Solar energy in Asia,
Reports from ISES solar world congress
in Kobe, Japan, September 1989
and from study visits in India and Pakistan

Lars Broman and Göran Eriksson
Solar Energy in Asia

Report from ISES Solar World Congress in Kobe, Japan, September 1989 and from Study Visits in India and Pakistan

Lars Broman and Göran Eriksson
## Contents

Abstract ......................................................... 3
1. Study visit in the Bombay, India Area ............... 5
1.1 Centre for Technological Alternatives for Rural Areas, Indian Institute of Technology .................. 5
1.2. Academy of Development Science .................. 6
1.3. Maharashtra Energy Development Agency .......... 8
2. Study visit to National Institute of Silicon Technology, Islamabad, Pakistan .......................... 9
3. ISES Solar World Congress, Kobe, Japan, September 4-8, 1989 .............................................. 13
3.1 Impressions from the Conference .................... 13
3.2. Impressions from the Exhibition ................... 14
3.3 Contacts and Discussions .............................. 15
Acknowledgements ............................................... 15
Appendix: Three Contributions to the ISES Congress .... 17
A: Lars Broman, Eva Lindberg and Kent Börjesson:
Optical Properties of the Czechoslovakian Fresnel Lens Measured Using a Laser Beam ......................... 19
B: Lars Broman:
An Electricity Experiment Kit for Secondary Schools Using Photovoltaic Generated Electricity ........... 25
C: Svante Nordlander, Mats Rönnelid,
Per Isakson and Lars Broman:
PRESIM - A Graphical Interactive Preprocessor for Modular Simulation Programs ........................ 31
(last page 35)
Abstract

The ISES Solar World Congress Clean and Safe Energy Forever was held in Kobe, Japan, September 4-8, 1989. Short impressions from the conference and the simultaneous exhibition are given. On our (separate) ways to Kobe, Eriksson visited institutions in the Bombay, India area, and Broman one institution in Islamabad, Pakistan. Accounts of these visits are given. Three papers presented in Kobe are included in an Appendix.
1. Study visit in the Bombay, India Area

Göran Eriksson

1.1 Centre for Technological Alternatives for Rural Areas,
Indian Institute of Technology

I visited CTARA and its Director Anil W. Date at IIT in August 25 - 30 1989. I had met Prof. Date in Borlänge when he visited SERC and the Future’s Museum and had some lectures about appropriate technology, CTARA and Academy of Development Sciences, which he was one of the founders of. Now I had the opportunity to see these institutions.

I was met by prof. Date at the airport, and he took me to IIT’s Guest House. It is a very nice house in the campus area with the most beautiful view of a lake and mountains, and so many trees and birds around the house, that you hardly could believe you were in such a big city as Bombay. After I had installed in my room I went to CTARA, and prof. Date told me the program for the visit. It included one day in CTARA’s office with discussions, and a lecture about solar energy in Sweden, a day trip to Academy of Development Science, visit to Maharashtra Energy Development Agency, meeting with Dr. R. L. Datta, and an indian dinner in Prof. Date’s home.

CTARA is a small institution in IIT, and it has R&D of different technical solutions on problems that are important for the rural people, and that are inexpensive and simple so that poor peasants both can understand and afford them. Some 10 persons are working there, both researchers, engineers and mechanics. The institution is situated in the basement of the mechanical department building, and has both a workshop for production of prototypes, a small library and work places for construction and studies, all in one room. They also have a test area, where they can test different prototypes.

I gave a short lecture about solar energy in Sweden with CTARA staff as audience, and we discussed energy and developing projects. I was shown many of the projects CTARA is working with and some of them are these: Constructing a type of house, or rather six houses built together with their
short sides making a hexagon. The roofs are inclining towards the hexagon, which makes a water reservoir to save water from the monsun period to the dry period. In the test area they are building a house of that type, and they also test different building methods on the six different houses. A brick-press was also constructed and it makes it possible to produce bricks with no extra energy need than manpower and sunshine. With a lever you can press the clay enough to make bricks that only need sun-drying, and you save wood for other needs. These bricks however are not water resistant, so you need to plaster the wall with cow dung. Much work is also made to find better cooking stoves that are "non-smoking" and energy efficient. They had several models of cooking stoves in their workshop, both traditional and new models. Different types of manual "power stations" are developed such as a pedal driven lathe, wood saving wheels and a wind pump with an up- and downgoing sail instead of a propeller. This construction gives better efficiency in low wind speeds.

