The Reactor Physics Computer Programs in PC's Era

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ABSTRACT

The main objective of reactor physics analysis is the evaluation of flux and power distribution over the reactor core. For CANDU reactors sophisticated computer programs, such as FMDP and RFSP, were developed 20 years ago for mainframe computers. These programs were adapted to work on workstations with UNIX or DOS, but they lack a feature that could improve their use and that is "user friendly". For using these programs the users need to deal with a great amount of information contained in sophisticated files. To modify a model is a great challenge. First of all it is needed to bear in mind all the geometrical dimensions and accordingly, to modify the core model to match the new requirements. All these must be done in a line input file.

For a DOS platform, using an average performance PC system, it could be possible:

- To represent and modify all the geometrical and physical parameters in a meaningful way, on screen, using an intuitive, graphic user interface?
- To reduce the real time elapsed in order to perform complex fuel-management analysis "at home"?
- To avoid the re-write the mainframe version of the program?

The author's answer is a fuel-management computer package operating on PC, 3 time faster than on a CDC-Cyber 830 mainframe one (486DX/33MHz/8MbRAM) or 20 time faster (Pentium-PC), respectively.

I. INTRODUCTION

The purpose of this paper is to highlight the concepts of user friendly and graphic interface for the CANDU physics design programs. We will present these concepts applied to SERA, a program developed by the authors. This program was used for several years and some results obtained with this code were presented in specialized literature [1],[2].

First chapter presents shortly SERA program. This program is based on a similar diffusion module as programs developed at AECL (CHEBY, FMDP, RFSP). SERA contains also a module based on LATREP-T3S for neutronic cell properties. It includes also modules for fuel management studies, such as the autorefuel module and the random channel age generating module.

Second chapter presents the graphic interfaces developed for the pre and post processor. This graphic interface uses 2D representations for input modeling and as well for results interpretation. This graphic interface could be easily adapted to work with any similar program.

In the third chapter we describe mass storage subroutines. These subroutines permit a great flexibility for the whole package. Due to these subroutines the program can run on a PC 386 platform and as well on a P5 PC.

Chapter 4 presents shortly some comparative results and finally, in chapter 5 the conclusions are provided.

II. SERA - General presentation

This program was developed for advanced fuel cycles studies and has the following features:

Macroscopic properties are obtained using age-diffusion approximation for reaction rates and Wescott formalism in order to obtain microscopic cross section for heavy isotopes contained in fuel. This part of the code includes the LATREP-T3S program, a version developed from AECL's Cycle-4 LATREP version. Some modifications were performed for modeling axial refueling schemes and fuel irradiation taking into account the power and irradiation histories. This version allows studies involving fuel based on other fissile elements and in the same time considers burnup effect on the neutronic parameters and on the flux and power distributions. This module permits studies on different types of cylindrical geometry and different types of isotopic compositions in the bundle's rings.

An option to use the bi-group diffusion approximation with neutronic properties obtained from WIMS program is also included.

The reactivity devices are considered by their incremental macroscopic cross section that are provided separately.

The diffusion equations are solved in age-diffusion approximation using the finite differences method and the Gauss-Seidel numerical algorithm.

The program includes two modules for instantaneous power distributions, one is based on the random age method and the other uses automatic refuel simulation.

Using SERA one can obtain discharge burnup distribution that satisfies the criticality equation. This process is automated and requires only the rapport's between discharge burnups. We used a linear interpolation method between to successive iterations to obtain the final discharge burnups.

Using data files we have performed also termohydraulic studies based on HYDNA-3 and NUCCP AECL's computer programs.

III. GRAPHIC INTERFACES

Graphic interfaces were developed to improve program use, starting with core and devices modeling, having some information regarding flux distribution in main core area section during computing time and ending with final interpretation for the important values interesting the physics core design. The final part of calculations includes 2D maps generating and as well a written report that can be included in any word processor.

This version of the program includes an active core CAD preprocessor program. The purpose of this program is to take user input and to transfer it into the diffusion part. This is done in a friendly manner using 2D section in XY, XZ and YZ slices throughout the core.

Actually the most important section is the XY one. Usually this section is used to divide the channel into 12 or many calculus planes. The other two sections (XZ and YZ) represent the middle slice through core. Some examples are provided in Figures 1-4. These figures were transformed from color to gray form due to printing limitations.

