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Abstract: This report is part “d” of the Task 5.1 of the Dispower project. It identifies the market-driven services relevant to DG+RES to be further developed in the WP, describes their data contents according to a definite structure including explanatory part, the designation of interested parties, a detailed description of input and output parameters (data source/sink, attributes, units, time steps, formats), the way of data processing as well as graphical user interface, if available.

The partners involved in the sub-task are LABEIN (task leader), ISET (sub-task leader), ICCS, APX, ALSTOM and UMIST.

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1 Introduction

This report is part “d” of the Task 5.1 of the Dispower project. The overall objective of the WP5 is the development of internet-based information network with service pools providing existing and new developed information services. Sub-task 5.1d introduces the market-driven services to be further developed in the WP 5, describes their data contents according to the unified form.

Firstly, the services relevant to DG+RES are identified within the WP. Secondly, the description of services follows a definite structure including explanatory part, the designation of interested parties, a detailed description of input and output parameters (data source/sink, attributes, units, time steps, and formats), the way of data processing as well as graphical user interface, if available.

The partners involved in the sub-task are LABEIN (task leader), ISET (sub-task leader), ICCS, APX, ALSTOM and UMIST.

Section 2 developed by ALSTOM provides the bidding principles to be used in Market Operation and defines the input and output data for a bidding strategy.

Sections 3 and 4 developed by APX provide the functional specification of the day ahead market and the concept specification for adjustment market in the Amsterdam Power Exchange. These fully describe the respective market processes providing necessary data inputs and outputs as well as graphical user interface where available. The possibility of participation of RES and CHP units in the electricity trading on the APX is also considered in the work.

An evaluation model to monitor real time power feed-in form wind turbines into a large supply area is described by ISET in Section 5. The online monitoring model observes power output from several representative wind farms and is able to extrapolate it to larger areas with a high level of precision. The online monitoring combined with the accurate numerical weather prediction and the determination of accessory wind turbines power output, using artificial neural networks form a base for the advanced wind power prediction tool developed by ISET and represented in Section 6.

The description of another wind power prediction tool developed in the framework of the project MORE CARE, which is based on the three main approaches – adaptive fuzzy-neural networks, parametric power curve model, and artificial neural networks model – is provided by ICCS in Section 7.

The Section 8 provided by LABEIN deals with advanced power plants scheduling, which objective is to make the scheduling of the power plants based not only on the market arrangements but to take into account the adjustments that have to be done to cope with the generation of renewables.

It is considered in the Section 9 prepared by ISET that a wind power plant operator will be able to provide the voltage control service by injection or absorption of reactive power, if variable-speed turbines are used and a control signal form utility is given.

Section 10 provided by UMIST describes active management of distribution networks, which presents opportunities to create a whole range of new services that can be provided by DG to or by distribution network operators to DG companies.

Section 11 makes an overview of the data requirements form previous Sections. The data will be needed to develop the information system in the WP 5 to provide new market-driven services demanded by different players in the liberalised electricity markets.

2 PRINCIPLES OF MARKET OPERATION – STRATEGY AND BIDDING

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2.1 Introduction

Traders, power producers and industrial energy consumers have today several opportunities to buy and sell energy on power exchanges and/or balancing markets. This trading diversity will introduce more and more complexity to the market participants in evaluating the potential revenue they can get out of these different markets.

A decision support application can help the user in the determination of a bidding strategy by maximizing his expected profit while keeping his risk exposure below a limit value. The application would take advantages of the market price forecasts and their standard deviations while taking into account transmission, technical and strategic constraints.

Such an application can be used by all the market participants. Indeed, it can be used by a GenCO trying to sell its remaining energy and/or trying to buy energy in order to reduce its scheduled energy if it is economic to do so. At the same time, it can be used by an industrial consumer (eligible consumer) to buy energy or to sell its previously contracted energy if it is economic to do so. In this paper, by generation bids, we will consider a generation increase for a GenCO and a scheduled consumption decrease for a load. By load bids, we will consider a generation decrease for a GenCO and a consumption increase for a load.

However, defining a bidding strategy is particularly complex for a GenCO owning power wind farms. When awarded, the GenCO could be exposed to pay a deviation penalty (depending on the market rules) in case of wind power delivery failure. Such a risk has to be mitigated hedging partly its renewable energy bids with conventional generation.

The bidding strategy is highly linked with risk strategy. It would vary significantly from a user to another depending of his risk-loving or risk-adverse behaviour. There is a trade-off to define between risk and reward: to obtain a greater expected profit, one must be willing to take on greater risk. In a more concrete formulation, by putting a higher price on generation bids, we can expect a better payoff, but we increase the risk not to be selected, and consequently to loose a potential revenue. The risk exposure of a strategy must be correctly evaluated, and the risk measure has to be relevant to get pertinent results. As a result, the risk measure should represent these potential profit losses (lost opportunity).

Once bids have been determined (including for each bid the energy quantity and price, and targeted market place), these bids can feed a bidding interface application. This application is able to deal with different market places, whatever is the market place type (day-ahead market, balancing market, ...). The application interfaces automatically to the market places supplying the required data and retrieving results through an adapted mechanism. Depending of the concerned market place, it can be a CSV file, an XML file, etc. More, the bidding interface application has the following main characteristics:

- Market place restricted access requirements
- Automatic or on-request bid submission
- Automatic or on-request bid award and market information retrieval
- Audit trail and technical log

Last, the bidding strategy application may also be used for an after-the-fact analysis, comparing the real results with the expected results. It would help the GenCos to correct their bidding strategy.

2.2 Information Requirements

Input of the bidding strategy application

The following data are required in input to define a bidding strategy from the current scheduling situation:

- Global data
  - Minimum profit [Euros]
- Generator / load data
  - Entity location [area]
  - Overgeneration factor [-]
  - Initial schedule [MW]
  - Ramp Up [MW/hour]
  - Ramp Down [MW/hour]
  - Incremental blocks by period:
    - Incremental MW block [MW]
    - Incremental block cost [Euros/MWh]
  - Decremental blocks by period:
    - Decremental MW block [MW]
    - Decremental block cost [Euros/MWh]
- Market data
  - Location [Area]
  - Price history and/or forecast
    - Market price by period [Euros/MWh]
    - Market standard deviation by period [-]

    or

    - Market price range by period [Euros/MWh]
    - Market range realization probability by period [-]

Output of the bidding strategy application

The results of the bidding strategy application (i.e. the bid data) will feed the bidding interface application. The main results will be:

- Global data
  - MW blocks
    - Market MW block [MW] by market, generator/load and period
    - Market MW price [Euros/MWh] by market, generator/load and period
    - Market MW maximum profit [Euros] by market, generator/load and period
    - Market MW expected profit [Euros] by market, generator/load and period
    - Market MW awarding probability [-] by market, generator/load and period
- Global Risk exposure [Euros]
- Profit
  - Total maximum profit [Euros]
  - Total minimum profit [Euros]
  - Total expected profit [Euros]

3 Functional Specification for Day Ahead Market in the Amsterdam Power Exchange

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3.1 Introduction

Until the early nineties the power market was dominated by power generating and –consuming institutes, the distribution companies. These institutes were in the possession of communities and governmental departments. Common use was that these institutes closed long term (years) contracts for the production, supply and distribution of electricity. Most industries and citizens were designated to their local electricity supplier. They had no choice to select a supplier of electricity and hence the Power institutes had no driving force to improve efficiency. In fact the Power market was closed.

In the beginning of 1990 people began to realize that the power market was not a free competitive market. In some countries an incentive rose to liberalise the Power market. England and Norway started to change laws to enable liberalisation. As a consequence the first Power Exchange started in 1992 in Norway which is called Nordpool. From 1996 a Power Exchange was erected in the England named UKPX which was not really successful. Nordpool appeared to be quite successful with the exchange of electricity contracts for the Day Ahead (Spot contracts) and serves now Sweden and Finland too. Producers and consumers were able to balance their position by means of these contracts. Nowadays Nordpool services also future- and forward contracts. Per 1-1-1998 OMEL in Spain started a Power Exchange for the Spot Market. This Exchange is highly regulated by the government meaning that the Exchange costs are socialised and every participant in the electricity spot market is obliged to balance herself via OMEL.

In May 1999 the Amsterdam Power Exchange (APX) in the Netherlands was opened. This Exchange produces daily contracts for the Day Ahead Market (DAM) involving about 15% of the daily electricity consumption in the Netherlands. Late 1999 Germany opened its Power spot market in Leipzig named LPX followed by France (Powernext), Poland (Guilda) and Slovenia (Borzen).

All exchanges are based on an order driven system except UKPX. An order driven system concerns an Auction System. This means that Participants in the Power Market submit sale- or purchase orders for the 24 hours of the following day. The auction System matches these orders to one common Market Clearing Price (MCP) and one Market Clearing Volume (MCV). Each order can be contracted for its whole- or partly volume.

3.2 Purpose of a Day Ahead Market

All activities as mentioned in the previous chapter had one objective in common namely increase of competition and transparency of the electricity- or Power market. The philosophy behind this is that electricity prices will reduce due to a force for improvement of generation- and distribution efficiency. The 24 hour prices, produced by a DAM, will be used as reference for bilateral contracts and hence used as reference in contractual negotiations. These daily 24 prices are referenced as a price index which is also used for margining of forward contracts.

Participants who own a solar-, wind-, wave or CHP generation system (DG&RES) can make use of the DAM by submitting price limit hourly orders or – block of hour orders directly or via a Power Exchange Member (PEM). The purpose of a PEM is to decrease the financial- and operational barrier for such a participant in operating on a DAM. A PEM is of absolute importance in creating liquidity in the spot market and hence transparency. They can have an important share in decreasing the effects of Market Power Abuse.

3.3 Inputs to the Process of DAM

Participants (Producers, Distributors and PEM's) who wish to obtain a sale- or purchase contract have to submit their 24 hour requirements for the Day Ahead. For this purpose they have a secured client interface on their PC at their disposal. They have to submit following data as described in par 3.1 and 3.2.

