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OUTLINE

- Process Systems Design and Implementation (PSDI) Laboratory

- Renewable Hydrogen & Renewable Power generation
  - Design and Optimization of multi-generation Stations (power generation systems, renewable energy systems)
  - Energy Management of autonomous or grid connected multi-generation energy production and storage stations

- Power and Hydrogen infrastructures - production and distribution
  - Systematic design and integration - Integrated supply chain network
  - Smart and resilient operation based on Industrial Internet of Things (IIoT) architecture
Process Systems Design and Implementation (PSDI) Laboratory

Established in 2009

Design and Construction of complex process systems – Industrial Automation

Energy and Fuels Production from Renewable Energy Sources

Chemical co-production Reactors in solid electrolyte fuel cells

Advanced methods for Process Optimization & Control

System Integration – Energy & Resources Management Solutions

**Mission**

PSDI laboratory has developed state-of-the-art technology in the areas:

- Modeling and design optimization of complex systems
- Energy management of autonomous power and hydrogen production stations
- Model predictive control for process systems
- System integration through advanced optimization techniques
- Supervisory control and data acquisition systems for industrial processes
Small scale hybrid systems

- Design and development of automated hybrid systems for vehicular applications
- Battery management systems (BMS)
- Backup power systems (fuel cell enabled)

Power Generation RES integration (PV, Wind)

- Analysis, design and construction of autonomous power generation stations using multiple renewable sources
- Optimum and efficient Energy Management Strategies (EMS)
- Development of remote monitoring applications for unattended long term operation
- Dynamic decision making for long-term sustainability

Renewable Hydrogen

- Implementation of hydrogen stations (from design to commissioning stage)
- Hydrogen production station through water electrolysis:
  - long-term hydrogen storage
  - with on site water purification

Smart-grid Systems

- Design, deployment and operation of isolated or grid connected microgrids
- Manage electricity demand in a reliable and economic manner
- Develop Control methods to optimize the distribution of energy
- Deploy flexible ICT infrastructures:
  - Performance monitoring
  - Remote management
  - On demand data reporting
  - Condition based maintenance
Renewable Hydrogen & Power generation

Motivation & Usage of Hydrogen as Energy Carrier

Renewable Hydrogen lays the ground for a Sustainable Energy Economy
- as an environmentally friendly alternative to fossil fuel, hydrogen can be a cost-effective, zero-emission energy solution
- provide a solution to the intermittency of solar energy

Advantages of Hydrogen

Clean: Causes no pollution when used in Fuel Cells for power generation
Distributed production: Hydrogen production is not restricted to certain regions or limited deposits, ensuring constant supply
Efficient and Versatile: Can be generated with any primary energy source

Usage of Hydrogen
- Fuel cell systems (stationary, mobile and portable)
- Energy Carrier (storing energy during off-peak hours in electricity grids)
- For stabilizing wind and solar energy systems
Renewable Hydrogen & Power generation

Hydrogen production methods
- Steam reforming from hydrocarbons
- Natural gas reforming
- Water electrolysis using Renewable Energy Sources

Sustainable & Renewable
Efficient storage
On-site production

Hydrogen is the cleanest fuel available when renewable energy sources (RES) are used for the water electrolysis

Applications
- Off grid locations where the transportation of fuels is difficult
- Refueling at small islands for submarines
- Fixed or mobile camps with fuel cell enabled portable devices, vehicles, power generation stationary systems

Design of Hydrogen Stations – Challenges
- Integration of heterogeneous subsystems
- Selection of proper automation infrastructure for optimum device handling
- Consideration of numerous alternatives for subsystems interconnection
- Large variability in the behavior of renewable energy sources
Renewable Hydrogen & Power generation

Autonomous Solar-Hydrogen Station at CERTH

Main features
- Supervisory Control & Unattended Operation
- Remote On-line Monitoring
- Industrial grade automation system & safety handling
- Smart microgrid controls the electricity flow
- Adjustable operation according to weather conditions

Model-based Optimal Operation Framework

Results (monthly)
- El/zer Operation: 6hrs/day
- Produced H₂: 300Nm³
- Efficiency of H₂: 72%

The station was designed & constructed by PSDI lab.
Operation since April 2012
Renewable Hydrogen & Power generation

Multi-generation Station at SUNLIGHT Systems SA

Design goals
• Optimum decision making
• Interoperability, extensibility & automated operation
• Integration of heterogeneous subsystems
• Translation of field data & device data into OPC based format due to homogeneity reasons

Operation Features & Capabilities
• Flexible load demand fulfillment
• Multi-source energy production
• Hydrogen long term storage
• Autonomous & Unattended operation

Control architecture - Centralized SCADA
• Collects, processes, distributes real-time data
• Implement automated algorithms
• Power Management Strategies

User can control the subsystems and make changes on key variables, such as power supply of the PEM electrolyzer & current drawn from the PEM fuel cell

The station was designed & constructed by PSDI lab. Operation since May 2008
Renewable Hydrogen & Power generation

Energy Management & Control of production

The operation of the stations depends on the developed Energy Management Strategy (EMS) that dictates the operational decisions for each subsystem.

