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Totally Integrated Power

Technical Series Edition 10

Liberalised Energy Market – Smart Grid, Micro Grid

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Totally Integrated Power

Comparable to that of a vital blood vessel, the supply of electrical energy is the basis for reliable and efficient functioning of all building facilities. Thus, integrated solutions are wanted in the question of electric power distribution. Our answer is one of: Totally Integrated Power.

A lot of discussion has lately revolved around the smart grid, energy turnaround and electricity grids in need of upgrading. To better understand and assess the content of this discussion, a basic knowledge of the liberalised energy market with its legal tasks and structures is needed. The energy turnaround, including its regenerative, decentralised energy generation, provides new opportunities for consumers regarding purchasing the power. They are comprised within the smart grid and micro grid concepts.

A description is given of the interdependencies and participants of the liberalised electricity market as well as the procurement operations of power suppliers and consumers. Emphasis is very much placed on the consumer's viewpoint who is both a part of the liberalised power market and a participant within a smart grid.

Various scenarios illustrate the possibilities for the consumer as part of a smart grid. Suggestions from the consumer's point of view will also be sketched in as to how consumption and purchasing behaviour can be optimized.



Liberalised Energy Market

The liberalised energy market has been statutorily laid down within the European Union (EU) since the turn of the millennium. The resulting changes in the market have been implemented. The liberalised power market is part of the liberalised energy market.

History of the Liberalised Energy Market

Monopolies have established themselves since electrical energy was distributed at the end of the 19th century. In Germany this monopoly position was cemented through the Energy Industry Act from 1935 in conjunction with the GWB § 103(a) Act to prevent competition constraints. However later, the EU did not want to continue with its energy industry monopoly but wished to liberalise the power market instead.

In December 1996 an EU Directive specified what the liberalisation of the power market entailed. Its implementation into the legislation of the individual member states was concluded in 1999.

The monopoly position of the energy suppliers was lifted. The following divisions were established:

- Power generation,
- Power transfer,
- Power distribution and
- Power supply.

The idea was for this unbundling - brought about by separating generation, transmission, distribution and sales - to strengthen electricity supplier competitiveness. The power grids themselves were split into transmission and distribution grids but with the monopoly situation continuing to exist. The Bundesnetzagentur in Germany monitors nondiscriminatory access to the power grids and prevention of any extra benefits arising for users in grid usage payments and grid connection conditions.

An energy exchange was set up for power to be traded in conformity with market conditions.

Since the liberalisation of the power market, consumers have been free to choose their electricity supplier according to what they want (CO₂-neutral power, optimum-price power ...).

Electricity market liberalisation classifies the individual participants into a physical and a commercial category.

The energy/power from the power station flows across the power grids on the basis of the recognized rules of physics. As such, the flow of electricity is split into a meshed network, for instance, in accordance with the Kirchhoff rules.

Trade and billing of energy is reflected on the commercial side.

The customer is supplied with electricity by the electricity supplier who, in turn, purchases it from power stations or through the energy exchange.

In Germany there are 300 power generators (power stations) each generating over 1MW. The power grid operators include four transmission grid operators and approx. 940 distribution grid operators.

There are 1,150 electricity suppliers in Germany for consumers to choose from. 125 accredited electricity traders represent the electricity suppliers at the energy exchange. All in all, there are 45 million consumers ranging from domestic households through to industry and large enterprises. Besides the energy exchange in Leipzig, there are ten others in Europe.



Fig 1: Liberalised energy market

Functions and Roles of those Participating in the Liberalised Energy Market

Power generator

The power generator generates electricity in power stations and feeds it into either the transmission grid (> 100 MW) or a distribution grid. In the Rhineland brown coal mining area, RWE Power AG operates power station units in Niederaußem with a total of 3,864 MW of gross electrical output. For Grevenbroich the figure is 4,400 MW. As well as RWE Power AG, EnBW Kraftwerke AG, Vattenfall Europe AG and Steag GmbH operate large-scale power station units. The large-scale VW industrial power station in Wolfsburg has, for instance, a gross electrical output of 440 MW.

Transmission grid

The transmission grid is a supra-regional electricity grid transmitting large quantities of energy over considerable distances. Its operating voltages are 380 kV and 220 kV. Germany is divided into four transmission grids run by AMPRION, Tennet TSO, TransnetBW and 50Hertz Transmission.

Aside from transmitting energy, the transmission grid operator (TGO) ensures that frequency and voltage are controlled within the limits of EN 50160. As only the infrastructure belongs to the transmission grid operator, he must acquire the controlling power ranges (primary, secondary and tertiary reserves) to provide the frequency and voltage control on the market and call them up, if required.

The tasks and obligations of the transmission grid operator are saved as a set of standards & codes in the Transmission Code.

Distribution grid

Das The distribution grid supplies local areas with electricity; its operation is the responsibility of the distribution grid operator (DGO). The distribution grid obtains the electricity from the transmission grid and provides it for the consumer. Aside from a failure-free, continuous distribution of energy, the distribution grid operator is also responsible for voltage control within the limits of EN 50160. The consumer can be supplied with both low voltage and medium voltage electricity. Distribution grid operators are legally independent companies which have emerged from municipal or regional utilities.

As the distribution grid operator only owns the infrastructure he must procure the loss energy in his grid on the market.

The tasks and obligations of the distribution grid operator are saved as a set of standards & codes in the Distribution Code.

For operating the connection at the distribution grid, the consumer concludes a grid connection contract and a grid use contract for using the distribution grid with the distribution grid operator.

Metering point operator

The metering point operator owns and operates the measuring appliance between distribution grid operator and consumer. He provides the consumer, distribution grid operator and electricity supplier with the measurements in the near term and the consumer pays a fee for that.

The consumer has the right to freely choose his metering point operator.

Balancing group

Each consumer is assigned to a balancing group. Consumers with a consumption under 100,000 kWh/a are evaluated on the basis of standard load profiles; those with a larger purchasing quantity are defined by their own load profile.

Load profile

Load profiles characterize the demand behaviour of the consumer.

Beginning with each hour, the metering point operator measures the imported energy of customers with more than 100,000 kWh/a at ¼ -hour intervals. The ¼-hour demand values originate from the measured energy figures.

Some of the load profiles are also designated as load course, load curve, day or yearly curves.

Energy exchange

The European Energy Exchange (EEX) is a market place for energy and energy-related products. As a private trading company and an institution under public law, the EEX is subject to German Stock Exchange Law. Electricity is traded on the spot, intra-day and futures markets.

Electricity trader

Only authorized traders may trade at the energy exchange. They implement the orders of the electricity suppliers at the exchange.

Electricity supplier

Electricity suppliers supply the agreed quantities of electricity to the consumers. The electricity supplier bundles the purchase orders of his customer and purchases the electricity as base load, peak load, off-peak load or as hourly contracts directly at the power station or via the electricity traders at the energy exchange. The consumer concludes an electricity supply contract with the electricity supplier.

