US 20240371290A1

(19) United States
(12) Patent Application Publication
Kane et al.

(10) Pub. No.: US 2024/0371290 A1
(43) Pub. Date: Nov. 7, 2024

(54) **SYSTEM AND METHOD FOR TRAINING A USER VIA AN EMULATED REAL-WORLD BUILDING ENVIRONMENT**

(71) Applicant: **Northeastern University**, Boston, MA (US)

(72) Inventors: **Michael Bruce Kane**, Cambridge, MA (US); **SungKu Kang**, Boston, MA (US)

(21) Appl. No.: **18/646,540**

(22) Filed: **Apr. 25, 2024**

Related U.S. Application Data

(60) Provisional application No. 63/498,063, filed on Apr. 25, 2023.

Publication Classification

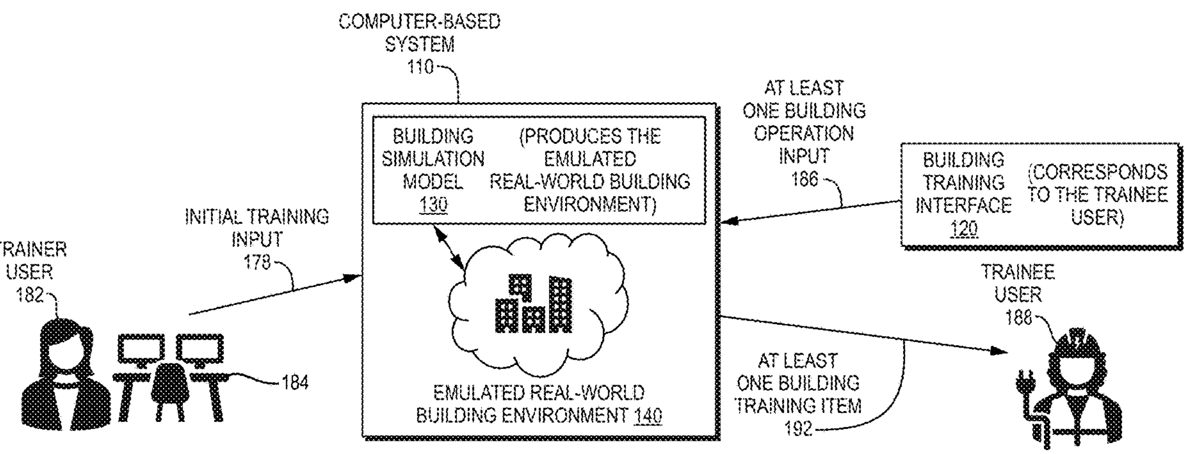
(51) **Int. Cl.**

G09B 9/00	(2006.01)
G06F 3/01	(2006.01)

(52) **U.S. Cl.**
CPC ***G09B 9/00*** (2013.01); ***G06F 3/01*** (2013.01)

(57) **ABSTRACT**

A computer-based system and corresponding computer-implemented method for training a user via an emulated real-world building environment are provided. Based on an initial training input from a trainer user, a building simulation model is implemented. The building simulation model is configured to produce an emulated real-world building environment. For an iteration of the building simulation model, a value of at least one forcing function is determined. The at least one forcing function is associated with the emulated real-world building environment. Based on the value of the at least one forcing function determined and at least one building operation input received from a trainee user via a building training interface, a current state of the building simulation model is transformed into an updated state of the building simulation model. Based on the updated state and the initial training input, at least one building training item is generated for the trainee user.



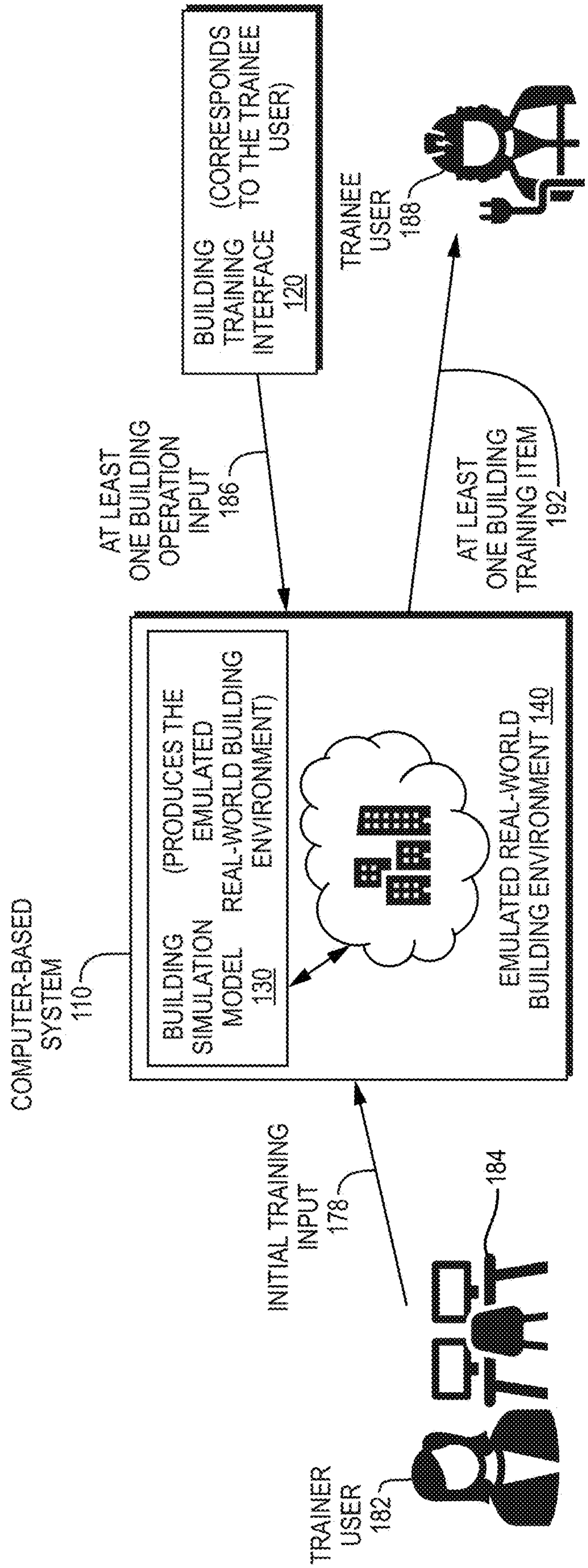
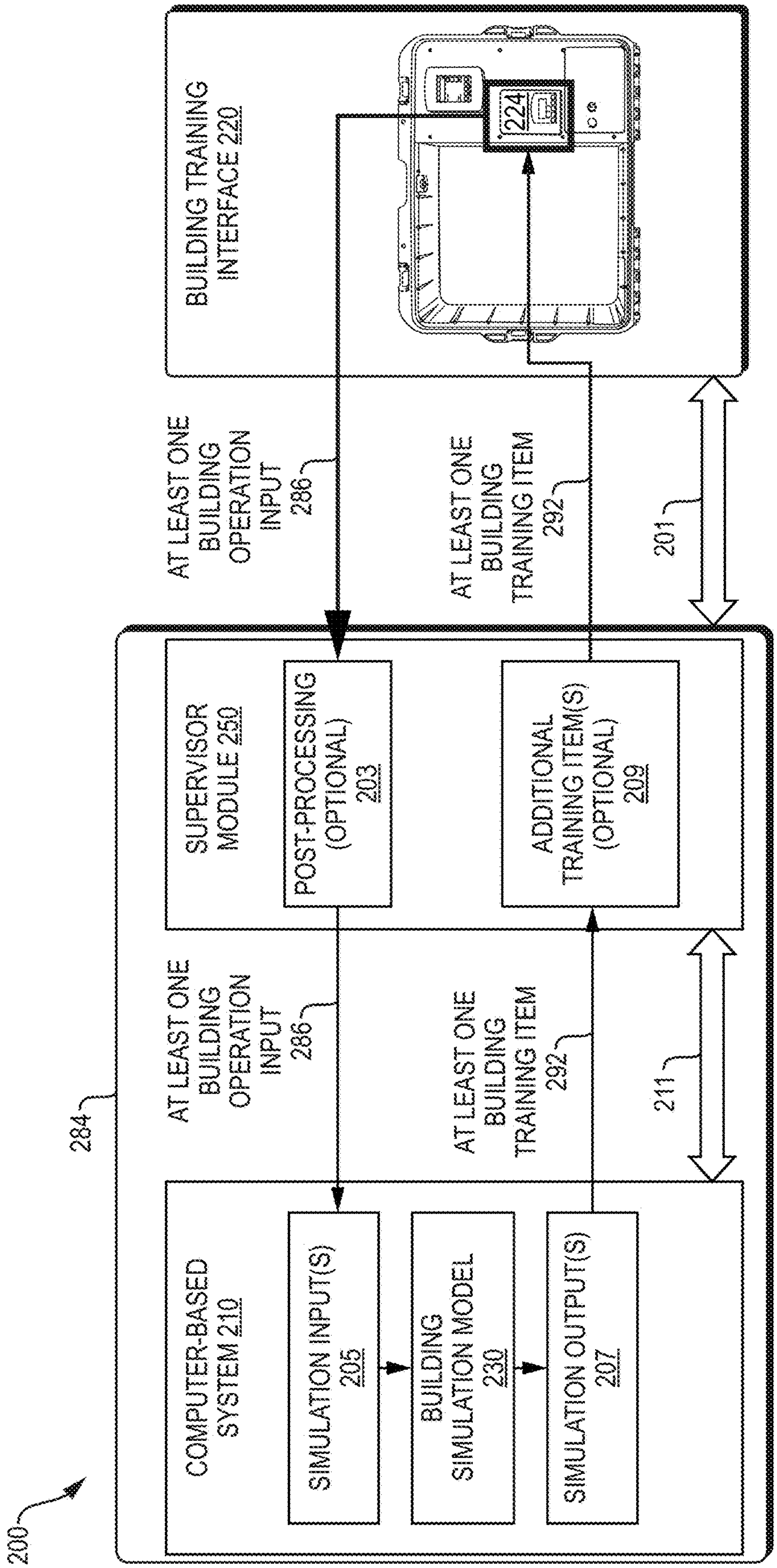

BUILDING TRAINING INTERFACE 120
(CORRESPONDS TO THE TRAINEE USER)
TRAINEE USER 188
AT LEAST ONE BUILDING OPERATION INPUT 186
AT LEAST ONE BUILDING TRAINING ITEM 192
COMPUTER-BASED SYSTEM 110
BUILDING SIMULATION MODEL 130
(PRODUCES THE EMULATED REAL-WORLD BUILDING ENVIRONMENT)
EMULATED REAL-WORLD BUILDING ENVIRONMENT 140
INITIAL TRAINING INPUT 178
184
TRAINER USER 182

FIG. 1



200
284
COMPUTER-BASED SYSTEM 210
SIMULATION INPUT(S) 205
BUILDING SIMULATION MODEL 230
SIMULATION OUTPUT(S) 207
AT LEAST ONE BUILDING OPERATION INPUT 286
AT LEAST ONE BUILDING TRAINING ITEM 292
211
SUPERVISOR MODULE 250
POST-PROCESSING (OPTIONAL) 203
ADDITIONAL TRAINING ITEM(S) (OPTIONAL) 209
AT LEAST ONE BUILDING OPERATION INPUT 286
AT LEAST ONE BUILDING TRAINING ITEM 292
201
BUILDING TRAINING INTERFACE 220
224

FIG. 2

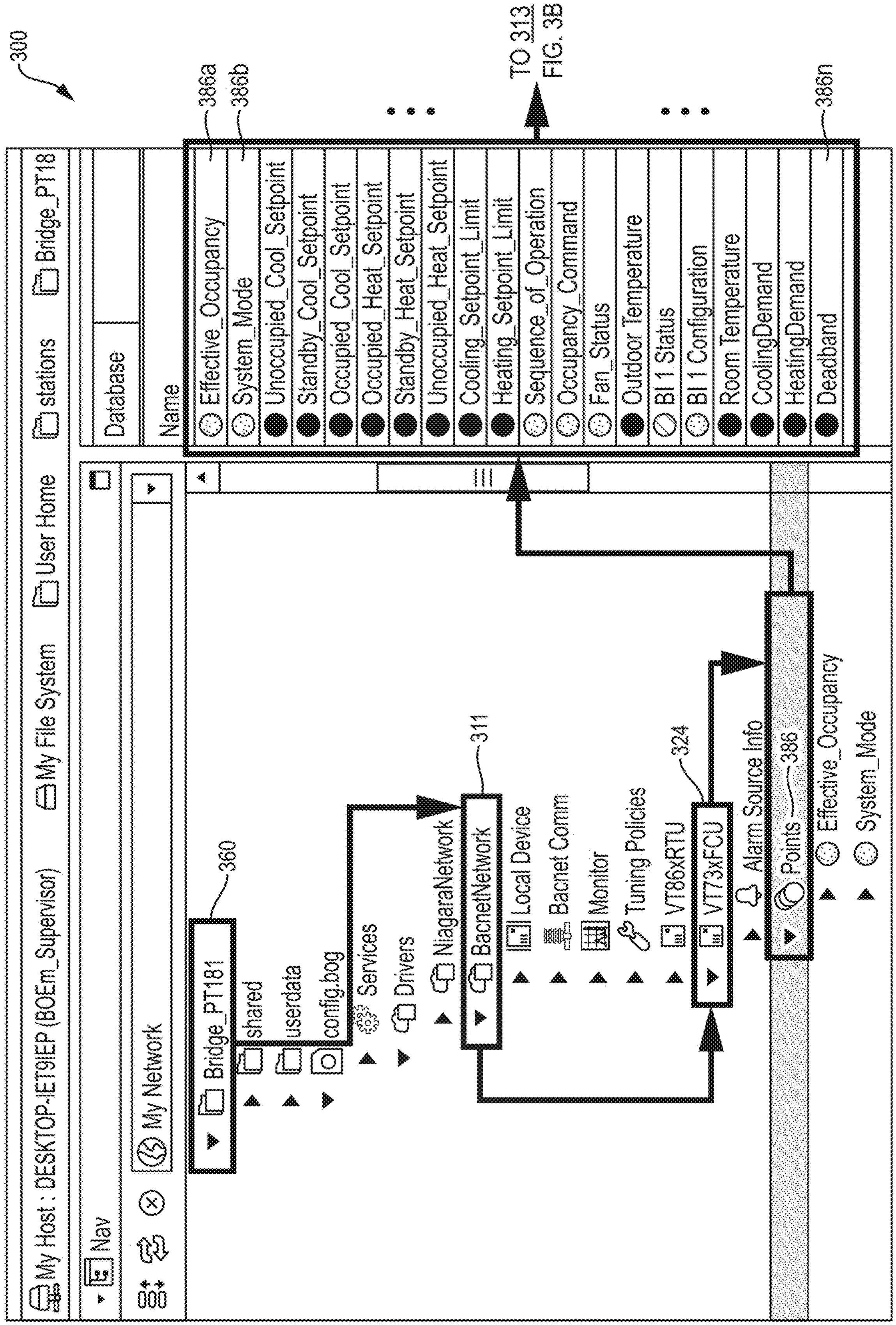

300
My Host : DESKTOP-IET9IEP (BOEm_Supervisor)
My File System
User Home
stations
Bridge_PT18
Nav
My Network
Database
Name
360
Bridge_PT181
shared
userdata
config.bog
Services
Drivers
NiagaraNetwork
311
BacnetNetwork
Local Device
Bacnet Comm
Monitor
Tuning Policies
VT86xRTU
324
VT73xFCU
Alarm Source Info
Points
386
Effective_Occupancy
System_Mode
386a
386b
Effective_Occupancy
System_Mode
Unoccupied_Cool_Setpoint
Standby_Cool_Setpoint
Occupied_Cool_Setpoint
Occupied_Heat_Setpoint
Standby_Heat_Setpoint
Unoccupied_Heat_Setpoint
Cooling_Setpoint_Limit
Heating_Setpoint_Limit
Sequence_of_Operation
Occupancy_Command
Fan_Status
Outdoor Temperature
BI 1 Status
BI 1 Configuration
Room Temperature
CoolingDemand
HeatingDemand
Deadband
386n
TO 313
FIG. 3B

FIG. 3A

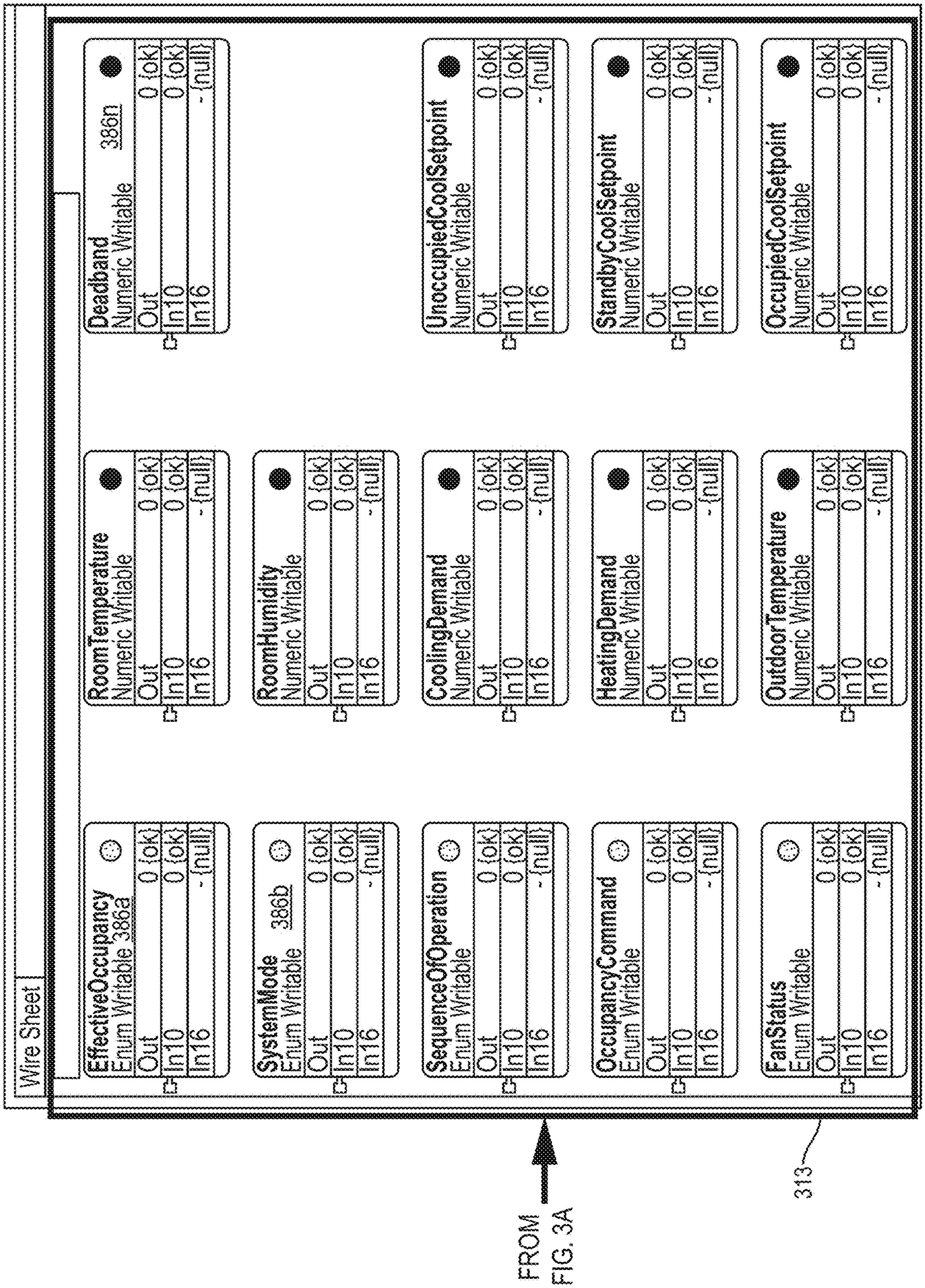

Wire Sheet
EffectiveOccupancy
Enum Writable 386a
SystemMode
Enum Writable 386b
SequenceOfOperation
Enum Writable
OccupancyCommand
Enum Writable
FanStatus
Enum Writable
RoomTemperature
Numeric Writable
RoomHumidity
Numeric Writable
CoolingDemand
Numeric Writable
HeatingDemand
Numeric Writable
OutdoorTemperature
Numeric Writable
Deadband
Numeric Writable 386n
UnoccupiedCoolSetpoint
Numeric Writable
StandbyCoolSetpoint
Numeric Writable
OccupiedCoolSetpoint
Numeric Writable
Out 0 {ok}
In10 0 {ok}
In16 - {null}
FROM FIG. 3A
313

