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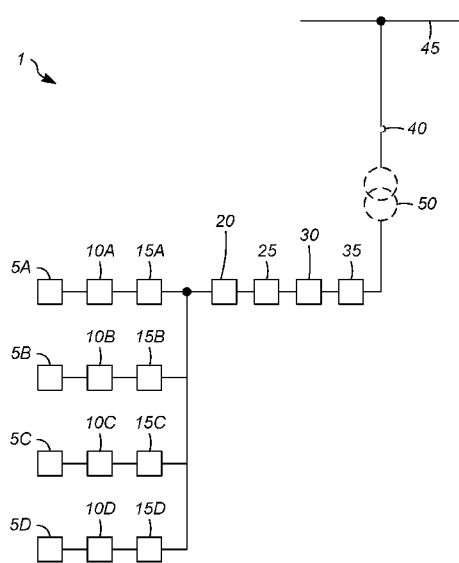


FIG. 1

(57) **Abstract:** Apparatus and methods for recovering energy in a petroleum, petrochemical, or chemical plant as described. The apparatus includes a fluid process stream flowing through a petroleum, petrochemical, or chemical process zone. There are at least one variable-resistance power-recovery turbine, a portion of the first process stream flowing through the first power-recovery turbine to generate electric power as direct current therefrom. There is a single DC to AC inverter electrically connected to at least one power-recovery turbine, and the output of the DC to AC inverter electrically connected to a first substation.



CONSOLIDATION AND USE OF POWER
RECOVERED FROM A TURBINE IN A PROCESS UNIT

5 BACKGROUND OF THE INVENTION

Typically, when power-recovery turbines are installed in process streams in petroleum, petrochemical, and chemical process plant, the power is sent through mechanical means to a driver for a pump or compressor because this generally has a higher efficiency than conversion to electricity through a generator. However, these systems have lower reliability than an electrical generator, require that power recovered matches closely with the power consumed in a single driver, and require a lot of connection equipment in couplings, gears, switchgear, clutches, and the like that all must be in a limited space. These issues have been addressed by generating electrical power at the power recovery point and providing that as fungible power for any driver within the process unit. Where power recovery is greater than that consumed within the process unit, it must be exported into the higher voltage level on the plant grid. This has been the case for most major power recovery installations seen to date.

However, sending power to the plant's power grid presents its own set of difficulties. It requires several steps of electricity conditioning, voltage transformation and frequency regulation. Now higher technology equipment is available in the power recovery field that can bring down unit cost to allow economic power recovery at lower power generation sources. When more cost efficient turbines are installed as control elements in process streams, multiple installations may be desirable. However, the power conditioning, transformer, electrical components and safety equipment to protect the high voltage grid is costly for multiple installations.

Therefore, there is a need for improved electricity handling processes and apparatus for using power-recovery turbines.

30 BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is an electrical connection diagram of one embodiment of the present invention.

Fig. 2 is an electrical connection diagram of another embodiment of the present invention.

DETAILED DESCRIPTION

The invention relates to recovering power in petroleum, petrochemical, or chemical plants by producing electrical power including one or more power-recovery turbine generators. The power-recovery turbines can be used as control elements in the process. The power outputs of the turbine generators are combined and conditioned before being connected to a three-phase low voltage (for example, <600VAC, such as 480 or 240 VAC) distribution system. Delivering power at the low voltage avoids the equipment capital costs of step-up transformation and medium voltage (for example, 5kVAC or 15kVAC class) switchgear and protective relaying. This approach saves equipment capital expense, plot space, field cable runs, maintenance costs, and increases reliability.

Installation of power recovery turbines in petroleum, petrochemical, or chemical processing units is limited due to capital expense, plot area, cost for cable runs, space in the switchgear lineup, and equipment needed to transform the power up from low voltage (e.g., <600VAC) to the medium voltage (e.g., 5kVAC or 15kVAC class). Until recently, there has been a lack of smaller power recovery units (e.g., <500kW recovered power) that are economical and practical with respect to the space required for the necessary equipment. As a result, only large electrical power recovery generators have been installed, meaning the electrical power generated must be exported from the unit (for example, fluid catalytic cracking (FCC) flue gas power recovery turbines).

In some embodiments, the cost of transforming the electricity up to a higher grid voltage is completely avoided by producing AC power at the low voltage (e.g., <600VAC) level of the drivers used in the process unit itself. In this way, the amount of power drawn from the grid is reduced as the net power draw of the process unit on the plant grid bus is reduced by the amount of power produced by the power recovery unit. This is particularly interesting for very cost efficient, compact, small scale power recovery units

which will generate less power than is consumed within the process unit. In other embodiments, a portion of the electricity is converted to a higher voltage.

The use of a cost effective power recovery device such as disclosed in US 5,481,145 allows the economical recovery of electrical power from otherwise wasted energy (such as control valve letdowns) with good payback. However, in order to maintain a low new unit or revamp cost for the application and to allow for minimal perturbation to the plant electrical system, the electrical transmission from the power recovery device should be limited to the AC bus within the process substation electrical distribution system and conform to the same low voltage (e.g., <600VAC) and frequency and phase pattern therein. It is desirable for the power recovery device, which could act as a flow controller and thereby have fluctuating current, voltage and frequency output in AC mode, to operate decoupled from the constraints of synchronizing up to the low voltage (e.g., <600VAC) grid. One way to accomplish this is to rectify the power-recovery turbine power to DC current and then have a dedicated AC inverter to synchronize the output voltage with the process low voltage AC bus.