Electricity trading

The base load refers to a complete day (24 h) with a 1 MW supply. It is traded in 24 MWh units.

The peak load is the medium load and refers to the time between 8:00am and 8.00pm with a 1 MW supply. It is traded in 12 MWh units.

The off-peak load is hourly-based between midnight and 8:00am and between 8:00pm to midnight with a power supply of 1 MW. It is traded in 1 MWh units.

The hourly contract is the peak load on an hourly basis between 8:00am and 8:00pm with a energy supply of 1 MWh.

Intra-day trading involves 1 MWh energy supply being traded within the day for the following hour. Trading is possible up to 45 minutes before actual supply.



Fig 2: Electricity trading

Consumer

Physically, the consumer gets his electricity from the distribution grid operator and commercially from the electricity supplier. All told, he has four different contracts:

- the electricity supply contract with the electricity trader
- the grid use contract with the distribution grid operator
- the grid connection contract with the distribution grid operator
- the contract with the metering point operator on metering point operation at the end of the distribution grid.





② Load profile



Fig 3: Participants/roles on the liberalised electricity market

Notes:

A customer changing his electricity supplier has no effect on the electricity grid since the consumer's behaviour has not changed.

The entire liberalised energy market is based on forecasts. Any variations in forecasting need to be offset through the market.

Processes and Handling Steps

The liberalisation of the energy market within the EU (European Union) has resulted in the establishment of the processes and handling steps of the individual participants. Each participant assumes his role and seeks his optimisation within the legislation as laid down.

Electricity Procurement

The demand of all consumers needs to be forecast so as to adjust the production of electricity to the changing daily needs. Electricity production is then aligned to these forecasts.

Electricity supplier

Each electricity supplier within a distribution grid forecasts his load profile which is purchased by the Purchasing Dept. of the electricity supplier either directly at the power stations or by way of the energy exchange. The load profile is derived from the total of the load profiles of his customers (customers with under 100,000 kWh/a on the basis of standard load profiles, customers over 100,000 kWh/a on the basis of customer-specific load profiles).

Long-term forecasts are prepared for longer periods than a week; as such, the electricity suppliers cover their long-term demands directly at the power stations and/or via the exchange.

Extremely exact load profiles arise when the energy is forecast for the following week (on Thursday for the following week). The weather forecasts for calculating wind and solar power go into these forecasts. These weather forecasts with a prediction accuracy of over 90% are provided by specialist companies. Deviations resulting from the long-term forecasts and weekly ones are offset by purchasing or selling on the energy exchange.

In order to allow for short-term changes, a comparison of the weekly and daily forecasts for the following day is carried out every day. Here again, the differences are offset via the energy exchange (day-ahead trading).

The smallest unit of a set/actual comparison is one hour for the following hour. These differential quantities are traded in intra-day trading on the energy exchange.

All the differences between forecast and actual demand must be covered by the primary, secondary and tertiary reserve. Those causing this demand pay for the costs arising on a prorated basis.



Fig 4: Purchasing electricity

Consumers

The following mechanisms only relate to consumers with an energy consumption of over 100,000 kWh/a and who have a supply contract with ¼ h active-power metering.

In some cases even today a schedule clause within the supply contract is made use of:

".... Before the electricity is supplied - and to the extent as required - the parties to the contract will use the customer's load sequences to draw up a schedule and update it, as the case may be. In order to keep the required operating reserve as low as possible, the customer undertakes to inform the energy supplier in writing of any deviations from the usual consumption up to a week in advance." This schedule clause makes a forecast of the energy demand absolutely necessary.

Aside from preparing the forecast, the consumer must also keep to the resulting schedule. This necessitates a functionality on the consumer's side which monitors adherence to the schedule and possibly switches loads on /off and controls them.

The liberalised energy market is based on forecasts. If the consumer helps the electricity trader with reliable fore-casts, this support is remunerated.

Energy Schedule

The schedule results from the weekly forecast and is supplemented by an optimisation of the daily forecasts. The energy quantities specified here are ordered from the energy supplier and must be paid for. A tolerance range is allocated to the schedule within which the energy is delivered under fixed prices.

Adherence to the ¼ h Schedule Values

Controlling defined loads, generators or storage units within the ¼ h cycle enables ongoing demand to be adjusted so that the value from the schedule is kept to. The loads, generators and storage units are saved in a priority list and activated accordingly.

By leaving this tolerance range, energy costs arise from an increase in demand which orientate themselves to those of the current market. Reduced consumption is not rewarded.

Loads, generators and storage units are defined by their possible variable capacity, basic load, minimum and maximum switch-on time and their maximum switch-off time.



Fig 5: Electricity acquisition of the consumer

Scope for Influencing the Forecast

The possible scope for influencing is described in the example of an office building.

The forecast is composed of the individual parts of the demand of consumer load, storage unit and generator.

Each one independently prepares its own forecast made up of their sub-groups. Not every sub-group can be controlled. Only the readily available sub-groups are of interest for optimisation purposes. All the other sub-groups represent fixed loads; generation is positive and consumption is negative. This perspective simplifies an optimisation algorithm.

PV systems cannot be drawn upon for optimisation purposes. Energy production is determined by weather forecasts and the day/night cycle.

Co-generation of heat & power plants and geo-thermal plants are heat-controlled and thus not of interest for optimisation unless heat generation can be pushed between boiler and co-generation/geothermal plant.

Not being subject to any restrictions, generators - e.g. diesel machine units not operated as co-generation heat & power plants - can be included into optimisation. However, minimum turn-on times, minimum turn-off times, costs for running up/down and for the fuel are limiting in their effect. Heat accumulators, cold storage cylinders and batteries can be drawn upon for optimisation. Both their dead times and storage losses need to be taken into account.

Air conditioners must provide the heat and cold energy should the surrounding conditions need it. Shifting the operating point within the comfort zone can be drawn upon for optimisation.

The use of the building cannot be drawn upon for optimisation. The loads must be considered as given. Typical usage in the office comes from PCs, monitors, printers and lighting.

For a dependable forecast, the interdependencies between electricity, heat and cold need to be known. An (operating cost) optimisation can only come about through these interdependencies.

One can only resort to storage units and generators without co-generation of heat & power to optimise/change the forecast curve.

This is also the case when the dependencies of other types of energy (cold, heat) are included.

Note

If embedded generation produces more electricity within the plant than needed, this electricity is automatically fed back into the distribution grid. The distribution grid operator can stop this feedback should he have problems in controlling the grid. In instances of where the generating capacity is above 100 kW and feedback is undertaken, the distribution grid operator can draw upon these units to control/support the grid. Thus the change in the deployment conditions of the electricity generators as against forecast planning also gives rise to a difference between forecast and actual demand. The resulting follow-on costs for electricity suppliers must be borne by the consumer himself - if the forecast can no longer be upheld.

