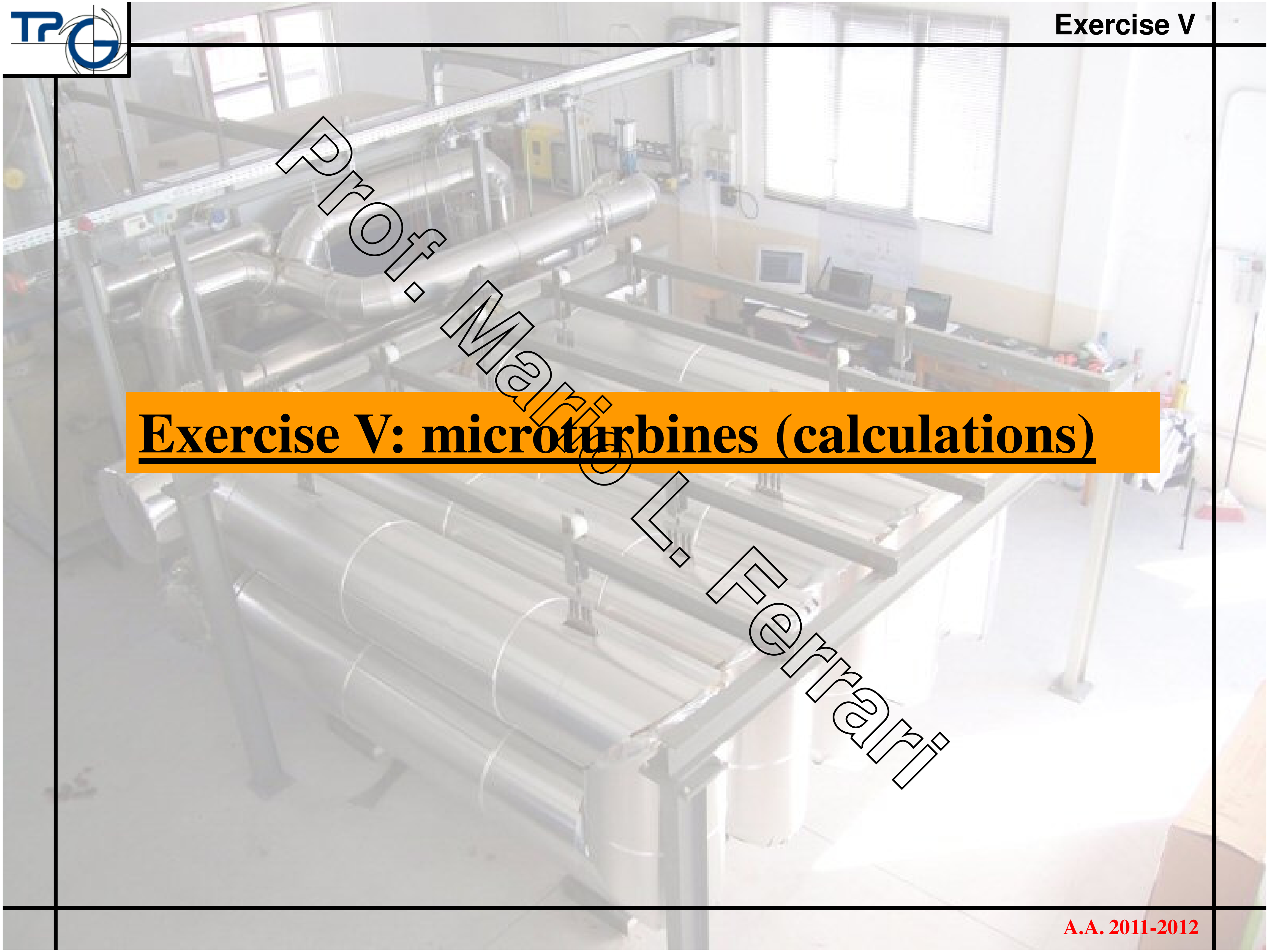
Sustainable Energy

Mod.1: Fuel Cells & Distributed Generation Systems

Dr. Ing. Mario L. Ferrari

Thermochemical Power Group (TPG) - DiMSET – University of Genoa, Italy



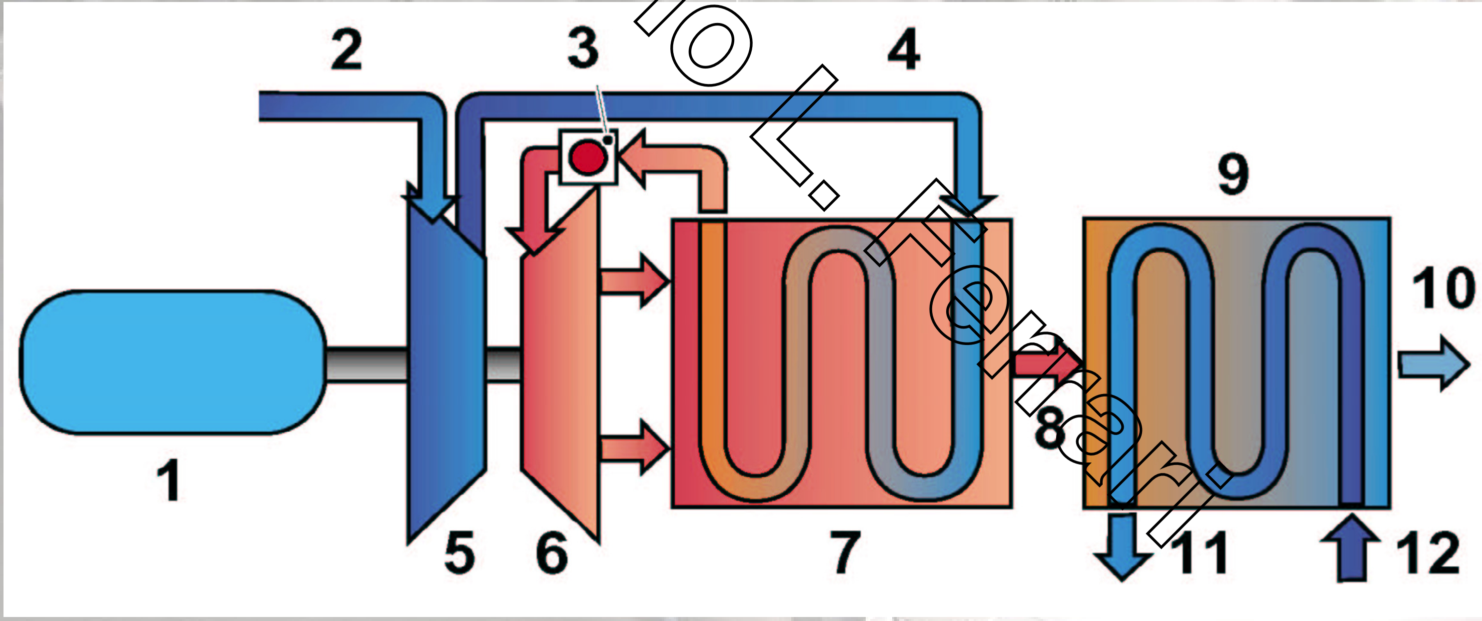
Exercise V: microturbines (calculations)

Exercise 1: Calculate electrical and total efficiency for the T100 machine with the following data:

- Ambient condition: 15°C, 1.013 bar ($p_4=p_1$)
- Air mass flow rate: 0.8 kg/s
- Compression ratio: 4.5
- Compressor efficiency: 0.72
- Recuperator effectiveness: 0.88
- Compressor-turbine pressure loss: 6%
- Combustion efficiency: 0.995
- Fuel LHV: 48000 kJ/kg
- Expander efficiency: 0.82
- TOT: 645°C
- Mechanical efficiency: 0.99
- Electrical efficiency: 0.96
- Auxiliary power: 7.4 kW
- Water outlet temperature: 95°C
- Water-Exhaust temp. difference - efficiency: 20°C – 0.95

Plant layout:

Legend: 1. Generator; 2. Inlet air; 3. Combustion chamber; 4. Air to recuperator; 5. Compressor; 6. Turbine; 7. Recuperator; 8. Exhaust gases; 9. Exhaust gas heat exchanger; 10. Exhaust gas



Solution (1/2):

1. Assumption: air $c_{p\_a} = 1.014$ kJ/kgK (so: $k_c = 1.39$)
2. Compressor outlet temperature: $T_2=T_1+(1/\eta_c)*T_1*(\beta_c^{\theta c}-1) = 498.29$ K
3. Compressor outlet pressure: $p_2 = p_1*\beta_c = 4.56$ bar
