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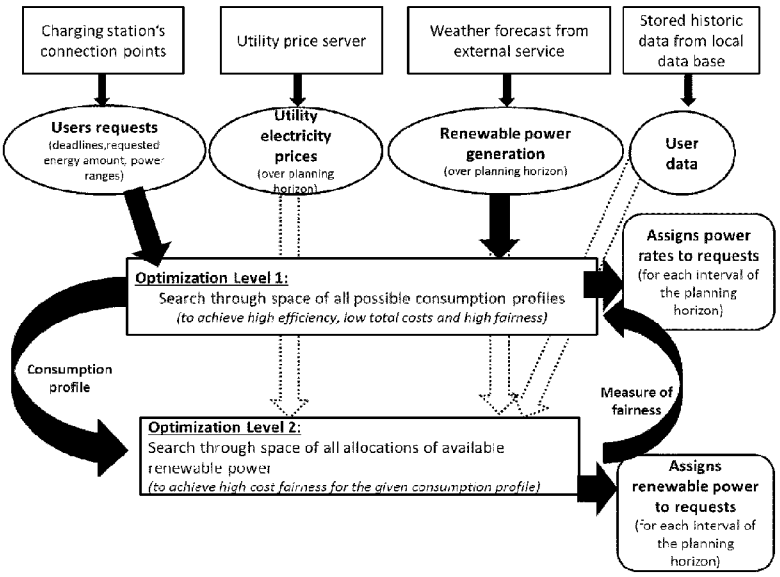


Fig. 2

(57) Abstract: For allowing a control of load balancing, wherein renewable energy is nearly optimally used and power allocation is fair between the users, a method for controlling load balancing within an energy system is claimed, wherein a renewable energy source for sharing local renewable energy consumption between a predetermined number of users is provided, wherein a back-up energy source for buying back-up energy by the users is provided for situations when the energy demand of the users exceeds the availability or a predetermined availability level of renewable energy from the renewable energy source and wherein the users operate power-controllable loads. The method is characterized in that the loads demand a definable amount of energy E, and specify a deadline Di until which the amount of energy E, has to be charged to the individual loads, that a control of load balancing is performed by determining total energy rates and renewable energy rates which have to be allocated to each load for enabling charging of the amount of energy E, to the individual loads by the deadline D, and that the control of load balancing is performed under consideration of a maximization of the users" local renewable energy consumption and under consideration of cost-fairness between the users regarding the assignment of the renewable energy to the users and regarding the buying and/or prices of back-up energy from the back-up energy source. Further, an according energy system is claimed, preferably for carrying out the above mentioned method.

A METHOD FOR CONTROLLING LOAD BALANCING WITHIN AN ENERGY SYSTEM AND AN ACCORDING ENERGY SYSTEM

The present invention relates to a method for controlling load balancing within an energy system, wherein a renewable energy source for sharing local renewable energy consumption between a predetermined number of users is provided, wherein a back-up energy source for buying back-up energy by the users is provided for situations when the energy demand of the users exceeds the availability or a predetermined availability level of renewable energy from the renewable energy source and wherein the users operate power-controllable loads.

Further, the present invention relates to an energy system, wherein a renewable energy source for sharing local renewable energy consumption between a predetermined number of users is provided, wherein a back-up energy source for buying back-up energy by the users is provided for situations when the energy demand of the users exceeds the availability or a predetermined availability level of renewable energy from the renewable energy source and wherein the users operate power-controllable loads of the energy system.

Recent technology improvements make various renewable energy systems more available and easier to deploy, even in urban areas. Increasing penetration of renewable energy and government targets for even wider use of renewables demand new control strategies and business models for the integration of Renewable Energy Sources, RES. Also, due to less government incentives such as guaranteed feed-in rates and availability of grid-parity systems, see Fulton et al., “The German feed-in tariff, Recent policy changes”, the energy is going to be consumed locally for what new algorithms are needed.

New control strategies are necessary, in particular for multi-user systems with a shared fluctuating energy source such as RES. Furthermore, a shared resource refers to systems built from user investments, or systems built and maintained by a third-party. In the latter case, users might sign a restricted flat-rate contract that allows them to use as much renewable energy as they wish if the energy is abundant.

In both cases, user or third-party owned systems, when the supply is lower than the demand, a control method needs to distribute the limited resource. While considering many aspects in demand management, one of the crucial concerns is the distribution in a fair manner. Though, the concept of fairness in resource allocation has been investigated for algorithms in other related fields such as computer science and network engineering, it is a new concern in sharing power from an intermittent energy supply.

