REVISION OF THE FUEL MANAGEMENT STUDIES OF THE ATUCHA-2 REACTOR. IMPLEMENTATION OF AN AUTOMATIC REFUELLING SIMULATION PROGRAM

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ABSTRACT

Atucha-2 is a 745 MWe (gross) nuclear station, pressure vessel type designed by Siemens (Germany), moderated and cooled with heavy water, located 120 km NW from Buenos Aires. This work presents the results of a revision of the fuel management strategy. For some of these studies, REC_AUT, a Fortran 90 program, was implemented to perform detailed refuelling simulations with automatic selection of the channels to be refuelled. This program showed very good agreement with detailed simulations done with manual channel selection and permitted to reduce significantly the time required for this type of studies. This new tool was successfully used in the redesign of the fuel management strategy because of a reduction of the thermo-hydraulics channel power limits.

I. INTRODUCTION

Atucha-2 is a nuclear station, pressure vessel type designed by Siemens (Germany), moderated and cooled with heavy water, located 120 km NW from Buenos Aires. The plant thermal power is 2160 MW, and the gross electrical power is 745 MWe.

The Atucha-2 reactor is fuelled on power and has a radial shuffling scheme.

Some studies required by the neutronic design for the simulation of transient or postulated accidental conditions, require instantaneous burnup and power distributions, representative of the equilibrium burnup core. The traditional way to obtain these distributions for the Atucha reactors is by performing a detailed core simulation of the operation of the plant which represents explicitly the burnup changes in the core associated with each of the fuelling operations.

Usually, the selection of channels to be refuelled (two in each fuelling operation) is done manually and is time consuming because it involves the action of an expert to evaluate different alternatives of fuelling operations trying to maximize fuel exit burnup and ensure compliance with channel and linear power limits and other requirements related to symmetry of the core power distribution in each step in the calculation.

This work presents the main results of a revision of the fuelling strategy and the fuel management studies performed for the Atucha-2 reactor.

It also presents REC_AUT, a new Fortran 90 (F90) program developed during the course of this revision and oriented to perform detailed refuelling simulations with an automatic selection of the channels to be refuelled. The experience with the use of this program was good and allowed to reduce significantly the time needed to perform detailed refuelling simulations for Atucha-2 and in particular may be useful to evaluate some practical criteria for channel selection for the fuelling engineers.

In summary, this paper presents:

a) A brief description of the Atucha-2 reactor.
b) A description of the fuel management strategy
c) A description of the methodology used for fuel management studies
d) A description of REC_AUT and the selection criteria implemented

e) Main results
f) Conclusions
The results include:
a) A summary of the main results of the detailed simulation, including margins to the channel power limits of each hydraulic zone.
b) A comparison of time averages of channel powers from the detailed simulation with the corresponding values from the "time average" case.
c) A comparison of results obtained with detailed simulations with manual and automatic selection of channels to be fuelled.

II. BRIEF DESCRIPTION OF THE ATUCHA-2 REACTOR

The Atucha-2 reactor core has 451 vertical coolant channels, which contain the fuel assemblies (FA) and separate the coolant from the moderator. The average coolant temperature is 296.3°C and the average moderator temperature is 177.3 ºC. A section of the core can be seen in Figure 1. FA are natural UO_2 37 active rod vertical clusters, 5.3 meters long. Fuelling is on power. Expected average FA discharge burnup is ≈ 7800 MWd/tU, which is equivalent to 1.46 FA/fpd.
Power regulation is made through twelve absorber rods, three made of hafnium, usually called black, and nine made of steel, called gray. In normal operation the insertion corresponds to an excess reactivity of about 7 mk. Power measurements for the regulation are obtained with four out of core compensated ion-chambers.

The coolant flow in the fuel channels is reduced from the center to the periphery of the core according to the channel powers, in such a way as to have approximately constant outlet channel temperatures. The temperature increase in the channels at full power is about 35 °C. No coolant boiling is allowed at the channel outlets. To obtain that, there are 5 "hydraulic regions" with different nozzles, numbered 1 to 5, from the periphery to the center. The power distribution in equilibrium burnup conditions is quite flattened and for that reason zone 5 (without flow restrictions) is relatively large and contains 253 channels. Channel power limits are defined for each hydraulic region as can be seen in Table 1. The reactor has 90 in-core vanadium flux detectors that give indications of local flux to the operators.

