



Adaptive Near-Optimal Compensation in Lossy Polyphase Power Systems

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Abstract

The role of compensation in power system efficiency optimization is to reduce the line losses, so that most of the source power is delivered to the load (See Fig. 1).

Our basic objective is the construction of an adaptive near-optimal compensator that relies only on measurements of the load voltage and current so as to allow precise control of P_{load} , the real power delivered to the compensated load, as well as P_{comp} , the real power flowing out of the compensator, while reducing P_{line} , the power dissipated in the line impedance, to within a few percent of its theoretical minimum.

Problem Description

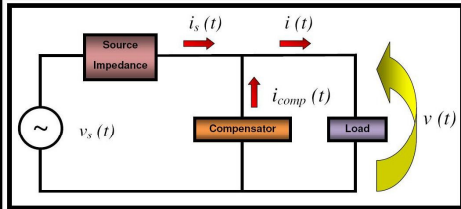
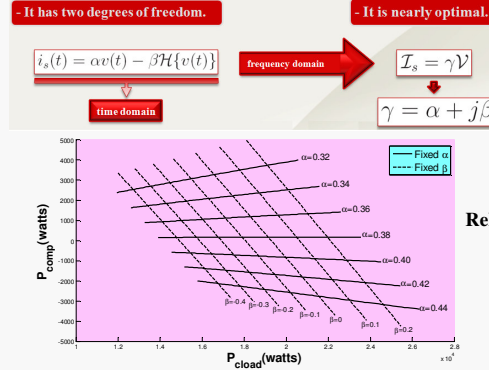


Figure 1

Motivation and Significance

- Minimization of line losses.
- Solution under significant source (line) impedance conditions.
- Near-optimal self-adjusting compensator that relies only on on-site load voltage and current.

Quad-Fryze Compensation



Iterative Compensation

$$I_{comp}(k+1) = I(k) - \gamma V(k)$$

When the iteration process has converged, we have:

$$I_s = \gamma V$$

- No control over $P_{load} = \Re\{I_s V^H\}$.
- $P_{comp} = 0$ is not guaranteed.

Our objectives in order of priority

- Minimize P_{line} .
- Achieve $P_{comp} = 0$ in steady state and $P_{comp} \approx 0$ during iteration.
- Control the steady-state value of P_{load} .

Adaptive Near-Optimal Compensation with Significant Source Impedance

Adaptive Adjustment of α :

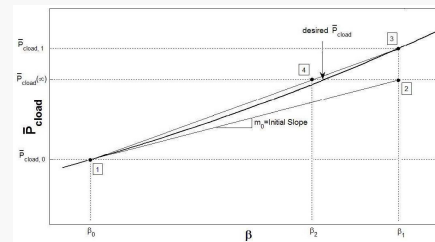
$$\alpha(k) = \Re\{\gamma(k)\} = \frac{\Re\{I(k)V^H(k)\} - P_{comp,desired}}{\|V(k)\|^2}$$

Proposed iterative scheme

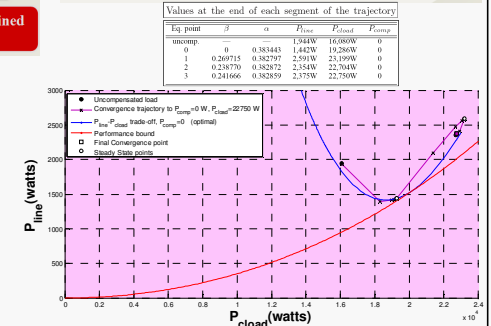
$$I_{comp}(k+1) = I(k) - [\alpha(k) + j\beta] V(k)$$

Adjustment of β - Iterative Search Procedure (Secant Method):

- The convergence to a certain value of P_{load} is given by the predetermined value of β in $\gamma(k) = \alpha(k) + j\beta$.



Convergence Trajectory of the Adaptive Near-Optimal Compensator:



Case of Study: A three-phase Unbalanced Induction Motor

Source Voltage: $V_s = [138.6 \quad -38.54 - 118.6j \quad -100 + 118.6j \quad 13.86 \quad -6.928 - 12j \quad -6.928 + 12j]$

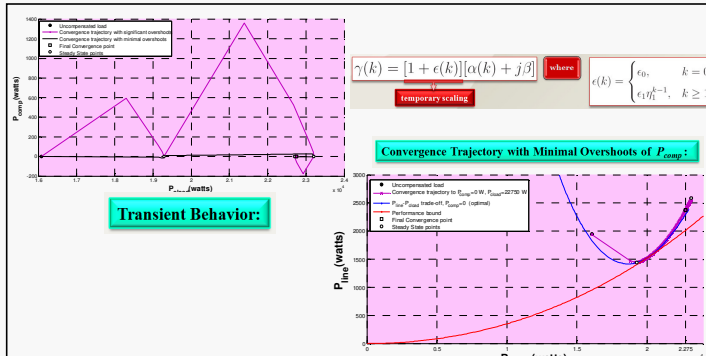
Source Impedance: $Z_s = 0.195 \begin{bmatrix} 1+2j & 0 & 0 & 0 & 0 & 0 \\ 0 & 1+2j & 0 & 0 & 0 & 0 \\ 0 & 0 & 1+2j & 0 & 0 & 0 \\ 0 & 0 & 0 & 1+10j & 0 & 0 \\ 0 & 0 & 0 & 0 & 1+10j & 0 \\ 0 & 0 & 0 & 0 & 0 & 1+10j \end{bmatrix}$

Induction Motor Admittance: $Y = \begin{bmatrix} Y_1 & 0 \\ 0 & Y_2 \end{bmatrix}$

$$Y_1 = \begin{bmatrix} 1.047 - 2.447j & 1.093 - 0.9531j & -0.2024 - 1.212j \\ -0.2024 - 1.212j & 1.047 - 2.447j & 1.093 - 0.9531j \\ 1.093 - 0.9531j & -0.2024 - 1.212j & 1.047 - 2.447j \end{bmatrix}$$

$$Y_2 = \begin{bmatrix} 0.1464 - 0.8491j & -0.0212 - 0.1271j & -0.0347 - 0.1014j \\ -0.0347 - 0.1014j & 0.1464 - 0.8491j & -0.0212 - 0.1271j \\ -0.0212 - 0.1271j & -0.0347 - 0.1014j & 0.1464 - 0.8491j \end{bmatrix}$$

Adaptive Near-Optimal Compensation with Significant Source Impedance



Concluding Remarks

Our adaptive procedure scheme for load compensation relies only on instantaneous (dynamic) phasors obtained from measurements of the load voltage and current. It achieves nearly optimal performance even when the source impedance is not negligible in comparison with the load impedance.

Acknowledgments

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References

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- [2] H. Lev-Ari and A.M. Stankovic, "Fundamental Performance Limits in Lossy Polyphase Systems: Apparent Power and Optimal Compensation", *IEEE Int. Symp. on Circuits and Systems*, 27(30):61-64, May 2007.
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