LUT

Lappeenranta

University of Technology

Electrical Drives Research at LUT

Gråsten 28.8.2018

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

About myself

Master of science in Electrical Engineering at LUT 1990

- Scholarship student at RWTH Aachen 1988-1989
- Diploma thesis ”Unterschuhung von IGBT’s und Entwicklung einer Treiberstufe”

R&D Engineer at ABB Finland 1990-1993

- Development of new generation frequency converter control

Laboratory Manager and PhD student at LUT 1993-1998

- Doctoral thesis ”Analysis and Control of Excitation, Field Weakening and Stability of DTC Controlled Electrically Exited Synchronous Motor Drives”

Professor in Applied Control Engineering at LUT 1998-2007

Chief Technology Officer, The Switch, 2007-2010

- Main product wind power generators, wind power converters and industrial high speed motors

Professor in Control Engineering & Wind Power Technology at LUT, 2010...

- My approach in renewables is based mostly on <u>electrical</u> and <u>control</u> engineering

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LUT IN BRIEF

1969 founded in 1969, combining technology and business from the start

860 journals per year

4500 bachelor and master students (technology and business administration)

600 doctoral students

THE ranked

80 M€ Funding from Ministry of Education and Culture 60 %, supplementary 40 %

1000 staff members

70 different nationalities on campus

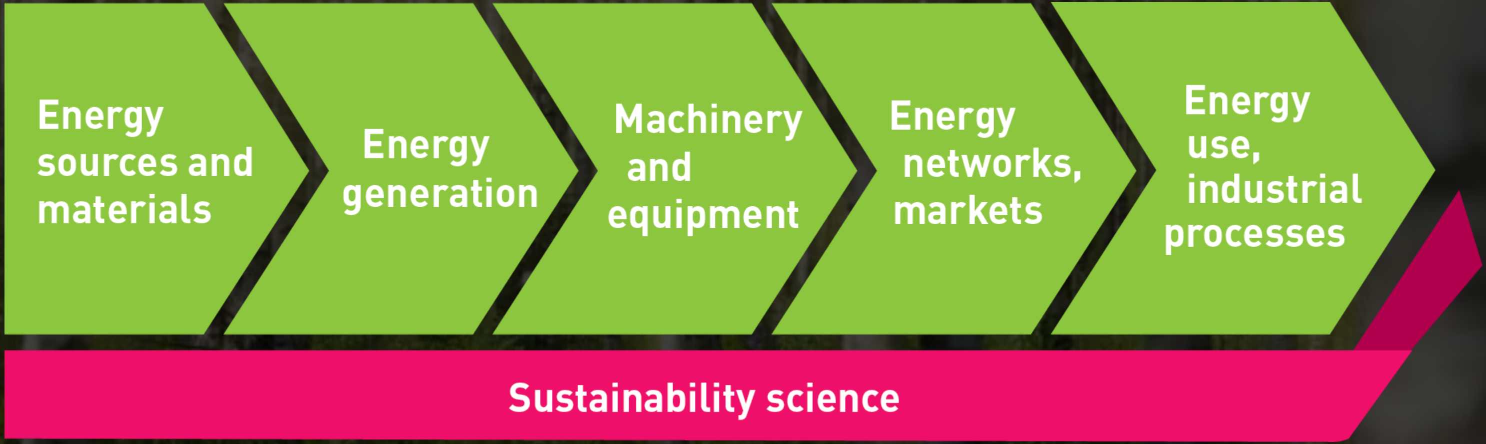
⅓ of incoming students are foreign

QS ranked

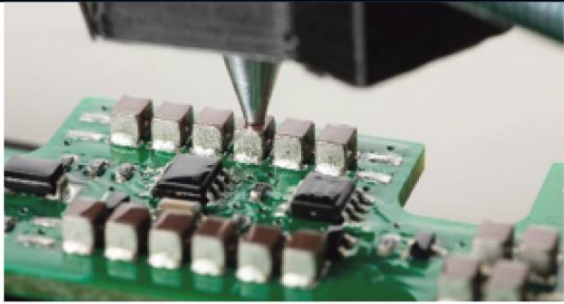
LUT SCHOOL OF ENERGY SYSTEMS [LES]

