Renewable Energy Sources and Applications

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Collaborators
Outline

• Brief on Transilvania University of Brasov

• Renewable Energy Sources - overview
  • Solar
  • Wind
  • Water

• Smart Grids and Power Storage

• Application:
  • X3D Sensor-based Thermal Maps
Transilvania University of Brasov

Since 1948
- Comprehensive university
- Departments: 17
- Teaching staff: 700+
- Students: 20,000+

Research institute focused on Sustainable Development with 12 labs
Electrical Engineering and Computer Science Department

- Electro-mechanical Engineering (cc.1962)
- Electrical Engineering (1975)
- Electronics and Computers (1990)
- Industrial Automation and Informatics (1991)

1500+ Students (2016)
75+ Staff

Programs:
- **Bachelors** (Electrical Engineering, Electronics, Automation Industrial Informatics, Computer Science)
- **Masters** (Embedded Systems, Energy Efficiency, Informatics)
- **Doctoral** (Electronics, Computer Science, Electrical Engineering, Energy Management)
Renewable Energy
Renewable Energy Sources

Solar

Wind

Geothermal

Biomass
Sun Energy Budget

- Direct radiation captured by photovoltaic panels
- Direct & reflected radiation captured by thermal panels
- Air atmosphere movements (winds) captured by wind turbines
- Solar radiation captured by vegetal world => Biomass
- Solar radiation captured by oceans water => wave, tidal
- Solar radiation captured by clouds, and oceans’ water generate precipitation and river streams energy => Hydro generation

https://edro.wordpress.com/energy/earths-energy-budget/
Sun – replacing fossil fuels

Electrical energy generation:
- Wind generators & wind farms
- Solar photovoltaic or concentrated power generators
- Solar Thermal generators
- Hydro power generators
- Tidal & wave generators
- Biomass based power generators
- Geothermal generators

Pollution consequences:
- Climate changes
- Increasing power of atmospheric phenomena: e.g. hurricanes (Matthew)
- Global heating
- Melting glaciers
- Ocean waters levels change
Renewable Energy Sources - Sustainability

Social acceptance

Equitable
Economic

Viable

Environment
Beareable

SUSTAINABLE
Wind potential - global average value of wind @240 feet

Wind generators

Wind energy

Two different designs are possible, but established thermal power plants for wind turbines. Systems with gearbox 1 increase the low speed of the generator to a reasonable speed for the generator.

1. Example of a system with gearbox

- Diameter: 3.0 m
- Rotor diameter: 80 m
- Tower height: up to 80 m
- Speed: 12 revolutions per minute

2. Example of a system without gearbox

- Diameter: 3.0 m
- Rotor diameter: 80 m
- Tower height: up to 80 m
- Speed: 12 revolutions per minute

The wind turbine is connected to the grid in an asynchronous direct current circuit. The electricity generated by the generator is transformed by the wind turbine to the wind turbine. Each wind turbine consists of a rotor, a generator, and a control system. The wind turbine is controlled by a wind sensor, which measures the wind speed and direction.
Wind farms

Maximum power 7,58MW

\[ P = \frac{1}{2} \cdot 0.59 \cdot \rho \cdot v^3 \cdot A \]
Pico, Micro-Hydro generators

The hydro-generators features:
- Head of power plant
- Flow rate of the water stream
- Nominal parameters: voltage, power, current, temperature, water quality, etc.
- Type of turbine

http://www.flovel.net/products-turbines-kaplan.asp?lk=pro1_c

http://www.flovel.net/products-turbines-francis.asp?lk=pro1_b

https://en.wikipedia.org/wiki/Pico_hydro
Geothermal power plants

• Dry steam power plant - Use high temperature to drive the turbine of the power plant.

