Market Access for Smaller Size Intelligent Electricity Generation (MASSIG)

Deliverable 4.2

Measures to influence the properties of DG Clusters

(clusters adjustment to market demand)

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Content

GLOSSARY

CHP	Combined Heat and Power
DG	Distributed generation
ECMWF	European Centre for Medium Range Weather Forecasts
IMM	Intelligent Management Method
kW	Kilowatt
MASSIG	Market Access for Smaller Size Intelligent Electricity Generation
OTC	Over The Counter (trade)
PV	Photovoltaics
RES	Renewable Energy Source
WT	Wind Turbine

1. Introduction

Nowadays there are different market options for trading electricity from conventional, renewable and distributed generation.
Presently none of the existing options recognizes the special situation of smaller and micro- scale renewable and distributed electricity generation.

To overcome this problem we have to pave the way for investors/owners of RES and DG to find proper market participation approaches, making their investments secure and more independent from subsides and grants.

To identify promising management options which enable electricity market trade for smaller and micro-scale distributed power generators we have to take into consideration all advantages and disadvantages of those generation technologies: controllable and constant nature of hydro generation and its ability to backup power and to serve as electricity storage to increase electricity supply, variations of the total energy output available for combined heat and power (CHP) generation technology depending on heat demand, intermittency of wind power and photovoltaic generation, dependence of their total output on weather conditions. Especially unpredictable fluctuations and deviations in the forecasted generation profiles may result in limitations for electricity market trade due to a risk of financial losses resulting from liabilities for balancing measures provided by the third parties.

For a successful participation in electricity market trade smaller size distributed power generators have to satisfy a number of strict requirements. The most important one is that tradable power generation output has to correspond to minimum bid/offer sizes in accordance with the concrete market requirements. Also the market participant needs to be able to deliver the contracted energy in accordance with the contract conditions: delivery time period and agreed energy amount.

2. Intelligent Management Method

As for controllable/constant power generation technologies such as hydro power and (within certain limitations) CHP it is relatively easy to correspond with the main market conditions mentioned above because it will require performing just a couple of operations:

- Determine the generation profiles of the individual technologies. In case of prioritised adjustment to local/regional consumption consider the corresponding loads that need to be supplied by the generators and make any necessary adaptations in the operation schedules to serve those local loads
- Add up resulting generation profiles to each other to produce the final power generation profile
- Define for which of the electricity market trade options the final power generation profile as well as power generation amount is most relevant for: direct electricity trade on Day Ahead auction base or to Intraday trade or to Over The Counter trade(OTC) and/or also to provision of reserve service for balancing
- Make a final optimisation of the operation schedules in order to adjust the power output characteristic to the selected trade option.

To complement the shapes of the generation profiles of each of the generation technologies adjusted to the local load demand profiles (if any exists and is prioritised) and therefore to optimise the shape of the final power generation profile, backup sources and / or storage devices are necessary.

When we deal with the wind power and photovoltaic (PV) power generation technologies working as clusters of a number of generation units or being included together with controllable/constant power generation technologies into a common operation portfolio, the task of adjustment of such aggregations (clusters) of “mixed” type to the electricity market requirements becomes more complicated.

The reason is that specific features of wind power and PV power generation (such as variations in the wind speed value within the day and night periods or the limited day operation time period of PV modules) combined with the weather forecast error lead to a changing and partly unpredictable generated power amount which might result in imbalances of the total power generation output.

Therefore the process of the adjustment of mixed type DG clusters to the electricity market requirements is more complex and time-consuming due to an increased amount of operations.

This means that to cover power generation imbalances caused by deviations in wind power and PV power generation output it is necessary to adjust generation profiles of controllable/constant power generation units not only to

the local load demand profile (if prioritised) but also to the varying wind power and PV power generation profiles, taking also into account the operation of backup power and/or storage power sources.
Type, number and order of operations necessary to adjust the cluster's generation process to electricity market rules and requirements represent an Intelligent Management Method (IMM) developed by authors of this Deliverable on the bases of the relevant experience study.

