Integrated Market-fit and Affordable Grid-scale Energy Storage (IMAGES)

Four Months Progress Meeting

Jihong Wang, Jacek Wojcik, Xing Luo. Wei He, Jianguo Wang

Warwick (Engineering)

10th March 2017

Outline of the presentation

1. Overview
2. Report of the project progress
    - 2.1 CAES-TES dynamic modelling and simulation tool development
    - 2.2 Further investigation on HTTS integration
    - 2.3 Integration of energy storage
3. Introduction of New RF – Dr Jianguo Wang
4. Work plan

1. Overview

Staff: Dr Jianguo Wang joined us from 1st March 2017

Students:

- Mr Anand Ganesan, Uncertain?
- Mr James Lam, to join us in May 2017

Dr Xing Luo has given his full support and worked on the project.

Jianguo Wang

- March 2017 – , Research Fellow, University of Warwick

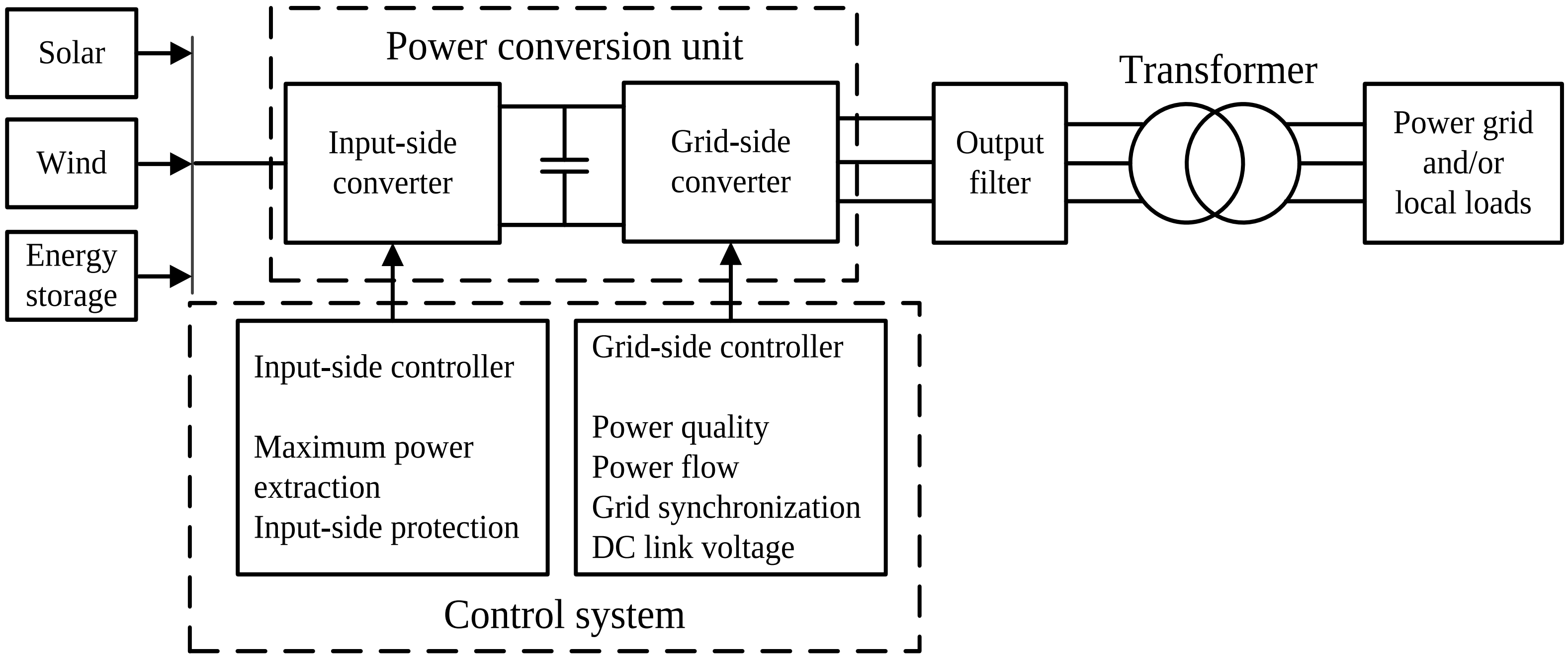
- Nov. 2016 – Feb.2017, Research Associate, PE group, University of Warwick
- Aug – Oct. 2016, Research Associate, University of Liverpool

- July 2016, PhD, Electrical and Electronic Engineering, University of Liverpool
- June 2013, MEng, Electrical Engineering, Dalian University of Technology
- June 2010, BEng, Electrical Engineering, Dalian University of Technology

Main research interests and expertise:

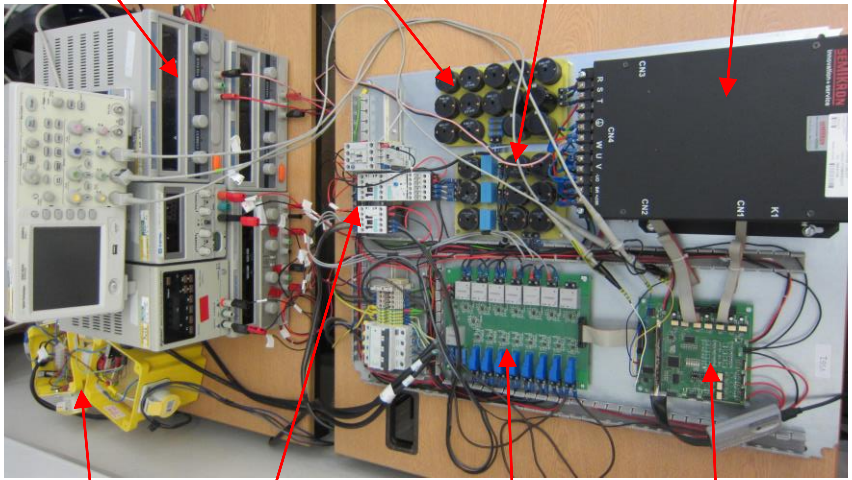
Power electronics for renewable energy systems, especially when integration with power network.

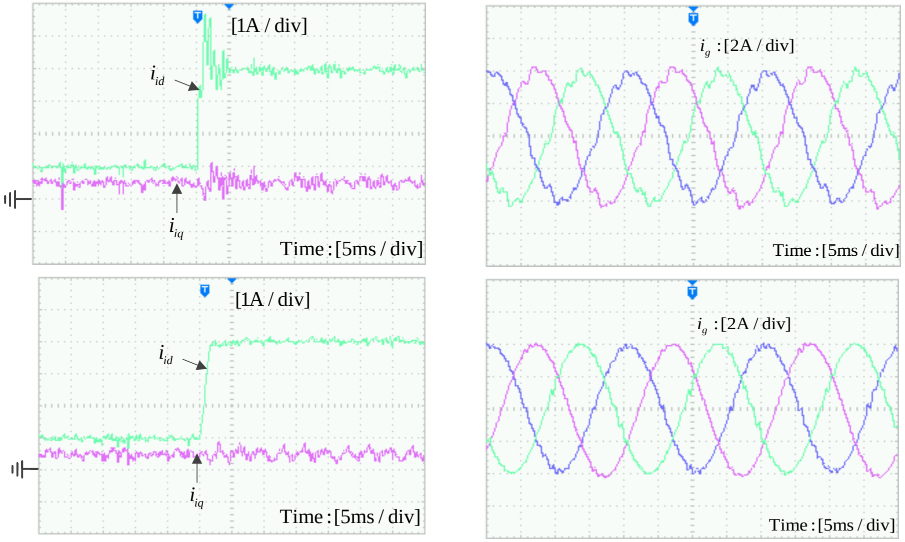
Research experience



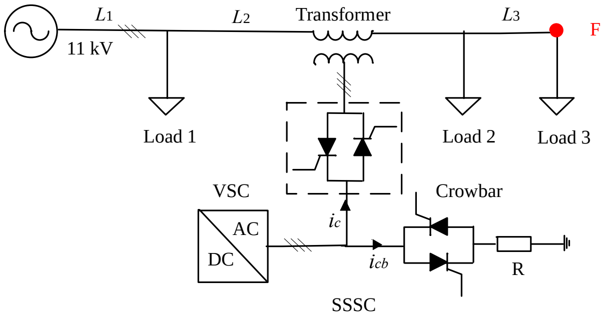
PhD research project carried out **comprehensive stability studies** and proposed **novel current control methods** to study and improve the performance of grid-tied converters, in terms of **system stability, power quality, power flow, transient response, grid synchronization, robustness, and fault ride-through capability.**

