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(54) **SYSTEMS AND METHODS FOR MONITORING AND CONTROLLING AN ENERGY PLANT**

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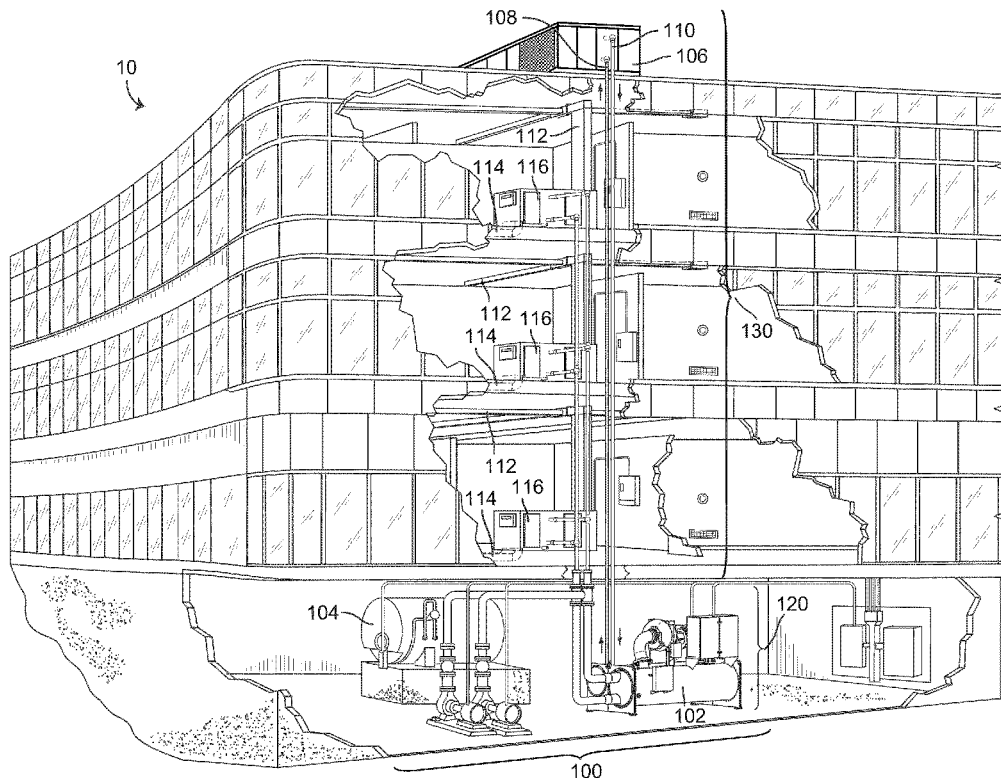(63) Continuation-in-part of application No. 15/387,512, filed on Dec. 21, 2016.

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(57) **ABSTRACT**

An energy plant includes a plurality of subplants, a high level optimizer, a low level optimizer, and a controller. The plurality of subplants include a cogeneration subplant configured to generate steam and electricity and a chiller subplant electrically coupled to the cogeneration subplant and configured to consume the electricity generated by the cogeneration subplant. The high level optimizer is configured to determine recommended subplant loads for each of the plurality of subplants. The recommended subplant loads include a rate of steam production and a rate of electricity production of the cogeneration subplant and a rate of electricity consumption of the chiller subplant. The low level optimizer is configured to determine recommended equipment setpoints for equipment of the plurality of subplants based on the recommended subplant loads. The controller is configured to operate the equipment of the plurality of subplants based on the recommended equipment setpoints.
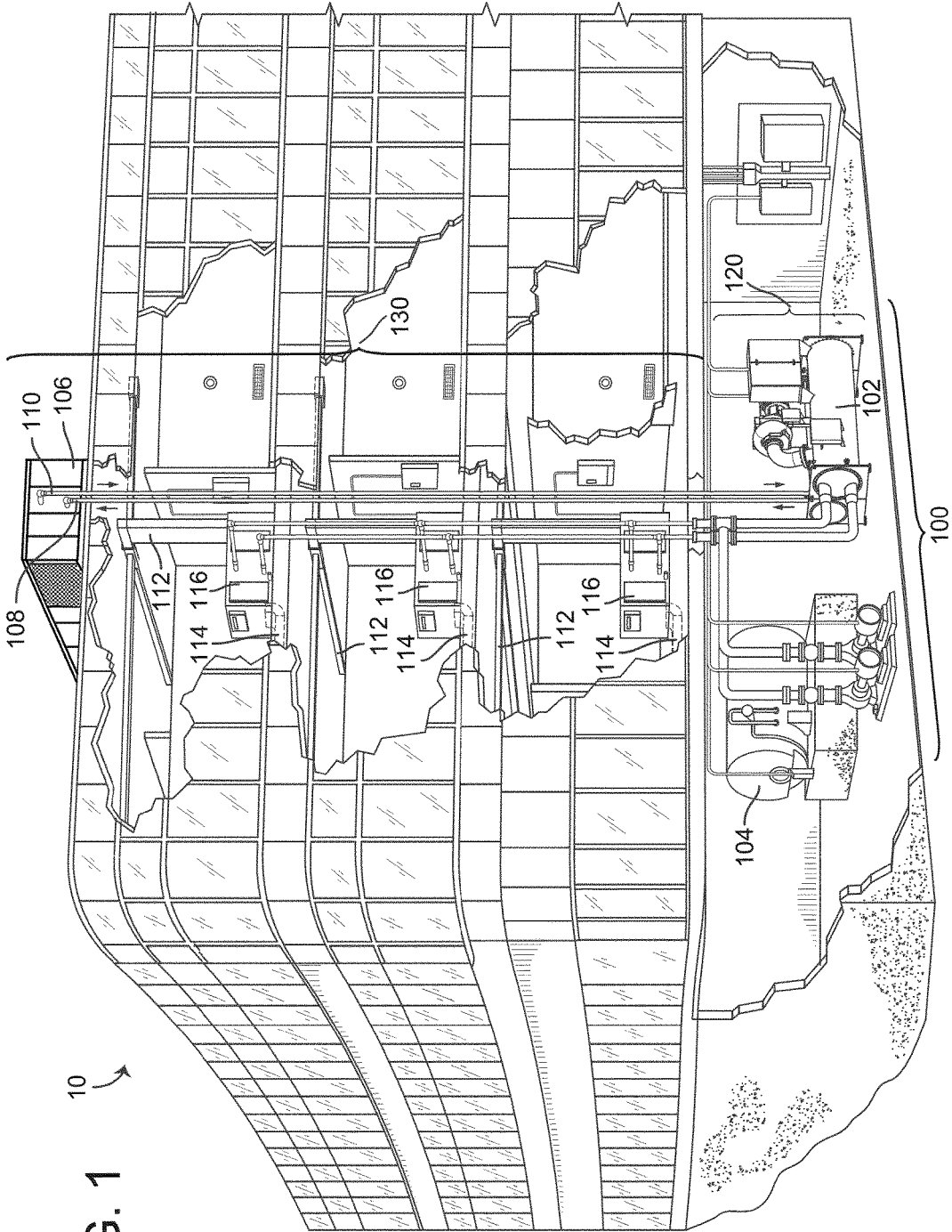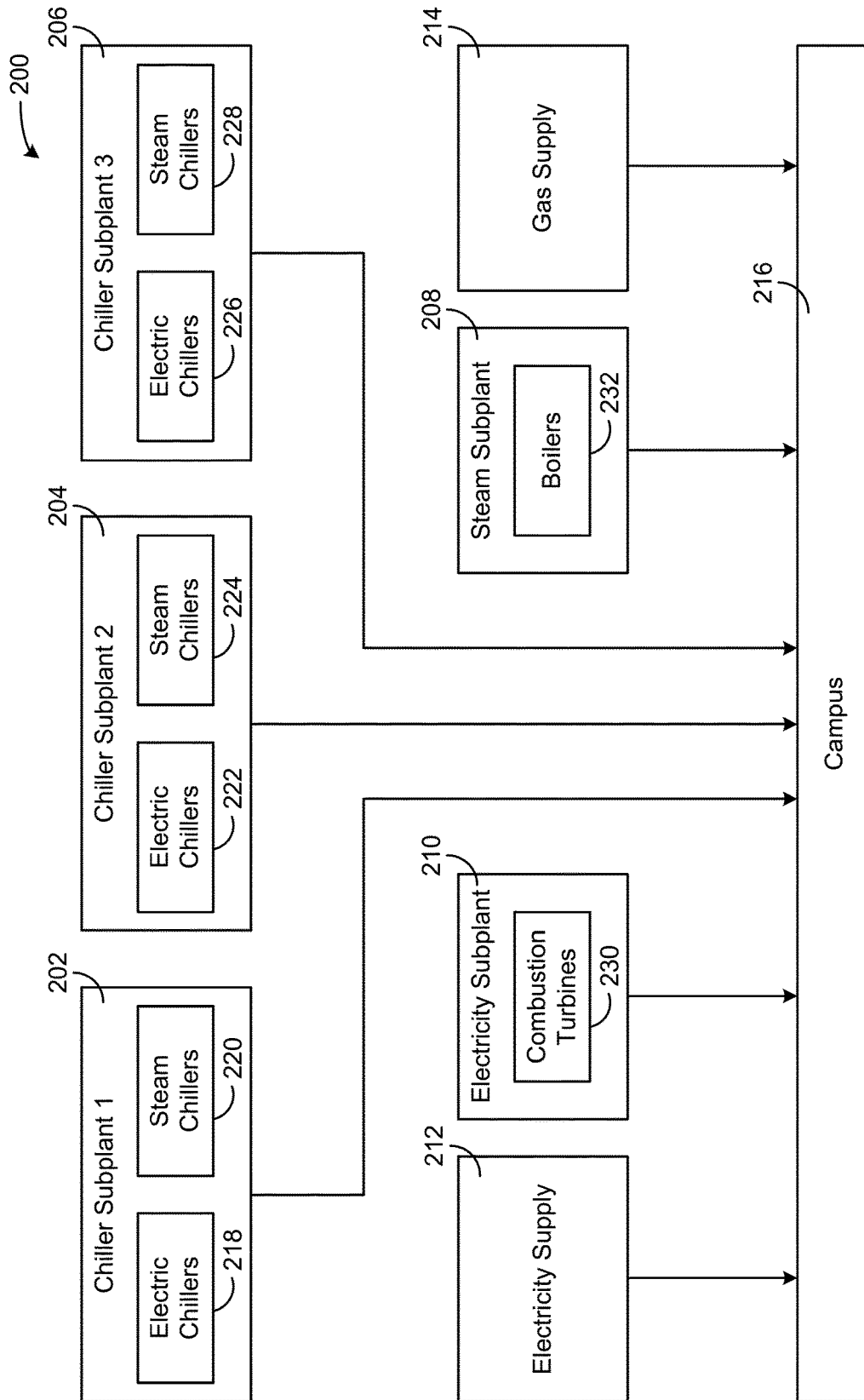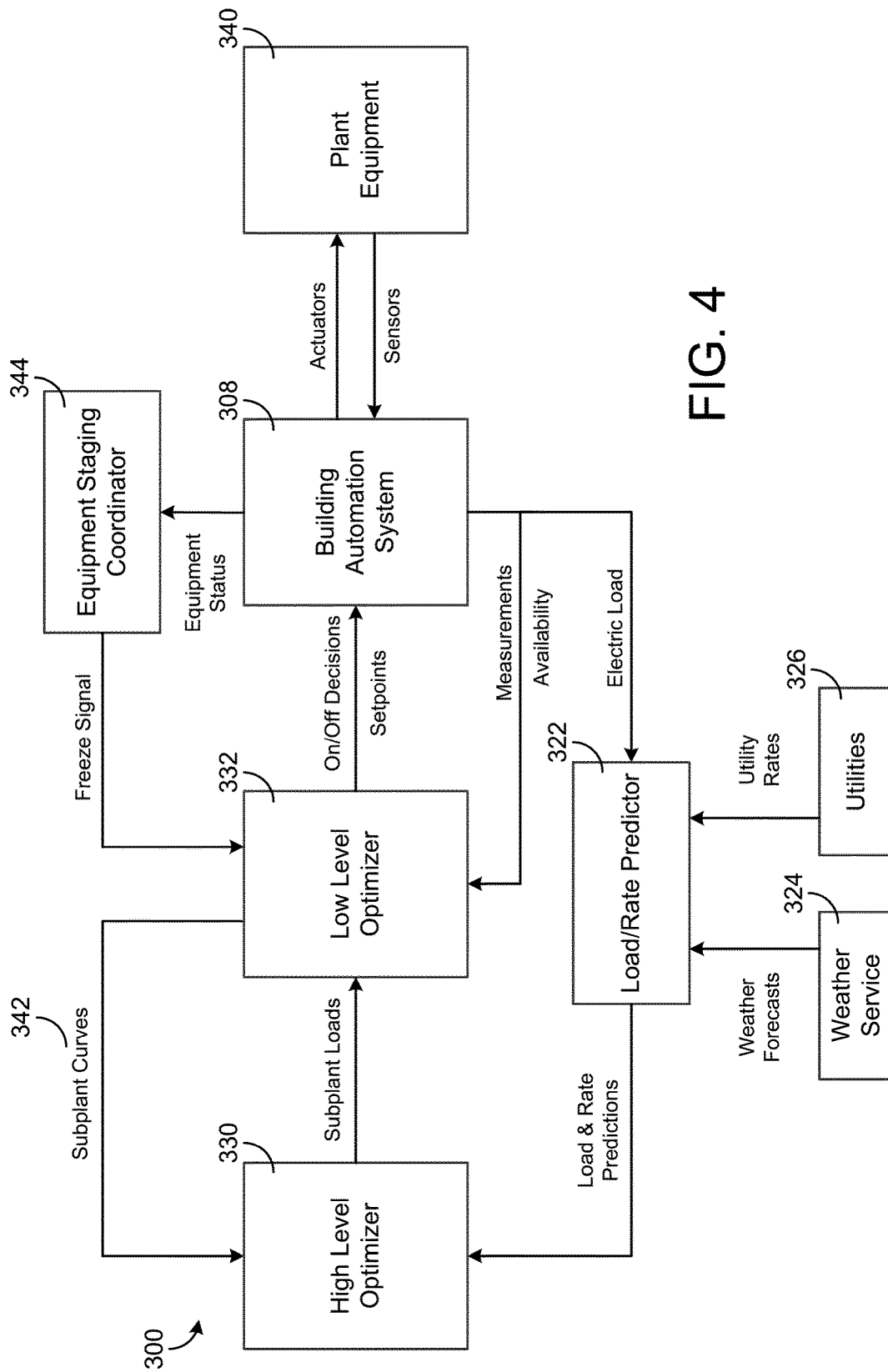
FIG. 1