4. Calculation of compressor power: $P_c = m_a*c_{p\_a}*(T_2-T_1) = 170.47$ kW
5. Combustor inlet temperature: $T_5 = (T_4-T_2)*\varepsilon+T_2 = 867.77$ K
6. Turbine inlet pressure: $p_3 = p_2-\Delta p_{2-3} = 4.29$ bar
7. Assumption: air $c_{p\_t} = 1.14$ kJ/kgK (so: $k_t = 1.34$)
8. Expansion ratio: $\varepsilon_t = p_3/p_4 = 4.23$
9. Turbine inlet temperature (TIT): $T_3 = T_4/(1-\eta_t+\eta_t/\varepsilon_t^{\theta t}) = 1226.31$ K
10. Assumption: air $c_{p\_a\_ht} = 1.15$ kJ/kgK
11. Fuel (fuel h neglected): $m_f = [m_a*c_{p\_a\_ht}*(T_3-T_5)]/(LHV*\eta_b) = 6.9$ g/s
12. Calculation of turbine power: $P_c = (m_a+m_f)*c_{p\_t}*(T_3-T_4) = 283.47$ kW
13. Calculation of mechanical power: $P_m = (P_t-P_c)*\eta_m = 111.87$ kW
14. Calculation of net electrical power: $P_e = P_m*\eta_{el}-P_{aux} = 100.00$ kW
15. Calculation of machine electrical efficiency: $\eta_g = P_e/(m_f*LHV) = 0.30$
16. Calculation of exhaust temperature: $T_7 = T_w+\Delta T_{7-W} = 115$°C
17. Assumption: air $c_{p\_a\_rec} = 1.09$ kJ/kgK
18. Rec. out. (hot): $T_6=T_4-[m_a*c_{p\_a\_rec}*(T_5-T_2)]/[(m_a+m_f)*c_{p\_t}]=567.90$ K

Solution (2/2):

19. Calculation of thermal power: $P_{th}=(m_a+m_f)*c_{p\_t}*(T_6-T_7)*\eta_{sc}=157.1$ kW
20. Calculation of total efficiency: $\eta_{total}=(P_e+P_{th})/(m_f*LHV)= 0.776$