INTELLIGENT AMBIENT SOFTWARE TO OPTIMIZE ENERGY AND POWER SYSTEMS

D A Sanders

Systems Engineering Research Group, University of Portsmouth, Portsmouth, PO1 3DJ UK.

Email: *david.sanders@port.ac.uk*

Abstract

A system is presented that assists in designing and analysing thermodynamic cycles. Performance characteristics are displayed, including the properties at a number of states, the performance of components and cycle efficiencies. Effects of separate input parameters on cycle performance are also displayed. Libraries of examples and thermodynamic logic (intelligent knowledge) are used to detect inconsistencies. Decision windows show what has caused the inconsistency along with a list of assumptions that caused the inconsistency. Sensitivity analysis allows for optimization of the power and energy system design by considering one input variable at a time over a specified range of values.

Key words: ambient intelligence, design, energy, programming, power.

Introduction

Ambient Intelligence techniques provided an opportunity to create systems that assist the user to give accurate analysis for power and energy systems (Sanders and Gegov, 2006). The ambient intelligence paradigm builds upon ubiquitous computing so that several computational functions are simultaneously used.

A new ambient intelligence system has been developed so that information and intelligence is hidden within a software system but the user interface remains perceivable by users.

The software is anticipatory

History

These are developments from early work in Ambient Intelligence at Philips.

In 1998, Philips commissioned a series of internal workshops to investigate different scenarios that would transform the high-volume consumer electronic industry from the current “fragmented-with-features” world into a world in 2020 where user-friendly devices support ubiquitous information, communication and entertainment. In the years after, these developments grew more mature. In 1999, Philips joined the Oxygen alliance, an international consortium of industrial partners within the MIT Oxygen project (Oxygen, 2006) aimed at developing technology for the computer of the 21st century.

In 2000, plans were made to construct a feasibility and usability facility dedicated to Ambient Intelligence. This opened in 2002.

Along with the build up of the vision for Philips, a parallel track was started to open up the vision. Following the advice of the Information Society and Technology Advisory Group, the European Commission used the vision for the launch of their sixth framework (FP5) in Information, Society and Technology.

The Commission played a crucial role in the further developments in Ambient Intelligence. More recently, several major initiatives have been started in the USA, Canada, Spain, France and the Netherlands

Intelligent software

The computer system helps with the design and analysis of thermodynamic cycles. Modelling is based on the laws of thermodynamics such that a thermodynamic cycle is a collection of components that takes in heat and produces work (or vice versa). The components in the software include sources and sinks (required for modelling open cycles), heaters and coolers, compressors, turbines and pumps, throttling valves, reactors, heat exchangers, mixing chambers and separators.

The software works in two modes: building or analysis. In the building mode, graphical Editors are used to place components and connect them. The designer uses a pointer (Sanders, 2005) to create a structure and then the Analysis Mode is used to specify the working fluid and modelling of each component. The property values for the components and substance are entered via a computer keyboard.

The output automatically displayed performance characteristics, including properties at various states, the performance of each component and cycle efficiency. The effect of any input parameter on the cycle performance can also be shown.

Ambient intelligence techniques were used to support the user in a natural way by using information and intelligence hidden from the user in a network that was integrated into the software so that only the user-interface remained perceivable by the user. The network provided access to a virtual library of examples stored on the internet.

The ambient intelligence paradigm built upon ubiquitous computing so that the user did not realise that they were engaging several systems simultaneously. Information processing was integrated into objects and activities.

Thermodynamic logic (intelligent knowledge) was installed in a database on a local server and context awareness techniques were used to detect conflicts in the use of the logic within the architecture suggested by the user. Context-awareness in ubiquitous computing was introduced by Schilit (1994a and 1994b). The system made assumptions about the user's current situation and made icons larger if they were expected to be used next and smaller if they were not expected to be used. This along with the automatic calculations made the system context-aware so that application-relevant data was customised. A decision window displayed rules that had been violated and the list of assumptions that caused the inconsistency.

Design optimization of the power and energy system was achieved by carrying out sensitivity analysis for one input variable at a time.

The system was adaptive in that feedback loops allowed the response to changes to the system to be considered. For example a constant repetitive action meant that icons became larger and larger. This also made the system anticipatory in that the systems anticipated future use of icons with the pointer without the user consciously changing the system or the software.

Construction, analysis and improvement of a hybrid gas turbine cycle

The construction, analysis and improvement of a novel hybrid gas turbine (Brayton : Ericsson) cycle proposed by Frost (1997) and Wu (1999) are illustrated in this paper as an example. This is similar to the system used by Wu (1999) and to the combined Brayton : Ericsson cycle (a single Brayton cycle and a single Ericsson cycle in cascade). It employed one working fluid in the two cycles so that the full waste heat from the top Brayton cycle served as the heat source for the bottom Ericsson cycle. Total power output of the combined cycle was the summation of the power produced by the top and bottom cycles.

