Development of 600V Industrial DC Microgrid for Highly Automated Manufacturing Applications: Factory and Laboratory Infrastructure Experience

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09.05.2018

RTU
ENERĢĒTIKAS UN ELEKTROTEHNIKAS FAKULTĀTE

Outline

- *Why reconsider power distribution at automated factory level?*
- *Expected challenges of DC type distribution.*
- *Physical demonstrator development project at industry and university.*
- *Outcomes and results.*

Why reconsider power distribution at automated factory level?

- Energy efficiency
- Emission reduction (2020 goals)
- Power quality and availability
- Integration of renewable sources and storage

Industrial robot vs Automobile

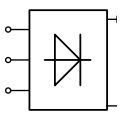

Fuel


Combustion engine


Mechanical drive


Brakes


AC Grid

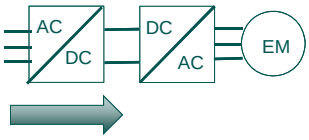

AC/DC Conversion


Electric drive

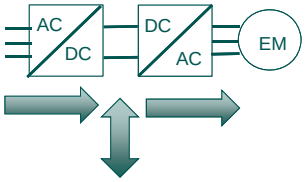

Brake resistor

Transitons in power supply

Internal combustion car
Gasoline

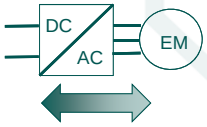


Hybrid, Plug-In hybrid car
Gasoline & Electric

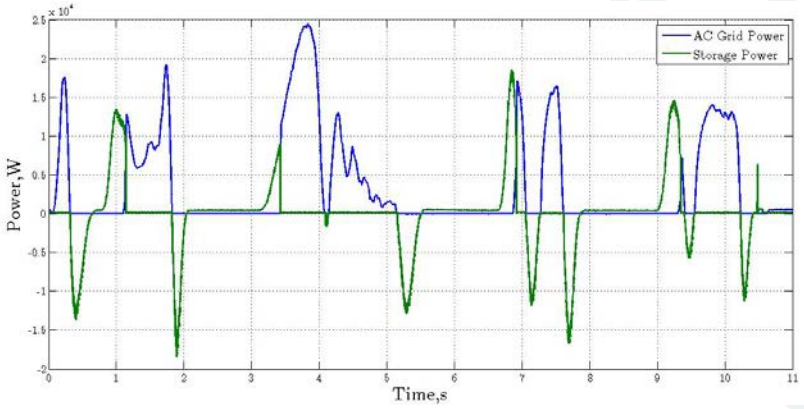


Pure electric car

Electric



Mixed AC and DC (Hybrid) solution.



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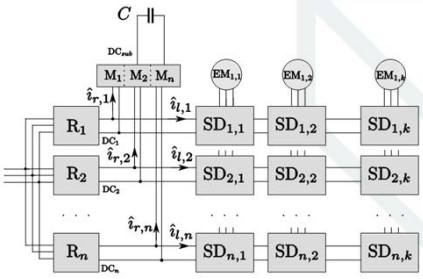
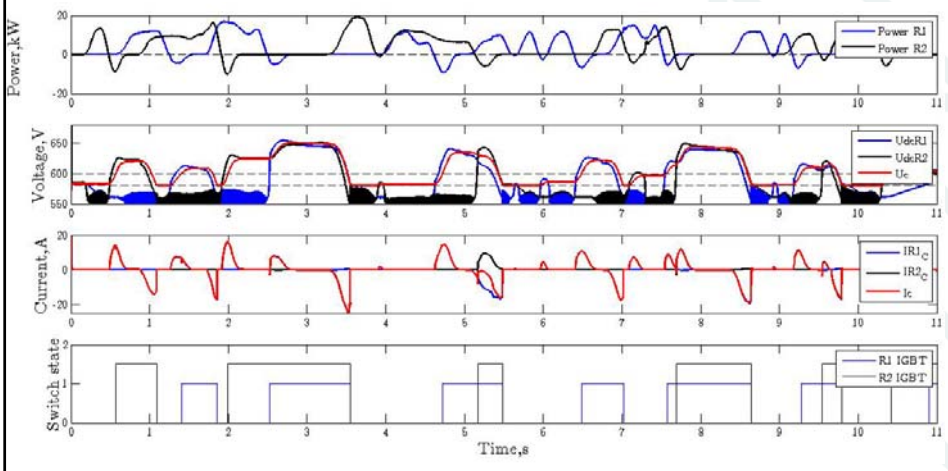


