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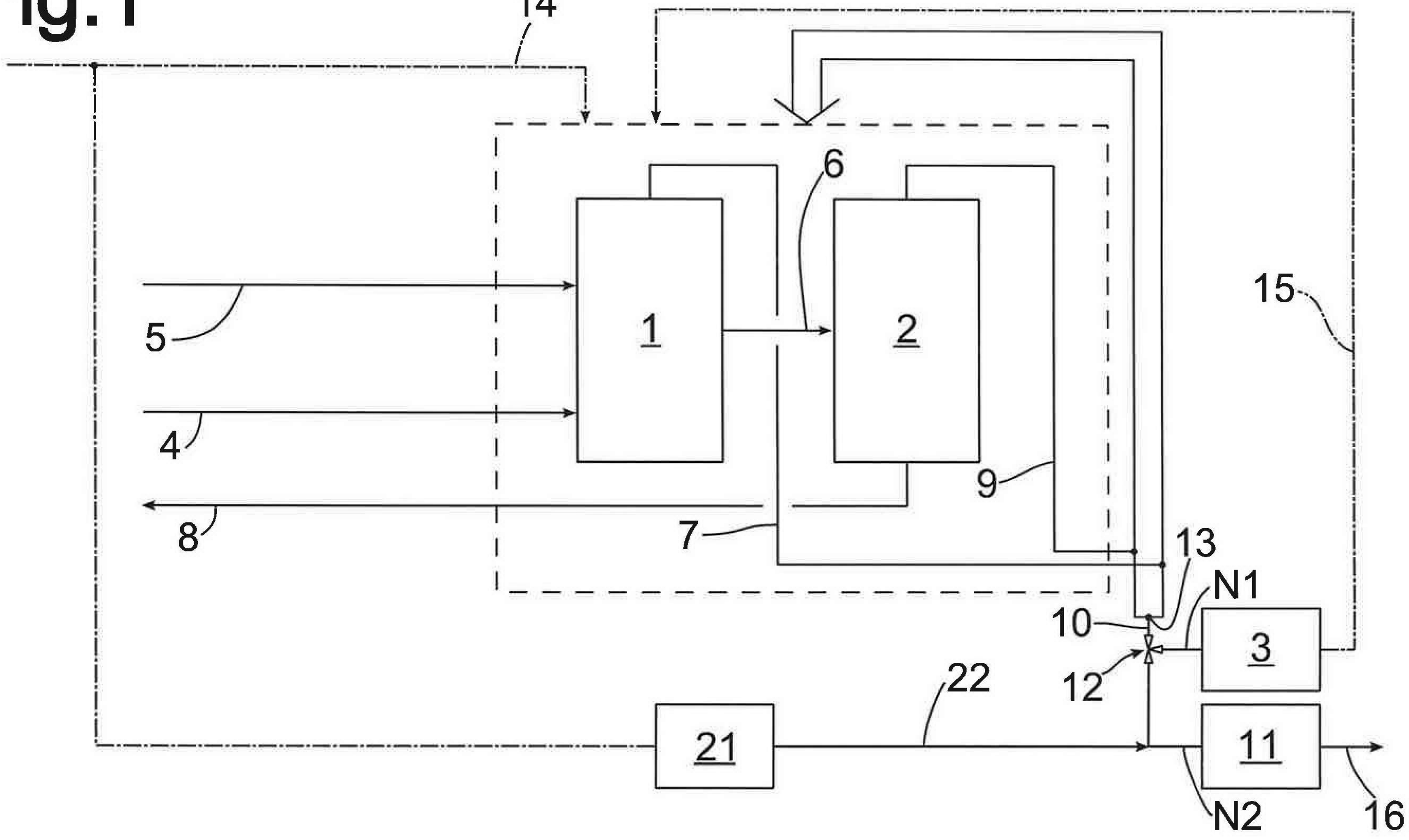
Abstract:

The invention relates to a plant complex for steel production comprising a blast furnace (1) for producing pig iron, a converter steel works (2) for producing crude steel and a gas-conducting system for gases that occur in the production of pig iron and/or in the production of crude steel. According to the invention, the plant complex additionally has a chemical or biotechnological plant (11) connected to the gas-conducting system and a plant (21) for producing hydrogen. The plant (21) for producing hydrogen is connected to the gas-conducting system by a hydrogen-carrying line. Also the subject of the invention is a method for operating the plant complex.

Fig. 1

Fig.1



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Plant complex for steel production and method for operating the plant complex

Technical field

The invention relates to a plant complex for steel production and to a method for operating the plant complex.

Background

The plant complex for steel production comprises at least one blast furnace for producing pig iron, a converter steel works for producing crude steel, and a gas-conducting system for gases that occur in the production of pig iron and/or in the production of crude steel. The plant complex may also have a power-generating plant for electricity generation, which is designed as a gas-turbine power-generating plant or gas-turbine and steam-turbine power-generating plant and is operated with a gas that comprises at least a partial amount of the blast-furnace top gas that occurs in the production of pig iron in the blast furnace and/or a partial amount of the converter gas that occurs in the converter steel works.