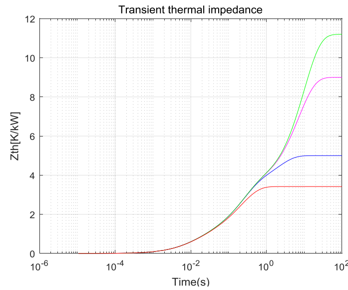
Research experience





Power converter protection





1. Overview

Journal Papers published:

•Wojcik, J D, Wang, J, Technical feasibility study of Thermal Energy Storage (TES) integration into conventional power plant cycle, *Energies*, Feb 2017

•He, W., Wang, J., Feasibility study of energy storage by concentrating/desalinating water: Concentrated Water Energy Storage, *Applied Energy*, Vol. 185, pp872-884, Jan 2017.

Journal Papers submitted

•He, W., Luo, X., Evans, D., Busby, J., Garvey, S., Parkes, D., Wang, J., Exergy storage of compressed air in cavern and cavern volume estimation of the large-scale Compressed Air Energy Storage system, submitted to *Applied Energy*

•Luo, X., Wang, J., Shpanin, L., Dooner, M., A new scroll-type air motor with magnetic spirals, submitted to *IEEE/ASME Trans on Mechatronics*

2. Report of the project progress

WPs that Warwick leads

WP2.2 Task 1. Improving the round trip efficiency of large scale adiabatic CAES systems ✔ Completed

WP2.2 Task 2. Hybrid integration of wind power generation with CAES ✔ Completed

WP2.2 Task 3. Software tool development for complete CAES processes ✔ On-schedule

WP2.2 Task 4. Supporting the whole system techno-economic study ✔ On-going

WPs that Warwick supports

WP2.3 Integrated ES: Warwick team has developed a number of thermal storage model and simulation library blocks which can be used by WP2.3. ✔ On-schedule

WPs1.5/2.4 HTTS: Using the unique simulation facility at Warwick, Warwick team has conducted the feasibility study of HTTS integration into power plant cycle for both subcritical oil-fired power plant model and supercritical coal-fired power plant model. ✔ On-schedule

2. Report of the project progress

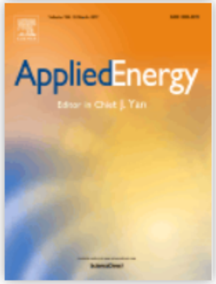
WPs that Warwick leads

WP1.2 Task 2. Update the overview in CAES and other ES technology development.

Continued through the work EERA-EASE Roadmap Technology Section – CAES

- meeting for discussion on 15th March 2017 in Brussel

2. Report of the project progress



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2. Report of the project progress

WP1.4 Task 2. CAES specific opportunities in the UK

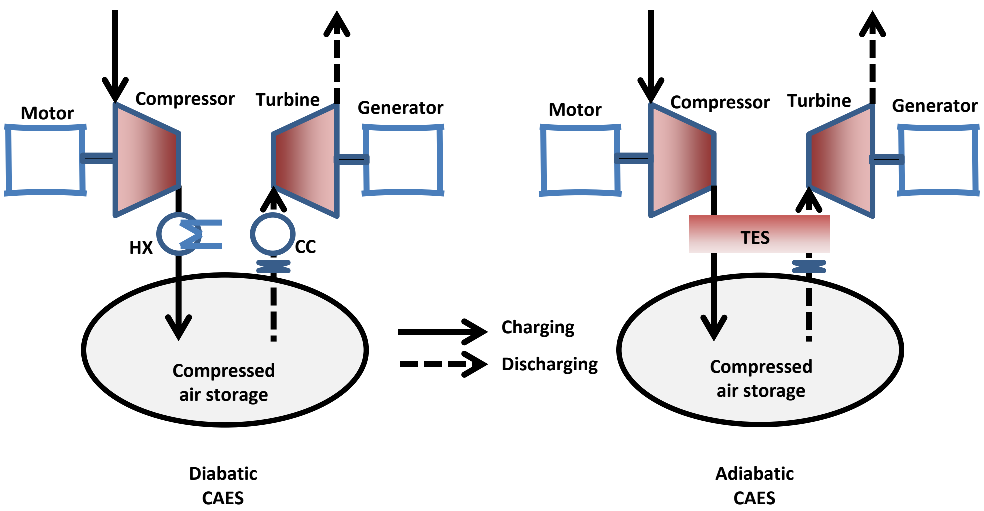
Exergy storage capacity calculation of cavern-based large-scale CAES system

