Distributed Generation and Renewables in Electricity Markets

Władysław Mielczarski, Błażej Olek, Michał Wierzbowski
Lodz University of Technology, Lodz, Poland

wladyslaw.mielczarski@p.lodz.pl
blazej.olek@p.lodz.pl
michal.wierzbowski@p.lodz.pl
• Project to provide support, as an Energy Expert, to Committee of Regions (European Parliament) in 2012/2013 to prepare the opinion on the document

• Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions – Brussels 6.6.2012, COM(2012) 271 Final

• Renewable Energy: a major player in the European energy market
Commission Communication

EUROPEAN COMMISSION

Brussels, 6.6.2012
COM(2012) 271 final


Renewable Energy: a major player in the European energy market
Committee of Regions accepted the opinion on 31 January 2013
Two case studies for Renewables in Middle and Low Voltage networks

Michał Wierzbowski, „Optimization of distribution electrical networks in the modern power systems”, PhD project completed in September 2013

Błażej Olek, „Optimization of energy balancing and Ancillary Services in low voltage networks”, PhD project completed in September 2013
Share of Renewables

• The share of renewables in the European energy consumption counts for 12.4% in year 2012. The consumption increased 1.9% from the level in 2008.

• The Commission indicates that ...current policy initiatives are not adequate to achieve our long-term energy and climate policy objectives, as the 2050 Roadmap suggests, renewable energy annual growth would slump from 6% to 1%.”

• It is also highlighted that “...a supportive policy framework will be needed to address remaining market or infrastructure inadequacies”.
RES and electricity markets

- The subsidies currently used for the RES separate renewables from the competitive energy market.
- Feed-in tariffs (including premium) and green certificates eliminate market risks sending incorrect economic signals to the investors.

**European Commission:**

Whatever form the *post 2020* renewable energy milestones take, they must ensure that renewable energy is part of the European energy market, with limited but effective support where necessary and substantial trade.
Reactions of the member states

• Spontaneous growth of RES has led to the significant increase of subsidy costs and technical problems in operation of power grids. In reaction, some Member States start the introduction of measures to limit the development of RES.

• Dynamic growth of RES is observed in Germany, but loop flows resulting from the excess of wind energy in Northern Germany, which cannot be accommodated in the German power systems, have negative impact on adjacent grids in Nederland, Belgium, Poland and the Czech Republic.

• To protect power systems against instability caused by loop flows these countries have been introducing phase shifting transformers in cross border lines separating, in practice, domestic grids from the internal electricity market.
Technical aspects of RES operation

• Most RES are connected to the distribution networks, which are not dedicated to accommodate energy from such unstable generation.

• Broad implementation of RES requires investments and time to refurbish distribution and transmission grids allowing for the operation within technical limits.

• Power generated by some RES such as wind farms or PV cells is volatile so energy storage is needed to allow for the stable network operation.

• New ideas to erect large wind farms in Northern Sea and install PV-cells clusters in Southern Europe and transport the energy generated by long direct current electricity highways to the main loads in the Central Europe should be realistically evaluated taking into account physical principles of power system operation.
Loop flows caused by RES -2011 and 2012

Source: THEMAs Consulting Group, based on data from 16 TSOs
Unscheduled power flows

Evolution of monthly averages values of Realised Schedules, Measured Load Flows and Unplanned Flows for the border between Germany and Poland
Joint study by ČEPS, MAVIR, PSE and SEPS regarding the issue of Unplanned flows in the CEE region (January 2013)
Recommendation for RES

• It seems that the current problems with RES development stem from uncoordinated policies relating to the RES support systems used by various Member States.

• The climate policy aims at ambitious goals leaving Member States the application of practical measures to achieve the RES production targets, in particular charges to cover RES subsidies, power grid development and the accommodation of RES in power grids and electricity markets.
A need for infrastructure

• The infrastructure development is critical for the success of the single market and for the integration of renewable energy.