Pig iron is obtained in the blast furnace from iron ores, additives and also coke and other reducing agents such as coal, oil, gas, biomasses, recycled waste plastics or other substances containing carbon and/or hydrogen. CO, CO_2, hydrogen and water vapour inevitably occur as products of the reduction reactions. Apart from the aforementioned constituents, a blast-furnace top gas drawn off from the blast-furnace process often has a high content of nitrogen. The amount of gas and the composition of the blast-furnace top gas are dependent on the feedstock and the operating mode and are subject to fluctuations. Typically, however, blast-furnace top gas contains 35 to 60% by volume N_2, 20 to 30% by volume CO, 20 to 30% by volume CO_2 and 2 to 15% by volume H_2. Around 30 to 40% of the blast-furnace top gas produced in the production of the pig iron is generally used for heating up the hot air for the blast-furnace process in air heaters; the remaining amount of top gas may be used externally in other areas of the works for heating purposes or for electricity generation.

In the converter steel works, which is arranged downstream of the blast-furnace process, pig iron is converted into crude steel. By blowing oxygen onto liquid pig iron, troublesome impurities such as carbon, silicon, sulphur and phosphorus are removed. Since the oxidation processes cause an intense development of heat, scrap is often added in amounts of up to 25% with respect to the pig iron as a coolant. Furthermore, lime is added for forming slag and an alloying agent. A converter gas that has a high content of CO and also contains nitrogen, hydrogen and CO_2 is drawn off from the steel converter. A typical converter gas composition has 50 to 70% by volume CO, 10 to 20% by volume N_2, about 15% by volume CO_2 and about 2% by volume H_2. The converter gas is either burned off or, in the case of modern steel works, captured and passed on to be used for providing energy.

The plant complex may optionally be operated in combination with a coking plant. In this case, the plant complex described at the beginning additionally comprises a coke-oven plant, in which coal is converted into coke by a coking process. In the coking of coal into coke, a coke-oven gas occurs, containing a high hydrogen content and considerable amounts of CH_4. Typically, coke-oven gas contains 55 to 70% by volume H_2, 20 to 30% by volume CH_4, 5 to 10% by volume N_2 and 5 to 10% by volume CO. In addition, the coke-oven gas has fractions of CO_2, NH_3 and H_2S. In practice, the coke-oven gas is used in various areas of the works for heating purposes and in the power-generating process for electricity generation. In addition, it is known to use coke-oven gas together with blast-furnace top gas or with converter gas for producing syngases. According to a method known from WO 2010/136313 A1, coke-oven gas is separated into a hydrogen-rich gas stream and a residual gas stream containing CH_4 and CO, the residual gas stream being fed to the blast-furnace process and the hydrogen-rich gas stream being mixed with blast-furnace top gas and processed further into a syngas.

It is known from EP 0 200 880 A2 to mix converter gas and coke-oven gas and use them as a syngas for methanol synthesis.

In an integrated metallurgical plant that is operated in combination with a coking plant, approximately 40 to 50% of the raw gases that occur as blast-furnace top gas, converter gas and coke-oven gas are used for chemical engineering processes. Approximately 50 to 60% of the gases produced are fed to the power-generating plant and used for electricity generation. The electricity produced in the power-generating plant covers the electricity demand for the production of pig iron and crude steel. Ideally, the energy balance is closed, so that, apart from iron ores and carbon in the form of coal and coke as sources of energy, no further energy input is necessary and, apart from crude steel and slag, no product leaves the plant complex.

Summary

It would be advantageous if embodiments of the present invention could allow improving the cost-effectiveness of the overall process and providing a plant complex with which it is possible to reduce the costs for steel production.

In accordance with a first aspect of the present invention relates to a plant complex for steel production comprising: a blast furnace for producing pig iron, a converter steel works for producing crude steel, a gas-conducting system for gases that occur in the production of pig iron and/or the production of crude steel, wherein the plant complex additionally comprises a chemical plant or biotechnological plant connected to the gas-conducting system and a plant for producing hydrogen, wherein the plant for producing hydrogen is connected to the gas-conducting system by a hydrogen-carrying line, wherein the plant complex additionally comprises a power-generating plant which is designed as a gas-turbine power-generating plant or gas-turbine and steam-turbine power-generating plant and is operated with a useful gas comprising (i) a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace, (ii) a partial amount of a converter gas that occurs in the converter steel works, or (iii) a combination thereof, and wherein the gas-conducting system comprises a connectable gas diverter operationally controllable for dividing streams of the useful gas that are fed to the power-generating plant and the chemical plant or biotechnological plant, wherein the hydrogen-carrying line is connected to a mixing device, which is arranged upstream of the gas diverter relative to the direction of flow, and wherein at least one of the blast furnace top gas and the converter gas is enriched with hydrogen prior to entering the mixing device.

