

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*

Systems and methods for optimized operation of an energy-intensive industrial batch
production facility

5

Description

The invention relates to a production scheduling and execution system and to an energy provision system for optimized operation of an energy-intensive industrial batch production facility, where the production scheduling and execution system comprises a production scheduling unit arranged to determine an initial production schedule for the industrial batch production facility, and where the energy provision system comprises an energy demand scheduling unit. The invention further relates to a corresponding integrated system for production scheduling and energy provision and to corresponding methods performed by the systems.

In today's industrial batch production facilities, the optimized operation of the production is ensured by applying so called production provision systems. The term "industrial batch production facility" hereby refers to those enterprises which belong to the process industry dealing for example with metals, pulp and paper, plastics, cement and electrolysis. In a batch production facility, stage by stage production processes are applied to so called batches of pre-products or semi-finished products, where each batch has its own characteristics and where all pre-products or semi-finished products are kept in the same batch throughout the whole production. After one batch has passed a certain production stage, it is common that the machinery involved may have to be stopped, cleaned and adjusted for the next batch which has different characteristics than the previous batch.

Production scheduling systems often provide the operator of a production plant with the possibility to optimize the operation of the plant with respect to different optimization goals, such as resource efficiency, reaction times and product quality. Known production scheduling

systems with optimization functionality are for example ABB's Collaborative Production Management (CPM) solutions.

Another system, which was particularly developed for the steel industry, is ABB's Melt Shop

5 Schedule Optimizer (MSO), which is a scheduling solution that can optimize batch-scheduling problems to so called global optimality. MSO is especially aimed at a steel melt shop but the solution technology can in principle be applied to any batch industry case. The specific optimization goal of resource efficiency is currently gaining more and more importance, in particular with respect to energy efficiency. This is especially true for energy-
10 intensive industry sectors, producing or dealing for example with steel, aluminum, chemicals, pulp and paper, glass or petroleum, since the impact of optimized energy usage is particularly high.

Apart from improved energy efficiency, the availability of energy is another topic which is of
15 increasing interest as it is becoming more and more fluctuating. This is due to different reasons. For instance, the European Union is striving to increase the share of renewable energy sources and supports main investments in solar and wind power. It is evident that the production of energy will not be as stable as with e.g. nuclear power. Solar power cannot produce any electricity during darkness and their efficiency is extremely low during rainy or
20 heavily clouded days. Similarly, wind power capacity varies significantly with the changing weather conditions. Consequently one challenge is energy storage; with current storage technologies and capacities it is not possible to completely compensate for the varying conditions. Furthermore the transmission of the electrical energy is also a limiting factor, due to which renewable energy may not be always accessible to all regions.

25 Accordingly, the aspect of optimizing production processes in the processing industry with respect to a minimized energy demand or an optimal use of available energy resources is coming more and more into focus. The latter brings flexibility into the energy markets by allowing consuming industries, e.g. process industries, to consume less energy when
30 needed and an increased amount of energy when there is an excessive supply of energy available.

In WO 03/056480 A2, a system for dynamic, model-based scheduling and optimization of production processes is disclosed. There, in a first step, a first production schedule is
35 automatically generated based on information about available resources, including raw materials and energy resources. This first production schedule is optimized in a second step

with respect to the production goal. In case of unexpected changes in the available resources, the optimized production schedule may then be adapted to these changes.

In other words, the production scheduling system of WO 03/056480 A2 uses information about expected available energy resources at the one time when the first production schedule, which is an un-optimized, long-term production schedule, is generated. After a subsequent optimization of the long-term schedule with respect to the production goal, the production scheduling system only reacts to status information and accordingly adapts a short-term production schedule in case that unexpected changes occur. Such short-term re-scheduling is usually sub-optimal since the little time available for reaction to the unexpected changes does not allow for all the adaptations necessary for an optimal response. As a result, productivity decreases.

The problem of adapting a production schedule to the availability of energy resources is also dealt with in WO2012/048808. There, the point of an increased use of renewable energy resources is raised, which results in the currently observable spread of so called smart grids connected with an increasing time-dependent variability of the amount of available energy. In WO2012/048808, a production scheduling system optimizes a production schedule with respect to two goals: the availability of energy and the energy consumption. This is done in a coordinated manner. The two optimization results are afterwards assessed with respect to an overall optimization goal.

Apart from the aspect of production scheduling, further tools are available on the market, which provide solutions for monitoring, managing and optimizing the energy usage of an industrial batch production facility. One such tool is known as cpmPlus Energy Manager. It produces energy demand forecasts for the industrial batch production facility and, based on the expected energy demand, plans the energy supply to the industrial batch production facility and initiates its according implementation. Energy Manager is based on a so called discrete-time approach, which allows a straightforward possibility to pose energy balances at any time point. For example, the energy demand or energy consumption forecast delivered for the energy consuming side may be used by the energy supplying side to plan ahead the production of the requested energy in adaptation to these forecasts, where the energy production is changed by switching on or off an appropriate number of power generating units

The term "energy" is used in the following to refer to any utility providing energy to a production facility, in particular electricity, industrial gas and steam.

Today's methodologies do not offer an automatic connection between energy provision and production scheduling. Instead they are done separately as described above. For batch processes, this is especially the case as subsequent processing steps or production stages are linked together and the relationships between these are often critical, e.g. one processing step must conclude for the whole batch before another processing step may start. The time between subsequent steps is restricted or there may be some physical constraints, for instance for the transport times and distances between the production equipment.

One factor that has hindered so far a naturally combined optimization of production scheduling and energy provision is that the different systems are often completely decoupled and working in a "competitive" manner, i.e. there is not a collaboration approach in place between production scheduling and execution and energy provision.

It is the object of the present invention to provide systems and methods for simultaneous handling of production scheduling and execution and energy provision applied to optimizing the operation of an energy-intensive industrial batch production facility, in particular a melt shop for production of metals, with respect to production constraints as well as the availability of energy resources.

This object is achieved by a production scheduling and execution system, an energy provision system, a combined system containing the production scheduling and execution system and the energy provision system as well as corresponding methods according to the independent claims.

As is known from the art, the production scheduling and execution system comprises a production scheduling unit and a first communication interface. The production scheduling unit is arranged to determine an initial production schedule of the industrial batch production facility taking into account at least one production constraint, where the initial production schedule contains schedule parameters defining a sequence in which at least two production steps are to be performed or at least two batches having different characteristics are to be produced by one and the same production step, and defining an expected energy demand for each of the at least two production steps or batches. The first communication interface is arranged to transmit the initial production schedule to a first control system for controlling the operation of the industrial batch production facility according to the initial production schedule.

In the art, the energy provision system of an industrial batch production facility comprises a third communication interface unit arranged to be connected to the production scheduling and execution system and to receive the initial production schedule from the production scheduling and execution system. It further comprises an energy scheduling unit arranged to
5 determine based on the initial production schedule an initial energy schedule including an overall energy demand forecast of the industrial batch production facility. And the energy provision system comprises a fourth communication interface unit arranged to be connected to the first or a second control system of the industrial batch production facility and to transmit the initial energy schedule to the first or second control system for controlling
10 according to the initial energy schedule at least one energy supplying facility of the industrial batch production facility

According to the invention, the production scheduling unit of the production scheduling and execution system is arranged to further determine for at least one of the schedule
15 parameters a range within which the at least one schedule parameter may be varied while at the same time meeting the at least one production constraint. Further, the production scheduling and execution system comprises a second communication interface unit which is arranged to be connected to an energy provision system for controlling the operation of energy supplying facilities of the industrial batch production facility, where the second
20 communication interface unit is arranged to transmit the initial production schedule and the range of the at least one schedule parameter to the energy provision system and to receive from the energy provision system a value for the at least one schedule parameter chosen by the energy provision system within its range. The production scheduling unit is arranged to then adjust the initial production schedule to the received value for the at least one schedule
25 parameter before forwarding the initial production schedule to the first communication interface unit for transmittal to the first control system.

In the energy provision system according to the invention, the third communication interface unit is arranged to further receive for at least one of the schedule parameters a range within
30 which the at least one schedule parameter may be varied, the energy scheduling unit is arranged to determine the initial energy schedule based on the initial production schedule and on the range of the at least one schedule parameter, by choosing a value for the at least one schedule parameter within its range so that at least one time-dependent energy constraint is as closely met by the initial energy schedule as possible.

35

The term "production schedule" is used here for a time-dependent plan or timetable which defines as a minimum when what kind and what amount of energy resources is to be used in

each of the production steps or in the production of each of the batches during operation of the industrial batch production facility. The production steps can be given as a sequence of batches per production equipment or as a sequence of equipment used per batch, and the characteristics of the batches define in particular the corresponding production process

5 variables for the one and same production step which is performed by one and the same production equipment, where the process variables are for example temperature, pressure, process duration, kind and amount of source material and/or additional ingredients to be used in that production step etc..

10 The term “production constraint” covers all production related conditions which influence the production schedule, like for example a minimum transport time needed to move a batch from one production equipment to another, or a minimum resting time during which a batch needs to cool down or recover after having finished a certain production step.

15 The term “energy supplying facility” refers to any facility belonging to the industrial batch production facility which is able to generate or transform energy or which belongs to a distribution system for bringing the energy directly to the production equipment of the industrial batch production facility or feeding surplus energy into an external energy distribution network.

