PAUWES and UoT ongoing projects on energy security in Africa

Prof. Lotfi BAGHLI
Lotfi.Baghli@univ-tlemcen.dz
Université de Tlemcen

Prof. Ramchandra BHANDARI
ramchandra.bhandari@th-koeln.de
ITT – TH Koeln

ITT
Institute for Technology and Resources Management in the Tropics and Subtropics
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**
  - Renewable Energy Management (REM)
    - Energy Efficiency
    - Photovoltaics and Solar Thermal Systems
    - Wind Energy and Hydropower
    - Decentralized Energy Systems
    - [http://www.rem-master.info](http://www.rem-master.info)

- **NRM**
  - 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](http://www.nrm-master.info)

- **IWRM**
  - Integrated Water Resources Management (IWRM)
    - Watershed Management
    - Water Economics and Governance
    - Sanitation and Public Health
    - Water System Analysis
    - [http://www.iwrm-master.info](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 - RARSUS](Project – PAUWES/SEMALI)

![Project – PAUWES/SEMALI](Project - :BEFSec)

Emails man

Project - :metabolon

PhDs

PhDs
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**

- ITT: Research focus on energy
- ZEF: Research focus on water (modeling, management, governance)
- UNU: Research focus on water and energy (students, labs)
- PAUWES: Research focus on water, energy, food, health and climate change nexus

**PAUWES (UoT) graduates**

- UoT: Students as ‘agents of change’

**Outreach program**

- (Pilot-) project for implementing PAUWES research agenda
- strengthen PAUWES / UoT’s integration into research/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

Measure 1:
Kick off workshop in autumn 2017 in Bamako, Mali

Measure 5:
Mid-term workshop in 2018 in Germany (combined with RARSUS mid-term workshop)

Measure 6:
Summer school in Germany in 2018 (or 2019) for Malian students and researchers; additionally Malian students will be invited to online summer school planned under the RARSUS project

Measure 7:
Researchers and students exchange (Exchange of researchers and students for short term research stay and master thesis between Mali and Germany)

Measure 8:
Final workshop in Niger in 2019 (Combined with RARSUS final workshop)

Measure 2:
Research focus sustainable energy supply in Mali, a Malian researcher carries out research activities in a close collaboration with consortium partner

Measure 3:
Research focus agricultural supply chains Mali, linking of RARSUS research activities in Niger to Malian context

Measure 4:
Integration of research results to digital learning environment, integration of educational activities under RARSUS to partner institutions in Mali

Research, teaching, postgraduate training and capacity building
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 ---

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

--- Injected power at all buses ---

### Generated power:

<table>
<thead>
<tr>
<th>Bus</th>
<th>real</th>
<th>imag</th>
<th>magnitude</th>
<th>arg(deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>Sg[0] =-1.2957</td>
<td>-0.07489</td>
<td>1.2979</td>
<td>-3.308</td>
</tr>
<tr>
<td>SOUTH</td>
<td>Sg[1] =-0.4</td>
<td>0.3004</td>
<td>0.50024</td>
<td>36.907</td>
</tr>
<tr>
<td>LAKE</td>
<td>Sg[2] =0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MAIN</td>
<td>Sg[3] =0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ELM</td>
<td>Sg[4] =0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Power demand:

<table>
<thead>
<tr>
<th>Bus</th>
<th>real</th>
<th>imag</th>
<th>magnitude</th>
<th>arg(deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>Sd[0] =0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOUTH</td>
<td>Sd[1] =-0.2</td>
<td>-0.1</td>
<td>0.23261</td>
<td>-153.43</td>
</tr>
<tr>
<td>LAKE</td>
<td>Sd[2] =-0.45</td>
<td>-0.15</td>
<td>0.47434</td>
<td>-161.57</td>
</tr>
<tr>
<td>MAIN</td>
<td>Sd[3] =-0.4</td>
<td>-0.05</td>
<td>0.40311</td>
<td>-172.87</td>
</tr>
<tr>
<td>ELM</td>
<td>Sd[4] =-0.6</td>
<td>-0.1</td>
<td>0.60828</td>
<td>-170.54</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Busi</th>
<th>Busj</th>
<th>real</th>
<th>imag</th>
<th>mag (pu)</th>
<th>arg(deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>SOUTH</td>
<td>S[0,1] =-0.8853</td>
<td>-0.052619</td>
<td>0.8909</td>
<td>-3.3891</td>
</tr>
<tr>
<td>NORTH</td>
<td>LAKE</td>
<td>S[0,2] =-0.40717</td>
<td>0.039527</td>
<td>0.4009</td>
<td>5.547</td>
</tr>
<tr>
<td>SOUTH</td>
<td>NORTH</td>
<td>S[1,0] =-0.87443</td>
<td>0.094925</td>
<td>0.87957</td>
<td>173.8</td>
</tr>
<tr>
<td>SOUTH</td>
<td>LAKE</td>
<td>S[1,2] =-0.24691</td>
<td>0.057391</td>
<td>0.25349</td>
<td>13.085</td>
</tr>
<tr>
<td>SOUTH</td>
<td>MAIN</td>
<td>S[1,3] =-0.27932</td>
<td>0.051541</td>
<td>0.28403</td>
<td>10.455</td>
</tr>
<tr>
<td>SOUTH</td>
<td>ELM</td>
<td>S[1,4] =-0.54812</td>
<td>0.089007</td>
<td>0.55543</td>
<td>9.395</td>
</tr>
<tr>
<td>LAKE</td>
<td>NORTH</td>
<td>S[2,0] =-0.39526</td>
<td>-0.0037805</td>
<td>0.39527</td>
<td>-179.45</td>
</tr>
<tr>
<td>LAKE</td>
<td>SOUTH</td>
<td>S[2,1] =-0.24339</td>
<td>-0.48649</td>
<td>0.24786</td>
<td>-169.1</td>
</tr>
<tr>
<td>LAKE</td>
<td>MAIN</td>
<td>S[2,3] =-0.18868</td>
<td>-0.41563</td>
<td>0.1932</td>
<td>-12.423</td>
</tr>
<tr>
<td>MAIN</td>
<td>SOUTH</td>
<td>S[3,1] =-0.2749</td>
<td>-0.83836</td>
<td>0.27756</td>
<td>-172.87</td>
</tr>
<tr>
<td>MAIN</td>
<td>LAKE</td>
<td>S[3,2] =-0.18832</td>
<td>0.04263</td>
<td>0.19309</td>
<td>167.24</td>
</tr>
<tr>
<td>MAIN</td>
<td>ELM</td>
<td>S[3,4] =-0.06331</td>
<td>0.0033229</td>
<td>0.063398</td>
<td>3.0045</td>
</tr>
<tr>
<td>ELM</td>
<td>SOUTH</td>
<td>S[4,1] =-0.53687</td>
<td>-0.056066</td>
<td>0.53979</td>
<td>-174.84</td>
</tr>
<tr>
<td>ELM</td>
<td>MAIN</td>
<td>S[4,3] =-0.063003</td>
<td>-0.0024023</td>
<td>0.063049</td>
<td>-177.82</td>
</tr>
</tbody>
</table>

--- Power summary ---

- **Total generation:** 1.6957 + j0.22551
- **Total demand:** -1.65 + j-0.17449
- **AC losses:** 0.045704 + j0.18037

No excess power transfer

--- Links ---

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://bagli.com/power.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) ⇒ 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, …)
Wind turbine emulator

- DFIG: Double Fed Induction Generator
- Built and used at LAT / UoT
- https://www.youtube.com/playlist?list=PLXYd8IvLhtrGcGafeWjq_vEM_VI4lvusuC
- 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

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/sprabt0/sprabt0.pdf
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

- 3 kW = 12*250 W; 12*150 € + 3 GTI (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://www.solarcity.com/residential](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
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

PAUWES
RESEARCH 2 PRACTICE FORUM 2018
ENERGY, WATER SECURITY AND CLIMATE CHANGE IN AFRICA
16th - 18th APRIL, 2018
TLEMCE, ALGERIA