A self-balancing oriented, intelligent management method procedure consists of the following steps:

a) Determination of the local demand profile or demand profile over a certain (larger) area which needs to be supplied by the distributed generation units (if prioritised and any local load exists)
b) Determination of the generation profile of wind and/or PV power generation units taking into account values of weather prediction errors
c) Adjustment of the schedules for stable/controllable generation units – CHP and Hydro to demand profiles combined with the generation profiles of wind and PV power generation units
d) Determination of the energy storage amount necessary for covering generation imbalances due to a lack of wind power and PV generation output
e) Based on the result obtained from steps c) and d) determination and scheduling of the final power generation amount available for electricity market trade

If the Intelligent Management Method is merely oriented at direct trading into the electricity markets, it consists of the followings steps:

a) Determination of the generation profile of wind and/or PV power generation units taking into account values of weather prediction errors
b) Adjustment of the schedules for stable/controllable generation units – CHP and Hydro to the generation profiles of wind and PV power generation units
c) Based on the result obtained from step b) adjustment to the most feasible marketing option
d) Determination of the thermal storage amount necessary for decoupling electricity and heat production (CHP) in case of electricity and heat delivery schedules falling apart
e) Based on the result obtained from step d) determination and scheduling of the final power generation amount available for electricity market trade

The tradable power generation amount can also be determined as a calculation result obtained from the energy balance equation composed for the particular power generation aggregation.

For that purpose the IMM rules have to be transformed into an energy balance equation:

P (avail. for el. market trade) = P(wind) + P(PV) + P(CHP) + P(Hydro) – P(Storage) -P(Load)*. (1)

Where:

P (avail. for el. market trade) [kW] – power available for trading into the electricity markets

P(wind) [kW] – wind power generation

P(PV) [kW] – PV power generation

P(CHP) [kWel] – CHP el. power generation

P(Hydro) [kW] – Hydro power generation

P(Storage) [kW] – Storage power (positive: charging, negative: discharging)

P(Load)* [kW] – Local load, if prioritised and any local load exists

3. Measures to increase the chances for DG clusters for participation in electricity market trade

3.1 Increasing the number of generation units in the cluster

One of the possible ways to increase the chances for DG clusters for participation in electricity market trade is to increase the number of generation units included into aggregation (cluster).

It was found [1] that the aggregation of a number of wind turbines smoothes the net power output compared to the power output from an individual turbine.

Figure 1 [1] shows the variation in power output as a percentage of the average output for a single wind turbine and for the aggregated outputs of 2, 3 and 4 turbines.

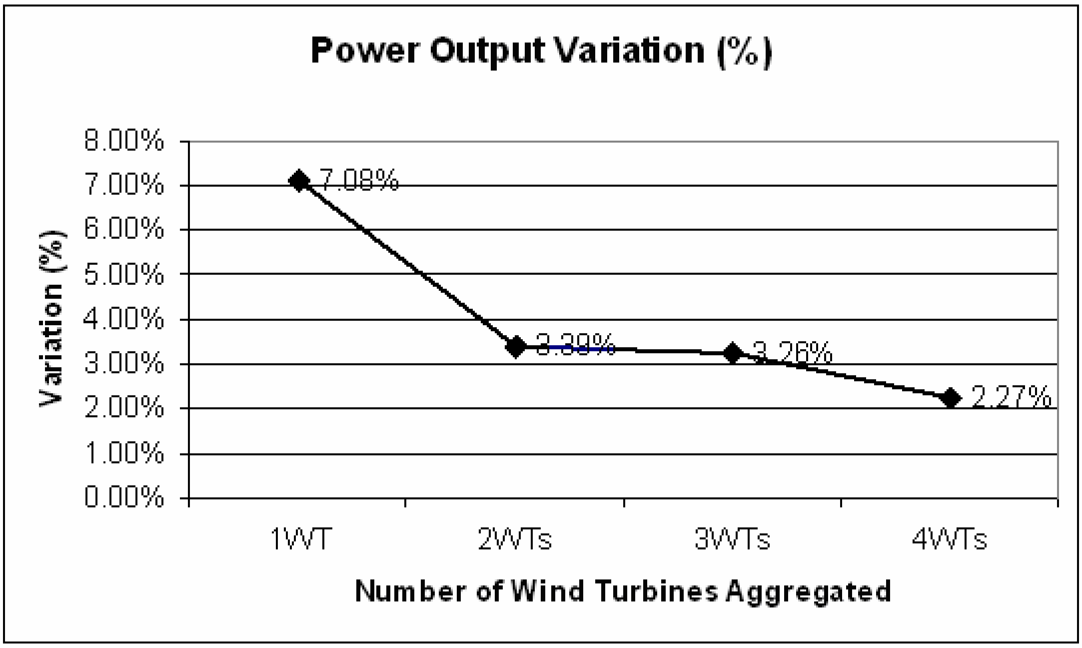

Fig.1. Power output variations for different numbers of aggregated WTs

It can be seen that the variations decrease, from approximately 7% to 2%, as the number of aggregated turbines increases.

