TECHNISCHE UNIVERSITÄT DRESDEN

Chair of Construction Machines and Conveying Technology

OpenModelica Workshop 2014

Splitting Algebraic Loops for Improved Performance and Parallelization

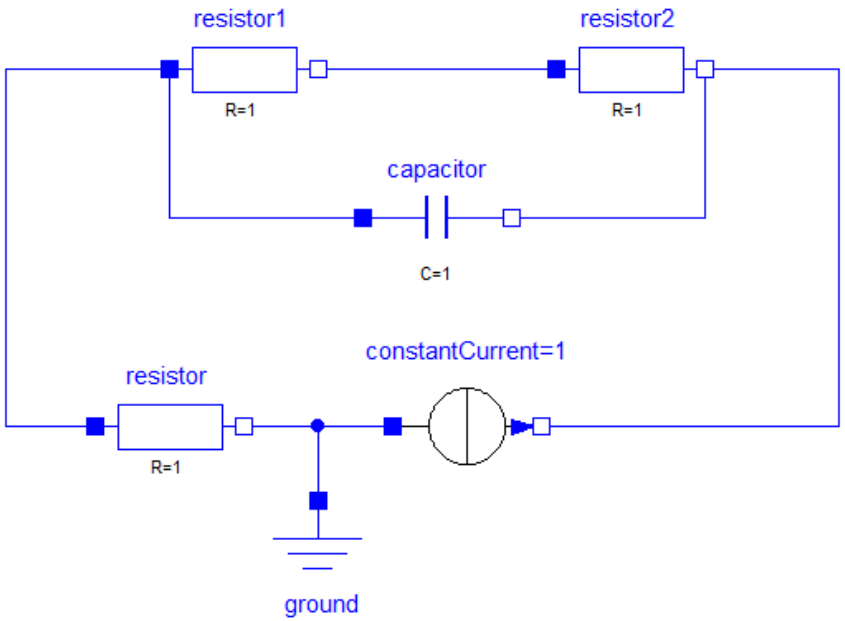
Linköping, 03/02/2014

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

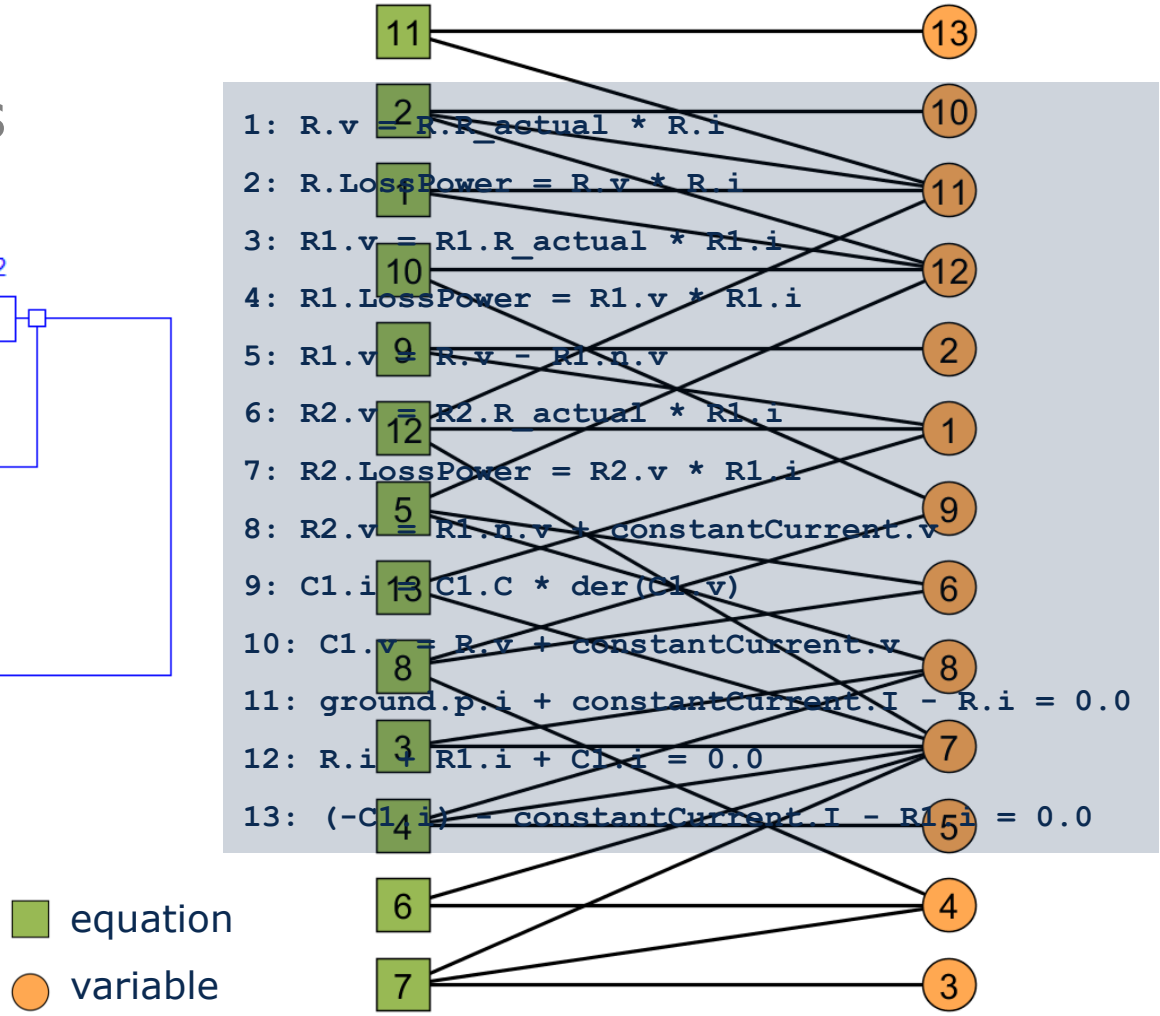
Outline

1. Algebraic Loop
2. Resolving Loops
3. Effects of Resolving Loops
4. Summary and Outlook

Algebraic Loops