One aspect of the invention is an apparatus for recovering energy in a petroleum, petrochemical, or chemical plant. In one embodiment, the apparatus comprises a petroleum, petrochemical, or chemical process zone; at least a first fluid process stream flowing through the process zone; at least a first variable-resistance power-recovery turbine, a portion of the first process stream flowing through the first power-recovery turbine to generate electric power as direct current therefrom; a single DC to AC inverter electrically connected to the first power-recovery turbine, the output of the DC to AC inverter electrically connected to a first substation, such as three-phase, low voltage (e.g., <600VAC) power grid. The fluid process stream can be liquid or gas, or mixtures thereof

A process substation is an electrical area dedicated to electrical power distribution to a group of process unit services. There are typically several process and utility substations within a refinery, or petrochemical or chemical plant, and there is one main substation where the main distribution system is located. The process substation is comprised of transformers, an electrical building, switchgear of different voltage levels, motor control centers (MCCs) and single phase distribution panels. Most process substations serve a very large kW electrical load, some of it at low voltage (e.g., <600V) and some of it at medium

voltage (for the larger motors, for example, $\geq 250\text{HP}$). As a result, a typical process substation will have both medium and low voltage buses.

When power is recovered, the output of the inverter can be connected to the process substation's low voltage distribution system or, if a sufficiently large amount of power is recovered, it can be stepped-up to the process substation's medium voltage distribution system. Large amounts of recovered power with stepped-up voltage can also be connected to medium voltage systems in other process substations or in the main substation (medium voltage is generally used to reduce voltage drop). However, this incurs additional costs of transformation, switchgear, cabling, etc. and requires significant real estate for the additional equipment.

In some embodiments, the first substation is electrically connected to a piece of equipment in the process zone.

In some embodiments, there is at least a second fluid process stream flowing through the process zone; and at least a second variable-resistance power-recovery turbine. A portion of the second process stream flows through the second power-recovery turbine to generate recovered electric power as direct current therefrom. The second power recovery turbine is electrically connected to the single DC to AC inverter.

In some embodiments, there is a DC bus electrically connected to the first and/or second power-recovery turbines and to the DC to AC inverter.

In some embodiments, the power-recovery turbines comprise adjustable guide vane power-recovery turbines or variable load power-recovery turbines, or combinations thereof.

The apparatus can be used in a wide variety of processes, including, but not limited to, at least one of an alkylation zone, a separation zone, an isomerization zone, a catalytic reforming zone, a fluid catalyst cracking zone, a hydrocracking zone, a hydrotreating zone, a hydrogenation zone, a dehydrogenation zone, an oligomerization zone, a desulfurization zone, an alcohol to olefins zone, an alcohol to gasoline zone, an extraction zone, a distillation zone, a sour water stripping zone, a liquid phase adsorption zone, a hydrogen sulfide reduction zone, an alkylation zone, a transalkylation zone, a coking zone, and a polymerization zone.

In some embodiments, there are three or more power-recovery turbines electrically connected to the DC to AC inverter.

In some embodiments, there may be more than one DC to AC inverter, with each of the DC to AC inverters electrically connected to one or more power-recovery turbines. The grid output of each of the DC to AC inverters is electrically connected to a low voltage (e.g., <600VAC) power. The power grids can be the same for all of the DC to AC
5 inverters or they can be different.

In some embodiments, the substation comprises at least one alternating current bus, and the output of the DC to AC inverter is electrically connected to the at least one alternating current bus, such as a low voltage (e.g., <600VAC) bus, in the substation.

In some embodiments, the substation comprises at least one alternating current
10 bus, and the output of the DC to AC inverter is electrically transformed up to medium voltage and then connected to a medium voltage (e.g., 5 kVAC or 15kVAC Class) bus within the process substation.

In some embodiments, there is a second substation, and the output of the first substation is electrically connected to the second substation. In some embodiments, the
15 second substation has a higher voltage than a voltage of the first substation, and there is a step-up transformer to step-up the voltage of the DC to AC inverter to the higher voltage of the second substation, such as a medium voltage.

In some embodiments, the first substation is electrically connected to at least two petroleum, petrochemical, or chemical process zones. In some embodiments, the output
20 of the first substation is electrically connected to a piece of equipment in the at least two process zones.

Another aspect of the invention is a process for recovering energy from a petroleum, petrochemical, or chemical plant. In one embodiment, the process comprises providing at least a first fluid process streams in a petroleum, petrochemical, or chemical
25 process zone; controlling a flow rate of the first process stream by directing at least a portion of the first process stream through the first power-recovery turbine to generate recovered electric power as direct current therefrom; converting the recovered direct current into recovered alternating current in a single DC to AC inverter; and providing the recovered alternating current to a first substation.

