VALIDATION OF CERBRRS AGAINST GENTILLY-2 STATION DATA

E. Varin[1], J. Mao[2], S. Kaveh[3] and A. Baudouin[4]
[1] Atomic Energy of Canada Limited, Montréal, Québec, Canada
[2] Atomic Energy of Canada Limited, Mississauga, Ontario, Canada
[3] Hydro-Québec, Montréal, Québec, Canada
[4] Nucléonex, Montréal, Québec, Canada

Abstract

CERBRRS models the CANDU 6 reactor regulating system (RRS) in CERBERUS transient core calculations. The validation of CERBRRS described here is performed against Gentilly-2 reactor data. The present validation focuses on the liquid zone controller (LZC) modelling, specifically the LZC fill rates. Two core transient measurements were compared to CERBRRS results: a shutdown system manual trip and the 1995 adjuster bank test. The standard CERBRRS model is found to produce a slower fill rate than observed at G2 in the SDS1 trip test. A modified LZC model was developed to reproduce the SDS1 trip test results, and compared to the 1995 adjuster bank test data. The CERBRRS results compared to the measurements show good agreement of the average LZC fill level, which is a key parameter in the RRS logic. These comparisons against Gentilly-2 station data also provide additional confidence in the overall performance of the CERBRRS.

1. Introduction

The CERBRRS module [4] originates from the incorporation of the reactor regulating system routines from SMOKIN-G2 [2] into the CERBERUS [3] time-dependent module in RFSP [1]. The CERBERUS and CERBRRS modules share the Fortran routines required to solve the two-energy-group neutron kinetics diffusion equation by means of the improved quasi-static (IQS) method. [5] The use of CERBRRS also allows the simulation of fission product transients, e.g. xenon. The CERBRRS module models the CANDU® 6 reactor regulating system, verified for Gentilly-2 and Point Lepreau reactors.

After the implementation of the regulating system in CERBRRS, the RRS routines were verified against SMOKIN-G2 [2] and against the Gentilly-2 simulator [7]. These efforts allowed the verification of the setback, stepback and power error calculations. The present validation of CERBRRS focuses on the liquid zone controller (LZC) modelling, specifically the LZC fill rate depending on the LZC valve lift opening.

The LZC modelling of the 14 zones is validated against observed LZC valve lifts and LZC levels during Gentilly-2 transients. The reactor power and reactor power error are collected to assess the CERBRRS kinetics calculations and the reactor core modelling in RFSP. Gentilly-2 station data were collected for two specific cases: a shutdown system (SDS1) manual trip test in 2006 and an adjuster bank test in 1995. During the SDS1 trip, RRS sets the LZC valve lifts at a preset value, so as to fill the zones at 30% of the maximum fill rate, bypassing the regular rules for control of reactor power. This case is used to evaluate the LZC fill rate model in CERBRRS. The adjuster bank test involves the movement of one adjuster rod (the last rod) in a highly centrally-peaked core, as 20 of

21 adjusters are already out. In this case, the zones are driven by RRS to maintain reactor power, compensating for the relatively large positive reactivity insertion rate caused by the withdrawal of the adjuster rod located in the high flux region at the centre of the core. CERBRRS is used to simulate these two cases and the results of which are compared to experiments.

In this paper, the LZC modelling is described in section 2. The two reactor measurement tests are presented in section 3. The validation results are presented in section 4 and conclusions are drawn in section 5.

2. Liquid Zone Controller Representation and Modeling

Light water is constantly poured into and drained from the zone-controller tubes, the desired water level being achieved through the interplay between the inflow and outflow. The inflow is regulated by the opening (lift) of the inlet valve, while the outflow is constant and is determined by the cover gas differential pressure between the compartment and the downstream collection tank (located at a higher elevation) as illustrated in Figure 1. The *BIAS* value of a zone controller is defined as the inlet valve lift that makes the inflow equal to the outflow, maintaining a constant water level. The reactor regulating system controls the LZC levels through the calculation of the inlet valve lift (*YVZ)*. The *YVZ* calculations are based on the power error, the individual zone powers, and the individual water levels in the LZC compartments.

Small drifts in the system helium pressure and H_2O inlet pressure can cause small drifts in the actual valve neutral position (BIAS value), which will slightly change the relationship between the water level movement and the valve position.

The LZC levels are measured by bubblers, i.e. the differential pressure between the common helium inlet pressure and the gas region of each zone compartment, as shown in Figure 1. The system is at its most accurate during steady state operation or slow transients. The accuracy is expected to degrade during fast transients during which a change in level on all 14 zones has been observed to cause fluctuations in the helium balance header pressure, which in turn affects the level indication on all 14 zones simultaneously. This presents some challenges in the interpretation of transient level data for the validation of CERBRRS.

The LZC level dynamic modeling in CERBRRS is only a function of the valve lifts (*YVZ)* and *BIAS* values. In general, the water level increases, i.e. the LZC fill rate is positive, when YVZ is larger than BIAS for a specific LZC. Even though the LZC system is a complex system, composed of two independent circuits; one circuit for helium and one circuit for feed water, the LZC fill rate is assumed to be linear with respect to the valve lift.

The simulation of the LZC compartment water levels in CERBRRS computes the actual water levels ZL_i (in % of full level) as a function of the valve lifts YVZ_i, biases $BIAS_i$ and the LZC-dependent slope parameters S_i. The new water levels after Δt seconds are computed by:

$$ZL_i(t+\Delta t) = ZL_i(t) + R_i \cdot \Delta t \qquad \text{[\%level]} \qquad (1)$$

where the LZC fill rate R_i is:

$$R_i = S_i \times (YVZ_i - BIAS_i) \qquad \text{[\%level/s]} \qquad (2)$$

However, this fill rate model is not standard in CERBRRS. The standard CERBRRS LZC model is defined as follows:

$$R_i = ZFLMX \frac{100}{T_{fill,i}} \frac{YVZ_i - BIAS_i}{1 - BIAS_i} \qquad \text{[\%level/s]} \qquad (3)$$

The slopes are function of the biases $BIAS_i$, of a zone fill rate scaling factor ZFLMX, and of a total time to fill a zone i from 0 to 100% (T_{fill}) when YVZ=1. The normal value used for ZFLMX in the standard model is 0.50366. The model has been reformulated as shown in equation (2) to allow the adjustment of the fill rates to be independent of the BIAS values.

During the CERBRRS validation exercises, the slope parameters S_i were adjusted to reproduce the SDS1 manual trip data. During that test, the measured LZC fill rate was around 1.1%/s on average while a value of 0.975%/s was defined in CERBRRS, when RLIF=YVZ-BIAS=15%. This adjusted model is then applied in the simulation of the 1995 adjuster bank test.

