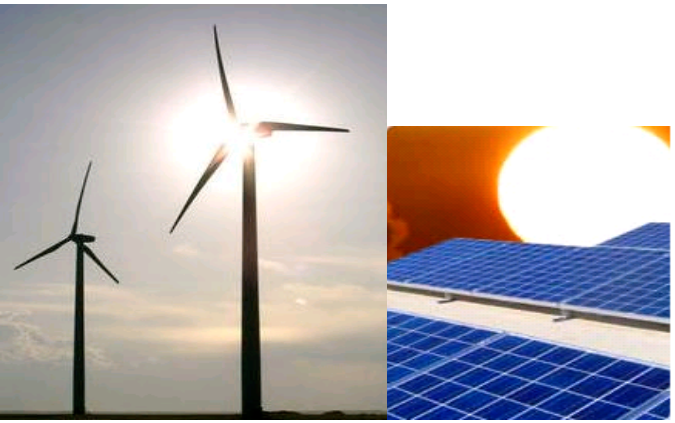
Control of Renewable Integrated Systems Targeting Advanced Landmarks (CRISTAL)

2 years: Dec.'07-Dec'09

Coordination Action - *project overview*



Presented by Consortium Coordinator:

Professor Marcian Cirstea,

Head of Computing & Technology Department

Anglia Ruskin University, Cambridge, UK

19 June 2009

CleanPower 2009, Murray Edwards College, New Hall, University of Cambridge

6th FRAMEWORK PROGRAMME - PRIORITY 6. SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS

Sub-priority: 1. Sustainable Energy Systems

(i) Research activities having an impact in the short and medium term

- *Section 6.1.3.1.1.2:* Large scale integration of renewable energy sources and energy efficiency;
- *Specific programme:* Integrating and Strengthening the European Research Area;
- *Activity code:* SUSTDEV-2005-1.1.7-1 **Grid Issues – *Distributed Electricity Generation***

- **Participants:**

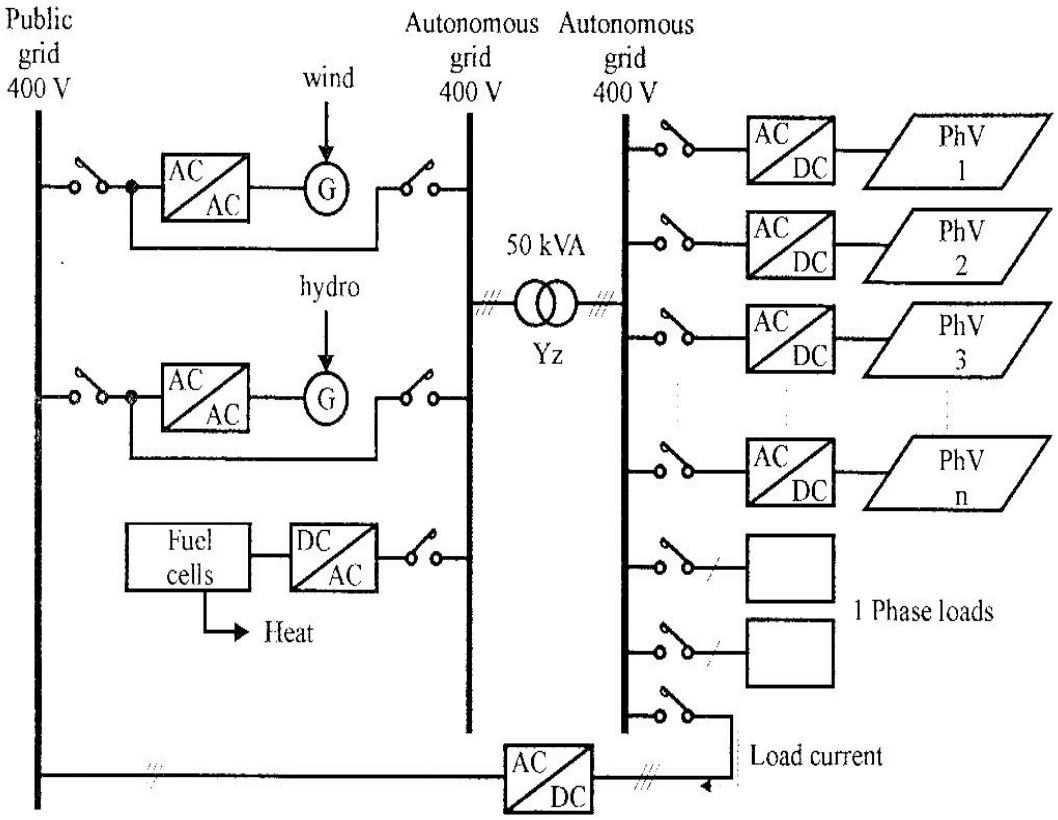
1. **ARU - Anglia Ruskin University, UK - coordinator**
2. **AAU - Aalborg University, Denmark**
3. **PUT - Politecnico di Torino, Italy**
4. **ENV - Environment Park S.P.A., Italy**
5. **TUB - Transilvania University of Brasov, Romania**
6. **WUT - Warsaw University of Technology, Poland**
7. **UPB - University Politehnica Bucharest, Romania**
8. **TEI - Technological & Educational Institute of Patra, Greece**
9. **NAS - Cummins Generators Technology, UK**
10. **STS - Sustainable Technology Solutions, UK**
11. **DIT - Dublin Institute of Technology, Ireland**