20

The term “energy schedule” is used for a time-dependent plan or timetable which defines as a minimum when what kind and what amount of energy is available to the industrial batch production facility, where this is understood as the overall energy demand forecast. The energy schedule may further define schedules for the energy supplying facilities, i.e. when
25 what kind and what amount of energy should be generated by energy generation facilities, or transformed from one energy type into another by energy transformation facilities, or fed as surplus energy to an external network by energy feed facilities.

30 The term “energy” is mainly used for electricity, but covers also additional types of energy delivered to a production site via supply lines and ready to be used directly, without any transformation into another energy form, such as steam, industrial gases or heated water.

The term “energy constraint” defines for example a maximum amount of energy available or a minimum amount to be consumed during a certain period of time or a certain condition
35 under which energy is available, such as a preferred time for supplying a certain kind or amount of energy or a price to be paid for it.

Both types of schedules cover a time period into the future in a mid-term or long-term range, where mid-term range means that the schedule lies ahead between half a day up to a couple of weeks, maximum 6 weeks, and where long-term range means between one to a few months, maximum 6 months, into the future.

5

Opposed to the art, where the energy provision system determines and optimizes the energy schedule for the production facility based on a fixed production schedule, the invention suggests providing additional information on a possible range of one or multiple parameters of the production schedule. Thereby, the flexibility of the energy scheduling unit is increased, allowing it to better adapt the energy schedule to the energy constraints, such as an expected reduced availability of solar energy during cloudy weather or an expected increased availability of wind energy during stormy weather. The range of the scheduling parameter or parameters is thereby chosen so that given production constraints are always complied with. In addition, the invention differs from the art in that it is no longer a one-way flow of information from the production scheduling and execution to the energy provision system, but instead the production scheduling and execution system receives feedback information from the energy provision system in the form of the chosen value for the flexible scheduling parameter, so that the production schedule can be updated accordingly.

10

15

20

25

In this way, production scheduling and energy provision are handled in a simultaneous way and the resulting schedules take into account both production constraints as well as energy constraints reflecting the availability of energy resources. Accordingly, the timetables of energy demand and energy supply can be matched in an optimized way, thereby ensuring operation of the industrial batch production facility at an optimized productivity level while minimizing the necessity for the installation of additional energy back-up or energy storage devices. Further, the energy distribution grid connected to the production facility is stabilized due to the optimally adjusted energy demand and the operation of energy generation facilities is simplified since the number of interventions with respect to switching on or switching off of back-up power plants is reduced.

30

In an embodiment of the energy provision system, the at least one schedule parameter is a start time and/or end time of one of the at least two production steps or batches, and the energy scheduling unit is arranged to move the start time and/or end time of said production step or batch, i.e. to choose a different start and/or end time, while meeting the expected energy demand of said production step or batch.

35

In particular, the energy scheduling unit may be arranged to move both the start time and end time in an identical way, i.e. in the same direction and for the same length of time, or to move the start and end time independently and to adjust an amount of power provided to said production step or batch so that the overall energy demand of said production step or batch is equal to the expected energy demand of said production step or batch.

The advantage of keeping the expected energy demand at the level determined by the production scheduling and execution system is that the energy provision system does not interfere with the production scheduling and execution as such, i.e. both systems are still kept to work independently from each other without needing to know what is going on inside the other and without adding too much extra communication between them. In this way, existing production scheduling and execution and energy provision systems can easily be upgraded to the functionality presented here and can still be used.

In an embodiment of the production scheduling and execution system, the second communication interface unit is arranged to receive from the energy provision system the initial energy schedule, the production scheduling unit is arranged to determine an adapted production schedule based on the initial production schedule and the initial energy schedule by re-scheduling the at least two production steps or batches so that the expected energy demand of the at least two production steps or batches is adapted to the at least one time-dependent energy constraint while at the same time meeting the at least one production constraint and so that the range of the at least one schedule parameter is adapted accordingly. Further, the second communication interface unit is arranged to transmit the adapted production schedule and the adapted range to the energy provision system and to receive from the energy provision system a value for the at least one schedule parameter chosen by the energy provision system within its adapted range, the production scheduling unit is arranged to adjust the adapted production schedule to the received value for the at least one schedule parameter before forwarding the adapted production schedule to the first communication interface unit, and the first communication interface unit is arranged to transmit the adapted production schedule to the first control system for controlling the operation of the industrial batch production facility according to the adapted production schedule instead of the initial production schedule.

The term "re-scheduling" is used to describe that the time-tables created during scheduling of the at least two production steps or batches are changed so that the energy demand of the production steps or batches is adapted to the availability of the energy as closely as possible. In its simplest form a re-scheduling could be achieved by shifting the production step for one

batch process from a time period with low to a time period with high availability of energy, or in other words, by just re-arranging the time-table of the overall production process. But preferably, the re-scheduling is a much more advanced function which re-plans individual and multiple time-tables belonging to different equipment used during production.

5

In a corresponding embodiment of the energy provision system, the third communication interface unit is arranged to transmit the initial energy schedule as well as the at least one time-dependent energy constraint to the production scheduling and execution system and to receive from the production scheduling and execution system an adapted production

10

schedule and an adapted range of the at least one schedule parameter. The energy scheduling unit is arranged to determine an adapted energy schedule based on the initial energy schedule, the adapted production schedule and the adapted range, by choosing the value for the at least one schedule parameter within its adapted range so that the at least one time-dependent energy constraint is as closely met by the adapted energy schedule as

15

possible. The third communication interface unit is arranged to transmit the value for the at least one schedule parameter to the production scheduling and execution system, and the fourth communication interface is arranged to transmit the adapted energy schedule to the first or second control system for controlling the energy facilities of the industrial batch production facility according to the adapted energy schedule instead of the initial energy

20

schedule.

The re-scheduling of the production plan is advantageous when the initial energy schedule does not fully comply to the energy constraint. In that case, a re-scheduling of production steps or batches may help to further optimize the corresponding energy demands. According to this embodiment, optimal load shifting is enabled, which means that the active product portfolio is timed in an energy-optimal way and a corrective sequencing between the different batches may take place if this impacts the related energy load curve in a positive way.

25

The re-scheduling and thereby amending of the production plan and the afterwards updating of the energy schedule may be performed as often as necessary in the above described iterative way, until the energy constraint itself or until any other abort criteria is fulfilled, such as reaching a predefined number of iteration steps or reaching a predefined limit in a parameter which is strongly coupled to the energy constraint. Any further adapted production and/or energy schedule may be determined taking into account not only the results of the previous iteration but also of iterations lying further in the past, such as the initial production schedule and the initial energy schedule.

30

35

In a particular embodiment, the information reflecting the at least one time-dependent energy constraint contains information about an expected shortage and/or abundance of energy available to the industrial batch production facility, and the production scheduling unit is arranged to perform the re-scheduling step in such a way that the expected energy demand of at least one of the at least two production steps or batches is reduced during a time period of expected energy shortage and is increased during a time period of expected energy abundance..

In that way, energy availability and energy usage are aligned with each other as much as possible. From the perspective of the energy provision system, it would of course be preferable that the increase of the energy demand is planned for a time period when available energy is clearly in abundant supply. However, in certain situations, for example when these time periods lie apart considerably or when deadlines have to be met, it may be advantageous for the production facility to shift the energy demand of the at least two production steps or batches from a time period of energy shortage to just a time period with normal or average availability of energy. The energy provision system will then, in the next iteration step, get the chance to adapt its energy schedule accordingly.

In a further embodiment of the production scheduling and execution system, the production scheduling unit is arranged to determine the initial production schedule based on at least a schedule of a required output of the production, where the term "required output" means the amount of a certain product or batch of certain products required to be finished at a specified point in time in the future.

On the other side of the interaction cycle, the energy scheduling unit is preferably arranged to determine the initial energy schedule by further taking into account a forecast for an availability of energy sources, in particular a weather forecast. A weather forecast is useful in order to predict the availability of renewable energy sources, such as wind, sun or water. In addition, it supports the estimation of weather-dependent production process conditions, such as the influence of temperature differences between outdoors and indoors. For example, in steel production, scrap is stored outdoors and therefore requires varying degrees of pre-heating before it can be entered into the production process which itself takes place indoors and/or uses another energy profile in the processing. Other possible forecasts for an availability of energy sources can for example be a delivery plan for fossil energy carriers, like coal, oil and gas, to be delivered to an energy generation facility, i.e. a power plant, belonging to the industrial batch production facility.

In addition, the first communication interface of the production scheduling and execution system might be arranged to receive information about an unexpected and sudden change in the energy schedule, and the production scheduling unit may then be arranged to determine an ad-hoc production schedule taking into account the unexpected change, where the ad-hoc production schedule is then transmitted in the usual way to the first control system.

This embodiment takes into account unplanned changes in the energy supply of the production facility, due for example to power outages or malfunctions. The production schedule is then adapted accordingly. The ad-hoc production schedule is a short-term production schedule with a time horizon of only a few hours up to one or two days in the future, i.e. with respect to time it stands in contrast to the regular mid-term or long-term production schedule.

In yet a further embodiment of the production scheduling and execution system, the production scheduling unit is arranged to determine the initial or adapted production schedule by further taking into account at least one of a pre-defined capacity utilization, energy efficiency, output quality and throughput time of the industrial production or manufacturing facility.