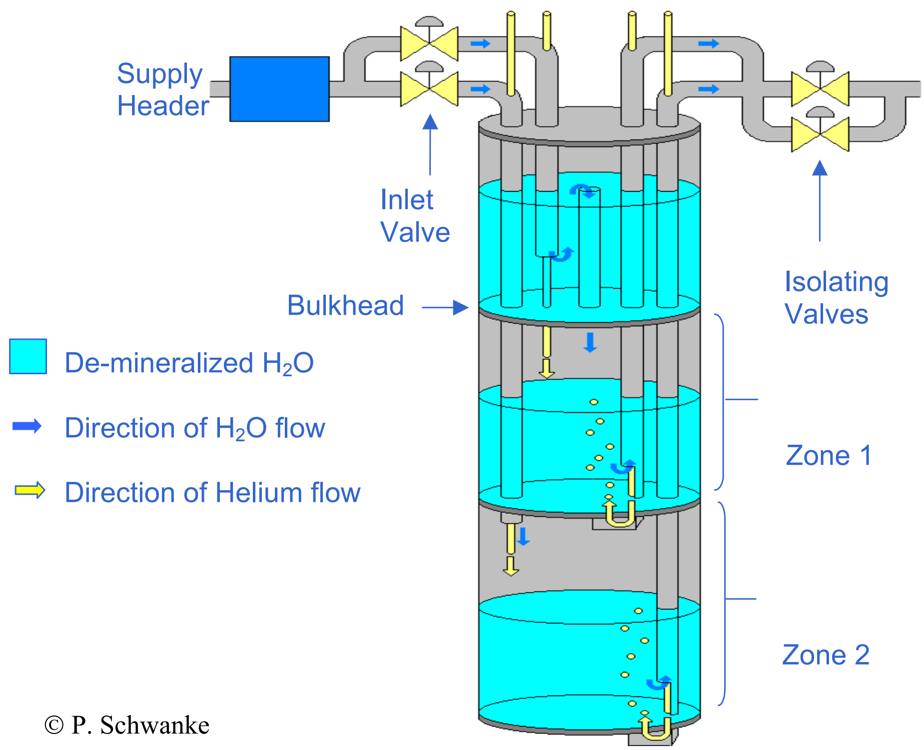


Figure 1 Zone Controller Compartment Layout

3. Description of the Gentilly-2 Validation Cases

Gentilly-2 data were collected for two specific cases: a shutdown system (SDS1) manual trip test in 2006 and an adjuster bank tests in 1995. The two transients are presented in the following sections.

3.1 Manual trip test

The 2006 SDS1 manual trip test was performed during a station restart in October 2006. At the beginning of the test, a manual SDS1 trip was initiated. All shutoff rods (SOR) dropped into the core. The mechanical control absorbers (MCA) would normally also drop into core, but were not dropped because the stepback routine in the digital control computer (DCC) was inhibited for this test. The LZC filled at 30% of their maximum rate in accordance with the RRS rules when a reactor trip is in progress (SDS1, SDS2 or Stepback). Figure 2 shows the measured power and the average zone level (AVZL) during the trip. The measured power shown is the variable PLGCA, calibrated log power, which is computed by the DCC and converted to fraction of full power (FFP). When the average water level reaches 80%, the mechanical control absorber rods are inserted in sequence according to the RRS rules.

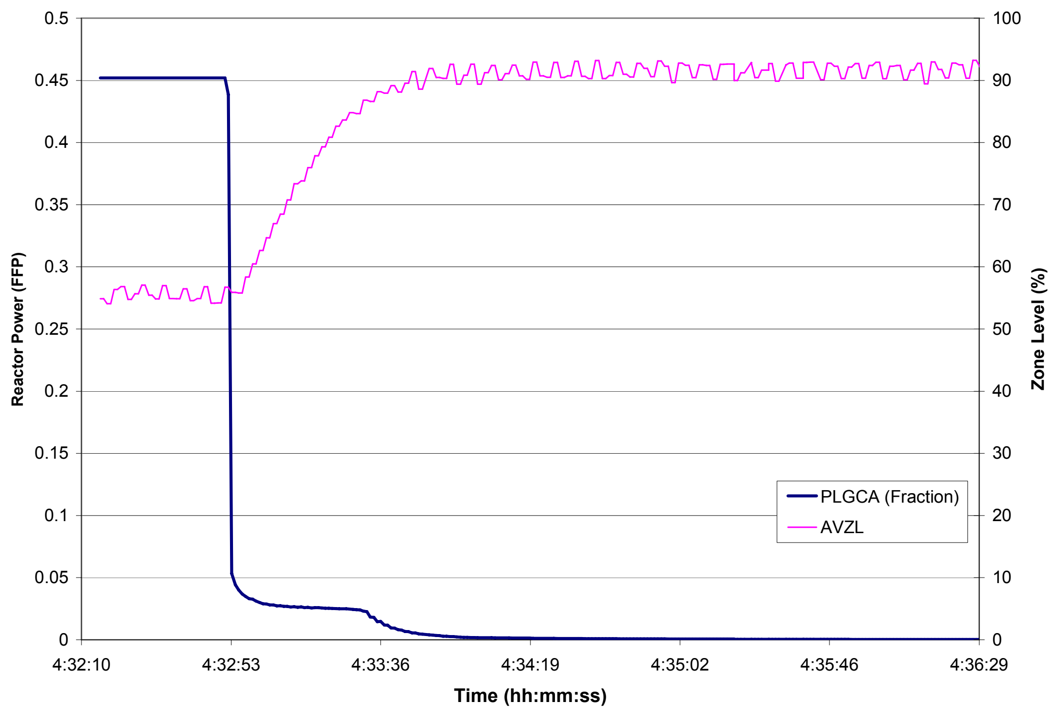


Figure 2 Measured Data during the 2006 SDS1 Manual Trip at Gentilly-2 site

3.2 Adjuster bank test

The Gentilly-2 adjuster bank test was performed during the power reduction prior to the annual maintenance outage in 1995. The test was originally performed to verify the re-allocation of the two adjuster rods in bank 7 into two single-rod banks. The test consisted of a power reduction, in steps, from 100% FP to 80% FP, and then to 44% FP, and the withdrawal of all adjuster rods under RRS rules as xenon built up. The test started at 20:00:05 April 16, 1995 and ended at 23:53:46 April 16, 1995, lasting around four hours (see Figure 3). The xenon transient was not sufficient to cause the withdrawal of all the adjuster rods, leaving the last rod (bank 8) still in core. Moderator poison was therefore added in steps until the AVZL decreased below 20%, the level at which RRS initiates the withdrawal of the last adjuster bank. Data relevant to the LZC modelling was collected every 2 seconds between 22:53:56, to 23:53:46. The station-measured average zone levels and reactor power during that period are shown in Figure 4. The station data indicates the reactor power is relatively steady during the first 9 minutes. Then poison was manually added in the moderator to decrease the average zone level to below 20%, triggering the withdrawal of the last adjuster from the core. After 23:10:02, the reactor power is further decreased to 40%FP and the last adjuster bank is re-inserted. At 23:16:12, the last adjuster rod is again withdrawn when the average zone fill reaches 20% and the site measurements are continued.