FIG. 3B

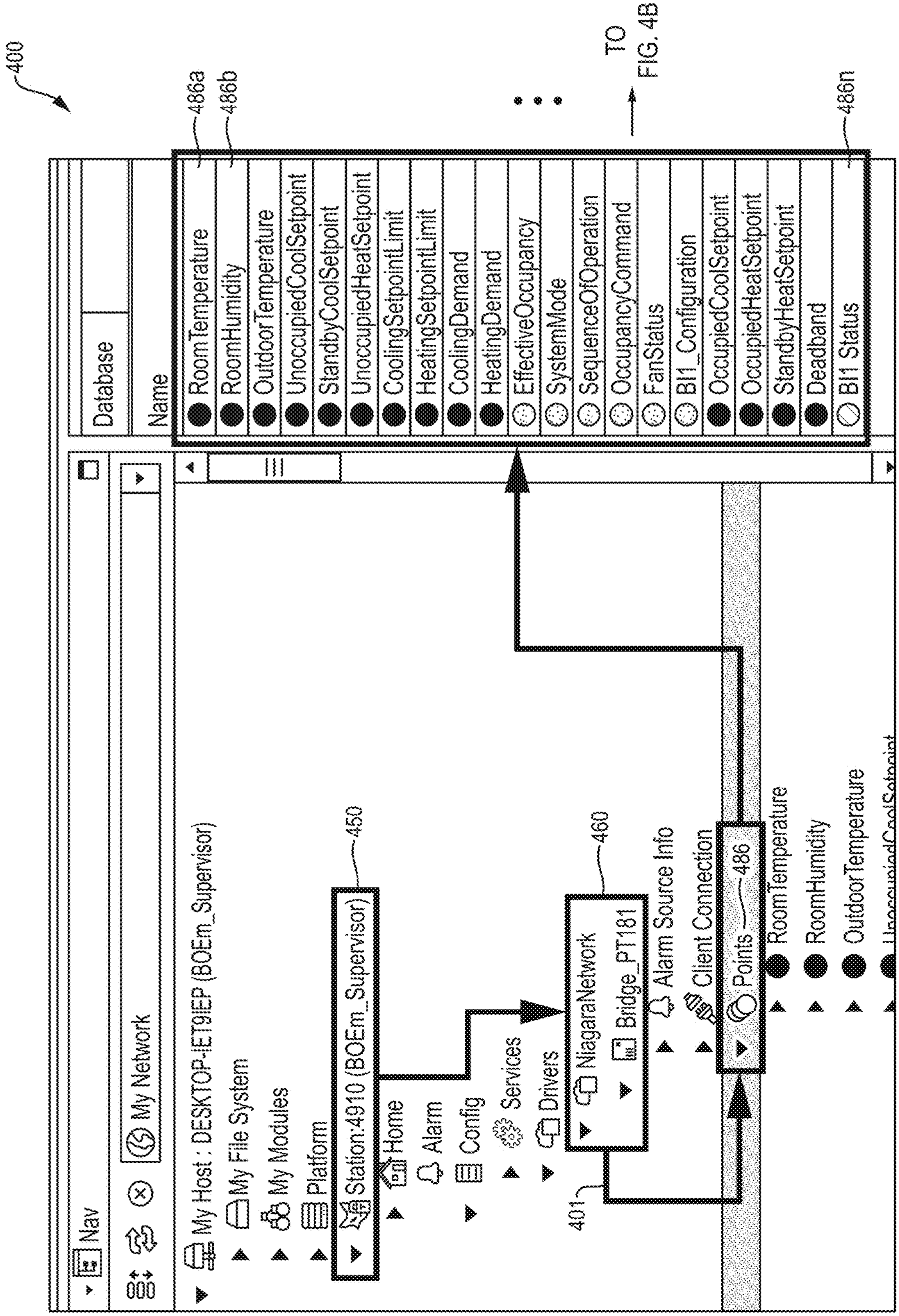

400
Nav
My Network
My Host : DESKTOP-IET9IEP (BOEm_Supervisor)
My File System
My Modules
Platform
Station:4910 (BOEm_Supervisor)
450
Home
Alarm
Config
Services
Drivers
NiagaraNetwork
460
Bridge_PT181
Alarm Source Info
Client Connection
Points
486
401
RoomTemperature
RoomHumidity
OutdoorTemperature
Database
Name
RoomTemperature
RoomHumidity
OutdoorTemperature
UnoccupiedCoolSetpoint
StandbyCoolSetpoint
UnoccupiedHeatSetpoint
CoolingSetpointLimit
HeatingSetpointLimit
CoolingDemand
HeatingDemand
EffectiveOccupancy
SystemMode
SequenceOfOperation
OccupancyCommand
FanStatus
BI1_Configuration
OccupiedCoolSetpoint
OccupiedHeatSetpoint
StandbyHeatSetpoint
Deadband
BI1 Status
486a
486b
486n
TO FIG. 4B

FIG. 4A

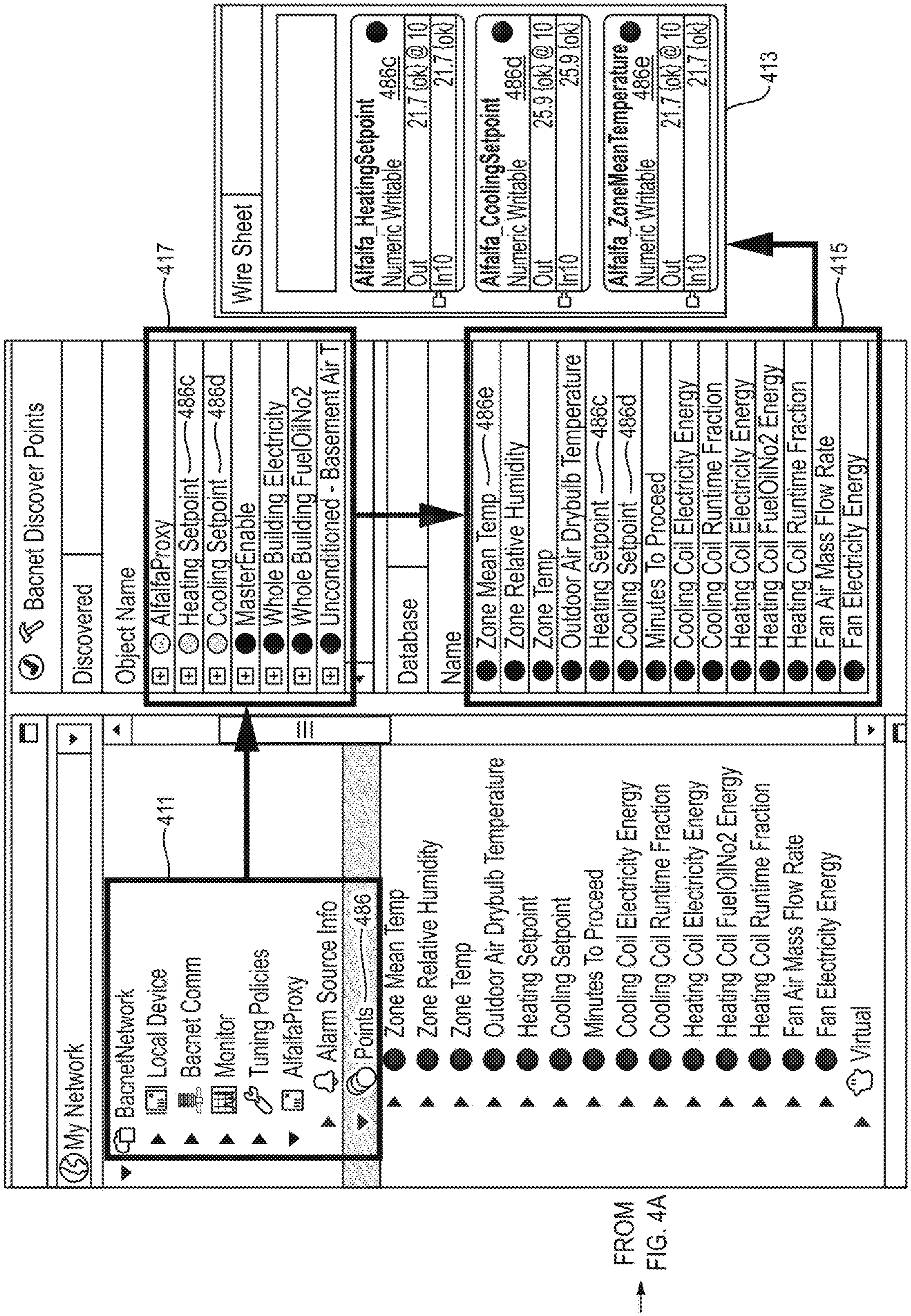

FROM FIG. 4A
My Network
BacnetNetwork
Local Device
Bacnet Comm
Monitor
Tuning Policies
AlfalfaProxy
Alarm Source Info
Points
486
411
Zone Mean Temp
Zone Relative Humidity
Zone Temp
Outdoor Air Drybulb Temperature
Heating Setpoint
Cooling Setpoint
Minutes To Proceed
Cooling Coil Electricity Energy
Cooling Coil Runtime Fraction
Heating Coil Electricity Energy
Heating Coil FuelOilNo2 Energy
Heating Coil Runtime Fraction
Fan Air Mass Flow Rate
Fan Electricity Energy
Virtual
Bacnet Discover Points
Discovered
Object Name
AlfalfaProxy
Heating Setpoint
486c
Cooling Setpoint
486d
MasterEnable
Whole Building Electricity
Whole Building FuelOilNo2
Unconditioned - Basement Air T
417
Database
Name
Zone Mean Temp
486e
Zone Relative Humidity
Zone Temp
Outdoor Air Drybulb Temperature
Heating Setpoint
486c
Cooling Setpoint
486d
Minutes To Proceed
Cooling Coil Electricity Energy
Cooling Coil Runtime Fraction
Heating Coil Electricity Energy
Heating Coil FuelOilNo2 Energy
Heating Coil Runtime Fraction
Fan Air Mass Flow Rate
Fan Electricity Energy
415
Wire Sheet
Alfalfa_HeatingSetpoint
Numeric Writable
486c
Out 21.7 {ok} @ 10
In10 21.7 {ok}
Alfalfa_CoolingSetpoint
Numeric Writable
486d
Out 25.9 {ok} @ 10
In10 25.9 {ok}
Alfalfa_ZoneMeanTemperature
Numeric Writable
486e
Out 21.7 {ok} @ 10
In10 21.7 {ok}
413

FIG. 4B

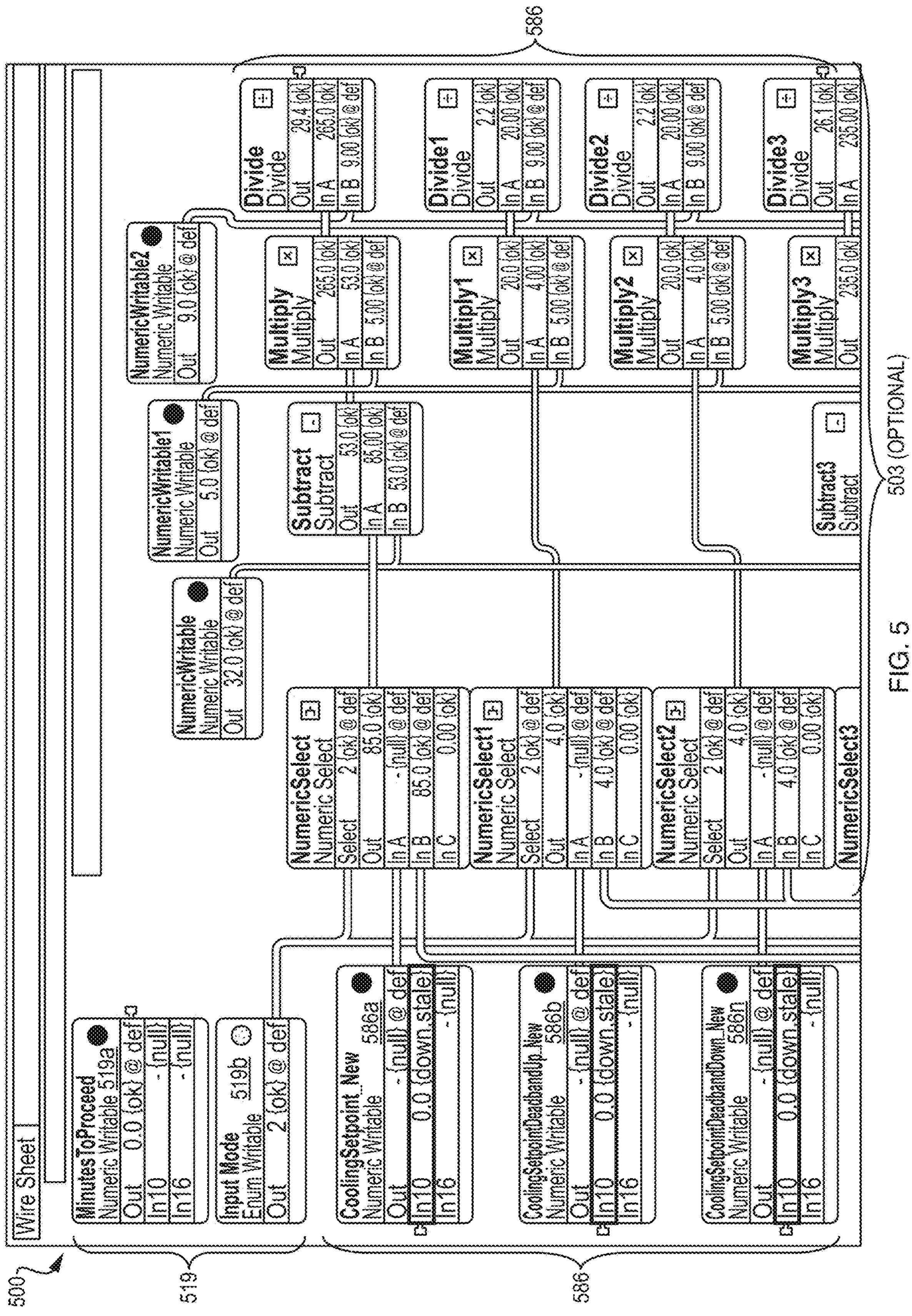

500
Wire Sheet
519
MinutesToProceed
Numeric Writable 519a
Out 0.0 {ok} @ def
In10 - {null}
In16 - {null}
Input Mode 519b
Enum Writable
Out 2 {ok} @ def
586
CoolingSetpoint_New 586a
Numeric Writable
Out - {null} @ def
In10 0.0 {down,stale}
In16 - {null}
CoolingSetpointDeadbandUp_New 586b
Numeric Writable
Out - {null} @ def
In10 0.0 {down,stale}
In16 - {null}
CoolingSetpointDeadbandDown_New 586n
Numeric Writable
Out - {null} @ def
In10 0.0 {down,stale}
In16 - {null}
NumericSelect
Numeric Select
Select 2 {ok} @ def
Out 85.0 {ok}
In A - {null} @ def
In B 85.0 {ok} @ def
In C 0.00 {ok}
NumericSelect1
Numeric Select
Select 2 {ok} @ def
Out 4.0 {ok}
In A - {null} @ def
In B 4.0 {ok} @ def
In C 0.00 {ok}
NumericSelect2
Numeric Select
Select 2 {ok} @ def
Out 4.0 {ok}
In A - {null} @ def
In B 4.0 {ok} @ def
In C 0.00 {ok}
NumericSelect3
NumericWritable
Numeric Writable
Out 32.0 {ok} @ def
NumericWritable1
Numeric Writable
Out 5.0 {ok} @ def
NumericWritable2
Numeric Writable
Out 9.0 {ok} @ def
Subtract
Subtract
Out 53.0 {ok}
In A 85.00 {ok}
In B 53.0 {ok} @ def
Subtract3
Subtract
503 (OPTIONAL)
Multiply
Multiply
Out 265.0 {ok}
In A 53.0 {ok}
In B 5.00 {ok} @ def
Multiply1
Multiply
Out 20.0 {ok}
In A 4.00 {ok}
In B 5.00 {ok} @ def
Multiply2
Multiply
Out 20.0 {ok}
In A 4.0 {ok}
In B 5.00 {ok} @ def
Multiply3
Multiply
Out 235.0 {ok}
Divide
Divide
Out 29.4 {ok}
In A 265.0 {ok}
In B 9.00 {ok} @ def
Divide1
Divide
Out 2.2 {ok}
In A 20.00 {ok}
In B 9.00 {ok} @ def
Divide2
Divide
Out 2.2 {ok}
In A 20.00 {ok}
In B 9.00 {ok} @ def
Divide3
Divide
Out 26.1 {ok}
In A 235.00 {ok}
586

FIG. 5

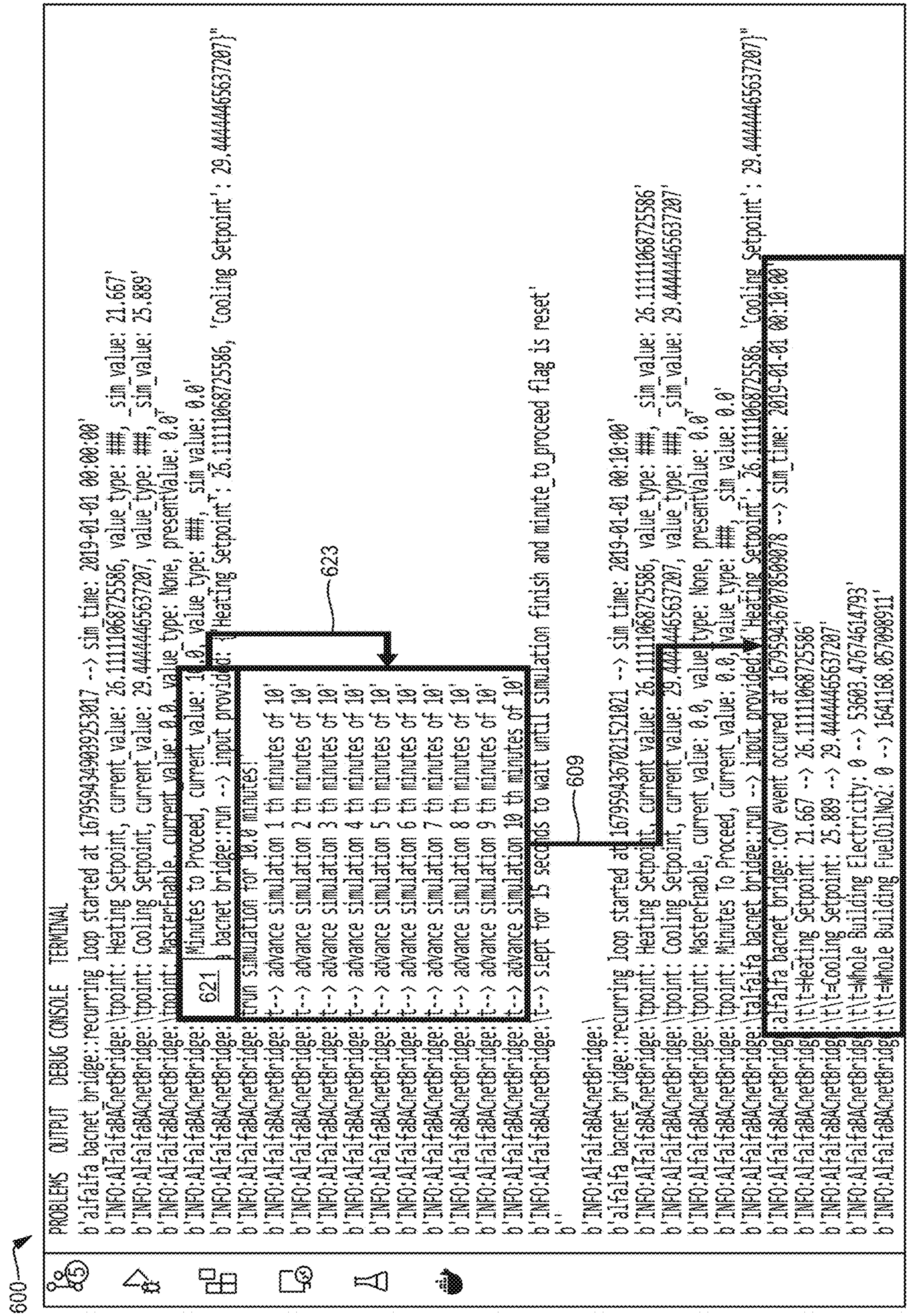

600
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
b'alfalfa bacnet_bridge::recurring loop started at 1679594349039253017 --> sim time: 2019-01-01 00:00:00'
b'INFO:AlfalfaBACnetBridge:\tpoint: Heating Setpoint, current_value: 26.11111068725586, value_type: ###, _sim_value: 21.667'
b'INFO:AlfalfaBACnetBridge:\tpoint: Cooling Setpoint, current_value: 29.444444465637207, value_type: ###, _sim_value: 25.889'
b'INFO:AlfalfaBACnetBridge:\tpoint: MasterEnable, current_value: 0.0, value_type: None, presentValue: 0.0'
b'INFO:AlfalfaBACnetBridge:\tpoint: Minutes to Proceed, current_value: 10.0, value_type: ###, _sim_value: 0.0'
b'INFO:AlfalfaBACnetBridge:\talfalfa bacnet bridge::run --> input provided: {'Heating Setpoint': 26.11111068725586, 'Cooling Setpoint': 29.444444465637207}"
b'INFO:AlfalfaBACnetBridge:\trun simulation for 10.0 minutes!'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 1 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 2 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 3 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 4 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 5 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 6 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 7 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 8 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 9 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> advance simulation 10 th minutes of 10'
b'INFO:AlfalfaBACnetBridge:\t--> slept for 15 seconds to wait until simulation finish and minute_to_proceed flag is reset'
b''
b'INFO:AlfalfaBACnetBridge:\'
b'alfalfa bacnet bridge::recurring loop started at 1679594367021521021 --> sim time: 2019-01-01 00:10:00'
b'INFO:AlfalfaBACnetBridge:\tpoint: Heating Setpoint, current_value: 26.11111068725586, value_type: ###, _sim_value: 26.11111068725586'
b'INFO:AlfalfaBACnetBridge:\tpoint: Cooling Setpoint, current_value: 29.444444465637207, value_type: ###, _sim_value: 29.444444465637207'
b'INFO:AlfalfaBACnetBridge:\tpoint: MasterEnable, current_value: 0.0, value_type: None, presentValue: 0.0'
b'INFO:AlfalfaBACnetBridge:\tpoint: Minutes To Proceed, current_value: 0.0, value_type: ###, _sim_value: 0.0'
b'INFO:AlfalfaBACnetBridge:\talfalfa bacnet bridge::run --> input provided: {'Heating Setpoint': 26.11111068725586, 'Cooling Setpoint': 29.444444465637207}"
b'INFO:AlfalfaBACnetBridge:\talfalfa bacnet_bridge::CoV event occured at 1679594367078509878 --> sim time: 2019-01-01 00:10:00'
b'INFO:AlfalfaBACnetBridge:\t\t-Heating Setpoint: 21.667 --> 26.11111068725586'
b'INFO:AlfalfaBACnetBridge:\t\t-Cooling Setpoint: 25.889 --> 29.444444465637207'
b'INFO:AlfalfaBACnetBridge:\t\t-Whole Building Electricity: 0 --> 53603.47674614793'
b'INFO:AlfalfaBACnetBridge:\t\t-Whole Building FuelOilNo2: 0 --> 1641168.057098911'
621
623
609