In a further embodiment of the energy provision system, the energy scheduling unit is arranged to determine the initial or adapted energy schedule by further taking into account at least one of a pre-defined mixture of different energy sources, amount of stored energy, available energy storage capacity, ramp-up and shut-down time of at least one power generation unit.

The invention covers also all method steps performed by the elements of the production scheduling and execution system and the energy provision system which correspond to the above described embodiments.

According to a method for operating an industrial batch production facility known from the art, the following steps are performed: determining an initial production schedule of the industrial batch production facility taking into account at least one production constraint, where the initial production schedule contains schedule parameters defining a sequence in which at least two production steps are to be performed or at least two batches having different characteristics are to be produced by one and the same production step, and an expected energy demand for each of the at least two production steps or batches, transmitting the initial production schedule to a first control system for controlling the operation of the

industrial batch production facility according to the initial production schedule. This method is extended according to the invention by the steps of determining for at least one of the schedule parameters a range within which the at least one schedule parameter may be varied while at the same time meeting the at least one production constraint, transmitting the
5 initial production schedule and the range of the at least one schedule parameter to an energy provision system for controlling the operation of energy supplying facilities of the industrial batch production facility.

Another method known from the art for operating an industrial batch production facility
10 comprises the steps: receiving an initial production schedule from a production scheduling and execution system of the industrial batch production facility, where the initial production schedule contains schedule parameters defining a sequence in which at least two production steps or production of at least two batches having different characteristics are to be performed and an expected energy demand for each of the at least two production steps or
15 batches, determining based on the initial production schedule initial energy schedule including an overall energy demand forecast of the industrial batch production facility, and transmitting the initial energy schedule to a first or second control system for controlling according to the initial energy schedule at least one energy supplying facility of the industrial batch production facility. According to the invention, the following further steps are added:
20 receiving for at least one of the schedule parameters a range within which the at least one schedule parameter may be varied, determining the initial energy schedule based on the initial production schedule and on the range of the at least one schedule parameter, by choosing a value for the at least one schedule parameter within its range so that at least one time-dependent energy constraint is as closely met by the initial energy schedule as
25 possible.

The invention and its embodiments will become apparent from the example and its embodiments described below in connection with the appended drawings which illustrate:

- Fig. 1 a block diagram of a production scheduling and execution system and an energy
30 provision system interacting with each other,
Fig. 2 a flow diagram of a method performed by the production scheduling and execution system,
Fig. 3 a flow diagram of a method performed by the energy provision system,
Fig. 4 time diagrams of a production schedule and an overall energy demand forecast
35 as known from the art,
Figs. 5-7 time diagrams of a production schedule and an overall energy demand forecast applying the invention,

Fig. 8 a time diagram showing the treatment of energy as a product by the energy provision system.

Fig. 1 shows as an example an energy-intensive industrial batch production facility 2 from the steel industry, in particular a melt shop.

The production equipment PROD of the melt shop comprises for illustrative purposes, at least one electric arc furnace 13 for melting steel scrap, at least one argon oxygen decarburization unit 14 for processing the molten steel by oxygen (O₂) blowing, at least one ladle furnace 15 where for alloying purposes temperature and chemistry adjustments are made and at least one continuous caster 16 for casting slabs, which are then cut to length and transferred to downstream storage and/or rolling mills.

In the melt shop, the electric arc furnaces (EAF) can easily alone temporarily consume energy amounts that correspond to the production of a small to mid-size power plant. Similarly, in a blast furnace (BF) based plant, lots of process gases are produced and consumed and an optimal integration can significantly reduce the need of purchasing external natural gas. Thus, there are several production-related aspects that tie the process to energy usage. For said furnaces, the most energy-intensive operation modes are often the final melting phases. This is the reason for a commonly applied restriction, namely to operate the multiple of furnaces used in one steel plant in a time-shifted manner, with only part of the furnaces being operated simultaneously. Due to the invention, it becomes possible to lift this restriction and to couple the number of simultaneously operated furnaces directly to the amount of available energy.

Furthermore, what makes the steel processing especially challenging is the multi-stage batch process nature. In practice, this means that if a certain batch, which in steel production is called heat, is already being processed, it is very expensive to stop the processing as any waiting times between subsequent steps result in a cooling of the batch. The cooling equals to energy losses and/or it may compromise the resulting material quality. Further looking at the process, the final step, which is the continuous casting, is often done in a series of several batches. This means that if the first of for instance five batches is currently in production, the remaining four batches must immediately follow the first batch. If this is not possible, a major re-scheduling of the production needs to take place.

A melt shop represents the primary metals stage in metals processing. In a melt shop, the most significant consumers of electricity are:

- Electric arc furnaces (EAF),
- Ladle furnaces (LF), and
- Pumps, compressors, drives and motors

5 Another energy form used in a melt shop is gas. The main gas consumption takes place at

- Basic oxygen furnaces (BF),
- Argon-oxygen decarburization units (AOD), and
- the Vacuum degasser.

10 In order to perform the production scheduling, the melt shop of Fig. 1 comprises a production scheduling and execution system 1. Further, a control system CONTR1 and production equipment PROD, including the above named electricity and gas consumers, is shown, where the operation of the production equipment PROD is controlled by the control system CONTR1, which may be any known process control system.

15

The production scheduling and execution system 1 contains a production scheduling unit SCHED1 having data processing functionality, a first communication interface COM1, a second communication interface COM2 and a data storage unit DB1. All elements contained in the production scheduling and execution system 1 exchange data via internal

20 communication lines indicated by block arrows. These data can be transmitted by the first communication interface COM1 to the first control system CONTR1 via data communication line 7. The first control system CONTR1 sends actuating information ACT1 to and receives measurement and/or status information MEAS1 from the production equipment PROD via communication line 8, where measurement and/or status information MEAS1 may for

25 example include information reflecting a delay of production execution which is then taken into account for a later re-scheduling.

In Fig. 1, it is further seen an energy provision system 4, also belonging to the melt shop, a second control system CONTR2, and energy generation and supplying equipment ENG,

30 operation of which is controlled by the second control system CONTR2. The energy provision system 4 contains an energy scheduling unit SCHED2 having data processing functionality, a third communication interface COM3, a fourth communication interface COM4 and a data storage unit DB2. All elements contained in the energy provision system 4 exchange data via internal communication lines indicated by block arrows. These data can

35 be transmitted by the fourth communication interface COM4 to the second control system CONTR2 via data communication line 9. The second control system CONTR2 sends actuating information to and receives measurement and/or status information from the

energy generation and supplying equipment ENG via communication line 10. Further, the energy provision system 4, and in particular its energy scheduling unit SCHED2, may deliver actuating information ACT2 which directly influences operation of the production equipment PROD, such as set points for operation of the electrodes of the at least one electric arc furnace 13. This production related actuating information ACT2 is sent via data communication line 9 to the second control system CONTR2 from where it is forwarded to production equipment PROD via communication line 11. In the alternative, second control system CONTR2 could derive the actuating information ACT2 from an energy schedule received from energy scheduling unit SCHED2. During processing operation of the energy scheduling unit SCHED2, measurement information MEAS2 from the production equipment PROD may be taken into account, which is indicated by the double arrow of communication line 11. Measurement information MEAS2 may for example include information reflecting the current energy demand or time dependent temperature curve of specific elements of production equipment PROD or of specific batches. The energy generation and supplying equipment ENG delivers energy to the production equipment PROD via an energy supply line 6.

According to the invention, a bi-directional communication link 5 exists between the production scheduling and execution system 1 and the energy provision system 4 for exchanging of production and energy schedules and further information, respectively. The communication link 5 can for example be a wireless or wire-bound data communication line or network, or it can be established via a commonly accessible database.

As is indicated by rectangular frame 3, the production scheduling and execution system 1 and energy provision system 4 may be integrated in one and the same overall system. This would, however, not change the inner structure of systems 1 and 4.

Examples for the interaction between the production scheduling and execution system 1 and the energy provision system 4 are now explained with respect to the further figures.

There are several possible ways to impact the energy consumption of a melt shop, such as:

- variation of the timing of the EAFs, i.e. to delay or to bring forward heats,
- to reduce or increase the EAF/BF exit temperature within allowed limits and to compensate for it later in e.g. the AOD or LF, and
- to use buffering capacity of the melt shop before moving on to the next metals stage, i.e. casting

Taking a broader perspective, buffering capacity is also of interest between the melt shop and a following hot rolling facility. Slabs leaving the melt shop could be stored in a slab yard for a predetermined time in order to shift the energy demand of the hot rolling to a later stage.

5

Through these actions, the energy consumption can be temporarily increased or decreased, and accordingly be adapted to the availability of energy.

10

These possibilities for influencing the expected energy demand of single production steps or batches of the melt shop are used by the production scheduling and execution system 1.

15

In the upper part of Fig. 4, an initial production schedule of the energy-intensive industrial batch production facility 2, which is here the melt shop, is shown, which is determined by production scheduling and execution system 1 in a manner known from the art. The initial production schedule contains the plans for two types of production equipment Equipm.1 and Equipm.2, for example for a first and a second electric arc furnace. For each of the production equipment, two heats, i.e. two batches, are planned with the start and end times and the electric power required during the corresponding production step. Accordingly, each heat H1 to H4 represents one batch, where part of the batches, batches H1 and H3, is produced by a first production step of a first production equipment Equipm.1 and where the remaining part of the batches, batches H2 and H4, is produced by a second, parallel production step of a second production equipment Equipm.2. The scheduling parameters defining these steps are the start times ts_1 to ts_4 , the end times te_1 to te_4 and the value for the electric power P_1 to P_4 required between the respective start and end time. The power values P_1 to P_4 multiplied with the corresponding time periods $\Delta T = (ts - te)$ define the expected energy demand per batch.