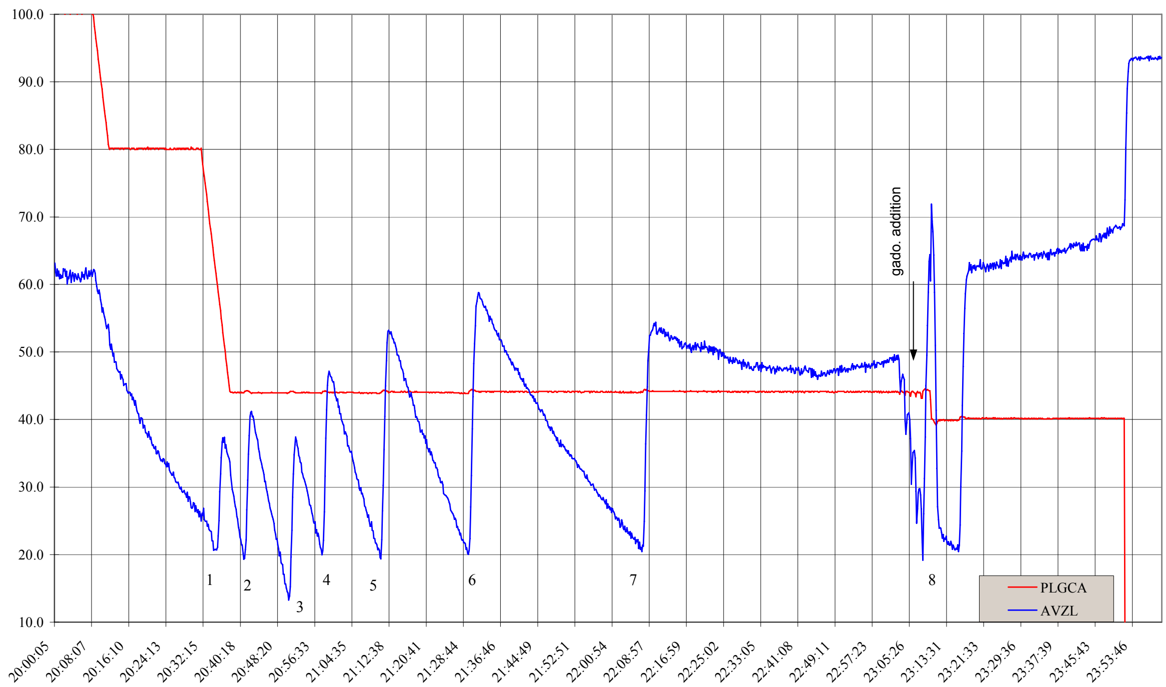
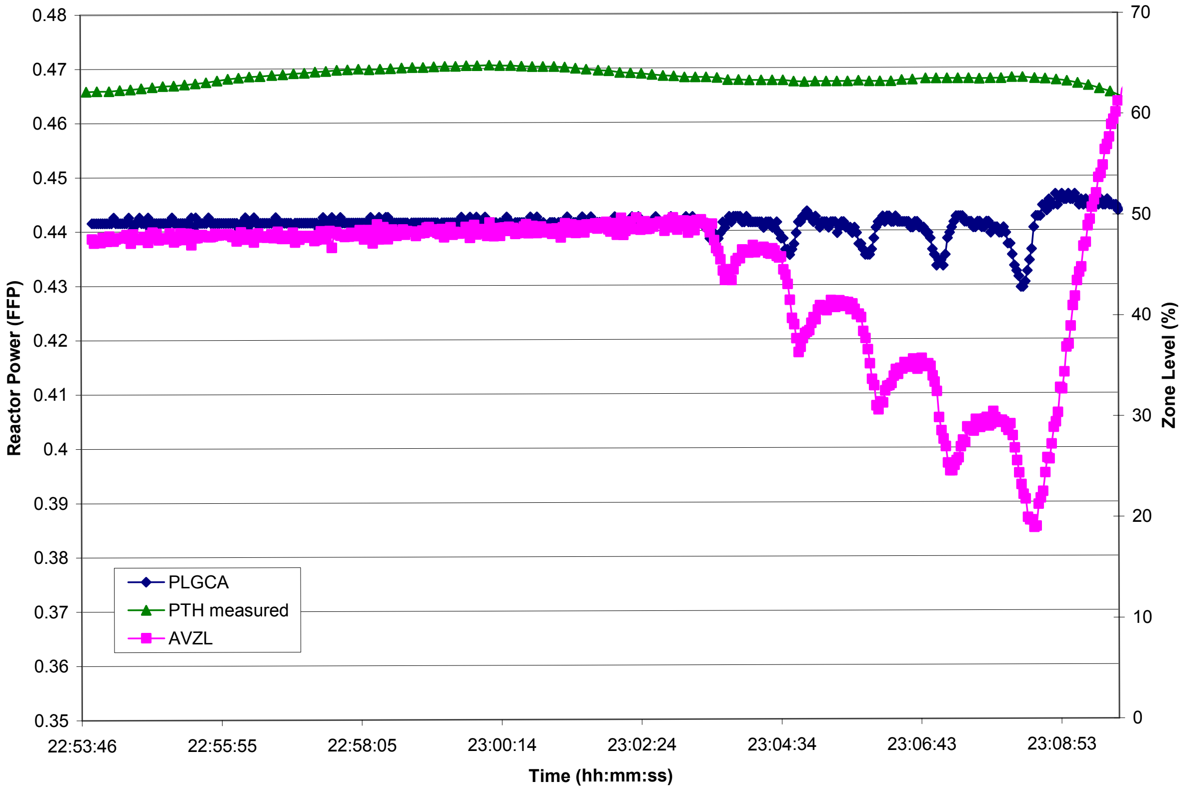


Figure 3 Power Rundown on April 16th, 1995, Identified as Adjuster Bank Test

Note: The numbers 1 through 8 indicate the time at which each adjuster bank is withdrawn from the core.


Reactor Power (FFP)
Zone Level (%)
Time (hh:mm:ss)
PLGCA
PTH measured
AVZL
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0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
70
60
50
40
30
20
10
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22:53:46
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23:02:24
23:04:34
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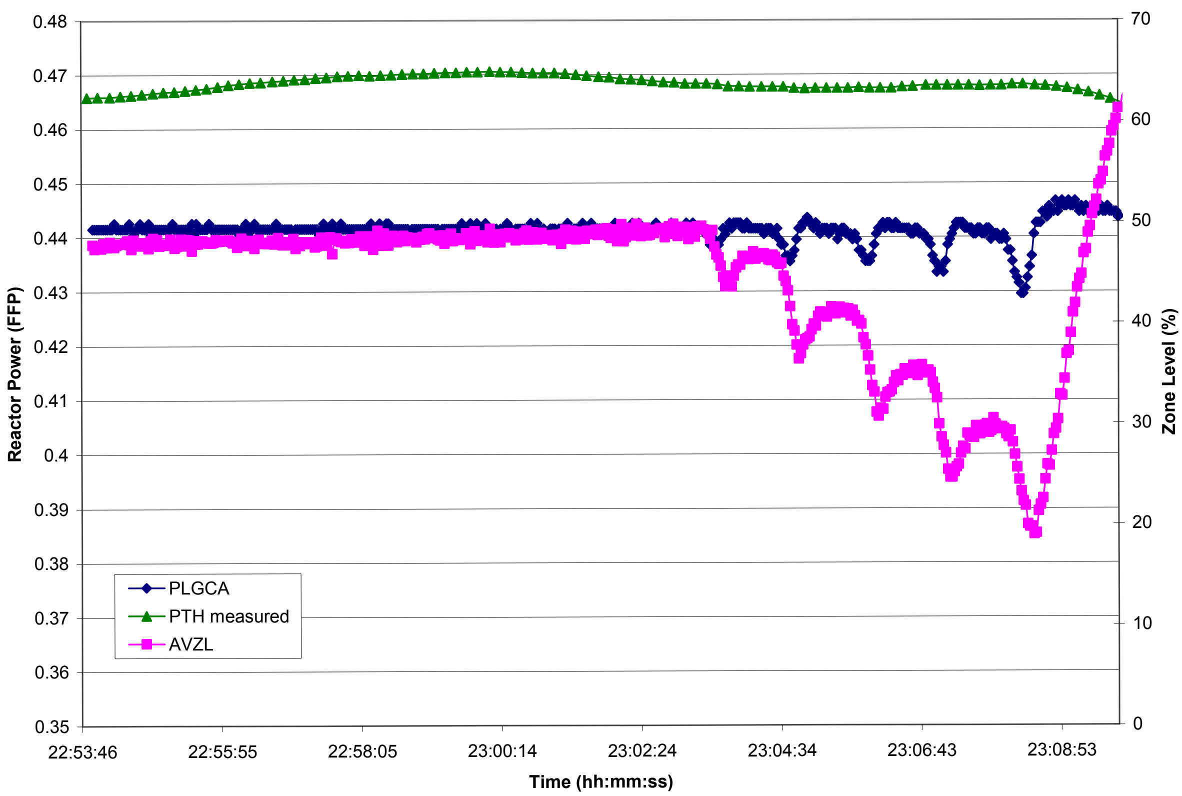
23:08:53


Reactor Power (FFP)
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70
60
50
40
30
20
10
0
22:53:46
22:55:55
22:58:05
23:00:14
23:02:24
23:04:34
23:06:43
23:08:53

Figure 4 Measured Reactor Power and Average Zone Level during the CERBRRS Transient of the 1995 adjuster bank test

4. CERBRRS Validation Results

RFSP version REL-3-04-01 was used to model the Gentilly-2 reactor. The reactor was modelled with most of the structural materials and all of the devices (LZCs, adjusters, MCAs, SORs). Their properties were computed using DRAGON [9]. All RFSP calculations were carried out using 2-group WIMS-based [8] cross-sections using the SCM method [11]. Results of the CERBRRS validation are discussed in the following sections.

