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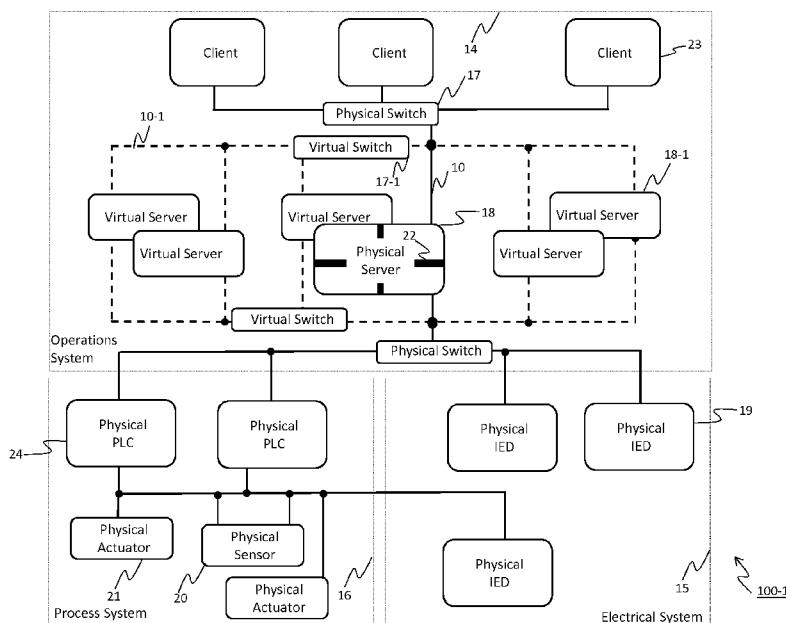
(54) Title: SYSTEM AND METHOD FOR VISUALIZING A COMBINED PHYSICAL AND VIRTUAL COMMUNICATION NETWORK OF A POWER PLANT

Fig. 2

(57) Abstract: A system and a method for visualizing a communication network interconnecting technical equipment of a power plant are presented. The system comprises a user interface (1), a graphical display unit (5), a data storing unit (6) and a data processing unit (3). The technical equipment comprises physical (17, 18, 19, 20, 21, 23, 24) and virtual network devices (17-1, 18-1) and physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1). The data storing unit (6) provides the data relating to these devices and communication connections. The data processing unit (3) is arranged to transform all the device data and all the network data into displayable information. The graphical display unit is arranged to visualize the image representations and further displayable information according to the image handling parameters in one and the same graphical image. The physical network devices (17, 18, 19, 20, 21, 23, 24) are visualized in a different way than the virtual network devices (17-1, 18-1), and the physical communication connections (10, 11, 12, 13) are visualized in a different way than the virtual communication connections (10-1, 11-1, 12-1,

13-1). The key aspect of the invented system and method is that it enables the user to quickly understand combined physical and virtual communication networks.

System and method for visualizing a combined physical and virtual communication network
of a power plant

Description

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The invention relates to a system and a method for visualizing a communication network interconnecting technical equipment of a power plant, where the method is performed by the system. The system comprises a user interface arranged for receiving image handling parameters, a graphical display unit arranged for visualizing displayable information in at
10 least one graphical image taking into account the image handling parameters, a data storing unit arranged for providing data relating to the technical equipment and a data processing unit arranged for retrieving the stored data, for transforming them into the displayable information and for providing the displayable information to the graphical display for visualization.

15

With the term "power plant" any industrial facility for the generation of electric power is meant. The best known example is a power station with a generator, where a rotating machine converts mechanical power into electrical power by creating relative motion between a magnetic field and a conductor. Further examples for power plants are thermal
20 power stations and stations for converting power from renewable energy, e.g. hydro-electricity, pumped-storage hydroelectricity, sunlight, wind or ocean power.

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During the whole life cycle of such a power plant, different types of computer-implemented tools are used which individually support the related personnel in connection with different stages of the life of the power plant, such as planning, installation, implementation, configuration, operation, maintenance or servicing of the technical equipment in the power plant. Further, separate tools may be required when dealing with different technical aspects of the plant, for example a distributed control system versus an electrical system installation versus a monitoring and surveillance system.

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Each of the different tools usually provides a graphical user interface (GUI) which allows for the visualization of the technical equipment of the power plant. The GUIs commonly provide

functionality to design or configure or monitor, respectively, the technical equipment, depending on the specific purpose of the tool.

5 During the last few years, a trend towards an integration of these tools behind one and the same GUI can be observed, as is for example described in the brochure "System 800xA for Power Generation: Integrated automation for the power industry", by ABB Ltd, 2009, Document ID – 9AKK104295D3513, which is available online.

10 The current focus of this trend towards tool integration, which is reflected in this brochure, lies on the functional aspects, i.e. to generate synergy effects with respect to faster project execution, easier handling of plant data and reduction of costs.

15 With respect to the visualization of the data generated, modified and used by the integrated tools, it is mentioned in the brochure that a single window environment is used to represent different kinds of data. However, from the brochure it becomes clear that still each tool gets its own visual representation in the single window, which means that for the above named different stages and technical aspects related to each tool, different parts of the technical equipment of the plant become visible.

20 Today, systems with combined physical and virtual communication networks exist. In the following these networks are referred to as "combined physical and virtual communication network", even when "communication networks" or "networks" are discussed.

25 A combined physical and virtual network is a computer network that consists, besides physical devices and physical communication connections at least in part of virtual devices and virtual communication connections. Generally, a physical device may emulate one or more virtual devices. For example, a physical server may emulate a virtual server. The virtual devices exist, as the term "virtual" refers to, only virtually and not physically. Often a virtual server is referred to as a virtual machine. A virtual communication connection of a network is
30 a connection that does not consist of a physical (wired or wireless) communication connection between two computing devices, but only internally inside the physical device emulating the virtual devices which are interconnected by the virtual communication connection.

35 In the state of the art, physical computer devices and physical communication connections are visualized by separate tools and in separate windows compared to virtual computer devices and virtual communication connections. The visualization often takes place in the

form of network topology diagrams or lists, where the network topology diagrams or lists are usually created manually, mainly for cabling purposes. Hence, it is often complicated to get an overview of combined physical and virtual networks since they are handled differently.

- 5 It is the object of the present invention to suggest an optimized system and method for visualizing a combined physical and virtual communication network of a power plant.

This object is achieved by a system and a method according to the independent claims.

- 10 In the system according to the invention, the technical equipment comprises physical and virtual network devices of the power plant. The communication network comprises physical and virtual communication connections of the power plant. According to the invention, the data storing unit is arranged to provide the data relating to the physical and virtual network devices in the form of device data, and to provide the data describing the physical and virtual
15 communication connections in the form of network data. The device data describe all of the physical and virtual network devices which are connected to the communication network and belong to the power plant. The network data describe all of the physical and virtual communication connections between the network devices.

- 20 The data processing unit is arranged to transform all the device data and all the network data into displayable information which contains image representations of all of the physical and virtual network devices and of all of the physical and virtual communication connections.

- Further the graphical display unit is arranged to visualize the image representations and
25 further displayable information according to the image handling parameters, wherein the physical network devices are visualized in a different way than the virtual network devices, and the physical communication connections are visualized in a different way than the virtual communication connections.

- 30 Accordingly, the invention is based on three general ideas:
- first, to visualize the complete combined physical and virtual communication network in one and the same graphical image and
- second, to visualize the physical network devices in one graphical image in a different way than the virtual network devices, and the physical communication connections in a different
35 way than the virtual communication connections and
- third, to graphically represent the technical equipment of the plant not from a functional perspective, but instead from a perspective of network communication.

The method according to the invention comprises all the functional steps performed by the elements of the above described system.

5 The inventors have realized that present networks comprise both physical and virtual network devices and physical and virtual network connections. In the beginning of a development process of a power plant, the physical devices may emulate virtual devices, later in the development process the virtual devices may be replaced by the physical devices. Therefore, it is advantageous to have an overview of which devices and which communication connections are physical and which are virtual. To avoid misinterpretation, 10 the virtual devices, the virtual hosts and the virtual communication connections represented in a different way than the physical devices, the physical hosts, and the physical communication connections. Therefore the overview over the combined network is enhanced, the whole topology is easier to understand and switching between different tools, windows and formats is reduced.

15 The system merges automatically real and virtual layouts in an overview diagram and it shows the real topology diagram (real nodes) and the virtual topology diagram (virtual nodes) in different layouts. With this invention, engineers get a better and more complete view of a power plant. The user will take advantage in the engineering process, maintenance and 20 service activities because new functionalities can be planned with a better understanding of the dependencies and affected parts in case a modification or new configuration is done.

The present invention may serve as a connection diagram and more importantly it may provide a placeholder of the configuration of all physical and virtual network devices. In case 25 of a network breakdown, information concerning the cabling and the configuration is additionally saved in the system according to the present invention. Therefore, the solution according to the invention can also be used as a backup file, enhancing security and robustness.

30 Furthermore the inventors have realized that nowadays the technical equipment of a combined physical and virtual communication network installed in a plant is connected to at least one data communication bus, where the different data communication busses of one and the same plant are connected with each other and form a global communication network of the plant. In today's GUIs, only selected parts of the technical equipment are visualized at 35 once, where the selection of these parts is performed according to their functional interrelations. For example, a distributed control system (DCS) of the plant is visualized separately from an electrical system installed in the same plant. For the DCS, pictograms of

industrial controller devices may be shown connected to pictograms of the machines, actuators and/or production facilities which they control, whereas the electrical system may be depicted in a separate image based on a so called single-line diagram. As a result, a user who mainly wants to see information of the DCS, but who also needs to get additional
5 information from the electrical system, has to switch between different views or windows.

Power plants have an extensive electrical system, to provide reliable power to all of the network devices in the power plant. The main function of the electrical system is to integrate generated power and to distribute the power to the plant devices under the normal startup,
10 running and emergency conditions.

According to the invention, this functional separation during visualization of the plant is overcome by regarding the whole plant from the point of view of combined physical and virtual network communication and by no longer distinguishing between the technical or
15 functional aspects of the nodes of the network, i.e. of the devices which are connected to the plant network. The term "network devices" in this context means literally all devices which in any way are connected to the combined physical and virtual communication network, where the communication network of the plant is usually a network consisting of different network types interconnected with each other. As a result of the invention, the whole topology of the
20 plant communication network becomes visible in one graphical view. This graphical view may become the starting point for all activities to be performed with the above described integrated system which combines the different computer-implemented tools for planning, installation and operation of the plant behind one and the same GUI. From this starting point, a user may navigate to the specific parts and devices of the plant which are of current
25 interest to him. At the same time, he may move back upwards for getting more general overview information which may help him to better understand the broader context of what is currently being done. The switching between different tools, windows and formats is thereby overcome.

30 In a preferred embodiment of the invention, the data processing unit is arranged to generate a physical view, where the physical view contains the image representations in such a way that a physical network device is marked with an emulation indicating tag when it emulates at least one virtual network device. By marking a physical network device, which emulates one or more virtual network devices, it becomes obvious which physical device emulates virtual
35 devices. Advantageously, it is simple for a user to get a first overview over the combined physical and virtual communication network. For an emulation indicating tag several different

styles can be used, for example different colors, line-styles, line colors, font sizes and / or font types, frames and / or circles.

In a further embodiment the data processing unit is arranged to generate a basic view, where
5 the basic view contains the image representations in such a way that the physical network device indicates the number of emulated virtual network devices. A user can therefore not only see which physical device emulates a virtual device by the emulation indicating tag, also the number of virtual devices emulated by the physical network device appears directly.

Several representations are possible to indicate the number of emulated virtual devices:

10 tagging the number directly to the physical device, tagging the number in the form of circles around the physical device and / or assigning different colors to different numbers and tagging the colors to the physical device.

It is possible to merge both (real and emulated) topologies and visualize every detail in a
15 single window using the following procedure: The hosts and virtual devices must have different representation than real devices avoiding misinterpretation. In the basic view the system represents the existence of virtual nodes using dedicated symbols (e.g. gray circles) around the hosts. Hence, the real topology is used as canvas and information is added around the hosts symbols.

20 In a preferred embodiment of the invention, the user interface is arranged for receiving plant related input data, the data storing unit is arranged for updating the device data and network data in accordance with the plant related input data or in accordance with update information received from an external data source, the data processing unit is arranged to automatically
25 update the image representations as soon as the device data and network data are updated, and the graphical display unit is arranged to automatically update the visualization of the image representations and further displayable information as soon as the image representations are updated. The system is automatically updating the total network topology when the data changes, therefore engineering time needed for the manual adaption of
30 drawings is saved.