FIG. 2

FIG. 3

FIG. 4

330

High Level
Optimizer

Optimal
Subplant Loads

500

Optimal
Subplant Loads

332   Optimal
Equipment
Setpoints

Low Level
Optimizer

338   Planned and
Actual Subplant
Utilization Data

Subplant
Monitor

502

Subplant
Utilization
Database

Optimal
Equipment
Setpoints

200

Energy Plant

Actual Subplant
Utilization Data

506

Dispatch GUI
Generator

Dispatch
GUI

504

User Interface

FIG. 5

602

Determine optimal subplant loads for a
plurality of subplants of an energy plant

600

604

Determine optimal setpoints for equipment of each
subplant to achieve the optimal subplant loads

606

Automatically provide the optimal equipment
setpoints to the energy plant to control the equipment

608

Present planned and actual subplant utilization
data to a user via a graphical user interface

FIG. 6

```
                    330                    Recommended                              700
         ┌───────────────────┐            Subplant Loads                    ↙
         │   High Level      │──────────────────────────────┐
         │   Optimizer       │                              │
         └───────────────────┘                              │
            │                                                │
   Recommended                332  Recommended               │    Recommended
   Subplant Loads         ┌────────  Equipment               ▼    and Actual          502
            │             │          Setpoints     ┌──────────────┐  Subplant    ┌──────────────┐
            ▼             ▼                   338   │              │  Utilization │              │
         ┌───────────────────┐            ┌─────────│  Subplant    │──────────────│  Subplant    │
         │   Low Level       │────────────▶│ Monitor  │  Monitor     │    Data      │  Utilization │
         │   Optimizer       │            └─────────│              │              │  Database    │
         └───────────────────┘                  ▲   └──────────────┘              │              │
                                                │                                 └──────────────┘
                                     Actual Subplant                                    │
                                     Utilization Data                                   │
            308                                    200                                  ▼
         ┌───────────────────┐  Equipment    ┌──────────────┐                   506 ┌──────────────┐
         │   Building        │  Control Signals│            │                       │  Dispatch GUI│
         │   Automation      │───────────────▶│ Energy Plant │                      │  Generator   │
         │   System          │               │              │                       └──────────────┘
         └───────────────────┘               └──────────────┘                              │
            ▲                                                                          Dispatch
   User-Defined                                                                        GUI    704
   Setpoints        309                    702        Recommended                        ▼  ┌──────────────┐
            │    ┌───────────────────┐  User-Defined ┌──────────────┐ Setpoints    ┌──────────────┐
         ┌───────────────────┐  Setpoints           │              │◀─────────────│  EOS User    │
         │   BAS User        │◀──────────────────────│    User      │              │  Interface   │
         │   Interface       │◀──────────────────────│              │              └──────────────┘
         └───────────────────┘                       └──────────────┘
```

FIG. 7

```
                 ┌──────────────────────────────────────────────────────┐  802
                 │  Determine recommended subplant loads for a          │
                 │  plurality of subplants of an energy plant           │
                 └──────────────────────────────────────────────────────┘
      800                              │
        ↘                              ▼
                 ┌──────────────────────────────────────────────────────┐  804
                 │  Determine recommended setpoints for equipment of each│
                 │  subplant to achieve the recommended subplant loads   │
                 └──────────────────────────────────────────────────────┘
                                       │
                                       ▼
                 ┌──────────────────────────────────────────────────────┐  806
                 │  Present recommended and actual subplant              │
                 │  utilization data to a user via EOS user interface    │
                 └──────────────────────────────────────────────────────┘
                                       │
                                       ▼
                 ┌──────────────────────────────────────────────────────┐  808
                 │  Receive user-defined setpoints at BAS user interface │
                 └──────────────────────────────────────────────────────┘
                                       │
                                       ▼
                 ┌──────────────────────────────────────────────────────┐  810
                 │  Generate control signals for the subplant            │
                 │  equipment based on the user-defined setpoints        │
                 └──────────────────────────────────────────────────────┘
```