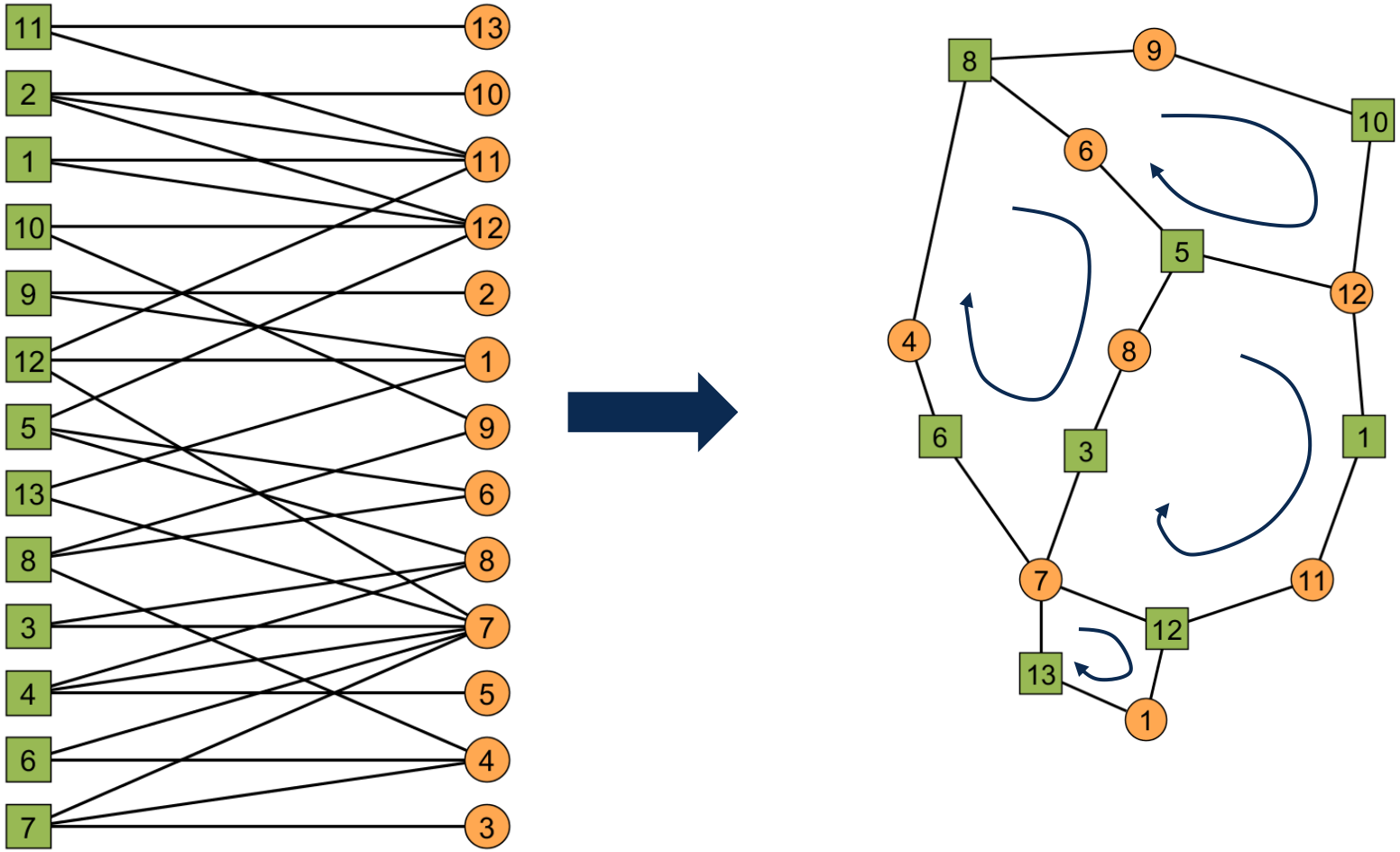


1: R.v = R.R_actual * R.i
2: R.LossPower = R.v * R.i
3: R1.v = R1.R_actual * R1.i
4: R1.LossPower = R1.v * R1.i
5: R1.v = R.v - R1.n.v
6: R2.v = R2.R_actual * R1.i
7: R2.LossPower = R2.v * R1.i
8: R2.v = R1.n.v + constantCurrent.v
9: C1.i = C1.C * der(C1.v)
10: C1.v = R.v + constantCurrent.v
11: ground.p.i + constantCurrent.I - R.i = 0.0
12: R.i + R1.i + C1.i = 0.0
13: (-C1.i) - constantCurrent.I - R1.i = 0.0



