Development of a cross-section interface for PARCS

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Abstract

This paper deals with the development of an interface allowing feeding the PARCS core simulator with realistic material constants corresponding to any heterogeneous PWR core. Since the CASMO-4/SIMULATE-3 code package is predominantly used in Sweden, such an interface is based on the use of the binary library file created by CASMO-4 and read by SIMULATE-3. This binary library file contains the results of the 2-dimensional transport calculations of all the fuel/reflector assemblies loaded in a specific core and for all the possible operating conditions. More precisely, SIMULATE-3 is used for reading this file and for interpolating the data at the operating points necessary for representing the dependence of the material constants in PARCS. The full dependence of the material constants on history variables, instantaneous variables, and exposure can thus be reconstructed in a consistent way with the PARCS formalism. Such an interface is demonstrated to accurately represent the actual dependence of the material constants.

KEYWORDS: material constants, core calculations, code development

1. Introduction

In order to perform realistic calculations, material constants and kinetic parameters representative of the actual local conditions, of the exposure, and of the history effects should be used for defining the complete heterogeneous structure of a nuclear core. Nevertheless, the dependence of the material constants and kinetic parameters cannot be determined simply. Rather, detailed 2-D transport calculations should be performed for each fuel assembly loaded in a nuclear core. Purdue University has recently developed an interface allowing feeding the 3-D core simulator PARCS [1] with the results of such transport calculations. PARCS is actually using so-called PMAXS (Purdue MAcroscopic Cross-Section) files, constructed by this interface, named GenPMAXS (Generation of the Purdue MAcroscopic Cross-Sections) [2]. So far, GenPMAXS is only able to create such PMAXS files from the Studsvik Scandpower HELIOS code [3]. Purdue University is actually working on extending this interface to the Studsvik Scandpower CASMO-4 code [4].

The CASMO-4 code is the code predominantly used in Sweden to perform routine transport calculations and cross-section generation. A preliminary study actually revealed that developing an interface based on the use of the Studsvik Scandpower 3-D core simulator SIMULATE-3 [5]

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was both feasible and could be a very good complement to the solution Purdue University is currently working on [6]. Namely, SIMULATE-3 can be used to read the binary library file containing all the material constants and kinetic parameters of all the fuel assemblies loaded in a specific core. Since SIMULATE-3 is used to read the binary library file, no new transport calculation is required, i.e. constructing the PMAXS files is rather fast. Furthermore, using SIMULATE-3 allows editing the data in a formalism consistent with SIMULATE-3, before using these data to construct the PMAXS files in a formalism consistent with PARCS. More precisely, the data need to be edited at specific operating conditions, burnup, and histories in order to construct the PMAXS files properly. When using SIMULATE-3 for such a task, the interpolation of the data to the required operating conditions, burnup, and histories, is performed according to the interpolation scheme of SIMULATE-3. Since this interpolation scheme is well validated, the data can be reliably used for constructing the PMAXS files.

In this paper, the cross-section models of SIMULATE-3 and PARCS are briefly presented. A description of the interface is thereafter given.

2. Cross-section models

2.1 Cross-section model in SIMULATE-3

SIMULATE-3 is an advanced 2-group nodal code for the analysis of both PWRs and BWRs [7-8]. The code is based on a neutronic model which uses the transverse integration technique with quadratic transverse leakage integration, for both static cases and kinetic cases. The 2-group, 3-dimensional, transverse-integrated neutron diffusion equations are solved using fourth-order fast group flux expansions and fourth-order or analytic thermal flux expansions. Regarding the thermal-hydraulics, an explicit channel hydraulic calculation is performed for each fuel assembly. Two models are available, especially for BWRs: a simple transient mixture mass and energy model, and an explicit mixture mass, energy, and momentum model that solves the drift flux equations. This thermal-hydraulic model gives a set of thermal-hydraulic conditions from which the actual nuclear cross-section can be obtained for each node. According to the methodology used in the CASMO-4/SIMULATE-3 codes, the macroscopic and microscopic two-group cross-sections, discontinuity factors, fission product data, and detector data are developed as the sum of partials, where each partial can be a function of up to three variables [9]. Any of these parameters P can thus be expressed in a generic form as:

$$P(A,B,C) = P(A_0,B_0,C_0) + \Delta P_A(A) + \Delta P_B(A,B) + \Delta P_C(A,B,C) \tag{1}$$

where $P(A_0,B_0,C_0)$ is the base value and with:

$$\Delta P_A(A) = \int_{A_0}^{A} \frac{\partial}{\partial A'} P(A',B_0,C_0)\, dA' \tag{2}$$