In accordance with a second aspect of the present invention, there is provided a method for operating a plant complex which has a blast furnace for producing pig iron, a converter steel works, a chemical plant or biotechnological plant and a plant for producing hydrogen, a) wherein, a useful gas comprising (i) at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace, (ii) a partial amount of a converter gas that occurs in the production of crude steel, or (iii) a combination thereof, is used after a gas-conditioning operation, as a syngas for producing a product, b) wherein the useful gas, prior to being used as syngas, is enriched with hydrogen that is formed in the plant for producing hydrogen, wherein a part of the useful gas is fed to a power-generating plant and used for electricity generation, wherein the power-generating plant and the chemical or biotechnological plant are connected in parallel, and wherein streams of the useful gas that are fed to the power-generating plant, and to the chemical or biotechnological plant, are controlled.

In accordance with a third aspect of the present invention, there is provided the use of a chemical or biotechnological plant in conjunction with a plant for producing hydrogen, for coupling to a plant complex according to the first aspect, with the proviso that (i) at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron, (ii) at least a partial amount of a converter gas that occurs in the converter steel works, or (iii) a combination thereof, are used as a useful gas for operating the chemical or biotechnological plant and the power-generating plant, wherein a part of the useful gas that is used for operating the chemical or biotechnological plant is, after a gas-conditioning operation and after an enrichment with hydrogen, used as a syngas for producing a product.

In the chemical plant, chemical products can be produced from syngases that respectively contain the components of the end product. Chemical products may be for example ammonia or methanol or else other hydrocarbon compounds.

For producing ammonia, a syngas that contains nitrogen and hydrogen in the correct ratio must be provided. The nitrogen can be obtained from blast-furnace top gas. Blast-furnace top gas or converter gas may be used as the hydrogen source, hydrogen being produced by conversion of the CO fraction by a water-gas-shift reaction ($CO + H_2O \rightleftharpoons CO_2 + H_2$). For producing hydrocarbon compounds, for example methanol, it is necessary to provide a syngas consisting substantially of CO and/or CO_2 and H_2 that contains the components carbon monoxide and/or carbon dioxide and hydrogen in the correct ratio. The ratio is often described by the module $(H_2 - CO_2) / (CO + CO_2)$. The hydrogen may be produced for example by conversion of the CO fraction in the blast-furnace top gas by a water-gas-shift reaction. Converter gas may be used for providing CO. Blast-furnace top gas and/or converter gas may serve as a source of CO_2.

In the case of the concepts described above, however, it is not possible for the C content or N content of the mixed gas to be used in full since there is a shortage of hydrogen. In order for it to be possible for the C content or N content of the gases that occur during the production of pig iron and/or the production of crude steel to be used in full for producing chemical products, embodiments of the present invention meters in hydrogen that is formed in a plant for producing hydrogen. The hydrogen is produced preferably by electrolysis of water, wherein the electrolysis of water is operated expediently by electric power which has been produced from renewable energy. The electrolysis of water also produces oxygen that can be used in the blast furnace for producing pig iron and/or in the converter steel works for producing crude steel.

It is also within the scope of embodiments of the present invention for syngas to be produced from converter gas and enriched with hydrogen. The enrichment with hydrogen that is produced within the plant complex, in accordance with the hydrogen requirement, makes it possible to adjust the H_2 content of the converter gas to any desired value.

It is also possible to use blast-furnace top gas and converter gas to produce a mixed gas which, after a gas-conditioning operation and enrichment with hydrogen, is used as syngas for producing chemical products. It is expedient here for the hydrogen to be produced by electrolysis of water using electricity obtained from renewable energy.

Within the scope of embodiments of the present invention, a biotechnological plant may also be used instead of a chemical plant for producing products from syngas. The plant concerned is a plant for the fermentation of syngas. The syngas is used biochemically by way of a fermentation process, it being possible to produce products such as alcohols (ethanol, butanol), acetone or organic acids. These products, which are produced by fermentation of syngas, are also only mentioned by way of example in the present case.

According to an embodiment of the invention, the plant complex additionally comprises a coke-oven plant. If the production of pig iron and the production of crude steel are operated in combination with a coking plant, a partial amount of the blast-furnace top gas that occurs in the production of pig iron and/or a partial amount of the converter gas that occurs in the converter steel works may be mixed with a partial amount of the coke-oven gas that occurs in the coke-oven plant and the mixed gas may be used as a useful gas. A mixture of coke-oven gas and blast-furnace top gas or a mixed gas comprising coke-oven gas, converter gas and blast-furnace top gas may be used as a useful gas for producing a syngas, for example for ammonia synthesis. A mixed gas comprising coke-oven gas and converter gas or a mixed gas comprising coke-oven gas, converter gas and blast-furnace top gas is suitable for producing hydrocarbon compounds. The described chemical products that can be produced in a chemical plant from blast-furnace top gas, converter gas and coke-oven gas are only application examples for explaining the variants of the method that are described in the patent claims.