20

25

30

35

Based on this initial production schedule, the energy provision system 4 derives an initial overall energy demand forecast in a known manner, as shown in the lower part of Fig. 4. The initial energy forecast is then discretized by the energy provision system 4, as indicated by the dots on the solid line, where the discretization is performed according to the needed granulation; and for each discretization point an energy strategy is determined, as is indicated by the figure of the flow network below one of the discretization points. In the flow network, the bigger circle to the left indicates an energy source and the bigger circle to the right an energy export, such as an infeed of energy into an external distribution network. The arrows emanating from the energy source indicate different energy types and each node indicates a production step or batch.

The energy provision system 4 builds energy balances around each node of the flow network, at each discrete time point, applying laws of thermodynamics and taking into account energy conversions as well as measurement information MEAS2. These energy
5 balances are then optimized w.r.t. energy availability on the energy market, and they form the basis for controlling energy generation, energy transformation, energy supplying and energy feed of the melt shop.

Fig. 4 represents a one-way information flow between production scheduling and execution
10 system 1 and energy provision system 4. According to the invention, a two-way information flow is enabled between the two systems 1 and 4, by exchanging information and parameters that can steer the behavior of each system.

In Fig. 2, a method is shown which is performed by the production scheduling and execution
15 system 1 and in Fig. 3 a method is shown which is performed by the energy provision system 4 concurrently with the method of Fig. 2 and by applying the present invention.

First, the initial production schedule Sched_P_ini according to Fig. 4 is determined by production scheduling unit SCHED1 as a function f1 which depends on a requested time-
20 dependent output outp of the production of a certain number of heats, which are here for illustrative purposes heats H1 to H4, where the production is planned for a time period which lies two weeks ahead. Function f1 further depends on at least one production constraint p_constr and on scheduling parameters pm, which in this example are the start times ts1 to ts4, the end times te1 to te4 and the power values P1 to P4. Production scheduling unit
25 SCHED1 further determines a range rge(pm) for the start and end times of heats H2 and H3, which is indicated in Figs. 5 to 7 as a shaded area.

Then, the second communication interface unit COM2 transmits the initial production schedule Sched_P_ini and the range rge(pm) via communication link 5 to the energy
30 provision system 4, and there in particular to the third communication interface unit COM3 where it is received (first step of Fig. 3). From the initial production schedule Sched_P_ini and further information, energy scheduling unit SCHED2 determines an initial energy schedule Sched_E_ini via an optimization function f4, where the optimization function f4 takes into account the range rge(pm) and at least one energy constraint e_constr. The
35 energy scheduling unit SCHED2 determines the initial energy schedule Sched_E_ini by choosing a value PM for the at least one schedule parameter pm within its range rge(pm) so

that the at least one energy constraint e_constr is as closely met by the initial energy schedule as possible.

This initial energy schedule $Sched_E_ini$ contains information of an overall energy demand forecast E_fcst , shown in the lower part of Figs. 5 to 7, as well as information reflecting the at least one energy constraint e_constr . This information together with the value or values PM is then sent by the third communication interface unit $COM3$ via communication link 5 to the second communication interface unit $COM2$ of the product scheduling and execution system 1, where it is received (Fig. 2).

Afterwards, the production scheduling unit $SCHED1$ adapts the initial production $Sched_P_ini$ to the value or values PM , illustrated by a function $f2$.

Different possible ways which may be taken by energy scheduling unit $SCHED2$ to choose the value PM are now explained with respect to Figs. 5 to 7.

In Figs. 5 to 7, the energy scheduling unit $SCHED2$ moves the start time $ts2$, $ts3$ and/or end time $te2$, $te3$ of batches $H2$ and $H3$ while meeting the expected energy demand of both batches, i.e. $E2=P2 \cdot (ts2-te2)$ and $E3=P3 \cdot (ts3-te3)$ are kept constant. The energy constraint e_constr which is to be fulfilled is to not exceed a maximum power level of 50 MW. This would not be possible when determining the initial energy schedule $Sched_E_ini$ in the traditional way. Fig. 4 shows that between $ts3$ and $te2$ an unwanted peak of 70 MW occurs due to the overlapping of heats $H2$ and $H3$ which cannot be altered by the energy provision unit 4.

According to the invention, the peak of 70 MW can now be avoided by appropriately choosing the start and end times of $H2$ and $H3$, where the energy scheduling unit $SCHED2$ can choose between different possibilities depending on possible further energy constraints.

In Fig. 5 shows a first possibility, where the energy scheduling unit $SCHED2$ moves both the start time $ts2$ and end time $te2$ of batch $H2$ in an identical way, until batch $H2$ starts directly after batch $H1$ has finished. The start time $ts2$ and end time $te2$ are hereby both kept within their allowed range. As a result, the power demand of $H2$ is shifted to the left without changing its value of 25 MW, and batches $H2$ and $H3$ and their corresponding power demands $P2$ and $P3$ no longer overlap.

According to a second possibility shown in Fig. 6, the energy scheduling unit SCHED2 moves the start times ts_2 , ts_3 and the end times te_2 , te_3 independently, all to the outer limit of their corresponding ranges. The amount of power P_2 , P_3 provided to the batches H2, H3 is then adjusted so that the overall energy demand of batches H2, H3 is equal to their expected energy demands E_2 , E_3 . Accordingly, the power demand of batch H2 is reduced from 25 to 13 MW and of batch H3 from 45 to 25 MW. As a result, the overlapping of batches H2 and H3 only results in a power demand of 38 MW, which is clearly below the limit of 50 MW. Due to the extension of batch H3, now an additional overlap occurs, between batches H3 and H4. This is allowable, as the power demand of H3 plus H4 results to 45 MW, i.e. is less than 50 MW as well.

A third possibility is illustrated by Fig. 7, where the energy scheduling unit SCHED2 again moves the end time te_2 independently from the corresponding start time ts_2 which is not moved at all. The end time te_2 is moved in such a way that the resulting power demand of H2 equals exactly 50 MW. As a result, again the overlap of batches H2 and H3 disappears.

The energy provision system 4 may realize the above described choosing of scheduling parameters in its flow network model by handling energy consumption as an inventory that must be consumed within a given time, or – in other words – by treating energy as an intermediate or final product with some special characteristics. This is explained in connection with Fig. 8. At the start time ts_2 of batch H2, a given energy level in MWh is assumed. This given energy level must be reduced to zero at the end time te_2 . The distance between start and end time is given by the maximum limits of the ranges of start and end time, and the steepness of the reduction is defined by physical process constraints, i.e. the minimum and maximum consumption levels of production equipment Equipm.1. In the flow network, the simultaneous flows of the energy curves of potentially overlapping batches can be limited by constraining the corresponding flow variables. In this way, the energy scheduling unit SCHED2 can in fact decide the actual start and end times of a batch within the provided limits.

In the example of Figs. 5 to 7, both the production constraints p_constr and the energy constraints e_constr are already met after the first information exchange between production scheduling and execution system 1 and energy provision system 4, so that no further iterations would be necessary.

However, assuming that the energy constraints would be to not exceed a power demand level of 40 W, the energy provision system 4 would not be able to achieve this goal alone, by

just shifting the scheduling parameters within their ranges. In that case, the next step of energy provision system 4 would be to send, via the third communication interface COM3, the at least one energy constraint e_constr and the overall energy demand forecast E_fcst belonging to the initial energy schedule $Sched_E_ini$, to the second communication interface COM2 of production scheduling and execution system 1 (see Figs. 3 and 2).

The production scheduling unit SCHED1 would then further optimize the production schedule by re-scheduling the batches H1 to H4, by applying an optimization function $f3$ to the initial production schedule $Sched_P_ini$ and the initial energy schedule $Sched_E_ini$, the latter being taken into account via the overall energy demand forecast E_fcst and the energy constraints e_constr , and by further taking into account feedback information from the currently running production via at least a first measurement value MEAS1 determined from the industrial batch production facility. The optimization function $f3$ re-schedules in particular energy-intensive production processes, in this example the use of the electric arc furnaces, in order to better oblige to the energy constraints while at the same time fulfilling the production constraints p_constr . The overall energy demand forecast E_fcst and the energy constraints e_constr could also be combined in a so called energy target profile, which may contain either concrete target values or min-max energy ranges. The output of optimization function $f3$ is an adapted production schedule $Sched_P_ad$. The range of the scheduling parameters is adapted by production scheduling unit SCHED1, too, in accordance with the adapted production schedule $Sched_P_ad$. Both are then sent to the third communication interface COM3 of energy provision system 4.

The energy scheduling unit SCHED2 inputs the initial energy schedule $Sched_E_ini$, the adapted production schedule $Sched_P_ad$, the adapted range of scheduling parameters $rge(pm)_ad$ and at least a second measurement value MEAS2, determined from a currently running process in the industrial batch production facility, to an optimization function $f5$ which again determines the overall energy demand forecast and tries to adapt it to the energy constraints e_constr by choosing the value PM for the at least one schedule parameter pm within its adapted range $rge(pm)_ad$ so that the at least one time-dependent energy constraint e_constr is as closely met by the adapted energy schedule as possible. The at least one newly chosen value PM is then sent back to the second communication interface COM2 of production scheduling and execution system 1, where the adapted production schedule $Sched_P_ad$ is adjusted accordingly and then output via first communication interface COM1 to the first control system 1 for controlling the operation of the melt shop in accordance with the adapted production schedule $Sched_P_ad$.