3.2 Spread of a number of power generation units over larger territory

The precision of the weather forecast and consequently the production forecast for renewable power generation (especially on wind and photovoltaic power generation technologies) changes significantly if a number of generation units spread over the larger areas are being considered.

There are two aspects which increase forecast accuracy in such cases:

- Equalization of fluctuations for different locations which are not correlated with each other

- Summation of errors for different systems containing uncorrelated error elements in the prediction models will also partly level out the individual errors

It was also found that with increasing distance the correlation between individual forecast errors will become lower.

Figure 2 [2] below demonstrates the correlation of wind prognosis errors for two locations in Germany as a function of distance and the forecast horizon. It can be seen that correlation decreases significantly with increasing distance and that for shorter forecast horizons correlation becomes smaller.

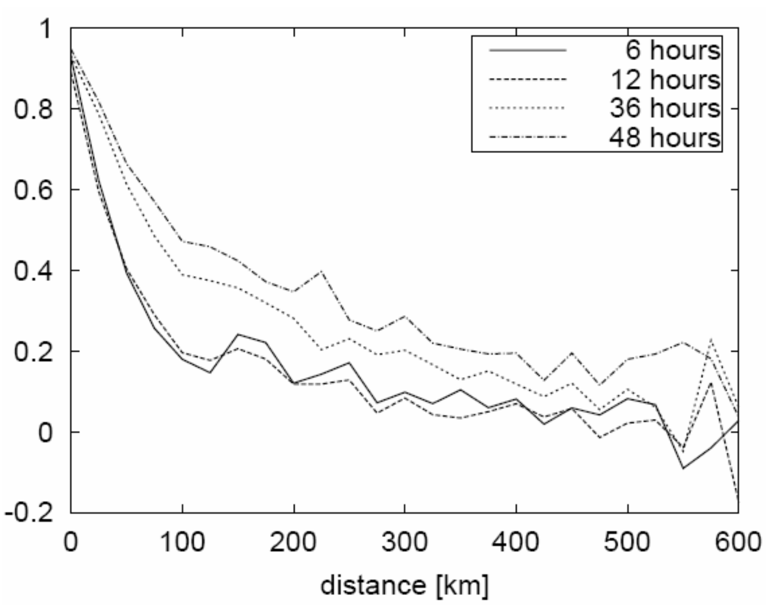

Fig.2. Correlation of wind prognosis errors for two locations in Germany depending on the distance and the forecast period [2]

Leveling out of individual forecast errors for a number of systems located very near to each other will be relatively small, since the weather conditions for such systems show a high correlation to each other, as shown in Figure 2.

Analysis of two curves for 6 and 12 hours demonstrates that positive improvements of the correlation coefficient value can be visible starting from the distance between two locations about 30km, when correlation coefficient value is reduced from 0.9 to 0.6.

At the same time for 36 and 48 hours forecast periods (reflected relevant to MASSIG project day-ahead forecast period) positive improvements of the correlation coefficient value can be visible starting from the distance between two locations about 50 and 60 km respectively, when correlation coefficient value is reduced from 0.9 to 0.6.

The greater increasing of the distance between two locations leads to the greater reduction of the correlation coefficient for prediction value.

Forecasting the generation of Photovoltaic systems requires predictions about the global irradiation at the installation site. One source for data might be the European Centre for Medium-Range Weather Forecasts (ECMWF) which offers forecasts for values of global irradiation on the basis of a global model with a spatial resolution of about 25 km x 25 km and a temporal resolution of three hours. Investigations done in [3] using ECMWF forecast data gave information about the correlation coefficient of forecast errors for solar irradiation for two locations as a function of the distance between the locations.