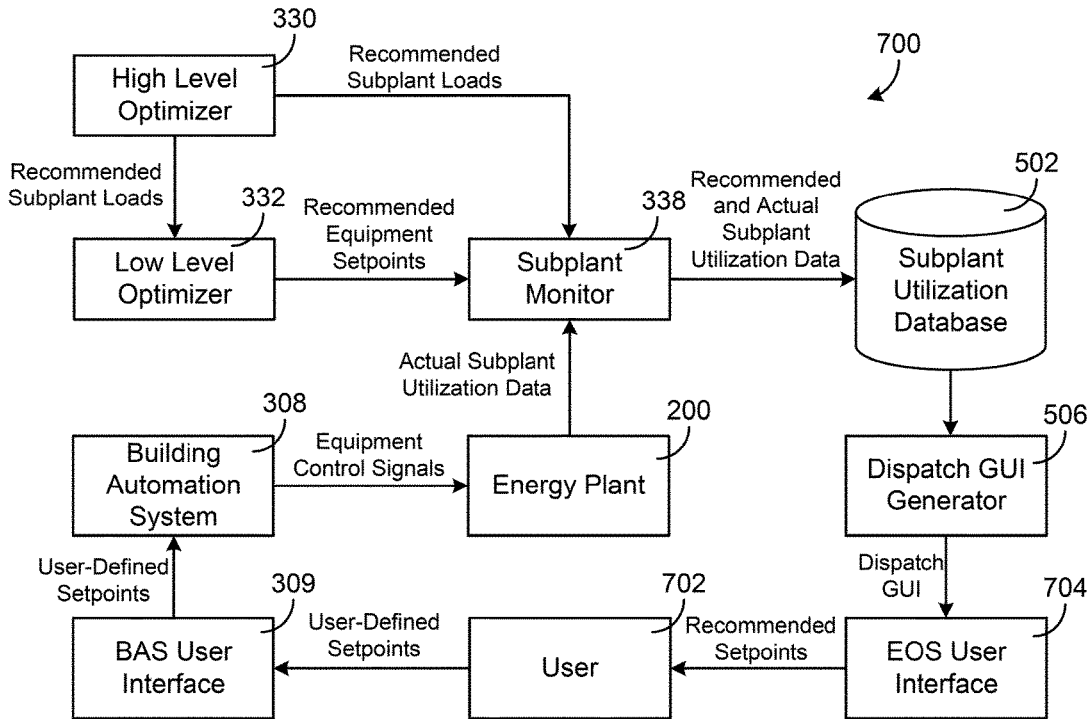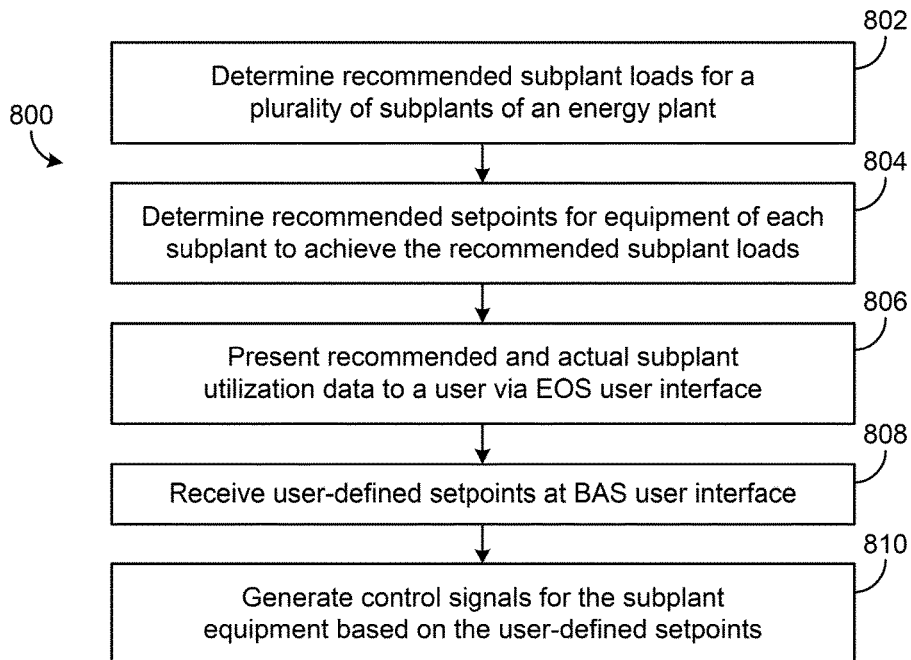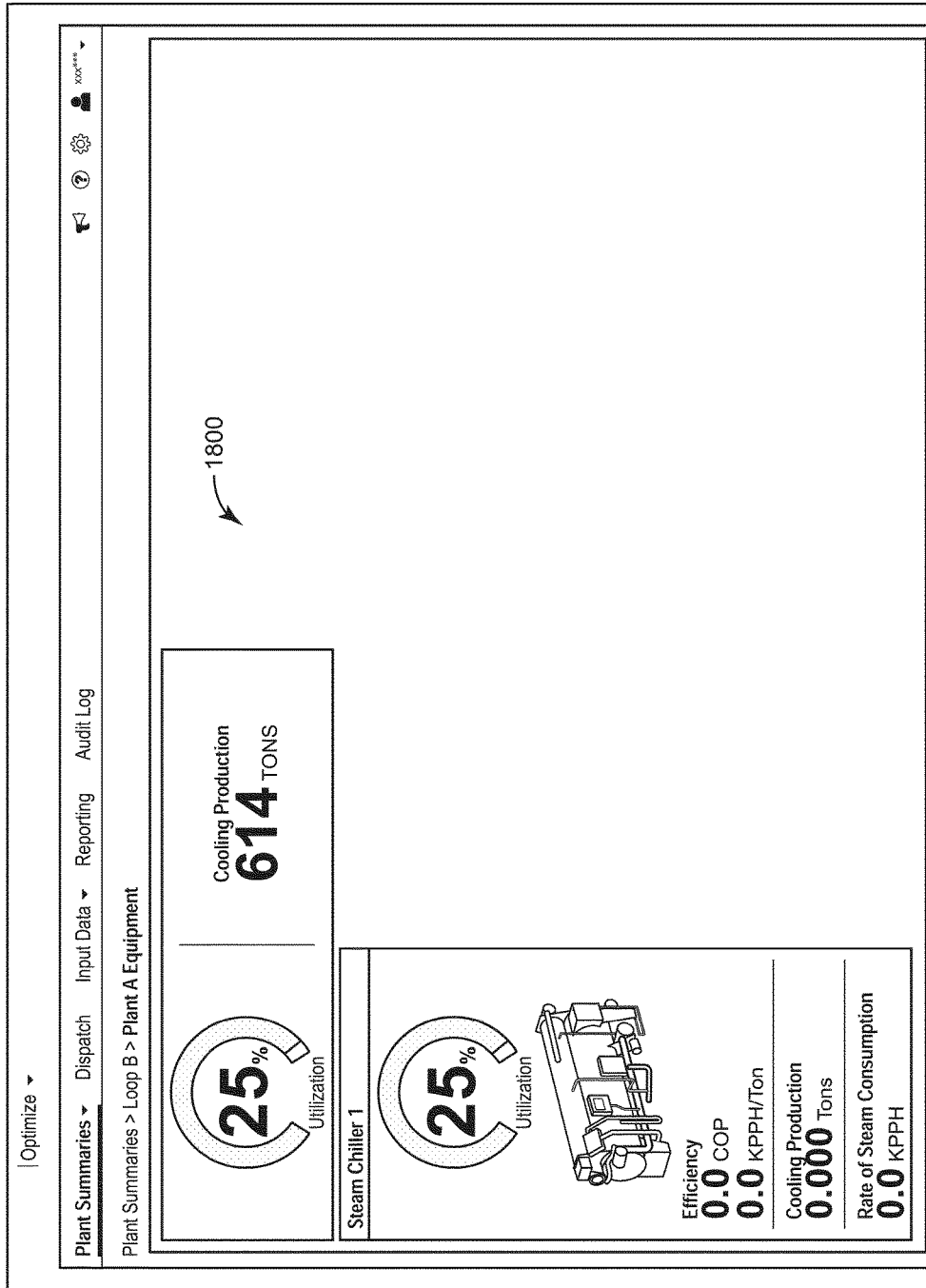## FIG. 8

FIG. 9

FIG. 10

FIG. 11

Campus	Electricity (kW)		Chilled Water (Tons)	Steam (KPPH)	Gas (Mcf/hr)
	22.7	10.4	1,787 3,712 1,655	164	1,200

1200

Loop B

25%

Utilization

— 1104

Plant B

37%

Utilization

1202

Plant A

37%

Utilization

1204

Plant C

37%

Utilization

1206

— 1208

— 1210

1212

1108

Campus

Chilled Water (Tons)

2,867   614   231

FIG. 12

1300

Loop A

25%
Utilization

1102

Plant D

37%
Utilization

1302

Plant E

37%
Utilization

1304

Plant F

37%
Utilization

1306

1308

1310

1312

1108

Campus	Chilled Water (Tons)		
	1,012	121	654

FIG. 13

FIG. 14

|Optimize ▼

Plant Summaries ▼   Dispatch   Input Data ▼   Reporting   Audit Log

Plant Summaries > Loop A > Plant F Equipment

Cooling Production
654 TONS

25%
Utilization

Steam Chiller 1

25%
Utilization

Efficiency
0.0 COP
0.0 KPPH/Ton

Cooling Production
0.000 Tons

Rate of Steam Consumption
0.0 KPPH

Steam Chiller 2

25%
Utilization

Efficiency
0.0 COP
0.0 KPPH/Ton

Cooling Production
0.000 Tons

Rate of Steam Consumption
0.0 KPPH

1500

FIG. 15

FIG. 16

Optimize ▾

Plant Summaries ▾   Dispatch   Input Data ▾   Reporting   Audit Log

Plant Summaries > Loop A > Plant D Equipment

Cooling Production
1,012 TONS

25%
Utilization

1700

Electric Chiller 1

25%
Utilization

Efficiency
0.0 COP
0.0 kW/Ton

Cooling Production
0.000 Tons

Rate of Electric Consumption
0.0 kW

Steam Chiller 1

25%
Utilization

Efficiency
0.0 COP
0.0 KPPH/Ton

Cooling Production
0.000 Tons

Rate of Steam Consumption
0.0 KPPH

FIG. 17

FIG. 18

|Optimize ▾

Plant Summaries ▾   Dispatch   Input Data ▾   Reporting   Audit Log

Plant Summaries > Loop B > Plant C Equipment

1900

25% Utilization

Cooling Production
231 TONS

Electric Chiller 1

25% Utilization

Efficiency
0.0 COP
0.0 kW/Ton

Cooling Production
0.000 Tons

Rate of Electric Consumption
0.0 kW

FIG. 19

FIG. 20

FIG. 21

FIG. 22A

FIG. 22B

FIG. 22C

2300

|Operate ▾ | Campus ▾ |

Next Dispatch: 12:32 | Advisory Mode ▾ |

xxx***

Site ▾ Dispatch ▾ Input Data ▾ Response Program ▾ Reporting ▾ Audit Log

Present Dispatch Interval : 16:30 - ⚠ Dispatch Failed

Dispatch Mode: UnavailableAdvisory

2302

2310

2312

2314

2304 2306 2308

∨ Loop C

SequencingProperties/OnOffStatus (NAU) — EOS | BAS | Actual

	EOS	BAS	Actual
Tower			
Tower10			
Tower10			
Tower10			
Tower10			

Electricity/Power (kW) — EOS | BAS | Actual

CondenserWater/Power (kW) — EOS | BAS | Actual

CondenserWater/Output/Flow (gpm) — EOS | BAS | Actual

CondenserWater/OutputPressure (ft wc) — EOS | BAS | Actual

CondenserWater/Output/Temperature (°F) — EOS | BAS | Actual

CondenserWater/DeltaPressure (ft wc) — EOS | BAS | Actual

SequencingProperties/OnOffStatus (NAU) — EOS | BAS | Actual

Electricity/Power (kW) — EOS | BAS | Actual

CondenserWater/Power (kW) — EOS | BAS | Actual

CondenserWater/Output/Flow (gpm) — EOS | BAS | Actual

	EOS	BAS	Actual
Chiller			
Chiller4			
Chiller4			
Chiller4			

ChilledWater/OutputPressure (ft wc) — EOS | BAS | Actual

ChilledWater/Power (kW) — EOS | BAS | Actual

ChilledWater/DeltaPressure (ft wc) — EOS | BAS | Actual

ChilledWater/Output/Temperature (°F) — EOS | BAS | Actual

ChilledWater/Output/Flow (gpm) — EOS | BAS | Actual

CondenserWater/DeltaPressure (ft wc) — EOS | BAS | Actual

	EOS	BAS	Actual
Chiller			
Chiller4			
Chille4			
Chille4			

CondenserWater/Power (kW)   Steam/DeltaPressure (ft wc)   Steam/Output/Flow (gpm)

FIG. 23A

ENTERPRISE OPTIMIZATION SOLUTION   2310   Next Dispatch: 03:58 | Advisory Mode ▾

Site ▾   Dispatch ▾   Input Data ▾   Response Program ▾   Reporting ▾   Audit Log