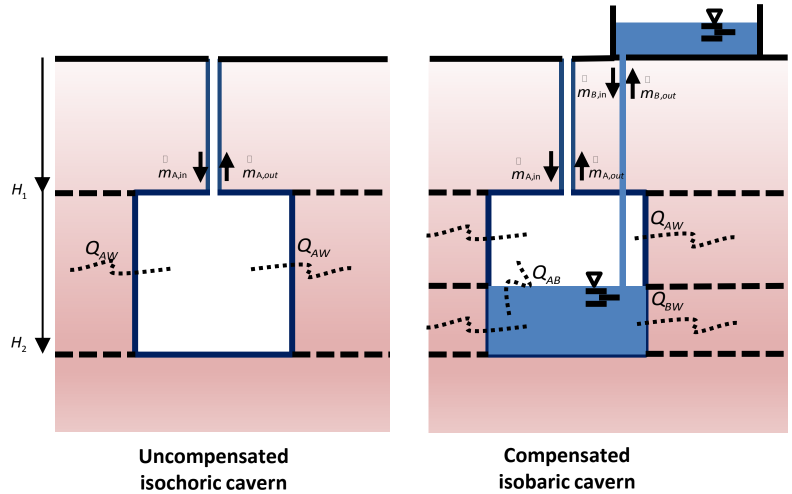
Large-scale cavern-based CAES system

- Diabatic CAES
- Adiabatic CAES

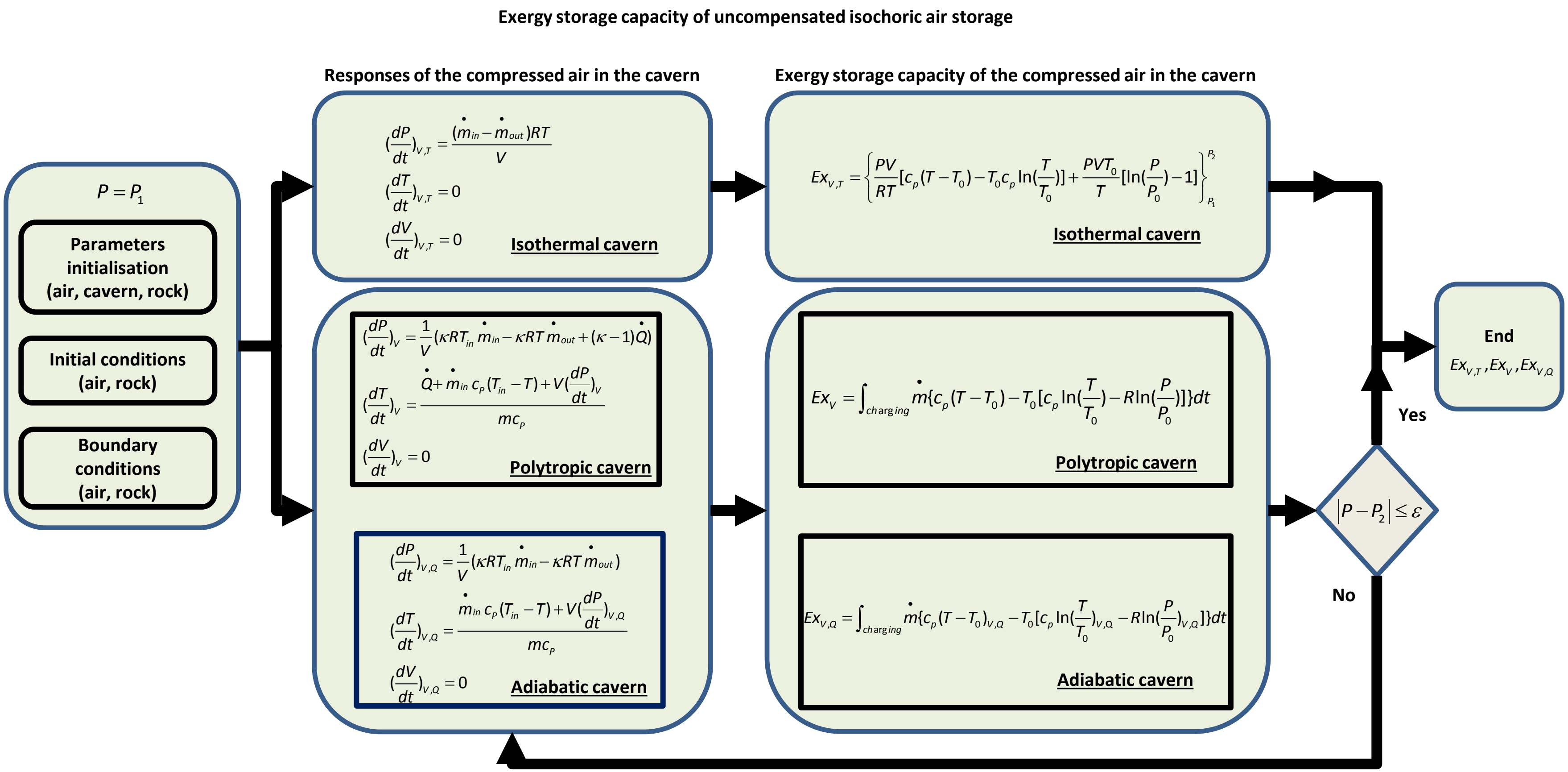
Cavern operational scenarios

- Uncompensated isochoric cavern
- Compensated isobaric cavern

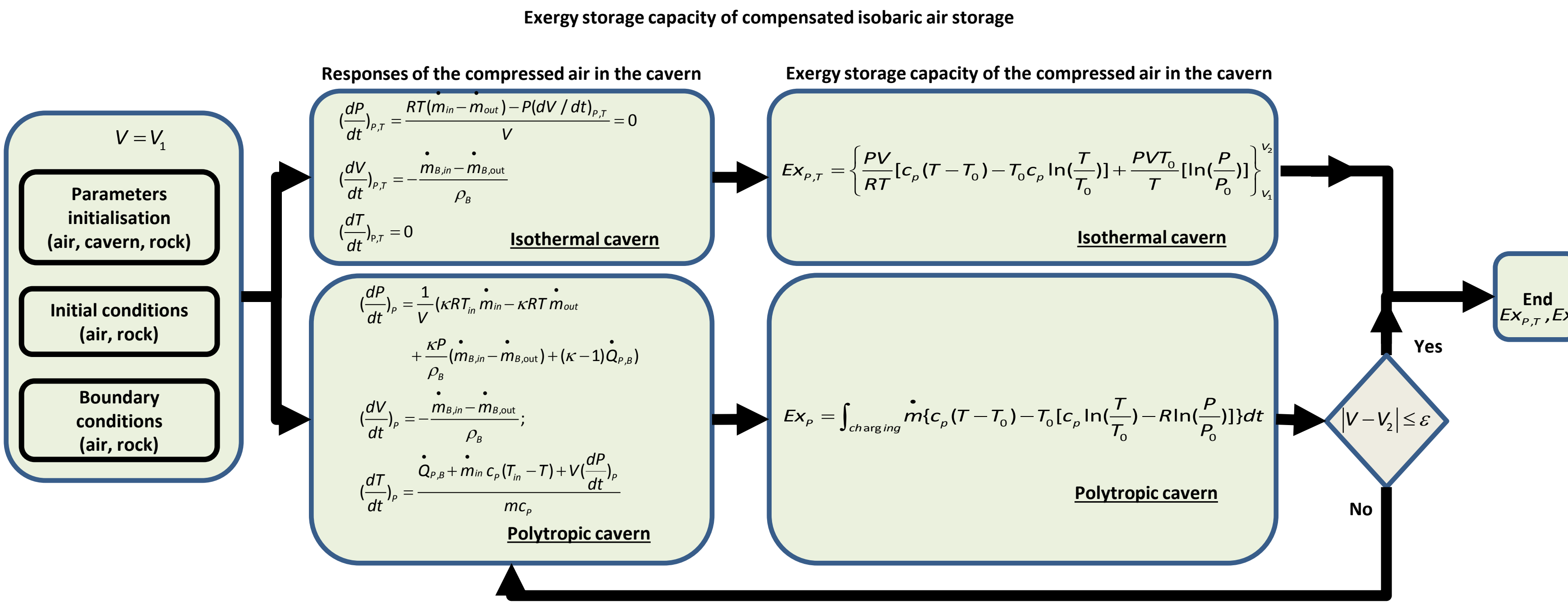




Flowchart of exergy storage calculation: uncompensated isochoric air storage



Flowchart of exergy storage calculation: compensated isobaric air storage



Two case studies: Huntorf and Hornsea underground gas storage facility

Huntorf (uncompensated isochoric mode)

Cavern type	Isothermal cavern	Polytropic cavern	Adiabatic cavern
Maximum exergy stored, MWh	838	711.1	603
Charging time, hrs	22.47	18.97	16.05
Mass stored, kg	8,736,336	7,375,500	6,240,240
Input power, MW	37.29	37.49	37.57
Exergy stored after throttling, MWh	782.6	664.5	567.2

Huntorf (compensated isobaric mode)

Cavern type	Isothermal cavern	Polytropic cavern
Maximum exergy stored, MWh	1,983	1982
Charging time, hrs	50.52	50.51
Mass storage, kg	19,642,176	19,634,400
Input power, MW	39.25	39.21

Hornsea gas storage facility (uncompensated isochoric mode)

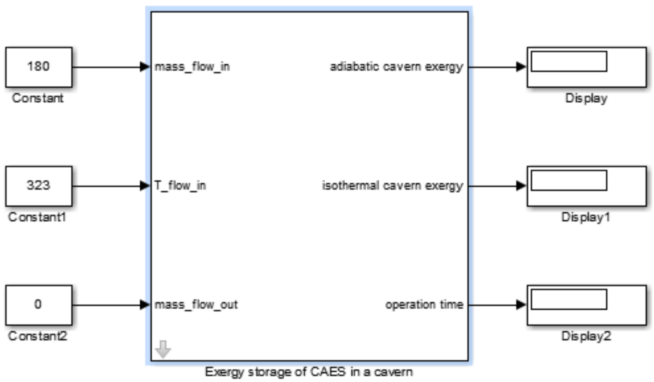
Cavern type	Isothermal cavern	Polytropic cavern	Adiabatic cavern
Maximum exergy stored per cavity, MWh	4,489	3,919	3,287
Total maximum exergy stored, MWh	40,401	35,271	29,583
Mass stored per cavity, kg	35,930,000	31,250,000	26,070,000
Exergy stored after throttling per cavity, MWh	4089	3,570	3,011
Total exergy stored after throttling, MWh	36,801	32,130	27,099