30 In some embodiments, the first substation is electrically connected to a piece of equipment in the process zone.

In some embodiments, the first substation is electrically connected to at least two petroleum, petrochemical, or chemical process zones. In some embodiments, the process includes providing the recovered alternating current to a piece of equipment in the at least two process zones.

5 In some embodiments, the process comprises providing at least a second fluid process stream flowing through the process zone; controlling a flow rate of the second process stream by directing at least a portion of the second process stream through at least a second variable-resistance power-recovery turbine to generate recovered electric power as direct current therefrom; combining the direct current from the first and second power
10 recovery turbines; and converting the combined recovered direct current into the recovered alternating current in the DC to AC inverter.

In some embodiments, combining the recovered direct current from the first and second power-recovery turbines comprises combining the recovered direct current from the first and second power-recovery turbines in a DC bus electrically connected to the first
15 and second power-recovery turbines and to the DC to AC inverter.

In some embodiments, the process substation comprises at least one alternating current bus, and wherein the output of the DC to AC inverter is electrically connected to the at least one alternating current bus.

In some embodiments, there is a second substation, and the output of the first
20 substation is electrically connected to the second substation.

In some embodiments, the second substation has a higher voltage than a voltage of the first substation, and the process further comprises stepping up the output of the DC to AC inverter to the higher voltage of the second substation.

In some embodiments, the process also comprises receiving information
25 from the external power grid and a plurality of pressure reducing devices, the plurality of pressure reducing devices comprising: one or more power-recovery turbines; a control valve; or, both; determining a power loss value or a power generated value for each of the pressure reducing devices; determining a total power loss value or a total power generated value based upon the power loss values or the power generated
30 values from each of the pressure reducing devices; and, displaying the total power loss value or the total power generated value on at least one display screen.

In some embodiments, the process also comprises adjusting at least one process parameter in the processing zone based upon the total power loss value or the total power generated value.

5 In some embodiments, the process also comprises displaying the total power loss value or the total power generated value on at least one display screen.

In some embodiments, the process comprises, after the at least one process parameter has been adjusted, determining an updated power loss value or an updated power generated value for each of the pressure reducing devices; determining an updated total power loss value or an updated total power generated value for the process
10 zone based upon the updated power loss values or the updated power generated values from each of the pressure reducing devices; and, displaying the updated total power loss value or the updated total power generated value on at least one display screen.

In some embodiments, the process also comprises receiving information associated with conditions outside of the process zone, wherein the total power loss
15 value or the total power generated value is determined based in part upon the information associated with conditions outside of the process zone.

In some embodiments, the process also comprises receiving information associated with a throughput of the process zone, wherein the total power loss value or the total power generated value is determined based in part upon the information
20 associated with the throughput of the process zone.

In some embodiments, the process also comprises maintaining the throughput of the process zone while adjusting the at least one process parameter of the portion of a process zone based upon the total power loss value or the total power generated value.

25 The power will be generated via power-recovery turbines with variable resistance to flow made possible by either guide vanes or variable load on the electrical power generation circuit. The power emanating from the turbines will be DC and can be combined into a single line and sent to an inverter that converts the DC power to AC in sync with and at the same voltage as a power grid. Because the power-recovery turbines produce DC output, it allows their electrical current to be combined without concern for

synchronizing frequencies, rotational speeds, etc. for the controlling power-recovery turbines that may have fluctuating and variable rotational speeds individually.

In some embodiments, the process for controlling a flowrate of and recovering energy from a process stream in a processing unit comprises directing a portion of the process stream through one or more variable-resistance power-recovery turbines to control the
5 flowrate of the process stream using a variable nozzle turbine, inlet variable guide vanes, or direct coupled variable electric load, to name a few, to vary the resistance to flow through the turbine.

The resistance to rotation of the variable-resistance turbine can be varied by an
10 external variable load electric circuit which is in a magnetic field from a magnet(s) that is rotating on the turbine. As more load is put on the circuit, there is more resistance to rotation on the turbine. This in turn imparts more pressure drop across the turbine and slows the process stream flow. An algorithm in the device can also calculate the actual flow through the device by measuring the turbine RPM's and the load on the circuit. The resistance to rotation
15 flow can also be varied by variable position inlet guide vanes. In some embodiments, the power will be generated via power-recovery turbines with variable resistance to flow made possible by either guide vanes or variable load on the electrical power generation circuit. An algorithm to calculate actual flow using the guide vanes position, power output and RPM's can be used.

If slow control response of the turbine is an issue, then the use of the turbine is
20 limited to slow responding or "loose" control point applications. A slow responding application is contemplated to have a response time to reach half way (i.e., 50% of a difference) between a new (or target) steady state condition (e.g., temperature, pressure, flow rate) from an original (or starting) steady state condition when the new (or target) condition
25 differs from the original (or starting) condition of at least 10%, of at least one second, or even greater, for example, ten seconds, at least one minute, at least ten minutes, or an hour or more, for half of the change to completed.