Different notation of fairness for shared resources can be defined. For instance, delay-fairness which considers the wait times experienced by users can be used for deferrable loads. With power-controllable loads where is possible to adjust power consumption of a given user, proportional-share fairness can be considered. In this case, users are supposed to receive an amount of renewable energy that is proportional to their shares in the system.

Electricity pricing schemes may still differ from country to country but a general trend towards dynamic electricity pricing is obvious. With the electricity market deregulation and penetration of renewable energy at grid scale, a widely accepted view is that in future electricity price will depend on time of use, matching supply and demand. In this way residential customers would get a day-ahead “menu” with electricity prices changing every 15-30 min. Some variations of this pricing scheme are already in use.

With dynamic electricity pricing schemes emerging at end-customer level, even residential customers will become aware that the energy value depends on time-of-use. These prices are to be paid by users consuming energy when additional electricity from the grid is needed to supplement renewable generation in order to guarantee all user-specified deadlines. A central question here is who gets renewable energy when grid electricity prices are high, what normally happens when demand is high and generation is low. This is not only an economical question but also a technical, since the users that are not assigned renewable energy can decide to reduce their consumption over periods of high prices if their deadlines and systems conditions allow waiting. General trends show that

automatic solutions for all load balancing problems will be needed in the future to avoid active user involvement.

Currently, renewable energy sharing systems are still not common. Hence, load balancing schemes perform load balancing of the entire load and do not distinguish different users. Also, there are works on the cost reduction under dynamic electricity pricing for a group of loads but without the concept of sharing and fairness. However, it is easy to envision shared Electric Vehicle, EV, charging stations built through investments of the neighborhood and other examples of energy sharing systems with power-controllable loads.

It is an object of the present invention to improve and further develop a method for controlling load balancing within an energy system and an according energy system for allowing a control of load balancing, wherein renewable energy is nearly optimally used and power allocation is fair between the users.

In accordance with the invention, the aforementioned object is accomplished by a method comprising the features of claim 1 and by an energy system comprising the features of claim 23.

According to claim 1 the method is characterized in that the loads demand a definable amount of energy E_i and specify a deadline D_i until which the amount of energy E_i has to be charged to the individual loads, that a control of load balancing is performed by determining total energy rates and renewable energy rates which have to be allocated to each load for enabling charging of the amount of energy E_i to the individual loads by the deadline D_i and that the control of load balancing is performed under consideration of a maximization of the users` local renewable energy consumption and under consideration of cost-fairness between the users regarding the assignment of the renewable energy to the users and regarding the buying and/or prices of back-up energy from the back-up energy source.

According to claim 23 the energy system is characterized in that the loads demand a definable amount of energy E_i and a deadline D_i until which the amount of energy E_i has to be charged to the individual loads, that means for performing a

control of load balancing by determining total energy rates and renewable energy rates which have to be allocated to each load for enabling charging of the amount of energy E_i to the individual loads by the deadline D_i are provided and that the means are designed for performing the control of load balancing under consideration of a maximization of the users` local renewable energy consumption and under consideration of cost-fairness between the users regarding the assignment of the renewable energy to the users and regarding the buying and/or prices of back-up energy from the back-up energy source.

According to the invention it has been recognized that a very important and suitable notation of fairness for users is cost-fairness. The combination of maximization of the users' local renewable energy consumption with such cost-fairness aspects results in a very sustainable notation of fairness and allocation of generated renewable energy.

Within a preferred embodiment of the method the determining step can be performed over at least one predetermined time interval of a planning horizon. Thus, individual time intervals can be defined for carrying out the inventive method.

Within a further preferred embodiment the loads can be given as the amount of energy E_i that has to be recharged until the deadline D_i with flexibility in recharging power given as an allowed power range $[P_i^{min}, P_i^{max}]$. These loads can correspond to EV charging requests. Thus, a simple definition of loads is possible.

Within a further preferred embodiment the determining can provide a demand of energy of at least one load over time. In other words, the control determines when the user demand will be served, respecting the requested amount of energy and the deadline.

For providing very actual situations and a best possible control of load balancing under consideration of maximization of renewable energy consumption and cost-fairness the determining can be done periodically at an adjustable frequency. By

each new determining the consideration of changed circumstances is possible in this case.

Further, for providing a very fair load balancing future back-up energy prices or dynamic back-up energy pricing schemes can be considered within the determining step.

Additionally or alternatively, prediction or forecast of renewable energy generation of the renewable energy source can be considered within the determining.

With regard to a very simple performance of the method the method can be performed in a first level and in a second level, wherein different processes and aspects can be realized or considered within said levels.