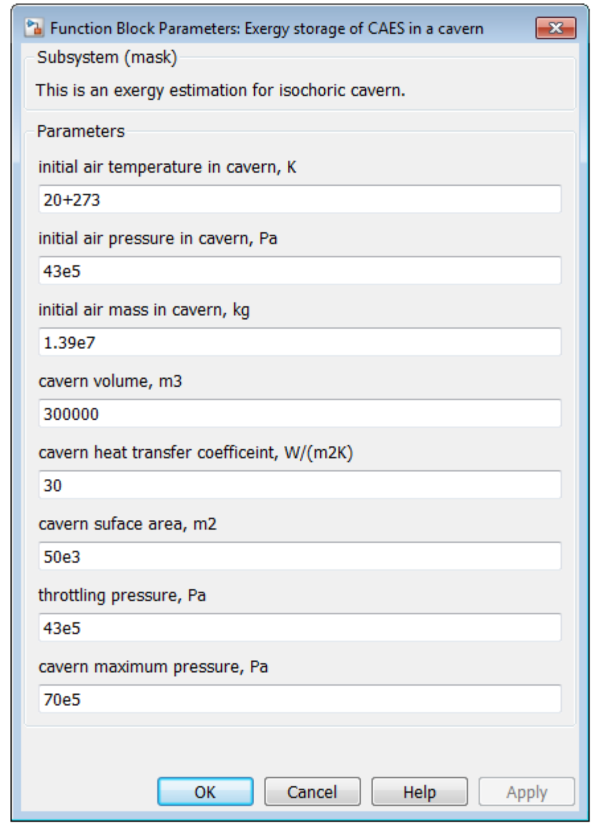
Hornsea gas storage facility (compensated isobaric mode)

Cavern type	Isothermal cavern	Polytropic cavern
Maximum exergy stored per cavity, MWh	7,394	7,367
Mass storage per cavity, kg	55,584,000	55,386,000
Total maximum exergy stored, MWh	66,546	66,303

WP1.4 Task 2. CAES specific opportunities in the UK

The Simulink module of CAES exergy storage in the cavern



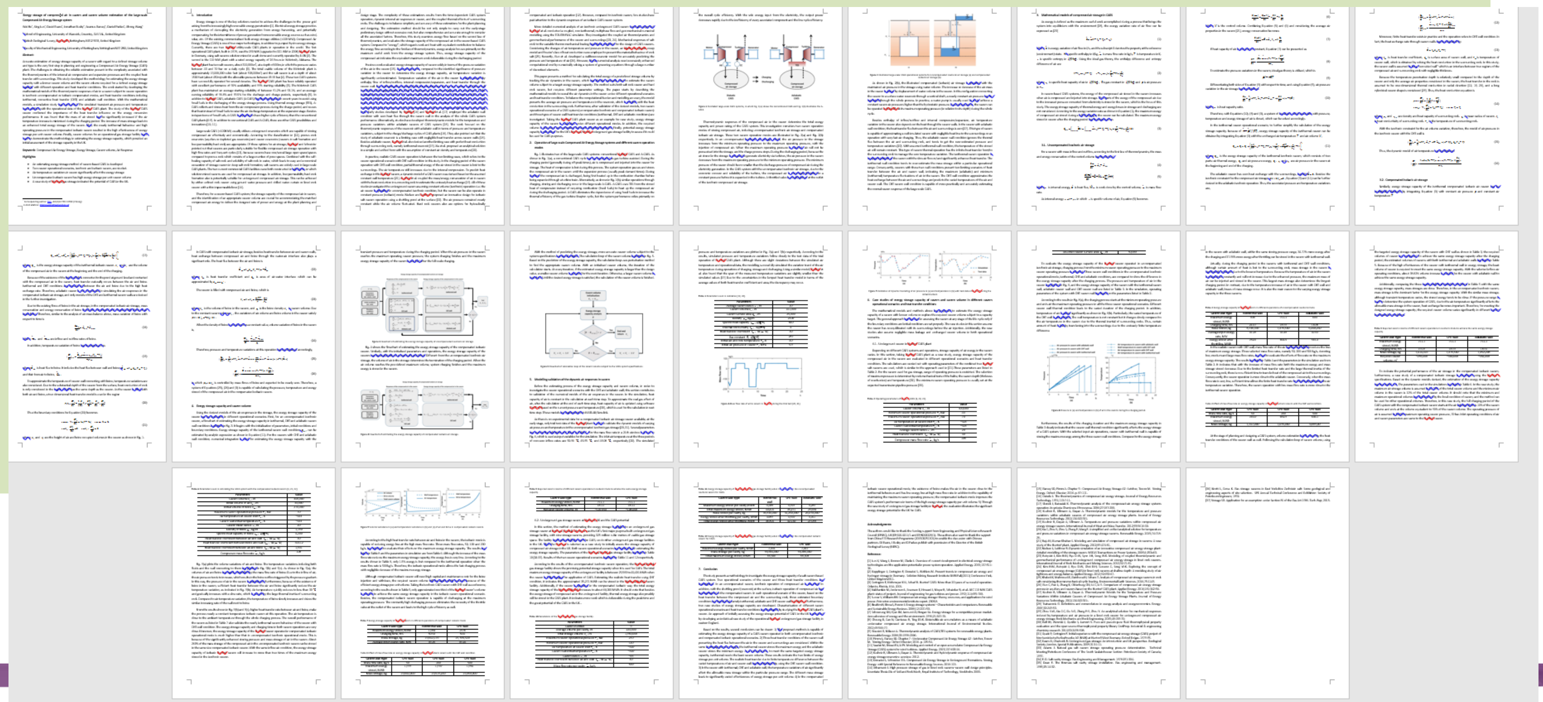


2. Report of the project progress

WPs that Warwick leads

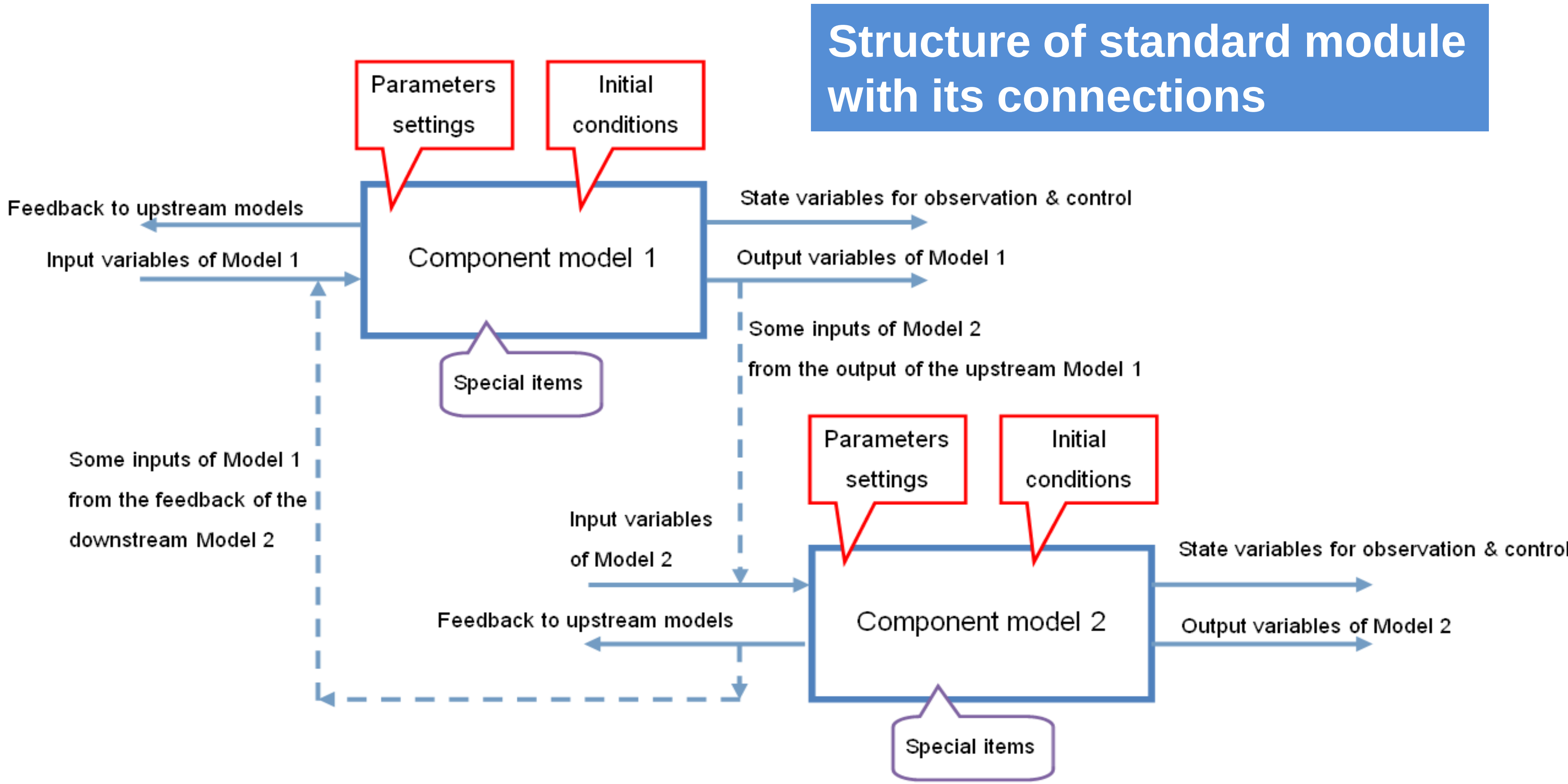
WP1.4 Task 2. CAES specific opportunities in the UK

