A Trip to the University College, Swansea, and the Central Electric Generating Board, Gloucester

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Abstract

This report summarizes experiences and conclusions from a trip to University College Swansea, Swansea, Wales, the Central Electric Generation Board (CEGB), Barnwood, Gloucester, England and Marconi Instruments Limited, Scotland. The aim of the trip was to exchange information and discuss various issues in computer aided control engineering.

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1. Visit to Swansea

Sven Erik Mattsson, Dag Brück and Tomas Schönthal from the Department of Automatic Control, Lund Institute of Technology, Lund, Sweden visited University College Swansea, Swansea, Wales February 5–6, 1987. Hosts were Professor Tony Barker, Department of Electrical and Electronic Engineering and Dr Peter Townsend, Department of Mathematics and Computer Science.

The departments of Electrical and Electronic Engineering and Mathematics and Computer Science, University College Swansea participate in the SERC Programme of research in Computing and Design Techniques for Control Engineering (CDTCE).

1.1 Graphics

Their projects are focused on interactive graphics and man-machine interfaces for control system design (Barker et al, 1986, 1987). The current capabilities of their system CES (the Control Engineering (work)Station) allows the user to create and edit block diagrams and signal flow diagrams in a Macintosh-like style. An icon editor allows the user to create new block diagram icons. M. Chen is the main implementor of the graphics interface. He works on automatic generation of signal flow diagrams from block diagrams. He has found it difficult to lay out nice looking signal flow diagrams automatically.

To allow definition of the mathematical content of a block they are working on an editor and parser which allows the user to enter expressions (typically rational transfer functions) in "standard" mathematical format. They asked about our opinion. To their disappointment we told them that our experiences were that last typists preferred to enter expressions in a linear format (as for example in TeX). It is messy to jump between the cursor keys and the alpha-numeric ones. It is necessary to have a good editor which allows you to move around and copy parts of the expression. Compared to the linear input approach this may imply that that the user has to learn yet another editor and that he cannot use **his** favourite editor. Their approach also requires good graphics capabilities with fonts of different types and sizes. But we also told them that they should carry on and let the users give their opinion.

They are implementing CES in C on a SUN-3. Their experiences of SUN in general were good. However, they had found that the Pascal compiler was poorer than the C and Fortran compilers. It was impossible to use the color graphics from Pascal. In order to maintain acceptable performance, the image on the screen is updated, and only rarely redrawn. Redraw time is around two seconds. They had also found the tape drive to be incredibly slow. It was a pain to make back-up.

Their aim was to follow the SERC recommendation to use the GKS graphics standard. Unfortunately, the existing implementations were too poor. A basic problem is that the existing ones do not support sampled or event input. Another problem is that since C is not standardized, there are no standard C name bindings in GKS. Their approach was to use SUN Core and write routines to mimic GKS and use GKS standard full names. They had not carried this approach completely through; text is handled in a way more similar to

Sun-Core, some segment operations are missing, general polygon fill pattern primitive is missing and some routines had a different semantics.

1.2 Symbolic Manipulation

Another of their interests is symbolic manipulation. They had used Prolog to reduce signal flow graphs (Jobling and Grant, 1986). Only 7 rules were needed. Prolog is very useful for this kind of applications, since it is good at pattern matching.

They were about to start a project to use MACSYMA for implementing analysis of non-linear systems using describing function ideas with higher order harmonics.

1.3 Conclusions and Actions

We have common interests in man-machine interfaces and in this area it is of special importance to be able to exchange ideas and experience. They also expressed an interest to collaborate.

As a first step they got Simnon and Idpac. An exception handling package for C was sent later. We got CES and examples of how to use SUN's window and menu facilities from inside a program. This will facilitate our work.

They were very interested to use Simnon in their education and as the simulation tool in CES. Other common interests, which we were not aware of before the visit, are symbolic manipulation and MACSYMA.

The discussion on the user interface gave us good inputs for the next version of Simnon.

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2. Visit to CEGB

Karl Johan Åström, Sven Erik Mattsson, Dag Brück, Tomas Schönthal from the Department of Automatic Control, Lund Institute of Technology, Lund, Sweden and Leif Persson and Ann-Britt Östberg from Sydkraft, Malmö, Sweden visited the Central Electricity Generating Board (CEGB), Barnwood, Gloucester, UK February 9–11, 1987. The visit was organized and planned by Mr M.J. Whitmarsh-Everiss who is head of the Plant Kinetics Group, Boiler Plant Branch, Plant Engineering Department, Generation Development & Construction Division in Barnwood, Gloucester. The program for the visit is found in Section 2.6. The aim was to exchange information and discuss various issues in computer aided control engineering and modelling of power plants.