This embodiment provides a main advantage over the existing art. Currently, when a graphical overview over the whole of the technical equipment belonging to a power plant is required, it is common practice to draw such an overview by hand, using for example
35 graphical software tools as Visio. This means that changes in the technical equipment, for example in the number or type of combined physical and virtual devices or in their arrangement or combined physical and virtual interconnections result in a considerable effort

to amend the drawing accordingly. Further, whenever a different view of the overview was requested, this different view had to be created by hand as well. This effort is now completely avoided since any changes in the technical equipment as well as in the desired way of representation are reflected automatically in the graphical overview of the network shown on the screen. In the system, changes may be caused either by a user who for examples re-configures network devices or their combined physical and virtual communication connections, who deletes or adds combined physical and virtual network devices in a planned installation provided by the data storing unit or who requests a different way of graphical network representation via a change in the image handling parameters. Or, the changes in the data storing unit may be caused by an external data source, where the external changes are then reflected in the data provided by the data storing unit. External changes can for example originate from at least one computer-implemented engineering tool or from a system for monitoring and surveillance of the status of the technical equipment.

In a further embodiment of the invention, the combined physical and virtual communication network of the plant is divided into part-networks where at least two of the part-networks are implemented with differing physical layers and/or with differing combined physical and virtual network communication protocols and/or where the boundary of at least one of the part-networks is defined by corresponding image handling parameters. Since according to the invention, the whole combined physical and virtual communication network of the plant is visualized in one and the same screen, the term part-network is introduced to allow for a differentiation of the elements of the combined physical and virtual network with respect to different attributes.

The attribute of differing physical layers makes reference to the OSI model of computer networking, which is shown in Fig. 14. The physical layer is the lowermost layer of the seven layers of the OSI model, and it describes the hardware and basic transmission related aspects of the respective combined physical and virtual network connection. Examples for part-networks which are defined by their physical layer are an Industrial Ethernet part-network, a RS-485 serial communication part-network used for field bus communication and an analogue 4-20 mA current loop.

Typical examples for physical /virtual network communication protocols which may be used to distinguish part-networks from each other are HART, Profibus, Modbus, Profinet,

Foundation Fieldbus, EtherCAT, IEC61850 and Ethernet, in particular Industrial Ethernet.

Apart from these OSI related differentiations, a part-network in the graphically displayed combined physical and virtual communication network of the plant may also be defined by selecting it via the user interface. In this sense, the part-network may be defined by graphical boundaries which are input to the system in the form of so called image handling parameters.

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According to a preferred embodiment of the system, a first of the part-networks comprises as network devices plant controller devices of a distributed control system and/or a second of the part-networks comprises as network devices automation devices of an electrical system providing power to the network devices and/or a third of the part-networks comprises as network devices operation servers and/or operation clients for monitoring plant controller devices and/or automation devices.

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Typically known plant controller devices of the first of the part-networks can be the various DCS controllers available on the market, such as AC700F or AC800M by ABB, as well as programmable logic controllers (PLCs). Other network devices which may belong to the first of the part-networks are actuators and industrial sensors or instruments. The automation devices of the power supply system belonging to the second of the part-networks are also known under the term Intelligent Electronic Devices (IEDs). The third of the part-networks may cover the whole operations part of the communication network, i.e. not only the operation servers and clients themselves, but all other devices available for example in the central control room of the plant and connected via a network connection to the operation servers and/or clients, such as printers and terminals.

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Each of the part-networks contains of course further network devices, where the further network devices fulfill functions directly related to the network communication itself, such as switches, routers, firewalls, gateways and industrial defenders.

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With the suggested system it is possible to configure which information should be displayed at any time in any area of the topology (IP addresses, port configuration, redundancy and device names). A flexible presentation method in which it is possible to achieve any level of abstraction is presented. The system is very convenient for documentation purposes where the user can specify different levels of details on the diagram.

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

- Fig. 1 a system for visualizing technical equipment of a power plant,
- 5 Fig. 2 a first system topology view,
- Fig. 3 a second system topology view of Fig. 2,
- Fig. 4 a third system topology view of Fig. 2,
- Fig. 5 a fourth system topology view of Fig. 2,
- Fig. 6 a fifth system topology view of Fig. 2,
- 10 Fig 7 a sixth system topology view of Fig. 2,
- Fig 8 a seventh system topology view of Fig. 2,
- Fig. 9 the arrangement of image representations in an organic way,
- Fig. 10 the arrangement of image representations in a circular way,
- Fig. 11 the arrangement of image representations in an orthogonal way,
- 15 Fig. 12 the arrangement of image representations in a tree-like way,
- Fig. 13 a neighbor view of the network of Fig. 2,
- Fig. 14 the osi model of computer networking,
- Fig. 15 a zoomed view of the network of Fig. 2,
- Fig. 16 a zoomed view of the network of Fig. 2 with search functionality,
- 20 Fig 17 a collapsed view of the network of Fig. 2,
- Fig 18 a combined view of the communication network of a power plant and
- Fig 19 a plant view of a solar power plant.

In Fig. 1, a system for visualizing the technical equipment of a power plant is shown, where
 25 the system comprises a user interface 1, which is connected to a user input device 4. The user input device 4 can be a mouse and/or a keyboard and/or a headset. The user interface 1 is arranged for receiving so called image handling parameters, which are input to the system via the user interface 4 by a user. Image handling parameters are parameters which define in which way the displayable information is visualized on the screen. Image handling
 30 parameters can be for example a desired zoom level or level of information density or a specific type of additional information etc. In the following, image handling parameters will be explained in connection with the other figures.

The system of Fig. 1 comprises further a graphical display unit 5 arranged for visualizing
 35 displayable information in at least one graphical image taking into account the image handling parameters, a data storing unit 6 arranged for providing data relating to the technical equipment of the power plant and a data processing unit 3 arranged for retrieving

the provided data, for transforming them into the displayable information and for providing the displayable information to the graphical display 5 via a graphics interface 2 for visualization.

5 The data storing unit 6 may be any kind of unit which is arranged for keeping data ready for further processing, i.e. it may contain a volatile and/or a non-volatile data memory. According to the invention, the data storing unit 6 is arranged to provide the data relating to the technical equipment in the form of device data which describe physical and virtual network devices all connected to a combined physical and virtual communication network of the power plant and belong to the power plant, and network data which describe all the physical and virtual communication connections between the physical and virtual network devices. 10 The data processing unit 3 is arranged to transform all the device data and all the network data into displayable information which contains image representations of all of the physical and virtual network devices and of all of the physical and virtual communication connections, and the graphical display unit 5 is arranged to display the image representations and further displayable information, such as text indicating the type of the displayed network device or network connection. 15

Computer implemented engineering and/or operations tools 7, 8 and 9 are connected to the data processing unit 3 and are arranged to be executed by the system of Fig. 1. The 20 engineering and/or operations tools 7 to 9 may be for example a first engineering and / or operation tool for designing a DCS, a second engineering and / or operation tool for programming IEDs and a third engineering and / or operation tool for monitoring and controlling the operation of a production line.

25 Fig. 2 shows an example of a first system topology view. The graphical image contains an advanced system topology view of the combined physical and virtual communication network indicating part-networks 100-1. The first system topology view shows a graphical image as it may be displayed by the graphical display unit 5. The combined physical and virtual communication network comprises as physical network devices 17, 18, 19, 20, 21, 23, 24: 30 three physical operation clients 23, one physical server 18, two plant controller devices in the form of physical PLCs 24, one physical sensor 20, two physical actuators 21, one physical sensor 20, three physical automation devices of a power supply system in the form of physical IEDs 19 and two physical network switches 17.

35 As virtual network devices 17-1, 18-1 the network comprises: five virtual servers 18-1 and two virtual network switches 17-1. The virtual network devices 17-1, 18-1 are emulated by

the physical server 18. The image representations of the physical and virtual network devices are in this example rounded rectangles, see for example IED 19. Any other graphical representation may of course be used, such as individual icons for each device type or small bitmaps of photographs of the devices.

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The image representations of the physical communication connection 10 between the physical network devices 17, 18, 19, 20, 21, 23, 24 of Fig. 2 are straight solid lines. Whereas the image representation of the virtual communication connection 10-1 between the virtual network devices 17-1, 18-1 are dashed lines. The physical server 18 which is emulating the five virtual serves 18-1 is marked with an emulation indicating tag 22, in this exemplary figure with a black cross.

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For example the physical server 18 and the virtual server 18-1 which are located in the middle of the network are linked directly. Further, the physical 10 and the virtual communication connections 10-1 are linked. This is illustrated by a small black dot between the solid and the straight line, which is visible at the right side of the upper and lower virtual network switch 17-1.

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In addition, three part-networks are made visible by surrounding them each with a thin dashed-line and by including text information about the type of the part-network. Accordingly, it can be seen from the advanced system topology view that a first part-network 16 comprises the physical PLCs 24, the physical actuators 21 and the physical sensor 20. This first part-network 16 represents the process system of the power plant. A second part-network 15 comprises the physical IEDs 19, it represents the electrical system providing power to the network devices. A third part-network 14 represents the technical equipment needed for the operations aspects of the plant and comprises, the physical network clients 23, the physical 18 and virtual servers 18-1, the physical switches 17, the virtual network switches 17-1, physical communication connections 10 and virtual communication systems 10-1. The third part-network 14 represents the operations system of the power plant.

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The advanced system topology view of a combined physical and virtual communication network of Fig. 2 gives a user a total overview of the complete combined physical and virtual network topology, as opposed to commonly known Ethernet network or DCS tools. Advantageously, it is possible to distinguish at one glance among physical 17, 18, 19, 20, 21, 23, 24 and virtual network devices 17-1, 18-1 and among physical 10 and virtual communication connections 10-1. Such visualization may be used as entry point for different groups of users, where each group has a specific role and task with respect to the stages

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and technical aspects of the plant and where each role requires a different kind of knowledge.

Since these different user groups may prefer different ways of how the combined physical and virtual network topology is actually presented, the following figures are examples for embodiments of the invention, suggesting different types of views which can be adjusted to the particular needs of a user by corresponding image handling parameters.

Fig. 3 shows a second system topology view. The second system topology view depicts an advanced system topology view of a combined physical and virtual communication network indicating part-networks and network protocols 100-2. Additionally to Fig. 2, the different network protocols are shown. The physical network devices 17, 18, 19, 20, 21, 23, 24 and the virtual network devices 17-1, 18-1 are arranged the same way in the three part-networks 14, 15, 16 as in Fig. 2.

The different network protocols are indicated in small round circles as P1, P2, P3, VP1, VP2, VP3 on the respectively physical 10, 11, 12, 13 and virtual communication connections 10-1, 11-1, 12-1, 13-1. The protocols used for communication via physical communication connections are indicated as P1, P2 and P3 and the protocols used for communication via virtual communication connection are indicated as VP1, VP2 and VP3.

Accordingly, it can be seen from the advanced system topology view that the first part-network 16 comprises parts of a physical communication connection 13 with protocol P3 and parts of a physical communication connection 12 with protocol P2. The second part-network 15 comprises a part of the physical communication connection 12 with protocol P2 and a part of the physical communication connection 11 with protocol P1. The third part-network 14 comprises a part of the physical communication connection 10 with protocol P1. Further it comprises a virtual communication connection with four different protocols: One virtual communication connection 10-1 with the virtual protocol VP1 located at the upper left side of the physical server 18. Another virtual communication connection 11-1 with the virtual protocol VP2 located opposed to the virtual communication connection 10-1 on the lower right side of the third part-network 14, between the physical server 18, the lower virtual switch and the two virtual servers on the right side. Another virtual communication connection 12-1 with the virtual protocol VP3 is on the lower left side between two virtual servers and one virtual switch. The fourth virtual communication connection 13-1 with the virtual protocol VP3 is on the upper right side between two virtual servers and one virtual switch.

Identical to Fig. 2, the physical server 18 is marked with an emulation indicating tag 22, exemplary a black cross.

Fig. 4 shows a third system topology view. The third system topology view shows a system view of a combined physical and virtual communication network 100-3 of the previous figures, Fig. 2 and Fig. 3. The depicted figure shows which communication paths are available between the physical network devices 17, 18, 19, 23, 24 and virtual servers 18-1, i. e. which physical and virtual network devices may theoretically communicate with each other due to an available communication link between them.

It is explicitly pointed out, that the overlapping servers can communicate with each other. Hence, the couple of overlapping virtual servers on the right and on the left side and the couple of the physical server overlapping the virtual server in the middle of the network can communicate with each other.

The black point between the physical communication connection 10 and the virtual communication connection 10-1 indicates, that the virtual communication connection 10-1 can communicate with the physical communication connection 10. Hence, the data from the physical bus can be transferred to the virtual bus.

Fig. 5 depicts a fourth system topology view. The fourth system topology view shows a logical view of a combined physical and virtual communication network 100-4 of Fig. 2. When comparing Fig. 4 and Fig. 5, it becomes obvious that not all of the virtual servers exchange information with all of the physical PLCs and that not all of the physical PLCs communicate with each other, even though they could be arranged to do that since they are all connected via communication connections to each other. In Fig. 5 exemplary only two virtual servers 18-1 exchange data via the virtual communication connection 10-1 and via the physical communication connection 10 with the physical network devices 18, 19, 23, 24. In other words, the logical view represents the peer to peer connections between network devices.

