PAUWES and UoT ongoing projects on energy security in Africa

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LAT

ITT
Institute for Technology and Resources Management in the Tropics and Subtropics

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PAUWES

RESEARCH 2 PRACTICE FORUM 2018

ENERGY, WATER SECURITY AND CLIMATE CHANGE IN AFRICA

16th - 18th APRIL, 2018
TLEMCEN, ALGERIA

African Union Commission

Federal Ministry for Economic Cooperation and Development

Federal Ministry of Education and Research

Supported by:

giz

DLR Projektträger

DAAD

PAU Pan African University Institute of Water and Energy Sciences

UNITED NATIONS UNIVERSITY UNU-EHS

Center for Development Research

ITT Institute for Technology and Resources Management in the Tropics and Subtropics

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TH Köln – some figures

- Technische Hochschule Köln (University of Applied Sciences)
- Founded in 1971
- 25000 students, thereof 3500 international
- Annually about 5000 new students
- About 120 PhD candidates (in cooperation with Universities)
- 11 faculties, 48 Institutes
- > 90 study programs (51 Bachelor- and 45 Master programs)
- About 1600 employees, thereof about 420 Professors and 600 academic staffs
- > 200 Partner universities and international contacts

ITT's master programmes

- REM
- NRM
- IWRM

Renewable Energy Management (REM)

- Energy Efficiency
- Photovoltaics and Solar Thermal Systems
- Wind Energy and Hydropower
- Decentralized Energy Systems

http://www.rem-master.info

Natural Resources Management and Development (NRM)

- Land Use Systems
- Ecological and Social Risks
- Food Security
- Resources Efficient Buildings and Quarters

http://www.nrm-master.info

Integrated Water Resources Management (IWRM)

- Watershed Management
- Water Economics and Governance
- Sanitation and Public Health
- Water System Analysis

http://www.iwrm-master.info

Renewable energy systems group

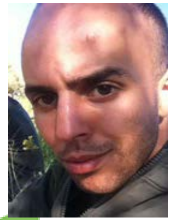
- **Who we are and what we do?**
- In our renewable energy systems group, we develop energy models, simulate energy scenarios and analyze the role of renewable to the energy mix of countries
- We focus our research on system approach: technology, economics, environmental impacts and policy of renewable energy systems

Project - WESA

Project - RARSUS

Project – PAUWES/SEMALI

Emails man



Project - :BEFSec

Project - :metabolon

PhDs

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Educational and capacity building projects

Completed projects:

- PAUWES, Algeria (July 2014 - June 2016)
- GIZ-PA (developing MOOC on powering Agriculture) (September 2015 – September 2016)
- JOGIRES, Jordan (May 2016 – November 2016)

Ongoing projects:

- PAUWES phase II (January 2017 – August 2018)
- RARSUS (January 2017 – December 2019)

Research projects

Completed projects:

- DFG, Jordan (July 2015 - September 2015)

Ongoing projects:

- WESA-ITT, Algeria (November 2016 – December 2019)
- RARSUS (January 2017 – December 2019)
- SEMALI (July 2017 – December 2019)
- BEFSec (September 2017 – February 2019)
- :metabolon: LCA of bio-energy routes (January 2017 – Dec 2020)

Project – PAUWES II

Second Phase of the DAAD (GIZ/BMZ) funded project: PAUWES – ZEF/ITT/UNU consortium for

- building on the established partnership, utilizing joint experience and focusing on:
  - ✓ targeted support to PAUWES MSc Programs (Summer Schools on Water and Energy)
  - ✓ enhancing exchange of students (and staff) in context with the summer schools and stays of German students at PAUWES and UoT
  - ✓ strengthening integration of PAUWES into the African / International research/capacity building landscape (conference at PAUWES, link to WASCAL)
  - ✓ utilizing synergisms with further projects of the ZEF-ITT-UNU-Consortium related to PAUWES

Project - WESA

PAUWES research agenda

PAUWES (UoT) **graduates**

ITT	ZEF	UNU	PAUWES	UoT
Research focus on energy	Research focus on water (modeling, management, governance)		Research focus on water and energy (students, labs)	

Research on water, energy, food, health and climate change **nexus**

Outreach program

(**Pilot-**) project for im-plementing PAUWES **research** agenda

strengthen PAUWES / UoT's integration into re-search/education **networks**

supporting infra-inst-staff **developing** of PAUWES

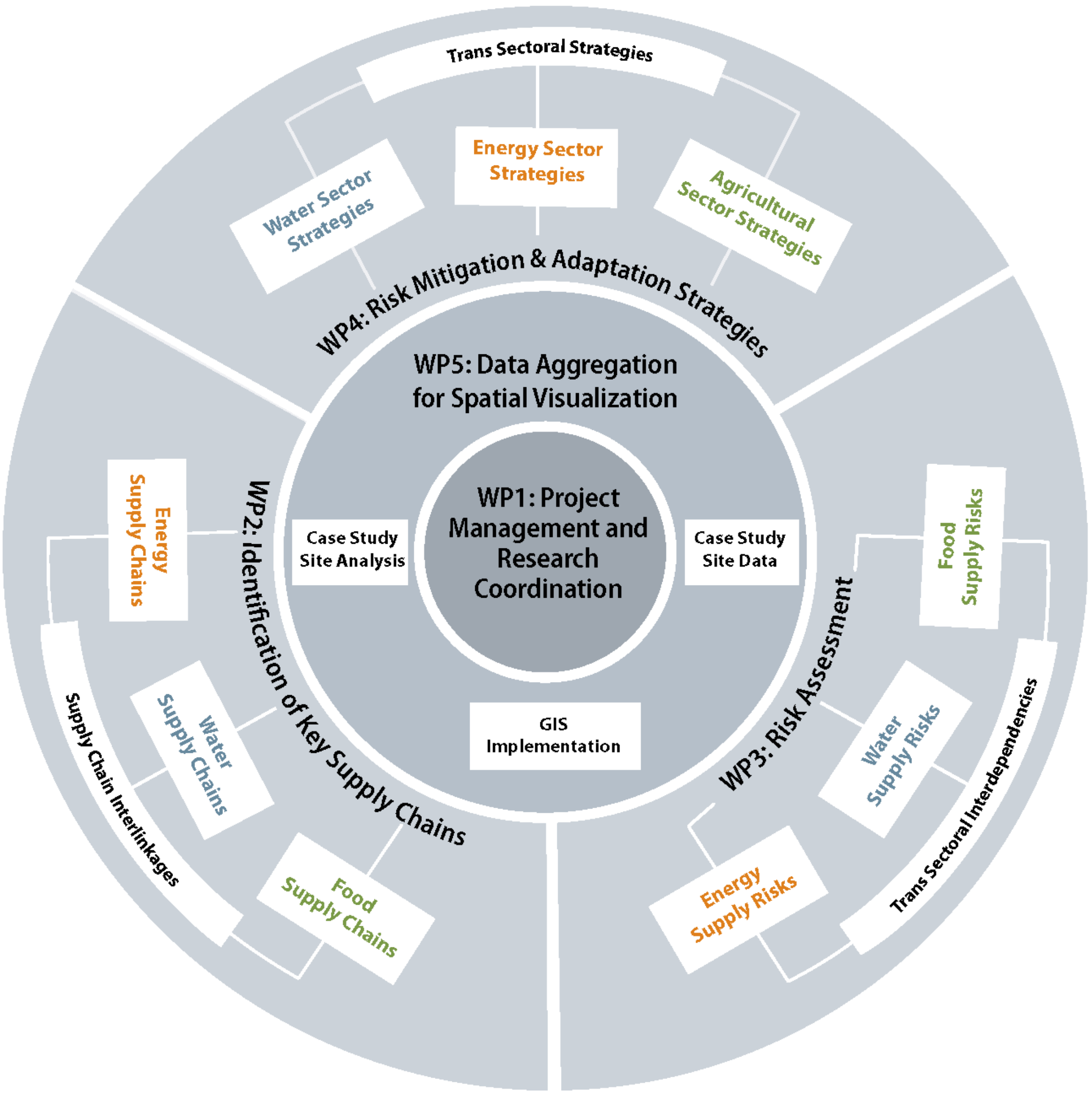
Students as ‚agents of change'