**Objectives**
- Efficient hydrogen production
- Full utilization of the available renewable energy
- Protect the lifetime of the subsystems
- Smooth response for involved subsystems

**Requirements**
- Flexible demand-response methods
- Complex and dynamic decision making
- Multi-level design & operating decisions

**Operation Framework – Deployed Solutions**

- **Supervisory Level**
  - EMS
  - START/STOP System

- **Operational Level**
  - Wait for Conditions
  - Enable/Disable Devices
  - Equipment specific Algorithms
  - Appropriate device handling

- **I/O Field**
  - Actuators
  - Sensors

**Supervisory Interfaces**

- **Supervisory Operation**
  - Select AUTO ON
  - Battery Voltage

- **Fuel Cell & Electrolyzer**
  - EL Start

**Operation Framework – Deployed Solutions**

**Laboratory of Process Systems Design & Implementation (PSDI)**

**Sustainability in Defense (SfD)**

Athens, 10th - 11th June 2014
Renewable Hydrogen & Power generation

Multi-source RES Infrastructures & Integrated Solutions

- Scale appropriate systems (small-scale, pilot plant, autonomous stations)
- Model-based control and optimization for design and operation
- State of the art On-line Monitoring and Data Acquisition Systems
- Development of a novel and flexible Supervisory Algorithms

Long term performance evaluation of the hydrogen and renewable power stations

- Excellent integration of the various heterogeneous subsystems
- Superior performance based on the synergy of modular systems with innovative supervisory control techniques
From Hydrogen Infrastructures to Smart Power Networks

Challenges
• Disperse locations and Variability of power supply
• Environmental conditions (such as extreme temperatures)
• Operation with low noise and low heat consideration

Requirements and Specifications
• Security of supply, rerouting of energy based on dynamically evolving conditions
• Redundancy of the energy routes combined with backup reserves
• 24/7 Availability and minimum time between redistribution of energy
• Automatic decision support based on available resources
• Forecasting of demand at daily or long term basis
From Hydrogen Infrastructures to Smart Power Networks

**Smart Integrated Energy Networks**

Distributed energy generation networks:
1. Integration of distributed & variable renewable generation
2. Electricity and hydrogen storage
3. Redundant back-up power systems

Security of electric grid by applying
1. Dynamic Secure Enclave (DSE) strategy to Supervisory Control and Data Acquisition (SCADA) control systems
2. Smart Grid Technologies & applications
3. Secure micro-grid for sustained mission assurance and emergency support

**Proposed Solution**

**Strategic & Tactical Level**

- Optimum Design
- Supply Chain Networks

**Operational Level**

- Internet of Things (IoT) Architecture
- Optimum Operation

Smart Energy Infrastructures

Optimum Design → Supply Chain Networks → Smart Energy Infrastructures → Internet of Things (IoT) Architecture → Optimum Operation
From Hydrogen Infrastructures to Smart Power Networks

Infrastructure Design – Objectives & Solutions

- Modeling using Supply chain network (SCN) equivalent
- Optimization of the structure and its placement of the network
- Centralized Optimal Model-based Control System

Under an extreme disruptive event, the network must be:
- a. Resilient
- b. Robust
- c. Adaptable
- d. Flexible
Smart Integrated Energy Networks

- Optimum Design
- Supply Chain Networks
- Internet of Things (IoT) Architecture
- Optimum Operation

- Determine location, technology type and capacity for power generation
- Forecasting behavior
- Identify patterns of demand and supply
- Identify power load schedule under power generation disruption
- Model based optimization of the fuel/energy supply chain

- Energy Management Strategy
- Dynamic Routing of energy decisions
- Implementation considerations
- Online Performance monitoring
- Over usage warning and bottleneck alarming
- Advanced Control for network level decision making
- Selection of site specific technology for greater resiliency and flexibility
- Respond under disruptions and disturbances
Conclusions

✓ Hydrogen can be used as a sustainable and efficient energy carrier that can enhance the performance of traditional energy supply infrastructures

✓ Long-term hydrogen storage can be an alternative option to the distribution of energy and when combined with fuel cells it is sustainable and environmental solution

✓ A new model for distribution of energy based on renewable hydrogen and renewable energy sources is presented
  ➢ The supply chain network (SCN) modeling approach can provide the optimum choices for the design of smart grids
  ➢ An Industrial Internet of Things (IoT) architecture can increase the resiliency and flexibility of smart grids
  ➢ Dynamic rerouting of energy options can significantly improve the robustness and optimum use of the available resources
  ➢ Model-based control of an asset’s behavior (device, system, network) can deliver the maximum of its capabilities under a wide range of conditions

The synergy between the renewable poly-generation systems and innovative ICT architectures can result to a viable and sustainable solution for dynamically connected smart grids and stationary refueling hydrogen stations
We would like to thank

✓ our partners

✓ our financial contributors

✓ the personnel of CPERI
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