Market Access for Smaller Size Intelligent Electricity Generation
(MASSIG)

Deliverable D4.1

Measures and approaches to meet market requirements by operation management

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Contents

1. GLOSSARY

APX Power UK	Major Power Exchange in UK
CHP	Combined Heat and Power
DG	Distributed Generation
DNO	Distribution Network Operators
FIP	Feed-in Premium
FIT	Feed-in Tariff
EEG	Energy Exchange in Germany
KW	Kilowatt
MW	Megawatt
OCT	Over the Counter Trade
PCC	Point of Common Coupling
PRC	Production Responsible Company
PV	Photovoltaic
RES	Renewable Energy Source
ROC	Renewable Obligation Certificate
STOR	Short Term Operating Reserve
TSO	Transmission System Operator
VPP	Virtual Power Plant
UK	United Kingdom

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Introduction

Nowadays there are different market options for electricity trade for conventional, renewable and distributed electro generation (RES/DG). Presently none of the existing options is specifically adjusted for smaller and micro- scale renewable and distributed electro generation.

MASSIG project will pave the way for investors/owners of RES and DG to find alternative marketing approaches, making their investments more independent from subsides and grants.

Main task of Deliverable 4.1 is to " identify and describe the physical and technical operation and management options, which will be relevant for marketing concepts of the produced energy output."

To identify promising management options for electricity market trade for smaller and micro- scale renewable power generators we have to take into consideration all advantages and disadvantages of the renewable power generation technologies:

- Intermittency of wind power and photovoltaic generation and total dependence of their output on weather forecast quality (weather forecast error), which results in a failure of generation output and causes limitations for electricity market trade due to high risk of financial losses
- Variations of the total energy output available for combined heat and power (CHP) generation technology, especially for smaller CHP generation units
- Controllable and constant nature of hydro generation and its ability to backup power and to serve as electricity storage to increase electricity supply

Intelligent management of a single operation unit or of an aggregation of units of different renewable technology types also includes conventional generation units and required controllable loads.

It can help RES/DG units owners to adjust their generation schedules to an electricity market requirements and rules and become a real participant of electricity trade market providing it with needed amount of electricity, balancing and ancillary services etc.

2. Preconditions for smaller renewable technologies for participation on electricity market trade

Most relevant types of RES and DG technologies in four researched countries: Denmark, Germany, Poland and UK, have been defined in Deliverable 2.1: “wind power < 5000 kW (max. 5 MW at a single metering point,” no wind farms”), hydro power < 5000 kW, PV< 1000 kW, thermal conversion generators (potential CHP installations) < 5000 kWe …”
(p. 11 Deliverable 2.1)

For identification of technical and management options for smaller RES/DG generation units most common preconditions have been taken into account:

- Physical integration of smaller scale RES/DG into (at least) low voltage electricity network.

- Smaller RES/DG generation technologies, mostly locally orientated, partly are small businesses without significant scale of income therefore their participation at electricity markets may be limited by economic and financial reasons:

    - Affordability of market requirements such as market accreditation procedure (sometimes rather long, complicated and expensive) as well as membership fees, collateral requirements, purchase of metering installations etc.

    - Relatively high transaction and grid utilisation fees (UK).

- Technical preconditions for single generation unit participation in electricity trade are based on electricity market requirements (carried out in Deliverable 3.1) and include min bid/offer contract size – 0.1MWh (relevant for Day Ahead markets in Germany and Denmark and Intraday market in Germany) and 1MWh[1], which is also common for Power Exchange markets: Future (Denmark, Germany Poland, UK), Day Ahead (Poland and UK) and Intraday (Denmark).

  In all four researched countries, minimum duration of electricity delivery is 1 hour (with only exception for APX Power UK – 0.5 hour).

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[1]Here we have to mention that min bid/offer size, 1MWh is a significant barrier for market trade for generation units with smaller output amount. Generation units with smaller output amount (excluding exceptions) can participate in electricity market trade just being included in aggregations of generation units.

- Economic support schemes: Feed-in Tariff, Feed-in Premium, Quota obligations, and their influence on management options for smaller RES/DG generation.

- Legal entities (in those countries, where it is one of the main conditions for “conventional “market participation

3. Economic support schemes for renewable generation in four countries: Denmark, Germany, Poland and UK and their influence on electricity market trade

Presently four researched countries (Denmark, Germany, Poland and UK) use two different support schemes: Feed-in Tariff (FIT) (and/or Feed-in Premium (FIP)) and Quota Obligations. Germany follows FIT, Denmark follows FIT and/or FIP scheme, UK and Poland follow Quota Obligations scheme. Differences of support schemes cause differences in approaches for electricity markets participation for smaller scale RES/DG generation.

3.1 Feed-In Tariff

Technically Feed-In Tariff (FIT) is paid to the RES/DG generator by the Distribution Network Operators (DNO) of those grids to which the RES/DG plant is physically connected and acts on the annual base.

Under a feed-in tariff regime RES/DG generators do not financially participate in the electricity market. RES/DG generators sell produced electricity at the regulated (guaranteed) price to the utilities, and therefore integrate into their portfolio, and then directly sell electricity to utility’s customers. Thus the produced RES/DG electricity is directly transformed to the demand load profile and electricity market prices are not relevant for RES/DG generators.

In other words fixed feed-in tariff isolates RES/DG generators from market price, electricity market and risks. Under feed-in tariff the price risk transferred to consumers.

Also all RES/DG generators that sell their electricity under the feed-in tariff scheme are exempt from the balancing responsibility. They neither have to deliver generation schedules nor carry balancing costs. Forecasting, scheduling and balancing of RES/DG production is done by Transmission System Operator (TSO).

Therefore it is reasonable to conclude that in the countries following FIT support scheme smaller RES/DG generators aiming to participate in electricity market trade by themselves have to be independent on FIT obligations and have to just correspond to common preconditions listed above.