• Three main methods of transforming the power systems by making the following improvements to its infrastructure include:
  • (a) investment in distribution grids;
  • (b) upgrades to transmission infrastructure;
  • (c) development of smart grids.
A new support scheme for renewables

- All existing support schemes separate renewables from competitive electricity market.
- Subsidies aim at the support of operation; less the investment.
- If Renewables are to reach 50% or more of the total electricity generation: can the competitive market operate in such circumstances?
- It essential to draw up and implement a simple support scheme for the RES development, which would be uniform throughout the European Union.
European support scheme for RES (1)

- Establish a pan-European fund to support RES;
- Harmonize RES support schemes at European level;
- Increase the role of the regions in allocating RES support;
- Optimize use of the RES technologies based on availability of renewable resources in the regions;
- Operate at two levels: European level for large installations and regional level for small installations and micro-sources;
European support scheme for RES (2)

- Grant subsidies for investment at a level enabling the full participation of RES in the competitive energy market;
- Support the development of electricity grids linked to the development of RES;
- Limit the negative impact of RES on the operation of grids through support for packages on RES and storage facilities;
- Share the costs of RES development fairly among the people of Europe by ensuring that Member States participate in the European RES support fund in proportion to their national income.
Ways for the effective RES operation

• Fully participate in competitive electricity markets with the same rules as other parties;
• Participate in capacity/power markets
• Provide Ancillary Services in particular in distributed network to improve quality of supply;
• Move from the first stage “Generate and forget” to the second more advances phase “Coexistence with the power networks”
Case study for Renewables in Middle Voltage network

Key Message

• Increase the penetration of RES and Distributed Generation in production of electric energy by the Local Balancing System in MV distribution network

• Such Balancing should be based on competitive market rules consistent in all levels: high, middle and low voltages.
Local Balancing in MV network

„System responsibilities” in DG production by implementation of Local Balancing performed by

Coordinating System Operator

1. ENERGY BALANCING
   • Local energy balancing and coordination of active and reactive power flows
   • Minimization of network operation costs
   • Minimization of power losses
   • Coordination of MV/LV nodes operation (Nodal Area Operator) – in Europe
     • By: Local Balancing Market with trade info, and balancing bids implementation

2. PRESERVING NETWORK PARAMETERS
   By Ancillary Services – reactive power compensation
Benchmark MV network
Optimization and Local Balancing

Target:
Optimization of the active and reactive power generation in the network taking into account power flows and losses (in 24h horizon)

Results:
Operating Schedule for units (24h)

Objective Function (nonlinear): Total welfare of the network operation including costs of generation

Optimised variables: P and Q of units with prices coming from balancing bids submitted at the LBM for P/Q generation/ consumption/ reduction (~700 of variables)

Constraints: network and units parameters, power quality such as voltages (~3000)
Simulation Scenarios

Scenario 1 – Reference scenario
Traditional solution - Demand is supplied by the external HV system

Scenario 2
Maximization of local generation (DG and RES) – produce and forget

Scenario 3
Maximize generation (DG and RES) preserving network technical standards – system responsibilities
<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Scenario</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
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<tbody>
<tr>
<td><strong>P for 24h</strong></td>
<td></td>
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<tr>
<td>Flow from HV system</td>
<td>MWh</td>
<td></td>
<td>755</td>
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<td><strong>Q for 24h</strong></td>
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<tr>
<td>Flow from HV system</td>
<td>MVArh</td>
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<td>254</td>
<td>227</td>
<td>163</td>
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<tr>
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<td>MVArh</td>
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<td>58</td>
<td>31</td>
<td>3</td>
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<td><strong>P for 1h</strong></td>
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<td></td>
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<tr>
<td>Peak flow from HV system</td>
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<td>32</td>
<td>34</td>
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<td>Minimum flow from HV system</td>
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<td>15</td>
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<td>Variation of flow from HV system</td>
<td>MWh-h</td>
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<td>25</td>
<td>19</td>
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<td><strong>Q for 1h</strong></td>
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<td>Peak flow from HV system</td>
<td>MVArh-h</td>
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<td>MVArh-h</td>
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<td><strong>Network parameters</strong></td>
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<td>Voltage constraints violation</td>
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<td>Average network usage</td>
<td>%</td>
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<td>49</td>
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<td>34</td>
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</table>
Conclusions 1

1. In order to increase the penetration of DG and RES it is necessary to replace of *produce and forget* approach by *system responsibilities* approach – *It can be achieved by the introduction of Local Balancing System.*

2. Optimal management of MV distribution networks including local energy balancing and coordination of power flows can be achieved by use of the constrained optimization methods.
Conclusions 2

3. Management of demand and energy production, at the various voltage levels, should be consistent in order to provide smooth operation between High, Middle and Low voltage systems.

4. Optimization of the MV distribution network management allows for:
   - Increase of DG and RES penetration without violation of technical standards
   - Reduction of power losses
   - Avoid the development of high voltage grids by better utilization of local energy resources.
Case study for Renewables in Middle Voltage networks

Key Message

• Increase the penetration of the DG and RES by introduction of Local Balancing in LV distribution networks.