FIG. 6

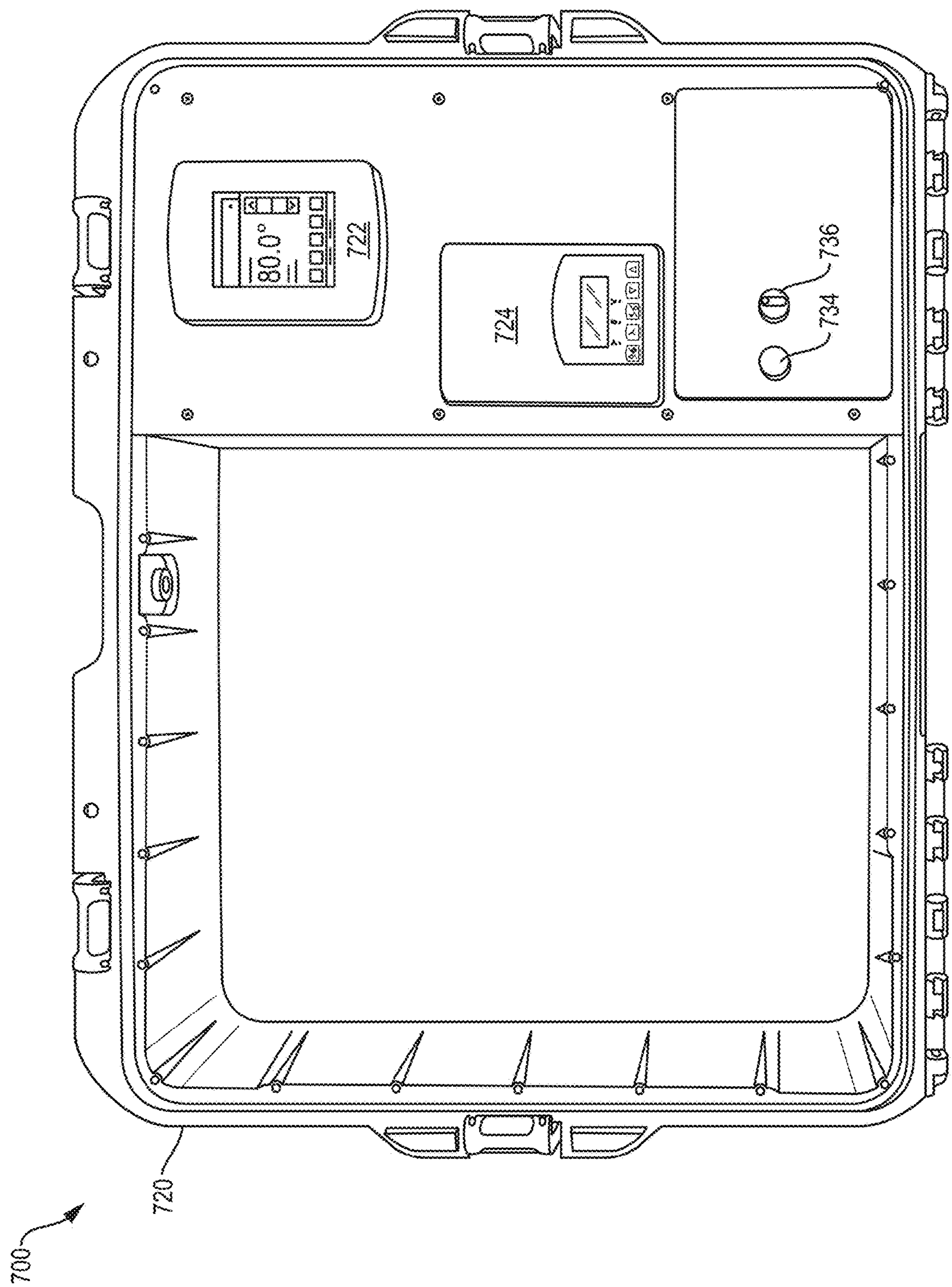


FIG. 7

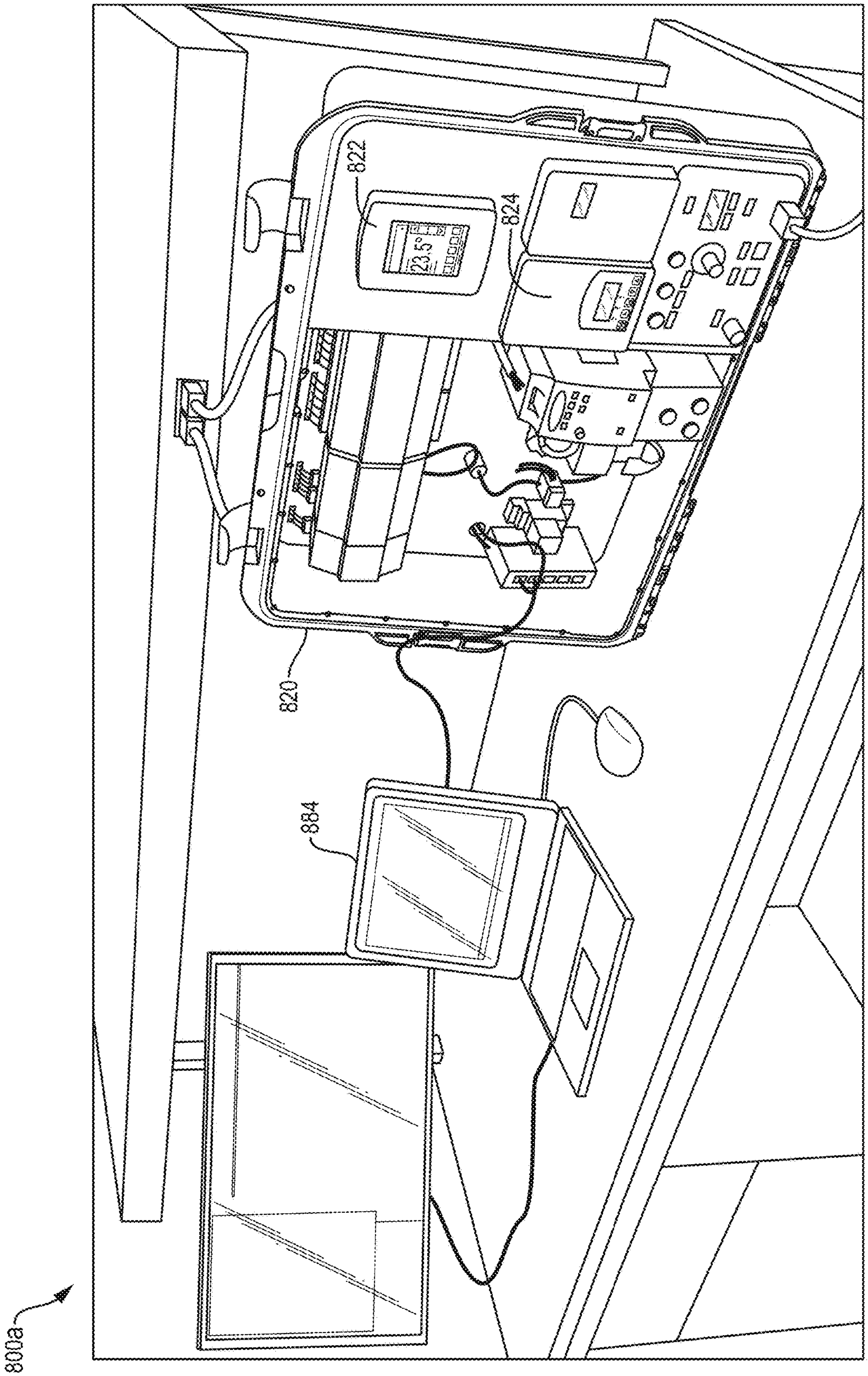


FIG. 8A

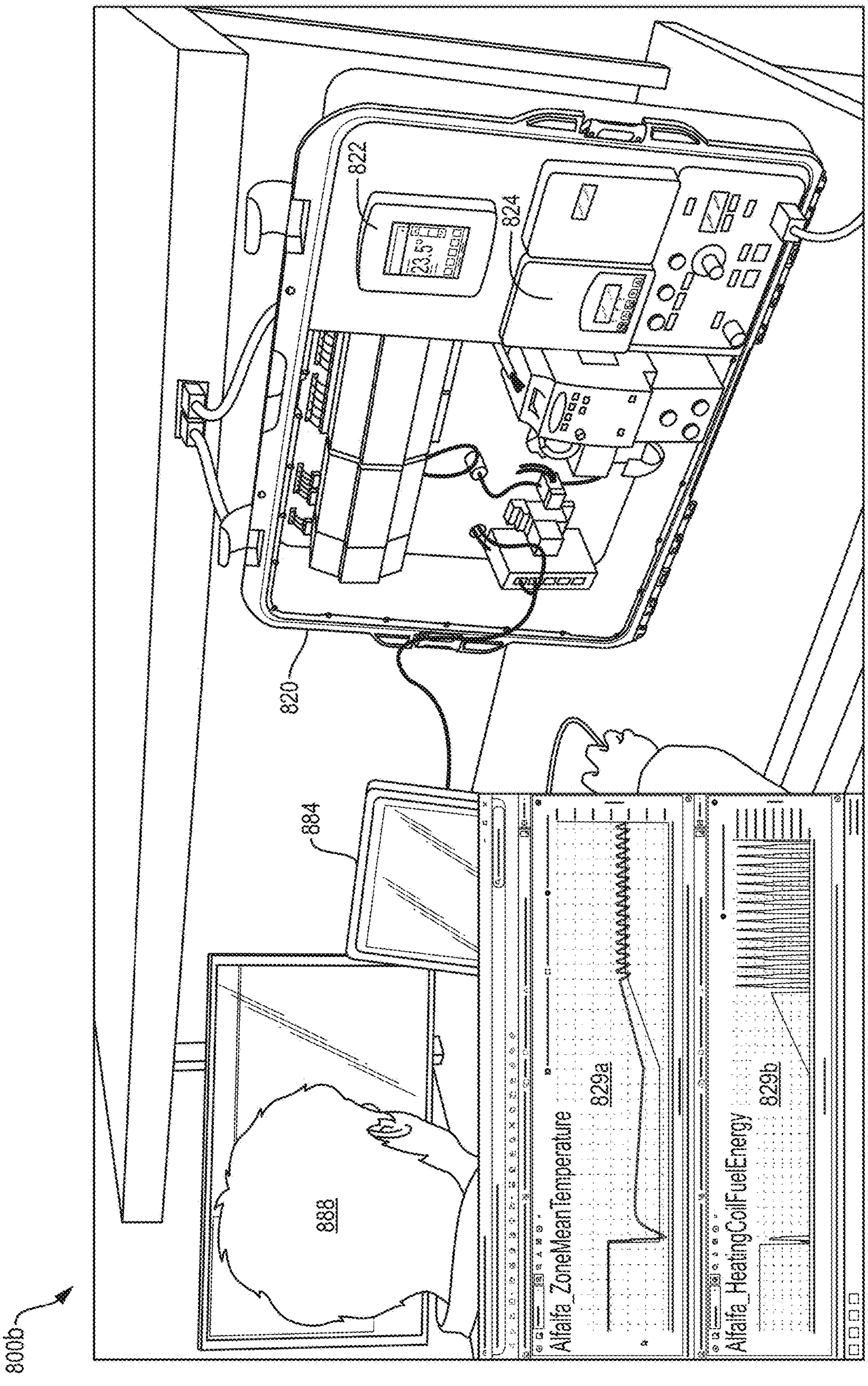

800b
822
23.5°
824
820
884
888
829a
Alfalfa_ZoneMeanTemperature
829b
Alfalfa_HeatingCoilFuelEnergy

FIG. 8B

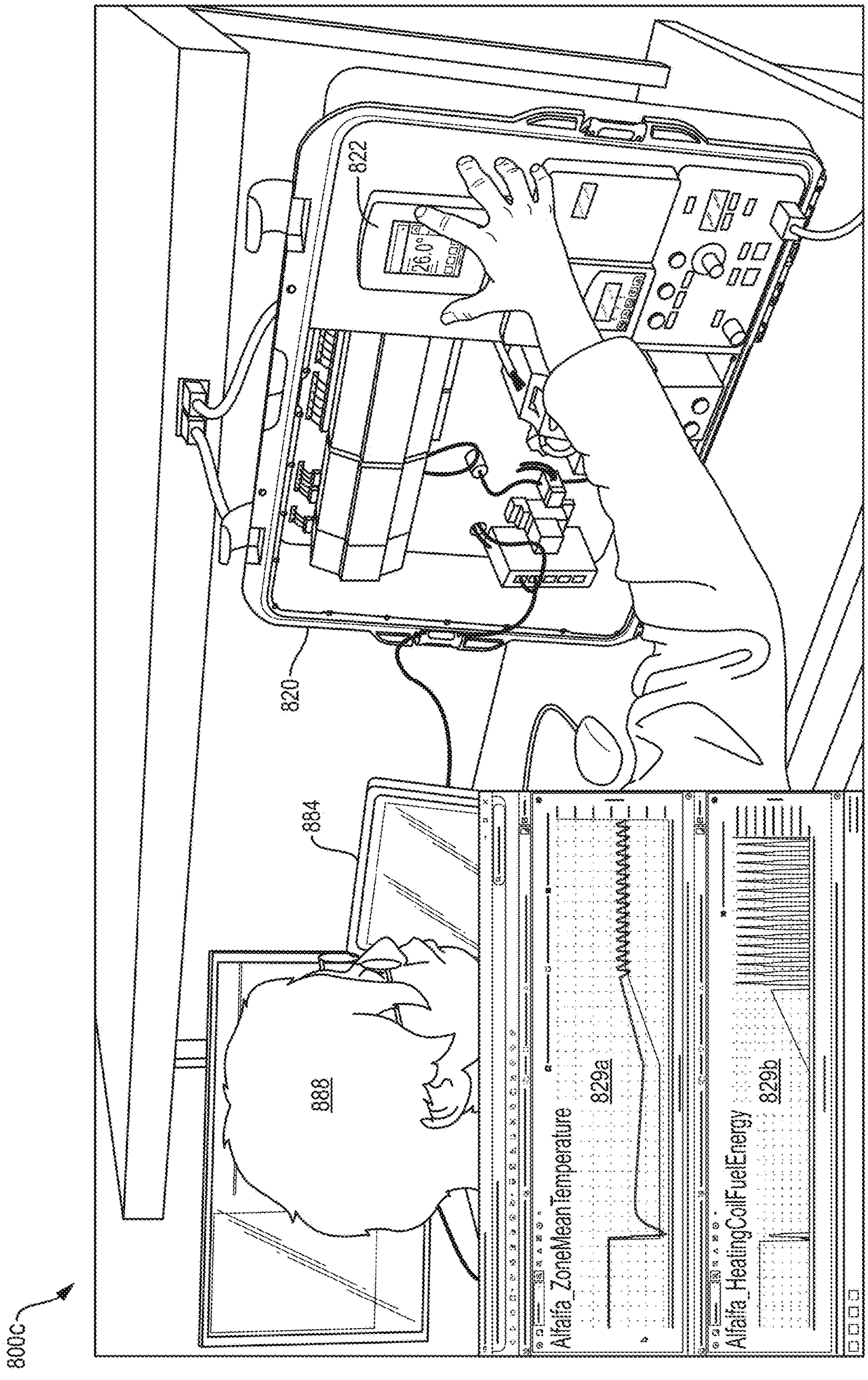
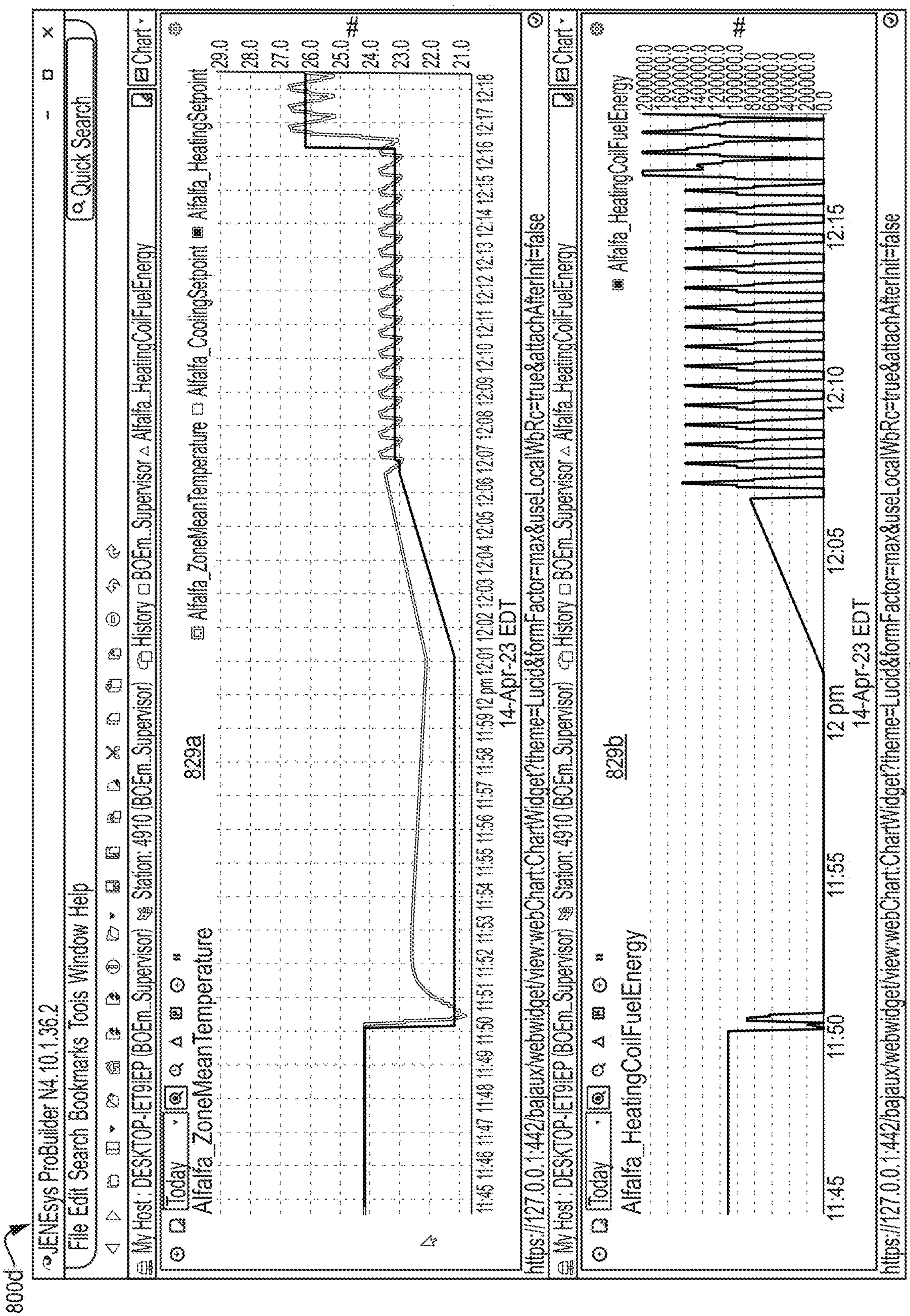

800C
820
822
26.0°
884
888
Alfalfa_ZoneMeanTemperature
829a
Alfalfa_HeatingCoilFuelEnergy
829b

FIG. 8C


800d
JENEsys ProBuilder N4.10.1.36.2
File Edit Search Bookmarks Tools Window Help
Quick Search
My Host : DESKTOP-IET9IEP (BOEm..Supervisor) Station: 4910 (BOEm..Supervisor) History BOEm..Supervisor Alfalfa..HeatingCoilFuelEnergy
Today
Alfalfa_ZoneMeanTemperature
829a
Alfalfa_ZoneMeanTemperature Alfalfa_CoolingSetpoint Alfalfa_HeatingSetpoint
14-Apr-23 EDT
https://127.0.0.1:442/bajaux/webwidget/view:webChart:ChartWidget?theme=Lucid&formFactor=max&useLocalWbRc=true&attachAfterInit=false
Alfalfa_HeatingCoilFuelEnergy
829b
Alfalfa_HeatingCoilFuelEnergy
11:45
11:50
11:55
12 pm
12:05
12:10
12:15
14-Apr-23 EDT
FIG. 8D