3.1.1 Self-marketing under FIT

Further progress in FIT development (and therefore its influence on better penetration of RES generation in electricity trade) has been achieved since 1 April 2009 due to amendments in German "Act Revising the Legislation on

Renewable Energy Sources in the Electricity Sector and Amending Related Provisions – Renewable Energy Sources Act – EEG 2009".

In the document it was stated, that owners of RES systems can decide on a monthly basis, whether they want to get paid by the EEG feed-in tariffs, or if they want to sell their energy themselves at the electricity markets they must inform their grid operator a month in advance about their decision and about the volume of RES power, they would like to sell (it is possible to sell only a certain percentage of the RES system output).

Presently, due to that renovated document, there are three options for participation of PV power generation in electricity market:

- Following by FIT
- Self marketing
- Self consumption with additional bonus

The last option is relevant for PV generation with up to 30 kW output. PV generators awarded by special additional bonus (€ 0.2501) will be motivated not only to produce electricity but to consume it locally and also provide self-balancing.

Therefore this amendment will significantly increase flexibility of RES/DG generation units (including smaller ones) in scheduling their participation on the Power Exchange.

3.2 Feed-in Premium

As it known Premium tariff is an additional payment (remuneration) on top of the electricity market price. And such remuneration is independent on electricity market price. But because of deviation of electricity market price the total level of remuneration cannot be determined in advance.

Except that, neither TSO, nor electricity market participants have any purchase obligations. RES/DG generators are fully responsible for generation results and they face higher risk in electricity trade.

Naturally, FIP can provide sellers with significantly higher benefits, especially at peak demand periods, but wind power producers and PV generators being totally dependent on quality of weather predictability, are hardly able to share those benefits.

Therefore FIP does not isolate RES/DG generators from participation in electricity trade market totally, taking into account changing of market prices and responsibility for generation result which presumed either remuneration or charges.

For example in Denmark due to support of CHP plants less 5MW, producers may sell their generated power using Triple Tariff. Moreover CHP plants, used in generation of both natural gas and biogas, are supported with premium on top of selling price for electricity amount which is produced due to biogas.

Due to that RES/DG generators can choose a form of their participation in electricity market trade e.g., type of balancing service or power exchange market type. It means that they are able to follow management options to be better adjusted to the market requirements and conditions.

3.3 Quota Obligations

Independent RES/DG producers can sell their Renewable Obligation Certificates (ROCs) directly to traders or suppliers via purchase agreements or at the auctions.

Being ROCs holders RES/DG producers need no special mechanism to integrate the renewable electricity into the electricity market.

Being fully independent RES/DG producers may sign bilateral contracts with utilities or traders that further integrate sold electricity into their portfolio. But at the same time RES/DG generators are fully responsible for electricity sales, grid integration and balancing and have to pay full imbalance charges. Thus they fully carry balancing risk.

4. Short description and characteristic of renewable generation technologies. Their suitability for electricity market trade

4.1 Wind power generation

Wind power generation is low cost generation technology, and it is one of the most developed and distributed renewable energy sources in four researched countries.

One of its most important features is intermittency of generation process and resultant fluctuations of electricity output within various time scales: from intra-minute to hours and days depending on location of the site of production (e.g. see breezes are significantly more constant than land breezes, etc).

In the case of application of wind generation technology, the main task is to find ways to avoid intermittency in power generation.
Therefore quality of weather forecasting is one of the uppermost important conditions for successful result of wind generation.

The closer weather forecast is to the real time of wind power generation the higher quality this forecast is. Increase in quality of weather predictability is the only way to increase generation output of the single unit, to prevent energy generation losses and to protect wind turbine blades against damage caused by higher (then it requires) wind speed.

Another highly recommended way to avoid intermittency in wind power generation is a spread of number of wind power generation units over a geographically wide area, e.g.: north-south, up-hill-near-coast.

Research of real experience of hourly swing in power output in Denmark resulted in a conclusion that:

"The maximum hourly swing in output power from distributed wind, rarely, if ever, exceeds 20% of the installed capacity of the wind plant. The standard deviation of the hourly swing is 3%.

The maximum measured change in output per minute from 2400 MW of wind in Western Denmark is about 6MW".

These data can be successfully correlated for smaller size wind generation as well.

Preliminary Conclusion

- To minimise possible imbalance in generation output (connected to weather prediction error), electricity trading deals for wind power generation (as for single standing generation unit, as for aggregation of the number of units) have to be closed for the time period nearest to starting point of electricity delivery and consumption
- When using an aggregation of a number of wind generation units, they have to be spread over a geographically wide area
- To avoid possible imbalance in generation output and to prevent wind generation losses (occurs in periods of wind generation at maximum limits coincided with low energy demand) each single standing generation unit or aggregation of number of generation units can be connected with energy storage unit and/or with output controllable generator(s) (CHP, hydro)

On a bigger scale the last option is presently exploited in Denmark, Germany, Norway and Sweden due to good interconnection among their national grids. As a result, Denmark can trade wind power on the spot markets in time of excessive supply, and wind generation surpluses can be stored in hydropower storage facilities in Norway and vice versa: Danish operators can purchase electricity generation surpluses form Norway (Germany or Sweden) at times of low wind generation.

4.2 Hydro power generation

Hydro generation of smaller size (relevant for MASSIG project) is a low cost technology[2]
There are two most important types of hydro power generation: run-of river plants and dams.

[2]A Report by Enviros Consulting Limited 1 September 2005 DTI The Cost of supplying renewable energy

Hydro generation also faces seasonal “intermittency”, when water reservoir levels drop down. But due to rainfalls and snow melting, water reserves are refilling.

Of course hydro generation owners must take every opportunity for power generation using available water. Spillway flow and evaporation loss must be minimised and reservoir capacity must be considered against the size and run-off behaviour of the catchment, seasonal weather variations and turbine rating.

Except natural water accumulation, pump water facilities also help to provide needed water level in reservoirs and therefore support constant electricity generation output. So, it is possible to control amount of electricity generation output, avoiding generation intermittency, all year long.

Great advantage of hydro power generation is its ability to be a backup power and to serve as electricity storage (in form of pumped-hydro or hydro reservoirs) for years to increase an electricity supply. Fully loaded hydro facility can replace a conventional power station for several hours if needed.