Working closely with BGS and Nottingham to study the method to give more accurate calculation/estimation of energy storage capacity with consideration of dynamic process of compression and expansion. The paper has been submitted.

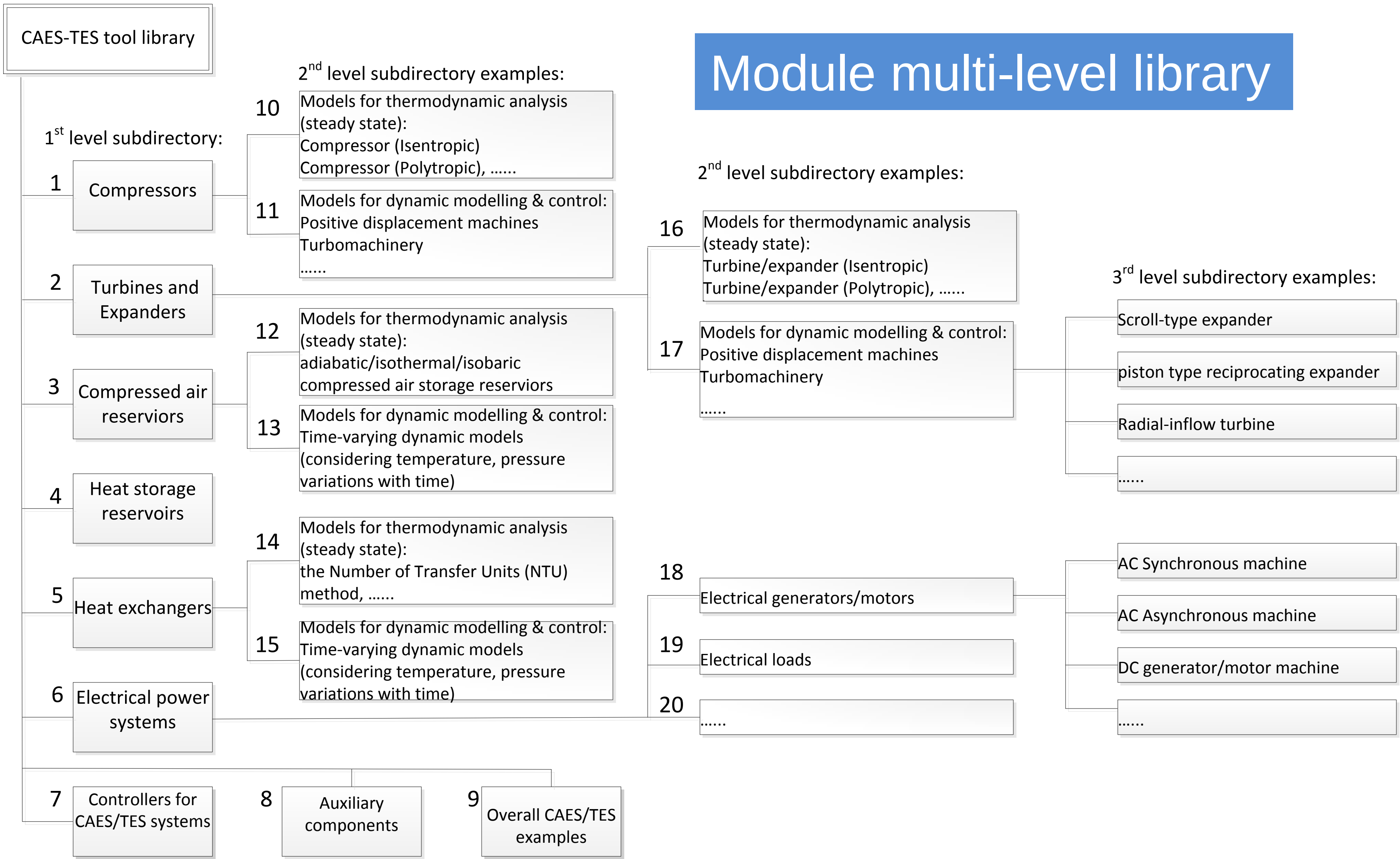


WARWICK

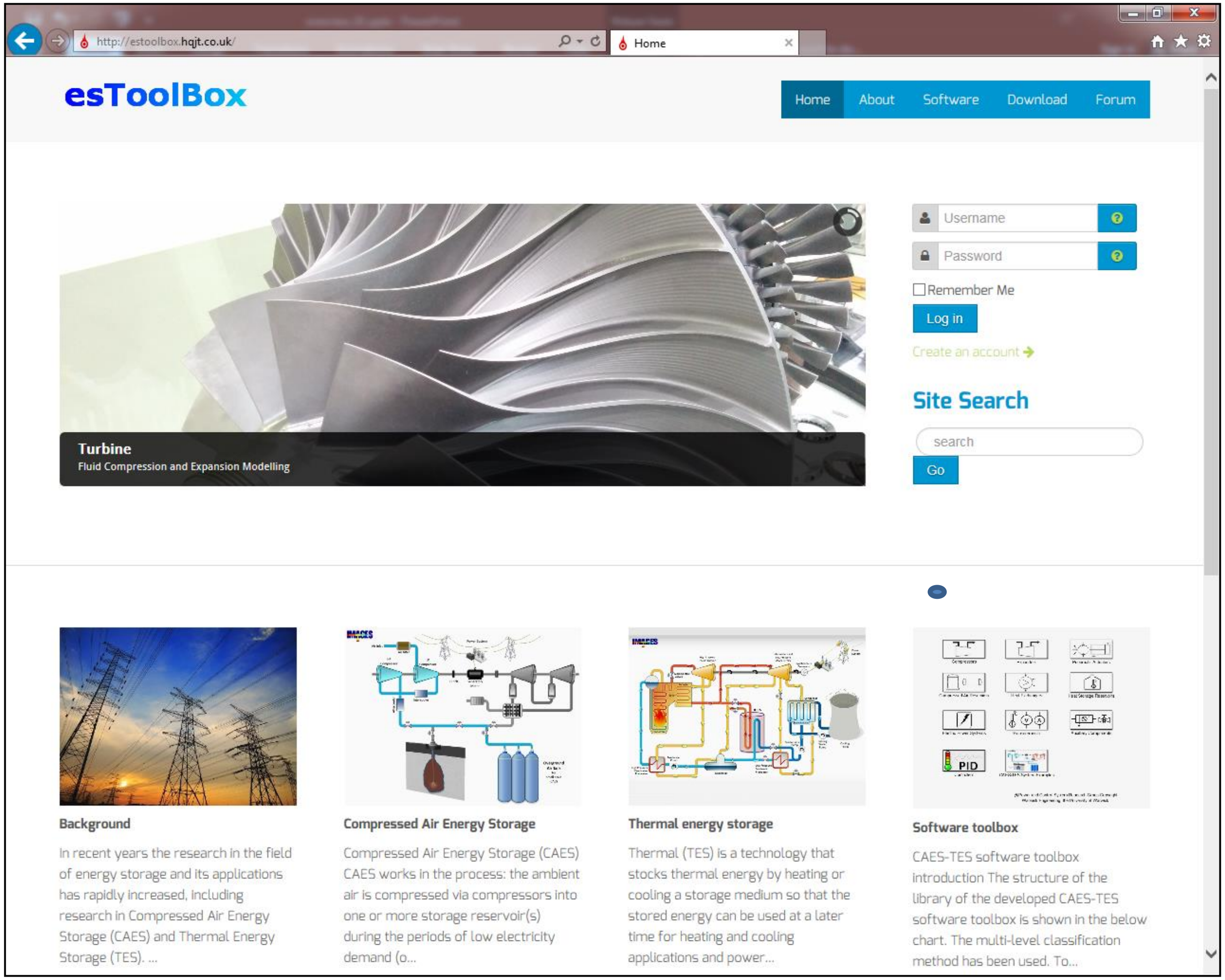
2.1 CAES-TES dynamic modelling & software



