PV Grid integration and the need for Demand Side Management (DSM)

Mr. Nikolas Philippou
FOSS / UCY
Motivation for enabling DSM

- High PV penetration may lead to stability and reliability problems

Source - EPRI: The integrated grid
Demand Side Management (DSM)

- Two main programs
  - Demand response programs/load shifting
  - Conservation and energy efficiency

- Outcomes:
  - Reduction on the customers’ electricity bill
  - Decrease the operation and maintenance costs
  - Decrease carbon footprint and making the whole network more reliable and secure

- Objective:
  - Flatten the electricity profile demand
  - Direct use of available energy from RES

Energy to grid/ESS/PHEV
Demand Side Management (DSM)

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Pilot site – enabling Demand Response

- 300 prosumers participate
- Price-based DSM
  - Time-Of-Use pricing (TOU)
- Information send to end users:
  - In-House Displays (IHD)
  - Web application
  - Electricity bill

Smart Meters

- Able to enable price-based DSM (tariff registers)
- Data-sets acquired PV production and household consumption profiles
- Monitoring through IHDs and web applications
DSM: Dynamic tariff tool

ToU blocks
- Two step method:
  - Statistical step
  - Optimization step

ToU tariffs
- Optimization
- Neutral cost effect
Results – Correlation rates

- The participants' load profile was correlated with the average consumption profile as provided by the EAC.

<table>
<thead>
<tr>
<th>Period</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>96.41%</td>
</tr>
<tr>
<td>Middle</td>
<td>96.28%</td>
</tr>
<tr>
<td>Winter</td>
<td>92.56%</td>
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</table>
Results – seasonal profiles and ToU

- Seasonal average profiles from the SmartPV sample and the corresponding charge based on the ToU tariffs

**ToU tariffs provisionally approved by CERA**

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Price (€cents/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak</td>
<td>18,85</td>
</tr>
<tr>
<td>Shoulder</td>
<td>14,85</td>
</tr>
<tr>
<td>Off-peak</td>
<td>10,85</td>
</tr>
</tbody>
</table>

Winter
Conclusions

- Need DSM for higher PV penetration
- Develop ToU tariffs in an attempt to reduce consumption peaks
- Examine how energy behaviour alters under different forms of monitoring - information send to end users via:
  - IHDs
  - Web access
  - Bi-monthly mail bill
- Strong correlation rates between the selected sample and the domestic consumers ⇒ any behaviour change due to the application of the ToU tariffs can be extrapolated to a larger scale
- Derive new policies/schemes
Grid Integration of PVs and the need for forecasting

Mr. Ioannis Koumparou
FOSS / UCY
Motivation: PV Capacity in Cyprus

- Installed capacity of PV systems increasing rapidly
- Towards the 2020 goals

By 3/2016:
- 1900 FiT PV systems
- 8300 Net metering Systems

PVs are distributed throughout the island in various sizes

Great need to accurately forecast the PV energy production in advance
Characterisation & Classification of Daily Sky Conditions

Probability of Persistence, POP$_{day}$ (%)

Clearance Index, K$_{day}$ (%)

<table>
<thead>
<tr>
<th>Classes ( % occurrence)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
<tr>
<td>2011</td>
<td>45.75</td>
<td>1.1</td>
<td>1.64</td>
<td>30.41</td>
<td>11.78</td>
<td>1.64</td>
<td>2.74</td>
<td>4.93</td>
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<tr>
<td>2012</td>
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<td>2.19</td>
<td>0.55</td>
<td>22.68</td>
<td>14.48</td>
<td>2.19</td>
<td>3.83</td>
<td>4.92</td>
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<tr>
<td>2013</td>
<td>49.04</td>
<td>6.3</td>
<td>1.37</td>
<td>15.62</td>
<td>21.64</td>
<td>0.82</td>
<td>0.55</td>
<td>4.66</td>
<td>0</td>
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<tr>
<td>2014</td>
<td>47.12</td>
<td>1.64</td>
<td>1.64</td>
<td>30.68</td>
<td>13.42</td>
<td>0.82</td>
<td>2.19</td>
<td>2.47</td>
<td>0</td>
</tr>
<tr>
<td>2015</td>
<td>51.78</td>
<td>2.47</td>
<td>1.92</td>
<td>23.84</td>
<td>10.96</td>
<td>3.01</td>
<td>1.64</td>
<td>4.38</td>
<td>0</td>
</tr>
<tr>
<td>Average %</td>
<td>48.3</td>
<td>2.74</td>
<td>1.42</td>
<td>24.65</td>
<td>14.46</td>
<td>1.7</td>
<td>2.19</td>
<td>4.27</td>
<td>0</td>
</tr>
<tr>
<td>Average Days</td>
<td>176</td>
<td>10</td>
<td>5</td>
<td>90</td>
<td>54</td>
<td>6</td>
<td>8</td>
<td>16</td>
<td>0</td>
</tr>
</tbody>
</table>