equation
variable

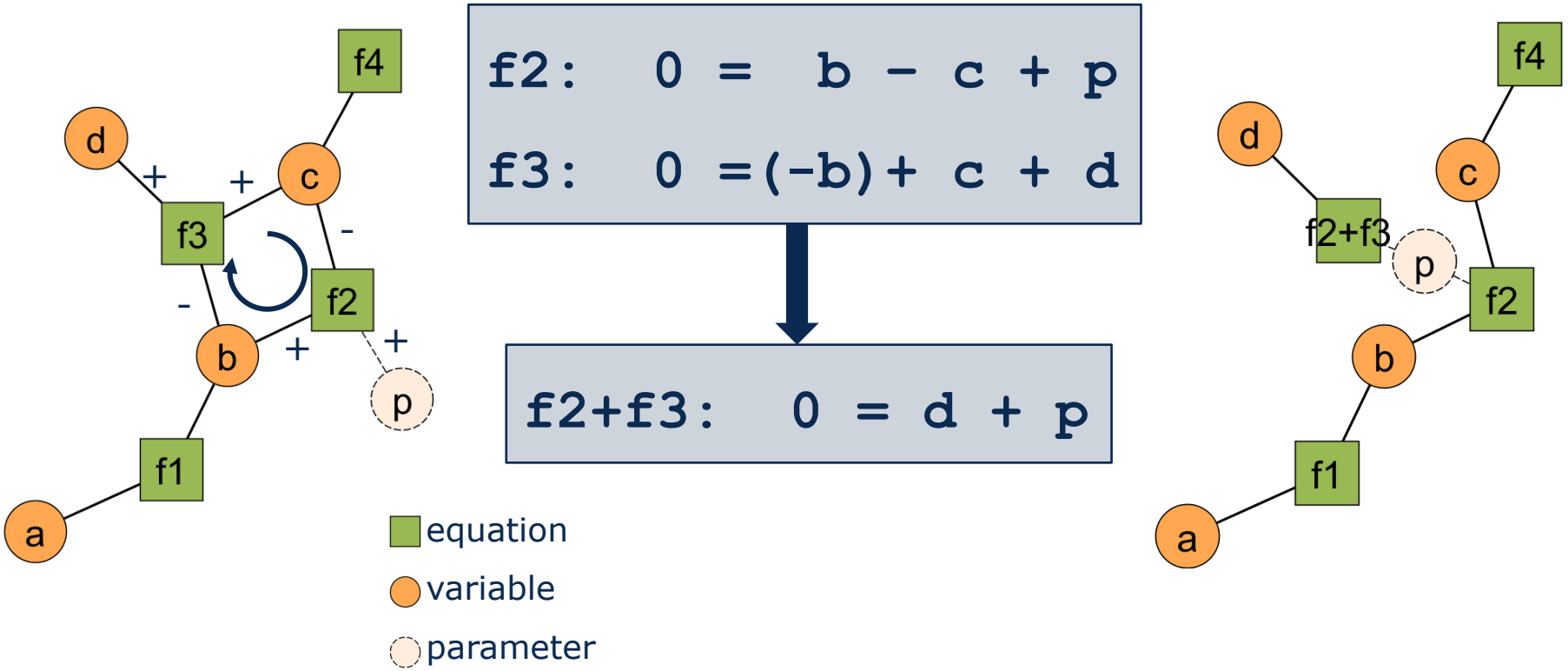
Algebraic Loops



How to handle an algebraic loop?

- Solving as an equation system with a linear or nonlinear solver routine
  - → expensive solving of big equation systems
  - → singular systems not treatable
  - → special treatment to parallelize systems
- Choose tearing-variables + Newton iteration
  - → tearing heuristic
  - → reduce sparse system to dense system
- Splitting loop
  - → resolve equations of the loop

What does it mean to resolve a loop?



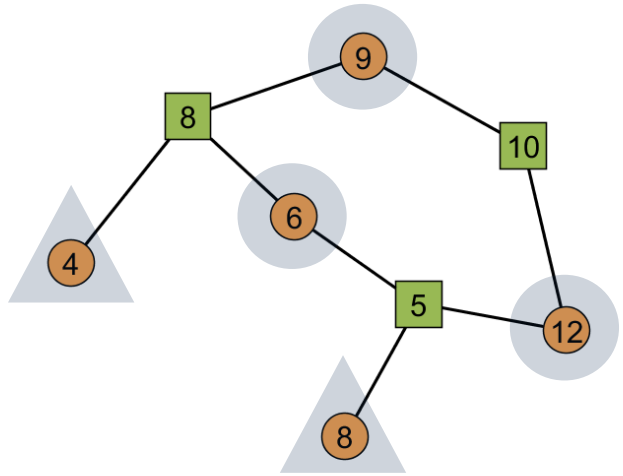
Resolving Loops

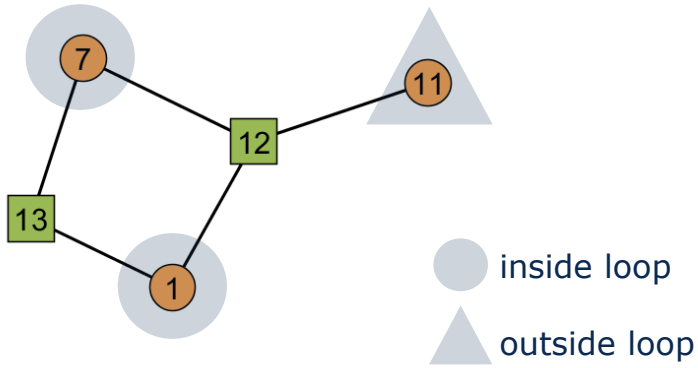
extract linear equations and adjacent variables
$0 = \sum_{i=1}^{k} x_i + n$