The program has an extended range of options. It allows inserting / deleting mesh points on X, Y or Z with rearranging the actual inserted devices into the new lattice points. The user is able to

modify the neutronic parameters of each materials and as well to insert new materials. This program does not allow to create a new material by combining two materials into one cell. However this limitation does not restrict the use of program it just reflects the options in material construction for the core representation.

Using the mouse or the keyboard one user can easily model a CANDU core having on a computer monitor the meaning of his action.

During the time the program performs diffusion calculations for equilibrium situation or instantaneous/refueling situation, the user can observe the iterative process represented as a colored flux/power map. The color scale was chosen to reflect as much as possible the common color sense. This map is completed by some numeric information regarding the iterative process.

The third phase of calculation is the results' interpretations and evaluations. This process is done by studying the channels/bundles powers' maps, discharge burnup maps, dwell time maps, etc.

We developed a program for this part of calculation process. This program was written bearing in mind the same ideas as for the first part. Simplicity in use and a large number of parameters investigated are the main characteristics of this post-processor program. Simplicity in use is due to the extensive use of the mouse in choosing options. Authors have included a large spectrum of parameters to be represented by this program. However any new parameters or new representations could be added with minimum of effort. The main information provided by this program are:

- general power information
- channel information (channel power map, radial power distribution, axial channel power, CPPF map, equilibrium dwells time map, channel age map)
- bundle information (bundle power maps, discharge burnup map, BPPF map, power envelopes).

Figure 4 is a sample to illustrate the information provided above. This figure was transformed from color to gray form due to printing limitations.

IV. MASS STORAGE SUBROUTINES

These subroutines were developed to permit adaptation of this program from a CDC CYBER minimainframe to a PC platform. We used the same names for the PC subroutines as they were for CDC CYBER version.

We have rewritten these subroutines from scratches. These subroutines use random access and fixed length record offered by any FORTRAN compiler. We have simulated the random access random length using the above mentioned feature. These subroutines use a hard drive (or a ram drive) to store the information. In this manner the program is able to run on a low end PC platform such as 386, no coprocessor, 2 MB ram and 4 MB free space on hard disk. However we improved this package by adding a set of subroutines that bypasses the hard disk by writing in memory. This set was developed for the high end PC platforms (486 DX or Pentium and at least 8 MB RAM) and increased the program speed by a factor of 2 to 10 depending on the hardware.

These subroutines permit a great flexibility for the program installation. For example on a 4MB platform, a medium size model (42x28x22) and a proper system configuration the program still runs with maximum of speed. If the model is increased then a better choice would be a ram drive, doubled by specific programs such as Double Space, Drive Space or Stacker. Although the speed with decrease by a factor of 2, everything will remain in RAM memory so the program will run as fast as possible.

As we mentioned the program could run on a low end PC platform but we do not recommend this, due to intensive hard disk utilization. A better choice would be a Pentium machine, the faster the better. We developed and tested these subroutines on a P75 8MB machine.

V. COMPARATIVE RESULTS

In the previous section we have highlighted the importance of the hardware on the performance. However we have discovered that even some fine tunings on systems could lead to some performances' gains. For examples, authors discovered that on a 486 DX 50 with 16 MB RAM used for FMDP calculations, reserving a small memory for hard disk cache, a SMARTDRIVE memory allocation of about 500k could increase the speed by 25 %. This will not be the case for SERA because its design avoids, as much as possible, intensive hard disk utilization. However a fine tuning for the system, setup level, could squeeze an extra 5 to 10 % performance.

In Table 1, we compare one step full core (42x28x22 mesh points) execution's time for several platforms and configurations. The ram drive situation means that the mass storage subroutines use a RAM virtual hard disk simulated by the operating system. The other situations use the subroutines in bypass mode.

These results show the bottleneck produced by the slow memory compared to processor speed.

