UPGRADE OF THE STARTUP TEST INSTRUMENTATION (ANMS) WITH INNOVATED I&C SYSTEM AT THE DUKOVANY VVER 440/213 UNITS

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ABSTRACT

The paper summarizes the innovation procedures of startup tests instrumentation (ANMS) used in Dukovany NPP connected with I&C system refurbishment of the Dukovany VVER 440/213 units. The following matters are further presented in this paper:

- Changes in ANMS design, whose has been carried out due to reflect the situation connected with I&C innovation;
- Process of consistency checking during implementation stage;
- Results of the physics startup tests with upgraded ANMS in 2005 (introduction of Gd-2 fuel on DNPP).

1. INTRODUCTION

A successful realization of the physics startup tests - and generally all startup tests as well – is conditioned by fulfillment of various requirements, which are ranged into following steps:

1. Preparation of theoretical datasets according to estimated conditions during measurement stage (if evaluation of the test requires the comparison of experimental values with theoretical ones) [1];

2. Calibration of the measurement strings to exclude all unwanted signal properties. Derived configuration is used for all realized test;
3. Receiving all the necessary primary parameters for the correct evaluation in sufficient quality;
4. Displaying all the parameters, which are important to make decisions in test management during measurement;
5. Conversion of the received parameters into values corresponding to theoretical ones (reactivity effects and coefficients);
6. Calculation of appropriate deviations and controlling the fulfillment with criterions, i.e. taking the preliminary results;
7. Creation the appropriate documentation output (protocols), where the conditions of measurement are described and results confirmed (or not);
8. After startup realization there should be possibility to review the results using theoretical values according to real conditions during measurements or using alternate methodology [2] for experimental values determination. These activities are reflected in Final Summary and Evaluation Report, which is published 1 month after startup.

These requirements should by fulfilled using a compact system which enables to perform these steps (especially steps 3÷7) with adequate response during tests realization ("adequate" in this case means, that the results will be available in sufficient time and quality).

In conditions at DNPP these described requirements are concentrated into used startup test instrumentation (ANMS) properties, developed and designed by NPPRI, with reflection to the specifications defined by DRP-DNPP.

Refurbishment of I&C System (brief description is in [L5]), planned for period 2002-2009 (details in Figure No.1) had affected the properties of ANMS, especially in the range of the resources. Properties of new I&C system now enable to obtain all necessary parameters using standard procession. However, this "standardization" has another effect – we had to verify, that the delay and alternation of the signals induced by standard procession didn't change their properties to perform correct procession in ANMS (see Chapter 4 for details).

2. ORIGINAL CONCEPT OF PHYSICS STARTUP TESTS INSTRUMENTATION

Original design of ANMS was based on the fact, that the data, which are necessary for correct evaluation, are not accessible using standard information system (IVS, later IVS+BLAN) due its ability to store the data with period, which is not suitable for evaluation (measurements of n.flux, temperature, pressure, etc…) or didn't have appropriate output for synchronized archivation (CA position). For the purposes of measurement with frequency lower or equal to 1s there was the "nonstandard" room (NMS) established, where the appropriate signals are concentrated using the parallel connections from the sensors. All these parameters (analog values) are transformed into their current representation, almost in range 5÷20mA.

The design of the ANMS, used at DNPP since 1992, developed by NPPRI, is adequate to the date of its creation and to conditions at DNPP in that time. Its basic features are (more in [L4]):

- Transportable system;
- 2 nodes – one is located in NMS (NOD1 - communication with analog devices), the second (NOD2) is at MCR, used for managing tests, storing the datasets and for evaluation purposes;
- Procession of 83 analog signals and 111 binary signals, whose are concentrated in 2 switch-boxes in NMS room;
- N.flux for physics tests evaluation is derived from dedicated IC from AKNT-2 (MPIC in channel No.3), signal of n.flux and reactivity is transferred to ANMS via reactivity meter DRN-501;
- 2x PC486 based system, OS QNX, ARCNET net cards, 2x EPSON FX-850 Printer, Roland DXY 1200 Plotter;
- Analog devices in NMS room (connected to NOD1) :
    - Tektronix VX 1401 - switching exchange unit for analog signals processing Tektronix commutator VX 4332, VX 4372 (88 channels);
    - 2-state measuring switching exchange MESIT;
    - CA-positioner (NPPRI prototype).
- Data are stored in proprietary binary format (s.c. KRI-files), the number of values and time interval are limited;
- All ANMS applications are written in ANSI-C with additional specification of supplied QNX cc-compiler (QNX-Windows).

During the years, ANMS was, according to possibilities, partially upgraded :

- 1998 – introduction of DRN-501 reactivity meter;
- 1998 – developing the application, which converts binary KRI-file into 2 ASCII files, readable by MS Excel;
- 1999 – evaluation part of ANMS was converted into ANVS software pack, which allows (together with DRN-510 capacity to store data) to reconstruct the necessary datasets in the case of ANMS failure. This property was used in implementation stage to evaluate the tests from datasets created in new I&C system (details in Chapter 4);
- 1999 – change of QNX Version 2.15 to 2.21 to solve Y2K problem;
- 2000 – replacement of NOD2 computer with better ones to raise its performance;

- 2001 – new modules were implemented into ANVS to evaluate the tests based on DCAWM methodology.

Unfortunately, these activities couldn‘t prevent the origination and evolution of following problems:

1. The incompatibility of the QNX with the ČEZ standards (Windows, HP-UX) has complicated the maintenance of ANMS;
2. The properties of AKNT-2 and restrictions for its operation, declared in guidelines, have been caused, that after its successful examination in year 2000, the measurement of CA worth using DCAWM methodology, has been interrupt and planned to continue in future;
3. After the implementation of the new methodology of rod drop test evaluation [L1], the evolution of the discrepancies between experimental and theoretical values was observed. Analysis and corrective actions in period 2001-2002 have been indicated, that the philosophy, used for calibration of the IC before the tests realization, is incomplete and needs to be modified;
4. After year 2000 we observed the increased frequency of ANMS parts failures, whose have delayed the startup process or did make the handicaps in evaluations of the tests due the incomplete datasets.
5. The repair procedures were almost accompanied with lack of spare parts.

Limitations of the system and problems, mentioned above, were lead to requirements to replace ANMS with ones, to be sufficient in operation in next 10÷15 years, in better case to the end to DNPP lifetime.

All these problems have contributed to the fact, that the planned I&C refurbishment have had invoke the urgency to upgrade the ANMS not only from the side of sources, but to solve problems mentioned above, too.