3.3.1 Data contents of the input

From Participant to Auction:

1 *Ordinary order:*

1 PA code

2 Date/time

3 Type: Sale/Purchase

4 Volume/hour in MW with a tick of 0.1 MW

5 Price/hour with a tick of €0.01

2 *Block order:*

1 PA code

2 Date/time

3 Type: Sale/Purchase

4 Volume in MW with a tick of 0.1 MW

5 Start/end hours

6 Limit price with a tick of €0.01

3.3.2 Graphical user interface

This interface is the tool for a participant to input his daily orders.

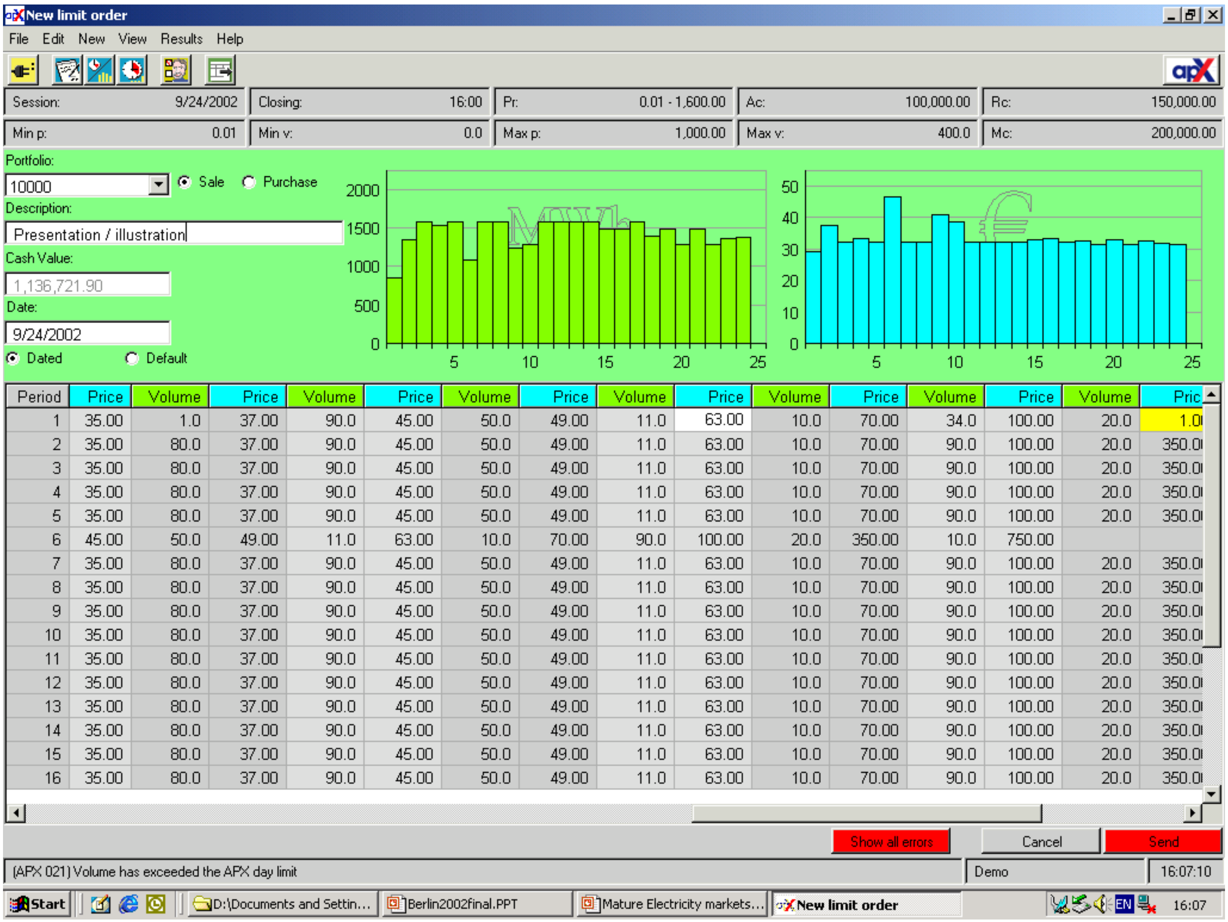

Figure 3-1: Graphical user interface for bidding.

This interface protects a trader to enter mistakes by real-time alerts. Mistakes lighten in yellow or read the entry in the screen. Per price/volume pair the financial limits of a particular trader are checked. Also the total volume and value of the traders' portfolio are checked against its limits. The limits are adjustable for each trader by the Participants System Manager.

3.4 Functional Description of the Process of DAM

3.4.1 Market opening

The DAM opens in the morning at 8:00hrs in case of the Dutch APX. During the opening, participants can send in orders for each hour of the following day. These orders can be:

- Ordinary Limit orders for each hour. The limit concerns the maximum price which a buyer is willing to pay or the minimum price which a seller is prepared to receive.

- Block Limit order. This order is defined by a number of consecutive hours with an equal volume per hour. The order is contracted when the volume for all hours is contracted and when the average MCP does not hit the limit price. Block Orders are flexible in duration and time position.

The APX applies an auction-based (order driven) trading system. The system receives from opening at 8:00AM orders (bids and offers per hour or block of hours) from the participants until closing time at 10:30AM. Received orders are checked by so called Market Operators at APX to look for particularities which require verbal communication with the concerning trader.

3.4.2 Matching

After closure the matching of sale- and purchase orders starts. This means that the system aggregates these orders into a supply curve and a demand curve, the market clearing price (MCP) and -volume (MCV) being determined at the intersection. See Figure 3-2.

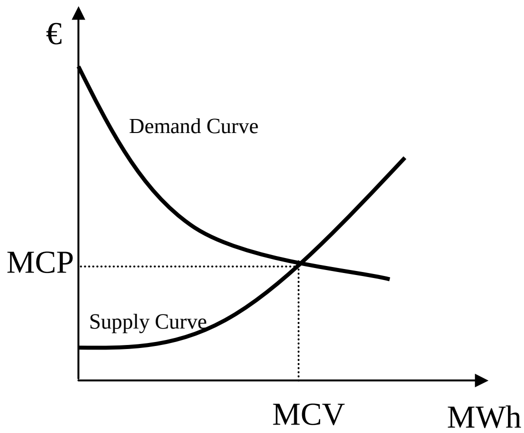

Figure 3-2: Determination of MCP and MCV.

Figure 3-2 concerns the matching of one hour. After a complete matching, the system has generated 24 MCP's and MCV's. Block Orders are only matched when the average MCP during their hours is equal or higher than their sale limit price and equal or lower than their purchase limit price. Moreover their complete volume has to be matched.

3.4.3 Clearing

After matching the contracted volumes and prices of each participant are published. Each participant can only see his own results per submitted order. Following the system publishes at 11:00AM the MCP's and MCV's and 24 aggregated sale- and purchase curves to a public Website of APX. The MCP's are referenced as the APX price index.

3.4.4 Settlement

This sub process calculates for each participant his debts or revenues, Debts will be deducted from a participants collateral. Moreover the system defines for each participant an E-schedule. All this information will be sent to each participant. The participant uses his E-schedule to compose his own schedule which he has to submit to the Transmission System Operator (TSO). The APX system sends for each participant his E-schedule to the TSO. In this way the TSO can make consistency checks for each participant.

For security reasons each participant has to deposit and maintain a collateral on a bank account. Only when this collateral is sufficient the participant can submit purchase orders.

Each seventh day the participant will be invoiced for his aggregated debts or revenues.

3.5 Outputs from the process of DAM

3.5.1 Data contents of the output

<u>To Participant</u>

1 Volume (matched)

2 Hour

3 MCP

4 MCV

5 Required Collateral

6 Costs or revenues

<u>To TSO:</u>

1 Participant name

2 Participant Code

3 Date

4 Hour

5 Volume (sale or purchase)

3.5.2 Graphical user interface

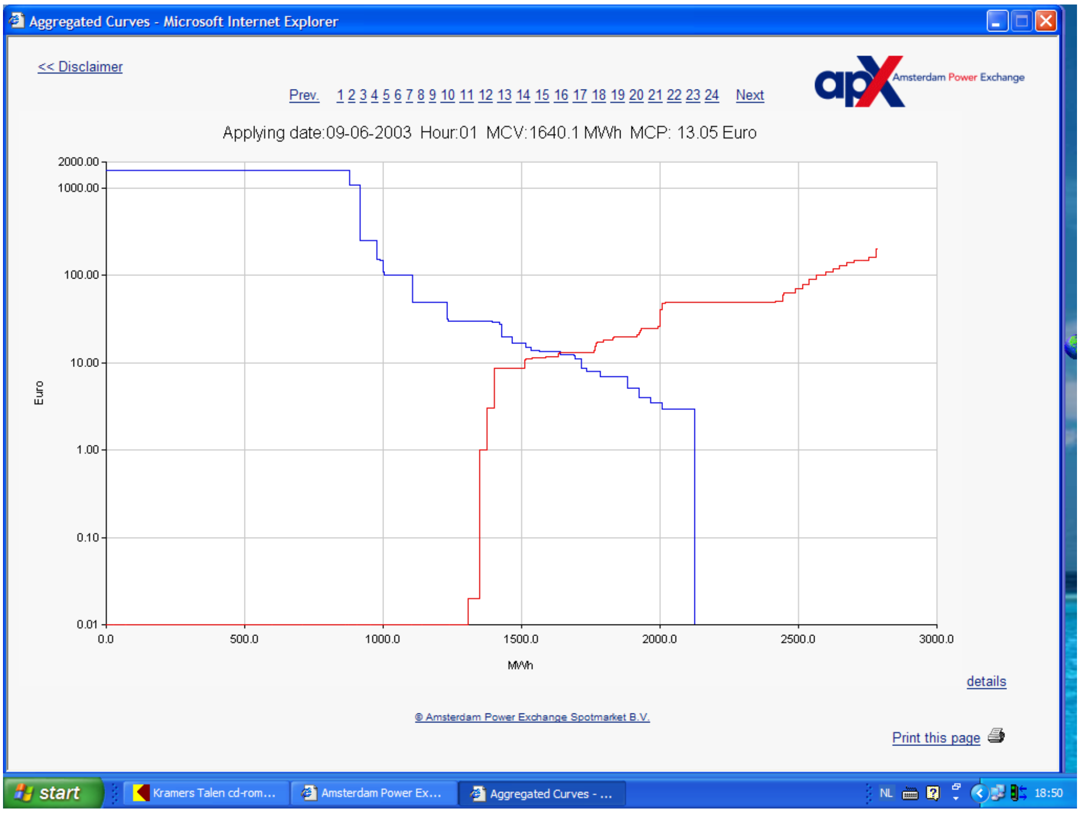

Figure 3-3: Graphical user interface – trade results.

