Integrated Grid-Coupled Power Electronic Energy Conversion Systems using a PC-Based Controller

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Introduction

- Grid-coupled distributed energy resources
- Hardware architecture selection
- Software framework
- Benchmark
- Conclusions

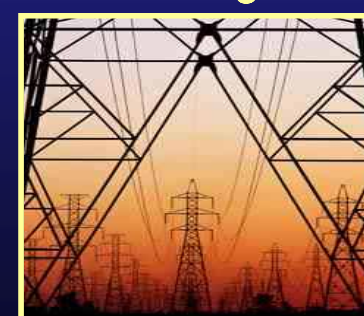
Grid-coupled distributed energy resources

- Converter hard- and software selection
- Unidirectional power flow application

Solar panels

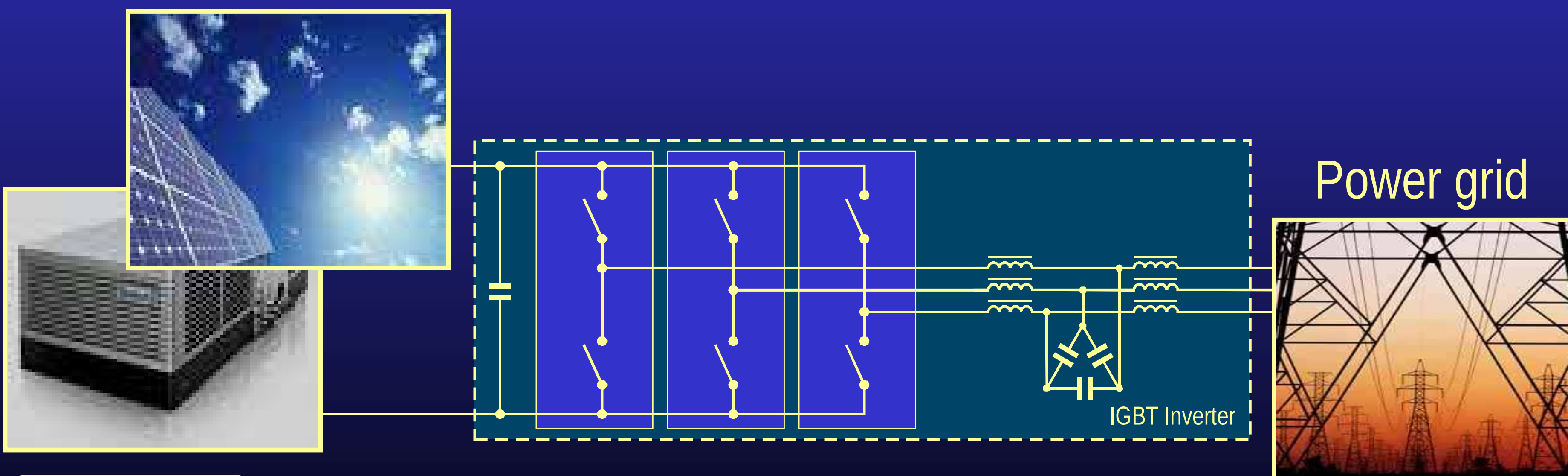
Fuel cells

Power grid

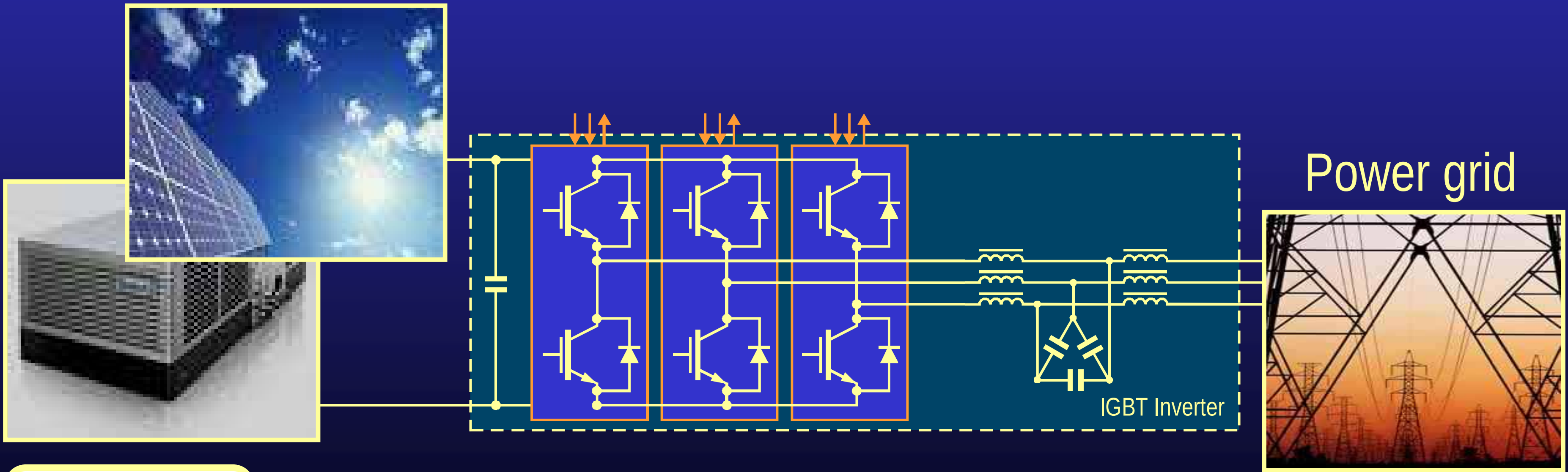


Grid-coupled distributed energy resources

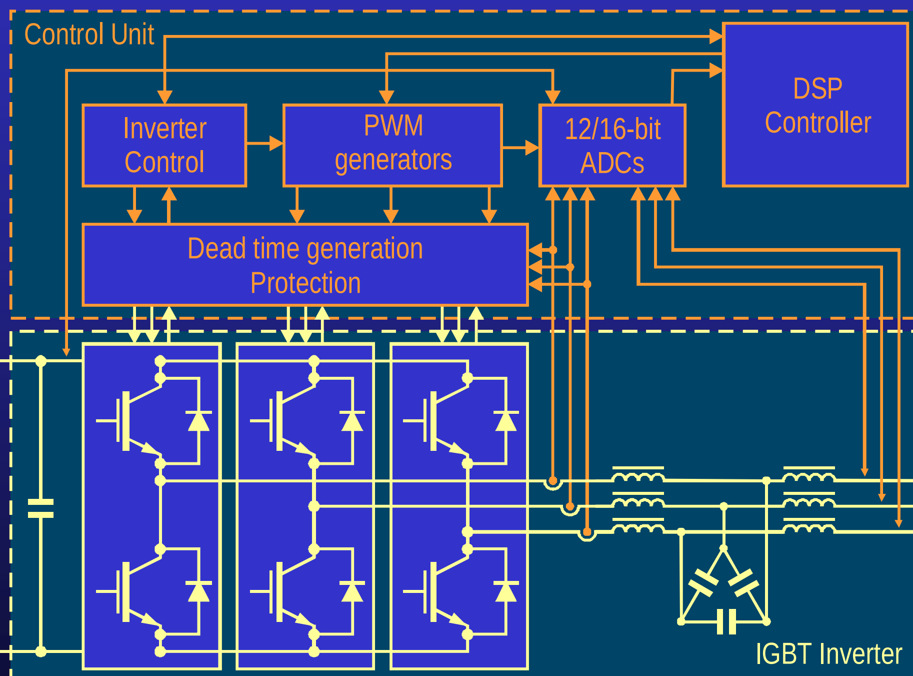
- Three-leg inverter
- LCL filter



Grid-coupled distributed energy resources



Grid-coupled distributed energy resources



Power grid

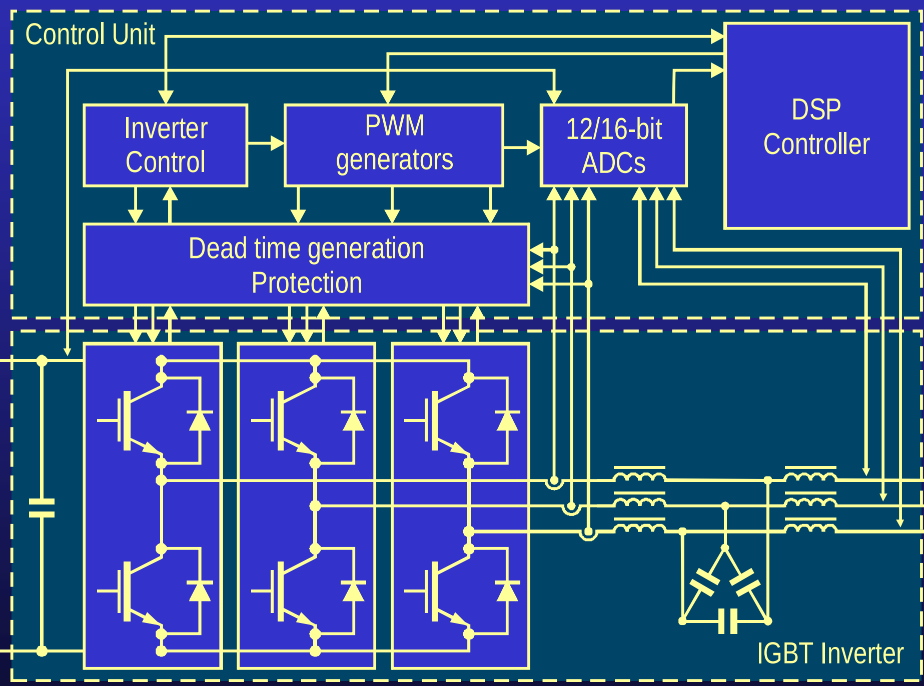
Grid-coupled distributed energy resources

