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Distributed Real-Time Simulation System for Power Converter-Dominated Grid

Peilin Zhang
Avasition Electric Co. Ltd.

艾思逊 VASITION

上海电力大学 SHANGHAI UNIVERSITY OF ELECTRIC POWER

Agenda

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- Motivation and requirements
- State-of-the-art technologies and problems
- Solutions
  - Software-in-the-Loop (SiL) solution
  - Real-time (RT) solution
- Application example – wind farm simulation
- Conclusion

Motivation and requirements

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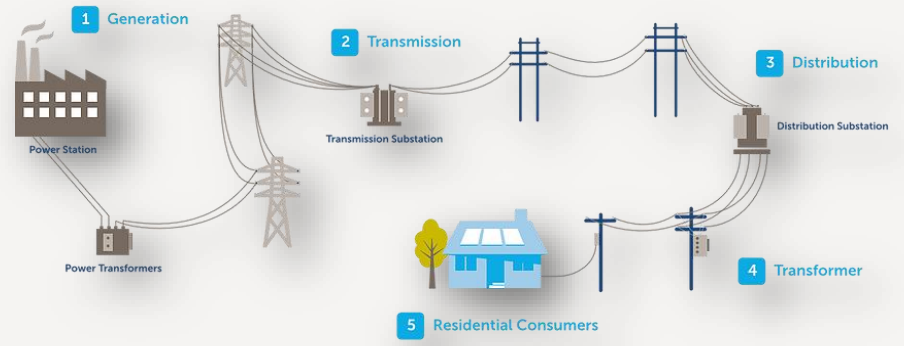
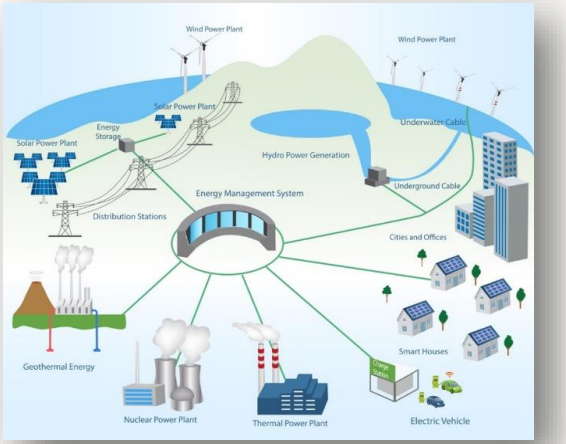
- The power grid is now changing from the conventional centralized structure to a decentralized converter-dominated structure
- Requirements on simulation tool
  - Large-scale system including hundreds of power converters
  - High-accuracy electromagnetic transient (EMT) simulation in µs