Matching results applying date: 09-06-2003

Indices for the HUB NL

	Average Price	Volume
Day (All hours)	11.60 eur.	39926.4 MWh
Peak hours (8 to 23)	15.15 eur.	25460.5 MWh
Off Peak hours (24 to 7)	4.52 eur.	14465.9 MWh

Hourly Details for the HUB NL

	1	2	3	4	5	6	7	8	9	10	11	12
Volume (MWh.)	1640.1	1777.3	1743.9	1841.0	1821.8	1938.6	2073.2	1813.0	1513.5	1591.9	1600.0	1563.9

Price (Eur.)	13.05	.45	.94	1.00	.55	.10	.01	2.94	4.05	9.11	16.96	18.34

	13	14	15	16	17	18	19	20	21	22	23	24
Volume (MWh.)	1549.5	1581.6	1555.9	1671.1	1628.8	1560.1	1429.2	1471.6	1563.1	1602.6	1764.7	1630.0
Price (Eur.)	17.16	15.33	14.00	14.00	14.00	14.00	17.40	18.34	21.76	22.00	22.96	20.04

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4 Concept Specification for Adjustment Market

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4.1 Introduction

After the erection of a Power Exchange for the Day Ahead Market the requirements rose for a Intraday- or Adjustment Market in several countries in Europe. This appeared to be the fact in Spain were OMEL operates such a market and in Finland the exchange ELBAS which serves Sweden, Norway and Finland. This latter exchange is a separate additional service to the Nordpool Power Exchange for the Day Ahead in those countries. OMEL is an integrated Power Exchange for the Day Ahead and Intraday.

The Adjustment Market must be seen as a complement to the Day Ahead Market. The Day Ahead Market results combined with a Forecasting Tool are generally the input to an Adjustment Market.

APX does not operate an Adjustment Market yet. However at the moment several solutions for such a market are under study. This document describes a concept which may be feasible for implementation.

4.2 Purpose of an Adjustment Market

Participants who are operating on the electricity spot market (Day Ahead Market) often have the need to adjust their contractual obligations established by this market. There can be many causes like disturbances of the electricity generation, deviation of electricity consumption due to fall out of a product plant, sudden changes of environmental (weather) conditions etc.

A change of weather conditions can be predicted accurately by sophisticated forecasting systems nowadays. These systems predict an adjustment on top of the contractual obligations for the Day Ahead or even in the course of the running day.

Reason why a participant wishes to adjust his electricity production or –consumption program is to avoid high imbalance costs to be paid to his Transport System Operator (TSO). This reason is in fact an economical reason.

Conclusion is that a participant wants to mitigate his risk by access of an Adjustment Market which is so liquid that it supplies:

a) Resilience. This means the ability to buy or sell electricity without disturbing the price too much (with predictable variation).

b) Immediacy. Ability to buy or sell immediately.

4.3 Inputs to the Process of an Adjustment Market

Data contents of the input from Day Ahead Market Auction:

1 Limit order:

2 PA code

3 Date/time

4 Type: Sale/Purchase

5 Volume/PTU in MW with a tick of 0.1 MW

6 Limit Price/PTU with a tick of €0.01

Data contents of the input from Participant:

1 Limit order:

2 PA code

3 Date/time

4 Type: Sale/Purchase

5 Volume/PTU in MW with a tick of 0.1 MW

6 Limit Price/PTU with a tick of €0.01

4.4 Functional Description of the Process of Adjustment Market

4.4.1 Adjustment Time Horizon

The time horizon for effect of adjustments is established by the Dutch Transport System Operator (TSO). In the Netherlands a participant in the electricity market has to submit his daily 24 hour electricity consumption- or production schedule (E-program) for the day ahead to the TSO before 12:00AM. This E-program can be the result of a contract concluded by the APX-auction or bilateral contract. Between 12:00AM and 2:00PM corrective communication between a participant and TSO is possible. At 4:00PM the TSO confirms the firmness of the E-programs for the day ahead to the participants. After 4:00PM a participant can submit adjustments for the E-program of the day ahead but also during the day of execution of the E-program.

During the adjustment time horizon adjusted E-programs have to be sent to the TSO at least one hour before the adjustment can be made effective. This is the so called Gate Closure Time (GCT). For instance when a participant wants an adjustment for hour N:00, he has to send in his E-program before hour N-1:00.

4.4.2 Adjustment Market Products

After submission of a participant’s E-program for the day ahead there may be many events which require adaptation or reshape of an E-program. Since an E-program is based on a

Program Time Unit (PTU) of 1 hour, it can contain 24 hours for which a participant may wish to alter the volume. For this reason the Adjustment Market serves 24 hour products as a basis. It is APX in consideration to decrease the PTU to 15 minutes.

A product specification consists of {PTU; volume; type; limit price} where type can be a Purchase- or Sale Limit Order.

Products are tradable for the current day and the next day only when the GCT has not been exceeded.

4.4.3 Adjustment Market Process

Opening Phase

After the auction of the Day Ahead Market (DAM) at 11:00 the orders which are not matched (contracted) are transferred to the system for the Adjustment Market (AM) and placed in its order book. Participants who own these orders are able to delete or modify these orders. At 2:00PM, after agreement of the E-program with the TSO, a participant is able to submit adjustment orders for the day ahead to the AM.

The Opening Phase executes a process for simulation to determine an indicative opening price and an indicative surplus – i.e. demand or supply – for each of the products eligible for trading. The algorithm will be applied to the orders and quotes entered until that moment. The potential opening prices and surpluses are published to all participants through a Market Window.

No real execution of trades (contracting) is undertaken during this phase.

Only limit orders and quotes will be taken into account for indicative opening price calculation.

Products eligible for trading are products which are executable. This means that they are beyond their Gate Closure Time (GCT)>

Freeze Phase

This phase involves the matching and contracting of all tradable orders at the Executable Time Line (ETL) at 2:30PM. The resulting E-programmes will be sent to TSO before 4:00PM to become in effect for the time span of 5:00PM until the next day at 24:00. Tradable orders which are not matched stay in the order book for the following ETL.

ETL’s are definable by the Market Operator of the Power Exchange. Definition of the ETL’s will be negotiated with the Participants.

It is foreseen that at least 2 ETL’s are required: one at 2:30PM and one at 7:30AM on the next day. Depending on market requirements more ETL’s can be activated.

4.4.4 Clearing

After matching the contracted volumes and prices of each participant are published. Each participant can only see his own results per submitted order. Following the system publishes 30 minutes after each ETL the MCP’s and MCV’s and 24 aggregated sale- and purchase curves to a public Website of APX. The MCP’s are referenced as the APX Adjustment Market price index.

4.4.5 Settlement

This sub process calculates for each participant his debts or revenues, Debts will be deducted from a participants collateral resulting in his Actual Collateral. Moreover the system defines for each participant a new adjusted E-program which will be submitted to the Transmission System Operator (TSO). According to the newly implemented system code in NL, participants do not need to send in there adjusted E-program. This so called Single Sided Nomination (SSN) relieves participants of administrative burden.

For security reasons each participant has to deposit and maintain a collateral on a bank account. Only when this collateral is sufficient to cover the intended transaction the participant can submit purchase orders.

Each seventh day the participant will be invoiced for his aggregated debts or revenues.

4.5 Outputs from the process of Power Exchange

Data contents of the output To Participant

1 Volume (matched)

2 PTU

3 MCP

4 MCV

5 Actual Collateral

Data contents of the output To TSO:

1 Participant name

2 Participant Code

3 Date

4 PTU

5 Volume (sale or purchase)

5 Online wind power monitoring

Kurt Rohrig; Bernhard Ernst; Cornel Ensslin; Alexander Badelin

Iset e.V.

Transmission system operators need up-to-date information about the cumulative power injection into the network as well as detailed information about intermittent power injections aggregated by network regions and nodes. However, the equipping of all WTGs with measurement systems is hardly realistic.

Online monitoring requires an evaluation model which allows the observed time power output of representative wind farms to be transmitted to the total feed-in from WTGs of a larger supply area. This model transforms the observed power output from representative wind farms into the total wind power input into the grid.

The actual wind power input is determined by extensive equation systems and parameters, which consider various conditions, such as the spatial distribution of WTGs or environmental influences. The observed data from the selected wind farms is thereby transmitted online to the control centre.

The wind generation curves evaluated online are retrospectively compared with curves computed by the "Spatial Extrapolation based Power Calculation Model", SEPCaMo developed by ISET, and are continually conformed and improved by means of parameter optimising.

SEPCaMo generates data concerning simultaneously fed-in wind power from all WTGS in arbitrarily defined supply areas, through the evaluation of observed power and wind signals. To achieve this, measured wind and power data at selected locations, is transferred to all WTGs operating in the close proximity. This regular testing and conforming of parameters obtains a high level of precision for the described procedure.

The online monitoring of wind power production can be provided for different objects:

- single wind turbine
- wind farm
- cluster
- control area (this example)
- country.