- Algorithm levels

Level	Typical task	Computational Complexity	Hard real-time	Typical network connection	
				Grid	Data
Low	• Phase current control • Inverter protection	Low - High	Yes	Yes	
Medium	• Grid stability e.g. voltage and frequency control • Resource management e.g. battery charger, MPP tracker	Medium	Yes	Yes	Possibly
High	• Grid safety • Resource dispatching	Medium - High	No		Yes

Hardware architecture

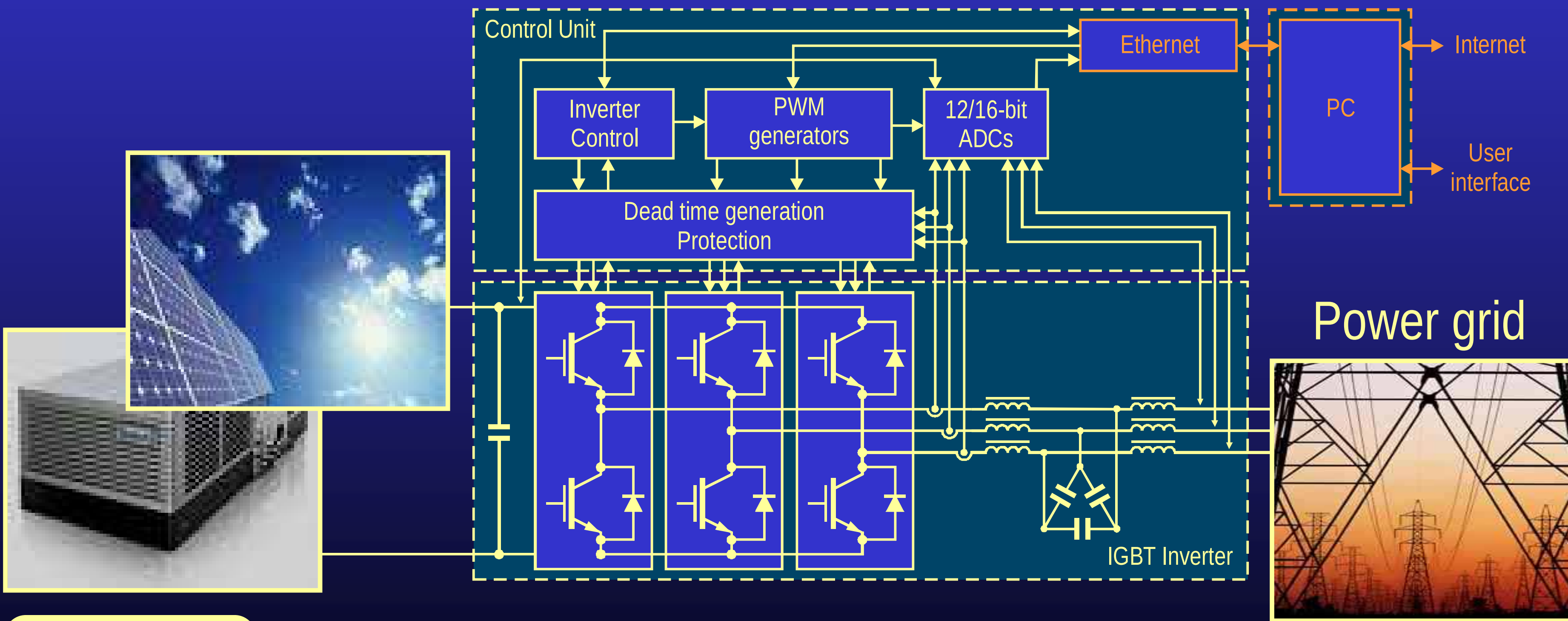
- From DSP…



Power grid

Hardware architecture

- ...to PC



Hardware architecture

- Ethernet as power electronics interface
  - No PCI / PC104 / PCIe / PCMCIA interface card
  - High speed (100..1000 Mb/s)
  - High EMI immunity