Table 1: Original channel power limits assumed in each hydraulic zone

Hyd. Zone	C.P Limit (kW)
1	3640
2	3815
3	4860
4	5800
5	6920

III. ATUCHA-2 FUEL MANAGEMENT STRATEGY

For fuel management, a radial shuffling scheme is used. A given fuelling strategy is defined as a set of **burnup zones** (approximately circular o annular) and **fuelling paths.** A **burnup zone** is a set of fuel channels where the fuel enters with an approximately given entry average burnup for the zone and leaves the zone when it reaches the exit burnup of that zone. In some cases it is taken out of the reactor and in others it is transferred to another zone. A **fuelling path** is a set of two burnup zones, the first one with higher average burnup and the second with lower average burnup. Typically, the FA with highest average burnup of the first burnup zone of a given fuelling path is taken out of the reactor. The highest burnup FA of the second burnup zone of the same path is moved to the empty channel, and a fresh FA is inserted in the empty channel of that zone. Sometimes, not the highest burnup channels, but one of the highest is selected to avoid overpowers or power tilts.

The refuelling strategy scheme proposed for Atucha-2 considers 6 burnup zones, as can be seen in Figure 1, and three paths. In path 1 the fresh fuel assembly enters the reactor in zone 6, stays in that position until it reaches the transfer burnup and then is transferred to zone 5, where it stays until it reaches the average exit burnup and then is extracted. Path 2 is similar with fuel entry in zone 2 and exit from zone 4, and in path 3 the FA enters zone 3, stays for some time, then is transferred to zone 1, where it remains until it reaches the exit burnup.

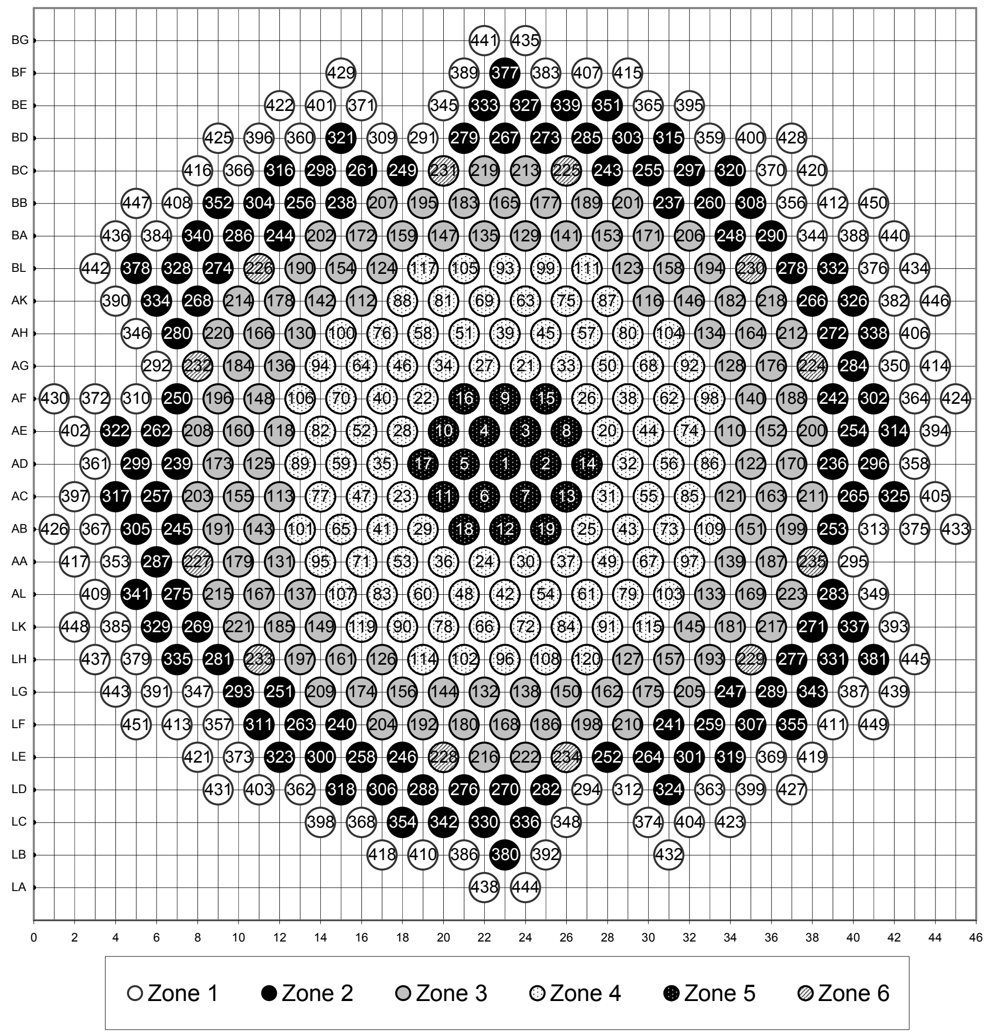

Figure 1: Radial shuffling fuelling scheme of the Atucha-2 reactor
Note: Paths are described in section III.

IV. OVERVIEW OF THE CALCULATION METHODS

The study was performed with the PUMA code. PUMA is a three dimensional (x-y-z and R-Θ-Z), multigroup, diffusion core program developed in CNEA [1], with capabilities for fuel management, space dependent xenon, thermo-hydraulic feedback and space dependent kinetics (using the improved quasistatic method). It can also perform “time average” fuel management calculations.