Potentially hydropower storage facilities can be used within minutes by opening their gates.

Preliminary Conclusion

For elaboration of management options for adjustment of smaller hydro power generation to electricity market requirements:

- Possibility to start and stop generation process within the short time period (if it will be required)
- When started, generation process is constant
- Ability to be a backup power and to serve as electricity storage

4.3. PV power generation.

Photovoltaic cells convert sun light directly into electrical energy. Amount of produced energy strictly depends on the sunshine intensity and the angle of radiation flow to PV cells. PV generation also has its seasonal and daily variations as well as dependency on weather fluctuations (weather predictions error) – rain fall, clouds, etc.

Seasonal variations of electricity generation have a peak during summer period as well as daily variations, usually with a peak during midday. Short term weather fluctuations such as clouds, rain fall, etc., have additional impact on inter-hourly amount of generated electricity.

Therefore weather forecast error can significantly influence PV generation result.

Preliminary Conclusion

Elaboration of management options for adjustment of PV generation to electricity markets requirements:

- short term fluctuations can be mitigated by geographically wide distribution of PV generation panels (similar to wind generation)
- to avoid possible imbalance in generation output within periods of short term intermittency in generation, and to prevent power generation losses using electricity storage units (batteries and other energy storage devices) is highly recommended
- to minimise possible imbalance (connected with weather prediction error) electricity trading deals for PV generation have to be closed for the time period nearest to starting point of electricity delivery and consumption

4.4 Combined Heat and Power (CHP) generation

Combined Heat and Power (CHP) generation based on total or partial use of bio fuel (in solid, liquid and gaseous state) mostly depends on availability of these types of fuel.

CHP plants that use planted biomass crop and local agricultural crop remains can face seasonal fluctuations in supply and therefore intermittency in CHP generation process can only be caused by lack of biofuel, specific for each technological type of CHP plant.

It can be avoided using storage facilities provided with thoroughly calculated amount of buofuel reserve of correspondent type.

CHP generation based on Biomass/Coal co-firing is a low cost technology, at the same time CHP generation based on Biomass (stand alone) is a high cost technology[3].It means that economic factor can play a significant role in elaboration of management options for market trade for that type of CHP plants.

High electrical efficiency in CHP plants can only be achieved through high live steam pressure and temperature (170 bar, 600°C) at given condensation conditions. Live steam temperature in biomass plants is limited because of the increased danger of corrosion due to alkali metals, sulphur and chlorine present in the fuel. CHP plants of low and medium output are designed for lower live steam conditions.

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[3] A Report by Enviros Consulting Limited 1 September 2005 DTI The Cost of supplying renewable energy

Heat demand can be satisfied either by heat storage devices (for example using different media – heated water, as it used in Denmark) where heat, produced in a period of low electricity consumption, can be kept for further usage or by operating of standby boilers. Heat demand also can be satisfied by drawing down the thermal inertia in the system.

In small CHP generators (based on reciprocating engines and gas turbines) it is normal for each turbine or engine to be operated either at maximum continuous rating, or not at all. Flexibility can be achieved during periods when generators are not required to operate continuously.

Micro turbines (gas)-based CHP are ideally suited for distributed generation applications due to their flexibility in connection methods, ability to be stacked in parallel to serve larger loads, ability to provide stable and reliable power, and low emissions.

For their successful application:

- relatively coincident electric and thermal loads
- electric demand to thermal demand ratios in the 0.5 to 2.5 range

Preliminary Conclusion

- CHP generation is non intermittent, stable operating type of technology and also CHP generation units are able to be stacked in parallel to serve larger loads
- By proper correlation between electricity and heat generation output it becomes possible to achieve an increase in electricity output in periods of high electricity demand. It can be adjusted either for electricity market trade and/or for peak generation and peak shaving provision
- Heat power can be successfully generated by operation of standby boilers or in periods of low electricity demand and kept in heat storage devices

5. Electricity market trade options and their relevance to smaller renewable technologies

5.1 Future market trade

Future electricity trade market, based on electricity trade occurs long before the real time of its physical delivery, and its mostly financial. Min bid/offer size for future electricity trade is 1 MWh.

It is clear that wind, CHP, hydro and PV generation units, which maximum generation output is lower than min bid/offer size-1 MWh automatically have to be excluded from their Future electricity trade market participation.

Low quality weather forecast for wind and PV generation made long in advance of real generation period results in significant imbalance between really generated and traded electricity amount.

In turn (in a majority of cases) electricity generation imbalance has to be covered by significant imbalance fees, paid by imbalance responsible party - generators, traders, suppliers or Transmission System Operators (TSOs).

Therefore it almost completely excludes wind and PV power generation represented by smaller sized single generation units from participation in trade at Future electricity market.

As for aggregations of wind power generation units or aggregations of a number of PV panels (with total output result not less than 1 MWh), spread widely over the large territory (for mitigation impact of intermittency on generation result), their participation in Future electricity market trade seems possible but risky because of a possibility of imbalance fees. In both cases imbalance responsible party is a sole decision maker.

Smaller single hydro and CHP generation units as well as their aggregations (with single unit or total output result not less than 1 MWh), being predictable and stable in their generation (due to technological variations and storage options as it mentioned above), are able to take part in Future electricity market trade.

5.2 Day Ahead market

Day-ahead market with min bid/offer size 0.1 MWh or 1MWh and electricity delivery period up to 48 h (in UK) can give a real opportunity for trade to wind power and PV power producers, because schedules (submitted to the system operator (SO) and estimate electricity feed-in or consumption) can be modified within 1-3 hour before real-time delivery being based on more exact weather forecast results.

Therefore participation of smaller single wind power generation unit as well as a single PV generation unit (with output result not less than 0.1 MWh) in electricity trade at Day Ahead market becomes reasonable, especially if the trading deals can be closed for the time period nearest to starting point of electricity delivery.