The power grid comprises a power grid internal to the process substation, a
30 power grid external to the process substation, or both. When the power grid is internal to the process substation, the output of the DC to AC inverter can be used in the process substation directly. For example, there may be one or more alternating current buses in the process substation. Alternatively, when the power grid is external to the process substation, it may

be at a higher voltage than the process substation. In this case, there is a transformer at the process substation that steps-up the output of the DC to AC inverter to the higher voltage of the power grid external to the process substation.

Fig. 1 illustrates an electrical connection diagram of an embodiment of the process 1 of the present invention. Power-recovery turbines 5A, 5B, 5C, 5D are direct coupled to synchronous generators 10A, 10B, 10C, 10D respectively. The AC currents generated are converted to DC by rectifiers 15A, 15B, 15C, 15D and then combined onto the DC bus. The DC current is sent to inverter 20 wherein it is converted back to AC current. The AC current is conditioned by sine-filter, DC choke and RFI suppression filter 25 before it is sent to AC bus 45. Closure of inverter main contactor 30, main switch 35 and circuit breaker 40 enables this action. If the power recovered exceeds the capacity of the substation low voltage bus, an optional step-up transformer 50 (shown with dashed lines) can be installed to transform the low voltage to medium voltage. As shown, AC bus 45 (either low voltage or medium voltage) can be connected to one or more pieces of equipment in the process zone or zones to which the substation is connected.

Fig. 2 illustrates an electrical connection diagram of a second embodiment of the process 100 of the present invention. Power-recovery turbines 105A and 105B are direct coupled to synchronous generators 110A and 110B respectively. The AC currents generated are converted to DC by rectifiers 145A and 145B and then combined onto the DC bus. The DC current is sent to inverter 115A wherein it is converted back to AC current. The AC current is conditioned by sine-filter, DC choke and RFI suppression filter 120A before it is sent to AC bus 125A. Closure of inverter main contactor 150A, main switch 155A and circuit breaker 140A enables this action.

Another branch has a similar arrangement of power-recovery turbines 105C and 105D with direct coupled synchronous generators 110C and 110D. The AC currents generated are converted to DC by rectifier 145C and 145D and then combined onto the DC bus. The DC current is sent to inverter 115B wherein it is converted back to AC current. The AC current is conditioned by sine-filter, DC choke and RFI suppression filter 120B before it is sent to AC bus 125B. Closure of inverter main contactor 150B, main switch 155B and circuit breaker 140B enables this action.

As shown, AC bus 125A and 125B are connected to transformers 130A and 130B respectively, and are separated by a normally-open tie circuit breaker 135. This

arrangement is a typical secondary-selective distribution system common in large industrial plants.

AC bus 125A and/or 125B can be connected to one or more pieces of equipment in the process zone or zones to which the substation is connected.

5 The devices and processes of the present invention are contemplated as being utilized in a petroleum, petrochemical, or chemical process zone. As is known, such petroleum, petrochemical, or chemical process zone units utilize a process control system, typically on a computer in a control center.

10 The process control system described in connection with the embodiments disclosed herein may be implemented or performed on the computer with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, or, the
15 processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be a combination of computing devices, e.g., a combination of a DSP and a microprocessor, two or more microprocessors, or any other combination of the foregoing.

20 The steps of the processes associated with the process control system may be embodied in an algorithm contained directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is in communication with the processor such the processor reads information from, and writes information to, the storage medium. This includes the storage
25 medium being integral to or with the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. Alternatively, the processor and the storage medium may reside as discrete components in a user terminal. These devices are merely intended to be exemplary, non-limiting examples of a computer readable storage medium. The processor and storage medium or memory are also typically in communication
30 with hardware (e.g., ports, interfaces, antennas, amplifiers, signal processors, etc.) that allow for wired or wireless communication between different components, computers processors, or

the like, such as between the input channel, a processor of the control logic, the output channels within the control system and the operator station in the control center.

In communication relative to computers and processors refers to the ability to transmit and receive information or data. The transmission of the data or information can be a wireless transmission (for example by Wi-Fi or Bluetooth) or a wired transmission (for
5 example using an Ethernet RJ45 cable or an USB cable). For a wireless transmission, a wireless transceiver (for example a Wi-Fi transceiver) is in communication with each processor or computer. The transmission can be performed automatically, at the request of the computers, in response to a request from a computer, or in other ways. Data can be pushed, pulled, fetched,
10 etc., in any combination, or transmitted and received in any other manner.

According to the present invention, therefore, it is contemplated that the process control system receives information from the power recovery turbines 105A, 105B, 105C, 105D relative to an amount of electricity generated by the power recovery turbines 105A, 105B, 105C, 105D. It is contemplated that the power recovery turbines 105A, 105B, 105C, 105D
15 determine (via the processor) the amount of electricity it has generated. Alternatively, the process control system receiving the information determines the amount of electricity that has been generated by the power recovery turbines 105A, 105B, 105C, 105D. In either configuration, the amount of the electricity generated by the power recovery turbines 105A, 105B, 105C, 105D is displayed on at least one display screen associated with the computer in
20 the control center. If the petroleum, petrochemical, or chemical process zone comprises a plurality of power recovery turbines 105A, 105B, 105C, 105D, it is further contemplated that the process control system receives information associated with the amount of electricity generated by each of the power recovery turbines 105A, 105B, 105C, 105D. The process control system determines a total electrical power generated based upon the information
25 associated with the each of the power recovery turbines 105A, 105B, 105C, 105D and displays the total electrical power generated on the display screen. The total electrical power generated may be displayed instead of, or in conjunction with, the amount of electrical power generated by the individual power recovery turbines 105A, 105B, 105C, 105D.