The first level can provide the total energy consumption for each user over each considered or over each defined time interval of a planning horizon. The provision can be performed until a definable or until the last deadline of a load or of the loads. Preferably the first level can consider allowed or defined power ranges and/or generation forecast and/or user requests for providing a very effective determining step. Within the first level the maximization of the users' local renewable energy consumption and/or low total costs of all users and/or cost-fairness can be considered depending on individual situations.

The second level can provide the assignment of the renewable energy to the users over each considered or over each defined time interval of a planning horizon. Generally, the assignment of the renewable energy can be performed over a definable time interval. Such a time interval can be defined by the user or a third party.

Alternatively or additionally the second level can also consider a cost-fairness between the users. For interleaving both levels and for providing a very effective determining step a measure of cost-fairness and/or the assignment provided within the second level can be considered within the first level. In this regard the first level can amend a prior determining step after consideration of such measure of

cost-fairness and/or assignment of the renewable energy by the second level, so that the first and the second level can preferably be completely interleaved.

Generally, the second level can consider prediction or forecast of renewable energy generation of the renewable energy source and/or back-up energy prices over a planning horizon and/or total energy consumptions assigned to each user over each considered time interval and/or user data. User data can comprise user shares in the system and/or previous renewable energy consumption and/or previous paid electricity prices and/or previous paid electricity amounts, depending on individual situations and requirements.

With regard to a simple and reliable realization of the processes within the first level and/or second level genetic algorithms can be used within the first and/or second level.

Within a concrete embodiment cost-fairness can comprise the meaning that users with generally equal shares or with generally equal assigned amounts of renewable energy pay on average the same or comparable back-up energy prices. By such a meaning a very sustainable notation of fairness can be provided.

Within a further concrete embodiment users that consumed less renewable energy than other users can get lower prices for back-up energy than the other users. In this way a balance regarding costs can be provided between the users.

Within a further concrete embodiment at least one of the power-controllable loads can be a rechargeable battery or accumulator. Thus, the present invention can be applied to the field of electro-mobility and the loads can be batteries or accumulators within an EV.

Preferred aspects of embodiments of the above mentioned method and energy system can be explained as follows:

If dynamic electricity pricing is assumed and grid energy is needed to complement the renewable generation, a central question here is how the available renewable

energy is allocated to the users. In this way, we come to another notation of fairness – cost-fairness. Though some variations of the definition are possible, with cost-fairness we assume that in general users with equal shares in the system should pay on average comparable prices for kWh of energy used from the grid. It's also possible to achieve lower grid energy price for users that consumed less renewable energy.

The problem considered by this invention is how to maintain cost-fairness while assigning total and renewable power to competing users sharing a renewable energy source. When demand exceeds renewable supply, additional energy is obtained from the grid in order to satisfy user-specified deadlines. This additional energy is paid by users according to users' consumption schedules and time-of-use tariffs that are known in advance. Besides cost-fairness, the control should maximize the use of locally generated renewable energy and minimize the total costs paid to the utility.

Here it is proposed a control method for load balancing that maintains cost-fairness among competing users in a shared renewable energy system. The proposed control method determines the total power and renewable power rates allocated to each request over each interval of the planning horizon. Users are assumed to have power-controllable loads that request a certain amount of energy and specify a deadline until which the energy has to be charged. In situations when demand is higher than supply, additional energy is bought from the grid at dynamically changing prices.

An embodiment of the claimed method refers to an optimization-based power allocation method that maintains cost-fairness among competing users sharing an energy source:

- With a fluctuating power output obtained at no cost, preferably from a renewable source.
- The system is connected to an electricity grid from which energy can be bought at dynamically changing prices that depend on time-of-use.

- Competing users represented by power controllable loads given as the allowed power range [P_i^{min}, P_i^{max}].
- Users requests specify the amount of energy and a hard deadline until which the requested energy has to be recharged.

A preferred method distributes the available free energy to user requests or demands and determines when additional energy must be bought from the grid in order to satisfy user-specified deadlines:

- The planning decisions are made over a planning horizon for each time interval with specified time resolution.
- A weather forecast is assumed to be available to predict shared resource energy generation over the planning horizon.
- Grid electricity prices are known in advance over the planning horizon.
- The method is driven by optimization problems that maximize the local use of renewable energy, reduce the total costs paid to the external entity – electricity utilities – and maintains cost-fairness among users.