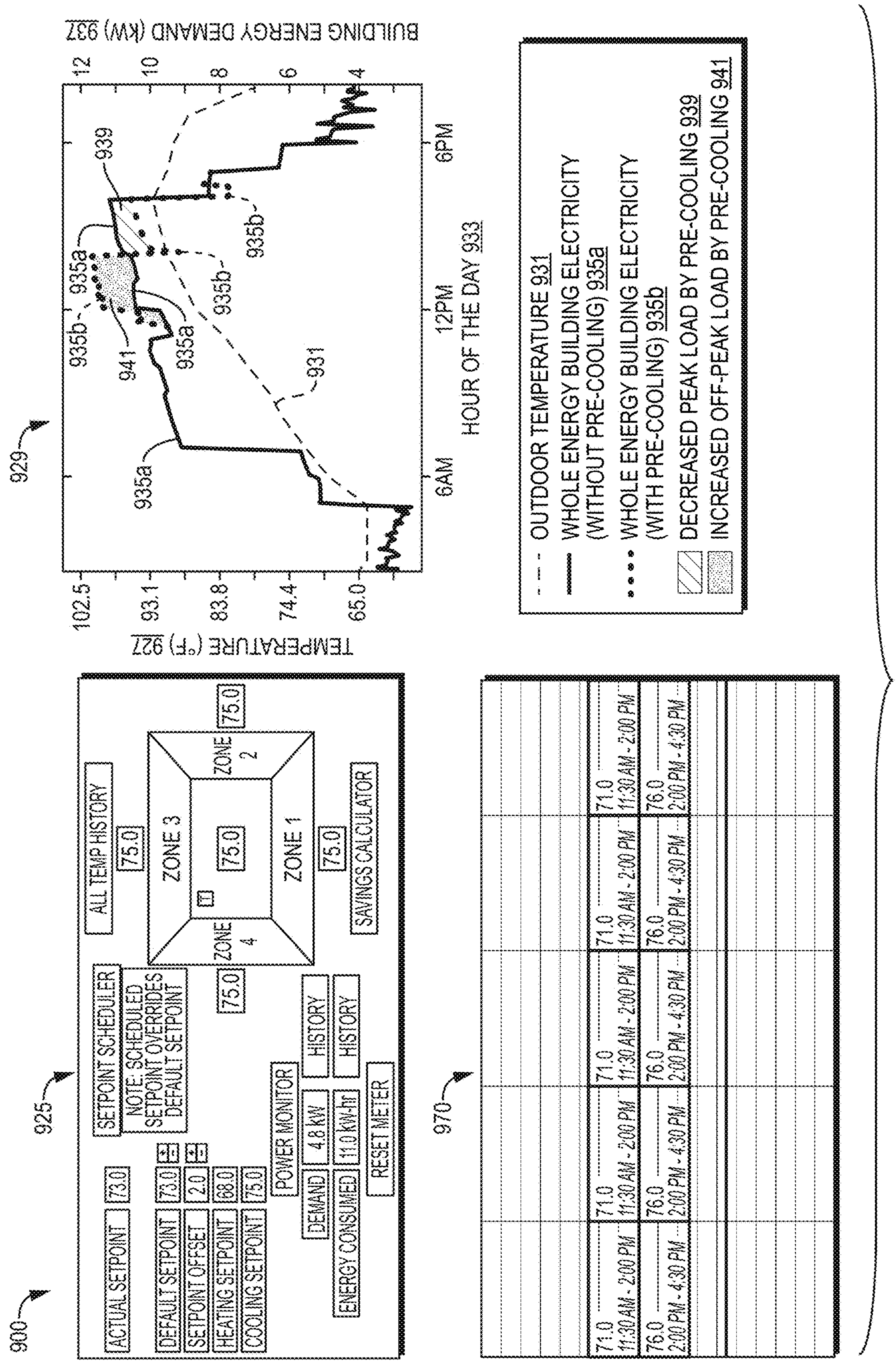

900
925
ACTUAL SETPOINT
73.0
DEFAULT SETPOINT
73.0
SETPOINT OFFSET
2.0
HEATING SETPOINT
68.0
COOLING SETPOINT
75.0
SETPOINT SCHEDULER
NOTE: SCHEDULED SETPOINT OVERRIDES DEFAULT SETPOINT
POWER MONITOR
DEMAND
4.8 kW
ENERGY CONSUMED
11.0 kW-hr
RESET METER
HISTORY
HISTORY
ALL TEMP HISTORY
75.0
ZONE 3
ZONE 4
ZONE 2
ZONE 1
75.0
75.0
75.0
75.0
SAVINGS CALCULATOR
970
71.0
11:30 AM - 2:00 PM
76.0
2:00 PM - 4:30 PM
929
TEMPERATURE (°F) 927
102.5
93.1
83.8
74.4
65.0
BUILDING ENERGY DEMAND (kW) 932
12
10
8
6
4
6AM
12PM
6PM
HOUR OF THE DAY 933
931
935a
935b
939
941
OUTDOOR TEMPERATURE 931
WHOLE ENERGY BUILDING ELECTRICITY (WITHOUT PRE-COOLING) 935a
WHOLE ENERGY BUILDING ELECTRICITY (WITH PRE-COOLING) 935b
DECREASED PEAK LOAD BY PRE-COOLING 939
INCREASED OFF-PEAK LOAD BY PRE-COOLING 941

FIG. 9

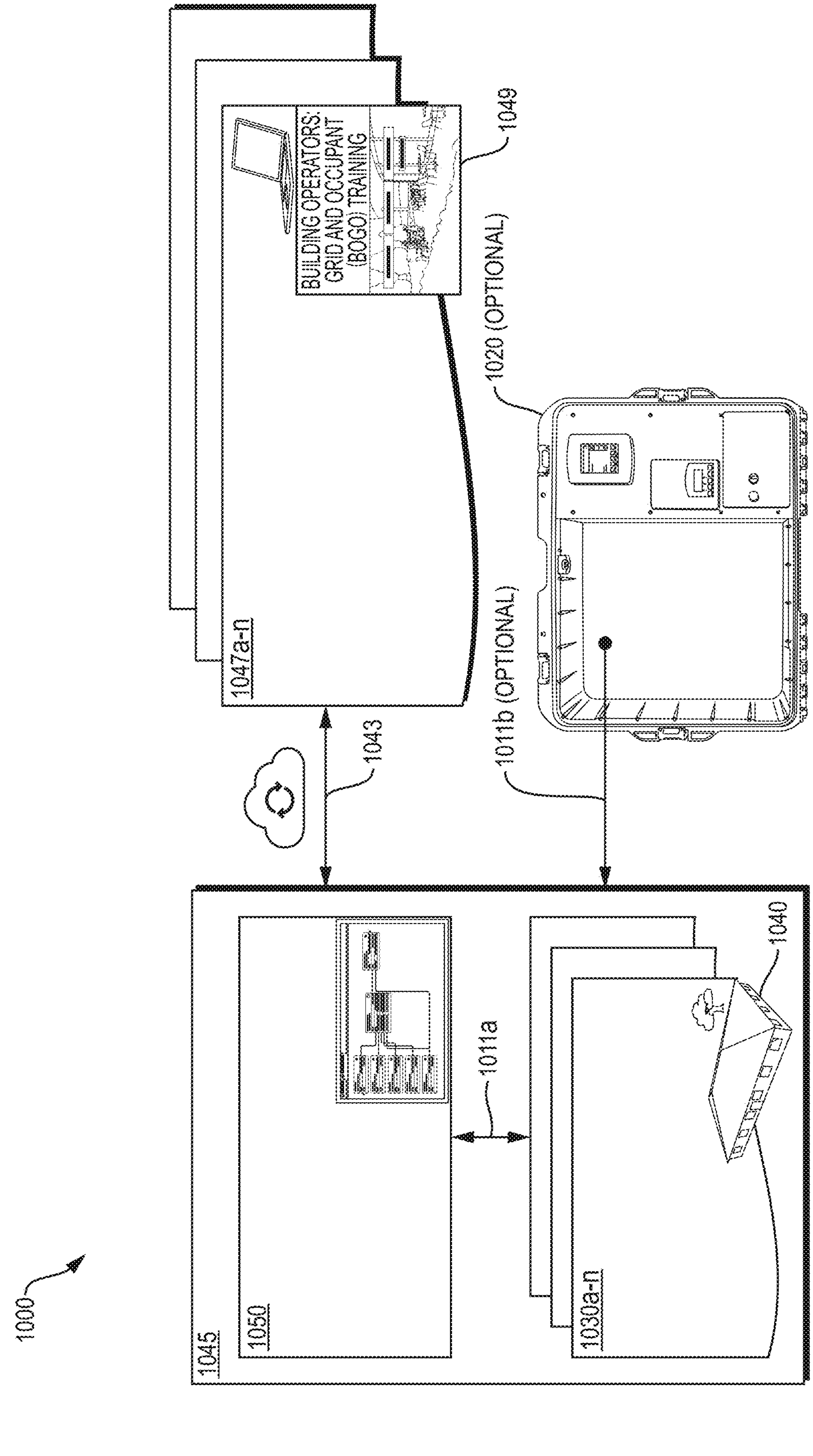

1000
1045
1050
1011a
1030a-n
1040
1043
1011b (OPTIONAL)
1020 (OPTIONAL)
1047a-n
1049
BUILDING OPERATORS: GRID AND OCCUPANT (BOGO) TRAINING

FIG. 10

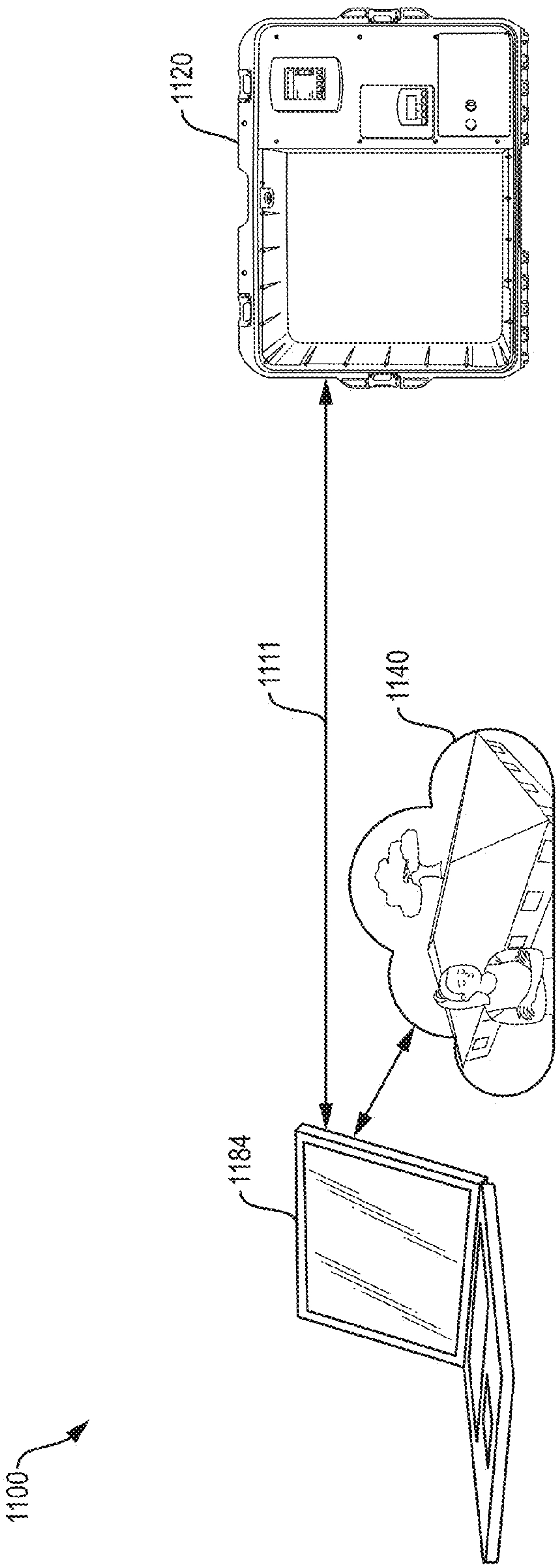


FIG. 11

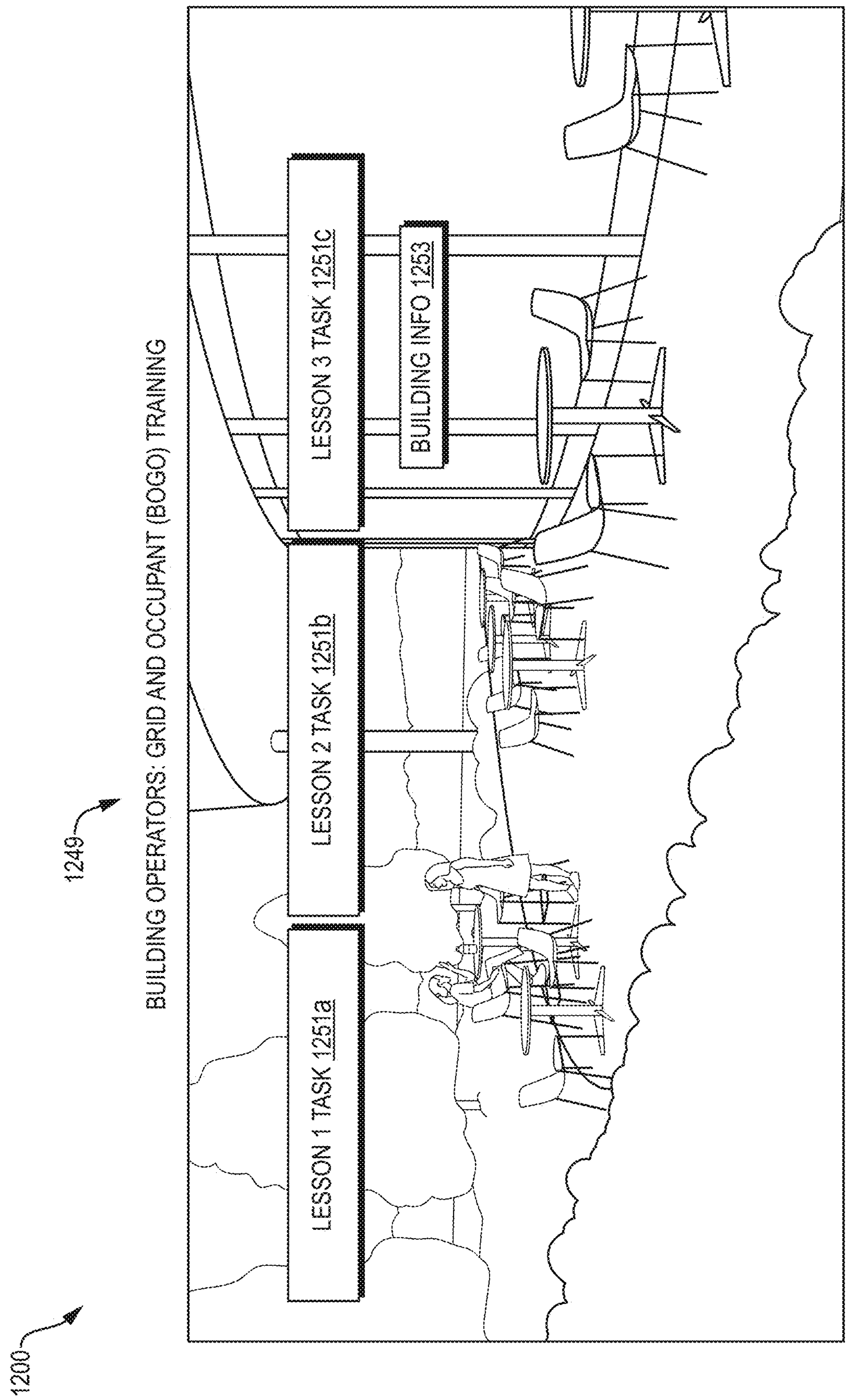

1200
1249
BUILDING OPERATORS: GRID AND OCCUPANT (BOGO) TRAINING
LESSON 1 TASK 1251a
LESSON 2 TASK 1251b
LESSON 3 TASK 1251c
BUILDING INFO 1253

FIG. 12

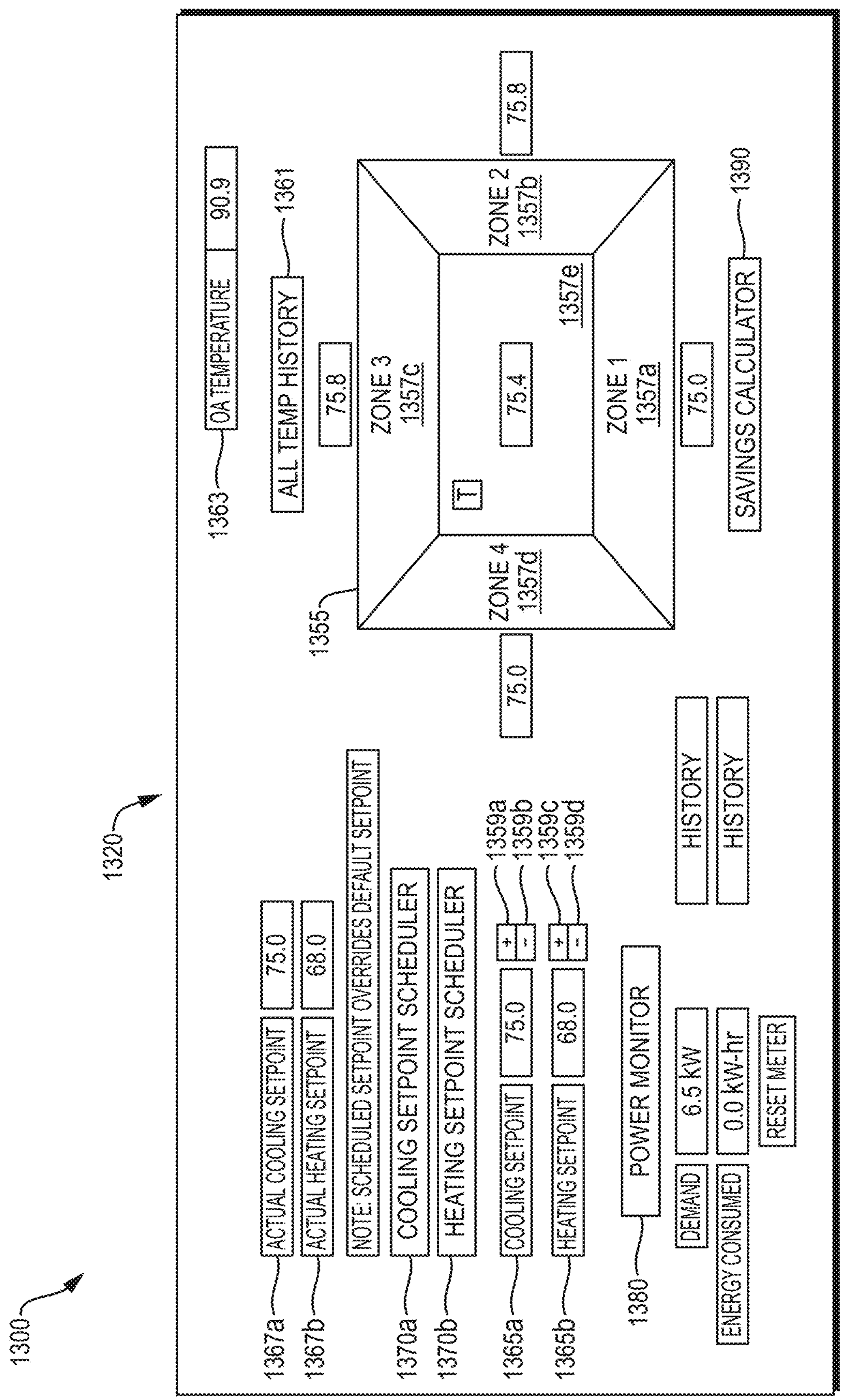

1300
1320
1363
OA TEMPERATURE
90.9
ALL TEMP HISTORY
1361
75.8
75.8
ZONE 3
1357c
75.4
ZONE 1
1357a
75.0
ZONE 2
1357b
1357e
ZONE 4
1357d
T
1355
75.0
SAVINGS CALCULATOR
1390
1367a
ACTUAL COOLING SETPOINT
75.0
1367b
ACTUAL HEATING SETPOINT
68.0
NOTE: SCHEDULED SETPOINT OVERRIDES DEFAULT SETPOINT
1370a
COOLING SETPOINT SCHEDULER
1370b
HEATING SETPOINT SCHEDULER
1365a
COOLING SETPOINT
75.0
1365b
HEATING SETPOINT
68.0
+
-
1359a
1359b
1359c
1359d
HISTORY
HISTORY
1380
POWER MONITOR
DEMAND
6.5 kW
ENERGY CONSUMED
0.0 kW-hr
RESET METER