In the building mode, the user selected a source, sink, two coolers (intercooler and cooler), four compressors, a heater (combustion chamber) and two turbines and connected them. This construction was then analysed in the same way that a human engineer would, by:

1. Defining each device (process) of the cycle.

2. Selecting a working fluid (for example: air, ammonia, water or refrigerants).

3. Inputing numerical values.

4. Displaying numerical results.

5. Conducting sensitivity analysis.

6. Making cycle improvements.

Compressors and turbines were defined as adiabatic processes with 100 per cent isentropic efficiency, and the combustion chamber, the cooler and the intercoolers as isobaric processes. A working fluid was selected and evaluation of working fluid properties was achieved by calculation from internationally agreed formulations. The available property data range of the working fluids was limited to that encountered in normal engineering practice. Automatic interpolation and unit conversion were included in the software.

Air was selected as the working fluid for the top cycle and bottom cycle. Numerical values were input to the Brayton : Ericsson cycles. Air entered the adiabatic compressor at 20°C and 1 bar and left at 8 bar; air entered the isobaric heater (combustion chamber) at 8 bar and left at 1100°C; air entered the high-pressure adiabatic turbine at 1100°C and left at 1 bar; air entered the low-pressure adiabatic turbine and left at 0.04 bar; air entered the first-stage adiabatic compressor and left at 0.2 bar; air entered the isobaric low-pressure intercooler and left at 20°C; air entered the second-stage adiabatic compressor and left at 0.6 bar; air entered the isobaric high pressure intercooler and left at 20°C; and air enters the third-stage adiabatic compressor and left at 1 bar.

Numerical results were displayed and properties were searched. The energy balance of each component was calculated.

The performance of the air Brayton : Ericsson cycle was successfully calculated and the results were displayed. The thermodynamic efficiency and the net power output of the combined plant were shown.

Sensitivity analysis checked the effect of each input parameter on the performance of the combined cycle. The cycle efficiency, h, was chosen as a dependent parameter and the outlet pressure of the second-stage compressor, p, as an independent parameter. Selecting a range for pressure p, a graphical h–p sensitivity analysis was displayed and the maximum combined cycle efficiency occurred at p_0.45 bar. Similarly, the maximum combined cycle efficiency occurred at p6_0.15 bar.

If real compressors and turbines with 90 per cent isentropic efficiency were specified, the thermodynamic efficiency and the net power output of the combined plant would become 38.94 per cent and 318.7 kW.

The design of different arranged Brayton : Ericsson cycles could be performed and adding one more compressor to the Brayton : Ericsson cycle.

Other improvements could include a re-heater added in the Brayton : Ericsson cycle of the combined cycle, more re-heaters and more turbines.

Discussion and conclusions

Benefits of using this software included: less time spent on numerical analysis; multi-cycle combined systems could be analysed; effects of varying input parameters could be displayed; and cycle parameters could be optimised.

Quick and accurate cycle analysis predictions were provided. More time could be spent on optimizing operational parameters and selecting different combinations of fluids and less time spent on tedious number crunching.

Future work

For the moment, the ambient intelligence in the system is mainly about the interactions between the human user and the system. Internal functioning of the software is not considered deeply and the software is not connected to the environment.

The systems described here do consider user experience so that users can design things from a user's point of view but more work is required to make the ambient intelligence more user-centred so that the user is placed nearer the centre of the design activity taking place rather than just receiving feedback through evaluations. Tests to improve the design (or even co-create the design together with the designer) could be introduced.

The distributed networks could be made dynamic. The communication with the network is seamless but interoperability could be improved and they could be made to auto-configure to remove the need for software configuration programs to interface and begin operation. The interfaces could use intelligent agents as well as context awareness. The intelligent agent could observe the design process and assist the user.

References

Frost TH, Anderson A and Agnew B (1997). A hybrid gas turbine cycle (Brayton : Ericsson): an alternative to conventional combined gas and steam turbine power plant, Proc. Instn Mech. Engrs, Part A, Journal of Power and Energy, 211(A2), pp 121–131..

Oxygen (2006). http://www.oxygen.lcs.mit.edu

Sanders DA and Gegov A (2006). Ambient Intelligence. Journal of computing in systems and engineering, 7(1). Pp 78 – 82.

Sanders DA, Urwin-Wright SD, Tewkesbury GE et al (2005). Pointer device for thin-film transistor and cathode ray tube computer screens. Electronics Letters 41 (16), pp 894-896.

Schilit B, Adams N, and Want R (1994a). Context-aware computing applications. IEEE Workshop on Mobile Computing Systems and Applications (WMCSA'94), Santa Cruz, CA, US: 89-101.

Schilit BN and Theimer MM (1994b). Disseminating Active Map Information to Mobile Hosts. IEEE Network 8 (5): 22–32.

Wu C (1999). Intelligent Computer Aided Optimization of Power and Energy systems**.** Proceedings of the I MECH E Part A Journal of Power and Energy, 213 (1), pp. 1-6.