3KEYRELAP5 – Improvements and Applications

Igor Arshavsky

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Quick Overview

• 2007 – R&D Initiative to Develop 3KEYRELAP5

• Projects
  ▪ PWR: FP&L St.Lucie, Turkey Point; NINGDE
  ▪ BWR: PPL Susquehanna
  ▪ CANDU: Bruce-B, Bruce-A

• 3KEYRELAP5 Technology
  ▪ R3K Interface Software Layer
  ▪ RELAP5 xml-based Editor
  ▪ Control Interpreter - SCATER
  ▪ RELAP5-3D Real Time Improvements
St. Lucie Reactor Vessel
3KEYRELAP5 Technology
RELAP5 – 3KEYMASTER Interface

- all interactions between 3KEYMASTER and RELAP5
- no need to change RELAP5 source code
- possibility to run RELAP5 in stand alone mode
- solid ground for further development stages
RELAP5 as a 3KEYMASTER Task

- Flexible RELAP5 Time Step Adjustment
- Flexible RELAP5 Task CPU Assignment
- RELAP5 Data Presentation in form of Trends, Tables and Dynamic Drawings
- Possibility to run several Real-Time RELAP5 Tasks under same simulator load
- Full control through Instructor Station
- Real time change of boundary conditions
- Access to all RELAP5 ME variables
• make time advancement
• write restart file
• read restart file
• setup model time
• setup mode
  ▪ steady-state / transient
  ▪ components to run (hydro, htadv, rkin)
  ▪ print major edit
  ▪ debug mode on/off
• generate list of ME variables
• output specified variables
• input parameters of TDC and control variables
• programming features
  ▪ LAG input/output parameter
  ▪ change heat capacity of specified material
  ▪ change fouling factor of specified heat structure
  ▪ change form loss coefficients and/or hydraulic diameter of specified junction
R3K – time advancement

RELAP5 3KEYMASTER Task

- set up iteration limit and components frequencies
- Loop
  - Determine component semaphores
  - Process time dependent components and trips
    - htadv
    - hydro
    - rkin
    - dtstep
### R3K – Fixed Frequencies

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- **TH Time**
- **CR Time**
- **Clock Time**
R3K – Floating Frequencies
R3K – Floating Frequencies

![Graph showing floating frequencies with markers at intervals (1, 20, 39, 58, 77, 96, 115, 134, 153, 172, 191, 210, 229, 248, 267, 286, 305, 324, 343, 362, 381, 400, 419, 438, 457, 476). The graph compares 'FF' and 'small dt' with a downward trend.]
R3K- RELAP5 Variables Access

```
r3k.tdcomp
<name of variable>  <component number>  <Lag time>

r3k.medit
<name of variable>  <component number>  <Lag time>
```
R3K – RELAP5 Variables Access
R3K – RELAP5 Variables Access
if (*rlp_th_refuel)
{
    OPENPVLV(cntrlvar645, 0.1);

    double addLevel = (MAXVOID - *voidg670010000)* MAXLEVEL;

    if (addLevel > MAXLEVEL)
    {
        addLevel = MAXLEVEL;
    }

    *cntrlvar10 = *cntrlvar10 + addLevel;
}
else
    CLOSEPVLV(cntrlvar645, 0.1);
R3K – snap/reset file

- each restart in separate file
- fully compatible with stand alone RELAP5
- possibility to replace RELAP5 components after restart
- possibility to change model time after restart
- backtrack options
  - run in separate thread
  - run on another CPU
  - automatic compress
Options to develop Control System

- RELAP5 Input Deck
  - complex when logics involved
  - changes require re-snap ICs
- 3KEYMASTER task C++ program
  - have to build task

Symbolic Calculations and Transfer - SCATER

- implemented in YACC
- invoked on every time step
- no declarations, simple and handy
density[] = {
    80.0, 1011.838,
    100.0, 1005.543,
    150.0, 988.4994,
    300.0, 922.7115
}

dp50 = (r5.p052020000 + r5.rho052010000 * 15.93) – r5.p050010000

dp50lag = lag(dp50, 1.5);

reftemp = 0.09 * r5.tempg050010000 + r5.cntrlvar6761 * 0.91;

level50 = density[reftemp] * 25.2 + dp50;

r5.cntrlvar50 = nconv[level50];

if (aa > 1.5 || 2.4 < dd) {
    dd = 1.0;
}
vvv = time;
vvv = dt;

conv[ ] = {
  "m-inch", 1011.838 \n  "cnn", 1005.543 \n  "cnn", 998.9754 \n}

cc = cc * conv["m-inch"];

bb = bb + (aa +sin(0.5)*3.0 + aa);
XML definition in external file
First Version - Validator