Present Dispatch Interval : 12:00 - 12:15

—Plant B Electricity

Precooled Combustion Turbine	SequencingProperties/OnOffStatus (NAU)			NaturalGas/Power (mcf/hr)			Electricity/Power (kW)(kW)		
	EOS	BAS	Actual	EOS	BAS	Actual	EOS	BAS	Actual
Gas Turbine 1	Off	On	On	0.00		0.00	0.00		0.00
Gas Turbine 2	Off	Off	Off	0.00		0.00	0.00		0.00

Precooled Combustion Turbine	HotGas/Output/Temperature (°F)			HotGas/Input/Temperature (°F)		
	EOS	BAS	Actual	EOS	BAS	Actual
Gas Turbine 1	32.00	32.36		32.00		31.95
Gas Turbine 2	32.00	33.32		32.00		31.14

—Plant B Steam

Heat Recovery Steam Generator	SequencingProperties/OnOffStatus (NAU)			Steam/Power (KPPH)			Steam/Output/Pressure (psi)		
	EOS	BAS	Actual	EOS	BAS	Actual	EOS	BAS	Actual
Boiler 5	Off	On	Off	0.00		0.00	0.00	0.00	0.00
Boiler 4	Off	On	On	0.00		0.00	0.00	0.00	0.00

Precooled Combustion Turbine	Steam/Input/Pressure (psi)			Steam/Output/TMassFlow (kg/s)		
	EOS	BAS	Actual	EOS	BAS	Actual
Gas Turbine 1	0.00		0.00	0.00		0.00
Gas Turbine 2	0.00		0.00	0.00		0.00

—Plant B Steam

Duct Burner	SequencingProperties/OnOffStatus (NAU)			Steam/Power (KPPH)			Steam/Output/Pressure (psi)		
	EOS	BAS	Actual	EOS	BAS	Actual	EOS	BAS	Actual
Boiler 5 Duct Burner	Off	On	Off	0.00		0.00	0.00		0.00

SequencingProperties/OnOffStatus (NAU)   NaturalGas/Power (kW)   Steam/Power (KPPH)

Dispatch Mode: Advisory

2300   2312   2302   2314   2304   2306   2308

FIG. 23B

ENTERPRISE OPTIMIZATION SOLUTION

Next Dispatch: 01:45 Advisory Mode ▾

Site ▾   Dispatch ▾   Input Data ▾   Response Program ▾   Reporting ▾   Audit Log

Select Plants ▾   12/12/2017   □ EOS On ▥ EOS Off ▨ Out of Service ■ No Dispatch ▾ Off Clock
                                                                                      ▾ Dispatch
                                                                      * EOS dispatch times are an approximation

2350

— Plant B Electricity

Gas Turbine 1
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

Gas Turbine 2
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

— Plant B Steam

Boiler 5
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

Boiler 5 Duct Burner
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

Boiler 4
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

Boiler 6
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

Boiler 7
11:30   11:45   Current Interval 12:00   12:15   12:30   12:45   13:00

+ Loop B

+ Loop C

— Loop A

— Plant F

Chiller 1 (s)

FIG. 23C

FIG. 24

FIG. 25

FIG. 26A

FIG. 26B

FIG. 27A

FIG. 27B

FIG. 28A

FIG. 28B

FIG. 29

Plant Summaries▾   Dispatch   Input Data▾   Performance Monitoring   Audit Log

Input Data > Forecast Inputs > Weather

3000

Dry Bulb Temperature (°F) [▾]   [Override]   [Edit Override]

3002

100 deg F

0 deg F

30. Sep   12:00   1. Oct   12:00   2. Oct   12:00   3. Oct   12:00   4. Oct   12:00   5. Oct   12:00   6. Oct   12:00   7. Oct

Hour Ending Time
(HE 14 represents 1:01 to 2:00)

3004

	HE 01	HE 02	HE 03	HE 04	HE 05	HE 06	HE 07	HE 08	HE 09	HE 10	HE 11	HE 12	HE 13	HE 14	HE 15	HE 16	HE 17	HE 18	HE 19
9/30/2016	54.0	52.6	51.0	49.8	48.9	49.1	48.3	48.5	48.3	50.1	56.9	61.7	64.8	67.5	70.4	72.4	73.0	74.2	74.3
9/30/2016	56.6	54.6	53.3	52.0	51.1	50.5	50.2	49.4	49.1	51.2	557.1	62.6	66.3	66.8	71.8	73.8	75.4	78.3	78.9
9/30/2016	62.5	60.7	57.4	56.9	56.0	55.5	54.4	53.9	53.4	55.0	60.7	65.8	65.6	77.3	74.1	75.9	77.4	80.4	81.7
9/30/2016	62.2	61.3	57.9	56.6	55.8	55.6	54.5	54.3	54.5	56.5	64.3	72.4	76.3	76.3	80.8	82.8	84.5	86.6	87.5
9/30/2016	64.9	62.6	61.9	59.5	59.0	59.3	59.4	59.0	58.8	60.5	67.8	75.2	75.10	80.4	82.9	85.3	87.6	89.6	90.9
9/30/2016	66.6	63.8	61.7	60.4	59.4	57.9	57.2	56.9	57.2	58.0	65.0	71.8	76.7	80.6	83.7	86.1	88.0	90.3	91.7
9/30/2016	64.8	63.2	62.2	60.7	59.9	59.8	59.6	60.3	60.8	62.5	68.3	73.4	78.4	80.7	82.6	84.7	86.6	86.9	87.3
9/30/2016	64.7	61.9	60.2	58.8	57.5	56.7	56.0	55.5	54.8	55.9	61.8	66.6	69.9						

FIG. 30

3000

3002

3004

3006

3010

Plant Summaries▾   Dispatch   Input Data▾   Performance Monitoring   Audit Log

Input Data > Forecast Inputs > Weather

Dry Bulb Temperature (°F) ▾   [Override] [Edit Override]

100 deg F

0 deg F

30. Sep   12:00   1. Oct

5. Oct   12:00   6. Oct   12:00   7. Oct

Override

* Denotes required fields

Start Date & Time*

| MM/DD/YYYY | ▦ | 1:00 PM | ▾ |

End Date & Time*

| MM/DD/YYYY | ▦ | 2:00 PM | ▾ |

Change By*

| Select | ▾ | | °F |

Add Reason for Override*

[Cancel] [Save]

	HE 01	HE 02	HE 03		13	HE 14	HE 15	HE 16	HE 17	HE 18	HE 19
9/30/2016	54.0	52.6	51.0	49	3	67.5	70.4	72.4	73.0	74.2	74.3
9/30/2016	56.6	54.6	53.3	52	3	66.8	71.8	73.8	75.4	78.3	78.9
9/30/2016	62.5	60.7	57.4	56	3	77.3	74.1	75.9	77.4	80.4	81.7
9/30/2016	62.2	61.3	57.9	56	3	76.3	80.8	82.8	84.5	86.6	87.5
9/30/2016	64.9	62.6	61.9	59	0	80.4	82.9	85.3	87.6	89.6	90.9
9/30/2016	66.6	63.8	61.7	60		80.6	83.7	86.1	88.0	90.3	91.7
9/30/2016	64.8	63.2	62.2	60	4	80.7	82.6	84.7	86.6	86.9	87.3
9/30/2016	64.7	61.9	60.2								

58.8   57.5   56.7   56.0   55.5   54.8   55.9   61.8   66.6   69.9

FIG. 31

FIG. 32

FIG. 33

FIG. 34

FIG. 35A

FIG. 35B

| Energy Optimization Solution | Next Dispatch: 12:32 | Advisory Mode ▾ |

Plant Summaries ▾   Dispatch   Input Data ▾   **Reporting**   Audit Log   📢 ⑦ ⚙ 👤 xxx*** ▾

Home > **Dispatch**

From
[11/03/2016 ✕] [📅]

To
[11/05/2016 ✕] [📅]

⌄ **Cost/Revenue**

Electric Usage Cost ($)	Demand Cost ($)	Gas Cost ($)	ELDR Revenue ($)	Total ($)
808,577	1,712,755	3,604,121	+871,623	5,253,851

⌄ **Chilled Water**

	Production (Tons)
Loop B	3,890,355
Electric Chiller 1	1,238,793
Electric Chiller 2	1,238,793
Electric Chiller 3	1,238,794
Steam Chiller 1	173,955
Loop A	2,855,538
Plant F	831,235
Steam Chiller 1	415,617
Steam Chiller 2	415,618
Plant E	825,700
Electric Chiller 1	412,850
Electric Chiller 2	412,850
Plant D	1,198,603
Electric Chiller 1	1,184,189
Steam Chiller 1	14,414
Loop B	8,836,470
Plant A	29,996
Plant C	277,574
Plant B	8,528,900
Electric Chiller 1	3,551,029
Electric Chiller 2	3,551,029
Steam Chiller 1	1,426,842
Loop B	15,582,363

⌄ **Electrical**

3600

FIG. 36A

3600

∨ Electrical

Production (kWh)			Consumption (kWh)	
Plant B	38,169,221		Campus	75,241,320
Combustion Turbine 1	9,094,069		Loop C	1,850,981
Combustion Turbine 2	29,075,152		Electric Chiller 1	616,472
Utility Import	45,235,997		Electric Chiller 2	616,473
Total	83,405,219		Electric Chiller 3	616,473
			Steam Chiller 1	1,563
			Loop A	1,184,483
			Plant F	28,185
			Steam Chiller 1	14,093
			Steam Chiller 2	14,092
			Plant E	825,700
			Electric Chiller 1	412,850
			Electric Chiller 2	412,850
			Plant D	643,570
			Electric Chiller 1	643,570
			Steam Chiller 1	0
			Loop B	4,542,591
			Plant A	3,078
			Plant C	146,952
			Plant B	4,392,561
			Electric Chiller 1	2,141,951
			Electric Chiller 2	2,141,952
			Steam Chiller 1	108,659
			Plant B	562,380
			Boiler 6	281,190
			Boiler 7	281,190

∨ Steam

Production (KPPH)			Consumption (KPPH)	
Plant B	137,057,825		Campus	128,979,389
Boiler 4	82,430,785		Loop C	842,246
Boiler 5	22,276,759		Steam Chiller 1	842,246
Boiler 6	16,200,141		Loop A	4,061,450
Boiler 7	16,200,140		Plant F	3,991,020
Total	137,057,825		Steam Chiller 1	1,995,510
			Steam Chiller 2	1,995,510
			Plant D	70,430
			Steam Chiller 1	70,430
			Loop B	3,174,741
			Plant A	150,145
			Plant B	3,024,596
			Steam Chiller 1	3,024,596
			Total	137,057,826

FIG. 36B

Example of Add a Note Dialog

Add A Note

Type your note here.