- 26 full professors
- More than 70 other research scientists (D.Sc.)
- Staff in total 340
- Scientific publications 220 / a
- 15 M€ research budget / a (external funding sources)
- 16 M€ teaching budget / a (Ministry of Education and Culture)

LES FOCUS: MANAGEMENT OF ENERGY CHAIN



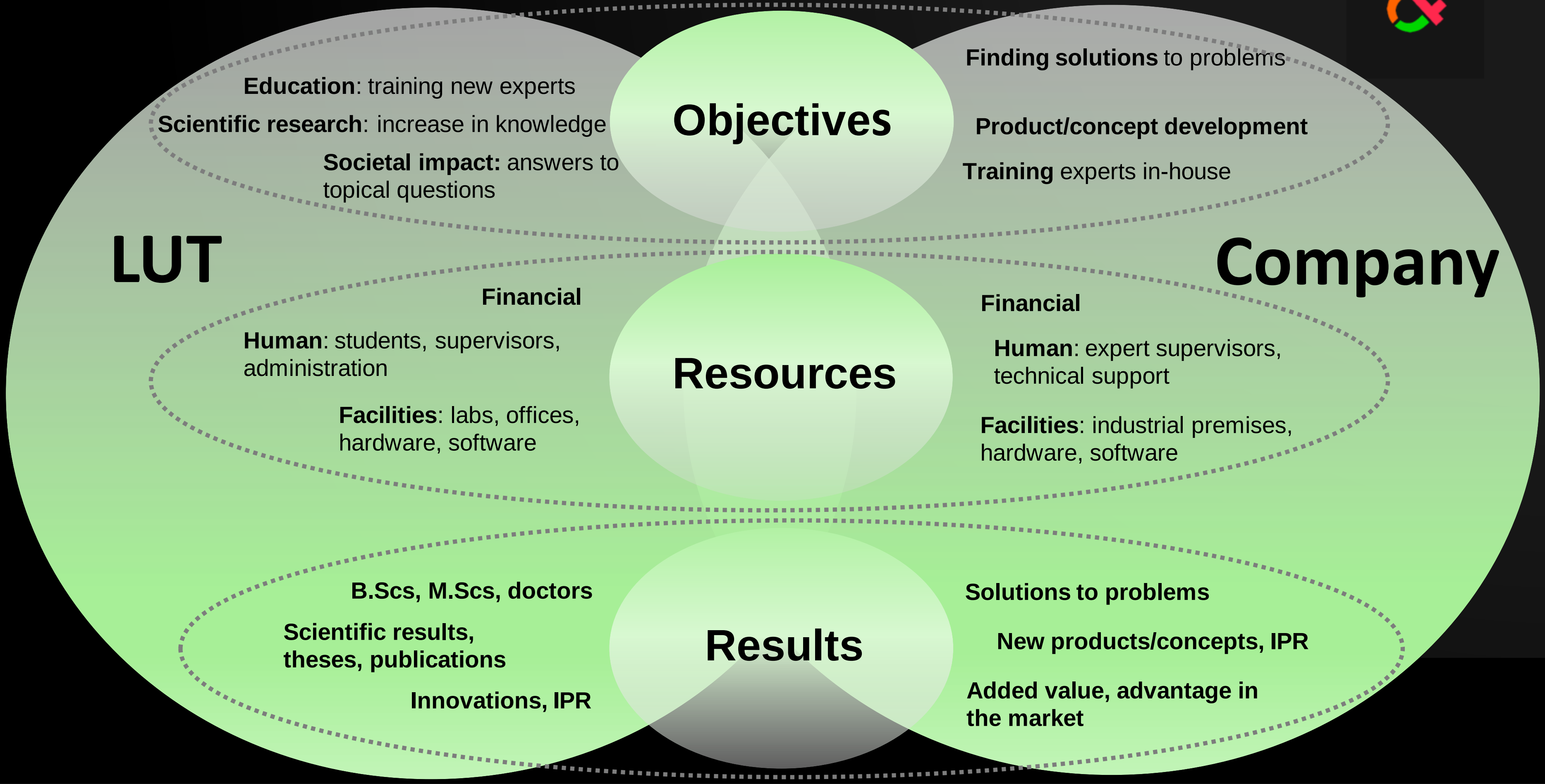
LUT SCHOOL OF ENERGY SYSTEMS: ELECTRICAL ENGINEERING