1.2. Academy of Developement Science

August 26 was planned for a trip to Academy of Developement Science. At 6.30 we started with bus from the IIT campus to the railway station from where the train took me and my companion Mr. Patankar on a two hour trip to Kirjat, where we waited half an hour in the rain for the right bus. Half an hour busride later we arrived in the village next to where Academy of Developement Science has its headquarter. After the compulsory cup of tea, we walked the last two miles in the beautiful green Indian landscape.
The academy is a developing project started among students and teachers at IIT, Bombay and they have a vocational school with education in mechanics, building, and carpentry. A fruit processing "industry" was also built up in the village. Women in the village pick fruit in the forest, freely, and in the factory they make juice, jam, chutney and marmalade, which they sell in IIT's student shops and lunch rooms. The food processing has different advantages, it gives women a monetary income that helps their economy. It is also a part in the wood-saving project. The food project makes the forest economically interesting, and therefore gives the people a new reason to preserve their forest from deforestation. The academy also has educational programs in public health, ayurvedic medicine, irrigation and water supply. Another project is to develop a "grain-bank" that will provide the farmers with good seed-grain without being dependent on expensive seed dealers and usurers.

The general theme of this project is self-reliance, and I think it is a very good approach for developing projects. It is the rural people themselves, not helpers from outside that have to decide what to do, and to do it. The project staff is primarily consulting and teaching.

It was a very interesting visit and I had some good discussions with staff members Mr. Kulkarni about village economy, energy stores and education, and with Dr. Kale about ayurvedic medicine, the traditional Indian medicine.

In Academy of Development Science, they didn't have any working solar energy equipment. Even the most simple solar heater is regarded too complicated and expensive in this practically non-monetarian economy, at least for the time being.
August 29 was the last day in Bombay, and also the first day in the city. Prof. Date called a good taxi driver he knows, and he took me the one hour trip through through suburbs with all kinds of buildings, from the poorest slum to the most fashionable houses, sometimes wall to wall, and finally to Bombay city and MEDA, Maharashtra Energy Development Agency. MEDA is a governmental organisation and its task is to promote and develope non conventional energy sources. They have projects on solar thermal, PV, wind, biogas and energy conservation as well as "public awareness" campaigns. I met the director of MEDA, Dr. Goel and we had some hours of interesting discussions on renewable energy in India and Sweden, development projects, and problems with new technology in rural areas, both regarding maintenance and financing.
2. Study visit to National Institute of Silicon Technology, Islamabad, Pakistan

Lars Broman

I spent the four days August 30 - September 2 in Islamabad as the guest of National Institute of Silicon Technology (NIST) and its Director General, Dr. Atique Mufti. I had met Dr. Mufti at two earlier occasions (in Baghdad and Tripoli in 1988) and found him a most interesting person with great knowledge about the science and technology of solar energy as well as of international politics and north-south relations. Dr. Mufti, with the help of some of his co-workers at NIST, treated me with great hospitality. Most of my time was spent at the institute, were I got to see the laboratories as well as the other facilities, but I got to see some other sights as well.

One of my days in Pakistan was the Moslem holiday Friday, and NIST was closed. I was given the opportunity to see Islamabad, the less than 30 years old capital of Pakistan, as well as the nearby older city of Rawalpindi,
the town of Murree in the hills up towards Himalaya, the archeological site of Taxila, and the recently inaugurated Faisal Masjid Mosque. The impression I got of this part of Pakistan was a beautiful green country with friendly people, generally good standard of buildings and roads - and the most beautifully decorated busses and trucks in the world!

During my stay at NIST I gave two seminars; one on August 31 about SERC and a summary of our research program, and one on September 2 about PRESIM and computer simulation of solar heating plants. Both seminars were attended by about twenty people. On September 2, I also got the opportunity to inaugurate a part of the exhibition Astronomia: A 5 cm dia. model of the nearest star Proxima Centauri in the scale 1:10 billion, here situated at approx. the correct distance from the 15 cm dia. model sun in Göteborg. The ceremony took place in the presence of most of the NIST senior scientists. Dr. Mufti gave a short speech, which also the guests in Frölunda Kulturhus, where the major part of Astronomia was simultaneously inaugurated, could enjoy by means of a long-distance phone call.

NIST was established in 1981 and moved into its present building in 1986. The building was a very nice white-and-brick two-storey house built around a small garden in the outskirts of Islamabad. Its 5000 sqm housed a number of laboratories, offices, a library and rooms for supporting activities. I was impressed to see the laboratories, equipped to handle the complete process from silicon to PV modules: Single crystal growth, wafer cutting, doping, contact making, encapsulation, and solar cell module making. There was also equipment for testing and a computer room for programming and data handling. While the technical equipment was of high standard and up-to-date, the library was not; lack of convertible currency obviously prevented the library staff from keeping up with the continuous publication of scientific journals and books.