4.1 SDS1 Manual Trip Results

The CERBRRS simulation of the manual SDS1 trip was carried out for a 12-minute period, in 0.5-second time steps.

The shutoff rod positions versus time in the simulation were obtained from the measured positions at the station during the test. Within 2 seconds, all the shutoff rods were fully inserted. The measured trip time was at 4:32:52, when the valve lifts were constant, being exactly equal to BIAS + 15%.

The average LZC level is shown in Figure 5 for both the computed and measured data. The error bars represent ±1% fill level for the measured data. As seen in Figure 5, the average zone fill (AVZL) calculated by CERBRRS is within 1% of the measured data until the measured average zone fill reaches the 92% fill level. Table 1 shows the LZC fill rates for the standard model, the adjusted model (defined in section 2) and the measurements. As indicated in Section 2, the slope parameters S_i of the model were adjusted to reproduce the SDS1 manual trip data. The measured LZC fill rate is approximately 1.1%/s on average. A value of 0.975%/s was used in the CERBRRS model for an RLIF value of 15%. The standard model, on the other hand, with the usual value of 0.50366 for the ZFLMX multiplier, produces a slower fill rate than observed, as shown in Table 1. However with the ZFLMX multiplier equal to 1.0, the fill rates are faster than measured. Therefore, this parameter can provide an adjustment tool to the LZC fill rate model in CERBRRS.

The difference between the measurement and the CERBRRS results after AVZL reaches 92% are not attributed to the LZC response model but to the effective BIAS value in the LZC system versus the BIAS value used in the RRS control routine in the G2 DCCs. To explain this BIAS issue, the measured and computed valve lifts for LZC #1 are shown in Figure 6. Between 4:32:52 and 4:33:14, the measured and predicted valve lifts are exactly equal to BIAS + 15% as set by the RRS rule for the trip condition. The BIAS value for LZC #1 was 0.57 prior to trip, as determined from the observed valve lift. The same value was used in CERBRRS as both measured and computed valve lifts are equal as shown in Figure 6. From 4:33:14 to 4:34:15, the relative valve lift RLIF (=YVZ-BIAS) is limited by the RLIFMAX equation (in which valve lift is a function of water level) that is applied in the RRS routines to avoid overfilling the zones. The goal of the RLIFMAX equation is to limit the water level to be no greater than 95% , i.e. to reach RLIF=0 (YVZ=BIAS) when the water level reaches 95%. In Figure 6, from 4:33:14 to 4:34:15, both the computed and measured valve lift YVZ slowly decreases as the RLIFMAX term comes into play. The computed valve lift decreases down to YVZ=BIAS=0.57.

However the observed water level becomes constant at 92% when the measured YVZ decreases no lower than 0.62. This means that YVZ=0.62 is the "effective" BIAS value defined as the inlet valve lift that makes the inflow equal to the outflow. At site, the RRS routine set the valve lift in LZC #1 to be equal to 0.57 when the water level reaches 95%. But the "effective" BIAS is 0.62, thus when the RRS routine decreases the YVZ to less than 0.62, the water level actually decreases instead of increases.

The valve lifts predicted by CERBRRS have the theoretically expected behaviour, and are close to the measured valve-lift trend. The 3% difference in the steady state average water level at the end of the transient is an effect of the LZC system complexity and shows the difficulties in level prediction when the RRS is controlling only indicated level and not neutron power.

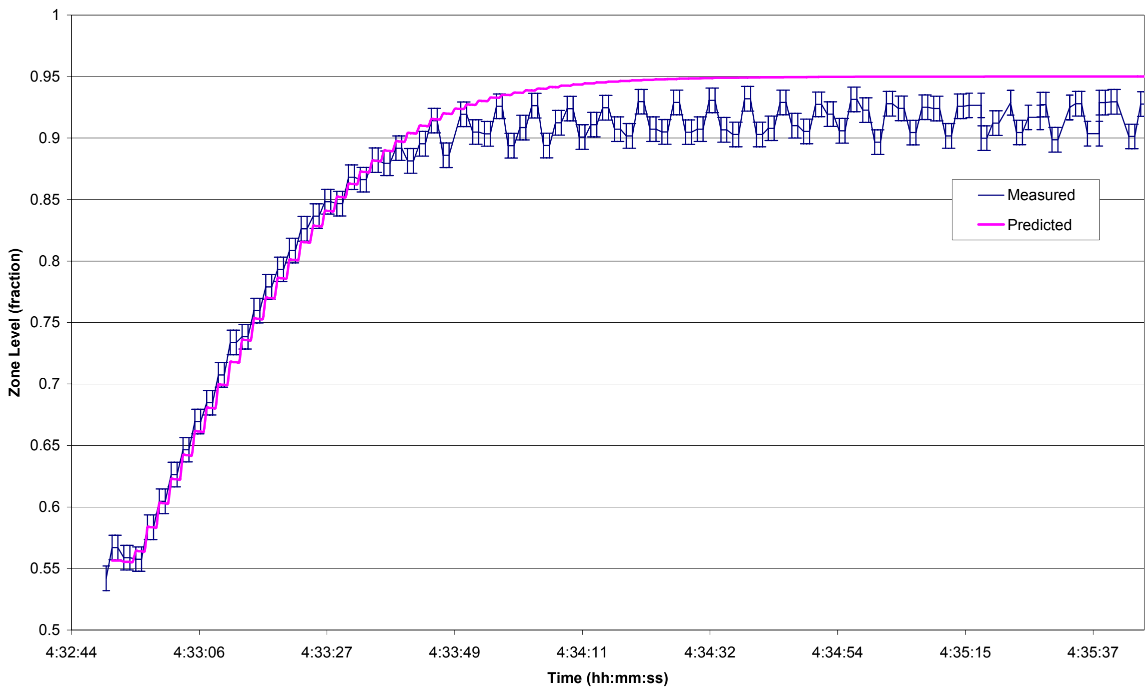

Figure 5 Average LZC Level during the SDS1 Manual Trip Test

LZC #	G2 Measurements [%/s]	Standard Model with ZFLMX=0.50366 [%/s]	Standard Model with ZFLMX=1 [%/s]	Adjusted Model [%/s]
LZC01	1.101	0.360	0.714	0.975
LZC02	1.027	0.600	1.190	0.975
LZC03	1.087	0.600	1.190	0.975
LZC04	1.192	0.600	1.190	0.975
LZC05	1.133	0.600	1.190	0.975
LZC06	1.054	0.360	0.714	0.975
LZC07	1.056	0.600	1.190	0.975
LZC08	1.068	0.360	0.714	0.975
LZC09	0.906	0.600	1.190	0.975
LZC10	1.359	0.600	1.190	0.975
LZC11	1.143	0.600	1.190	0.975
LZC12	1.315	0.600	1.190	0.975
LZC13	1.294	0.360	0.714	0.975
LZC14	1.104	0.600	1.190	0.975
Average	1.131	0.531	1.054	0.975