• Binary power plant - Collects by heat converter the energy of geothermal waters using low temperature vaporization liquids

• Flash steam power plant - Hot water is sprayed into a tank at a much lower pressure than the fluid

Second largest in the world geothermal power plant on Hengill volcano - South of Iceland (Hellisheidarvirkjun)

http://www.thinkgeoenergy.com

https://www.extremeiceland.is/en/information/about-iceland/hellsheidi-geothermal-power-station
Global solar radiation map

WORLD MAP OF DIRECT NORMAL IRRADIATION

Long-term average of:

- Annual sum
- Daily sum

kWh/m²
Factors influencing efficiency:

- Type of cell
- Temperature
- Dust
- Aging

http://www.electricaltechnology.org/2015/06/how-to-make-a-solar-cell-photovoltaic-cell.html
## Solar-Cell characteristics

### Temperature dependence of the solar cell

![Graph showing the temperature dependence of the solar cell](https://www.researchgate.net/figure/284970252_fig2_Figure-2-The-four-PV-modules-used-in-the-test-and-close-up-views._0252_fig2_Figure-2-The-four-PV-modules-used-in-the-test-and-close-up-views.png)

The four PV modules used in the test and close-up views.

### Characteristics and maximum power point

![Graph showing characteristics and maximum power point](https://www.researchgate.net/figure/284970252_fig2_Figure-2-The-four-PV-modules-used-in-the-test-and-close-up-views._0252_fig2_Figure-2-The-four-PV-modules-used-in-the-test-and-close-up-views.png)

The characteristics and maximum power point of the solar cell.

### Panel types

<table>
<thead>
<tr>
<th>Type of the cell</th>
<th>Technology</th>
<th>$\nu$ [%]</th>
<th>$V_{OC}$ [V]</th>
<th>$I_{SC}$ [A]</th>
<th>$P_{Max}$ [w/m$^2$]</th>
<th>$\Delta$ [\mu m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalline</td>
<td>Monocrystalline</td>
<td>24.7</td>
<td>0.5</td>
<td>0.8</td>
<td>63</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Polysilicon</td>
<td>20.3</td>
<td>0.615</td>
<td>8.35</td>
<td>211</td>
<td>200</td>
</tr>
<tr>
<td>Amorphous Silicon</td>
<td></td>
<td>11.1</td>
<td>0.63</td>
<td>0.089</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>Thin film cell</td>
<td>CdTe (Cadmium Tellennium)</td>
<td>16.5</td>
<td>0.86</td>
<td>0.029</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>CIGS (Copper Indium Gallium, Selenide)</td>
<td>19.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Multi-junction</td>
<td>Three layers</td>
<td>40.7</td>
<td>2.6</td>
<td>1.81</td>
<td>476</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>Four layers</td>
<td><strong>44.7</strong></td>
<td>4.16</td>
<td>0192</td>
<td>1000</td>
<td>-</td>
</tr>
</tbody>
</table>
Multi-junction photovoltaic cells

http://pubs.rsc.org/en/content/articlelanding/2013/cs/c2cs35288e/unauth#divAbstract

Multi junction cell

Solar power plants & concentrated ones

Forrestal Power plant position

Advantages:
- Robust
- Low temperature Phase Change Materials (liquids)
- Good efficiency (30-55%)
Landscape/architectural integration

Facades & Architecture

Section 1
Classic four-sided linear supported thermally insulating façade glazing system

Section 2
Structural sealant glazing without mechanical fixtures (ETAG Type IV)

Section 3
Window wall system with architectural fin providing shading and integration of photovoltaic modules, tilted to increase electricity yield and shading

Section 4
Unitized curtain wall with architectural framing providing façade structural interest and integration of photovoltaic capability

Mixed type of PV panels & Geometry & Architecture
Energy storage - Batteries

- Lead Acid 2.2V
- NiMH 1.2V
- Li-Ion 3.6V
- LiFePO₄ 3.0V

http://beckettenergy.com/why-lithium-ion-batteries/

http://pubs.rsc.org/en/content/articlelanding/2014/ee/c4ee01432d#!divAbstract

http://www.hybridcars.com/johnson-controls-to-research-lithium-ion-battery-packs-cooling/
Energy Storage - Ultra-Capacitors

Ultra capacitors types:
- With aqueous electrolyte 0.8-1V
- With organic electrolyte 2.7V
- Pseudo-capacitors 3.5-4V

Ultra capacitors features:
- Very high cycle-ability >500,000 cycles
- Extended temperature range in comparison with batteries
- Very high power density

http://berc.berkeley.edu/storage-wars-batteries-vs-supercapacitors/
Home automation evolution