The raw gases - coke-oven gas, converter gas and blast-furnace top gas - may be conditioned individually or in combinations as a mixed gas and then fed to the chemical plant as syngases. The conditioning of coke-oven gas in particular comprises a cleaning of the gas to separate out troublesome contents, in particular tar, sulphur and sulphur compounds, aromatic hydrocarbons (BTX) and high-boiling hydrocarbons. A gas-conditioning operation is also necessary for producing the syngas. In the course of the gas conditioning, the proportion of the components CO, CO_2 and H_2 within the raw gas is changed. The gas conditioning comprises for example pressure swing adsorption for separating out and enriching H_2 and/or a water-gas-shift reaction for converting CO into hydrogen and/or a steam reformer for converting the CH_4 fraction into CO and hydrogen in the coke-oven gas.

According to an embodiment of the invention, the plant complex comprises a power-generating plant for electricity generation which is designed as a gas-turbine power-generating plant or gas-turbine/steam-turbine power-generating plant that is operated with a gas that comprises at least a partial amount of the blast-furnace top gas that occurs in the production of pig iron in the blast furnace and/or a partial amount of the converter gas that occurs in the converter steel works. The power-generating plant for electricity generation and the chemical plant or biotechnological plant are connected in parallel, as seen in relation to the flow guidance of the gases. The steams of gas that are fed to the power-generating plant, on the one hand, and to the chemical or biotechnological plant, on the other hand, can be controlled.

In the case of the method according to embodiments of the present invention, at least a partial amount of the blast-furnace top gas that occurs in the production of pig iron in the blast furnace and/or a partial amount of the converter gas that occurs in the converter steel works is used as raw gas, in order to produce products, that is to say substances of value, from them by chemical reactions in a chemical plant or by biochemical processes in a biotechnological plant. As a consequence of using part of these gases, the plant complex has a deficit of electricity, which has to be obtained externally. The externally obtained electricity may originate from conventional power-generating plants or be obtained from renewable energy sources. Preferably, the externally obtained electricity is obtained completely or at least partially from renewable energy and originates for example from wind turbine generator plants, solar plants, geothermal power-generating plants, hydroelectric power-generating plants, tidal power-generating plants and the like. To achieve operation of the plant complex that is as cost-effective as possible, at times of low electricity prices electricity is bought in and used for supplying to the plant complex and the part of the useful gas that is not used for producing electricity is used for producing chemical products after a gas-conditioning operation in the chemical plant or the biotechnological plant. At times of high electricity prices, on the other hand, the useful gas is completely or at least mostly fed to the power-generating plant in order to produce electricity for supplying to the plant complex. The chemical plant or biotechnological plant is correspondingly operated at a lower output at times of high electricity prices. The same applies for the electrolysis of water operated with electric power. If, in the event of high electricity prices, the chemical plant is operated at a lower output, it is also the case that the level of hydrogen required is low. If, in contrast, in the event of electricity prices being low, the chemical plant is operated with a high production output, it is also possible for the hydrogen to be produced cost-effectively by electrolysis of water. A closed-loop control system is provided for operating the method, establishing the alternating operation of the power-generating plant on the one hand and the chemical plant or biotechnological plant on the other hand in dependence on a variable process parameter. The process parameter is preferably determined in dependence on a function that includes the price for the externally obtained electricity and the costs for producing the power-generating plant electricity as variables.

The method according to embodiments the present invention makes it possible for the plant complex to be operated cost-effectively. The method according to embodiments of the invention thereby also makes use in particular of the fact that the efficiency of a power-generating process for producing electricity is worse than the efficiency of a chemical plant or a biotechnological plant in which chemical products are produced by chemical reactions or by biochemical processes from syngas.

The power output of the chemical plant or of the biotechnological plant is controlled in dependence on the amount of syngas fed to this plant. A major challenge for the chemical plant is that of finding a way of operating dynamically with changing plant loads. The way of operating with changing plant loads can be realized in particular by the chemical plant having a plurality of small units arranged in parallel, which are individually switched on or off depending on the available stream of useful gas.

The use of a biotechnological plant has the advantage that a biotechnological plant is more flexible with respect to load changes than a chemical plant.