When used for the first time, efficiency optimisations on the units impact on the energy forecast; this optimisation is considered as a normal demand in the forecasts that follow. The forecast figures are correspondingly lower.



Fig 6: Effects on forecasts

Costs from the Consumers' Point of View

Liberalisation of the electricity market forces the consumer to enter into contracts with the electricity supplier, distribution grid operator and metering point operator. The state then allocates its taxes and charges to these costs.

Costs from the electricity supply contract by the consumer to the electricity supplier

The electricity supply contract is based on the quantity of energy supplied. The electricity price arises from multiplication with the kilowatt-hour rate. If load profiles have been agreed to with the electricity supplier, the electricity price results from the quantity of energy used plus the costs from non-adherence to the curve form.

Costs from grid use by the consumer to the distribution grid operator

The grid use payment arises from the quantity of energy supplied multiplied by the price per kWh.

Grid connection contract costs from the consumer to the distribution grid operator

The grid connection payment arises from the maximum ¼ h peak within a calendar year or also from the average of a number of peaks (see contract with the DGO) multiplied in each case with the demand charge.

Taxes and charges from the consumer to the state and/or municipality

These costs are supplemented by the taxes and charges. They include:

Concession levy

The concession levy is a payment paid to local authorities for conceding rights of way for the construction and operation, for instance, of power lines.

<u>Electricity tax</u> (also known colloquially as the eco-tax) Since 1999 this tax has been raised with its original intention of promoting climate-related goals. However, practically all its proceeds find their way into the old-age pension fund.

Co-generation of heat & power levy

This levy has been in existence since the year 2000 and serves to promote the generation of electricity from cogeneration plants.

Renewable Energies Act (EEG) levy

This levy is for promoting the generation of energy from renewables. Green power is purchased from the producers at the statutorily stipulated prices. They are above the market rates. The difference is paid by the consumers through the EEG levy. <u>§19 Levy</u> (levy based on §19 Section 2 of the Electricity Grid Payment Ordinance)

This "Special customer levy" from 2012 transfers the eluded earnings of the grid operators due to heavy industry having been exonerated from the grid use payment onto the private consumer.

Offshore liability levy (in acc. with the Energy Industry Act EnWG, Amendment 2012)

Since January 2013 the offshore levy has been a constituent of the price of electricity. It transfers most of the compensation costs which have arisen from delays or interruptions in connecting offshore wind parks to the power grid onto the final private consumer. The offshore levy amounts to 0.25 ct/kWh.

Sales tax (Value-added tax)

The sales/value-added tax is calculated at 19 % of the net price of electricity (total of the above price constituents).

Calculation example

The consumer has a yearly energy demand of 19,890,722 kWh, a demand peak of 5,994 kW and a resulting period of use (ratio between yearly energy and maximum peak load) of 3,318 hours..

Grid connection and grid use costs

In the case of the distribution grid operator in this example, consumer differentiation comes about, on the one hand, from his period of use into two categories and, on the other, from the grid connection level (drawing grid level).

System of the yearly demand rate								
Withdrawal network level	Load utilisation period							
	≤ 2.5	00 h/a * *)	> 2.500 h/a **)					
	Demand rate	Kilowatt-hour rate	Demand rate	Kilowatt-hour rate				
	[€ pro kW/a]	[ct pro kWh/a]	[€ pro kW/a]	[ct pro kWh/a]				
Medium voltage	2,70	4,80	117,84	0,19				
Transformation to low voltage	-	7,76	193,90	-				
Low voltage	2,81	5,03	67,84	2,43				

Fig 7: Parts of the demand charge

Costs of 744,175 \in for the customer/consumer to be paid to the distribution grid operator arise from transfer at the medium-voltage level. They are split between 706,382 \in for the provision of power and 37,792 \in for use of the grid.

Costs for the supply of electricity

Costs of 2,386,887 € arise at a kilowatt hour price of 12 €Cent/kWh.

In total

Taxes and charges are calculated on the basis of the cost total for electricity supplier, grid use and grid connection of $3,131,061 \in$.

Effects of Decentralised Energy Generations

Both distributed and regenerative energy generation are promoted by the government.

The connection and purchasing commitment of the grid operators to take on electricity from renewable energies as well as fixed remuneration rates for the electricity fed in are firmly anchored by law in the Renewable Energies Act (EEG).

Falling within the scope of the EEG are photovoltaic systems (PV systems), wind power plants, biogas plants and combined heat and power plants using regenerative primary energy. PV systems range from those installed on houses involving low outputs and fed into the low-voltage grid to solar parks with several MW of generating capacity (e.g. a 20 hectare area with a maximum generating capacity of 11MWp) which are connected to the mediumvoltage grids.

Wind power plants tend to have larger capacities (> 1 MW) and feed directly into the medium-voltage grid. Hardly any small wind power plants are currently being installed.

From animal excrement (liquid manure, manure) and energy crops (maize, rape), biogas plants generate biogas which is either fed into the gas grid or transformed on the spot into electricity and heat in combined heat & power plants. The electrical power of biogas plants ranges from a few 10 kW up to large-scale plants with 20 MW and more. The average electrical capacity figure for biogas plants is 700 kW. The capacity of the biogas plants determines whether they are connected to the low-voltage or medium-voltage grid.

Within the distribution grids, problems are caused by including decentralised energy generators. The current flow direction i.e. from the power station via transmission and distribution grids to the consumers is the requirement behind the design of many grids. It can, of course, happen that more electricity is generated within a distribution grid than the sum of all consumer demands. In such an instance, the surplus is fed back into the transmission grid from the distribution grid. Maintaining the voltage quality in keeping with EN 50160 is becoming a problem for the distribution grid operator.

Digression:

The voltage drop at a line is calculated from $\Delta U = R * I$. By setting the value R (line resistance) as a constant, ΔU is directly dependent on current I. In a fictitious example, the firm voltage U_x is to be present at a grid point x. The result of current I flowing through a line from this point is for the voltage at the end of the line to come from U_x - ΔU . Should the direction of current be reversed with the current flowing from the end of the line to the grid point x and should the voltage at the grid point x continue to be U_x, then this must bring about a rise in the voltage to U_x + ΔU

and should the voltage at the grid point x continue to be U_x, then this must bring about a rise in the voltage to U_x + Δ I at the end of the line. According to EN 50160 the voltage within the distribution grid may vary by + 10 % of the standard voltage

According to EN 50160 the voltage within the distribution grid may vary by \pm 10 % of the standard voltage (e.g. between 440V and 360V).

Substantial electricity variations within the line lead to considerable current variations at its end. This problem is accentuated should the current change its direction.



Fig 8: Voltage drop at lines

The act stipulates that the transmission grid operator has also to ensure that the 50 Hz standard frequency is maintained. The frequency is conditional upon the balance between the generated and consumed power. If the generated output is greater than that consumed, then the frequency rises. Conversely, if less power is generated, then the frequency falls.