- Remote acting
- Ubiquitous (everywhere & every time)
- Integrated and self aggregated
- React in real time
- Self healing systems
- Intelligent acting
  - To be able to auto-zoom the and to focus to the principal, on essential events that could appear into the system
  - To be able to monitor, collect, classify, memorize, utilize and dynamically adapt their strategies as “opportunity” functions
- Self adaptable systems
- High availability, reliability and resilience
A typical home energy management system

- Distribution grid
- Advanced Metering Infrastructure (AMI)
- Local generators based on RES
- Interconnection elements & protections
- Local consumers
- Local server (scheduler for power devices)
- Communication lines

Local Network (power lines)
Definitions:

• **Smart Grids (EU):** Power network that efficiently integrates the behavior and the actions of all users interconnected – generators, consumers (loads), different participants into the grid in order to offer sustainable and reliable functioning.

• **Smart Grid Strategic Group (IEC):** A concept for modernization of power networks that integrate the energy and information technologies in any point of the network from generation to consumption.

- **Intelligent:**
  - Metering (Advanced Metering Infrastructure),
  - Controlling (SCADA, prevention of outages, self healing, optimization of power excursion, usage of smart storage systems, frequency monitoring),
  - Scheduling of power generation & consumption – profiling and acting in accordance with determined demand profile
  - Transmission of power
  - Distribution of power

- **Automatic reaction in case of exceptions that appear in functioning of the power network**
- **Awareness of consumer about energy consumption consequences**
- **Transforming of consumer in prosumer (producers & consumers of energy)**

A generic definition means to offer for every body the synergic mean to be more efficient in the govern of complex networks.

Fusion between:

- Power network and information networks (Energy & Information)
Trinomial model for the Smart Grid

- **Consumers**
  - Local consumer’s network
  - RES management
  - Smart appliances
  - Building Energy Manager
  - Smart metering

- **Electric Energy Producers**
  - Operational network
    - Power plant automation
    - Generation & Load Balancing
    - Station Sub-Station automations
    - Feeder automation and monitoring

- **Electric Energy Traders**
  - Commercial network:
    - TSO Transmission System Operator
    - DSO Distribution System Operator
    - Automated billing system
    - Dynamic tariff applicable for *prosumers*
    - Market place interaction

- **Gateway**
  - AMI (Advance Metering Infrastructure)
Role of **Storage Facilities** used on Smart Grids

- **Energy consumption vs PV production**

- **Energy consumption breakdown by source (self sufficiency)**
  - 26% consumed directly from PV
  - 35% consumed directly from the battery
  - 39% bought from the grid
  - 61% self sufficiency

- **PV production breakdown by destination (auto consumption)**
  - 17% energy directly consumed
  - 23% energy stored
  - 4% energy lost
  - 56% energy sold to the grid
  - 40% PV auto consumption PV+Battery

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ENGIE The Battery Revolution is the future now? Nov2015 London
Smart home, smart electric cars, future of RES technologies

- Running with 0 $ daily
- 0 gas greenhouse emissions when is charged from a RES
- High dynamic performances
- Admit distribution power balancing services

75 kWh or 90 kWh microprocessor controlled, lithium-ion battery
Range more than 260 miles

Dynamic performances:
2.6 sec from 0 to 63 miles/hours
1088HP / 1600Nm
222 miles/hour maximum speed
Intelligent and autonomous sensors

“Mote” systems

Mica 2 “smart dust” sensor

Structure & Functionality of sensors:
- Sensors;
- Processors;
- Energy sources

Topology of the networks:
- Mesh
- Star

Support for design and operating
- Operating systems - TinyOS
- Energetic autonomy
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Motivation

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Civil Engineering and Construction Management
GSU
Thermal Comfort

• A complex problem: 6 major factors (environmental & personal)

• Our goal is to improve building energy efficiency:
  • Pre-construction (design phase) - through simulation of 3D thermal maps.
  • Post-construction - through data collection and visualization of thermal data
Building Owners

- who would like to discover potential issues with the degradation of the building insulation, building envelopes or building enclosures
- address these issues to improve on future designs

R-Value is KEY...
• **Energy Audits** are already required in **EU** (achieve energy savings of 20% or more, by 2020). Specific measures and policies are to be implemented to ensure major energy savings for consumers and industry companies (Implementing the Strategic Energy Technology Plan – the EU’s strategy to **accelerate the development and deployment of low carbon technologies such as solar power, smart grids, and carbon capture and storage**)

