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Utilisation of Gd II Fuel Assemblies at Bohunice NPP Unit 3, 4

O. Grežďo, M. Kačmar 9/2006

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Contents

1. Brief summary of Bohunice V-2 (3. and 4. unit) NPP fuel cycle

In the fig. 1. you can see evolution of nuclear fuel cycle in Bohunice V-2 up to the moment. This changes results in better nuclear fuel cycle economy and reduction of neutron flux on reactor vessel.

The close changes of fuel cycle is expected in connection with increase of the reactor power:

-104% (2008 3.unit)
-105%(2009 4.unit)
-107%(2010 3 and 4. unit).

Number of leakage assemblies is in the fig.2

2.Gd II fuel licensing for 3. and 4. unit Bohunice NPP

Choice of supplier and fuel licensing took aproximately four years. Regulatory authority accept new fuel 26 months after contract was signed. If we want prepare new contract in 2011 year(current contract is valid to 2010), we dont have a lot of time.

3. Consequences of Gd II fuel utilization

3.1Change of operational limits and conditions

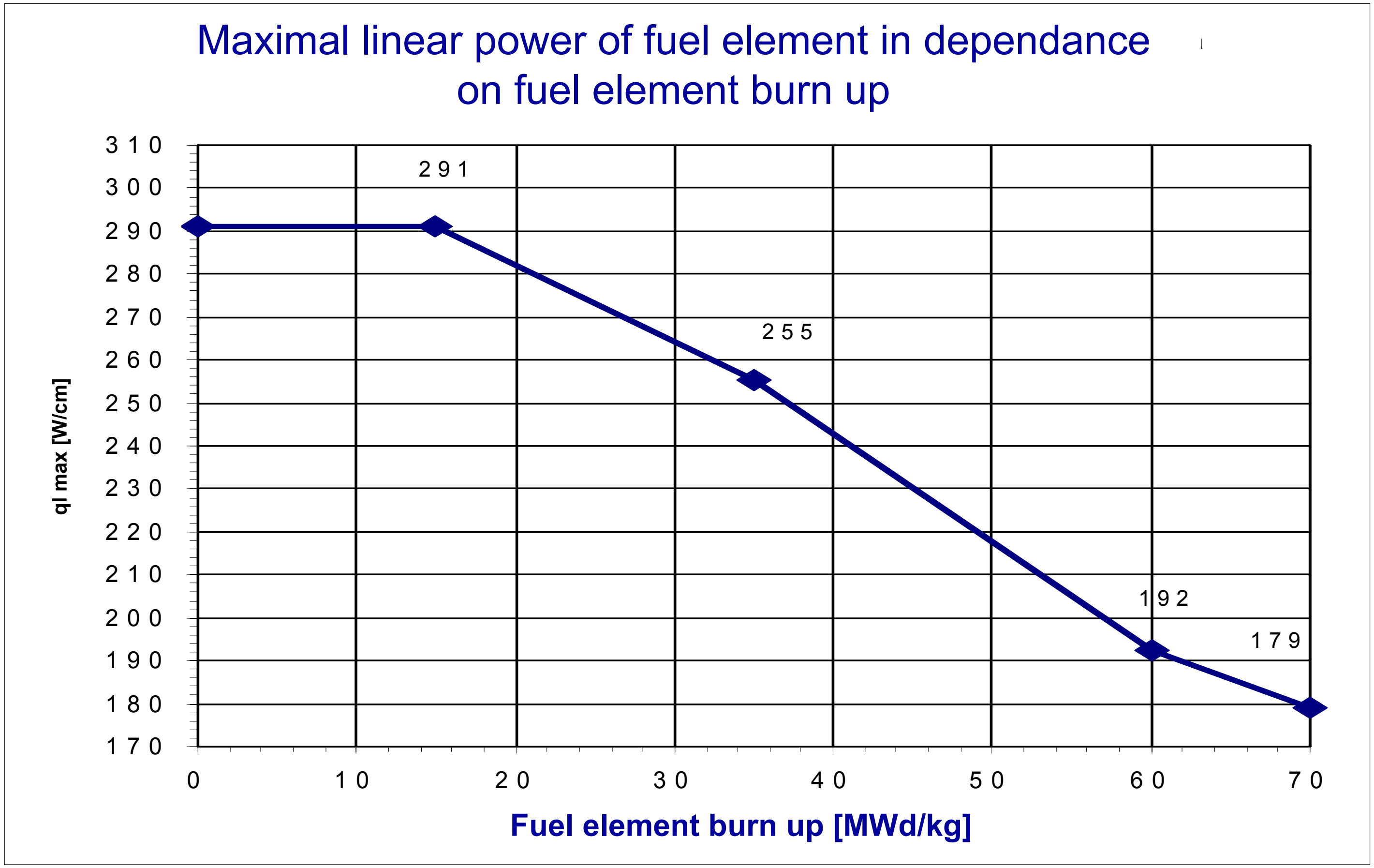
Power distribution

both $k_q \leq 1{,}40 \frac{N_{dov}}{N}$ and kq $\leq$ 1,8 - for 1.generation fuel

both $k_r \leq 1{,}60 \frac{N_{dov}}{N}$ and $k_r \leq 2{,}2$ - for 1.generation fuel

both $k_r \leq 1{,}66 \frac{N_{dov}}{N}$ and $k_r \leq 2{,}2$ - for 2.generation fuel

Maximal linear power of fuel element



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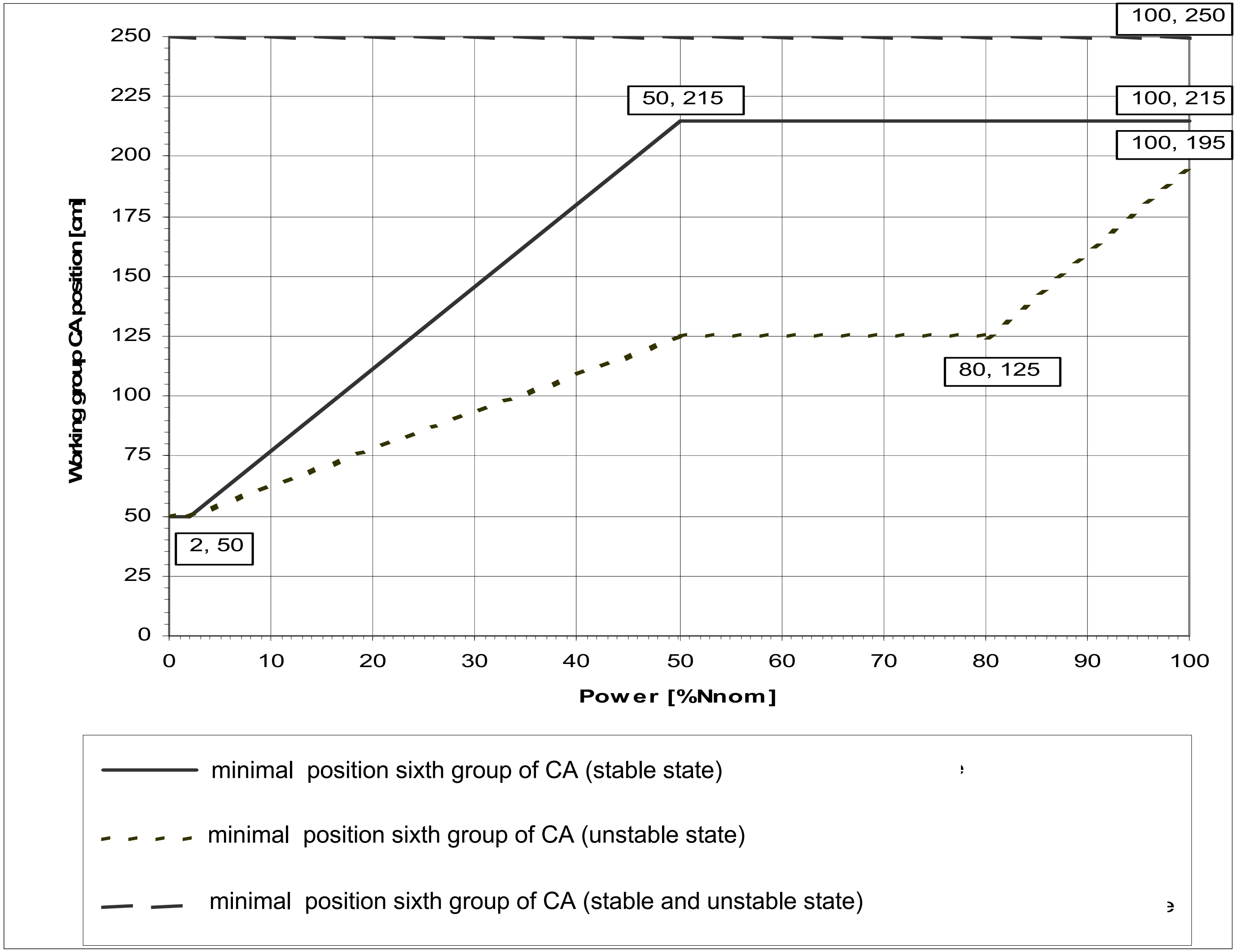
Working CA group position



3.2 Core monitoring system(CMS) SCORPIO upgrade

System SCORPIO evaluates signals from temperature and neutron detectors placed in the reactor and gives information about the core power distribution to the reactor operator and physicists.

Main functions of CMS SCORPIO:

- Processing of mesurement data
- Temperature sensor calibration
- 3-D power distribution reconstruction
- Limit checking and termal margin calculation
- Calculation of margin to PCI
- Primary circuit coolant activity monitoring
- Reactivity measurement during start-up
- Predictive mode and strategic planning
- Automated set up for new cycle
- Data archiving

Core follow mode provides:

- Monitoring of measured and calculating parameters of reactor, fuel assemblies and fuel pins
- Checking the status of the in-core detectors
- Evaluation of margins to operational and safety limits and alarm indication
- Displaing of the trend curves of selected parameters, display of detailed core map
- Displaing the status of each modules
- Archiving of selected parameters in the user forms

Core predictive mode (strategy generator)

Core predictive mode provides information for optimization of expected power changes for the 168 hours ahead

System calculates:

- minimal changes of boron acid concentration during power transients
- power distribution during expected power changes
- critical boron concentration
- control fuel assembly critical position
- shutdown boron concentration

Main monitoring (limits) parameters of core:

- Outlet temperature of fuel assemblies
- Coolant temperature rises in the fuel assemblies
- Radial assembly-wise power peaking factors kq
- Pin-wise power peaking factors kr
- linear power q_{lin}

Other monitoring parameters of core:

- Nodal power peaking factors kv
- Nuclear heat flux hot channel factors Fq
- Departure from nucleate boiling ratio DNBR
- Margin of subchannel output coolant temperature to the saturation temperature t_{SAT}

CMS Scorpio software upgrade

- Change from 20/40 calculation point along the height of core to 42 calculation point.
- Changes of neutron- physical model as a result of geometric and material changes.
- Implementation of diffusion libraries for new fuel type.
- KRITEX(Reactivity measurement during start-up) module changes.
- STRATEGIC GENERATOR(Predictive mode) module changes
- Add an option to do correction of assemblies outlet temperature in dependence on power distribution profile in Gd II assembly(This option don´t use up to the moment).
- Possibility of manual set CA position.

4. First experience with new fuel with burnable absorber and upgraded core monitoring system

Following figures and tables summarize first comparsion between theoretical and „experimental „ values.

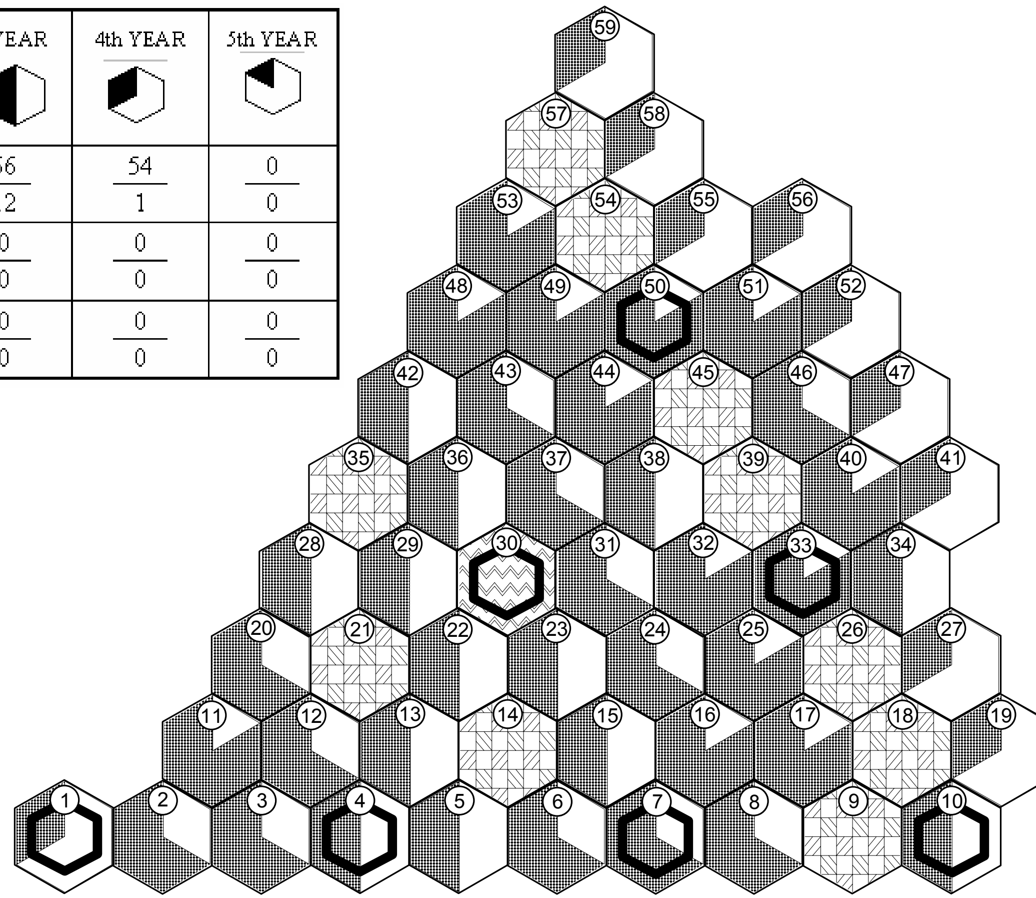
„experimental“ values – experimental values measured during physical start-up (nonstandard measure system)
– values calculated with CMS SCORPIO (MOBYDICK)

theoretical values - values calculated with BIPR-7

4.1 Operation with Gd II fuel
22.cycle 4.unit Bohunice NPP

Core loading pattern

number of FA / number of CA	FRESH FUEL	1st YEAR	2nd YEAR	3rd YEAR	4th YEAR	5th YEAR
ENRICHMENT 3,82%	0/0	66/12	66/6	66/12	54/1	0/0
ENRICHMENT 4,25% + Gd_2O_3	60/0	0/0	0/0	0/0	0/0	0/0
ENRICHMENT 3,84% + Gd_2O_3	0/6	0/0	0/0	0/0	0/0	0/0