Table 1. Time elapsed for 1 iteration (42x22x22 points) for several configurations

COMPUTER	CYBER-830 CPU time	486 DX 33 Dos time (Ram drive)	486 DX 33 Dos time	P 75 Dos time (Ram drive)	P 75 Dos time
1 Iteration time	6 sec	6 sec	2 sec	2 sec	0.3 sec

VI. CONCLUSIONS

We presented in this paper a different approach to the problems regarding use of computers for neutronic physics design purposes. We focused on three issues:

- a graphic user interface package to facilitate the pre and post data processing complex input and output files
- a software package to adapt the program(s) with minimum of effort for any type of X86 hardware
- a fuel management code for designing, evaluating and academic purposes

Graphic interfaces allow a faster, more accurate and elegant way to design and evaluate the results for CANDU design. Although we were concentrating on a fuel management program, the ideas exposed here are applicable to thermal hydraulic codes as well. The pre and post processing packages are practically independent and could easily be adapted to work with similar codes such as CERBERUS, CHEBXEMAX, CHEBY, FMDP, RFSP and as well with thermal hydraulic codes such as NUCCP or FIREBIRD.

REFERENCES

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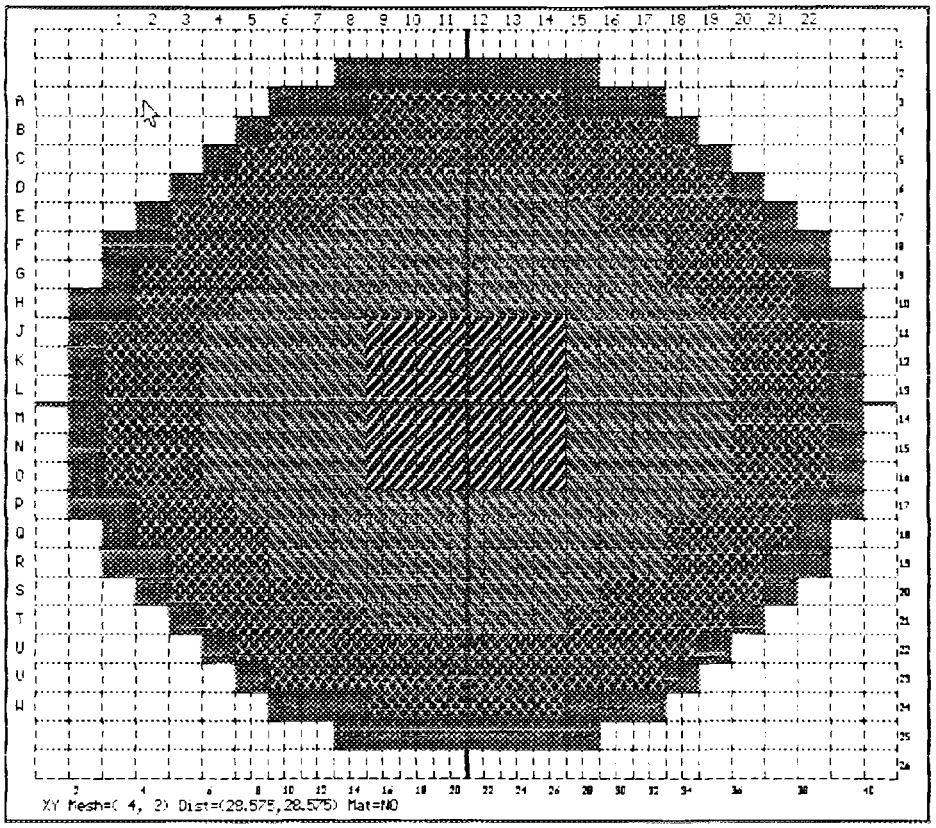

Figure 1. Graphic representation for discharge burnup region (includes reflector at exterior)

