# Chapter 6

# PROGRAM CBC: ADJUSTER ROD CONTROL

## 6.1 ADJUSTER RODS

In a CANDU-6 reactor there is a total of twenty one adjuster rods. They are normally all inserted in the core. Their functions are:

- Flatten the flux shape, in order to improve fuel utilization.
- Provide a sufficient margin again Xenon transients for power maneuvering.
- Permit operation of the core for prolonged periods (two to three weeks) when refueling is interrupted.

The adjuster rods are slightly absorbing stainless steel cylinders. They sit vertically in the core, perpendicular to the fuel channels.. They are also confined inside zircalloy guide tubes, which are pierced to provide adequate cooling of the rods.

The adjusters are are moved by a motorized pulley system. The rotation speed of this system permits the change of position and speed of each rod individually.

The twenty one adjusters are worth about 15 mk of reactivity. The length of each adjuster depends of it's location in the core. The rods in the periphery are shorter than the more centrally located ones. Furthermore, in order to

flatten the flux effectively, the neutron absorption capacity of a rod varies along it's length, by using a variable thickness of the rod material.

For automatic control purposes, the twenty one adjuster rods are grouped in seven sets called "banks". The adjuster banks are moved sequentially by the CBC program. Individual adjusters can also be moved manually by the operator when circumstances warrant it. The assignation of adjuster rods to their bank is given in Table 1. Note that these assignations are valid only for the CANDU-6 reactor.

## 6.2 SLOW AND FAST PARTS OF CBC

CBC is executed entirely every 0.5 second. It is thus made of a fast part only. There is no function of CBC executed by the slow regulation process every two seconds.

## 6.3 END RUN TEST

The positions of each adjuster rod is read by CBC. When an adjuster is fully inserted, there is an electric contact that closes, indicating that then end point is reached. If the position reading and this electric contact are not consistent, an alarm message is sent to the control room to inform the operator of this situation.

## 6.4 ADJUSTER INHIBIT

Any movement of adjusters is prevented in the following circumstances:

- Reactor stepback in progress
- SDS1 not armed
- SDS2 not armed
- CPLOG (of CEP) greater than 97% FP

These inhibits will have priority over any other decisions of CBC concerning adjuster movement.

The justifications for this are easy to understand. A reactor stepback, the firing of SDS1 or of SDS2 constitute circumstances during which it is not desirable to insert positive reactivity, or to increase power levels. This is part of the defense in depth philosophy. As an adjuster is moved, it can have positive or negative effects on the power, depending of location in the core and position along the vertical course. It is thus preferable to stop its movement.

The inhibit on CPLOG > 97% comes from the fact that we want to stay away from channel and bundle powers which could lead to fuel failure, or that would fire the shutdown systems via the ROP system.

## 6.5 CONTROL RULES

The control rules used to regulate the adjuster movements are relatively simple. The decision to insert or extract the adjusters is taken with the variables ERPU, out of CEP, and NMBL, out of CBL. An "operation point" is obtained by placing the couple (ERPU,NMBL) on the control rule diagram shown on Figure 6.1.

We note that when NMBL falls below 20%, the decision will generally be to extract a bank,, in order to increase NMBL. In the same way, the decision to insert a bank is generally taken when NMBL becomes greater than 70%. The "no change" region means that if adjusters are moving, whether in insertion or extraction, and that the operation point falls in this region, then the adjuster movement will continue.

If the operation point crosses the insertion to extraction regions, or vice-versa, then the adjuster movements will follow this new order. This could lead to oscillations between LZC and adjusters, via the NMBL variable.

## 6.6 ADJUSTER SPEED

The adjuster speed depends only on the power error, ERPU, coming out of CEP. The speed is calculated in terms of fraction of full course, FPC. The 100% speed corresponds to maximum velocity, which is sixty seconds to fully insert a rod that was completely out of core, or to fully extract a rod sitting in the fully inserted position, in the center of the core.

## 6.7 INSERTION / EXTRACTION SEQUENCE

The sequence in which insertion or extraction of adjusters is performed is also determined by CBC. The banks are extracted in increasing bank number, after verification that a least one adjuster in a given bank is available for extraction of this bank. If no adjuster is available in the current bank, the bank number is increased, and the same tests are performed.

In the same way, adjuster insertion sequence is determined by decreasing bank numbers. A bank will be inserted if at least one adjuster of this bank is available for insertion. If there is no adjuster available in the current bank, the bank number is decreased by one, and the same tests are performed.

| Bank | Adjuster Belonging to Bank |
|---|---|
| 1 | 1,7,11,15,21 |
| 2 | 2,6,18 |
| 3 | 4,16,20 |
| 4 | 8,9,13,14 |
| 5 | 3,19 |
| 6 | 5,17 |
| 7 | 10,12 |

