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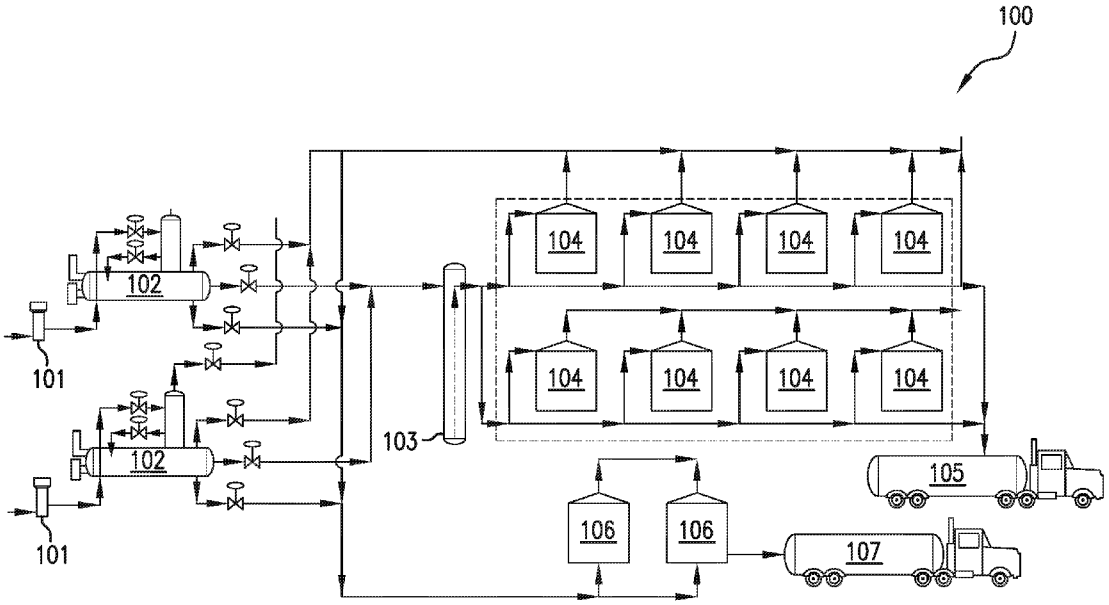


FIG. 1

(57) Abstract: Systems and methods of automated management and control for oilfield operations are provided. Data is acquired from measurement devices associated with production and storage operations in a hydrocarbon producing field. The production operations include producing formation fluids from production wells located throughout the hydrocarbon producing field. The storage operations include storing the formation fluids produced from the production well s at the hydrocarbon producing field for offsite transport. Input parameters related to the respective production and storage operations are determined based on the acquired data. The input parameters are applied to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold. At least one of the production operations or the storage operations in the hydrocarbon producing field are control led, based on the estimated time remaining.

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AUTOMATED TANK HAULING WORKFLOW FOR OPTIMIZED WELL PRODUCTION AND FIELD OPERATIONS

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates generally to monitoring and control of wellsite operations and particularly, to monitoring and control of tank hauling and oilfield production operations.

BACKGROUND

[0002] Hydrocarbon production has been steadily increasing over the past few years and is forecasted to continue increasing at a similar rate going forward. Any event that may lead to non-productive time in a hydrocarbon producing field can have a considerable impact on the field's production levels and revenue. Downtime in the petroleum supply chain is largely due to a lack of synchronization between the production of fluids from wells in the field and the transport of those fluids from the field to offsite gathering and processing centers. Other reasons for such downtime may include equipment failure that causes one or more wells in the field to be shut down, fluid production from the wells exceeding the capacity of storage tank batteries in the field for storing the produced fluids, and/or non-availability of trucks to provide tank hauling services for hauling the produced fluids away from the field to offsite facilities for gathering and/or refining.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is a diagram of an illustrative multi-well hydrocarbon production system.

[0004] FIG. 2 is a table showing examples of inputs and outputs for different field operations associated with the multi-well production system of FIG. 1.

[0005] FIG. 3 is a block diagram of an illustrative computer system for automated management and control of production and storage operations in a hydrocarbon producing field.

[0006] FIG. 4 is a block diagram of an illustrative operations manager for the automated management and control system of FIG. 3.

[0007] FIG. 5 is a diagram of an illustrative neural network model according to an embodiment of the present disclosure.

[0008] FIG. 6 is a flowchart of an illustrative process for automated management and control of production and storage operations in a hydrocarbon producing field.

[0009] FIG. 7 is a flowchart of an illustrative process for automated scheduling of tank hauling services to optimize production and storage operations in a hydrocarbon producing field.

[0010] FIG. 8 is a block diagram of an exemplary computer system in which embodiments of the present disclosure may be implemented.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0011] Embodiments of the present disclosure relate to automated management and scheduling of service trucks for tank hauling or fluid transport services for optimizing production and storage operations in a hydrocarbon producing field. While the present disclosure is described herein with reference to illustrative embodiments for particular applications, it should be understood that embodiments are not limited thereto. Other embodiments are possible, and modifications can be made to the embodiments within the spirit and scope of the teachings herein and additional fields in which the embodiments would be of significant utility. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the relevant art to implement such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0012] It would also be apparent to one of skill in the relevant art that the embodiments, as described herein, can be implemented in many different embodiments of software, hardware, firmware, and/or the entities illustrated in the figures. Any actual software code with the specialized control of hardware to implement embodiments is not limiting of the detailed description. Thus, the operational behavior of embodiments will be described with the understanding that modifications and variations of the embodiments are possible, given the level of detail presented herein.

[0013] In the detailed description herein, references to "one embodiment," "an embodiment," "an example embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment.

[0014] As will be described in further detail below, embodiments of the present disclosure may be used to monitor and control different operations in a hydrocarbon producing field so as to optimize hydrocarbon production. Such field operations may include various hydrocarbon production and storage operations. During production operations in the field, different fluids (e.g., oil, gas and/or water) may be produced from a subsurface reservoir formation via production wells at one or more wellsites throughout the field. The fluids produced from the production well at each wellsite may be processed through different types of production equipment, e.g., phase separators and vapor recovery units, before being stored within a collection of storage tanks (or "tank battery"). The production rate of such a petroleum (oil and/or gas) field may be significantly reduced or depleted when most of the storage tanks in the field become full (e.g., reach their maximum threshold levels) or when one or more of the storage tanks is taken offline for maintenance or repair. Thus, in addition to storing the fluids produced from the production wells within the storage tanks, the storage operations for the field may include monitoring fluid levels of the individual tanks as well as the storage capacity of the tank battery overall. In one or more embodiments, the storage operations may also include transport operations for transporting or "hauling" the fluids from the storage tanks in the field to offsite processing or refining facilities when a total storage capacity of the tank battery is determined to reach a critical level (e.g., meet or exceed a maximum fluid threshold). During such transport operations, one or more tanker trucks operated by a tank hauling service provider may be scheduled for fluid transport, e.g., according to a predetermined transport schedule or upon request based on current fluid levels in the storage tanks and the remaining amount of the tank battery's total storage capacity at that time.

[0015] In one or more embodiments, machine learning may be used to estimate or predict the rate of hydrocarbon production expected for the field over time based on various input parameters associated with the production at each wellsite. Examples of such parameters include, but are not limited to, fluid properties, pressure-volume-temperature (PVT) and rock properties of the formation, specific gravity, fluid levels of storage tanks connected to each well, decline rate of the storage tank fluid levels, and any other parameter that can be measured or calculated from data collected by measurement devices coupled to the well and/or storage tanks. The expected production rate for the field may

then be used in conjunction with parameters associated with the storage capacity of the field to estimate the amount of time remaining for the production and storage operations until the total storage capacity of the field reaches a maximum threshold. Examples of such storage parameters include, but are not limited to, the number of available storage tanks in the tank battery, the storage volume of each tank, the maintenance schedule for each tank, and the fluid transport schedule associated with the tank hauling service provider(s) for the field.

[0016] In one or more embodiments, the production rate and storage capacity of the field may be used to predict when the production rate may exceed the total storage capacity of the field and manage or control relevant field operations accordingly. This may include, for example, automatically locating and scheduling tanker trucks to provide tank hauling services for the field. In some implementations, the locating and scheduling may be based on direct communications between an operations management system in the field and location tracking and scheduling system in the truck, as will be described in further detail below. Further, real-time adjustments may be made to production operations in order to control the current rate of production depending on the timing and availability of tanker trucks, e.g., by reducing the production flow rate so as to reduce the rate at which the storage tanks are filled and thereby delay the need for tank hauling services. Additionally, the maintenance schedule for the storage tanks and production equipment in the field may be automatically managed to further control the production rate and available storage capacity in order to optimize field operations and reduce potential issues that may lead to operational downtime and lost revenue.

[0017] Illustrative embodiments and related methodologies of the present disclosure are described below in reference to FIGS. 1-8 as they might be employed in, for example, a computer system for automated management and control of production and storage operations in a hydrocarbon producing field. The various features and advantages of the disclosed embodiments will be or will become apparent to one of ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional features and advantages be included within the scope of the disclosed embodiments. Further, the illustrated figures are only exemplary and are not intended to

assert or imply any limitation with regard to the environment, architecture, design, or process in which different embodiments may be implemented.

[0018] FIG. 1 is a diagram of an illustrative multi-well hydrocarbon production system 100. As shown in FIG. 1, system 100 may include multiple wellheads 101 for producing fluids from one or more subsurface reservoir formations in a hydrocarbon producing field. Wellheads 101 may correspond to the locations of production wells drilled at various wellsites throughout the field. Each wellhead 101 may be connected via flow lines or pipes to a variety of equipment in the field for processing and storing the produced fluids. Such equipment may include, for example and without limitation, separators 102 (e.g., two-phase separators for separating the produced fluids into liquid (oil or water) and gas), a vapor recovery tower 103, oil storage tanks 104, one or more oil tanker trucks 105 for hauling or transporting stored oil and/or gas away from the field, water storage tanks 106, and one or more water tanker trucks 107 for hauling or transporting stored water away from the field. It should be appreciated that the number of wellheads 101 as well as the number and type of equipment as shown in FIG. 1 are merely illustrative and that the disclosed embodiments are not intended to be limited thereto.