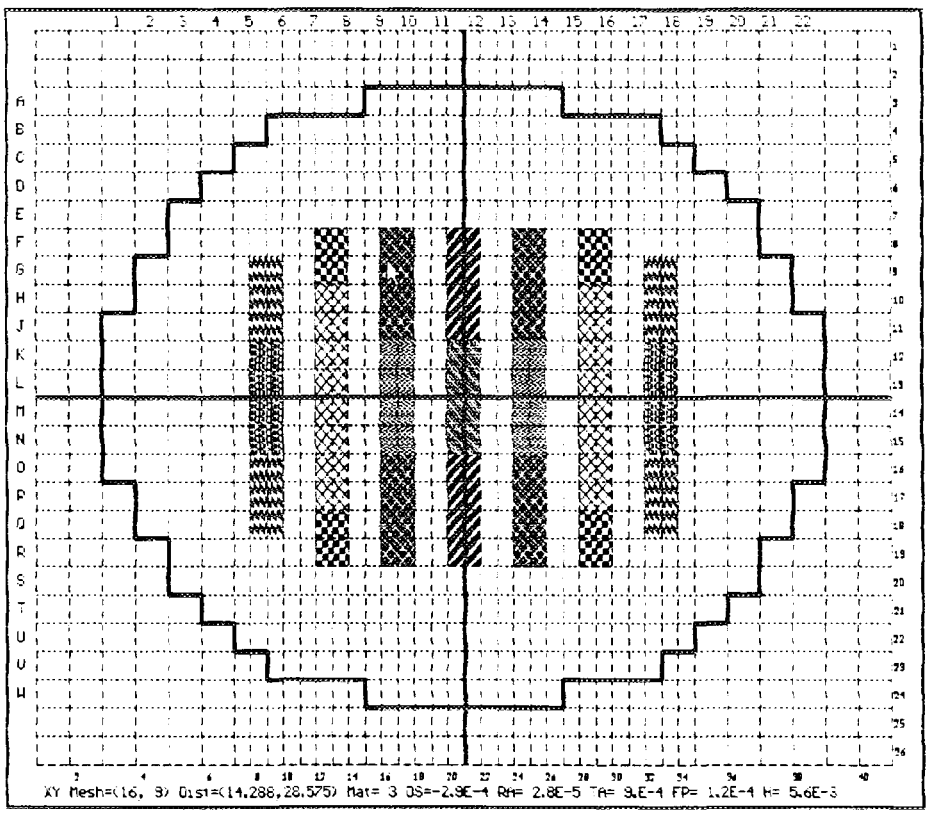

Figure 2. Graphic representation for XY section with adjuster rods

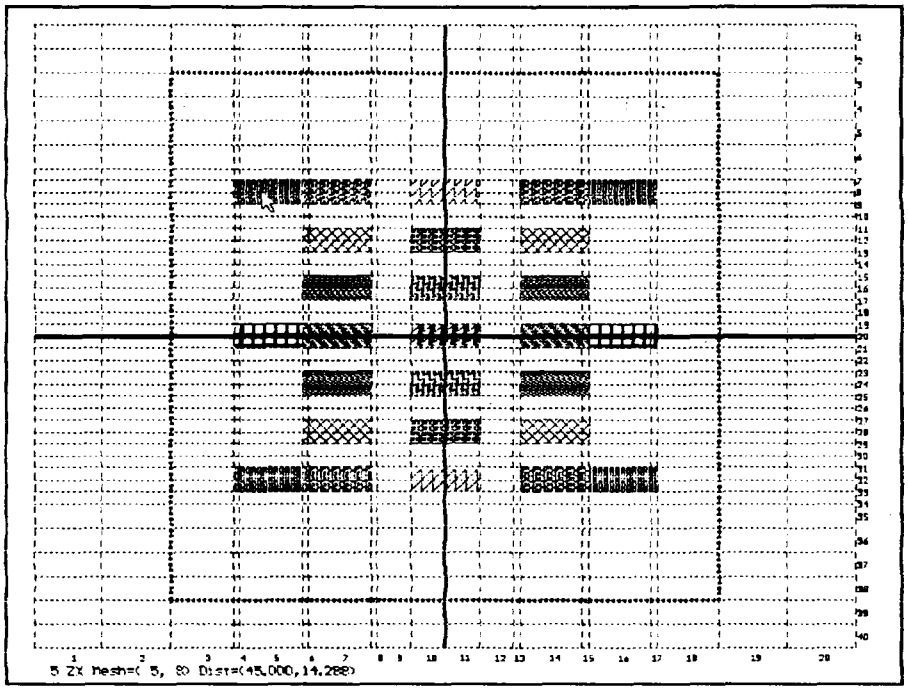

Figure 3. Graphic representation for ZX section (median slice).