NIST staff includes Dr. Atique Mufti; NIST founder and Director General; Dr. Parvez Akhter, Chief Research Officer; three Principal Research Officers; four Senior Research Officers; and sixteen Research Officers. The technical staff numbered 12 and the supporting staff 35, bringing the total staff to over 70.

In my opinion, Dr. Mufti has clearly demonstrated that a modern high-tech laboratory can be built and made productive also in a country outside the so-called industrialized world. He runs NIST on a surprisingly low budget, 6.3 million rupees per year (or about half that amount in Swedish currency SEK).

A next obvious step for NIST is a pilot scale crystal silicon (X-Si) PV module manufacturing plant. R&D activities within thin-film PV would complement the X-Si work. The ultimate goal must be to create within the country the scientific and technological capability to build and run full-
scale PV module production. It seems to me that NIST has come far towards this goal.

This facility could however be put to even better use if more young Pakistan scientists and engineers got the opportunity to learn by working here. The building and the equipment could probably be utilized by well over twice the present staff. The increased spending would be well used for the development of the country - solar electricity will probably be the major technology (among several) meeting the increased demand for electricity worldwide within a decade. Countries like Pakistan and, for that matter Sweden, should not let a few large industrialized countries have the monopoly of this important technology.

NIST also houses the headquarters of the Inter-Islamic Network on Renewable Energy Sources with Dr. Mufti as its present President. Within the framework of IIN, advanced courses in renewable energy technology are held; the next advanced PV technology course will be held at NIST in May, 1990.

During my visit to NIST, oral agreement was reached on future co-operation between NIST and SERC. One part of this is the exchange of laboratory reports. Another part is an R&D project with manufacturing and testing of linear PV modules with booster mirrors. In January 1990, a number of tempered glass strips were sent to NIST for module fabrication.

NIST address: No 25, H-9; Islamabad; Pakistan; P. O. Box 1672; phone +92-51 851 987 or 850 847.
3. ISES Solar World Congress, Kobe, Japan, September 4-8, 1989

3.1 Impressions from the Conference

700 delegates from 54 countries had a tough program: 26 lectures and 430 presentations (papers and posters). There were few really big news, but two new world records were reported: An Australian research group had reached the efficiency 23.2% for a crystalline silicon PV cell, and a Japanese group had achieved 16.8% for an amorphous silicon PV cell (in tandem with an X-Si cell). (A newspaper note in the Pakistan Nation that I stumbled upon on my way back to Sweden mentioned an American group that had achieved 31% efficiency for a PV cell under 3-500 suns.) The photovoltaic market is presently growing quickly, and reports from Italy tell about plans for 25 MW large scale PV installed up to 1995.

Regarding solar heating, it has finally been understood outside the Swedish borders that R&D work must deal with both low cost and high efficiency in combination. Heat storage, simulations and thermal insulation of components draw highest attention this year.

Not much new passive solar was presented, but rather old knowledge in new clothes, mixed with fantasy-filled creations that had little to do with reality. The most important contributions dealt with simulations and computer calculations of passive systems for heating and cooling.

Unusually few contributions dealt with developing country applications like solar cookers - in spite of the fact that this is just the technology that has the prospective of being useful for 60% of the earth's population. Only two papers on wind energy were presented. Wind seems to be the presently most successful of the renewables with 300 MW installed yearly and 2 TWh electricity produced in 1988.

We had three contributions to the conference, one oral and two posters, and they were all well received. We got requests for lab. experiment sets for testing when such are available, and for PRESIM programs (also for
testing) when the program is ready. The papers are included as Appendix A-C in this report.

ISES' new president after Corrado Corvi is Douglas Lorriman (from Canada) and he usually asks himself three questions in order to determine whether a conference was successful or not: Did I learn something? Did I meet make new and renew old contacts? Did I have fun?

We would no doubt answer "yes" to all three questions, but firstly to No. 2 and secondly to No. 3

3.2. Impressions from the Exhibition

The Solar World Exhibition '89 Kobe was housed in Kobe International Exhibition hall near to the Conference Center. It was open September 5 - 8 and had 46 exhibitors. There were four main parts of the exhibition namely solar cars/boats, photovoltaics, solar thermal and instruments.