Since electrical power always needs to be generated when used (the grid cannot store any energy/output for the future), it is vital that a continuous form of power regulation is used to match generation to consumption. The transmission grid operator only has the transmission grid. He secures the power station outputs required for the controlling power range on the market. He purchases any controlling power to be provided and the controlling power itself. There is both positive and negative controlling power. In the case of positive controlling power, power is generated given demand and with a negative one power is taken from the grid. Aside from the costs of provision, those relating to the generated/reduced power arise when recourse is taken to the controlling power. The operating reserves are divided into primary, secondary and tertiary categories.

The contractually negotiated primary output must be 100% available within 15 seconds, the secondary reserve after a maximum 5-minute period and the tertiary reserve at 100% after 15 minutes.

All power stations must keep 2% of their momentarily generated output as a primary reserve.

The forecasts of the electricity suppliers, distribution and transmission grid operators are essential to keep operating reserves to a tolerable scale. As the forecasts of the electricity suppliers are covered at the power stations by base load, peak load, off-peak load and hourly contracts, the controlling power is only needed for any deviations from the forecasts.

In order to prevent any damage, both the Transmission and Distribution Codes allow grid operators to directly access the generators - PV systems > 30 kW and power generators > 100 kW - and to involve them in grid control. Grid control affects power increase, power minimization, shut-down and generation of reactive power. Arrangements are also made as to how long the power producer must feed in electricity at a voltage below the standard voltage before he may disconnect from the grid.



Fig 9: Decentralised energy generation on the liberalised energy market

The energy generated from regenerative energy sources is managed within its own control loops and offered for sale on the market at the energy exchange. If a higher or lower price than that stipulated in the feed-in payment is obtained on the exchange, then the difference is universalized through the grid use.

Smart Grid / Micro Grid

The smart grid ensures stability in the power grid. Making use of intelligent energy distribution, it balances power generation, consumption and energy storage. It also permits a large number of decentralised energy producers to be incorporated.

http://www.siemens.de/energiewende-deutschland/ intelligente-verteilung-und-energiespeicher.html ?stc=deccc020226 Micro grids represent enclosed regional energy systems in which decentralised energy producers, consumers and optionally energy storage units are incorporated.

http://w3.siemens.com/smartgrid/global/de/produktesysteme-loesungen/grid-applications/microgrids/ pages/default.aspx

Smart Grid

According to NIST (National Institute of Standards and Technology), the term "Smart Grid" includes the communicative networking and control of power generators, energy storage devices, electrical consumers and grid operating resources in energy transmission and distribution grids of the electricity supply sector.

In Germany, the law on the supply of electricity and gas (EnWG Energiewirtschaftsgesetz) continues to apply. It includes implementation of the European Union law into the field of energy supply through power lines. Based on the liberalisation of the electricity market, the smart grid comprises the power stations, distribution and transmission grids with their decentralised power generators, electricity suppliers and the consumer given that he obtains electricity from the distribution grid. The consumer mutates to a micro grid if he himself produces electricity. For the micro grid it does not matter whether the consumer generates electricity for his own consumption or feeds it back into the distribution grid either temporarily or continuously. An isolated grid operation - with open coupling to the distribution grid - is neither customary in the EU nor is it specified as a goal.

Digression:

The power generated in an isolated grid is well below that of a distribution grid and far lower than that of a transmission grid. Any changes in power consumption rapidly make themselves felt in the grid frequency. This is because generation control reacts significantly more slowly. Following disconnection from the distribution grid, the frequency in the isolated grid ceases to run synchronously to the distribution grid. This also applies to the voltage following disconnection from the grid.

Voltage, frequency and phase relation need to match if the isolated grid is to be re-coupled to the distribution grid. No coupling is possible if not all three factors match across a tolerance range.

As the distribution grid represents the principal factor, the isolated grid must be adjusted to it through control systems. When coupling takes place, the power needed in the isolated grid needs to be generated from embedded generation.

These mechanisms can be explained by looking at two mechanical systems:

if two mechanical shafts are to be closed by force, then their rotational speed and position are to be aligned to the cog wheels. Only when both parameters correspond can a force-closure be affected. Carried over to the electrical engineering world, this means the frequency corresponding to the rotational speed and the voltage to the position of the cog wheels.

In electrical engineering, however, the phase relation must also match. This would mean in the mechanical model: there is only one cog that needs to grip into a defined cog gap.

The difficult part of synchronization is undertaking force-closure with both systems running.



Fig 10: Synchronisation of two mechanical systems

The frequency and phase relation of a micro grid operated with a grid coupling corresponds to that of the smart grid. Differing voltages at the interface are synchronised from the smart grid side.

If as much power is generated within the micro grid as is used within it, then there is no flow of current between smart grid and micro grid.

Micro Grid

A micro grid features both consumers and generators within its environment. As a micro grid always involves a manageable environment, considerable efficiency benefits come from both interconnected systems (co-generation of power & heat) and energy storage devices. However, the dependencies of the various energy types one to another in interconnected systems are not to be ignored. For instance, roughly 40 % electricity and 60 % heat is generated from the primary energy in cogeneration plants. It should not be forgotten either that heat system operations are thermally controlled (heat provision takes precedence). Looked at in this way, the electricity generated resembles a

"by-product". Moreover, the seasonal weather determines the demand for heat.

With energy storage devices, consideration is always to be given to efficiency aspects. A lithium battery as an example of an energy storage device has an approx. 86% efficiency (consumption from the grid through to feedback into the grid). The efficiency of heat accumulators and cold storage cylinders is conditional upon the storage Brief differences within the micro grid between generation and consumption are offset by the smart grid; they have no impact on the voltage and frequency within the micro grid.

time. The longer the energy is stored, the worse the efficiency.

Solar cells generate thermal and/or electrical energy based on both the weather and the time of day.

Heat pumps require electrical energy to produce the heat. The heat balance is heat-controlled - thus the electrical energy demand is oriented to heat requirements.

Compressors for cold production are cold-controlled; as such, the electrical energy demand is determined by the load needed for cooling.

Most of the wind power plants are in the capacity class upwards of 1 MW. The future will most certainly see smaller units also establishing themselves on the market and will then become of interest for micro grid operators. Wind power plants are, of course, weather-dependent.

In many instances there is both a micro grid connection to the smart grid and one to the district heating network.



Fig 11: Interdependencies of various energy types within a micro grid

A proper mode of operation - and certainly not an optimised one - cannot be implemented without the consumer providing energy demand forecasts.

This is where forecasts develop into the centre-piece of optimisation work. Only when the demand is known can energy generators and/or energy transformations and import from the smart grid be planned and subsequently be optimally deployed.

Besides the energy demand, the costs of acquiring electricity, district heating and primary energy will be playing a major role in optimisation. Apart from providing reliability of supply, the point of optimisation is also to optimise overall costs.

