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Title

EXERCISE 10: PLL FOR UNBALANCED GRID CONDITIONS

Course Name

EE-465 Industrial Electronics I

1 INTRODUCTION

The basic PLL that was already implemented does not allow for efficient tracking of phase angle and synchronization to the grid under non-ideal conditions. More advanced techniques such as Double Decoupled Synchronous Reference Frame PLL (DDSRF-PLL) or Double Second-Order Generalized Integrator PLL (DSOGI-PLL) allow for better tracking and grid synchronization.

2 TASKS DESCRIPTION

1. The skeleton model generates for you the grid voltages in *abc* frame, your PLL inputs. In addition, the real grid frequency and angle are provided as outputs for comparison purpose. Please ensure that for the points 2 to 4 the parameter h is set to 0. The grid voltage expression is

$$v_g = V_g \begin{bmatrix} \cos(\omega t + \varphi) \\ \cos(\omega t - 2\pi/3 + \varphi) \\ \cos(\omega t + 2\pi/3 + \varphi) \end{bmatrix}$$

   Import your PLL from exercise 8, it will serve for comparison with the more advanced methods.

2. Implement the DDSRF-PLL as presented in the lecture. Tune the low pass filters for the optimal damping factor. The basic PLL part can be tuned as usual, targeting a settling time $t_s = 100$ms.
   For the report, show a PLECS capture of the content of the DDSRF-PLL subsystem, one decoupling network, and the basic PLL part.

3. Implement a DSOGI-PLL as presented in the lecture. This can be achieved by separating the positive and negative sequences with a DSOGI and using the positive sequence as an input to a basic PLL.
   In the template, you have to complete the DSOGI PLL subsystem by completing the SOGI-QSG and basic PLL blocks and interconnecting them properly.
   In your report, show a PLECS capture of the content of the DSOGI-PLL subsystem, SOGI-QSG block, and the associated basic PLL block.

4. Compare the performance of two advanced methods against the performance of the basic PLL. Show a full capture of the scope of the PLECS template. Discuss the dynamics of the different methods for the phase and frequency steps at $t = 0.4s$ and $t = 0.8s$. Discuss the behavior of the three different PLLs during the unbalanced grid conditions.

5. In a real grid, some voltage harmonics are likely going to be present. The parameter h initially set to 0 in the template can be used to add a harmonic in the generated voltages in the form of $v_g' = v_g + v_h$, where

$$v_h = V_h \begin{bmatrix} \cos(h(\omega t + \varphi) + \varphi_h) \\ \cos(h(\omega t - 2\pi/3 + \varphi) + \varphi_h) \\ \cos(h(\omega t + 2\pi/3 + \varphi) + \varphi_h) \end{bmatrix}$$

   with $V_h = 0.05V_g$. h is therefore the order of the harmonic injected on top of the fundamental frequency. Set h to 3, 5 and 7 and briefly discuss how the different PLLs are affected.