Synchronization of isolated microgrids with renewable energy sources under distorted voltages

Ricardo Alzate, María A. Mantilla and Fabián L. Forero

Universidad Industrial de Santander. School of Electrical Engineering. Bucaramanga - Colombia
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I. Introduction
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- Colombia is a privileged country in terms of wide access to natural resources.
- High levels of solar radiation are complemented with richness of hydraulic resources spread all over the country.
- Particular features of local geography makes difficult to provide electricity to communities at certain rural zones.
- In isolated (i.e. non interconnected) areas it is typical the use of low-power generator-sets to attend electric power demand.
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- Reasons motivating the latter include the need of technical and technological tools to handle the intermittency and volatility of non conventional energies.
- Poor performance of commercial equipment operating at low power rates (power quality of cheap generator-sets).
- The development of low-cost, microgeneration systems including renewable sources, becomes an interesting topic for R&D projects supporting economical and social development at rural zones.
II. Isolated microgrid under study
Problem statement
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- The performance of conventional generators operating at low-power and the volatility of renewable sources constitute challenges (from the technical and technological viewpoint) to achieve that goal.
- Besides the local control of every source, a more complicated situation becomes their parallel interconnection as a grid, requiring a high degree of synchronization.
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How to achieve synchronization of sources in an isolated microgrid including renewable resources, where the reference generator is a generator-set with harmonic content?
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- 1.0 kW, photovoltaic unit, composed of a panel array, coupled to a DC/DC boost power converter and a single phase power inverter.
- Induction machine of 2 HP acting as self-excited generator representing the turbine, coupled to a three-phase rectifier, a DC/DC boost power converter and a single phase power inverter.
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- LCL type filter couplings.
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Further work is currently developed on a real prototype of the system.
III. Synchronization strategy
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- PLLs were originally developed for applications in telecommunication systems. However, same ideas can be extended to synchronization of power generators.
- A conventional PLL tracks the phase of a sinusoidal signal, assuming there are not variations in amplitude and frequency parameters.
- A robust approach in practice is the so-called Enhanced PLL (EPLL), being able to recover the phase and amplitude of the original sinusoidal signal.
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- Moreover, frequency variations in the reference waveform are captured by the EPLL constituting an adaptive correction for the filter.
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- Moreover, frequency variations in the reference waveform are captured by the EPLL constituting an adaptive correction for the filter.
- The sinusoidal waveform at the output of the EPLL block is fed as the reference signal of a double-loop resonant controller regulating current and voltage values at the output of each power inverter.
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- The interconnection of sources is conditioned to values of a cross-correlation index (Pearson's correlation coefficient), measuring the similarity between the output signal of the power inverter and the filtered version of the voltage reference.
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\[ \rho = \frac{\sigma_{V_c V_g}}{\sigma_{V_c} \sigma_{V_g}} , \]

being \( \sigma_{V_c V_g} \) the covariance of \( (V_c, V_g) \), \( \sigma_{V_c} \) the standard deviation of \( V_c \) and \( \sigma_{V_g} \) the standard deviation of \( V_g \).
PLL
\[ \Gamma(s) = \frac{k_s}{s^2 + 2\zeta\omega_n s + \omega_n^2} \]
IV. Results
Simulation scenario
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- The synchronization scheme was applied independently to each generator (i.e. photovoltaic and turbine) with respect to the reference generator (i.e. generator-set).
- The general scenario starts at $t = 0$ with the generator-set feeding a load of 1.5 kW.
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- for $t = 2$, the turbine unit connects allowing a power share of 33.3%.
- for $t = 3$, a perturbation is applied to the reference voltage, altering its amplitude, frequency and phase.
- Results allow to confirm that synchronization is recovered in spite of disturbances.
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Filtering
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Parameters
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PV unit
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V. Conclusions
Concluding remarks
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- A synchronization scheme composed of an EPLL, an adaptive bandpass filter and a cross-correlation index, has been proposed to perform interconnection of sources in an isolated microgrid combining renewable resources with a generator-set including harmonic content.
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- Simulation results unveiled the robustness of the proposed scheme to disturbances applied to parameters of the voltage reference signal.
Concluding remarks

- A synchronization scheme composed of an EPLL, an adaptive bandpass filter and a cross-correlation index, has been proposed to perform interconnection of sources in an isolated microgrid combining renewable resources with a generator-set including harmonic content.
- Simulation results unveiled the robustness of the proposed scheme to disturbances applied to parameters of the voltage reference signal.
- Ongoing work is currently devoted to experimental verification of the proposed synchronization strategy on a laboratory prototype built at the Universidad Industrial de Santander.
Acknowledgements
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Questions?

Thank you for your attention !!!

ralzatec@uis.edu.co
marialem@uis.edu.co
fabian.forero1@correo.uis.edu.co