87.41 %

320 days
Forecasting Tool: Development Phases

- Forecasting PV production
- Nowcasting PV production
- Real time PV production

- NWP
- Weather Data
- Smart Meter Data
- PV Capacity update
- Real PV production – Distribution SS

- Central DB

- Historical Timeseries data
- “Long term” prediction – Current day data
- Real time data

- Physical / Statistical approaches
- Statistical approaches
- Statistical approaches

- Day-ahead PV forecast
- Hour-ahead PV forecast
- Real time PV production

- Current phase
  - Day ahead predictions

- Deployed a network of 17 weather stations and 300 smart meters (100 for PV)
  - Used for the training of the expert system
Currently:
- Cyprus tessellated in 4 tiles
- 4 districts of Cyprus (Nicosia, Limassol, Larnaka, Paphos)
- Numerical Weather Predictions for each tile is acquired from the MSC

Assumptions
- PV systems are superpositioned
- All PV systems are polycrystalline
- Mounting is same for all systems

PV Forecasting tool is under continues development and upgrade
- Current Version (delivered to DSOC)
Forecasting tool for all PV Systems in Cyprus
- Accurate
- Easy to use by non experienced employees

Obstacles
- PV systems distributed throughout the island in various sizes, technologies and characteristics
- Limited information of the actual PV production in Cyprus is yet to be acquired
- Solar irradiance is intermittent in nature → Difficulty in predicting intra day fluctuations

Advantages
- Distributed nature of PV systems smoothen the effect of local solar fluctuations
- Infrastructure developed for monitoring the weather conditions and PV production
Grid integration of PVs and the need of storage

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PV Technology
PVs are a clean power source
Gaining popularity
Too much peak power injected into the grid
Battery Storage - Solution

- Smooth injected peak power
- Smart energy management and power flow
- Increase self-consumption
- Network stabilisation
Battery Storage – AC & DC Systems

In an AC-system the battery is separately connected to the household AC grid via an inverter and DC converter.

In a DC-system the battery is connected between the DC converter and the actual inverter.
Battery Storage – DC System

- + Fewer Components
- + More Efficient
- + Cheaper
- - Replace String Inverter to Battery Inverter
Battery Storage – AC System

- Easily fitted to existing installations
- Better expandability
- Need String Inverter + Battery Inverter
Battery Storage – Fronius System

Courtesy of Fronius
Battery Storage – Targets

- Modelling and Simulations
- Battery Technologies for a Hybrid System
- Smart Energy Management and Power Flow Algorithms
- Profit and Payback Period Estimation
Grid integration of Electric Vehicles

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University of Cyprus
PV Technology
1. Introduction

Why Electric Vehicles?

- Transportation takes over 20% of total CO₂ emissions
- Driving on electricity is less expensive per km compared to fossil fuel
- Reduce GHG emissions
- Storage capacity with huge management flexibility
- Balance the fluctuation of RES
- Ancillary services, voltage stability, and peak reduction
2. Challenges & Objectives

- **Challenges:**
  - Not enough grid capacity for high penetration levels
  - Fast charging may lead to overloads and disturbances
  - Potential increase in peak electrical demand
  - Very few recharge points

- **Objectives:**
  - Determine the impacts on the electric grid
  - Efficient management of EV charge
  - Combine EVs and RES
3. Charging Scenarios and Assumptions

Charging scenarios:
- Uncontrolled charging without considering the mobility curves.
- Uncontrolled charging considering mobility curves.
- Smart Charging (Off-peak periods).
- Smart Charging in a V2G configuration.

Assumptions:
- 50,000 EVs in Cyprus by 2030.
- 36 kWh Li-Ion battery.
- Recharge at a constant rate (SOC: 0 – 100%).
6. Off – peak EV charging using TOU tariffs

- Overlaps the peak hours of the original load → Stress of the electric power system
- During off-peak periods electricity rates are cheaper
- Maximise: \( LF = \frac{\text{Average Load [kW]}}{\text{Maximum Load [kW]}} \)