5.1 Input

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	SCADA		1	Active power mean value	kW	1 sec - 15 min	XML or ASCII
			2	Location	Node		
2	Installation database	ISET	1	Location	Long/lat	One-time	
			2	WT data (rated power, hub height, control type)			
			3	Roughness length	m		

5.2 Processing

ISET

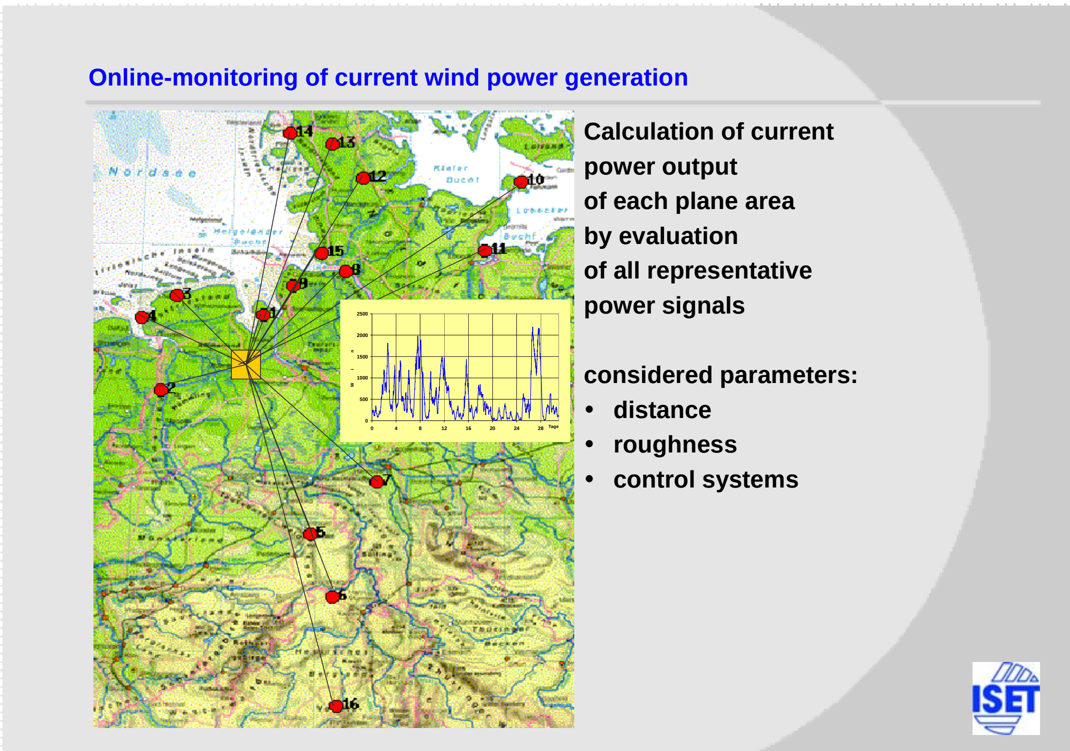


Figure 5-1: Online monitoring of current wind power generation.

5.3 Output

Data contents of the output:

#	Designation	Receiver	Data contents				
			#	**Attribute**	**Unit**	**Time step**	**Format**
1	Wind power production	TSO	1	Active power mean value	kW	15 min	XML or ASCI
			2	Location	Node		

The output of predicted data corresponds to curve points (see below).

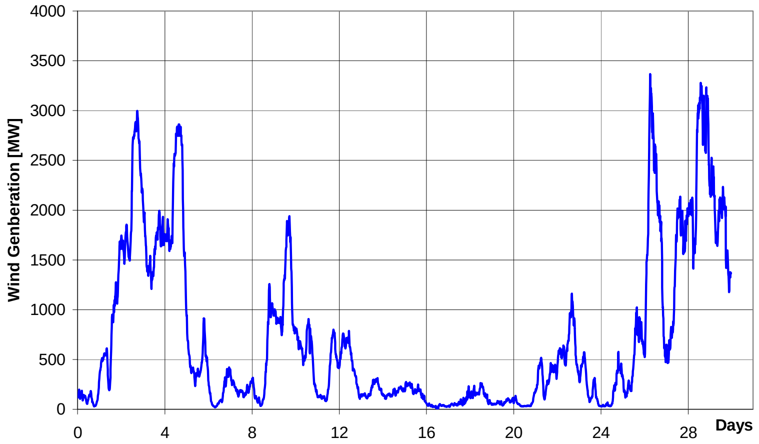


Figure 5-2: Output of on-line monitoring tool.

6 The ISET Advanced Wind Power Prediction Tool

Kurt Rohrig; Bernhard Ernst; Cornel Ensslin; Alexander Badelin
Iset e.V.

A major barrier to the integration of wind power into the grid concerns its variability. Because of its dependence on the weather, the output cannot be guaranteed at any particular time. This makes planning the overall balance of the grid difficult, and biases utilities against the use of wind power.

Accurate monitoring and forecasting of power inputs from all wind turbine generator systems (WTGS) into the grid will improve the perception of wind power and considerably increase its market value. The improved integration of wind generation into the electrical power system will lead to new assessment and a higher capacity level.

Therefore, a procedure is required, which determines the actual and expected wind power in a precise and detailed manner, and conveys this information to the power system management as well as to the wind farm operators.

The development and verification of this procedure depends on three steps:

- the exact statistical analysis of observed power inputs from WTGS in the supply areas concerned
- the online monitoring of wind power inputs
- the precise determination of the expected wind power

Network operators of major energy supply utilities and electricity transmission companies currently make use of numerical weather prediction (NWP) and Artificial Neural Networks (ANN) to predict the general level of electricity demand. ANNs operate by emulating the way a human brain functions. Their advantages over standard computing are that they can both 'learn' from experience, and 'guess' or interpolate results, even when their inputs are contradictory or incomplete.

The wind power prediction model is effectively based on a hybrid of three proven approaches:

- the accurate numerical weather prediction
- the determination of the accessory WTG power output, using ANNs
- the transformation of the predicted power to the total power input into the utilities' grid by the online-model.

The inputs to the ANN include the observed power from WTGS and the predicted wind speed and direction. The model is trained, using past wind and power data, to recognise the relationships between variations in the wind and the power output of the WTs.

These trained networks compute the predicted wind power output of the representative wind farms which is used for input of the online model. Therefore the online model allows a prediction of the total wind power feed-in of large utility supply areas, based on only a few locations with predicted wind speed.

The model can provide wind power prediction for different time spans:

- 1 hour
- 1 day (this example)
- 1 week
- 1 month
- 1 quarter
- 1 year

as well as for different objects:

- single wind turbine
- wind farm
- cluster
- control area (this example)
- country.

6.1 Input

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Meteorological data for the period of prediction	DWD	1	Wind speed mean-value	m/s	One hour	XML or ASCII
			2	Wind direction	Grad		
			3	Air pressure mean value	hPa		
			4	Air temperature	°C		
			5	Air humidity	%		
			6	Location	Long/lat Height		
2	SCADA	Owner	1	Active power mean value	kW	15 min - one hour	XML or ASCII
			2	Reactive power mean value	kVar		
			3	Apparent power mean value	kVA		
3	Installation database	ISET	1	Location	Long/lat	One-time	
			2	WT data (rated power, hub height, control type)			
			3	Roughness length	m		

6.2 Processing

ISET

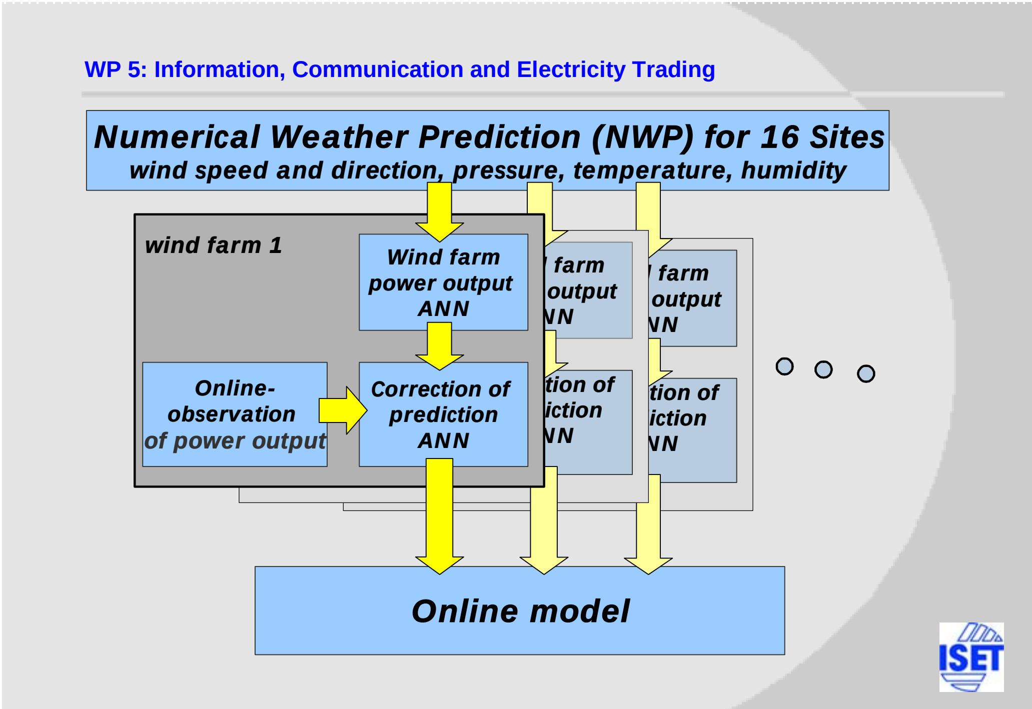


Figure 6-1: Representation of the data processing for wind power prediction

The prediction can be regularly updated when new data comes. The horizon of prediction can be set to needed values.