Table 1: Measured and predicted LZC fill rates for the 2006 SDS1 Trip Test

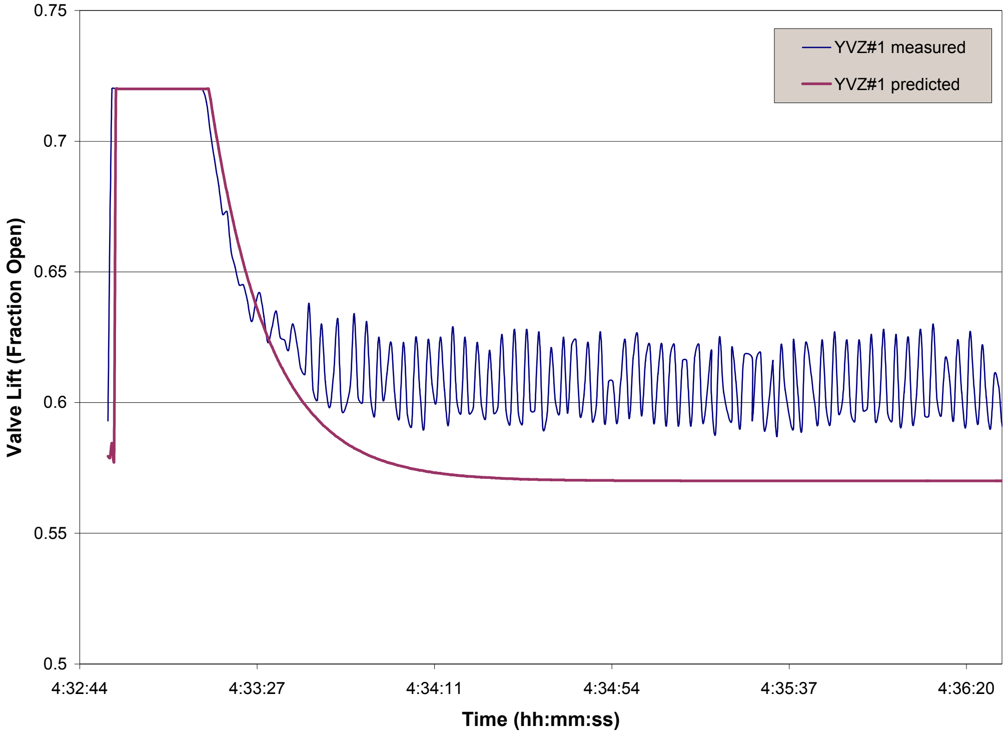

Figure 6 Valve Lift during the SDS1 Manual Trip Test (LZC#1)

The predicted average zone fill has reached 80% at a similar time as the measured data. The mechanical control absorbers are thus inserted in accordance with the RRS rules at about the same time during the measurements and the CERBRRS calculations. Figure 7 shows the position of the MCAs during the trip test. The movement of the MCAs was calculated by CERBRRS, with the 100% travel time reduced from the design value of 150s to a value 145s as determined by the test data.

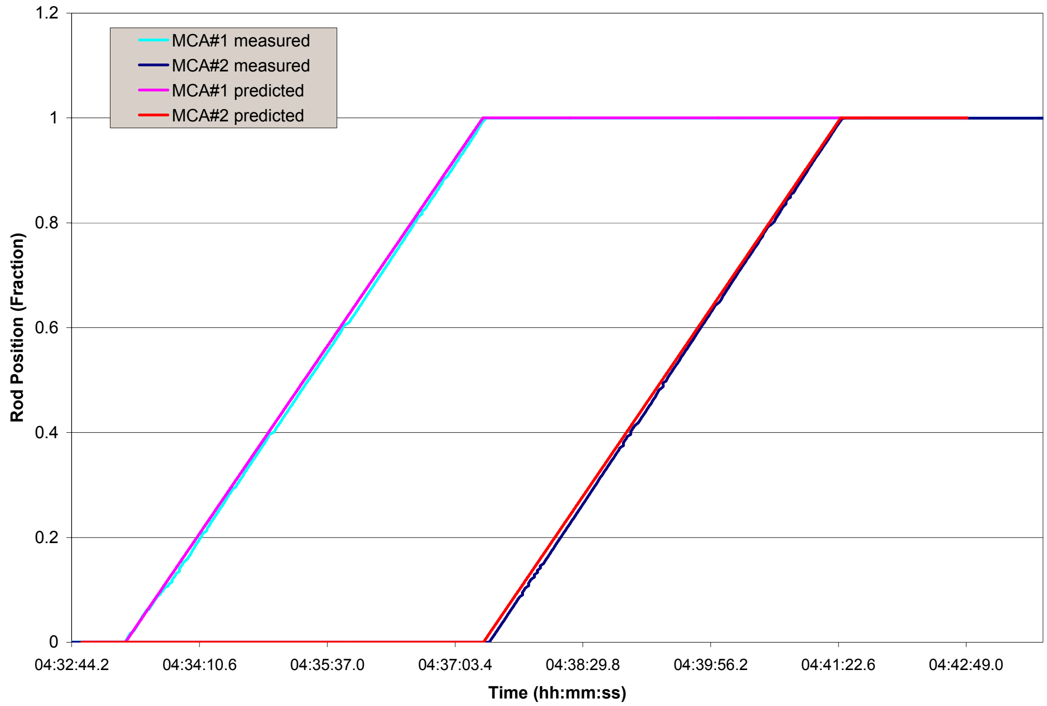

Figure 7 MCA Positions during the SDS1 Manual Trip Test

4.2 Adjuster Bank Test in 1995

The CERBRRS simulation of the adjuster bank test shown in Figure 4 concentrates on the 16 minutes between 22:53:56 and 23:09:46. The CERBRRS simulation requires an adequate representation of the core prior to 22:53:56. The reactor conditions were modelled for that purpose by following the steps:

- An RFSP Core-follow simulation for 18 FPDs prior to the test using G2 station data (refuelling channels, LZC levels and moderator parameters). The first core configuration was extracted from a G2 core-tracking simulation carried out with a previous Gentilly-2 RFSP model. The core-tracking information is recovered from the HQSIMEX core tracking input files.
- An RFSP (SIMULATE) core simulation of the power reduction from 100% FP to 80% FP, then to 44% FP, until seven banks of adjusters are fully withdrawn. The device positions and the reactor power levels are recovered from the HQSIMEX simulations [12].
- An RFSP (SIMULATE) simulation of the poison addition to define the required boron concentrations before the last adjuster is withdrawn. Boron is added to the moderator in the core model to match a target keff and the LZC levels are recovered at each step from the station data.

The simulation was performed using the SCM methodology and the micro-depletion methodology [10] separately. The CERBRRS results from 22:53:56, to 23:09:46 are presented below. A time step of 0.5 second was used in the simulation. The transient simulation was divided into three periods for analysis:

1. The no-perturbation period from 22:53:56 to 23:03:00 [i.e. 0 s to 550 s of simulated time];

2. The moderator poison additions from 23:03:00 to 23:08:08 [i.e. 550s to 860s of simulated time];
3. The last poison addition and the adjuster bank withdrawal, from 23:08:08 to 23:09:46 [i.e. 860s to 950s of simulated time].

The reactor power setpoint in CERBRRS was set to 46% FP during the transient. The measured LZC levels at 22:53:56 were entered in CERBRRS at time 0. The phinoms fluxes or nominal zone fluxes implemented in the station DCC during the 1995 test were used in the CERBRRS simulation.