3. PROJECT T544 (DUKOVANY NPP I&C REFURBISHMENT) AND IT’S INFLUENCE AT PHYSICS STARTUP TESTS

From the point of view to use data in ANMS we are concerned primarily at systems producing parameters of n.flux (DNIS), reactivity (IDMS-NCU) and CA positions (RRCS). Table No.1 describes their properties in order to using them in ANMS (for comparison the properties of old I&C system are described too), locations of new DNIS ICs are shown at Figure No.3.

Initial information, derived from the T544 documentation in autumn 2001, have been indicated, that the PCS will concentrate all data (including output from all ICs and CA positions measurement) and will be able to create the access point for ANMS. Due this fact, initial requirements, defined in related PoM (Project 5125 – "Conversion of ANMS") in 01/2002 were concerned on the following properties:

- Data should be scanned with basic period 1000ms;
- In the case of values related to n.flux and CA position this period is required about 100÷200ms (after measurements and analysis, performed in 2002÷2003, this value was adjusted to 200ms);
- ANMS will be able to use extended set of parameters, whose weren't accessible in previous version (data from all ICs, all CA positions, neutronic and thermal reactor power calculated in KVRK, values of boron acid concentration from BN-160 boron acid concentration meters, …);
- ANMS will be connected to PCS via access point (DZEU) as a client of PCS network;
- ANMS will be installed on transportable computer (class notebook) with additional external devices (LCD monitor, mouse, keyboard, DVD recorder, …);
- Due to restrictions in new I&C system [3] the configuration for n.flux procession will be performed in ANMS using all available methodology developed in last 5 years (based at the possibility to select the filtration method, application of the offset procession, …). Of course, the fulfillment of that requirement expects, that the procession of that signal will reflect the possible alternation induced by procedures used in signal procession in I&C system. In the best case, ANMS will be able to process "as most possible" primary values;
- There will be the possibility to setup this configuration for off-line analysis in ANVS;
- The adjusted configuration of reactivity calculation will be validated using the deviations between average values of reactivity calculated in ANMS and reactivity obtained from in-hour formula;
- Since year 2004 the program SCORPIO-KRITEX as a primary tool for controlling the criticality achievement is used. Reflecting this fact, the similar program in ANMS environment (ANMS-KRITIKA) will now be able to perform this control using alternate methodologies (extrapolation of the boron acid concentration changes, inverse counting method, "doubling-time" methodology,…) and inputs, too;
- All actions in ANMS environment, especially configuration changes, will be logged;
- The ANMS environment (program interface, data structure) should be compatible with CEZ standards and easy-to-use (this property covers the ability of the user-friendly interface, simplification of the installation procedure, diagnostic and validation of received parameters);
- ANMS will be in full operation by startup of DNPP Unit 3 in 04/2005 (according to finalize the refurbishment process at this unit).

Reflecting these requirements the initial concept and design of the improved ANMS (iANMS) described in Initial Project had the following additional features:

- Data will be transferred using TCP/IP protocol at DZEU using the O-GATE client program (O-GATE is the server application on the PCS side, which is communicating with external users);
- All data, which are described in database, will be stored during ANMS operation into proprietary format related to licensed database engine - DSC (Datalogging and Supervisory Controle), developed by National Instruments in MS Windows (Windows XP);
- Applications to manage the received data will be developed in LabView 7.0 environment (maintenance, data exporting and importing). Export from database will be realized using new defined KRI data format;
- Evaluation part of ANMS will use the new defined KRI files as an input and will be compatible with present ANVS;
- Hardware : 2x notebook IBM Pentium 4M, 2GHz, 512 MB RAM, 40GB HDD, ATI Mobility Radeon 7500, Ethernet Intel PRO/100 WE (RJ-45), modem Agere Systems AC97, 14“ TFT, Matshita UJDA730 DVD/CD-RW, USB DVD-RW, EIZO LCD monitor 19“, optical USB mouse, external PS2 keyboard.

During the implementation stage at DNPP Unit 3 in period 2002÷2005 the I&C project documentation was precised in more details, so we were able [4] in year 2003 [L3] to define the usable signal set (output current from ICs as the primary set, neutron powers and filtered currents from ICs – details in Table No.1 - as the alternate sets).

The problems with the ANMS failures and the fact, that after 2003 there will be together 13 startups at the units with old I&C system and we wanted to use the new properties of iANMS in these startups, have leaded to requirement to replace NOD1 with better one. The Project 5110 – “NOD1_2003s – The provisional replacement of NOD1” was realized in period 2003÷2004 and Project 5125 was adjusted to implement new properties to run iANMS with both configurations. The PCE of the iANMS was divided into 2 sections also – one was realized in year 2004 by startup of Unit 3 in 05/2004 (pilot version of iANMS), the second at the same unit in 04/2005 (final version of iANMS).

4. PROCESS OF IMPLEMENTATION IN PERIOD 2002÷2004

Checking the consistency with previous version of ANMS was performed in specific conditions according to schedule plan of I&C changes:

- There was a set of testing programs for DNIS and IDMS-NCU systems developed to verify the properties of these systems including the comparison with previous systems (AKNT-2, DRN-501) in their response to a specific power changes. Some of the results were used in the ANMS consistency verification and some test programs were implemented into guide for startup test (P011a – “Physics startup test”) as a standard one;

- During the period the quality of datasets produced on the new I&C system wasn’t the same. The sufficient data for physics tests results were available since 2004, when the complete way of n.flux signals translation (IC→NDCU→PPU→IDMS-NCU→IDMS-SSU→PCS) was realized. In years 2002÷2003 the datasets from EX-CORE and IDMS-NCU were recorded at the tester. Due the incompatibility of the structure of these datasets with the inputs to ANVS modules we couldn’t evaluate adequate tests and that fact was leaded to the adjusting the format of new KRI-files;
- According to schedule plan there was in year 2004 the MPIC from channel No.3 removed. Due this fact there was in year 2003 the provisional connection between NDCU output (analog signal 0÷10[V]) of the middle IC (HLIC(A)) in provisional DNIS string in channel No.11 and switch-box in NMS room established (configuration of provisional DNIS string is at Figure No.2) to compare the response of MPIC with DRN-501 in channel No.3 and output from the HLIC(A) in channel No.11 and next, in year 2004, to realize physics startup tests using the output from HLIC(A) in channel No.11 and pilot version of iANMS programs with NOD1_2003s running.

A specific set of tests in years 2002-2004, reflecting the state of T544 project, has been realised:

4.1 STARTUP OF UNIT 3 IN YEAR 2002

A first provisional DNIS string was loaded into channel No.11. Commissioning tests during Unit 3 outage and operation were performed to adjust HLIC and LLIC characteristics.