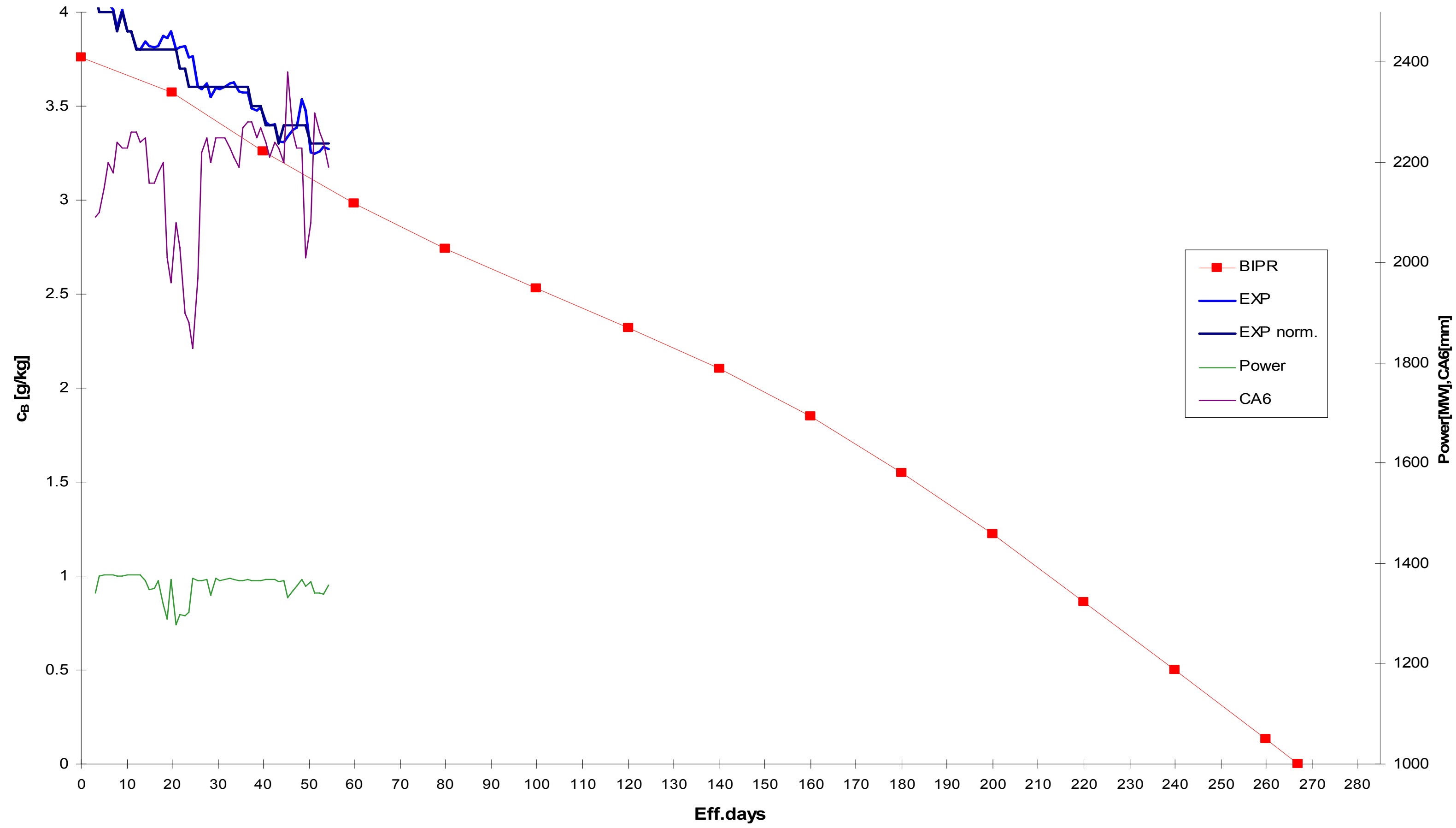


Physical start-up results

Duration: from 13.7.2006 9.24 to 16.7.2006 3.00

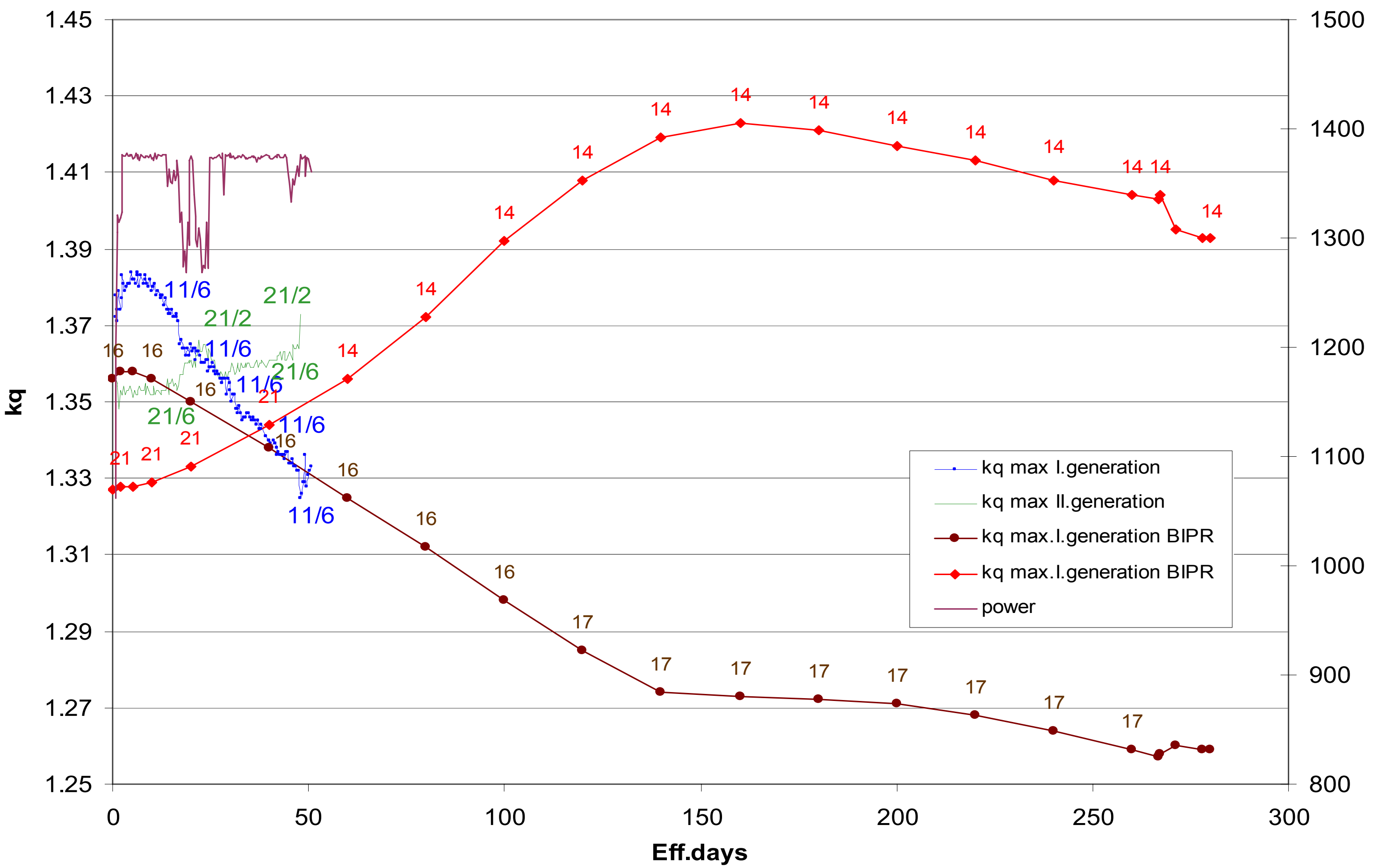
		Theoretical	Experimental	Deviation	Criteria
Critical concentration H3BO3 in PC [g/kg]		7.78	7.55	-0.22	±0.4 g/kg
Asymetry coeficients	min	1	0.964	-0.036	-7%rel
	max	1	1.064	0.064	7%rel
Asyptotic period	min	-	-	-13.40%	-30%rel
	max	-	-	6.40%	30%rel
	200 [^{O}C]	-0.61	-0.74	0.13	±0.4*10^{-2} %/^{o}C
	210	-0.74	-0.85	0.11	±0.4*10^{-2} %/^{o}C
	220	-0.87	-0.97	0.10	±0.4*10^{-2} %/^{o}C
Temperature reactivity coefficient [10^{-2}%/^{o}C]	230	-0.99	-1.11	0.12	±0.4*10^{-2} %/^{o}C
	240	-1.12	-1.26	0.14	±0.4*10^{-2} %/^{o}C
	250	-1.25	-1.44	0.19	±0.4*10^{-2} %/^{o}C
	260	-1.38	-1.65	0.27	±0.4*10^{-2} %/^{o}C
CA system total worth [%]		12.5	12.34	1.40%	±21%rel
CA system total worth with CA 03-46 stuck[%]		8.26	7.68	7.00%	±20%rel
Worth of "ejected" CA 06-49 [%]		0.52	0.59	-11.90%	±20%rel
CA drop time [s]		8 to 13	10.2 to 11.6	-	from 8 to 13 s
Boron acid worth [%kg/g]		-1.48	-1.44	2.80%	±17%rel
Worth of working CA [%]		0.81	0.87	-6.90%	±17%rel
Isothermal state	TČ	-	< 0.5	< 0.5	< 0.5
	OT	-	< 0.2	< 0.2	< 0.2

Graph of boron acid concentration



Maximal radial assembly-wise power peaking factors kq

Comparsion BIPR-SCORPIO



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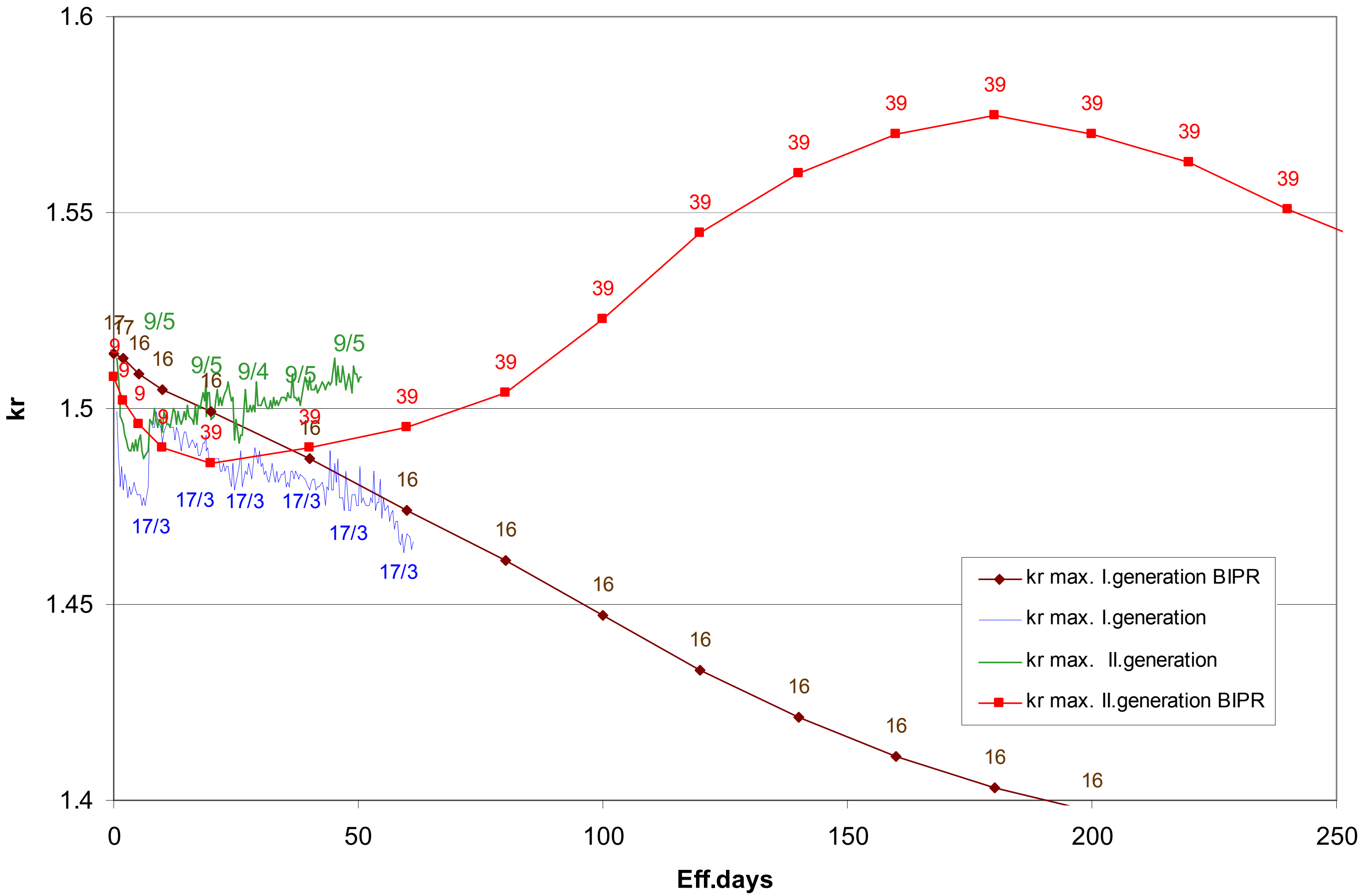
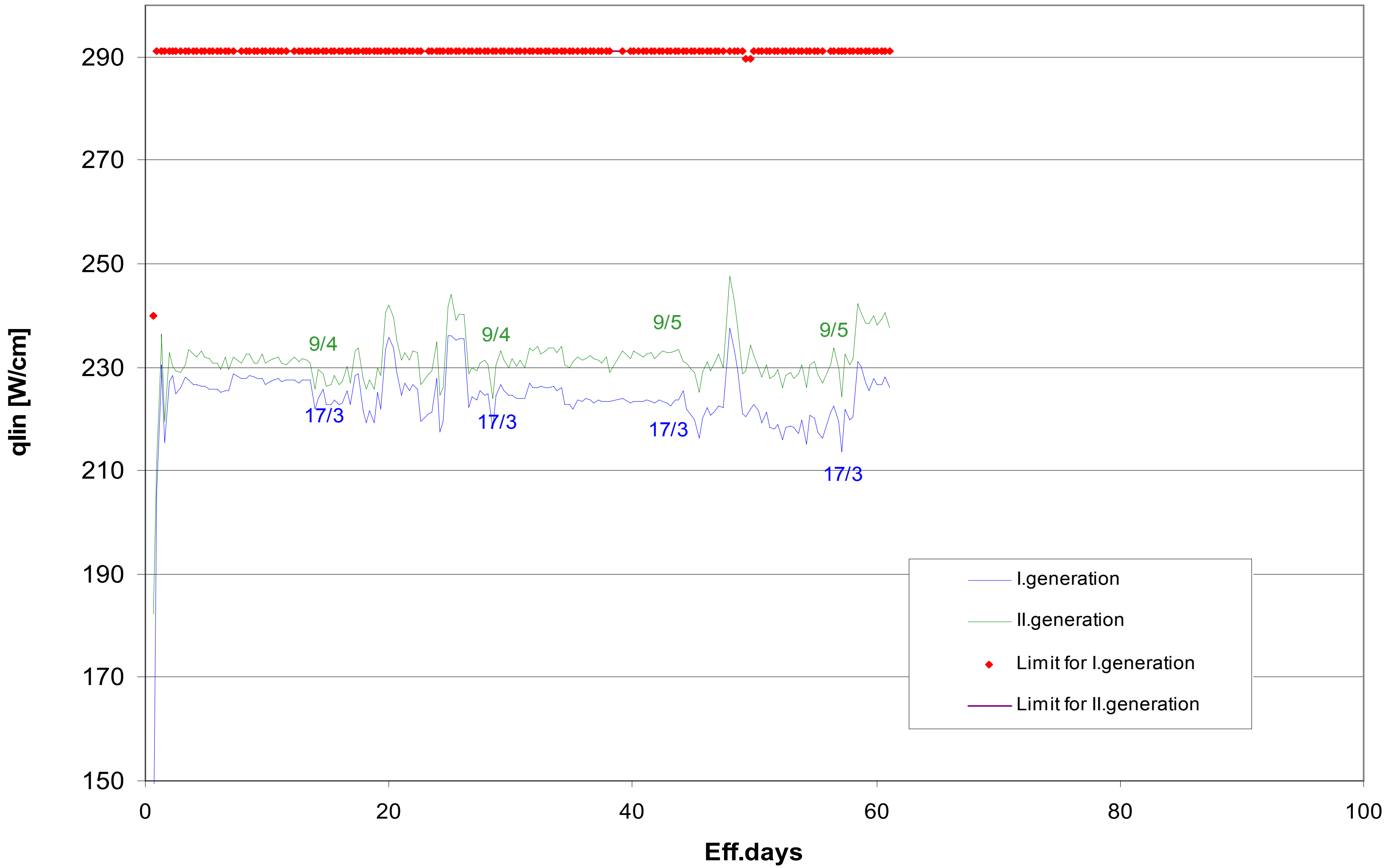
Pin-wise power peaking factors kr