Conventional power grid



Converter-dominated power grid

State-of-the-art simulation technologies

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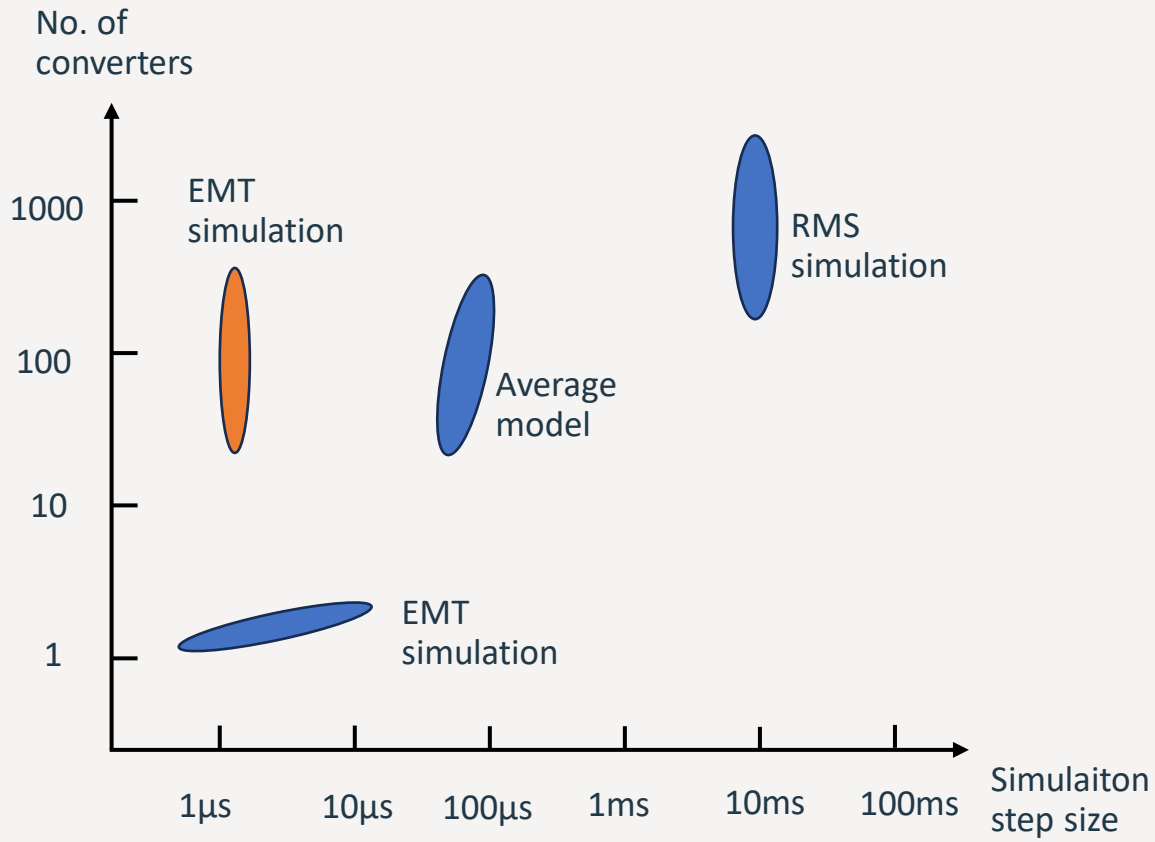
State of the art

- High-accuracy EMT simulation in device level (few converters)
- Large-scale root mean square (RMS) simulation in grid level (converters with strongly simplified model)
- Average model in approx. 100 µs step size

Requirements

- High-accuracy EMT simulation for large-scale system consisting hundreds of power converters in µs step size
- In case of RT simulation: very low time latency between coupled subsystems (simulation nodes) in µs level



Advanced simulation software - VIAvento

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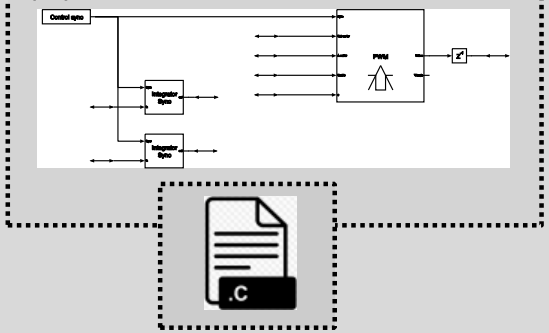
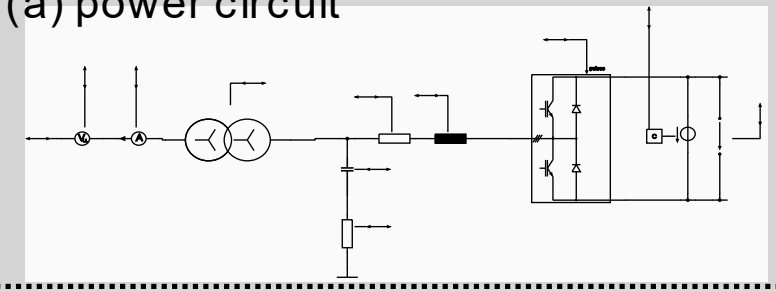
(b) converter control