It is provided a control method for load balancing based on:

- Control method for supply-demand balancing for power-controllable loads combining the following goals: maximization of local use of renewable – free – energy, minimization of the total costs paid to the utility, maintenance of cost-fairness among users.
- Recharging decisions are made based on optimization of different goals
  - A measure of cost-fairness is maximized by control of distribution of the available free energy to active users; this is done for the evaluated user consumption schedule within a nested optimization step and returned to the higher level optimization in which the schedule is evaluated for efficiency, costs and fairness.
- The control method offers flexibility to select the exact notation of cost-fairness, for instance, smaller users should pay less per kWh of energy on

average, or all users should pay similar price per kWh; furthermore additional parameters can be introduced such as users' shares in the system.

As the result of the control method, users are motivated to provide flexible/loose deadlines knowing that the deadlines directly affect their bill. In this way providing a short deadline would affect only the very user and not others as it would be the case with schemes that would share electricity costs proportionally to consumption or according to any other user agreements.

Further important aspects of embodiments of the present invention can be listed as follows:

- The control method distinguishes between different users in order to maintain cost-fairness while still improving efficiency of use of locally produced energy and minimizing the total costs paid to the utility.

- Optimization of cost-fairness is interleaved with the charging optimization that targets efficiency in use of renewable energy and total costs paid to the external source.

- As the result of the proposed automatic control, users are motivated to provide loose deadlines since their costs are directly affected by the time of use of energy if additional energy needs to be fetched from the utility.

- Furthermore, deadline/demand of a given user can affect other users only if the user's accumulated "benefit" is lower, otherwise other users will have higher priority to use energy when it is cheaper and will also get a higher fraction of the renewable generation.

Embodiments of the present invention provide a supply-demand balancing control method with a nested optimization process for combining high efficiency of local

supply utilization, cost minimization and cost-fairness between users on the energy service from energy backup/support system.

An embodiment of the energy system is characterized by

- intermittent and/or resource-limited energy resource sharing system,
- prediction of the local energy resource generation,
- dynamically submitted power-controllable loads with deadlines, and
- dynamic energy pricing schemes.

The method of the present invention can schedule or determine costs in accordance with previous consumption patterns. There can be provided different impacts by the present invention:

a. Technical: High utilization of RES, Use schedules/costs in accordance with previous consumption patterns.
b. Economical: Minimizing energy costs paid to the back-up energy system, minimizing cost variations between competing users - cost-fairness.
c. Social: User behavior modification - Users are motivated to take responsibility for their behavior, for example by provision of loose deadlines.

Weather forecast – solar irradiance or wind speeds – is needed to predict power generation. However, this is a well-established field and does not represent a significant obstacle, especially because high accuracy is not crucial for the control method. The prediction inaccuracy can be easily handled through small modifications. For example, the actual available power can be shared proportionally to the power assignment at the scheduling time or within the determining step. The present invention can be used for electricity storage and EV charging. Also, it can be a product specifically designed for community EV-charging stations.

Within a preferred embodiment of the present invention a power profile of one or more loads can be determined and adjusted for maintaining cost-fairness under consideration of a maximization of the users' local renewable energy consumption.

There are several ways how to design and further develop the teaching of the present invention in an advantageous way. To this end it is to be referred to the patent claims subordinate to patent claim 1 on the one hand and to the following explanation of preferred examples of embodiments of the invention, illustrated by the drawing on the other hand. In connection with the explanation of the preferred embodiments of the invention by the aid of the drawing, generally preferred embodiments and further developments of the teaching will be explained. In the drawings

Fig. 1 is illustrating in a diagram a demand of a load according to an embodiment of a method of the present invention and

Fig. 2 is illustrating a two-level optimization approach according to one preferred embodiment of the present invention.

According to embodiments of this invention, we propose a method for automatic control of total power and renewable power allocation to users sharing a fluctuating energy source complemented by grid electricity. The grid electricity prices depend on time-of- use and they are known over the planning horizon considered in power assignment. Fig. 1 depicts the assumed system characteristics in the form of an example of an environment behaviour over time:

- Fluctuating renewable power supply. Renewable Supply – given as input.
- Changing grid electricity prices known in advance. Price – given as input.
- User power demand. Demand – output of the control method.

Demand over time as shown in Fig. 1 is an output of the control algorithm since the control determines when the user requests will be served, respecting the deadlines and optimizing different goals.

One of the main features of the proposed control method is that recharging and power distribution is performed in a way that cost-fairness is maintained while the total users' costs are minimized and high efficiency of use of locally generated energy is achieved.