As discussed above, the electrical energy recovered by the power recovery
30 turbines 105A, 105B, 105C, 105D is often a result of removing energy from the streams that was added to the streams in the processing unit. Thus, it is contemplated that the processes according to the present invention provide for the various processing conditions associated with

the petroleum, petrochemical, or chemical process zone to be adjusted into order to lower the energy added to the steam(s).

It is contemplated that the process control system receives information associated with the throughput of the petroleum, petrochemical, or chemical process zone, and determines a target electrical power generated value for the turbine(s) since the electricity represents energy that is typically added to the overall petroleum, petrochemical, or chemical process zone. The determination of the target electrical power generated value may be done when the electricity is at or near a predetermined level. In other words, if the amount of electricity produced meets or exceeds a predetermined level, the process control system can determine one or more processing conditions to adjust and lower the amount of electricity generated until it reaches the target electrical power generated value.

Thus, the process control system will analyze one or more changes to the various processing conditions associated with the petroleum, petrochemical, or chemical process zone to lower the amount of energy recovered by the turbines of the petroleum, petrochemical, or chemical process zone. Preferably, the processing conditions are adjusted without adjusting the throughput of the processing unit. This allows for the petroleum, petrochemical, or chemical process zone to have the same throughput, but with a lower operating cost associated with the same throughput. The process control software may calculate and display the difference between the target electrical power generated value and the total electrical power generated on the display screen.

For example, the process control software may recognize that the total electrical power generated exceeds a predetermined level. Accordingly, the process control software may determine the target electrical power generated value. Based upon other data and information received from other sensors and data collection devices typically associated with the petroleum, petrochemical, or chemical process zone, the process control software may determine that the amount of fuel consumed in a piece of equipment can be lowered. While maintaining the throughput of the petroleum, petrochemical, or chemical process zone, the amount of fuel consumed in the piece of equipment is lowered. While this may lower the electricity generated by the turbine, the lower fuel consumption provides a lower operating cost for the same throughput.

Thus, not only does the present process convert energy that is typically lost into a form that is used elsewhere in the petroleum, petrochemical, or chemical process zone, the

petroleum, petrochemical, or chemical process zone is provided with opportunities to lower the energy input associated with the overall petroleum, petrochemical, or chemical process zone and increase profits by utilizing more energy efficient processes.

5 It should be appreciated and understood by those of ordinary skill in the art that various other components, such as valves, pumps, filters, coolers, etc., were not shown in the drawings as it is believed that the specifics of same are well within the knowledge of those of ordinary skill in the art and a description of same is not necessary for practicing or understanding the embodiments of the present invention.

10 While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the
15 invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

SPECIFIC EMBODIMENTS

20 While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

A first embodiment of the invention is an apparatus for recovering energy in a petroleum, petrochemical, or chemical plant comprising a petroleum, petrochemical, or
25 chemical process zone; at least a first fluid process stream flowing through the process zone; at least a first variable-resistance power-recovery turbine, a portion of the first process stream flowing through the first power-recovery turbine to generate recovered electric power as direct current therefrom; a single DC to AC inverter electrically connected to the first power-recovery turbine, the output of the DC to AC inverter electrically connected to a first
30 substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the first substation is

electrically connected to a piece of equipment in the process zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising at least a second fluid process stream flowing through the process zone; and at least a second variable-resistance power-recovery turbine, a portion of the second process stream flowing through the second power-recovery turbine to generate recovered electric power as direct current therefrom, the second power recovery turbine electrically connected to the single DC to AC inverter. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising a DC bus electrically connected to the first power-recovery turbine and to the DC to AC inverter. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the power-recovery turbine comprises an adjustable guide vane power-recovery turbine or a variable load power-recovery turbine, or combinations thereof. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the process zone comprises at least one of an alkylation zone, a separation zone, an isomerization zone, a catalytic reforming zone, a fluid catalyst cracking zone, a hydrocracking zone, a hydrotreating zone, a hydrogenation zone, a dehydrogenation zone, an oligomerization zone, a desulfurization zone, an alcohol to olefins zone, an alcohol to gasoline zone, an extraction zone, a distillation zone, a sour water stripping zone, a liquid phase adsorption zone, a hydrogen sulfide reduction zone, an alkylation zone, a transalkylation zone, a coking zone, and a polymerization zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein there are three or more power-recovery turbines electrically connected to the DC to AC inverter. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the first substation comprises at least one alternating current bus, and wherein the output of the DC to AC inverter is electrically connected to the at least one alternating current bus. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising a second substation and wherein the output of the first substation is electrically connected to the second substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first

embodiment in this paragraph wherein the second substation has a higher voltage than a voltage of the first substation, and further comprising a step-up transformer to step-up an output of the first substation to the higher voltage of the second substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first
5 embodiment in this paragraph wherein the first substation is electrically connected to at least two petroleum, petrochemical, or chemical process zones. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein an output of the first substation is electrically connected to a piece of equipment in the at least two process zones.