The car/boat part was the most spectacular part with some extreme boats, for example one with solar sterling engine. We wondered how you can keep the paraboloid reflector directed towards the sun when the boat is floating. Many of the cars were only good looking, but not really interesting.

Solar cars on the exhibition

The PV part of the exhibition was partly about the cells, and many different manufacturers participated. It also contained a section with applications of PV in many different ways, for example electric lighted mailboxes, car battery chargers and also some refrigerators and water pumps.

Solar thermal was another part, and it was interesting to see the differences between Swedish solar collectors and those in the exhibition. They
are mostly for hot water and not for heating, small systems "ready to use" with collector and tank built together. There were no big news, and the prizes were rather high.

The instrumental part contained insolation instruments, laboratory suns and other testing and R&D equipment.

As a whole, the exhibition was not so interesting, but we took pamphlets from the manufacturers and we are in the process of making a register of the companies that are of interest in Sweden, and to find out whether there are dealers closer to us.

3.3 Contacts and Discussions

Several important contacts were renewed and a couple of new were made. We had discussions with Prof. W. Beckman, Solar Lab., Univ. of Wisconsin on our continued cooperation in developing the PRESIM front-end to the TRNSYS simulation program, which was developed by him and co-workers and is still developed and maintained by Univ. of Wisconsin. Our discussions lead to the week-long stay of Ruth Urban at SERC later in the fall; she is presently TRNSYS Engineer at Solar Laboratory.

The idea of creating an International Association for Solar Energy Education was discussed with many of the delegates and arose a great interest. Several of them we met have since accepted to become members of this Association (which was founded in December), namely Dr.s Salah Arafa, Kairo; W. W. S. Charters, Melbourne; Terry Hollands, Waterloo; Leslie Jesch, Birmingham; George Lof, Denver; A. A. M. Sayigh, Reading; and Harry Tabor, Jerusalem. Several others have since then become national contact persons or members of IASEE.

The idea of making IASEE an Educational Working Group of ISES was discussed with, among others, ISES' secretary Wal Read and Douglas Balcomb, who chairs the ISES Committee on Working Groups.

Our participation in North Sun '90 and World Renewable Energy Congress, which both will take place in Reading, U.K in September 1990 were discussed with the Chairman of the conferences Dr. Sayigh. One of us (L.B) received invitations to give plenary lectures on both conferences. The first membership meeting of IASEE will also be held during WREC.

Acknowledgements

Lars Broman's participation in the ISES Congress was paid for by Swedish Council for Building Research. Contract No. 890274-0
Appendix: Three Contributions to the ISES Congress
A: Lars Broman, Eva Lindberg and Kent Börjesson: 
Optical Properties of the Czechoslovakian Fresnel Lens 
Measured Using a Laser Beam

ABSTRACT

Linear glass Fresnel lenses have been experimentally investigated by means of a narrow He-Ne laser beam, both at normal incidence and at various combinations of meridional and sagittal angles of incidence. Both rays incident on the flat and on the grooved side were studied. Results were compared with previous ray tracing results by Franc et al. The experiments suggest, contrary to ray tracing, that the grooves should face the sun in other than sun-tracking applications.

KEYWORDS
Solar energy; concentration; Fresnel lens; measurements.

INTRODUCTION

Linear Fresnel lenses of glass with widths 750 and 2x375 mm have been designed, produced and used in Czechoslovakia for some time. A thorough theoretical discussion of the lenses, in particular the 375 mm lens, has been published by Franc et al. (1986). Ray tracing showed, among other things, that rays hitting the flat side under normal incidence and exiting through facets do meet at a focal line. In an application with complete tracking of the sun, this is the obvious way to use the lens, since the focal line is replaced by a focal “band” during non-normal incidence or when the side with the grooves faces the sun.

In the present paper, we report results from ray tracing through the Czechoslovakian Fresnel lens, only we did it experimentally instead of with computer. Our aim was to investigate whether measurements could verify the calculations. Experimental results regarding rays incident at different angles to the normal should be especially interesting, since different stationary or semi-stationary applications of the lens have been suggested by Franc et al.
**EXPERIMENTAL SETUP**

The bulk of measurements was done on a lens sample, 375 mm wide and approx. 200 mm long. This was mounted in a frame with the grooves vertical. The frame could be rotated around a horizontal axis (in the plane of the lens); in this way different sagittal angles for rays incident on both the flat and the grooved side could be investigated.