The model used in this study for Atucha-2, uses x-y-z geometry, has 53 planes in x direction, 61 in y direction and 31 in z direction. The fuel cell was represented in the x-y plane by 4 mesh volumes (2x2). The fuel was divided in 20 intervals in z-direction.

The two group condensed and homogenized cross sections of the fuel cell were calculated with WIMS D5 [2]. The control rods and the lances with the in core detectors are represented in PUMA as incremental cross sections. These incremental cross sections were calculated with the DRAGON [3, 4] code using 2D supercell models similar to the one showed in Figure 2. Although the FA are located in the reactor in a triangular lattice, the supercell model considers a square grid of the same cell area, because the results in the reactor calculations demonstrated not to be sensitive to this change, and the model is much simpler. The black region in Figure 2 highlights the homogenization area for incremental cross sections calculations. Comparisons of DRAGON supercell results with MCNP [5, 6] calculations showed that the detail in the x-y grid is important in order to obtain accurate results [7] for control rod reactivity and channel power distributions.

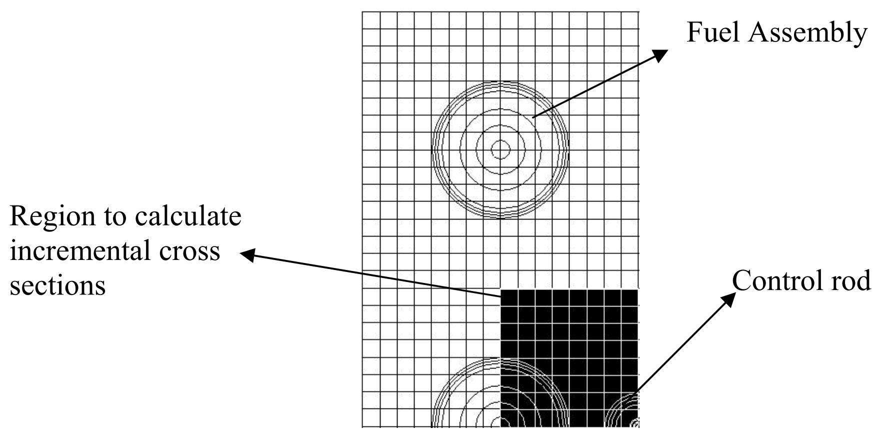

Figure 2: Typical DRAGON supercell model for incremental cross sections calculations

As can be seen in Figure 2 the model represents the mechanisms as tubes parallel to the fuel channels. As the control rods are introduced slightly obliquely in the core and are represented in the model as vertical, the incremental cross sections calculated in this way are divided by the cosine of the angle of the rod axis with the vertical in order to consider the extra length of the rod in the supercell.

V. TIME AVERAGE METHODOLOGY IMPLEMENTED FOR ATUCHA-2

To analyze and improve the fuelling strategy in a reactor with on power fuelling, methods that evaluate “time-average” (TAV) conditions are useful because they provide a simple first step to get a first approximation to an adequate fuelling strategy.

The “time average” methodology used for CANDU reactors with an axial fuelling scheme (see for example [8]) was adapted to Atucha-2 and its radial fuelling scheme.

Then, for each axial section of each fuel, cell cross-sections averaged between the entry and the exit burnup are used. The entry and exit burnups are obtained using an iterative procedure of flux/power calculations, entry and exit burnup adjustment, flux power calculations, entry and exit burnup adjustment, until convergence is obtained in the flux calculation and in the exit and transfer burnup distributions. Usually, convergence is obtained in about 30-40 external iterations. With the computers (Pentium 4 Dual Core 3 GHz) used for the first part of the study and with the more detailed core models of Atucha-2 of 16 mesh volumes per channel, this took about 0.5 hour of processing time.

This methodology permits to obtain:

a) Average exit burnup, or the burnup corresponding to a k-effective of 1.0 or the k-effective assumed for the critical condition (assuming biases for the calculation methods).
b) Average burnup values to transfer fuel from one burnup zone to another.
c) Time-averaged channel and axial sector powers.

This methodology cannot provide the power variations of a fuel assembly during its residence in a given position. Usually, when a given FA enters a burnup zone with approximately the entry burnup, it produces an increase of channel power. Afterwards, when the burnup of the FA increases, the power is gradually reduced until the FA is taken out or transferred to other zone (see Figure 1). These variations should be obtained through detailed refuelling simulations.

As mentioned in the previous section the fuelling strategy is defined as follows:

The channels in the core are divided in non overlapping sets called **paths** C_i ($i = 1,nc$), (nc number of paths in the reactor) and the set of channels in each path is further subdivided in zones Z_{ij} ($j=1,nz(i)$), ($nz(i)$ is the number of zones of path C_i).

