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Comparison between FLL and PLL in frequency estimation to supply distributed virtual inertia.

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1. Introduction

The supply of virtual inertia (VI) in a DC-AC converter that transfers the energy received by photovoltaic cells to the electrical grid, emulates the inertia of a synchronous generator, since the energy stored in the DC-Link is used in analogy to the inertia of the rotor of the synchronous generator. In the process it is necessary to estimate the frequency of the grid, for which methods such as Phase Locked Loop (PLL) and Frequency Locked Loop (FLL) are used; this paper makes a comparative analysis of both methods.

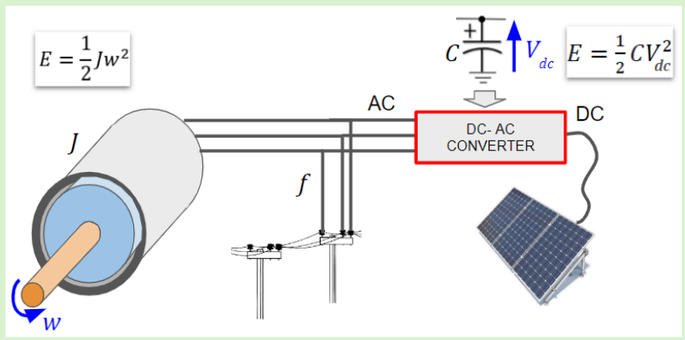

Fig. 1. Comparison between the kinetic energy in a generator with the energy stored in the DC-Link capacitance.

2. PLL and FLL

In the design of a voltage source inverter (VSI) with VI, a PLL will be used to estimate the frequency in the control strategy for supplying virtual inertia, because the design is less complex than an FLL. However, the PLL is a design that estimates the phase, and the obtained frequency is susceptible to noise and disturbances, so it is necessary to filter it. In the case of the FLL, there is a direct estimate of the frequency, but the design is more complex and quite non-linear, so linearization around the network frequency to be estimated are necessary.

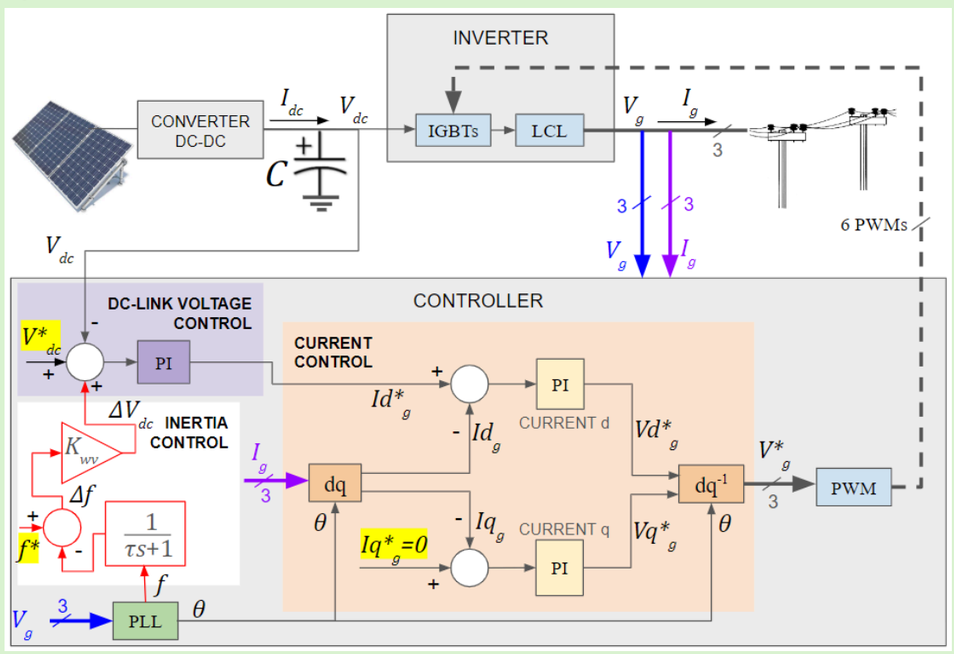

Fig. 2. VSI with VI with frequency estimation using a PLL.