FIG. 13

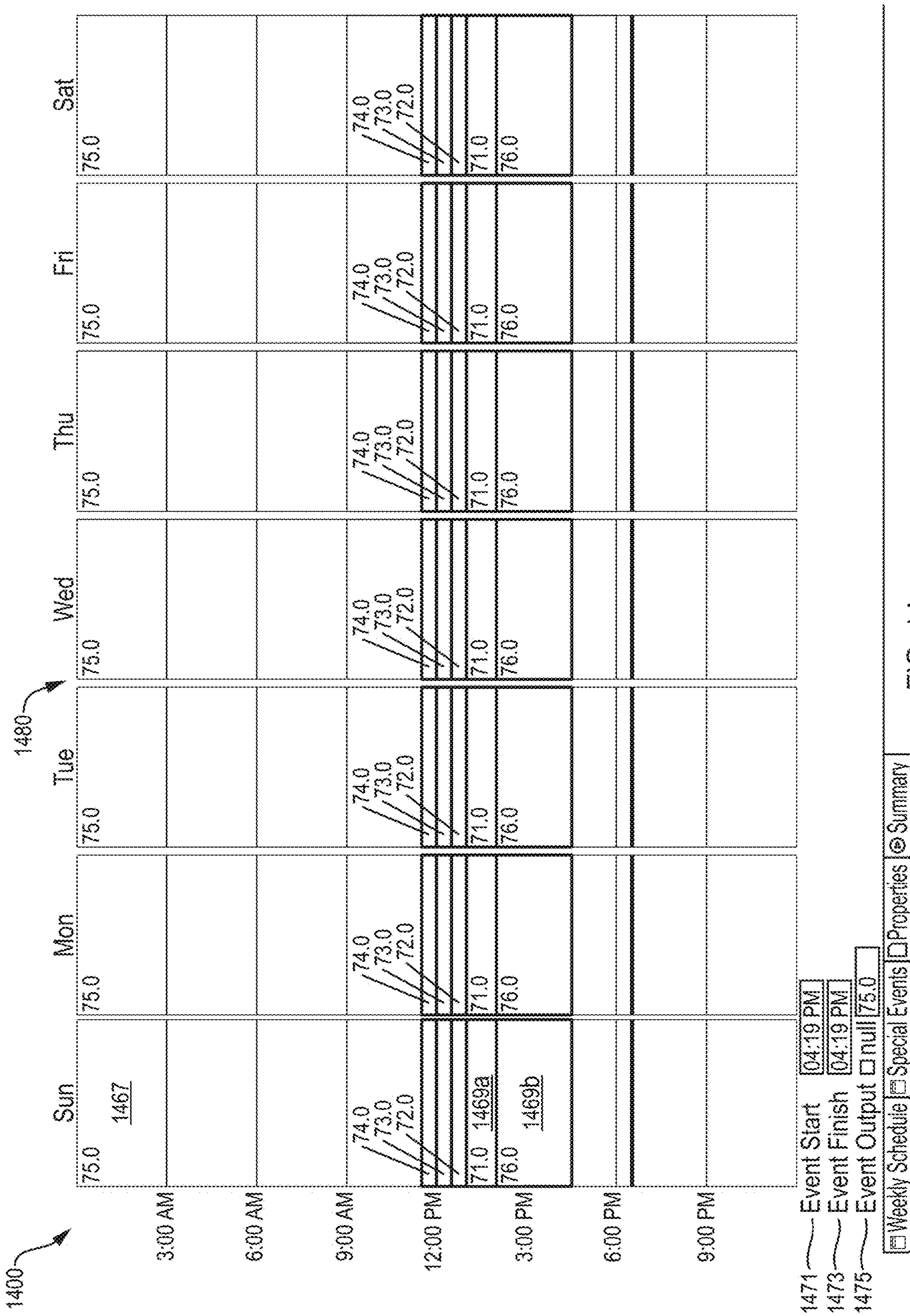

1400
1480
Sun
Mon
Tue
Wed
Thu
Fri
Sat
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
1467
1469a
1469b
75.0
74.0
73.0
72.0
71.0
76.0
1471 Event Start 04:19 PM
1473 Event Finish 04:19 PM
1475 Event Output null 75.0
Weekly Schedule
Special Events
Properties
Summary

FIG. 14

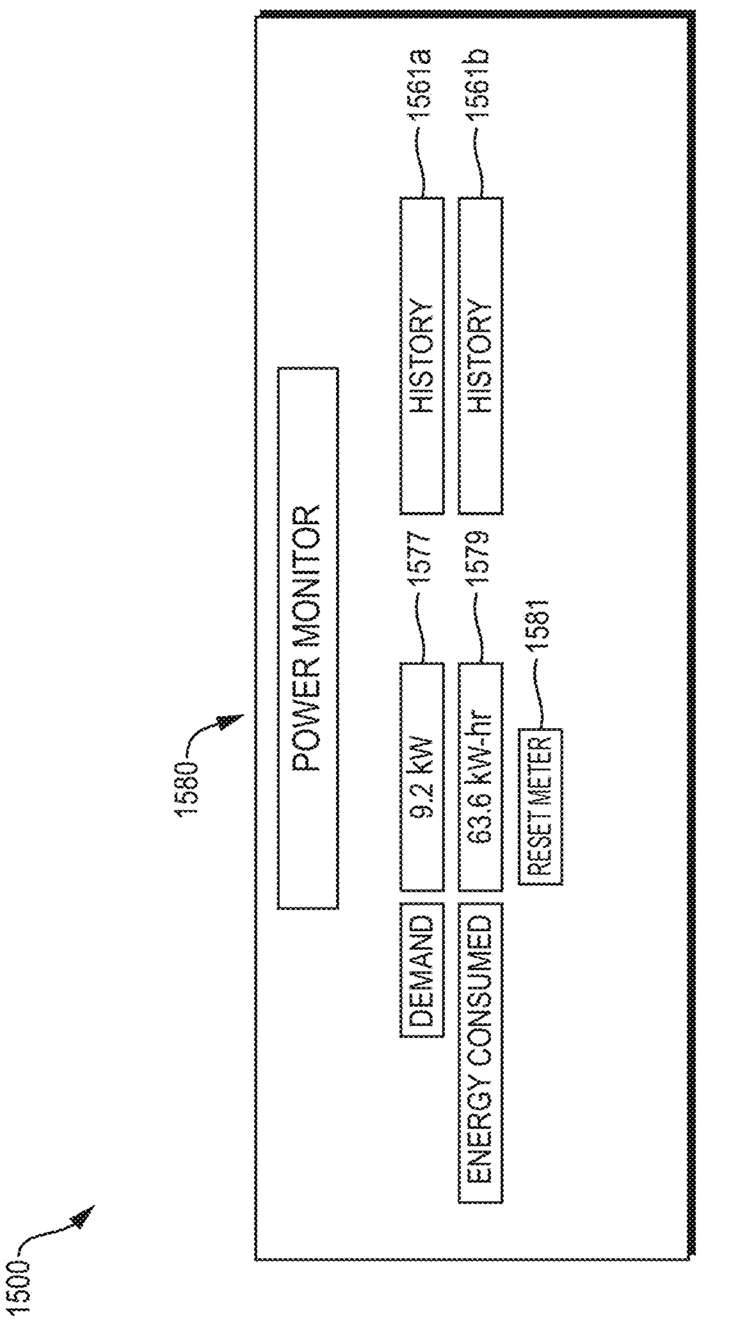

1500
1580
POWER MONITOR
DEMAND
9.2 kW
1577
HISTORY
1561a
ENERGY CONSUMED
63.6 kW-hr
1579
HISTORY
1561b
RESET METER
1581

FIG. 15

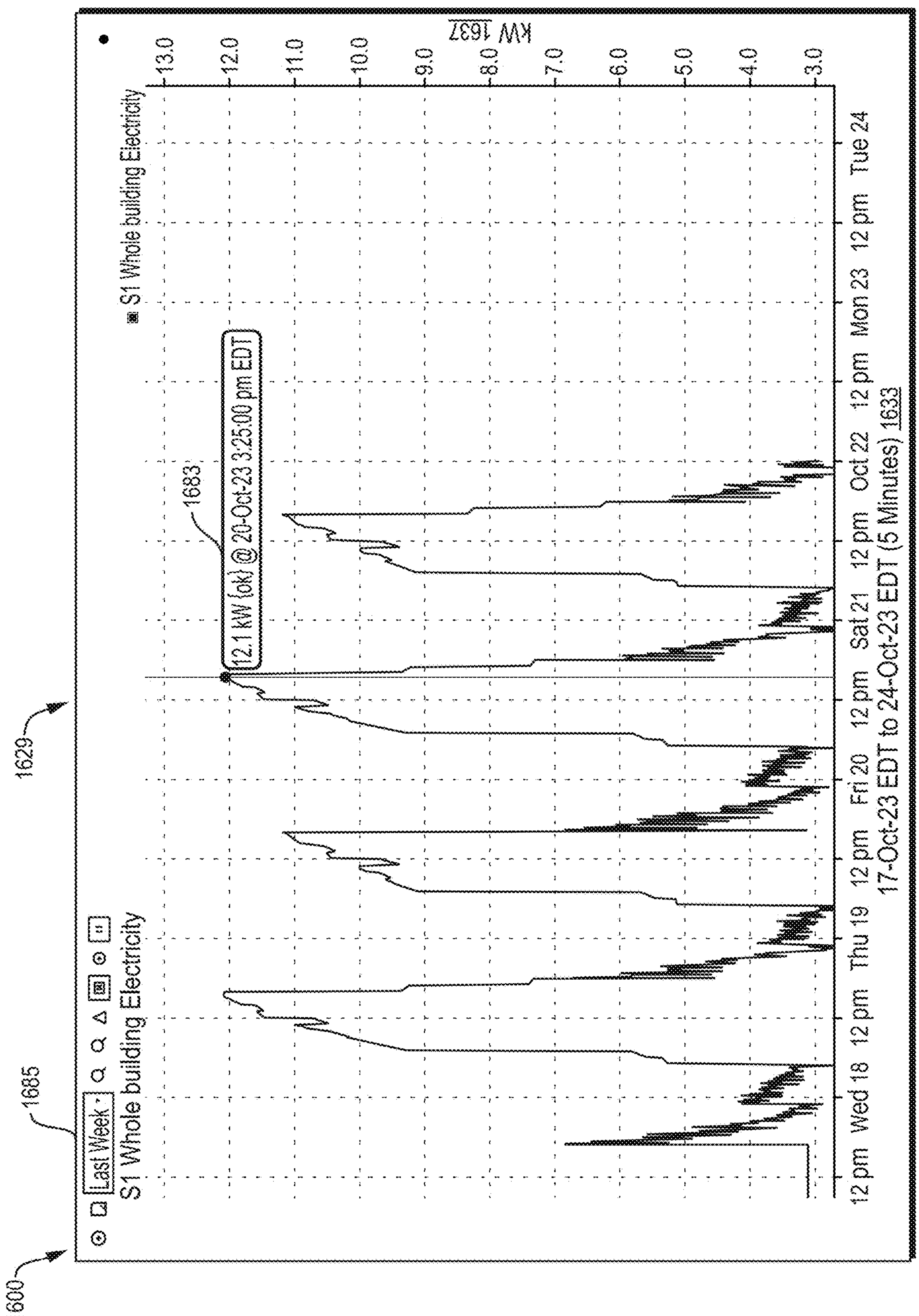

1600
1629
1685
1683
Last Week
S1 Whole building Electricity
S1 Whole building Electricity
12.1 kW {ok} @ 20-Oct-23 3:25:00 pm EDT
kW 1637
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
12 pm
Wed 18
12 pm
Thu 19
12 pm
Fri 20
12 pm
Sat 21
12 pm
Oct 22
12 pm
Mon 23
12 pm
Tue 24
17-Oct-23 EDT to 24-Oct-23 EDT (5 Minutes) 1633

FIG. 16

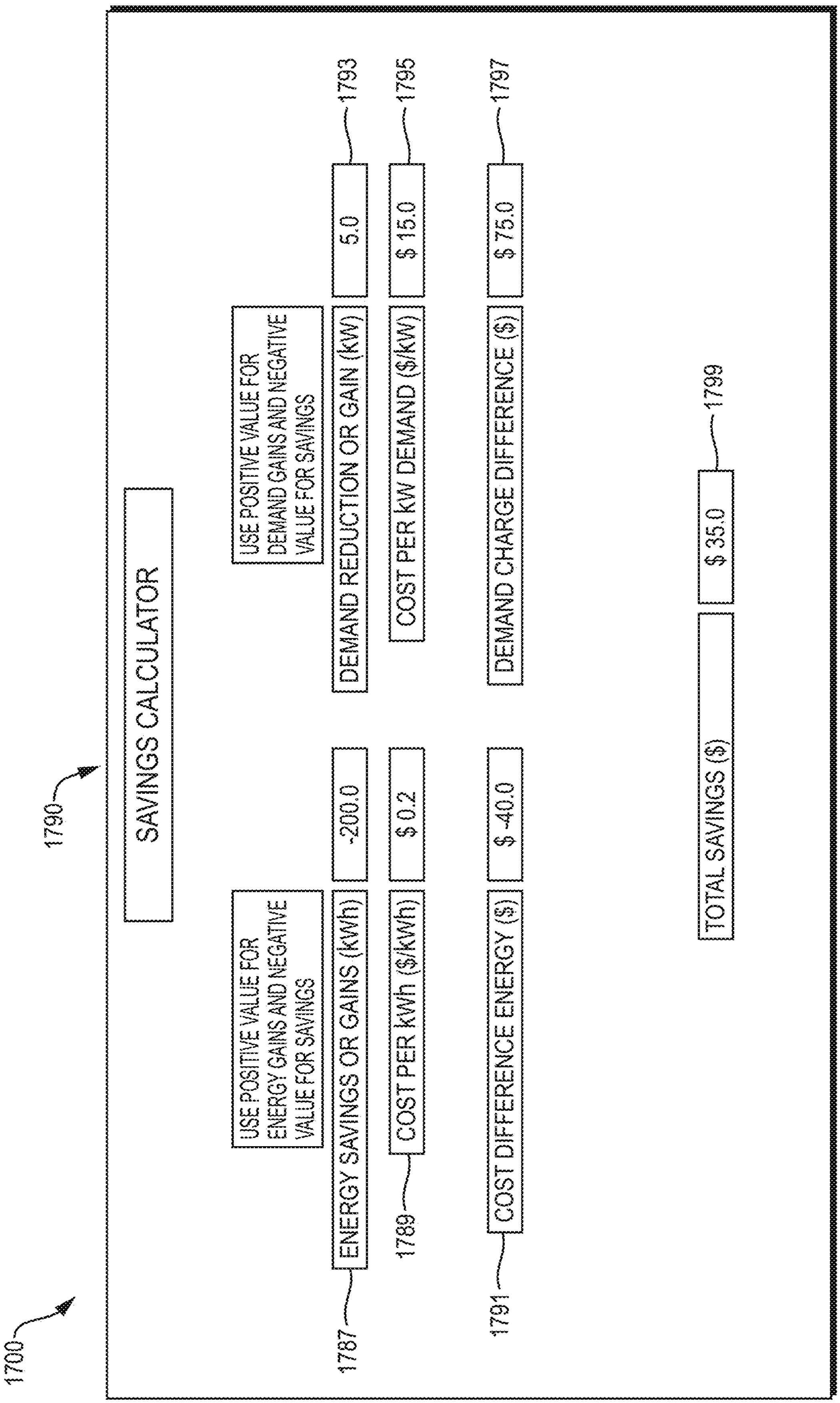

1700
1790
SAVINGS CALCULATOR
USE POSITIVE VALUE FOR ENERGY GAINS AND NEGATIVE VALUE FOR SAVINGS
ENERGY SAVINGS OR GAINS (kWh)
-200.0
1787
COST PER kWh ($/kWh)
$ 0.2
1789
COST DIFFERENCE ENERGY ($)
$ -40.0
1791
USE POSITIVE VALUE FOR DEMAND GAINS AND NEGATIVE VALUE FOR SAVINGS
DEMAND REDUCTION OR GAIN (kW)
5.0
1793
COST PER kW DEMAND ($/kW)
$ 15.0
1795
DEMAND CHARGE DIFFERENCE ($)
$ 75.0
1797
TOTAL SAVINGS ($)
$ 35.0
1799

FIG. 17

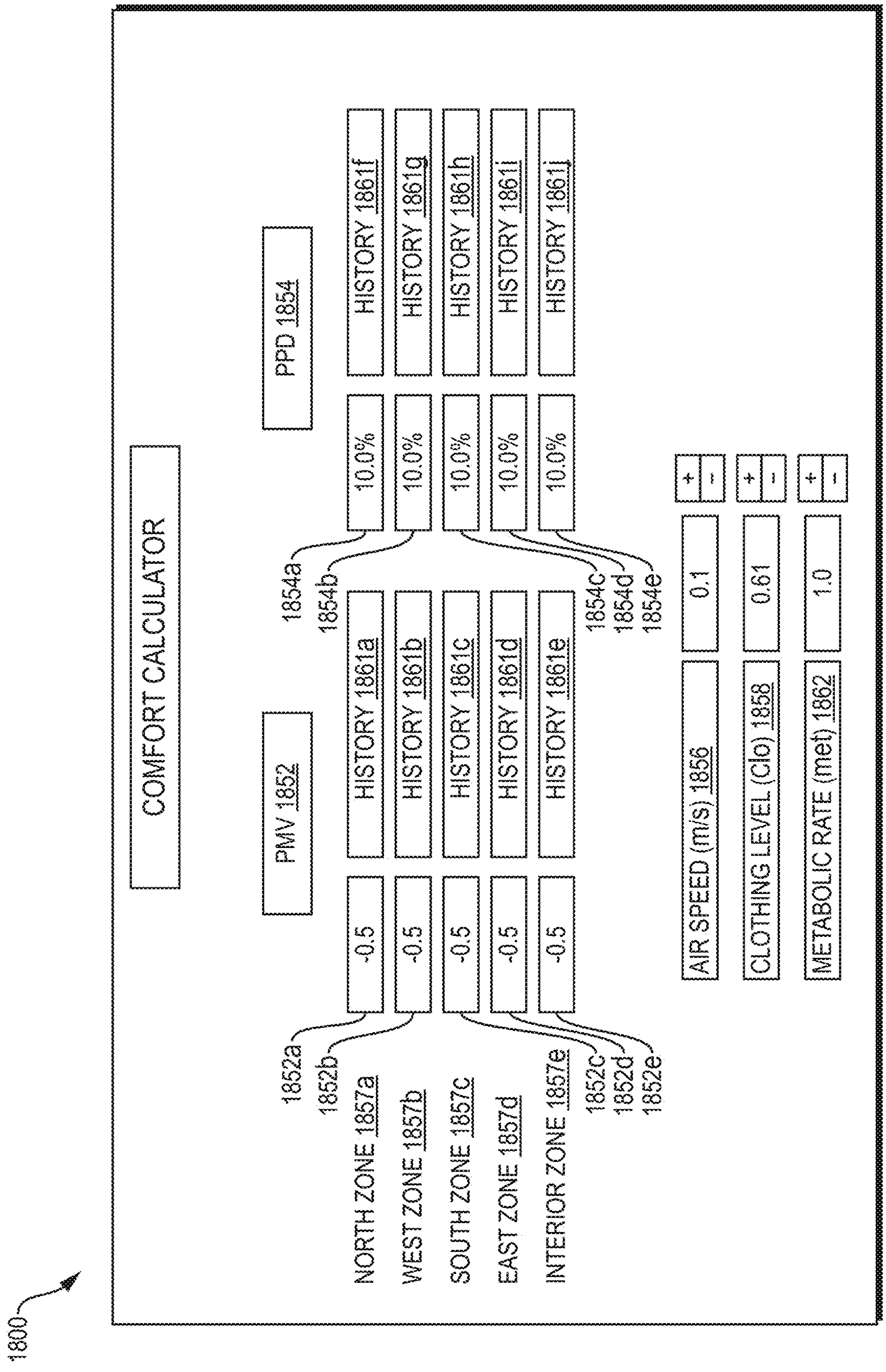

1800
COMFORT CALCULATOR
PMV 1852
PPD 1854
NORTH ZONE 1857a
WEST ZONE 1857b
SOUTH ZONE 1857c
EAST ZONE 1857d
INTERIOR ZONE 1857e
1852a
1852b
1852c
1852d
1852e
-0.5
-0.5
-0.5
-0.5
-0.5
HISTORY 1861a
HISTORY 1861b
HISTORY 1861c
HISTORY 1861d
HISTORY 1861e
1854a
1854b
1854c
1854d
1854e
10.0%
10.0%
10.0%
10.0%
10.0%
HISTORY 1861f
HISTORY 1861g
HISTORY 1861h
HISTORY 1861i
HISTORY 1861j
AIR SPEED (m/s) 1856
0.1
CLOTHING LEVEL (Clo) 1858
0.61
METABOLIC RATE (met) 1862
1.0
+
-
+
-
+
-