Application	DC-Bus sharing	Average Power kW	Difference, %
Handling, 20 min., no tool	none	6.23	-
Handling, 20 min., no tool	enabled	4.92	-21.1%
Handling, 20 min., 150 & 200 kg tools	none	8.67	-
Handling, 20 min., 150 & 200 kg tools	enabled	6.70	-22.7%

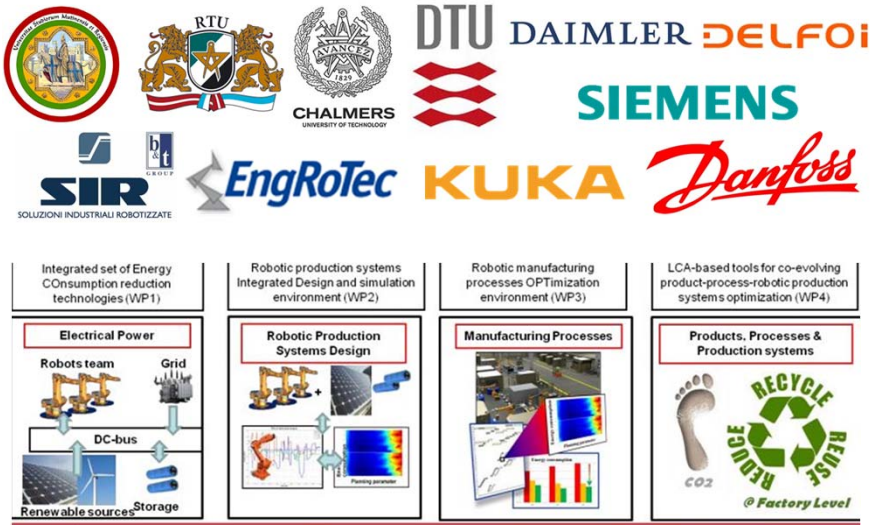
Mixed AC and DC (Hybrid) solution.



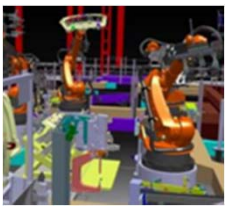
Expected challenges of DC type supply.

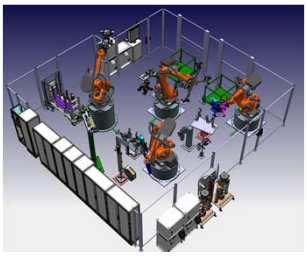
- DC component availability at supplier portfolios
- Standards
- Safety considerations
- Conversion of existing tools for DC supply

AREUS PROJECT
Partners and Research Topics



AREUS Experimental Validation (WP5)





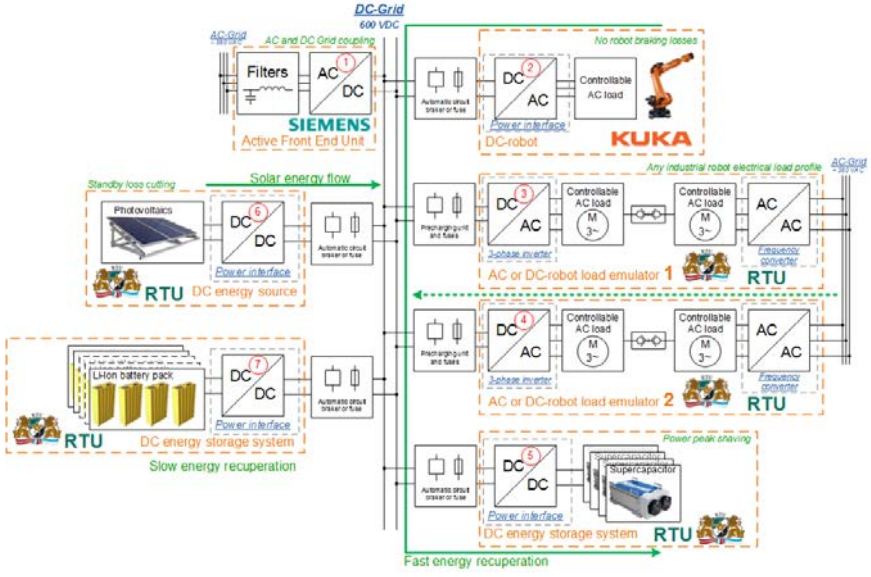
DC power cabinet and PLC control panel @DAI

