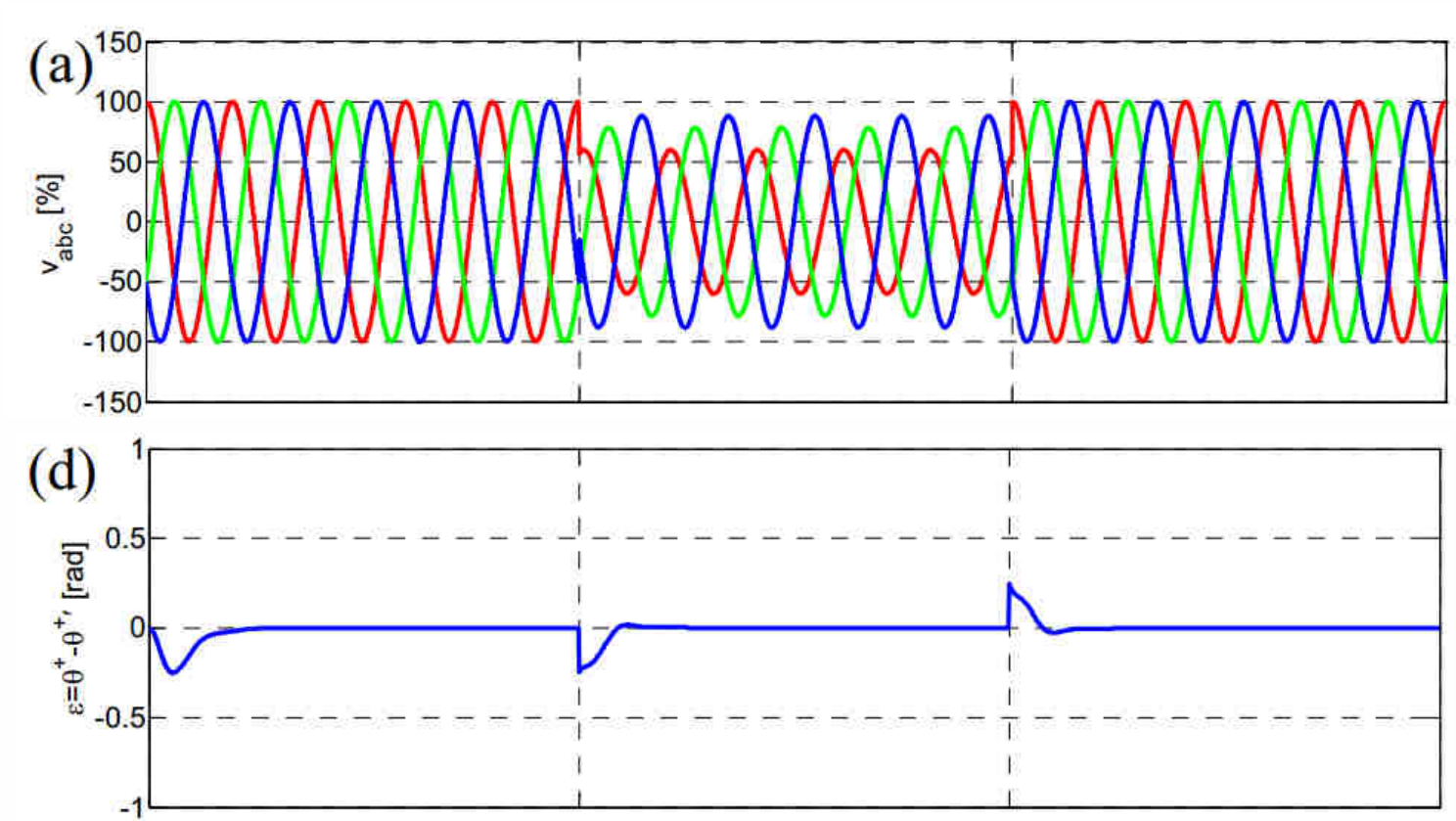