(A being the primary variable),

$$\Delta P_B(A,\boldsymbol{B}) = \int_{B_0}^{B} \frac{\partial}{\partial B'} P(A,B',C_0)\, dB' \tag{3}$$

(B being the primary variable, and A the secondary variable),

$$\Delta P_C(A,B,\boldsymbol{C}) = \int_{C_0}^{C} \frac{\partial}{\partial C'} P(A,B,C')\, dC' \tag{4}$$

(C being the primary variable, and A and B being the secondary and tertiary variables,

respectively).

The construction of data from Eqs. (1) - (4) is graphically represented in Fig. 1. The CASMO-4 raw multi-dimensional data are reduced into additive series of tables containing the partial functions. No more than three variables can be handled for the dependence of the macroscopic and microscopic two-group cross-sections, discontinuity factors, fission product data, and detector data. Consequently, assumptions have to be made to reduce the number of variables used to describe these parameters with three or fewer variables. Where assumptions of separability are needed, the variables that are not varied are supposed to be at their base case conditions, usually taken as the reactor-averaged or beginning-of-life states. When data from the CASMO-4 lattice calculations are not available for constructing the tables, second-order Lagrangian interpolation is used to generate the missing values.

Figure 1: Construction of the macroscopic and microscopic two-group cross-sections, discontinuity factors, fission product data, and detector data in the CASMO-4/SIMULATE-3 code package (derived from [9]).
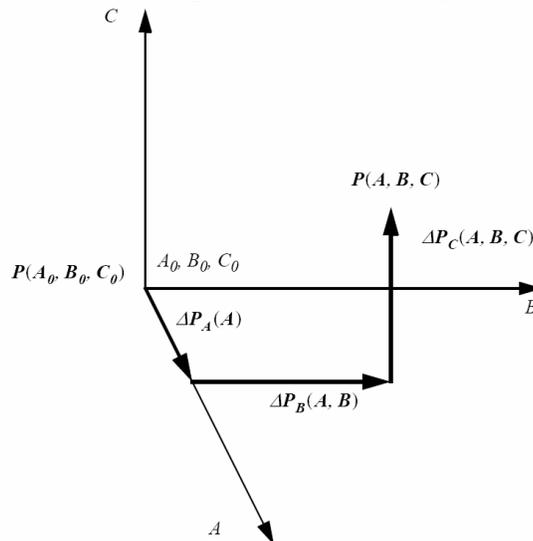
For the pin-by-pin power distributions, corner-point flux ratios, detector flux peaking factors, detector microscopic cross-sections, two-group neutron velocities, effective neutron precursor yields, and precursor decay constants, only one-dimensional table sets in exposure are used for representing the principal variation of the data [9]. The additional dependencies of the data are modeled by one-dimensional tables of the derivatives of the data as a function of exposure. Any of these parameters P can thus be expressed in a generic form as:

$$P(b,B,C,...,Z) = P(b,B_0,C_0,...,Z_0) + \Delta P_B(b) + \Delta P_C(b) + ... + \Delta P_Z(b) \tag{5}$$

with b representing the exposure (burnup) and:

$$\Delta P_B(b) = \int_{B_0}^{B} \frac{\partial}{\partial B'} P(b,B',C_0,...,Z_0) \, dB' \tag{6}$$

$$\Delta P_C(b) = \int_{C_0}^{C} \frac{\partial}{\partial C'} P(b,B_0,C',...,Z_0) \, dC' \tag{7}$$

$$\Delta P_Z(b) = \int_{Z_0}^{Z} \frac{\partial}{\partial Z'} P(b,B_0,C_0,...,Z') \, dZ' \tag{8}$$