During start-up stage an additional test - measurement of CA system total worth with one CA stuck in position 21-46 – was realised in order to compare the symmetrised results of the IC response in channels No.3 and 11.

The discrepancies between theoretical and experimental values of total CA system worth over the criteria value was identified in the case of measurement with CA at position 06-55 stuck (standard test). Reflecting the analysis and corrective actions (using results from datasets of HLIC(A) too) there was a request to properly configure signal processing in ANMS enforced.

The comparison of the results [5] (with correction for results from DRN-501) is in Table No.2. Figure No.4 shows the course of n.flux and reactivity (uncorrected and corrected values) from MPIC-03. Correction was made using offset value for output current ($I^{offset} = 3.05x10^{-10}$[A]).

4.2 STARTUP OF UNIT 3 IN YEAR 2003

A set of test procedures to qualify the IDMS-NCU as a lead reactivity meter (to display data at MCR) after 2004 was performed.

A connection between NDCU output and NMS room was established in order to receive synchronized response of MPIC-03 and HLIC(A) from channel No.11 in the ANMS. During the tests procedures (CA connection checking) there has been identified, that the HLIC(B) is connected instead the HLIC(A), so we didn't realise the planned comparison. For analysis and comparison [L3] there was an off-line datasets from tester used. As a result the primary set of input parameters and configuration for reactivity calculation was recommended.

4.4 STARTUP OF UNIT 3 IN YEAR 2004

A 2 additional PDNIS strings were loaded into channels 3 and 19. A set of procedures to validate properties of DNIS by the various forms of inserted reactivity was performed.

A pilot version of iANMS in configuration for old I&C system was successfully tested together with NOD1_2003s and HLIC(A)-11 as primary source of n.flux signal. Comparison of the results for selected physics tests (temperature reactivity coefficient during coolant heat-up to 260°C, measurement of CA system total worth with one CA stuck at position 21-46) using various sources of primary signals was performed :

- Figure No.5 displays the comparison of HLIC(A) response (n.flux, reactivity) by the coolant heat-up using the DRN-501 and average values from IDMS-NCU (values from every channel processed in IDMS-NCU weren't transferred yet);
- Figure No.6 displays the values of temperature coefficient calculated from various sources of primary signal (n.flux from DRN-501, output current from HLIC(A)-11 stored in PCS, average current from IDMS-NCU);
- Table No.3 is contenting the values of CA system total worth with CA at position 21-46 stuck using various sources of signal (signal received on ANMS, output current from all HLICs, average current and reactivity from IDMS-NCU – for this test only HLIC(A)-11 was included), theoretical values were calculated for response in channel No.11 and the axial center of the channel.

4.5 MEASUREMENT OF HLIC RESPONSE AT SMALL REACTIVITY CHANGES AT NOMINAL POWER

Quality of IC output signal (scanning period and possible alternation) is the key property for evaluation of the test "Measurement of power reactivity coefficient at nominal power", based on the small reactivity changes related to CA working group (Bank No.6) movements (6 cm below the initial position, 4s paused, back to initial position).

In 12/2004 there was a measurement performed, which aim was to receive data during these manipulations to verify quality of received parameters (output current) in order to adjust the procession of this type signal in program ANVS-VYKORE. Figure No.7 shows its response in comparison with other processed signals (reactor power, filtered current by IDMS-NCU) – delay and alternations induced by the procession in new I&C system are identified here.

5. REALISATION OF PHYSICS STARTUP TESTS IN 2005

The outage of Unit 3 in 2005 was realized in specific conditions, reflecting the changes in technology (finalization of I&C refurbishment process and turbines low-pressure parts change, etc.). Duration of this outage was 71 days, startup process was divided into 5 periods and together 106 tests were realized.

A new type of fuel (Gd-2) was loaded and this fact has been implicated, that the physics tests were realized in extended configuration - together 18 tests, 9 of them were performed using iANMS. Table No.4 shows the list of criteria test, deviations between experimental and theoretical values (with the acceptable values), where the iANMS-ANVS outputs were used.

A validation of reactivity calculation in iANMS was performed using datasets received during DNIS validation procedures. Table No.5 shows the comparison between reactivity average values obtained from the procession in iANMS (ICs output current at input, no further "preprocession") and reactivity average values obtained from in-hour formula (reference calculation). Average values were calculated from selected data segment by reactor power change after insertion of negative reactivity by CA working group movement approximately 8 cm below the initial position (reactor power was decreased from level 10^{-1} to 10^{-5} [$\%N_{nom}$]). Because the deviations didn't exceed value ±5[%rel.] and noise was below 0.5[cent], this configuration was selected for further procession.

Comparison of the experimental and theoretical values in test "Measurement of CA total worth with one CA (06-55) stuck" was realized for all HLICs around the core (see Table No.6).

Measurement of CA working group worth and "ejected" CA worth was realized using both methodologies (DCAWM and boron acid concentration changes). Results of these tests confirm (see Table No.4, Figure No.8 and 9), that the methodology, which uses boron acid concentration change, can be replaced by DCAWM methodology in future.

Values, obtained from both "dynamic" tests, demonstrate the reliability of the procedures used in data preparation as well (MOBYDICK-SK for simulations and n.flux response at the sensors around the core, SIMUR2N for reactivity effect calculations).

6. CONCLUSION

Properties of the new I&C system, whose allow to realize all physics tests, modifications of the requirements to properly perform the calibration of the ICs in the conditions of new I&C system, advance in the procession of n.flux conversion into reactivity in last 5 years, possibility to use the new resources and analytical tools to validate results – all these aspects have been participated on the fact, that the process of ANMS conversion wasn't only the simple conversion of the validated procedures used in original ANMS, but it was an improvement of its properties – support for this claim is demonstrated using the results obtained from the startup of Unit 3 in 2005.

REMARKS

[1] - Activities, connected with Step 1, especially in the case of "dynamic" tests (nonsymmetrical reactivity insertion, i.e. measurement of CA system total worth with one CA stuck, measurement of "ejected" CA without boron acid concentration change – s.c. DCAWM methodology), represent huge amount of work in the stage of preparation and have not direct connections with the requirements defined for startup test instrumentation, but their consistence with Steps 4 and 5 (simulation process, kinetic parameters preparation) is important for correct evaluation. For conditions at DNPP they are based on applying the technology derived from the implementation of spatial effect response on the sensors around the core (see [L1], [L2] for details).

[2] – "Alternate" means in this case, that the primary signal procession (Step 5) can be performed, if the alternatives for "preprocession" (i.e. before reactivity determination – filtering method selection, offset applying, ..) are available (more in Chapter 3 or [L3]).