2.1 Computer Aided Control Engineering at CEGB

CEGB has a long experience in designing and using programs for computer aided engineering, starting in the late fifties with analog computers.

The Federated Computer Design Suite

Our host Mr Whitmarsh-Everiss initiated in 1970 the development of what today is a federated computer design suite for operational dynamics, control system design, fault studies and analysis of plant operational data (Whitmarsh-Everiss, 1986; Chambers and Whitmarsh-Everiss, 1984). The development of this suite is done in cooperation with the CEGB Computing and Information Systems Department at Park Street in London.

Files are used for communication between the packages. Simulation is mainly handled by the Plant Modelling System Program, PMSP (PMSP, 198?, 1985; Mann, 1987). The basic structure follows the specification established by the Technical Committee on Continuous Simulation and under the auspices of Simulation Councils, Inc. (SCi) in Simulation 9 (1967) pp. 281–303. Consequently, the language for defining models is very similar to other commercial simulation packages such as ACSL from Mitchell and Gauthier Ass. PMSP is designed for large (IBM) main frames and is essentially a batch program. To display the results the conversational graphing program VISION (Cooper and Kitchen, 1982) is used. An interactive version of PMSP is under development. An effort of 220 man-years has been spent on the development of PMSP and there are about 400 users in the UK.

The suite also contains programs for model reduction (DAMSEL, BALANC), linear analysis and design (ALADDIN), parameter estimation from time responses (DEKMAD) and program for data processing (FILTER) (Lee 1985a,b). All these programs are developed by CEGB except for ALADDIN which is a version of CLADP developed at Cambridge University.

Numerics

The numerical routines are a strong point. All calculations are executed in double precision to the limiting accuracy of the machine. To avoid testing, over-kill is used. The exception is integration, where the user can specify a desired accuracy. Their algorithms become robust through application.

PMSP has powerful numeric steady state finders and fast and robust integration routines (Chambers and Whitmarsh-Everiss, 1984; Mann, 1987). Particular attention has been given to large stiff systems, and advanced sparse matrix algorithms are used. PMSP has been used to simulate large models; 500–4000 states is a typical size range. The developer of the numerical routines, Trevor Chambers, presented the program GLUT (Generalized Look Up Tables). In power plants there are many liquids, water being the most common. The calculation of a liquid's properties when simulating is time consuming. To speed up the simulation, look up tables are used instead. If GLUT is given

1. any function $f(x, y)$ of two variables
2. a rectangular region R in which $f(x, y)$ is "reasonably behaved"
3. user specified tolerances ϱ and α

it automatically generates a look up table $\widehat{f}$ with linear interpolation such that the error criterion $|f - \widehat{f}| \leq \varrho|f| + \alpha$ is satisfied almost everywhere in R. The mesh is generated automatically and may be irregular. Triangular tiles are used to get a continuous function in every direction.

Model Libraries

A basic paradigm is to use a big reference model as a base. This model should be validated using real data. If smaller and simpler models are desired reduction techniques are used. This is in some cases wasting of computer power. There is, however, a tremendous saving in engineering man hours. If special simple models are used, extensive validation and testing are required.

Steady state models are e.g. derived by setting the derivatives to zero. A robust model that should cover all cases becomes very large. For example, zero flow or empty boiler requires models that consideration at other phenomena than occur in normal operation. A few years ago the reference models were typically written in Fortran (PMSP is a preprocessor which converts the model to a Fortran program). Today there is an ongoing work to convert the models to the PMSP model language. PMSP has no submodel concept. To modularize the model, a text macro facility like that in ACSL is used. A macro has a name, an input list and an output list. When invoked the macro call is actually replaced in-line with the body of the macro definition modified in the following way: the formal names given in the input and output lists are substituted with the actual ones and internal variables of the macro are given automatically generated names starting with "ZZ". A drawback with this a approach is that it is difficult for the user to reach internal variables of the macro. Debugging of the model is often done at the Fortran level, using translation tables for internal names.

MMI and Graphics

There is ongoing work to improve and make the user interface more interactive (Adams, 1985). They have purchased the Computer Aided Manufacturing Management system CAMM, which is a computer based data display system with animated graphics. Original CAMM is written in Pascal and implemented on IBM PC XT. CEGB is porting it to a large IBM mainframe and are developing interfaces to PMSP. In CAMM the user can define pictures by composing trend charts, text, rectangles, circles, dots and lines. Variables can be connected to vary shape dimensions, color and position. In this way mimic diagrams can be designed. The user interface when designing a picture is poor. CAMM displays a menu and the user selects an item by typing in a number. Positions are defined with a cross hair.

The idea is to show the results of a simulation in different ways: as trend charts, numeric displays, mimic diagrams. For example a pump designer could visualize how the operating point of the pump moves around in the flow-pressure diagram. There should also be facilities for postprocessing like adding of text and graphics.