This then leads to greater requirements being placed on the optimisation when prices can change within short periods. Smart grid thinking is also bound up with coupling the prices for electrical energy to its availability. Low prices arise should considerable energy be available in the smart grid. Prices rise when the availability of electrical energy is decreasing.

From the costs angle, energy obtained from the smart grid may be cheaper than with embedded generation. If con-

versely the energy in the smart grid is very expensive, it may make sense to feed energy into the smart grid. This extra acquisition or feedback of energy is always based on the micro grid forecast. These forecasts have a 15-minute precision. Consequently, optimisation must be in a position to calculate acquisition, embedded generation and consumption of the total system at least every 15 minutes.

Should the micro grid be run as an isolated grid - without coupling to the smart grid - the requirements placed on optimisation are considerably more demanding. In particular, the weather-dependent power generators such as wind power and photo-voltaic systems have a pronounced tendency to generate electricity erratically (resulting from passage of clouds, lulls in the wind, strong winds). The seasonal demand for cooling load and heat demand also affects electricity generation and/or electricity demand.

Scope for Optimisation

In most cases, the scope for optimisation is sought under cost aspects. But, of course, other objectives such as a reduction of CO2 emissions from use, for example, of predominantly regenerative energy sources are also to the fore.

Within the liberalised electricity market, the consumer has the opportunity of choosing his electricity providers and metering point operators. However, he is dependent on his local distribution grid provider for grid use and connection. Negotiations can bring about a degree of latitude here which is to be made use of. Opportunities are extended once a smart grid becomes a reality. Further optimisation is possible by using surpluscapacities when generating and/or limiting one's consumption given shortages in capacity.

The aim of a micro grid is to effect supply from its own resources. Optimisation puts this very much to the fore and cost optimisation continues to be accorded a high priority.

Optimisation on the Liberalised Power Market

On the liberalised energy market, the electricity price consists of the demand-oriented and energy-related components.

The demand-oriented component is governed by the maximum ¼ h figure within a calendar year. A cost benefit arises from lowering this maximum demand (peak demand). Usually a load management scheme is installed to use this potential. It caps the maximum permitted power by shutting down/down-regulating units or switching on/up-regulating generating capacity. A load management scheme needs to be continuously run.

The energy-related component can be made use of through energy saving steps. The reference here is to efficiency-optimised drives, controllable drives, regenerative drives and also to optimisation steps within

Transparency of electricity flows

The basis of any optimisation is transparency; only when electricity flows within the distribution of energy are known and clearly depicted can optimisation be put into practise.

The feed-in energy transferred is metered by the metering point operator in ¼-hour values. This applies to both the energy obtained from the distribution grid and for that fed back into it. The readings are made available to the consumer as a data record. An S0 interface (pulse interface) is usually used to supply load management on the consumer side from the metering point operator's meter. This interface always delivers a defined pulse on the set energy quantity per pulse being attained. The load management system registers the energy quantity by adding the pulses over time. By extrapolating it onto the ¼-h end, defined variable loads are specifically switched to prevent the set maximum power demand value from being exceeded. the automation software which only operate the generating units when required for the process. All in all, the talk here is improving operations, units and components. As a rule, an efficiency optimisation represents a non-recurrent and/or cyclical service. It is precisely this part in ISO 50001 which plays such a major role.

Selecting a suitable electricity supplier enables the price per supplied kilowatt hour to be reduced.

Prices agreed with the distribution grid operator are usually fixed and cannot be negotiated on.

Taxes and charges are statutorily fixed and cannot be negotiated on.

At the transformer level, voltage U, current I, apparent power S and the power factor of all three phases are to be measured. Voltage metering documents the extent to which standard voltage Un ±10% is maintained. Since the maximum voltage drop is included in the calculation for distribution project planning, there is no longer any need to continue metering the voltage. Given that the voltage drop relates to the maximum current within the line, but is at its maximum when the plant is in operation, its maximum value is at the specified planning value - and normally always under it. The transformer's capacity utilisation results from measuring the apparent power S. Electronic consumers tend to generate harmonic components should never exceed 8 % in feed-in operations. The THD share represents the total of all harmonic components at this metering point. The configuration of a power distribution system is projected on the basis of the currents to be controlled - hence metering the currents indicates the extent of capacity utilisation of the distribution.

Major consumer loads represent distribution outgoing circuits. In addition to measuring the current, it makes sense to measure the power factor / cosl for assessing the reactive component. Drives are supplied via the distribution outgoing circuits and should be correspondingly handled in a metering sense. Drives are defined by their active power P, for documentation purposes their active power P consumed must be recorded.

Digression:

In tenancy situations, the energy consumed in rented areas is charged by the lessor. This bill is based on recording the energy W consumed. If offsetting is only done internally through cost centres, then a non-certified meter suffices. However, a MID (Measurement Instruments Directive) certified meter must be used for billings.

Die The MID certification only applies to the first time when the meter was brought onto the market. This does not affect the stipulations for rendering proof of precision within the life cycle. A renewed certification is necessary to demonstrate the accuracy of electronic meters after eight years of operation.

Generators represent sources of power comparable to those of transformers. Measuring the voltage U is then vital when the generator is to be employed as a grid substitute. Whilst current I, power P and the power factor/cosl document the capacity utilisation/operating mode over time, energy metering W documents the quantity of energy generated.



Fig 12: Recommended measurements

The average electricity price (DSP)

As the basis of a cost centre allocation internally, the electricity price is normally only calculated from the electricity supply contract, grid use and grid connection; no consideration is given to taxes and charges. The average electricity price [\in /kWh] is usually updated every month. The average electricity price (AEP) is calculated from the sum of the electricity supplied, grid use and grid connection divided by the quantity of electricity supplied.

AEP $[\in/kWh]$ = (electricity supplied $[\in]$ + grid use $[\in]$ + grid connection $[\in]$) / amount of electricity [kWh]

The effect of presenting the AEP as a function of the operating life (peak power /energy) results in various optimisation possibilities by varying consumption and power peak. What finally comes about in the diagram is an "optimisation window" defined by the following key points:

- Ongoing average price of electricity
- Possible energy savings while retaining the maximum power demand
- Possible power demand saving while retaining the amount of energy consumed
- Possible revised electricity price given the above energy savings

• Possible revised grid connection price given the above power purchase savings

Remember that it is not the absolute costs of electricity which are to be read off in the "optimisation window" but the average electricity price per consumed kilowatt hour of energy. The electricity costs are shown together with the energy consumption and the associated power in the above flags.



Fig 13: Impact of saving steps on the average electricity price (AEP)

For energy purchasing purposes, the energy consumption forecast will become ever more important. The weekly forecast is to be prepared at ¼-h intervals for a week in advance (Thursday for the following week from Sunday 12:15 am to midnight Saturday). The daily forecast has to specify the deviation from the weekly forecast at ¼-h intervals for the following day

(00:15 am to midnight). In the light of these forecasts, the electricity supplier provides the energy as forecast. Deviations lead to additional costs.