> Our aim is to gain a deep, system-level understanding of the transition to a carbon-free energy system and its economic, environmental and technical factors as well as competitiveness.
>
> Professor Jarmo Partanen

University-Industry Collaboration Towards Common Goals

Research projects and problem solving with students at Bachelor's, Master's and Doctoral levels



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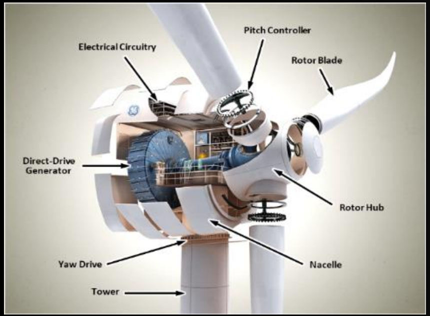
LUT ELECTRICAL ENGINEERING

LABORATORIES:

- Electrical Machines and Drives
- Control Engineering and Digital Systems
- Applied Electronics
- Electricity Market and Power Systems
- Solar Economy

- 7 full professors + 2 tenure professors (open position in power electronics!)
- 20 other doctors in average
- Staff number about 120

Research approach – from theory to practise



Spin-offs

Society

Products

Prototypes

Laboratories

Processibility

Virtual Testing

Materials

Simulation

Structures

Modelling

Theory

Collaboration between laboratories

Industrial collaboration

International academic network

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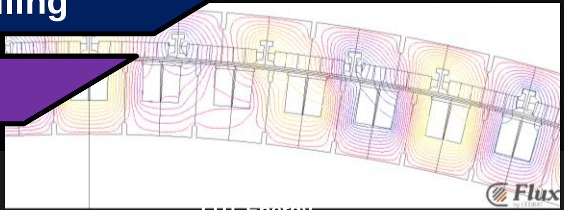
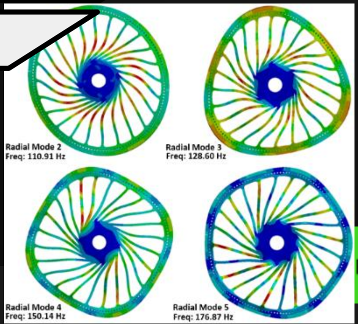
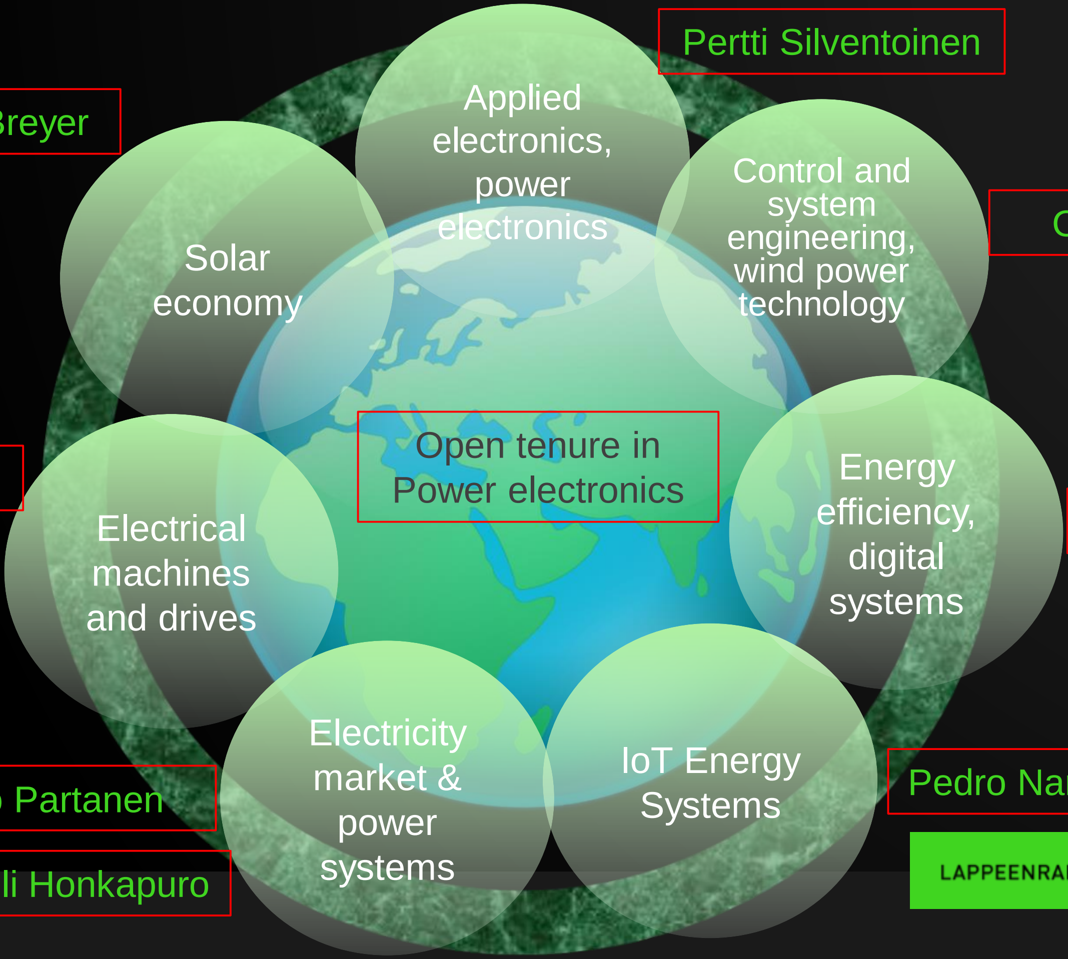