Project - WESA

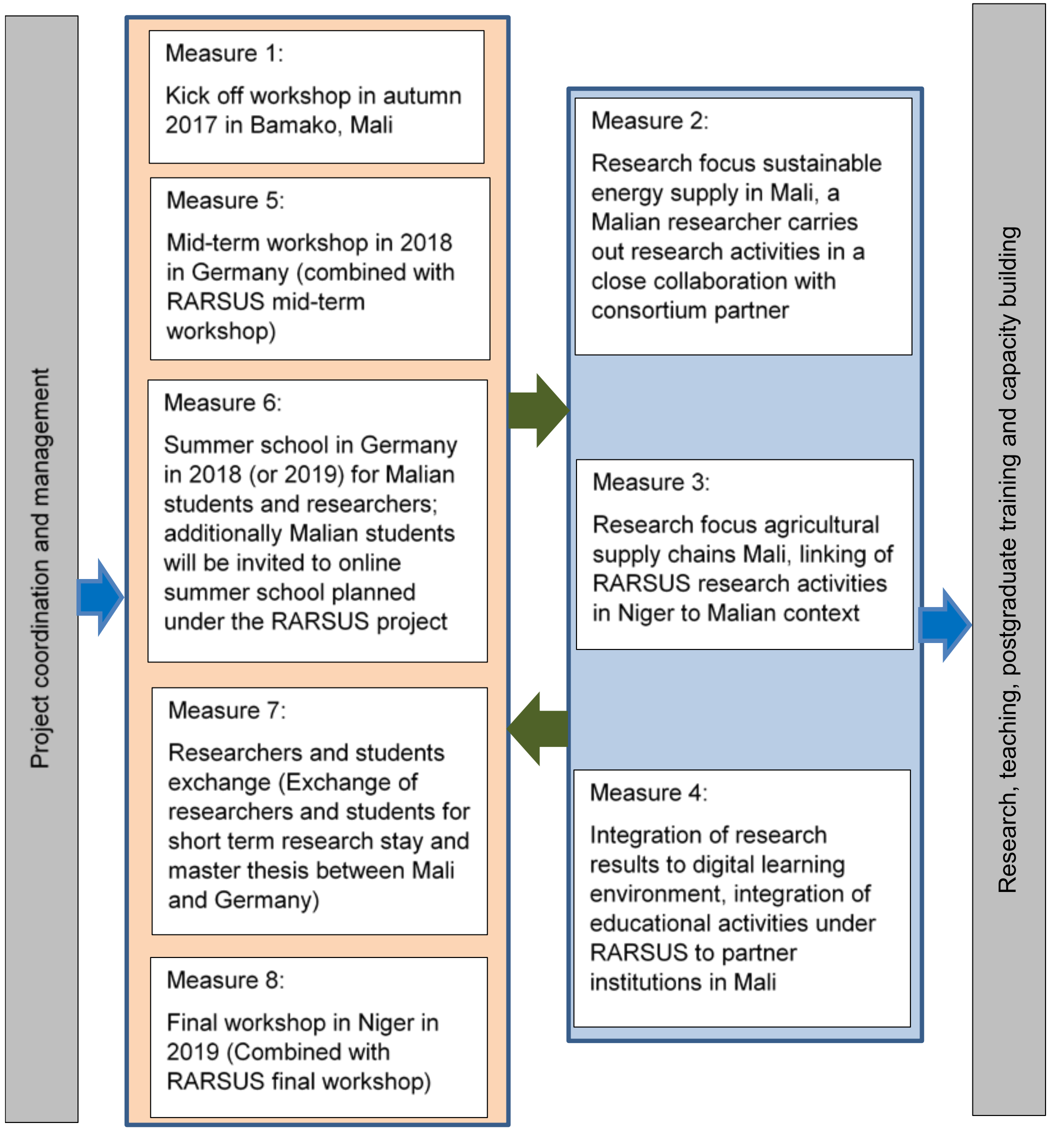
The role of ITT in this project comprise i) renewable energy security in Africa (WP2) and ii) energy - climate change - water nexus (WP4); and the activities include:

- co-supervision of 1 postdoc and 2 (+2) PhD students
- integration of methods/results of PhD and postdoc research towards nexus-based sustainable energy supply
- expanding the cooperation with other partners in Africa and beyond to strengthen the position of PAUWES/UoT in the applied research
- direct and close link and methods transfer from research to teaching and capacity building (e.g. MSc theses in combination with PhD projects), and
- using the results in practice (clean and efficient energy supply in Africa).