[Cancel]   [Confirm]

3700   From [05/26/2016]   To [05/26/2016]

Date & Time ⇕	Username ▾	Note ⇕	Type: Input ▾ ⬍
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	General Input
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input Schedule
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Mode
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas
February 9, 2016 4:22 PM	John Smith	Corrected rate schedule per provider agreement	Input - Natural Gas

[Add Schedule]

1-10 of 20 Show [10 ▾]   [▼] [1] [▲] 1 of 2

FIG. 37

SYSTEMS AND METHODS FOR MONITORING AND CONTROLLING AN ENERGY PLANT

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 15/387,512 filed Dec. 21, 2016, which claims the benefit of and priority to U.S. Provisional Patent Application No. 62/286,287 filed Jan. 22, 2016. This application also claims the benefit of and priority to U.S. Provisional Patent Application No. 62/476,510 filed Mar. 24, 2017. The entire disclosures of each of these patent applications are incorporated by reference herein.

BACKGROUND

[0002] The present disclosure relates generally to an plant that includes multiple subplants configured to serve the energy loads of a building or campus. The present disclosure relates more particularly to systems and methods for monitoring and controlling multiple subplants and the equipment within each of the subplants.

[0003] An energy plant may include a number of subplants configured to serve the heating, cooling, electric, and other energy loads of a building or campus. For example, the energy plant may include a heater subplant, a chiller subplant, a heat recovery chiller subplant, a cogeneration subplant, a steam subplant, a hot thermal energy storage (TES) subplant, and/or a cold TES subplant. The subplants may include a variety of HVAC equipment configured to serve heating, cooling, and electric loads (e.g., heaters, boilers, chillers, heat recovery chillers, electric generators, cooling towers, etc.). The energy plant may be controlled by an energy plant controller that distributes a requested or predicted energy load (e.g., a heating load, a cooling load, an electric load, etc.) across the plurality of subplants. It can be difficult and challenging to monitor and control the operation of an energy plant.

SUMMARY

[0004] One implementation of the present disclosure is an energy plant. The energy plant includes a plurality of subplants, a high level optimizer, a low level optimizer, and a controller. The plurality of subplants are configured to serve energy loads of a campus and include a cogeneration subplant and a chiller subplant. The cogeneration subplant is configured to generate steam and electricity. The chiller subplant is electrically coupled to the cogeneration subplant and configured to consume the electricity generated by the cogeneration subplant. The high level optimizer is configured to determine recommended subplant loads for each of the plurality of subplants. The recommended subplant loads include a rate of steam production and a rate of electricity production of the cogeneration subplant and a rate of electricity consumption of the chiller subplant. The low level optimizer is configured to determine recommended equipment setpoints for equipment of the plurality of subplants based on the recommended subplant loads. The controller is configured to operate the equipment of the plurality of subplants based on the recommended equipment setpoints.

[0005] In some embodiments, the chiller subplant is fluidly coupled to the cogeneration subplant and configured to chill the steam generated by the cogeneration subplant. The recommended subplant loads may include a rate of steam consumption and a rate of chilled steam production of the chiller subplant.

[0006] In some embodiments, the energy plant includes a user interface configured to receive manual subplant loads specified by a user. The low level optimizer can be configured to determine the recommended equipment setpoints for the equipment of the plurality of subplants based on the manual subplant loads.

[0007] In some embodiments, the energy plant includes a dispatch graphical user interface (GUI) generator configured to generate a dispatch GUI and present the dispatch GUI via the user interface. The dispatch GUI may include the recommended subplant loads and the manual subplant loads.

[0008] In some embodiments, the dispatch GUI includes an operating mode selector configured to display a plurality of operating modes and to receive a user selection of one of the operating modes. The plurality of operating modes may include an automatic operating mode, an advisory operating mode, and a manual operating mode.

[0009] In some embodiments, the low level optimizer is configured to operate in (1) an automatic operating mode in which the low level optimizer determines a first set of recommended equipment setpoints to achieve the recommended subplant loads and (2) a manual operating mode in which the low level optimizer determines a second set of recommended equipment setpoints to achieve the manual subplant loads.

[0010] In some embodiments, the high level optimizer is configured to determine an amount of overproduction or underproduction resulting from the manual subplant loads by comparing the manual subplant loads to a campus energy load.

[0011] In some embodiments, the plurality of subplants include an energy storage subplant. The user interface may include an indication of an amount of time until the energy storage subplant is (1) fully depleted based on the amount of underproduction or (2) filled to capacity based on the amount of overproduction.

[0012] In some embodiments, the energy plant includes a subplant monitor configured to monitor the energy plant and identify actual subplant loads for each of the plurality of subplants. In some embodiments, the energy plant includes a dispatch graphical user interface (GUI) generator configured to generate a dispatch GUI comprising the recommended subplant loads and the actual subplant loads.

[0013] Another implementation of the present disclosure is a method for monitoring and controlling an energy plant including a plurality of subplants that operate to serve energy loads of a campus. The method includes operating a cogeneration subplant of the plurality of subplants to generate steam and electricity, operating a chiller subplant of the plurality of subplants to consume the electricity generated by the cogeneration subplant, and determining recommended subplant loads for each of the plurality of subplants. The recommended subplant loads include a rate of steam production and a rate of electricity production of the cogeneration subplant and a rate of electricity consumption of the chiller subplant. The method includes determining recommended equipment setpoints for equipment of the plurality of subplants based on the recommended subplant loads and operating the equipment of the plurality of subplants based on the recommended equipment setpoints.

[0014] In some embodiments, the method includes operating the chiller subplant to chill the steam generated by the cogeneration subplant. The recommended subplant loads may include a rate of steam consumption and a rate of chilled steam production of the chiller subplant.

[0015] In some embodiments, the method includes receiving manual subplant loads specified by a user via a user interface and determining the recommended equipment setpoints for the equipment of the plurality of subplants based on the manual subplant loads.

[0016] In some embodiments, the method includes generating a dispatch GUI and presenting the dispatch GUI via the user interface. The dispatch GUI may include the recommended subplant loads and the manual subplant loads.

[0017] In some embodiments, the method includes receiving a user selection of one of a plurality of operating modes via an operating mode selector of the dispatch GUI. The plurality of operating modes may include an automatic operating mode, an advisory operating mode, and a manual operating mode.

[0018] In some embodiments, the method includes operating in an automatic operating mode to determine a first set of recommended equipment setpoints to achieve the recommended subplant loads and operating in a manual operating mode to determine a second set of recommended equipment setpoints to achieve the manual subplant loads.

[0019] In some embodiments, the method includes determining an amount of overproduction or underproduction resulting from the manual subplant loads by comparing the manual subplant loads to a campus energy load.

[0020] In some embodiments, the plurality of subplants include an energy storage subplant. The user interface may include an indication of an amount of time until the energy storage subplant is (1) fully depleted based on the amount of underproduction or (2) filled to capacity based on the amount of overproduction.

[0021] In some embodiments, the method includes monitoring the energy plant to identify actual subplant loads for each of the plurality of subplants. In some embodiments, the method includes generating a dispatch GUI comprising the recommended subplant loads and the actual subplant loads.

[0022] Those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices and/or processes described herein, as defined solely by the claims, will become apparent in the detailed description set forth herein and taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a drawing of a building equipped with a building automation system and served by an energy plant, according to an exemplary embodiment.

[0024] FIG. 2 is a schematic diagram of an energy plant including a number of subplants configured to serve the energy loads of the building of FIG. 1, according to an exemplary embodiment.

[0025] FIG. 3 is a block diagram of an energy optimization system (EOS) configured to monitor and control the energy plant of FIG. 2, according to an exemplary embodiment.

[0026] FIG. 4 is a block diagram of a plant system illustrating a cascaded optimization process which may be performed by the EOS of FIG. 3, according to an exemplary embodiment.

[0027] FIG. 5 is a block diagram illustrating the operation of the EOS of FIG. 3 in an automatic operating mode, according to an exemplary embodiment.

[0028] FIG. 6 is a flow diagram illustrating the operation of the EOS of FIG. 3 in the automatic operating mode, according to an exemplary embodiment.

[0029] FIG. 7 is a block diagram illustrating the operation of the EOS of FIG. 3 in an advisory operating mode, according to an exemplary embodiment.

[0030] FIG. 8 is a flow diagram illustrating the operation of the EOS of FIG. 3 in the advisory operating mode, according to an exemplary embodiment.

[0031] FIG. 9 is a block diagram illustrating the operation of the EOS of FIG. 3 in a manual operating mode, according to an exemplary embodiment.

[0032] FIG. 10 is a flow diagram illustrating the operation of the EOS of FIG. 3 in the manual operating mode, according to an exemplary embodiment.

[0033] FIG. 11 is a drawing of a site summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0034] FIG. 12 is a drawing of a chilled water loop summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0035] FIG. 13 is a drawing of another chilled water loop summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0036] FIG. 14 is a drawing of an equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0037] FIG. 15 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0038] FIG. 16 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0039] FIG. 17 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0040] FIG. 18 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0041] FIG. 19 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0042] FIG. 20 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0043] FIG. 21 is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0044] FIG. 22A is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0045] FIG. 22B is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0046] FIG. 22C is a drawing of another equipment summary interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0047] FIG. 23A is a drawing of a dispatch schedule interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0048] FIG. 23B is a drawing of another dispatch schedule interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0049] FIG. 23C is a drawing of another dispatch schedule interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0050] FIG. 24 is a drawing of a dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0051] FIG. 25 is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0052] FIG. 26A is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0053] FIG. 26B is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0054] FIG. 27A is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0055] FIG. 27B is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0056] FIG. 28A is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0057] FIG. 28B is a drawing of another dispatch chart interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0058] FIG. 29 is a drawing of a weather forecast input interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0059] FIG. 30 is a drawing of a dry bulb temperature forecast input interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0060] FIG. 31 is a drawing of an override interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0061] FIG. 32 is a drawing of a utility pricing forecast input interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0062] FIG. 33 is a drawing of an out-of-service schedule interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0063] FIG. 34 is a drawing of a campus schedule interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0064] FIG. 35A is a drawing of a reporting interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0065] FIG. 35B is a drawing of another reporting interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0066] FIGS. 36A and 36B are drawings of a site summary report which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

[0067] FIG. 37 is a drawing of an audit log interface which may be generated by the EOS of FIG. 3, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0068] Referring generally to the FIGURES, systems and methods for monitoring and controlling an energy plant are shown, according to an exemplary embodiment. The energy plant may include a plurality of subplants configured to serve the heating, cooling, and electric loads of a building or campus. For example, the energy plant may include a heater subplant, one or more chiller subplants, a heat recovery chiller subplant, a cogeneration subplant, a steam subplant, a hot thermal energy storage (TES) subplant, and/or a cold TES subplant. The subplants may be located within the same building or distributed across multiple buildings. The energy plant may be controlled by an energy optimization system (EOS) that distributes a requested or predicted energy load (e.g., a heating load, a cooling load, an electric load, etc.) across the plurality of subplants. In some embodiments, the EOS performs an optimization process to determine an optimal load distribution across the plurality of subplants for each of a plurality of time steps within a prediction window.

