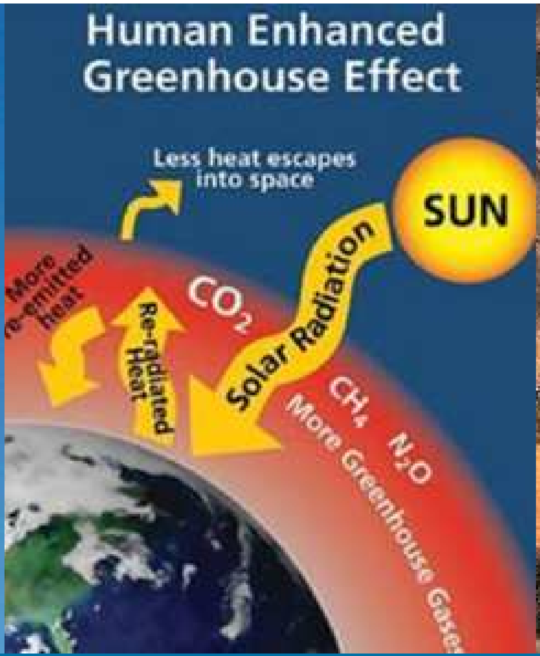

Supplying a Renewable Energy Single Phase Microgrid from a Biomass Generator Using a Three Phase Induction Machine

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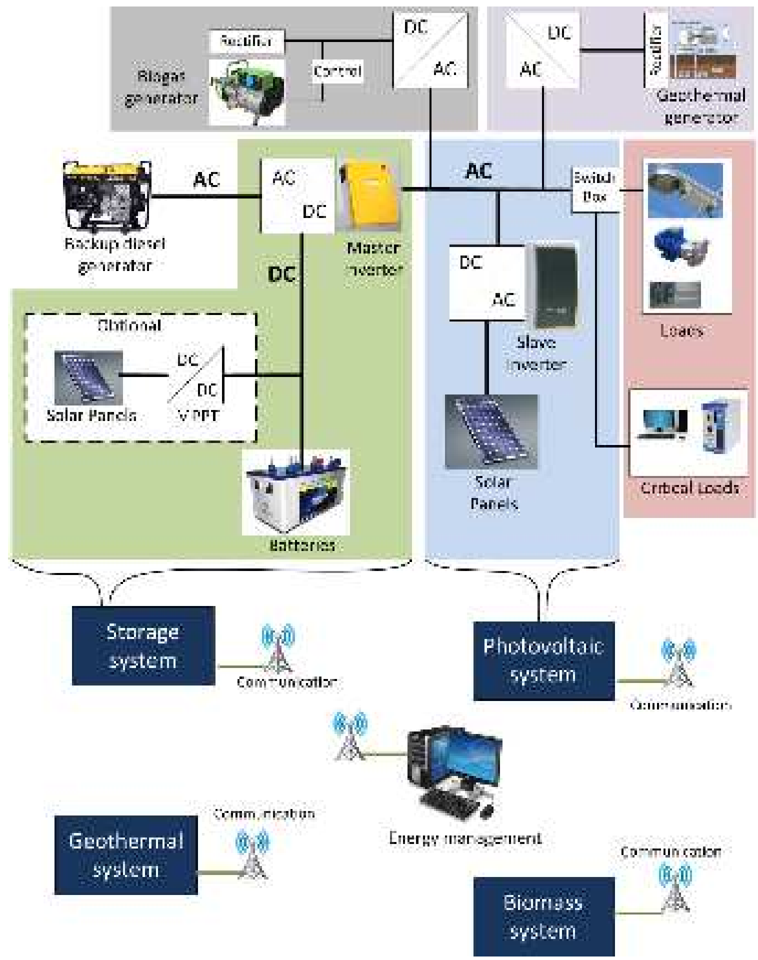
Introduction

- Motivation for renewable energies:
  - the rapid growth of energy demand,
  - climate change,
  - global decline of fossil fuels,
  - high and unpredictable oil prices
  - high costs of grid extensions to remote areas
- One way to integrate renewable energies are the **microgrids**
- Renewable energy microgrids can be defined as small-scale electricity grids that combine:
  - Renewable generation (photovoltaic, wind, biomass, geothermal),
  - Storage,
  - Loads