Comparsion BIPR-SCORPIO



Maximal linear power q_{lin}



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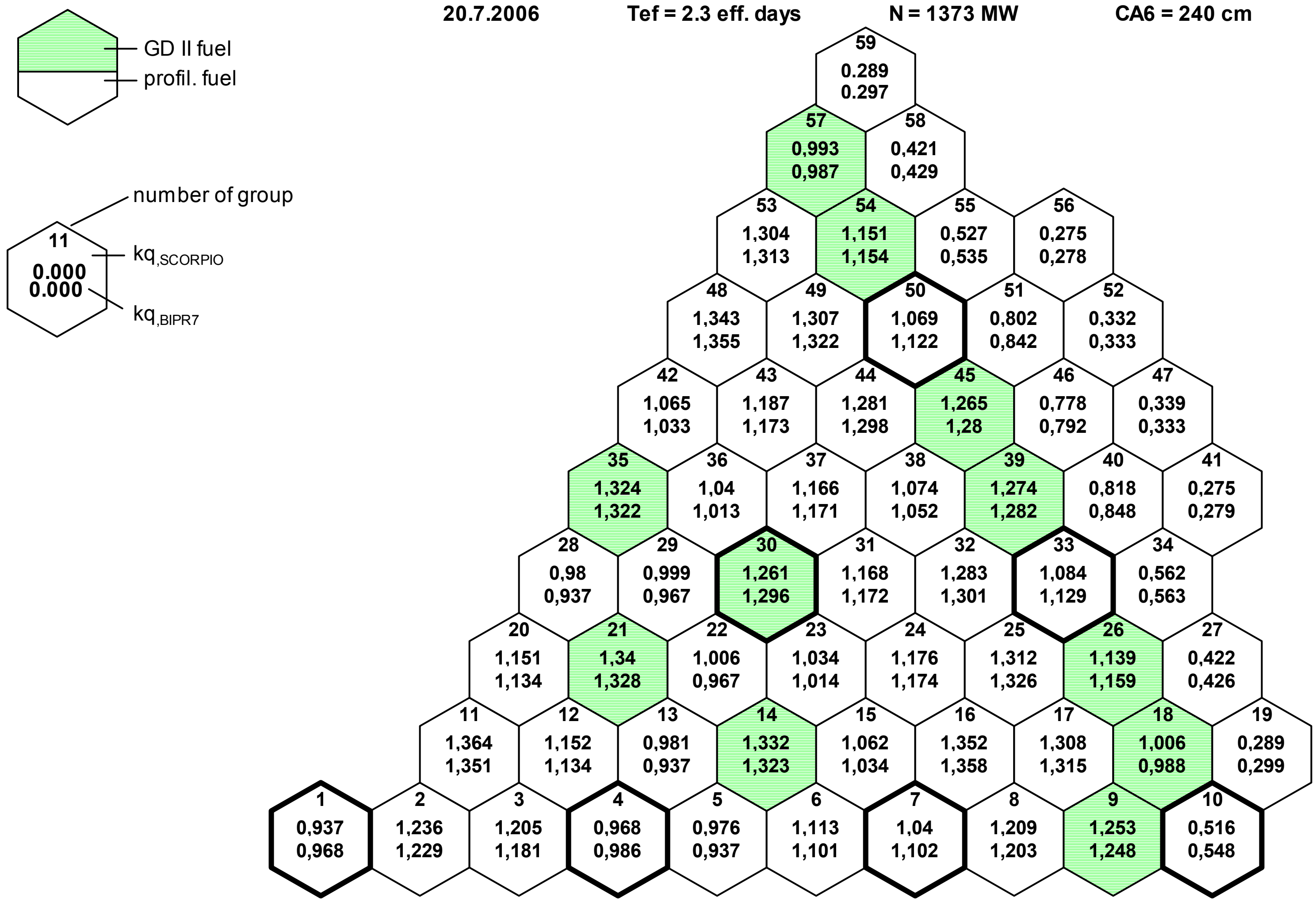
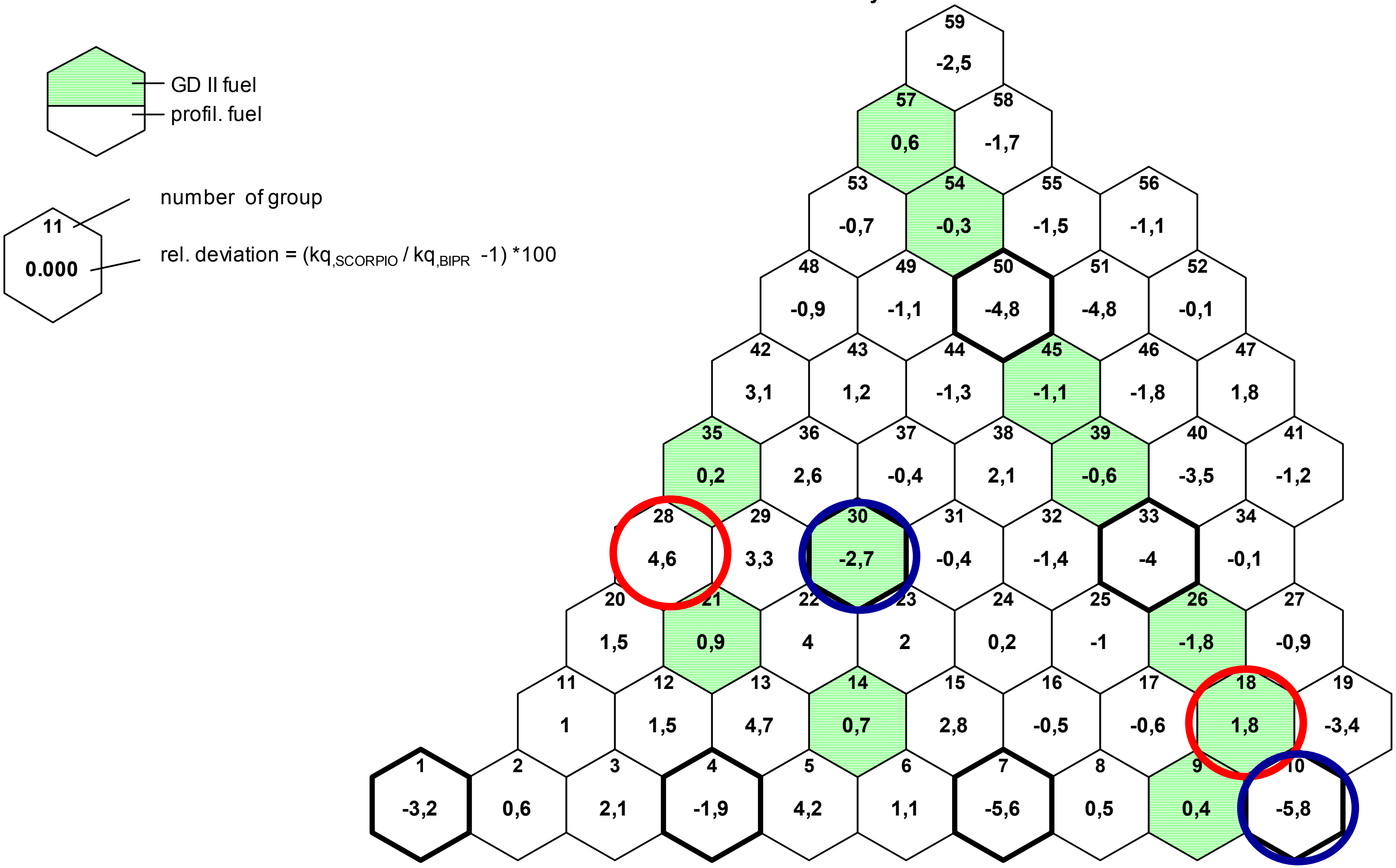
Comparsion between experimental(SCORPIO) and teoretical(BIPR) group kq and relative deviation 2.eff.days