The control method is invoked periodically, for instance every 10 minutes. The power assignments are computed considering the current user requests, the available weather/generation forecast and future grid electricity prices. After an assignment plan is made, the system continues according to the current plan until the next invocation of the control method. Then the assigned power rates are recomputed considering new requests and possible changes in weather forecast. New rates are used until the next recomputation, and so on.

The proposed control method is optimization-based, comprising of two levels as shown in Fig. 2. This approach interleaves two different types of assignments: total power assigned to a user over a given time interval and renewable power assigned to the same user over the same time interval. The difference between the total and renewable power consumption over an interval is assumed to be obtained from the grid and paid by the user at the corresponding time-of-use electricity price.

At the first level of the optimization, a solution from the solution space gives the total power consumption for each user over each considered time interval of the planning horizon, this means until the last deadline. In other words, a solution at this level determines **Demand** line from Fig. 1. A feasible solution satisfies constraints given by the allowed power ranges – between min and max recharging power of each user or equal to 0 for no-charging – and user-specified deadlines. This level optimizes for high efficiency in local use of renewable energy, low total costs of all users and cost-fairness. For a considered feasible solution at the level 1, a measure of (sub) optimal cost-fairness is found at the second level of optimization which assigns the available renewable generations over each interval to the users assigned to be active over the time interval. This measure of cost-fairness is returned to the first level of optimization where the optimization search is continued.

The second level of optimization takes as inputs the generation forecast, electricity prices over the planning horizon, total power consumptions assigned to each user over each considered interval and user data. User data such as user shares in the system, previous renewable energy consumption, previous paid electricity prices and amounts, are used to allocate the available renewable generation to competing users in a manner that is cost-fair. If the allocated amount of renewable energy is not sufficient to cover user's planned consumption over an interval, the user is obliged to obtain the difference from the grid at the actual price. This is considered when calculated the used objective function representing fairness. If demand exceeds renewable supply, the entire supply is allocated to the active users.

According to a preferred embodiment the objective function of the level 1 optimization is to be maximized and can be formulated as follows:

$$Efficiency + \alpha/TotalGridCost + \beta FairnessMeasure \quad (1)$$

where **Efficiency** represents the portion of load served from renewable energy, *TotalGridCost* is the total cost paid by all users over the planning horizon according to the solution being evaluated, and *FairnessMeasure* is the output of the level 2 optimization reflecting the degree of cost-fairness that can be achieved for the level 1 solution currently being evaluated. The parameters α and β are used to tune the behavior of the control approach. The problem constraints should reflect the deadline requirements and ensure that recharging rates are within the allowed ranges or equal to 0 – no charging. This problem can be solved with genetic algorithms.

On the other hand, the problem corresponding to Control Level 2 can be formulated with the following objective function which is to be minimized:

$$\sum_{i,j} |AveragekWhCost_i/TotalRenewCons_i - AveragekWhCost_j/TotalRenewCons_j| \quad (2)$$

where $AveragekWhCost_k$ represents the average price that the user k is supposed to pay per kWh after its remaining load is served according to the current power assignments. $TotalRenewCons_k$ is the total amount of renewable energy used by the user k over the current accounting period, e.g. a month.

The problem constraints should reflect that the entire generation of renewable energy within the considered time step is allocated, if demand is greater than the current supply. Furthermore, a user should not get more power assigned that his/her total consumption is over a given time interval. Again, e.g. genetic algorithms can be used to solve this problem.

Many modifications and other embodiments of the invention set forth herein will come to mind the one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. A method for controlling load balancing within an energy system, wherein a renewable energy source for sharing local renewable energy consumption between a predetermined number of users is provided, wherein a back-up energy source for buying back-up energy by the users is provided for situations when the energy demand of the users exceeds the availability or a predetermined availability level of renewable energy from the renewable energy source and wherein the users operate power-controllable loads,
characterized in that the loads demand a definable amount of energy E_i and specify a deadline D_i until which the amount of energy E_i has to be charged to the individual loads,
that a control of load balancing is performed by determining total energy rates and renewable energy rates which have to be allocated to each load for enabling charging of the amount of energy E_i to the individual loads by the deadline D_i and
that the control of load balancing is performed under consideration of a maximization of the users` local renewable energy consumption and under consideration of cost-fairness between the users regarding the assignment of the renewable energy to the users and regarding the buying and/or prices of back-up energy from the back-up energy source.

2. A method according to claim 1, wherein the determining step is performed over at least one predetermined time interval of a planning horizon.

3. A method according to claim 1 or 2, wherein the loads are given as the amount of energy E_i that has to be recharged until the deadline D_i with flexibility in recharging power given as an allowed power range $[P_i^{min}, P_i^{max}]$.