DC bus rail system @DAI

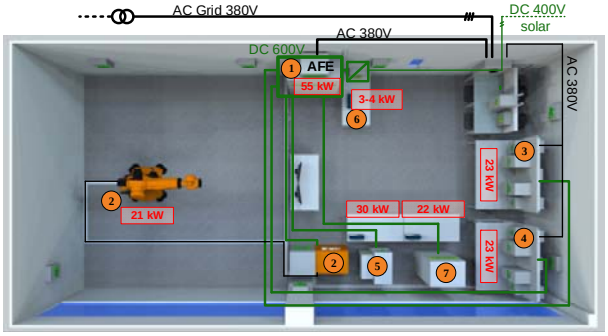
Robot load emulator @RTU Demo Cell

AREUS Experimental Validation (WP5) at RTU

Industrial DC-Grid at RTU Demo Lab – for SME application

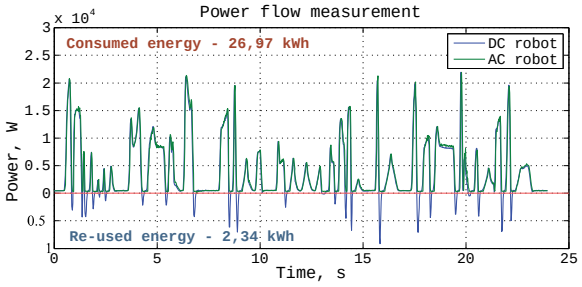


Industrial DC-Grid at RTU Demo Lab – for SME application



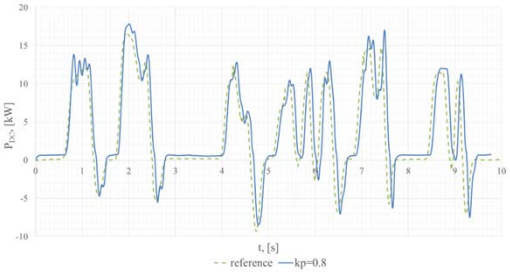
1- AFE
2- DC Robot & Controller
3- Robot emulator
4- Robot emulator
5- SuperCap storage
6- Solar DC/DC converter
7- Li-Ion storage system

First experimental tests carried out by scientists of RTU and UNIMORE shows that, if comparing AC and DC robots with the same movement trajectory and no tool attached, possible amount of reusable electrical energy is **up to 9%**.

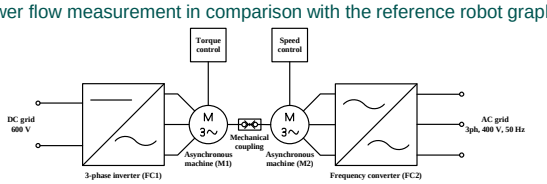


Robot emulators - Drive stands

Electrical installation and mechanical setup of both DC Power flow emulators has been accomplished in the AREUS RTU laboratory. The system can replicate the robot power graph with an 99.95% accuracy.



Power flow measurement in comparison with the reference robot graph

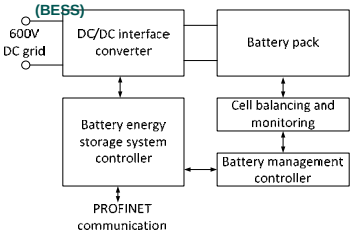


A controller has been developed for the emulator, enabling:

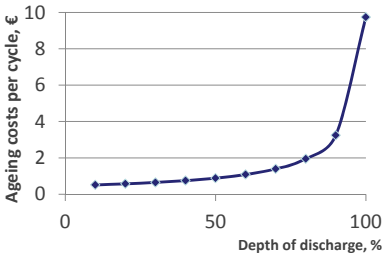
- Automatic control – preprogrammed power cycle
- PLC control
- Manual control (switches, potentiometer)
- DC power monitoring

Battery energy storage system

Structure of Battery energy storage system (BESS)



Challenge: Lifetime vs Power parameters?