Figure 8 shows the computed and measured reactor powers. During the no-perturbation period, the reactor power in CERBRRS was maintained at 46%FP as requested in the code input. Figure 8 shows that the power computed with SCM agrees well with the power computed with the micro-depletion method. The reactor power setpoint was set to 46% FP in CERBRRS during this phase of the transient. This differs from the demand power of 44% FP at the station, and was chosen to better reproduce the actual reactor thermal power from the secondary side indications (PGVM). The RRS indicated power (PLGCA) at the station is close to 44%FP in Figure 8. The best-estimate power was used in CERBRRS to reproduce more closely the xenon transient, which is a strong function of reactor power.

Figure 8 shows that the computed power in CERBRRS is indeed kept constant at 46%FP prior to the poison addition. The step-changed moderator poison additions in the simulations result in power jumps for both the SCM and Micro-depletion method. The actual thermal power at the station is not affected by the boron addition, which in reality is more gradual (see Figure 8, PLGCA). Thus the maximum difference between the measured thermal power (PGVM) and predicted RRS power (PLGCA) is 2.5%FP for both the SCM and Micro-depletion methods during the poison addition.

During the last period between 860 seconds to 950 seconds, the simulation includes a final poison addition and power setpoint reduction to 44%FP in CERBRRS to decrease the AVZL to below 20% so as to initiate the withdrawal of the last rod. As shown in Figure 8, the CERBRRS reactor power decreases to 44%FP following the RRS power manoeuvre. The maximum difference between the measured RRS power (PLGCA) and the predicted power is 1.3%FP for both the SCM and Micro-depletion methods.

Figure 9 shows the measured and computed average zone levels (AVZL). The error bars on the measured data represent ±1% fill level. The computed AVZL changes during the first 50 seconds. The average level then stablizes during the no-perturbation period. The differences between the measured and computed LZC levels during the first 50 seconds are due to the mismatch between the zone power setpoints (phinoms) entered in CERBRRS and the zone powers that the CERBRRS flux-mapping routines compute. When the reactor is stable, i.e. no external perturbations, it can be shown that the LZC spatial control is driven directly by the differences between the phinoms and the flux-mapped zone powers. The average difference between the measured and predicted AVZL is 3.3 ± 0.5 % fill level for the SCM method and 2.6 ± 0.5 % fill level for the Micro-depletion method.

Even if the AVZL differs by up to 3.2% between the measured and predicted values just prior to the poison additions, the difference tends to decrease during the poison additions. This is due to the fact that the poison concentrations are computed using the measured LZC levels, and the poison concentration step-changes are calculated to reproduce the measured LZC trend. The maximum difference between the measured and predicted AVZL during the poison addition is 7.2% fill level for the SCM method and 6.4% fill level for the Micro-depletion method.

Figure 10 shows the measured and computed average zone levels, together with the measured and computed adjuster rod positions during the last period of the transient. The error bars on the measured data represent ±1% level. The AVZL decreased slowly to 20%, which is the threshold that triggers the adjuster bank withdrawal at the station. The small difference between the AVZL in the CERBRRS simulation and that from the station as well as the small amount of noise in the AVZL seen by the RRS at the station caused the adjuster bank withdrawal to initiate a few seconds sooner at the station than in the CERBRRS simulation. To synchronize the initiation of the rod withdrawal in the simulation to that at the station (for comparison of the LZC fill rates, which is the focus of this simulation exercise), a further boron addition and a 2% reduction in the setpoint power to 44% FP were introduced in the CERBRRS simulation. Once withdrawal was initiated, the length of time to withdraw the rod at full speed was found to be similar between the measurements and the calculations (i.e. 66 seconds from site data and 60 seconds from CERBRRS). This difference would not significantly impact the LZC response.

The computed AVZL increased as the rod was withdrawn. The average computed fill rate (1.0%/s) was very close to the average measured fill rate (1.06 %/s). The computed AVZL reached a maximum when the rod was half withdrawn, while the measurements still showed an increase in the AVZL. The differences between the measured and predicted AVZL were between 2% to 5% level until 910 seconds. After that time, the differences in the predictions increased up to 13% level. To obtain the correct rate of AVZL change, the total reactivity worth of both the AVZL and of the adjuster rod #10 needs to agree with plant data, as does the speed at which the device positions change. The agreement in the early phase of the rod withdrawal indicates that the speed components are in reasonable agreement.

The poorer agreement at the end of the rod withdrawal indicates that there is a discrepancy between the calculated LZC reactivity worth and the adjuster #10 reactivity worth in the strongly peaked flux distribution of the xenon transient.