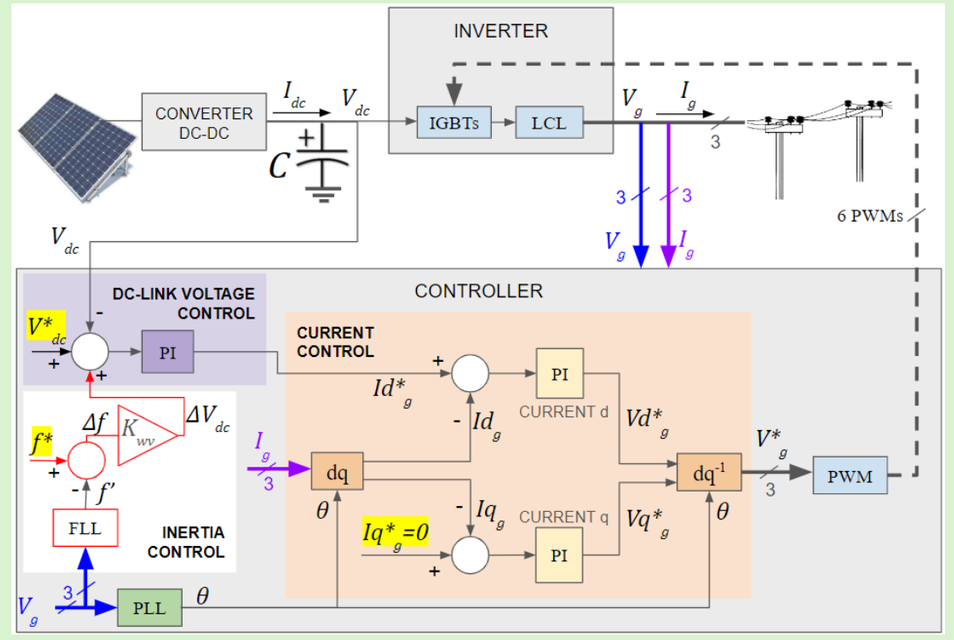

Fig. 3. VSI with VI with frequency estimation using a FLL.

3. Results

For the tests, simulations in PSIM were used where the electrical network signal with a frequency of 60 Hz is forced to a step drop of 0.3 Hz in which white noise of 0.02 Hz has been included. The frequency estimation by the PLL requires a low pass filter, in which it has been tested for 5 Hz, 10 Hz and 20 Hz, it is notable that the greater the bandwidth the response is faster, but it is more susceptible to noise. In any case, the frequency estimate by the FLL is better.

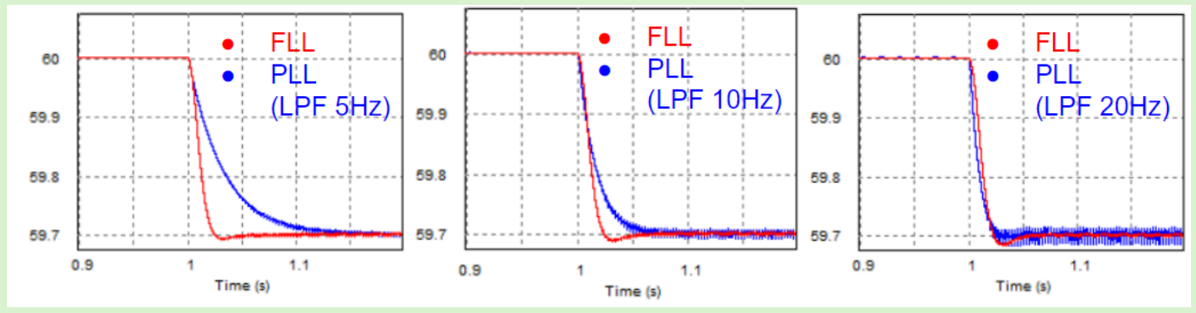

Fig. 4. Comparison between FLL and PLL with low pass filter at frequencies of 5Hz, 10 Hz and 20 Hz, for a 0.3 Hz drop on grid.