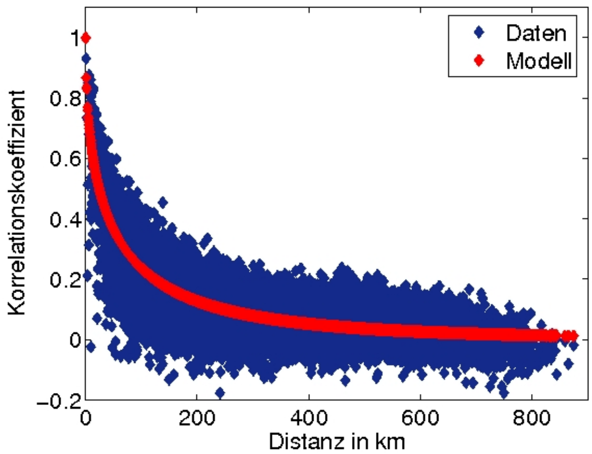

Fig.3. Correlation coefficient of forecast errors for solar irradiation for two locations as a function of the distance between the locations [3]

Analysis of the red curve shows that equal to Fig.2 we have to note that positive improvements of the correlation coefficient value can also be visible starting from the distance between two locations about 30km, when correlation coefficient value is reduced from 0.8 to 0.5. That could be recognized as the initial factor positively influencing the final power generation amount.

Further increase of the distance between two locations can theoretically drop to 0 the correlation coefficient for prediction value of the irradiation.

3.3 Split of operation time of power generation units of controllable/constant technologies

Another promising option to optimise DG clusters operation in order to increase their chances for participation in electricity market trade is to split operation time of power generation units of controllable/constant technologies. It also can be done by using of the IMM procedure.

The operation time of the controllable/constant (hydro, CHP) power generation units has to be split in accordance with the availability of intermittent energy resources and their generation output amount during the operation time periods of the day.

This means a decrease in generation output of CHP and/or hydro power units within periods of wind and/or PV high generation output. Within the periods of low (limited by the availability of resources) wind and PV power generation output the CHP and/or hydro power units generation output should be increased.

Figure 4 below [4] is provided to illustrate the application of such an approach for the optimization of the power generation by an ensemble of different (renewable and conventional) energy sources based on data for the Virtual Power Plant “Badenova” Freiburg, Germany.

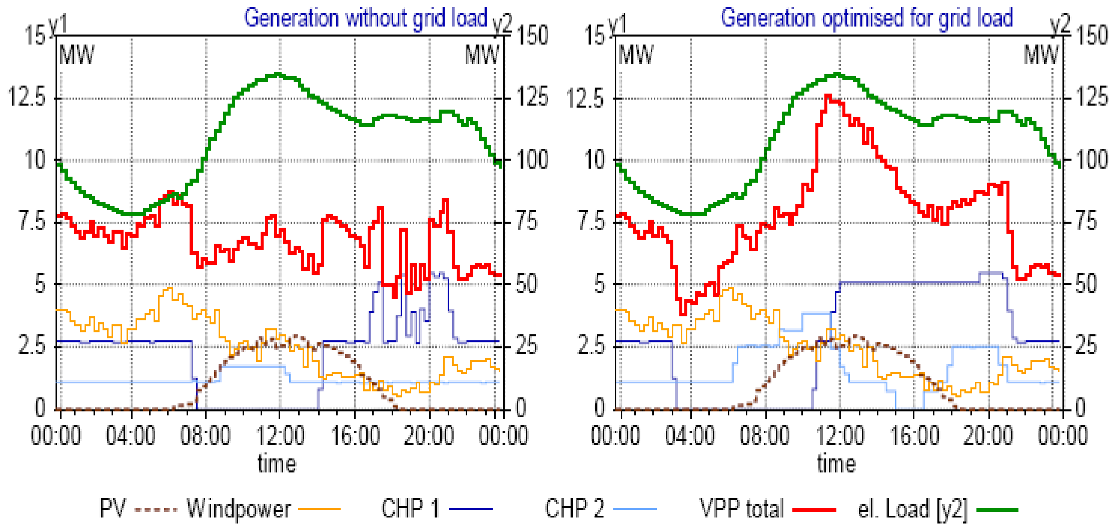

Fig.4. Comparison of standard operation of the distributed generators (left fragment) and a situation, where the CHP schedules were adjusted in a way to operate especially during times of high demand and lower wind power production (right fragment) (a day in August 2004) [4].

In the Fig.4 (right fragment) we can see that by adjusting of both CHP generation schedules to predicted wind and PV generation and by adjusting all that to the local load prognosis it can be possible to obtain a significant correspondence between total generation and loads profiles.

Another example [5], presented in Figure 5 below, also demonstrates the effect that intelligent energy management of the distributed energy resources might have.