Smart Grid

Forecasts become the standard instrument where a consumer is a smart grid participant purchasing energy - yet not feeding it back into the grid. Higher electricity costs will arise for consumers without any forecasts.

For the forecasts to be kept to, the consumer needs to install a management system aligning actual demand to that of the forecast. This forecast management system acts within the ¼-hour cycle and controls/regulates consumer energy consumption to the figure forecast.

A dependable forecast cannot be undertaken without transparency of energy flows. For transparency purposes alone an appropriate measurement technology has to be installed, the analyses of which have to be implemented and the scope for controlling from its capacity and variance over time has to be drafted.

Within the smart grid, power surplus or under-capacities may arise which through corresponding price signals are offered to the consumers. The consumer can then decide the extent to which he accepts the offer and the energy quantity he wants to buy. He can either purchase surplus energy from the grid in addition to the figure forecast or dispense with some of this demand as forecast given a shortage of power in the smart grid. Forecast management then has to keep to the resulting revised energy consumption.

At the latest, a resilient forecast is to be drawn up and its adherence needs to become mandatory when the consumer wishes to participate in the smart grid. The communication mechanisms between smart grid and consumer are currently not standardised - the standardisation committees are working on these aspects.

Micro Grid

The fact of the consumer developing a micro grid within his environment means that his own supply of energy is in focus. However the interface to the smart grid - forecasts, use of surplus and under capacities within the smart grid remains as an option. As a rule, optimisation follows under cost aspects.

In a case of micro grid optimisation, all the energy types are to be considered and correlated one to the other. Consequently, electrical forecasts as well as those for cold and heat are to be prepared. Weather forecasts need to be included to forecast regenerative energy generators such as wind power, solar thermal systems and photovoltaics. Communication mechanisms to weather portals are to be set up.

The reference forecasts are built up from the consumption and generating forecasts.

Interconnection optimisation functions are used to regulate all units generating several energy types from a pri-

mary energy source (e.g. cogeneration of heat & power) up to an overall optimum. The costs of heat and power generated, for instance, in a co-generation system fired on gas are considered in the overall costs. Furthermore, the costs from the gas purchasing contract represent a further optimisation criterion. Liberalisation of the gas market functions just as it does on the electricity market except that hourly cycles are involved.

Electrical power distribution in field level with switching/protection concepts is the basis and offers information for the functions that are part of the liberalised energy market, smart grid and micro grid. The functions are software functions, which are based on the measurements on field level. The functions are shown as organised; the smart grid includes the functions of liberalisation, the micro grid includes those of the smart grid.



Fig 14: Organising functions from the field level to the micro grid

Graphic Depiction of Measured Value Sequences

In an energy management system, measured values as rows of numbers provide the basis for the various diagrams. Once the diagrams have been analysed, the user can detect the reactions of individual components and inter-dependencies between usage and the corresponding energy demand.

Digression:

In determining the average, the time correlation allows power and energy consumption to be mutually derived from one another in the 15-minute interval.

Measurement: mean active power P in kW in the 15-minute interval mean energy consumption E = P * 0.25 hMeasurement: mean energy consumption E in kWh in the 15-minute interval mean active power P = E / 0.25 h

Load curves

Load curves represent diagrams of measured values in their order over time. The time and measured values are plotted on the x-axis and y-axis respectively. A yearly load curve begins with the measured value of the first day of the year at 12.15 am and ends with the value for the last day of the year under consideration at midnight. The averages at intervals of 15 minutes are plotted - beginning with the whole hour. For power load curves, the average power of a 15-minute interval is plotted above the associated period. The following shows typical interpretations which can be read from a load curve:

- When did the customer demand high power quantities?
- Is a typical energy consumption pattern shown (e.g. a typical time/power pattern)?
- Are there temporal interdependencies complete with pronounced changes of the power measured values?
- How high is the base load?

It should be taken note that with given mixed usage within the infrastructure, specific load curves for the different applications are to be evaluated. These kinds of evaluations can be offered to the lessees and users as a service. Depending on the time axis resolution, more specific statements can be made at all times - for instance, on reactions accompanying extraordinary situations or trend statements.

Evaluation of yearly load curves is a suitable method to obtain an overview of:

- Load response
- Continuity across months
- Power peaks at certain times of the year
- Seasonal variations
- Annual plant closures and other special company features
- Minimum power requirements as a power base



The diagram of a monthly load curve (Diagram 2/4) can be used to illustrate a possibly typical response:

- Similarity of the power import
- Continuity at the weekends
- Power import at nights
- Base load
- Public holidays/bridging days/weekends and other days
 when companies close



Fig 16: Monthly load curve

Day-specific differences become clear here:

- Daily demand
- Daily variations
- Typical workshift response
- Demand peaks



Fig 17: Weekly load curve

Individual 15-minute intervals are plotted for the daily load curves to detect, for instance, the following times:

- Precise course of the daily demand and times of change
- Breaks
- Work shift change-over



Fig 18: Daily load curve

Evaluation Profiles

In order to illustrate interdependencies, characteristic power values and conditions by means of charts, the measured values are processed in differing evaluation profiles, for instance:

- Load profile
- Frequency distribution
- Maxima evaluation

Load profile

The load profile reveals the power values on the x-axis; the number of hours at which the respective power value has been measured is plotted on the y-axis. The power profile based on the 15-minute power measured values begins with the base load and ends with the maximum purchased power. Thanks to the load profile, power focal points can be identified - i.e. those power values of a plant or system which are demanded most of all. The load distribution profile is essential for considering efficiencies. It can thus enable inferences to be made on the performance:

- Equipment designs (e.g. transformers)
- Loss considerations (life-cycle costs)



Fig 19: Load profile

Frequency distribution

The frequency distribution supplements the load profile statistically by depicting cumulative values. In the frequency distribution the number of the hours is plotted on the x-axis and this is the case on the y-axis for the power needed for the respective number of hours. As the number of hours is plotted in an ascending order, the curve of the frequency distribution begins with the maximum purchased power and ends with the base load. The frequency distribution allows inferences to be drawn as to import continuity. Deviations from the mean course of the curve, in particular, allow these kinds of inferences to be made. Typical utilisations which can be realised from frequency distributions are:

- Accentuation of peak loads
- Delivery continuity
- Work shift model
- Base load



Fig 20: Frequency distribution

Maxima evaluation

Maxima presentation involves plotting the largest measured power values with the associated date and time in a descending order. Two auxiliary lines are often drawn in to reveal a peak load reduction of 5 % and 10 %. It becomes clear from a power maxima presentation, in how many 15minute intervals and with which power reductions a load management system would have had to intervene so as not to exceed a supposed peak value. Variants of maxima presentation map the daily-specific distribution of power peaks or reveal the monthly maxima to identify starting points for a load management system or a modified form of plant management.