Micorgrid example

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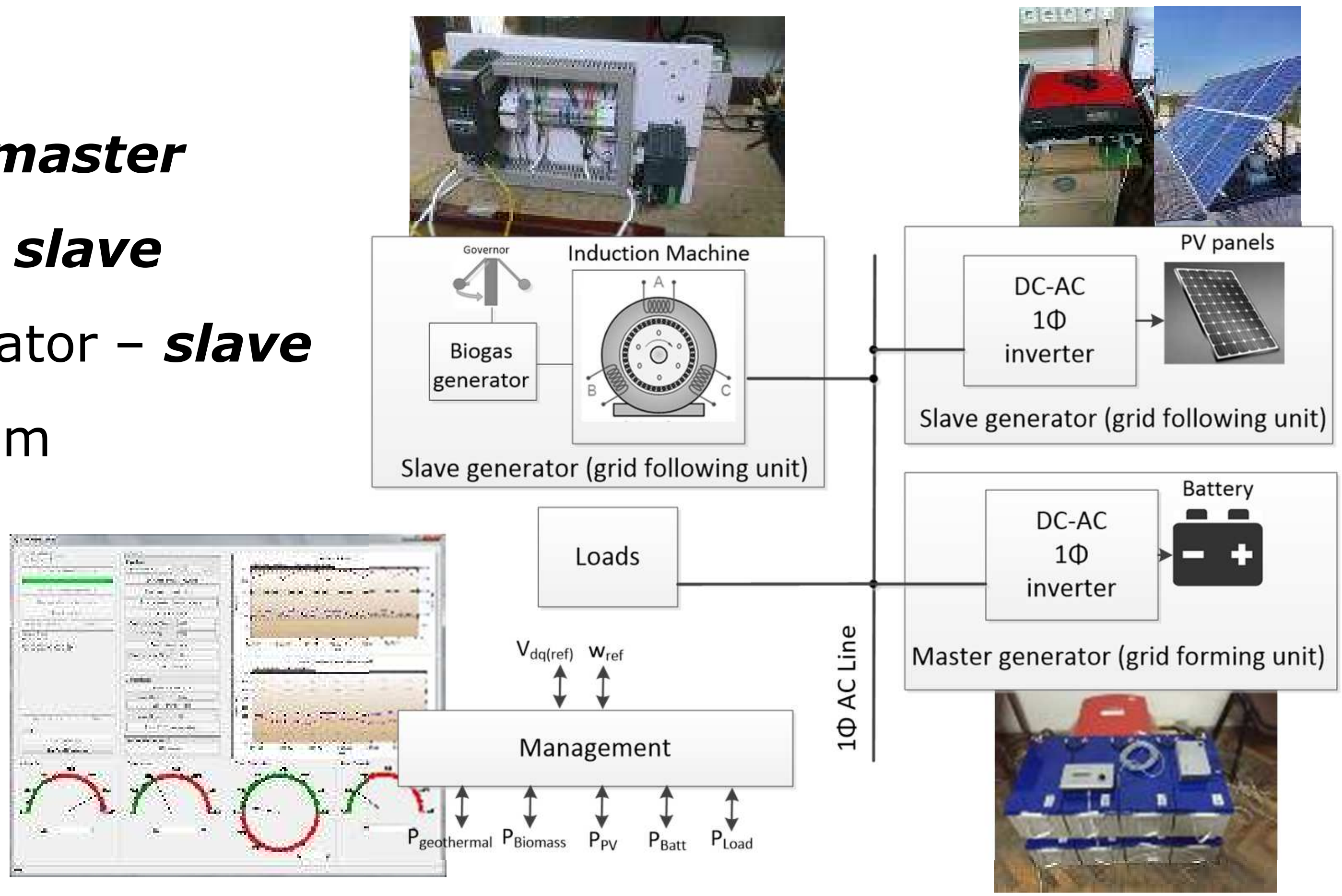
Proposed microgrid

Components

- Battery inverter - ***master***
- Biogas generator - ***slave***
- Photovoltaic generator – ***slave***
- Management system