Since the additional dependencies are only functions of exposure, the base values for the independent variables have to be chosen in the mid-range of variation. A second-order polynomial fit to the base value and its two neighboring points is used for the evaluation of the additional dependencies, i.e. for Eqs. (6) - (8). Table 1 summarizes the data functionalization usually performed for PWR cases [9-10]. This Table is intended to give an overview of the most typical dependence of the data. In some specific cases, additional variables and different data dependence might exist, depending on the needs of the user. The different variables used in this Table are abbreviated by b for the exposure (burnup), T_f for the fuel temperature, HT_f for the history-averaged fuel temperature, T_m for the moderator temperature, HT_m for the history-averaged moderator temperature, C_b for the boron concentration, HC_b for the history-averaged boron concentration, α_{CR} for the control rod insertion, $H\alpha_{CR}$ for the history-averaged control rod insertion, b_{BP} for the burnable absorber exposure (burnup), and $T_{cooling}$ for the shutdown decay time. As can be seen from Table 1, the data are represented as multidimensional tables of three variables at the most for both the base values and the additional dependencies (referenced in some cases as deltas).

Table 1: Typical data functionalization for PWR cases in the CASMO-4/SIMULATE-3 code package (the variables in bold represent the primary variables).

Parameter P	Fuel segment	Reflector segment
D_1, D_2, $\Sigma_{1\to2}$, $\Sigma_{a,1}$, $\Sigma_{a,2}$, $\nu\Sigma_{f,1}$, $\nu\Sigma_{f,2}$, κ/ν, $\sigma_{a,1}^{B^{10}}$, $\sigma_{a,2}^{B^{10}}$	$P\left(b,\boldsymbol{HT_m}\right)+\Delta P_{HC_b}\left(b,\boldsymbol{HC_b}\right)+\Delta P_{C_b}\left(b,\boldsymbol{C_b}\right)$ $+\Delta P_{T_m}\left(b,\boldsymbol{T_m}\right)+\Delta P_{T_f}\left(b,\boldsymbol{T_f}\right)+\Delta P_{\alpha_{CR}}\left(b,\boldsymbol{\alpha_{CR}}\right)$ $+\Delta P_{T_{cooling}}\left(b,\boldsymbol{T_{cooling}}\right)\left[+\text{ optionally }\Delta P_{b_{BP}}\left(b,\boldsymbol{b_{BP}}\right)\right]$	$P\left(\boldsymbol{C_b}\right)$ for radial and bottom reflectors $P\left(C_b,\boldsymbol{T_m}\right)$ for top reflector
ν, $\gamma_{I^{135}}$, $\gamma_{Xe^{135}}$, $\gamma_{Pm^{149}}$, $\gamma_{Sm^{149}}$, $\sigma_{a,2}^{Xe^{135}}$, $\sigma_{a,2}^{Sm^{149}}$, Gd fraction remaining	$P\left(b,\boldsymbol{HT_m}\right)+\Delta P_{HC_b}\left(b,\boldsymbol{HC_b}\right)+\Delta P_{C_b}\left(b,\boldsymbol{C_b}\right)$ $+\Delta P_{T_m}\left(b,\boldsymbol{T_m}\right)+\Delta P_{T_f}\left(b,\boldsymbol{T_f}\right)+\Delta P_{\alpha_{CR}}\left(b,\boldsymbol{\alpha_{CR}}\right)$ $+\Delta P_{T_{cooling}}\left(b,\boldsymbol{T_{cooling}}\right)\left[+\text{ optionally }\Delta P_{b_{BP}}\left(b,\boldsymbol{b_{BP}}\right)\right]$	-
discontinuity factors	$P\left(b,\boldsymbol{T_m}\right)+\Delta P_{C_b}\left(b,\boldsymbol{C_b}\right)+\Delta P_{T_f}\left(b,\boldsymbol{T_f}\right)$ $+\Delta P_{\alpha_{CR}}\left(b,\boldsymbol{\alpha_{CR}}\right)+\Delta P_{T_{cooling}}\left(b,\boldsymbol{T_{cooling}}\right)$ $\left[+\text{ optionally }\Delta P_{b_{BP}}\left(b,\boldsymbol{b_{BP}}\right)\right]$	$P\left(\boldsymbol{C_b}\right)$ for radial and bottom reflectors $P\left(C_b,\boldsymbol{T_m}\right)$ for top reflector