- **Associated Third Parties:**
  - **West Beacon Farm, Napantan, Loghborough, UK – Prof. Tony Marmont**
  - **Bryte Energy Ltd., Loughborough, UK – Dr. Rupert Gammon**
  - **E.ON, Nottingham, UK – Dr. Richard Hair**
  - **Institute of Hydroelectric Studies and Design, Bucharest, Romania – Dr. Florica Popa**

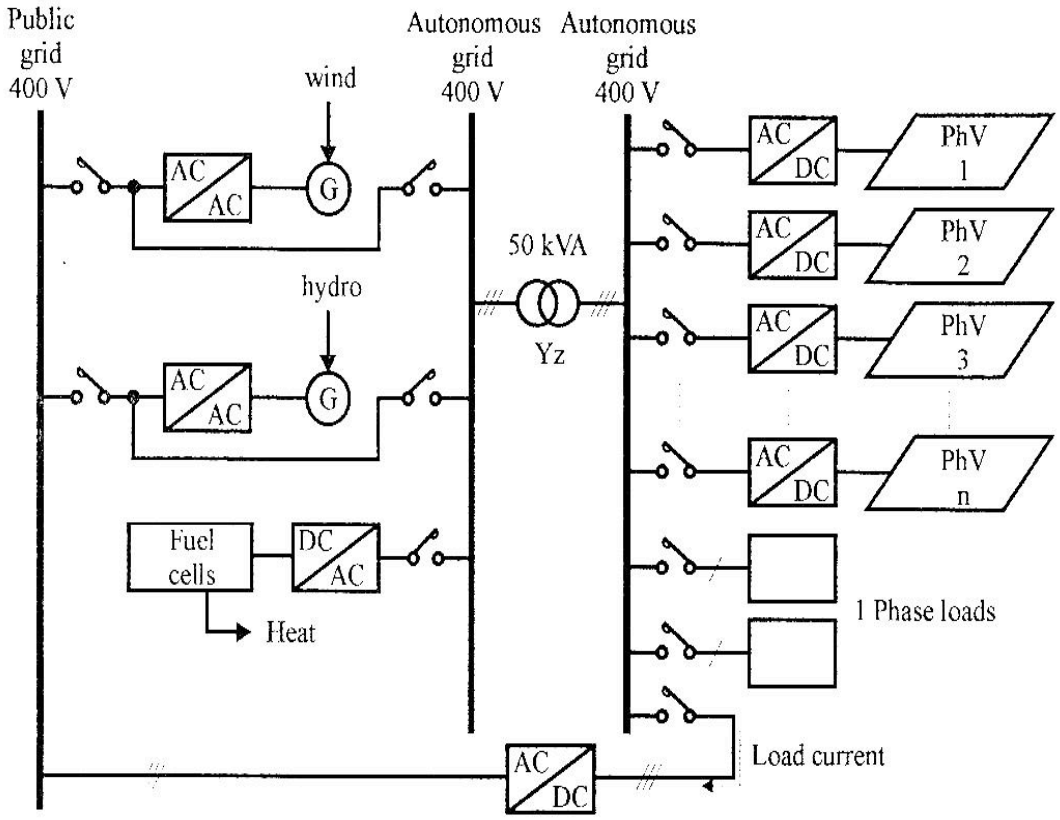
Project aims to contribute to the integration and strengthening of European research on Renewable Energy Sources, associated power converters and controllers

- Objectives:
- coordination of the DER modelling, simulation and system integration work, identification of controllers enabling high efficiency operation and solutions to grid connection issues.
- exchange of expertise through visits, longer studies, meetings, conferences
- technical issues: concerned with solar, wind and micro-hydro systems control in conjunction with energy storage systems (fuel cells, hydrogen) and / or connection to the grid
- development of key enabling technologies for distributed / smart energy networks, with high **power quality and service security**
- securing a leading role for Europe in sustainable energy systems, Distributed Energy Resources (DER), energy storage technologies, grid connection
- Expected benefits include:
- increased awareness & enhanced knowledge on sustainable energy systems for participants / general public
- correlated European research in DER
- identification of niche areas for further coordinated research, to comply with EC/national policies.

Sample targeted system topology



Sample targeted system topology



CRISTAL Activities

- Setup of a website : http://www.anglia.ac.uk/cristal Dec.'07.
- Submission of 8 conference papers for IEEE OPTIM Conference. Target exceeded, 16 papers submitted. Jan'07.
- One special session on Renewable Energy and Sustainability at IEEE OPTIM Conference. May 2008
- 1st set of 4 visits: correlating existing research on Distributed Renewables, summarising solutions. June 2008
- 2 longer duration (2 months) study visits July 2008 – Dec. 2008
- A first general meeting December 2008, Cambridge.