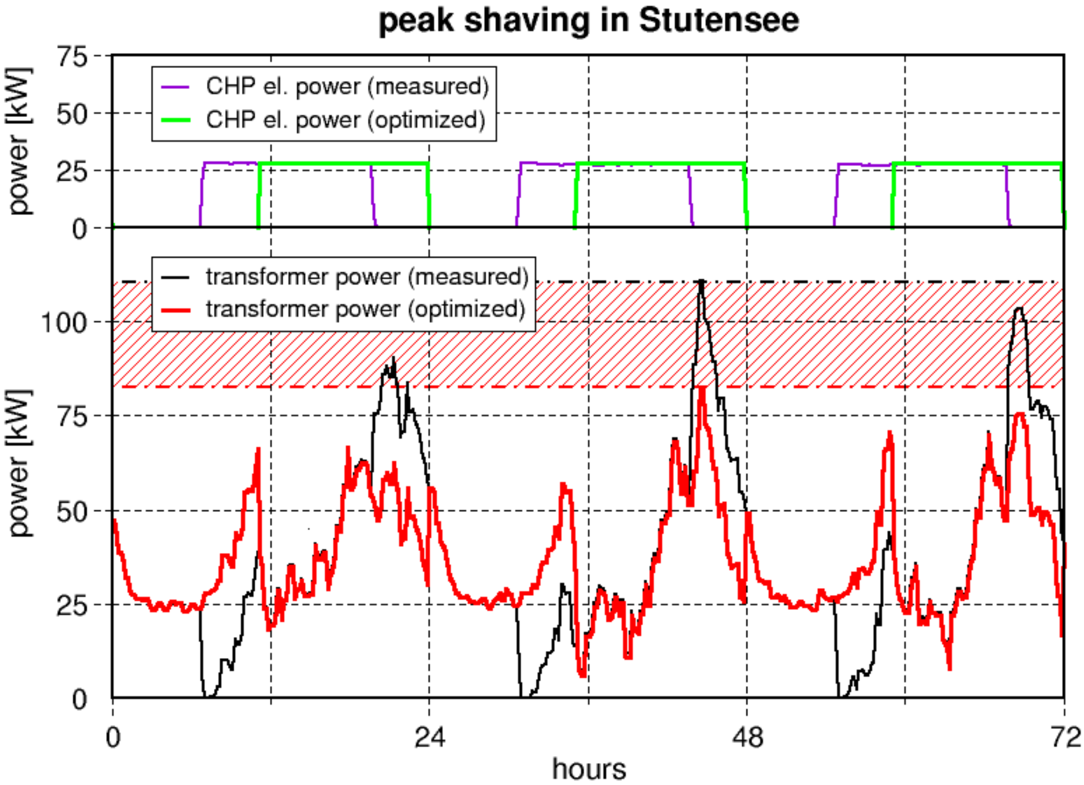

Fig.5. Peak shaving effects at the pilot installation “Am Steinweg” Stutensee (Germany).

Peak shaving effects have been achieved at the pilot installation “Am Steinweg” Stutensee by adjusting CHP and battery operation.

This figure demonstrates a simulation of results for improving MV transformer energy balance [5].

It can be seen, that the peak power demand from the MV grid (measured at the transformer) could be reduced significantly.
Besides technical advantages this is also lowering costs for the operator of the distribution grid regarding fees which have to be paid for the use of the MV grid.

Note that the electricity production by the PV system also was considered for the overall energy management, since the PV output power significantly influences the energy flow within the entire distribution grid.

By means of day-ahead prognosis it became possible to estimate the PV generation schedule for the next day and adjust CHP operation accordingly to compensate low PV production by increased CHP generation.

4. Conclusion

1. To optimise the shape of the cluster's total generation profile adjusted to the local load demand profile (if any exists), the application of an Intelligent Management Method (IMM) is may be helpful.

2. The tradable power generation amount can also be determined as a calculation result obtained from the energy balance equation composed for the particular power generation aggregation.

3. It was found that the variations of power output decrease as the number of aggregated units (turbines) increases.

4. It was found that positive improvements of the correlation coefficient value for solar irradiation prognoses and for wind for 6 and 12 hours forecast periods can be visible starting from the distance between two locations about 30km.

   Positive improvements of the correlation coefficient value for wind for 36 and 48 hours forecast periods can be visible starting from the distance between two locations about 50 and 60 km respectively.

5. To optimise DG clusters' operation in order to increase their chances for participation in electricity market trade it is necessary to split or adjust the operation time of power generation units of controllable/constant technologies to complement the generation profiles of intermittent power generation sources (wind and photovoltaic) and local load demand profiles (if prioritised and any exist).

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