Using RastrWin3 software for planning and control of active-adaptive (smart) grids

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"RastrWin" is a suite of integrated electrical engineering software solutions. The first version was released in 1989. Mainly used in Russia, Kazakhstan, Kyrgyzstan, Uzbekistan, Belarus, Moldova, Mongolia, Yugoslavia.

Our team took part in projects mainly by request of System Operator (SO). Also we collaborate with FEES, NP ATS, project and research institutes ("Energosetproject", "VNIIE", "NIIPT“ ...).
We have took part in projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Details</th>
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<tr>
<td>Mechanism of assembling united calculation model of UPS (so-called</td>
<td>&quot;Actualization&quot;).</td>
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<td>Constraint optimal power flow for united calculation model of UPS.</td>
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<td>Dynamic simulation</td>
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<td>Thermal unit commitment for day ahead market.</td>
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<td>Monitoring system of available transmission capability for north areas</td>
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<td>of Tyumen.</td>
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<td>installation in System Operator Siemens SCADA/EMS software.</td>
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RastrWin key features

**Power Flow**
[RastrWin]

**Dynamic Simulation**
[RusTab]

**Nonlinear Optimal Power Flow**
[LincorWin]

**Fault Analysis**
[RastrKz]

**Network reduction**

**Synthesis large calculation model of UPS**
[Actopus,Bars]

**Representation data and results on single line diagram**

**Representation data and results on detailed single line diagram**
[RastrKS]

**Power Transfer Distribution Factors**

**Determination of weak interface**
[RastrMDP]

Import data from: PSS/E, Eurostag, PowerCC, Mustang, Kocmoc, ARM SRZA, TKZ-3000, CSV.
Software has module architecture. Graphical user interface disconnected from calculation module. All interaction through COM-interfaces. This separation allows use all calculation functions from 3rd party applications, such as Excel, Word etc.
Graphical user interface

- simple Tab-View;
- complex tables, produced from two simple tables;
- hierarchical representation with help of so called "Selector", (all data represented in hierarchical tree);
- coloring by nominal voltages using different thick for different nominal voltages.
- diagram gradient filling based on the value of selected parameter;
Advanced single line diagram – full view
Advanced single line diagram – single substation view
Built-in macro language is dialect of VbScript.

Built-in database.

Access to all calculation functions through COM interfaces.
De-facto standard of power flow analysis in Russia.
Calculation method full AC Newton-Raphson technique capable efficiently performing power flow analysis on system containing more then 200000 buses. Can model DC links and FACTS.
Constrained nonlinear optimal power flow

Generator cost models

Average Heat Rates

Incremental Heat Rate

Bid, rub./MW

Penalty function, rub./MW

Pseudo bid, rub./MW
1. \[
\begin{cases}
\varphi_i(V, \delta, K, P_i^{\text{ren}}) = 0 \\
\phi_i(V, \delta, K, P_i^{\text{ren}}) = 0
\end{cases}
\]
Steady state equations in polar coordinates

2. \[Q_i^{\text{min}} \leq Q_i \leq Q_i^{\text{max}}
\]
Min/max reactive power producing and mini/max voltage module

3. \[K_v^{\text{min}} \leq K_v \leq K_v^{\text{max}}
\]
Active and reactive components in transformation ratio

4. \[I_v(V, \delta, K) - I_v^{\text{aton}} \leq 0
\]
Transmission line current

5. \[P_G^{\text{min}} \leq \sum_{G} P \leq P_G^{\text{max}}
\]
Maximal generators output for single and group of generators (Unit generation limits)

6. \[P_s^{\text{min}} \leq P_s(V, \delta, K) \leq P_s^{\text{max}}
\]
Max/min flow through interface

7. \[B_G^{\text{min}} \leq \sum_{j} \sum_{G} P_i^{\text{ren}}(t_{j+1} - t_j) \leq B_G^{\text{max}}
\]
Integral fuel consumption and water resources

8. \[-V_i^{\text{up}}(t_{j+1} - t_j) \leq \left( P_{i,t_{j+1}}^{\text{gen}} - P_{i,t_j}^{\text{gen}} \right) \leq V_i^{\text{up}}(t_{j+1} - t_j)
\]
Ramp rate limits of generator
Solution provided by interior point method.

Module determine:
1) generators output
2) Voltage module for reactive power sources
3) Active and reactive component of transformation ratios.

Current solved problem on CDU level consist of:
- Buses — 6223
- Branches — 9480
- Generators — 733
- Interfaces — 346
- Integral constraints on power produce — 51

Module produce bus marginal prices.

Time for planning on 24 intervals took near 5 minutes.
Thermal unit commitment

\[ \sum_{t=1}^{T} \sum_{i \in G} (c_{g_i}^t \cdot P_{g_i}^t + c_{up_i}^t \cdot u_i^t) \rightarrow \min, \]

- Maximal generators output for single and group of generators (Unit generation limits)
- Integral fuel consumption and water resources
- Max/min flow through interface
- Ramp rate limits of generator

Used linear mixed integer solver CPLEX.

Generators – 400
Interfaces – 200
Time for planning on 96 intervals took near 20 minutes
Fault Analysis

Provides a network solution of fault currents:

- three-phase
- single-line to ground
- line-to line,
- and double line to ground

Buses – 2962
Branches – 3671
Generators – 322

Calculate equivalent resistance.

Have import from ARM SRZA and TKZ-3000.
Detection of weak interface

In process-time detection of weak interface and maximal power. Allows to determine the maximum MW transfer possible between two parts of the power system without violating any limits.

Algorithm consist from follow steps:
1. Continuation before steady-state voltage stability limit will be reached
2. Calculation markers of weak interface
3. Relaxation to normal steady-state on relaxation coefficient
Weak interface construction

1) Choose line with max coefficient
2) Disconnect this line
3) Find shortest path between nodes of first line
4) go to 1

While (scheme not divided)
• Short-time and long-time transient simulations.
• Robust methods of integration.
• Integration are use methods with variable step size.
• High calculation performance (Uses SIMD processor commands)
• Automatic relay actions based on relay settings.
• Unlimited sequence of events and actions.
• Large library of verified models. Included DC links and FACTS.
• User-Developed dynamic models.
Model of Automatic Turbine Speed Controller

\[
\begin{align*}
\text{Const}(\Omega_{\text{Ref}}, Z_n, \Sigma, Mv_{\text{Min}}, Mv_{\text{Max}}, Vp_{\text{Min}}, Vp_{\text{Max}}, T_g); \\
\text{Variable}(\Omega, \mu_0); \\
\text{Control}(\mu);
\end{align*}
\]

\[
\begin{align*}
\text{function Init}() \\
\{ \\
\quad I_0 = \mu_0; \\
\quad W_0 = 0;
\}
\end{align*}
\]

\[
\begin{align*}
\text{function Main}() \\
\{ \\
\quad \text{Signal} = \text{sum}(\text{dband}(\Omega - \Omega_{\text{Ref}}, Z_n) / \Sigma, \mu_0, -\mu); \\
\quad \text{Servo} = \text{limit}(\text{w}(\text{Signal}, T_g, W_0), Mv_{\text{Min}}, Mv_{\text{Max}}); \\
\quad \mu = \text{limit}(\text{integral}(\text{Servo}, I_0), Vp_{\text{Min}}, Vp_{\text{Max}}); \\
\quad \text{Ret} \mu;
\}
\]
Thank you for your attention!

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