In accordance with a further aspect of the present invention, there is provided a plant complex for steel production comprising:

a blast furnace for producing pig iron;

a converter steel works for producing crude steel;

a gas-conducting system for gases that occur in the production of pig iron and/or the production of crude steel; and

a closed-loop control system;

wherein the plant complex additionally comprises a chemical plant or biotechnological plant connected to the gas-conducting system and a plant for producing hydrogen, wherein the plant for producing hydrogen is connected to the gas-conducting system by a hydrogen-carrying line, wherein the plant

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complex additionally comprises a power-generating plant which is designed as a gas-turbine power-generating plant or gas-turbine and steam-turbine power-generating plant and is operated with a useful gas comprising at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace and a partial amount of a converter gas that occurs in the converter steel works, wherein the gas-conducting system comprises a connectable gas diverter operably connected to the closed-loop control system for selectively altering a ratio of streams of the useful gas that are fed to the power-generating plant and the chemical plant or biotechnological plant, wherein:

at a first electricity price, a portion of the streams of the useful gas is diverted from the power-generating plant to the chemical plant or biotechnological plant;

at a second electricity price, a portion of the streams of gas is diverted from the chemical plant or biotechnological plant to the power-generating plant; and

the second electricity price is greater than the first electricity price;

wherein the hydrogen-carrying line is connected to a mixing device, which is arranged upstream of the chemical or biotechnological plant relative to the direction of flow and is arranged for producing a mixed gas consisting of blast-furnace top gas and converter gas, and
wherein the mixed gas is enriched with hydrogen prior to being used as syngas in the chemical plant or biotechnological plant.

In another aspect, there is provided a method for operating a plant complex which has a blast furnace for producing pig iron, a converter steel works for producing crude steel, a chemical plant or biotechnological plant and a plant for producing hydrogen,

a) wherein, a useful gas comprising at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace and a partial amount of a converter gas that occurs in the production of crude steel is used after a gas-conditioning operation, as a syngas for producing a product,

b) wherein the useful gas, prior to being used as syngas in the chemical plant or biotechnological plant, is enriched with hydrogen that is formed in the plant for producing hydrogen,

wherein a part of the useful gas is fed to a power-generating plant and used for electricity generation, wherein the power-generating plant and the chemical or biotechnological plant are connected in parallel, and wherein streams of the useful gas that are fed to the power-generating plant, and to the chemical or biotechnological plant, are controlled in a manner such that:

at a first electricity price, a portion of the streams of the useful gas is diverted from the power-generating plant to the chemical plant or biotechnological plant;

at a second electricity price, a portion of the streams of gas is diverted from the chemical plant or biotechnological plant to the power-generating plant; and

the second electricity price is greater than the first electricity price.

Brief Description of the Drawings

A specific embodiment of the invention is explained below on the basis of the accompanying drawings that merely represents an exemplary embodiment. Schematically,

Figure 1 shows a greatly simplified block diagram of a plant complex for producing steel comprising a blast furnace for producing pig iron, a converter steel works for producing crude steel, a power-generating plant, a chemical or biotechnological plant and a plant for producing hydrogen,

Figure 2 shows the greatly simplified block diagram of a plant complex which, in addition to a blast furnace for producing pig iron, a converter steel works for producing crude steel, a power-generating plant, a chemical or biotechnological plant and a plant for producing hydrogen, also comprises a coke-oven plant.

Detailed Description of Specific Embodiments

The plant complex for steel production that is represented in Figure 1 comprises a blast furnace 1 for producing pig iron, a converter steel works 2 for producing crude steel, a power-generating plant 3 for electricity generation and a chemical or biotechnological plant 11.

In the blast furnace 1, pig iron 6 is obtained substantially from iron ore 4 and reducing agents 5, in particular coke and coal. Reduction reactions cause the production of a blast-furnace top gas 7, which contains nitrogen, CO, CO_2 and H_2 as the main constituents. In the converter steel works 2 that is arranged downstream of the blast-furnace process, pig iron 6 is converted into crude steel 8. By blowing oxygen onto the liquid pig iron, troublesome impurities, in particular carbon, silicon and phosphorus, are removed. For cooling, scrap may be added in amounts of up to 25% with respect to the amount of pig iron. Furthermore, lime is added for forming slag and an alloying agent. At the top of the converter, a converter gas 9 that has a very high proportion of CO is drawn off.

The power-generating plant 3 is designed as a gas-turbine power-generating plant or gas-turbine and steam-turbine power-generating plant and is operated with a gas that comprises at least a partial amount of the blast-furnace top gas 7 that occurs in the production of pig iron in the blast furnace 1 and/or a partial amount of the converter gas 9 that occurs in the converter steel works 2. A gas-conducting system is provided for carrying the gases.

According to the overall balance represented in Figure 1, carbon is fed to the plant complex as a reducing agent 5 in the form of coal and coke and also iron ore 4. Occurring as products are crude steel 8 and raw gases 7, 9, which differ in amount, composition, calorific value and purity and are used again at various points in the plant complex. In an overall consideration, 40 to 50%, usually approximately 45%, of the raw gases 7, 9 are returned again into the metallurgical process for producing pig iron or producing crude steel. Between 50 and 60%, usually approximately 55%, of the raw gases 7, 9 can be used for operating the power-generating plant 3. The power-generating plant 3 operated with a mixed gas 10 comprising blast-furnace top gas 7 and converter gas 9 is designed in such a way that it can cover the electricity demand of the plant complex.