The fuelling strategy consists of selecting a given path C_i for the refuelling operation, (frequently the path that corresponds to the channel with the highest relative burnup with respect to the exit burnup of the zone). Then for the first zone Z_{i1} of that path (with the highest average burnup) the highest burnup FA is taken out. Then the FA with the highest average burnup of the following zone Z_{i2} is transferred to the empty channel of zone 1, and continuing in that way until a fresh FA is inserted in the last channel. In Atucha–2 each fuel assembly occupies normally two positions in the core *(nz(i)=2)*.

If we start from a given axial power distribution $P(ic,ia)$ for each channel ic, and axial sector ia, we can make the following assumptions.

The increase in average burnup of a FA during the stay in a given channel ic in Z_{ij} is

$$\Delta\overline{B}_{s,ic} = \overline{B}_{s,ic} - \overline{B}_{e,ic} = P_{ic} * t_{ic} / Mu_{ic}$$

where $\overline{B}_{s,ic}$ is the average exit burnup of the fuel in channel ic, $\overline{B}_{e,ic}$ is the average entry burnup of the fuel in channel, t_{ic} is the residence time in the channel and Mu_{ic} is the uranium mass in the channel ic.

On the other side, each day refuelling operations are made, to compensate the burnup increase due to power generation. Let’s assume that the average increase in burnup of all the channels in the burnup zones of path C_i in a time Δt is :

$$\frac{\Delta\overline{B}(path = C_i)}{\Delta t} = \frac{\overline{P}(path = C_i)}{Mu(path = C_i)}$$

This is valid for each of the burnup zones of path C_i

$$\frac{\Delta\overline{B}(path = C_i, zone = Z_{ij})}{\Delta t} = \frac{\overline{P}(path = C_i, zone = Z_{ij})}{Mu(path = C_i, zone = Z_{ij})}$$

The increase in burnup in a given Δt in all the regions of a path is compensated by refuelling with a refuelling rate *R.R. (ref/d)*, which depends only on the path and is the same for all the zones of a given path

$$B_{s,ic,ia} - B_{e,ic,ia} = P_{ic,ia} * t_{ic} / Mu_{ic,ia}$$

where $B_{s,ic,ia}$ is the exit burnup of the fuel in channel *ic*, axial sector *ia*, where $B_{e,ic,ia}$ is the entry burnup of the fuel in channel *ic*, axial sector *ia*, t_{ic} is the residence time in the channel and $Mu_{ic,ia}$ is the uranium mass in the channel *ic*, axial sector *ia*.

The "time average" procedure provides a quick first approach to test a fuel management strategy. Different burnup zones distributions can be evaluated rapidly and in this way it is possible to test them in order to obtain a reduction in the maximum channel power maintaining the exit burnup.

VI. GENERAL REFUELLING CRITERIA

The main refueling criteria assumed for Atucha-2 are as follows:

a) Give priority to FA with highest average burnup to be extracted or transferred
b) Channel powers limits should be respected, and small additional margins are included.
c) Linear power limit should be respected, and small additional margins are included.
d) Compliance with power ramp (pellet cladding interaction) failure prevention criteria
e) The core is assumed divided in 6, approximately equal, azimuthal regions. Maximum asymmetry factors between opposite zones are established.
f) Minimum transfer or exit burnups are specified in order to avoid introducing too fresh fuel in the corresponding burnup zones.

VII. SIMULATION WITH MANUAL SELECTION OF CHANNELS TO BE REFUELLED

A simulation was done for a period of 400 full power days (FPD) starting with a random age burnup distribution with manual selection of the channels to refuel based on compliance of the criteria mentioned in section VI. The refueling scheme was taken from [9] but an updated nominal position of the control rods was used. During the simulation, the maximum channel power (MCP) accepted was 6.8 MW, below the margin of 6.92 MW. The outer rods linear power was always below the limit of 522 W/cm, and the maximum value was 471 W/cm.

After a core calculation of the power and burnup distributions, the fuel channels in the core are sorted by average fuel burnup. The highest average burnup bp_1, would correspond to channel nc_1, in burnup zone Z_{i1}, in fuelling path C_i, the second highest would be bp_2, and would correspond to channel nc_2 in zone Z_{j1} and path C_j, and so on. The first choice is to select the FA in channel nc_1 to be extracted, and the channel with the highest burnup of the entry burnup zone (Z_{i2}) of the same path (C_i), with burnup bt_1 (Z_{i2} C_i), to be transferred. A calculation of PUMA is performed, and the results are evaluated to see if they comply with the acceptance criteria. If it does, the simulation is continued for another Δt, and if it doesn't, a new pair of channels to refuel is selected. After that a new core case is run. The main selection criteria are to maximize the exit burnup, to keep the channel and local power below the limits and to prevent azimuthal power tilts. A period of 400 full power days (596 reactor cases) was initially simulated.