[0019] In one or more embodiments, the flow lines in system 100 may be used to route the fluids produced from each wellhead 101 to the appropriate equipment at different stages of a workflow for processing and storing the fluids in the field and eventually, transporting the fluids from the field to offsite processing facilities (e.g., petroleum refineries). The different stages of the workflow may correspond to production, storage and transport operations in the field, as described above. For example, the fluids produced from wellheads 101 may be separated into oil and water during the production stage of the workflow before being stored within oil storage tanks 104 and water storage tanks 106, respectively, during the storage stage for later transport during the transport stage. Accordingly, the collection of oil storage tanks 104 shown in FIG. 1 may constitute a tank battery for storing the oil and/or gas produced from wellheads 101 in the field. Likewise, the collection of water storage tanks 106 may constitute a separate tank battery for storing water in the field. The stored oil and water may be transported away from the field by tanker trucks 105 and 107 associated with one or more tank hauling service providers. However, it should be appreciated that some of the water in water storage tanks 106 may be

retained for any secondary recovery operations that may be performed in the field, where the water may be injected into a wellbore for stimulating hydrocarbon production from the formation.

[0020] While not shown in FIG. 1, each of the wellheads and production equipment in the field may be associated with a corresponding data processing device. As will be described in further detail below, such data processing devices may include wellsite data processing devices for processing and storing data collected by various downhole and surface measurement devices. Such measurement devices may be any of various types of sensors or metering devices used to measure the flow of hydrocarbons at each wellsite. Similar measurement devices or sensors may be coupled to each piece of equipment to measure the hydrocarbon flow at different stages of the production operation, as described above. In some cases, the type of measurement device used in a part of the field may be related to the type of artificial lift employed (e.g., electric submersible, gas lift, pump jack). In other cases, the type of measurement device used in an area of the field may be based on a particular quality of an associated well's hydrocarbon production, e.g., a tendency to produce hydrocarbons with excess water content or asphaltenes (e.g., hydrogen sulphide).

[0021] In some implementations, one or more of the measurement devices may be in the form of a multi-phase flow meter. A multi-phase flow meter has the ability to not only measured hydrocarbon flow from a volume standpoint, but also give an indication of the mixture of oil and gas in the flow. One or more of the measurement devices may be oil flow meters, having the ability to discern oil flow, but not necessarily natural gas flow. One or more of the measurement devices may be natural gas flow meters. One or more of the measurement devices may be water flow meters. One or more of the measurement devices may be pressure transmitters measuring the pressure at any suitable location, such as at the wellhead, or within the borehole near the perforations. In some implementations, such pressure transmitters may be coupled with a temperature measurement sensor.

[0022] In the case of measurement devices associated with artificial lift, the measurement devices may be voltage measurement devices, electrical current measurement devices, pressure transmitters measuring gas lift pressure, frequency meter for measuring frequency of applied voltage to electric submersible motor coupled to a pump, and the like. Moreover, multiple measurement devices may be present on any one hydrocarbon

producing well. For example, a well where artificial lift is provided by an electric submersible pump may have various devices for measuring hydrocarbon flow at the surface, and also various devices for measuring performance of the submersible motor and/or pump. As another example, a well where artificial lift is provided by a gas lift system may have various devices for measuring hydrocarbon flow at the surface, and also various measurement devices for measuring performance of the gas lift system.

[0023] In system 100 as shown in FIG. 1, measurement devices coupled to each of wellheads 101 may include various sensors for measuring production data including, but not limited to, wellhead pressure, choke valve actuation (e.g., opening and closing), flow rate, temperature, and flow volume. Sensors coupled to each of separator 102 may be used to measure separator pressure, choke pressure at separator, PVT of produced reservoir fluids at that point, and other data that may help facilitate differential calculation of reservoir fluid properties and phase behavior. Sensors coupled to oil storage tanks 104 may provide data on the current or actual capacity of each storage tank and whether that capacity has reached or exceeded an upper or lower threshold storage limit. In one or more embodiments, such storage capacity data may be used along with the production data from separators 102 and wellheads 101 to estimate the amount of time it will take to fill up each of storage tanks 104 or the amount of time remaining until each tank reaches its maximum storage capacity or some other predefined level. In this example, production data relating to the PVT properties of the produced fluids as well as equipment data assuring no flow-related issues are present may help improve the accuracy of the estimate.

[0024] The estimated time to fill a single storage tank may then be extended to determine the estimated time for multiple tanks (e.g., the entire tank battery) in the field. This time estimate may then be used to automatically request tank hauling services, e.g., by sending notifications to one or more hauling trucks 105 within a predetermined distance of the field, based on their respective GPS locations. This helps to increase the efficiency of production and storage operations in the field as well as reduce or avoid any downtime or disruption in the production workflow and the petroleum supply chain between the field and offsite processing facilities. By tracking the tanker trucks, various metrics on the performance and reliability of different tank hauling service providers may be generated. Such service metrics may be used to rank the service providers and select only the highest-

ranked provider(s), e.g., the most reliable, efficient or highest-performing provider(s) based on their service metrics.

[0025] In one or more embodiments, the information collected by the wellsite measurement devices, as described above, may be processed and stored at the respective data processing devices and/or transferred to a centralized data store. In some implementations, measurements collected by such measurement devices may be provided to the respective data processing devices as a stream of data that is indexed as a function of time and/or depth before being stored at the devices and/or data store. The indexed data may be stored in any of various data formats. For example, measurement-while-drilling (MWD) or logging-while-drilling (LWD) data may be stored in an extensible markup language (XML) format, e.g., in the form of wellsite information transfer standard markup language (WITSML) documents organized and/or indexed against time/depth. Other types of data related to the stimulation, drilling or production operations at each wellsite may be stored in a non-time-indexed format, such as in a format associated with a particular relational database. In other cases, historical production data for production wells corresponding to the wellheads in the field may be stored in a binary format from which pertinent information may be extracted for data mining and analysis purposes.

[0026] The indexed data may include, for example, measurements of input parameters relating to different field operations, e.g., the hydrocarbon production, storage and transport operations associated with the field. In one or more embodiments, the input parameters may be applied to a predictive model to estimate or predict corresponding output parameters relating to these operations as well as the field's hydrocarbon production rate and storage capacity. In some implementations, the predictive model may be a neural network model, as will be described in further detail below. An example of the input and output parameters for the different field operations illustrated in the multi-well production system of FIG. 1 is shown in table 200 of FIG. 2.

[0027] Table 200 shows one or more input parameters 202 and one or more output parameters 204 for field operations associated with each of the different types of field equipment shown in system 100 of FIG. 1, as described above. The field operations in this example may include any one or combination of the production, storage, and transport operations described above.

[0028] As shown in the first row of table 200, input parameters 202 for production operations associated with wellheads 101 of FIG. 1 may include, but are not limited to, reservoir pressure, flowing wellhead pressure and choke setting (e.g., choke valve opening size or frequency). The values of these parameters may be based on data acquired from measurement devices coupled to wellheads 101. The corresponding output parameters 204 for wellheads 101 may include estimated well flow rates and various other parameters. In one or more embodiments, output parameters 204 may be estimated from applying input parameters 202 to one or more predictive models. Such predictive models may employ, for example, standard petroleum engineering calculations to estimate Vertical Lift Performance (VLP), Inflow Performance Relationship (IPR), production decline rates, flow assurance relationship, and other types of production parameters. In some implementations, VLP and IPR may be estimated through a nodal analysis of the formation, wellbore and surface systems, based on a machine learning model (e.g., an artificial neural network). The production decline rate output parameter may also be assessed by utilizing production history and applying decline curve analysis based on one or more decline models or curves, e.g., exponential decline, harmonic decline, hyperbolic decline, etc.

[0029] As shown in the second row of table 200, input parameters 202 for the operations associated with separators 102 may include measured flow rates of oil, gas and water. Such measurements may be used to estimate or determine a volume of fluid production as output parameter 204. In some implementations, a percentage of a total production volume may be allocated to each well or reservoir zone in the field based on the corresponding input parameter measurements acquired for that well or zone. This information may then be used for purposes of accounting, managing reserves and conducting technical studies of the field for further hydrocarbon exploration and production.

[0030] The ratio of vapor recovery helps in defining the quantities of hydrocarbon available for sale, and in calculating the economic viability of the production.

[0031] Once we have this data (knowing the flow rate and knowing the capacity of the tank), the rate of tank-fillage can be calculated. A maintenance schedule of the tanks can be determined based on usage, and quality of the fluids being stored. With this we can

estimate the time it will take for the tanks to fill. Based on the capacity of the hauling truck and the distance we can link the truck which matches the time (example tank a will take 4 hours and we have two hauling trucks one at 3 hours away and one at 3.45 hours away. We notify the truck which is 3.45 hours away.)

[0032] This way the efficiency is improved and we have a consistent supply chain mechanism. Also there can be an economic model attached to this supply chain mechanism were the supply demand can be regulated by crude oil price. If the price is high there can be more trucks needed and if we have multiple contractors automatic assignment of trucks can be done using this proprietary model. If the oil price is low the less efficient trucks can be eliminated from the process.

[0033] Inputs used in the predictive model to estimate production rate over time would include reservoir pressure, flowing wellhead pressure, choke opening, historical oil/water/gas rates, PVT properties of the formation fluids, ratio of vapor recovery etc.

[0034] The initial storage capacity of tanks is obtained by calculating internal tank volumes based on their geometry. As these tanks are filled up, and emptied by tank haulers, an automated software system keeps track of the fluid volumes in each tank.

[0035] Some of the outputs may not directly affect scheduling of tank hauling and control of field operations. They are auxiliary benefits of the automated system, for example, reporting to regulatory authorities regarding the amount of emissions such as methane emissions. Economic analysis in line 3 of the Figure 2 refers to calculation of liquid versus gas component of the produced hydrocarbon, and associated revenue versus cost of operating equipment.

[0036] As will be described in further detail below with respect to FIG. 3, the output parameters derived from the predictive model may be used for automated management and control of field operations to optimize hydrocarbon production and storage capacity. This may include, for example, automatically locating and communicating with nearby tank hauling service providers (or tanker trucks thereof) for purposes of requesting or scheduling the transport of oil and/or water from the field. This may also include automatically controlling production and storage operations in the field, for example, by controlling the rate of production, allocation of storage tanks, and/or maintenance of production and

storage equipment in order to anticipate the storage capacity needs of the field and thereby mitigate any operational downtime and associated costs.

