Characteristics of the new Power System Dynamic Simulator in NEPLAN

BCP

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June 26, 2008

Hybrid System Representation

- **D**ifferential **S**witched-**A**lgebraic State **R**eset Equations (DSAR)

$$
\begin{aligned}
\dot{x} &= f(x, y, z) \\
\dot{z} &= 0 \\
0 &= g^{(0)}(x, y, z) \\
0 &= \begin{cases} g^{(i^-)}(x, y, z) & y_{s,i} < 0 \\ g^{(i^+)}(x, y, z) & y_{s,i} > 0 \end{cases} \qquad \mathrm{i} = 1, \ldots, \mathrm{s} \\
z^+ &= h_j(x^-, y^-, z^-) \qquad y_{r,j} = 0 \qquad \mathrm{j} = 1, \ldots, \mathrm{r}
\end{aligned}
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- DSAR captures the **dynamic**, **non-linear** and **hybrid** nature of power system components
- Implemented in **MATLAB** and **NEPLAN**

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Implementational Issues

- Implementations in
  - **MATLAB** – ODE Solvers
  - **NEPLAN** – Trapezoidal, Gear's Method
- Simulation Process
  - Simultaneous solution of DAE's
  - Sparse Matrix Solution Techniques
- Interface Functions for the Simulation Kernel
  - **MATLAB** – M-code of the model
  - **NEPLAN** – DLL of the Model
- Model Creation
  - Automatic Code Generation

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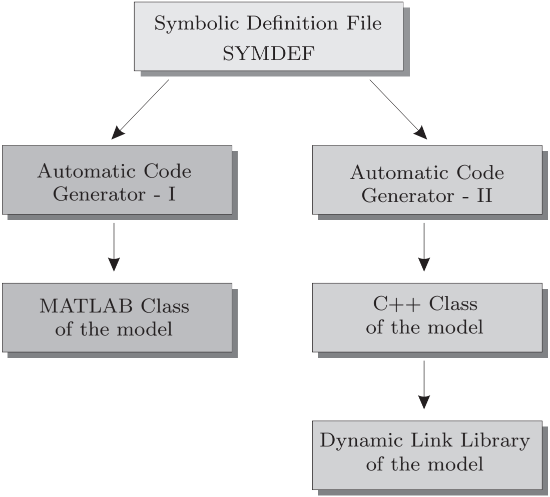
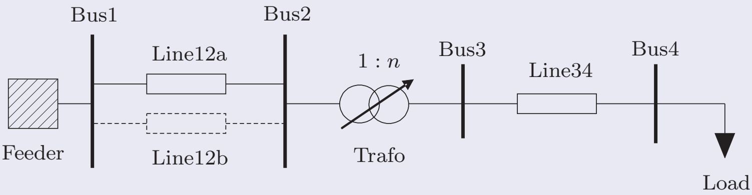
Automatic Code Generation



Tap Changing Transformer

Simple Test Case



Line12a $\rightarrow R = 0 \;\; X = 0.65$

Line12b $\rightarrow R = 0 \;\; X = 0.40625$

Line34 $\rightarrow R = 0 \;\; X = 0.80$

Trafo $\rightarrow V_{low} = 1.04 \;\; N_{max} = 1.1 \;\; T_{tap} = 20.0 \;\; N_{step} = 0.0125$

Feeder $\rightarrow |V| = 1.05 \;\; \angle V = 0$

Load $\rightarrow P_0 = 0.4 \;\; Q_0 = 0.0 \;\; T_p = 5 \;\; T_q = 5 \;\; A_s = 0 \;\; A_t = 2 \;\; B_s = 0 \;\; B_t = 2$

Tap Changing Transformer Logic

- As long as the voltage measured at the high-voltage end of the transformer is within the allowed deadband or the tap is at the upper limit, the timer is blocked.
- The timer will start to run if the voltage gets outside the deadband.
- If the timer reaches the time set for tap delaying, a tap change will occur and the timer will be reset but not necessarily blocked.
- Blocking and resetting of the timer takes place if the voltage moves back to within the deadband.

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Tap Changing Transformer Logic ⇒ DSAR Structure

```
%-----------------------
definitions:
%-----------------------
dynamic_states timer
discrete_states N timeron
external_states ed1 eq1 id1 iq1 ed2 eq2 id2 iq2
internal_states Vt
parameters Vlow Nmax Ttap Nstep
events +insideDB -outsideDB +tapmax_ind -t_until_tapchange
```

```
%-----------------------
f_equations:
%-----------------------
dt(timer) = timeron
```

```
%-----------------------
g_equations:
%-----------------------
g1 = insideDB - (Vt - Vlow)
g2 = outsideDB - (Vt - Vlow)
g3 = t_until_tapchange - (Ttap - timer)
g4 = tapmax_ind - (N - Nmax + Nstep/2)
g5 = ed2 - ed1*N
g6 = eq2 - eq1*N
g7 = id1 + id2*N
g8 = iq1 + iq2*N
g9 = Vt - sqrt(ed2^2 + eq2^2)
```

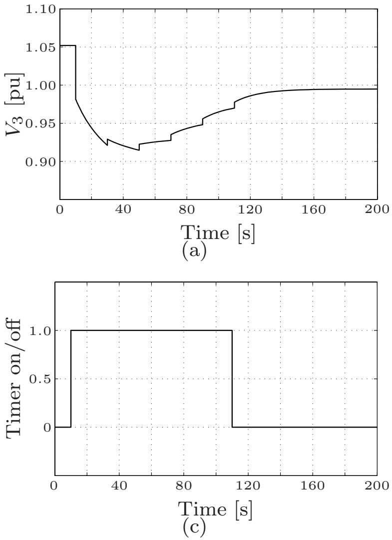
```
%-----------------------
h_equations:
%-----------------------
if insideDB == 0
    timer+ = 0
    timeron+ = 0
end

if outsideDB == 0
    timer+ = 0
    timeron+ = 1
end

if tapmax_ind == 0
    timer+ = 0
    timeron+ = 0
end

if t_until_tapchange == 0
    timer+ = 0
    N+ = N + Nstep
end
```

Simulation Results



Power System Representation

- EMT - (Electromagnetic Transients)
  - Instantaneous Values of the electrical quantities
    $$x(\tau) = \Re\left\{\sum_{k=0}^{\infty} X_k(t) \cdot e^{jk\omega_s\tau}\right\}$$
  - Accurate, Inefficient
- RMS - (Transient Stability)
  - Fundamental Frequency Components of the electrical quantities
    $$x(\tau) \approx \Re\left\{\sum_{k=1} X_k(t) \cdot e^{jk\omega_s\tau}\right\}$$
  - Efficient, Not accurate
- DYNPH - (Dynamic Phasor Representation)
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