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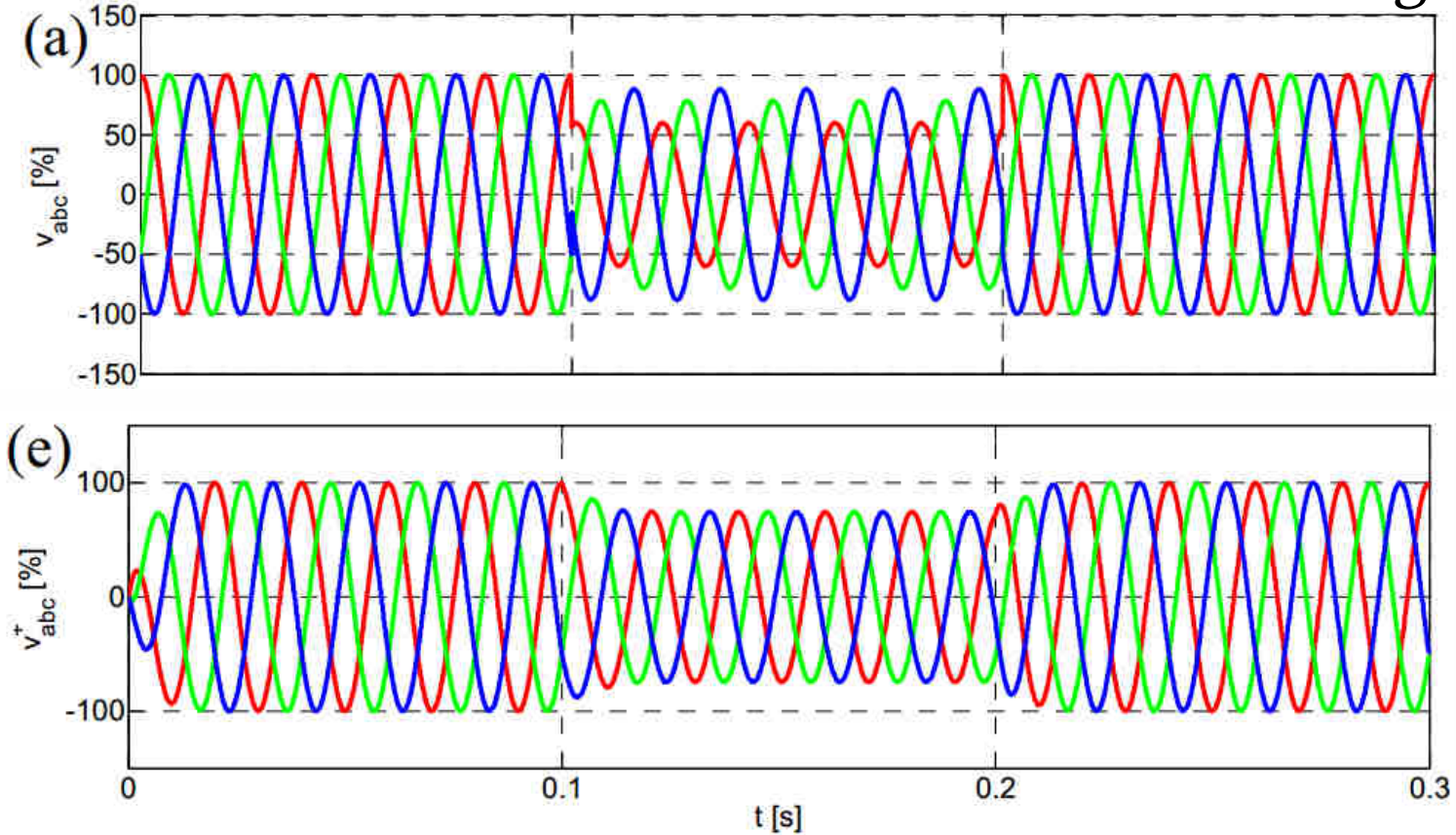