2.1 CAES-TES dynamic modelling & software



2.1 CAES-TES dynamic modelling & software



Demo
- X Luo

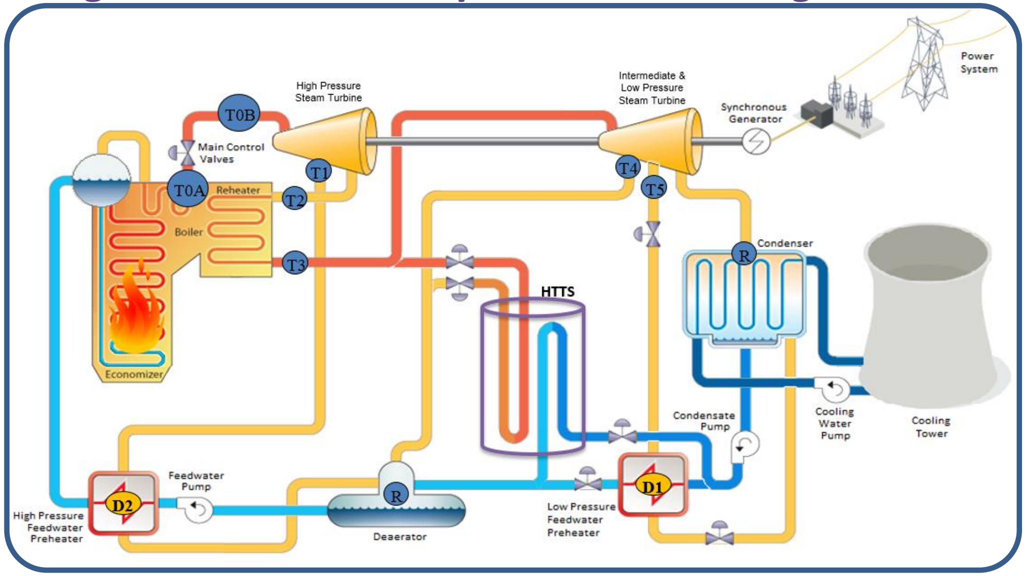
2.2 Further investigation on HTTS integration

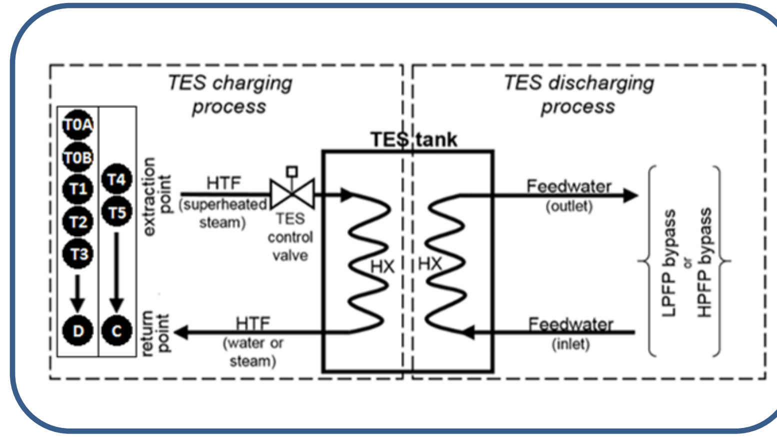
WPs that Warwick supports

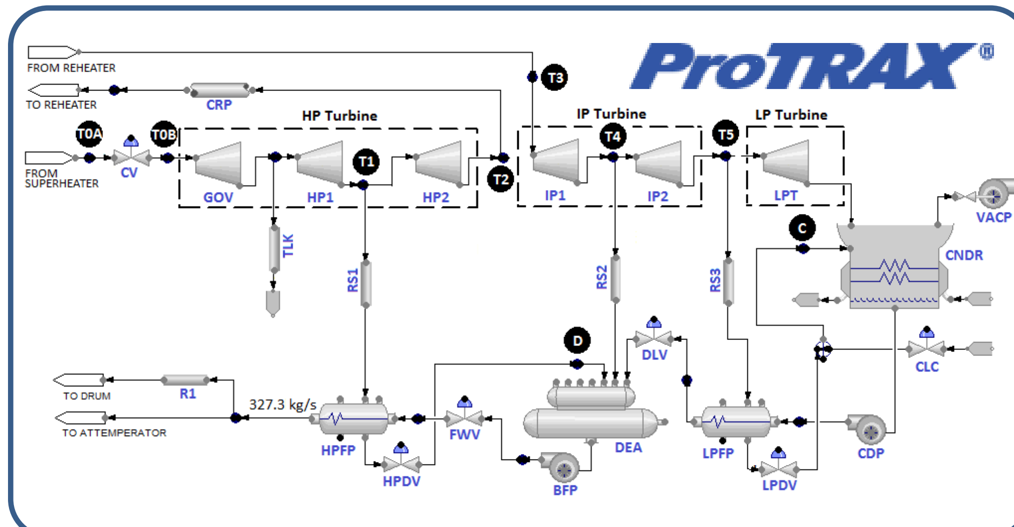
WPs1.5/2.4 HTTS: Using the unique simulation facility at Warwick, Warwick team has conducted the feasibility study of HTTS integration into power plant cycle for both subcritical oil-fired power plant model and supercritical coal-fired power plant model.

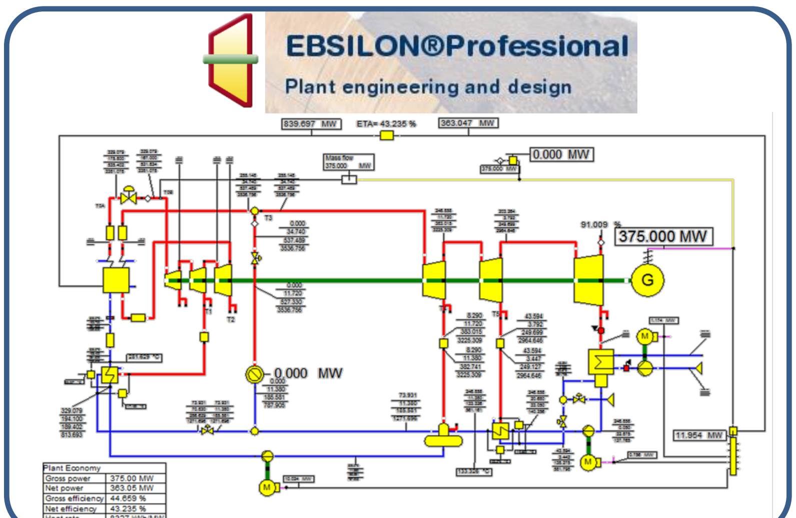
2.3 Further investigation on HTTS integration