The energy provision system 4 outputs the adapted energy schedule Sched_E_ad via fourth communication interface COM4 to the second control system CONTR2 for controlling at least one energy supplying facility of the melt shop in accordance with the adapted energy schedule Sched_E_ad.

5

As can be understood from Figs. 2 and 3, the production scheduling and execution system 1 and the energy provision system 4 interact by performing a kind of handshaking during their respective scheduling, where each of the two systems waits with the next iteration step until the other system delivers its updated schedule.

Claims

1. Production scheduling and execution system (1) of an energy-intensive industrial batch production facility (2), comprising
 - a production scheduling unit (SCHED1) arranged to determine an initial production schedule (Sched_P_ini) of the industrial batch production facility (2) taking into account at least one production constraint (p_constr), where the initial production schedule contains schedule parameters (pm) defining a sequence in which at least two production steps are to be performed or at least two batches (H1 to H4) having different characteristics are to be produced by one and the same production step, and an expected energy demand (P1 to P4) for each of the at least two production steps or batches,
 - a first communication interface unit (COM1) arranged to be connected to a first control system (CONTR1) of the industrial batch production facility and to transmit the initial production schedule (Sched_P_ini) to the first control system (CONTR1) for controlling the operation of the industrial batch production facility (2) according to the initial production schedule,characterized in that
 - the production scheduling unit (SCHED1) is arranged to determine for at least one of the schedule parameters a range (rge(pm)) within which the at least one schedule parameter may be varied while at the same time meeting the at least one production constraint (p_constr),
 - the production scheduling and execution system (1) comprises a second communication interface unit (COM2) which is arranged to be connected to an energy provision system (4) for controlling the operation of energy supplying facilities of the industrial batch production facility (2),
 - the second communication interface unit (COM2) is arranged to transmit the initial production schedule (Sched_P_ini) and the range of the at least one schedule parameter (rge(pm)) to the energy provision system (4) and to receive from the energy provision system (4) a value (PM) for the at least one schedule parameter (pm) chosen by the energy provision system (4) within its range,

- the production scheduling unit (SCHED1) is arranged to adjust the initial production schedule (Sched_P_ini) to the received value (PM) for the at least one schedule parameter before forwarding the initial production schedule (Sched_P_ini) to the first communication interface unit (COM1) for transmittal to the first control system (CONTR1).

2. Production scheduling and execution system according to claim 1, wherein

- the second communication interface unit (COM2) is arranged to receive from the energy provision system (4) an initial energy schedule (Sched_E_ini) of the industrial batch production facility including information reflecting at least one time-dependent energy constraint (e_constr),
- the production scheduling unit (SCHED1) is arranged to determine an adapted production schedule (Sched_P_ad) based on the initial production schedule (Sched_P_ini), the initial energy schedule (Sched_E_ini) and at least a first measurement value (MEAS1) determined from the industrial batch production facility, by re-scheduling the at least two production steps or batches (H1 to H4) so that the expected energy demand (P1 to P4) of the at least two production steps or batches is adapted to the at least one time-dependent energy constraint (e_constr) while at the same time meeting the at least one production constraint (p_constr) and so that the range of the at least one schedule parameter is adapted accordingly (rge(pm)_ad),
- the second communication interface unit (COM2) is further arranged to transmit the adapted production schedule (Sched_P_ad) and the adapted range (rge(pm)_ad) to the energy provision system (4) and to receive from the energy provision system (4) a value (PM) for the at least one schedule parameter (pm) chosen by the energy provision system (4) within its adapted range,
- the production scheduling unit (SCHED1) is arranged to adjust the adapted production schedule (Sched_P_ad) to the received value (PM) for the at least one schedule parameter before forwarding the adapted production schedule (Sched_P_ad) to the first communication interface unit (COM1), and
- the first communication interface unit (COM1) is arranged to transmit the adapted production schedule (Sched_P_ad) to the first control system (CONTR1) for controlling the operation of the industrial batch production facility (2) according to the adapted production schedule instead of the initial production schedule (Sched_P_ini).

3. Production scheduling and execution system according to claim 1 or 2, wherein
 - the information reflecting the at least one time-dependent energy constraint (e_constr) contains information about an expected shortage and/or abundance of energy available to the industrial batch production facility (2),
 - the production scheduling unit (SCHED1) is arranged to perform the re-scheduling step in such a way that the expected energy demand of at least one of the at least two production steps or batches (H2, H3) is reduced during a time period of expected energy shortage and is increased during a time period of expected energy abundance.
4. Production scheduling and execution system according to any of the previous claims, wherein the production scheduling unit (SCHED1) is arranged to determine the initial production schedule (Sched_P_ini) based on at least a schedule of a required output (outp) of the batch production.
5. Production scheduling and execution system according to claim 4, wherein the production scheduling unit (SCHED1) is arranged to determine the initial and/or adapted production schedule by further taking into account at least one of a pre-defined capacity utilization, energy efficiency, output quality and throughput time of the industrial batch production facility.
6. Production scheduling and execution system according to any of the previous claims, wherein the initial and adapted production schedules cover a time period which lies in the future between half a day up to a few months ahead.
7. Energy provision system (4) of an energy-intensive industrial batch production facility (2), comprising
 - a third communication interface unit (COM3) arranged to be connected to a production scheduling and execution system (1) of the industrial batch production facility (2) and to receive an initial production schedule (Sched_P_ini) from the production scheduling and execution system (1), where the initial production schedule contains schedule parameters (pm) defining a sequence in which at least two production steps or production of at least two batches (H1 to H4) having different characteristics are to be performed and an expected energy demand (P1 to P4) for each of the at least two production steps or batches,

- an energy scheduling unit (SCHED2) arranged to determine based on the initial production schedule (Sched_P_ini) an initial energy schedule (Sched_E_ini) including an overall energy demand forecast (E_fcst) of the industrial batch production facility (2), and
- a fourth communication interface unit (COM4) arranged to be connected to a first (CONTR1) or a second control system (CONTR2) of the industrial batch production facility (2) and to transmit the initial energy schedule (Sched_E_ini) to the first or second control system for controlling according to the initial energy schedule at least one energy supplying facility of the industrial batch production facility,

characterized in that

- the third communication interface unit (COM3) is arranged to further receive for at least one of the schedule parameters a range (rge(pm)) within which the at least one schedule parameter (pm) may be varied,
- the energy scheduling unit (SCHED2) is arranged to determine the initial energy schedule (Sched_E_ini) based on the initial production schedule (Sched_P_ini) and on the range of the at least one schedule parameter (rge(pm)), by choosing a value (PM) for the at least one schedule parameter (pm) within its range (rge(pm)) so that at least one time-dependent energy constraint (e_constr) is as closely met by the initial energy schedule as possible, and
- the third communication interface unit (COM3) is arranged to transmit the value (PM) for the at least one schedule parameter to the production scheduling and execution system (1).

8. Energy provision system according to claim 7, wherein the at least one schedule parameter (pm) is a start time and/or end time of one of the at least two production steps or batches (H2, H3) and wherein the energy scheduling unit (SCHED2) is arranged to move the start time and/or end time of said production step while meeting the expected energy demand of said production step.
9. Energy provision system according to claim 8, wherein the energy scheduling unit (SCHED2) is arranged to move both the start time and end time in an identical way.
10. Energy provision system according to claim 8, wherein the energy scheduling unit (SCHED2) is arranged to move the start and end time independently and to adjust an amount of power (P2, P3) provided to said production step or batch (H2, H3) so that

the overall energy demand of said production step is equal to the expected energy demand of said production step.

11. Energy provision system according to any of claims 7 to 10, wherein
 - the third communication interface unit (COM3) is arranged to transmit the initial energy schedule (Sched_E_ini) as well as the at least one time-dependent energy constraint (e_constr) to the production scheduling and execution system (1) and to receive from the production scheduling and execution system an adapted production schedule (Sched_P_ad) and an adapted range of the at least one schedule parameter (rge(pm)_ad),
 - the energy scheduling unit (SCHED2) is arranged to determine an adapted energy schedule (Sched_E_ad) based on the initial energy schedule, the adapted production schedule, the adapted range and at least a second measurement value (MEAS2) determined from the industrial batch production facility, by choosing the value (PM) for the at least one schedule parameter (pm) within its adapted range (rge(pm)_ad) so that the at least one time-dependent energy constraint (e_constr) is as closely met by the adapted energy schedule as possible,
 - the third communication interface unit (COM3) is arranged to transmit the value (PM) for the at least one schedule parameter to the production scheduling and execution system (1), and
 - the fourth communication interface (COM4) is arranged to transmit the adapted energy schedule (Sched_E_ad) to the first or second control system (CONTR1, CONTR2) for controlling the energy facilities of the industrial batch production facility according to the adapted energy schedule (Sched_E_ad) instead of the initial energy schedule (Sched_E_ini).
12. Energy provision system according to any of claims 7 to 11, where the at least one energy supplying facility is an energy generation, energy transformation, energy supply or energy feed facility.
13. Energy provision system according to any of claims 7 to 12, wherein the energy scheduling unit (SCHED2) is arranged to determine the initial energy schedule (Sched_E_ini) by further taking into account a forecast for an availability of energy sources, in particular a weather forecast.