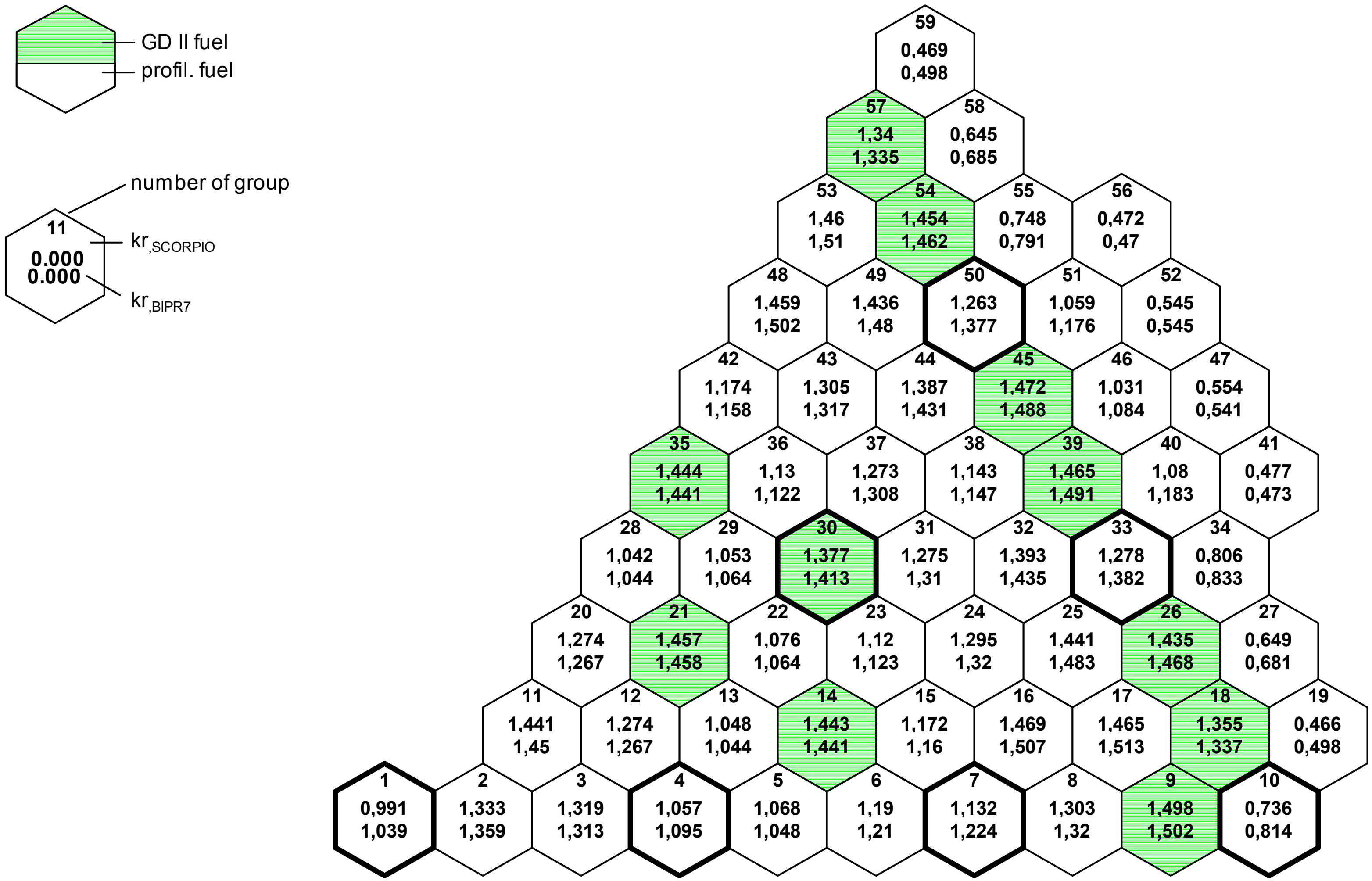


20.7.2006 Tef = 2.3 eff. days N = 1373 MW CA6 = 240 cm

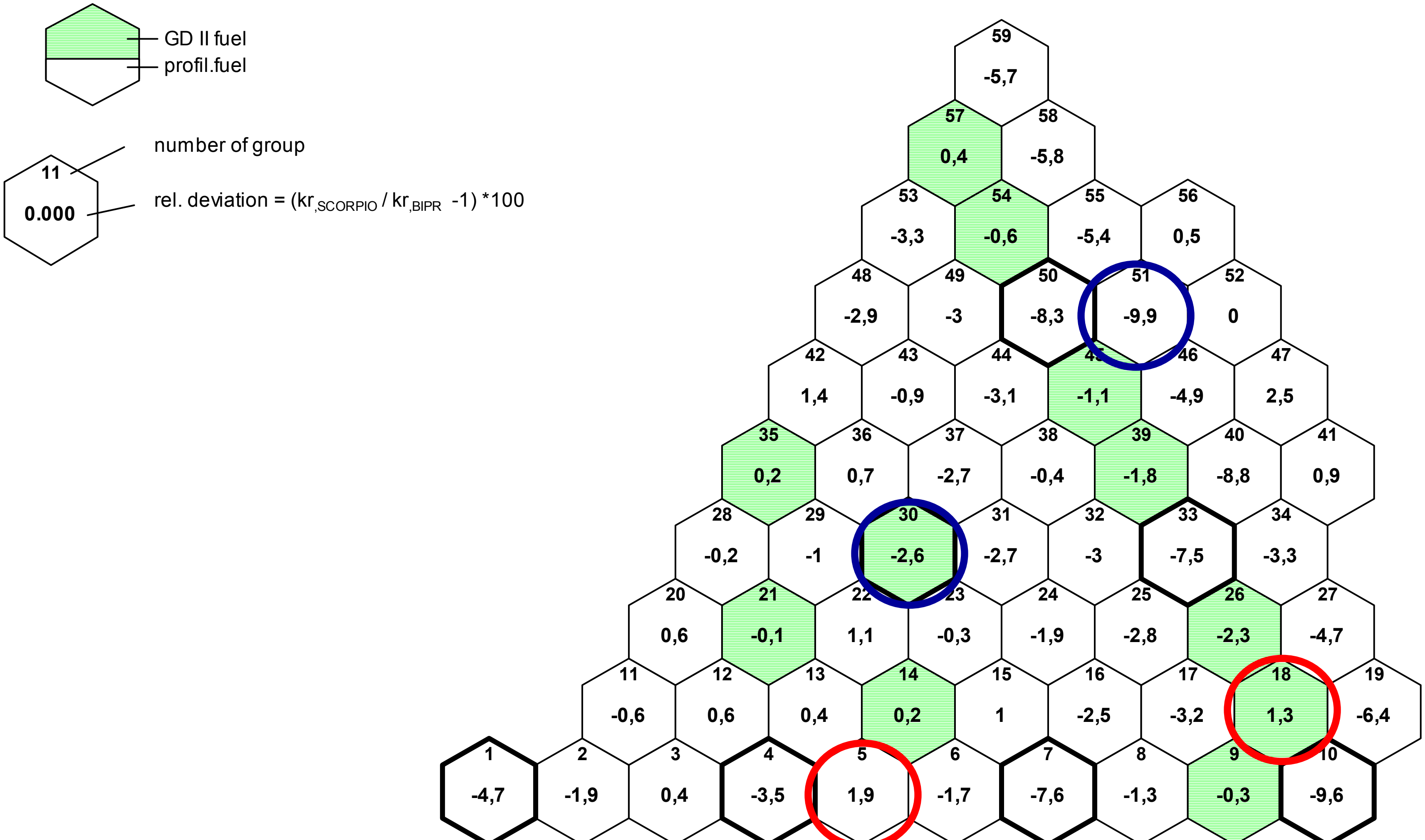


Comparsion between “experimental”(SCORPIO) and teoretical(BIPR) group kr and relative deviation 2.eff.days

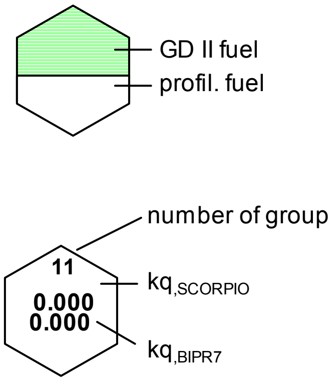
20.7.2006 **Tef = 2.3 eff.days** **NR = 1373 MW** **h6 = 240 cm**



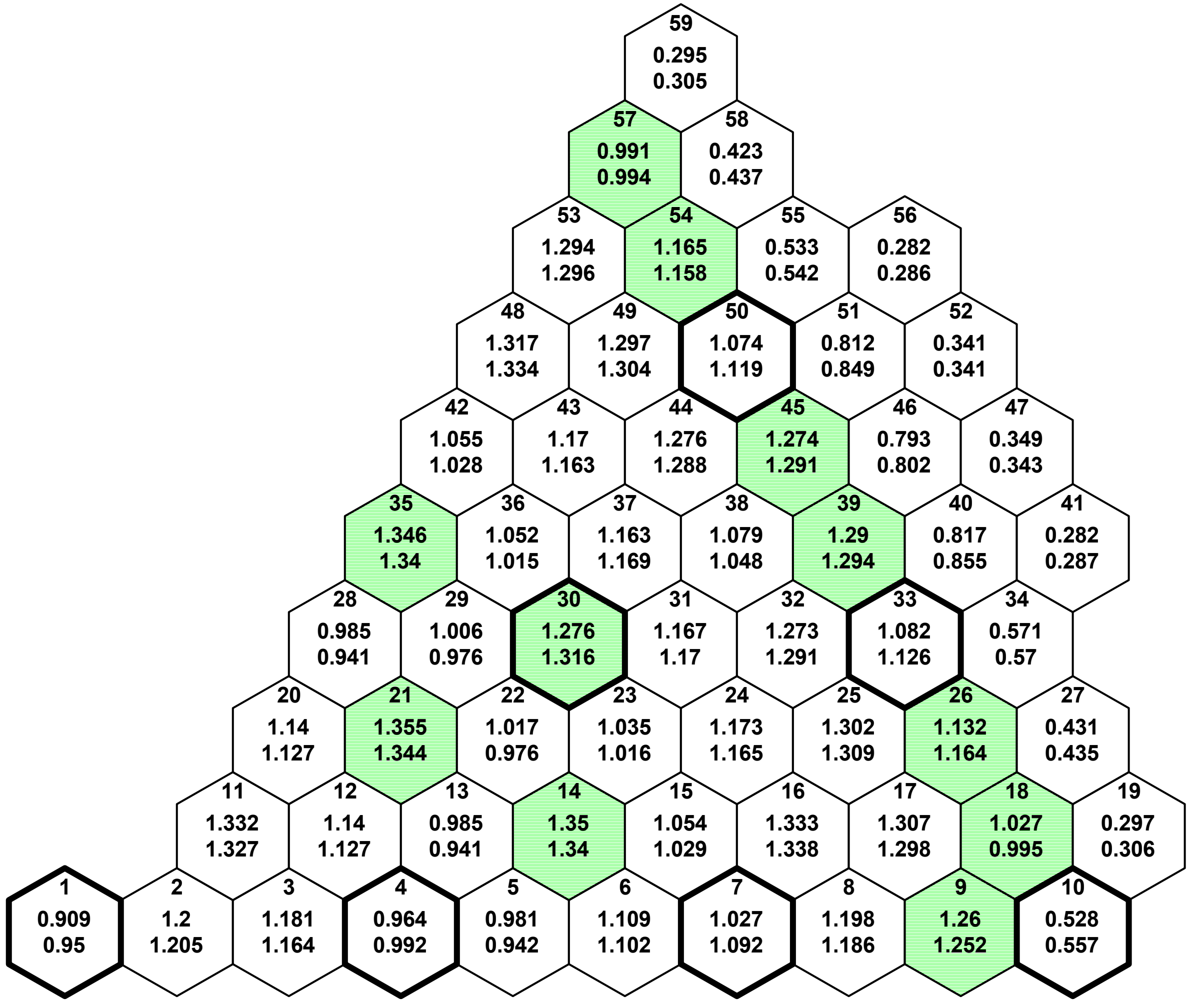
20.7.2006 **Tef = 2.3 eff.days** **NR = 1373 MW** **h6 = 240 cm**



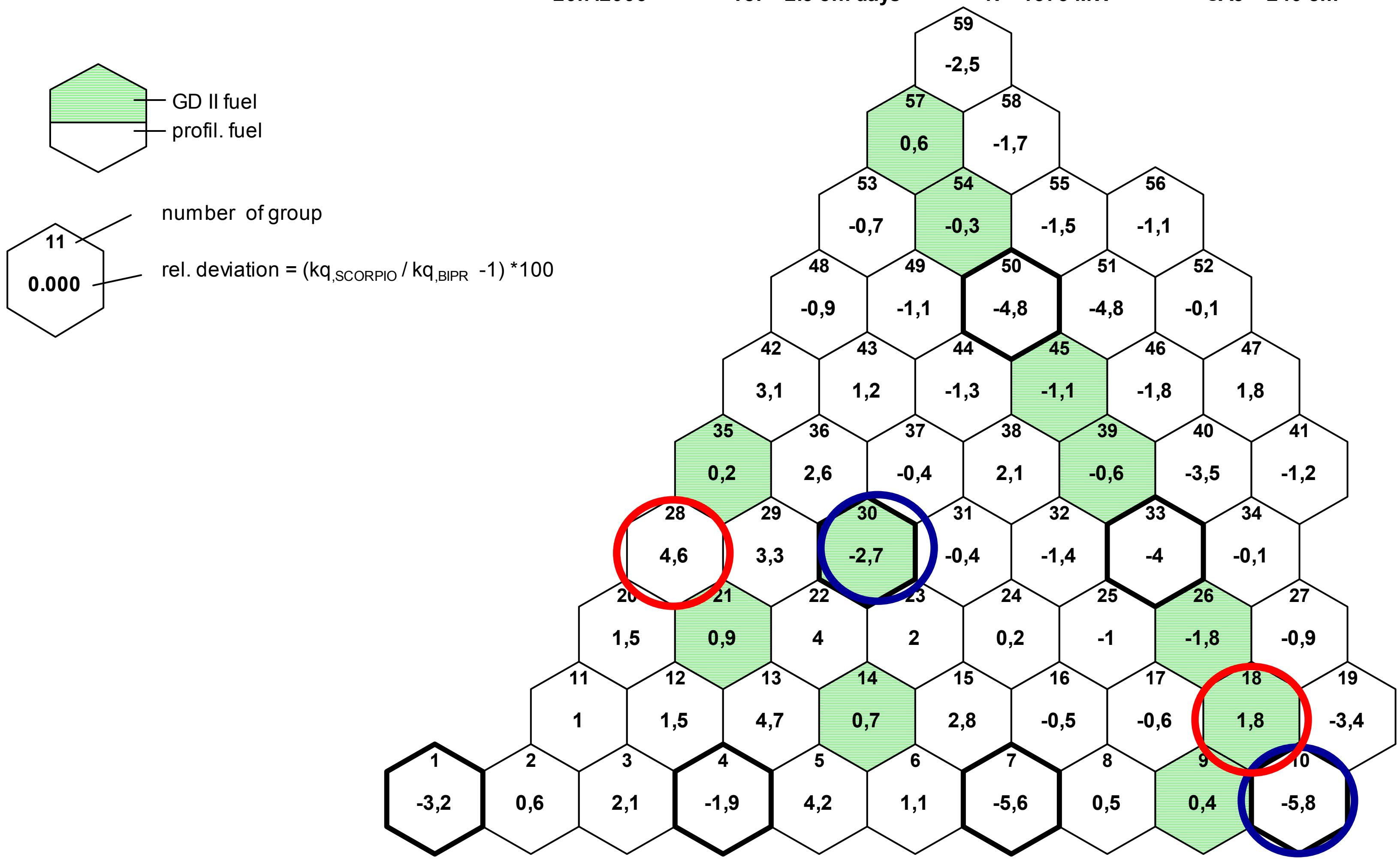
Comparsion between experimental(SCORPIO) and teoretical(BIPR) group kq and relative deviation
40.eff.days