As for aggregations of number of wind or PV generation units (with total output result not less than 0.1 MWh or 1 MWh) their participation in Day Ahead market trade is considerably more productive. Still, it has a risk of imbalance fees payment for single generation unit as well as for aggregation.

For smaller hydro and CHP generation (predictable and stable) participation in Day Ahead market trade using single generation unit or an aggregation (with single unit or total output result not less than0.1 MWh or 1 MWh) is one of the best options for electricity trade.

5.3 Intraday market

Presently Intraday markets act only in two out of four researched countries: Denmark and Germany.

Short time period of gate closure before the physical delivery of electricity are 60 min in Denmark and 75 min in Germany (that practically means electricity trade in a real time) as well as operating time 24 hours 7days a week during the year are very attractive conditions of trade especially for smaller wind power and PV generation.

Intraday market conditions give an opportunity to improve (and/or even exclude) weather forecast errors for intermittent and low predictable wind and PV generation and also all surpluses of electricity, generated in accordance with Day Ahead contract terms and conditions, can be sold on Intraday market.

Intraday Market participation can be a way to cover generation and financial losses for smaller single weather forecast dependent power generation unit (wind or PV) as well as for aggregations of wind or PV generation units.

This can be demonstrated by the results obtained in 2001 from the research data[2] for Nordpool (area West Denmark):

Due to reduction of forecasting period for wind generation from12-36 hrs to 6-12 hrs and from 12-36 hrs to 2 hrs, forecasting error was decreased from 39% to 30% and from 39% to 18% respectively.

This allowed to update wind power bids (in accordance with improved forecast) and significantly decrease (or even avoid) imbalance.

For smaller hydro and CHP generation (predictable and stable) as for single generation unit and as for their aggregation, participation in intraday market trade is also one of the attractive options for production trade.

5.4 Over the Counter trade

Presently, Over the Counter Trade (OTC), based on bilateral contract usage, is one of the most extended forms of market trade in four researched countries.

Independent of bilateral trading type in use, either standard form of bilateral contracts, based on matching bids and offers or bilateral contracts between buyer and seller, (strictly confidential, containing specific financial, technical and other requirements for both sides) are a good way of trade for smaller RES/DG producers.

The reason being, that bilateral contract market is rather more flexible than Day Ahead market in respect to price formation, and because of possibility of adjustment to offers/bids and requirements each of contract sides in the best way possible.

An example of electricity market trade based on bilateral contracts between renewable power generators and Production Responsible Companies (PRC) in Denmark is given below.

Before 12:00 of the day ahead of physical electricity delivery to consumers, owners of small RES/DG generation units (or their aggregations) can offer their production (not less than minimum bid size) at spot market for each of 24 hours of day ahead at such a low price to be a certain tender winner.

Being a winner, smaller RES/DG generation unit owners get a payment (remuneration) in accordance with electricity amount that has been traded (sold) at a certain spot market. They are provided with a payment without any connection whether they will really generate and deliver sold electricity amount at a certain hour day ahead or not.

Sometimes obligations are not fulfilled by owners of small RES/DG generation units due to insufficient quality of day ahead weather forecast or technical reasons that appeared during the process of electricity generation.

If imbalance occurs and smaller RES/DG generation unit owners won't be able to fulfil their obligations they will be punished by PRCs. Correspondent fee size will be defined based on undelivered amount of electricity.

5.5 Balancing market

Balancing market is also a real time market closely connected with Intraday market.

Having a short gate closures, balancing market, in principle, can be an option for participation for both types of smaller RES/DG generation technologies: for controllable/constant generation (CHP and hydro) and for weather forecasts depending generation (wind and PV).

Because of a low relevance of technical requirements smaller RES/DG generation (especially for standing alone units with output less than 1MW) is very limited or even isn't able to take part in balancing provision of national networks.

5.6 Reserve market

Technical requirements for primary and secondary control provision, including big bid/offer sizes (up to100 MWh in UK), initially have been set up for large scaled conventional electricity plants provided with automatic control equipment and therefore certainly cannot be accepted by smaller RES/DG generation.

Technical requirements for tertiary control are mostly based on Grid Code requirements (adjusted only for large conventional generation units), which are barriers for that kind of balancing provision by smaller RES generation units.

Tertiary control is practically a manual type of power control, which is traded daily and due to relatively small range of bid sizes in four researched countries (1-15 MWh) it could be afforded either by single RES/DG generator or by aggregations of RES/DG generators (which will be discussed below).

Due to stability in CHP generation and flexibility in their power production schedule (connected to the correlation between electricity and heat generation output, to achieve an increase of electricity production) smaller CHP plants are able to provide grid with the tertiary control service.

Hydropower generation, due to its ability to be a backup power and to serve as electricity storage can also provide grid with tertiary reserve.

Technologies dependent upon weather forecast (wind and PV generation), would be able to participate in tertiary control provision if connected with energy storage systems or with another controllable generation unit.

Solo use of wind and PV generation for tertiary control provision can bring failure to tertiary control obligations fulfilment due to intermittency in generation process.

Balancing provision of the system closely connected with amount of intermittent power (wind, PV) that is coming for trade: the higher amount of intermittent power coming for trade the bigger probability of system imbalance. This requires, either to attract a bigger amount of regulation power for balancing provision and increases regulation cost, or to use different management options for system imbalance mitigation.

5.7 Other Reserves

5.7.1 Peak shaving

At certain periods during the day energy consumption goes over a particular threshold starting at the period of peak consumption. The peak price of electricity also goes up significantly.

To avoid electricity consumption from the grid, and therefore high charges within peak period, independent energy generation unit can be used. This brings to “peak shaving” and it is one of the balancing market services.

Independent energy generation unit starts working prior to reaching the high price threshold and turns off when electricity consumption becomes less than the high price threshold.

As a result both participants of that service, energy consumers and energy producers benefit from the “peak shaving”. Energy consumers can decrease their electricity bills and energy generators have additional income.

In Germany “peak shaving” service participants also benefit from reduction of grid utilisation cost. The reason being, that calculations of grid utilisation cost also include an amount of power consumption during the peak load hours during the year.