FIG. 18

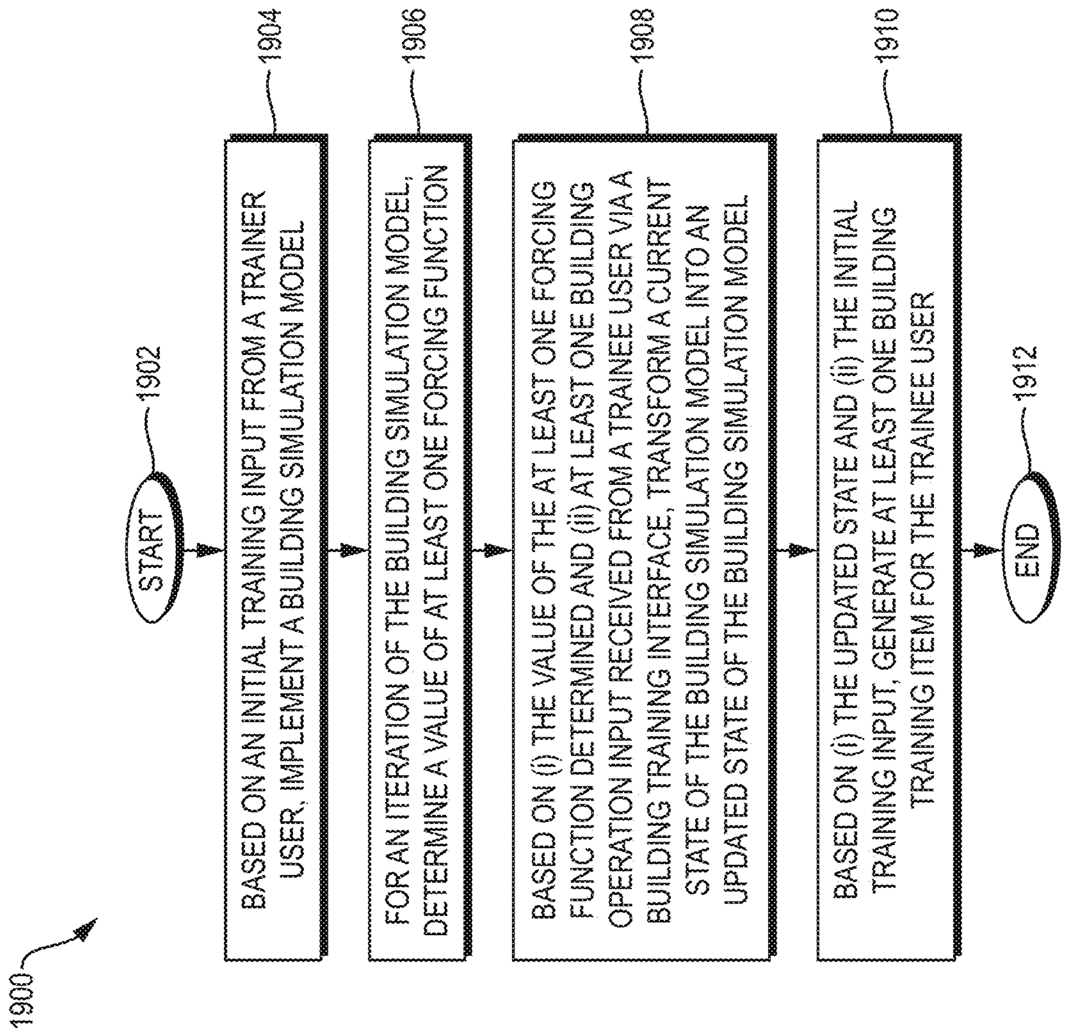

1900
START
1902
BASED ON AN INITIAL TRAINING INPUT FROM A TRAINER USER, IMPLEMENT A BUILDING SIMULATION MODEL
1904
FOR AN ITERATION OF THE BUILDING SIMULATION MODEL, DETERMINE A VALUE OF AT LEAST ONE FORCING FUNCTION
1906
BASED ON (i) THE VALUE OF THE AT LEAST ONE FORCING FUNCTION DETERMINED AND (ii) AT LEAST ONE BUILDING OPERATION INPUT RECEIVED FROM A TRAINEE USER VIA A BUILDING TRAINING INTERFACE, TRANSFORM A CURRENT STATE OF THE BUILDING SIMULATION MODEL INTO AN UPDATED STATE OF THE BUILDING SIMULATION MODEL
1908
BASED ON (i) THE UPDATED STATE AND (ii) THE INITIAL TRAINING INPUT, GENERATE AT LEAST ONE BUILDING TRAINING ITEM FOR THE TRAINEE USER
1910
END
1912

FIG. 19

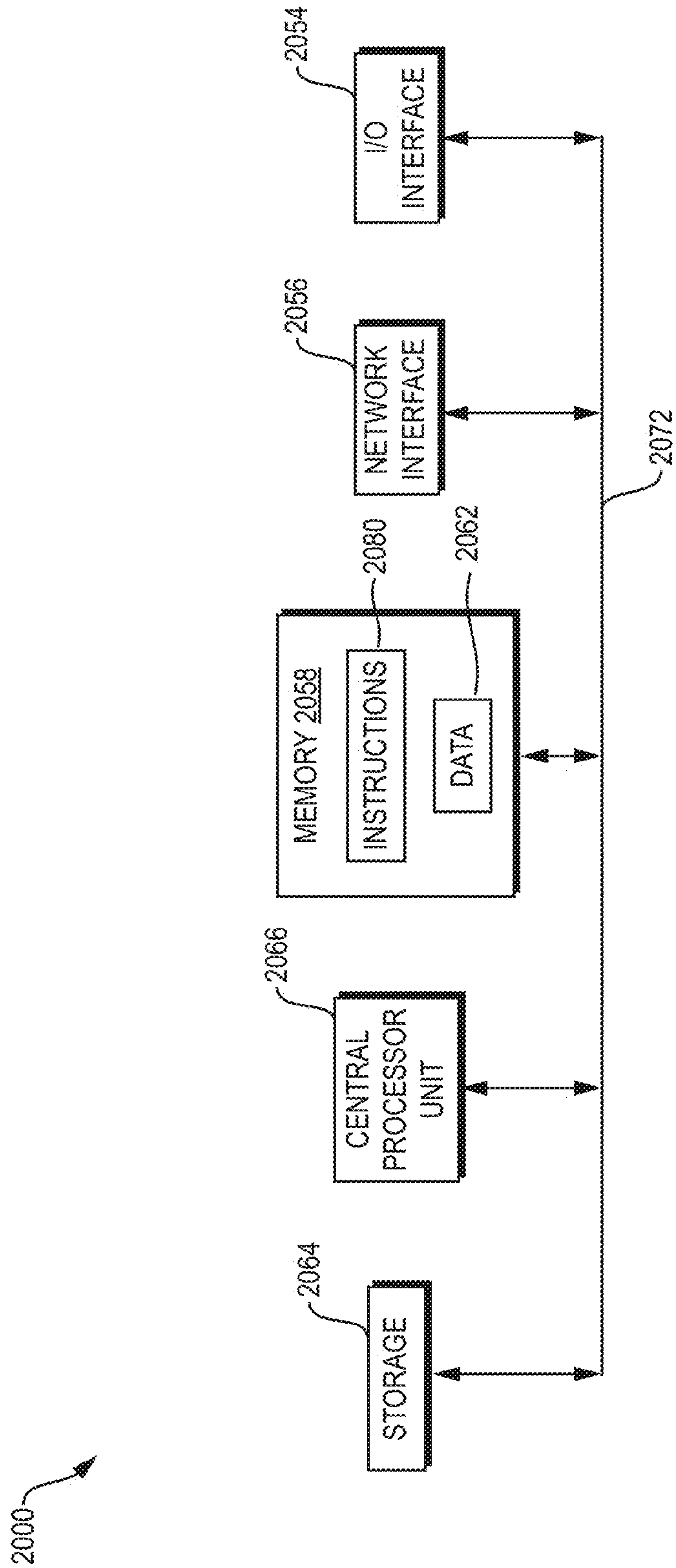

2054
I/O INTERFACE
2056
NETWORK INTERFACE
2072
2080
2062
MEMORY 2058
INSTRUCTIONS
DATA
2066
CENTRAL PROCESSOR UNIT
2064
STORAGE
2000

FIG. 20

SYSTEM AND METHOD FOR TRAINING A USER VIA AN EMULATED REAL-WORLD BUILDING ENVIRONMENT

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 63/498,063, filed on Apr. 25, 2023. The entire teachings of the above application are incorporated herein by reference.

GOVERNMENT SUPPORT

[0002] This invention was made with government support under Grant No. DE-EE0009742 from the Department of Energy. The government has certain rights in the invention.

BACKGROUND

[0003] The use of building systems, e.g., building automation systems (BAS) and heating, ventilation, and air conditioning (HVAC) systems, has increased over time. However, current approaches for training building operators remain inadequate.

SUMMARY

[0004] A building operator is a person who manages and maintains, e.g., building automation systems (BAS) and heating, ventilation, and air conditioning (HVAC) systems, in buildings. Buildings are becoming increasingly energy efficient, and thus building operators may be well positioned to impact, e.g., facility energy consumption, operational costs, grid-interactivity, and occupant complaints about discomfort. Among other things, embodiments disclosed herein provide "Building Operator: Grid-Occupant" (BOGO) training modules to expand training of building operators (e.g., entry-level operators) to include not just energy efficiency and peak demand reductions, but also energy flexibility. Such grid-interactive efficient buildings (GEBs) can shed, shift, and modulate their loads to provide added value to the grid at a levelized cost of energy (LCOE) less than traditional and renewable sources, a potentially $15B/year market opportunity. Achieving these benefits may require advanced controls, the operation of which is often outsourced to contractors working with building operators, yet many building operators may struggle to work together effectively and share responsibilities. A training program is thus needed for operators of, e.g., mid- and large-sized buildings, to improve their GEB literacy, which training program may also include content on, e.g., maintaining indoor environmental quality (IEQ)/indoor air quality (IAQ) expectations of occupants, such as through occupant-centric control (OCC), to increase occupant satisfaction with GEB initiatives. Embodiments address these and other building operator training needs unmet by existing systems.

[0005] Among other things, embodiments provide a new educational tool that allows building operators to learn through simulation-based training. Current building operator curriculums assume trainees are already working in the field and can learn-by-doing in their own buildings. An example embodiment provides a standardized prototype building model, which may leverage EnergyPlus® or other suitable known tool, that is co-simulated in real-time (or faster than real-time) with a BAS demonstrator, which may be a hardware-based demonstrator, for non-limiting example. This allows students to simulate real-life building scenarios and learn how to, e.g., modify schedules and setpoints to meet energy management objectives. Embodiments deliver novel solutions to the problems of limited access to skilled mentors, limited types of training scenarios, and risks associated with training on real, physical buildings, for non-limiting examples.

[0006] According to an example embodiment, a computer-based system for training a user via an emulated real-world building environment comprises a building training interface, at least one processor, and a memory with computer code instructions stored thereon. The building training interface corresponds to a trainee user. The at least one processor and the memory, with the computer code instructions, are configured to cause the system to, based on an initial training input from a trainer user, implement a building simulation model. The building simulation model is configured to produce an emulated real-world building environment. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system to, for an iteration of the building simulation model, determine a value of at least one forcing function. The at least one forcing function is associated with the emulated real-world building environment. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system to, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from the trainee user via the building training interface, transform a current state of the building simulation model into an updated state of the building simulation model. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item for the trainee user.

[0007] In an example embodiment, the building training interface may be a first building training interface. The building simulation model may be a first building simulation model. The trainee user may be a first trainee user. In this example embodiment, the system may further comprise a second building training interface corresponding to a second trainee user. The at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to, based on the initial training input from the trainer user, implement a second building simulation model. The second building simulation model may be configured to produce the emulated real-world building environment. The at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to, for the iteration, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from the second trainee user via the second building training interface, transform a current state of the second building simulation model into an updated state of the second building simulation model. The at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to, based on (i) the updated state of the first building simulation model, (ii) the updated state of the second building simulation model, and (iii) the initial training input, generate the at least one building training item for the first trainee user. In this example embodiment, the at least one building training item may include a comparison of building operation performance of the first trainee user and building operation performance of the second trainee user.

[0008] According to an example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to iteratively determine the value of the at least one forcing function and the transform the current state of the building simulation model into the updated state of the building simulation model on an ongoing basis while the trainee user is interacting with the building training interface, during times when the trainee user is not interacting with the building training interface, or based on input from the trainer user. In another example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to iteratively determine the value of the at least one forcing function and transform the current state of the building simulation model into the updated state of the building simulation model in real-time or faster-than-real-time. In yet another example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to iteratively determine the value of the at least one forcing function and transform the current state of the building simulation model into the updated state of the building simulation model in at least one of: a periodic mode, an event driven mode, and a mode defined by the trainer user.

[0009] In an example embodiment, a forcing function of the at least one forcing function may relate to at least one of: (i) weather conditions, (ii) electricity costs, (iii) energy costs, and (iv) occupant behavior.

[0010] According to an example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to, based on subsequent training input from the trainer user, configure at least one parameter of (i) the building simulation model or (ii) a forcing function of the at least one forcing function. In another example embodiment, the subsequent training input may represent at least one of a simulated malfunction of the real-world building environment and a simulated weather event for the real-world building environment.

[0011] In an example embodiment, the initial training input may include at least one criterion for a building operation certification. The at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to perform a determination of whether the updated state of the building simulation model satisfies the at least one criterion. In this example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to, responsive to the determination performed indicating that the updated state of the building simulation model satisfies the at least one criterion, generate the at least one building training item. The at least one building training item may include an indication that the trainee user has achieved the building operation certification. According to another example embodiment, a criterion of the at least one criterion may relate to an energy optimization objective or an occupant satisfaction objective.

[0012] According to an example embodiment, the at least one processor and the memory, with the computer code instructions, may be further configured to cause the system to generate a visual comparison of (i) one or more states of the building simulation model and (ii) one or more states of a baseline model. A building training item of the at least one building training item generated may include the visual comparison generated. In another example embodiment, the one or more states of the baseline model may represent (i) states of the emulated real-world building environment simulated by the trainer user or (ii) historical states of the real-world building environment.

[0013] In another example embodiment, a computer-implemented method for training a user via an emulated real-world building environment comprises, based on an initial training input from a trainer user, implementing a building simulation model. The building simulation model is configured to produce an emulated real-world building environment. The method further comprises, for an iteration of the building simulation model, determining a value of at least one forcing function. The at least one forcing function is associated with the emulated real-world building environment. The method further comprises, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from a trainee user via a building training interface, transforming a current state of the building simulation model into an updated state of the building simulation model. The method further comprises, based on (i) the updated state and (ii) the initial training input, generating at least one building training item for the trainee user.

[0014] Alternative computer-implemented method embodiments parallel those described above in connection with the example computer-based system embodiment.

[0015] According to yet another example embodiment, a non-transitory computer-readable medium has encoded thereon a sequence of instructions which, when loaded and executed by at least one processor, causes the at least one processor to, based on an initial training input from a trainer user, implement a building simulation model. The building simulation model is configured to produce an emulated real-world building environment. The sequence of instructions further causes the at least one processor to, for an iteration of the building simulation model, determine a value of at least one forcing function. The at least one forcing function is associated with the emulated real-world building environment. The sequence of instructions further causes the at least one processor to, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from a trainee user via a building training interface, transform a current state of the building simulation model into an updated state of the building simulation model. The sequence of instructions further causes the at least one processor to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item for the trainee user.

[0016] Alternative non-transitory computer-readable medium embodiments parallel those described above in connection with the example computer-based system embodiment.

[0017] It is noted that example embodiments of a system, method, and computer-readable medium may be configured to implement any embodiments, or combination of embodiments, described herein.

[0018] It should be understood that example embodiments disclosed herein can be implemented in the form of a system, method, apparatus, or computer-readable medium with program codes embodied thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing will be apparent from the following more particular description of example embodiments, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments.

[0020] FIG. **1** is a block diagram of a computer-based system that includes an example embodiment of the present disclosure.

[0021] FIG. **2** is a block diagram of an example embodiment of an architecture for training a user via an emulated real-world building environment.

[0022] FIGS. **3**A-**3**B are block diagrams of an example embodiment of an implementation of reading at least one building operation input from a thermostat.

[0023] FIGS. **4**A-**4**B are block diagrams of an example embodiment of an implementation of importing at least one building operation input from a thermostat.

[0024] FIG. **5** is a block diagram of an example embodiment of an implementation of feeding at least one building operation input from a thermostat to a computer-based system.

[0025] FIG. **6** is a block diagram of an example embodiment of an implementation of running a simulation.

[0026] FIG. **7** is an image of a building automation system (BAS) training interface according to an example embodiment.

[0027] FIGS. **8**A-**8**D are images of training a user via an emulated real-world building environment according to an example embodiment.

[0028] FIG. **9** is a block diagram of an example embodiment of a curriculum.

[0029] FIG. **10** is a block diagram of another example embodiment of an architecture for training a user via an emulated real-world building environment.

[0030] FIG. **11** is a block diagram of yet another example embodiment of an architecture for training a user via an emulated real-world building environment.

[0031] FIG. **12** is a block diagram of an example embodiment of a user interface including a homepage.

[0032] FIG. **13** is a block diagram of an example embodiment of a lesson task interface including a building training interface.

[0033] FIG. **14** is a block diagram of an example embodiment of a user interface including a setpoint scheduler.

[0034] FIG. **15** is a block diagram of an example embodiment of a user interface including a power monitor.

[0035] FIG. **16** is a block diagram of an example embodiment of a user interface including a history chart.

[0036] FIG. **17** is a block diagram of an example embodiment of a user interface including a savings calculator.

[0037] FIG. **18** is a block diagram of an example embodiment of an interface for calculating occupant comfort.

[0038] FIG. **19** is a flow diagram of an example embodiment of a computer-implemented method.

[0039] FIG. **20** is a block diagram of an example embodiment of an internal structure of a computer optionally within an embodiment disclosed herein.

DETAILED DESCRIPTION

[0040] A description of example embodiments follows.

[0041] Buildings interact with a grid in complex ways that vary over, e.g., time and space, weather, occupants, and hidden conditions in the grid. It is not expected that building operators are experts in all these areas, yet they should be able to effectively communicate and coordinate with such experts. Trainees often rotate through various hands-on demonstrators such as refrigerant loops, wiring, and steam fitting, which are important for learning tactile skills and understanding system interactions. However, no such demonstrator trains users on interactions between systems in a building, e.g., building automation systems (BAS) and heating, ventilation, and air conditioning (HVAC) systems, building physics, the environment, and occupants, for non-limiting examples. Among other things, example embodiments of the present disclosure provide such a first-of-its-kind hands-on building operation demonstrator, which leverages pure simulation-based approaches such as Alfalfa, for non-limiting example.

[0042] According to an example embodiment, a hands-on whole-building operation demonstrator may be a valuable instructional tool to achieve learning objectives described herein, because no current building operator curriculum leverages the benefits of simulation-based learning. The building operation demonstrator may leverage techniques for real-time co-simulation. An example embodiment may provide a standardized prototype building model, which may leverage EnergyPlus® or other suitable known tool in, e.g., a Building Controls Virtual Testbed (BCVTB), that is co-simulated in real-time (or faster than real-time) with a BAS demonstrator, which may be a hardware-based demonstrator. In another example embodiment, a building operation demonstrator may provide a user interface (UI) and user experience (UX) with a design that evokes real BAS interfaces, yet is simplified to be approachable by a novice. Further, in yet another example embodiment, a building operation demonstrator may provide online connectivity for remote learning.

[0043] In an example embodiment, a building operation demonstrator may simulate for a student the first days on a job supervised by an excellent mentor who provides clear tasks in controlled environments that provide opportunities for learning. The building operation demonstrator may provide these learning opportunities without risk to building owners and without need of such a real-life, skilled mentor, which may be difficult to come by in an aging workforce with rapidly changing technologies. For instance, the building operation demonstrator may provide a real BAS interface where a trainee user can modify schedules and setpoints to meet needs of occupants in a case study, and explore how, e.g., precooling, conservation setpoints, and occupant overrides, may play a role in achieving energy management objectives like efficiency and peak reduction.

[0044] Example embodiments disclosed herein may integrate, e.g., an EnergyPlus® BCVTB with a hands-on BAS simulator into a real-time BAS hardware-in-the-loop (HwIL) simulator. Example embodiments disclosed herein may provide an interface for a building operation simulator that closely resembles interfaces seen by real-life building operators. Optionally, example embodiments disclosed herein may provide virtualization of hands-on components for institutions, such as educational institutions, that cannot afford a commercial hardware BAS simulator or where a curriculum is to be taught online. Example embodiments disclosed herein may specify prototype buildings, a simplified interface, and case studies that integrate into a BOGO curriculum.

[0045] According to an example embodiment, demand for BOGO training modules from, e.g., utilities, building owners, and state programs, may catalyze adoption of a new Building Operator Certification (BOC) Fundamentals program targeted at vocation technical (VoTech) high schools and community colleges (CCs) with integrated internship programs. This workforce development may be timely because, for instance, a current workforce of 45,000 plus in Massachusetts alone is growing 10% per year faster than the national labor market, yet employers may list lack of qualifications and ability to adapt to changing technologies as two of their greatest challenges. The learning modules may combine classroom and e-learning with a first-of-a-kind hands-on whole-building demonstrator. The simulation-based case-studies may not only teach fundamentals of BAS components, but also show how a whole building acts as a system and introduce an array of contractors that a building operator may need to effectively communicate with to operate and maintain a building.