Progress – HTTS conceptual & modelling work





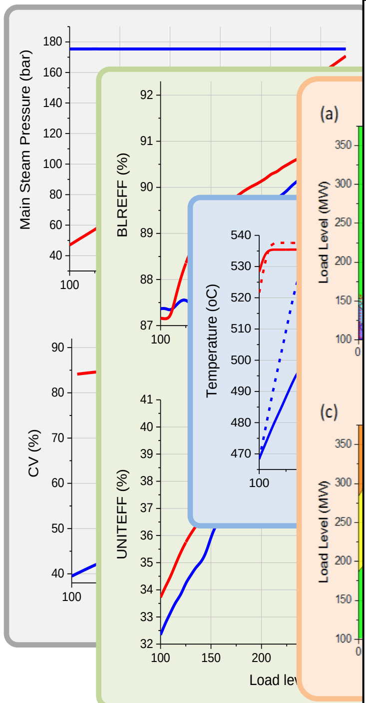




2.3 Further investigation on HTTS integration

Progress – The Results

ProTRAX®



energies

MDPI

Article

Technical Feasibility Study of Thermal Energy Storage Integration into the Conventional Power Plant Cycle

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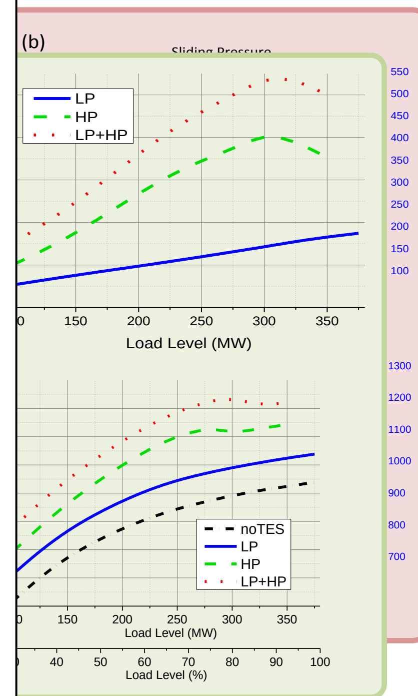
Abstract: The current load balance in the grid is managed mainly through peaking fossil-fuelled power plants that respond passively to the load changes. Intermittency, which comes from renewable energy sources, imposes additional requirements for even more flexible and faster responses from conventional power plants. A major challenge is to keep conventional generation running closest to the design condition with higher load factors and to avoid switching off periods if possible. Thermal energy storage (TES) integration into the power plant process cycle is considered as a possible solution for this issue. In this article, a technical feasibility study of TES integration into a 375-MW subcritical oil-fired conventional power plant is presented. Retrofitting is considered in order to avoid major changes in the power plant process cycle. The concept is tested based on the complete power plant model implemented in the ProTRAX software environment. Steam and water parameters are assessed for different TES integration scenarios as a function of the plant load level. The best candidate points for heat extraction in the TES charging and discharging processes are evaluated. The results demonstrate that the integration of TES with power plant cycle is feasible and provide a provisional guidance for the design of the TES system that will result in the minimal influence on the power plant cycle.

Keywords: thermal energy storage (TES); flexible operation; power plant; efficiency; steam cycle



IMAGES

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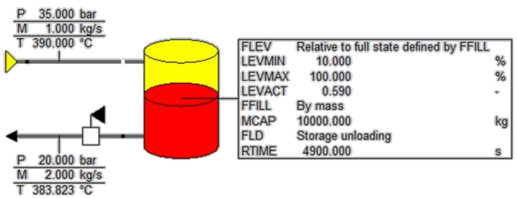
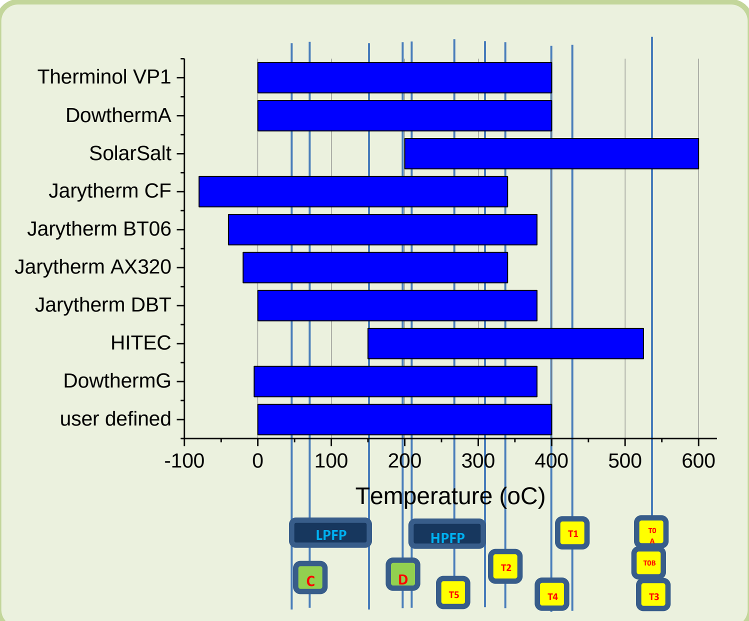
2.3 Further investigation on HTTS integration

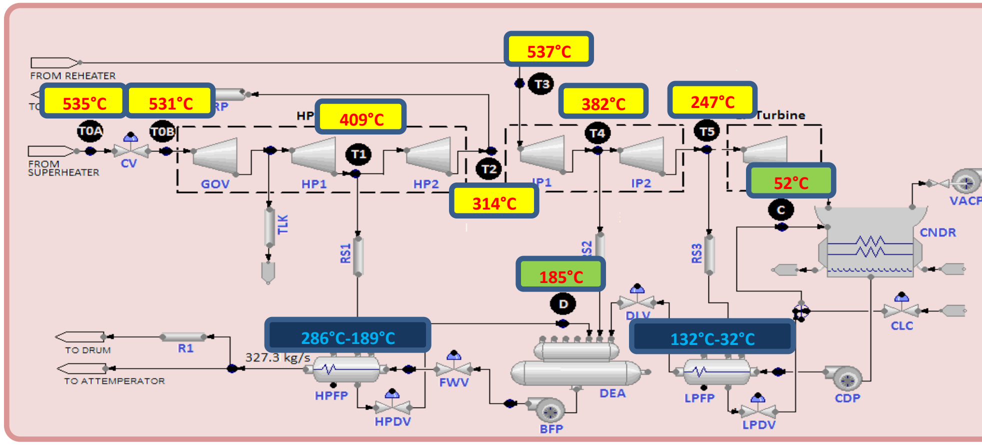
Progress – TES modelling in Ebsilon

EBSILON®Professional
Plant engineering and design



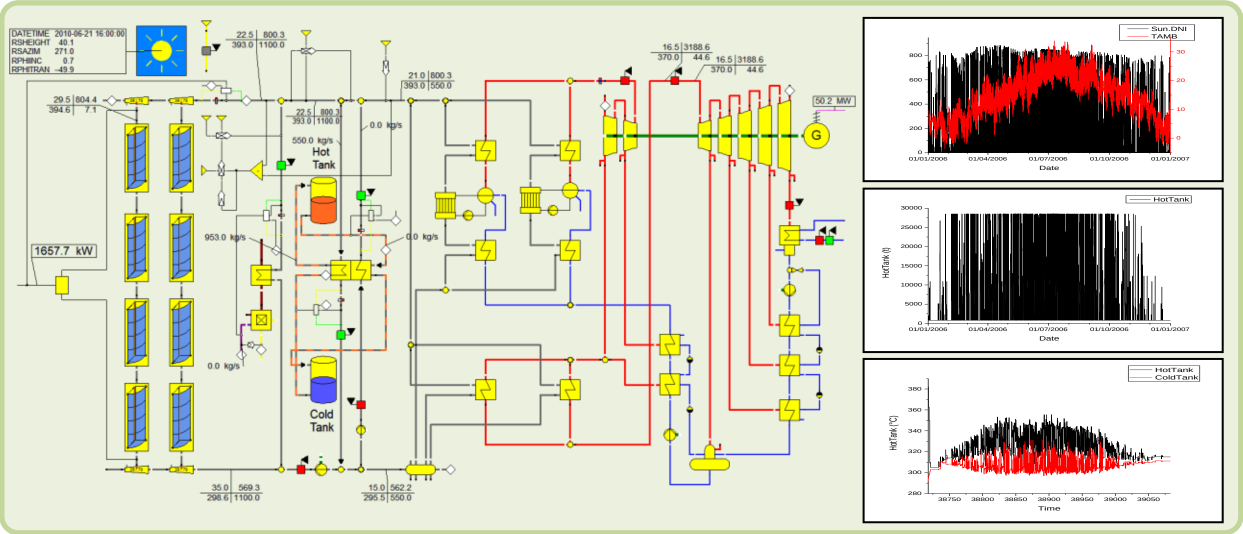
	Thermo liquid	company	Molweight [kg/kmol]	t_min [oC]	t_max [oC]	h_min [kJ/kg]	h_max [kJ/kg]
1	Therminol VP1	Solutia	165.97	0	400	0	818.62
2	DowthermA	Dowtherm	166	0	400	-0.33	833.33
3	60% NaNO3+40% KNO3		91.438	200	600	292.81	899.39
4	JARYTHERM CF	JARYTHERM	10000	-80	340	-129.7	804.27
5	JARYTHERM BT06	JARYTHERM	10000	-40	380	-59.63	801.36
6	JARYTHERM AX320	JARYTHERM	10000	-20	340	-35.89	776.51
7	JARYTHERM DBT	JARYTHERM	10000	0	380	0	807.9
8	HITEC HTSalt	HITEC	10000	150	525	234.25	819.88
9	DowthermG	Dowtherm	204.6	-5	380	-7.33	813.25
10	user defined	-	100	0	400	0	833.33