[0037] In one or more embodiments, field operations may be further optimized based on one or more optimization factors. Examples of such factors include, but are not limited to, an oil price index, one or more production constraints, one or more characteristics of the storage facilities, one or more wear factors associated with each of the production equipment and the storage tanks, and a predetermined maintenance schedule associated with the production and storage equipment.

[0038] FIG. 3 is a block diagram of an illustrative computer system 300 for automated management and control of production and storage operations in a hydrocarbon producing field, e.g., the multi-well hydrocarbon producing field described above with respect to FIG. 1. It should be appreciated that system 300 may be described with reference to multi-well system 100 of FIG. 1 for discussion purposes only and that system 300 is not intended to be limited thereto. As shown in the example of FIG. 3, system 300 includes a data manager 310 and an operations manager 312. System 300 may be implemented using any type of computing device having at least one processor and a memory. The memory may be in the form of a processor-readable storage medium for storing data and instructions executable by the processor. The storage medium may be, for example and without limitation, a semiconductor memory, a hard disk, or similar type of memory or storage device. Examples of such a computing device include, but are not limited to, a tablet computer, a laptop computer, a desktop computer, a workstation, a server, a cluster of computers in a server farm or other type of computing device. In some implementations, system 300 may be a server system located at a data center associated with the hydrocarbon producing field. The data center may be, for example, physically located on or near the field. Alternatively, the data center may be at a remote location away from the hydrocarbon producing field.

[0039] Also, as shown in FIG. 3, system 300 may be communicatively coupled via a communication network 302 to a supervisory control and data acquisition ("SCADA") system 320, plurality of wellsite data processing devices 330a-n, at least one tank battery 340 and at least one tank hauling service provider 350 (or tanker truck thereof). While only tank battery 340 is shown in FIG. 3, it should be appreciated that system 300 may be communicatively coupled via network 302 to any number of tank batteries (e.g., an oil tank

battery and a water tank battery). Also, while only tank hauling service provider (or tanker truck) 350 is shown, system 300 may be communicatively coupled via network 302 to any number of truck hauling service providers (or tanker trucks).

[0040] Network 302 in this example can be any type of network or combination of networks used to communicate information between different computing devices. Network 302 can include, but is not limited to, a wired (e.g., Ethernet) or a wireless (e.g., Wi-Fi or mobile telecommunications) network. In addition, network 302 can include, but is not limited to, a local area network, medium area network, and/or wide area network such as the Internet.

[0041] In one or more embodiments, system 300 may use network 302 to communicate with SCADA system 320 or wellsite data processing devices 330a-n or a combination thereof to obtain data relating to hydrocarbon production operations in the field. For example, a different one of wellsite data processing devices 330a-n may be associated with each of the wellheads shown for the hydrocarbon producing field of multi-well system 100 in FIG. 1, as described above. While not shown in FIG. 3, system 300 may also be communicatively coupled via network 302 to data processing devices associated with the different equipment used to conduct other stages of the production operations in the field, e.g., operations related to processing reservoir fluids produced from the wellheads, as described above with respect to system 100 of FIG. 1. SCADA system 320 may include a database or other type of data store (not shown) for storing the data obtained via network 302 from wellsite and other data processing devices in the field. The data stored in SCADA system 320 and/or in a memory of computer system 300 may include, for example, historical production data that has been aggregated over a period of time for one or more of the production wells. The aggregated production data may be in the form of time-series data including a series of production values recorded for each well at predetermined production intervals over time (e.g., hourly, daily, monthly, or at evenly spaced 30-day, 60-day or 90-day production time increments).

[0042] In one or more embodiments, data manager 310 of system 300 may communicate with SCADA system 320 to obtain the stored field data via network 302. Alternatively, data manager 310 may obtain the data directly from the data processing devices in the field via network 302. In addition to the production data obtained from

either SCADA system 320 or the appropriate wellsite data processing devices, data manager 310 may obtain data relating to the storage operations associated with tank battery 340. Such data may be acquired from tank monitoring devices associated with the individual storage tanks within tank battery 340. Such devices may include any of various measurement devices or sensors for collecting data relating to the storage capacity and current fluid level of each storage tank.

[0043] In one or more embodiments, data manager 310 may also communicate via network 302 with tank hauling provider 350 to acquire information relating to the location and availability of tanker trucks. Such information may include the location of tanker trucks within a predetermined distance of the hydrocarbon producing field and the availability of each truck to provide tank hauling services to the field. In some implementations, data manager 310 may acquire this information by communicating with a centralized server or computing device of tank hauling service provider 350 via network 302. Alternatively, data manager 310 may communicate directly with a global positioning system (GPS) of a tanker truck to acquire the location of the truck. In some implementations, the tanker truck may also be equipped with a computing device configured to communicate with data manager 310 for sending location data from its GPS along with scheduling information in response to requests received from data manager 310 via network 302. This information along with the well production and fluid storage data acquired by data manager 310 from SCADA system 320 and the appropriate data processing devices in the field may be provided to operations manager 312, e.g., via an internal data bus of computer system 300.

[0044] FIG. 4 is a block diagram showing an illustrative implementation of operations manager 312 of system 300. As shown in FIG. 4, operations manager 312 may include a predictive modeler 402, a production controller 404 and a storage tank controller 406. However, it should be appreciated that operations manager 312 may include additional components and/or subcomponents for providing the automated tank hauling and field operations control functionality disclosed herein.

[0045] In one or more embodiments, predictive modeler 402 may determine input parameters corresponding to the production and storage operations in the hydrocarbon producing field, based on the data acquired by data manager 310 of FIG. 3, as described

above. The input parameters may correspond to, for example, the input parameters associated with the field operations shown in table 200 of FIG. 2, as described above. Predictive modeler 402 may then apply the input parameters to a predictive model to estimate a production rate of a plurality of wellsites in the field. For example, predictive modeler 402 may apply data relating to the input parameters of various field operations (e.g., production, storage and transport operations in the field) to one or more predictive models for predicting future hydrocarbon production from a specific production well of interest or from the hydrocarbon producing field overall, including all of the production wells within the field. Such a predictive model may be implemented using any of various machine learning models.

[0046] In one or more embodiments, the neural network model may be an artificial neural network, e.g., a deep learning neural network. However, it should be appreciated that embodiments of the present disclosure are not intended to be limited thereto and that other types of machine learning or predictive models, e.g., any of various statistical models, may be used instead or in addition to a neural network. An example of such a neural network will now be described with respect to FIG. 5.

[0047] FIG. 5 is a diagram of an illustrative neural network 500. In the example as shown in FIG. 5, neural network 500 includes a plurality of input nodes 510a, 510b, and 510c ("input nodes 510a-c"). Input nodes 510a-c may represent points within an input layer of neural network 500 at which input parameters for different field operations are provided for processing and calculations within a hidden layer 520 of neural network 500. Hidden layer 520 includes hidden nodes, where each hidden node may be coupled to some or all of input nodes 510a-c. The results of the processing and calculations within hidden layer 520 may include output parameters that are produced at output nodes 530a and 530b ("output nodes 530a-b") of an output layer of neural network 500.

[0048] In one or more embodiments, each of the hidden nodes of hidden layer 520 may perform a mathematical function or operation for estimating or predicting an output parameter. The mathematical function/operation may be determined or learned during a training phase of neural network 500. The mathematical operation may be performed based on the input parameter data provided at the particular input node(s) to which the hidden node is coupled. Likewise, output nodes 530a-b may perform mathematical

operations based on data provided from the hidden nodes of hidden layer 520. Accordingly, each of output nodes 530a-b may represent an estimated or predicted output parameter based on the input parameter data provided at input nodes 510a-c. While three input nodes 510a-c and two output nodes 530a-b are shown in FIG. 5, it should be appreciated that neural network 500 may include any number of input and output nodes, as desired for a particular implementation. Also, while only layer 520 is shown in FIG. 5, it should be appreciated that neural network 500 may include any number of additional hidden layers, where each hidden layer may include any number of hidden nodes, as desired for a particular implementation.

[0049] In one or more embodiments, neural network 500 may be provided with real-time data relating to input parameters from the field. From the values provided to input nodes 510a-c, neural network 500 may produce values for output parameters at output nodes 530a-b. Such output values may include an estimated production rate of the hydrocarbon producing field. In some implementations, the output values may also include an estimated time for the storage capacity of the field to reach a critical level. Accordingly, this information may be used to automatically schedule tank hauling services for the field and/or control production so as to regulate the current fluid levels in the storage tanks. This may allow production bottlenecks due to lack of sufficient storage capacity to be predicted ahead of time and thereby reduce the potential for any operational downtime.

[0050] Referring back to FIG. 4, neural network model 500 of FIG. 5 or other predictive model used by predictive modeler 402 may be updated periodically based on additional production data obtained from the production well(s) in the hydrocarbon producing field over time. In some implementations, new production data from the field may be acquired in real-time, e.g., from SCADA system 320 via communication network 302 of FIG. 3, as described above. The data may be processed and applied to the predictive model as the data is acquired by predictive modeler 402 (e.g., directly from the field or via data manager 310) in order to produce updated predictions of future hydrocarbon production as the well production data changes over time. The results of the predictive modeling may be presented to a user of computer system 300 of FIG. 3 via, for example, a display device (not shown) coupled to system 300.

[0051] In one or more embodiments, predictive modeler 402 may apply input parameters relating to other field operations in a similar manner to one or more predictive models for predicting output parameters for these operations. Such operations may include, for example, operations performed by various hydrocarbon production and storage equipment in the field, as described above and shown in table 200 of FIG. 2. It should be appreciated that the same or a similar type of predictive model may be used with different input and output parameters that are related to the particular field operation(s) or equipment with which the parameters are associated. For example, the input parameters relating to the production and storage operations in the field may include, but are not limited to, the capacity of one or more tank batteries (e.g., tank battery 340 of FIG. 3, as described above), different fluid properties, PVT properties, specific gravity, petrophysical parameters, production decline rate and well to tank connectivity. Data relating to these parameters may be applied by predictive modeler 402 to one or more predictive models to estimate the time required for each tank battery (or storage tank therein) to fill up completely or to reach a predetermined threshold level. In one or more embodiments, a machine learning model, e.g., neural network 500, may be used as the predictive model, where the aforementioned input parameters associated with the respective production and storage operations may be applied to separate input nodes of the model corresponding to the production and storage operations. In some implementations, the output produced by the predictive model(s) may also be used to estimate wear and determine appropriate maintenance schedules, e.g., based on a predetermined number of fill-empty cycles.