• Improvement of supply quality by Ancillary Services provided by Renewable Sources and Distributed Generation.
Local Balancing in LV network

1. ENERGY BALANCING
   - Local energy balancing
   - Power flow coordination
   - Operation costs reduction
   - Power losses reduction
   - Cooperation of LV and MV networks

2. PRESERVING TECHNICAL STANDARDS OF SUPPLY
   Ancillary Services
   - Reactive power compensation
   - Asymmetry reduction
   - Harmonics reduction

Nodal Area Operator and its duties
Benchmark LV network
Optimization and Local Balancing

Target:
Optimization of DG power generation (including power losses reduction)

Optimal usage of Ancillary Services to preserve technical standards

Result:
Operating Schedule for units (24h)

Objective Function (nonlinear):
total welfare of the network operation (1440 variables)

Optimised variables:
- energy generation $P[kWh]$
- reactive power compensation $Q[kVArh]$
- operation asymmetry $A[\%]$
- distortion of voltage wave forms $H[\%]$ (THD)

Constraints:
- DG, AL and ES technical parameters,
- network congestions (lines capacity)
- and technical standards (voltage)

(4752 constraints)
Simulation Scenarios

Scenario 1 – Reference scenario
Local network demand is supplied by the external Middle Voltage system

Scenario 2
Maximization of local generation (DG and RES) – produce and forget

Scenario 3
Optimization of local generation (DG and RES) by Local Balancing System

Scenario 4
Optimization of o includes local generation (DG and RES) by Local Balancing System and use of Ancillary Services
## Results - Summary

### Results of scenarios 2-8

<table>
<thead>
<tr>
<th>FINAL SUMMARY</th>
<th>Reference scenario</th>
<th>Uncontrolled DG operation</th>
<th>Local Energy Balancing</th>
<th>Energy balancing and Ancillary Services</th>
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</thead>
<tbody>
<tr>
<td><strong>Energy balancing</strong></td>
<td></td>
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<tr>
<td>Import from external network</td>
<td>100%</td>
<td>0,1%</td>
<td>73%</td>
<td>72%</td>
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<tr>
<td></td>
<td>1303kWh</td>
<td>-74,1kWh</td>
<td>781,6kWh</td>
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<tr>
<td>Power losses</td>
<td>100%</td>
<td>67%</td>
<td>68%</td>
<td>44%</td>
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<tr>
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<td>60,2kWh</td>
<td>40,3kWh</td>
<td>40,9kWh</td>
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<tr>
<td>Reverse power flows</td>
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<td>NO</td>
<td>NO</td>
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<tr>
<td><strong>Reactive power</strong></td>
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<tr>
<td>Import of reactive power</td>
<td>100%</td>
<td>96%</td>
<td>98%</td>
<td>65%</td>
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<td>52,6kVarh</td>
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<td>51,6kVarh</td>
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<td>Reactive power losses</td>
<td>100%</td>
<td>50%</td>
<td>64%</td>
<td>41%</td>
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<td>25,4kVarh</td>
<td>32,5kVarh</td>
<td>20,8kVarh</td>
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<td><strong>Harmonics</strong></td>
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<tr>
<td>Maximum voltage THD</td>
<td>100%</td>
<td>97%</td>
<td>96%</td>
<td>59%</td>
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<td></td>
<td>11,1%</td>
<td>10,8%</td>
<td>10,7%</td>
<td>6,5%</td>
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<tr>
<td>Power losses caused by harmonics</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>37%</td>
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<td>19,1kVArh</td>
<td>19,1kVArh</td>
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<tr>
<td><strong>Summary</strong></td>
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<tr>
<td>Total violation of constraints</td>
<td>100%</td>
<td>92%</td>
<td>90%</td>
<td>11%</td>
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<td>Evaluation</td>
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</table>

N/A – not acceptable
LV networks - summary

1. Uncontrolled operation of DG and RES threatens reliability of supply

2. Management of local generation should be carried out according to legal and market rules

3. Introduction of the balancing mechanism proposed allows for:
   • reduction operation costs
   • Improvement of supply reliability
   • reduction of supply from external feeding network
   • Increase the energy production from DG and RES

4. Proposed system of Ancillary Services provided by RES and DG allows for preserving technical standards.
Further development of Distributed Generation and RES is limited by the separation from competitive electricity market rules and network operation.

Sooner or later RES and DG have to be a part of electricity markets with the responsibilities for their impact on the network operation.

The initial research indicates that RES and DG can operate in electricity markets supporting the network operation by Ancillary Services.
Thank you for attention!

Władysław Mielczarski, Błażej Olek, Michał Wierzbowski
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wladyslaw.mielczarski@p.lodz.pl
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