build partitions of subgraphs

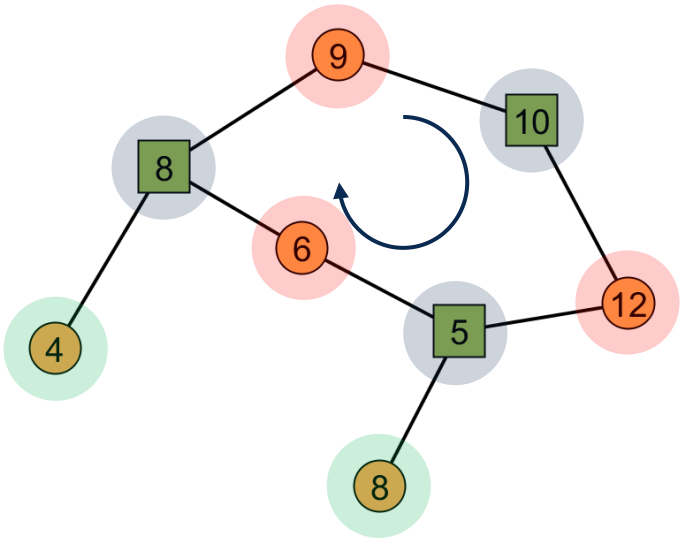
resolve?
→ compare number of variables
$n_{out} \leq n_{in}$

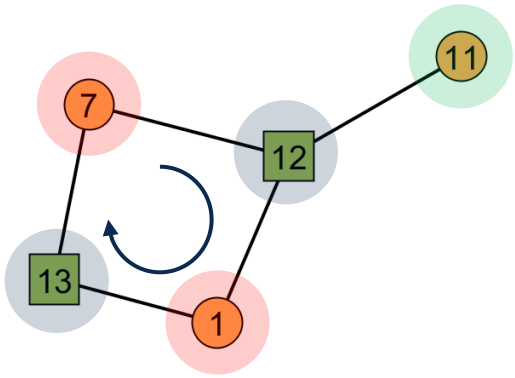
resolve loops





Resolving Loops





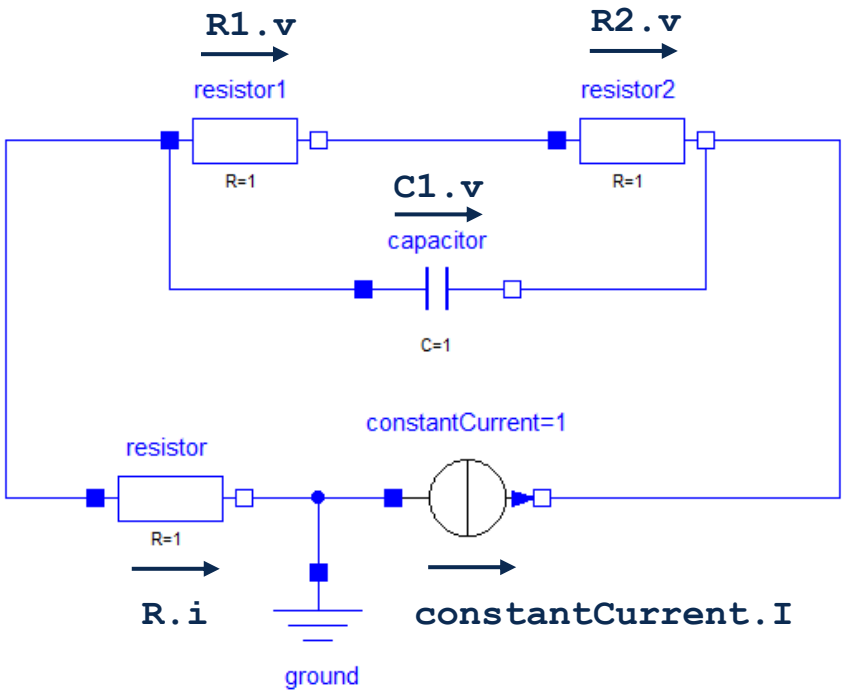

```
R1.v = R.v - R1.n.v
C1.v = R.v + constantCurrent.v
R2.v = R1.n.v + constantCurrent.v
```

```
0.0 = C1.v + (-R2.v) - R1.v
```

```
R.i + R1.i + C1.i = 0.0
(-C1.i) - constantCurrent.I - R1.i = 0.0
```

```
0.0 = constantCurrent.I - R.i
```

Resolving Loops



Kirchhoff's current law

```
0.0 = constantCurrent.I - R.i
```

Kirchhoff's voltage law

```
0.0 = C1.v + (-R2.v) - R1.v
```

connect equations ⟶ node and mesh equations (similar to fluid domain)