The ray used to study the refracting properties of the lens came from a .5 mW He-Ne laser, mounted horizontally on a holder that could slide along an optical bench; the angle between the laser and the bench was kept fixed (at 90 degrees) during the measurements. For studying rays incident at different meridional angles, the whole bench was moved to another position on the table.

The beam from the laser was narrowed by means of a vertical slit, approx. 1 mm wide, mounted directly on the exit aperture. After the ray had passed the lens it hit a cross-ruled screen on the wall, vertical and situated some 50 cm behind the lens. The ray could be traced by determining, in a horizontal plane, the place of the laser exit aperture, the point where the ray passed through the lens, and the edges of the illuminated patch on the screen. The experimental setup is shown in Fig. 1.

![Fig. 1. Experimental setup. (a) laser, (b) optical bench, (c) Fresnel lens in holder, (d) screen. Shown is the setup for ray tracing at meridional angle 24 degrees and sagittal angle 45 degrees.](image)

**MEASUREMENTS AND RESULTS**

Rays through the lens were traced for the lens with both the flat side and the grooved side towards the laser. Tracing was performed at nine different angles of incidence, the combinations of sagittal angle (as measured towards the normal in a plane parallel to the grooves) equal to 0, 22.5 and 45 degrees and meridional angle (as measured towards the normal in a plane perpendicular to the grooves) equal to 0, 12 and 24 degrees. These angles were chosen to facilitate comparison with the computer ray tracing results by Franc et al.
The lens has a central face and 20 facets at each side, in total 41 facets. For each of the nine combinations, a ray was traced through each facet. Thus, 41 rays were traced (or, at least as many as could be traced; see Fig. 5b) for each combination. The whole series of measurements was done twice along two different lines on the lens; very good agreement was achieved between the two series.

Fig. 2 shows the exiting rays for several combinations. In order to make the diagrams easier to view, only every second ray from the least central grooves is drawn. On the other hand, two lines are drawn for each ray, showing the spread of the ray after exit. We have in each case estimated the edges of the major part, approx. 90% of the beam; minor parts sometimes deviated far outside these limits. For each ray, the spot used was the one giving the least spread of the exit beam.

Fig. 2. Rays after refraction through the Fresnel lens for some different combinations of sagittal and meridional angle of incidence. Examples are given both for the flat side and the grooved side facing the laser. Grooves are perpendicular to the plane of the Fig.
As is evident from Fig. 2, there is always a spread in the exit beam. This spread is due to irregularities in the lens surface, a result from the manufacturing process. This fact is demonstrated in Fig. 3, which was achieved in the following way: The laser beam was reflected from the flat lens surface at near normal incidence. The major part of the illuminated spot on the screen was traced on the screen. The measurement was repeated ten times, and Fig. 3 shows the ten spots drawn on top of one another with the axes marked in degrees instead of centimeters. The effect is as large as expected, and accounts for most of the beam spread in the ray tracing measurements.

For control, some ray tracing measurements were also performed on a full size Fresnel lens, all at normal incidence. They all agree with one another and with the results above regarding the beam spread and the focal length. It can thus be assumed that the results of the large series of measurements are representative.

**DISCUSSION**

Fig. 4 and 5 summarizes the computed ray tracing results published by Franc et al. (1986) and the measured results from this paper. In Fig. 4 is presented computed and experimental focal lengths, defined as the distance between the lens and the area of highest concentration for at least 90% of the rays as measured perpendicular to the plane of the lens. In Fig. 5 is presented the smallest width of at least 90% of the beams.

![Fig. 4. The measured focal length as a function of sagittal and meridional incident angles.](image)
From Fig. 4 is evident that computed and measured focal lengths agree well. The measured decrease in focal length for increased sagittal angle is however smaller than the computed one. This is a positive result, since then, in an application with grooves in the east-west direction and a horizontal east-west rotation axis, or in an application with the grooves and the rotation axis both parallel to the polar axis, the distance between the lens and the absorber can be kept constant.

![Figure 5: The measured width of the focal band as a function of sagittal and meridional incident angles.](image)

From Fig. 5 is seen that the width of the focal band is quite constant for all measured incident angles when the grooves face the laser, while this holds only for meridional angle equal to 0 degrees when the flat side faces the laser. This result implies that the flat side of the lens can face the sun in the geometries described in the preceding paragraph, while it seems more favorable to let the grooved side face the sun in applications where both the sagittal and meridional angles vary. This may be the case when the lens is combined with a trough with reflecting sides (Collares-Pereira et al., 1977; Broman et al., 1989).

**ACKNOWLEDGEMENTS**

Discussions with B. Nabelek are gratefully acknowledged.

