PROGRAM FLU

INTRODUCTION

The FLU module is quite different from the other regulation programs. it has no fast or slow part. The intensive calculations that it performs is so demanding on control computer resources that it is executed in three phases. They are executed in turn every forty seconds or so, and a complete execution is thus terminated every two minutes. This slow execution frequency, relative to other RRS modules, is quite consistent with Vanadium flux detectors, whose readings vary very slowly with time and which furnish the main input data to FLU.

MODAL SYNTHESIS

The main task of FLU is to perform a modal synthesis to reconstruct the neutron flux in the core. Three dimensional flux distributions, pre-calculated at the design stage, are linearly superposed by means of the formula

$$\phi_{ijk} = \sum_{l=1}^{NM} \psi_{ijk}^{l} \cdot a_l \qquad \textbf{(9.1)}$$

where the Ψ_{ijk}^{l} are the (NM) pre-calculated modes and the a_l are the "modal amplitudes". The thermal part of natural harmonics of the neutron diffusion equations are used as the modes. The fundamental mode and the first fourteen harmonics are retained in Equation 9.1, so that NM = 15. This number can be increased in special circumstances, such as when MCA's are kept in core for a prolonged period of time.

MODAL AMPLITUDES

The FLU module starts by determining the modal amplitudes by using the readings from the 102 Vanadium detectors. A pre-calculated matrix [M] of dimension 15 x 102, obtained from the method of least squares applied to the Ψ^{l}_{ijk} and the 102 Vanadium flux detectors positions, is post-multiplied by the 102 detector readings arrange in a vector [V], corrected by the sensitivity factor of each detector:

$$[\,A\,] = [\,M\,] \cdot [\,V\,] \tag{9.2}$$

A verification is then performed to check that the Vanadium detector readings as reconstructed from modal synthesis is consistent with the readings. If the reconstructed readings differ from the measured readings by more than 30% or -60%, the corresponding measurements are replaced by the calculated values, and the calculation of Equation 9.2 is redone, and an alarm is sent to the control room, identifying the detectors whose readings were thus replaced.

Once a set of modal amplitudes consistent with detector readings has been obtained, the subsequent calculations can then be done.

ZONAL CORRECTION FACTORS

The power of each control zone can the be calculated by simple reconstruction,

$$[\,P\,] = [\,Z\,] \cdot [\,A\,] \tag{9.3}$$

where the matrix [Z] is a 14 x 15 matrix, 14 zones by 15 amplitudes. The elements of this matrix are the integrals of the modes over each control zones. This gives the power of each of the zones. The reference zonal powers PZR_i are easily calculated by the formula

$$PZR_i = \frac{\phi_i}{\phi_{nomi}} \tag{9.4}$$

where the ϕ_{nomi} are target zonal fluxes specified in advance by the designer. Then the deviation between the reference zonal powers and the Platinum detector readings are obtained by

$$ADI_i = PZR_i - PIUF_i \tag{9.5}$$

where the $PIUF_i$ are outputs of the MCP module. The ADI_i will then be limited between -0.2 and +0.2. Since they will be used to calibrate the zonal powers used in LZC control, and that we do not want the total reactor power to be modified by Vanadium detector readings, the deviations between the individual ADI_i and their average are sent to the MCP module. The average is

calculated by,

$$\overline{AD} = \sum_{i=1}^{14} ADI_i \tag{9.6}$$

and then

$$ADI^* = ADI - \overline{AD} \tag{9.7}$$

It is these ADI* that are sent to the MCP module for zonal power calibration. The ADI* are filtered in MCP to become the FCZ_i.

FLUX IN 500 FUEL BUNDLES

The flux in 500 selected fuel bundles is then calculated, also by modal synthesis,

$$FLUX_k = [\,N\,] \cdot [\,A\,]$$

where [N] is a 500 x 15 matrix. The 15 maximum values of these fluxes are retained, and the fifteenth largest, labeled PGMAX, is sent to the reactor setback program.

OTHER CALCULATIONS

The channel power map and the flux at SDS1 detectors are then calculated using this same modal synthesis method. The results of these calculations can be examined at all times by the operators.