Hardware architecture

- Advantages of PC controller
  - Broad availability
  - Well tested – mature toolchain
  - Obvious migration path to embedded production systems
- Disadvantages of PC controller
  - Power consumption for conversion systems < 1kW
  - Not always suitable for mass production

Software framework

- Open source operating system
  – Linux
  – Xenomai real-time extension
- Develop controllers in Matlab / Simulink / RTW
- Run resulting code as normal programs
  – Alongside each other
  – Protected from each other

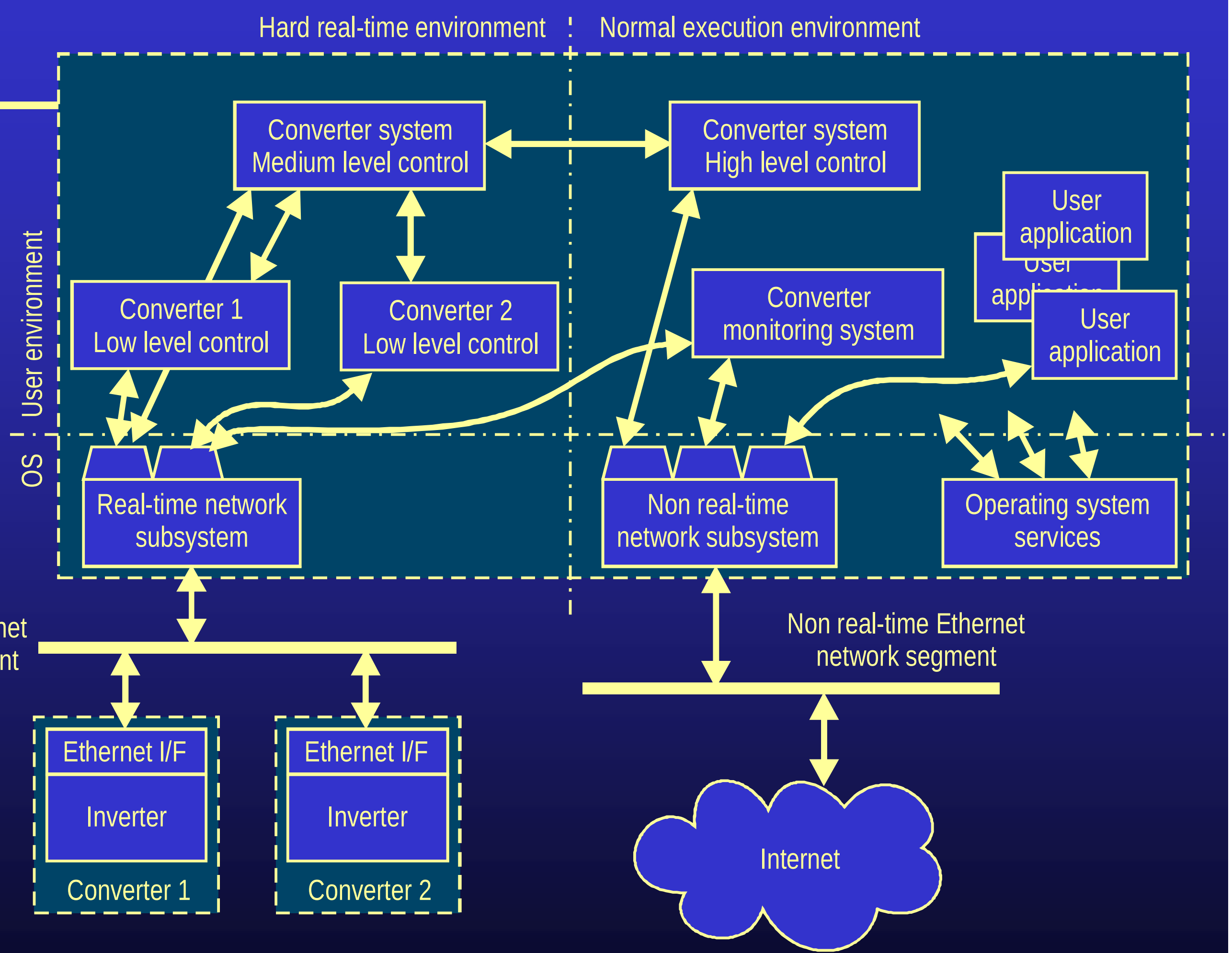
Software framework

- Linux TCP/IP services
  - Communication with other power conversion systems
  - Development instrumentation
  - Software maintenance and upgrading
- Security
- Integration of fieldbuses
  - EtherCAT