<PIPE>
  <CardNo0001 MaxNumber="0001" option="Required" wno="1" help="pg_0070">
    <W1 name="Vol num" type="int" range="GT 0 AND LT 100" update="var" value="0" N="1" help="pg_0070"/>
  </CardNo0001>
  <CardNo0003 MaxNumber="0003" option="Optional" wno="5" help="pg_0072">
    <W1 name="Magnetic f str" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
    <W2 name="Duct wall cond" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
    <W3 name="Duct wall thickness" type="float" range="GE 0" update="var" value="0" help="pg_0072"/>
    <W4 name="Duct geometry type" type="int" range="EQ 1 AND EQ 2" update="var" value="1" wopt="opt" help="pg_0072"/>
    <W5 name="Fringe volume flag" type="int" range="GE -1 AND LE 2" update="var" value="0" wopt="opt" help="pg_0072"/>
  </CardNo0003>
  <CardNo0101 MaxNumber="0199" option="Required" wno="2" help="pg_0073">
    <W1 name="Area X" type="float" range="GE 0" update="var" value="0.0" help="pg_0073"/>
    <W2 name="Vol No" type="int" range="GT 0" update="var" value="1" help="pg_0073"/>
  </CardNo0101>
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Boundary Checker Task
RELAP5-3D Real Time Improvements
Pump Two-Phase Multiplier

\[
\alpha_L \leftarrow \frac{1}{2} (\alpha_{j-1} + \alpha_j)
\]
\[
\left( \frac{\rho_f - \rho_g}{\rho_f \rho_g} \right) (P_L - P_{KS}) + \frac{\alpha_{gs} \rho_{gs} A_g}{\alpha_{gl} \rho_{ga} A_L} (v_{gL} - v_{gs}) + \frac{\alpha_{gd} \rho_{gd} A_g}{\alpha_{gl} \rho_{ga} A_L} (v_{gL} - v_{gd}) + \frac{1}{2} \frac{\alpha_{jKS} \rho_{jKS} (v_{gS}^2 - v_{gKS}^2)}{\alpha_{jKS} \rho_{fa}} = 0
\]

\[
\frac{\alpha_{jS} \rho_{jS} A_s}{\alpha_{jL} \rho_{ja} A_L} (v_{jL} - v_{jS}) + \frac{\alpha_{jD} \rho_{jD} A_s}{\alpha_{jL} \rho_{ja} A_L} (v_{jGL} - v_{jD}) + \frac{1}{2} \frac{\alpha_{jKS} \rho_{jKS} (v_{jS}^2 - v_{jKS}^2)}{\alpha_{jKS} \rho_{fa}} = 0
\]

\[
\alpha_{gl} = \frac{1}{2} (\alpha_{gL} + \alpha_{gj})
\]

\[
\alpha_{jL} = \frac{1}{2} (\alpha_{jL} + \alpha_{j})
\]
RELAP5 Real Time Improvements
• Dalton-Gibbs Equations Convergence Failure

• Noncondensables First Appearance Criteria

• Velocities Flip-Flop for Selected Junctions
Parallel Threads Execution
Parallel Threads

- **TaskMain**
  - **htadv**
    - **new N buffer**
  - **hydro**
    - **wait for signal**
    - **information exchange**
    - **time step end**
- **rkin**
  - **parallel thread**
  - **new TH buffer**
Parallel Threads

Performance Results Comparison

- Sequential execution, TH time step 0.05 sec., N time step 0.2 sec.,
  CPU load: 1 – 5%, 2 – 70%

- Sequential execution, TH time step 0.01 sec., N time step 0.1 sec.,
  CPU load: 1 – 5%, 2 – 95%

- Parallel execution, TH time step 0.01 sec., N time step 0.1 sec.,
  CPU load: 1 – 50%, 2 – 60%
QUESTIONS