Cell balancing:
- A balancing module per cell
- Switched resistor balancing
- Voltage monitoring
- Temperature monitoring
- Ring topology data exchange

Battery pack:
- 144 LiFePO4 cells
- 432 – 526V
- 40Ah
- 40A charge/discharge
- 8 subpacks of 18 cells

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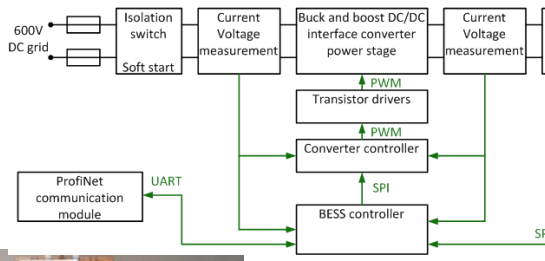
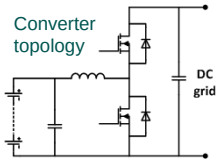
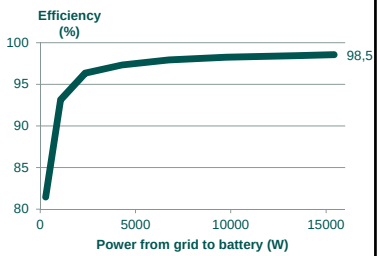
Battery energy storage system



Converter topology



DC/DC interface converter:
Non-isolated bidirectional converter
Buck converter from grid to battery
Boost converter from battery to grid
Up to 97% efficiency
Power 18kW
4U 19'' case



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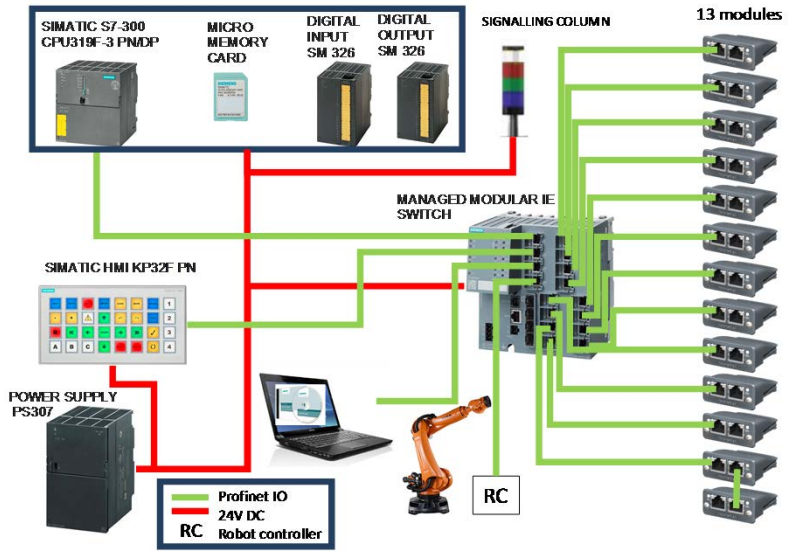
RTU Demo Cell PLC System layout



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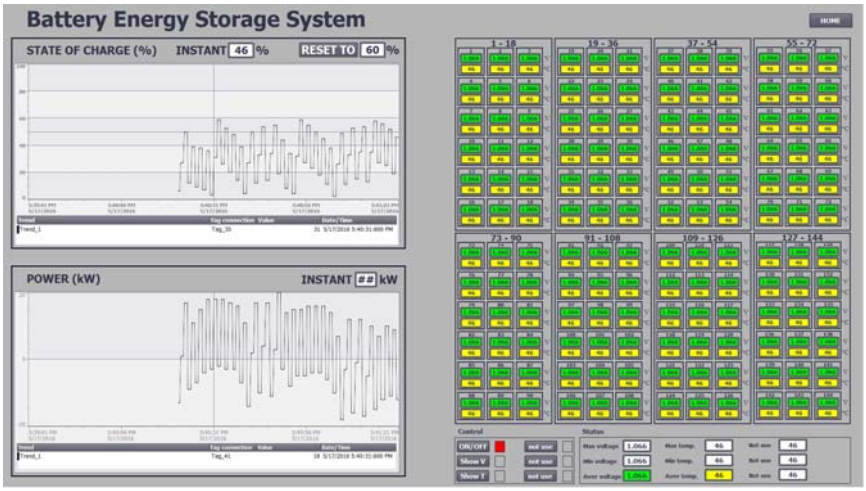
Industrial DC-Grid at RTU Demo Lab – for SME application



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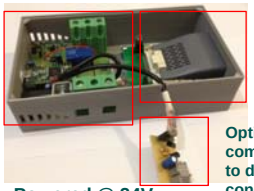
RTU developed AC and DC power measurement system