[0046] In an example embodiment, a BOGO curriculum may provide soon-to-become building operators with literacy in the fundamentals of how buildings interact with a grid and how such interactions may affect occupants. Three exemplary curriculum modules may amount to, e.g., 14 hours, of classroom time to cover the following exemplary learning objectives:

- **[0047]** a) GEB-1: Explain how regular building operations decisions affect a building's energy and power consumption.
- **[0048]** b) GEB-2: Identify availability and benefits of commercial building grid-interactive building programs such as time-of-use pricing, demand response, etc.
- **[0049]** c) OCC-1: Identify properties of a building, an HVAC system, and an electric grid that can limit an operator's ability to provide occupant thermal comfort.
- **[0050]** d) OCC-2: Understand how occupant behaviors can impact a built environment and building energy performance: from occupant, to building, to grid scales.
- **[0051]** c) BOGO-1: Explain how a good relationship between building operators and occupants can help make buildings more efficient and effective GEBs.
- **[0052]** f) BOGO-2: Understand potential strategies for using tenant engagement, communication, and education efforts to enhance occupant behaviors, comfort, and building energy use.

[0053] Example embodiments disclosed herein may catalyze a pipeline of building operators prepared with competencies and passion necessary to operate a current and next generation of grid-interactive efficient buildings.

[0054] FIG. **1** is a block diagram of a computer-based system **110** that includes an example embodiment of the present disclosure. In the example embodiment of FIG. **1**, the system **110** comprises a building training interface **120**, at least one processor (not shown), and memory (not shown) with computer code instructions (not shown) stored thereon, such as disclosed further below with respect to FIG. **20**. The building training interface **120** corresponds to a trainee user **188**. The at least one processor and the memory, with the computer code instructions, are configured to cause the system **110** to, based on an initial training input **178** from a trainer user **182**, implement a building simulation model **130**, which may utilize, e.g., an EnergyPlus® tool. The trainer user **182** may employ or alternatively may be a user device **184** such as a personal computer (PC), laptop, table, smartphone, or any other suitable known user device. The user device **184** may also be configured to execute the system **110**. Continuing with reference to FIG. **1**, the building simulation model **130** is configured to produce an emulated real-world building environment **140**. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system **110** to, for an iteration of the building simulation model **130**, determine a value of at least one forcing function (not shown). The at least one forcing function is associated with the emulated real-world building environment **140**. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system **110** to, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input **186** received from the trainee user **188** via the building training interface **120**, transform a current state (not shown) of the building simulation model **130** into an updated state (not shown) of the building simulation model **130**. The at least one processor and the memory, with the computer code instructions, are further configured to cause the system **110** to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item **192** for the trainee user **188**.

[0055] FIG. **2** is a block diagram of an example embodiment of an architecture **200** for training a user via an emulated real-world building environment. In the example embodiment of FIG. **2**, the architecture **200** includes a computer-based system **210**, a building training interface **220**, a building simulation model **230**, and a supervisor module **250**. The building training interface **220** may be, e.g., an iConnect® Training PT-181 BAS portable training unit provided by North Park Innovations Group, Inc. (Ellicottville, NY) or other suitable known building training interface. In addition, the building training interface **220** may serve as a hands-on component of a whole-building operation demonstrator for a trainee user (not shown). The building training interface **220** may also include a thermostat **224**, which may be, e.g., a smart thermostat or other suitable known thermostat. The system **210** may execute on user device **284**, which may be, e.g., a PC, laptop, table, smartphone, or any other suitable known user device. Alternatively, the system **210** may execute on a cloud server (not shown). In addition, the system **210** may employ a web service such as Alfalfa or other suitable known web service. The supervisor **250** may be, e.g., a component provided as part of the Niagara Framework® or other suitable known framework.

[0056] In an example embodiment, the system **210** may be configured to, based on an initial training input (not shown) from a trainer user (not shown), implement the building simulation model **230**. The trainer user may employ or alternatively may be the user device **284**. To continue, the building simulation model **230** may be configured to produce an emulated real-world building environment (not shown). The system **210** may be further configured to, for an iteration of the building simulation model **230**, determine a value of at least one forcing function (not shown). The at least one forcing function may be associated with the emulated real-world building environment.

[0057] According to an example embodiment, at least one building operation input **286** may be entered by the trainee user via the thermostat **224** of the building training interface **220** and may include, e.g., cooling/heating setpoint(s) and/or deadband information, for non-limiting examples. In another example embodiment, the at least one building operation input **286** may be imported from the building training interface **220** via, e.g., BACnet® or other suitable known communication protocol such as a protocol used for building automation and control (BAC) networks. Further, in yet another example embodiment, the imported at least one building operation input **286** may be transmitted to the supervisor **250** via network **201**, which may be, e.g., a network provided as part of the Niagara Framework® or other suitable known network.

[0058] In an example embodiment, the supervisor **250** may optionally apply post processing **203** to the at least one building operation input **286**. The optional processing **203** may include, e.g., unit conversion such as Fahrenheit to Celsius conversion.

[0059] Further, in yet another example embodiment, the system **210** may receive the at least one building operation input **286** (optionally with processing **203** applied) from the supervisor **250**. The at least one building operation input **286** may also include other data provided by the supervisor **250**, such as how much time to advance the building simulation model **230**. The at least one building operation input **286** may be received by the system **210** from the supervisor **250** via network **211**, which may be, e.g., a network employing BACnet® or other suitable known communication protocol such as a protocol used for BAC networks. According to an example embodiment, the system **210** may interface with the network **211** by utilizing a BACnet® adapter for Alfalfa, e.g., the Alfalfa BACnet® Bridge or other suitable known tool.

[0060] Continuing with reference to FIG. **2**, the system **210** may be further configured to, based on (i) the value of the at least one forcing function determined and (ii) the at least one building operation input **286**, transform a current state (not shown) of the building simulation model **230** into an updated state (not shown) of the building simulation model **230**. In an example embodiment, transforming the current state of the building simulation model **230** may include generating updated simulation input(s) **205** for the building simulation model **230**. According to another example embodiment, producing the updated state of the building simulation model **230** may include generating simulation output(s) **207**.

[0061] Continuing with reference to FIG. **2**, the system **210** may be further configured to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item **292** for the trainee user. In an example embodiment, the at least one building training item **292** may include one or more of the following exemplary training item(s) relating to the emulated real-world building environment: indoor temperature, indoor humidity, energy usage, and/or outdoor temperature.

[0062] In an example embodiment, after receiving the at least one building training item **292** from the system **210** via the network **211**, the supervisor **250** may optionally include exemplary training item(s) **209** relating to the emulated real-world building environment such as a visualization of indoor environment history and/or analysis(es) of energy usage and/or occupant comfort, in the at least one building training item **292**.

[0063] According to another example embodiment, the at least one building training item **292** (optionally including the exemplary training item(s) **209**) may be provided to the building training interface **220** (i.e., corresponding to the trainee user) by the supervisor **250** via the network **201**. Further, in yet another example embodiment, providing the at least one building training item **292** to the building training interface **220** may include updating the thermostat **224** to show a virtual indoor environment of the emulated real-world building environment.

[0064] FIGS. **3A-3B** are block diagrams of an example embodiment of an implementation **300** of reading at least one building operation input **386*a*-386*n*** from a thermostat **324**. In the example embodiment of FIGS. **3A-3B**, a station module **360** may be deployed to a building training interface, e.g., building training interface **220** (FIG. **2**) or **720** (FIG. **7**), which may include the thermostat **324**. The station **360** may be, e.g., a component provided as part of the Niagara Framework® or other suitable known framework. The thermostat **324** may be, e.g., a smart thermostat or other suitable known thermostat. The station **360** may read or import the at least one building operation input **386*a*-386*n*** from the thermostat **324** via network **311**, which may be, e.g., a network employing BACnet® or other suitable known communication protocol such as a protocol used for BAC networks. The at least one building operation input **386*a*-386*n*** may include, e.g., effective occupancy information **386*a***, system mode information **386*b***, and/or deadband information **386*n***. After reading the at least one building operation input **386*a*-386*n***, the station **360** may store or save the imported at least one building operation input **386*a*-386*n*** as stored data **313**. The stored data **313** including the at least one building operation input **386*a*-386*n*** may in turn be forwarded to or accessed by a supervisor module, e.g., supervisor **250** (FIG. **2**) or **450** (FIG. **4A**), such as via a network, e.g., network **201** (FIG. **2**) or **401** (FIG. **4A**).

[0065] FIGS. **4A-4B** are block diagrams of an example embodiment of an implementation **400** of importing at least one building operation input **486*a*-486*n*** from a thermostat, e.g., thermostat **224** (FIG. **2**), **324** (FIG. **3A**), or **724** (FIG. **7**). In the example embodiment of FIGS. **4A-4B**, a station module **460** may be deployed to a building training interface, e.g., the building training interface **220** (FIG. **2**) or **720** (FIG. **7**), which may include the thermostat. The station **460** may be, e.g., a component provided as part of the Niagara Framework® or other suitable known framework. A supervisor module **450** may import the at least one building operation input **486*a*-486*n*** from the station **460** such as through network **401**, which may be, e.g., a network provided as part of the Niagara Framework® or other suitable known network. The supervisor **450** may be, e.g., a component provided as part of the Niagara Framework® or other suitable known framework. To continue, the supervisor **450** may also establish communication with a computer-based system, e.g., system **110** (FIG. **1**) or **210** (FIG. **2**), such as through network **411**, which may be, e.g., a network employing BACnet® or other suitable known communication protocol such as a protocol used for BAC networks. In addition, the supervisor **450** may store simulation data **413** including the at least one building operation input **486*c***, **486*d***, and

486*c*, which, as shown in FIGS. **4**A-**4**B, may correspond to, e.g., a heating setpoint, a cooling setpoint, and a zone mean temperature, respectively.

[0066] Continuing with reference to FIGS. **4**A-**4**B, according to an example embodiment, the at least one building operation input **486***c*-**486***e* may be retrieved from a database **415** of variables. In another example embodiment, the at least one building operation input **486***c*-**486***d* may be imported into the database **415** from a collection **417** of "discovered" datapoints.

[0067] FIG. **5** is a block diagram of an example embodiment of an implementation **500** of feeding at least one building operation input **586***a*-**586***n* from a thermostat, e.g., thermostat **224** (FIG. **2**), **324** (FIG. **3**A), or **724** (FIG. **7**), to a computer-based system, e.g., system **110** (FIG. **1**) or **210** (FIG. **2**). In the example embodiment of FIG. **5**, the at least one building operation input **586***a*, **586***b*, and **586***n* may correspond to, e.g., a cooling setpoint, a cooling setpoint deadband upper range, and a cooling setpoint deadband lower range, respectively. The at least one building operation input **586***a*-**586***n* may be provided to the computer-based system by a supervisor module, e.g., supervisor **250** (FIG. **2**) or **450** (FIG. **4**A).

[0068] Continuing with reference to FIG. **5**, in an example embodiment, additional input variables **519***a*-**519***b* may also be provided by the supervisor to the computer-based system. The additional input variables **519***a* and **519***b* may indicate, for instance, an amount of time (such as a number of minutes) for which a simulation, e.g., building simulation model **130** (FIG. **1**) or **230** (FIG. **2**), will be run and an input mode, respectively. According to another example embodiment, the input mode variable **519***b* may be include a value of, e.g., 1 (one) or 2 (two), which may indicate that the at least one building operation input **586***a*-**586***n* should be obtained from an actual interface component (such as a thermostat) or from other-possibly user-provided-data variable(s).

[0069] Continuing with reference to FIG. **5**, in yet another example embodiment, the supervisor may optionally apply post processing **503** to the at least one building operation input **586***a*-**586***n* and/or the additional input variables **519***a*-**519***b*. The optional post processing **503** may include, e.g., unit conversion such as Fahrenheit to Celsius conversion.

[0070] FIG. **6** is a block diagram of an example embodiment of an implementation **600** of running a simulation, e.g., building simulation model **130** (FIG. **1**) or **230** (FIG. **2**), according to an example embodiment. In the example embodiment of FIG. **6**, a computer-based system, e.g., system **110** (FIG. **1**) or **210** (FIG. **2**), may regularly check input data from a supervisor module, module, e.g., supervisor **250** (FIG. **2**) or **450** (FIG. **4**A). When a value of a "minutes_to_proceed" variable **621** is greater than zero, e.g., a value of 10 (ten), the computer-based system may run **623** the simulation for a given period, e.g., 10 minutes. Updated data **609** may be reported back to the supervisor.

[0071] FIG. **7** is an image **700** of a BAS training interface **720** according to an example embodiment. The BAS training interface **720** may be, e.g., an iConnect® Training PT-181 BAS portable training unit, and may serve as a hands-on component of a whole-building operation demonstrator. As shown in FIG. **7**, the BAS training interface **720** may include roof top unit (RTU) controller **722**, fan coil unit (FCU) thermostat **724**, pushbutton switch **734**, and position switch **736**.

[0072] The RTU controller **722** may provide for normal I/O of, e.g., a standard heat/cool room thermostat. In addition, the RTU controller **722** may be a programmable controller that can be configured for a wide range of applications including scheduled occupancy, economizer, and/or humidity control, among other examples. The RTU controller **722** can also be reconfigured to serve as, e.g., a heat pump (HP) unit controller.

[0073] The FCU thermostat **724** may be, e.g., a "smart" room thermostat that provides for control of a FCU (not shown) equipped with a fan and one or more analog type heat/cool valves.

[0074] With existing approaches to HwIL building simulations, a component in an EnergyPlus® model may be replaced with a physical component such as a HP. Sensors may feed a state of the physical hardware into the simulation, and actuators may modify the hardware or its environment to match the simulation.

[0075] In contrast, example embodiments disclosed herein may use a HwIL approach where a BAS portable training unit, e.g., the BAS training interface **720**, can serve as a physical foundation of an emulator. The BAS training interface **720** may show a real-time status of components such as dampers, thermostats (e.g., **722**, **724**), switches (e.g., **734**, **736**), and fans in a simulation (not shown). Students may manipulate the BAS training interface **720**, and BAS control signals may be fed into the simulation. The simulation may run on a computer (not shown) running a BAS system (not shown) directly connected to the BAS training interface **720**, or on a separate computer connected via network (not shown). At each time step of the simulation, the simulation may speak with the BAS training interface **720** using a BACnet® protocol.

[0076] FIGS. **8**A-**8**D are images **800***a*-**800***d* of training a user via an emulated real-world building environment according to an example embodiment. As shown in FIG. **8**A, a building training interface **820** and a user device **884** may be provided. The interface **820** may include a RTU controller **822** and a thermostat **824**. The user device **884** may be configured to execute a computer-based system, e.g., the system **110** (FIG. **1**) or **210** (FIG. **2**). In an example embodiment, the computer-based system may provide a hands-on learning tool with real-world hardware and/or software found in a building such as a commercial building, e.g., the emulated real-world building environment **140** (FIG. **1**). According to another example embodiment, as shown in FIGS. **8**B and **8**C, a student/trainee user **888** can adjust setting(s) of the controller **822**, the thermostat **824**, and/or system operation(s) (not shown). Further, in yet another example embodiment, as shown in FIG. **8**D, the student/trainee **888** can use history charts **829***a* and **829***b* to see real-time effects on, e.g., occupant comfort and energy consumption, respectively, in a simulated environment, e.g., the emulated real-world building environment **140**. Embodiments offer a practical way to learn building management systems.

[0077] FIG. **9** is a block diagram of an example embodiment of a curriculum **900**. In the example embodiment of FIG. **9**, a goal of the curriculum **900** may be to shift peak electricity demand outside of peak demand billing hours, for non-limiting example. In the example embodiment of FIG. **9**, the curriculum **900** may include a temperature/energy overview **925**, a setpoint schedule editor **970**, and a history chart **929**. The chart **929** may illustrate temperature **927**, e.g., degrees Fahrenheit (° F.), as a function of time **933**, e.g., hour of the day for non-limiting example, for outdoor temperature **931**, as well as energy demand **937**, e.g., building energy demand in kilowatts (KW), as a function of the time **933** for whole energy building electricity without pre-cooling **935***a* and with precooling **935***b*. In addition, the chart **929** may illustrate regions of decreased peak load by precooling **939** and increased off-peak load by precooling **941**.

[0078] FIG. **10** is a block diagram of another example embodiment of an architecture **1000** for training a user via an emulated real-world building environment. In the example embodiment of FIG. **10**, the architecture **1000** includes a cloud server **1045**, a supervisor module **1050**, building simulation model(s) **1030***a*-**1030***n* (which may utilize, e.g., EnergyPlus® or other suitable known tools), user device(s) **1047***a*-**1047***n*, an emulated real-world building environment **1040**, and a homepage **1049**. According to another example embodiment, the emulated real-world building environment **1040** may be a 5,500 square foot building including five zones with a rooftop HP and gas, subject to Denver, CO weather, and running 24/7. Further, in yet another example embodiment, the architecture **1000** may also optionally include a building training interface **1020**.

[0079] According to an example embodiment, the cloud server **1045** may execute a computer-based system, e.g., the system **110** (FIG. **1**) or **210** (FIG. **2**). In another example embodiment, the computer-based system may be configured to, based on an initial training input (not shown) from a trainer user (not shown), implement the building simulation model(s) **1030***a*-**1030***n*. The building simulation model(s) **1030***a*-**1030***n* may be configured to produce the emulated real-world building environment **1040**. The computer-based system may be further configured to, for an iteration of the building simulation model(s) **1030***a*-**1030***n*, determine a value of at least one forcing function (not shown). The at least one forcing function may be associated with the emulated real-world building environment **1040**.

[0080] In an example embodiment, at least one building operation input (not shown) may be entered by the trainer user and/or trainee user(s) or user group(s) (not shown) via corresponding building training interface(s) (not shown) executing on the user device(s) **1047***a*-**1047***n*. For instance, the trainer user may use the corresponding building training interface of the user device **1047***a* to interact with the building simulation model **1030***a* as a baseline, while the trainee user(s)/user group(s) may use the remaining corresponding building training interface(s) of the user device(s) **1047***b*-**1047***n* to interact with the remaining building simulation model(s) **1030***b*-**1030***n*. According to another example embodiment, the trainer user and/or trainee user(s)/user group(s) may use the user device(s) **1047***a*-**1047***n* and/or the corresponding building training interface(s) to, e.g., login to the homepage **1049** via a web browser with separate username(s)/password(s), step through a curriculum (such as the curriculum **900** of FIG. **9**), view current temperature(s)/temperature trend(s)/setpoints/power demand/costs, and adjust setpoint schedules. Further, in yet another example embodiment, the at least one building operation input may be transmitted to the supervisor **1050** (executing on the cloud server **1045**) via network **1043**, which may be, e.g., the Internet or other suitable known network.

[0081] According to an example embodiment, the supervisor **1050** may be, e.g., a component provided as part of the Niagara Framework® or other suitable known framework. In another example embodiment, the supervisor **1050** may provide functionality for the computer-based system and/or the building simulation model(s) **1030***a*-**1030***n* including, e.g., running "24/7" (i.e., continuously), determining sequence(s) of operations, analyzing/determining energy costs, simulating occupant(s), and establishing alarms and schedules. Further, in yet another example embodiment, the supervisor **1050** may periodically, e.g., in one-minute update intervals, transmit data and/or information to the computer-based system and/or the building simulation model(s) **1030***a*-**1030***n* including, e.g., temperature(s), setpoint(s), and submeter energy usage; the transmitting may occur via network **1011***a*, which may be, e.g., a network employing BACnet® or other suitable known communication protocol such as a protocol used for BAC networks.

[0082] Continuing with reference to FIG. **10**, in an example embodiment, the computer-based system may be further configured to, based on (i) the value of the at least one forcing function determined and (ii) the at least one building operation input, transform a current state (not shown) of the building simulation model(s) **1030***a*-**1030***n* into an updated state (not shown) of the building simulation model(s) **1030***a*-**1030***n*. According to another example embodiment, the computer-based system may be further configured to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item (not shown) for the trainer user and/or trainee user(s)/user group(s). Further, in yet another example embodiment, the at least one building training item may be provided to the corresponding building training interface(s) of the user device(s) **1047***a*-**1047***n* by the supervisor **1050** via the network **1043**.

[0083] Continuing with reference to FIG. **10**, the optional building training interface **1020** may be, e.g., an iConnect® Training PT-181 BAS portable training unit; other suitable known building training interfaces may also be used. According to an example embodiment, the optional building training interface **1020** may serve as a hands-on component to an immersive training simulator such as the computer-based system. In another example embodiment, the optional building training interface **1020** may include thermostat control(s) (not shown) to simulate a temperature of the emulated real-world building environment **1040**. Further, in yet another example embodiment, the optional building training interface **1020** may allow a trainee user (not shown) to watch a variable air volume (VAV) system (not shown) and fan controller (not shown) activate when needed by the emulated real-world building environment **1040**. According to an example embodiment, at least one building operation input (not shown) may be imported from the optional building training interface **1020** via optional network **1011***b*, which may be, e.g., a network employing BACnet® or other suitable known communication protocol such as a protocol used for BAC networks.