**REFERENCES**


ABSTRACT

An electricity experiment kit that incorporates photovoltaic cells has been constructed. The kit consists of a circuit board, a number of electric components, and a manual. The PV cells are used both in PV electricity experiments and as a source of DC current for experiments in general electricity. The kit works well technically and field tests in African secondary schools are in the planning.

KEYWORDS

Solar cells; photovoltaic; solar energy education; secondary school education.

INTRODUCTION

Whenever possible, physics teaching should include student laboratory experiments. Basic electricity experiments require only low voltage, usually supplied by a transformer for AC experiments completed with a rectifier for DC experiments. When grid current is not available, dry cell batteries constitute possible alternatives. Physics experiment kits using dry cells as the source of direct current have been developed at the Kenya Science Teachers College, at the University College of Falun/Borlänge (Broman and Eriksson 1973) and by others a long time ago. Electric experiments using dry cell batteries were also included in the New Unesco Source Book for Science Teaching (1973). Dry cells however wear out quickly and have to be replaced frequently at high cost.

Therefore we have developed an electricity experimental kit that employs rechargeable NiCd cells as the DC source and PV cells to charge them. Such kits can be used also by students at secondary schools not connected to any electric grid.
Furthermore, a set of electricity experiments has been designed which deals not only with elementary concepts but also with basic PV techniques.

Fig. 1. Electricity experiment kit with PV cells.
Another important field of education is the training of PV installers and maintenance technicians in developing countries. A successful program for training of PV technicians has been developed by the UN Pacific Energy Development Programme in Fiji and implemented in cooperation with the South Pacific Institute for Renewable Energy in Tahiti (Wade and Lai, 1989). Several hundred students have attended week-long training courses in basic home-scale PV installation, troubleshooting, and maintenance. Maybe the here presented experiment kit could be put to good use also in vocal training of this kind.

School laboratory equipment for studying solar heating has been developed by, among others, K. Reinhard (1988); he also describes a photovoltaic demonstration apparatus. This consists of a solar cell, which can be cooled and heated, and is loaded by a variable resistor.

THE KIT

The electricity laboratory experiment kit consists of the following parts:

* A circuit board, approx. 20x16 cm, with 5x4 connection points (terminal blocks)
* Five encapsulated solar cells (made of reject Si PV cell chips, .45 V, approx. .4 A max.)
* Wooden holder for the cells
* Two simple multimeters for AC/DC voltage and DC current measurements
* Two NiCd cells (size R14 with soldering tags)
* A rheostat (potentiometer 20 ohm, 4 W)
* A small DC motor (3 V, .9 A)
* Two switches (two kinds, one spring-back and one not)
* Bulbs 1.1 V, .22 A and 2.2 V, .25 A with sockets
* Two diodes
* Resistors (several with different values)
* Copper wire (varnished, for making electro-magnets)
* Resistance wire
* Several (insulated) leads with soldered tips, lengths 5-15 cm.
* A small set of tools (screwdriver, pliers)

Specifications are not that critical; materials were chosen not only for technical and pedagogical reasons, but also because they were readily available at reasonable cost (1989 retail cost in Sweden approx. SEK 400 or USD 60).

THE EXPERIMENTS

Basic Electricity Experiments

* Open and closed circuit
* The electric switch
* Voltage measurement
* Resistive load and current measurement
* Resistive loads in series
* Resistive loads in parallel
* Batteries in series
* Batteries in parallel
* Ohms law
* Resistance measurements
* Electromagnetism as a phenomenon
* Conversion of electric energy to heat, light and motion
* Electric circuits with rheostat
* The diode

**Photovoltaic Experiments**

* Open circuit voltage and closed circuit current
* PV cells in series and parallel
* Discharging of NiCd cells
* Charging of NiCd cells without diode
* Charging of NiCd cells with diode
* Electric circuits with PV cells
* Concentrating sunlight onto PV cells
* The PV cell as insolation meter
* The cosine effect

**Advanced Electricity Experiments**

* Characteristics of a diode
* Characteristics of a PV cell
* Temperature effect on output from a PV cell
* Efficiency of an electric motor
* Efficiency of charge-discharge cycle in NiCd cell
* Internal resistance of NiCd cell
* Kirchoff’s laws

**DISCUSSION**

The above described kit and most of the experiments have been tested at SERC and by a student at the University Technology of Falun/Borlänge (Persson, 1989). It has been proved that the kit works well technically and that the experiments can be performed. It should however be pointed out that all the non-PV experiments have been used extensively by the author in physics teaching in teacher training and in-service teacher training at the University College as well as in elementary and/or secondary Swedish schools.