Software framework

Single processor

- Runs all software
- Serves multiple converters

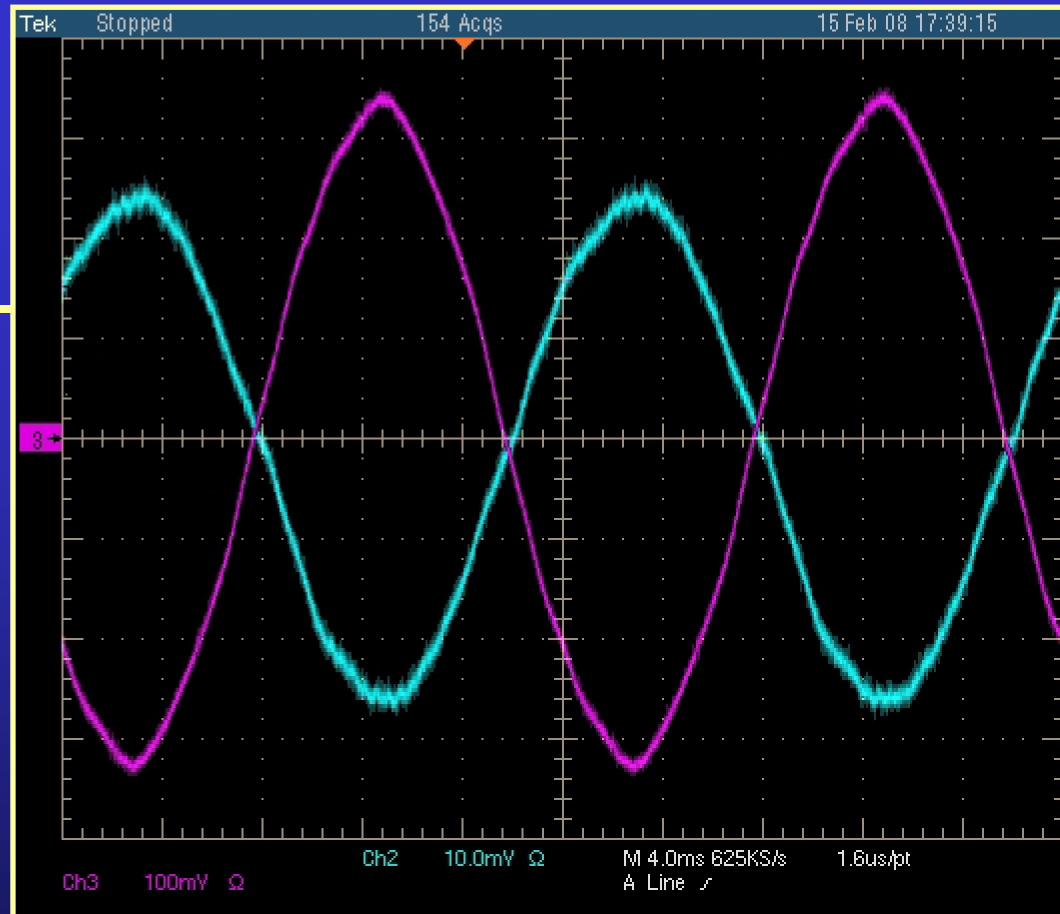


Benchmark

- Algorithm
  - Low level only
  - Sensorless
- Operating parameters
  - -10…+10 kW, -12.5…+12.5 kVA, 650 VDC, 400 VAC
  - Switching frequency: 16 kHz
  - Algorithm update frequency: 8 kHz

Benchmark

- 100V, 10A/div
- THD = 2.1%
- η = 94.2%



- CPU Load
  - 18% on 1 CPU
  - 91% computing power available

Conclusions

- All software for power conversion system on one processor
  - Open source Linux based solution
  - Low and medium level control in real-time
  - High level control using network access
- Scaleable architecture
  - New, complex and powerful algorithms
  - Facilitates development considerably
  - Field deployment feasible

Comments and questions