Powered @ USB $5V_{DC}$

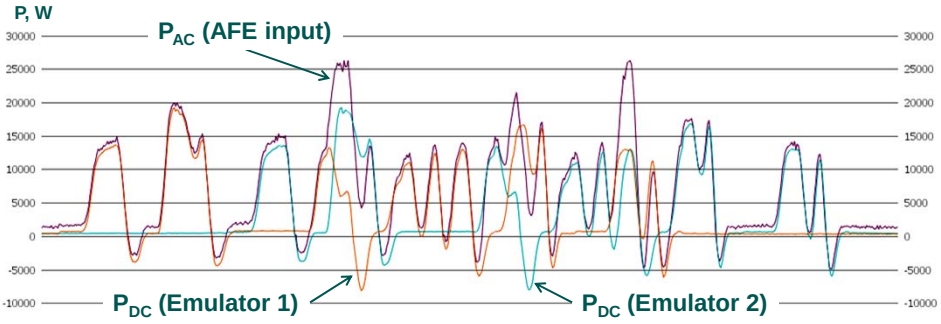
Power measurements
Voltage: DC 600V+/-20%
Current: +/-70A,
USB 5V = 24V
Max resolution: 1ms
Nominal resolution: 20ms



AnyBus module - Output to ProfiNet

Optical communication to data concentrator (PC)

Powered @ $24V_{DC}$



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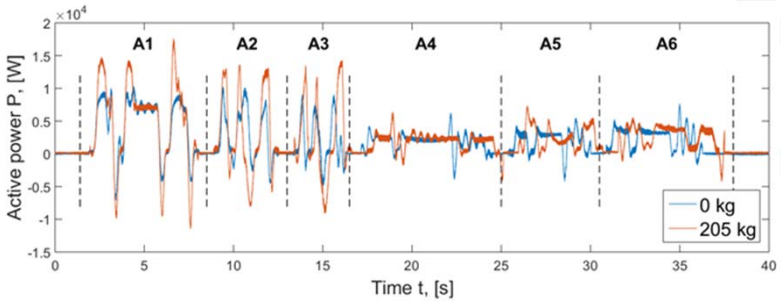
Robot tool mass and recuperated energy?



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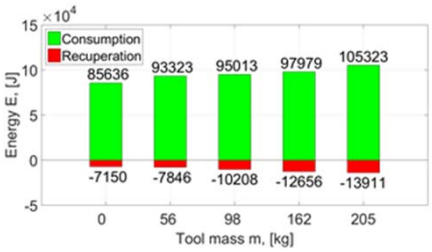
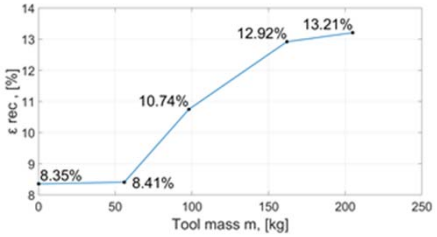
Robot tool mass and recuperated energy?





Robot consumption simulation platform

DAI and RTU developed tool provides:

Generation of sample production cycles

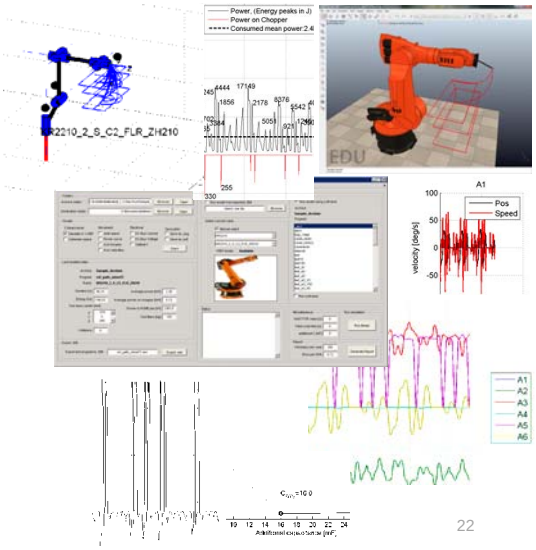
Power consumption of KUKA industrial robots

Easy system offline modelling

Power consumption of industrial tools (welding, clinching, gluing)