[3] – For example, the location of the interface parts of IDMS-NCU into rooms, which are not accessible for operational physicist and their design excludes, that the control of standard behavior of the reactivity meter (loading the appropriate set of kinetic parameters, change in configuration) will be realized by effective way.

[4] – In the initial analysis we had suppose, that the values, related to 0÷10[V] signal changes will be used as a primary set and the relevant procession of this type signal in iANMS was prepared. During the evolution of Project T544 these signals weren't included into set transferred from SP3 to PCS and there was no way to enforce our requirement. As a result the modification of n.flux procession in ANMS was modified.

[5] – Where used, the relative deviation between experimental ($value^{exp}$) and theoretical ($value^{teo}$) values is defined as :

$$\text{relative deviation} = (value^{exp} - value^{teo}) / value^{exp} * 100 \; [\%rel.]$$

LIST OF NOMENCLATURES

ANMS	-	Startup test instrumentation
ANVS	-	Analytical and evaluation system for physics startup tests
CA	-	Control Assembly
ECR	-	Emergency Control Room
EP	-	Power Level Range
DCAWM	-	Dynamic Control Assembly Worth Measurement
DNIS	-	Digital Neutron Instrumentation System
DNPP	-	Dukovany Nuclear Power Plant
DRP-DNPP	-	Dukovany NPP Reactor Physics Unit
DZEU	-	Data Access Point for External Users
HL	-	High Level
HLIC	-	Ionization Chamber – High Level Range
IC	-	Ionization Chamber
IDMS-NCU	-	Interface and Data Maintenance System – Nuclear Control Unit
IDMS-SSU	-	Interface and Data Maintenance System – System Surveillance Unit
KVRK	-	Core Surveillance and Monitoring System
LL	-	Low level
MCR	-	Main Control Room
MP	-	Intermediate Level Range
MPIC	-	Ionization Chamber – Intermediate Level Range
NDCU	-	Neutron Detector Conditioning Unit
NPPRI	-	Nuclear Power Plant Research Institute Trnava, Slovak Republic
PAMS	-	Post Accident Monitoring System
PCE	-	Program of Complex Examination
PCS	-	Process Computer System
PoM	-	Request for Modification
PPU	-	Parameters Processing Unit
PZ	-	Source Level Range
SP3	-	SPINLINE 3 – Digital Modular Technology for I&C System designed by a consortium between Data Systems & Solutions (DS&S) and Framatome ANP

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TABLES AND FIGURES

	Old I&C System	New I&C System
N.flux measurement		
Labeling	AKNT-2 (SUGAN)	EX-CORE (DNIS)
Level distinction (Values in [%N_{nom}])	3 PZ - ($1.0x10^{-8}÷2.5x10^{-2}$); MP - ($1.0x10^{-4}÷1.0x10^{+2}$); EP - ($1.0x10^{-1}÷1.1x10^{+2}$).	2 LL - ($1.7x10^{-7}÷3.4x10^{-3}$); HL - ($2.0x10^{-5}÷2.2x10^{+2}$).
Number of channels	3x6+2 Base System (SKZ); 1x3 ECR Support system (SKN); 1x6 SKVP; 1xdedicated IC MP (Channel No.3).	2x6
Detector types	PZ : BDPN3-17, movable; MP : BDPN3-16, movable, , γ-compensated; EP : BDPN3-15, fixed, , γ-compensated.	LL : CPNB44 ,fixed; HL : CC83VV,fixed, γ-compensated
Reactivity calculation		
Labeling	DRN-501	IDMS-NCU (A,B)
Number of processed channels	1	6
CA positioning		
Labeling	SORR	RRCS
Possibility to receive and store CA positions	None, CA positioner in ANMS used instead	Yes
Parameters available for ANMS		
N.flux (reactor power)	1x current from dedicated MPIC-03 in 0÷10 [V] and [A] representation; corrected signal from EP-1, MP-5, PZ-7 and PZ-8 (procession in Hindukush).	6x output signal from LL in [imp/s]; 6x output current from HL (PPU) in [A]; 6x power from LL (PPU) in [%N_{nom}]; 6x power from HL (PPU) in [%N_{nom}]; 6x filtered current from HL (NCU) in [A]; 1x av.value of filtered current from HL (NCU) in [A].
Period	-	3x period from LL (PPU) in [s]; 6x period from HL (PPU) in [s].
Reactivity	1x value in [β_{ef}]	6x values in [pcm], 1x av.value in [β_{ef}]
CA position	2x (from position meter) (one represents CA-group position, the second the individual CA position)	37x

Table No.1: Comparison of the properties of old and new I&C system in order to produced parameters usability in ANMS (n.flux, reactivity, CA position)

	2002	2003	2004	2005	2006	2007	2008	2009
Unit 3	□	□	□	■				
Unit 4					■	□	□	[]
Unit 1			□	□	□	■		
Unit 2				□	□	□	■	

□ - Short Outage ■ - Long Outage [] – extended Outage

Figure No.1: I&C system modernization process schedule

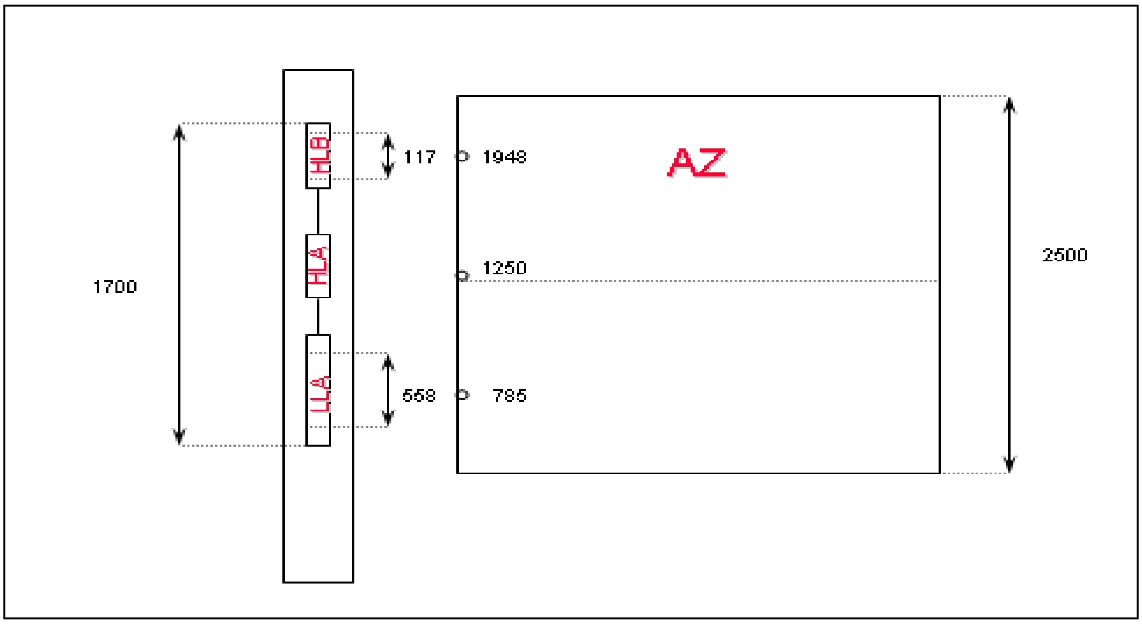

Figure No.2: Provisional configuration of DNIS channels in testing stage in 2002÷2004 (values in [mm])