14. Energy provision system according to any of claims 7 to 13, wherein the energy scheduling unit (SCHED2) is arranged to determine the initial and/or adapted energy schedule by further taking into account at least one of a pre-defined mixture of different energy sources, amount of stored energy, available energy storage capacity, ramp-up and shut-down time of at least one power generation unit.
15. Energy provision system according to any of claims 7 to 14, wherein the initial and adapted energy schedules cover a time period which lies in the future a couple of days up to a few months ahead.
16. System for optimized operation of an industrial batch production facility, comprising a production scheduling and execution system according to any of claims 1 to 6 and an energy provision system according to any of claim 7 to 15.
17. Method for operating an energy-intensive industrial batch production facility (2), comprising the steps
 - determining an initial production schedule (Sched_P_ini) of the industrial batch production facility (2) taking into account at least one production constraint (p_constr), where the initial production schedule contains schedule parameters (pm) defining a sequence in which at least two production steps are to be performed or at least two batches (H1 to H4) having different characteristics are to be produced by one and the same production step, and an expected energy demand (P1 to P4) for each of the at least two production steps or batches,
 - transmitting the initial production schedule (Sched_P_ini) to a first control system (CONTR1) for controlling the operation of the industrial batch production facility (2) according to the initial production schedule,characterized by the steps:
 - determining for at least one of the schedule parameters a range (rge(pm)) within which the at least one schedule parameter (pm) may be varied while at the same time meeting the at least one production constraint (p_constr),
 - transmitting the initial production schedule (Sched_P_ini) and the range of the at least one schedule parameter (rge(pm)) to an energy provision system (4) for controlling the operation of energy supplying facilities of the industrial batch production facility (2).

18. Method for operating an energy-intensive industrial batch production facility (2), comprising the steps
- receiving an initial production schedule (Sched_P_ini) from a production scheduling and execution system (1) of the industrial batch production facility (2), where the initial production schedule contains schedule parameters (pm) defining a sequence in which at least two production steps or production of at least two batches (H1 to H4) having different characteristics are to be performed and an expected energy demand (P1 to P4) for each of the at least two production steps,
 - determining based on the initial production schedule (Sched_P_ini) an initial energy schedule (Sched_E_ini) including an overall energy demand forecast (E_fcst) of the industrial batch production facility (2), and
 - transmitting the initial energy schedule (Sched_E_ini) to a first or second control system (CONTR1, CONTR2) for controlling according to the initial energy schedule (Sched_E_ini) at least one energy supplying facility of the industrial batch production facility (2),
- characterized by the steps:
- further receiving for at least one of the schedule parameters a range (rge(pm)) within which the at least one schedule parameter (pm) may be varied,
 - determining the initial energy schedule (Sched_E_ini) based on the initial production schedule (Sched_P_ini) and on the range of the at least one schedule parameter (rge(pm)), by choosing a value for the at least one schedule parameter within its range so that at least one time-dependent energy constraint (e_constr) is as closely met by the initial energy schedule as possible.