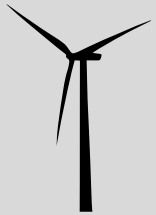


(a) power circuit



Scope of converter design

c) Componen building



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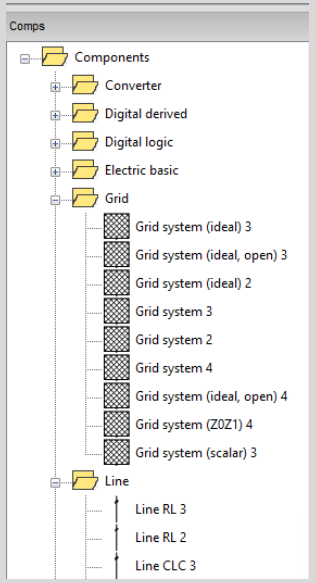
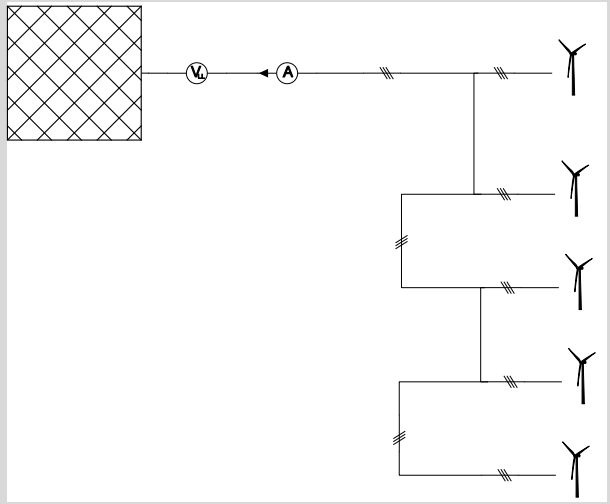
d) VIAvento comp. lab.