Loads

- Standard Loads
- Critical loads

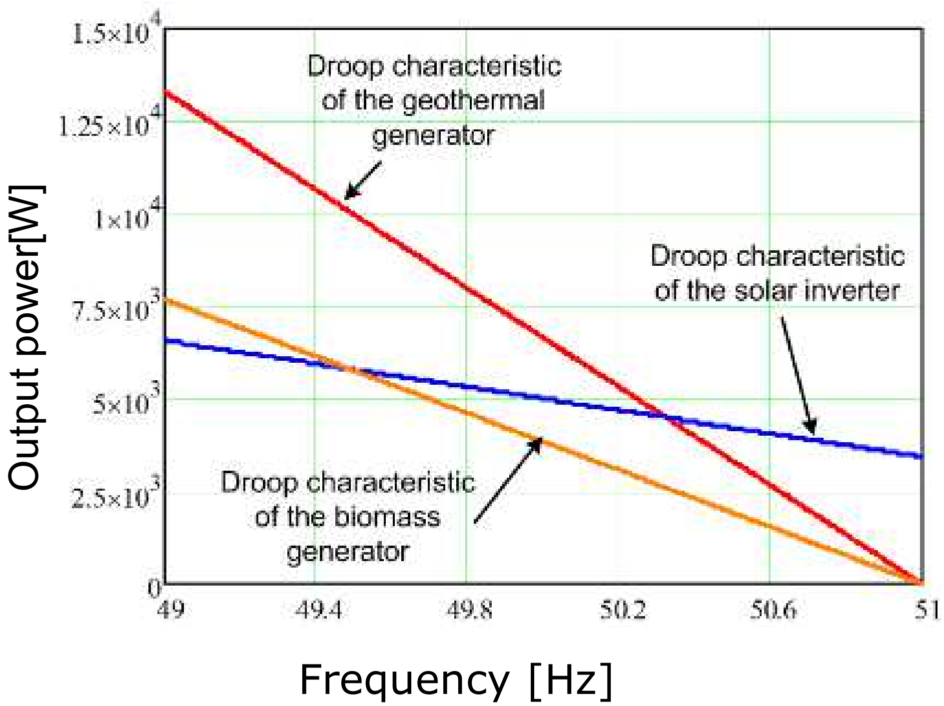


Proposed microgrid

Proposed microgrid - control

Two level control structure:

- *Primary level control* - Droop control
- *Secondary level control* - Communication based control – RS485 (MODBUS)



Droop control method

Induction generator droop

$$P_m(f) = k_m \cdot (f_0 - f)$$

Solar inverter droop

$$P(f) = P_o + k \cdot (f_0 - f)$$

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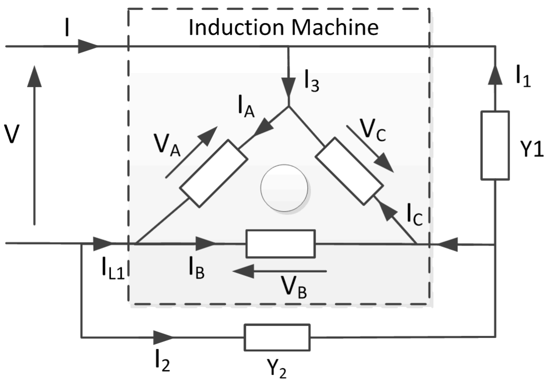
Objectives

- **The main objective** of the paper is to investigate the possibility of using a three phase induction generator to supply energy to the single phase AC grid from the biomass generator.
- **Secondary objectives**
  - Design a balancing circuit for the three phase generator,
  - Analyze the performance of the balancing circuit,
  - Develop a biogas generator emulator,
  - Develop a simulation model for the biogas generator emulator,
  - Compare the simulation and experimental results.

Balancing circuit



Connection of the three phase induction generator to a single phase grid

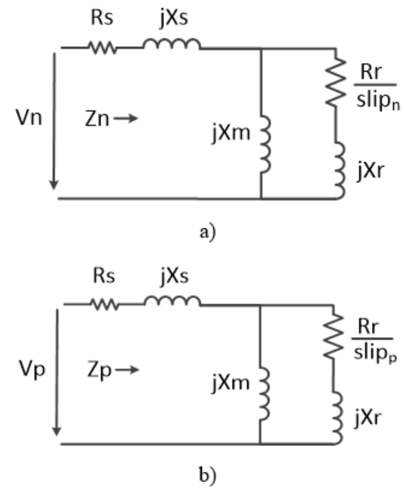
$$V = V_A$$

$$V_A + V_B + V_C = 0$$

$$I_1 = V_C \cdot Y_1$$

$$I_2 = V_B \cdot Y_2$$

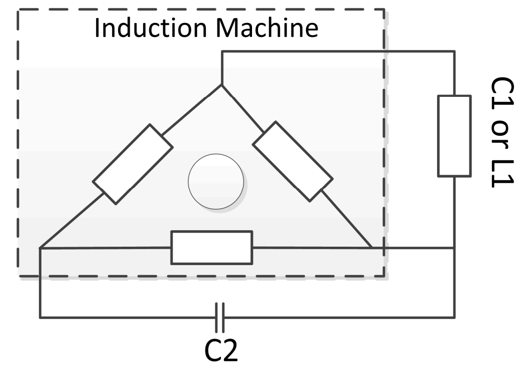
$$I_1 = I_B - I_C + I_2$$



Equivalent circuits for the positive (a) and negative (b) sequences

$$V_n = \sqrt{3}\cdot V \frac{Y_p + \frac{e^{j\pi/6}}{\sqrt{3}}Y_1 + \frac{e^{-j\pi/6}}{\sqrt{3}}Y_2}{Y_1 + Y_2 + Y_p + Y_n}$$