27.8.2006 **Tef = 40,4 eff. days** **NR = 1373 MW** **h6 = 225 cm**

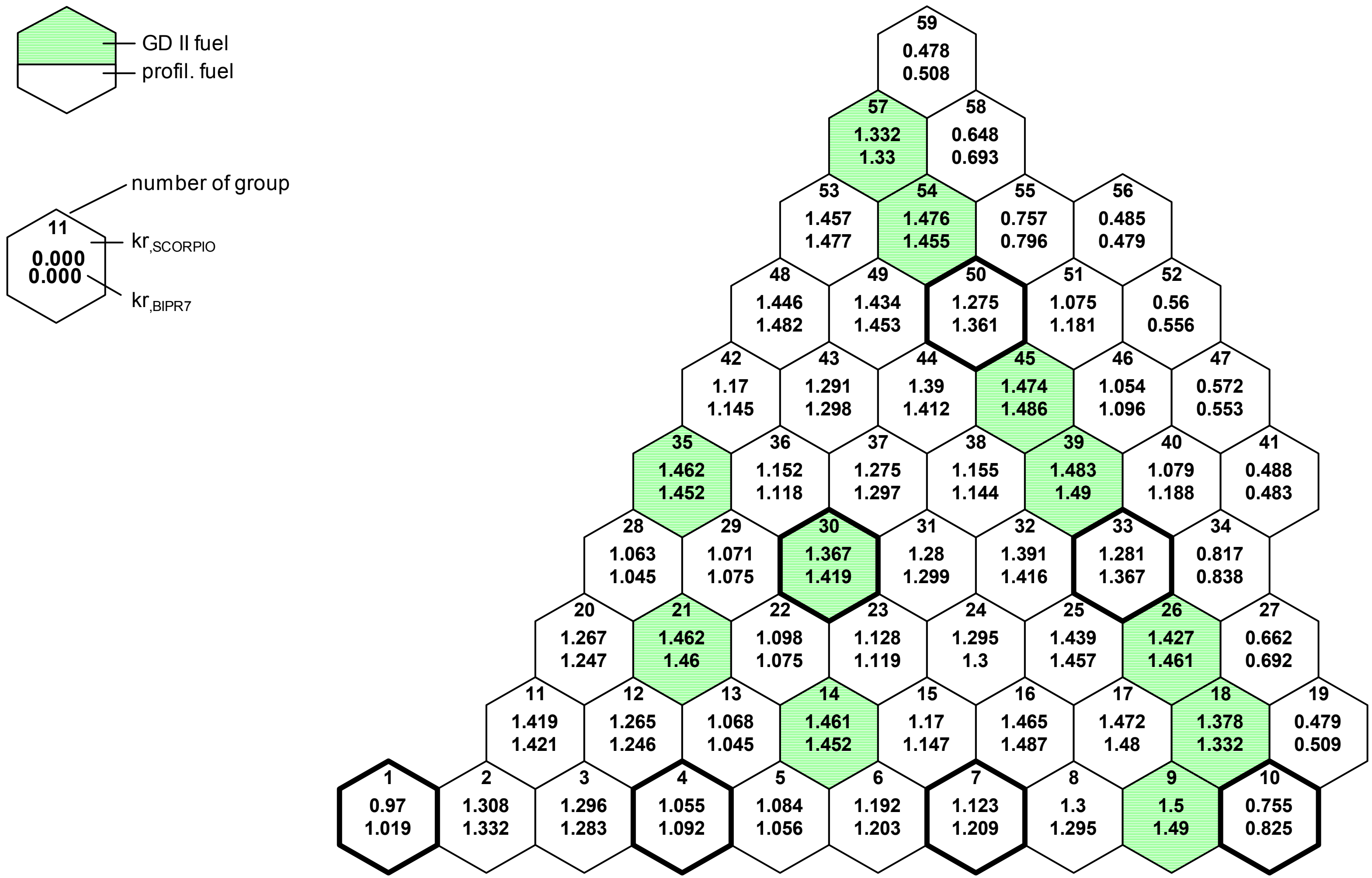


20.7.2006 Tef = 2.3 eff. days N = 1373 MW CA6 = 240 cm



Comparsion between “experimental”(SCORPIO) and teoretical(BIPR) group kr and relative deviation 40.eff.days

27.8.2006 **Tef = 40,4 eff.days** **NR = 1373 MW** **h6 = 225 cm**



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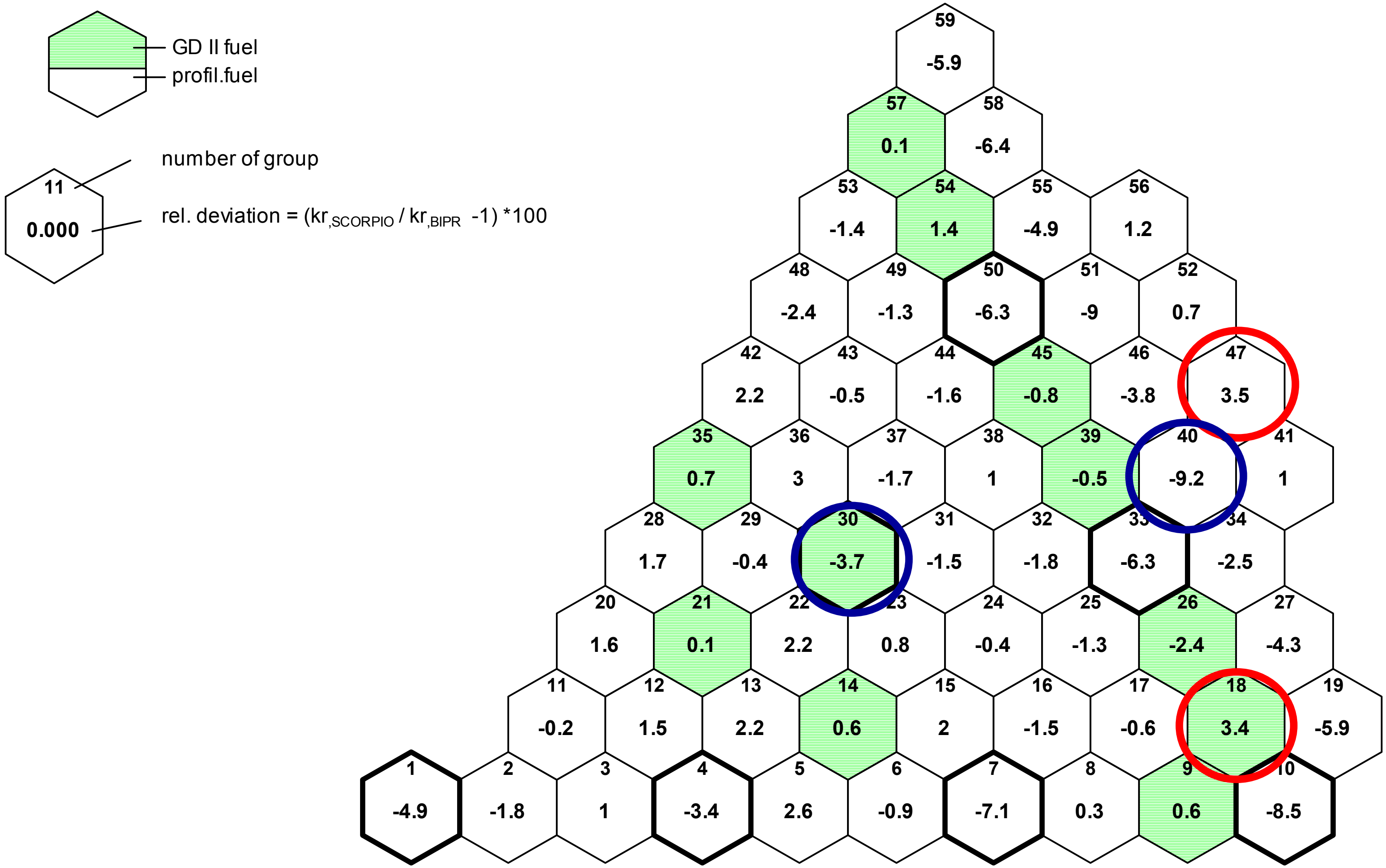
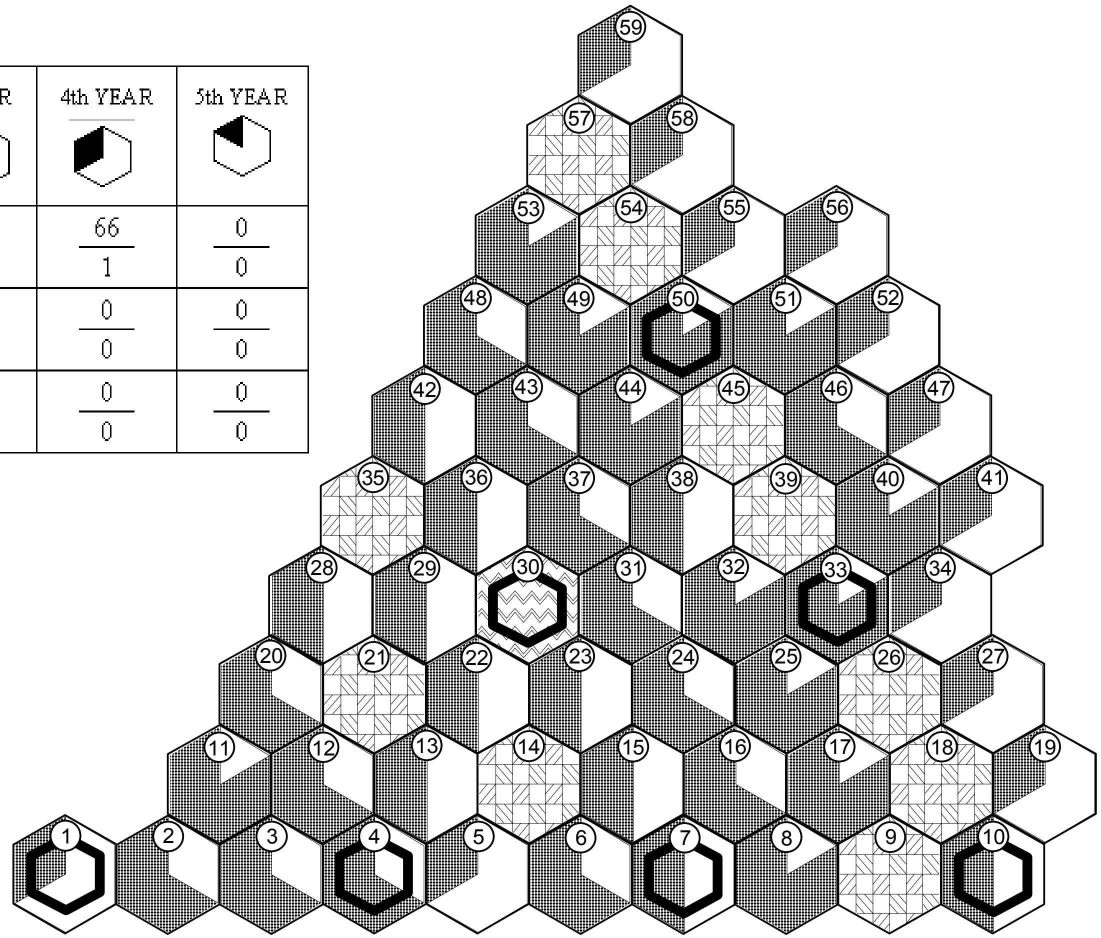


4.1 Operation with Gd II fuel
23.cycle 3.unit Bohunice NPP

Core loading pattern

number of FA / number of CA	FRESH FUEL	1st YEAR	2nd YEAR	3rd YEAR	4th YEAR	5th YEAR
ENRICHMENT 3,82%	0/0	60/12	72/6	54/12	66/1	0/0
ENRICHMENT 4,25%	60/0	0/0	0/0	0/0	0/0	0/0
ENRICHMENT 3,84%	0/6	0/0	0/0	0/0	0/0	0/0