	DIV I		DIV II		DIV III	
	LoP A	LoP B	LoP A	LoP B	LoP A	LoP B
● HL	02	11	10	19	18	03
● LL	01	14	09	22	17	06

○	05, 07, 13, 15, 21, 23	MP for diagnostic
○	04, 08, 12, 16, 20, 24	Not instrumented

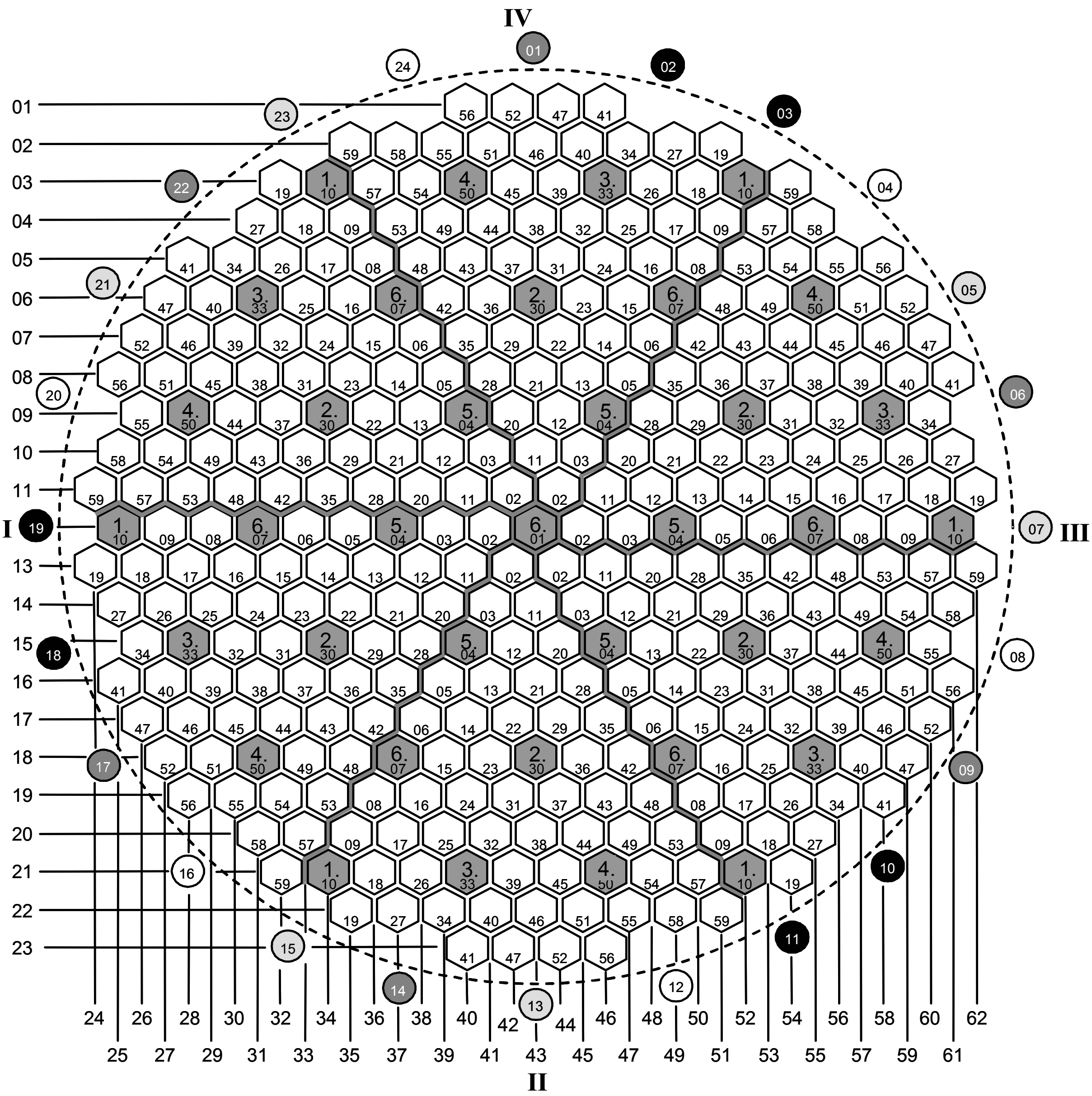

Figure No.3: DNIS channels geometry around the core since year 2005

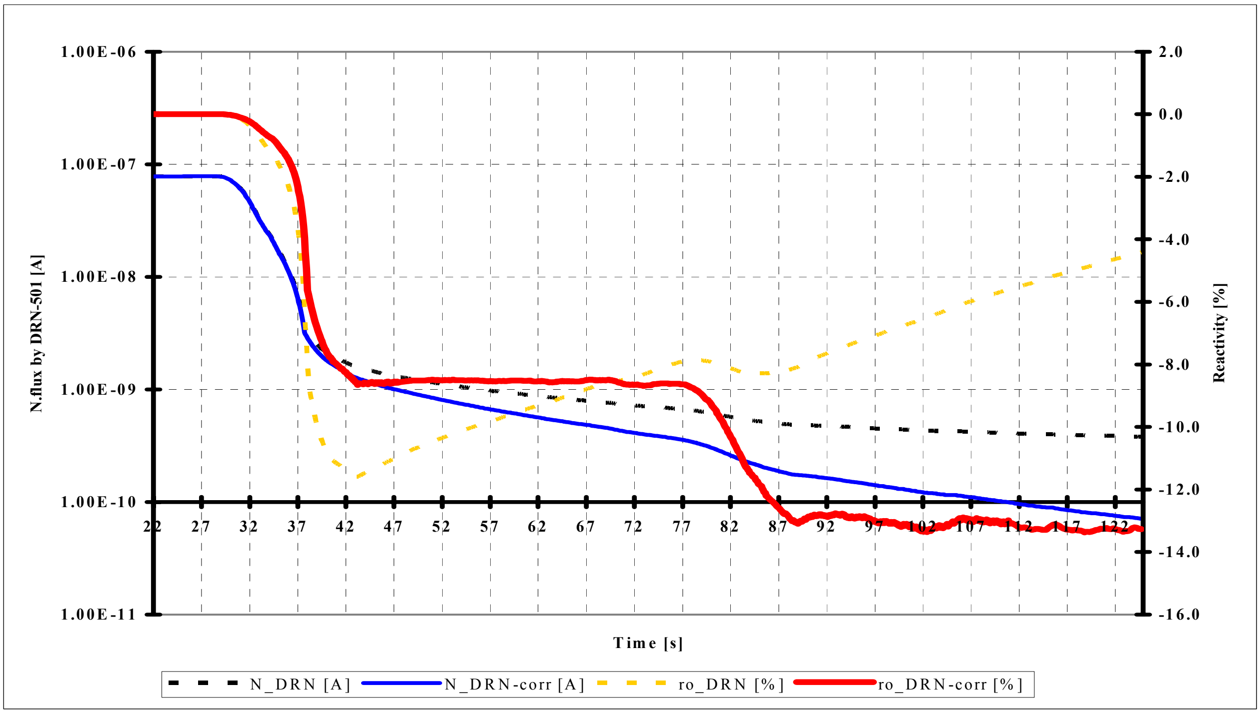

Figure No.4: Course of the n.flux and reactivity during the test "Measurement of CA system total worth with one CA (06-55) stuck ", DNPP Unit 3, Cycle 16 (2002), uncorrected and corrected values

	Experimental value MPIC-03 / HLIC(A)-11 [%/%]	Theoretical value [%]	Relative deviation [%rel./%rel.]