[0069] The EOS may predict the loads on each of the subplants throughout the prediction window. In some embodiments, the predicted subplant loads include a heating load served by the heating subplant, a heating load served by the heat recovery chiller subplant, a heating load served by the steam subplant, a cooling load served by the heat recovery chiller subplant, a cooling load served by the chiller subplant(s), an electric load served by the cogeneration subplant, a heating load served or stored by the hot TES subplant (e.g., a predicted rate at which the hot TES subplant will be charging or discharging), and/or a cooling load served or stored by the cold TES subplant (e.g., a predicted rate at which the cold TES subplant will be charging or discharging). In some embodiments, the EOS predicts a charge state for the TES subplants defining an amount of thermal energy stored in each of the TES subplants during each of the dispatch intervals. The predicted subplant loads and TES charge states for each of the future time steps may be stored in a subplant utilization database. The actual operation of the energy plant may be monitored to determine the actual subplant loads and TES charge stages during each of the time steps. The actual subplant loads and TES charge states may be stored in the subplant utilization database for each of the past and current dispatch intervals.

[0070] A dispatch graphical user interface (GUI) generator may access the data stored in the subplant utilization database and use the stored data to generate a dispatch GUI. The dispatch GUI may be a graph or chart that illustrates the actual subplant utilization data (e.g., past and current subplant loads) and the predicted subplant utilization data (e.g., future subplant loads) in a graphical format. In some embodiments, the dispatch GUI indicates the actual and predicted subplant loads for each of the subplants at each of the dispatch intervals represented in the dispatch GUI. The dispatch GUI may be configured to receive manual subplant loads specified by a user.

[0071] The dispatch GUI generator may provide the dispatch GUI to a user interface of a client device (e.g., a computer terminal, a workstation, a laptop, a tablet, a smartphone, etc.). In some embodiments, the dispatch GUI generator is a component of the energy plant controller. In other embodiments, the dispatch GUI generator may be a component of the client device. For example, the dispatch GUI generator may be a web browser or a specialized application running on the client device. In some embodiments, the dispatch GUI is rendered using specialized viewing software (e.g., an energy plant monitoring application) installed on the client device. In other embodiments, the

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dispatch GUI is provided via a web interface which allows the dispatch GUI to be rendered and viewed using a web browser without requiring any specialized applications or software to be installed on the client device.

[0072] The dispatch GUI may present recommended (i.e., optimal) subplant loads, manual subplant loads, and actual subplant loads in a variety of visual formats (e.g., diagrams, charts, graphs, etc.) that illustrate the operation of the energy plant. The dispatch GUI may include a first set of recommended equipment setpoints that result from the recommended subplant loads, a second set of recommended equipment setpoints that result from the manual subplant loads, and the actual equipment setpoints to provide details regarding the operation of each subplant. The dispatch GUI may include past dispatch data (e.g., past subplant loads, past equipment setpoints) and current dispatch data (e.g., current subplant loads, current equipment setpoints) to allow a user to view a history of energy plant operations. The dispatch GUI may also include future dispatch data (e.g., planned subplant loads, planned equipment setpoints) to allow the user to view planned energy plant operations into the future. Additional features and advantages of the dispatch GUI are described in detail below.

[0073] In some embodiments, the dispatch GUI generator and/or the dispatch GUI include some or all of the features described in U.S. Design patent application No. 29/515,801 filed Jan. 27, 2015, U.S. Provisional Patent Application No. 62/286,287 filed Jan. 22, 2017, and/or U.S. patent application Ser. No. 15/387,512 filed Dec. 21, 2016. The entire disclosure of each of these patent applications is incorporated by reference herein.

Building with HVAC System

[0074] Referring now to FIG. 1, a perspective view of a building 10 is shown. Building 10 is served by a building automation system (BAS). A BAS is, in general, a system of devices configured to control, monitor, and manage equipment in or around a building or building area. A BAS can include, for example, a HVAC system, a security system, a lighting system, a fire alerting system, any other system that is capable of managing building functions or devices, or any combination thereof.

[0075] The BAS that serves building 10 includes an HVAC system 100. HVAC system 100 may include a plurality of HVAC devices (e.g., heaters, chillers, air handling units, pumps, fans, thermal energy storage, etc.) configured to provide heating, cooling, ventilation, or other services for building 10. For example, HVAC system 100 is shown to include a waterside system 120 and an airside system 130. Waterside system 120 may provide a heated or chilled fluid to an air handling unit of airside system 130. Airside system 130 may use the heated or chilled fluid to heat or cool an airflow provided to building 10. In some embodiments, waterside system 120 is replaced with a central energy plant such as energy plant 200, described with reference to FIG. 2.

[0076] Still referring to FIG. 1, HVAC system 100 is shown to include a chiller 102, a boiler 104, and a rooftop air handling unit (AHU) 106. Waterside system 120 may use boiler 104 and chiller 102 to heat or cool a working fluid (e.g., water, glycol, etc.) and may circulate the working fluid to AHU 106. In various embodiments, the HVAC devices of waterside system 120 may be located in or around building 10 (as shown in FIG. 1) or at an offsite location such as an energy plant (e.g., a chiller plant, a steam plant, a heat plant,

etc.). The working fluid may be heated in boiler 104 or cooled in chiller 102, depending on whether heating or cooling is required in building 10. Boiler 104 may add heat to the circulated fluid, for example, by burning a combustible material (e.g., natural gas) or using an electric heating element. Chiller 102 may place the circulated fluid in a heat exchange relationship with another fluid (e.g., a refrigerant) in a heat exchanger (e.g., an evaporator) to absorb heat from the circulated fluid. The working fluid from chiller 102 and/or boiler 104 may be transported to AHU 106 via piping 108.

[0077] AHU 106 may place the working fluid in a heat exchange relationship with an airflow passing through AHU 106 (e.g., via one or more stages of cooling coils and/or heating coils). The airflow may be, for example, outside air, return air from within building 10, or a combination of both. AHU 106 may transfer heat between the airflow and the working fluid to provide heating or cooling for the airflow. For example, AHU 106 may include one or more fans or blowers configured to pass the airflow over or through a heat exchanger containing the working fluid. The working fluid may then return to chiller 102 or boiler 104 via piping 110.

[0078] Airside system 130 may deliver the airflow supplied by AHU 106 (i.e., the supply airflow) to building 10 via air supply ducts 112 and may provide return air from building 10 to AHU 106 via air return ducts 114. In some embodiments, airside system 130 includes multiple variable air volume (VAV) units 116. For example, airside system 130 is shown to include a separate VAV unit 116 on each floor or zone of building 10. VAV units 116 may include dampers or other flow control elements that can be operated to control an amount of the supply airflow provided to individual zones of building 10. In other embodiments, airside system 130 delivers the supply airflow into one or more zones of building 10 (e.g., via air supply ducts 112) without using intermediate VAV units 116 or other flow control elements. AHU 106 may include various sensors (e.g., temperature sensors, pressure sensors, etc.) configured to measure attributes of the supply airflow. AHU 106 may receive input from sensors located within AHU 106 and/or within the building zone and may adjust the flow rate, temperature, or other attributes of the supply airflow through AHU 106 to achieve setpoint conditions for the building zone.

Energy Plant and Control System

[0079] Referring now to FIG. 2, a block diagram of an energy plant 200 is shown, according to an exemplary embodiment. In brief overview, energy plant 200 may include various types of equipment configured to serve the thermal and electrical energy loads of a building or campus (i.e., a system of buildings). For example, energy plant 200 may include heaters, chillers, heat recovery chillers, cooling towers, or other types of equipment configured to serve the heating and/or cooling loads of a building or campus. Energy plant 200 may consume resources from a utility (e.g., electricity, water, natural gas, etc.) to heat or cool a working fluid that is circulated to one or more buildings or stored for later use (e.g., in thermal energy storage tanks) to provide heating or cooling for the buildings. In various embodiments, energy plant 200 may supplement or replace waterside system 120 in building 10 or may be implemented separate from building 10 (e.g., at an offsite location, distributed across multiple buildings, etc.).

[0080] Energy plant 200 is shown to include a plurality of subplants 202-210 including a first chiller subplant 202, a second chiller subplant 204, a third chiller subplant 206, a steam subplant 208, and a cogeneration subplant 210. Subplants 202-210 consume resources from utilities to serve the thermal and electrical energy loads (e.g., hot water, cold water, heating, cooling, steam, electricity, etc.) of a building or campus. For example, chiller subplants 202-206 may be configured to chill water in a cold water loop that circulates the cold water between chiller subplants 202-206 campus 216. Steam subplant 208 may be configured to generate steam and circulate the steam in a steam loop between steam subplant 208 and campus 216. Cogeneration subplant 210 can be configured to cogenerate both steam and electricity (e.g., by operating one or more combustion turbines 230).

[0081] Each of subplants 202-210 may include a variety of equipment configured to facilitate the functions of the subplant. For example, chiller subplants 202-206 are shown to include a plurality of electric chillers 218, 222, and 226 and steam chillers 220, 224, and 228. Electric chillers 218, 222, and 226 can be configured to remove heat from the cold water in the cold water loop, whereas steam chillers 220, 224, and 228 can be configured to cool the steam generated by boilers 232 and/or combustion turbines 230. Steam subplant 208 may include one or more boilers 232 configured to boil water to produce steam. Cogeneration subplant 210 may include one or more combustion turbines 230 configured to generate both steam and electricity. In some embodiments, steam subplant 208 burns gas from a gas supply 214. Chiller subplants 202-206 may consume electricity from an electricity supply 212 to generate the chilled water.

[0082] Referring now to FIG. 3, a block diagram illustrating an energy plant system 300 is shown, according to an exemplary embodiment. System 300 is shown to include an energy optimization system (EOS) 302, a building automation system (BAS) 308, and a plurality of subplants 202-210. Subplants 202-210 may be the same as previously described with reference to FIG. 2. For example, subplants 202-210 are shown to include a first chiller subplant 202, a second chiller subplant 204, a third chiller subplant 206, a steam subplant 208, and a cogeneration subplant 210.

[0083] Each of subplants 202-210 is shown to include equipment 340 that can be controlled by EOS 302 and/or building automation system 308 to optimize the performance of energy plant 200. Equipment 340 may include, for example, heating devices, chillers, heat recovery heat exchangers, cooling towers, thermal energy storage devices, pumps, valves, and/or other devices of subplants 202-210 (e.g., electric chillers 218, 222, and 226, steam chillers 220, 224, and 228, combustion turbines 230, and/or boilers 232). Individual devices of equipment 340 can be turned on or off to adjust the thermal or electrical energy load served by each of subplants 202-210. In some embodiments, individual devices of equipment 340 can be operated at variable capacities (e.g., operating a chiller at 10% capacity or 60% capacity) according to an operating setpoint received from EOS 302.