The present kit and set of experiments remain however to be tested. A laboratory experiment manual is in the writing and will be completed in a trial version during the fall of 1989. Field tests are planned to take place in The Gambia within the framework of SERC’s collaboration with The Gambia Renewable Energy Center GREC (Broman, 1988, Broman et al., 1987), and in the Karagwe region of Tanzania.

Furthermore, we have constructed a low-cost (1989 approx. SEK 160 or USD 24) experimental kit in digital electronics for a
Swedish Science Center (Broman, 1986). The kit contains a manual with 25 experiments, a circuit board with IC circuit holder and 24 screw contacts, five IC chips with simple gates, 4.5 V battery and supporting equipment. Digital electronics requires very little current, so the kit is easily converted to solar using four size R6 NiCd cells and a (commercially available) small solar battery charger. For use outside Sweden, the manual must however be translated, since it is presently only available in Swedish. The kit is in Sweden recommended for students from 15 years of age.

While laboratory science material at every (secondary) school is much wanted, there are other ways available to let students experiment, investigate and discover scientific phenomena. Science Centers, like Framtidsmuseet in Borlänge or Nehru Science Center in Bombay, with hands-on exhibits and interactive exhibitions is one such possibility. Such a center can serve many schools in a metropolitan region, and, by means of out-reach programs with travelling exhibitions, schools in rural areas as well.

The author welcomes communication about the electricity experiment kit as well as on Science Centers and travelling exhibitions. A copy of the laboratory manual can be sent free of charge, larger quantities and kits at nominal cost.

ACKNOWLEDGEMENTS

The assistance of Kent Börjesson and Irena Persson is gratefully acknowledged.

REFERENCES

ABSTRACT

PRESIM is a computer program for creating, storing, retrieving and changing input data for modular HVAC system simulation programs. The user works with CAD-style tools. The program also produces system schematics and other documentation. A first release of PRESIM will produce input data for the TRNSYS simulation program.

KEYWORDS

Simulation; system schematic; input data; front end; interactive; CAD; computer; documentation;

INTRODUCTION

Modular simulation programs are powerful tools that ought to be more frequently used. They make it possible to analyse in detail the thermal performance of a wide range of different HVAC system designs. An obstacle to a widespread use of these programs is their poorly developed user interfaces.

In this project we are designing a preprocessor, PRESIM, which integrates the systems definition process in a CAD-style working environment.

Our basic idea is that an overall system schematic should be the means to define type and number of components together with their interconnections. In the ordinary design process the overall system schematic plays a major role. We believe that it should play an equally important role when defining a model for a simulation program.

Especially considering a more wide spread use of simulation programs, exchange and comparisons of simulations, there is an obvious need for a dedicated program for preparing input data. Some benefits would be:

- Faster and safer systems definition.
- Easier to generate correct and standardized documentation.
- The same HVAC system could be simulated with different solvers.
THE SIMULATION ENVIRONMENT

'The simulation environment', which we would like to see, is outlined in figure 1. The system includes three major programs; 1) The solver (i.e., the modular simulation program) 2) a preprocessor and 3) a postprocessor.

As for the solver there is a number of programs capable of performing simulations on modularized system models. Apart from sheer performance it is most important that the program has a number of users, is well documented and provides a reliable support organization. The first version of PRESIM works with TRNSYS from Solar Lab at U of Wisconsin as the target solver.

POSTSIM, the post-simulation processor, provides a mean to analyse the simulation output data. This is analogous to handling data from experimental sites and by preference one uses the same programs. There is a number of suitable commercially available programs for statistical analysis and graphical presentation.

The weakest part of the simulation environment is the preparation of input data to the solver. Today there are basically two ways of doing this: Either the simulation program itself has a front end for defining the model to be studied, usually a text screen interface where the user selects menu items, fills in forms etc. Else there is only a data format prescribed, adhering to which the poor user, honouring a syntax obscured by backward compatibility, a text editor his only weapon, painstakingly arranges his model which shall be effectively hidden in a maze of keywords and arrays of numbers. Both of these methods lack in flexibility, overview, easy means to reuse subsystems, and production of full documentation. The editor method may be quite unsafe.

PRESIM will fill the gap. PRESIM is a CAD-style program for creating, storing, retrieving and changing input data to modular programs for HVAC system simulation. The input data consist of 1) the HVAC system description, 2) simulation control data, and 3) references to other relevant data, i.e., climate and load data.
THE FEM ANALYSIS PARALLELL

The simulation environment described above is not a new concept. This style of working is well known in the field of FEM, the Finite Element Method, extensively used for stress and heat transfer analysis of mechanical systems.