Scope of system engineering

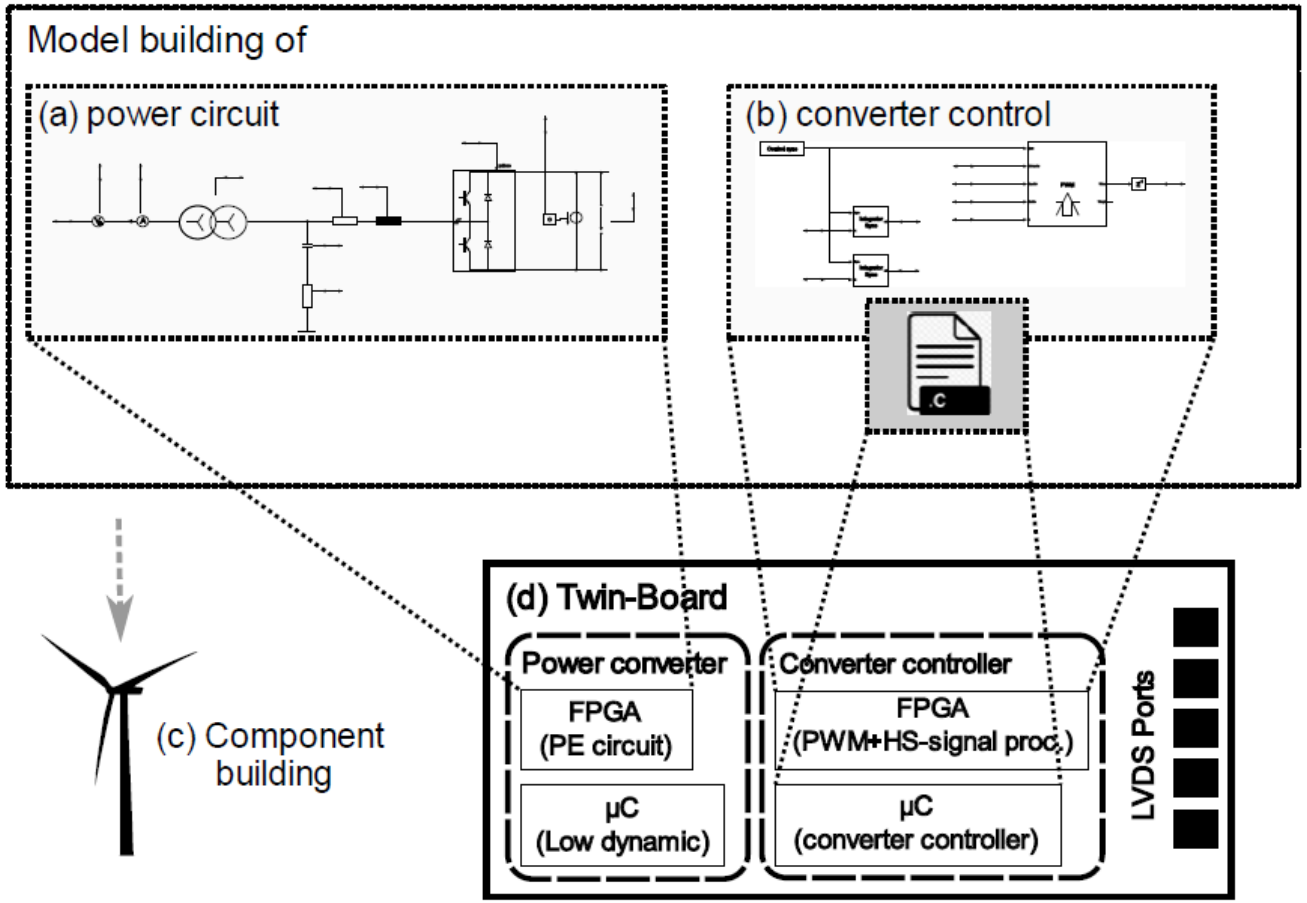
e) Wind farm simulation model



e) Test & report automatization

```
Var1 : Variant
{
    Circ1 : Circuit( 'Circuit', 'wtg_tuil_4' )
    Ev2 : Event( 'grid.A',  1.0, 0.1 )
    Ev2 : Event( 'wtg1.enable',  1.0, 0.5 )
    Ev2 : Event( 'wtg1.P_ref',  1.0, 1.0 )
    Ev2 : Event( 'wtg1.P_ref',  0.0, 2.2 )
    Ev2 : Event( 'wtg2.enable',  1.0, 0.5 )
    Ev2 : Event( 'wtg2.P_ref',  0.5, 1.2 )
    Ev2 : Event( 'wtg2.P_ref',  0.0, 2.2 )
    Ev2 : Event( 'wtg3.enable',  1.0, 0.6 )
    Ev2 : Event( 'wtg3.P_ref',  0.9, 1.4 )
    Ev2 : Event( 'wtg3.P_ref',  0.0, 2.2 )
```