Physical start-up results

Duration: from 2.9.2006 10.26 to 4.9.2006 5.10

		Theoretical	Experimental	Deviation	Criteria
Critical concentration H3BO3 in PC [g/kg]		7.62	7.9	0.28	±0.4 g/kg
Asymetry coeficients	min	1	0.981	-0.019	-7%rel
	max	1	1.024	0.024	7%rel
Asyptotic period	min	-	-	-10.70%	-30%rel
	max	-	-	14.70%	30%rel
Temperature reactivity coefficient [10^{-2}%/^{o}C]	200 [^{O}C]	-0.77	-0.77	0	±0.4*10^{-2} %/^{o}C
	210	-0.88	-0.94	0.06	±0.4*10^{-2} %/^{o}C
	220	-1.01	-1.11	0.1	±0.4*10^{-2} %/^{o}C
	230	-1.16	-1.28	0.12	±0.4*10^{-2} %/^{o}C
	240	-1.32	-1.45	0.13	±0.4*10^{-2} %/^{o}C
	250	-1.5	-1.62	0.12	±0.4*10^{-2} %/^{o}C
	260	-1.69	-1.79	0.1	±0.4*10^{-2} %/^{o}C
CA system total worth [%]		10.52	11	4.60%	±21%rel
CA system total worth with CA 03-46 stuck[%]		7.43	7.74	4.20%	±20%rel
Worth of "ejected" CA 06-49 [%]		0.45	0.42	-6.70%	±20%rel
CA drop time [s]		8 to 13	10.2 to 11.6	-	from 8 to 13 s
Boron acid worth [%kg/g]		-1.47	-1.35	8.20%	±17%rel
Worth of working CA [%]		0.83	0.94	-13.30%	±17%rel
Isothermal state	TČ	-	< 0.5	< 0.5	< 0.5
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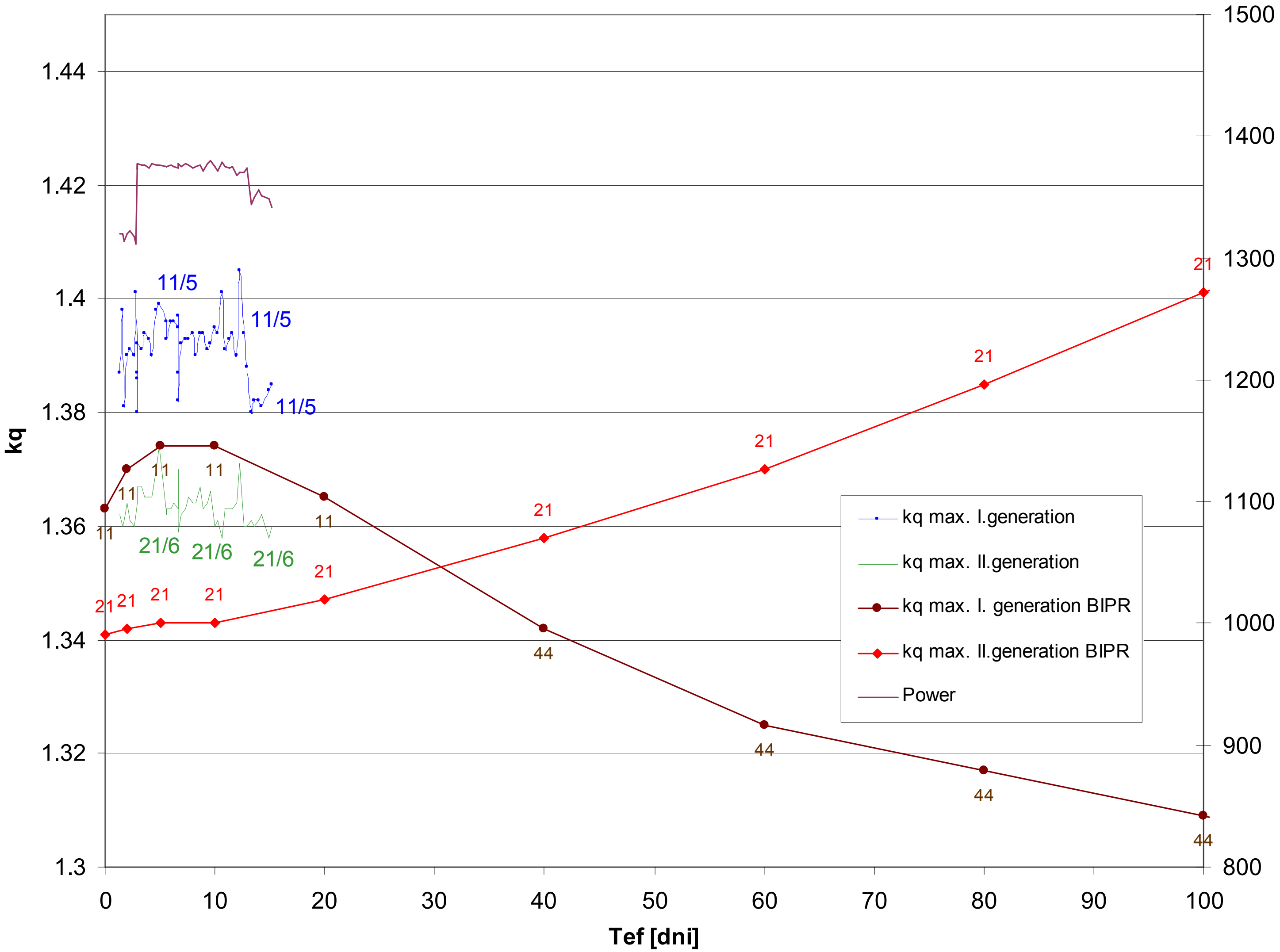
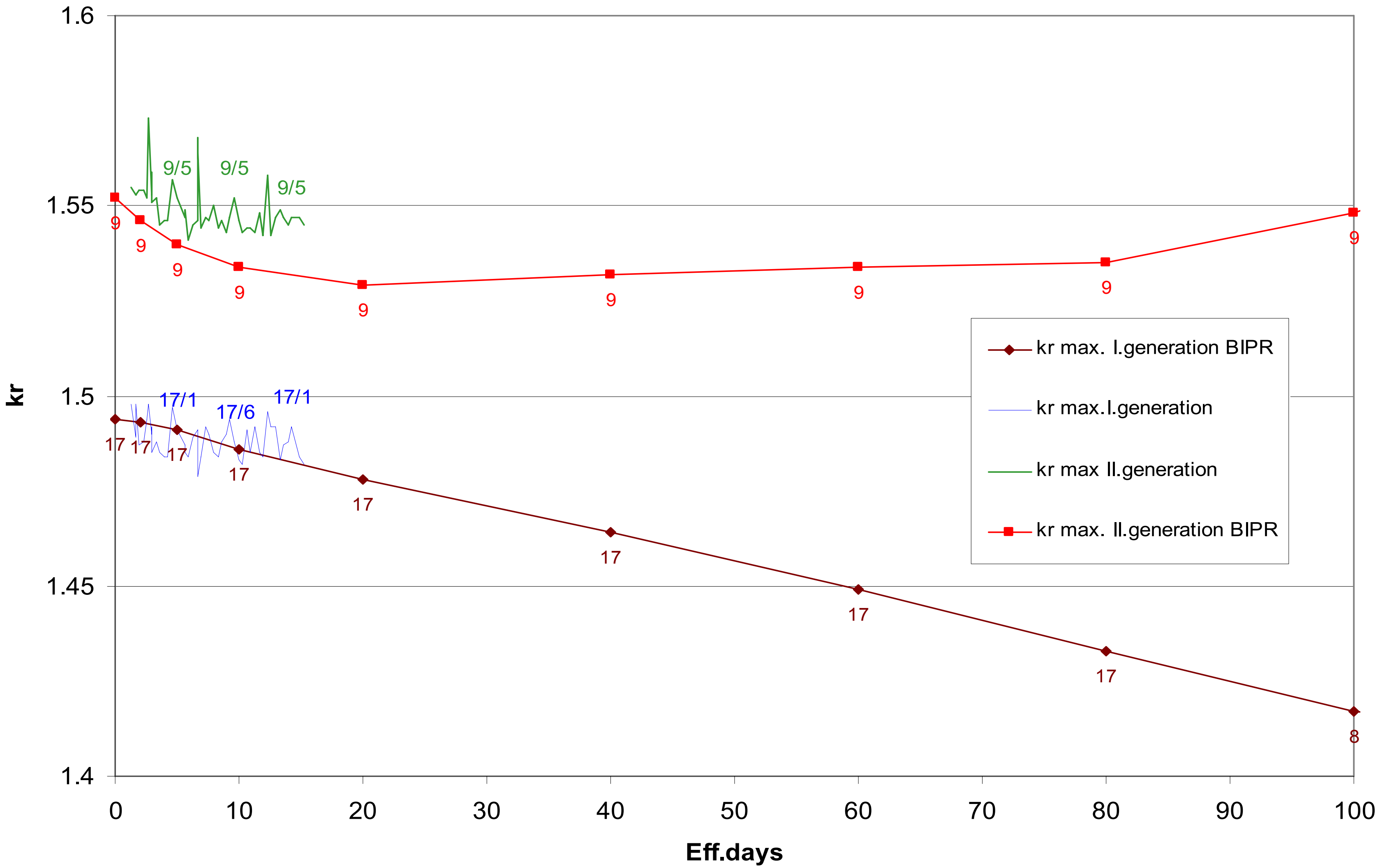
Maximal radial assembly-wise power peaking factors kq

Comparsion BIPR-SCORPIO

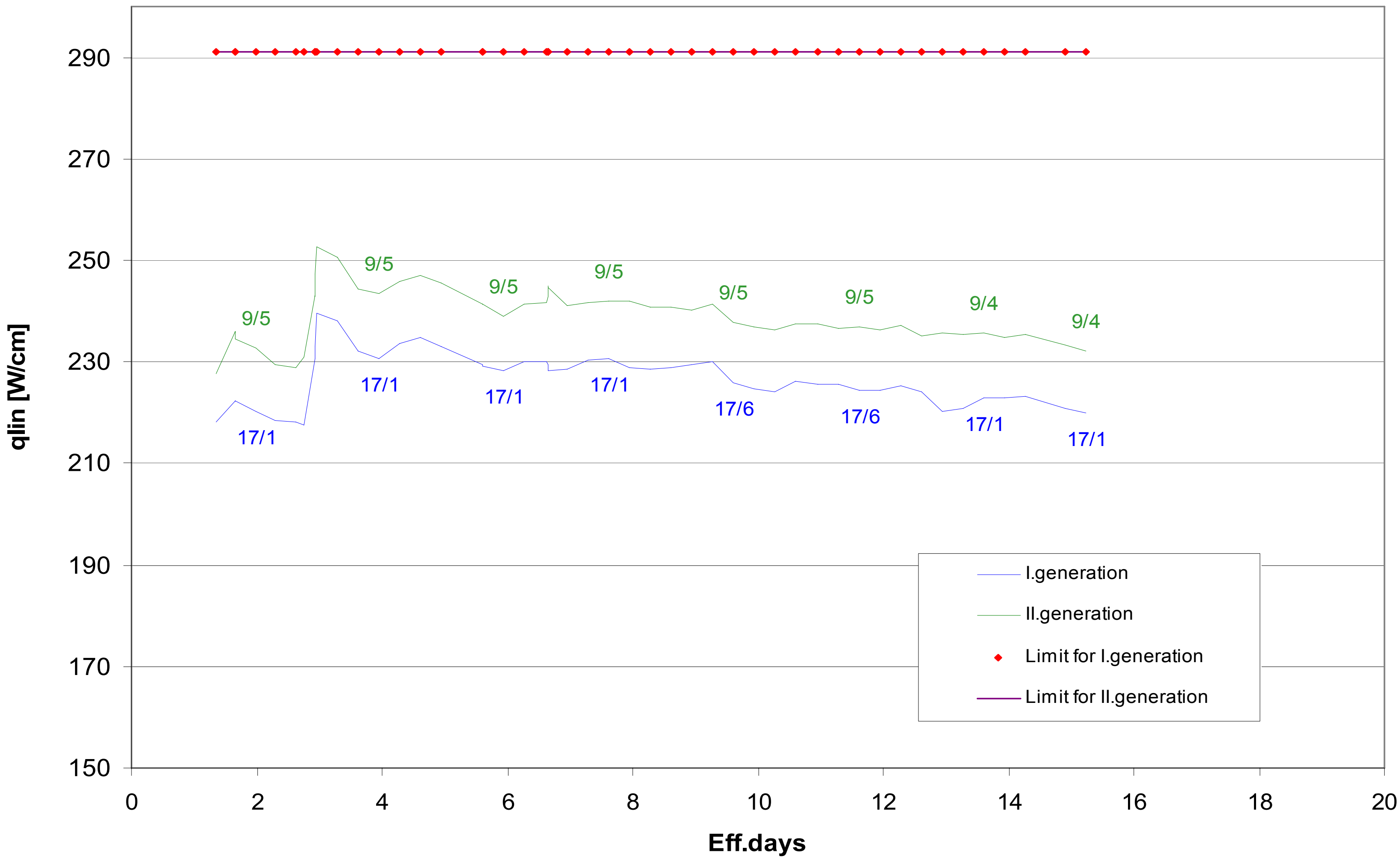


Pin-wise power peaking factors kr

Comparsion BIPR-SCORPIO



Maximal linear power q_{lin}



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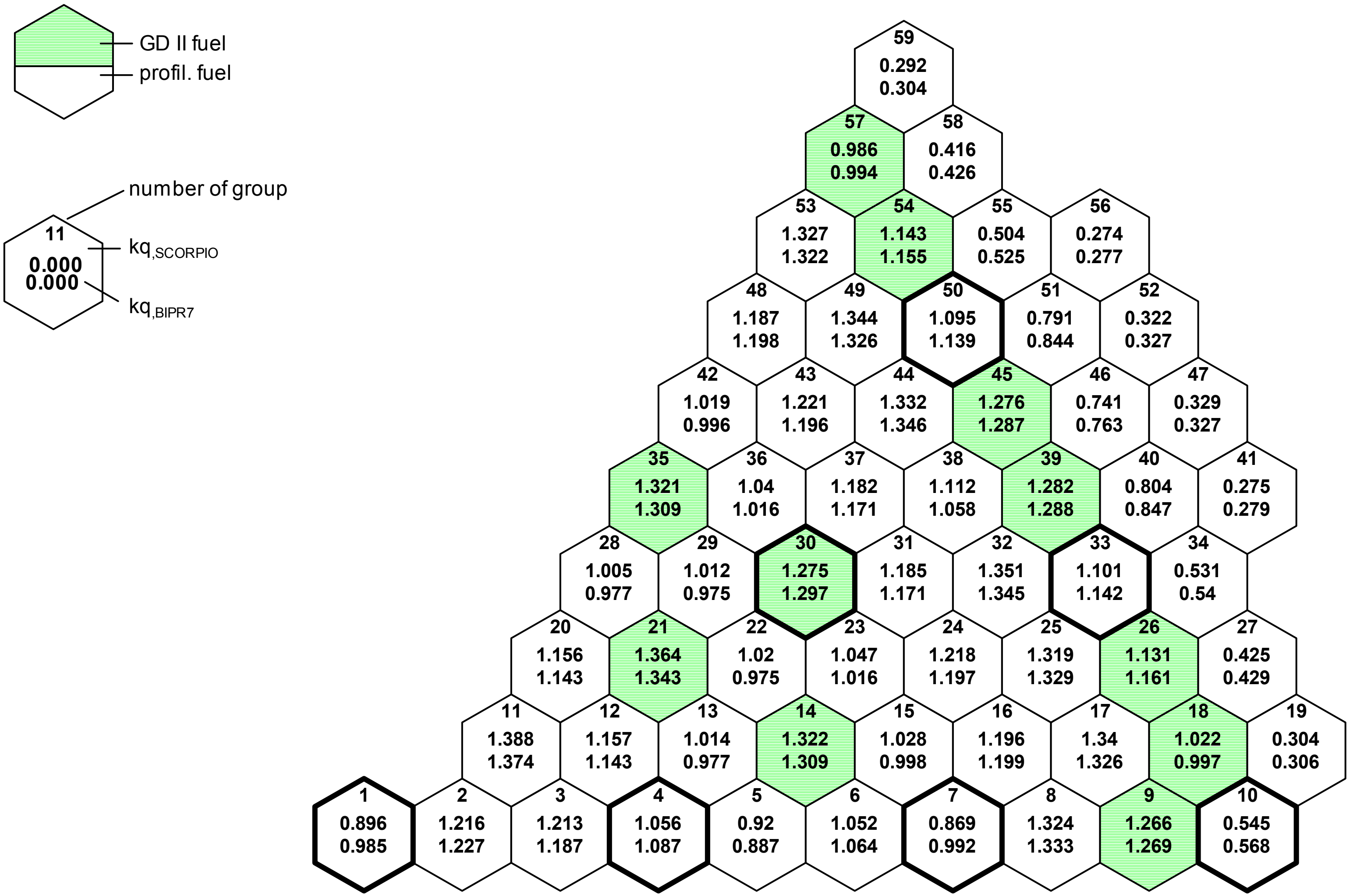
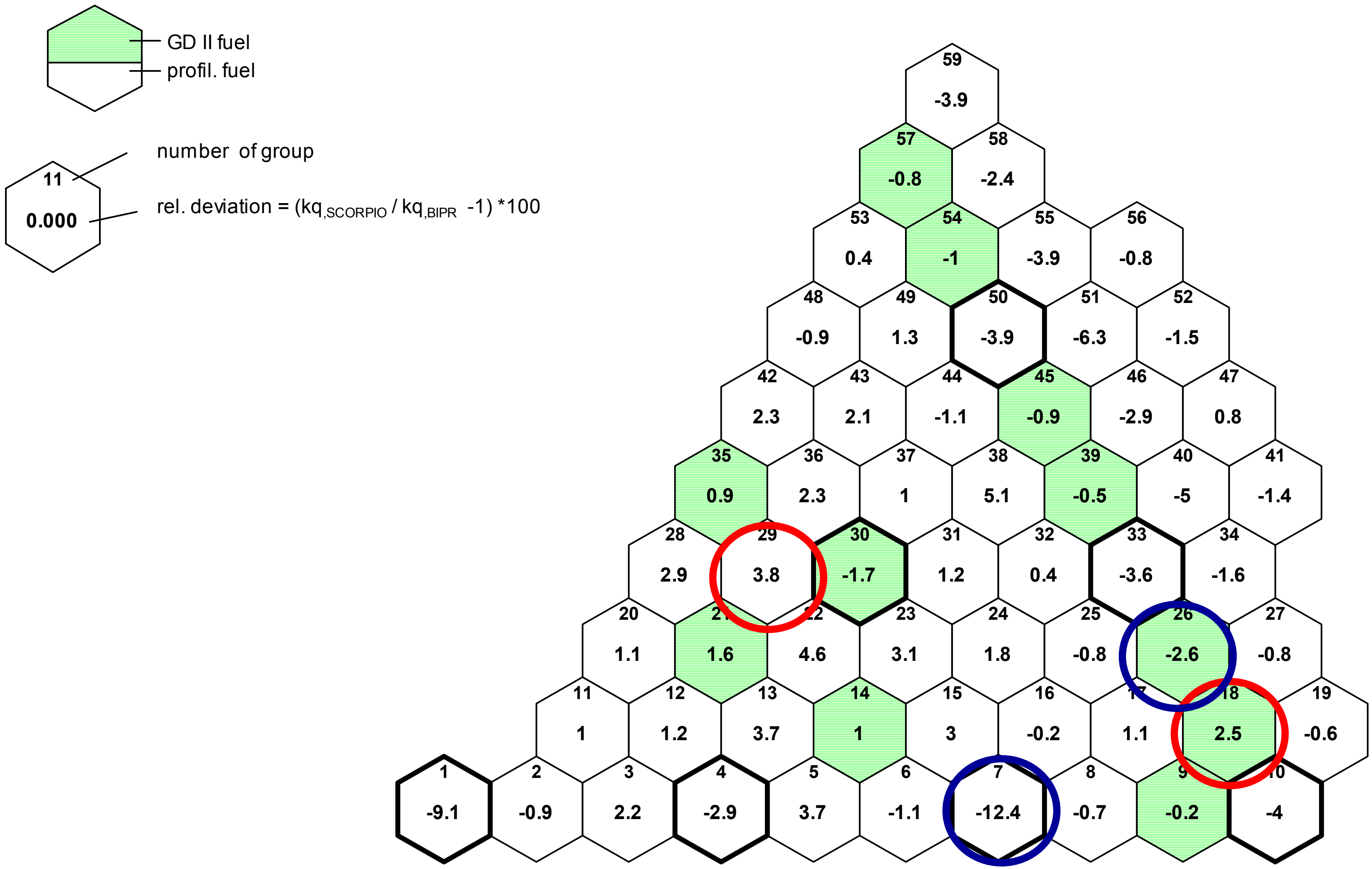
Comparsion between experimental(SCORPIO) and teoretical(BIPR) group kq and relative deviation
5.eff.days