Project - RARSUS



Project SEMALI

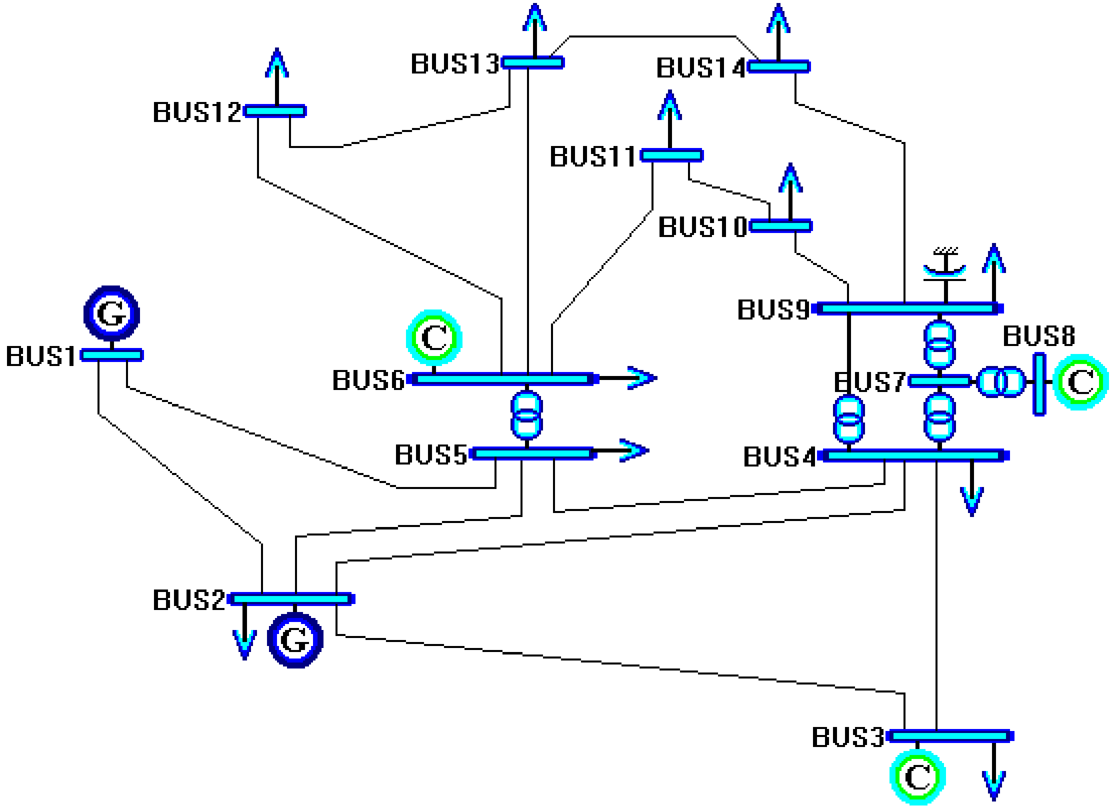


Research aspects

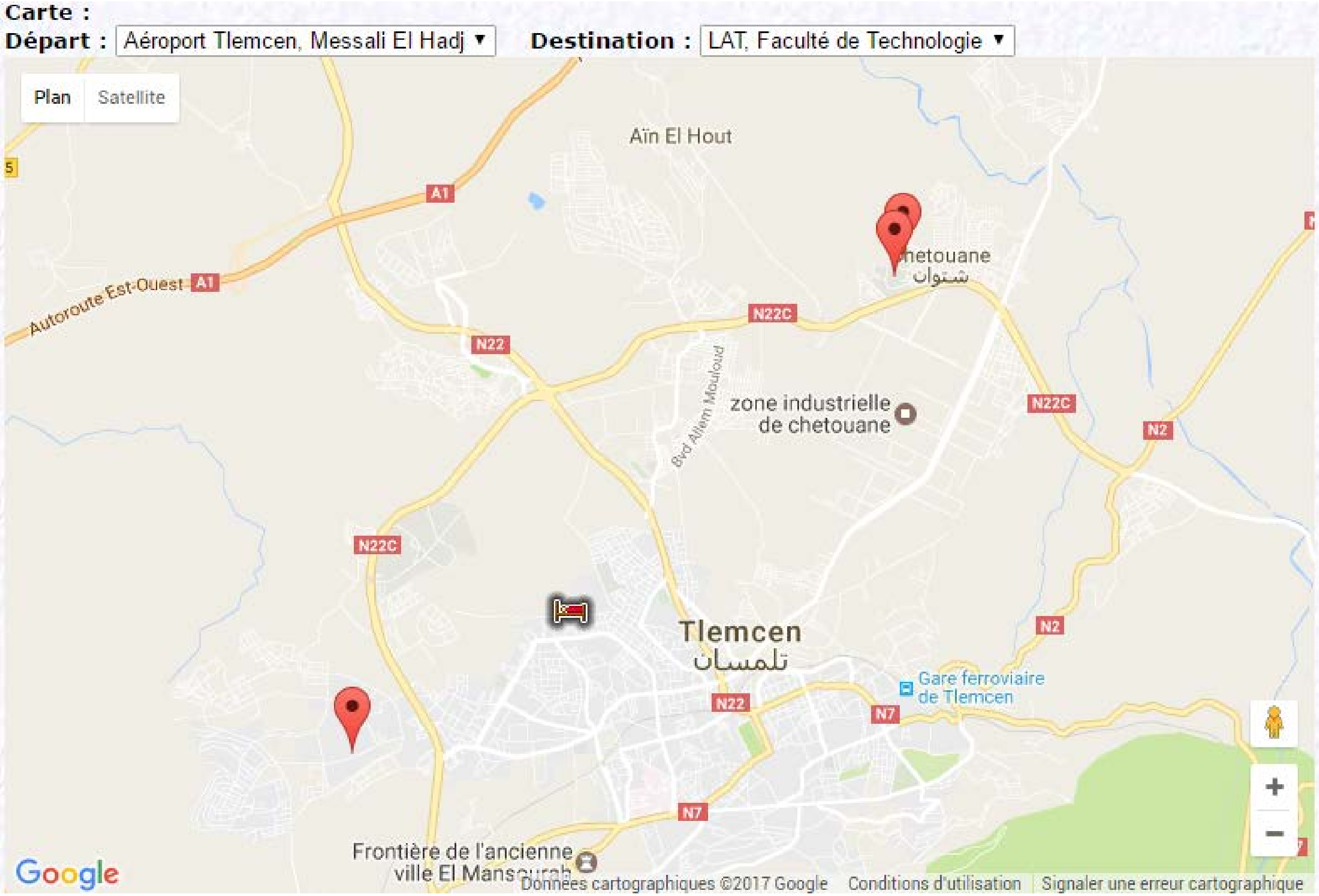
- Providing support to PAUWES in terms of practical work:
  - Renewable Energy Technologies
  - Applied Thermodynamics
- Supporting PAUWES to improve Master curricula

Technical studies and experiments

- Renewable energy systems
- Micro grids and integration to power grid
- Control of energy generation systems



LAT location



http://lat.univ-tlemcen.dz/contacts.php

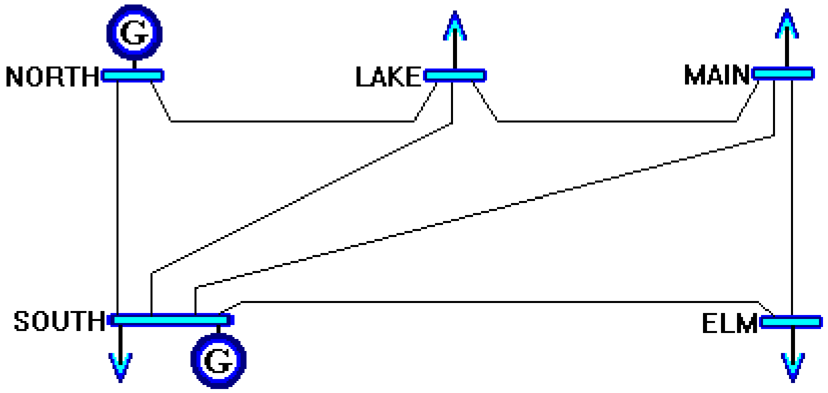
Securing energy availability

- Production, transport, distribution, consumption
- Daily load demand curve, Algeria
- Production = Consumption
- Not storable in its alternative form
- Low capacity chemical storage
- Pumped-storage hydroelectricity

Securing energy availability

- Load flow studies
- Transient and static stability
- Highly meshed power grid or radial structures, over several time zones
- Management of production and distribution costs (optimal load flow)

Load flow study



---------- Bus voltage ----------

Bus	real	imag	magnitude	arg(deg)
NORTH	V[0]=1.06	0	1.06	0
SOUTH	V[1]=1.0462	-0.051287	1.0475	-2.8065
LAKE	V[2]=1.0203	-0.089207	1.0242	-4.9967
MAIN	V[3]=1.0192	-0.095062	1.0236	-5.3287
ELM	V[4]=1.0121	-0.10905	1.018	-6.1496

------- Injected power at all buses ----------

Generated power :

Bus	real	imag	magnitude	arg(deg)
NORTH	Sg[0]=1.2957	-0.07489	1.2979	-3.308
SOUTH	Sg[1]=0.4	0.3004	0.50024	36.907
LAKE	Sg[2]=0	0	0	0
MAIN	Sg[3]=0	0	0	0
ELM	Sg[4]=0	0	0	0

Power demand :

Bus	real	imag	magnitude	arg(deg)
NORTH	Sd[0]=-0	-0	-0	0
SOUTH	Sd[1]=-0.2	-0.1	0.22361	-153.43
LAKE	Sd[2]=-0.45	-0.15	0.47434	-161.57
MAIN	Sd[3]=-0.4	-0.05	0.40311	-172.87
ELM	Sd[4]=-0.6	-0.1	0.60828	-170.54

----

	real	imag	magnitude	arg(deg)
Total generation	1.6957	0.22551	1.7106	7.5753
Total demand	-1.65	-0.4	1.6978	-166.37
AC losses	0.045704	-0.17449	0.18037	-75.322

----- Line power transfer (bus i --> j at i -----

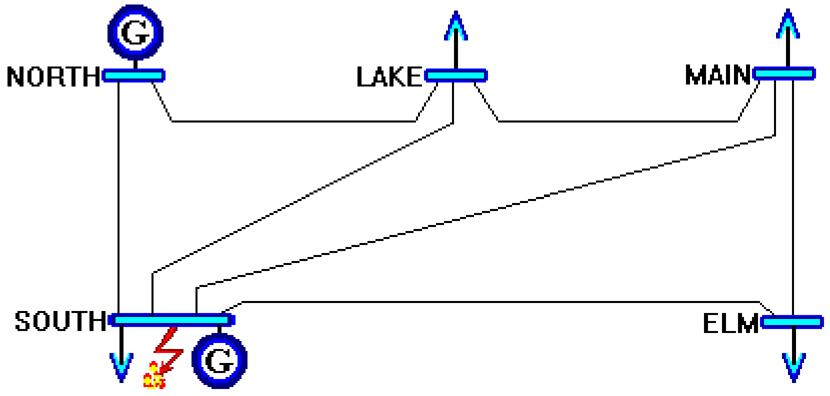
Busi	Busj	real	imag	mag (pu)	arg(deg)
NORTH	SOUTH	S[0 ,1]=0.88853	-0.052619	0.89009	-3.3891
NORTH	LAKE	S[0 ,2]=0.40717	0.039527	0.40909	5.5447
SOUTH	NORTH	S[1 ,0]=-0.87443	0.094925	0.87957	173.8
SOUTH	LAKE	S[1 ,2]=0.24691	0.057391	0.25349	13.085
SOUTH	MAIN	S[1 ,3]=0.27932	0.051541	0.28403	10.455
SOUTH	ELM	S[1 ,4]=0.54812	0.089807	0.55543	9.305
LAKE	NORTH	S[2 ,0]=-0.39526	-0.0037805	0.39527	-179.45
LAKE	SOUTH	S[2 ,1]=-0.24339	-0.046849	0.24786	-169.1
LAKE	MAIN	S[2 ,3]=0.18868	-0.041563	0.1932	-12.423
MAIN	SOUTH	S[3 ,1]=-0.2749	-0.038306	0.27756	-172.07
MAIN	LAKE	S[3 ,2]=-0.18832	0.04263	0.19309	167.24
MAIN	ELM	S[3 ,4]=0.06331	0.0033229	0.063398	3.0045
ELM	SOUTH	S[4 ,1]=-0.53687	-0.056066	0.53979	-174.04
ELM	MAIN	S[4 ,3]=-0.063003	-0.0024023	0.063049	-177.82