The graphics will also be used to define models. A PMSP macro could contain a definition of an icon. By positioning this icons and connecting them with lines the user should be able to set up his model from library macros. The library macros could also contain definition of graphical representation that could be used to set up a mimic representation of the plant.

2.2 Models of Power Plants

CEGB has developed very detailed models for power plant components like boilers and nuclear reactors.

Apart from the discussions at Barnwood, K J Åström also had the possibility to discuss NUMEL with B Chojnowski, Head of Heat Transfer Section at the Marchwood Engineering Laboratories during his visit to Edinburg. A particular code NUMEL has been developed extensively. This code has gained national acceptance in the nuclear plant area as the Reference Steam Generator Model. The code was first formulated in 1978 but it can be regarded as the culmination of two decades of boiler modeling work by various parties within the CEGB. The current position of NUMEL is

the reference once-through boiler code for modelling

the basic boiler code for analysis of fault transients in AGR

the definite code used in AGR plant operational kinetics

There is currently work going on to develop and validate the code further. Some references are NUMEL (198?), Lightfoot et al (1979), Scruton et al (198?), Green (1985), Lightfoot et al (1982), Green et al (1979), Deam (1979) and Deam et al (198?).

2.3 Simnon and the CACE Project

Karl Johan Åström gave an introduction to Simnon and Tomas Schönthal demonstrated the PC-version. CEGB was given a copy. Simnon was found to be of interest. Compared to PMSP it is interactive and easier to use on small examples.

Karl Johan Åström gave an overview of the CACE project and Sven Erik Mattsson presented Hibliz and Dag Brück ran the video demo. The hierarchical block diagram representation used in Hibliz was found to be an interesting idea. It was questioned if continuous panning and zooming were really needed. Perhaps direct block opening might serve the user just as well.

2.4 Conclusions and Actions

A collaboration between the CACE project at the Department of Automatic Control, Lund Institute of Technology and the groups under Whitmarsh-Everiss and Dick Adams at Barnwood and Trevor Chambers at Park Street, London would be of mutual benefit. We have many common areas.

CACE Methodology

We have a mutual interest in methods and ways of representing systems. Our different backgrounds stimulate to interesting exchange of ideas on how to view and discuss about systems. The work at CEGB stresses the fact that model development and simulation is a very important part of CACE.

The visualization of system parts in different ways is also a common interest. The representation of systems in Hibliz is purely mathematical. Dick Adams, who works with CAMM and the interactive PMSP, stressed that a simulator should support a user's conceptual view of the system. To achieve that, icons and mimic diagrams of various sorts could be used. CEGB can provide us with examples of how they think icons and mimic diagrams should look. Dick Adams has promised to send us the definition of his icons for power plant components.

We in turn have more experience of interactive programs and Dick Adams has been invited to us too see and discuss our work in more detail. It could also be noted that SattGraph 1000 developed by Hilding Elmqvist, SattControl could be a better alternative for him than CAMM. SattGraph 1000 has a much better user interface, which uses a mouse controlled cursor for menu selection and drawing. Furthermore, the CEGB implementation of CAMM is not yet in a stable and robust state.

The current projects at CEGB confirm our view that it is important to have good means for building and documenting model libraries.

John Hope was interested in using Simnon and he may give us useful feedback.

Numerics

CEGB's numerical routines for finding steady state and for integration are very good. It seems to be possible for us to get some of their routines. Trevor Chambers and Tony Mann in London are our contact persons. It would be nice if we could make them interested in differential/algebraic systems.

Modelling

CEGB has good models for power plant components and are currently building macro libraries in PMSP. Good models are of general interest for us and power plant models are of particular interest for the projects in power systems control. Sydkraft are very interested in getting models for conventional power plants. Contacts have been established between Ann-Britt Östberg, Sydkraft and Dick Adams. Dick will inform Ann-Britt about which models that are available and open for Sydkraft and us.

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2.6 Agenda

Day 1

09.15	Welcome – Divisional and Board organisation – Responsibilities of the Plant Kinetics Group within the Generation Development and Construction Division – relationship with the Computer Information and Services Department. (Mike Whitmarsh-Everiss)
09.30	Overview of the federated Design Suite for Operational Dynamics, Fault Analysis and Control System Design – Historical background – design philosophy – functional design. PMSP, Simulation Language – TSO easy, editing – VISION, graphics – DAMSEL, file handling – BALANC, model reduction – DEKMAD, transfer function fitting – ALADDIN, control system design – FILTER, plant data analysis – Composite MACRO generation, ENTS/POWSYD, WINA, Boolean algebra, relation to drawing office CAD system. (Mike Whitmarsh-Everiss)
11.00	PMSP numerical methods – steady state finding, linearisation, frequency response, eigenvalue and eigenvectors, numerical integration. (Trevor Chambers)
12.30	Lunch
13.45	FILTER, VISION. (Trevor Chambers)
14.15	BALANC, DEKMAD, ALADDIN. (John Hope)
15.00	Total plant modelling, method of working in batch – philosophy of MACRO STRUCTURE IN PMSP. (Dick Hunt)