$$Y_p + \frac{e^{j\pi/6}}{\sqrt{3}}Y_1 + \frac{e^{-j\pi/6}}{\sqrt{3}}Y_2 = 0$$

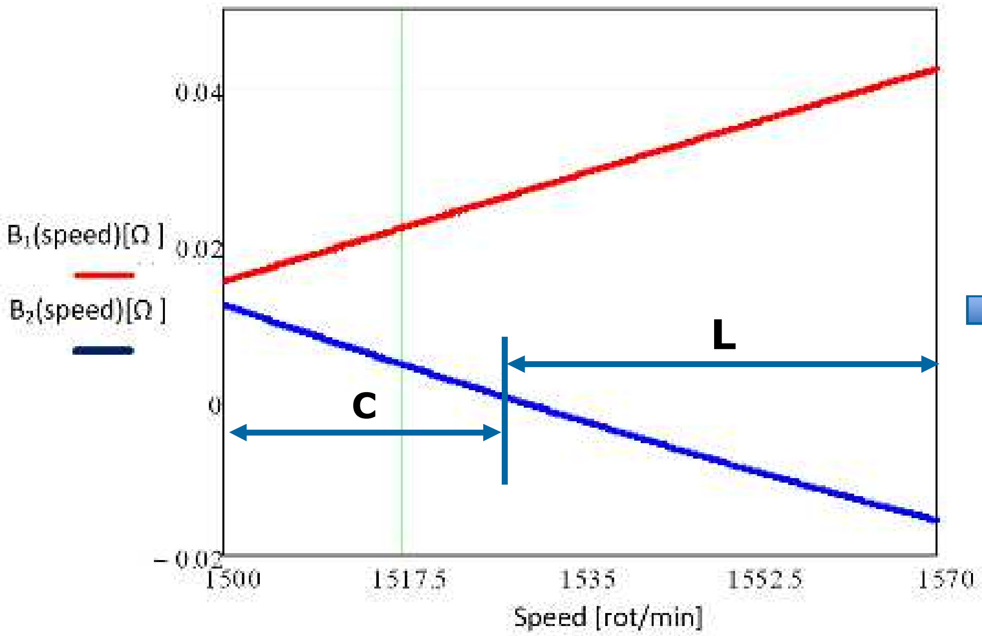


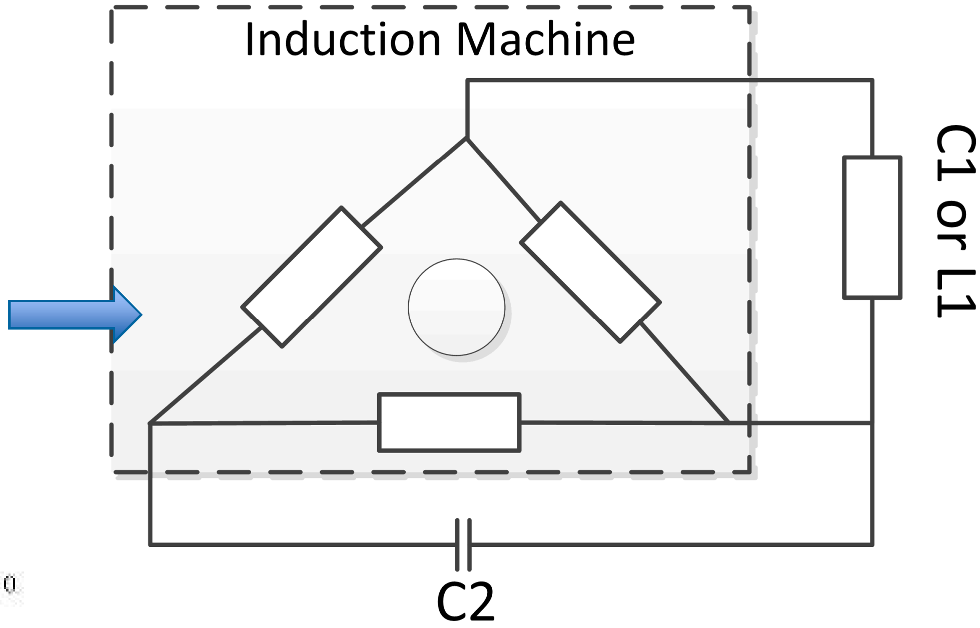
Balancing circuit schematic

$$B_1 = \sqrt{3}\cdot G_p + B_p = 2\left|Y_p\right|\sin\left(2\pi/3 - \Phi_p\right)$$

$$B_2 = -\sqrt{3}\cdot G_p + B_p = 2\left|Y_p\right|\sin\left(\Phi_p - \pi/3\right)$$