[0052] In one or more embodiments, storage tank controller 404 may use the output data produced by predictive modeler 402 to automatically schedule tanker trucks. The scheduling and/or availability of trucks may be based on various metrics in addition to the location of particular tank hauling or fluid transport service providers. Examples of such metrics include, but are not limited to, timeliness, pricing, efficiency and any other metric relating to the performance and reliability of each service provider over time. In one or more embodiments, the service metrics and location may be tracked for the service trucks associated with each service provider. Location may be based on information obtained from a GPS of each service truck. The service metrics may be based on information from electronic service records that are maintained for the various service trucks and providers.

The tracked location and service metrics may then be used to determine which trucks are available at any given time to provide tank hauling or fluid transport services for the field. For example, the service metrics associated with each service provider may be used to rank the service providers and select only the highest-ranked provider(s), e.g., the most reliable, efficient or highest-performing provider(s), which have at least one service truck located within a predetermined distance of the hydrocarbon producing field. If no trucks meeting the location and metrics criteria are available, adjustments may be made to production operations in the field, e.g., by adjusting the production rate so as to extend the time remaining until the storage capacity of the field reaches the maximum threshold. The tank hauling or fluid transport schedule for the field may then be adjusted accordingly.

[0053] The above-described scheduling functionality of storage tank controller 404 may be implemented via, for example, direct device-to-device communications. For example, storage tank controller 404 or other devices associated with a tank battery in the field may communicate directly with tanker trucks or a tank hauling service provider for requesting transport of fluids (e.g., oil or water or both) before the storage tanks are completely full and the field's storage capacity is reduced to nil. Such communication between field and remote devices may be accomplished using any of various well-known or proprietary communication protocols and standards, as desired for a particular implementation.

[0054] In one or more embodiments, production controller 406 may be used to monitor and control a current rate of production based on the production rate and storage capacity estimated for the field by predictive modeler 402. In some implementations, production controller 404 may control and optimize the current production rate by monitoring market conditions and current tank battery levels. The monitoring of market conditions by production controller 406 may be performed based on market data acquired from any of various third-party sources, e.g., via network 302 of FIG. 3, as described above. The monitoring of current tank battery levels may be based on data acquired from measurement devices or sensors for measuring the current fill level (or level of stored fluid) in each of the storage tanks associated with the tank battery.

[0055] FIG. 6 is a flowchart of an illustrative process 600 for automated management and control of production and storage operations in a hydrocarbon producing field.

[0056] In block 602, data is acquired from measurement devices associated with production and storage operations in a hydrocarbon producing field.

[0057] In block 604, input parameters the respective production and storage operations are determined, based on the data acquired in block 602. Such operations may occur at various production and storage facilities in the field, as described above.

[0058] In block 606, the input parameters are applied to one or more predictive models to estimate output parameters for the respective production and storage operations. In one or more embodiments, the output parameters may include an estimated production rate of the field.

[0059] In block 608, field operations, e.g., production, storage and/or transport operations, may be controlled based on the estimated or expected production rate and any other relevant output parameters relating to the field operations, as will be described in further detail below with respect to FIG. 7.

[0060] FIG. 7 is a flowchart of an illustrative process 700 for automated management and control of tank hauling and field operations to optimize production and storage capacity in the hydrocarbon producing field. The functions or operations associated with process 700 may be based on process 600 of FIG. 6, as described above. In block 702, a production rate of production equipment and a storage capacity of storage equipment in the field during a predetermined time period may be determined. The production equipment may include one or more wellheads at the production wells and the storage equipment may include storage tanks within the field. The determination in block 702 may be based on, for example, the data acquired from measurement devices (e.g., flow meters or other sensors) coupled to the wellheads and the storage tanks, as described above with respect to block 602 of process 600 shown in FIG. 6.

[0061] In block 704, the production rate and storage capacity determined in block 702 are used to estimate a time remaining for field operations until the storage capacity reaches a maximum threshold. Process 700 then proceeds to block 706.

[0062] Block 706 includes determining a transport schedule for the offsite transport of the stored formation fluids from the storage tanks to offsite processing facilities.

[0063] In blocks 708 and 710, it is determined whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck

locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance. In one or more embodiments, block 708 may also include locating tanker trucks that may be available to provide tank hauling services within the predetermined distance of the field. In one or more embodiments, the service metrics may include a reliability rating/rank associated with a particular tank hauling service provider and trucks thereof, as described above. Such metrics may be used, for example, to consider only those trucks and service providers that have a reliability rating/rank at or above a predetermined value in the availability determination of block 708, where service trucks/providers that fall below the predetermined rating/rank are filtered out.

[0064] If it is determined in block 710 that at least one available truck is available, process 700 proceeds to block 712, in which a tank hauling service request is sent to the available truck, e.g., a service truck that meets the location and service metrics/rating requirements as described above.

[0065] Otherwise, process 700 proceeds to block 714, which includes controlling production operations by adjusting (e.g., decreasing) a current production rate of the field so as to extend the time remaining until the available storage capacity of the field reaches the maximum threshold. This may also include adjusting the transport schedule so that tank hauling services can be provided as needed to free up a sufficient amount of storage capacity.

[0066] Process 700 may return to block 702 following block 714 and the operations in that block and subsequent blocks of process 700, as described above, may be repeated.

[0067] FIG. 8 is a block diagram of an exemplary computer system 800 in which embodiments of the present disclosure may be implemented. For example, processes 600 and 700 of FIGS. 6 and 7, respectively, as described above, may be implemented using system 800. System 800 can be a computer, phone, PDA, or any other type of electronic device. Such an electronic device includes various types of computer readable media and interfaces for various other types of computer readable media. As shown in FIG. 8, system 800 includes a permanent storage device 802, a system memory 804, an output device interface 806, a system communications bus 808, a read-only memory (ROM) 810, processing unit(s) 812, an input device interface 814, and a network interface 816.

[0068] Bus 808 collectively represents all system, peripheral, and chipset buses that communicatively connect the numerous internal devices of system 800. For instance, bus 808 communicatively connects processing unit(s) 812 with ROM 810, system memory 804, and permanent storage device 802.

[0069] From these various memory units, processing unit(s) 812 retrieves instructions to execute and data to process in order to execute the processes of the subject disclosure. The processing unit(s) can be a single processor or a multi-core processor in different implementations.

[0070] ROM 810 stores static data and instructions that are needed by processing unit(s) 812 and other modules of system 800. Permanent storage device 802, on the other hand, is a read-and-write memory device. This device is a non-volatile memory unit that stores instructions and data even when system 800 is off. Some implementations of the subject disclosure use a mass-storage device (such as a magnetic or optical disk and its corresponding disk drive) as permanent storage device 802.

[0071] Other implementations use a removable storage device (such as a floppy disk, flash drive, and its corresponding disk drive) as permanent storage device 802. Like permanent storage device 802, system memory 804 is a read-and-write memory device. However, unlike storage device 802, system memory 804 is a volatile read-and-write memory, such a random access memory. System memory 804 stores some of the instructions and data that the processor needs at runtime. In some implementations, the processes of the subject disclosure are stored in system memory 804, permanent storage device 802, and/or ROM 810. For example, the various memory units include instructions for automated tank hauling and control of field operations in accordance with embodiments of the present disclosure, e.g., according to processes 600 and 700 of FIGS. 6 and 7, respectively, as described above. From these various memory units, processing unit(s) 812 retrieves instructions to execute and data to process in order to execute the processes of some implementations.

[0072] Bus 808 also connects to respective input and output device interfaces 814 and 806. Input device interface 814 enables the user to communicate information and select commands to the system 800. Input devices used with input device interface 814 include, for example, alphanumeric, QWERTY, or T9 keyboards, microphones, and pointing

devices (also called "cursor control devices"). Output device interfaces 806 enables, for example, the display of images generated by the system 800. Output devices used with output device interface 806 include, for example, printers and display devices, such as cathode ray tubes (CRT) or liquid crystal displays (LCD). Some implementations include devices such as a touchscreen that functions as both input and output devices. It should be appreciated that embodiments of the present disclosure may be implemented using a computer including any of various types of input and output devices for enabling interaction with a user. Such interaction may include feedback to or from the user in different forms of sensory feedback including, but not limited to, visual feedback, auditory feedback, or tactile feedback. Further, input from the user can be received in any form including, but not limited to, acoustic, speech, or tactile input. Additionally, interaction with the user may include transmitting and receiving different types of information, e.g., in the form of documents, to and from the user via the above-described interfaces.

[0073] Also, as shown in FIG. 8, bus 808 also couples system 800 to a public or private network (not shown) or combination of networks through a network interface 816. Such a network may include, for example, a local area network ("LAN"), such as an Intranet, or a wide area network ("WAN"), such as the Internet. Any or all components of system 800 can be used in conjunction with the subject disclosure.

[0074] These functions described above can be implemented in digital electronic circuitry, in computer software, firmware or hardware. The techniques can be implemented using one or more computer program products. Programmable processors and computers can be included in or packaged as mobile devices. The processes and logic flows can be performed by one or more programmable processors and by one or more programmable logic circuitry. General and special purpose computing devices and storage devices can be interconnected through communication networks.

[0075] Some implementations include electronic components, such as microprocessors, storage and memory that store computer program instructions in a machine-readable or computer-readable medium (alternatively referred to as computer-readable storage media, machine-readable media, or machine-readable storage media). Some examples of such computer-readable media include RAM, ROM, read-only compact discs (CD-ROM), recordable compact discs (CD-R), rewritable compact discs (CD-RW), read-only digital

versatile discs (e.g., DVD-ROM, dual-layer DVD-ROM), a variety of recordable/rewritable DVDs (e.g., DVD-RAM, DVD-RW, DVD+RW, etc.), flash memory (e.g., SD cards, mini-SD cards, micro-SD cards, etc.), magnetic and/or solid state hard drives, read-only and recordable Blu-Ray® discs, ultra density optical discs, any other optical or magnetic media, and floppy disks. The computer-readable media can store a computer program that is executable by at least one processing unit and includes sets of instructions for performing various operations. Examples of computer programs or computer code include machine code, such as is produced by a compiler, and files including higher-level code that are executed by a computer, an electronic component, or a microprocessor using an interpreter.