Table 2 shows a comparison between the exit burnup predicted by the "time average" calculations for the six zones with the average values obtained in the manual simulation. It shows that the average values obtained for the exit burnup in the six zones have differences with the TAV predictions below 2 %.

Table 2: Comparison between TAV and average values of exit and transfer burnups in all refuelling operations in the manual simulation of 400 FPD

Path	Zone	Exit burnup (MWd/tU)				Diff (%)
		TAV	avg.	min	max	avg/TAV-1
1	6	2872	2914	2339	3830	1.45%
	5	7800	7674	7548	7857	-1.62%
2	2	3623	3564	3133	4233	-1.63%
	4	7800	7682	7498	7867	-1.51%
3	3	5359	5275	4837	5954	-1.56%
	1	7800	7660	7486	7861	-1.79%

A comparison of the maximum channel powers in the 5 hydraulic zones between the time average values and the average values of the detailed simulation cases can be seen in Table 3. As can be seen, the maximum channel powers reached during the simulation in the five zones are about 8 to 10 % above the time average values (fuelling ripple). Besides, the margins to the maximum channel power limits are relatively large in the peripheral zones but relatively small in the central zones

Table 3: Maximum channel power per hydraulic zone. Comparisons between TAV and manual simulation cases

Hydraulic Zone		1		2		3		4		5	
		Chann.	MCP (kW)	chann.	MCP (kW)	Chann.	MCP (kW)	chann.	MCP (kW)	chann.	MCP (kW)
LIMIT			3640		3815		4860		5800		6920
TAV		LB17	2525	AB43	3138	BE26	4065	LE16	5240	LG24	6315
Det. Simul.	Max	BF29	2746	AB43	3391	BE26	4458	LF33	5728	LG24	6804
	Min	LB17	2325	AB43	2922	LC20	3839	LF33	5150	BL17	6314
	avg		2523		3119		4106		5369		6552
Max/TAV-1			8.75%		8.06%		9.67%		9.31%		7.74%
Max/LIMIT-1			-24.56%		-11.11%		-8.27%		-1.24%		-1.68%

VIII. DETAILED REFUELLING SIMULATION WITH AUTOMATIC SELECTION

Recent thermohydraulic studies proposed a reduction in the channel power limits in the outer hydraulic zones. Initial CP limits were based on DNB (departure from nucleate boiling) prevention but recently it was considered convenient to set a limit on outlet coolant quality in 3%. The new proposed limits are shown in Table 4.

Table 4: Original channel power limits and new proposal

TH Zone	CP Limit (kW)	New proposed CP Limit (kW)	Change (%)
1	3640	2535	-30.36
2	3815	3190	-16.34
3	4860	4120	-15.23
4	5800	5800	0
5	6920	6920	0

In order to comply with these new limits some adjustments in the fuel management strategy were found necessary.

To reduce the time required to perform detailed refueling simulations, which up to that moment were normally done selecting manually the channels to refuel, the program "REC_AUT" (recambio automático in Spanish or automatic refueling) was implemented in Fortran 90. A set of acceptance criteria are defined which include (see Section VI):

a) Margins to the channel and local power limits
b) Margins in azimuthal power tilts (the fraction of power generated per sixth radial sector was allowed to be within 6% of its "time average value")
c) Minimum values for exit and transfer burnups (10% and 5% below the "time average" values respectively)

The program reads two input files. The first one includes the reactor data as power limits for each hydraulic zone and the distribution of the channels in hydraulics and burnup zones. The second file specifies the refuelling criteria, including the number of cases desired, the k effective at which refuelling operations are made, maximum linear power, extra margins considered to the thermal hydraulics power limits, range of acceptance for the power generated in each sixth radial sector to prevent azimuthal power tilts, entry and exit fuel burnup per burnup zone and burnup range for extract or move fuel assemblies. In the automatic simulation the criteria are applied strictly without the flexibility of the human decisions, so the criteria were in order to obtain a closer emulation to the manual channel selection.

The program operates as follows: after a core calculation of the power and burnup distributions, the fuel channels are sorted by average fuel burnup. The highest average burnup bp_1, would correspond to channel nc_1, which corresponds to a given fuelling path C_i. The first trial is to select the FA in channel with the highest burnup $bp_1\ (Z_{i1}, C_i)$ to be extracted and the channel with the highest burnup of the entry burnup (Z_{i2}) zone of the same path (C_i) with burnup $bt_1(Z_{i2}, C_i)$ to be transferred. A calculation of PUMA is performed. If the acceptance criteria are satisfied the simulation is continued. If they are not, the program first tries to maintain the channel of the exit zone with highest burnup and tries the channels in the entry zone with the second highest burnup ($bt_2(Z_{i2}, C_i)$), third highest burnup ($bt_3(Z_{i2}, C_i)$) until the power distribution is satisfactory or until the fuel burnup is below the accepted transfer burnup range. In the first case it continues the simulation and in the second it tries to select the second highest burnup channel in the core and repeats the process.