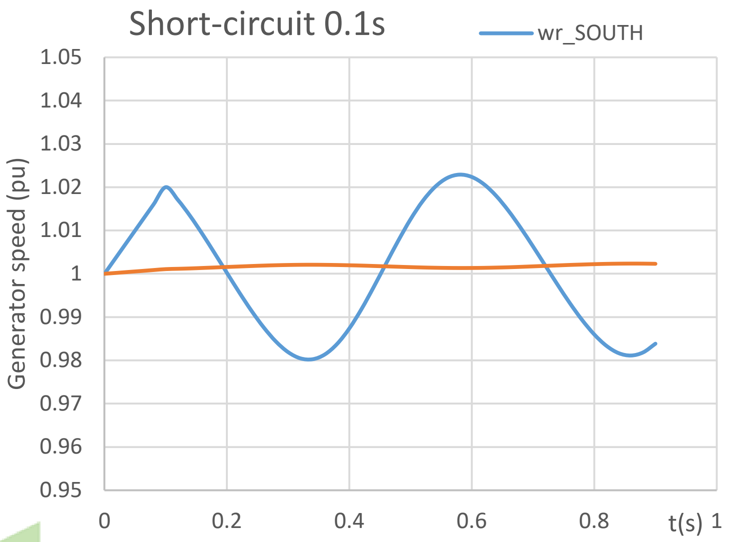
No excess power transfer

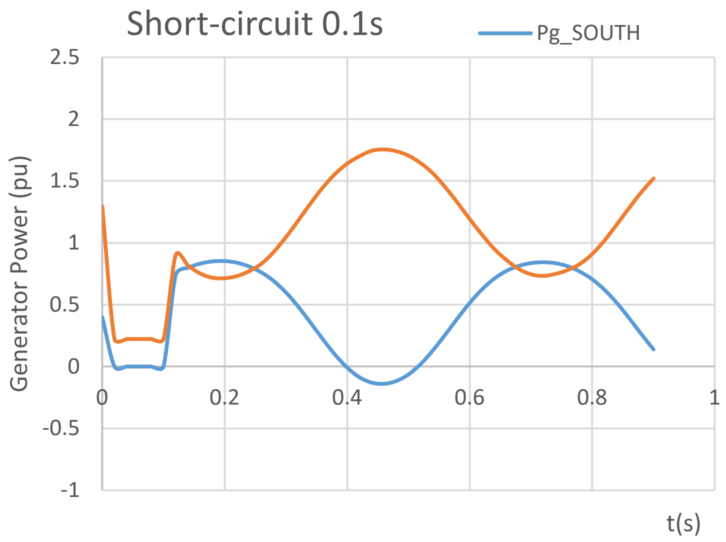
Transient stability studies

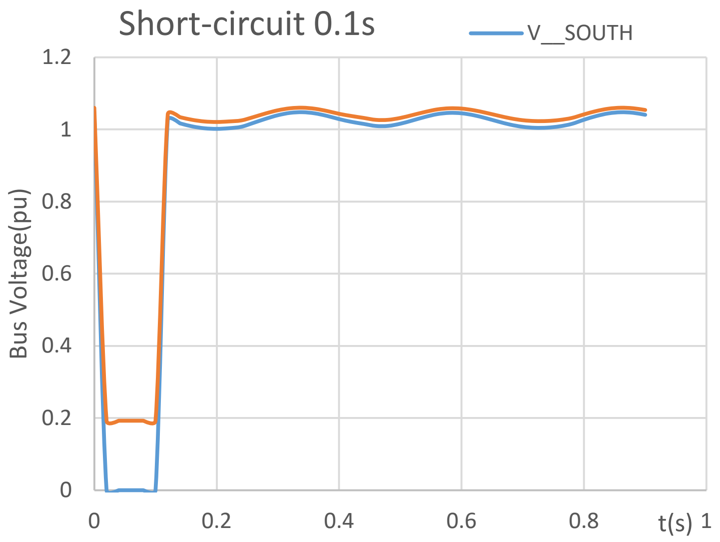
First swing stability

- Short-circuit fault at bus South, duration 0.1s
- Fault is cleared by protection systems after 0.1s
- The power grid is considered stable for this disturbance









http://baghli.com/powerd.html

Electrical Energy

- Forecast daily consumption of the next day
- Real-time adaptation of production to demand (consumption)
  - Power System Stabilisers : Automatic Voltage Regulator, Speed Governors
  - Restarting plants or generators
  - Load shedding scheme
- Reduce consumption peaks
- Avoid rapid changes
- Dealing with incidents, N-1 criterion:

  The power grid must continue operating after the loss of any one of its N components (line, generator,…). It is said to be “N-1 secure”

Renewable Energy

- Generation of energy from clean sources
- Generate where needed (consumption place) $\Rightarrow$ no losses in transportation lines
- Types:
  - Wind turbine, CSP Concentrated Solar Power
  - PV, the only one that can be easily installed in residential

https://cleantechnica.com/2016/10/31/how-csp-works
http://www.solar-constructions.com/wordpress/eoliennes