[0076] While the above discussion primarily refers to microprocessor or multi-core processors that execute software, some implementations are performed by one or more integrated circuits, such as application specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs). In some implementations, such integrated circuits execute instructions that are stored on the circuit itself. Accordingly, process 600 and 700 of FIGS. 6 and 7, respectively, as described above, may be implemented using system 800 or any computer system having processing circuitry or a computer program product including instructions stored therein, which, when executed by at least one processor, causes the processor to perform functions relating to these methods.

[0077] As used in this specification and any claims of this application, the terms "computer", "server", "processor", and "memory" all refer to electronic or other technological devices. These terms exclude people or groups of people. As used herein, the terms "computer readable medium" and "computer readable media" refer generally to tangible, physical, and non-transitory electronic storage mediums that store information in a form that is readable by a computer.

[0078] Embodiments of the subject matter described in this specification can be implemented in a computing system that includes a back end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described in this specification, or any combination of one or more such back end, middleware, or front end components. The components of the system can be

interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), an inter-network (e.g., the Internet), and peer-to-peer networks (e.g., ad hoc peer-to-peer networks).

[0079] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other. In some embodiments, a server transmits data (e.g., a web page) to a client device (e.g., for purposes of displaying data to and receiving user input from a user interacting with the client device). Data generated at the client device (e.g., a result of the user interaction) can be received from the client device at the server.

[0080] It is understood that any specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged, or that all illustrated steps be performed. Some of the steps may be performed simultaneously. For example, in certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0081] Furthermore, the exemplary methodologies described herein may be implemented by a system including processing circuitry or a computer program product including instructions which, when executed by at least one processor, causes the processor to perform any of the methodology described herein.

[0082] As described above, embodiments of the present disclosure are particularly useful for automated management and control of production, storage and transport operations in a hydrocarbon producing field. Accordingly, advantages of the present disclosure include optimizing oilfield operations by automatically synchronizing production and transport schedules such that fluids produced and stored in the field may be

transported to offsite gathering and processing centers with little or no downtime, e.g., due to equipment failure, lack of storage capacity in the field, or non-availability of trucks to provide tank hauling or transport services for the field or any combination of the foregoing.

[0083] A computer-implemented method of automated management and control of oilfield operations has been described. Embodiments of the method may include: acquiring, by a computer system via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport; determining, by the computer system, input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data; applying the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and controlling at least one of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

[0084] Likewise, embodiments of a computer-readable storage medium having instructions stored therein have been described, where the instructions, when executed by a processor, may cause the processor to perform a plurality of functions, including functions to: acquire, via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport; determine input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data; apply the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and control at least one

of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

[0085] The foregoing embodiments of the method or computer-readable storage medium may include any one or any combination of the following elements, features, functions, or operations: determining input parameters by determining input parameters related to production operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to production equipment within the hydrocarbon producing field, and determining input parameters related to storage operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to storage equipment within the hydrocarbon producing field; the production equipment includes one or more wellheads, and the storage equipment includes storage tanks for storing the formation fluids produced from the one or more wellheads; the time remaining is estimated based on output parameters of the respective production and storage equipment within the hydrocarbon producing field, and the output parameters include a production rate of the one or more wellheads and a storage capacity of the storage tanks during a predetermined time period; the controlling of the production operations or the storage operations includes determining a transport schedule for the offsite transport of the formation fluids from the storage tanks to offsite processing facilities, determining whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance, sending a service request to the at least one service truck for the offsite transport when it is determined that at least one service truck is available, and controlling production operations by adjusting the production rate so as to extend the time remaining until the storage capacity reaches the maximum threshold when it is determined that at least one service truck is not available; at least one of the production operations or the storage operations are controlled based on the time remaining and one or more optimization factors associated with the hydrocarbon producing field; and the one or more optimization factors are selected from the group consisting of an oil price index, one or more production constraints, one or more characteristics of storage equipment used to perform the storage operations, one or more wear factors associated with production and

storage equipment used to perform the respective production and storage operations, and a maintenance schedule associated with the respective production and storage equipment.

[0086] Furthermore, embodiments of a system including at least one processor and a memory coupled to the processor have been described, where the memory stores instructions, which, when executed by a processor, may cause the processor to perform a plurality of functions, including functions to: acquire, via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport; determine input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data; apply the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and control at least one of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

[0087] The foregoing embodiments of the system may include any one or any combination of the following elements, features, functions, or operations: determining input parameters by determining input parameters related to production operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to production equipment within the hydrocarbon producing field, and determining input parameters related to storage operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to storage equipment within the hydrocarbon producing field; the production equipment includes one or more wellheads, and the storage equipment includes storage tanks for storing the formation fluids produced from the one or more wellheads; the time remaining is estimated based on output parameters of the respective production and storage equipment within the hydrocarbon producing field, and the output parameters include a production rate of the one or more wellheads and a storage capacity of the storage tanks during a predetermined time period; the controlling of the production operations or the storage operations includes determining a transport schedule

for the offsite transport of the formation fluids from the storage tanks to offsite processing facilities, determining whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance, sending a service request to the at least one service truck for the offsite transport when it is determined that at least one service truck is available, and controlling production operations by adjusting the production rate so as to extend the time remaining until the storage capacity reaches the maximum threshold when it is determined that at least one service truck is not available; at least one of the production operations or the storage operations are controlled based on the time remaining and one or more optimization factors associated with the hydrocarbon producing field; and the one or more optimization factors are selected from the group consisting of an oil price index, one or more production constraints, one or more characteristics of storage equipment used to perform the storage operations, one or more wear factors associated with production and storage equipment used to perform the respective production and storage operations, and a maintenance schedule associated with the respective production and storage equipment.

[0088] While specific details about the above embodiments have been described, the above hardware and software descriptions are intended merely as example embodiments and are not intended to limit the structure or implementation of the disclosed embodiments. For instance, although many other internal components of the system 800 are not shown, those of ordinary skill in the art will appreciate that such components and their interconnection are well known.

[0089] In addition, certain aspects of the disclosed embodiments, as outlined above, may be embodied in software that is executed using one or more processing units/components. Program aspects of the technology may be thought of as "products" or "articles of manufacture" typically in the form of executable code and/or associated data that is carried on or embodied in a type of machine readable medium. Tangible non-transitory "storage" type media include any or all of the memory or other storage for the computers, processors or the like, or associated modules thereof, such as various

semiconductor memories, tape drives, disk drives, optical or magnetic disks, and the like, which may provide storage at any time for the software programming.

[0090] Additionally, the flowchart and block diagrams in the figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present disclosure. It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0091] The above specific example embodiments are not intended to limit the scope of the claims. The example embodiments may be modified by including, excluding, or combining one or more features or functions described in the disclosure.

[0092] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprise" and/or "comprising," when used in this specification and/or the claims, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The illustrative embodiments described herein are provided to explain the principles of the disclosure and the practical application thereof, and to enable others of

ordinary skill in the art to understand that the disclosed embodiments may be modified as desired for a particular implementation or use. The scope of the claims is intended to broadly cover the disclosed embodiments and any such modification.

CLAIMS

WHAT IS CLAIMED IS:

1. A computer-implemented method of automated management and control of oilfield operations, the method comprising:

acquiring, by a computer system via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport;

determining, by the computer system, input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data;

applying the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and

controlling at least one of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

2. The method of claim 1, wherein the determining comprises:

determining input parameters related to production operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to production equipment within the hydrocarbon producing field; and

determining input parameters related to storage operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to storage equipment within the hydrocarbon producing field.

3. The method of claim 2, wherein the production equipment includes one or more wellheads, and the storage equipment includes storage tanks for storing the formation fluids produced from the one or more wellheads.

4. The method of claim 3, wherein the time remaining is estimated based on output parameters of the respective production and storage equipment within the hydrocarbon producing field, and the output parameters include a production rate of the one or more wellheads and a storage capacity of the storage tanks during a predetermined time period.

5. The method of claim 4, wherein the controlling comprises:

determining a transport schedule for the offsite transport of the formation fluids from the storage tanks to offsite processing facilities;

determining whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance;

when it is determined that at least one service truck is available, sending a service request to the at least one service truck for the offsite transport; and

when it is determined that at least one service truck is not available, controlling production operations by adjusting the production rate so as to extend the time remaining until the storage capacity reaches the maximum threshold.

6. The method of claim 1, wherein at least one of the production operations or the storage operations are controlled based on the time remaining and one or more optimization factors associated with the hydrocarbon producing field.

7. The method of claim 6, wherein the one or more optimization factors are selected from the group consisting of: an oil price index; one or more production constraints; one or more characteristics of storage equipment used to perform the storage operations; one or more wear factors associated with production and storage equipment used to perform the respective production and storage operations; and a maintenance schedule associated with the respective production and storage equipment.

8. A system comprising:

a processor; and

a memory coupled to the processor having instructions stored therein, which when executed by the processor, cause the processor to perform a plurality of functions including functions to:

acquire, via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport;

determine input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data;

apply the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and

control at least one of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

9. The system of claim 8, wherein the functions performed by the processor include functions to:

determine input parameters related to production operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to production equipment within the hydrocarbon producing field; and

determine input parameters related to storage operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to storage equipment within the hydrocarbon producing field.

10. The system of claim 9, wherein the production equipment includes one or more wellheads, and the storage equipment includes storage tanks for storing the formation fluids produced from the one or more wellheads.

11. The system of claim 10, wherein the time remaining is estimated based on output parameters of the respective production and storage equipment within the hydrocarbon producing field, and the output parameters include a production rate of the one or more wellheads and a storage capacity of the storage tanks during a predetermined time period.

12. The system of claim 11, wherein the functions performed by the processor include functions to:

determining a transport schedule for the offsite transport of the formation fluids from the storage tanks to offsite processing facilities;

determining whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance;

when it is determined that at least one service truck is available, sending a service request to the at least one service truck for the offsite transport; and

when it is determined that at least one service truck is not available, controlling production operations by adjusting the production rate so as to extend the time remaining until the storage capacity reaches the maximum threshold.