Therefore, “Peak shaving” can be very attractive option even for small, local RES/DG generation. In principle this service can be successfully afforded either by intermittent RES/DG technologies in time periods of high wind speed and stable irradiation or definitely by technologies with stable generation result.

CHP generation stability and flexibility is connected with the correlation between electricity and heat generation output to achieve an increase in electricity production as well as ability of hydropower generation to be a backup power and to serve as electricity storage.

5.7.2 Net metering

Net metering is a regulatory policy that allows renewable energy generators to sell surplus electricity back to the grid from their own renewable energy facilities - such as solar PV, wind turbine, hydro, CHP.

Allowing consumers to generate their own electricity through grid-connected renewable generation units could give the grid a new degree of stability via “distributed generation”.

In selling electricity back to the grid, one method involves simply rolling the existing power meter backwards as excess energy is pushed back onto the grid.

Another method involves installing a separate meter to measure just outgoing energy.

As it follows from the net metering definition all types of renewable generation can be involved in this activity even in spite of amount of generated energy surpluses intended for sale.

5.7.3 Congestion management

If the system is unable to flow electricity in the way required due to congestion at one or more parts of the transmission network, definite actions in the market have to be taken to increase and decrease the amount of electricity at different locations on the network for their safe operation**.**

Technical requirements to manage congestion will be specific for each of locations and depends on a number of factors including local level of generation output and local level of system demand. Therefore this is a balancing service on a local level.

All renewable generation units, being able to change their generation output (to reduce or increase) as well as their demand in accordance with the grid requests can participate in this service.

CHP and hydro generation due to their generation stability and technological features:

- start (and to finish) generation process within short time period,
- change generation output amount in min-max limits ranges,
- store energy, etc

would have advantages in congestion management provision.

As for weather forecast dependent technologies (wind and PV generation), they can be managed only in periods of generation stability due to high wind speed and stable irradiation conditions, or being connected with energy storage devices, controllable power generation units and/or controllable load.

Balancing energy amount as well as another technical requirements and conditions for congestion management provision will have to be agreed in bilateral contracts**.**

6. Management options for smaller renewable technologies to participate in electricity trade

As it was agreed above maximal power range of single power generation unit cannot exceed 5000 MW at a single metering point. It means that we have to take into account a wide range of output sizes of power generation units starting from some tens of KW.

Such small sized and micro- generation units, being alone, are not able to afford market financial requirements or technical conditions in respect of bid/offer sizes (in some cases with exception for Elspot Day Ahead market in Denmark – 0.1 MWh, as was mentioned already) and therefore have no chance to participate in electricity market trade of any type independently.

To overcome this, there are several possible options to sell small and/or micro- sized power production:

- to be a third party (subcontractor) in electricity market trade for large power producers
- to be included in a common electricity trade package of large power producer
- to be included in aggregations of power generation units (of all RES/DG generation types, including conventional types of power generation)

Generation imbalances caused by using weather forecast dependent technologies: wind and PV generation; or accidentally caused by lack of biofuel for CHP generation or by seasonal intermittency of hydro generation and financial losses connected with them will lay on generators responsibility.

Mentioned above options can also be exploited by standing alone units with generation output size not less than 1MWh if they follow by at least one (main) precondition: to be physically integrated into (at least) low voltage electricity network.

First two options do not need additional comments because they are based on bilateral contracts between two (or possibly more) parties and contract conditions as usual are strictly confidential.

The last option, concerning aggregations of power generation units has a number of different applications, features and advantages and will be analysed separately in detail.

6.1 Management options for aggregations of smaller renewable generation units

Aggregations of power generation units can consist of:

- renewable generation units of common technological type and of same or different production output sizes (included or not units of conventional power generation technologies)
- renewable generation units of different technological types and of same or different production output sizes (included or not units of conventional power generation technologies)

6.1.1Aggregations of smaller renewable generation units of one technological type

Aggregations, including generation units of common technological type are reasonable enough for weather forecast dependent technologies as wind and PV generation.
Advantages of such aggregations are based on improving weather forecast error for some number of generation units dispersing over the geographically large territory.

This occurs because negative and positive generation results of each of individual turbines or PV generation unit (probably partly caused by weather forecasting error) are summarized and overlap each other decreasing (even to minimum) an imbalance.

Following general principle of electrical engineering, that the large system requires less reserve capacity we can come to conclusion that increase of a number of power generation units, included in to aggregation (and increasing, therefore, it total nominal output) and also dispersed over large territory (technical distribution) can significantly decrease output fluctuations (especially short term: intra- and inter-minute) also improving weather forecast error.

A number of generation units can also serve as a flexible capacity reserve for the aggregation.

Therefore, aggregations of wind power and PV generation units with increased total output in the range of several MW and minimized influence of weather forecast error can be real members of Power Exchange markets (Day Ahead market participation is a possible option and Intraday market is most relevant option) and also can participate in different types of balancing provision:

- Short Term Operating Reserve (STOR) is a service that provides additional active power from generation and/or demand reduction in the UK. It requires provision of only 3MW of generation fully delivered within 0-240 min. Tertiary reserve conditions in Poland require minimum bid size 1MWh, minimum/maximum bid duration 1h/1h).
- Peak shaving, net metering provision as well as congestion management are possible in periods of high wind speed and stable solar irradiation

Aggregations of generation units which face just seasonal output fluctuations (fully predictable and controllable), such as hydro power generation and CHP generation, due to:

- their stable non intermittent generation mode and
- being flexible in their power production schedule and
- having the ability to heat and electricity storage (as it was mentioned above)

are quite reasonable for participation in all types of electricity markets trade as well as for balancing service provision: tertiary control, peak shaving, congestion management.

6.1.2 Interconnection of aggregations of RES/DG units between them and between different grids

This option can be used in areas with high concentration of each type of power generation units: wind, hydro, PV and CHP.

To mitigate intermittency in power generation or to improve imbalance results (weather forecast error) for aggregations of wind and PV power generation unit, aggregations of hydro and/or CHP plants (or standing alone hydro and/or CHP units) can adjust their generation schedules to predicted generation result for wind and PV aggregations to provide them with a generation product in periods of low generation profile or to consume power generation surpluses.