System optimization with simulation data

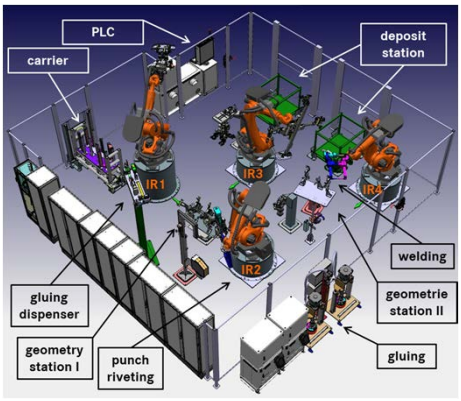
Energy consumption integration in VCS [continued by Daimler]



Industrial DC-Grid at DAIMLER – for large industry application

DAI has constructed a demonstration cell with 4 DC-power-supplied prototype industrial robots at DAI, Sindelfingen, Germany. Included subcomponents:

- Central AC/DC interface converter (Active Frontend)– rated power 450kW.
- Set of 4 KUKA industrial robot manipulator prototypes for DC type electrical infrastructure Quantec KR210 R2700 Prime.
- Aluminum spot welding tool mounted on industrial robot, DC prototype based on Bosch Rexroth product.
- Rivet clinching tool DC prototype related to existing equipment provided by Tox.
- Glue dispensing tool equipment prototype for DC electrical supply, developed by Daimler AG.



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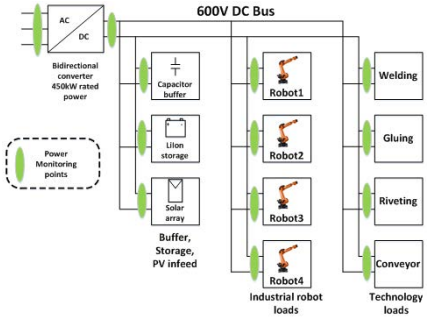
Synchronous multipoint power flow measurements.



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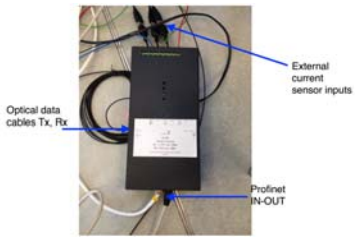
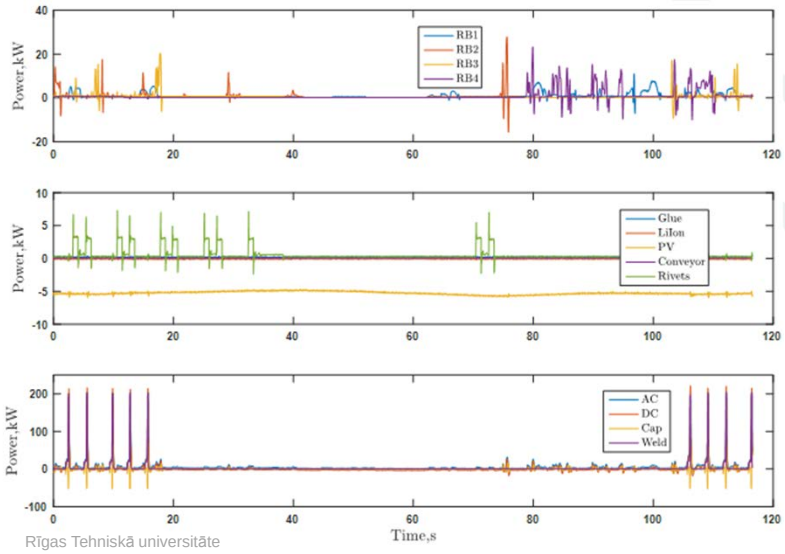
Measurement system



- 2.8 kHz sampling rate
- 20 ms averaging of power calculation
- Optic fiber data transmission

Power flows within DC cell.



Recuperated power

(1)

	DC load group (4 robots, tools, capacitor buffer)	Robot 1	Robot 2	Robot 3	Robot 4	Technology tools (4 units)	Capacitor buffer
P_{pos}, kW	8.01	0.99	0.94	0.68	0.64	3.51	1.25
P_{neg}, kW	1.06	0.012	0.1	0.04	0.04	0.04	0.82
P_{neg}/ P_{pos}, %	13.23	1.21	10.64	5.9	6.25	1	66

Overall 4 robot DC cell energy consumption presented 10% less energy consumed compared to AC supplied cell for particular process.

Outcomes

- Follow up project in Germany: DC Industrie.
- Interest from component suppliers, development of DC distribution and protection elements.
- Consideration of automotive battery pack utilization at production equipment supply.
- Detailed modelling of electrical loads and subsystems – like other automation equipment at factory design phase.


Thank you!