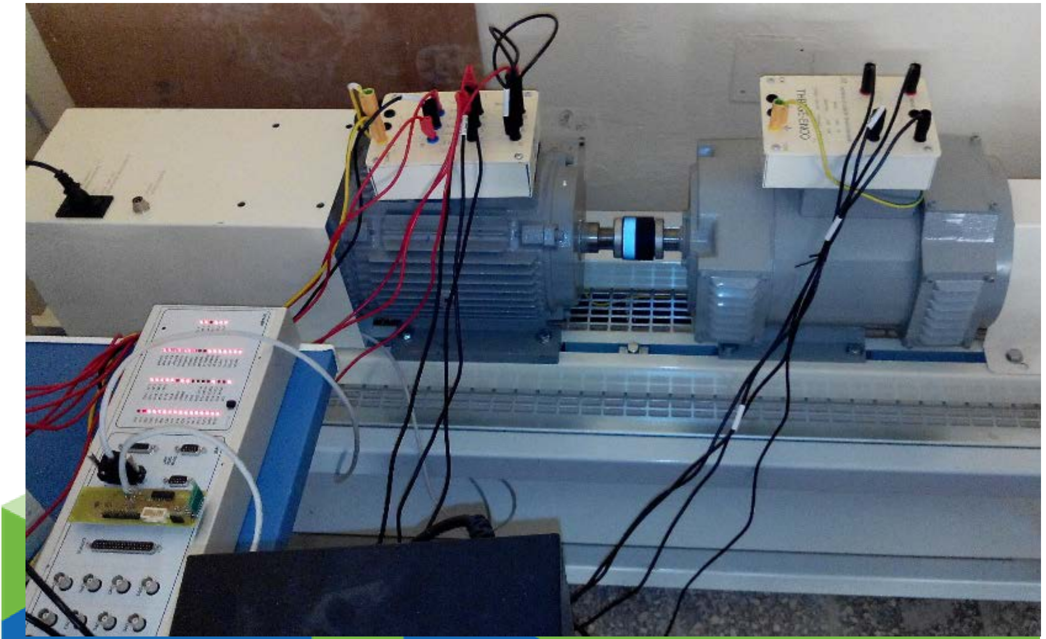
Wind energy injected into the grid

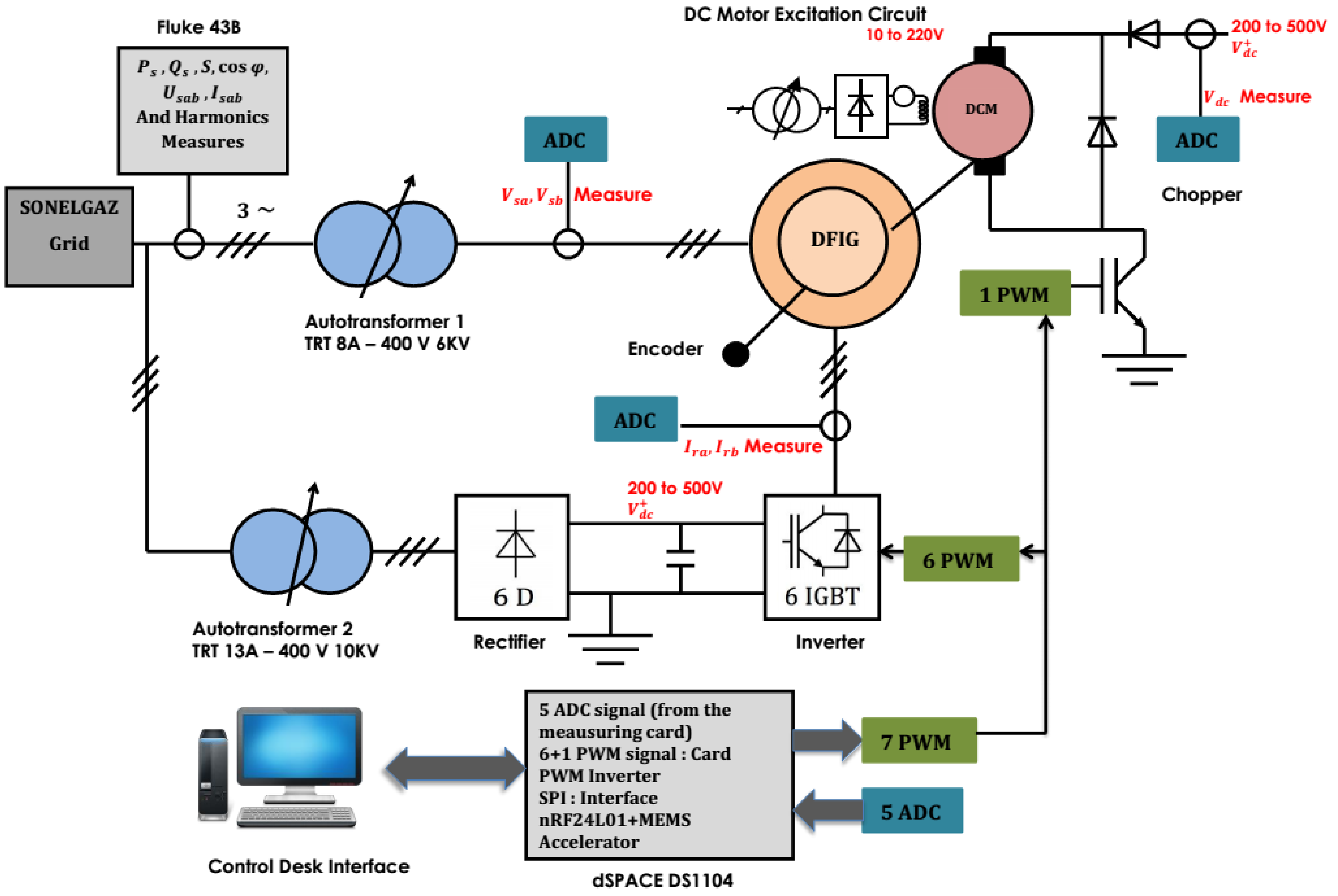
- Benefit
  - Power supply
  - Distributed generation of electricity
  - Resale to the operator (on grid)
  - Standalone use (off grid)
- How, technology
  - DFIG (Double Fed Induction Generator)
  - Off grid, requires large batteries
  - Typically 10 kW to 1 MW
- How, financially
  - Very expensive installation (>> PV)
  - Depending on the policy of the OS (price, ...)

https://www.eal.ei.tum.de/research/projects/research-abdelrahem1
https://www.mathworks.com/help/physmod/sps/powersys/ref/windturbinedoublyfedinductiongeneratorphasortype.html

Wind turbine emulator

- DFIG: Double Fed Induction Generator
- Built and used at LAT / UoT
- https://www.youtube.com/playlist?list=PLXYd8IyLhtrGcGafeWjq_vEM_VI4lvsuC
- Future:
- SG: Synchronous Generator





PV Grid Tie Inverter

- Benefit
  - Fulfil the production of state power plants
  - Huge solar potential in Africa
  - Free, clean and renewable energy
  - Generated and consumed at the point of production: distributed electricity production by micro-power plants
  - The power grid will only provide the difference or at night
  - The power grid allows the synchronization and transport of the surplus
  - The individual becomes an electricity producer and get sensitive to the energy savings: consume less to sell more

http://baghli.blogspot.com/2016/09/le-photovoltaique-pv-residentiel.html

PV Grid Tie Inverter

- How, technology
  - PV panels ready for purchase
  - GTI (APsystems,...) micro inverters for 1, 2 or 4 PV (60 to 72 cells) 250 W to 1 kW with individual MPPTs
  - GTI: DC / DC buck-boost chopper, capacitor, DC bus, single-phase inverter (synchronization)
  - Energy meter to count the active power produced and consumed

http://www.ti.com/lit/an/sprabr4a/sprabr4a.pdf
http://www.ti.com/lit/an/sprabt0/sprabt0.pdf
http://coder-tronics.com/c2000-solar-mppt-tutorial-pt1/

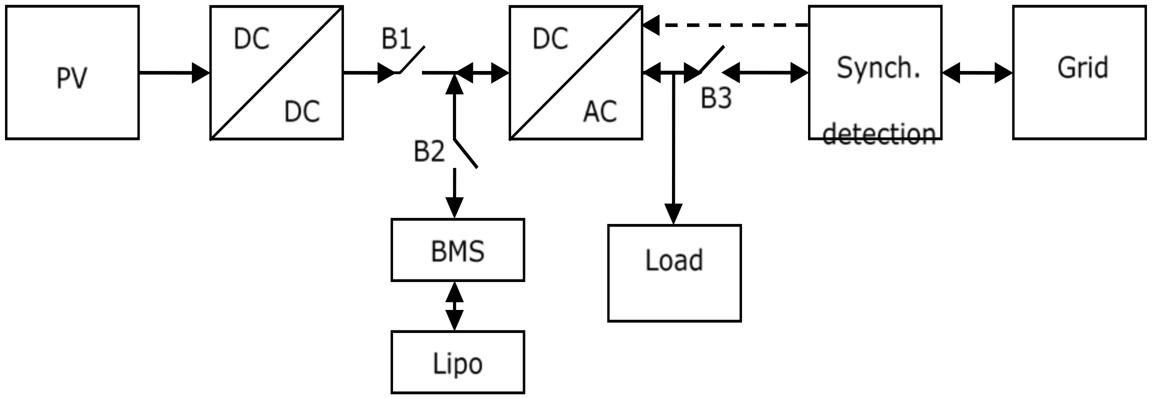
PV Grid Tie Inverter

- How, financially
  - Use of roofs or terraces of houses (cleaning)
  - Regulation for the resale of energy to the operator
  - Search for financing source (operator, APRUE)
  - Example of the Solar City project, by E. Musk

- http://baghli.blogspot.com/2016/09/le-photovoltaique-pv-residentiel.html
  - 3 kW=12*250 W;12*150 €+3GTI (300 €)+E.M.(100 €)=2800 €
    0.1-0.3 €/kWh
  - Avec 0.2 €/kWh, 2800/0.2 = 14000 kWh
    14000 kWh / 14 kWh/day = 1000 days = 3 years to amortize the investment
  - Avec 5.1488 DA/kWh, 2800*120/5.1488 = 65258 kWh
    65258 kWh / 14 kWh/day = 4661 days = 14 years

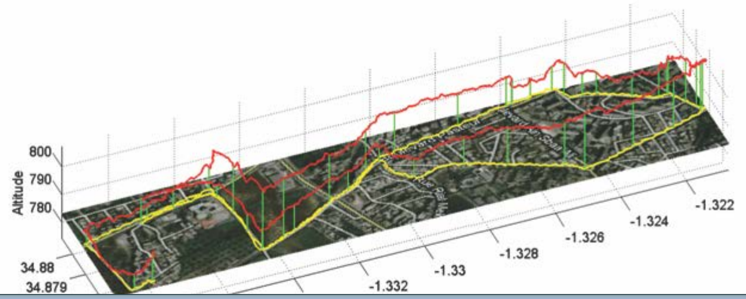
http://baghli.blogspot.com/2016/09/le-photovoltaique-pv-residentiel.html
http://www.solarcity.com/residential