6.3 Output

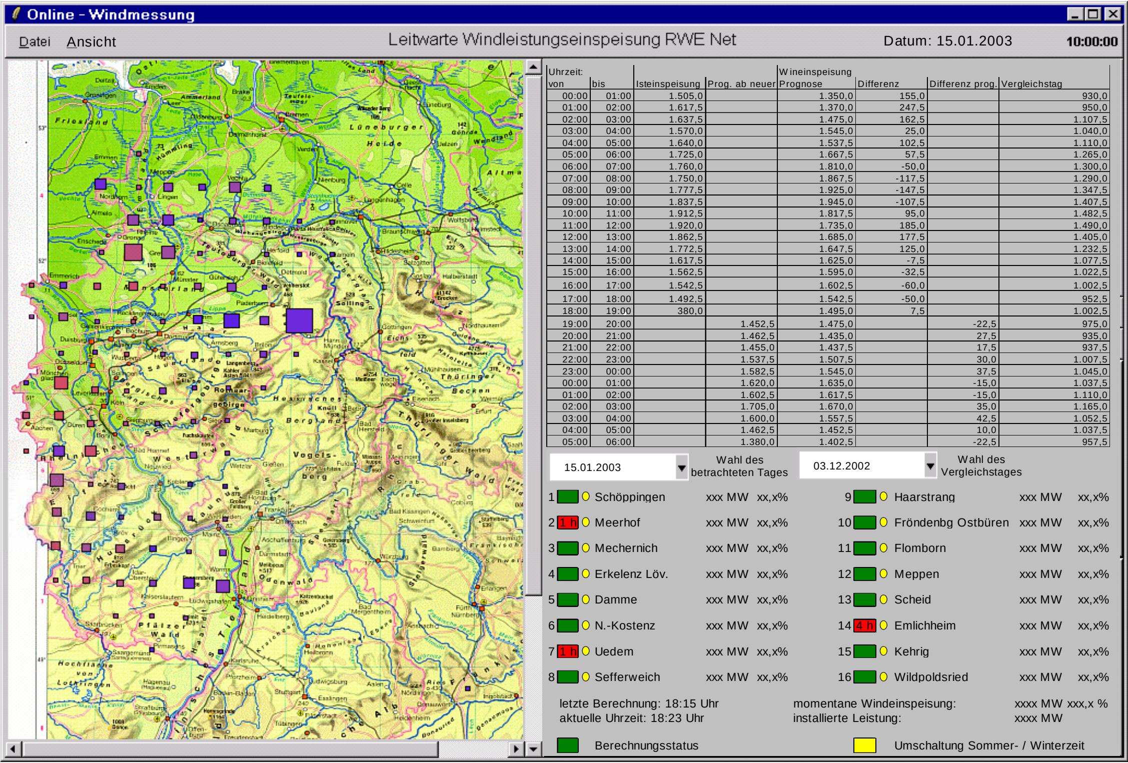
a) Data contents of the output:

#	Designation	Receiver	Data contents				
			#	**Attribute**	**Unit**	**Time step**	**Format**
1	Wind power predicted values	TSO	1	Active power mean value	kW	15 min - one hour	XML or ASCII
			2	Energy production	kWh		
			3	Fluctuation	%		
			4	Location	Node		

The output of predicted data corresponds to the table values and/or to curve points, presented in the proposed graphical user interface (see Figure 6-2).

b) Graphical user interface:

Gestaltungsvorschlag RWE-Net



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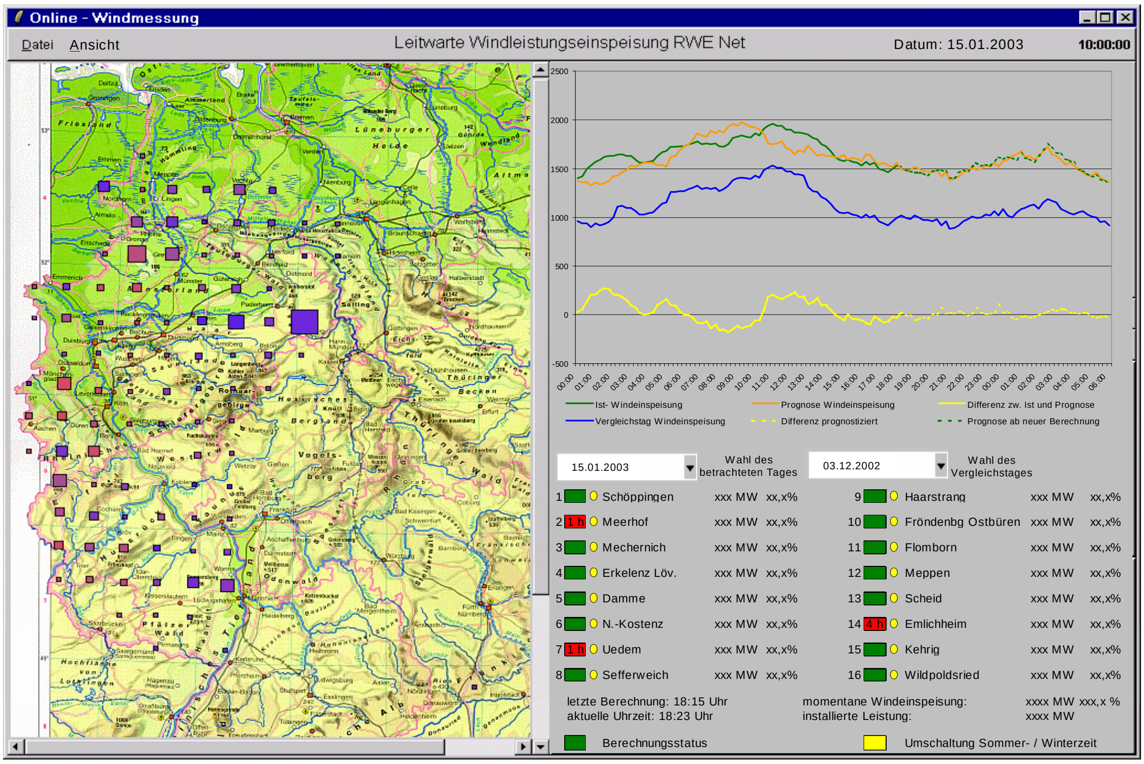

Figure 6-2: Graphical user interface of ISET wind power prediction tool.

7 The MORE CARE Wind Power Prediction Tool

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ICCS/NTUA

7.1 Introduction

Short-term forecasts of the wind farms production, up to 48 hours ahead, are necessary for secure and economic large-scale wind power integration. Wind power prediction tools are useful for end-users such as Independent Power Producers, Transmission and Distribution System Operators (TSO/DSO), Energy Service Providers (ESP) etc. In a liberalised electricity market environment, such tools enhance the competitiveness of wind power, since they reduce the penalties resulting from the wind resource intermittence. Reduced operational and financial risk for the wind farm developers is a motivating factor for undertaking investments on wind farms. Hence, accurate wind power prediction tools contribute indirectly to the increase of the installed wind power capacity.

In the frame of More-Care project three main approaches have been developed belonging mainly to the statistical approach:

{WF-1} Adaptive fuzzy-neural networks.

These are models based on adaptive fuzzy neural networks. Appropriate configurations were developed for short and long-term forecasting considering SCADA input and eventually numerical weather predictions.

{LF-2} Parametric power curve model.

This model is based on an optimised power curve that converts meteorological forecasts to wind power production.

{LF-3} Artificial neural networks model.

These are models based on classical backpropagation neural networks.

These prediction modules have been integrated in the More-Care Energy Management System together with other functions like economic dispatch, unit commitment etc (installed in Crete and Madeira), but also have been applied as a stand alone application having the unique function to predict the power output of a number of wind farms (application in Ireland).

The wind power forecasting modules provide:

1. Short-term forecasts for the next 8-12 hours ahead with a time-step of 10-20 minutes.

2. Longer-term forecasts for the next 48 hours with a time-step of 1 hour. These forecasts are updated every 1 hour as new data arrive (sliding window).

Frequent updates of the wind power predictions are necessary for systems with large penetration since they permit to reduce the prediction risk by considering recent available information.

7.2 Information Requirements and Services

Input

Source	Attribute	Type	Time step	Description
Meteorological Forecast	Pressure	mmHg	1h	Curves from Meteorological Prediction Station. There is a forecast for each WF separately
	Temperature	^{0}C		
	Wind Speed	m/sec		
	Wind Direction	Deg		
On line Data	Wind Farm Production	kW	20min	From SCADA
	Wind Speed	m/sec		
	Wind Direction	Deg		
Historic Data	Wind Farm Production	Curve (kW)	20min	From MORE CARE Database
Static Data	Wind Farm Location and Topological Data	Long,Lat, Height etc	Static	From MORE CARE Database
	Wind Farm Technical (Installed W/T, SCADA Details etc)			
	Wind Turbine Technical Data (Curves, Max power etc)			

Two types of on-line input are required according to the type of forecasting model. Short term models need historical and real-time input from the SCADA system, such as:

- wind speed values,
- wind direction,
- wind turbines power,
- wind turbines availability,
- pressure and
- temperature.

Models based on meteorological information use as input forecasts for the next 48 hours of:

- wind speed,
- direction,
- pressure and
- temperature.

The meteorological data are obtained from external to More-Care numerical weather prediction systems (such as HIRLAM for Eire or SKIRON for Crete) using FTP or similar services. The above data refer to specific geographical grid points and are used as input to the More-Care models to produce more accurate forecasts for each specific wind farm site.

A part from the on-line data is necessary to include the following input in the database:

- Data describing the directional correlation by wind direction sector derived from a Wasp model (if any) of the wind farm site. These correlations convert the wind speed/direction predicted by the Hirlam model (or measured at a specific point in the wind farm) to the appropriate wind speed at hub-height, allowing for directional effects. In the absence of wind direction data a default value is entered accounting for any difference in height between the prediction/measurement and hub-height of the wind turbines.
- The wind turbines characteristic power curves are included in the database as standard models to convert wind speed to power.
- For a more accurate conversion, a "dynamic power curve" for the wind farm can be included to convert wind speed to wind power. This may need to be a 3-D representation to account for wind speed and wind direction variables. The "dynamic power curve" will be updated on-line to correct for phenomena such as landscape, array effects, and any historical deterioration in performance.
- The values of the models coefficients are saved in the data-base. This will facilitate the model maintenance. Moreover, it is convenient that the implementation of a model in a computer code is generic, e.g. the number of parameters (order) in an ARMA model or the number of neurons in a neural network is parameterised and the corresponding value is archived in the database.

