SECRETS – Sustainable Energy Clusters Realized Through Smart Grids
Summary of Presentation

- Framework
- Motivation
- Project Objectives
- Project Overview
- Project Results
Renewable Energy Law (Loi 13-09) and Energy Efficiency Law (Loi 47-09) in Morocco

Increase in share of energy production based on variable renewable resources located at distribution level

What will be the effects of this change?
Since PV generation is approaching grid parity, it is expected that the installation of PV panels will increase largely in the years to come.

Massive distributed PV generation over LV grid will create large operation problems to the grid, namely:

- overvoltages that will trigger PV protections
- deterioration of quality of service due to voltage oscillations
Experiences in other countries – the German case

“Germany’s transition to renewable energy has strained Europe’s largest economy to its limit, the economy minister said on Tuesday, as he outlined reforms to a subsidy scheme that costs business and consumers €24bn a year.”

“Since May 1, the German government has been supporting the purchase of solar storage systems by awarding grants of up to €660 per kilowatt (kW) of a solar system’s installed capacity.”

“(…) This helps the grids, as they no longer have to be designed to keep up with the maximum feed-in rates of solar systems. Fewer new power lines have to be laid and solar storage systems allow existing power grids to absorb up to two thirds more power (…)”

*in The Financial Times, January 21, 2014*
Framework

Foreseen problems for distribution networks

- **Charging rate**
- **Power**
- **Voltages**
- **Increase load**
- **ESS**
- **House A**
- **House B**

Framework diagram showing integration of energy storage systems (ESS) and distribution networks to manage loads and voltages.
CAISO Duck curve
How can we deal with this?

Developing a set of innovative tools to allow managing and controlling inverters (solar, wind, EV, storage, flexible loads) that will avoid:

- Curtailment of this distributed renewable based energy sources
- Significant investment in distributed storage associated to all micro generation units
- Significant investment in network reinforcement
How can we develop and validate these tools?

- *Simulation results have proven the benefit of integrated DER management but does not reflect real world issues*
- *Pilot demonstration are often limited because significant investment must be done to proof the concept*
Motivation

Solution?

To develop a Smartgrids laboratory that will allow:

- Evaluate the impact of integrating RES
- Develop advanced control functionalities for DER
- Develop prototypes for RES inverters
- Validate the developed tools in a scenario that mimic real world
- Validate tests with at scale perspective in mind
Motivation

- Under the IRESEN call for proposal INNO-PV, the concept of a sustainable district under the smart grid paradigm is being implemented.

- With an innovative approach, one would maximize the use of endogenous energy sources, minimizing the need to import electricity from distribution network.
Project Objectives

- To develop a specification for a smart grid environment, able to deal with cluster-optimization

- To implement a laboratory facility able to test the relevant concepts and to produce specifications that may be passed to the industry

- Creation of new products that will stimulate the economy by producing jobs and opportunities

- Extend the concept and knowledge acquired to support the implementation of real pilots (the construction site of green city for example... )
Project overview

- **Budget Global**: 5 151 700,00 MAD
- **Financed by IRESEN**: 4 407 611,00 MAD
## Project Overview - Consortium

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<thead>
<tr>
<th>Partenaire Universitaire 1</th>
<th>ECOLE NATIONALE DES SCIENCES APPLIQUÉES KENITRA</th>
<th>With expertise in power systems and intelligent systems</th>
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<td>INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORESTEC - INESC TECNOLOGIA E CIÊNCIA</td>
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<td>UNIVERSITY OF HOUSTON</td>
<td>With expertise in networking application in smart grid and smart buildings</td>
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<td>Partenaire Industriel 1</td>
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<td>With expertise in defining the requirements for green city development in Morocco</td>
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<td>Partenaire Industriel 2</td>
<td>AGT MAROC</td>
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New collaborators in the project

- **University of Washington, Smart Energy Lab,**

- **Florida International University: Energy Systems Research Laboratory**

- **The University of Manchester: Electrical Energy and Power Systems Group.**

- **Aalborg University, Danemark: Department of Energy Technology Power Electronic Systems**

- **Smart Technology Group, USA**
The SECRETS project involves then two major developments:

- A set of functionalities, materialized in hardware and software, that will allow a higher integration of distributed energy resources
- A laboratory infrastructure that will allow validating these functionalities and constitute a test bed for future developments in Morocco

The different functionalities are organized under a hierarchical decentralized control structure that goes from household to the district or cluster level.