4. A method according to one of claims 1 to 3, wherein the determining provides a demand of energy of at least one load over time.

5. A method according to one of claims 1 to 4, wherein the determining is done periodically at an adjustable frequency.

6. A method according to one of claims 1 to 5, wherein future back-up energy prices or dynamic back-up energy pricing schemes are considered within the determining.

7. A method according to one of claims 1 to 6, wherein prediction or forecast of renewable energy generation of the renewable energy source is considered within the determining.

8. A method according to one of claims 1 to 7, wherein the method is performed in a first level and in a second level.

9. A method according to claim 8, wherein the first level provides the total energy consumption for each user over each considered or over each defined time interval of a planning horizon.

10. A method according to claim 9, wherein the provision is performed until a definable or until the last deadline of the loads.

11. A method according to one of claims 8 to 10, wherein the first level considers allowed or defined power ranges and/or generation forecast and/or user requests.

12. A method according to one of claims 8 to 11, wherein the first level considers the maximization of the users` local renewable energy consumption and/or low total costs of all users and/or cost-fairness.

13. A method according to one of claims 8 to 12, wherein the second level provides the assignment of the renewable energy to the users over each considered or over each defined time interval of a planning horizon.

14. A method according to claim 13, wherein the assignment of the renewable energy is performed over a definable time interval.

15. A method according to one of claims 8 to 14, wherein the second level considers a cost-fairness between the users.

16. A method according to one of claims 8 to 15, wherein a measure of cost-fairness and/or the assignment provided within the second level is considered within the first level.

17. A method according to one of claims 8 to 16, wherein the second level considers prediction or forecast of renewable energy generation of the renewable energy source and/or back-up energy prices over a planning horizon and/or total energy consumptions assigned to each user over each considered time interval and/or user data.

18. A method according to claim 17, wherein user data comprises user shares in the system and/or previous renewable energy consumption and/or previous paid electricity prices and/or previous paid electricity amounts.

19. A method according to one of claims 8 to 18, wherein within the first and/or second level genetic algorithms are used.

20. A method according to one of claims 1 to 19, wherein cost-fairness comprises the meaning that users with generally equal shares or with generally equal assigned amounts of renewable energy pay on average the same or comparable back-up energy prices.

21. A method according to one of claims 1 to 20, wherein users that consumed less renewable energy than other users get lower prices for back-up energy than the other users.

22. A method according to one of claims 1 to 21, wherein at least one of the loads is a rechargeable battery or accumulator.

23. An energy system, preferably for carrying out the method for controlling load balancing within an energy system according to any one of claims 1 to 22, wherein a renewable energy source for sharing local renewable energy consumption between a predetermined number of users is provided, wherein a back-up energy source for buying back-up energy by the users is provided for situations when the energy demand of the users exceeds the availability or a predetermined availability level of renewable energy from the renewable energy source and wherein the users operate power-controllable loads of the energy system,

c h a r a c t e r i z e d in that the loads demand a definable amount of energy E_i and a deadline D_i until which the amount of energy E_i has to be charged to the individual loads,

that means for performing a control of load balancing by determining total energy rates and renewable energy rates which have to be allocated to each load for enabling charging of the amount of energy E_i to the individual loads by the deadline D_i are provided and

that the means are designed for performing the control of load balancing under consideration of a maximization of the users` local renewable energy consumption and under consideration of cost-fairness between the users regarding the assignment of the renewable energy to the users and regarding the buying and/or prices of back-up energy from the back-up energy source.