3.900 kW		1/4h Wert	Datum / Uhrzeit		1/4h Wert	Datum / Uhrzeit		1/4h Wert	Datum / Uhrzeit	
3.800 KW	••••	3.840 kW 3.840 kW	Mi. 30.06.10 11:00 Mi. 14.07.10 11:00	KW 26 : KW 28 :	3.720 kW 3.716 kW	Mi. 30.06.10 11:30 Mi. 14.07.10 10:30	KW 26 : KW 28 :	3.672 kW 3.672 kW	Mi. 21.07.10 11:45 Do. 22.07.10 11:15	KW 29 : KW 29 :
3.700 kW		3.840 kW	Mi. 14.07.10 11:15	KW 28	3.696 kW	Mi. 30.06.10 10:15	KW 26	3.648 kW	Do. 10.06.10 10:45	KW 23
		3.792 kW	Mi. 14.07.10 10:15 Mi. 14.07.10 10:45	KW 28	3.696 kW	Do. 01.07.10 10:30	KW 26	3.648 kW	Mo. 28.06.10 11:00	KW 26
3.600 KW		3.792 kW 3.768 kW	Mi. 21.07.10 11:15 Do. 01.07.10 11:00	KW 29 : KW 26 :	3.696 kW 3.696 kW	Mi. 14.07.10 12:00 Do. 22.07.10 10:15	KW 28 : KW 29 :	3.648 kW 3.648 kW	Di. 29.06.10 11:30 Mi. 30.06.10 11:15	KW 26
3.500 KW -		3.768 kW	Mo. 12.07.10 10:45	KW 28	3.696 kW	Do. 22.07.10 11:00	KW 29	3.648 kW	Do. 01.07.10 11:30	KW 26
3.400 kW		3.768 KW 3.768 kW	Mi. 14.07.10 11:45 Mi. 21.07.10 10:45	KW 28 : KW 29 :	3.672 kW 3.672 kW	Di. 29.06.10 11:15	KW 23 : KW 26 :	3.648 KW 3.648 KW	Di. 13.07.10 10:45	KW 27 : KW 28 :
3.300 kW -		3.768 kW 3.768 kW 3.744 kW	Mi. 21.07.10 11:30 Do. 22.07.10 10:45 Do. 01.07.10 11:15	KW 29 KW 29 KW 26	3.672 kW 3.672 kW 3.672 kW	Mi. 30.06.10 11:45 Do. 01.07.10 10:45 Mo. 12.07.10 10:15	KW 26 KW 26 KW 28	3.648 kW 3.648 kW 3.648 kW	Fr. 16.07.10 10:45 Mi. 21.07.10 12:00 Mi. 21.07.10 12:15	KW 28 KW 29 KW 29
3.200 kW		3.744 kW 3.744 kW	Do. 01.07.10 11:45 Mi. 21.07.10 11:00	KW 26 KW 29	3.672 kW 3.672 kW	Mo. 12.07.10 11:00 Mi. 14.07.10 10:00	KW 28	3.648 kW 3.624 kW	Do. 22.07.10 10:30 Mo. 28.06.10 10:45	KW 29 KW 26
3.100 KW -		3.728 kW 3.724 kW	Di. 20.07.10 11:30 Mi. 30.06.10 10:45	KW 29 KW 26	3.672 kW 3.672 kW	Mi. 14.07.10 11:30 Do. 15.07.10 10:45	KW 28 - KW 20	3.624 kW	Di. 29.06.10 10:45	KW 26
	5 10 15 20 25 30 35 40 45 50									

-5%

Fig 21: Maxima evaluation

Characteristic Values

Characteristic values are there to provide an overview and enable comparisons to be made. Typical parameters are evaluated as monthly or yearly related total, maximum, average and/or minimum values. By clearly underlining, for instance, the spreads of time-conditioned required power, they can be the starting points for an energy management system.

Characteristic parameters are:

- Energy (vital for the kilowatt hour rate)
- Power maximum value (important for the demand charge)

- Operating life (important for prices)
- Hours of full load
- Simultaneity factor
- Unit-specific energy values such as work shift figures, unit values, time-specific operate values
- Maximum, average and minimum values of current, voltage, power factor, power.

	January 2010	February 2010	 November 2010	December 2010	2010
Power demond					
- max.	3.360 kW	3.384 kW	 3.480 kW	3.504 kW	3.840 kW
- mean	1.514 kW	1.723 kW	 1.994 kW	1.693 kW	1.832 kW
- min	408 kW	552 kW	 648 kW	600 kW	0 kW
Energy	1.126.149 kWh	1.157.922 kWh	 1.435.740 kWh	1.259.722 kWh	
cumulative	1.126.149 kWh	2.284.071 kWh	 14.788.202 kWh	16.047.924 kWh	16.047.924 kWh
Peak (Load)-share	2,22	1,96	 1,75	2,07	2,10
Usage period					
- in hours	335 h	342 h	 413 h	360 h	4.179 h
- % of the month	45 %	51 %	 57 %	48 %	48 %
CO ₂ Foot print					
600 g CO ₂ /kWh	676 t CO2	695 t CO2	 861 t CO2	756 t CO2	9.629 t CO2
Days					
total	31	28	 30	31	365
days Mo Fr.	21	20	 22	23	261

Fig 22: Characteristic values

Information:

These directly designated characteristic values can be the basis for other analyses which, in turn, can be used for building specification purposes (energy per usable area, energy demand related to the cooling load, ambient-specific dependencies on extreme values etc.) More on characteristic values, data evaluations and interpretations can be found in the book written by Manfred Weiß: "Data Evaluation of Energy Management Systems" (ISBN 978-3-89578-347-0).

Forecasts

In future, the electrical energy demand forecast will become absolutely necessary for smart grid participants. However, its realisation requires a good deal of preparation.

How to approach the matter

There are basically two approaches for setting up such a forecast - the bottom-up method and the black-box method.

The assumption behind the bottom-up method is that the power requirement of each individual consumer load is known of over time. The total consumption which needs to be imported from the electricity supplier is the result of adding up all the individual consumption values. The outlay required for this method is considerable bearing in mind that - depending on usage - each individual consumer has a different power demand. In the black-box method, units are externally considered as an entity without being aware of what is inside. Knowing the black-box control parameters enables the impact of control on the energy demand to be documented. This documentation provides the energy forecast for various operating points.

Digression:

The electricity for certain operating points is measured just once and transferred to a capacity utilisation profile.

The corresponding electricity demand is derived if capacity utilisation is known. Based on the capacity utilisation profile, changing the operating point either results in saving electricity or in an increased demand for electricity. The power is derived from the electricity.