2.2 Cross-section model in PARCS

PARCS is a 3-dimensional reactor core simulator [11]. The dynamic response to any external perturbation is calculated by solving the space- and time-dependent 2-group or multigroup neutron diffusion equations, or the SP3 transport equations [1]. The spatial discretization is based on either fuel assemblies or fuel cells. The coupling with the thermal-hydraulic part of TRACE or RELAP5 provides the temperature and flow field information, that allows updating the two-

group cross-sections according to the actual operating conditions of the reactor. A Coarse Mesh Finite Difference (CFMD) formulation is used to determine the neutron fluxes for the homogenized nodes, while the Analytical Nodal Method (ANM) is used to estimate the accurate coupling between adjacent nodes in the core. PARCS is able to perform eigenvalue calculations, transient (kinetics) calculations, depletion calculations, Xenon transient calculations, decay heat calculations, pin power calculations, and adjoint calculations. Originally in 1997, PARCS used a rather simple macroscopic cross-section model since the code was not intended to perform any depletion calculation. Namely, the macroscopic nodal cross-sections were functionalized as a function of the instantaneous variables only. In 2000, PARCS was made capable of performing core depletion analysis via an external depletion module called DEPLETOR, where the node-wise power determined from PARCS is used to calculate the region-wise burnup increment. Recently, a new cross-section model was also added to PARCS so that the burnup and history effects of the macroscopic cross-section dependence could also be taken into account. The purpose of the aforementioned GenPMAXS code is to construct the PMAXS files for this new cross-section model [2]. It has to be pointed out that PARCS currently uses a macroscopic depletion model in which the microscopic cross-sections and number densities are not tracked individually (except for the nuclides involved in the Xenon and Samarium poisoning). The macroscopic cross-sections are now functionalized as a function of burnup (b), up to two history variables ($H1$ and $H2$), the boron concentration (C_b), the square root of the effective fuel temperature (T_f), the moderator density (D_m) and temperature (T_m), and the effective rodded fractions (α_{CR}):

$$P\left(b,H,\alpha_{CR},D_m,C_b,T_f,T_m\right)=P\left(b,H,\alpha_{CR,0},D_{m,0},C_{b,0},T_{f,0},T_{m,0}\right)+\left.\frac{\partial P}{\partial \alpha_{CR}}\right|_{\left(b,H,\alpha_{CR,ref}\right)}\times\left(\alpha_{CR}-\alpha_{CR,0}\right)$$

$$+\left.\frac{\partial P}{\partial D_m}\right|_{\left(b,H,\alpha_{CR},D_{m,ref}\right)}\times\left(D_m-D_{m,0}\right)+\left.\frac{\partial P}{\partial C_b}\right|_{\left(b,H,\alpha_{CR},D_m,C_{b,ref}\right)}\times\left(C_b-C_{b,0}\right) \tag{9}$$

$$+\left.\frac{\partial P}{\partial \sqrt{T_f}}\right|_{\left(b,H,\alpha_{CR},D_m,C_b,T_{f,ref}\right)}\times\left(\sqrt{T_f}-\sqrt{T_{f,0}}\right)+\left.\frac{\partial P}{\partial T_m}\right|_{\left(b,H,\alpha_{CR},D_m,C_b,T_f,T_{m,ref}\right)}\times\left(T_m-T_{m,0}\right)$$

where H represents either one history variable or a vector of two history variables. Each history state is fully determined by two history variables together with the fuel burnup. Here, P has a broad meaning, and can be any parameter such as a macroscopic cross-section, etc. Kinetic parameters are treated as history- and burnup-dependent only parameters. The partial derivatives with respect to a given variable are dependent on variation of some of the other variables[a]. The subscript 0 denotes the base case, whereas the subscript *ref* represents the reference point, defined as the midpoint between the instantaneous value and the base value:

$$v_{ref}=\frac{v+v_0}{2} \tag{10}$$

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[a] Sensitivity studies demonstrated that the sequence of the independent variables for each partial derivative in Eq. (9) affects significantly the accuracy of the cross-section model [2]. The sequence adopted in Eq. (9) for the dependence of each partial derivative is the recommended one, where the independent variables were put in decreasing order of influence on the partial derivatives.