Regarding the virtual inertia supply, using the FLL produces a power peak of a little more than three times the nominal power of the VSI and a distortion after the inertia supply. In the case of the PLL, using a 20 Hz filter generates a peak power like the FLL, but the distortion is greater. And a PLL with a 5 Hz filter generates lower peak power and lower distortion. In either case, the same virtual inertia is supplied since the DC-Link voltage drop always has the same final value.

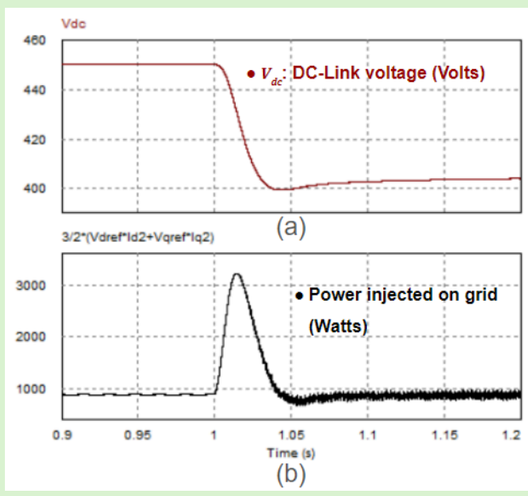

Fig. 5. Inertia emulation with FLL. (a) DC-Link Voltage Drop, (b) Power injected into the grid.

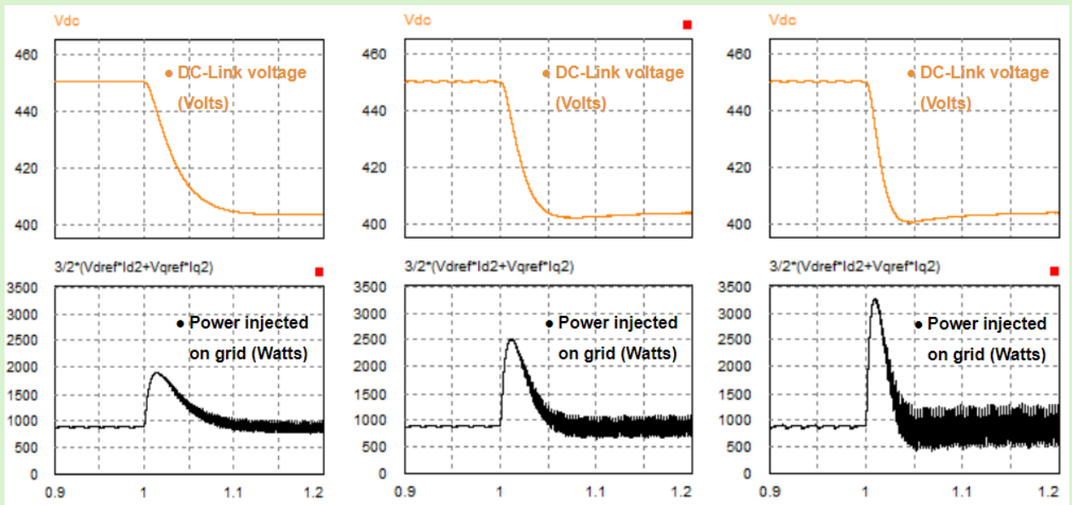

Fig. 6. DC-Link voltage and Power injected into the grid, using PLL with LPF: (a) 5 Hz, (b) 10 Hz y (c) 20 Hz.

4. Conclusions

The main conclusion of this paper is that the FLL can have a more precise and stable estimation of the grid frequency than that of the PLL, even the PLL needs a low-pass filter for an appropriate estimation of the frequency. However, inertial dynamics are relatively slow, so fast frequency estimation is not needed. For this reason, a PLL with an appropriate low-pass filter will provide the same virtual inertia as the FLL, but with a lower peak power. This result is good, since it implies less computational cost and less resizing of the inverter. It should be considered that the conclusion established is for the case of a step frequency drop, which is not realistic. An analysis with a ramp-type frequency drop, to resemble more real conditions or add a filter to the FLL or establish specific requirements for the supply of virtual inertia, can change the conclusion presented.

5. Acknowledgements

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