The idea is that different control capabilities are necessary for the different layers of the distribution network.
The system is divided in four main levels:

- **Local control**, responsible for controlling local resources such as loads, microgeneration and distributed storage as well as frequency and voltage control strategies.

- **Smart metering infrastructure**, working as a gateway between the local controllers and the microgrid central controller.

- **Microgrid central controller** concentrates the high level decision making for the technical and economic management of the MG, being responsible for coordinating all the Microgrid resources and ensures the interface with the higher control layers of the distribution system.

- **Cluster controller**, which is responsible for managing and coordinating a group of microgrids.
Laboratory functional scheme
Project Overview

The four main levels can be depicted in the figure.
Cluster Controller functionalities

• **This module is responsible for managing the energy cluster, based on the information received from the Microgrid controllers and from the smart metering equipment**

• **During normal interconnected mode the main objective should be to coordinate the operation of the microgrids in order to optimize the operation of the energy cluster, maintaining a balanced net zero-electric energy**

• **The following advanced functionalities incorporated at this level are:**
  
  - Renewable generation and load forecasting to provide the forecasts for the next hours or day of renewable based generation, namely wind and photovoltaic and for loads
  - Cluster energy management, based on the results of the forecasting algorithms will define the best strategy for the coordinated operation of the several microgrids connected downstream
The outputs of these platforms provide valuable information for the technical management of the energy districts and for the MG.

These are the results of the solar forecast model, but models were developed for wind and load.

The Root Mean Square Error and Mean Average error are low for the next 6 hours (below 10%), increasing for the day ahead.

These results were obtained and validated using a metering station in Portugal.
Cluster Controller functionalities – Energy Management

• The Cluster energy management tool will define the best strategy for the coordinated operation of the several microgrids connected downstream, based on the results of the forecasting algorithms.

• The optimization tool to be developed should be able to combine the maximization of DG and avoid technical problems, namely overvoltage or even congestion problems.

• The tool provides an optimal day-ahead scheduling in a distribution network, in order to minimize an objective function that may comprise several objectives beyond voltage regulation (losses, tap wear, overall power factor etc.).
For this purpose, the approach is to determine an optimal dispatch schedule over a suitable time period, rather than for a single dispatch period.

An example of result with loss reduction in the same network using the functionality.

This simulation is for a whole year and the forecast was received twice a day.

The total annual energy losses are 1348 MWh (2.92% of annual load demand) and 601 MWh (1.3% of annual load demand) for the baseline and optimal control scenario.
The MicroGrid (MG) is divided in two main layers constituted by the MG central controller (MGCC) and the local controllers:

- The MGCC is responsible for monitoring, control and managing the MG and incorporates high level algorithms to coordinate all the resources.

- The short-term balancing tools such as primary frequency and voltage regulation, and load shedding schemes were implemented at the local controllers, since they are expected to act in a very short time-frame.

- This approach is then complementary and guarantees that unexpected phenomena and other disturbances can be solved even if there is no communication.
The main objective of the DER active management tool is to manage the generation and consumption levels in LV grids in order to respect the technical constraints imposed by the cluster controller.

When potential grid constraints are detected the module will define a set of control actions considering the resources connected at the LV networks.

Four different types of controllers are considered, namely distributed storage units, distributed generation (DG) and controllable loads.

The control methodology proposed here follows a merit order of actuation of the controllable grid assets based on the objectives for the power system exploration, namely cost minimization and effective integration of distributed energy resources (DER).
MicroGrid Controller functionalities – DER Management

• Storage will be first considered for solving technical problems due to the high flexibility of this type of resource

• Load and distributed generation power limitation will only be considered as a last resource, in order to minimize renewable generation curtailment and minimize consumers’ discomfort.

• The outputs of this module are set-points of operation for different grid equipment, in the form of active power set-points to loads, DG units or storage devices

• The Centralized control, implemented at the level of the secondary substation and incorporated in the DTC (Distribution Transformer Controller) that represents the MGCC
This central controller can surveil the different resources using the Smart Meter Infrastructure available in the SECRETS Lab.

The advantage of this control is that it is implemented in a real smart metering solution, using existing communication capabilities (GPRS or PLC Prime).
This setup that was put together to validate the central control
Overvoltages due to solar power production

Storage device received a set point to increase absorbed power
The microgeneration inverters prototypes provide a local control, in terms of its active and reactive power to provide local support.

This capacity is based on a configurable droop controller that defines the response of the inverters both to voltage or frequency variation.
A test procedure was implemented

Status of the different distributed resources

Voltage at the different LV phases
Thank you!

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