Real-time implementation

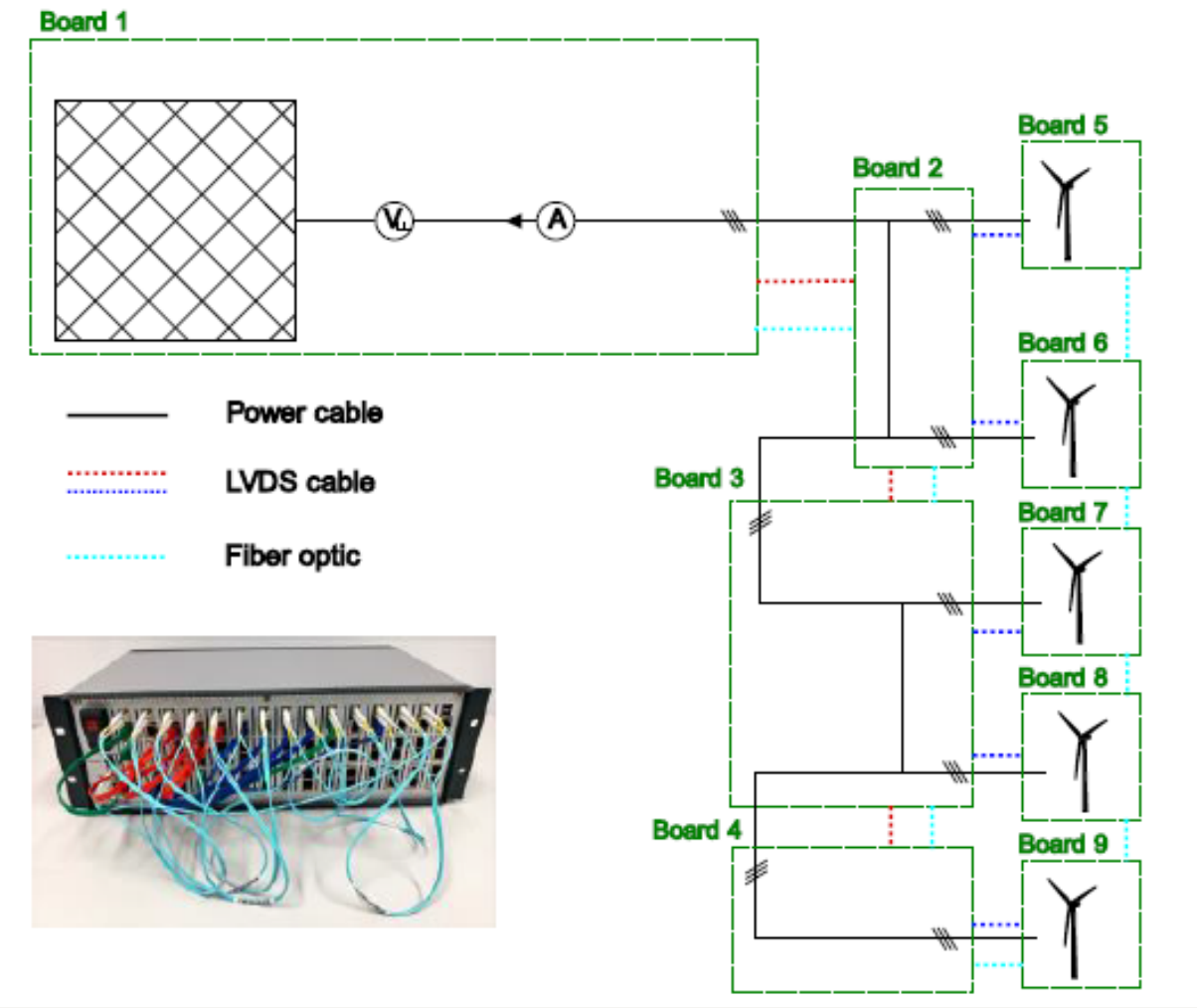


In case of RT mode each intelligent component is to be simulated on a single computational board including:

- an FPGA for high-dynamic power electronic circuit
- a µC for low dynamic parts

- a µC and a (smaller) FPGA for emulating converter controller

Application example – wind farm simulation



System description

- Power grid
- AC distribution cables
- 5 pcs. controlled WTGs
- Voltage and current measurements

Events

- Low voltage fault @ t = 7s
- Clearance of voltage fault @ t = 7.5s

For more information about the simulation demo, please visit the booth: Hall W2, C31

Application example – wind farm (FRT)