CA 06-55 stuck			
Total CA worth with one CA stuck	9.0 / -	7.6	+13.6 / -
Total CA worth	13.9 / 12.0	11.6	+16.8 / +3.3
CA 21-46 stuck			
Total CA worth with one CA stuck	- / 7.8	8.0	- / -1.9
Total CA worth	12.5 / 12.0	11.3	+7.2 / +3.4

Table No.2: Comparisons of CA system total worth with one CA stuck (06-55, 21-46) in startup of DNPP Unit 3 in year 2002

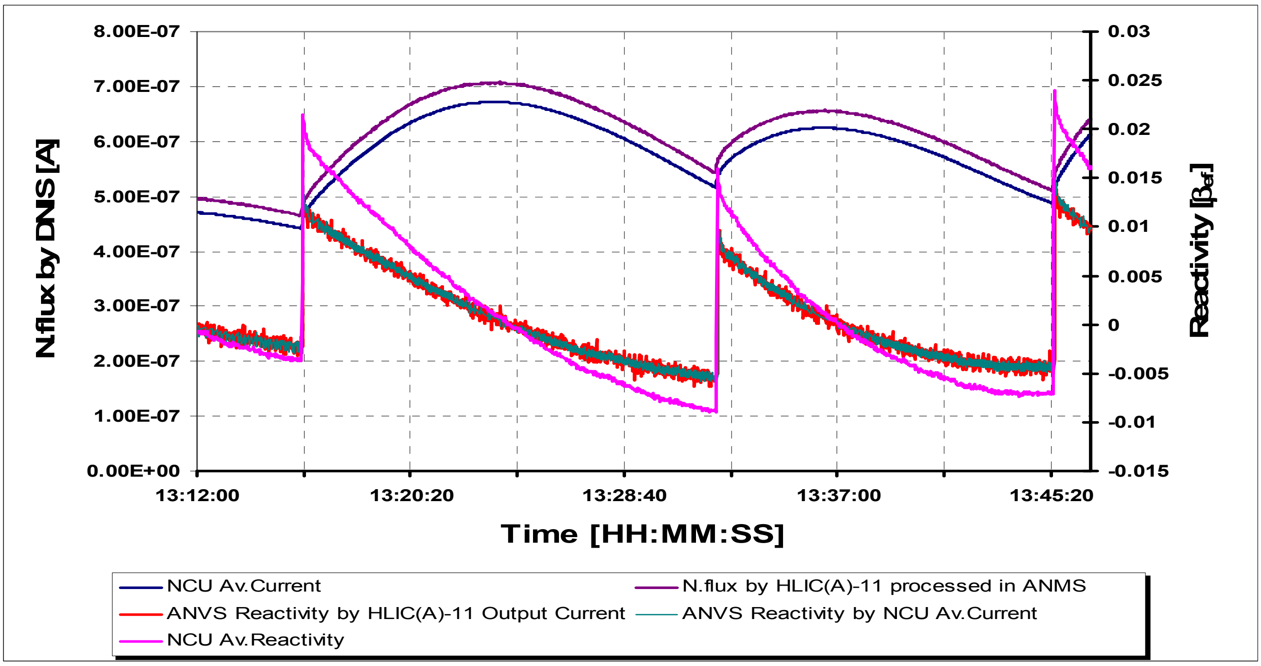

Figure No.5: Comparison of the course of the n.flux and reactivity during the test "Coolant heat up to 260°C", DNPP Unit 3, Cycle 18 (2004) – n.flux and associated reactivity from DRN-501 and IDMS-NCU + av.reactivity from IDMS-NCU (detail)