Professorships at Electrical Engineering



Pertti Silventoinen

Christian Breyer

Olli Pyrhönen

Juha Pyrhönen

Jero Ahola

Jarmo Partanen

Samuli Honkapuro

Pedro Nardelli

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Intelligent power electronics (IPE)

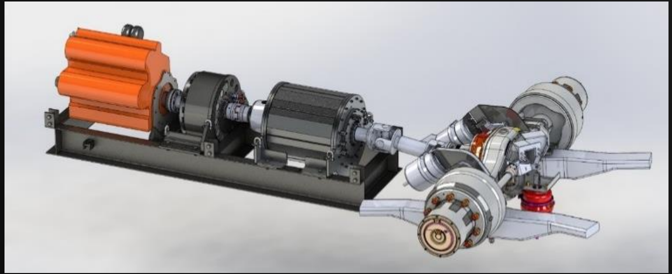
- Computational methods bring new intelligence for drives and power electronics
  - System identification and adaptive model-based control
  - System monitoring and diagnostics
  - Big data and machine learning a new oportunity for O&M
  - Virtual prototypes for human interaction analysis

- Possibilities for drives development
  - Identification of drive train mechanics, identification of grid parameters
  - On-line diagnostics for power electronics and drive systems
  - Self-tuning and adaptive controller methods
  - Protection schemes, preventive maintenance
  - System optimization taking human behaviour into account

Research examples for IPE

Model based drive train control for hybrid bus

- On-line Identification of traction dynamics using electric drive torque as an excitation signal
- Model parameter update using measured data and on-line identification
- Traction control adaptation using update model parameter
- Low slip, vibration damping smooth transitions can be achieved with advanced control



Research examples for IPE

Virtual prototyping for heavy electric machinery

- Work machine load characterization using real time multi-body simulation, control cabinet emulator and real test driver

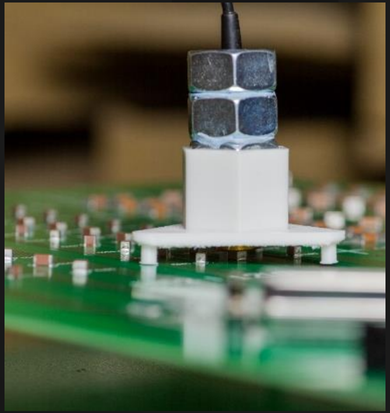
- Drive train analysis using hardware-in-loop methods

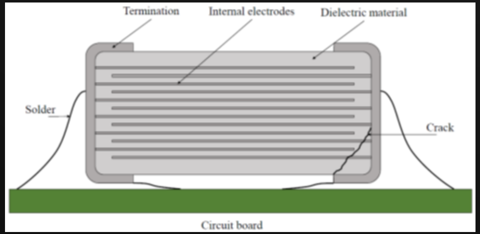
- Drive train dimensioning and control optimization based on virtual prototype results