It could be implemented in Germany where, due to cooperation among TSOs (four in Germany), small scaled RES/DG generators are provided with an option to deliver their produced electricity to all TSOs control areas even if not being connected directly with some of them.

On a bigger scale this management option is presently exploited in Denmark, Germany, Norway and Sweden due to good interconnection among their national grids.

As a result Denmark can trade wind power on the spot markets in time of excessive supply, and wind generation surpluses can be stored in hydropower storage facilities in Norway and vice versa: Danish operators can purchase electricity generation surpluses form Norway (German or Sweden) at times of low wind generation.

6.1.3 Aggregations of smaller renewable generation units of different technological types

Different types of renewable technologies being connected together can complement each other balancing total operation result. Aggregation of different technological types can combine advantages of each generation technology and to become self sufficient - experience of Denmark, Germany and UK can prove it.

There are several aims for use of aggregations of smaller renewable generation units of different technological types.

1. To combine power generation processes to get common power generation output not less than several or more MW to become a participant of electricity trade markets
2. To reduce intermittency effect on final generation amount
3. To get high level of flexibility in adjusting output amount to grid consumption requirements (needs)
4. To provide grid with different kinds of reserve service for balancing: tertiary reserve, self-balancing, local peak shaving, negative and positive reserve, congestion management, net metering.

Aggregations of smaller power generation units can be created for different options: either for participation in electricity markets for electricity trade and balancing service provision or just for electricity trade or balancing service taking into account type of installation, season, thermal inertia in heat distribution systems, etc.

Option 4 above assumes direct communication between aggregation and its running centre, standby generators and/or electricity consuming equipment of the partners.

Such aggregations can be composed as a continuously or temporary, operating power plant in time periods when national electricity system or local electricity grid is under stress and needs reserve and balancing service provision.

To achieve this we can use either combination of small RES/DG units together with conventional power generation units or a combination of small RES/DG generation units together with load (e.g. large power consumers):

- combination of one or more CHP (driven by natural gas and/or bio-fuel), and/or: storage system, boiler, PV
- combination of one or more CHP (driven by as given above) and/or: several motor generators driven by diesel fuel (mainly used for peak load supply), wind power generation unit(s), PV system(s)
- combination of one or more biomass CHP and/or: PV system, wind power units, boilers

To obtain maximum result from combined operation of number of stable/controllable in power generation sense units (like CHP and hydro power generation) and units of intermittent power generation type (like wind, PV, etc.) intelligent management is necessary.

Intelligent management operation has to consist of three stages:

a) Determination of demand profile for the electricity market product and for the local thermal demand

b) Prediction of the final RES generation profile includes all operated stable/controllable and intermittent power generation units. It can be done by adjusting the schedules of stable RES/DG generation units (CHP), boiler or/and motor generators and controllable loads to preliminary predicted generation results of intermittent power generation units (wind, PV)

c) Combining final RES generation profile with prognosis for the general load schedule to obtain final balance between them

Operation of aggregations has to be managed by the single control centre and practically they are Virtual Power Plants (VPP).

Simultaneous use of renewable technology units and boilers or/and motor generators and also controllable loads gives an opportunity not only to participate in all types of electricity markets trade but can significantly cover the area of balancing service provision, such as tertiary control, peak shaving, congestion management, etc.

Analysis of (VPP) work experiences shows that:

- “higher degree of freedom for CHP operation by using intelligent heat management integrating boiler and storage systems”– e.g. heat and electrical (batteries). That gives an opportunity to “compensate generation fluctuations from the PV system by adjusting CHP operation schedules according to solar irradiation prognoses” and to increase self balancing capability of the corresponding distribution grid.[3].
- CHP operation also can be adjusted to fluctuations of wind turbine generation to compensate them.

- Use of gas motors aiming to produce electrical and thermal energy during the periods of high consumption and high energy prices gives an opportunity to reduce peak loads and to avoid grid utilisation

- Proper combination of local heat management with the electrical grid management can improve operational time of CHP (single unit or number of ones) by shifting it in accordance with local electricity grid or power exchange requirements.

The last conclusion can be illustrated by results obtained during experience in operation of VPP “Badenova” [3].

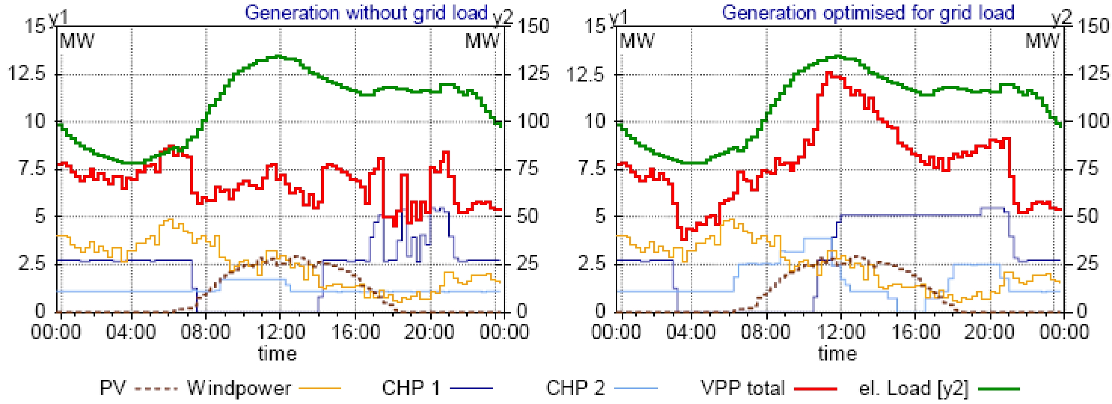
Case 1

To approve the idea that electrical grid management can improve operation time of CHP by shifting it in accordance with local electricity grid requirements "standard operation of the distributed generators was compared to a situation where the controllable loads were adjusted in a way to operate during times of high demand and lower wind power production."