According to the representation in Figure 1, a chemical or biotechnological plant 11 is provided, connected to the gas-conducting system and arranged in parallel with the power-generating plant 3 with respect to the gas supply. The gas-conducting system has an operationally controllable gas diverter 12 for dividing the streams of gas that are fed to the power-generating plant 3 and the chemical or biotechnological plant 11. Provided upstream of the gas diverter in the direction of flow is a mixing device 13, for producing the mixed gas 10 consisting of blast-furnace top gas 7 and converter gas 9.

In the case of the plant complex represented in Figure 1, at least a partial amount of the blast-furnace top gas 7 that occurs in the production of pig iron in the blast furnace 1 and a partial amount of the converter gas 9 that occurs in the production of crude steel are used as a useful gas for operating the power-generating plant 3 and the chemical or biotechnological plant 11. Externally obtained electricity 14 and power-generating plant electricity 15, which is produced by the power-generating plant 3 of the plant complex, are used to cover the electricity demand of the plant complex. The proportion of electricity accounted for by the externally obtained electricity 14 with respect to the overall electricity demand of the plant complex is established as a variable process parameter and the amount of useful gas N1 fed to the power-generating plant 3 is determined in dependence on this process parameter. The part of the useful gas N2 that is not used for producing electricity is used after a gas-conditioning operation as a syngas for producing chemical products 16 or is fed after a gas-conditioning operation to the biotechnological plant and used for biochemical processes.

The externally obtained electricity 14 is preferably obtained completely or at least partially from renewable energy and originates for example from wind turbine generator plants, solar plants, hydroelectric power-generating plants and the like. The process parameter on the basis of which the amount of useful gas N1 that is fed to the power-generating process is established is determined in dependence on a function that includes the price for the externally obtained electricity and the costs for producing the power-generating plant electricity 15 as variables. To achieve operation of the plant complex that is as cost-effective as possible, at times of low electricity prices electric power is bought in as external electricity 14 and used for supplying electricity to the plant complex, the part of the useful gas N2 that is not used for producing electricity being fed to the chemical or biotechnological plant 11 and used for producing chemical products 16 after a gas-conditioning operation. At times of high electricity prices, the raw gases 7, 9 that occur in the production of pig iron and the production of crude steel are fed to the power-generating plant 3 in order to produce electricity for supplying to the plant complex. The chemical plant 11 or the alternatively provided biotechnological plant is correspondingly operated at a lower output at times of high electricity prices.

In order that the carbon content and the nitrogen content of the raw gases that occur during operation of the plant complex can be used in full for producing chemical products, hydrogen has to be fed in order to compensate for a shortage of hydrogen. The plant complex therefore additionally has a plant 21 for producing hydrogen, which is connected to the gas-conducting system by a hydrogen-carrying line 22. The plant 21 for producing hydrogen may be in particular an electrolysis plant for the electrolysis of water. An electrolysis of water is energy-intensive to operate and is therefore primarily put into operation at times of low electricity prices, at which the chemical plant 11 or biotechnological plant is also operated and the power-generating plant 3 is operated at a lower output. The hydrogen that is additionally produced is fed to the chemical plant 11 together with the useful gas as syngas. This allows the capacity of the chemical plant 11 to be increased significantly. The same applies correspondingly if a biotechnological plant is provided instead of the chemical plant 11.

In the exemplary embodiment of Figure 2, the plant complex additionally comprises a coke-oven plant 17. In the coking of coal 18 into coke 19, coke-oven gas 20 occurs, containing a high proportion of hydrogen and CH_4. Parts of the coke-oven gas 20 may be used for the heating of the air heaters in the blast furnace 1. The gas-conducting system includes a gas distribution for the coke-oven gas 20. Provided upstream of the gas diverter 12 in the direction of flow is a mixing device 13, for producing a mixed gas 10 consisting of blast-furnace top gas 7, converter gas 9 and coke-oven gas 20. With the gas diverter 12, the streams of gas that are fed to the power-generating plant 3 and the chemical or biotechnological plant 11 can be controlled.

During the operation of the plant represented in Figure 2, a partial amount of the blast-furnace top gas 7 that occurs in the production of pig iron and/or a partial amount of the converter gas 9 that occurs in the converter steel works are mixed with a partial amount of the coke-oven gas 20 that occurs in the coke-oven plant 17. The mixed gas 10 is used for operating the power-generating plant 3 and, after a gas-conditioning operation and enrichment with hydrogen, as syngas in the chemical plant 11 or biotechnological plant.