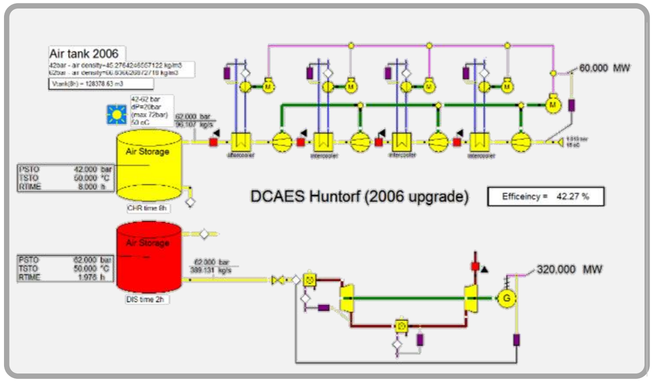


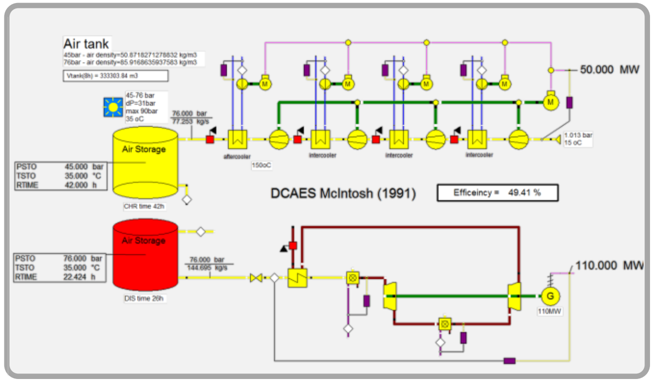


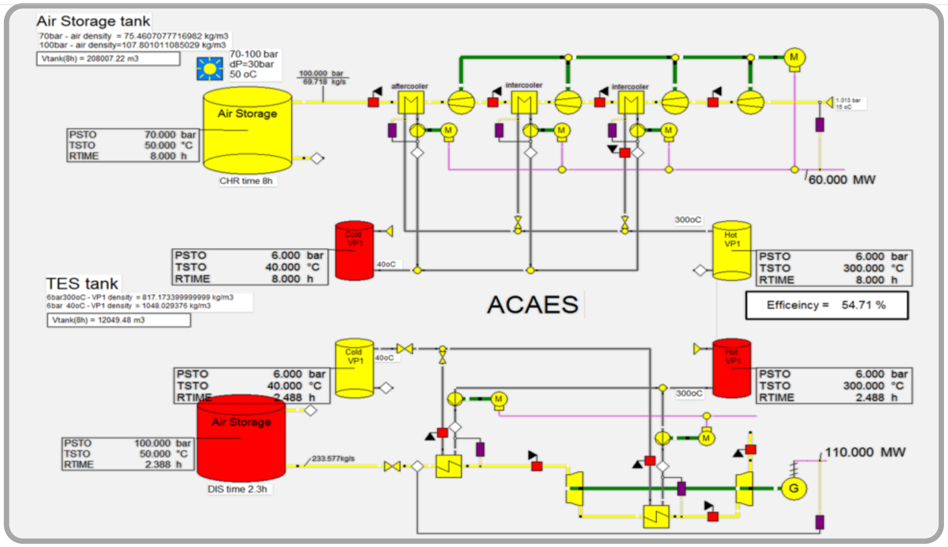
2.3 Further investigation on HTTS integration

Progress – TES implementation CSP & CAES



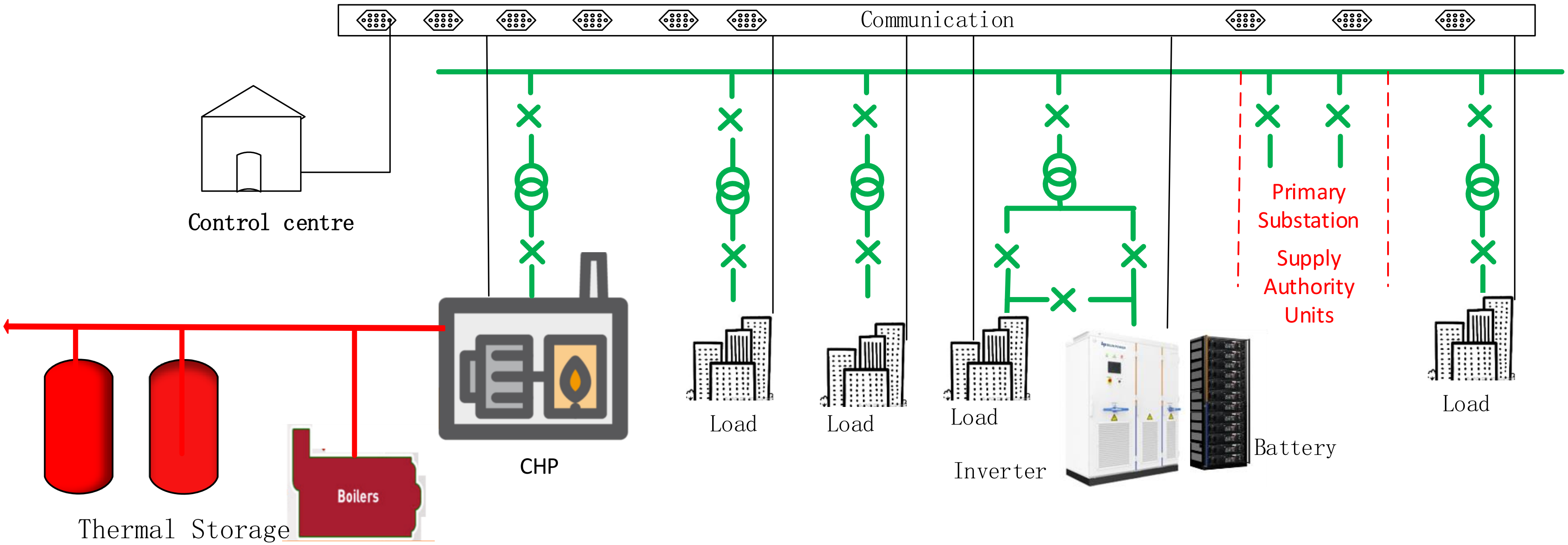






2.3. Integration of energy storage

University CHP system:



3. Work Plan

- To continue development of CAES-TES simulation tool – Web (Xing Luo)
- To continue WP1.4 Task 2. CAES specific opportunities in the UK (to support BGS' work?)
- To add an grid tied inverter to CAES test rig to study its dynamic characteristics when connected to grid (Jianguo Wang)
- To extend the project work to study of University CHP integration with energy storage to operate as a Virtual Power Plant in the broad context of grid operation (new PhD student).
- To conduct feasibility study on integration of CAES to thermal power plant operation process (Jacek)