IX. COMPARISONS BETWEEN MANUAL SELECTION AND AUTOMATIC SELECTION

To test the results of this automatic method a comparison with the manual simulation, described in the previous section, was done. A simulation over 400 full power days was run starting with exactly the same burnup distribution.

Table 5: Comparison of simulation results with manual and automatic selection

		Manual			Automatic			Diff (%)
Maximum Linear power		(W/cm)		FPD	(W/cm)		FPD	
	Maximum	471.4	BA16-4	183.1	471.2	BA20-5	51.8	-0.04%
	Minimum	422.4	AD33-4	286.8	422.5	AC36-5	449.2	0.02%
	Average	445.8	--	--	447.5	--	--	0.37%
Exit burnup		(MWd/ton)		FPD	(MWd/ton)		FPD	
	Maximum	7866.5	BL21	387.0	7898.5	AD23	66.2	0.41%
	Minimum	7486	LF09	293.7	7496.6	AL41	442.9	0.14%
	Average	7671.8	--	--	7662.2	--	--	-0.13%
Maximum Channel power		(MW)		FPD	(MW)		FPD	
	Maximum	6.804	LG24	92.1	6.833	LG24	404.8	0.43%
	Minimum	6.314	BB39	176.5	6.287	LG20	482.3	-0.43%
	Average	6.552	--	--	6.563	--	--	0.17%

Table 5 presents a comparison between parameters of both simulations. It shows that the linear power, exit burnup and channel power are very close in maximum, minimum and average values (differences less than 0.5 % in all the cases).

Figure 3 shows the evolution of the instantaneous exit burnup in both simulations (manual and automatic).

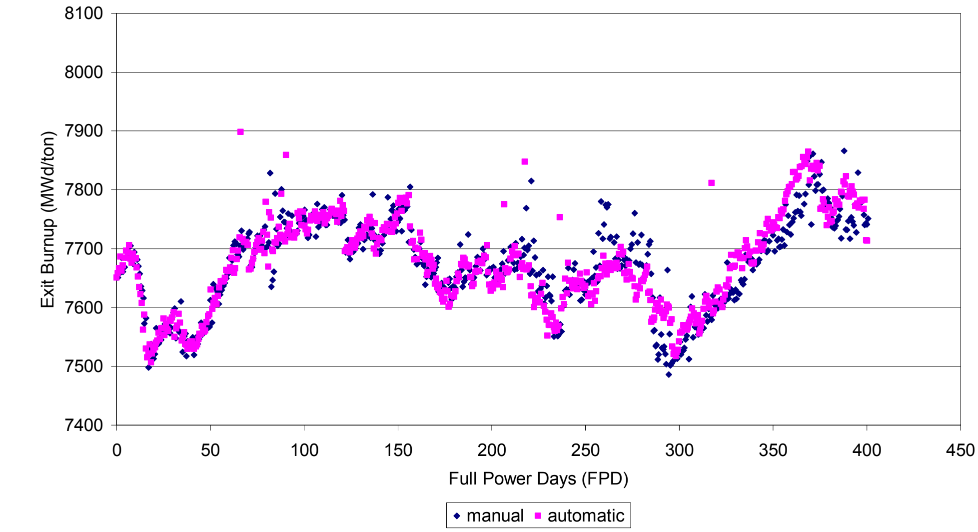

Figure 3: Comparison of exit burnups as a function of time

Figure 4 shows the cumulative exit burnup as a function of time and Figure 5 the axial asymmetry factor.

The three figures show that the global behaviour of the parameters in the manual and the automatic simulations is very similar.