Fig 23: Utilisation profile

The black-box method can also be applied to entire mechanical or electrical installations given a cyclically recurrent usage. In office buildings, for example, the energy demand follows the individual hours of the day specific to the week. In these instances, future consumption can be established by analysing feed-in metering. Since the metering point operator documents



Fig 24: Yearly course of load of an office building

More than 36,000 ¼-hour data records - a data volume that can no longer be handled - arise when a complete calendar year is considered. This problem can be solved by going the way of the synthetic load curves. Synthetic load curves specify the average power demand at ¼-hour intervals over the day and their mean and maximum value. The curves of the days of the week the imported energy amount at ¼-hour intervals and makes it available to the consumer, an analysis of this data is the basis for a forecast.

represent normal usage. Public holidays, bridging days, company holiday closures etc. are not considered.

In the synthetic load curve example, the values of the working days from Monday to Thursday and Saturday to Sunday were that close together that they were combined into one curve.



Fig 25: Synthetic load curve of an office building

An adjustment of the synthetic load curve from the measured values collected anew in each case produces curves which realistically reflect the energy demand for the usage. If there are changes in usage, they will automatically be included - after a delay - into the synthetic load curve. The synthetic load curve method can both describe the response of entire building types (e.g. office building with air-conditioning) and their sub-groupings (e.g. canteen).

Structured energy purchase

Forecasts determine the energy quantities required. The forecasts below are for the Purchasing Dept. so as to order the energy quantities needed. The talk here is of structured procurement.

The consumer draws up a forecast of the energy quantities of all his consumer loads and orders them from his electricity supplier. The forecast is undertaken in ¼- hour intervals beginning with each full hour.

Keeping to the forecasts

Only when the consumer complies with the schedule, there will be a cost benefit for him.

In practically all instances, actual consumption varies from that specified on the schedule. Not every consumer acts in the way as it was assumed in planning. For this reason, the The electricity supplier draws up a forecast of the energy quantities of all his customers and either orders directly at the power stations or through the energy exchange. The forecast is undertaken in hourly intervals beginning with each full hour.

The forecast is endorsed by the electricity supplier on a one-to-one basis or as a schedule following changes by the consumer.

consumer is granted a band in the electricity supply contract within which actual consumption can vary without leading to additional costs.



Fig 26: Loading with schedule



Fig 27: Loading deviation from the forecast plus tolerance band

A schedule management system offsets the deviations of ongoing consumption from the schedule. It works in a comparable manner to that of a load management system. The customer defines loads and power generators that are controllable and switchable in case of need. All loads and power generators are saved in a priority list in the order in which they are to be drawn on for performance adjustment purposes. Within the

¹⁄₄ hour, schedule management calculates at brief intervals (e.g. 10 seconds) the difference between ongoing demand and the energy quantity which the schedule permits. If too much is consumed, then schedule management regulates following the priority list.

Surplus and deficit generating capacities in the grid

Generation surplus capacities are on offer to a smart grid participant. These capacities are limited over time regarding their power.

In the event of power generating surplus capacities, the consumer can purchase – in addition to the schedule –energy at ongoing prices. Conversely, if the

Either consumers are shut down or down-regulated or power generators switched on or up-regulated.

If too little is consumed, then schedule management reacts in precisely the opposite way.

A schedule management system is absolutely necessary if a forecast – and hence adherence to a schedule – is demanded.

generating capacities in the grid are too low, the consumer can dispense with energy in the schedule and is reimbursed with the costs.

Schedule management obtains other set values based on these "new" values.

Digression:

In addition to the schedule, the idea is to consume 100 kW between 8:00 am and 9:00 am and save 100 kW between midday and 1:00 pm.

100 kW corresponds to an energy consumption of 25 kWh within a ¼ hour.



Fig 28: Modified schedule

The original schedule allows for a 10 % band. No band is allowed on the 100 kW of additional or reduced power.



Fig 29: Band with 100 kW of additional or reduced power

A schedule management must ensure that the power consumed stays within the schedule band. The power values which do not lie within the band are to be intercepted by the schedule management system. A consideration of the power in absolute terms which needs to be either saved or additionally consumed shrinks these 100 kW of additional or reduced power to 60 kW. This is because the ± 10 % band reserves are also taken into account.



Fig 30: Power values not within the band

In most cases, it is not the absolute amount which is decisive but the share relative to ongoing demand. If the demand varies throughout the day by a multiple of 7, then a different evaluation is put on the 100 kW in the low-load period than when there is maximum demand. Furthermore, the whole system was run down within the low-load times - except for the absolutely needed functions - and so there is practically no potential for optimisation. Actual power is to be adjusted by up to 14 % for those periods in which the additional power was bought in or where power was dispensed with. However, the power to be adjusted is up to 20 % higher within the low-load period. These kinds of power adjustments are difficult to implement, bearing in mind that the power demand is reduced to what is absolutely necessary within these periods. Whilst an energy storage device would bring some relief here, this would entail providing an energy storage management system in addition.



Fig 31: Power values not within the band

Measurement-related registration of various electricity suppliers

Being physically a medium, the electricity can only be measured once. Who generates or sells it is simply hidden. Should the consumer have several electricity supply contracts, it cannot be commercially proven that the individual contracts are being kept to from delivery point measurements of the metering point operator. Only by using the forecasts can a breakdown be undertaken on the individual contracts in order to examine or demonstrate adherence to them.

Even so, in instances of non-adherence to the forecast, the electricity suppliers cannot verify a contract infringement. A procedure for assigning additional or reduced costs must be contractually agreed upon.

Digression:

For instance, a schedule with an x % band can be used; any additional costs become due outside this band. Quantities (positive or negative) purchased in addition to those in the schedule have no tolerance bands and must therefore be purchased. The risk of actual consumption adjustment is met by the electricity supplier with whom the schedule was agreed.

Energy Mix

The promotion of regenerative energy generation started by the German government is having an effect. Between 2000 and 2011, wind power climbed by 380 % to a gross generating power of 29 GW; in the same period photovoltaic jumped 32,800 % to 25 GW. Power generation from coal and lignite is continuing to rise and that from nuclear power is falling.



Fig 32: Energy mix changes between 2000 and 2011

In a comparison of the capacity installed, photovoltaic systems reveal a very high figure. However this figure specifies the peak value which in the real power generation world only appears for a few hours in the course of the year. The high degree of utilization of coal, lignite and nuclear power as basic load generators means that they form the backbone of power supply in Germany.



Fig 33: Energy mix Germany 2011 (installed capacity)

Source:

http://de.wikipedia.org/wiki/Installierte_Leistung 23.07.2013

IC LMV MS Portfolio

Within the electrical infrastructure,

MS (Medium Voltage & Systems) stands for solutions within the medium voltage range for the primary and secondary technology and in respect of low voltage for the main distribution systems and busbar trunking systems. Solutions are on hand here for the promising energy storage market. The consulting service of Totally Integrated Power (TIP) covers the medium-voltage, transformer and low-voltage range and various types of uninterruptible power supply applications.

The SIMARIS[©] tool landscape ranges from dimensioning power distribution systems, setup and equipping of switchgear cabinets down to the preparation of tender specification texts.



Fig 34: Position determination - IC LMV MS Portfolio

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