Research examples for IPE

On-line diagnostics of power electronics components

- Analysis has shown, that acoustic emission changes as a function of aging
- Acoustic sensors are cost effective
- Audio signal spectral analysis can be used as an indicator for coming failure
- Both capacitors and IGBTs have been analyzed





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Electric Motor research

- DEE has a long tradition in motor technology research
- Fundamental research questions
  - Electromagnetic and thermal optimization
  - Insulation technology especially for inverter motors
  - Structural and material solutions for high-speed machines
  - World’s firs CNT-yarn winding motor
- Special constructions for different application fields
  - Wind power generators
  - Traction motors
  - High-speed motors
  - Direct liquid cooling
  - Integrated hydraulic motors
  - Integrated gear motors

Examples of EM research

Segmented solution for
low speed PM wind generator 3.7 MW

Solid rotor IM technology for
sub-sea gas compressor 10 MW

Integrated gear motor
for direct wheel traction

Special electric machines from ultra-high speed small machines to large high-speed machines and large direct drive wind power generators and their drive systems

Direct liquid cooled high
speed induction generator

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Drive train and drive system research

Drive train research focuses on

- Electric drive component analysis and optimization
- Modular converter structures
- Dynamic performance and control analysis
- Typical case a single motor/generator converter system (industrial drive, wind power drive, traction drive)

Drive system research focuses on

- System topology optimization for large drive system
- Energy management with energy storage and combustion engine included
- Typical application industrial drive system, marine vessel or hybrid working machine

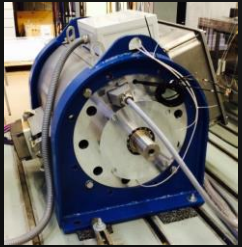
High-speed drive trains

- **High speed electrical drives**
  - High speed motor design
  - Active magnetic bearing control
  - Bearingless motor design and control
  - High speed inverter solutions
  - Collaboration with both academic and industrial partners

3 kW 30 krpm
PM + AMB machine

10 kW 30 krpm
Bearingless machine

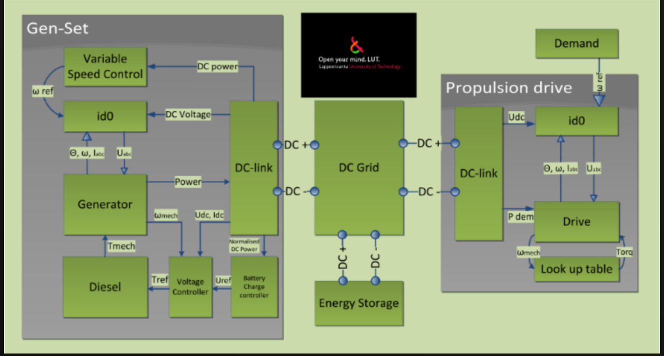
10 MW Gas compressor
MAN & The Switch



400 kW
15 krpm
Induction motor

Hybrid Electrical Systems

- Hybridization technologies
  - Hybrid off-road machines and busses
    - Motor and drives technology
    - System modelling and control
    - Man-machine interaction
  - Hybrid marine
    - Marine vessel grid system analysis
    - Battery technologies in marine vessels
    - Marine vessel energy system optimization



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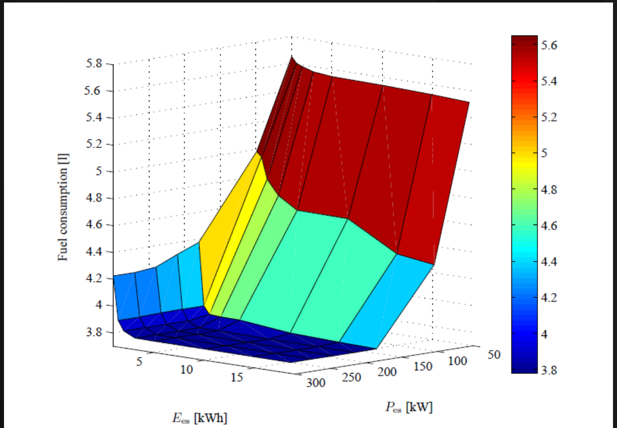
Battery optimization for Off-road machines & marine vessels, laboratory tests for model verification

