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System layout and performance prediction for a solar-hybrid micro-gas turbine

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Overview

- Background
- Solar-hybrid gas turbine systems in literature
- Application of a turbocharger as a micro-turbine
- Application of a turbocharger as a solar-hybrid MGT

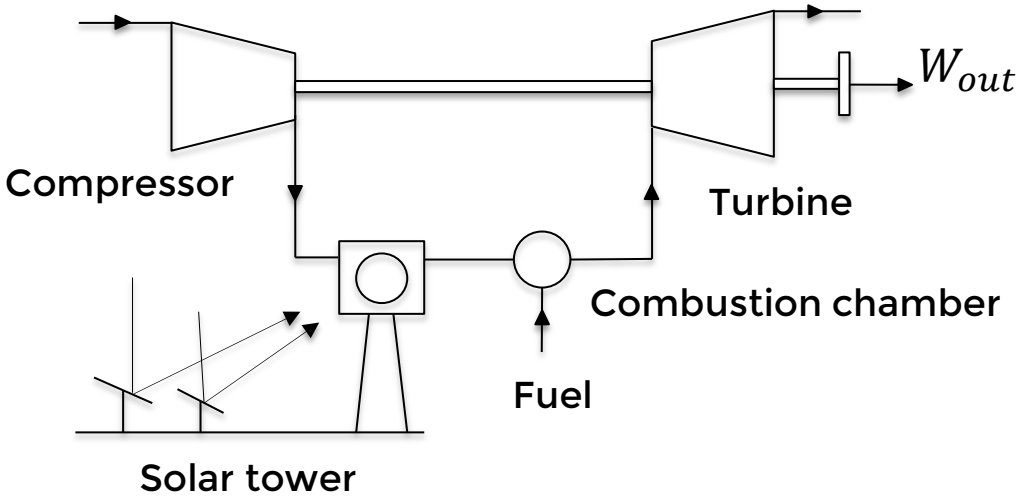
Background

- Solar-hybrid power systems combine solar energy and fossil fuel = reliable power with full dispatchability

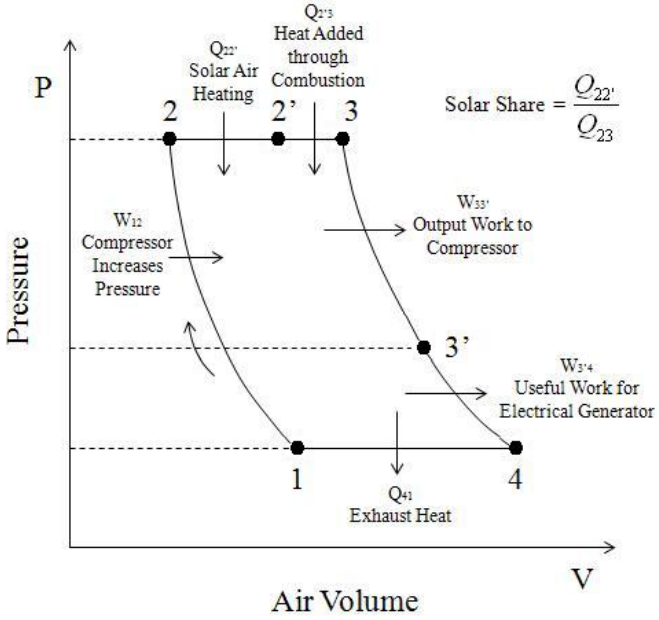
- Application of MGTs in solar power systems is a relatively new research field

- Past research has mainly focussed on the test and validation of receiver concepts

Background (cont'd)



Solar-hybrid gas turbine system



Solar-hybrid Brayton cycle

Solar-hybrid gas turbine systems in literature

- Include 3 European Commission funded projects; SOLGATE, SOLHYCO and SOLUGAS
- Employed commercial and relatively expensive gas turbines – also complicated in construction
- Gas turbines faced numerous operational challenges and eventually had to be shut down

Solar-hybrid gas turbine systems in literature (cont'd)