Balancing circuit

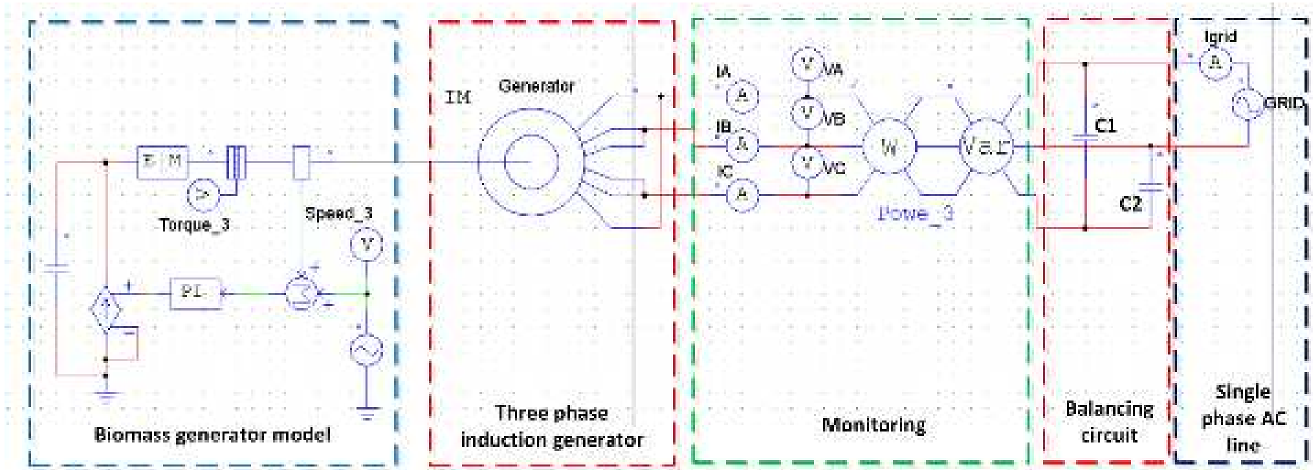




B_1 and B_2 as a function of rotor speed

Simulation model

- *Biomass generator model*
- *Induction machine*
- *Data acquisition*
- *Balancing circuit*
- *Single phase AC microgrid*



Simulation model

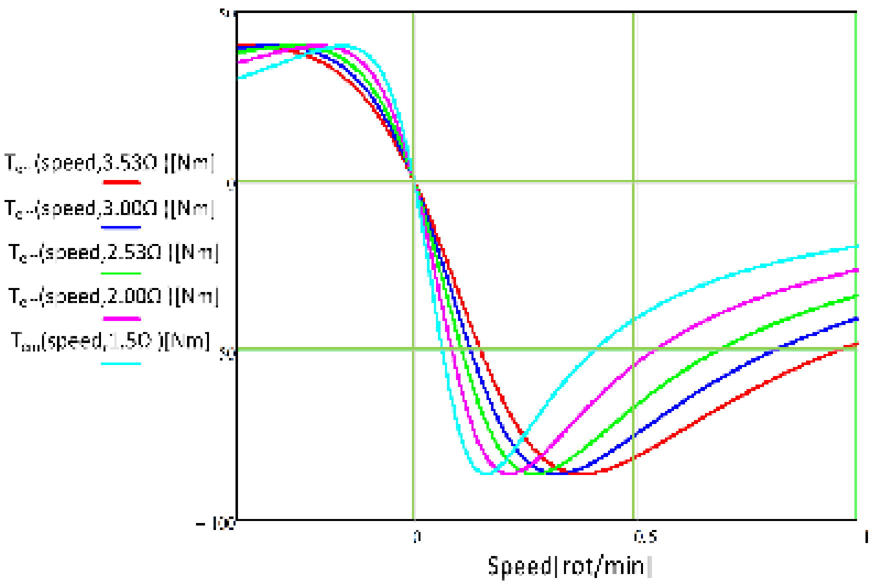
Induction generator characteristics

- Stator resistance R_s	= 9.141Ω;
- Stator leakage inductance L_s	= 0.013H;
- Positive-sequence rotor resistance R_{rp}	= 2.53Ω;
- Negative-sequence rotor resistance R_{rn}	= 4.0 Ω;
- Rotor leakage inductance L_r	= 0.014H;
- Magnetizing inductance at nominal voltage	= 0.178H;