10 A second embodiment of the invention is a process for recovering energy from a petroleum, petrochemical, or chemical plant comprising providing at least a first fluid process stream in a petroleum, petrochemical, or chemical process zone; controlling a flow rate of the first process stream by directing at least a portion of the first process stream through a first variable-resistance power-recovery turbine to generate recovered electric
15 power as direct current therefrom; converting the recovered direct current into recovered alternating current in a single DC to AC inverter; and providing the recovered alternating current to a first substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the first substation is electrically connected to a piece of equipment in the process zone. An
20 embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the first substation is electrically connected to at least two petroleum, petrochemical, or chemical process zones. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising providing the recovered
25 alternating current to a piece of equipment in the at least two process zones. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising providing at least a second fluid process stream flowing through the process zone; controlling a flow rate of the second process stream by directing at least a portion of the second process stream through at least a
30 second variable-resistance power-recovery turbine to generate recovered electric power as direct current therefrom; combining the direct current from the first and second power recovery turbines; and converting the combined recovered direct current into the recovered

alternating current in the DC to AC inverter. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the first substation comprises at least one alternating current bus, and wherein the output of the DC to AC inverter is electrically connected to the at least one

5 alternating current bus. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising a second substation, and wherein the output of the first substation is electrically connected to the second substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph

10 wherein the second substation has a higher voltage than a voltage of the first substation, and further comprising stepping up an output of the DC to AC inverter to the higher voltage of the second substation. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising receiving information from a plurality of pressure reducing devices, the plurality

15 of pressure reducing devices comprising one or more power-recovery turbines, a control valve, or both; determining a power loss value or a power generated value for each of the pressure reducing devices; determining a total power loss value or a total power generated value based upon the power loss values or the power generated values from each of the pressure reducing devices; and displaying the total power loss value or the total power

20 generated value on at least one display screen. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising adjusting at least one process parameter in the process zone based upon the total power loss value or the total power generated value. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second

25 embodiment in this paragraph further comprising displaying the power loss value or the power generated value on the at least one display screen. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising after the at least one process parameter has been adjusted, determining an updated power loss value or an updated power generated value for each of the

30 pressure reducing devices; determining an updated total power loss value or an updated total power generated value for the process zone based upon the updated power loss values or the updated power generated values from each of the pressure reducing devices; and displaying

the updated total power loss value or the updated total power generated value on the at least one display screen. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising receiving information associated with conditions outside of the process zone, wherein the
5 total power loss value or the total power generated value is determined based in part upon the information associated with conditions outside of the process zone. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising receiving information associated with a
10 throughput of the process zone, wherein the total power loss value or the total power generated value is determined based in part upon the information associated with the throughput of the process zone. An embodiment of the invention is one, any or all of prior
15 embodiments in this paragraph up through the second embodiment in this paragraph further comprising maintaining the throughput of the process zone while adjusting the at least one process parameter of the portion of a process zone based upon the total power loss value or the total power generated value.

Without further elaboration, it is believed that using the preceding description that one skilled in the art can utilize the present invention to its fullest extent and easily ascertain the essential characteristics of this invention, without departing from the spirit and scope thereof, to make various changes and modifications of the invention and to adapt it to
20 various usages and conditions. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limiting the remainder of the disclosure in any way whatsoever, and that it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

In the foregoing, all temperatures are set forth in degrees Celsius and, all parts
25 and percentages are by weight, unless otherwise indicated.

What is claimed is:

1. A process for recovering energy from a petroleum, petrochemical, or chemical plant comprising:

5 providing at least a first fluid process stream in a petroleum, petrochemical, or chemical process zone;

controlling a flow rate of the first process stream by directing at least a portion of the first process stream through a first variable-resistance power-recovery turbine (5A) to generate recovered electric power as direct current therefrom;

10 converting the recovered direct current into recovered alternating current in a single DC to AC inverter (20); and

providing the recovered alternating current to a first substation.

2. The process of claim 1 wherein the first substation is electrically
15 connected to a piece of equipment in the process zone.

3. The process of any of claims 1-2 wherein the first substation is electrically connected to at least two petroleum, petrochemical, or chemical process zones.

20 4. The process of any of claims 1-2 further comprising providing the recovered alternating current to a piece of equipment in the at least two process zones.

5. The process of any of claims 1-2 further comprising:
25 providing at least a second fluid process stream flowing through the process zone;

controlling a flow rate of the second process stream by directing at least a portion of the second process stream through at least a second variable-resistance power-recovery turbine (5B) to generate recovered electric power as direct current therefrom;

30 combining the direct current from the first and second power recovery turbines (5A, 5B); and

converting the combined recovered direct current into the recovered alternating current in the DC to AC inverter (20).