[0084] In some embodiments, one or more of subplants 202-210 includes a subplant level controller configured to control the equipment 340 of the corresponding subplant. For example, EOS 302 may determine an on/off configuration and global operating setpoints for equipment 340. In response to the on/off configuration and received global

operating setpoints, the subplant controllers may turn individual devices of equipment 340 on or off, and implement specific operating setpoints (e.g., damper position, vane position, fan speed, pump speed, etc.) to reach or maintain the global operating setpoints.

[0085] In some embodiments, the subplant level controllers receive subplant load setpoints from EOS 302. Each subplant level controller may use the subplant load setpoint for the corresponding subplant to select one or more devices of the equipment 340 within the subplant to activate or deactivate in order to meet the subplant load setpoint in an energy-efficient manner. In other embodiments, the equipment selection and staging decisions (i.e., deciding which devices to turn on/off) are performed by a low level optimizer 332 within EOS 302.

[0086] BAS 308 may be configured to monitor conditions within a controlled building or building zone. For example, BAS 308 may receive input from various sensors (e.g., temperature sensors, humidity sensors, airflow sensors, voltage sensors, etc.) distributed throughout the building and may report building conditions to EOS 302. Building conditions may include, for example, a temperature of the building or a zone of the building, a power consumption (e.g., electric load) of the building, a state of one or more actuators configured to affect a controlled state within the building, or other types of information relating to the controlled building. BAS 308 may operate subplants 202-210 to affect the monitored conditions within the building and/or to serve the thermal/electrical energy loads of the building.

[0087] BAS 308 may receive control signals from EOS 302 specifying on/off states and/or setpoints for equipment 340. BAS 308 may control equipment 340 (e.g., via actuators, power relays, etc.) in accordance with the control signals provided by EOS 302. For example, BAS 308 may operate equipment 340 using closed loop control to achieve the setpoints specified by EOS 302. In various embodiments, BAS 308 may be combined with EOS 302 or may be part of a separate building automation system. According to an exemplary embodiment, BAS 308 is a METASYS® brand building automation system, as sold by Johnson Controls, Inc. In some embodiments, BAS 308 is a controller that operates to control equipment 340 and/or operates equipment 340 to achieve the setpoints specified by EOS 302 (i.e., the setpoints generated by low level optimizer 332).

[0088] EOS 302 may monitor the status of the controlled building using information received from BAS 308. EOS 302 may be configured to predict the thermal/electrical energy loads (e.g., heating loads, cooling loads, electric, etc.) of the building for plurality of time steps in a prediction window (e.g., using weather forecasts from a weather service 324). EOS 302 may generate on/off decisions and/or setpoints for equipment 340 to minimize the cost of energy consumed by subplants 202-210 to serve the predicted heating and/or cooling loads for the duration of the prediction window. In various embodiments, EOS 302 may be integrated within a single computer (e.g., one server, one housing, etc.) or distributed across multiple servers or computers. In some embodiments, EOS 302 is integrated with a smart building manager that manages multiple building systems and/or combined with BAS 308.

[0089] EOS 302 may be configured to operate in multiple different operating modes including an automatic mode, an advisory mode, and a manual mode. In the automatic mode, EOS 302 may automatically control energy plant 200. For

example, EOS **302** may automatically determine optimal subplant loads for each of subplants **202-210**. EOS **302** may use the optimal subplant loads to determine optimal on/off decisions and operating setpoints for individual devices of equipment **340**. In the automatic mode, EOS **302** may provide the control signals to BAS **308** and/or equipment **340** to control equipment **340** without requiring user intervention or input. BAS **308** may relay the control signals to subplants **202-210** or may be bypassed entirely. In other words, EOS **302** may automatically control energy plant **200** in accordance with the optimized load setpoints and/or equipment setpoints when operated in the automatic mode. The automatic mode is described in greater detail with reference to FIGS. **5-6**.

[0090] In the advisory mode, BAS **308** may control energy plant **200**, whereas EOS **302** may provide advice. EOS **302** may still determine optimal subplant loads for each of subplants **202-210** and optimal on/off decisions and operating setpoints for equipment **340**. However, the optimal values determined by EOS **302** may be provided to BAS **308** as recommended subplant loads and recommended setpoints. The recommended loads and setpoints may also be presented to a user via a user interface. BAS **308** may determine whether to use the recommended loads and setpoints to control energy plant **200**. In some embodiments, BAS **308** uses input from a user to determine whether to apply the recommended loads and setpoints provided by EOS **302**. In some embodiments, EOS **302** displays the recommended loads/setpoints to a user and the user enters the recommended loads/setpoints as an input to BAS **308**. In other embodiments, BAS **308** receives the recommended loads/setpoints directly from EOS **302**. The advisory mode is described in greater detail with reference to FIGS. **7-8**.

[0091] In the manual mode, EOS **302** may control energy plant **200** based on user input. Similar to the advisory mode, EOS **302** may determine optimal subplant loads for each of subplants **202-210** and optimal on/off decisions and operating setpoints for equipment **340**. The optimal values determined by EOS **302** may be presented to a user (e.g., via a user interface) as recommended subplant loads and recommended setpoints. A user can accept the optimized values or enter user-defined (i.e., "manual") values for the subplant loads, equipment on/off decisions, and/or operating setpoints via the user interface. In some embodiments, the user-defined values override the optimized values when EOS **302** is operated in the manual mode. For example, EOS **302** may determine on/off decisions and control setpoints for equipment **340** based on the user-defined load setpoints for each of subplants **302-312**. The manual mode is described in greater detail with reference to FIGS. **9-10**.

[0092] Still referring to FIG. **3**, EOS **302** is shown to include a communications interface **304** and a processing circuit **306**. Communications interface **304** may include wired or wireless interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with various systems, devices, or networks. For example, communications interface **304** may include an Ethernet card and port for sending and receiving data via an Ethernet-based communications network and/or a Wi-Fi transceiver for communicating via a wireless communications network. Communications interface **304** may be configured to communicate via local area networks or wide area networks (e.g., the Internet, a building

WAN, etc.) and may use a variety of communications protocols (e.g., BACnet, IP, LON, etc.).

[0093] Communications interface **304** may be a network interface configured to facilitate electronic data communications between EOS **302** and various external systems or devices (e.g., BAS **308**, subplants **202-210**, etc.). For example, EOS **302** may receive information from BAS **308** indicating one or more measured states of the controlled building (e.g., temperature, humidity, electric loads, etc.) and one or more states of subplants **202-210** (e.g., equipment status, power consumption, equipment availability, etc.). Communications interface **304** may receive inputs from BAS **308** and/or subplants **202-210** and may provide operating parameters (e.g., on/off decisions, setpoints, etc.) to subplants **202-210** via BAS **308**. The operating parameters may cause subplants **202-210** to activate, deactivate, or adjust a setpoint for various devices of equipment **340**.

[0094] Still referring to FIG. **3**, processing circuit **306** is shown to include a processor **310** and memory **312**. Processor **310** may be a general purpose or specific purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a group of processing components, or other suitable processing components. Processor **310** may be configured to execute computer code or instructions stored in memory **312** or received from other computer readable media (e.g., CDROM, network storage, a remote server, etc.).

[0095] Memory **312** may include one or more devices (e.g., memory units, memory devices, storage devices, etc.) for storing data and/or computer code for completing and/or facilitating the various processes described in the present disclosure. Memory **312** may include random access memory (RAM), read-only memory (ROM), hard drive storage, temporary storage, non-volatile memory, flash memory, optical memory, or any other suitable memory for storing software objects and/or computer instructions. Memory **312** may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. Memory **312** may be communicably connected to processor **310** via processing circuit **306** and may include computer code for executing (e.g., by processor **310**) one or more processes described herein.

[0096] Still referring to FIG. **3**, memory **312** is shown to include a building status monitor **334**. EOS **302** may receive data regarding the overall building or building space to be heated or cooled with energy plant **200** via building status monitor **334**. In an exemplary embodiment, building status monitor **334** may include a graphical user interface component configured to provide graphical user interfaces to a user for selecting building requirements (e.g., overall temperature parameters, selecting schedules for the building, selecting different temperature levels for different building zones, etc.).

[0097] EOS **302** may determine on/off configurations and operating setpoints to satisfy the building requirements received from building status monitor **334**. In some embodiments, building status monitor **334** receives, collects, stores, and/or transmits cooling load requirements, building temperature setpoints, occupancy data, weather data, energy data, schedule data, and other building parameters. In some embodiments, building status monitor **334** stores data

regarding energy costs, such as pricing information available from utilities **326** (energy charge, demand charge, etc.).

[0098] Still referring to FIG. **3**, memory **312** is shown to include a load/rate predictor **322**. Load/rate predictor **322** may be configured to predict the energy loads ($\hat{l}_k$) of the building or campus for each time step k (e.g., k=1 . . . n) of an optimization period. Load/rate predictor **322** is shown receiving weather forecasts from a weather service **324**. In some embodiments, load/rate predictor **322** predicts the energy loads $\hat{l}_k$ as a function of the weather forecasts. In some embodiments, load/rate predictor **322** uses feedback from BAS **308** to predict loads $\hat{l}_k$. Feedback from BAS **308** may include various types of sensory inputs (e.g., temperature, flow, humidity, enthalpy, etc.) or other data relating to the controlled building (e.g., inputs from a HVAC system, a lighting control system, a security system, a water system, etc.).

[0099] In some embodiments, load/rate predictor **322** receives a measured electric load and/or previous measured load data from BAS **308** (e.g., via building status monitor **334**). Load/rate predictor **322** may predict loads $\hat{l}_k$ as a function of a given weather forecast ($\hat{\phi}_w$), a day type (day), the time of day (t), and previous measured load data (Y_{k-1}). Such a relationship is expressed in the following equation:

$$\hat{l}_k = f(\hat{\phi}_w, \text{day}, t | Y_{k-1})$$

[0100] In some embodiments, load/rate predictor **322** uses a deterministic plus stochastic model trained from historical load data to predict loads $\hat{l}_k$. Load/rate predictor **322** may use any of a variety of prediction methods to predict loads $\hat{l}_k$ (e.g., linear regression for the deterministic portion and an AR model for the stochastic portion). Load/rate predictor **322** may predict one or more different types of loads for the building or campus. For example, load/rate predictor **322** may predict a hot water load $\hat{l}_{Hot,k}$ and a cold water load $\hat{l}_{Cold,k}$ for each time step k within the prediction window.