As a result "a significant adaptation to the load curve could be achieved by shifting the operation times of the CHP units accordingly" [3]

Therefore by adjusting CHP generation schedules to predicted wind and PV generation results and by adjusting all that to the local loads prognoses it can be possible to obtain a significant correspondence between total generation and loads profiles.

This conclusion is illustrated below based on operation results obtained by VVP "Badenova" Freiburg, Germany.



Comparison between standard operation of the distributed generators and a situation, where the controllable loads have been adjusted in a way to operate especially during times of high demand and lower wind power production (one day in August).

Case 2

As it was mentioned above the large system requires less reserve capacity and also wider geographic distribution of decentralised weather forecast depending renewable technologies can improve their total power generation balance due to overlapping negative and positive generation result.

This idea has been successfully developed by creating "Combined Power Plant" project in Germany with common features of both "academic simulation and a "real field test". [3]

This project combines and controls 36 small wind, solar, biomass and hydropower generation units distributed over German territory.

Generation functions delivered to each generation unit have been defined based on advantages of each of generation technologies: wind turbines and solar modules generate electricity based on wind and sun availability, biomass and hydro power generation use to balance out short term fluctuations in generation (caused by errors of weather predictions for wind and solar generation) or temporarily stored.

Table below shows the energy generation portfolio for “Combined Power Plant”

	Wind	Solar	Biogas	Reservoirs	Import/Export	Total
Installed Capacity [MW]	12.6	5.5	4.0	1.06	-/1.0	-
Electrical energy [GWh/a]	26.5	6.2	10.8	-0.6	0.02/1.8	41.1 (43.5)
% of Total	60.9	14.3	24.8	-	-	100.0

The range of nominal power for the individual generation units is quite broad and lies in between 30kW gas turbine to 3 x 2.000 kW wind park.

Test results have proved that aggregation of distributed renewable fluctuating and controllable generation units being self sufficient and obtaining a total generation capacity of several MW can actually participate in electricity trade markets (including balancing trade and reserve provision, avoided grid utilisation, peak shaving) and supply any load profile needed for real consumers.

6.1.4 Load management. Demand Side Response (DSR)

Electricity produced in different time periods of the day has different value. This difference reflects in electricity prices, which are different for base and peak load power on the wholesale market.

“Load management” means reducing electricity consumption for short time periods when electricity grid is under stress.

If the marginal peak load price is higher than the value of services consumed by customers within the peak time period the conclusion can be made that peak time demand has to be modified, for example it is reduced by switching off electric devices or by reducing light consumption.

Another reason which can cause necessity of modification of electricity consumption from the grid is minimisation of the difference in predicted power amount and power amount has to be realised in a real time.

Deviations of the consumption predictions are closer to real consumption amount in the period of 5-15 min ahead, therefore to cover the difference each device has to be represented by a control agent, which tries to operate process associated with the device in an optimal economical way.

On a bigger scale it has to be done by using automatic electronic communication system between grid operator and DSR participants.

Therefore customer can benefit because that grid operator is indifferent whom to pay: a power producer to supply more output or to pay the same amount to a customer for reduction of electricity consumption.

Aggregations of “consolidation” DSR service providers, representing a bundle of householders at the wholesale market, are able to explore this market niche. It is also could be helpful to mitigate intermittency effect in power generation and supply.

As a result DSR makes the electricity demand curve more elastic and it is able to reduce the need for reserves in electricity markets.

To approve that approach, attracting the number of small power generators to participation in electricity market trade on a local or regional levels special project “Virtuelles Kraftwerk Harz” VPP has been realised in Germany [3]

In accordance with that project up to 1.000 micro CHP systems installed in private houses (with power in a range from 5-5,5 kW el. to 10,3-12,5 kW el.) and another 2 MW of large generation systems have been integrated in to a common energy generation portfolio.

Main project targets are: reduction of peak power demand in the regional grid and therefore reduction of electricity and grid utilisation costs.

6.2 Micro-grids

Micro-grid, a local energy network, offers integration of DER generation units with local electric loads.

Such advanced, integrated distribution system addresses the need for application in:

- locations with electric supply and/or
- delivery constraints, in remote sites, and
- protection of critical loads and
- economically sensitive development

Micro-grids are self-sufficient aggregations of micro power generation sources (< 500 kW), loads and energy storage devices, operating as a single system, providing both heat and power.

Micro-grids can be connected to the power network or can be operated autonomously similar to power systems of physical islands.

Micro-grid is connected to the distribution network through a single Point of Common Coupling (PCC) and appears to the network as a single unit composed by locally controlled loads and locally controlled generators.

As power generators in the micro-grids can be used micro-turbines, CHP, PV panels, reciprocating engines, wind and hydro generation units, etc. Micro-grid can take a form of industrial park or university campus.

Conditions and quality of service have to be determined by dependence of micro-grid on the need of the distribution system.

Main purpose of micro-grid management is an adjustment of the generation schedule to the availability of renewable sources, using information about weather conditions, energy price and forecasts of energy and thermal load demand. Scheduling has to be performed on an hourly base.

Example:

In a generic hour of the year (month or day) when load demand is low and wind speed is high and sale price is also high, micro-grid can sell energy to the network exploiting the wind generator at its maximum limit while other generation units remain switched off.

In another generic hour of the year (month or day) characterised by a good availability of high speed wind and a high load demand if purchasing energy, price is much higher than selling price, micro-grid can operate in island mode – satisfying its demand by its own generation output. As a result energy bills for all the customers of the micro-grid can be reduced.

7. Conclusion

1. To participate in electricity trade smaller RES/DG generators have to be physically integrated into (at least) low voltage electricity network.

2. RES/DG technologies of intermittent generation type (wind and PV generation) are unable to participate in electricity trade market if deals close long time ahead of physical delivery of energy. To minimise possible imbalance in generation output electricity trading deals for wind and PV generation (as for standing alone generation unit as for aggregation of the number of units) have to be closed for the time period nearest to starting point of electricity delivery and consumption.