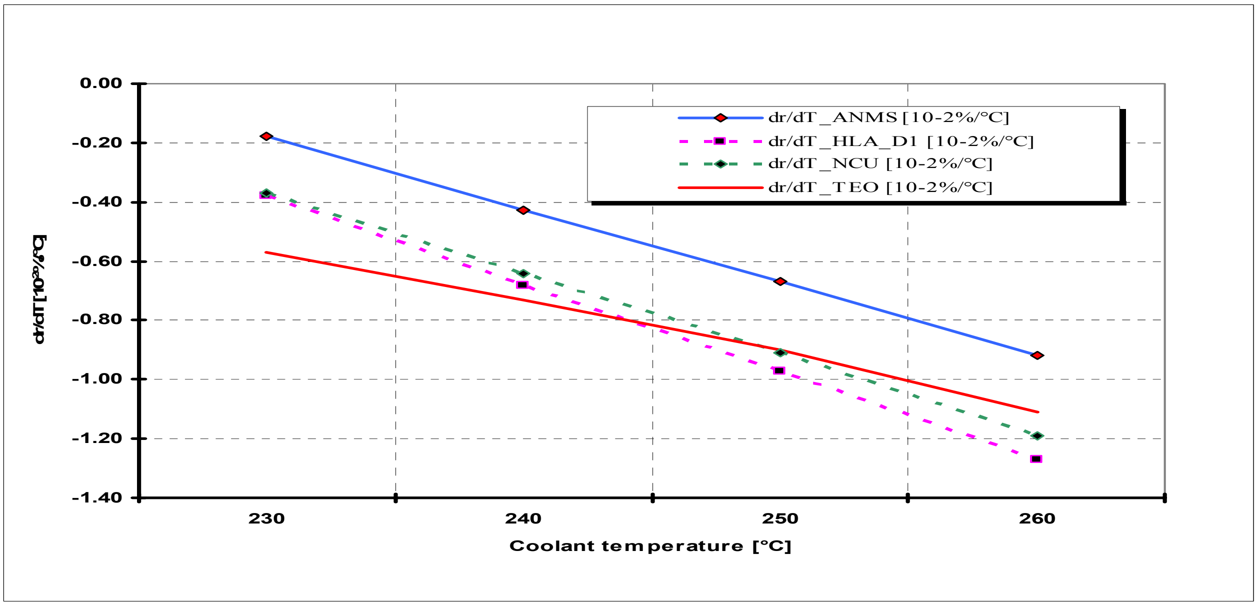

Figure No.6: Comparison of the temperature reactivity coefficient values obtaining from the datasets during the test "Coolant heat up to 260°C", DNPP Unit 3, Cycle 18 (2004)

Source for reactivity calculation	CA system total worth with CA 21-46 stuck	CA system total worth
	[%]	[%]
ANMS recording	8.34	11.98
HLIC(A)-11 current	8.38	11.83
HLIC(A)-11 power	8.40	11.84
HLIC(A)-19 current	-	11.74
HLIC(A)-03 current	-	11.84
HLIC(B)-11 current	8.05	11.49
HLIC(B)-19 current	-	11.63
HLIC(B)-03 current	-	11.70
Average NCU current (HLIC(A)-11 selected)	8.26	11.83
Average NCU reactivity (HLIC(A)-11 selected)	8.28	11.84
Theoretical value (response at HLIC(A)-11)	8.27	11.77

Table No.3: Comparison of the values from test "CA total worth with one CA (21-46) stuck" obtaining from the datasets received at ANMS and PCS, DNPP Unit 3, Cycle 18 (2004)

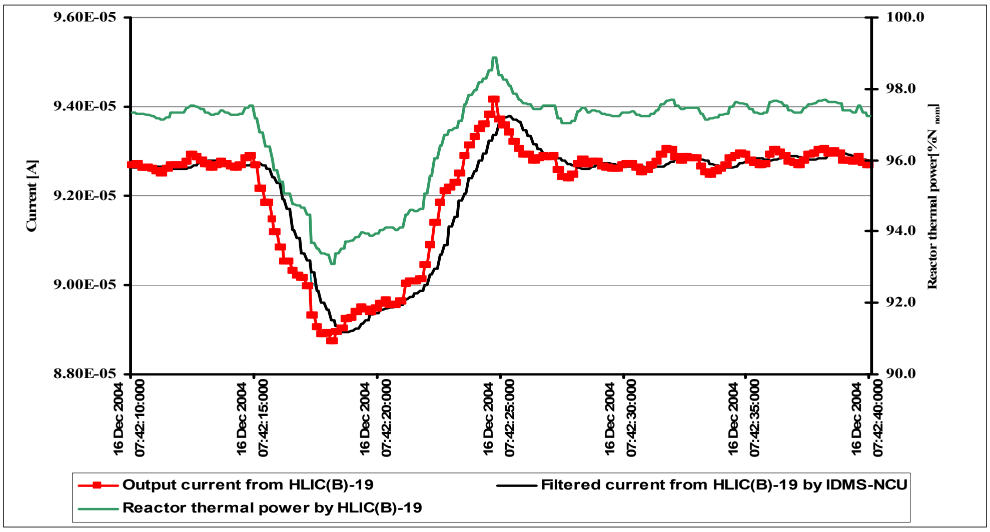

Figure No.7: Comparison of the output parameters from HLIC(B)-19 during the reactivity changes induced by CA working group movement according to realization of the test "Power reactivity coefficient measurement at nominal power", DNPP Unit 3, Cycle 18 (12/2004)

Name of test criteria	Type of deviation	Unit	Value	Criteria
Max deviation of temperature reactivity coefficient at zero power	Absolute	[10^{-2}%/°C]	+0.36 (at 260°C)	±0.50
Deviation of CA system total worth with CA 06-55 stuck (IC-03 response)	Relative	[%rel.]	+2.26	±17.0
Deviation of CA system total worth (IC-03 response)	Relative	[%rel.]	+1.47	±17.0
Deviation of worth of working CA group (HRK-6) (boron acid change)	Relative	[%rel.]	-3.06	±15.0
Deviation of worth of "ejected" CA 06-49 (boron acid change)	Relative	[%rel.]	+1.9	±15.0
Deviation of boron acid worth	Relative	[%rel.]	+1.6	±15.0
Deviation of CA working worth group (DCAWM methodology)	Relative	[%rel.]	-3.1	±15.0
Deviation of "ejected" CA 06-49 worth (DCAWM methodology)	Relative	[%rel.]	+3.7	±15.0
Deviation of power reactivity coefficient at nominal power	Relative	[%rel.]	+2.3	±20.0

Table No.4: Evaluation of physics startup test of DNPP Unit 3, Cycle 19 (2005), where the iANMS was used for evaluation

IC	Labeling in iANMS	Measured reactivity [cent]	Reference reactivity [cent]	Rel.deviation [%rel.]	Noise [cent]
IC-02 (D1 LoPA)	NTOKANMS1	-9.86	-10.13	-2.7	0.25
IC-10 (D2 LoPA)	NTOKANMS2	-9.90	-10.23	-3.2	0.30
IC-18 (D3 LoPA)	NTOKANMS3	-9.86	-10.12	-2.6	0.27
IC-11 (D1 LoPB)	NTOKANMS4	-9.88	-10.17	-2.9	0.24
IC-19 (D2 LoPB)	NTOKANMS5	-9.86	-10.12	-2.6	0.24
IC-03 (D3 LoPB)	NTOKANMS6	-9.95	-10.20	-2.5	0.27

Table No.5 : Reactivity comparison between measured and reference value, DNPP Unit 3, Cycle 19 (2005), realization of OP 051/05, reactor power change after reactivity prompt insertion -8 cm CA position change (26.4.2005, 02:00÷03:00, relative data segment 2181÷2703 [s])