13. The system of claim 8, wherein at least one of the production operations or the storage operations are controlled based on the time remaining and one or more optimization factors associated with the hydrocarbon producing field.

14. The system of claim 13, wherein the one or more optimization factors are selected from the group consisting of: an oil price index; one or more production constraints; one or more characteristics of storage equipment used to perform the storage operations; one or more wear factors associated with production and storage equipment used to perform the respective production and storage operations; and a maintenance schedule associated with the respective production and storage equipment.

15. A non-transitory computer-readable storage medium having instructions stored therein, which when executed by a computer cause the computer to perform a plurality of functions, including functions to:

acquire, via a communication network, data from a plurality of measurement devices associated with production operations and storage operations in a hydrocarbon producing field, the production operations including producing formation fluids from production wells located throughout the hydrocarbon producing field and the storage operations including storing the formation fluids produced from the production wells at the hydrocarbon producing field for offsite transport;

determine input parameters related to the respective production and storage operations within the hydrocarbon producing field, based on the acquired data;

apply the input parameters to one or more predictive models to estimate a time remaining for the production and storage operations until a storage capacity of the hydrocarbon producing field reaches a maximum threshold; and

control at least one of the production operations or the storage operations in the hydrocarbon producing field, based on the estimated time remaining.

16. The non-transitory computer-readable storage medium of claim 15, wherein the functions performed by the computer include functions to:

determine input parameters related to production operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to production equipment within the hydrocarbon producing field; and

determine input parameters related to storage operations in the hydrocarbon producing field, based on data acquired from measurement devices coupled to storage equipment within the hydrocarbon producing field.

17. The non-transitory computer-readable storage medium of claim 16, wherein the production equipment includes one or more wellheads, and the storage equipment includes storage tanks for storing the formation fluids produced from the one or more wellheads.

18. The non-transitory computer-readable storage medium of claim 17, wherein the time remaining is estimated based on output parameters of the respective production and storage equipment within the hydrocarbon producing field, the output parameters include a production rate of the one or more wellheads and a storage capacity of the storage tanks during a predetermined time period.

19. The non-transitory computer-readable storage medium of claim 18, wherein the functions performed by the computer include functions to:

determining a transport schedule for the offsite transport of the formation fluids from the storage tanks to offsite processing facilities;

determining whether at least one service truck is available for the offsite transport, based on the transport schedule and service truck locations within a predetermined distance of the hydrocarbon producing field, and service metrics associated with each service truck determined to be within the predetermined distance;

when it is determined that at least one service truck is available, sending a service request to the at least one service truck for the offsite transport; and

when it is determined that at least one service truck is not available, controlling production operations by adjusting the production rate so as to extend the time remaining until the storage capacity reaches the maximum threshold.

20. The non-transitory computer-readable storage medium of claim 15, wherein at least one of the production operations or the storage operations are controlled based on the time remaining and one or more optimization factors associated with the hydrocarbon producing field, and the one or more optimization factors are selected from the group consisting of: an oil price index; one or more production constraints; one or more characteristics of storage equipment used to perform the storage operations; one or more wear factors associated with production and storage equipment used to perform the respective production and storage operations; and a maintenance schedule associated with the respective production and storage equipment.

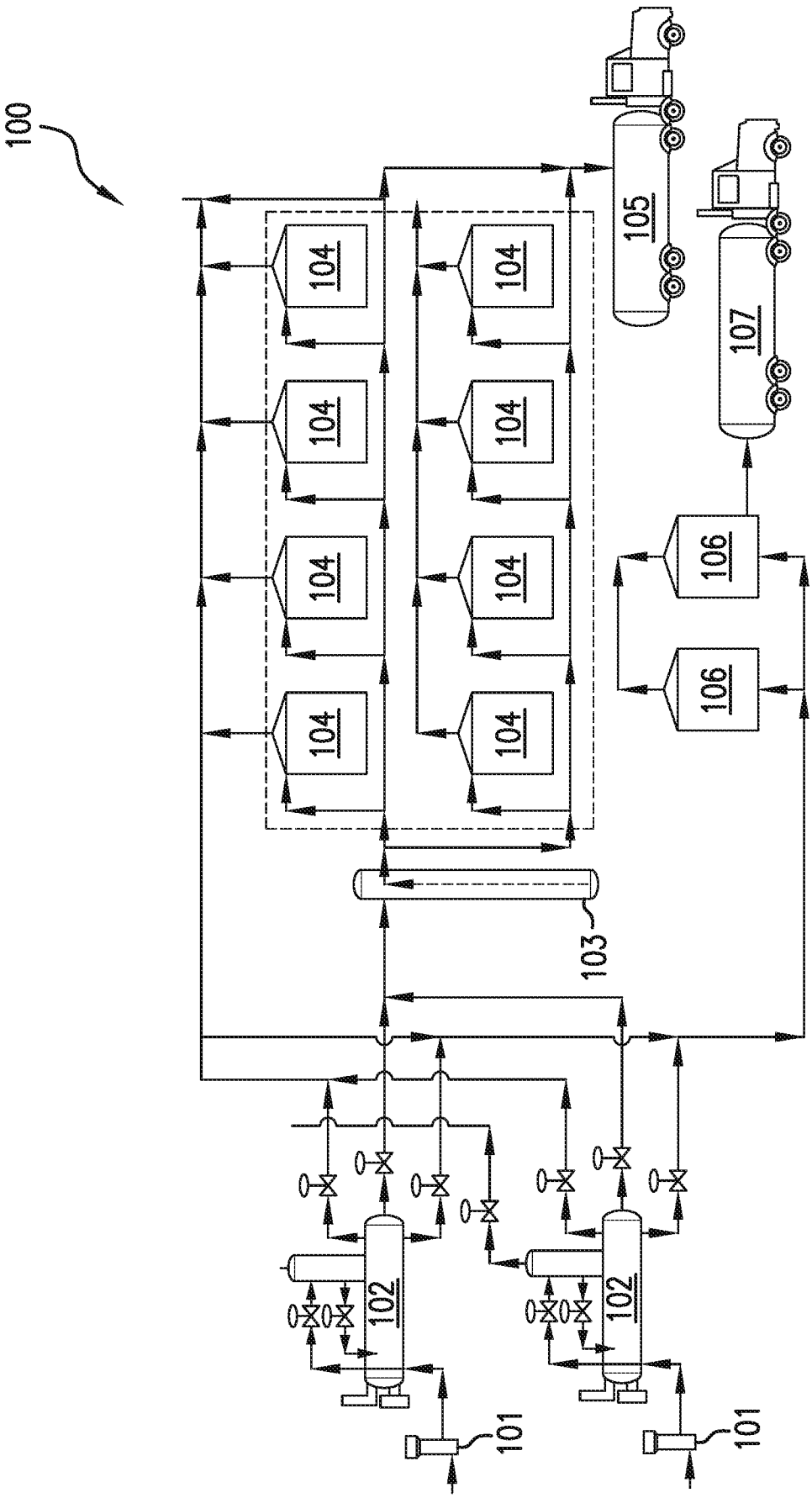

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101
101

FIG. 1

200

Field Equipment	Input Parameter(s) 202	Output Parameter(s) 204
101	Reservoir Pressure, Flowing Wellhead Pressure, Choke opening	Well rates; Inflow Performance Relationship (IPR); Vertical Lift Performance (VLP); production decline rate; flow assurance prediction
102	Oil/Water/Gas Rates	Allocated volumes from each well or reservoir zone
103	Ratio of vapor recovery	Vent gas flow rate/recovery rate
104, 106	Level of the fluid using level switch, capacity of tank, type of tank (open top, floating roof, fixed roof)	Predicted tank-fillage; Buildup of asphaltene/wax etc over time and maintenance schedule
105, 107	Location, Capacity of truck, Distance to well, Types of contract available (ownership, rent, lease etc), Cost/hr	Automated GPS allocation of trucks to a specific well/field location; metrics of truck performance (time, cost, efficiency)