- **SOLGATE**: Modified an Allison model 250 helicopter engine

- Faults with the oil system cut short the turbine tests

Phase 1	Phase 2
$T_{rec,out} = 800$ °C $P_{abs} = 6.5$ bar $P_{elec} = 230$ kWe $\eta_{turb} = 20$ % Solar fraction = 60% Total gas turbine operation time of 73 hours, 51 with solar radiation	$T_{rec,out} = 959$ °C $P_{abs} = 5.5$ bar $P_{elec} = 170$ kWe $\eta_{turb} = 18$ % Solar fraction = 70% Total gas turbine operation time of $61^1/_2$ hours, $45^1/_2$ with solar radiation

Solar-hybrid gas turbine systems in literature (cont'd)

- **SOLHYCO:** Initially adapted the SOLGATE gas turbine to bio-diesel operation
- Modified commercially available 100 kWe *Turbec* T100 micro-turbine for solar-hybrid cogeneration application
- Faulty oil cooling system cut short the bio-diesel turbine tests
- Output electric power also decreased and unstable control and surges occurred during operation and shutdown

Turbec T100 micro-turbine

Application of a turbocharger as a micro-turbine

- Turbochargers are relatively cheap and abundant
- Performance and efficiency of modern small turbochargers has greatly improved
- Availability of cheap highly efficient high speed motor generators
- MTT b.v. (Micro Turbine Technology) developed a 3 kW recuperated micro-turbine for CHP applications based on turbocharger technology

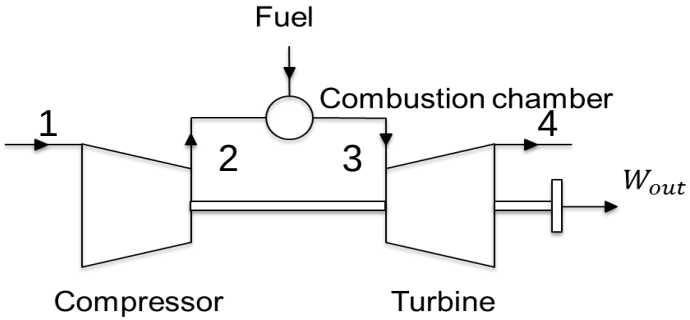
Application of a turbocharger as a micro-turbine (cont'd)

- Combined off-the-shelf turbocharger components with in-house built components
- Improved individual component performance so as to increase net electric output and efficiency
- Final test results showed increase in electric efficiency from 12.2% to 17.2%, at an electric output of 3.4 kWe

Gas generator tests	Simple cycle tests	Recuperated cycle tests
$P_{elec} = 3.25$ **kWe** $\eta_{th} = 6.34\%$ $N = 240\,000$ rpm	$P_{elec} = 2.8$ **kWe** $\eta_{elec} = 6.28\%$ $N = 218\,000$ rpm	$P_{elec} = 2.7$ **kWe** $\eta_{elec} = 12.2\%$ $N = 240\,000$ rpm

Application of a turbocharger as a solar-hybrid MGT

- The use of a turbocharger ensures a simple and modular structure, easy usage and low cost
- Determine design point performance for a simple gas turbine Brayton cycle



Simple micro-gas turbine system

Inputs:

PR_{comp} = 2.5

T_{03} = 1100 K

η_{comp} = 75%

η_{turb} = 68%

η_{comb} = 99%

ΔPb = 2% comp. deliv. press.

Application of a turbocharger as a solar-hybrid MGT (cont'd)

Results:

Specific work output = 54.5 kJ/kg

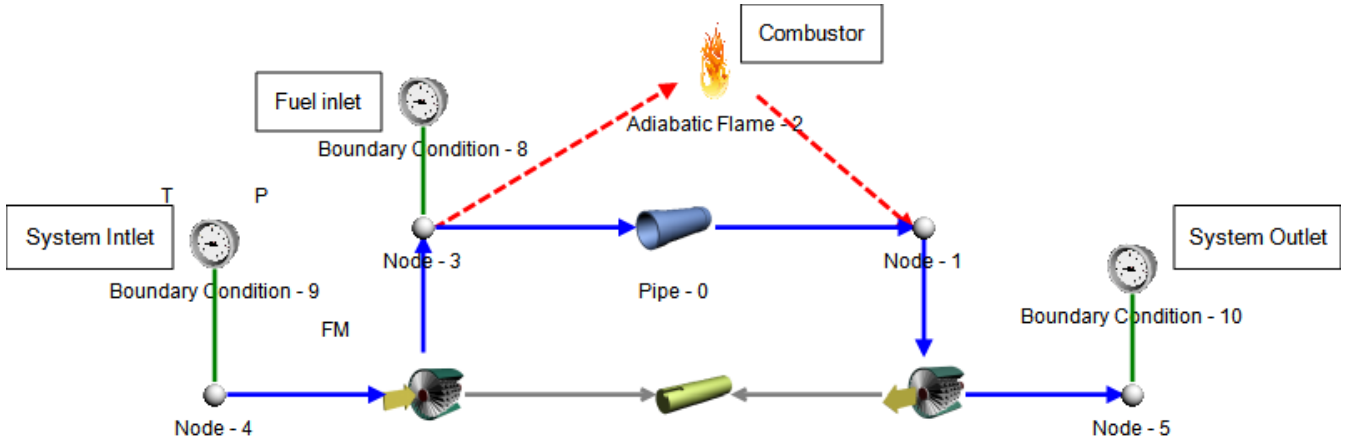
Air mass flow required (10 kW plant) = 0.183 kg/s

Specific fuel consumption = 0.345 kg/kWh

Cycle efficiency = 24%

Application of a turbocharger as a solar-hybrid MGT (cont'd)

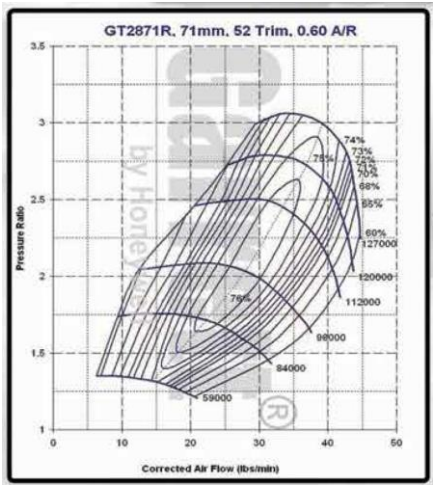
- Model simple gas turbine system in Flownex



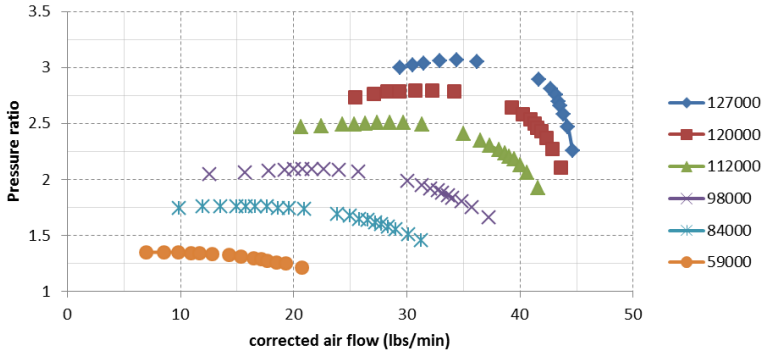
Simple gas turbine model in Flownex

Application of a turbocharger as a solar-hybrid MGT (cont'd)

- Select turbocharger from Garrett catalog and input compressor and turbine performance maps



GT2871R Garrett compressor map



Digitised compressor map

Application of a turbocharger as a solar-hybrid MGT (cont'd)

Work in pipeline:

- Design, build and test solar-hybrid MGT combustor at the Institute of Thermal Turbomachinery and Machinery Laboratory, University of Stuttgart

Thank you

ACKNOWLEDGEMENTS:

- Centre for Renewable and Sustainable Energy Studies (CRSES)
- Solar Thermal Energy Research Group (STERG)

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