Output

<table>
<tr><th>File</th><th>Attribute</th><th>Type</th><th>Time step</th><th>Description</th></tr>
<tr><td rowspan="4">Long Term Wind Forecast</td><td>WF Power Prediction</td><td>Curve (kW)</td><td rowspan="4">1h</td><td rowspan="4">48 Hours Horizon</td></tr>
<tr><td>WF Power Prediction Confidence Interval</td><td>Curve (kW)</td></tr>
<tr><td>WF Speed Prediction</td><td>Curve (m/sec)</td></tr>
<tr><td>WF Speed Prediction Confidence Interval</td><td>Curve (m/sec)</td></tr>
<tr><td rowspan="4">Short Term Wind Forecast</td><td>WF Power Prediction</td><td>Curve (kW)</td><td rowspan="4">20min</td><td rowspan="4">8 Hours Horizon</td></tr>
<tr><td>WF Power Prediction Confidence Interval</td><td>Curve (kW)</td></tr>
<tr><td>WF Speed Prediction</td><td>Curve (m/sec)</td></tr>
<tr><td>WF Speed Prediction Confidence Interval</td><td>Curve (m/sec)</td></tr>
</table>

The output of the two available types of models, time-series and meteorological, varies depending on the type of the model. Moreover, these two types of models produce forecasts with different time steps and different horizons. Short-term and long-term forecasts are combined to provide a common profile for the next 48 hours.

The output of the WPF module is a set of values for each wind park:

- forecasted wind speed profile (by short and long term models).
- forecasted wind speed direction (by long term models).

- forecasted wind turbines power output (directly predicted by short-term models or estimated after conversion of wind speed forecasts to power).

All the above types of output are stored into the database to gain flexibility (e.: since several Unit Commitment models may use their specific ways to project wind speed to power). The forecasted wind speed or power profile are characterised by the following quantities which are given for each time-step:

- a spot value (wind speed or power)
- the confidence intervals for this forecast.
- minimum and maximum expected values.

Output should be provided for either individual wind farms or groups of wind farms - this should be easily programmable by the user.

Horizon/Time-step

The time-series wind forecasting models produce efficient forecasts for horizons of 4-10 hours ahead. These horizons correspond to the main-UC and the ED functions. Such forecasts can be updated every 20 minutes using SCADA data (sliding window scheme).

The meteorological model based on SKIRON data produces forecasts once per day at 12:00 for the next 72 hours with an hourly step. The HIRLAM forecasts are provided with a similar frequency.

MMI requirements

The MMI should allow the user to easily see the forecast outputs from individual wind farms for 0 to 48 hours ahead in tabular and graphical format.

- The MMI should allow the user to easily see the forecast outputs from groups of windfarms for 0 to 48 hours ahead in tabular and graphical format.
- The MMI should allow the user to view historical data used by the program.
- The MMI should allow comparison of forecasts with actual data where it becomes available.
- The MMI should facilitate the export of output data to excel.

7.3 Description of information network services

The MORE CARE Environment

Particular emphasis has been placed on the provision of a user-friendly MMI interface to ensure acceptability by the system operators. Its basic philosophy is to provide all the essential information graphically on a single screen, while a number of “windows” is available on call to provide explanatory information or other results. The information permanently displayed provides the current state of the system (production and load), production, load and renewable forecast for 12 hours ahead contrasted to yesterday's values and permanent monitoring of the dynamic security for any of the disturbances selected. The user is able to specify which of the alternative modules are employed for each of the function, and parameters relevant to the operation of each module.

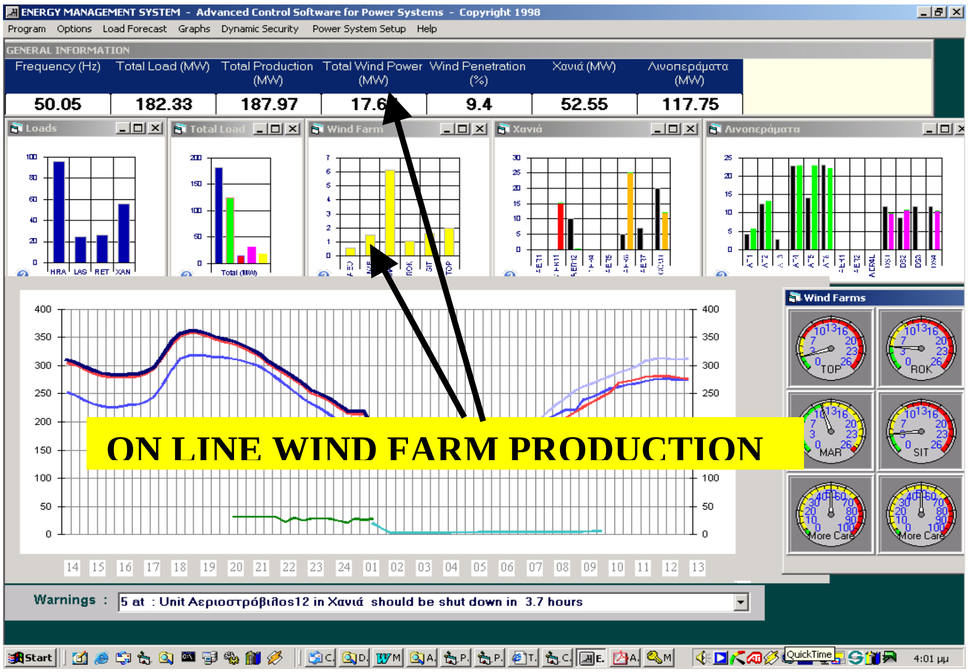

Figure 7-1: MORE CARE Environment

In Figure 7-1 the MORE CARE main screen is shown. The upper part, which includes the banner and the five small flow-charts provides an overview of the current operating state of the system as refreshed every minute by the SCADA online database. The main graph provides the forecasting information for the system with its recent history. This window spans a period of 24 hours.

The output of the Unit Commitment Module (see Figure 8-1) can be provided on call. This window spans also a period of 24 hours. The unit commitment module includes the wind farm production and takes into account security and system stability issues.

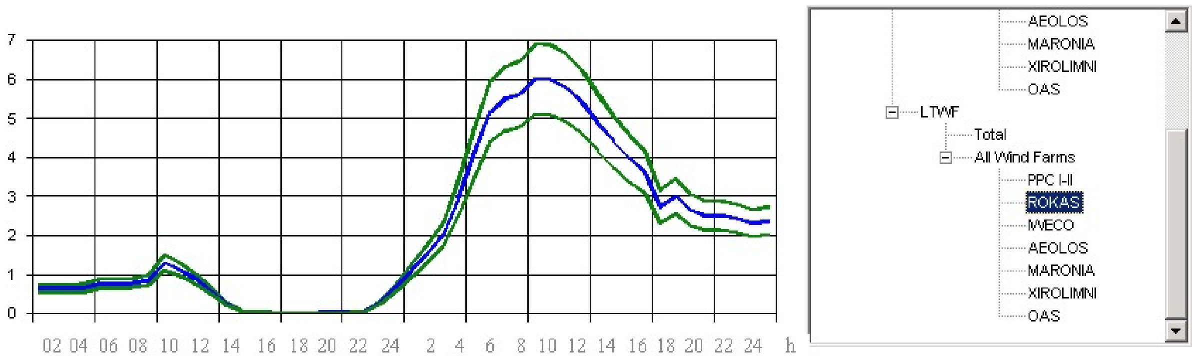

Figure 7-2: Wind Forecast Chart

The diagram of Figure 7-2 is the Wind Forecast. The operator can display forecasts for the next 8h (Short Term Forecast) or for the next 48h (Long Term Forecast) for each Wind Farm, as well as of the total wind power production. In addition, the confidence intervals of every forecast are provided. Finally, the operator has the facility to print the forecast in graphical or numerical form for further elaboration.

8 Advanced power plant scheduling

Inaki Laresgoiti
LABEIN

The objective of the advanced power plant scheduling is to make the scheduling of the power plants based not only on the market arrangements but to take into account the adjustments that have to be done to cope with the generation of renewables.

This service will provide the adjustments to the scheduling of the power plants that should need to be done with a large penetration of renewables taking into consideration that the current regulation in Spain forces the transmission and distribution companies to buy all renewable energy connected. Then, in this situation and to keep the balance between consumption and generation, the output of some controllable plants has to be modified.

8.1 Input

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Wind power plants generation curves	Owner	1	Energy-time curve	MWh	1 hour	XML of ASCII
2	Consumption curves	TSO	1	Energy-time curve	MWh	1 hour	XML of ASCII
3	Grid topology						
4	Market price	OMEL	1	Price-time curve	€/kWh	1 hour	XML of ASCII
5	Generator characteristics	Generator owner	1	Lower ramp rate	MW/min		
			2	Raise ramp rate	MW/min		
			3	Stop ramp rate	MW/min		
			4	Start ramp rate	MW/min		
			5	Maximum capacity	MWh		
			6	Minimum capacity	MWh		
			7	Operating cost-curve	€/hour-MW		
			8	Emission curve	Kg/hour-MW		

8.2 Processing

Processing of the data will amount to calculate the output curve of the generators, based on the renewables generation, environmental impact reduction, economic factors and generation ramp rates.

8.3 Output

a) Data contents of the output:

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Assigned generation curve	Generators	1	Energy-time curve	MWh	1 hour	

b) Graphical user interface

A graphical user interface is able to show the generation curve for each power plant.