Fig. 6 depicts a fifth system topology view, which shows a physical view of a combined physical and virtual communication network 100-5 of the same communication network of Fig. 2 to Fig. 5. Only the physical communication connections 10 which are connecting the physical network devices are visualized. Hence, only the physical cabling of the physical and virtual communication network is visible. Compared to Fig. 2 to Fig. 5, the virtual communication connections and the virtual devices are not shown in the form of device

icons, but are only indicated by an emulation indicating tag 22. Hence, it is obvious for a user that the physical server 18 emulates further virtual devices.

By using the physical view, a user may verify the status of implementation of network redundancy protocols in the plant, as for example RSTP (Rapid Spanning Tree Protocol), PRP (Parallel Redundancy Protocol), MRP (Media Redundancy Protocol), HSR (High-availability Seamless Redundancy Protocol). In addition to the information shown here, the visualization can be made more sophisticated in the sense that the image representations of the network devices clearly show to which data port the cables are connected and that text information is included for example about physical protocols and IP-addresses.

Fig. 7 shows a sixth system topology view. The sixth system topology view depicts a basic view of a combined physical and virtual communication network 100-6 of Fig. 2. Additionally to Fig. 6, the exemplary basic view indicates the number of emulated virtual network servers by virtual device tags 21 around the physical server 18. In this figure, the virtual device tags 21 are circles around the physical server. The abbreviation "VS" in each circle indicates that one circle represents one Virtual Server. As in the previous figures Fig 2 to Fig. 6, the physical server 18 is marked with an emulation indicating tag 22.

Fig. 8 shows a seventh system topology view. The seventh system topology view depicts an example of a so called location view of a combined physical and virtual communication network 100-7 of a power plant, where each of the displayed network devices is visible in relation to its geographical location inside the plant. In the example, the network devices of the control room are shown separated from the network devices of a server cabinet, and both are located separated from the network devices of cabinets A to D located in the field, i.e. located close to the actuators of the plant. With geographical location it is mostly meant that the building, cable tray or floor where the network devices are situated is identified in the view. The image handling parameters for this example configure the graphical image of Fig. 2 to not visualize the network connections and the network device with sole network functionality. In other words, the image representations of the network connections and the of the network devices with sole network functionality, which are provided by the data processing unit 3, are suppressed on the way to the screen of the graphical display unit 5.

Starting from an advanced system topology view of a combined physical and virtual communication network indicating part-networks shown in Fig. 2, a completely new concept for visualization is suggested for power plants, where the following may be shown in the same screen and at the same time:

1. the system topology of the electrical system,
2. the physical details of the power plant, and
3. process information or process values.

This particular combination of visual information is not currently used by automation control tools and it provides the advantage of making available simultaneously the above named graphical information without requiring any switching between different windows or tools.

A more detailed example of a power plant view can be seen in Fig. 19, where a solar power plant is shown with its solar field, divided into different sectors, and with the power generation part in the upper right corner. The sectors of the solar field are named and placed in the image according to their geographical location: north (NO), south (SO) and south-east (SE). Within the solar field, each PLC is graphically represented by a small black dot, and the network switches are represented by a larger black dot. The communication connections between the PLCs and network switches as well as with the power generation equipment are depicted as solid lines of varying color, depending on the type of communication bus.

Starting from this plant view, a user may zoom in and navigate to a more detailed view of a part of the solar power plant, which in connection with the present invention is called a part-network of the combined physical and virtual communication network of the power plant, where more detailed information, in particular process values of selected devices in the solar field or in the power generation part, may become visible.

The way, in which the nodes of a combined physical and virtual network topology are represented graphically, i.e. in which the physical and virtual network devices are arranged with respect to each other on the screen, can be chosen by the user by selecting corresponding image handling parameters. Figs. 9 to 12 show examples for an organic, a circular, an orthogonal and a tree-like way, respectively.

When wanting to see details of the above described system topology view or plant view, a user may be presented with different possibilities for how to present the detail information. In Fig. 13, a so called neighbor view of the network of Figs. 2 to 8 is shown, where a selected network device, here it is the physical switch 22, and its direct neighboring network devices and the corresponding communication connections are visualized at an increased zoom level and where the rest of the image representations of the communication network are shown at a reduced zoom level. The network devices of Fig. 13 are arranged in a circular way, where the physical switch 22 forms the central point of the circle. The direct neighbors, the physical server and two PLCs, are arranged on a first, innermost circle closest to the physical switch

22. The further neighbors which are one further network device away, in this example only one other physical switch, are arranged on a second circle surrounding the first circle and are shown at a reduced zoom level compared to the central network switch 22 and its direct neighbors. The zoom level of all other network devices is here set to zero.

5

Fig. 15 shows a zoomed view of the combined physical and virtual communication network of Fig. 2, where in the zoomed view a selected part-network of the combined physical and virtual communication network is visible at an increased zoom level and where the rest of the image representations of the combined physical and virtual communication network are visible at a reduced zoom level including a marking for the selected part-network. In the example of Fig. 15, the whole combined physical and virtual communication network is depicted in a so called mini-map, i.e. not only the rest of the image representations are shown at the reduced zoom level but the zoomed-in part-network as well, so that an overview of the whole combined physical and virtual communication network is shown at a reduced zoom level inside a frame. The frame or mini-map can be seen to the lower right side of Fig. 15. Within the mini-map, the zoomed-in part-network is marked by a circle. A mouse pointer in the form of a small arrow is shown here as well, indicating that a user has selected the part-network by placing the circle inside the mini-map via user input device 4. The selected part-network is shown at an increased zoom level together with surrounding parts of the combined physical and virtual communication network. A similar way for visualizing a selected part-network at an increased zoom level together with the remaining combined physical and virtual communication network at a decreased zoom level is a virtual magnifying glass. The magnifying glass is movable on the screen of graphical display unit 5 via input device 4, and everything below it is seen at the increased zoom level.

25

Apart from using a mouse for selecting a specific part of the combined physical and virtual communication network to be displayed at the increased zoom-level, also a keyboard or head set may be used. For example, as is shown in Fig. 16, a search engine may be provided which interacts with data storing unit 6 to allow for searches after text strings which are attached to the image representations. Such text strings could for example be the names or types of physical and virtual network devices or of physical and virtual communication connections. In Fig. 15, the text string is entered into a search dialogue window. All the hits matching the text string are highlighted in the mini-map. Additionally, the remaining parts of the combined physical and virtual communication network could be shown in a collapsed way, if so requested by the user via image handling parameters.

35

An example for a collapsed view is depicted in Fig. 17. On the left hand side, the physical and virtual communication network of Fig. 2 can be seen in its expanded view, and on the

right hand side, two selected part-networks are visible in a collapsed form represented by a corresponding graphical symbol and attached to the image representations of the rest of the communication network. The graphical symbol is here is dot with a plus sign attached. The two selected and collapsed part-networks are those parts which belong to the lowermost
5 ends of the hierarchy of the network: two actuators, one sensor and one IED on one side and two IEDs on the other side. Of course, the two collapsed part-networks can be expanded again, either at a specific request by the user or depending on the current type of view of the combined physical and virtual communication network.

10 Further examples for possible ways to show more details of a selected part-network are the so called detail view, where the physical and virtual communication network is shown at a varying zoom level with a selected level of constant information density. In other words, the further the user zooms into the combined physical and virtual communication network, the more additional information is made visible for each of the network devices and
15 communication connections which remain on screen. This can for example be combined with a pan-and-zoom functionality. The desired level of constant information density may be selected by the user as an image handling parameter.

An even further example for a zoomed-in or detailed view of a selected part-network is the so
20 called wrapped view, where the combined physical and virtual communication network is wrapped on a three-dimensional ovoid shape, resulting in the two-dimensional image representations located in the center of the visible part of the shape being shown at an increased zoom level compared to the image representations located closer to the boundary of the shape.

25 Depending on the specific needs of the user, the above described various views of the communication network and the different ways to graphically arrange the network devices can be applied in a combined view to more than one of its part-networks. An example for such a combined view can be seen in Fig. 18, where a simplified view is applied to the upper
30 part-network, a logical view with an organic arrangement of network devices is applied to the part-network shown to the lower left and a physical view with an organic arrangement of network devices is applied to the part-network to the lower right. In the example of Fig. 18, the data processing unit 3 is arranged to generate as part of the displayable information a hierarchical list of the network devices, in which list at least one of those network devices is
35 graphically highlighted which at the same time is visible with an increased zoom level in the image representations. The hierarchical list is shown in Fig. 18 to the left of the graphics representation of the physical and virtual communication network. The highlighted network

device is a controller, the image representation of which and the name of which are surrounded by a solid rectangle in the graphical view of the combined physical and virtual communication network and in the hierarchical list, respectively. It is suggested that the visual navigation through the combined physical and virtual communication network is possible both via the hierarchical list and the image representations, i.e. once an object is selected either in the graphics view or in the hierarchical list, it is automatically highlighted in both views.

In a further embodiment of the invention, the data processing unit 3 is arranged to generate at least one of the above described views for at least one of the part-networks or for the whole combined physical and virtual communication network showing the topology and configuration of the physical and virtual communication connections of the respective network according to a selected layer of the OSI model of computer networking. In other words, the data processing unit 3 is arranged to navigate through the OSI layers of the combined physical and virtual communication network provided by data storing unit 6 and to create a view where the specific information corresponding to a selected one of the OSI layers becomes visible.

For all the described views, it is common that the data processing unit 3 is arranged to generate as part of the displayable information displayable text which specifies at least one parameter of at least one of the network devices and/or communication connections. The displayable text may for example indicate the OSI layer which is currently displayed, or the type of a network communication protocol, the type of a network redundancy protocol, an IP address, a port configuration, a name of a device, or status information of a network device or of a communication connection. The status information could for example be an alarm or a particular process value of a network device. Further, the status information could relate to the status of configuration data and / or to the device status which are to be transferred between network devices or which are presented in different network devices. In particular, such data could be data to be downloaded from an engineering server to a controller device, where both devices are connected to the communication network. For example, the status information could indicate the version of the data which were last downloaded or it could indicate their consistency of data in the controller device with respect to the corresponding data in the engineering server.

In order to provide the user with even more visual information, the data processing unit 3 may be arranged to generate at least one image representation of a communication connection in highlighted form compared to the image representations of the other

communication connections, i.e. communication busses may for example be distinguished by their line color or line thickness.

As already mentioned above, a user may select and/or configure various image handling parameters in order to customize the visual representation of the communication network according to his specific needs. Therefore, the user interface is arranged for receiving image handling parameters which define at least one of

- the type of view for the network or the part-networks, respectively,
- the way of arranging the image representations,
- the selected network device,
- the selected part-network,
- the zooming level,
- the type of displayable text, and
- the level of constant information density.

In all the above described examples, only one physical and virtual communication network of the power plant is visualized. However, in one and the same plant there may exist separate technical installations, for example two separate power generation units, and each of these technical installations is equipped with an independent physical and virtual communication network. Accordingly, in the tools for engineering and operations, data of two separate network topologies are handled. In such a case, the user interface 1, the graphical display unit 5, the data storing unit 6 and the data processing unit 3 are arranged to visualize at least two of the combined physical and virtual communication networks of the power plant. Due to the simultaneous visualization of the several communication networks of one and the same plant, the handling is simplified since switching between different projects and/or different graphical windows is avoided.