Table 1: Adjuster Bank Assignments

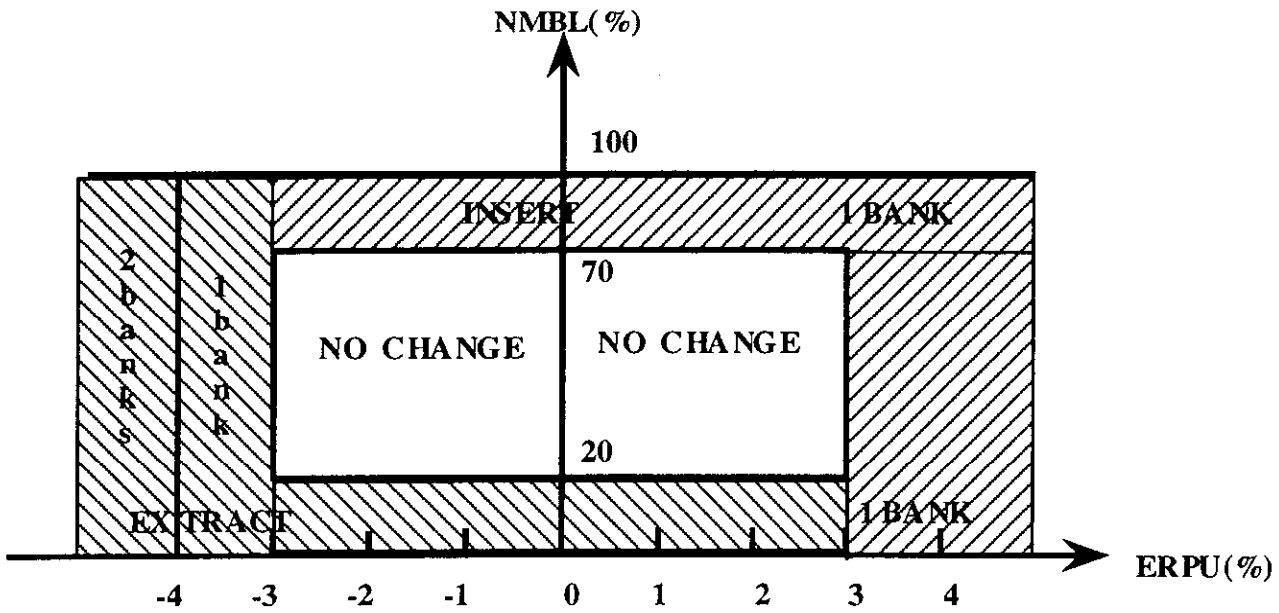


Figure 6.1: Adjuster Rod Control Rules

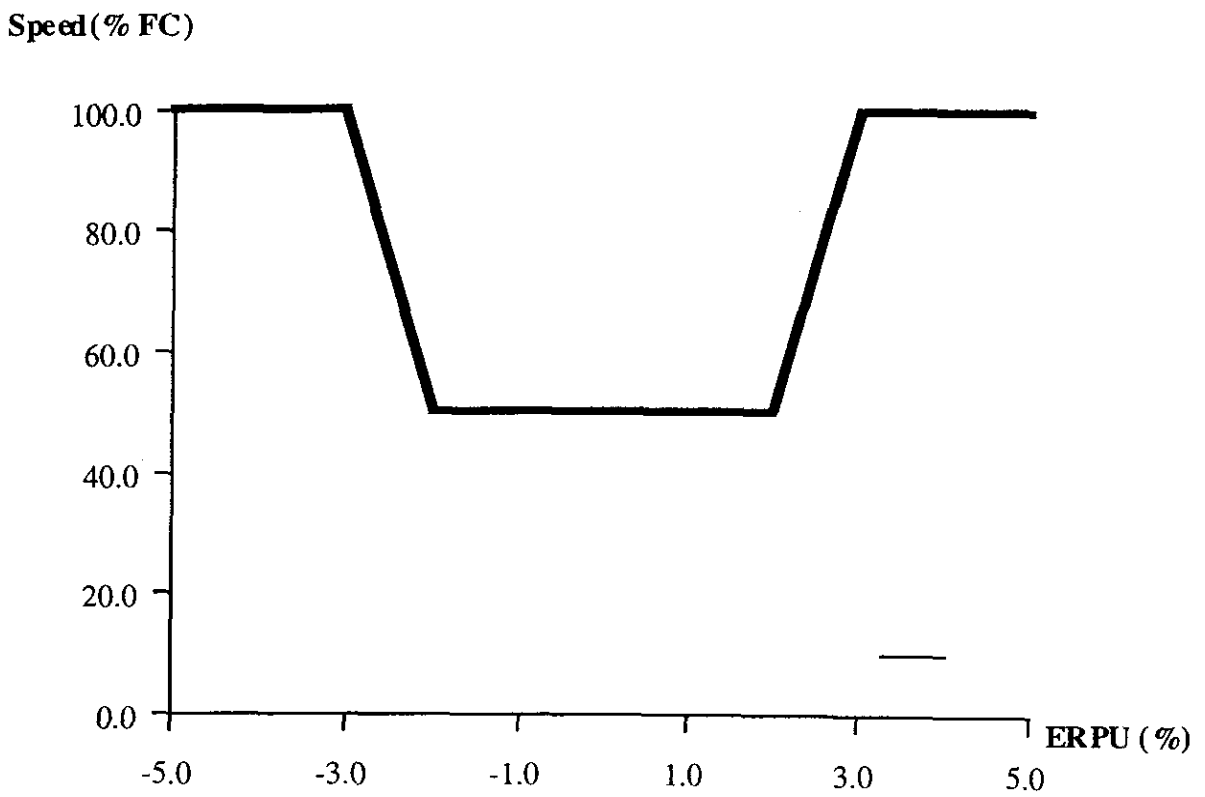


Figure 6.2: Adjuster Speed Calculation