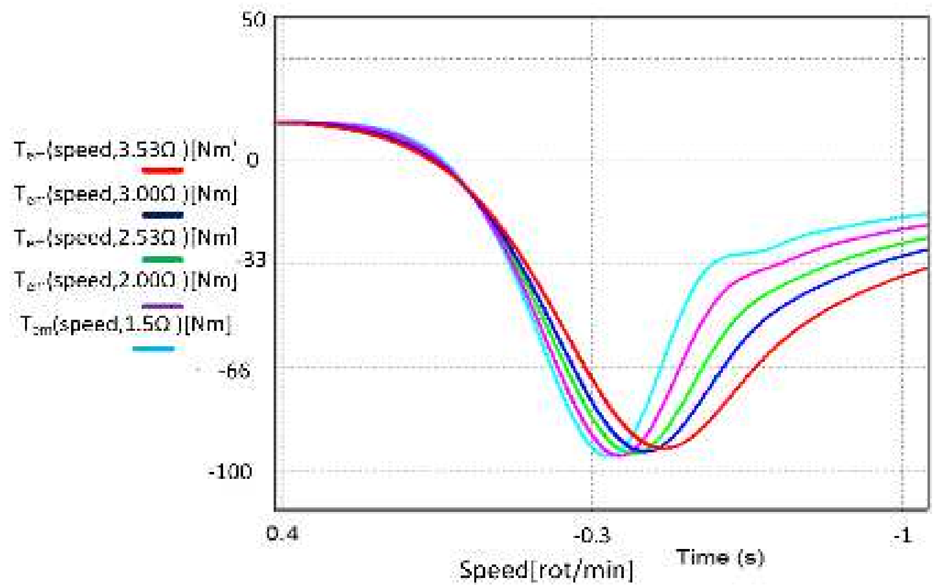
Simulation results

➢ Torque for different values of rotor resistance

Calculated

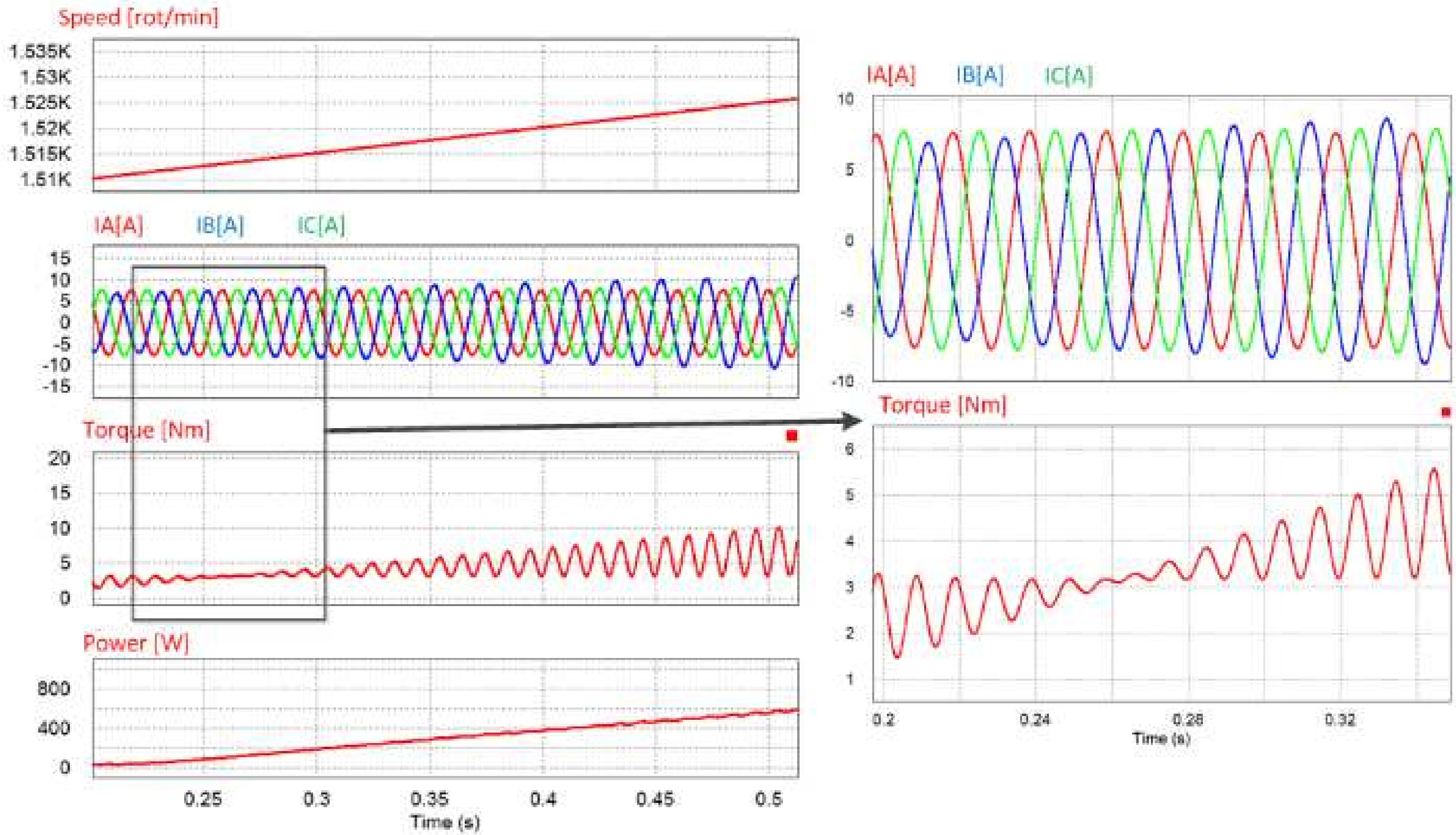


Simulated

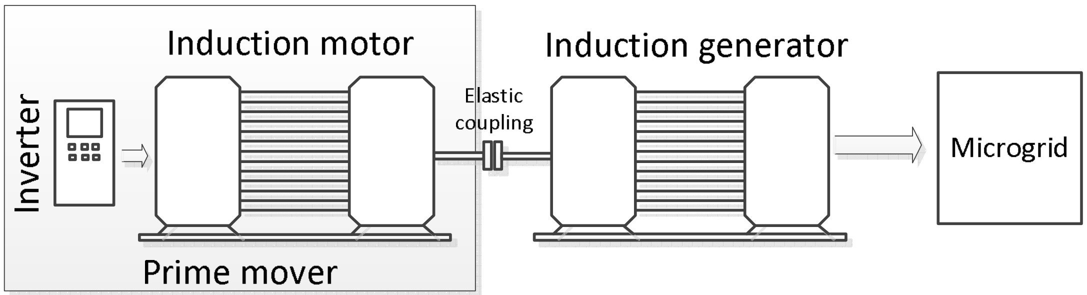


Simulation results