where v is the instantaneous value. Consequently, the reference point depends itself on the instantaneous value. This way of doing provides a second-order accuracy in the estimation of the cross-sections [2]. The partial derivative required in Eq. (9) for any parameter P with respect to a variable v can thus be calculated according to the following generic formulation:

$$\left.\frac{\partial P}{\partial v}\right|_{(u,v_{ref})} = \frac{P(u,v,w_0) - P(u,v_0,w_0)}{v - v_0} \tag{11}$$

In this Equation, u represents all the variables having their instantaneous values, whereas w_0 represents all the variables having their base values (therefore explaining the subscript 0). The sequence of the independent variables in the partial derivatives was chosen so that there is no dependence of the partial derivatives on any of the variables w_0.

PARCS follows an innovative structure for storing the data. For each parameter P, the data structure has three levels [2], each level having a "tree-leave" structure. The highest level represents the history cases, i.e. corresponds to depleting the lattice with different sets of operating conditions. The second level represents different possible instantaneous states for each history case, i.e. corresponds to perturbations at given burnup points of the instantaneous variables from the state used to deplete the history case. Finally, the third and lowest level is the subsequent burnup dependence of the data after the perturbation. Usually, the first level has a two-level tree structure, with several branches for the history variable $H1$ and for each $H1$ branch, several leaves for the history variable $H2$. For the second level, the states are divided into 6 groups: a base branch and different branches corresponding to different values of α_{CR}, D_m, C_b, T_f, and T_m. The partial derivatives are thus evaluated between the different leaves of the different branches, as illustrated by Eqs. (10) and (11). When any parameter is needed by PARCS at a given set of operating conditions, the data are retrieved within PARCS via two modules: a DEPLETION module (which deals with the dependence of the data on the history variables $H1$ and $H2$ and the burnup b), and a FEEDBACK module (which deals with the dependence of the data on the instantaneous variables α_{CR}, D_m, C_b, T_f, T_m). The DEPLETION module performs multi-dimensional linear interpolation with respect to the history variables and to the burnup for $P(b,H,\alpha_{CR,0},D_{m,0},C_{b,0},T_{f,0},T_{m,0})$ and each partial derivative in Eq. (9). The FEEDBACK module performs multi-dimensional linear interpolation with respect to the instantaneous values of the variables α_{CR}, D_m, C_b, T_f, T_m for the partial derivatives from the set of partial derivatives stored in the PMAXS files. It has to be pointed out that the set of branches does not need to form a regular grid, and the points in each linear interpolation do not need to be equidistant. This demonstrates the obvious advantage of a "tree-leave" structure compared to a table form.

3. Description of the interface

The interface that the Department of Nuclear Engineering, Chalmers University of Technology developed is based on the use of the SIMULATE-3 code for retrieving the data necessary to construct the PMAXS files from the binary library file. Consequently, access to the SIMULATE-3 code as well as to the binary library file (containing the data for all the fuel/reflector assemblies) is a prerequisite. Furthermore, a binary SIMULATE-3 restart file corresponding to the fuel cycle being studied is requested. The purpose of this restart file is to know which fuel

assemblies are actually present in the core, so that constructing the PMAXS files for fuel/reflector assemblies present in the library file but not loaded in the specific core being analyzed can be avoided. It has to be emphasized that only binary files (both the library file and the restart file are binary files) are required.

This interface has the following properties:

- the PMAXS files contain all the cross-section data, the discontinuity factors, the fission yields for I-135, Xe-135, and Pm-149, and the microscopic absorption cross-sections of Xe-135 and Sm-149 explicitly;
- the fission yields are functions of burnup, history of moderator density, and history of boron concentration, i.e. any of these parameters can be generically represented as $P(b, H)$; this representation is in accordance with the PARCS formalism;
- all the other data are functions of burnup, history of moderator density, history of boron concentration, instantaneous control rod position, instantaneous moderator density, instantaneous boron concentration, and instantaneous fuel temperature, i.e. any of these parameters can be generically represented as $P(b, H, \alpha_{CR}, C_b, T_f, T_m)$; it has to be noted that there is no explicit dependence on the moderator temperature as in Eq. (9), since for PWR cases the dependence on the moderator density is redundant with the dependence on the moderator temperature.