PV off Grid



- Benefit
  - Rural area not connected to the network
  - Solve the problems of load shedding
  - Reduced power < 2 kW or 1 kW
- How, technology
  - The day: Home appliances + battery charging
  - The night: LED lamps, TV and refrigerator: 500W peak, 200W off peak
  - Li-Po / Li-Fe batteries cover the peak demand: buffer tank
  - Giga factory lowers the cost of Li-Po (PowerWall)
  - MPPT PV to charge, DC bus voltage must be larger than that of batteries to charge. 1s 3.6V - 4.2V, 20s 84V <320V
  - The inverter deals with voltage fluctuations of the DC bus; 4Q- chopper as single-phase inverter
  - Several cells require the use of a BMS for balancing

CSE: Control of Electrical Systems

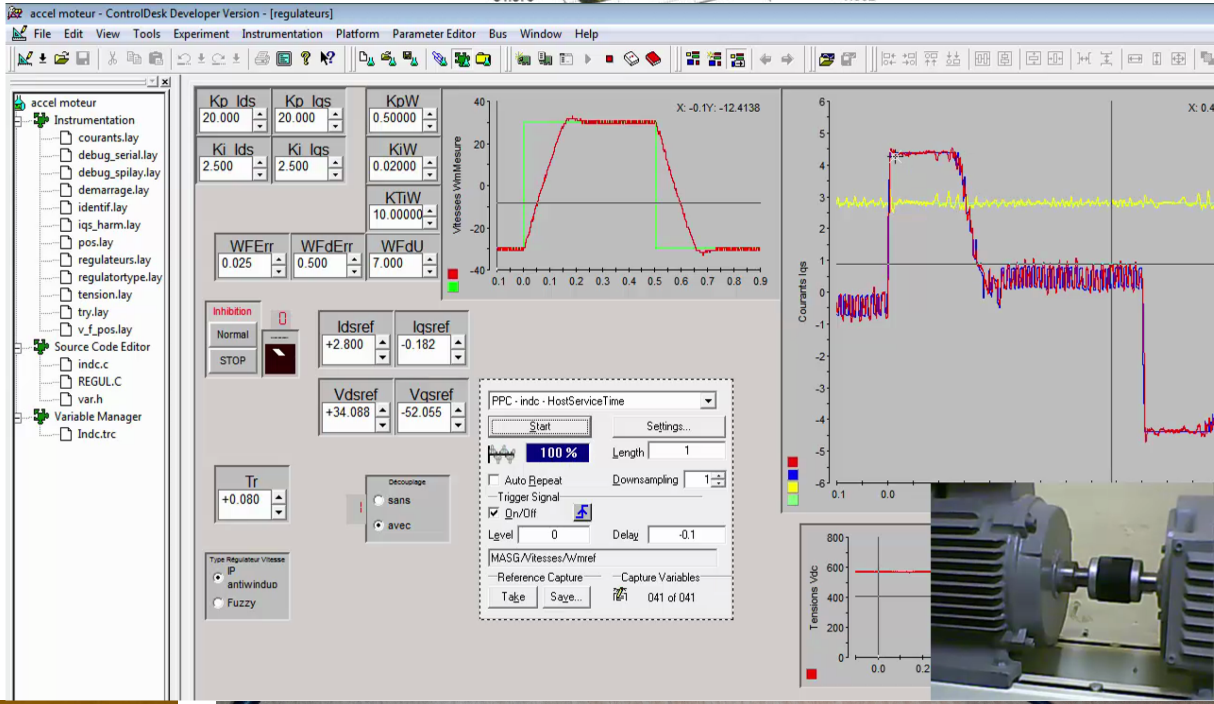


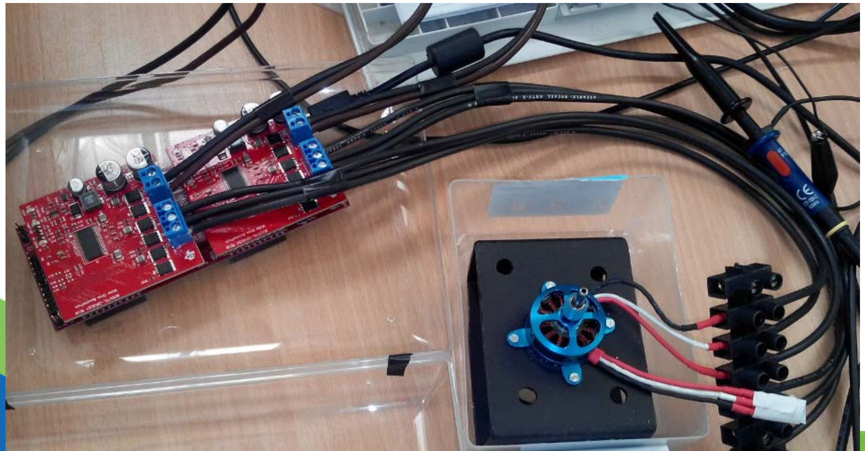
Prof. BAGHLI Lotfi

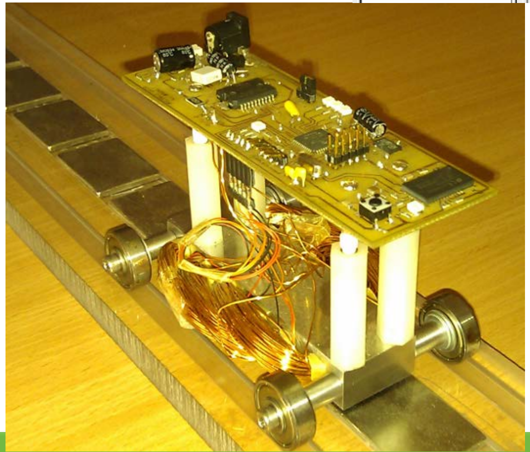
Control of synchronous and induction motors

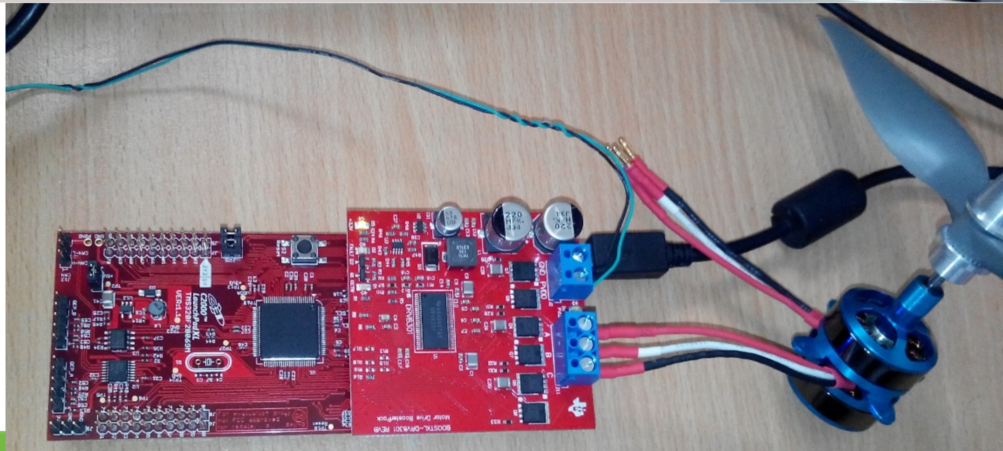
Controls of electric and hybrid vehicles

Control of electrical energy production systems: photovoltaic and wind energy (GTI, DFIG)