- Emulation tests for hybrid drive systems:
- Configurable power grid topology
  - Includes multiple motor drives and grid converters
- LFP and LTO battery systems as storage



150 kWh LiFePo @ DEE

Energy efficiency in electrical-motor-driven

- Intelligent application specific inverter control
- Model based process energy efficiency estimates
- Adaptation towards highest possible energy efficiency at each working point
- Large energy saving potential especially in pump and compressor drives

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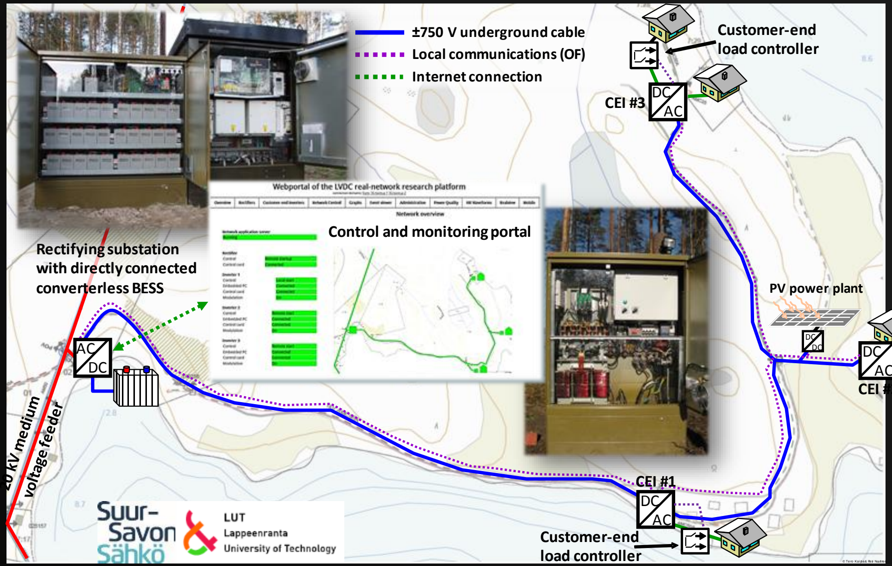
Smart grids research

- Energy transition changes power system infrastructure
  - Share of renewables increases
  - Distributed power generation is increasing
  - Reliability requirements are more demanding (in Nordic countries)
  - Energy storage solutions are becoming feasible
- DEE has smart grid research focus on DC-distribution systems
  - DC-distribution has higher power density than AC
  - Modern inverter technology offers affordable high-efficiency conversion
  - Distributed generation and storages are well compatible with DC-grid
  - Power system transients and failures can be isolated from consumption