➢2nd set of 4 visits: critically analysing existing models / systems, proposing solutions to improve operation, efficiency, stability and holistic control. *May / June 2009.*

➢One local public event organised by each consortium partner, to raise awareness on renewable energy. *July / August 2009.*

➢A general conclusive meeting, *Patras. November / December 2009.*

Workpackage titles / subject areas:

- **WP 1 Control of Power Converters for Renewables**
- **WP 2 Microhydro and Photovoltaics**
- **WP 3 Wind Energy Systems**
- **WP 4 Energy Storage, Fuel Cells, Hydrogen Technology**

Some research work of partners

- **ARU:** Holistic modelling of distributed energy systems, modelled in Matlab and Handel-C, include: PV, Wind, Fuel-Cells and digital controln.
- **AAU:** Optimised high efficiency topologies for PV inverters and wind turbine applications and their connection to the grid (Simulink, PSIM). Increased reliability/ efficiency, reduced volume/weight, stability analysis.
- **PUT:** Inverters with power quality control, DC-DC and DC-AC converters. Grid interfacing or islanding. Fuel Cell systems modelled using simulators (dSPACE, RTLAB). Inverters to control variable frequency AC generators (hydro turbines) and grid connection.
- **TUB:** Stand alone microgrids with microhydro generators and wind generators in parallel; power quality focus. Topologies: electronic dump load (DL) plus electronic voltage control by synchronous generator. Matlab-Simulink for simulation; implementation using dSPACE.
- **WUT:** Power converters with high performance DSP and FPGA controllers. Active rectifiers reducing PM generator torque pulsations. Sensorless control of stand alone double fed induction generator for high quality power. 4-wire systems and their control for unbalanced load supply in autonomous operation. Variable speed wind energy controllers. Hybrid wind-diesel power system with optional energy storage.
- **TEI:** PV cell parameters evaluation under various solar radiation conditions. Hybrid PV systems: + Wind, + Hydro and + irrigation. Refrigeration & Air Conditioning powered by PV or using solar thermal absorption chillers. Intelligent Energy Buildings.

Workpackage 1 in Aalborg, Denmark
Workpackage 2 in Patras, Greece

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Some research work of partners (cont.)

- **UPB:** Optimal operation of Small Hydro Plants by variable speed operation (Francis turbines). Electrical speed control using 4 quadrant inverters. Same system to operate both as turbine-generator or motor-pump.
- **NAS**: Use of a conventional wound rotor synchronous machine for wind energy. Wind energy tailoring of electrical machine design. Magnetic gearboxes in renewables.
- **ENV**: Hydrogen Production, Storage & Applications. Testing laboratory for components and systems of hydrogen chain. Green Building Lab - design of 3 of most interesting Italian green building projects: 1) Environment Park service center, 2) Photovoltaic Totem, 3) Hydro-electric power station.
- **STS:** Hybrid Power Generation Systems (Wind, Anaerobic Digestion, Gasification). Grid connection of multiple generators and weak grid issues. Autonomous operation of systems and issues of local grid stabilisation. Development of a WT simulator – motor driven generator. Grid Capacity study. Integrating small scale fuel cell power system onto a micro grid – operation & potential issues.
- **DIT**: Unified Power Quality Conditioner (UPQC). Performance of Wind Generator connected to the network with the phase unbalance. High levels of wind generation integration into transmission network. Improvement of phase unbalance with DFIG connected. Quantify benefits of considering probabilistic nature of both loads and wind energy in enhancing transmission network access.

Workpackage 3 in Warsaw, Poland
Workpackage 1 in Turin, Italy

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Future ideas/research needs identified

- Hardware-software co-design, for system-on-chip holistic control solutions and grid synchronisation
- Grid-connection of 1-phase inverters without grid transformer: DC current injection is main problem
- Supercapacitors as battery replacement for start-up / power peak shaving buffers
- SCADA systems for smart networks using microgrids.
- Replacing lead-acid-jelly batteries by Vanadium Redox Batteries (VRB);
- Replace batteries by fuel cell power generator units
- Consideration of an EU set of requirements for stand-alone renewable supply
- Using fuel cells & hydrogen storage for load clipping
- Hybridisation: wind energy systems with: diesel, hydro, PV, storage systems
- Improved control strategies - wind turbine converters with grid support functions: system voltage control, quality/unbalance/harmonic compensation, cluster control
- Grid low voltage fault ride-through with synchronous generator
- Microgrid cooperation of 2 + power sources, where each can control common network voltage

Concluding remarks on CRISTAL

- Good general progress, producing all deliverables for year 1, even some from year 2
- OPTIM papers outcome was exceeded, with more collaborative papers than planned
- Consortium partners have collaborated well, beyond the frame of the CRISTAL project (e.g IEEE ISIE'08 conference)
- Year 1 was more about presentation of existing activities
- Year 2 focused on critical analysis and identifying solutions, closer related to the WP objectives
- Good year 2 activity so far, expected to achieve all project objectives + creating a renewables expert group.

THANK YOU !