The blast-furnace top gas 7, the converter gas 9 and the coke-oven gas 20 may be combined with one another in any way desired. The combination of gas streams 7, 9, 20 depends on the desired syngas or the product that is to be produced from the syngas in the chemical plant 11 or the biotechnological plant. An additional enrichment with hydrogen, which is produced preferably by water electrolysis in the plant 21, takes place here.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A plant complex for steel production comprising:

a blast furnace for producing pig iron;

a converter steel works for producing crude steel;

a gas-conducting system for gases that occur in the production of pig iron and/or the production of crude steel; and

a closed-loop control system;

wherein the plant complex additionally comprises a chemical plant or biotechnological plant connected to the gas-conducting system and a plant for producing hydrogen, wherein the plant for producing hydrogen is connected to the gas-conducting system by a hydrogen-carrying line, wherein the plant complex additionally comprises a power-generating plant which is designed as a gas-turbine power-generating plant or gas-turbine and steam-turbine power-generating plant and is operated with a useful gas comprising at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace and a partial amount of a converter gas that occurs in the converter steel works, wherein the gas-conducting system comprises a connectable gas diverter operably connected to the closed-loop control system for selectively altering a ratio of streams of the useful gas that are fed to the power-generating plant and the chemical plant or biotechnological plant, wherein:

at a first electricity price, a portion of the streams of the useful gas is diverted from the power-generating plant to the chemical plant or biotechnological plant;

at a second electricity price, a portion of the streams of gas is diverted from the chemical plant or biotechnological plant to the power-generating plant; and the second electricity price is greater than the first electricity price;

wherein the hydrogen-carrying line is connected to a mixing device, which is arranged upstream of the chemical or biotechnological plant relative to the direction of flow and is arranged for producing a mixed gas consisting of blast-furnace top gas and converter gas, and

wherein the mixed gas is enriched with hydrogen prior to being used as syngas in the chemical plant or biotechnological plant.

2. The plant complex according to Claim 1, wherein the chemical plant or biotechnological plant is connected to a line for converter gas, and in that the hydrogen-carrying line is connected to the converter-gas line, so that the converter gas, for use in the chemical plant or biotechnological plant, can be enriched with the hydrogen.

3. The plant complex according to claim 1 or 2, wherein the plant for producing hydrogen has an electrolysis plant for electrolysis of water.

4. The plant complex according to Claim 3, wherein the electrolysis plant is connected to at least one of the blast furnace and the converter steel works for producing crude steel by means of an oxygen-return device.

5. A method for operating a plant complex which has a blast furnace for producing pig iron, a converter steel works for producing crude steel, a chemical plant or biotechnological plant and a plant for producing hydrogen,

a) wherein, a useful gas comprising (i) at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron in the blast furnace, (ii) a partial amount of a converter gas that occurs in the production of crude steel, or (iii) a combination thereof, is used after a gas-conditioning operation, as a syngas for producing a product,

b) wherein the useful gas, prior to being used as syngas in the chemical plant or biotechnological plant, is enriched with hydrogen that is formed in the plant for producing hydrogen,

wherein a part of the useful gas is fed to a power-generating plant and used for electricity generation, wherein the power-generating plant and the chemical or biotechnological plant are connected in parallel, and wherein streams of the useful gas that are fed to the power-generating plant, and to the chemical or biotechnological plant, are controlled in a manner such that:

at a first electricity price, a portion of the streams of the useful gas is diverted from the power-generating plant to the chemical plant or biotechnological plant;

at a second electricity price, a portion of the streams of gas is diverted from the chemical plant or biotechnological plant to the power-generating plant; and

the second electricity price is greater than the first electricity price.

6. The method according to Claim 5, wherein the syngas is produced from the converter gas and is enriched with the hydrogen.

7. The method according to Claim 5, wherein the blast-furnace top gas and the converter gas are used to produce a mixed gas which, after a gas-conditioning operation and enrichment with hydrogen, is used as the syngas for producing a chemical product in the chemical plant or in the biotechnological plant via biochemical processes.

8. The method according to any one of Claims 5 to 7, wherein the hydrogen is produced by electrolysis of water.

9. The method according to Claim 8, wherein the electrolysis of water is operated by electric power which has been produced from renewable energy.

10. The method according to Claim 8 or 9, wherein the oxygen formed during the electrolysis of water is used within at least one of (i) the blast furnace for producing the pig iron, and (ii) the converter steel works for producing the crude steel.

11. The method according to any one of Claims 5 to 10, wherein the amount of H_2 produced is such that the entire fraction of carbon and nitrogen in the useful gas can be used for converting into the product.

12. The method according to any one of Claims 5 to 11, wherein 5% to 60% of the amount of gas that occurs as (i) the blast-furnace top gas during the production of pig iron, (ii) the converter gas in the converter steel works, or (iii) a combination thereof, is fed to the chemical or biotechnological plant and used for producing the product.