List of References

- 1 user-interface
- 1-1 System for visualizing technical equipment of a power plant
- 2 graphics-interface
- 3 data-processing unit
- 4 user-interface
- 5 graphical-display
- 6 data-storing unit
- 7 first engineering and/or operation tool
- 8 second engineering and/or operation tool
- 9 third engineering and/or operation tool

- 10 physical communication connection
- 11 physical communication connection
- 12 physical communication connection
- 13 physical communication connection

- 10-1 virtual communication connection
- 11-1 virtual communication connection
- 12-1 virtual communication connection
- 13-1 virtual communication connection

- 14 third part network
- 15 second part network
- 16 first part network

- 17 physical switch
- 17-1 virtual switch
- 18 physical server
- 18-1 virtual server
- 19 physical IED

- 20 physical sensor
- 21 physical actuator
- 21 virtual device tag
- 22 emulation indicating tag

23 physical client

24 physical PLC

100-1 First system topology view

100-2 Second system topology view

100-3 Third system topology view

100-4 Fourth system topology view

100-5 Fifth system topology view

100-6 Sixth system topology view

100-7 Seventh system topology view

Patent Claims

1. System for visualizing a communication network interconnecting technical equipment of a power plant, comprising
 - a user interface (1) arranged for receiving image handling parameters,
 - a graphical display unit (5) arranged for visualizing displayable information in a graphical image taking into account the image handling parameters,
 - a data storing unit (6) arranged for providing data relating to the technical equipment,
 - a data processing unit (3) arranged for retrieving the provided data, for transforming them into the displayable information and for providing the displayable information to the graphical display (5) for visualization,

characterized in that

 - the technical equipment comprises physical (17, 18, 19, 20) and virtual network devices (17-1, 18-1) of the power plant,
 - the communication network comprises physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1) of the power plant,
 - the data storing unit (6) is arranged to provide the data relating to the physical and virtual network devices in the form of device data, and to provide the data describing the physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1) in the form of network data,
 - where the device data describe all of the physical (17, 18, 19, 20) and virtual network devices (17-1, 18-1) which are connected to the communication network and belong to the power plant, and
 - where the network data describe all of the physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1) between the network devices,
 - the data processing unit (3) is arranged to transform all the device data and all the network data into displayable information which contains image representations of all of the physical (17, 18, 19, 20) and virtual network devices (17-1, 18-1) and of all of the physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1) and
 - the graphical display unit (5) is arranged
 - to visualize the image representations and further displayable information according to the image handling parameters in one and the same graphical image, wherein

- the physical network devices (17, 18, 19, 20) are visualized in a different way than the virtual network devices (17-1, 18-1), and the physical communication connections (10, 11, 12, 13) are visualized in a different way than the virtual communication connections (10-1, 11-1, 12-1, 13-1).
- 2. System according to claim 1 or 2, where the data processing unit (3) is arranged to generate a physical view, where the physical view contains the image representations in such a way that a physical network device (17, 18, 19, 20) is marked with an emulation indication tag (22) when it emulates a virtual network device (17-1, 18-1).
- 3. System according to any of the preceding claims, where the data processing unit (3) is arranged to generate a basic view, where the basic view contains the image representations in such a way that the physical network device (17, 18, 19, 20) indicates the number of emulated virtual network devices (17-1, 18-1).
- 4. System according to any of the preceding claims, where
 - the user interface (1) is arranged for receiving plant related input data,
 - the data storing unit (6) is arranged for updating the device data and network data in accordance with the plant related input data or in accordance with update information received from an external data source,
 - the data processing unit (3) is arranged to automatically update the image representations as soon as the device data and network data are updated, and
 - the graphical display unit (5) is arranged to automatically update the visualization of the image representations and further displayable information as soon as the image representations are updated.
- 5. System according to any of the preceding claims, where the data storing unit (6) is arranged to provide the device data and network data according to a respectively assigned part-network (14 - 16), where a part-network is defined by its physical layer and/or by its network communication protocol and/or by a graphically selected boundary which is received by the user interface as corresponding boundary parameters, and where the data processing unit (3) is arranged to generate the image representations without or with a graphical representation of the assignment to the part-network, depending on the image handling parameters.

6. System according to claim 5, where a first of the part-networks (16) comprises as network devices plant controller devices of a distributed control system and/or where a second of the part-networks (15) comprises as network devices automation devices of an electrical system and/or where a third of the part-networks (14) comprises as network devices operation servers and/or operation clients for monitoring plant controller devices and/or automation devices.
7. System according to any of the previous claims, where the data processing unit (3) is arranged to generate at least one of a location view, a physical view, a logical view, a simplified view and a plant view, where the respective view contains the image representations in such a way that the following becomes visible:
 - a respective geographical location of the network devices inside the plant, or
 - physical connection lines between the network devices, or
 - implemented logical connections between the network devices, or
 - available communication paths between the network devices, or
 - both the geographical locations of the network devices inside the plant and one of the physical connection lines or implemented logical connections or available communication paths between the network devices, respectively.
8. System according to any of the previous claims, where the data processing unit (3) is arranged to generate at least one of a zoomed view, a neighbor view, a detail view, a collapsed view and a wrapped view, where the respective view contains the image representations in such a way that the following becomes visible:
 - a selected part-network at an increased zoom level together with the rest of the image representations of the communication network at a reduced zoom level including a marking for the selected part-network, or
 - a selected network device and its direct neighboring network devices and the corresponding communication connections at an increased zoom level and the rest of the image representations of the communication network at a reduced zoom level, or
 - the communication network at a varying zoom level with a selected level of constant information density, or
 - at least one selected part-network in collapsed form represented by a corresponding graphical symbol and attached to the image representations of the rest of the communication network, or
 - the communication network wrapped on a three-dimensional ovoid shape, resulting in the two-dimensional image representations located in the center of

the visible part of the shape being shown at an increased zoom level compared to the image representations located closer to the boundary of the shape, respectively.

9. System according to claims 5 or 6 with 7 or 8, where the data processing unit (3) is arranged to generate one of at least two different views for each of at least two of the part-networks.
10. System according to any of the previous claims 7 to 9, where the data processing unit (3) is arranged to generate at least one of the views for at least one of the part-networks or for the whole communication network showing the topology and configuration of the communication connections of the respective network according to a selected layer of the OSI model of computer networking.
11. System according to any of claims 7 to 10, where the data processing unit (3) is arranged to generate at least one of the views in such a way that the image representations of the network devices and communication connections are arranged in an orthogonal, organic, tree-like or circular way.
12. System according to any of the previous claims, where the data processing unit (3) is arranged to generate as part of the displayable information displayable text and/or a displayable icon which specify at least one parameter of at least one of the network devices and/or communication connections.
13. System according to claim 12, where the displayable text and/or the displayable icon specify a status of configuration data and / or a device status which are to be transferred between at least two network devices or which are present in at least two network devices.
14. System according to any of claims 7 to 13, where the user interface (1) is arranged for receiving image handling parameters which define at least one of
 - the type of view for the network or the part-networks, respectively,
 - the way of arranging the image representations,
 - the selected network device,
 - the selected part-network,
 - the zooming level,
 - the type of displayable text, and

- the level of constant information density.
15. System according to any of the previous claims, where the data processing unit (3) is arranged to generate at least one image representation of a communication connection in highlighted form compared to the image representations of the other communication connections.
 16. System according to any of the previous claims, where the user interface (1), the graphical display unit (5), the data storing unit (6) and the data processing unit (3) are arranged to visualize at least two of the communication networks of the power plant.
 17. System according to any of the previous claims, where the data storing unit (6) is arranged to exchange data with at least two computer-implemented engineering and/or operation tools (7 - 9).
 18. Method for visualizing a communication network interconnecting technical equipment of a power plant, comprising the steps
 - receiving image handling parameters,
 - visualizing displayable information in at least one graphical image taking into account the image handling parameters,
 - providing data relating to the technical equipment,
 - retrieving the stored data, for transforming them into the displayable information and for providing the displayable information to the graphical display for visualization,

characterized by the further steps

 - providing the data relating to the technical equipment in the form of device data and network data describing a communication network of the power plant,
 - where the device data describe all of the physical (17, 18, 19, 20) and virtual network devices (17-1, 18-1) which are connected to the communication network and belong to the power plant, and
 - where the network data describe all of the physical (10, 11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1) between the network devices which belong to the power plant,
 - transforming all the device data and all the network data into displayable information which contain image representations of all of the physical (17, 18, 19, 20) and virtual network devices (17-1, 18-1) and of all of the physical (10,

11, 12, 13) and virtual communication connections (10-1, 11-1, 12-1, 13-1), and

- visualizing the image representations and further displayable information according to the image handling parameters and
- visualizing the physical network devices (17, 18, 19, 20) in a different way than the virtual network devices (17-1, 18-1), and the physical communication connections (10, 11, 12, 13) in a different way than the virtual communication connections (10-1, 11-1, 12-1, 13-1).