Effects of Resolving Loops

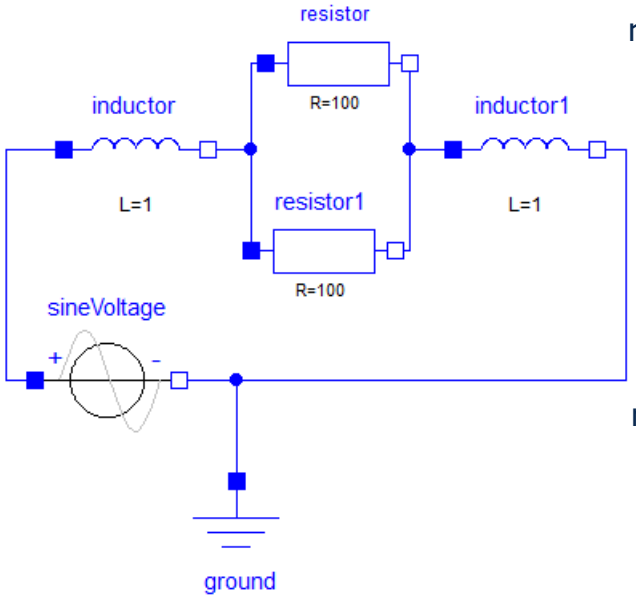
What is the effect of resolving loops?

For the presented model:

	no resolveLoops	with resolveLoops
equation system	{8x8} system	{3x3} system
speed up		1.14

→ reduce size of equation systems

Effects of Resolving Loops



Dymola User Manual Volume 2
p. 361

no resolveLoops

```
Error: When solving linear system
1 : resistor.i + resistor1.i - inductor.i = 0.0
2 : inductor1.i + (-resistor1.i) - resistor.i = 0.0
.
.
.
  U(2,2) = 0.0, which means system is singular for
variable resistor1.i.
```

2 (equal) states

with resolveLoops

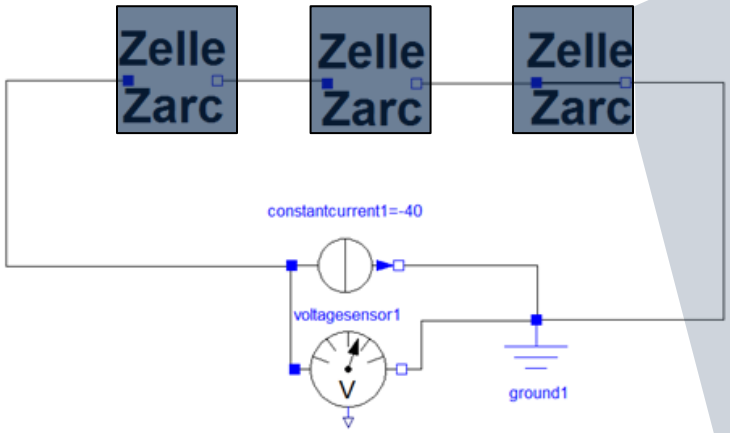
resolved equations:

```
0.0 = -ground.p.i
0.0 = inductor.i - inductor1.i
0.0 = resistor1.v - resistor.v
```