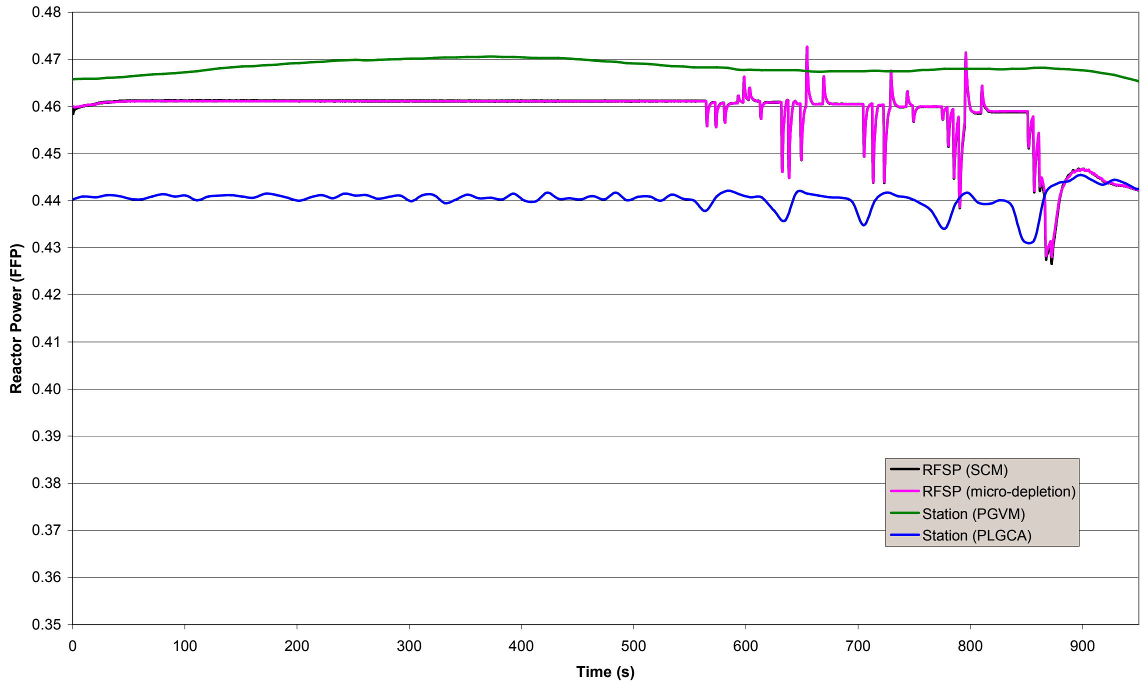

Figure 8 Measured and Predicted Reactor Power during the 1995 Adjuster Bank Test

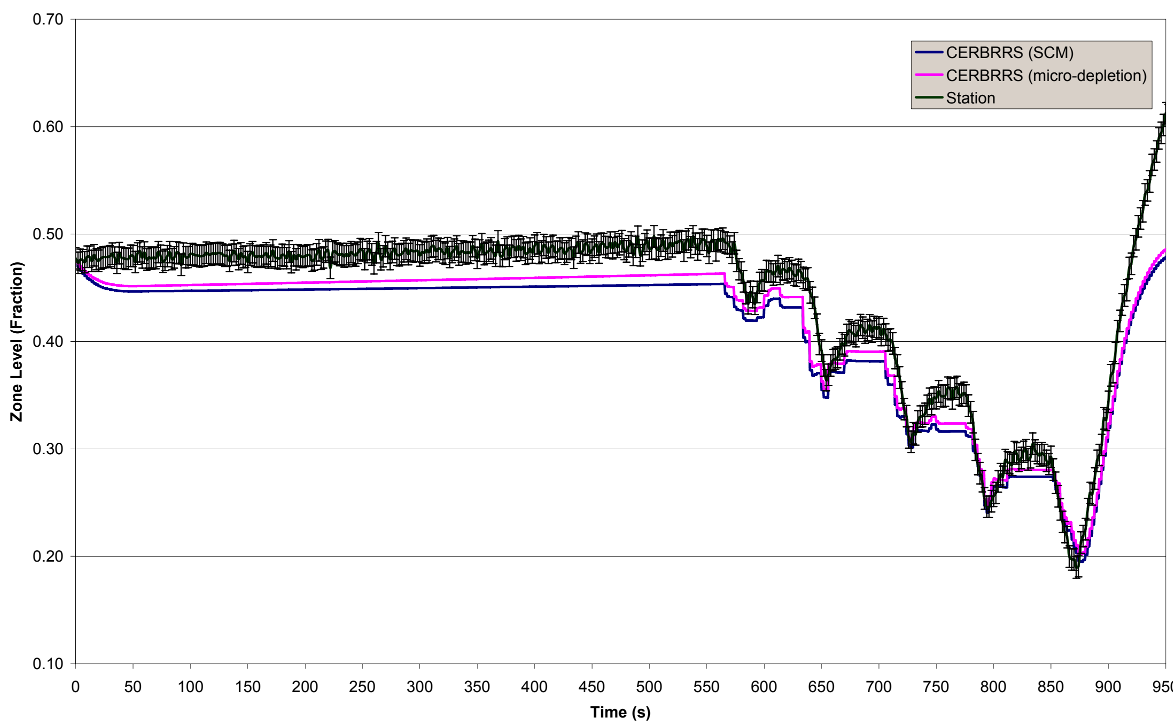

Figure 9 Measured and Predicted Average Zone Level during the 1995 Adjuster Bank Test

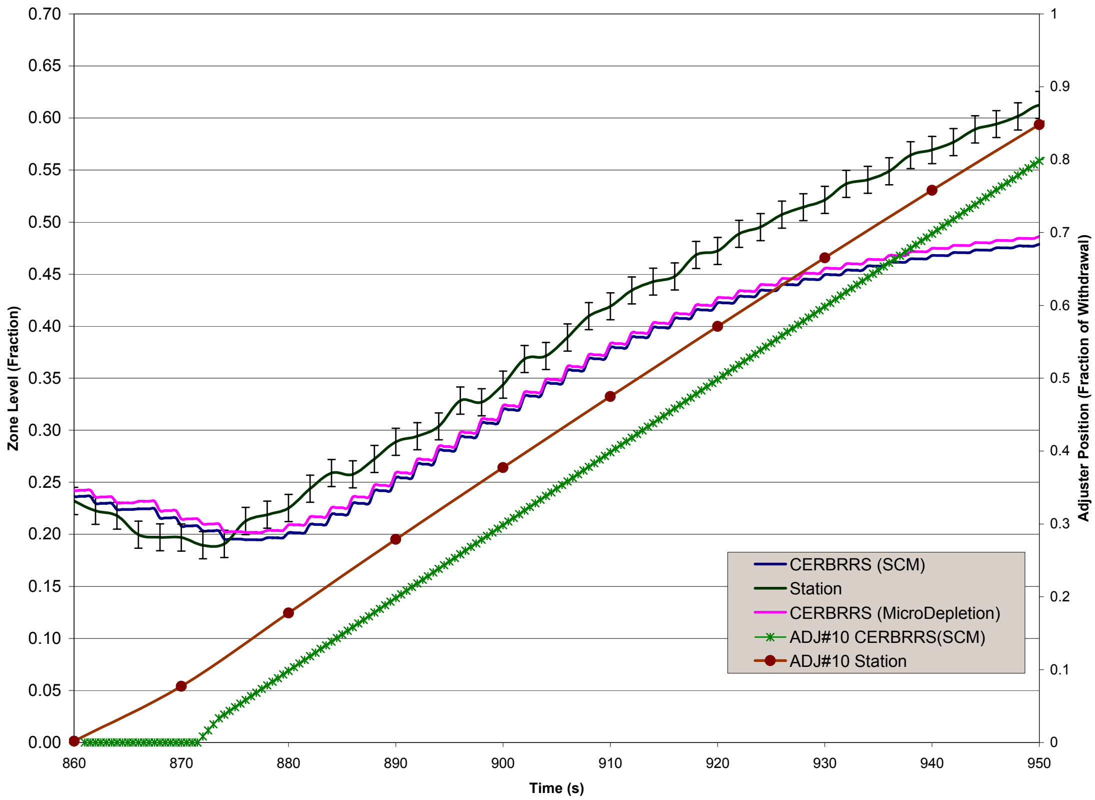

Figure 10 Measured and Predicted AVZL and Rod Position during the 1995 Adjuster Bank Test

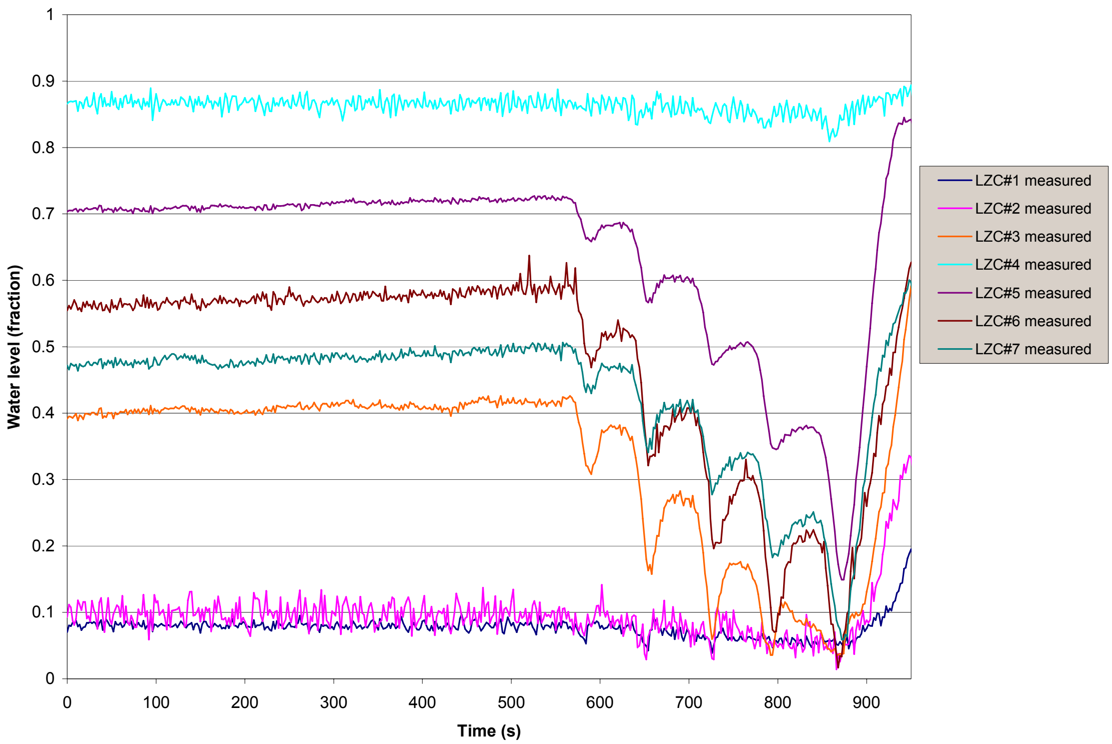

Figure 11 Individual Measured LZC Levels Transient During 1995 Adjuster Bank Test

During the CERBRRS transient, when almost all adjusters are extracted, many LZCs are at their spatial control limits. Figure 11 shows the measured LZC levels on the north side of the reactor. Figure 12 shows the LZC levels computed by CERBRRS using SCM. Although this case is considered an extreme case for physics code validation due to the large flux distortion, the overall LZC level transients are reproduced.