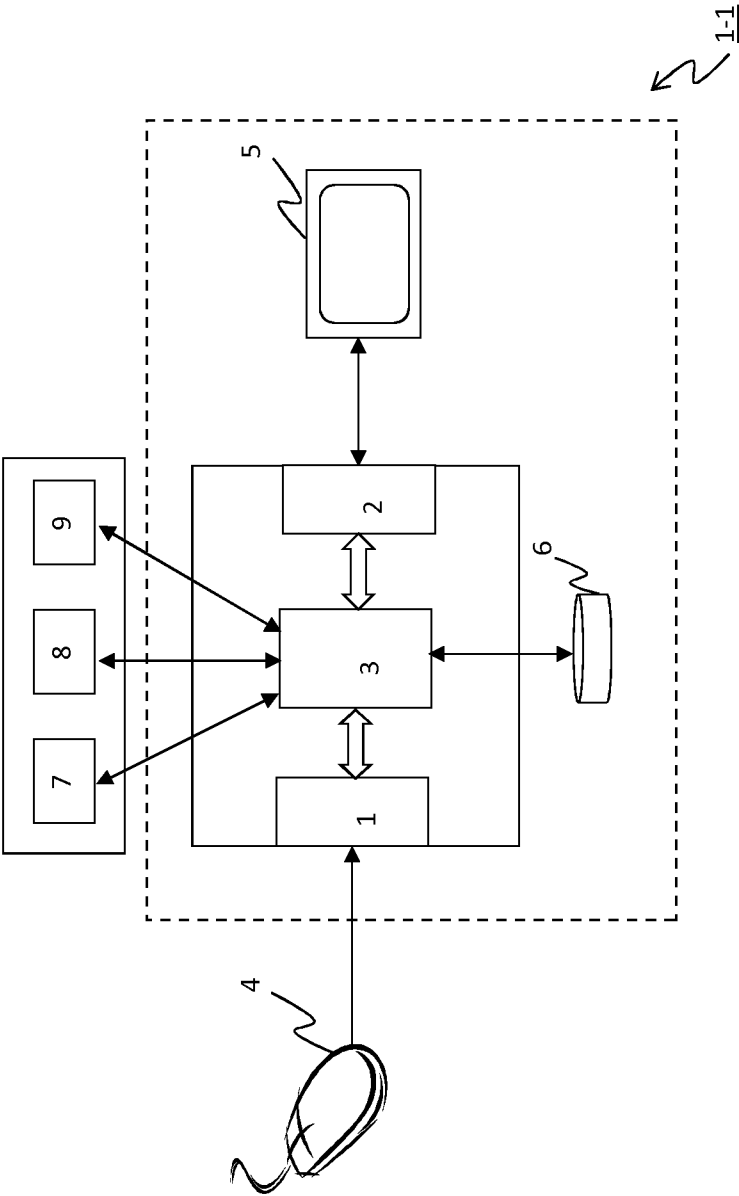


Fig. 1

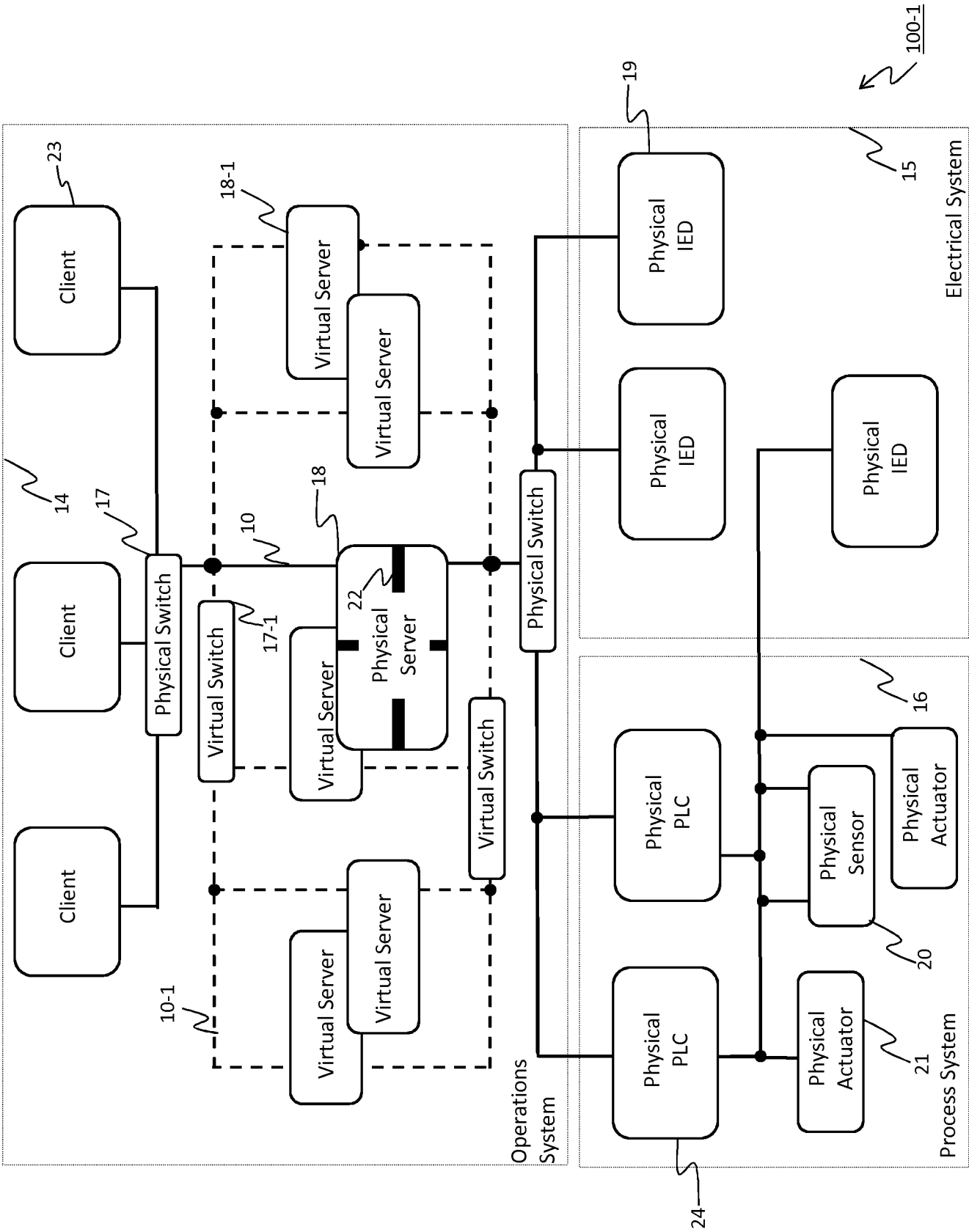


Fig. 2

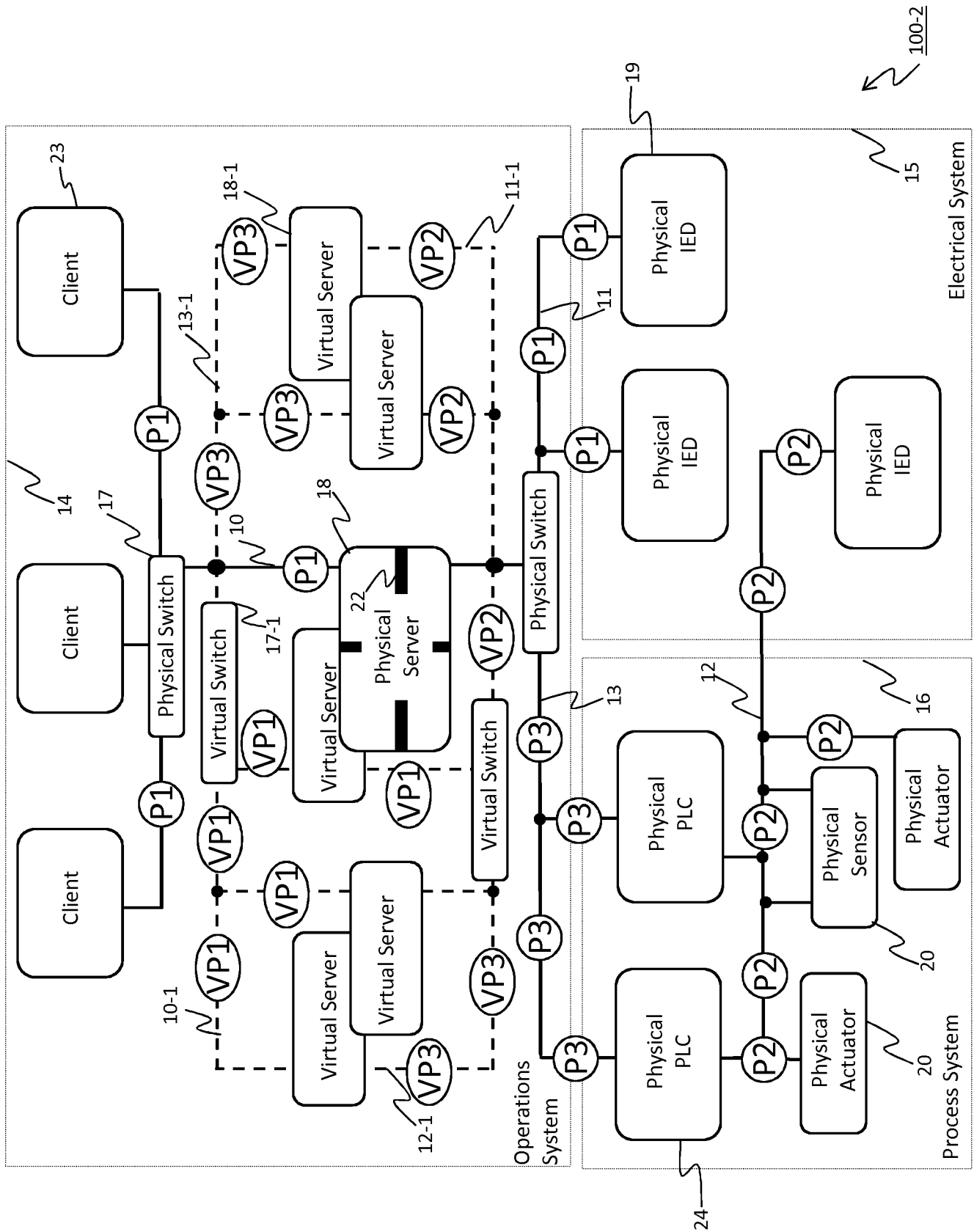


Fig. 3

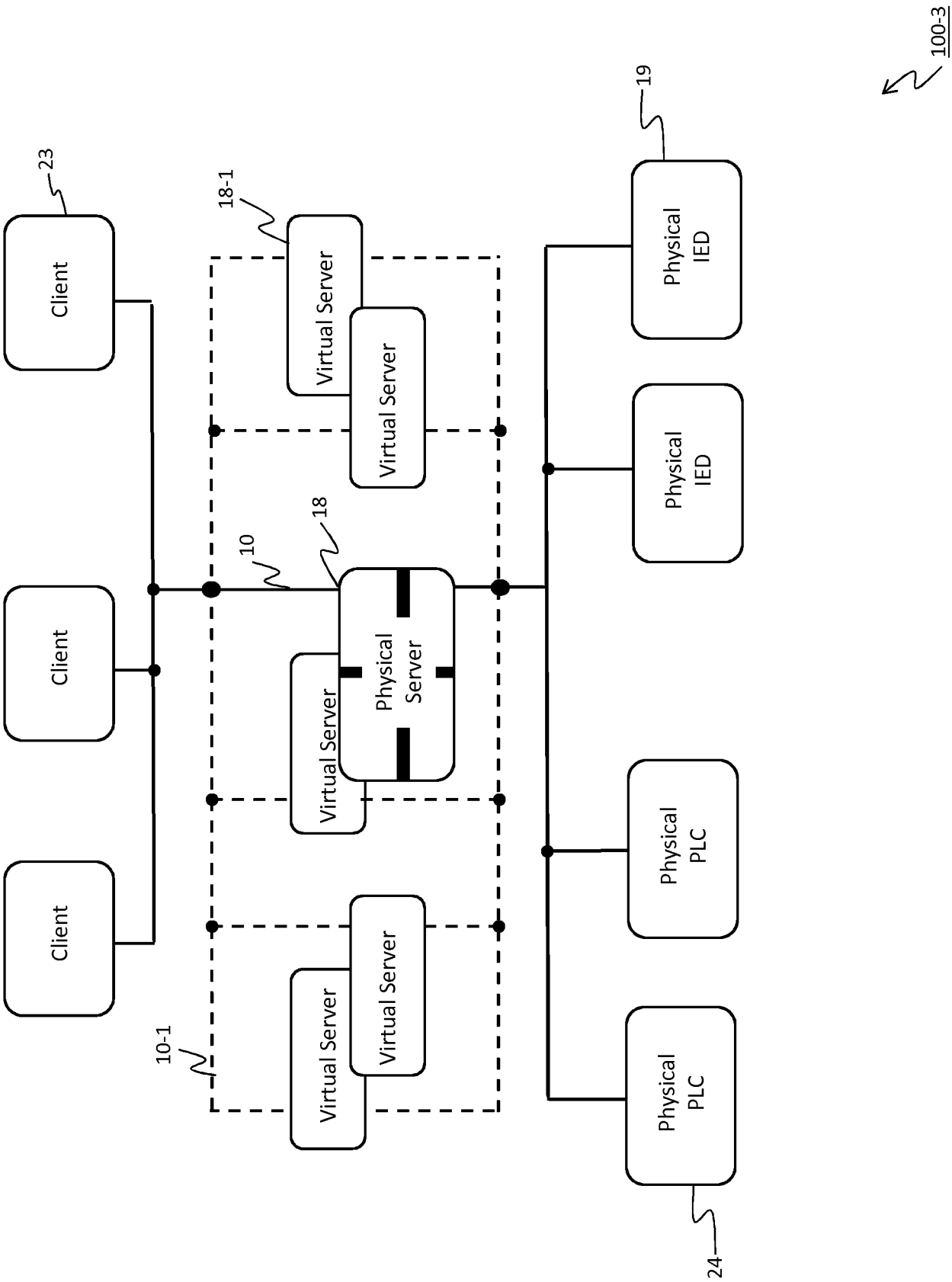