[0084] FIG. **11** is a block diagram of yet another example embodiment of an architecture **1100** for training a user via an emulated real-world building environment. In the example embodiment of FIG. **11**, the architecture **1100** may include a user device **1184** and a building training interface **1120**, the latter of which may be, e.g., a Direct Digital Controls (DDC) training unit. According to an example embodiment, the user device **1184** may be configured to execute a computer-based system, e.g., **110** (FIG. **1**) or **210**

(FIG. **2**). The building training interface **1120** may correspond to a trainee user, e.g., **188** (FIG. **1**) or **888** (FIG. **8**B). The computer-based system may be configured to, based on an initial training input, e.g., **178** (FIG. **1**), from a trainer user, e.g., **182** (FIG. **1**), implement a building simulation model, e.g., **130** (FIG. **1**), **230** (FIG. **2**), or **1030***a*-**1030***n* (FIG. **10**). The trainer user may employ or alternatively may be the user device **1184** such as a PC, laptop, table, smartphone, or any other suitable known user device. The building simulation model may be configured to produce an emulated real-world building environment **1140**. The computer-based system may be further configured to, for an iteration of the building simulation model, determine a value of at least one forcing function (not shown). The at least one forcing function may be associated with the emulated real-world building environment **1140**. The computer-based system may be further configured to, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input, e.g., **186** (FIG. **1**), **286** (FIG. **2**), **386** (FIG. **3**A), **486** (FIG. **4**A), or **586** (FIG. **5**), received from the trainee user via the building training interface **1120**, transform a current state (not shown) of the building simulation model into an updated state (not shown) of the building simulation model. The computer-based system may be further configured to, based on (i) the updated state and (ii) the initial training input, generate at least one building training item, e.g., **192** (FIG. **1**) or **292** (FIG. **2**), for the trainee user.

[0085] Continuing with reference to FIG. **11**, in an example embodiment, the computer-based system may have a target workforce (not shown) of, e.g., building operators and building commissioners, and may impart workforce skills (not shown) including, e.g., adjusting a BAS schedule to reduce peak power, understand BAS operating limits and tradeoffs, identifying causes of occupant thermal discomfort and temperature variations, and identifying faults and interpreting BAS alarms. According to another example embodiment, the building training interface **1120** may have a target workforce (not shown) of, e.g., DDC/BAS programmers and technicians, and may impart workforce skills (not shown) including, e.g., identifying key components of building automation, wiring BAS to HVAC (heating, ventilation, and air conditioning) system components, configuring BAS component hardware and software, and implementing and troubleshooting DDC programs.

[0086] FIG. **12** is a block diagram of an example embodiment of a user interface **1200** including a homepage **1249**. In the example embodiment of FIG. **12**, the homepage **1249** may be presented when a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), is logged in to a computer-based system, e.g., the system **110** (FIG. **1**) or **210** (FIG. **2**), with student-specific credentials. According to an example embodiment, an instructor, e.g., the trainer user **182** (FIG. **1**), may also be presented with the homepage **1249** when clicking on a student from an admin homepage (not shown). In another example embodiment, the homepage **1249** may include lesson task buttons **1251***a*-**1251***c* and building information button **1253**. Further, in yet another example embodiment, one student may not have access to other students' homepages.

[0087] FIG. **13** is a block diagram of an example embodiment of a lesson task interface **1300** including a building training interface **1320**. In the example embodiment of FIG. **13**, the building training interface **1320** may display a floor plan **1355** of a space (not shown) in a building, e.g., the emulated real-world building environment **140** (FIG. **1**), with five different exemplary thermal zones: South **1357***a*, East **1357***b*, North **1357***c*, West **1357***d*, and interior **1357***e*. The building training interface **1320** may also display a value for outside air (OA) temperature **1363** as well as values for actual setpoints **1367***a*-**1367***b*. The building training interface **1320** may include power monitor **1380** and savings calculator **1490**, as well as button **1361** for visualizing historical temperatures of the floor plan **1355**.

[0088] Continuing with reference to FIG. **13**, according to an example embodiment, because a purpose of the lesson task interface **1300** may be to simulate a precooling strategy during the hottest week of a year, a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), can change or modify default setpoints **1365***a* and **1365***b* (such as by using **+** (plus)/**–** (minus) buttons **1359***a*-**1359***b* and **1359***c*-**1359***d*, respectively) and/or schedule a setpoint change via setpoint schedulers **1370***a*-**1370***b*.

[0089] FIG. **14** is a block diagram of an example embodiment of a user interface **1400** including a setpoint scheduler **1480**. In the example embodiment of FIG. **14**, the setpoint scheduler **1480** may be used by a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), to program, e.g., a precooling strategy by modifying both a value and a duration of a setpoint (not shown). For instance, according to an example embodiment, the setpoint scheduler **1480** may be employed in an attempt to shift peak consumption by "overcooling" a space (not shown) in a building, e.g., the emulated real-world building environment **140** (FIG. **1**), **1040** (FIG. **10**), or **1140** (FIG. **11**), to a first temperature **1469***a* of 71° F., then allowing the space to reach a second temperature **1469***b* of 76° F. during warmest hours of a day, and eventually going back to a default temperature **1467** of 75° F. In another example embodiment, the setpoint scheduler **1480** may be used to create a new event by inputting values for the event start **1471**, event finish **1473**, and event output **1475**.

[0090] FIG. **15** is a block diagram of an example embodiment of a user interface **1500** including a power monitor **1580**. In the example embodiment of FIG. **15**, at a bottom left area of the interface **1500**, the power monitor **1580** may show an energy demand **1577** of a building, e.g., the emulated real-world building environment **140** (FIG. **1**), **1040** (FIG. **10**), or **1140** (FIG. **11**), in, e.g., kW, as well as energy consumption **1579** in, e.g., kilowatt-hours (kW-hr), from a last meter reset. According to another example embodiment, because a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), may need to figure out the energy consumption **1579** for a week (or month) of simulation, e.g., the building simulation model **130** (FIG. **1**), **230** (FIG. **2**), or **1030***a*-**1030***n* (FIG. **10**), meter reset button **1581** may facilitate starting from zero at a beginning of a task, and then writing down the energy consumed **1579** at an end of the task. Further, in yet another example embodiment, clicking on history button **1561***a* or **1561***b* may cause display of a history chart, e.g., the chart **1629** of FIG. **16** (described in more detail hereinbelow), for the energy demand **1577** or the energy consumption **1579**, respectively.

[0091] FIG. **16** is a block diagram of an example embodiment of a user interface **1600** including a history chart **1629**. In the example embodiment of FIG. **16**, the chart **1629** may illustrate energy demand **1637**, e.g., whole building electricity demand in kW for non-limiting example, as a function of time **1633**. According to an example embodiment, a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), can figure out peak demand by clicking on a history button, e.g., the history button **1561***a* (FIG. **15**), next to a demand value, e.g., the demand value **1577** (FIG. **15**). In another example embodiment, the chart **1629** can be easily adjusted for, e.g., a week or month, of data using dropdown list **1685** on a top left corner of the user interface **1600**. Further, in yet another example embodiment, by hovering with a mouse over a highest spike of the chart **1629**, a student can determine peak demand **1683** and use it on a savings calculator, e.g., calculator **1790** of FIG. **17** (described in more detail hereinbelow).

[0092] FIG. **17** is a block diagram of an example embodiment of a user interface **1700** including a savings calculator **1790**. In the example embodiment of FIG. **17**, a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), may receive from an instructor, e.g., the trainer user **182** (FIG. **1**), values (not shown) for total energy consumption and peak demand of a building, e.g., the emulated real-world building environment **140** (FIG. **1**), **1040** (FIG. **10**), or **1140** (FIG. **11**), running "business as usual." According to another example embodiment, once a student has figured out differences in total energy consumption **1787** and peak demand **1793**, the savings calculator **1790** (which may be accessible from a building training interface, e.g., the interface **1320** of FIG. **13**) may allow the student to easily figure out how much money in, e.g., dollars ($), the building saved (or lost) for energy costs **1791** and demand charges **1797**, respectively, as well as total savings (or loss) **1799**. Further, in yet another example embodiment, a student can also change energy consumption **1789** and demand **1795** rates if needed.

[0093] FIG. **18** is a block diagram of an example embodiment of an interface **1800** for calculating occupant comfort. In the example embodiment of FIG. **18**, the interface **1800** may display predicted mean vote (PMV) **1852***a*-**1852***e* and predicted percentage of dissatisfied (PPD) **1854***a*-**1854***c* values corresponding to zones **1857***a*-**1857***e* of a space (not shown) in a building, e.g., the emulated real-world building environment **140** (FIG. **1**), **1040** (FIG. **10**), or **1140** (FIG. **11**). According to an example embodiment, PMV may be an index that aims to predict a mean value of votes of a group of occupants on a seven-point thermal sensation scale; PPD may be an index that establishes a quantitative prediction of a percentage of thermally dissatisfied occupants (i.e., too warm or too cold). In another example embodiment, the interface **1800** may include buttons **1861***a*-**1861***e* for **1861***f*-**1861***j* for visualizing historical PMV **1852***a*-**1852***e* or PPD **1854***f*-**1854***j* data, respectively, corresponding to the zones **1857***a*-**1857***e*. Further, in yet another example embodiment, the interface **1800** may also enable a student, e.g., the trainee user **188** (FIG. **1**) or **888** (FIG. **8**B), to adjust values for air speed **1856** in, e.g., meters/second (m/s), occupant clothing level **1858**, and/or occupant metabolic rate **1862**.

[0094] FIG. **19** is a flow diagram of an example embodiment of a computer-implemented method **1900** for training a user via an emulated real-world building environment. The method **1900** begins **1902** and comprises, based on an initial training input from a trainer user, implementing (**1904**) a building simulation model. The building simulation model is configured to produce an emulated real-world building environment. The method **1900** further comprises, for an iteration of the building simulation model, determining (**1906**) a value of at least one forcing function. The at least one forcing function is associated with the emulated real-world building environment. The method **1900** further comprises, based on (i) the value of the at least one forcing function determined (**1906**) and (ii) at least one building operation input received from a trainee user via a building training interface, transforming (**1908**) a current state of the building simulation model into an updated state of the building simulation model. The method **1900** further comprises, based on (i) the updated state and (ii) the initial training input, generating (**1910**) at least one building training item for the trainee user. The method **1900** thereafter ends **1912** in the example embodiment.

[0095] According to an example embodiment, a computer-based system may provide simulation-based learning for building operators, which is not currently utilized in existing building operator curriculums. The system may employ a HwIL approach, where a BAS simulator, e.g., a physical simulator, interacts with a model, e.g., a model leveraging EnergyPlus® or other suitable known tool, in real-time (or faster than real-time). This is a unique approach that enables students to simulate real-life building scenarios. The system may allow for risk-free learning opportunities for building operators without a need for real, physical buildings, reducing a risk of damage or injury associated with traditional training methods. The system may allow for developing and scaling a wide variety of training scenarios with much less effort as compared to existing approaches, because a configuration of a target building can be easily customized by modifying an input of a simulation. The system may co-simulate a standardized model, e.g., a model leveraging EnergyPlus® or other suitable known tool, with a BAS simulator, e.g., a commercial hardware simulator, providing a more realistic simulation environment for students. The system may be provided in the form of a standalone product.

[0096] An example embodiment of the system may provide a hands-on and risk-free learning experience for building operators, allowing them to learn through simulation-based training in a controlled environment, which enhances their learning experience and improves their skill set. The system may eliminate a need for costly on-site training and reduce risk of damage or injury associated with traditional training methods, providing a cost-effective training solution for building operators. The system may co-simulate a standardized model, e.g., a model leveraging EnergyPlus® or other suitable known tool, with a BAS simulator, e.g., a commercial hardware simulator, providing a more realistic simulation environment for students, which can result in better decision making and energy management. The system may allow students to modify schedules and setpoints to meet energy management objectives, such as efficiency and peak reduction for non-limiting examples, resulting in improved energy efficiency and cost savings. The system can be developed into a standalone product, providing a scalable solution for building operator training, which can result in wider adoption of simulation-based training in the building industry.

[0097] An example embodiment of the system can be used as an educational tool to train building operators on how to operate and manage building systems effectively in a controlled and realistic simulation environment. The system can be utilized as a continuing education tool for building operators to improve their skills and stay up to date with the latest building automation technologies. The system can be used as a tool for building managers and engineers to optimize energy management strategies in real-time and evaluate impact of different energy-saving measures. The system can be used as a research tool for developing and testing new building automation technologies and strategies. The system can be used as a testing tool for certification programs, instilling building operators with skills and knowledge to operate and manage building systems effectively.

[0098] An example embodiment of the system may provide a unique tool to assess performance of building systems and recommend energy-saving strategies, resulting in improved decision-making and energy management. The tool can be utilized by, e.g., building operators or consulting firms that offer building automation and energy management services to their clients.

[0099] Example embodiments disclosed herein may provide a more cost-effective and scalable solution for building operator training and energy management optimization, resulting in improved energy efficiency, cost savings, and reduced risk of damage or injury. Example embodiments disclosed herein may provide a more realistic, hands-on, and risk-free learning experience for building operators, resulting in improved energy management, better decision-making, and a more skilled workforce in the building industry.

[0100] FIG. **20** is a block diagram of an example embodiment of an internal structure of a computer **2000** in which various embodiments of the present disclosure may be implemented. The computer **2000** contains a system bus **2072**, where a bus is a set of hardware lines used for data transfer among the components of a computer or digital processing system. The system bus **2072** is essentially a shared conduit that connects different elements of a computer system (e.g., processor, disk storage, memory, I/O ports, network ports, etc.) that enables the transfer of information between the elements. Coupled to the system bus **2072** is an I/O device interface **2054** for connecting various input and output devices (e.g., keyboard, mouse, displays, printers, speakers, etc.) to the computer **2000**. A network interface **2056** allows the computer **2000** to connect to various other devices attached to a network (e.g., global computer network, wide area network, local area network, etc.). A memory **2058** provides volatile or non-volatile storage for computer software instructions **2080** and data **2062** that may be used to implement embodiments (e.g., the computer-based system **110**, the computer-based system **210**, and the method **1900**, etc.) of the present disclosure, where the volatile and non-volatile memories are examples of non-transitory media. A disk storage **2064** provides non-volatile storage for the computer software instructions **2080** and data **2062** that may be used to implement embodiments (e.g., the computer-based system **110**, the computer-based system **210**, and the method **1900**, etc.) of the present disclosure. A central processor unit **2066** is also coupled to the system bus **2072** and provides for the execution of computer instructions.

[0101] As used herein, the terms "model," "module," "interface," and "framework" may refer to any hardware, software, firmware, electronic control component, processing logic, and/or processor device, individually or in any combination, including without limitation: an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), an electronic circuit, a processor and memory that executes one or more software or firmware programs, and/or other suitable components that provide the described functionality.

[0102] Example embodiments disclosed herein may be configured using a computer program product; for example, controls may be programmed in software for implementing example embodiments. Further example embodiments may include a non-transitory computer-readable medium that contains instructions that may be executed by a processor, and, when loaded and executed, cause the processor to complete methods (e.g., the method **1900**, etc.) described herein. It should be understood that elements of the block and flow diagrams may be implemented in software or hardware, such as via one or more arrangements of circuitry of FIG. **20**, disclosed above, or equivalents thereof, firmware, a combination thereof, or other similar implementation determined in the future.

[0103] In addition, the elements of the block and flow diagrams described herein may be combined or divided in any manner in software, hardware, or firmware. If implemented in software, the software may be written in any language that can support the example embodiments disclosed herein. The software may be stored in any form of computer readable medium, such as random-access memory (RAM), read-only memory (ROM), compact disk read-only memory (CD-ROM), and so forth. In operation, a general purpose or application-specific processor or processing core loads and executes software in a manner well understood in the art. It should be understood further that the block and flow diagrams may include more or fewer elements, be arranged or oriented differently, or be represented differently. It should be understood that implementation may dictate the block, flow, and/or network diagrams and the number of block and flow diagrams illustrating the execution of embodiments disclosed herein.

[0104] The teachings of all patents, published applications, and references cited herein are incorporated by reference in their entirety.

[0105] While example embodiments have been particularly shown and described, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the embodiments encompassed by the appended claims.

What is claimed is:

1. A computer-based system for training a user via an emulated real-world building environment, the computer-based system comprising:

a building training interface corresponding to a trainee user;

at least one processor; and

a memory with computer code instructions stored thereon, the at least one processor and the memory, with the computer code instructions, configured to cause the computer-based system to:

based on an initial training input from a trainer user, implement a building simulation model, the building simulation model configured to produce an emulated real-world building environment;

for an iteration of the building simulation model, determine a value of at least one forcing function, the at least one forcing function associated with the emulated real-world building environment;

based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from the trainee user via the building training interface, transform a current state of the building simulation model into an updated state of the building simulation model; and

based on (i) the updated state and (ii) the initial training input, generate at least one building training item for the trainee user.

2. The computer-based system of claim **1**, wherein the building training interface is a first building training interface, the building simulation model is a first building simulation model, and the trainee user is a first trainee user, and further comprising a second building training interface corresponding to a second trainee user, and wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

based on the initial training input from the trainer user, implement a second building simulation model, the second building simulation model configured to produce the emulated real-world building environment;

for the iteration, based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from the second trainee user via the second building training interface, transform a current state of the second building simulation model into an updated state of the second building simulation model; and

based on (i) the updated state of the first building simulation model, (ii) the updated state of the second building simulation model, and (iii) the initial training input, generate the at least one building training item for the first trainee user, the at least one building training item including a comparison of building operation performance of the first trainee user and building operation performance of the second trainee user.

3. The computer-based system of claim **1**, wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

iteratively determine the value of the at least one forcing function and the transform the current state of the building simulation model into the updated state of the building simulation model on an ongoing basis while the trainee user is interacting with the building training interface, during times when the trainee user is not interacting with the building training interface, or based on input from the trainer user.

4. The computer-based system of claim **3**, wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

iteratively determine the value of the at least one forcing function and transform the current state of the building simulation model into the updated state of the building simulation model in real-time or faster-than-real-time.

5. The computer-based system of claim **3**, wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

iteratively determine the value of the at least one forcing function and transform the current state of the building simulation model into the updated state of the building simulation model in at least one of: a periodic mode, an event driven mode, and a mode defined by the trainer user.

6. The computer-based system of claim **1**, wherein a forcing function of the at least one forcing function relates to at least one of: (i) weather conditions, (ii) electricity costs, (iii) energy costs, and (iv) occupant behavior.

7. The computer-based system of claim **1**, wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

based on subsequent training input from the trainer user, configure at least one parameter of (i) the building simulation model or (ii) a forcing function of the at least one forcing function.

8. The computer-based system of claim **7**, wherein the subsequent training input represents at least one of a simulated malfunction of the real-world building environment and a simulated weather event for the real-world building environment.

9. The computer-based system of claim **1**, wherein the initial training input includes at least one criterion for a building operation certification, and wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

perform a determination of whether the updated state of the building simulation model satisfies the at least one criterion; and

responsive to the determination performed indicating that the updated state of the building simulation model satisfies the at least one criterion, generate the at least one building training item, the at least one building training item including an indication that the trainee user has achieved the building operation certification.

10. The computer-based system of claim **9**, wherein a criterion of the at least one criterion relates to an energy optimization objective or an occupant satisfaction objective.

11. The computer-based system of claim **1**, wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

generate a visual comparison of (i) one or more states of the building simulation model and (ii) one or more states of a baseline model; and

wherein a building training item of the at least one building training item generated includes the visual comparison generated.

12. The computer-based system of claim **11**, wherein the one or more states of the baseline model represent (i) states of the emulated real-world building environment simulated by the trainer user or (ii) historical states of the real-world building environment.

13. The computer-based system of claim **1**, wherein the trainee user includes a trainee group of multiple users, each of the multiple users having a corresponding role in the trainee group, and wherein the at least one processor and the memory, with the computer code instructions, are further configured to cause the computer-based system to:

based on (i) the value of the at least one forcing function determined and (ii) multiple respective building operation inputs received from the multiple users via the building training interface, transform the current state of the building simulation model into the updated state of the building simulation model; and

based on (i) the updated state and (ii) the initial training input, generate the at least one building training item, the at least one building training item including an evaluation of relative building operation performance of the multiple users.

14. The computer-based system of claim **1**, wherein the building training interface includes a hardware-based interface or a cloud-based interface.

15. The computer-based system of claim **14**, wherein the hardware-based interface is a building automation system (BAS) training interface.

16. A computer-implemented method for training a user via an emulated real-world building environment, the computer-implemented method comprising:

based on an initial training input from a trainer user, implementing a building simulation model, the building simulation model configured to produce an emulated real-world building environment;

for an iteration of the building simulation model, determining a value of at least one forcing function, the at least one forcing function associated with the emulated real-world building environment;

based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from a trainee user via a building training interface, transforming a current state of the building simulation model into an updated state of the building simulation model; and

based on (i) the updated state and (ii) the initial training input, generating at least one building training item for the trainee user.

17. The computer-implemented method of claim **16**, further comprising:

iteratively determining the value of the at least one forcing function and transforming the current state of the building simulation model into the updated state of the building simulation model in at least one of: a periodic mode, an event driven mode, and a mode defined by the trainer user.

18. The computer-implemented method of claim **16**, further comprising:

based on subsequent training input from the trainer user, configuring at least one parameter of (i) the building simulation model or (ii) a forcing function of the at least one forcing function.

19. The computer-implemented method of claim **18**, wherein the subsequent training input represents at least one of a simulated malfunction of the real-world building environment and a simulated weather event for the real-world building environment.

20. A non-transitory computer-readable medium having encoded thereon a sequence of instructions which, when loaded and executed by at least one processor, causes the at least one processor to:

based on an initial training input from a trainer user, implement a building simulation model, the building simulation model configured to produce an emulated real-world building environment;

for an iteration of the building simulation model, determine a value of at least one forcing function, the at least one forcing function associated with the emulated real-world building environment;

based on (i) the value of the at least one forcing function determined and (ii) at least one building operation input received from a trainee user via a building training interface, transform a current state of the building simulation model into an updated state of the building simulation model; and

based on (i) the updated state and (ii) the initial training input, generate at least one building training item for the trainee user.

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