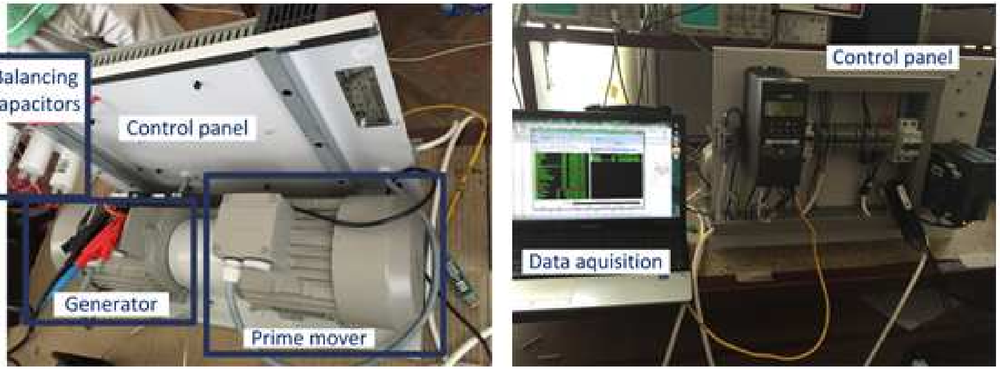
➢ The balancing circuit can obtain almost constant torque for a range of speeds



Experimental results



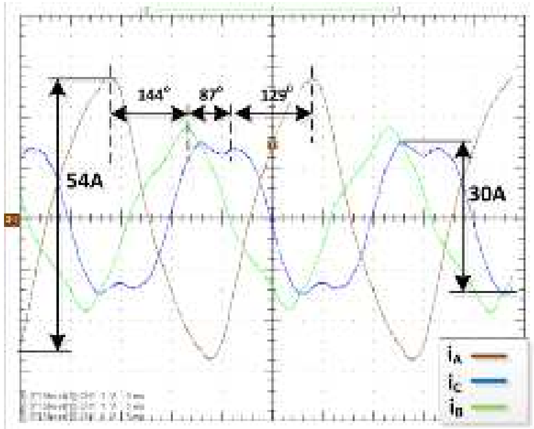
Schematic of experimental biomass emulator