6. The process of any of claims 1-2 wherein the first substation comprises at least one alternating current bus (45), and wherein the output of the DC to AC inverter is electrically connected to the at least one alternating current bus (45).

7. The process of any of claims 1-2 further comprising a second substation, and wherein the output of the first substation is electrically connected to the second substation.

8. The process of claim 7 wherein the second substation has a higher voltage than a voltage of the first substation, and further comprising stepping up an output of the DC to AC inverter to the higher voltage of the second substation.

9. The process of any of claims 1-2 further comprising:
receiving information from a plurality of pressure reducing devices, the plurality of pressure reducing devices comprising: one or more power-recovery turbines; a control valve; or, both;

determining a power loss value or a power generated value for each of the pressure reducing devices;

determining a total power loss value or a total power generated value based upon the power loss values or the power generated values from each of the pressure reducing devices; and,

displaying the total power loss value or the total power generated value on at least one display screen.

10. An apparatus for recovering energy in a petroleum, petrochemical, or chemical plant comprising:

a petroleum, petrochemical, or chemical process zone;

at least a first fluid process stream flowing through the process zone;

at least a first variable-resistance power-recovery turbine (5A), a portion of the first process stream flowing through the first power-recovery turbine (5A) to generate recovered electric power as direct current therefrom;

5 a single DC to AC inverter (20) electrically connected to the first power-recovery turbine (5A), the output of the DC to AC inverter (20) electrically connected to a first substation.