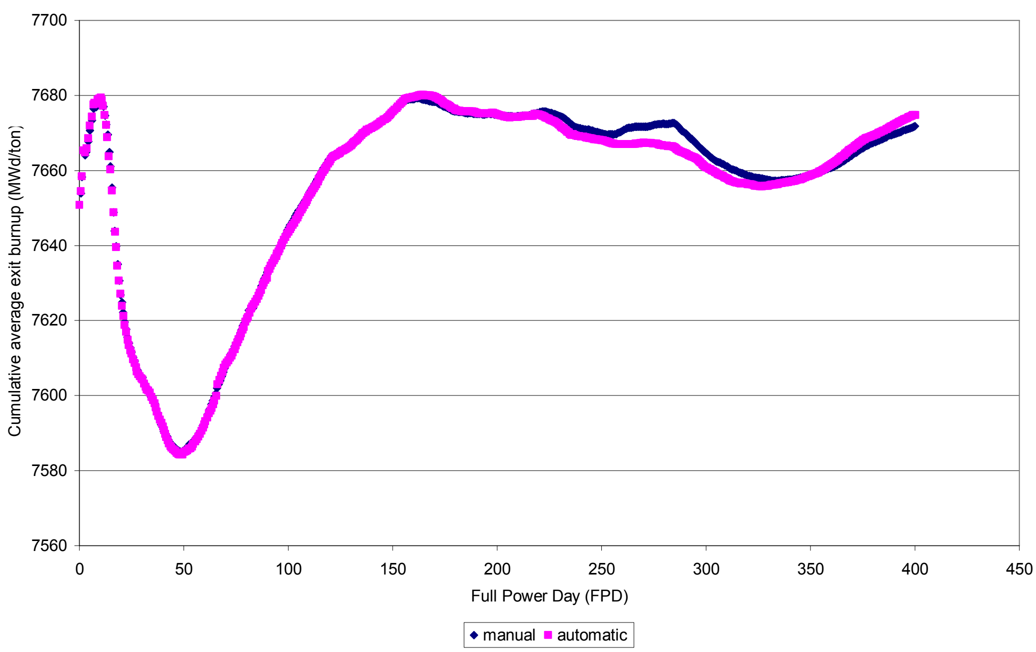

Figure 4: Comparison of cumulative exit burnup as a function of time

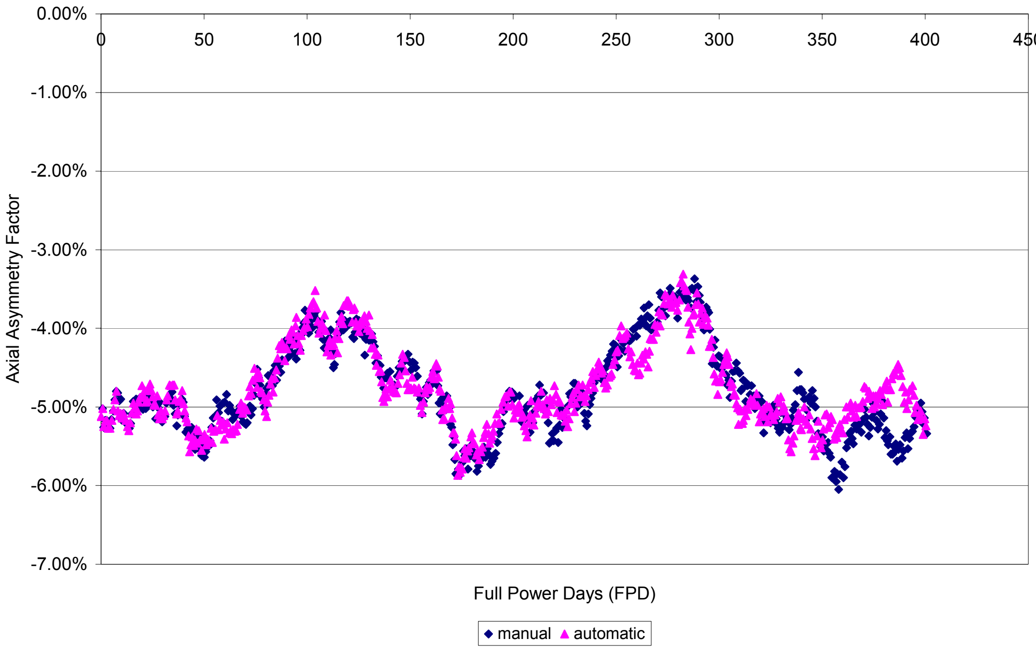

Figure 5: Axial asymmetry factor

X. COMPARISONS WITH TIME AVERAGE RESULTS

In order to comply with the new channel power limits the radial shuffling strategy was modified adjusting the 6 burnup zones using the "time average" procedure. The changes reduce the channel power in the outer zones with a small increase in the power of the central region.

With the updated strategy a new simulation over about 2400 FPD was run involving about 7000 reactor cases. The amount of cases allows comparing average detailed simulation values with "time average" values.

Table 6 shows the exit burnup in the six burnup zones predicted by the "time average" calculations with the fuelling strategy selected for the Atucha-2 reactor. In the same table, a comparison with the average values of the simulation can be found. As can be seen the relative differences in transfer and exit burnup are lower than 1% in all the zones.