Source	CA system total worth with CA 06-55 stuck			CA system total worth		
	Experimental value	Theoretical value	Rel. deviation	Experimental value	Theoretical value	Rel. deviation
	[%]	[%]	[%rel]	[%]	[%]	[%rel]
(IC-02)	9.44	9.89	-4.8	11.21	11.45	-2.1
(IC-10)	10.89	11.45	-5.1	11.10	11.46	-3.2
(IC-18)	11.03	11.47	-4.0	11.23	11.46	-2.0
(IC-11)	11.24	11.31	-0.7	11.43	11.30	1.1
(IC-19)	11.41	11.32	0.8	11.62	11.30	2.7
(IC-03)	7.51	7.34	2.2	11.58	11.31	2.3

Table No.6: Comparison of CA system total worth by DNIS channels response with CA at position 06-55 stuck

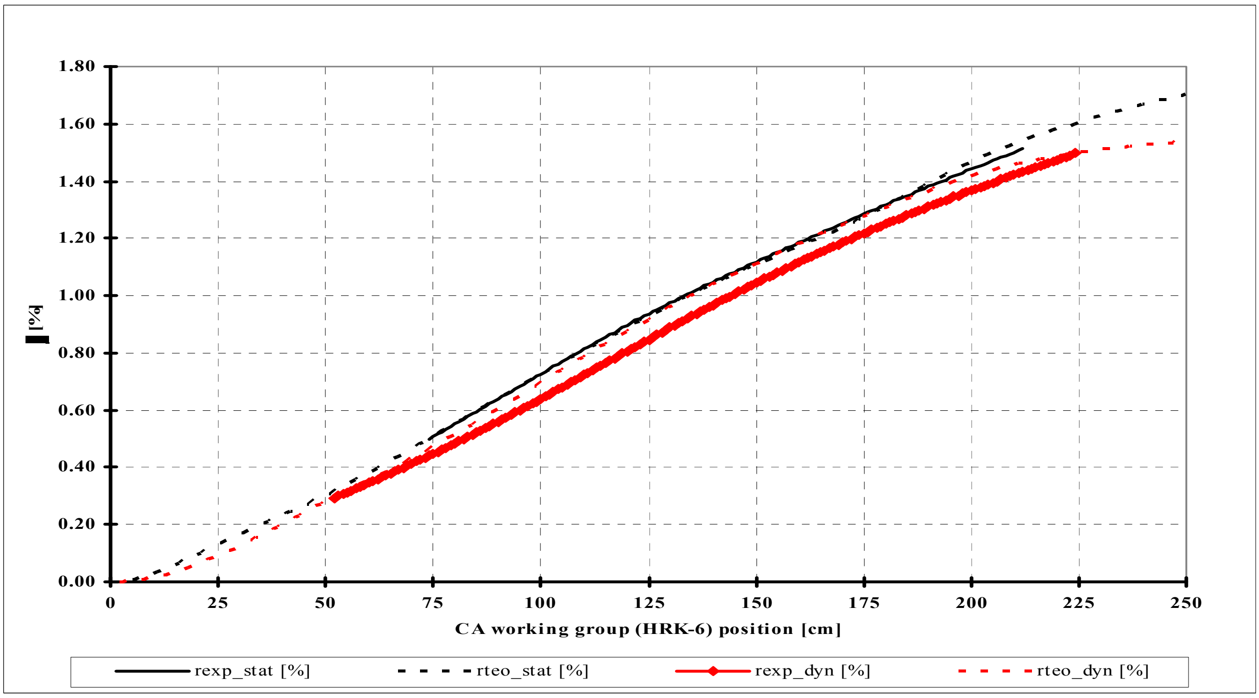

Figure No.8: Comparison of CA working group (HRK-6) integral characteristics using „dynamic“ and „static“ methodology

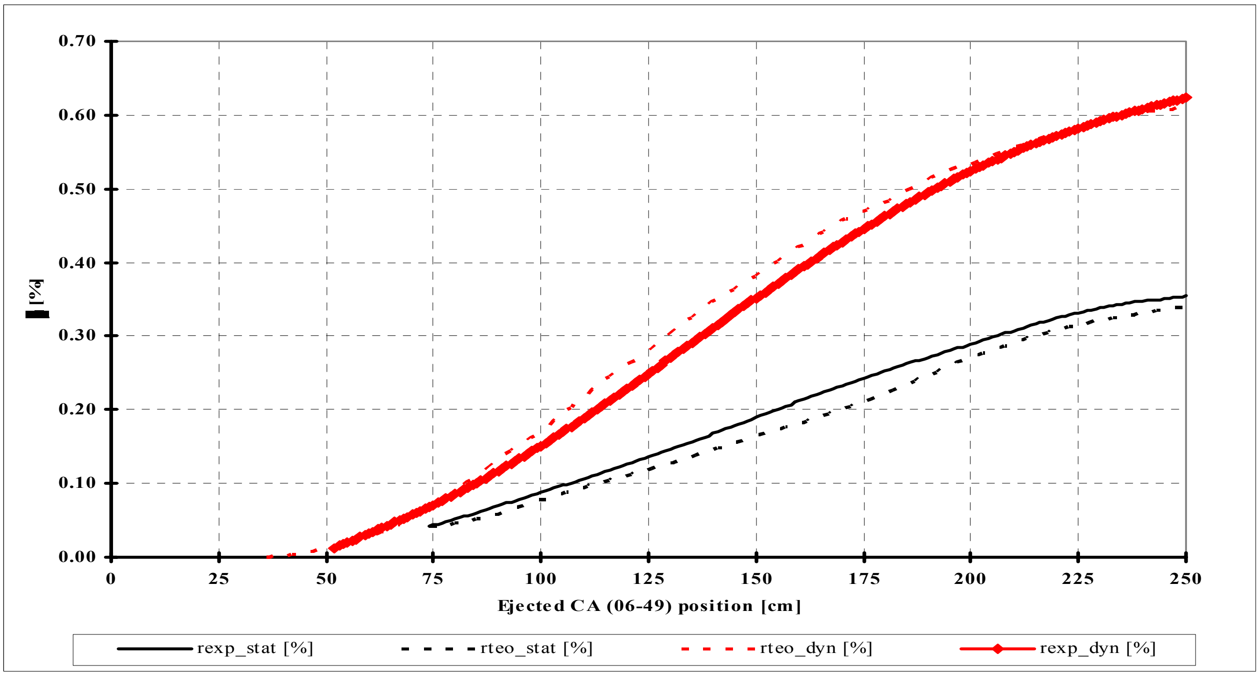

Figure No.9: Comparison of „ejected“ CA (06-49) integral characteristics using „dynamic“ and „static“ methodology