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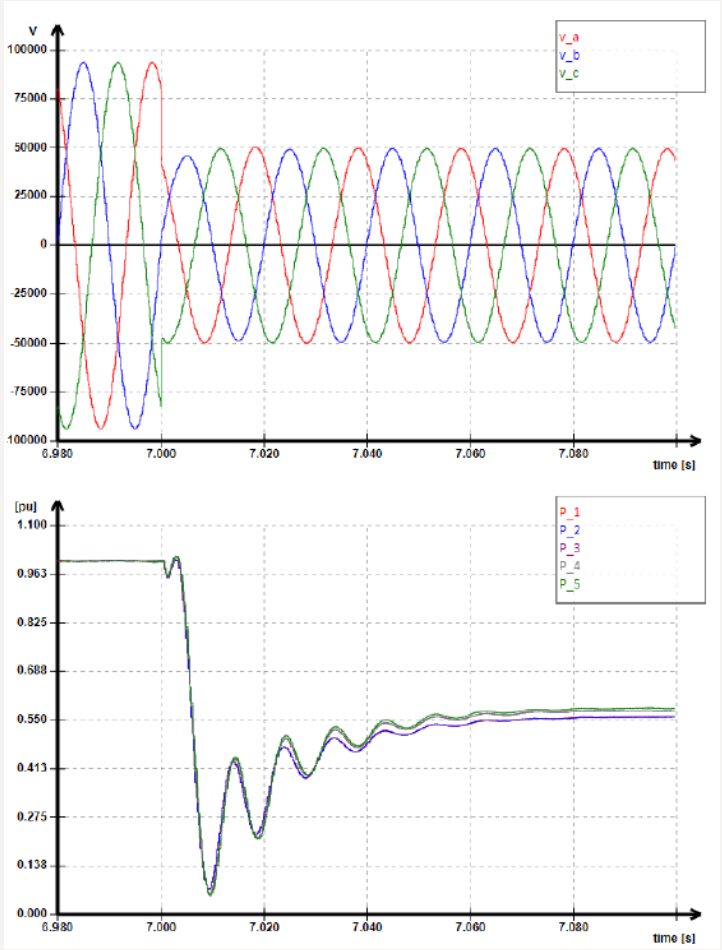
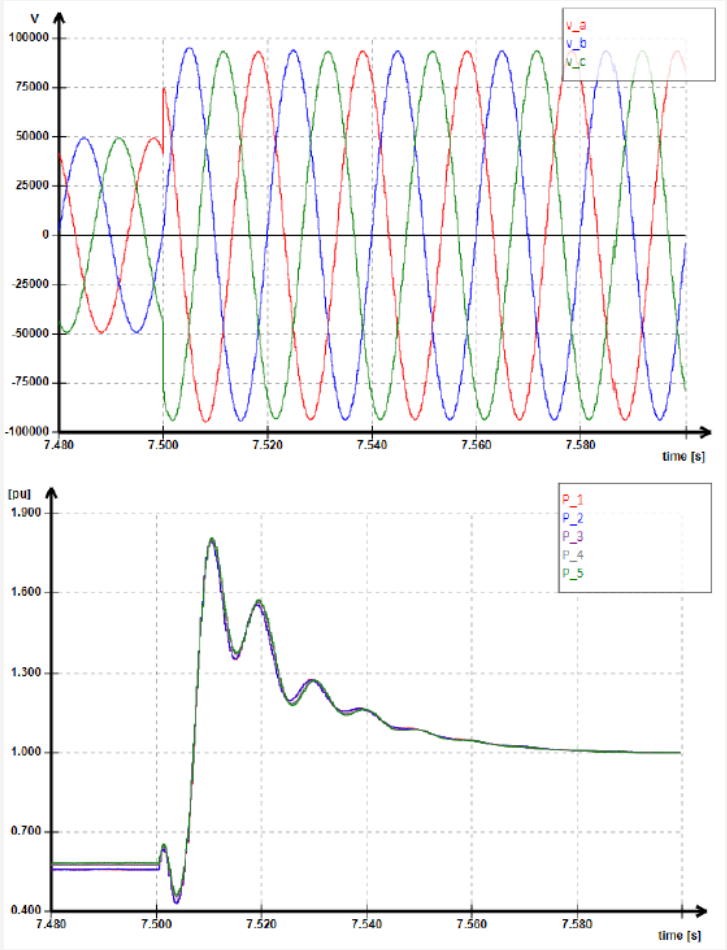


Grid voltage and actual power of wind turbine 1 to 5 at low voltage faut occurrence



Grid voltage and actual power of wind turbine 1 to 5 at low voltage faut clearance

Step to park-level wind farm simulation

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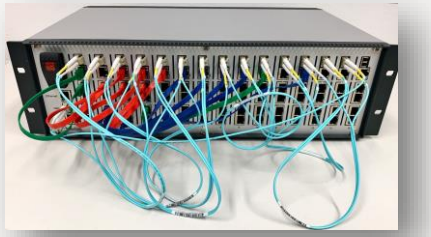
Digital twin for one WTG

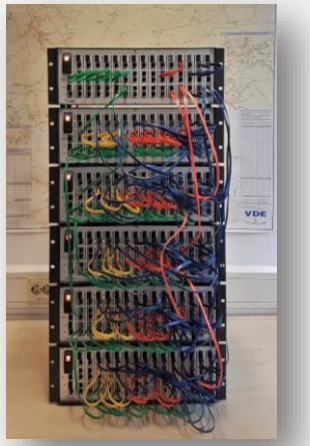
Digital twins for WTG string (Incl. Max. 15 WTG)

Digital twins for wind farms (i.e. incl. 90 WTGs)

= x 15

= x 6





Low-latency communication between coupled subsystems (simulation nodes) ensures unlimited expansion of system scope

Conclusion

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- Model converter-dominated grid requires novel tool to simulate power plant consisting hunnerts of power converters in very low simulation step size in µs
- The presented novel simulation tool VIAvento fulfils the required features (simulating 100 … 1000 converters in µs step size)
- For RT simulation a distributed simulation system is introduced and demonstrated
- Automatized simulation and reporting process enables fully automatic virtue verification

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Thank you for attention!

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For more details, welcome to visit our booth in:

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Contact us:

www.avasition.cn

info@avasition.cn