Fig. 4

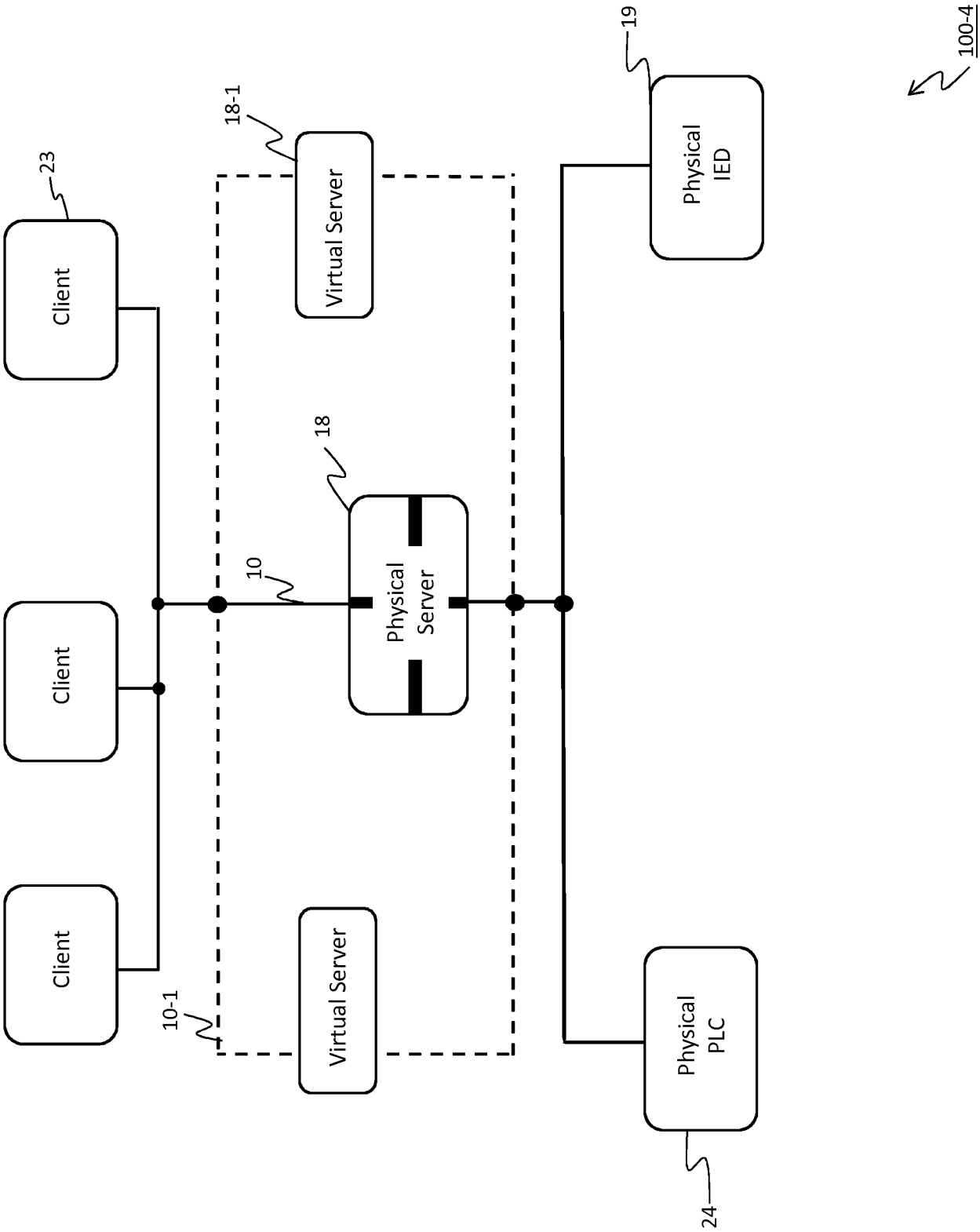


Fig. 5

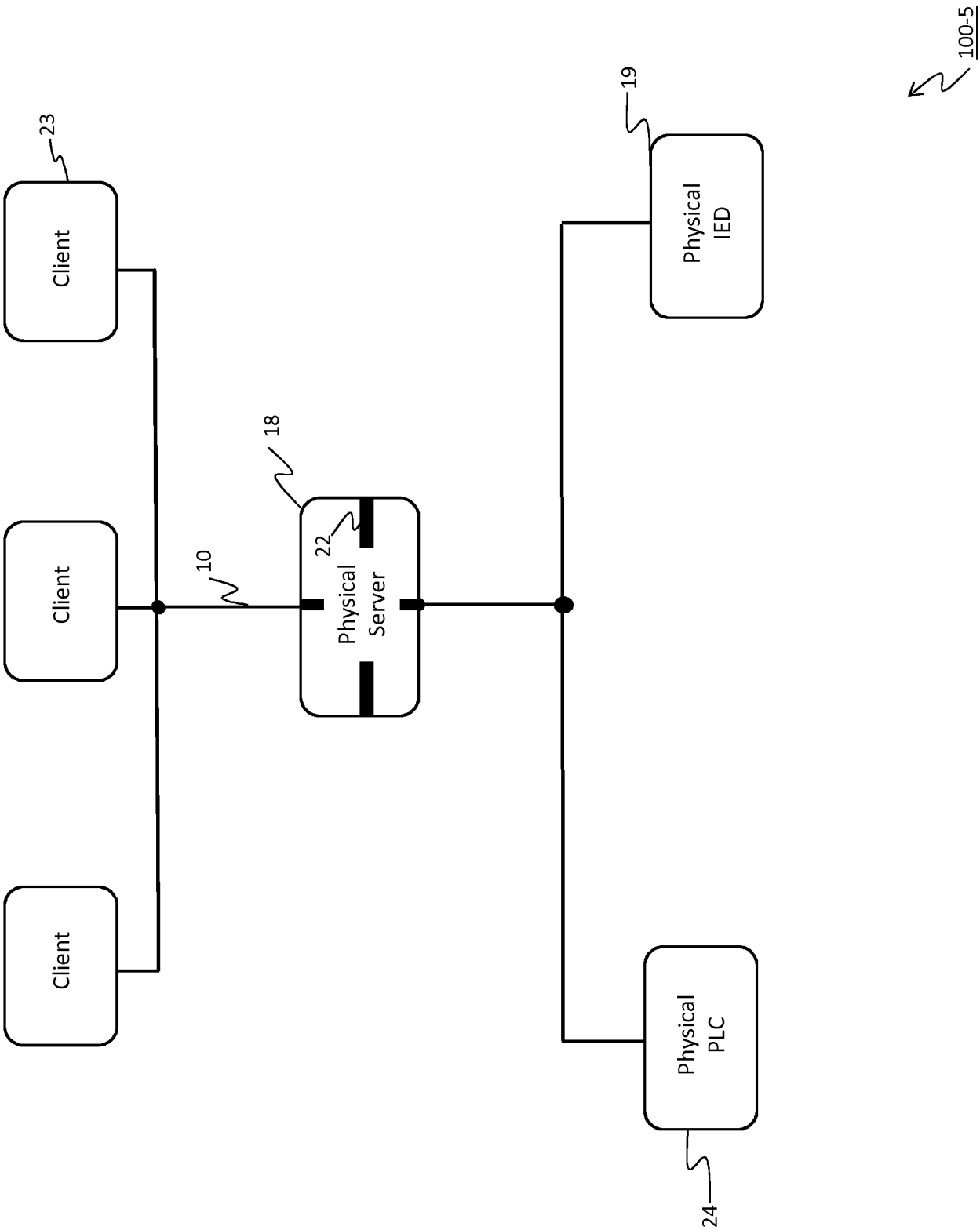


Fig. 6

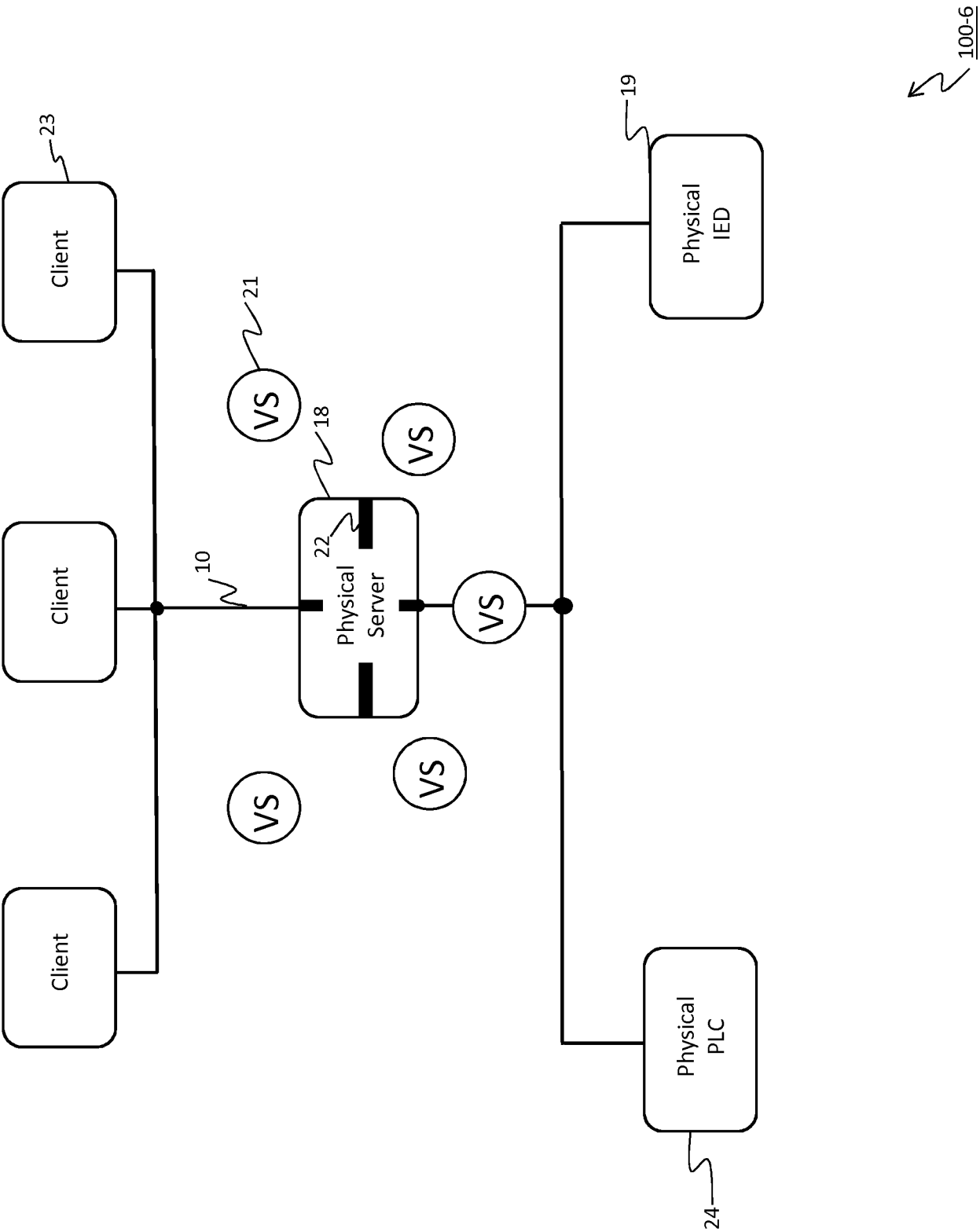
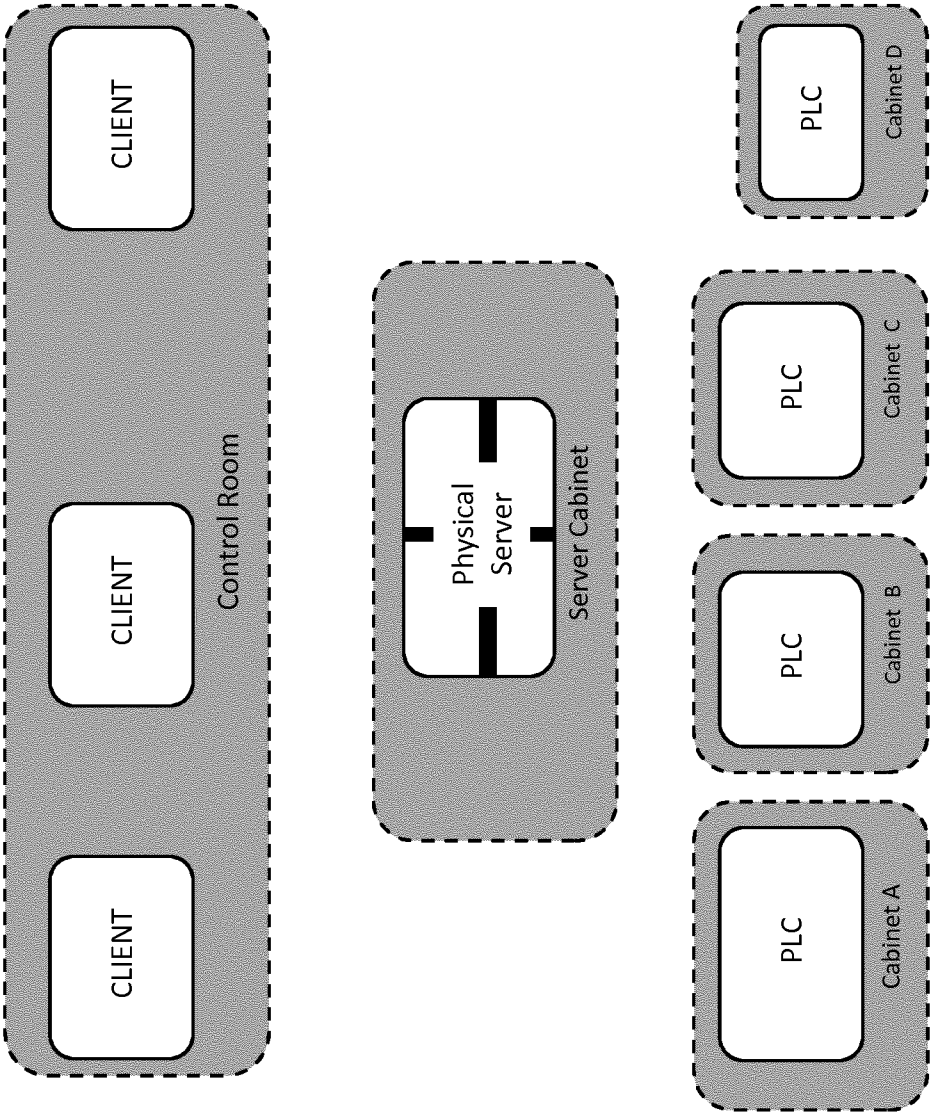