1 state
simulation succeeds

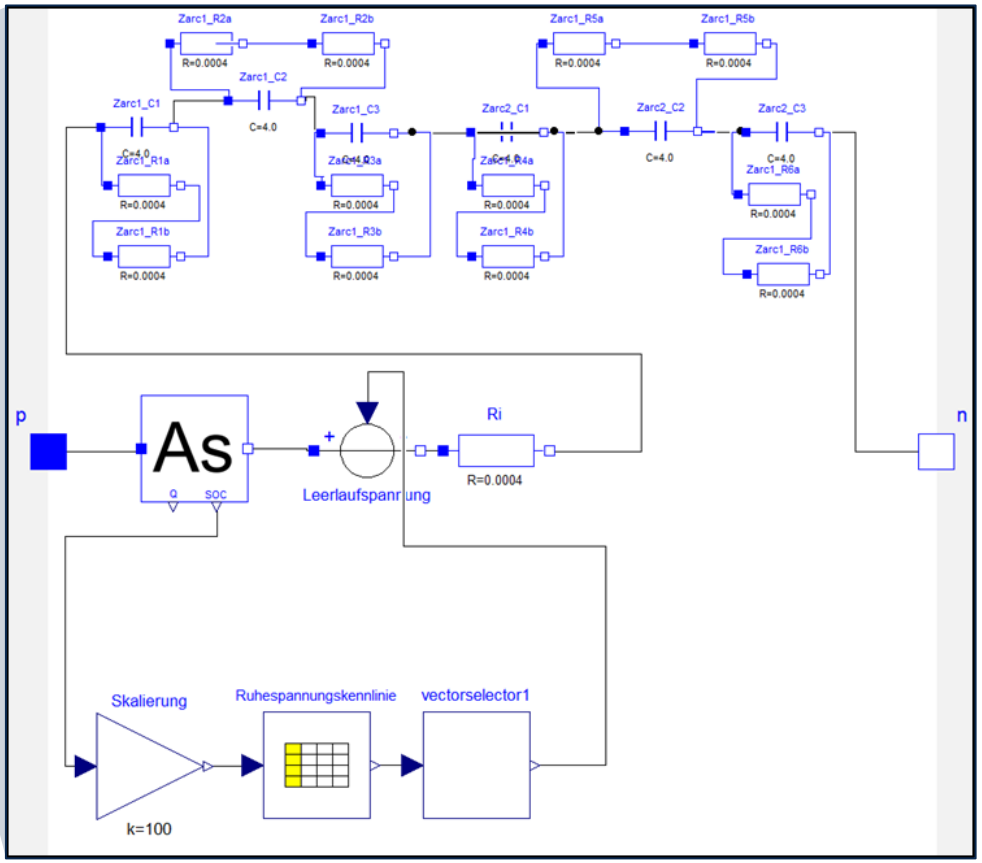
→ prevent singular systems

Effects of Resolving Loops



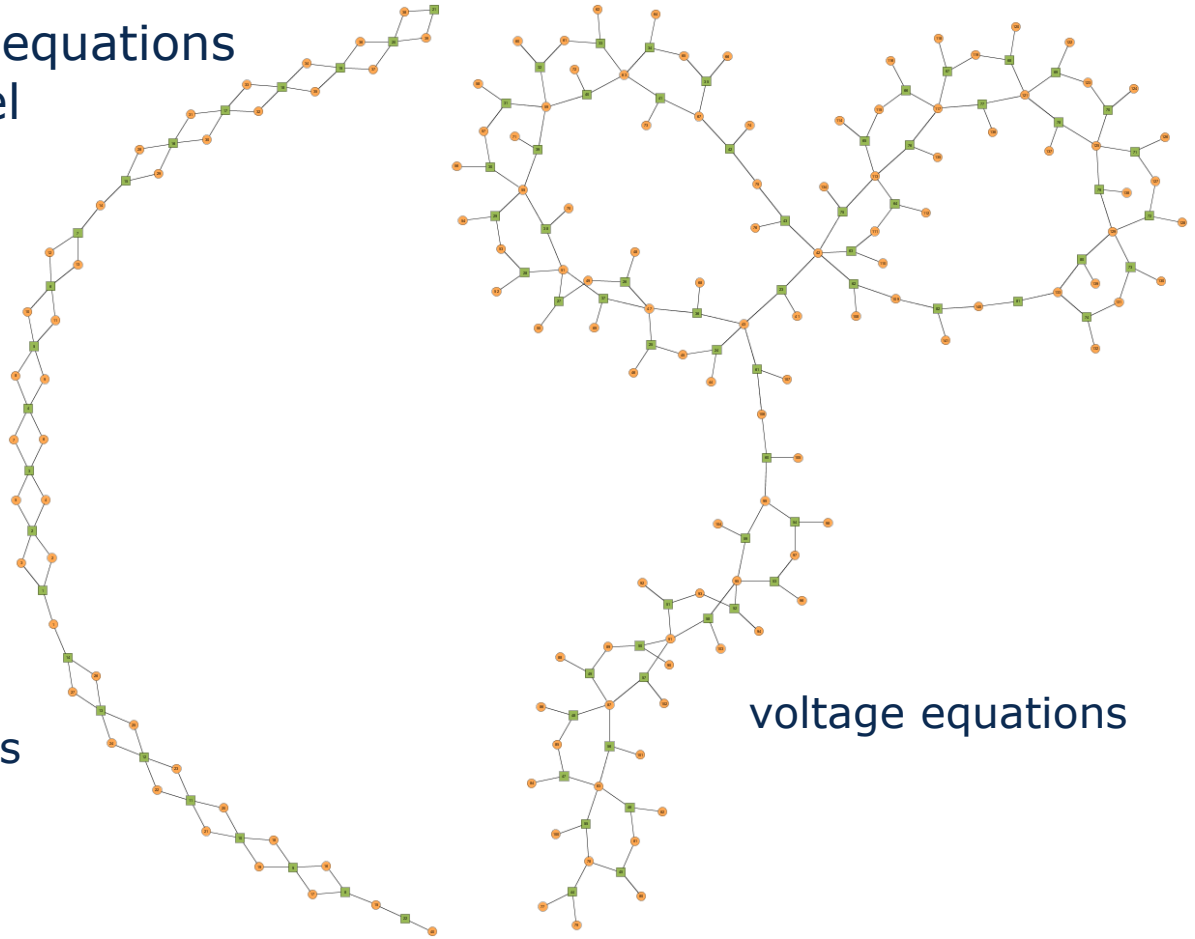
simplified battery model
for a hybrid car
(3 cells)