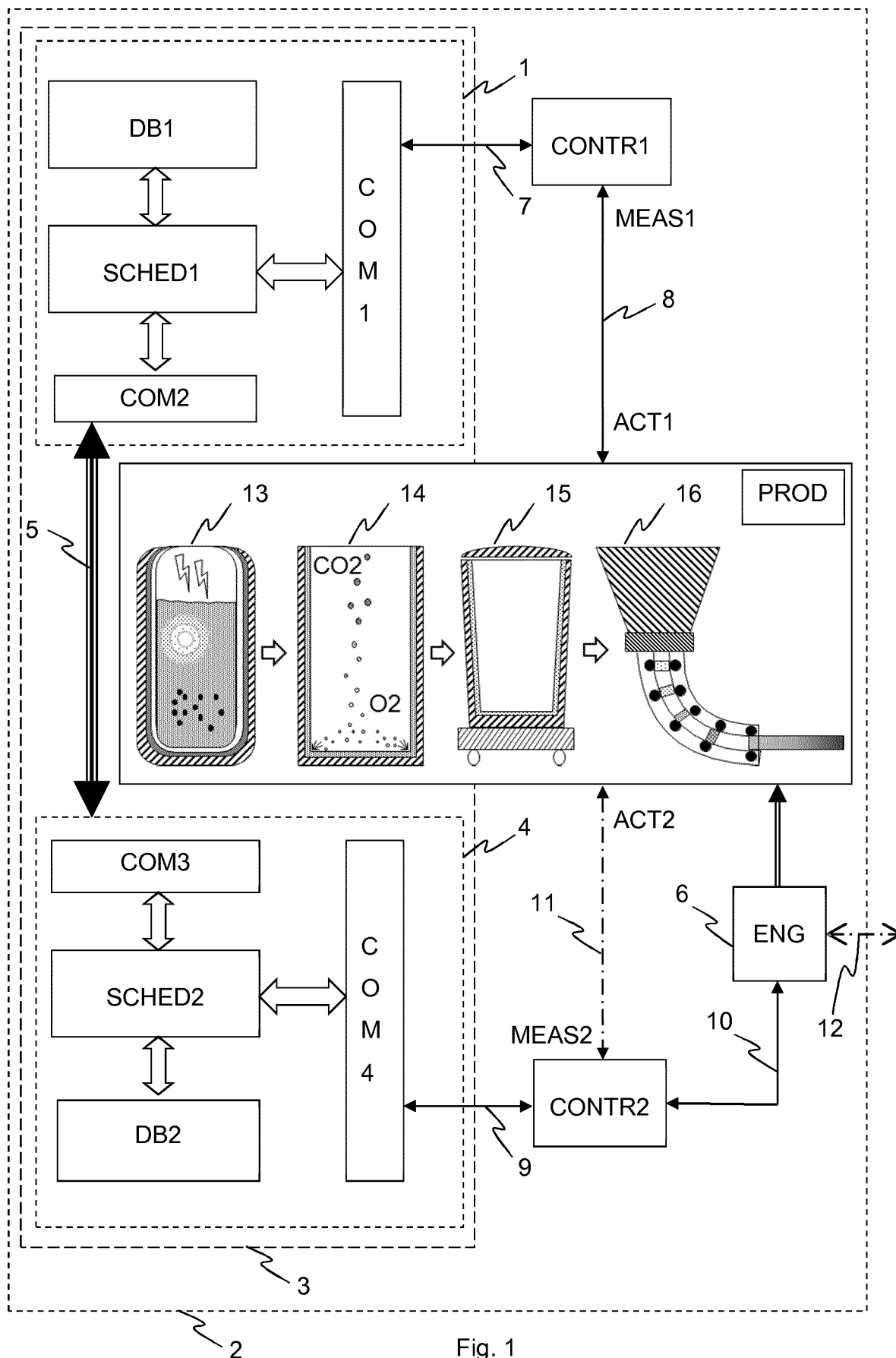


Fig. 1

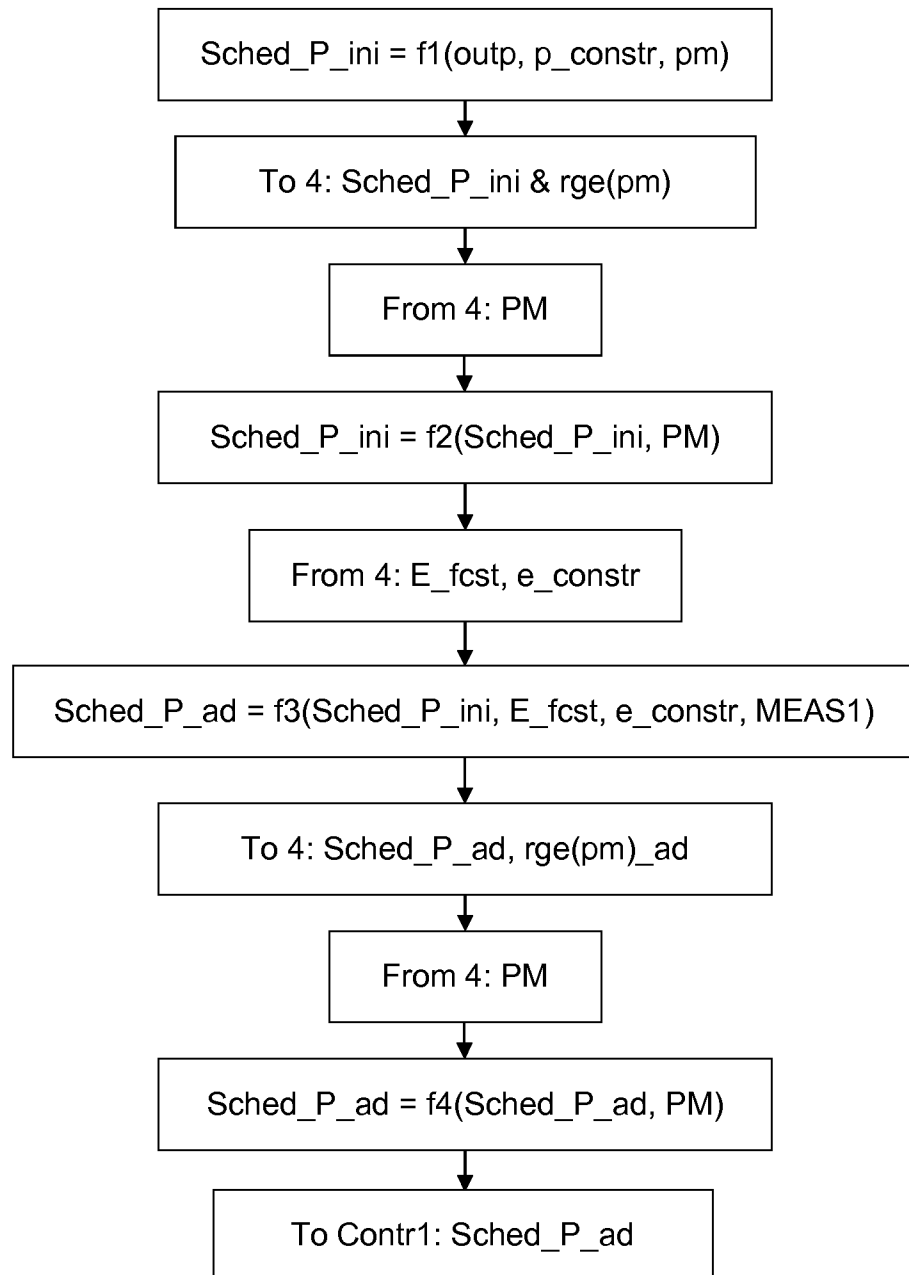


Fig. 2

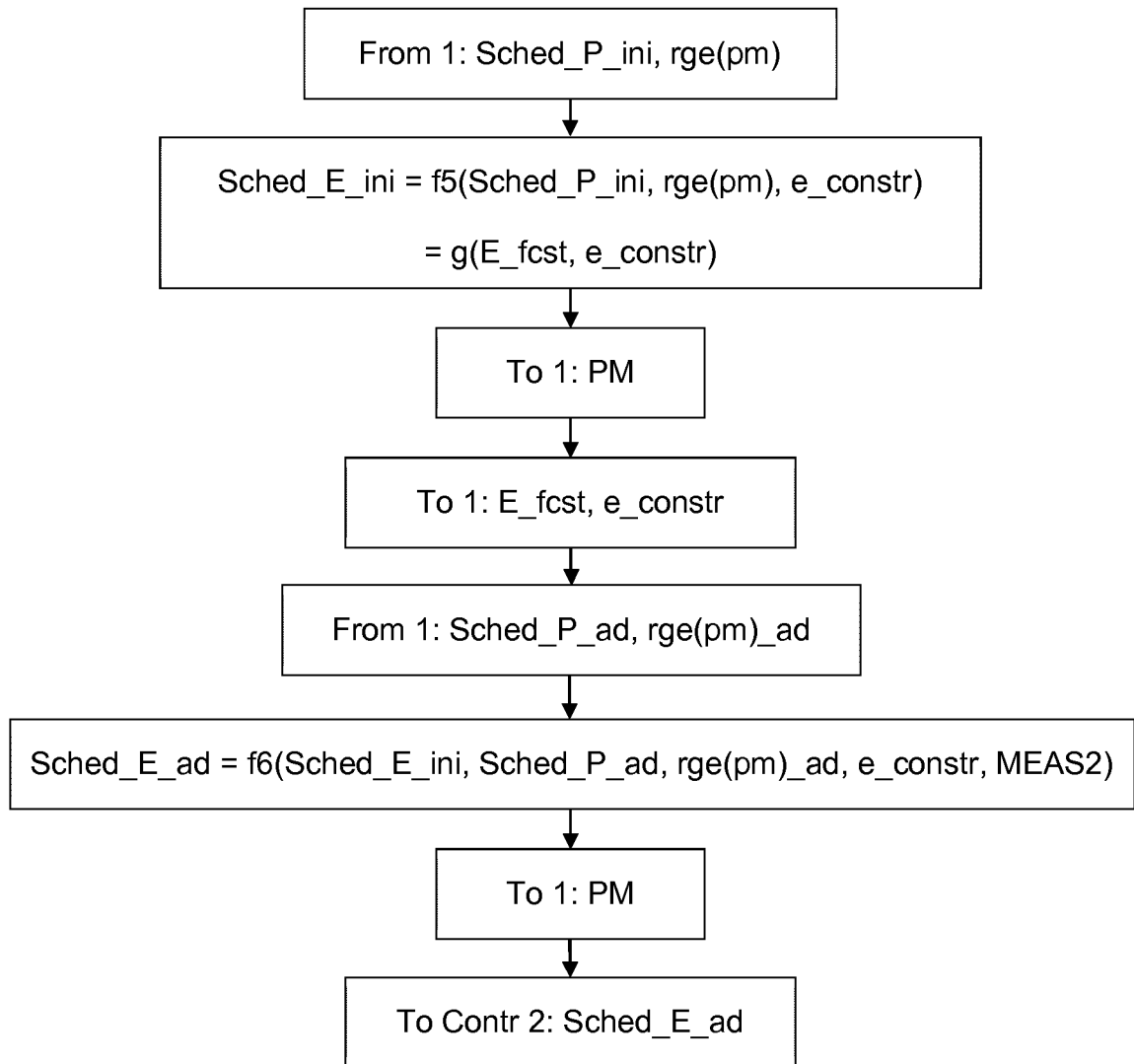


Fig. 3

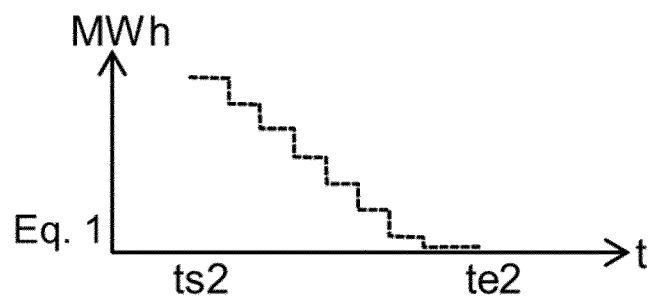


Fig. 8

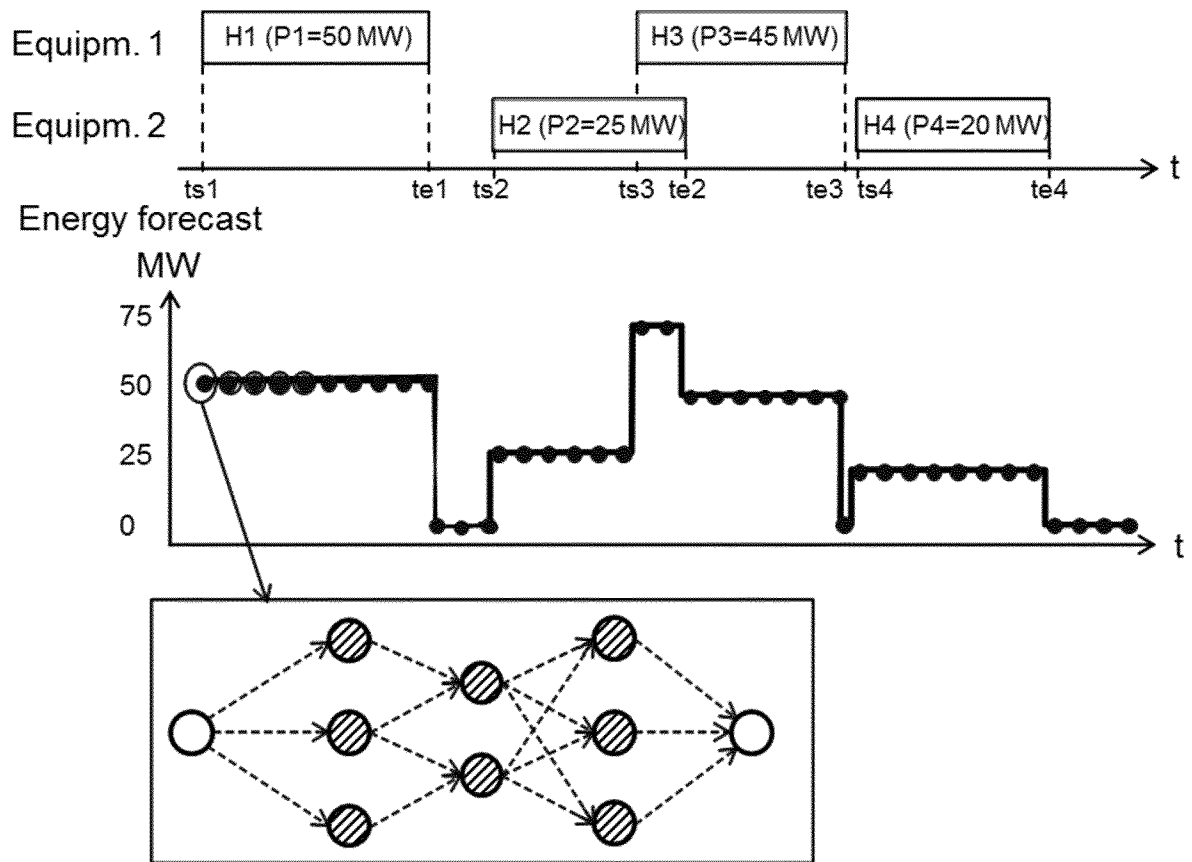


Fig. 4

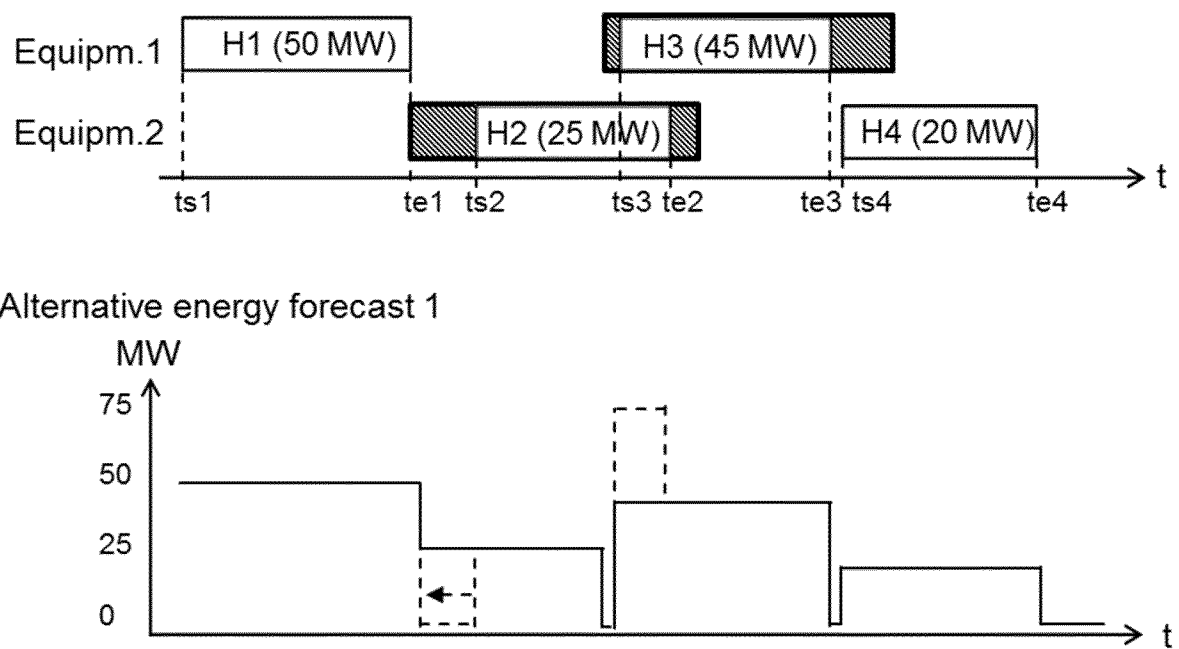
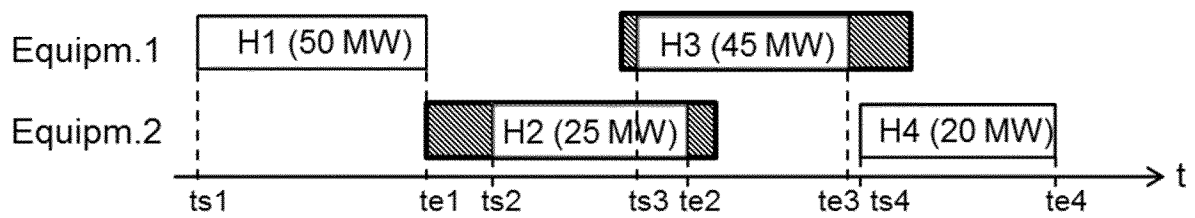


Fig. 5



Alternative energy forecast 2

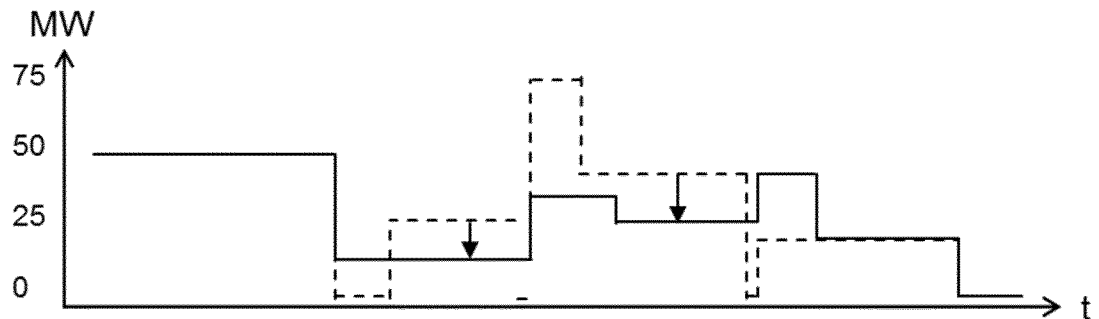
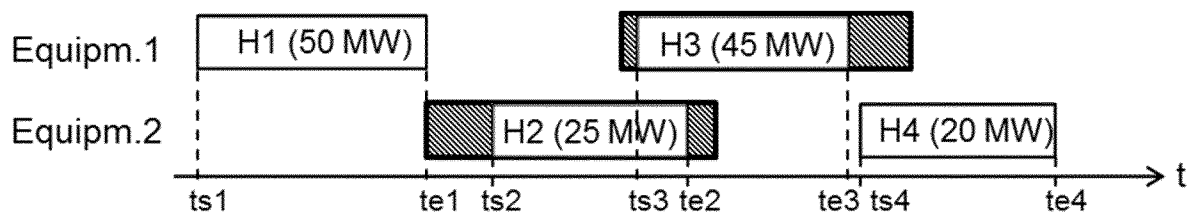


Fig. 6



Alternative energy forecast 3

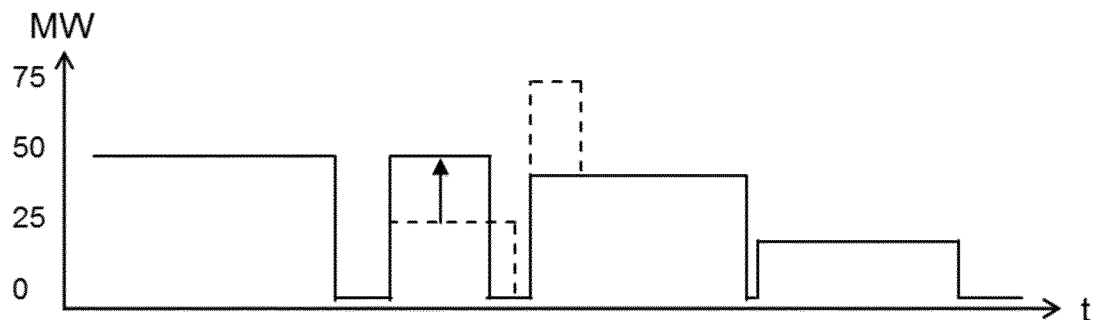


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074522

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06Q10/04 G06Q50/06 G06Q10/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2010 022462 A1 (ABB TECHNOLOGY AG [CH]) 8 December 2011 (2011-12-08) abstract; figure 2 paragraphs [0002], [0005], [0006] paragraphs [0009] - [0018] paragraphs [0024] - [0041] -----	1-18
X	ZHAOJIE WANG ET AL: "An integrated optimization model for generation and batch production load scheduling in energy intensive enterprise", 2012 IEEE POWER AND ENERGY SOCIETY GENERAL MEETING, 1 July 2012 (2012-07-01), pages 1-8, XP55062716, DOI: 10.1109/PESGM.2012.6345296 ISBN: 978-1-46-732728-2 the whole document ----- -/--	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 May 2013

Date of mailing of the international search report

29/05/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bauer, Rodolphe