• Savings through other means such as **improving the efficiency of heating systems**, **installing double-glazed windows** or **foam-insulating roofs**

• Also, the **public sector in European countries** should purchase energy efficient buildings, products and services every year, European governments will carry out energy efficient renovations on at least 3% of the buildings they own and occupy by floor area, empowering energy consumers to better manage consumption

• In **United States**, only level 3 energy audits by **ASHRAE** involves 3D computer models which would create simulations of real buildings. Combining this process with construction-grade cost estimating enables to support informed investment decisions.

• These audits require access to energy consumption and cost data analysis for a duration of up to 3 years. Once the analysis is performed, recommendations can be made as to which improvements/upgrades are appropriate for the investment type required by a funding agency

[https://ec.europa.eu/energy/en/topics/energy-strategy/2020-energy-strategy]
Building Thermal Performance (Contractors)

- thermal performance over a period of time through simulation of real-time energy usage may uncover important aspects of inefficient design (Dynamic Whole Building Energy Simulation - Green Building Studio uses the DOE 2.2 dynamic thermal whole building energy simulation engine to estimate building energy use and operating costs)

- Design considerations may be taken into account during early planning

- Cost-benefit evaluations can be made for houses in order to utilize an efficient energy plan over the life span of the construction or for retrofit of an existing equipment/material assembly
Thermal comfort simulations (Facility mgmt.)

- Thermal comfort is additionally important to be addressed for all human inhabitants through
  - understanding how communication between
    - volumes,
    - interior-exterior environment &
    - people

may be visualized with energy simulations!

Low and high humidity in a psychometric chart
Sensor-based and X3D thermal maps

- All building modeling visualization/simulations rely on proprietary visualization tools, available on the market for a fee (usually $$$)
- Our implementation (X3D) → not bound to a specific visualization tool, the user if free to choose any X3D player implementation solution
- As X3D is an open international standard, many X3D player implementations are available and can be customized to fit the specific user’s needs
Hardware/Software Implementation

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Computer Science and Information Technology
ASU
Sensor System Components – Block Diagram

Features:
- Standardized
- Versatile
- Very low power

*Wireless transceiver*

Bluetooth Low Energy v4.0, Wi-Fi or Zig-Bee

*Central Unit Processor*

AVR 8 bit processor

*Transducer*

Temperature & Humidity Sensor

*Non standard Sensor*

Analog or Digital Interface

*Sensor System Components*
Firmware and integration

Power on setup
- Initialize processor ports
- Initialize sensor & its interface
- Initialize transceiver

Integration into the network
- Settlement of sensor address
- Settlement of sensor parameters

Data Acquisition
- Wake-up
- Acquire data
- Memorize data acquired
- Power Management & wait

Firmware components

Wait data acquisition from server

Integration into the network
Applications – Embedded & Network

- Network controller
- Sensors server

Data acquisition cycle controlled by the CPU timer

- Wake-up
- Wait
- Acquire
- Memorize
- Sleep

Network DAQ

- Wake-up
- Receive command
- Pick-up data acquired
- Transmit data
- Sleep

Data transfer
X3D Data Representation

Semi-transparent walls

Scaling to Large Commercial Buildings

Results that are representative of the actual interior physics assuming a laminar air-flow, non-turbulent steady-state condition of airflow
Validation

• Validation method for the simulation system using infrared (IR) thermography with a thermal imaging camera
  • Mockup X3D model
  • Sensor data simulated through dynamic arrays

• Automatic validation through image analysis – under development.
Conclusions

- **Renewable Energy Sources**
  - clean energy systems,
  - protecting people, nature and environment.

- The smart grids enabling smart buildings hence smart cities are modern technologies resulting in:
  - Optimized solutions to people and industry needs,
  - Environment protection, hence **SUSTAINABILITY**

- Even if technologies are very diverse, nowadays their maturity facilitates scalability and performance.

- Future developments must treat these applications in their whole complexity and integrality

- The **MULTIDISCIPLINARY** approach is fundamental to these developments.
Thank you

For more info:

http://FelixLup.net