16.00	Concept of the Plant Analyser NPDA and ERPA – interactive PMSP – on-line graphics, CAMM. (Mike Whitmarsh-Everiss)
17.00	Break/Buffet
18.00	Demonstrations – ENTS, DEKMAD, VISION/FILTER, DAMSEL, BALANC, DEKMAD, VISION.

Day 2

09.15	Interactive graphics – CAMM. (Dick Adams)
10.00	Fluidised bed plant modelling. (Derek Brereton)
10.45	Fossil fired recirculation boiler plant. (Dick Adams)
11.30	Thermodynamic and transport properties of steam and other fluids – DAMPF, PPDS, LUST and GLUT. (Mike Whitmarsh-Everiss, Trevor Chambers)
12.00	Ergonomic Design Analyser. (Mike Whitmarsh-Everiss)
12.30	Lunch
13.45	Design and procurement of training simulators. (Mike Whitmarsh-Everiss)
14.45	Analyser computing engines, parallel processing, source translation and mapping algorithms. (Mike Whitmarsh-Everiss, Trevor Chambers)
15.15	Presentation from Lund Institute of Technology and Sydkraft AB, Sweden.
17.00	Break/Buffet
18.00	Demonstrations, Plant Design Analyser, Lund Software

Day 3

09.15	Programme to be arranged. (As necessary)

3. Visit to Marconi

K J Åström was invited to travel with Whitmarsh-Everiss and a CEGB delegation to Marconi Simulation in Edinburgh. Marconi has a long experience in developing simulators for military and civil purposes. They have developed the plant simulators for Hunterston B and Torness for SSEB (South Scotland Electricity Board). The Torness simulator was at the Marconi plant for final testing. The simulators were quite complicated as is seen from the summary in Table 1 (from Marconi, 1987). The simulators were based on special purpose parallel hardware. The typical calculations required in simulators of this type are not well suited for vectorization. Conventional array processor architectures are therefor of limited value. The Mk II simulator was based on parallel computers designed around the AM 2901 bit slice device from 1977. Improved versions of the processor has been used in the later models. Special chips for fast integer multiply and floating point calculation have also been used. The Mk IV system for Hunterston B had 52 microprocessors, two were allocated to the axial reactor model, 10 for the two-dimensional reactor model, and 18 for the boiler model. Microcode is used to speed up time critical operations. A low power CMOS version will be used in the new processor model Mk V. This system will also use a floating point processor with 10 Mflops computational speed.

A special high level language was developed for programming. This language which is similar to a high level assembler of the type PL/360 allows tight control of the hardware. The allocation of different pieces of the code to different processors and the real time scheduling was done manually. The compiler for the language was developed and maintained in house. A special graphics language SIMDAS had also been developed to allow simple creation of color mimic diagrams and dynamic displays.

There were discussions on the possibilities of putting the complete NUMEL model on the new generation of simulators and of the possibilities of automatic code generation from PSMP. I looked a little into this problem and it seems quite feasible to do code generation from Simnon.

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Table 1

ESTIMATED NUMBERS OF DIFFERENTIAL, ALGEBRAIC AND BOOLEAN EQUATIONS FOR THE HUNTERSTON B AND TORNESS SIMULATORS.

Plant Module	Hunterston B			Torness		
	Diff. Eqns.	Alg. Eqns.	Boolean Eqns.	Diff. Eqns	Alg. Eqns	Boolean Eqns.
Reactor - xy point representation	3359	2720	-	7636	6640	-
-9 plane axial	353	180	-	353	180	-
Rod Controllers	20	730	-	225	765	-
Gag flow	-	308	-	-	332	-
Gas Circuit through Boilers etc.	20	308	-	20	333	-
Circulators	24	96	-	24	96	-
Electrical System	20	1000	-	20	1000	-
Boilers	1170	2700	-	1690	3900	-
Turbine	120	550	-	120	550	-
Control Systems - excluding rods	33	200	-	33	200	-
Protection system, boiler trip logic, alarms and relay logic	-	-	>10 000	-	-	>20 000
Feed pumps - BFPT & 2 x SU/SB	10	50	-	10	50	-
Gas clean up & chemical monitoring	-	-	-	20	50	-
TOTALS	5129	8842	>10 000	10 151	14 096	>20 000