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074522

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 263 108 A1 (ROKE MANOR RESEARCH [GB]) 4 December 2002 (2002-12-04) abstract; figures 2,3,5,6,7 paragraphs [0006] - [0008] paragraphs [0014] - [0024] paragraphs [0033] - [0040]; tables 1, 2 paragraphs [0047] - [0070] -----	1-18
A	Sebastian Engell ET AL: "OPTIMAL OPERATION: SCHEDULING, ADVANCED CONTROL AND THEIR INTEGRATION", FOCAPO 2012, 11 January 2012 (2012-01-11), pages 1-13, XP55062690, Retrieved from the Internet: URL: http://focapo.cheme.cmu.edu/2012/proceedings/data/papers/087.pdf [retrieved on 2013-05-13] the whole document page 13; figure 1 4 -----	1-18
A	WO 03/056480 A2 (ABB RESEARCH LTD [CH]; KABORE POUSSA [DE]; KROLL ANDREAS [DE]) 10 July 2003 (2003-07-10) cited in the application the whole document -----	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/074522

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102010022462 A1	08-12-2011	AU 2011260643 A1	10-01-2013
		CA 2800842 A1	08-12-2011
		CN 102918733 A	06-02-2013
		DE 102010022462 A1	08-12-2011
		EP 2577829 A1	10-04-2013
		US 2013096975 A1	18-04-2013
		WO 2011151031 A1	08-12-2011

EP 1263108 A1	04-12-2002	CA 2388571 A1	01-12-2002
		EP 1263108 A1	04-12-2002
		US 2003009265 A1	09-01-2003

WO 03056480 A2	10-07-2003	AU 2002361182 A1	15-07-2003
		WO 03056480 A2	10-07-2003