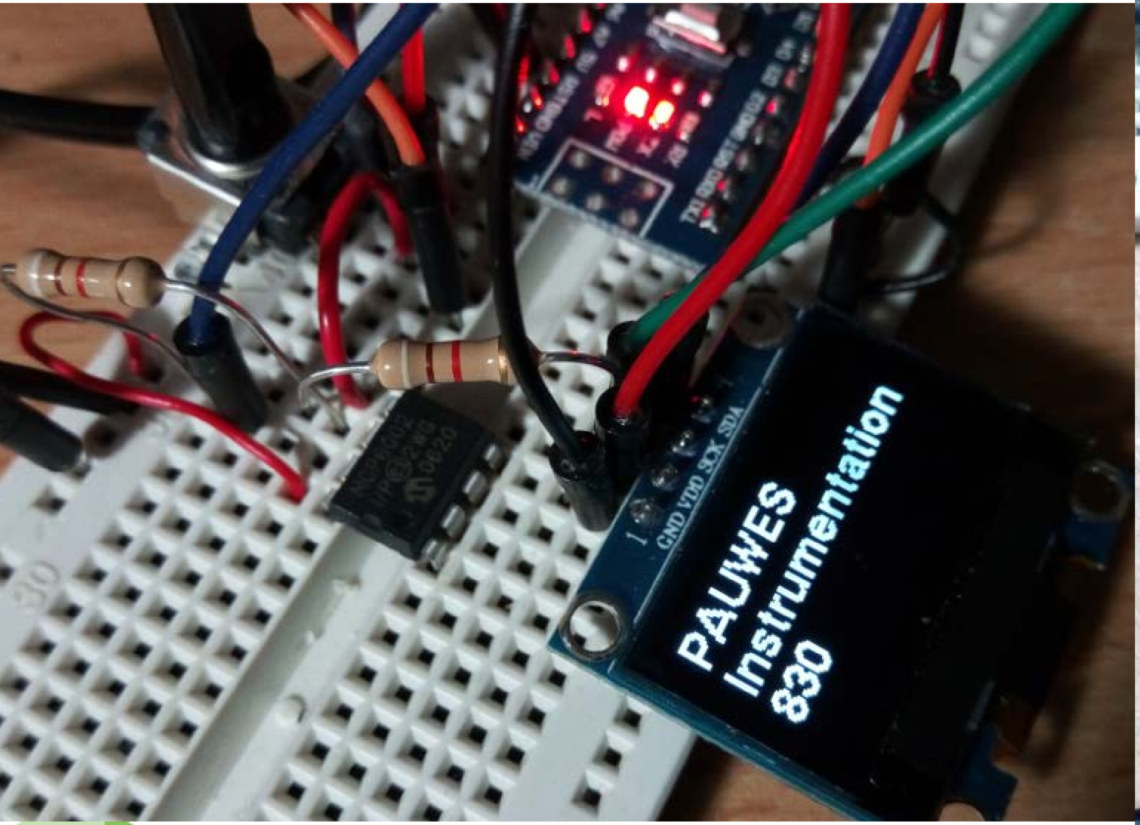


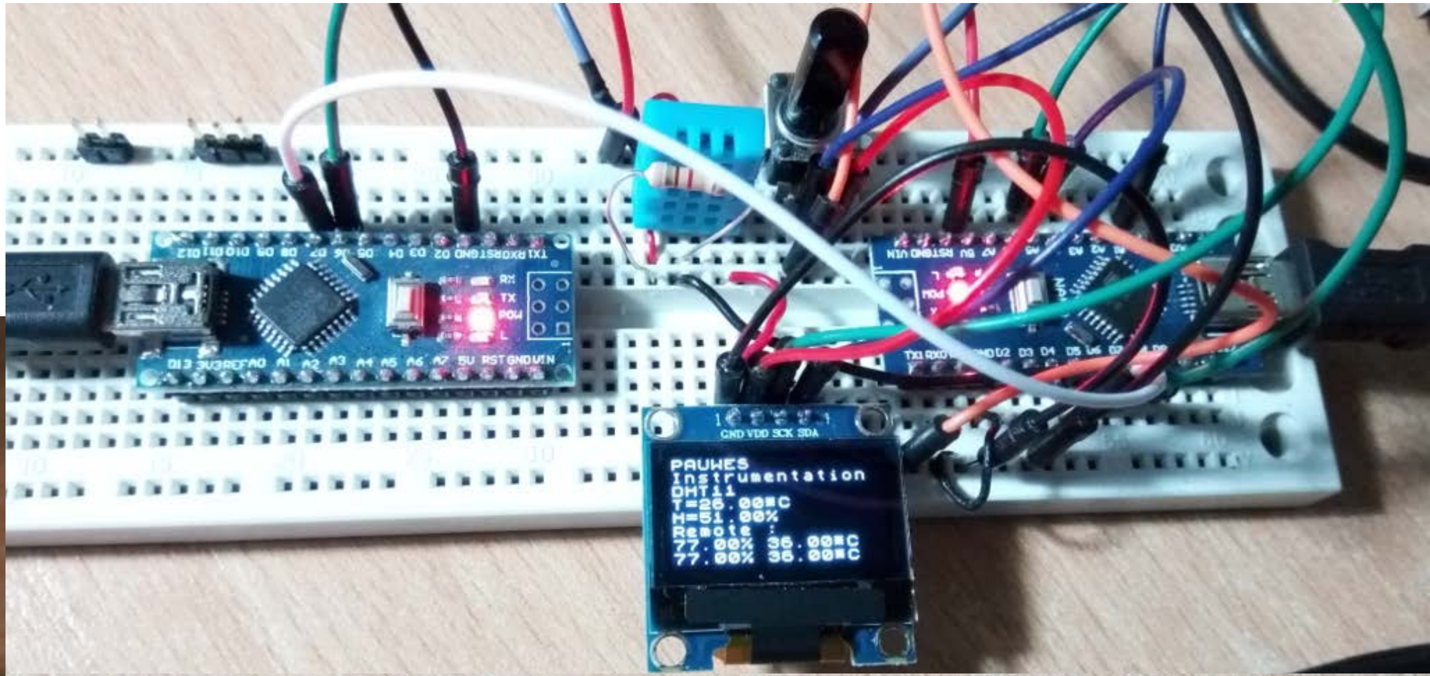


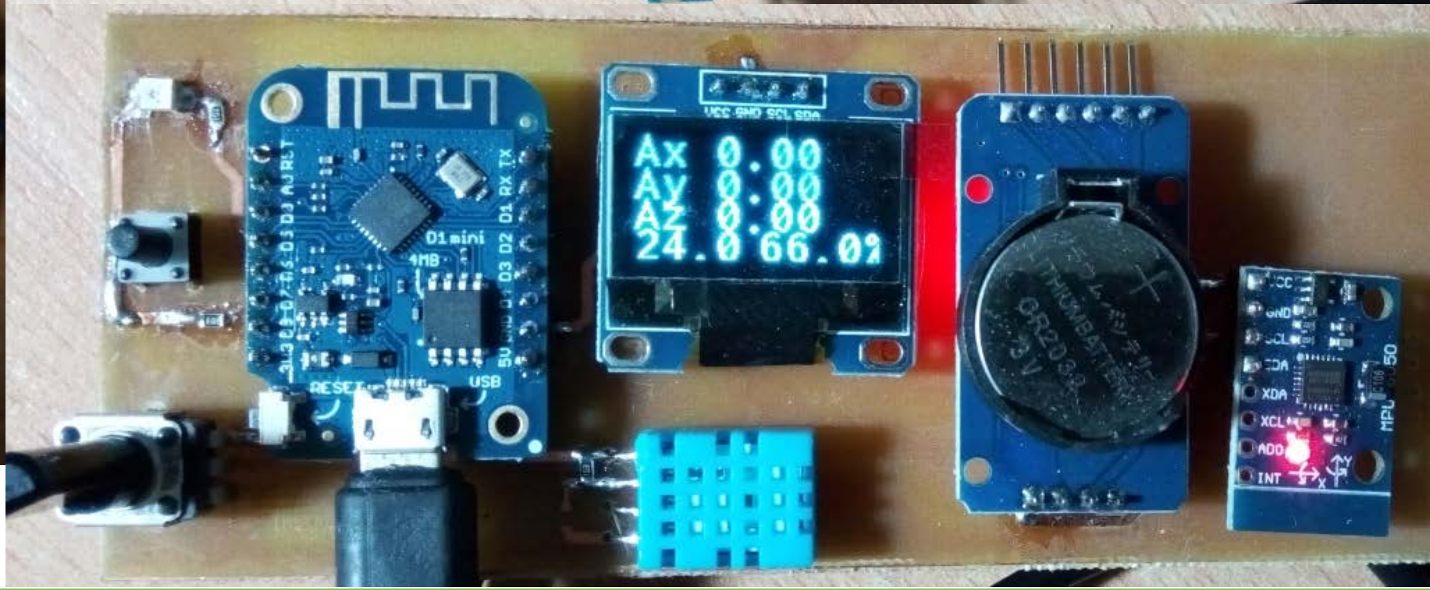


PAUWES Master courses

- Example:
- Instrumentation module

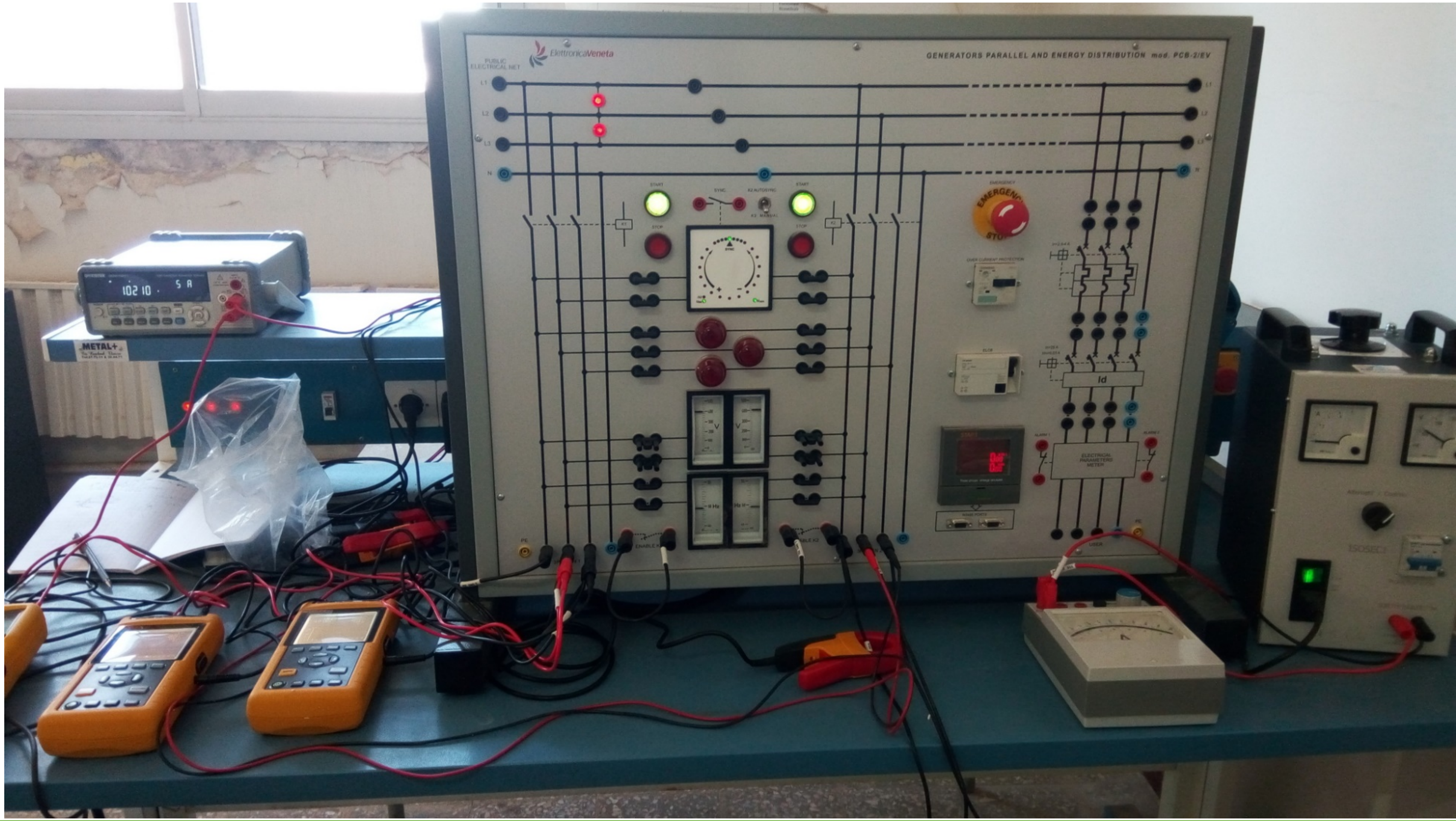






PAUWES Master courses

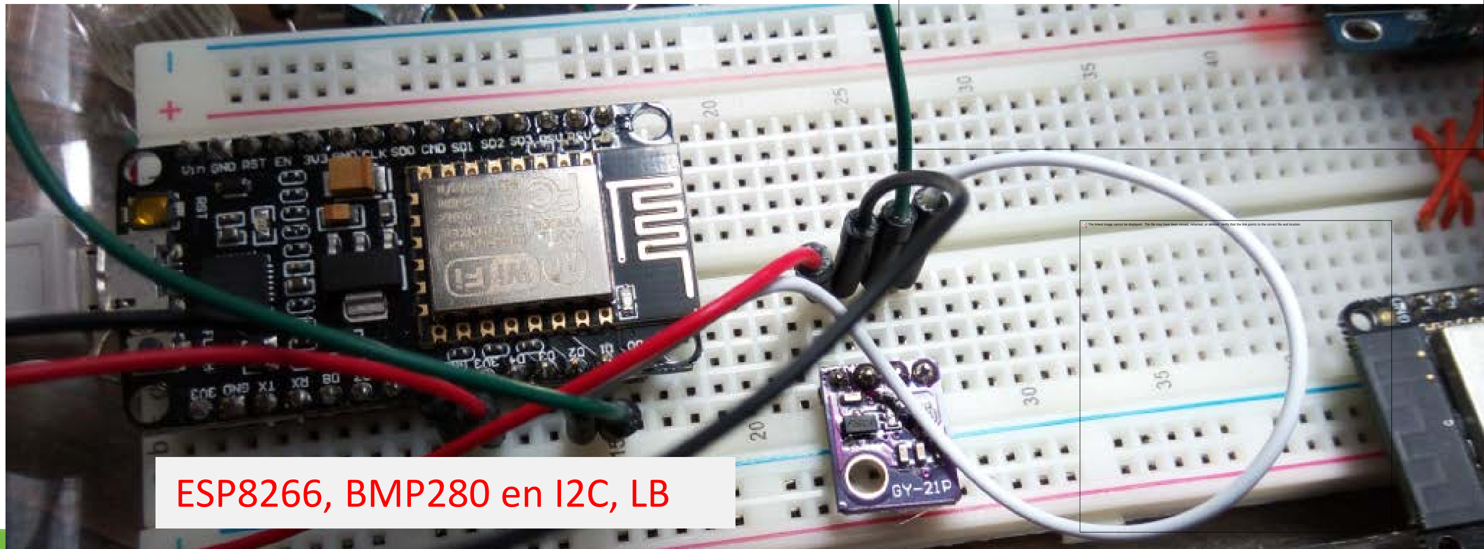
- Example:
- Urban and Rural Energy Supply



Ongoing analysis of air quality

- Onboard sensors (COx, NOx, O3, SO2, VOC, radioactivity ...)
- Weather Sensor (Temperature, Humidity, Pressure, Speed and Wind Direction, Sunshine, Rainfall)
- Sending information via GPRS / 3G / 4G to a remote BDD
- Real-time information processing and notification

RTC, Arduino nano V3, SIM900A GPRS, LB



ESP8266, BMP280 en I2C, LB

Skills at LAT laboratory

- Modeling, identification, simulation of systems
- Experimentation, testing and prototyping (machine benches and electronic boards)
- Real-time, offline image processing (OpenCV, Matlab, Rasp. PI, Android)
- 3D rendering, 3D animation, physical models, illustration (Unity, 3ds Max, OpenGL)
- Control of non-linear processes (unstable, underactuated _drones_)
- Three-phase motor control (vector, BLDC, V/f, DFIG)
- Torque, speed, position control, experiments
- Renewable energies (generation, control, storage)
- Electric vehicles (control, data gathering, CAN bus)
- Internet of Things (IoT), RF data transmission (Wifi, GPRS / 3G / 4G, nRF24, ...)
- MySQL database, Firebase, instant notification (Android, Web, embedded system)

Thank you
for your attention

Discussion

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