3. RES/DG technologies of constant/controllable generation type-CHP and hydro power generation are able to fulfil their contract obligations taken on long time before physical delivery of energy.

4. Participation in trade at Day Ahead market is a possible option for wind and PV generation, but it is necessary to be ready to bear financial punishment for possible imbalance that can occur in generation output. CHP and hydro power generation can participate in trade at Day Ahead market with low level of financial risk.

5. Participation in trade at Intraday market for wind and PV generation is a most promising option and risk of imbalance fees payment is moderate. CHP and hydro power generation can participate in Intraday market trade with minimal financial risk.

6. For expansion of options for electricity market trade for RES/DG technologies of intermittent generation type these technologies have to be in cooperation with energy storage systems and/or another RES/DG technologies and/or with technologies of conventional type.

7. To minimise possible imbalance in generation output connected with weather forecast error, electricity trading deals for wind power and PV generation (for standing alone generation unit and for aggregations of the number of units) have to be closed for the time period nearest to starting point of electricity delivery, and/or aggregation of a number of wind power or PV generation units have to be spread over a geographically wide territory and/or each standing alone generation unit or aggregation of number of generation units have to be connected with energy storage unit and/or with output controllable generator(s)–CHP and/or hydropower.

8. If small sized and micro- generation units, being alone, are not able to afford market financial requirements or technical conditions in respect to bid/offer sizes (0.1 MWh or 1 MWh, as was mentioned already) and therefore are not able to participate in electricity market trade of any type independently on they have another options to sell their generation result becoming a third party (subcontractor) in electricity market trade for large power producers or to be included in a common electricity trade package of large power producer or to be included in aggregations of power generation units of all RES/DG generation types, including conventional types of power generation

9. Creation of aggregations helps to increase total output in the range of several MW and decrease an influence of weather forecast error for wind and PV generation technologies in periods of high wind speed and stable solar irradiation and also CHP and hydro power technologies can participate in different types of balancing provision: tertiary control, peak shaving, net metering provision, congestion management.

10. To obtain maximum result from combined operation of number of stable/controllable power generation units-CHP and hydro power, and units of intermittent power generation type-wind power and PV, intelligent management is necessary.

11. Intelligent management operation has to consist of three stages:

    a) Determination of demand profile for the electricity market product and for the local thermal demand

    b) Prediction of the final RES generation profile includes all operated stable/controllable and intermittent power generation units. It can be done by adjusting the schedules of stable RES/DG generation units (CHP), boiler or/and motor generators and controllable loads to preliminary predicted generation results of intermittent power generation units (wind, PV)

    c) Combining final RES generation profile with prognosis for the general load schedule to obtain final balance between them

12. Simultaneous use of renewable technology units and boilers or/and motor generators and also controllable loads gives an opportunity not only to participate in all types of electricity markets trade but can significantly cover the area of balancing service provision, such as tertiary control, peak shaving, congestion management, etc.

13. Aggregations of “consolidation” Demand Side Response (DSR) service providers, representing a bundle of householders at the wholesale market, are able to mitigate intermittency effect in power generation and supply and to explore this market niche. As a result DSR makes the electricity demand curve more elastic and it is able to reduce the need for reserves in electricity markets.

14. Micro-grid - local energy network, offers an integration of RES/DG generation units with local electric loads connected to the distribution network through a single Point of Common Coupling(PCC) and appears to the network as a single unit composed by locally controlled loads and locally controlled generators. Micro-grid can sell energy to the network in the periods when electricity generation at its maximum limit coincides with high electricity price or to operate in island mode.

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9. APPENDIX

Table1 Correspondence of RES/DG single and aggregated technologies to marketing options

Type of RES/DG technologies with (total) output not less than 0.1 MWh	**Marketing options available**
CHP and Hydro power alongside standing generation unit	Future market, Day Ahead, Intraday, Tertiary Control*, Peak shaving, Net metering, Congestion management (including Avoided grid utilisation), Load management (Demand side respond), Micro-grids, OTC trade via Standard and Not Standard Bilateral Contracts
Aggregation of CHP and Hydro power generation units	Future market, Day Ahead, Intraday, Tertiary Control*, Peak shaving, Net metering, Congestion management (including Avoided grid utilisation), Load management (Demand side respond), Micro-grids, OTC trade via Standard Bilateral Contracts, OTC trade via Not Standard Bilateral Contracts
Wind power or PV alongside standing generation unit	Day Ahead**, Intraday, Tertiary Control*, Peak shaving**, Net metering**, Avoided grid utilisation**, Micro-grids, OTC trade via Not Standard Bilateral Contracts
Aggregations of Wind power or PV generation units	Day Ahead**, Intraday, Tertiary Control**, Peak shaving**, Net metering**, Avoided grid utilisation** Micro-grids, OTC trade via Not Standard Bilateral Contracts
Aggregations of different RES/DG technological types generation units (including Virtual Power Plants) using Intelligent Management	Future market, Day Ahead, Intraday, Tertiary Control*, Peak shaving, Net metering, Congestion management (including Avoided grid utilisation), Load management (Demand side respond), Micro-grids, OTC trade via Standard and Not Standard Bilateral Contracts

Table 1 (continuing)

Aggregations of different RES/DG technological types generation units(including Virtual Power Plants) and large conventional generation units and controllable load) using Intelligent Management	Future market, Day Ahead, Intraday, Tertiary Control*, Peak shaving, Net metering, Congestion management (including Avoided grid utilisation), Load management (Demand side respond), Micro-grids, OTC trade via Standard and Not Standard Bilateral Contracts
Aggregations of different RES/DG technological types generation units(including Virtual Power Plants) and large conventional generation units and controllable load) using Intelligent Management	Future market, Day Ahead, Intraday, Tertiary Control*, Peak shaving, Net metering, Congestion management (including Avoided grid utilisation), Load management (Demand side respond), Micro-grids, OTC trade via Standard and Not Standard Bilateral Contracts

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Legend

* Possible if (total) output is within range of 1-15 MW

** Possible in periods of high wind speed or stable sun irradiation