Fig. 7



100-7

Fig. 8

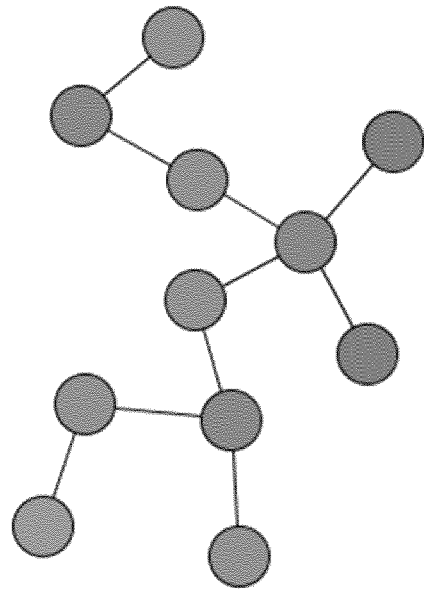


Fig. 9

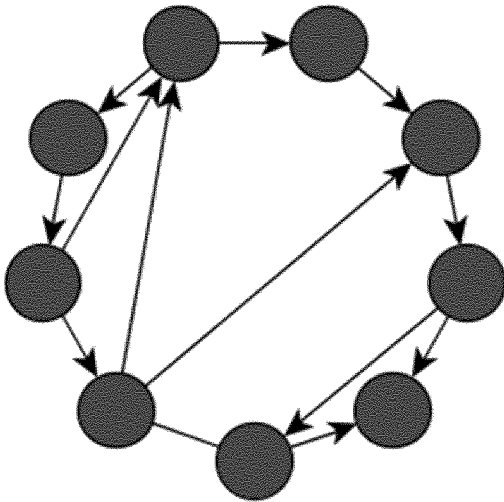


Fig. 10

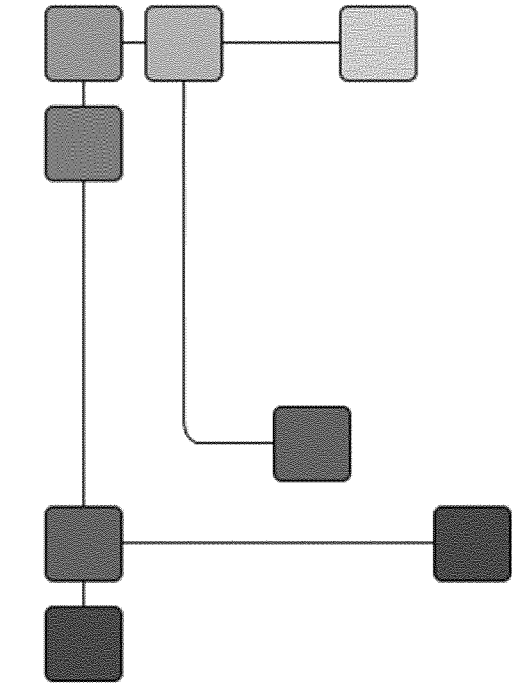


Fig. 11

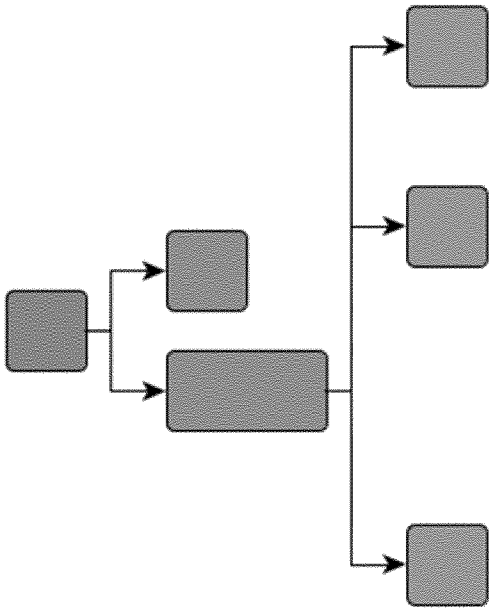


Fig. 12

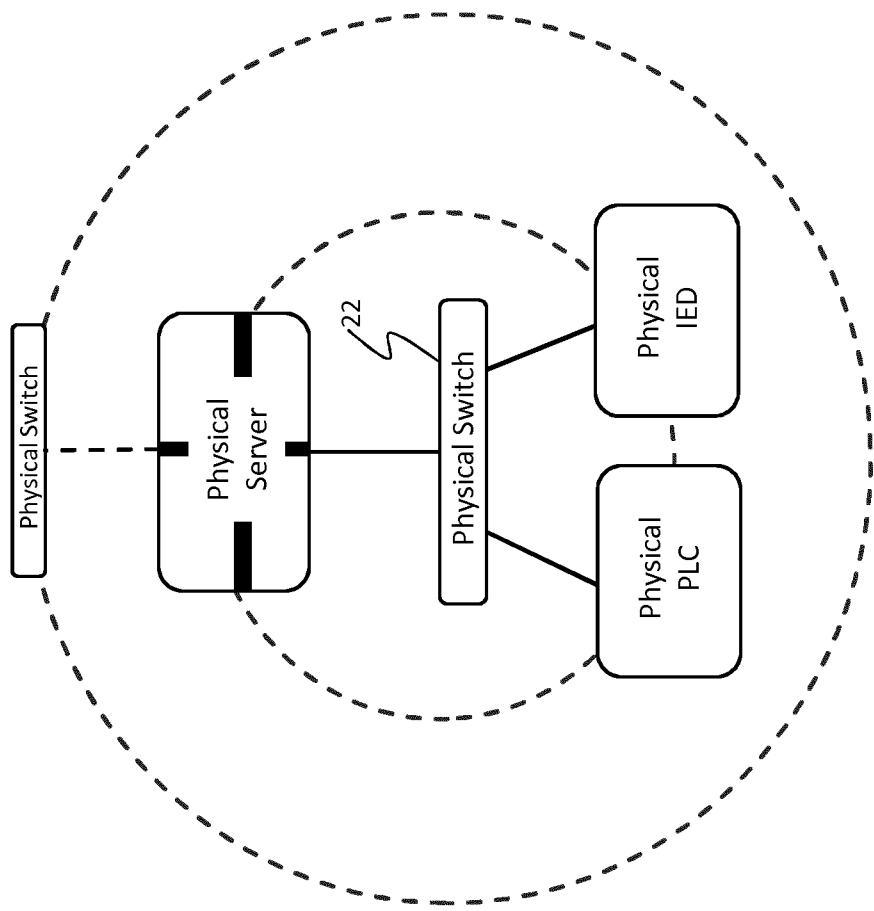


Fig. 13

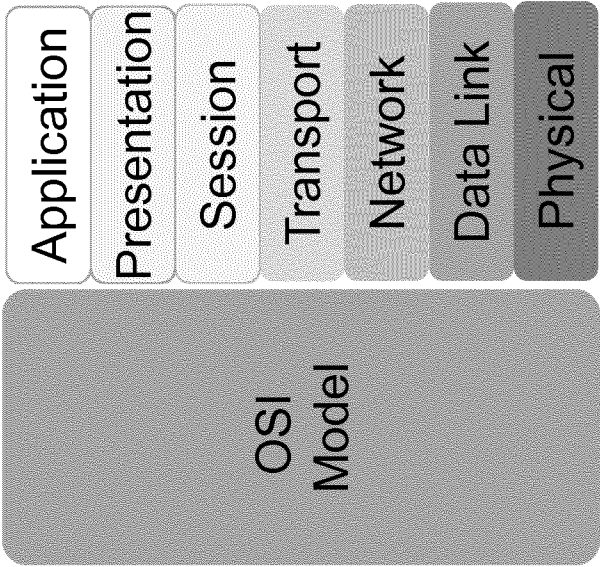


Fig. 14

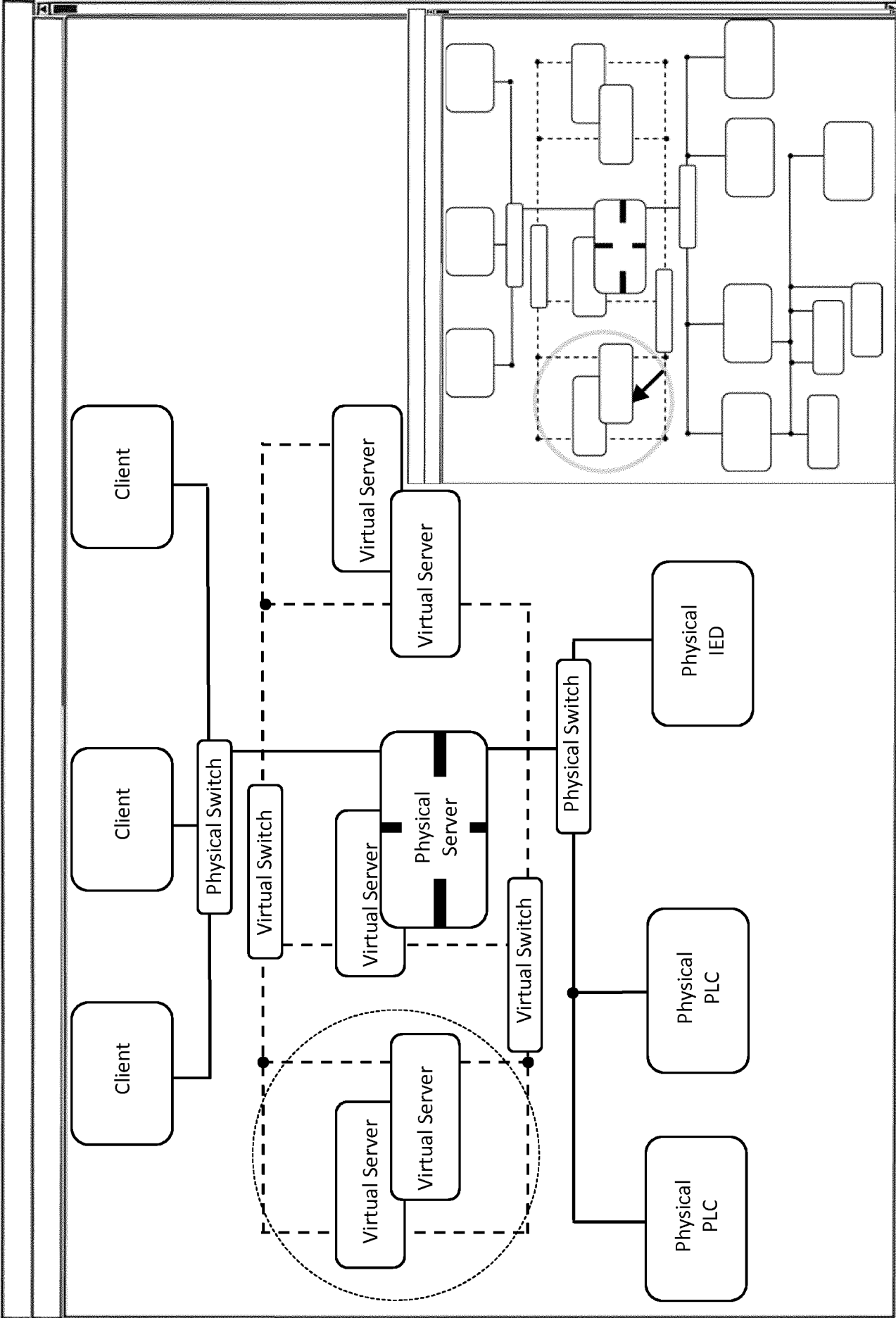


Fig. 15

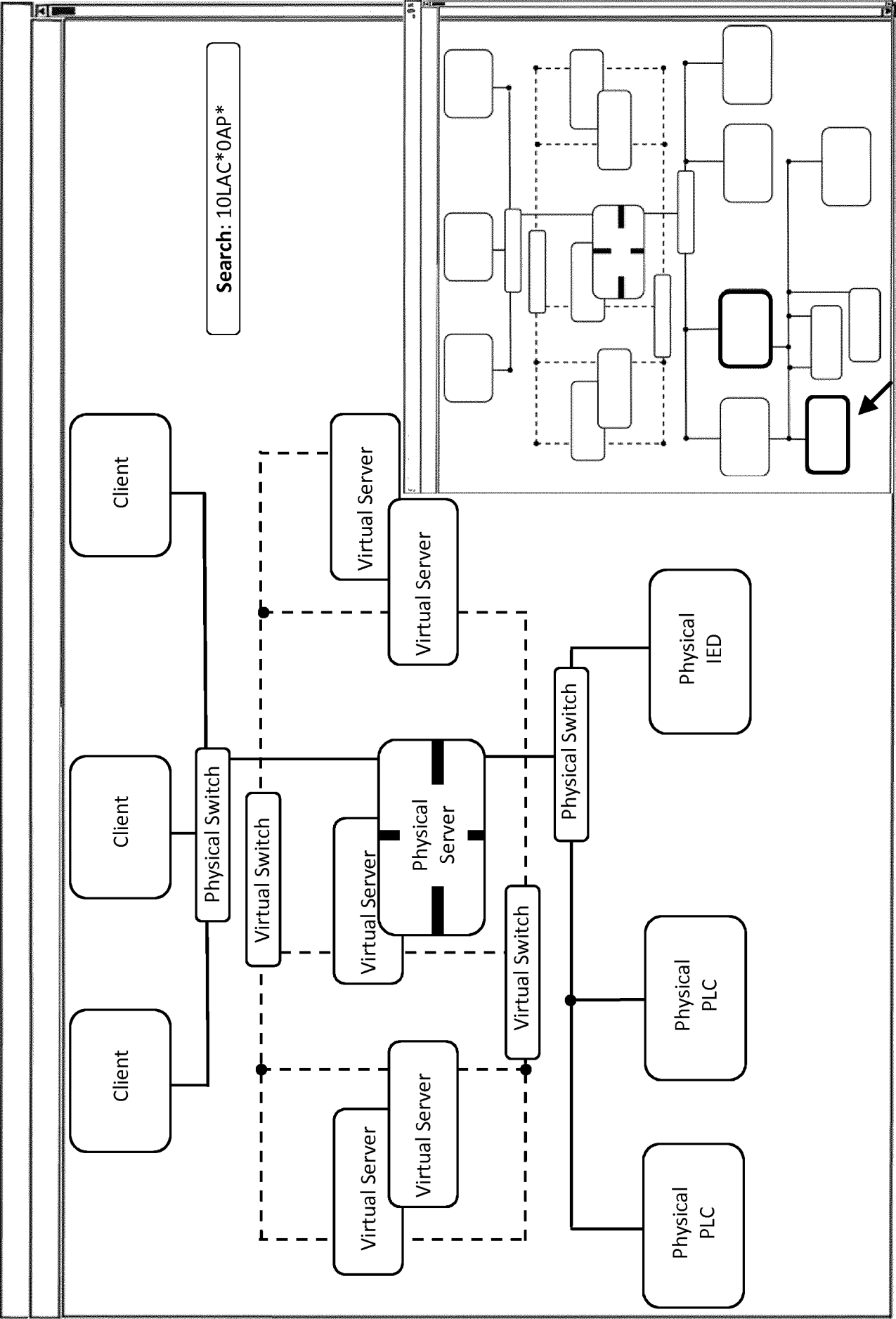


Fig. 16

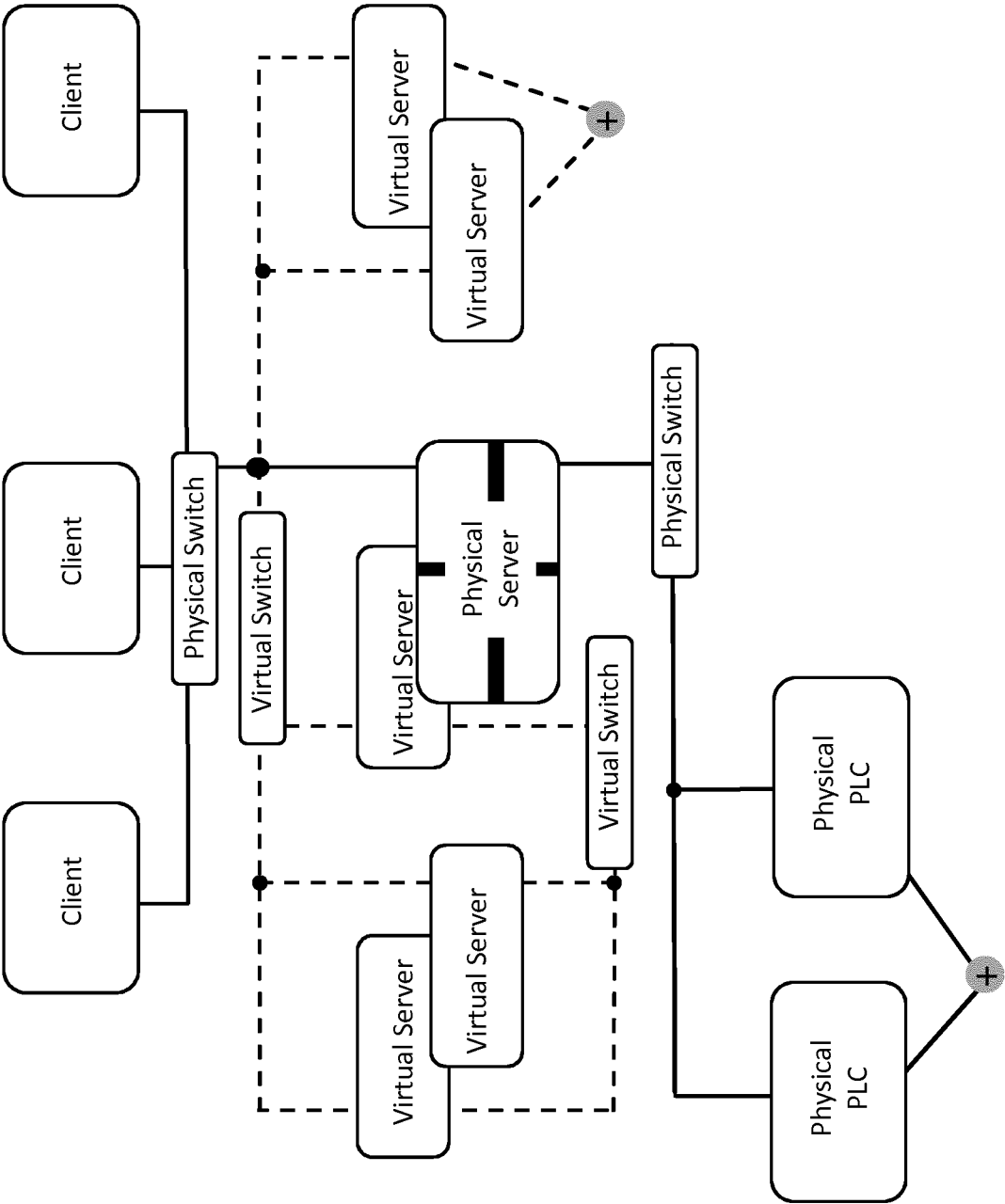


Fig. 17

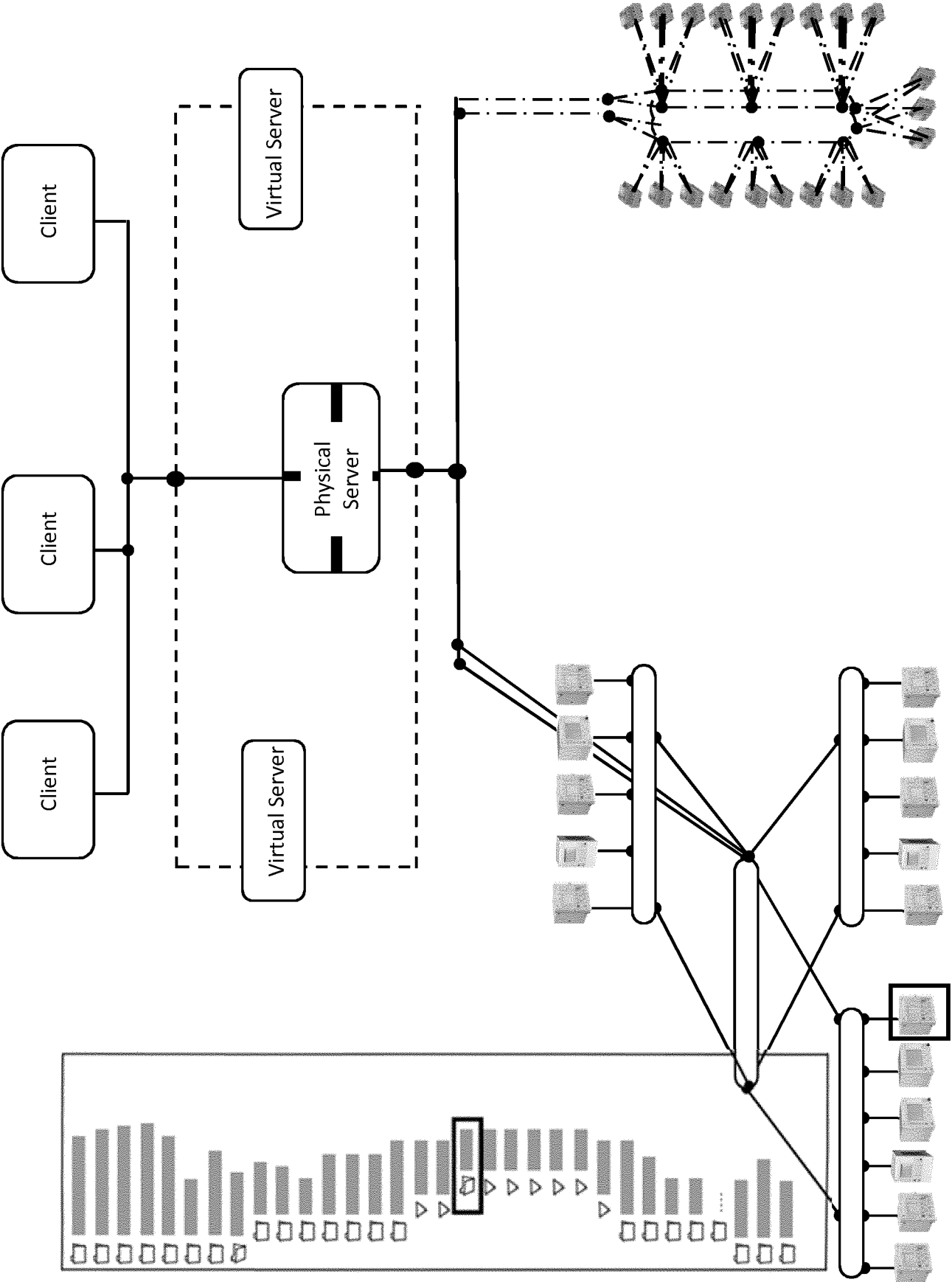


Fig. 18

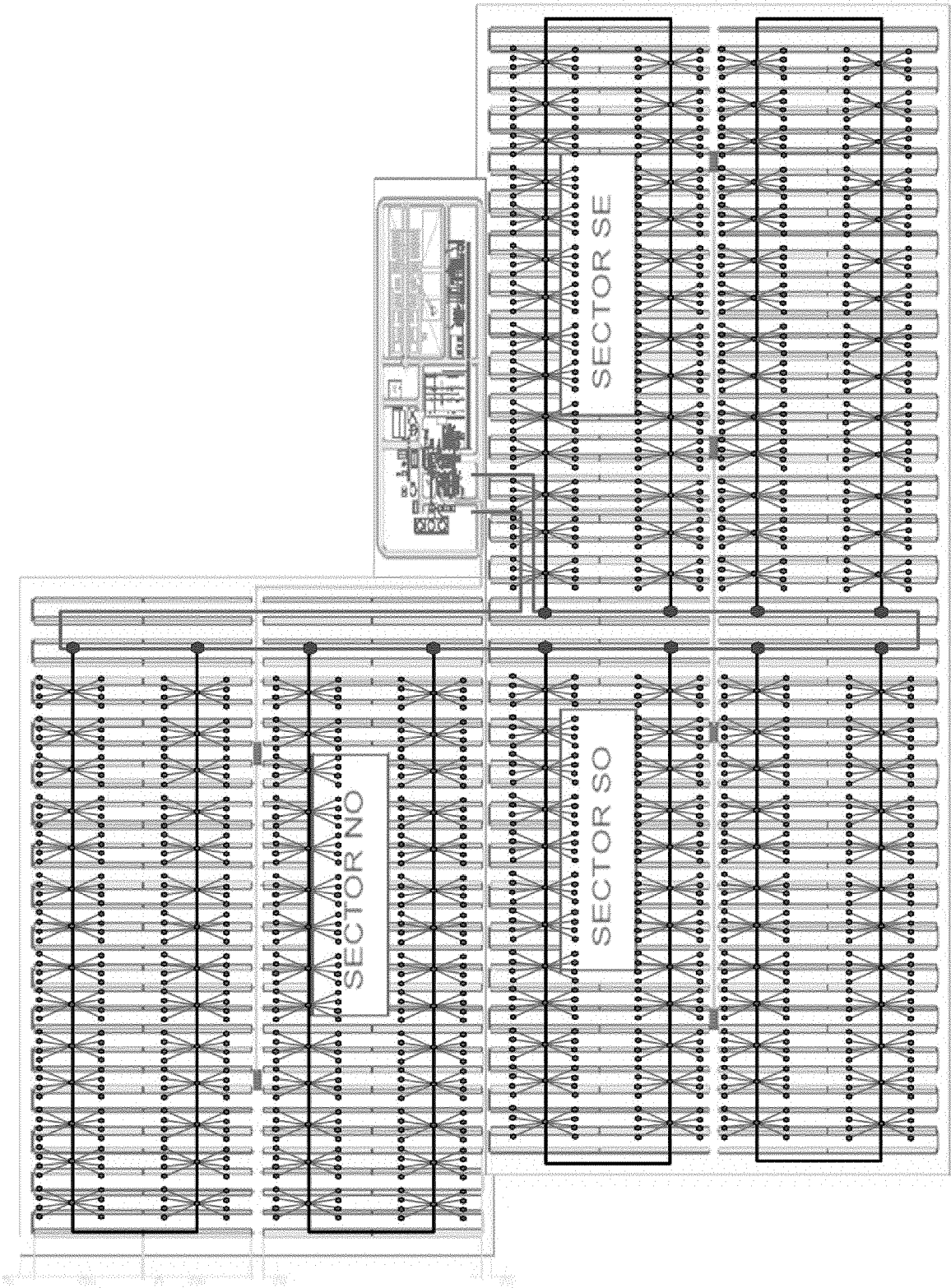


Fig. 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/072345

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06Q10/00 G06Q50/06
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/150929 A1 (VESTAS WIND SYS AS [DK]; KRISTENSEN TAGE [DK]; LIM SIEW HOON [SG]) 8 December 2011 (2011-12-08) the whole document -----	1-18
X	US 2009/319058 A1 (ROVAGLIO MAURIZIO [IT] ET AL) 24 December 2009 (2009-12-24) the whole document -----	1-18
X	US 2011/035693 A1 (UENO YOHEI [JP] ET AL) 10 February 2011 (2011-02-10) the whole document -----	1-18
X	US 2012/253479 A1 (RADL BRAD [US]) 4 October 2012 (2012-10-04) the whole document -----	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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Information on patent family members

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