There are several preprocessors for FEM programs, stand- alone or imbedded in CAD-systems, providing means for definition of a physical object, represented as a picture on a computer screen. The preprocessor has CAD-style means for manipulating, storing and retrieving models. There are functions for inputing simulation control, the element mesh, element properties and boundary conditions to the model.

Typically a preprocessor is capable of producing input data to several different calculation programs (solvers). The solver does the actual computation work, producing results in one or several formats. Finally there is also a variety of postprocessors for analyzing and making comprehensible the results, as screen pictures, plots or lists.

There are also nowadays systems providing preprocessing, solving and post-processing in an integrated, more or less seamless environment.

The FEM analysis environment outlined above has developed and matured during some twenty years, now offering efficient means for defining, documenting, solving and analyzing a great number of problems in the structural strength analysis and heat transfer areas.

PRESIM FEATURES

PRESIM is an interactive graphical program. The user works with a mouse or other pointing device and manipulates a system schematics on a graphical computer screen, much in the same way as with a modern, user- friendly CAD-system. The program runs under DOS on an IBM compatible machine.

The system schematic consists of symbols and connections. Typically, each symbol on the screen represents a component in the simulation program. When available, standard ISO symbols are used.

Special symbols will be used for functions that are usually not found on HVAC system schematic, e.g. climate data, load data, and simulation output control. It will be possible for the user to interactively change old symbols, create new ones and rearrange the symbol menus.

Parameter values such as collector area and efficiency, heat exchanger properties and so on are entered in forms with help texts, unit conversion and range checking. The user may save copies of individual components, with parameter values, and thus build a library of ready-to- use components.

Parts of the drawing may be saved as subsystems for later retrieval. Component data and interconnections are saved, making it easy to build new systems composed of tested modules.

Either on request or when appropriate, as when generating a set of input data or making a connection between components, the program will perform checks on the system regarding input-output type correspondence, physical appropriateness, and the like. Checks will either prohibit action (severe violations) or issue a warning.

The program will be a sufficient tool for providing all input data necessary for the simulation.
Figure 2 shows a computer screen as it looks during a PRESIM session, an HVAC systems schematic being assembled. The user evokes action by clicking with the mouse at various parts of the screen.

A click on one of the symbols in the COMPONENT SUBLIBRARY MENU loads a COMPONENT MENU which in turn contains a number of COMPONENTS. A component is copied from the menu to the DRAWING AREA by a click-and-drag action. The components have connection points to which connections snap.

A click on the FUNCTION MENU invokes a function, i.e., copy component, make new component, write TRNSYS input data file, write documentation, load or save model.

Depending on the function being carried out, the MESSAGE LINE informs the user what action the next click will cause.

DESIGNING THE PROGRAM

The program development is done jointly by SERC and MCE. Source code from HIDRAW, a commercial schematics drawing software package, is used as a basis for the PRESIM program.

We cooperate with the Solar Laboratory at the University of Wisconsin, USA. The Solar Lab will take part in design, testing and evaluation of PRESIM and intends to release it as a standard feature of the TRNSYS system.
SHIPPING, DOCUMENTATION, MAINTENANCE, SUPPORT

The first official version of PRESIM will be distributed in spring 1990, by the Solar Lab and SERC in Borlänge. This version will be able to produce input data for the TRNSYS program. As demand hopefully rises interfaces to other programs will be developed.

The PRESIM software will be documented, maintained and supported to enable safe operation by external users.

CONCLUSION

We identified a problem: It is awkward to prepare input to modular simulation programs.

We realized that we had a solid experience suitable for developing an interactive, graphical, preprocessing program that could solve the most severe parts of the problem.

The example of the evolution of a user-friendly and efficient environment for FEM analysis suggests that this is a fruitful approach.

To strengthen the group, we have been lucky to engage in cooperation with the Solar Lab at University of Wisconsin.

We feel reasonably confident that we will produce a well functioning tool.

ACKNOWLEDGEMENT

We greatly acknowledge the support by E. Figueroa and W. A. Beckman. The work presented here was carried out with financial support from BFR, the Swedish Council for Building Research (BFR) and the Swedish National Energy Board (STEV).

REFERENCES


Klein, S. A. and coworkers (1983 ) TRNSYS, a transient system simulation program. University of Wisconsin, Madison, WI 53706, USA.