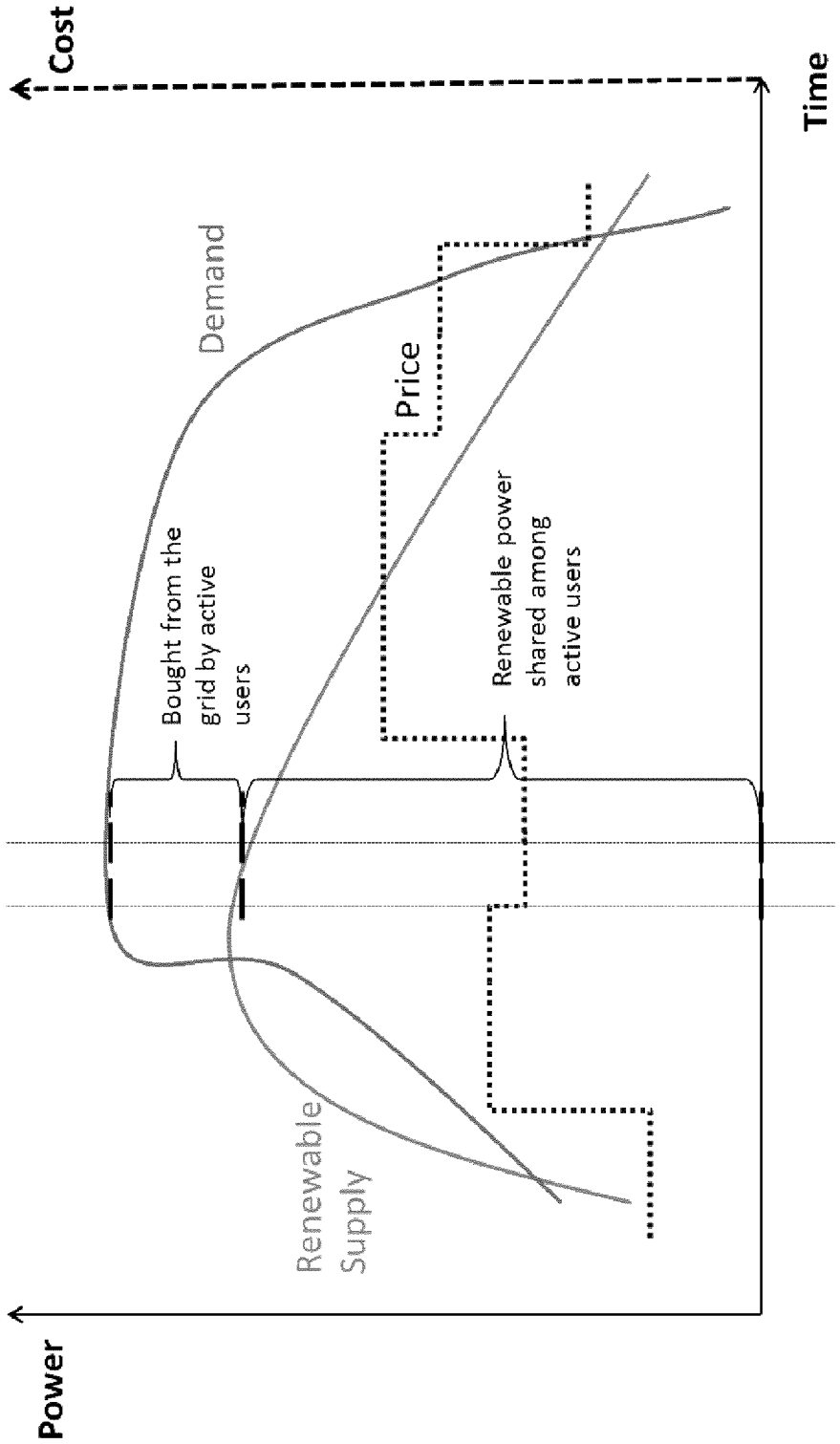

Cost
Time
Power
Demand
Price
Bought from the grid by active users
Renewable power shared among active users
Renewable Supply
t
t+1