10.9.2006 **Tef = 4.9 eff.days** **NR = 1375 MW** **h6 = 220 cm**

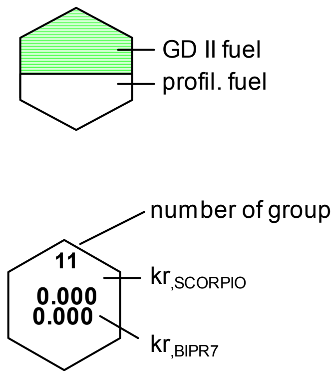


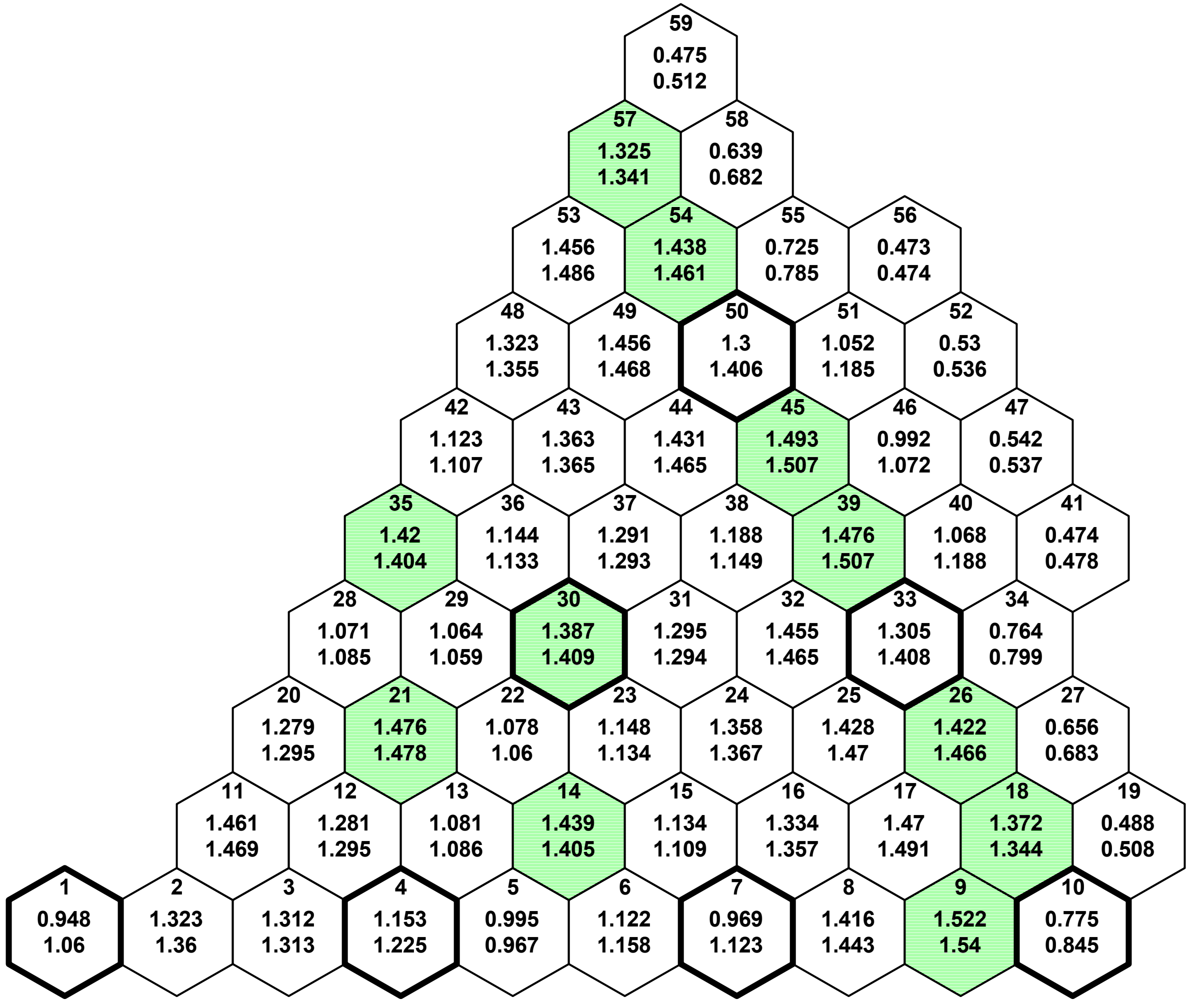
10.9.2006 **Tef = 4.9 eff.days** **NR = 1375 MW** **h6 = 220 cm**



Comparsion between “experimental”(SCORPIO) and teoretical(BIPR) group kr and relative deviation
5.eff.days

10.9.2006 Tef = 4.9 eff.days NR = 1375 MW h6 = 220 cm





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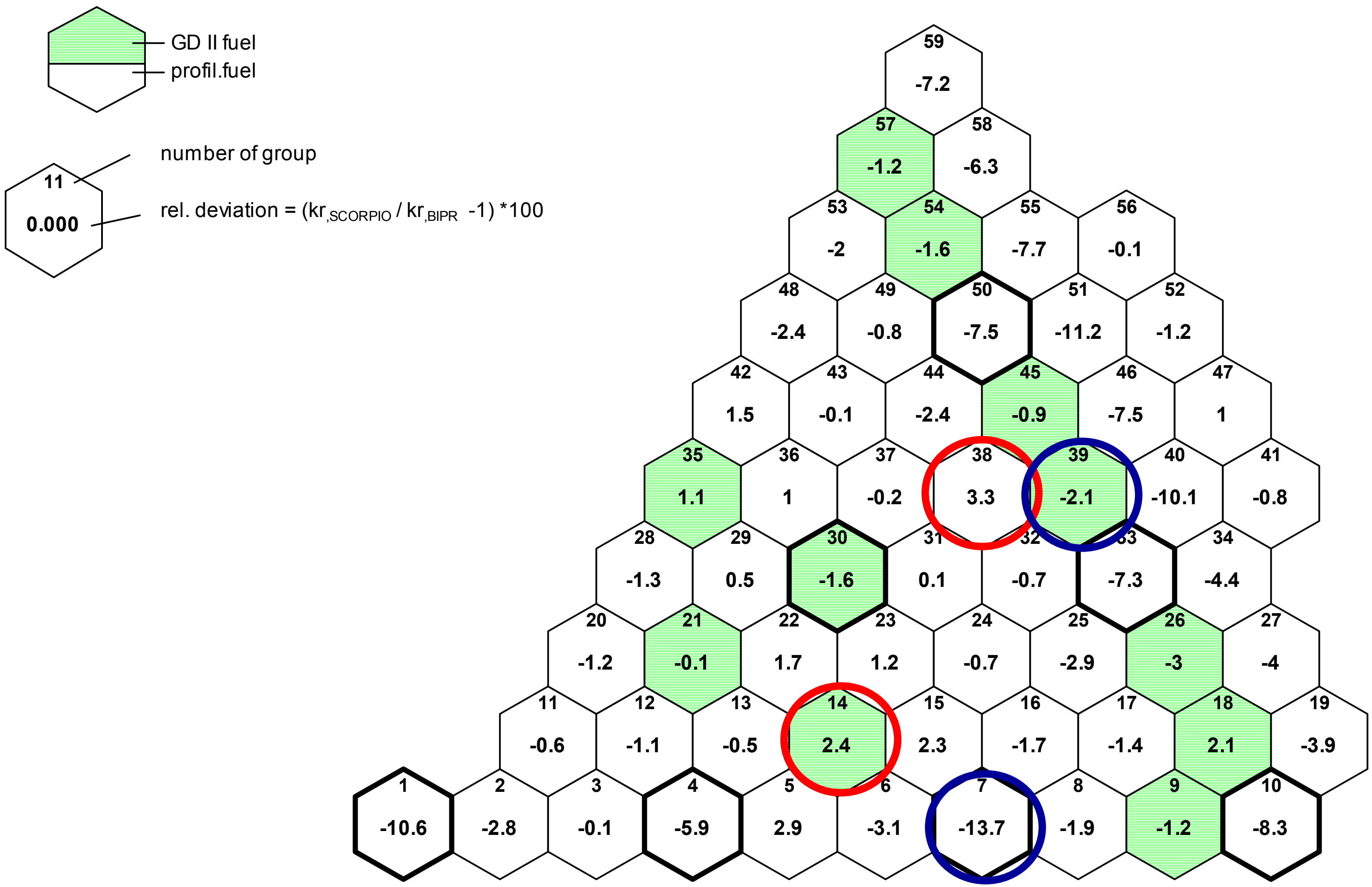


5.Conclusion

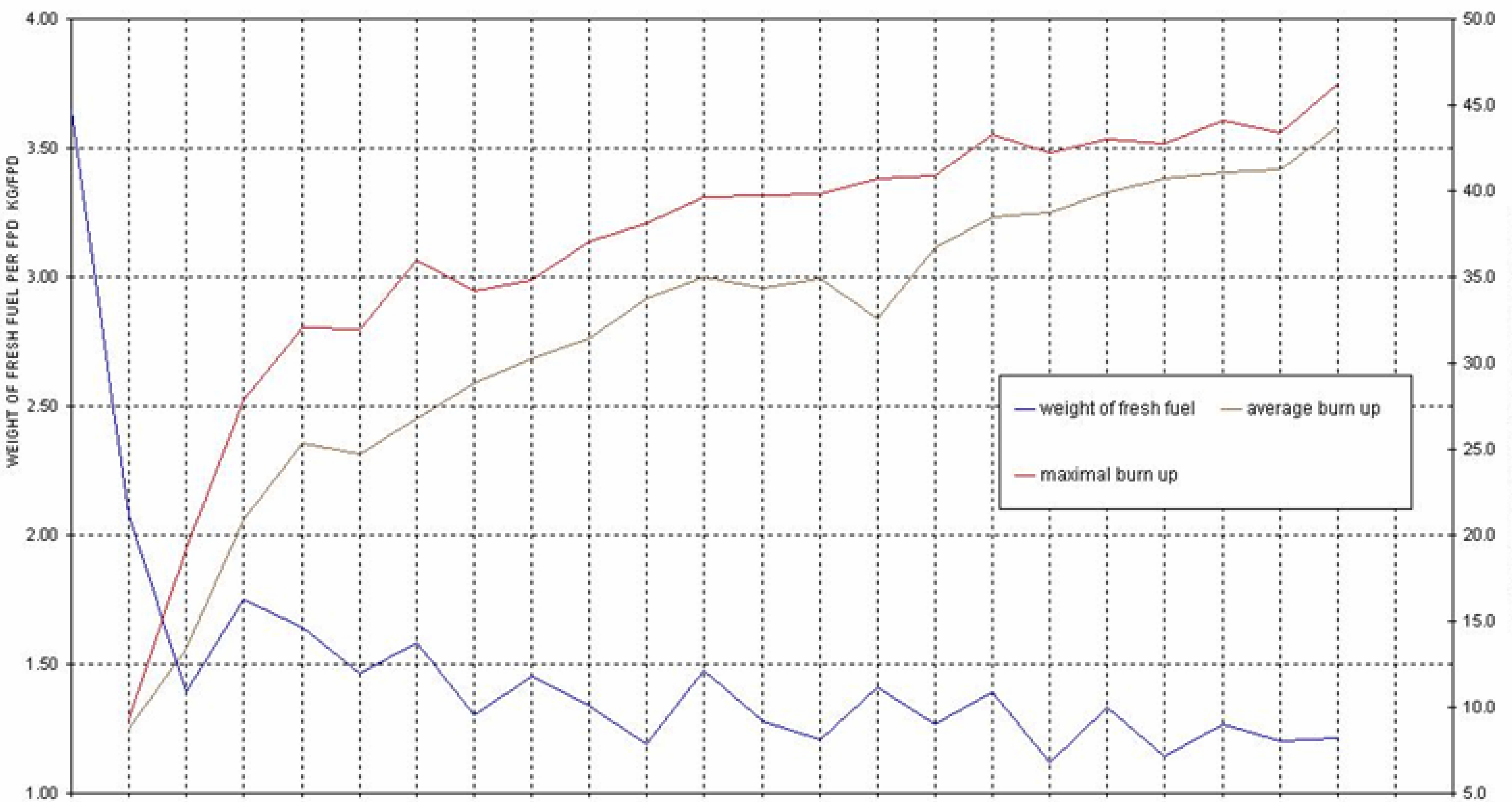
- -The close changes of fuel cycle in Bohunice V-2 NPP is expected in connection with increase of the reactor power to 107% in 2010
- Choice of supplier and fuel licensing took aproximately four years.
- Diferencies between theoretical(BIPR7) and experimental values measured during physical start-up are not significant.
- Diferencies between theoretical(BIPR7) and „experimental“(SCORPIO-MOBYDICK) values are not significant up to the moment.