Table 6: "Time average" exit and transfer burnups in each fuelling zone. Comparisons between TAV and average of detailed automatic simulation values

Path	Zone	Entry burnup (MWd/tU)	Exit burnup (MWd/tU)	Entry burnup (MWd/tU)	Exit burnup (MWd/tU)	Entry Diff (%)	Exit Diff (%)
1	6	0	2464	0	2482.53	0.00%	0.75%
	5	2464	7800	2482.53	7836.06	0.75%	0.46%
2	2	0	3365	0	3343.05	0.00%	-0.65%
	4	3365	7800	3343.05	7743.20	-0.65%	-0.73%
3	3	0	5433	0	5389.71	0.00%	-0.80%
	1	5433	7800	5389.71	7723.20	-0.80%	-0.98%

Table 7 shows the channel power, maximum, minimum and average, reached in the simulation. The maximum value exceeds the "time average" value due to the channel power variation related with the burnup cycles of the fuel assemblies. In Figure 6 the channel power variation of the central channel and comparison with the average and the "time average" channel power can be seen.

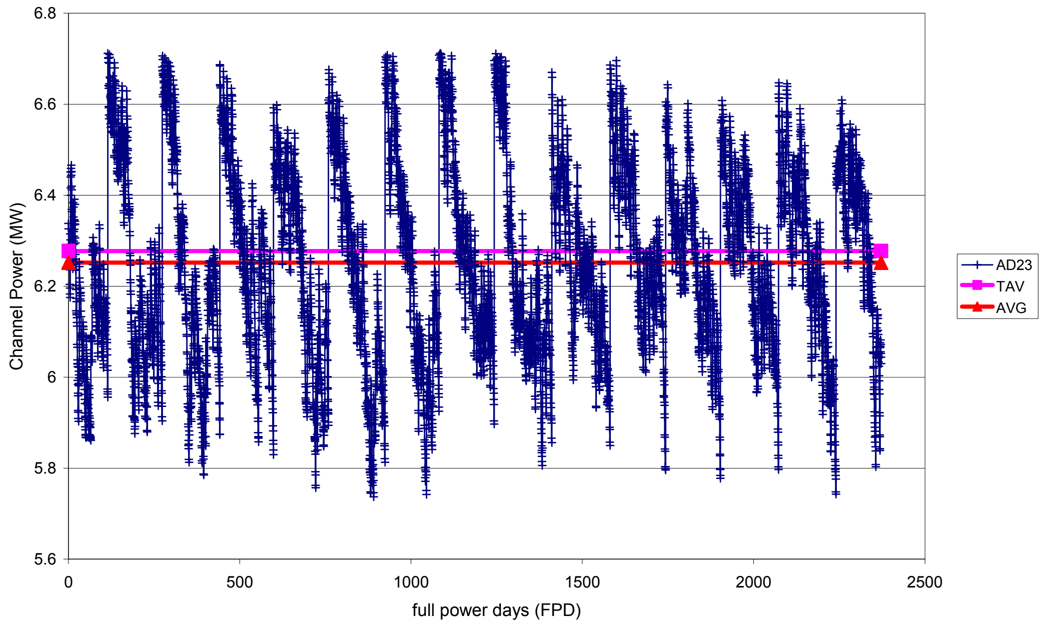

Figure 6: Channel power evolution of the central channel AD23

Maximum channel power is closer to the limits in the three inner zones (1.8% to 3.2%) and larger in the two external zones.

Table 7: Channel powers in each hydraulic zone. Comparisons between TAV and detailed automatic simulation

		Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
		chann.	MCP (kW)	chann.	MCP (kW)	chann.	MCP (kW)	chann.	MCP (kW)	chann.	MCP (kW)
LIMIT			2535		3190		4120		5800		6920
TAV		BE12	2052	BF21	2835	BE26	3899	LE16	5131	AC22	6330
SIMUL	max	BE12	2285	BF21	3061	BE26	4046	AE40	5614	AE14	6761
	min	BE12	1927	BF21	2684	BE26	3673	LF33	5054	AA34	6344
	avg		2067		2843		3894		5298		6594
Max/TAV-1			11.35%		7.97%		3.77%		9.41%		6.81%
Max/LIMIT-1			-9.86%		-4.04%		-1.80%		-3.21%		-2.30%

XI. CONCLUSIONS

The “time average” methodology provides a useful tool to obtain a first evaluation of a fuel management strategy in Atucha-2. Comparisons of the detailed manual simulation with the “time average” calculations show that the average exit burnup of the six burnup zones are close to the “time average” values within 2%. The maximum channel powers in the 5 hydraulic zones are between 8 and 10 % higher than the “time average” values.

The automatic fuelling management program REC_AUT was implemented and tested by comparing its results with the simulation with the manual channel selection. The program showed to provide results very close to the manual fuelling. The maximum, minimum and average values for linear power, channel power and exit burnup are similar to the manual simulation with differences bellow 0.5%.

Recent thermohydraulic studies proposed a reduction in the channel power limits in the outer hydraulic zones; in order to comply with these new limits the fuel management strategy was redefined. With REC_AUT a complete simulation of 2700 FPD was performed in about 81 hours with the present computers (Pentium Quad 2.4 GHz); doing the same task with a manual selection of the channels to refuel may take a couple of months. As can be seen the time economy is very significant.

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