FIG. 2

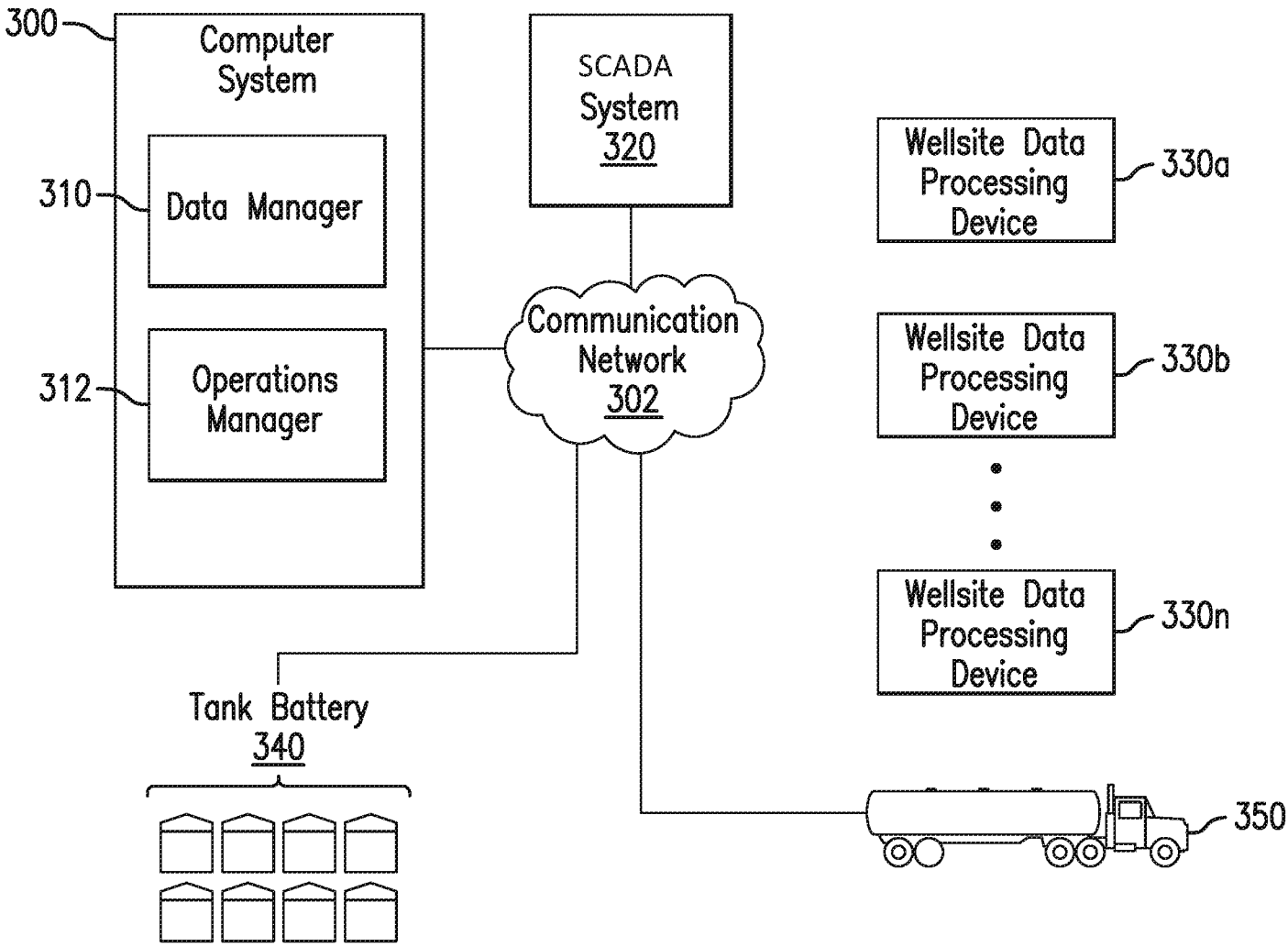

300
Computer System
310
Data Manager
312
Operations Manager
SCADA System 320
Communication Network 302
Wellsite Data Processing Device
330a
Wellsite Data Processing Device
330b
Wellsite Data Processing Device
330n
Tank Battery 340
350

FIG.3

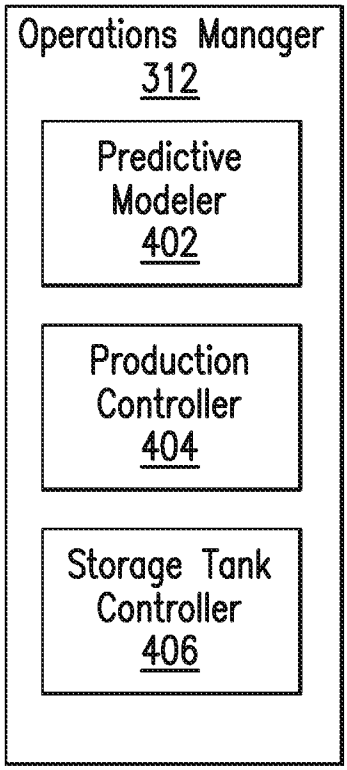

Operations Manager
312
Predictive
Modeler
402
Production
Controller
404
Storage Tank
Controller
406

FIG.4

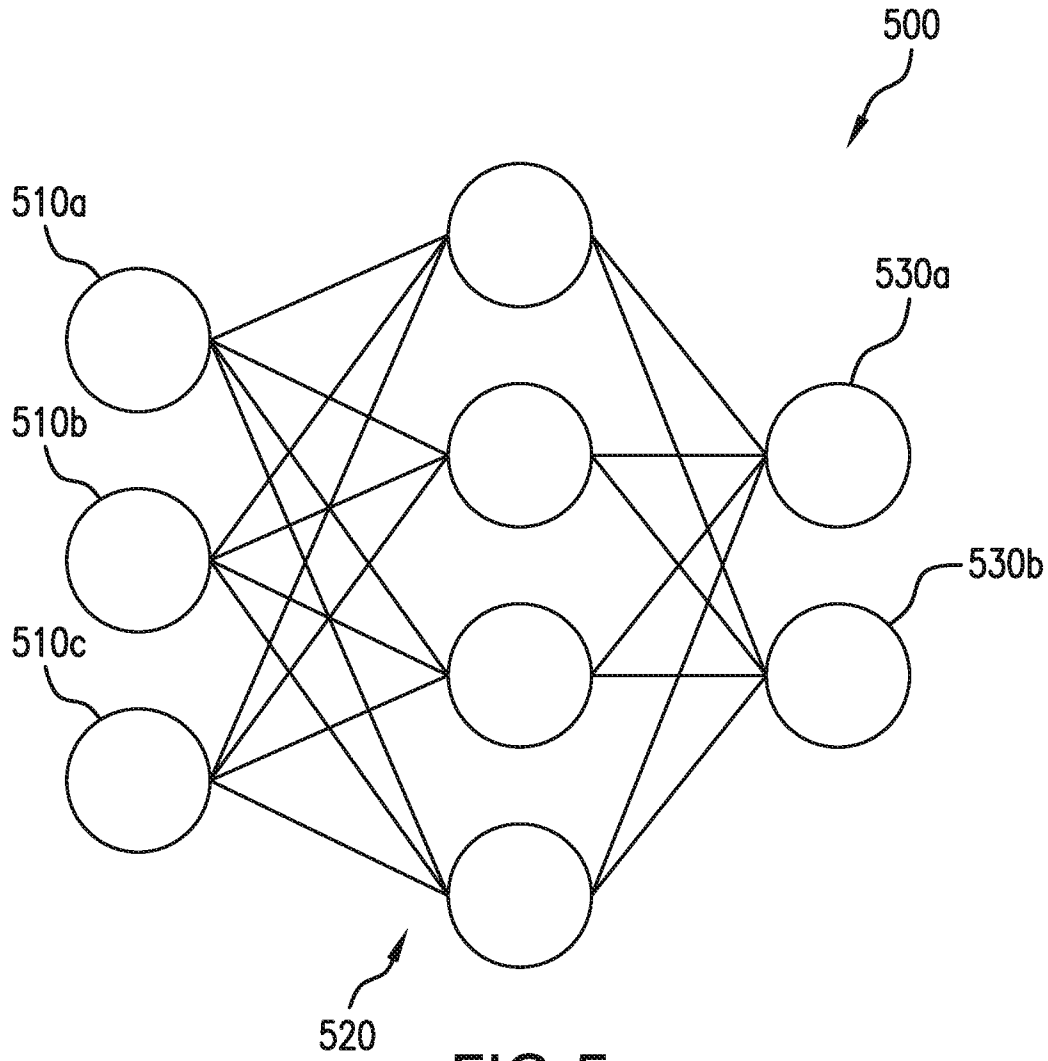


FIG.5

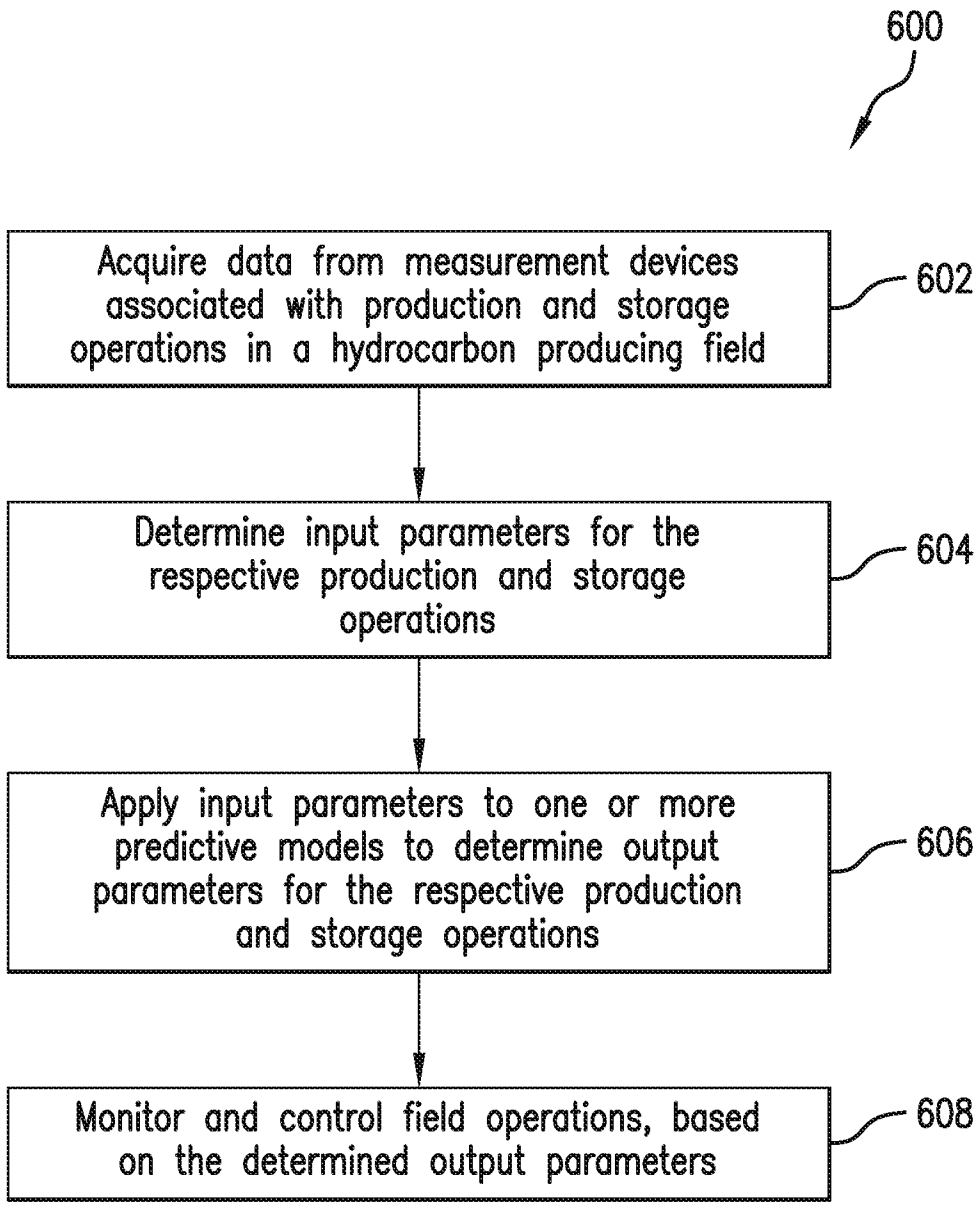

600
Acquire data from measurement devices associated with production and storage operations in a hydrocarbon producing field
602
Determine input parameters for the respective production and storage operations
604
Apply input parameters to one or more predictive models to determine output parameters for the respective production and storage operations
606
Monitor and control field operations, based on the determined output parameters
608