Fig. 1

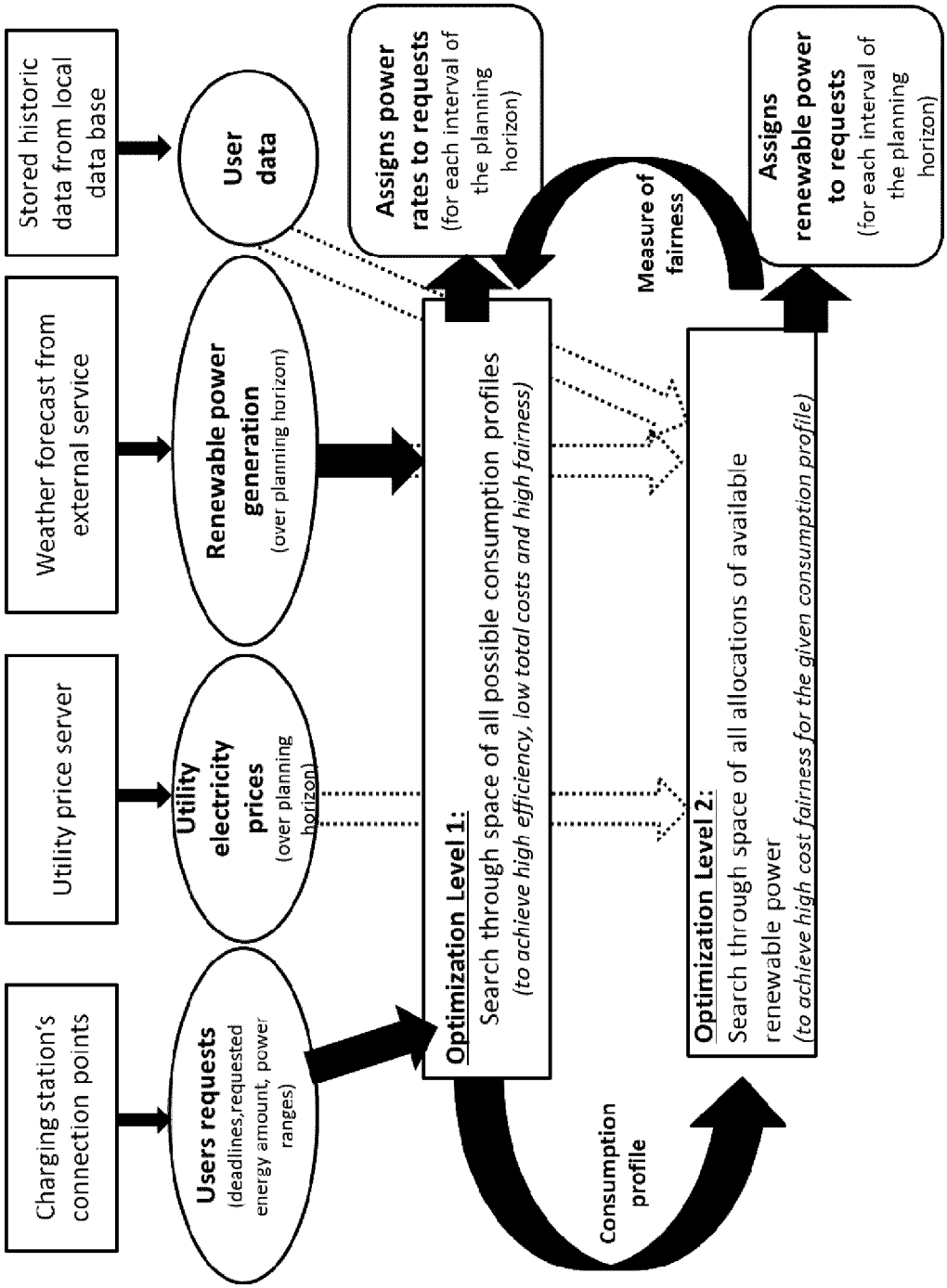

Charging station's connection points
Utility price server
Weather forecast from external service
Stored historic data from local data base
Users requests (deadlines,requested energy amount, power ranges)
Utility electricity prices (over planning horizon)
Renewable power generation (over planning horizon)
User data
Optimization Level 1:
Search through space of all possible consumption profiles
(to achieve high efficiency, low total costs and high fairness)
Assigns power rates to requests (for each interval of the planning horizon)
Measure of fairness
Assigns renewable power to requests (for each interval of the planning horizon)
Consumption profile
Optimization Level 2:
Search through space of all allocations of available renewable power
(to achieve high cost fairness for the given consumption profile)

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/051331

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J3/00 H02J3/14 H02J3/38
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)
H02J

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	EP 2 437 372 A2 (BOEING CO [US]) 4 April 2012 (2012-04-04) abstract; claims 1,2,9-11,13,15,17,19; figure 1 paragraphs [0008], [0012] - [0018], [0023] - [0025], [0030]	1-23
A	US 2011/231028 A1 (OZOG MICHAEL T [US]) 22 September 2011 (2011-09-22) abstract; claim 1; figure 1 paragraphs [0007], [0008], [0019] - [0023]	1-23
A	US 2009/027932 A1 (HAINES LANCE P [US] ET AL) 29 January 2009 (2009-01-29) the whole document	1-23

☐ 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

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"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	Date of mailing of the international search report
18 September 2014	29/09/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rother, Stefan

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/051331

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2437372 A2	04-04-2012	EP 2437372 A2	04-04-2012
		JP 2012085516 A	26-04-2012
		US 2012080942 A1	05-04-2012
US 2011231028 A1	22-09-2011	US 2011231028 A1	22-09-2011
		US 2014148963 A1	29-05-2014
US 2009027932 A1	29-01-2009	AU 2008248332 A1	13-11-2008
		CA 2686671 A1	13-11-2008
		CN 101765959 A	30-06-2010
		EP 2145374 A1	20-01-2010
		RU 2009145271 A	20-06-2011
		TW 200903945 A	16-01-2009
		US 2009027932 A1	29-01-2009
		US 2011254372 A1	20-10-2011
		WO 2008138016 A1	13-11-2008