THANK YOU FOR YOU ATTENTION!

Presentation prepare:
O.Grežďo

References:
M.Antal,M.Kačmar – fuel cycles,licensing
V.Mráz – 4.unit,SCORPIO
O.Grežďo – 3.unit

Fig. 1 Summary of Bohunice V-2 NPP fuel cycle.Weight of fresh fuel for FPD and burn up of discharged fuel.



4		1	2NZ	3	4	5	6	7 4Y	8	9	10	11	12	13	14	15	16	17	18PF,5Y	19	20	21	22Gd2,6Y	
3	1N	2Z	3	4	5	6	7	8	9 4Y	10	11	12	13	14	15	16	17	18	19 PF,5Y	20	21	22	23Gd2,6Y	
unit/year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	

DESIGN LOADINGS

Z- TRANSIT TO LOW LEAKAGE

N- TRANSIT TO NON-DESIGN

4Y- TRANSIT TO 4-YEAR CYCLES

NUMBER OF CYCLE

PF- PROFILED FUEL
5Y- 5YEAR CYCLE

Gd2 – Gd 2 fuel
6Y– 6YEAR CYCLE

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Fig.2 Number of leakage FA – 3. and 4.UNIT

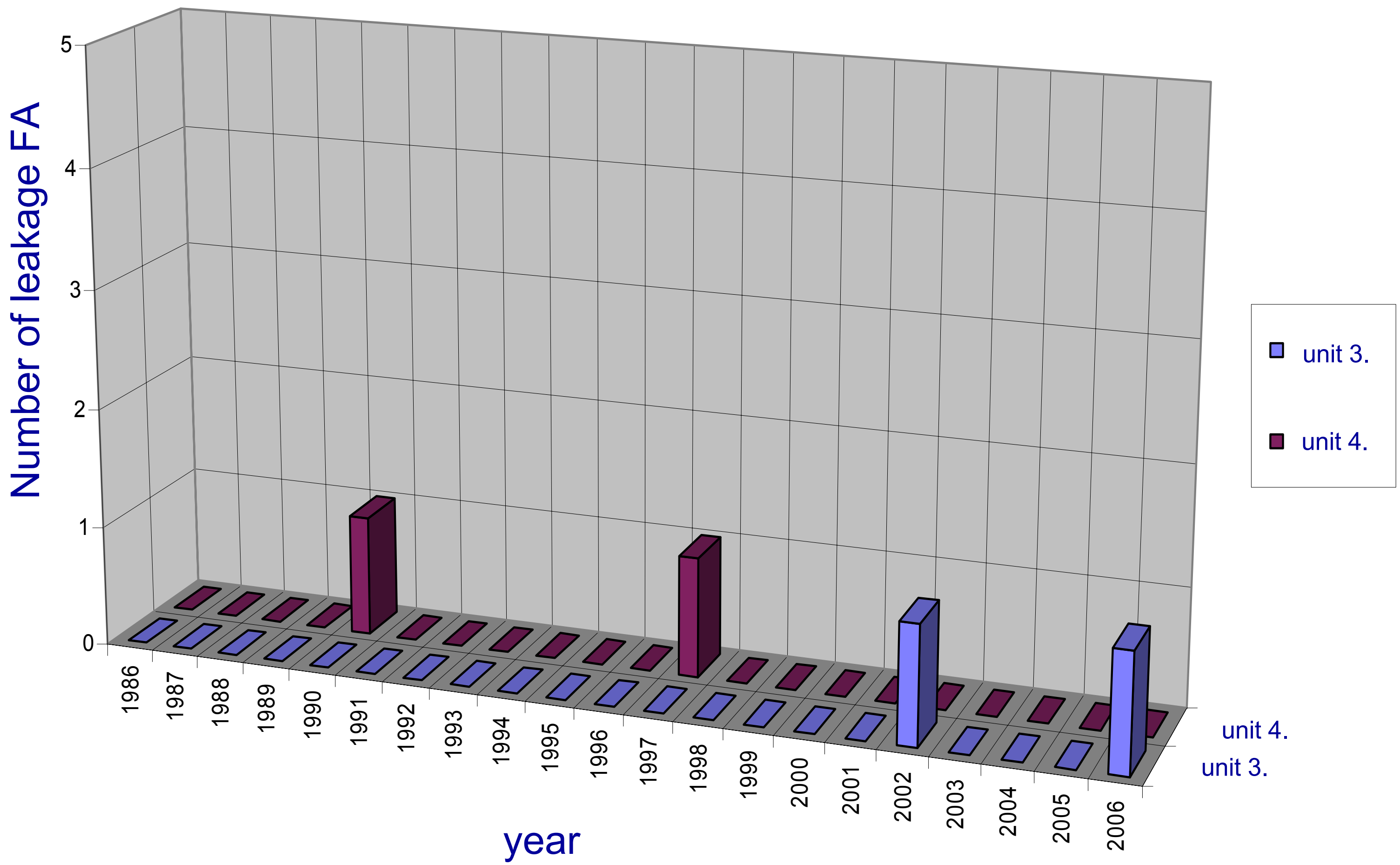

Fig 3. Screen - Power distribution (system tests)

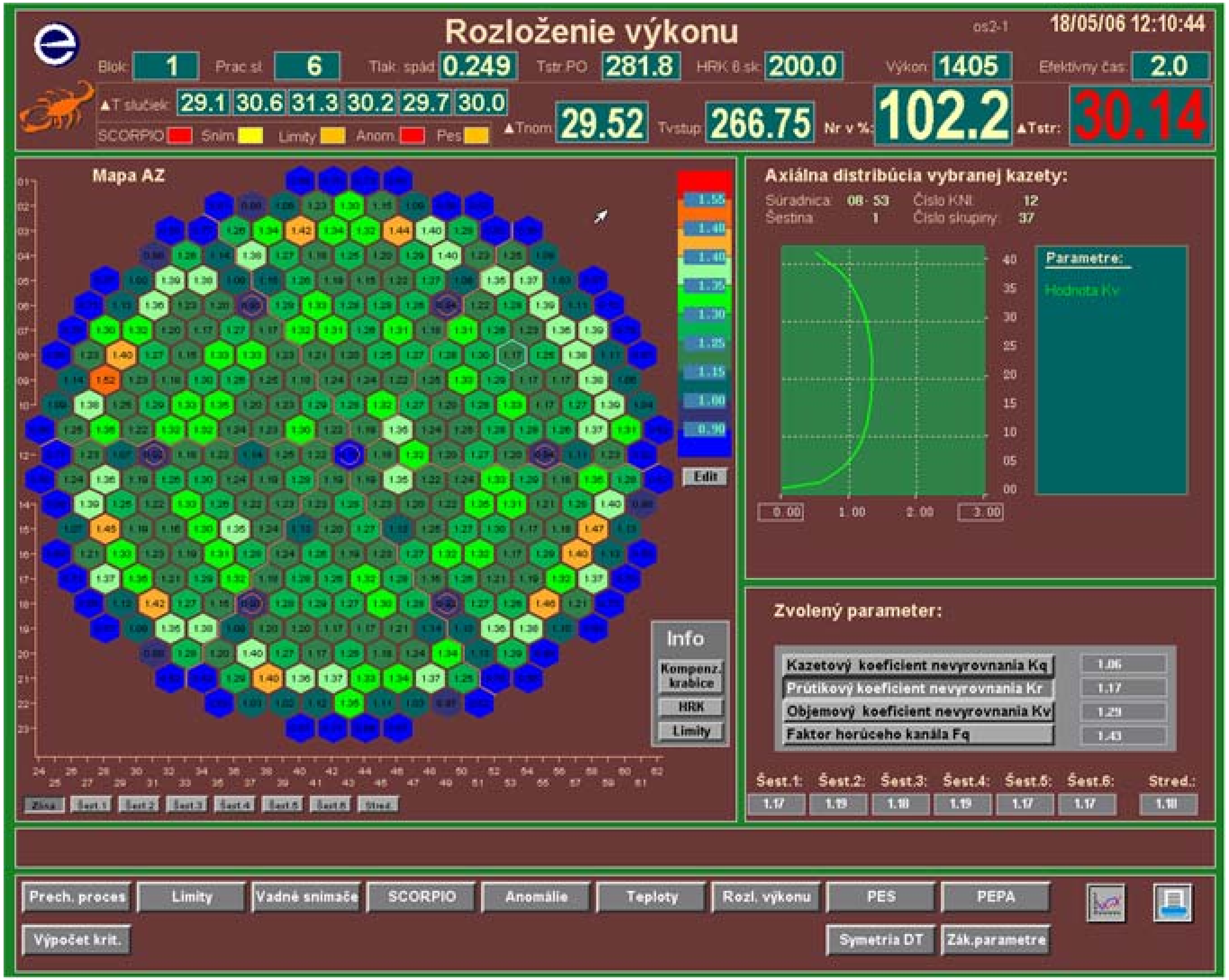

Fig.4 Screen – Strategy generator

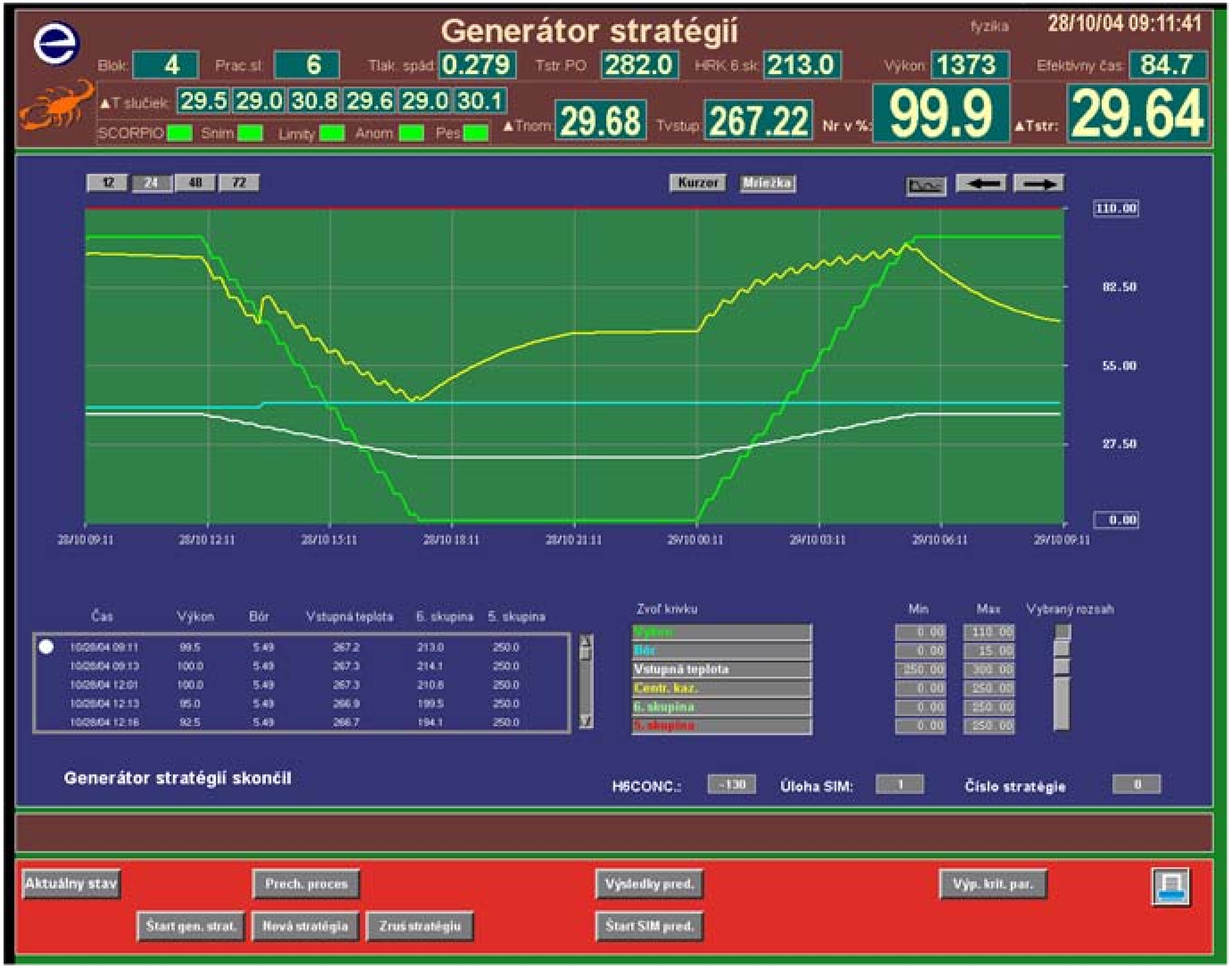

Fig.5 Screen – Limit checking(system test)