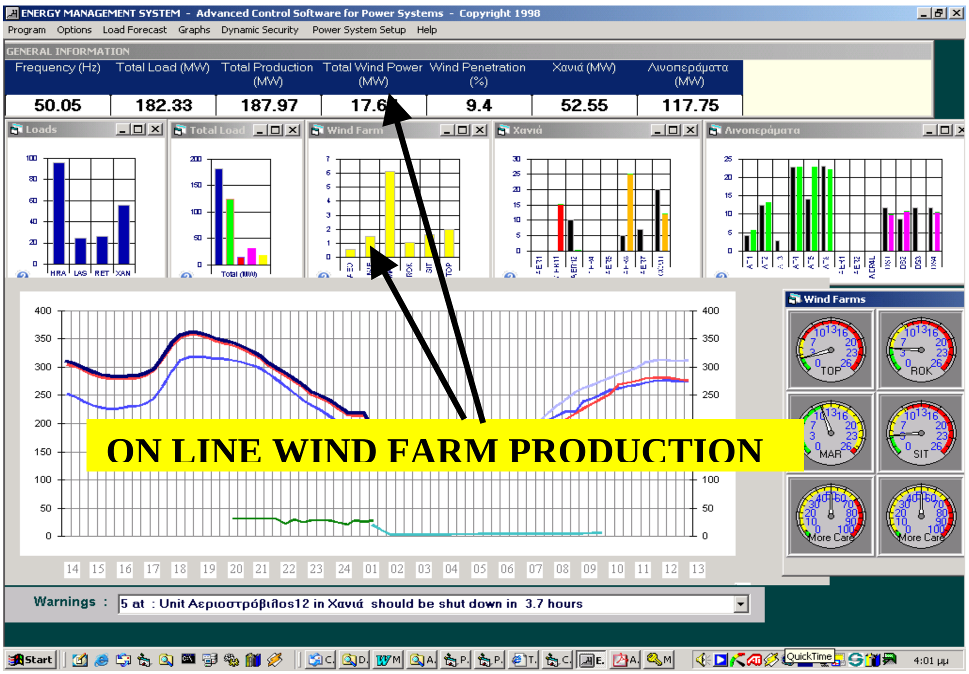

Figure 8-1: Conceptual graphical user interface

9 Reactive power supply and voltage control

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Iset e.V.

First wind plants using induction generators were installed with inadequate hardware for reactive power compensation. As a result, utilities experienced increased line losses and difficulty controlling system voltage.

But now, power electronics technology used with modern, variable-speed wind turbines has demonstrated a full range of power factor control under all operating conditions. Reactive power compensation even works when there is no wind and the rotor blades are not rotating.

It makes possible for a wind plant operator to provide the voltage control service by injection or absorption of reactive power. Of course, it would then be necessary for the utility to provide a signal for the demand for reactive power.

9.1 Input

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	SCADA	Owner	1	Location	Network node		XML or ASCII
			2	Reactive power current output	kVar	1sec-30 min	XML or ASCII
			3	Voltage	kV	1sec-30 min	XML or ASCII
2	Installation database	ISET (in Germany) Owner	1	Location	Long/lat	One-time	
			2	WT data (rated power, hub height, control type, reactive power capacity)			

9.2 Processing

The value of reactive power currently supplied (or consumed) by the respective wind farm is indicated alongside with the reactive power capacity, giving the currently available delta for voltage control.

9.3 Output

a) Data contents of the output:

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Current reactive power supply	TSO	1	Reactive power current output	kVar	15 min	XML or ASCII
2	Total reactive power capacity	TSO	1	Reactive power capacity	kVar	One time	XML or ASCII
3	Currently available reactive power capacity	TSO	1	Reactive power capacity	kVar	15 min	XML or ASCII
4	Location	TSO	1	Node			XML or ASCII

10 Distribution Network Services

Nick Jenkins; Joseph Mutale

UMIST

10.1 Type of services

Preliminary studies have indicated that active management of distribution networks can increase the amount of DG that can be connected to existing networks by a factor of 3 to 5 obviating the need to reinforce the networks. Active management of distribution networks presents opportunities to create a whole range of new services that can be provided by DG to distribution network operators (DNOs) or by DNOs to DG companies. Unbundling of distribution network services is an essential prerequisite to the realisation these services. Unbundling of distribution network services is discussed in the following section focusing on the type of services that can be offered.

10.2 Unbundling of Distribution Network Services

The primary responsibilities of distribution companies are (i) to maintain voltage fluctuations on the system within statutory limits (specified by corresponding standards) and (ii) to ensure that the service quality delivered to consumers of electricity is adequate. As a consequence of the historical development of distribution systems, distribution network operators (DNOs) have traditionally met these objectives by employing the operational and development practices involving the use of assets, facilities and resources owned and managed by the DNOs.

With introduction of DG, distribution networks, in addition, are expected to offer a non-discriminatory open access to the networks and facilitate competition in generation and supply sectors. This requirement introduces a new role of distribution networks. DNOs are now required to provide network services to generators and to enable them to take part in provision of such services.

The conventional approach to network operation considerably limits the amount of DG that can be connected, as DG is effectively excluded from the opportunity to support network operators in carrying out their primary duties and also from receiving enhanced services from the operator which would provide more choice in connection (active management).

Clearly, this new role of distribution networks requires unbundling of distribution network services and the development of commercial arrangements within which distribution network operators would carry out their responsibilities at least cost and efficiently, by using services from a number of potential providers (Figure 10-1). Under this scenario a DNO would maintain the responsibility of managing all components of service quality, but the means of achieving this objective would involve not only distribution network facilities, but also make use of the inputs provided by DG, and in general, by demand-side management, storage facilities, reactive compensation facilities including an active interchange of services between the DNO and transmission network operator (TNO) on the distribution-transmission boundary.

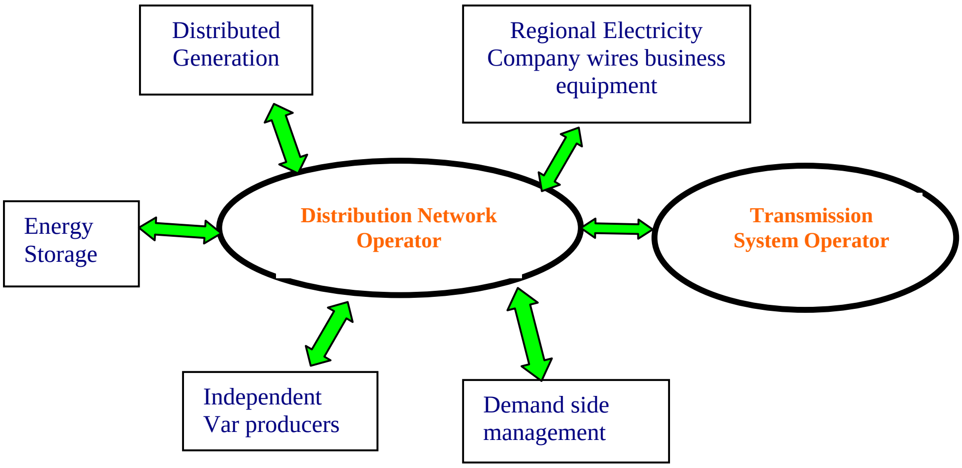

Figure 10-1: Framework for commercial integration of DG

In the context of DG, this concept would open a possibility for generators to provide DNOs with network support (substitute for network capacity), with voltage regulation and contribute to service quality.

On the other hand, DNOs could offer enhanced network services to generators, such as active distribution management and enable them to control their connection costs. The value of various services provided by and to DNOs could be determined on a market basis.

In this model clearly, DNOs would continue to manage physical assets on their networks but in addition would also act as market operators.

In the context of voltage regulation, for example, the relative competitiveness among alternative sources for the provision of voltage regulation services will depend on the cost associated with each individual option, its ability to impact the voltage and service quality (Figure 10-1).

It is important to recognise that the costs of some sources for voltage regulation are primarily capital in nature, while others are operational. For example, network assets and compensation devices normally have high investment component and relatively low operational expenditure associate with their usage, while constraining generators would incur cost associated with the lost opportunities in the energy markets (as described above). The evaluation of the most efficient portfolio of options will require minimisation of the overall services cost over a horizon of one to several years.

Although the development of a detailed commercial structure for the operation of unbundled distribution networks is beyond the scope of this work, the issue of access to distribution networks (and the risk of not having it) is at the heart of this approach and is hence discussed more in conceptual terms. This is very much related to the concepts of deep and shallow connection policies in relation to firm versus non-firm access.

In some countries, distributed generators are required to pay deep connection charges. Consistent with this connection policy, DGs should have firm access to energy market (unconstrained operation). This firmness is of course financial rather than physical. This should imply that the generators are financially protected from constraints on the distribution network. In other words, if distribution network limits the amount of energy that the generator is able to export, the DNO should compensate the generator for the loss of income (the fact that DNOs do not currently compensate generates is not relevant for this discussion).

By introducing active management, clearly, some portion of the output will be constrained. This is in line with the concept of non-firm access. Generator output will be constrained while DNOs would not be expected to compensate the generator for the curtailment. In this case, the generator should be required to pay only shallow connection cost.

The other important issue to be considered is the risk of maintaining the agreed level of access over the long run (level of constraints). However, the critical question here is whether this level of output could be guaranteed for the lifetime of the wind farm? For example, if the demand customers decide to relocate, the output of the wind farm would need to be constrained further because the voltage rise effect would become more binding, and will result in substantial additional curtailments of wind generation output. In this case, some of the wind farm assets would be stranded. Clearly, neither the DNO nor the wind farm developer has control over such a decision. Hence, the DNO cannot guarantee to absorb the output of the wind farm for an infinite period of time. Clearly, such an event would reopen the discussion between the DNO and the wind farm operator, as the previously agreed arrangement, whatever it might have been, would no longer be valid. The important consequence of this is that the risk of such events will need to be managed and it is likely to increase the capital cost of the wind farm, as the ability of the network to absorb the output would not be possible to guarantee over the long run.

A similar effect would occur if, at some point in the future, another generator wishes to connect at the same busbar. The DNO may not be able to deny the access of this new generator to their network on the basis of the existence of some other generator connected to the same feeder. Again, this will reopen the discussion between the DNO and the wind farm operator. One possible way of dealing with this particular situation would be establish a process by which these two generators would compete for the access to the DNO's network.