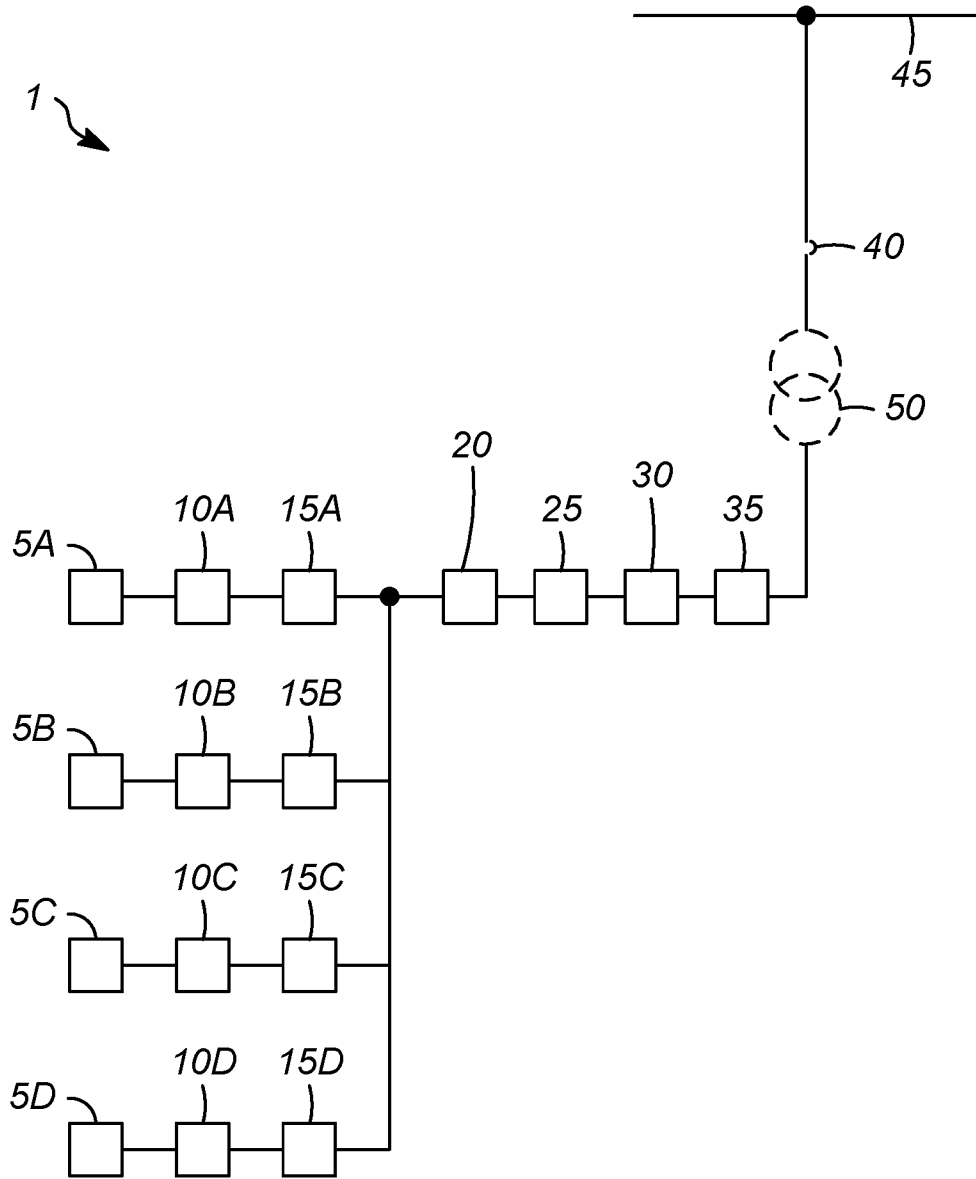


FIG. 1

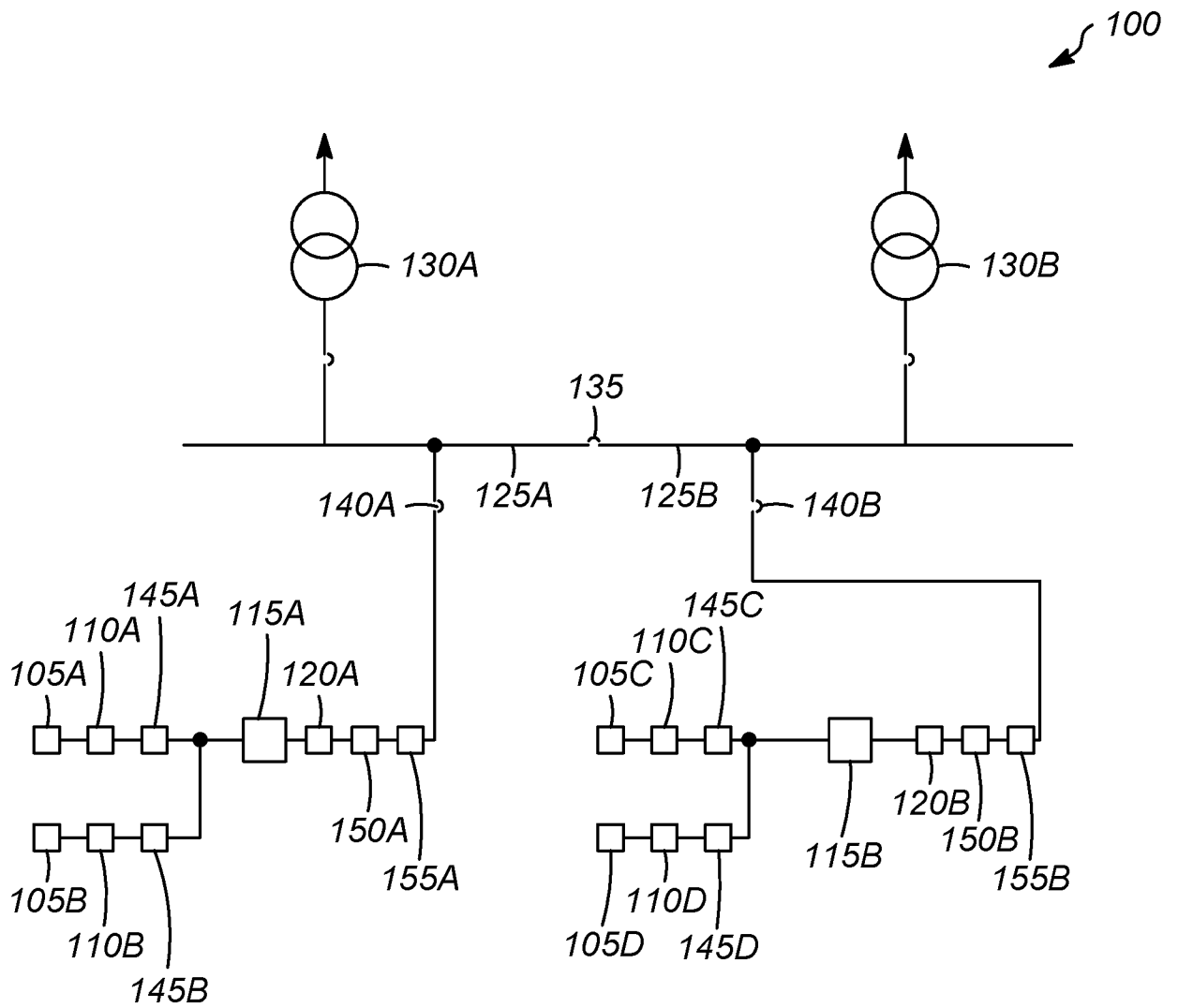


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2019/022431

A. CLASSIFICATION OF SUBJECT MATTER		
<i>F01D 15/10 (2006.01)</i> <i>H02M 7/00 (2006.01)</i>		
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)		
F01D, H02M		
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)		
PatSearch (RUPTO internal), Espacenet, DWPI, PAJ, USPTO, CIPO, PubMed, MEDLINE, PMJK		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7757493 B2 (UOP LLC) 20.07.2010, col. 1 lines 55-60, col. 5 lines 40-44	1,2,10
A		3-9
Y	US 2006/0056120 A1 (MAYEKAWA MFG. CO. LTD.) 10.02.2008, claim 5, [0025]	1,2,10
A		3-9
A	US 7062359 B2 (ABB AB) 13.06.2006	1-10
A	US 9752460 B2 (ECHOGEN POWER SYSTEMS LLC) 05.09.2017	1-10
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier document but published on or after the international filing date	“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
“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)	“&”	document member of the same patent family
“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		
Date of the actual completion of the international search	Date of mailing of the international search report	
15 May 2019 (15.05.2019)	20 June 2019 (20.06.2019)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer A. Savoskina Telephone No. (499) 240-25-91	