13. The method according to any one of Claims 5 to 12, wherein coke-oven gas is admixed with the useful gas.

14. The method according to any one of Claims 5 to 13, wherein an output of the power-generating plant is reduced to part-load or base-load operation, and the connectable gas diverter is used to restrict the part of the useful gas fed to the power-generating plant correspondingly, if the electricity price for electrical energy externally obtained from renewable energy is a predetermined factor lower than costs of the power produced in the power-generating plant.

15. Use of a chemical or biotechnological plant in conjunction with a plant for producing hydrogen, for coupling to a plant complex according to any one of claims 1 to 4, with the proviso that at least a partial amount of a blast-furnace top gas that occurs in the production of pig iron and at least a partial amount of a converter gas that occurs in the converter steel works, are used as a useful gas for operating the chemical or biotechnological plant and the power-generating plant, wherein a part of the useful gas that is used for operating the chemical or biotechnological plant is, after a gas-conditioning operation and

after an enrichment with hydrogen, used as a syngas for producing a product.

Fig.1

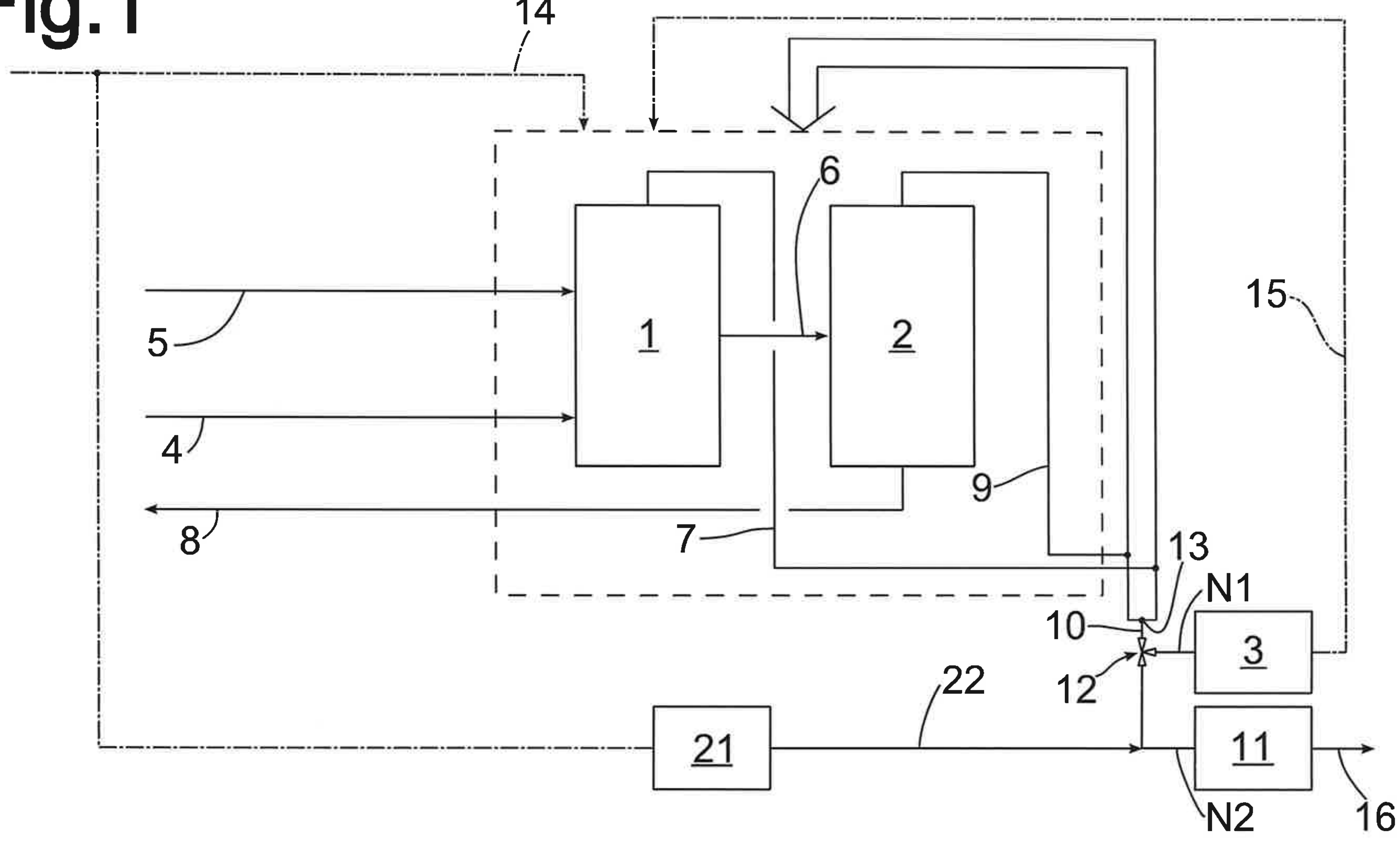

Fig.2