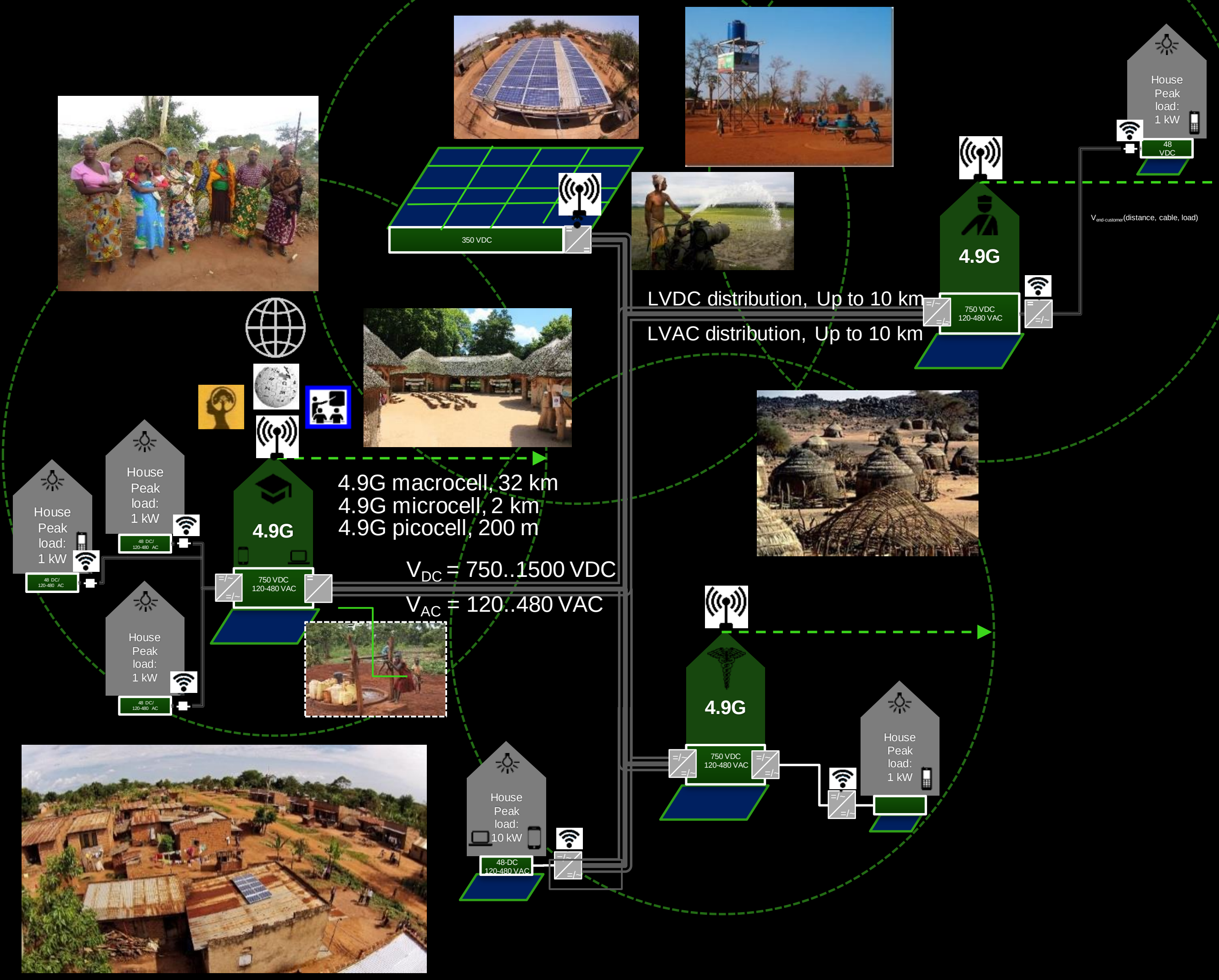
Real customer system as a research lab

- Pilot system with energy company
  - DC distribution ± 750 V
  - Tailor made inverters
  - Compatible with regulations
  - Full remote control (IoT)
  - Integrated storage
  - Distributed generation (PV)



Power & Connectivity

- Integrated microgrid and telecom solution
- National and international collaboration
- LUT responsible for microgrid topology and control
- NOKIA main partner
- Pilot in Africa 2020



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Electro-chemical power conversion

- Renewable production creates intermittency challenge
  - Seasonal storages are needed for renewable power systems
  - Chemical storages seem most promising alternative outside the solar belt
  - Synthetic hydrocarbons are compatible with existing infrastructure
- Basis for synthetic hydrocarbons is hydrogen production
  - Electrolysis a key process
  - Power electronics is needed for high efficiency hydrogen production
  - DEE is looking for advance power electronics solutions for the purpose

Advanced Power Electronics for H_2 Production

- Effect of power quality to electrolyzer cell lifetime and energy efficiency (PEM & alkaline electrolyzers)
- Process identification, estimation and control
- In-situ electrolysis concepts for power-to-food

Modern power electronics that enables energy efficient renewable hydrogen production

Hydrogen laboratory

PHIL laboratory for H_2

Together with VTT Finland:
- *Power to Fuel research*
- *Power to Food research*

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Summary

- Power electronics and drives key research area for DEE at LUT
- Intelligent control and IoT in important role in future power conversion
- Energy transition creates new application fields for power electronics

- DEE has many academic and industrial partners in various power conversion research topics
- Danfoss units in Finland (Vacon, Visedo) have been important partners for LUT many years
- We are open for new collaboration initiatives with international partners

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