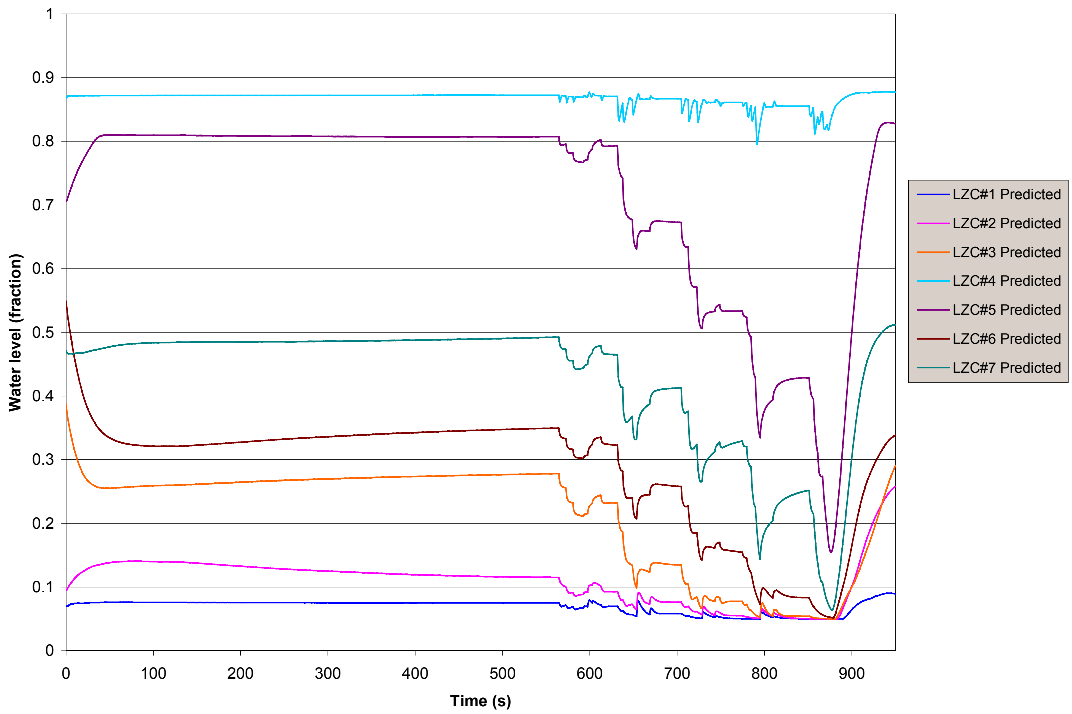

Figure 12 Individual Predicted LZC Levels Transient During 1995 Adjuster Bank Test

7. Conclusion

The present validation focuses on the liquid zone controller (LZC) modelling, specifically on the LZC fill rates. The LZC fill rate calculation in CERBRRS was modified and adjusted to reproduce the SDS1 manual trip test. The standard model is found to produce a slower fill rate than observed at G2. Using the adjusted LZC model, the 1995 adjuster bank test shows good agreement of the average LZC level computed by CERBRRS with the value measured at site. The average LZC level is a key parameter in the RRS logic. These comparisons against Gentilly-2 station data also provide additional confidence in the overall performance of the CERBRRS module of RFSPto model the reactor regulating system (RRS) in transient core calculations.

The study of the LZC fill rate and the comparison between the new LZC fill rate model and the standard method in CERBRRS (Table 1) have shown that LZC rates simulated in CERBRRS (eq. 2) are slower than measurements. Moreover it has been shown that the use of a scaling factor can modify the CERBRRS LZC fill rate model to obtain the presented results. This capability would be useful for sensitivity studies on the impact of the LZC fill rates on accident scenarios. The modified LZC fill rate model developed for this work represents the closest-to-measurements model of the LZC fill rate.

8. References

[1] B. Rouben, “RFSP-IST, The Industry Standard Tool Computer Program for CANDU Reactor Core Design and Analysis”, Proceedings of the 13th Pacific Basin Nuclear Conference, Shenzhen, China, 2002 October 21-25.

[2] J. Koclas, S. Alaoui, M.A. Petrilli, “Development of the Modal Kinetics Model for the Gentilly-2 G.S.”, 2nd International Conference on Simulation Methods in Nuclear Engineering, Montreal, Oct 14-16, 1986.

[3] G., Kugler, A.R., Dastur, “Accuracy of the Improved Quasi-Static Space-Time Method Checked with Experiment”, AECL-5553, Atomic Energy of Canada Ltd, Sheridan Park, 1976.

[4] H.C. Chow, B., Rouben, M.H., Younis, D.A., Jenkins, A., Baudoin, P.D., Thompson, “Capability to model Reactor Regulating System in RFSP”, 16th Annual Conference of the Canadian Nuclear Society, Saskatoon, 1995.

[5] K.O. Ott, D.A., Meneley, `` Accuracy of the Quasistatic Treatment of Spatial Reactor Kinetics Behaviour'', Nuclear Science and Engineering, Vol. **36**, pp 402-411, 1969.

[6] “Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants”, Canadian Standards Association, N286.7-99, 1999 (R2007).

[7] H. Chow, G. Delorme, A. Baudouin, J.D. Stebbing, “Simulations of Power Transients in a Loss of the Liquid-Zone-Control-System Pumps in CANDU-6 Reactors”, Proceedings of the 19^{th} Annual Conference of the Canadian Nuclear Society, Toronto, Canada, 1998 October.

[8] J.D. Irish and S.R. Douglas, “Validation of WIMS-IST”, Proceedings of the 23rd Annual Conference of the Canadian Nuclear Society, Toronto, Ontario, Canada, June 2-5 (2002).

[9] G. Marleau, A. Hébert and R. Roy, “A User Guide for DRAGON,” Report IGE-174 Rev.5, École Polytechnique de Montréal, 2000 April.

[10] W. Shen, “Development of a Micro-Depletion Model to Use WIMS Properties in History-Based Local-Parameter Calculations in RFSP”, Proceedings of the Sixth International Conference on Simulation Methods in Nuclear Engineering, Montreal, Quebec, Canada, October 13 – 15 (2004).

[11] F. Ardeshiri, J.V. Donnelly, B. Arsenault, “WIMS-AECL/RFSP Code Validation of Reactivity Calculations Following a Long Shutdown Using the Simple-Cell History-Based Method”, 19th Annual CNS Conference, Toronto, Oct 18-21, 1998.

[12] G. Hotte, M. Beaudet, J. Koclas and D. Rozon, “Accuracy of Burnup History Simulations Integrating In-Core Flux Detector Measurements and Diffusion Theory”, Proc. ANS/ENS PHYSOR-90, Marseille, 1990.