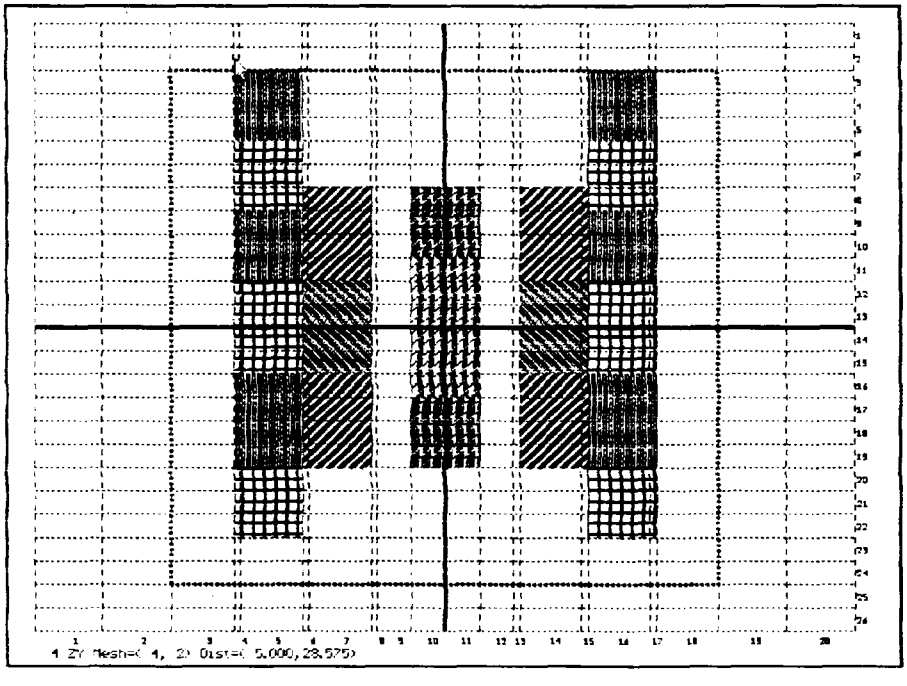

Figure 4. Graphic representation for ZY section (median slice).

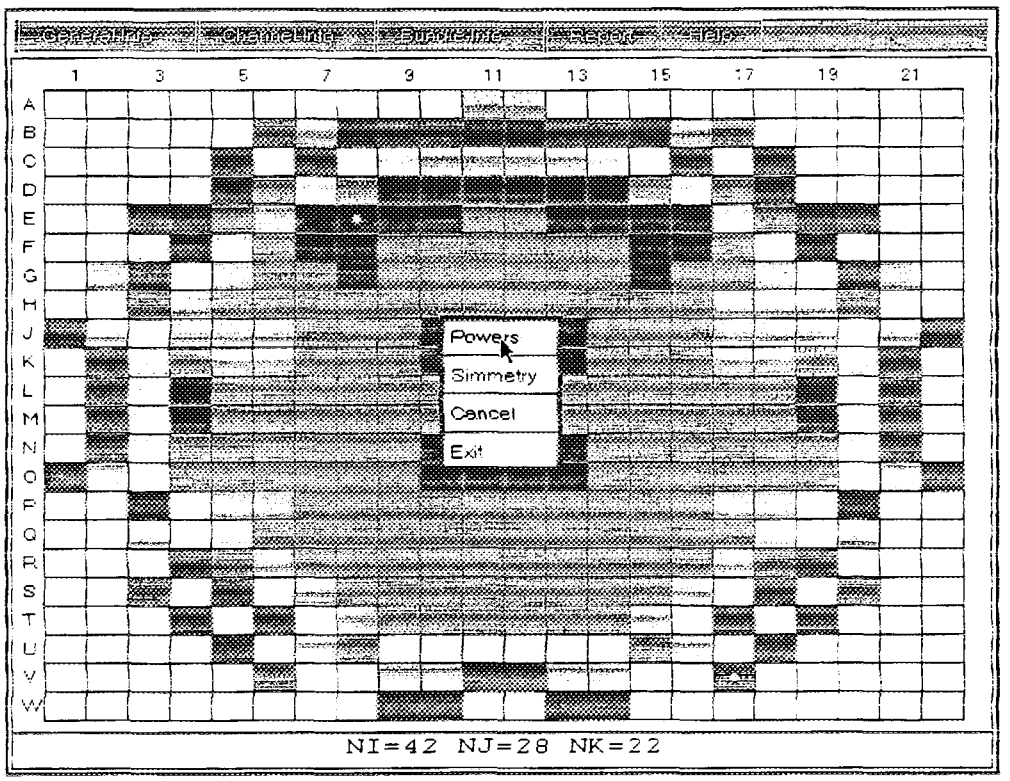

Figure. 5. Channel power map representation.