Similarly, if some new load connects to the busbar where the generator is connected, this will enable the wind farm to export its full output to the network and the active management services provided by the DNO will no be longer required and the generator should not be expected to pay for them. This would make DNOs active management facilities stranded.

Generally, access to electricity networks by users, both generators and loads, may be difficult to guarantee for a long period of time. Similarly, the users cannot guarantee the purchase of the network services from DNOs for a long period of time. This way the services provided to and by DNOs, in an arrangement shown in Figure 10-1 will need to be re-negotiated on a regular basis (perhaps every several years). Although this has not been particularly important due to small amounts of DG being connected, the issue of access will need to be addressed for larger penetrations.

10.3 Summary of data requirements

A summary of the data requirements in terms of inputs and outputs for realisation of the distribution management system necessary to support active management of distribution networks is presented below. The distribution management system controller (DMCS) is shown in Figure 10-2 with the inputs and outputs. The data inputs are shown in Table 10-1 below.

Table 10-1: Inputs

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Network data and Distribution Network topology	DN	1	R, X, B	Per unit	One time	XML or ASCII
			2	Topology		1 sec to 1 hour	

			3	OLTC settings	Per unit	1 sec to 1 hour	XML or ASCII
2	Distributed Generation data	Owner	1	Location	Node	One time	
			2	Output power	MW	1sec-30 min	XML or ASCII
			3	Reactive output	MVar	1sec-30 min	XML or ASCII
			4	Availability	%	24 hrs	XML or ASCII
2	Pseudo measurements	DN	1	Location	Node	One time	
			2	Voltage	V	One time	XML or ASCII
			3	Current	A	One time	XML or ASCII
			4	Active Power	MW	One time	XML or ASCII
			5	Reactive Power	MVar	One time	XML or ASCII
3	Local measurements	DN	1	Location	Node	1sec-30 min	
			2	Voltage	V	1sec-30 min	XML or ASCII
			3	Current	A	1sec-30 min	XML or ASCII
			4	Active Power	MW	1sec-30 min	XML or ASCII
			5	Reactive Power	MVar	1sec-30 min	XML or ASCII
4	Remote measurements	(RTU)	1	Location	Node	1sec-30 min	
			2	Voltage	V	1sec-30 min	XML or ASCII
			3	Current	A	1sec-30 min	XML or ASCII
			4	Active Power	MW	1sec-30 min	XML or ASCII
			5	Reactive Power	MVar	1sec-30 min	XML or ASCII
5	Ancillary service contracts	DNO	1	Long term (Price-quantity-time)	€/kWh	6 months to one year	XML of ASCII
			2	Short term (Price-quantity-time)	€/kWh	30 min -1 hour	XML or ASCII

Processing

Two groups of inputs are fed into the DMSC. One group can be classified as technical data inputs and the other as commercial data inputs. The technical data inputs include the network data and topology information, active and reactive power including, voltage measurements etc. The commercial inputs would comprise a portfolio of various ancillary service contracts (AS contracts: long and short term). The objective of the DMSC is to find the optimal control schedule that will satisfy all the technical and commercial constraints at least cost while maximising output of DG. The DMSC architecture is shown in Figure 10-2.

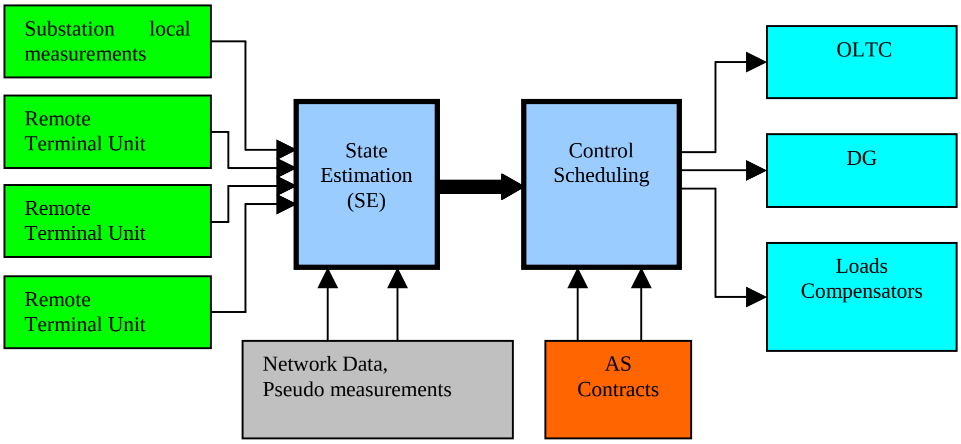

Figure 10-2: Distribution management system controller (DMSC) architecture

Outputs:

The main output of the DMSC is a control schedule indicating desired settings for transformer on-load tap changers, the optimal DG active power outputs, load levels for loads under demand side management schemes and desired output from energy storage schemes and lastly the reactive output for reactive power compensating devices. These outputs are summarised in Table 10-2.

Table 10-2: Data contents of the output:

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Control schedule	▪ DN wires (1) ▪ DG (2) ▪ Independent Var sources (4) ▪ TSO (1) ▪ Energy storage plant (3) ▪ Load management (3)	1	OLTC settings	Tap Position	1 sec – 1 hour	XML or ASCII
			2	DG active and reactive power output	MW/MVar	1 sec – 1 hour	XML or ASCII
			3	Load level	MW	1 sec – 1 hour	XML or ASCII
			4	Reactive compensation	MVar	1 sec – 1 hour	XML or ASCII

11 Overview of data requirements for the information system

- Characteristics of generators:

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Intermittent generators (here WT) database	Owner	1	Location	Long/lat Node	One-time	
			2	WT data: - rated power, - reactive power capacity, - hub height, - control type			
			3	Roughness parameter	m		
2	Characteristics of controllable DG	Owner	1	Location	Node	One time	
			2	Output power	MW		XML or ASCII
			3	Reactive output	MVar		XML or ASCII
			4	Availability	%	24 hrs	XML or ASCII

- Meteorological data

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Meteorological data for the period of forecast	DWD (Germany) MetOffice (UK)	1	Wind speed mean-value	m/s	One hour	XML or ASCII
			2	Wind direction	Grad		
			3	Air pressure mean value	hPa		
			4	Air temperature	°C		
			5	Air humidity	%		
			6	Location	Long/lat Height		
			7	Allocation to wind turbine / wind farm			
			8	Date, time			

- Current production and measurements

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	SCADA	Owner	1	Active power mean value	kW	1sec-30 min	XML or ASCII
			2	Reactive power mean value	kVar		
			3	Apparent power mean value	kVA		
			4	Location	Long/lat Node		
2	Calculated wind power production	ISET	1	Active power mean value	kW	15 min	XML or ASCII
			2	Reactive power mean value	kVar		
			3	Location	Node		
3	Pseudo measurements	DN	1	Location	Node	One time	
			2	Voltage	V	1sec-30 min	XML or ASCII
			3	Current	A	1sec-30 min	XML or ASCII
			4	Active Power	MW	1sec-30 min	XML or ASCII
			5	Reactive Power	MVar	1sec-30 min	XML or ASCII
4	Local measurements	DN	1	Location	Node	One time	
			2	Voltage	V	1sec-30 min	XML or ASCII
			3	Current	A	1sec-30 min	XML or ASCII
			4	Active Power	MW	1sec-30 min	XML or ASCII
			5	Reactive Power	MVar	1sec-30 min	XML or ASCII
5	Remote measurements	(RTU)	1	Location	Node	One time	
			2	Voltage	V	1sec-30 min	XML or ASCII
			3	Current	A	1sec-30 min	XML or ASCII
			4	Active Power	MW	1sec-30 min	XML or ASCII

			5	Reactive Power	MVar	1sec-30 min	XML or ASCII

- Prediction information

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Wind power predicted values for day ahead /hour ahead	TSO	1	Active power mean value	kW	15 min - one hour	XML or ASCII
			2	Energy production	kWh		
			3	Fluctuation	%		
			4	Location	Node /Area		
			5	Date, time			
2	Consumption curves	TSO	1	Energy-time curve	MWh	1 hour	XML of ASCII

- Scheduling

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Assigned generation curve	Generators	1	Energy-time curve	MWh	15 min- one hour	
2	Control schedule	▪ DN wires (1) ▪ DG (2) ▪ Independent Var sources (4) ▪ TSO (1) ▪ Energy storage plant (3) ▪ Load management (3)	1	OLTC settings	Tap Position	1 sec –1 hour	XML or ASCII
			2	DG active and reactive power output	MW/MVar	1 sec –1 hour	XML or ASCII
			3	Load level	MW	1 sec –1 hour	XML or ASCII
			4	Reactive compensation	MVar	1 sec –1 hour	XML or ASCII

- Market data

#	Designation	Source	Data contents				
			#	Attribute	Unit	Time step	Format
1	Market price	Power exchange	1	Price-time curve	€/kWh	1 hour	XML or ASCII
2	Ancillary service contracts	DNO	1	Long term (Price-quantity-time)	€/kWh	6 months to one year	XML or ASCII

			2	Short term (Price-quantity-time)	€/kWh	30 min -1 hour	XML or ASCII

3	Market price history and/or forecast	Trader	1	Market location (area)			
			2	Market price by period	€/MWh		
			3	Market standard deviation by period	-		
			4	Market price range by period	€/MWh		
			5	Market range realization probability by period	-		

- Bid data

#	Designation	Receiver	Data contents				
			#	Attribute	Unit	Time step	Format
1	Global data	Trader	1	Market location (area)			
			2	Date, time			
			3	Market block	MW		
			4	Market price	€/MWh		
			5	Market maximum profit	€		
			6	Market expected profit	€		
			7	Market awarding probability	-		
2	Risk	Trader	1	Global risk exposure	€		
3	Profit	Trader	1	Total maximum profit	€		
			2	Total minimum profit	€		
			3	Total expected profit	€		