The limitations of this interface are as follows:

- only PWR cases are handled by this interface for the time being;
- the kinetic data (precursor decay constants, fractions of delayed neutrons, inverse velocities) cannot be retrieved individually for each fuel/reflector assembly but only globally for the whole core at the considered operating conditions of the reactor;
- the corner discontinuity factors cannot be retrieved;
- the power form factors cannot be retrieved.

All the scripts allowing constructing the PMAXS files were developed under a UNIX/LINUX environment and are based on the ksh (korn-shell) and nawk/gawk programming languages. These scripts can also be run on Windows systems by using a UNIX emulator, such as Cygwin for instance. The only parameters the user needs to set up are the location of the SIMULATE-3 script (i.e. the script used for executing SIMULATE-3) and whether the nawk or gawk programming languages has to be used. Thereafter, three scripts need to be run consecutively for properly constructing the PMAXS files. The first script is meant for finding out what information is available from the library file. Based on this information, the second script requests editing the data in a formalism corresponding to PARCS, while making use of the interpolation scheme of SIMULATE-3 for editing the data. Finally, the last script constructs the PMAXS files. These three scripts are described in detail in the following.

The purpose of the first script is to determine which fuel/reflector assemblies are loaded in the core being studied (information retrieved from the binary SIMULATE-3 restart file) and which operating points, burnup, and histories are available in the library file for each of those assemblies (information retrieved from the binary SIMULATE-3 library file). More specifically, the script runs SIMULATE-3 to get hold of this information from the library and restart files, and then creates an output file containing a summary for each fuel/reflector segment.

From this summary file, the second script constructs a SIMULATE-3 input file for editing the data in the PARCS formalism and then executes SIMULATE-3. Editing the data from the binary

library file is possible via the use of the audit cards (AUD) in SIMULATE-3 [7]. The use of the audit cards is usually for debugging purposes. The purpose of this second SIMULATE-3 run is to reproduce the "tree-leave" structure for the dependence of the data in PARCS. Such an example of a "tree-leave" structure is given in Fig. 2. The highest level of this structure represents the history conditions. For PWR cases, these are the history of the moderator density and the history of the boron concentration. The second level represents the different possible instantaneous states of the control rod insertion, of the moderator density, of the boron concentration, and finally of the fuel temperature. It is essential to notice that the hierarchy in the branching process affects directly the determination of the PMAXS parameters and has thus to be carried out in the following order [2]: control rod branches, moderator density branches, boron concentration branches, and finally fuel temperature branches. The third level allows reproducing the dependence on burnup of the data. The list of burnup points was forced to be identical for a given fuel assembly between the different branches as well as between the different histories, since a single list of burnup points per fuel assembly was originally required by PARCS. This "tree-leave" structure does not correspond to the way the data are functionalized in SIMULATE-3, as can be seen in Table 1. In PARCS, the data are functions of seven variables for PWR cases. In SIMULATE-3, the data are sums of base values and partials, each of those being a function of up to two variables for PWR applications. Nevertheless, the SIMULATE-3 interpolation procedure can be used with confidence for following each branch in Fig. 2 and then editing the corresponding data. The value of the variables for editing the data corresponds to the value of the variables present in the library file. Since PARCS interpolates between the history cases, the interface allows editing the data for all possible combinations of history parameters, i.e. of the history of the moderator density and of history of the boron concentration [12]. The SIMULATE-3 output file containing the edit of these data for a complete core can thus be very large, since a core typically contains more than 10 different fuel/reflector segments. Furthermore, such a SIMULATE-3 run might take a couple of hours for a full core.