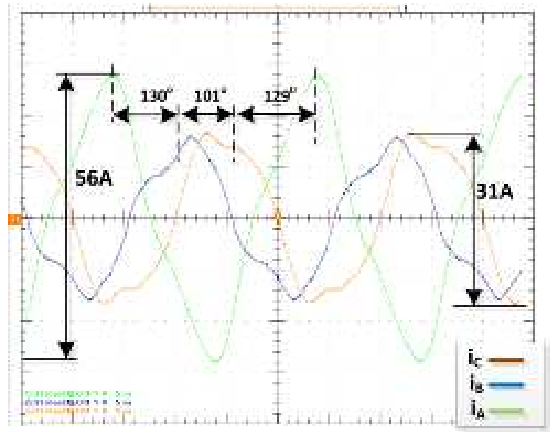
Laboratory setup

- Experimental setup
  - An induction motor drives the induction generator;
  - The induction motor is controlled by an inverter for constant speed;
  - The difference between the microgrid frequency and the mechanical frequency gives the output power.

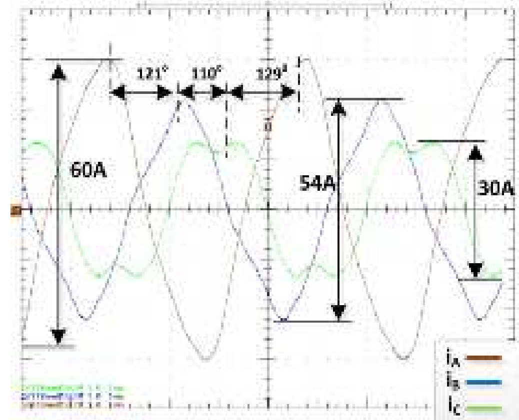
Experimental results



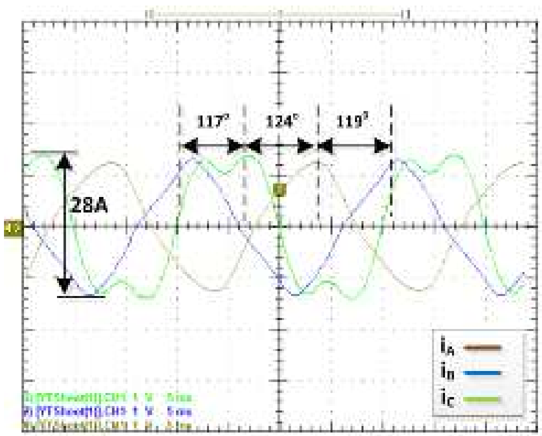
100W output power



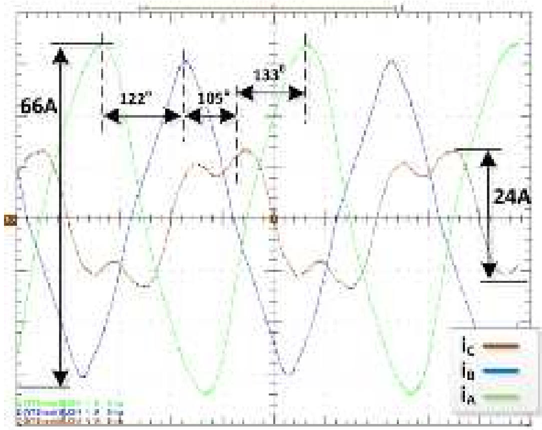
150W output power



200W output power



250W output power



300W output power

Power injected to the microgrid AC bus

Conclusions

- The paper presented an analysis of the possibility to use a three phase induction generator to generate power from a biogas generator and to supply it to a microgrid.
- The generator is coupled directly to the microgrid single phase AC bus.
- It was demonstrated that a three phase induction generator can be used successfully to produce power from the biogas generator and inject it in a single phase AC microgrid using a proper balancing network.
- In the case presented in the paper the network is composed of only two capacitors. For higher power ratings an inductor and a capacitor may be necessary.
- It was demonstrated that the generator is balanced at only one power level but it was shown that the balancing circuit can be used with average performances in a larger domain, from 150W to 300W.
- The experimental results validate the simulation model and the calculations for the balancing circuit.

Thank you!

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