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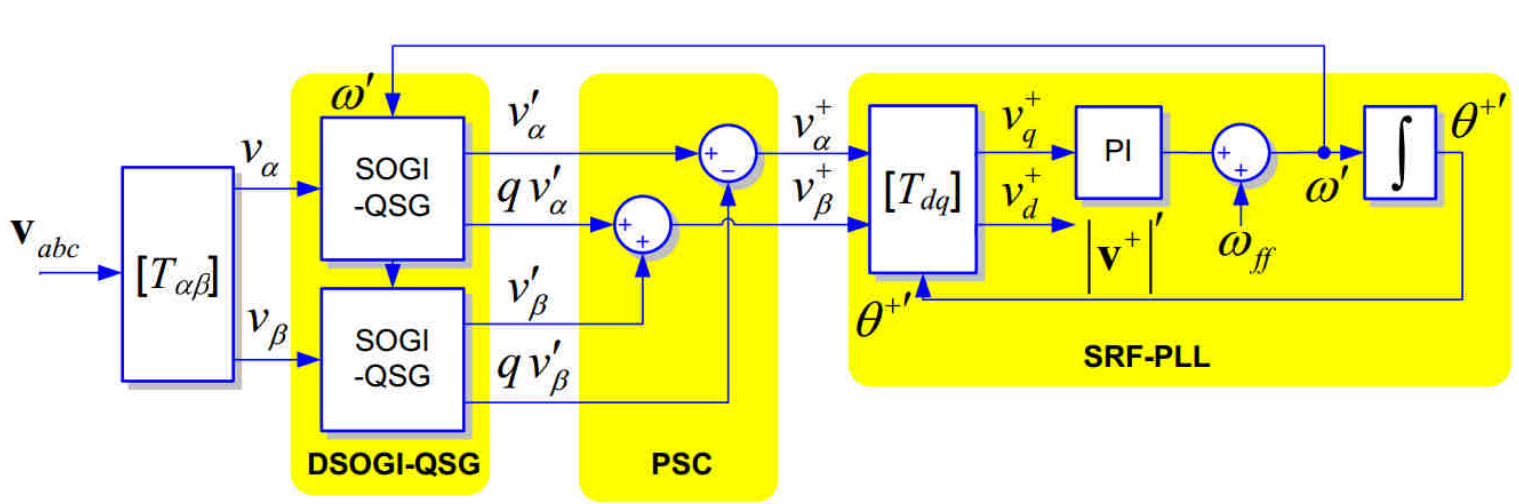
Inversor Fotovoltaico

- ✓ Retroalimentação da frequência para que a estrutura seja adaptativa à variações de frequência.



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Comparação entre PLLs

TABLE I

COMPARISON OF PLL METHODS

	SRF	DSRF	PSF	SSI	DSOGI
Distortion rejection	-	-	+	+	+
Unbalance robustness	-	+	+	+	+
Positive seq. detection	-	+	+	-	+
Structural simplicity	+	-	-	+	+
Single phase utilization	-	-	-	+	-

Fonte: L. R. Limongi, R. Bojoi, C. Pica, F. Profumo and A. Tenconi, "Analysis and Comparison of Phase Locked Loop Techniques for Grid Utility Applications," Power Conversion Conference - Nagoya, 2007. PCC '07, Nagoya, 2007, pp. 674-681.

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EStimate - Sistemas Fotovoltaicos

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https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Obrigado!

Heverton Augusto Pereira
Prof. Departamento de Engenheira Eletrica | UFV
Coordenador da Gerência de Especialistas em Sistemas Elétricos de Potência |Gesep
Membro do Programa de Pós-Graduaçao em Engenharia Elétrica | PPGEL/CEFET-MG
E-mail: heverton.pereira@ufv.br