From the results of this SIMULATE-3 run, the third script has to be run. The purpose of this script is to build up the PMAXS files for each fuel/reflector segment or for a specific fuel/reflector segment specified by the user. This is done by successively stacking the results of different sets of values for the history variables. For each set of values for the history parameters, the results corresponding to the reference branch (the one represented in bold in Fig. 2) are first stored for each burnup point. The partial derivatives associated to each instantaneous variable are then computed for each branch associated to a change of the considered instantaneous variable according to Eq. (11) and for each burnup point. As can be noticed from Eq. (11), the computation of the partial derivatives on a branch containing sub-branches has to be carried out at the base conditions for the variables associated to these sub-branches.

When constructing the PMAXS files, care has to be taken about the transport cross-sections and the macroscopic thermal absorption cross-section. For the former, the transport cross-sections are not given by SIMULATE-3, but can be easily calculated from the diffusion coefficients. For the latter, the macroscopic thermal absorption cross-section might contain the effect of the Xe-135 and Sm-149 poisons, depending on how the binary library file was created [13]. If PARCS is used for calculating the concentration of the poisons explicitly (case which is preferred especially for transients where the concentration of the poisons is different from the equilibrium concentration), the effect of the poisons has to be removed from the macroscopic thermal absorption cross-section.

Figure 2: Illustration of the "tree-leave" formalism in PARCS for a given set of history variables ($H1$, $H2$); each instantaneous variable is assumed to have two possible values (*0* for the base value, and *1* for the perturbed value); the "tree-leave" structure in bold represents the base case within the set of history variables; the last ramification (ramification due to the burnup dependence) is not explicitly represented for reasons of clarity of the chart; any parameter P is thus functionalized as $P\left(b, H1, H2, \alpha_{CR}, D_m, C_b, T_f\right)$.
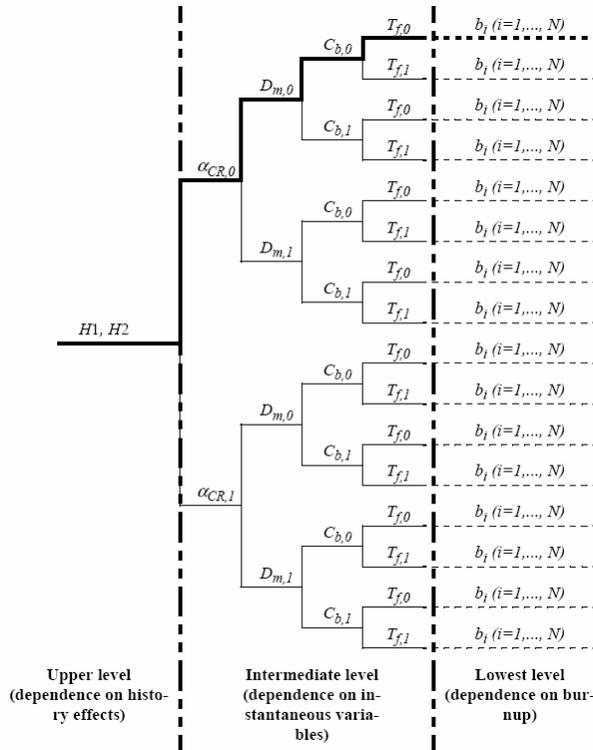
4. Conclusion

A unique interface between SIMULATE-3 and PARCS was developed for feeding PARCS with realistic sets of material constants for any heterogeneous PWR core. Once the data files are created by the interface, PARCS can be used to study any operating PWR, since the dependence of the data on instantaneous variables, history variables and burnup is fully represented in the data files. One of the main advantages of the interface is the fact that the inconsistencies in the representation of the data dependence between SIMULATE-3 and PARCS are handled by the interface. More specifically, the interface uses the SIMULATE-3 interpolation procedures to reconstruct the data in a formalism consistent with PARCS. This interface was applied to the Swedish Ringhals-3 PWR and comparisons between PARCS and measured data for several cycles and different core-averaged cycle exposures demonstrated that the constructed PMAXS files allow properly representing the actual dependence of the material constants of the reflector/fuel assemblies on histories, instantaneous variables, and exposure. The details of such a validation are reported in a companion paper [14].

Acknowledgements

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