→ real model has 30 cells



Effects of Resolving Loops

bipartite graph
of the “ resolvable “ equations
of the battery model

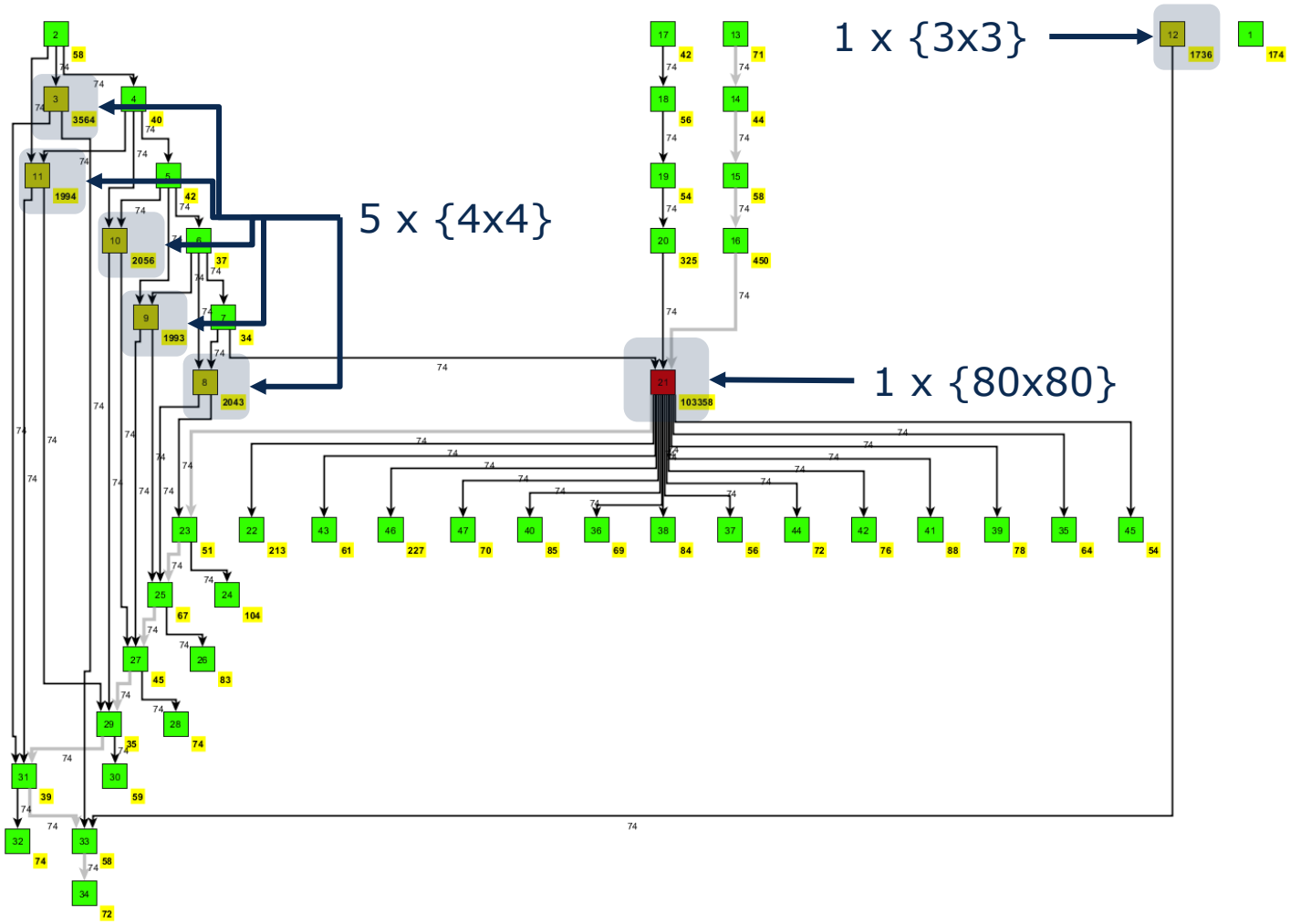


current equations

voltage equations

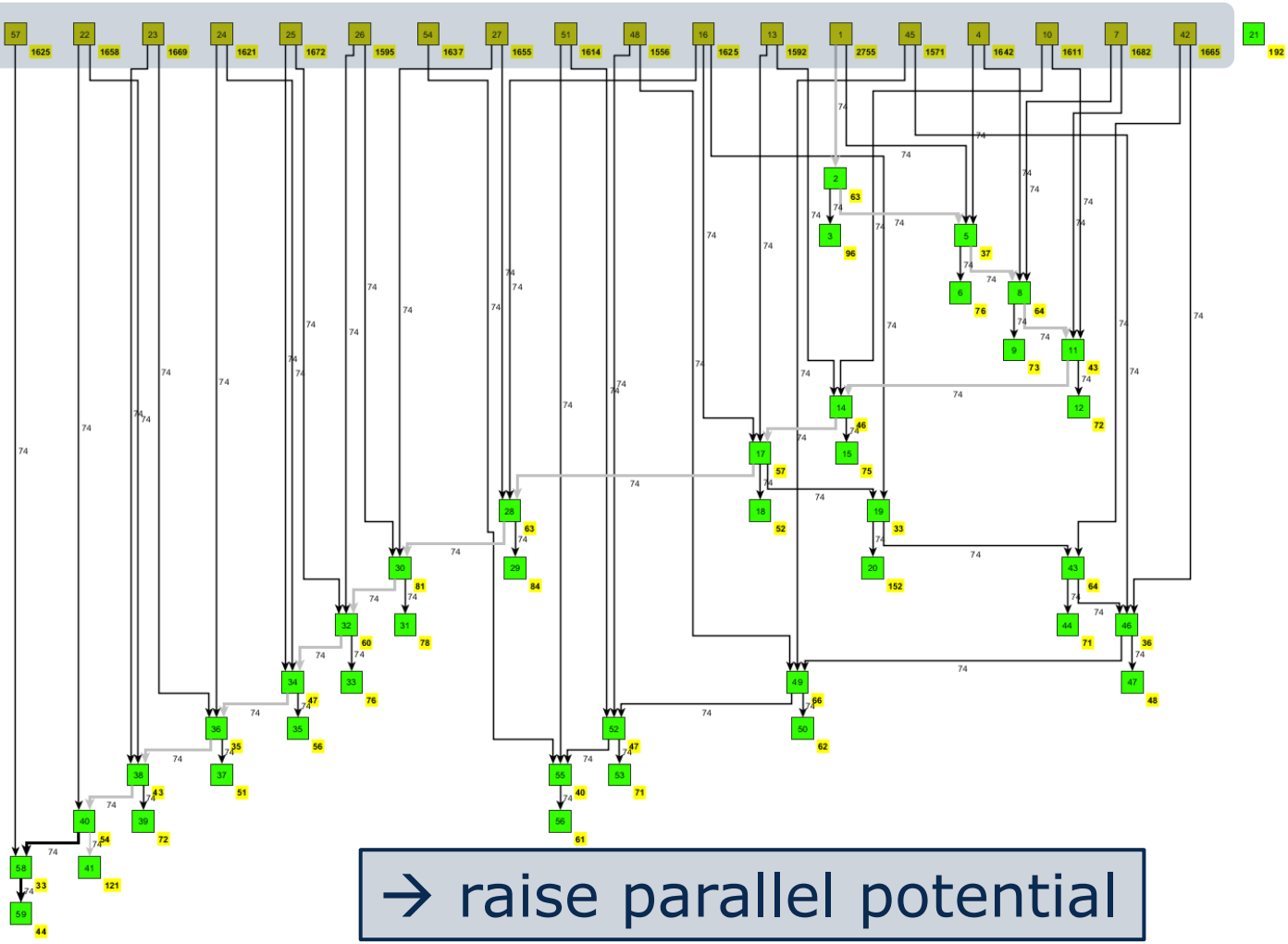
Effects of Resolving Loops

task graph
without
resolveLoops



Effects of Resolving Loops

18 x {3x3} →



task graph
with
resolveLoops

serial speedUp

1.98

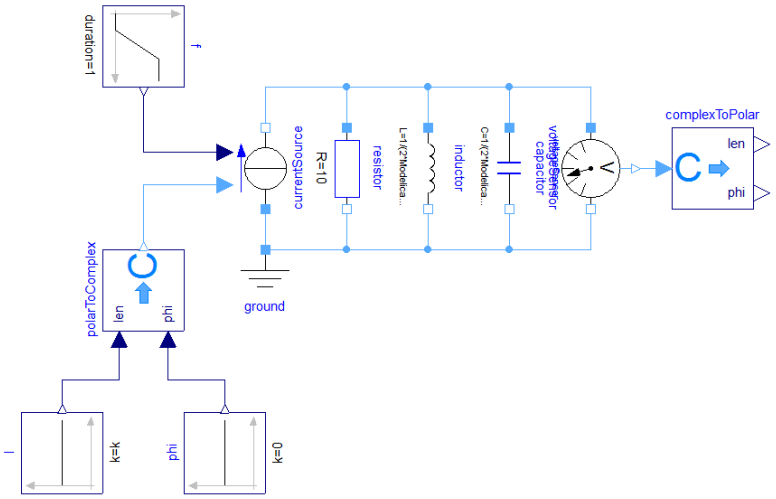
serial speedUp (30 cells)

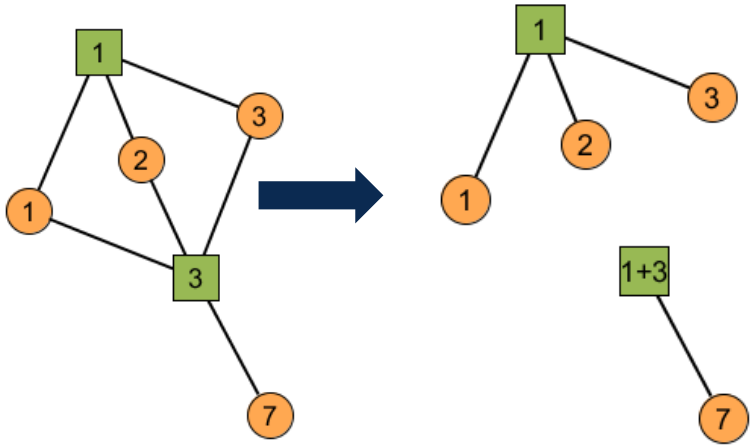
36.06

→ raise parallel potential

Effects of Resolving Loops

Electrical.QuasiStationary.SinglePhase.Examples.ParallelResonance





	no resolveLoops	with resolveLoops
strong Components	8 single equations	6 single equations

→ reduce number of SCCs

Summary

- Resolving algebraic loops can lead to:
  - → splitting up systems of equations
  - → prevent singular systems
  - → reduce number of ODE-equations
  - → raise parallel potential
- Serial and parallel speed up

Outlook

- Clarify: When to solve a loop?
  - Before or after index reduction?
  - Search for singularities or all loops?
  - Which and how many equations shall be replaced?
  - …
- Implementation for linear equations with constant coefficients
- Analyse more models from different domains

»Wissen schafft Brücken.«

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