FIG.6

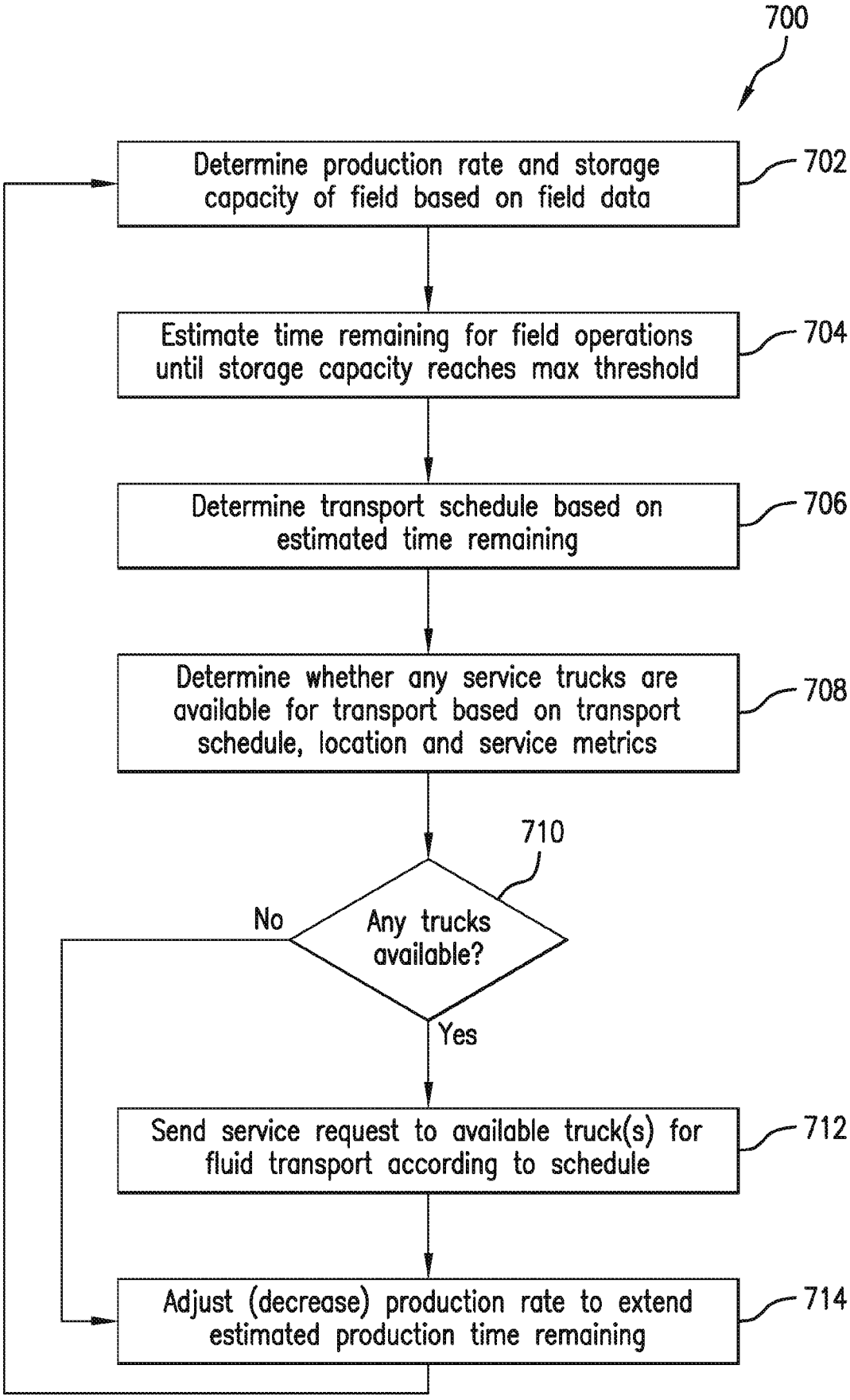

700
Determine production rate and storage capacity of field based on field data
702
Estimate time remaining for field operations until storage capacity reaches max threshold
704
Determine transport schedule based on estimated time remaining
706
Determine whether any service trucks are available for transport based on transport schedule, location and service metrics
708
710
Any trucks available?
No
Yes
Send service request to available truck(s) for fluid transport according to schedule
712
Adjust (decrease) production rate to extend estimated production time remaining
714

FIG.7

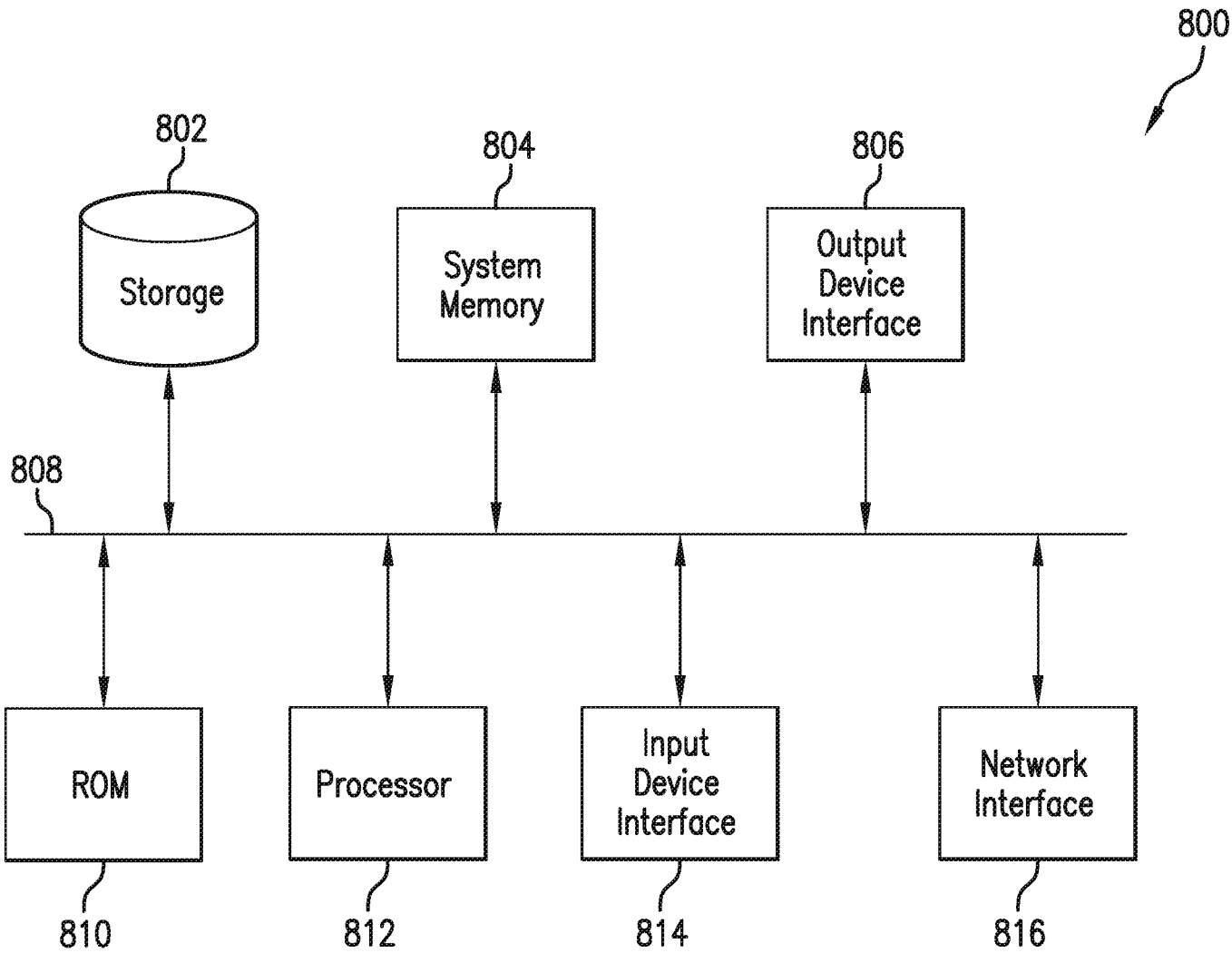

800
802
Storage
804
System Memory
806
Output Device Interface
808
ROM
Processor
Input Device Interface
Network Interface
810
812
814
816

FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/021207

A. CLASSIFICATION OF SUBJECT MATTER

G08G 1/123(2006.01)i, G08G 1/0968(2006.01)i, G05B 19/418(2006.01)i, G05B 19/042(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)
G08G 1/123; G05B 15/02; G06F 17/40; G06Q 10/08; G06Q 50/06; G08B 21/18; G08B 5/22; G08G 1/0968; G05B 19/418; G05B 19/042

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: well, fluid, storage, capacity, transport, threshold

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017-0186109 A1 (AMPLISINE LABS, LLC.) 29 June 2017 See paragraphs [0021], [0031], [0049], [0062], claims 1, 4 and figures 1-3.	1-20
A	US 2014-0195453 A1 (SHALEWATER SOLUTIONS, INC.) 10 July 2014 See claims 1-8 and figures 1-3.	1-20
A	US 2015-0324740 A1 (YUFEN SHAO et al.) 12 November 2015 See claims 1-10 and figures 1A-4.	1-20
A	WO 2014-110637 A1 (COSAN LUBRIFICANTES E ESPECIALIDADES S.A.) 24 July 2014 See claim 1 and figures 1-5.	1-20
A	US 2015-0287313 A1 (SILVERSMITH, INC.) 08 October 2015 See claims 1-8 and figures 1-5.	1-20

☐ 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
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 December 2019 (06.12.2019)	**06 December 2019 (06.12.2019)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/021207

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		AU 2018-204443 A1	12/07/2018
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		WO 2015-171286 A9	28/04/2016
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		CO 7461126 A2	30/11/2015
		GB 2524691 A	30/09/2015
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		US 9506795 B2	29/11/2016