[0101] Load/rate predictor **322** is shown receiving utility rates from utilities **326**. Utility rates may indicate a cost or price per unit of a resource (e.g., electricity, natural gas, water, etc.) provided by utilities **326** at each time step k in the prediction window. In some embodiments, the utility rates are time-variable rates. For example, the price of electricity may be higher at certain times of day or days of the week (e.g., during high demand periods) and lower at other times of day or days of the week (e.g., during low demand periods). The utility rates may define various time periods and a cost per unit of a resource during each time period. Utility rates may be actual rates received from utilities **326** or predicted utility rates estimated by load/rate predictor **322**.

[0102] In some embodiments, the utility rates include demand charges for one or more resources provided by utilities **326**. A demand charge may define a separate cost imposed by utilities **326** based on the maximum usage of a particular resource (e.g., maximum energy consumption) during a demand charge period. The utility rates may define various demand charge periods and one or more demand charges associated with each demand charge period. In some instances, demand charge periods may overlap partially or completely with each other and/or with the prediction window. Advantageously, energy plant optimizer **328** may be configured to account for demand charges in the high level optimization process performed by high level optimizer **330**. Utilities **326** may be defined by time-variable (e.g., hourly) prices, a maximum service level (e.g., a maximum rate of consumption allowed by the physical infrastructure or by contract) and, in the case of electricity, a demand charge or a charge for the peak rate of consumption within a certain period.

[0103] Load/rate predictor **322** may store the predicted loads $\hat{l}_k$ and the utility rates in memory **312** and/or provide the predicted loads $\hat{l}_k$ and the utility rates to energy plant optimizer **328**. Energy plant optimizer **328** may use the predicted loads $\hat{l}_k$ and the utility rates to determine an optimal load distribution for subplants **202-210** and to generate on/off decisions and setpoints for equipment **340**.

[0104] Still referring to FIG. **3**, memory **312** is shown to include an energy plant optimizer **328**. Energy plant optimizer **328** may perform a cascaded optimization process to optimize the performance of energy plant **200**. For example, energy plant optimizer **328** is shown to include a high level optimizer **330** and a low level optimizer **332**. High level optimizer **330** may control an outer (e.g., subplant level) loop of the cascaded optimization. High level optimizer **330** may determine an optimal distribution of energy loads across subplants **202-210** for each time step in the prediction window in order to optimize (e.g., minimize) the cost of energy consumed by subplants **202-210**. Low level optimizer **332** may control an inner (e.g., equipment level) loop of the cascaded optimization. Low level optimizer **332** may determine how to best run each subplant at the load setpoint determined by high level optimizer **330**. For example, low level optimizer **332** may determine on/off states and/or operating setpoints for various devices of equipment **340** in order to optimize (e.g., minimize) the energy consumption of each subplant while meeting the energy load setpoint for the subplant. The cascaded optimization process is described in greater detail with reference to FIG. **4**.

[0105] Still referring to FIG. **3**, memory **312** is shown to include a subplant monitor **338**. Subplant monitor **338** may collect and store information regarding the past, current, and future (e.g., planned) utilization of subplants **202-210**. For example, subplant monitor **338** may receive actual utilization data from BAS **308** and/or energy plant **200** indicating the actual energy loads served by subplants **202-210**. The actual utilization data may be current utilization data (e.g., the actual energy loads currently being served) or past utilization data (e.g., the actual energy loads served at a previous time). In some embodiments, the actual utilization data indicates a total heating load and/or a total cooling load requested to be served by energy plant **200** at a past or current time. The actual utilization data may also indicate any unmet heating and/or cooling load that is requested but not met by energy plant **200** at a past or current time. In some embodiments, the actual utilization data indicates a past or current rate of utility consumption (e.g., water consumption, electricity consumption, natural gas consumption, photovoltaic energy consumption, etc.).

[0106] The actual utilization data may be provided at various levels of granularity. For example, the actual utilization data for a given subplant (e.g., chiller subplant **202**) may include an aggregate value that represents the total energy load served by the subplant (e.g., the total load served by all of the chillers). In other embodiments, the actual utilization data may be provided for each of the individual devices within subplants **202-210** (e.g., the cooling load served by each of the chillers individually).

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[0107] In some embodiments, subplant monitor **338** receives the actual utilization data as a continuous data signal. In other embodiments, subplant monitor **338** receives the actual utilization data at regular intervals (e.g., every minute, every fifteen minutes, every hour, etc.). Subplant monitor **338** may store the actual utilization data in memory **312** or in a separate subplant utilization database. In some embodiments, subplant monitor **338** stores the actual utilization data at regular intervals such that the stored utilization data represents a history of the relevant operating information for energy plant **200** over time.

[0108] Subplant monitor **338** may receive predicted future utilization data indicating the thermal and electrical energy loads to be served by subplants **202-210** at a future time. In some embodiments, the predicted utilization data for subplants **202-210** is generated by energy plant optimizer **328** for multiple time steps during a prediction window. For example, the predicted utilization data may include the optimal subplant loads predicted by high level optimizer **330** and/or the optimal equipment on/off states predicted by low level optimizer **332** for each time step during the prediction window.

[0109] In some embodiments, the predicted utilization data indicates a total heating load and/or a total cooling load predicted by load/rate predictor **322**. The predicted utilization data may also indicate any unmet heating and/or cooling load that is predicted to be requested but not met by energy plant **200**. In some embodiments, the predicted utilization data indicates a predicted rate of utility consumption (e.g., water consumption, electricity consumption, natural gas consumption, photovoltaic energy consumption, etc.).

[0110] The predicted utilization data may be provided at various levels of granularity. For example, the predicted utilization data for a given subplant (e.g., chiller subplant **202**) may include an aggregate value that represents the total energy load estimated to be served by the subplant (e.g., the total predicted load served by all of the chillers). In other embodiments, the predicted utilization data may be provided for each of the individual devices within subplants **202-210** (e.g., the predicted cooling load served by each of the chillers individually).

[0111] In some embodiments, subplant monitor **338** receives the predicted utilization data for each of a plurality of time steps during a prediction window. For example, energy plant optimizer **328** may perform an optimization process (described in greater detail with reference to FIG. **4**) to generate subplant load values for each time step during a prediction window that extends from the current time to a predetermined prediction horizon. Each time step may have a defined duration (e.g., fifteen minutes, one hour, etc.). The predicted subplant load values may be updated each time the optimization process is performed. Subplant monitor **338** may store the predicted utilization data in memory **312** or in a separate subplant utilization database. In some embodiments, subplant monitor **338** stores the predicted utilization data at regular intervals (e.g., hourly intervals) such that the stored utilization data represents a planned dispatch schedule for energy plant **200** over time.

[0112] Data and processing results from energy plant optimizer **328**, subplant monitor **338**, or other modules of EOS **302** may be accessed by (or pushed to) monitoring and reporting applications **336**. Monitoring and reporting applications **336** may be configured to generate real time system health dashboards that can be viewed and navigated by a user (e.g., an energy plant engineer). For example, monitoring and reporting applications **336** may include a web-based monitoring application with several graphical user interface (GUI) elements (e.g., widgets, dashboard controls, windows, etc.) for displaying key performance indicators (KPI) or other information to users of a GUI. In some embodiments, the GUI elements include a chart or graph (e.g., a dispatch bar chart) that represents the actual and predicted utilization data provided by subplant monitor **338**. GUI elements or reports may be generated and shown based on actual and predicted utilization data that allow users to monitor the performance of subplants **202-210** and energy plant **200** as a whole using a single screen. An exemplary dispatch GUI that may be generated by monitoring and reporting applications **336** is described in greater detail with reference to FIGS. **11-37**.

[0113] Still referring to FIG. **3**, EOS **302** may include one or more GUI servers, web services **314**, or GUI engines **316** to support monitoring and reporting applications **336**. In various embodiments, applications **336**, web services **314**, and GUI engine **316** may be provided as separate components outside of EOS **302** (e.g., as part of a smart building manager). EOS **302** may be configured to maintain detailed historical databases (e.g., relational databases, XML databases, etc.) of relevant data and includes computer code modules that continuously, frequently, or infrequently query, aggregate, transform, search, or otherwise process the data maintained in the detailed databases. EOS **302** may be configured to provide the results of any such processing to other databases, tables, XML files, or other data structures for further querying, calculation, or access by, for example, external monitoring and reporting applications.

[0114] EOS **302** is shown to include configuration tools **318**. Configuration tools **318** can allow a user to define (e.g., via graphical user interfaces, via prompt-driven wizards, etc.) how EOS **302** should react to changing conditions in the energy plant subsystems. In an exemplary embodiment, configuration tools **318** allow a user to build and store condition-response scenarios that can cross multiple energy plant devices, multiple building systems, and multiple enterprise control applications (e.g., work order management system applications, entity resource planning applications, etc.). For example, configuration tools **318** can provide the user with the ability to combine data (e.g., from subsystems, from event histories) using a variety of conditional logic. In varying exemplary embodiments, the conditional logic can range from simple logical operators between conditions (e.g., AND, OR, XOR, etc.) to pseudo-code constructs or complex programming language functions (allowing for more complex interactions, conditional statements, loops, etc.). Configuration tools **318** can present user interfaces for building such conditional logic. The user interfaces may allow users to define policies and responses graphically. In some embodiments, the user interfaces may allow a user to select a pre-stored or pre-constructed policy and adapt it or enable it for use with their system.

[0115] Referring now to FIG. **4**, a block diagram illustrating a portion of energy plant system **300** in greater detail is shown, according to an exemplary embodiment. FIG. **4** illustrates the cascaded optimization process performed by energy plant optimizer **328** to optimize the performance of energy plant **200**. In the cascaded optimization process, high level optimizer **330** performs a subplant level optimization that determines an optimal distribution of thermal and

electrical energy loads across subplants **202-210** for each time step in the prediction window in order to minimize the cost of energy consumed by subplants **202-210**. Low level optimizer **332** performs an equipment level optimization that determines how to best run each subplant at the subplant load setpoint determined by high level optimizer **330**. For example, low level optimizer **332** may determine on/off states and/or operating setpoints for various devices of equipment **340** in order to optimize the energy consumption of each subplant while meeting the thermal and/or electrical energy load setpoint for the subplant.

[0116] One advantage of the cascaded optimization process performed by energy plant optimizer **328** is the optimal use of computational time. For example, the subplant level optimization performed by high level optimizer **330** may use a relatively long time horizon due to the operation of the thermal energy storage. However, the equipment level optimization performed by low level optimizer **332** may use a much shorter time horizon or no time horizon at all since the low level system dynamics are relatively fast (compared to the dynamics of the thermal energy storage) and the low level control of equipment **340** may be handled by BAS **308**. Such an optimal use of computational time makes it possible for energy plant optimizer **328** to perform the energy plant optimization in a short amount of time, allowing for real-time predictive control. For example, the short computational time enables energy plant optimizer **328** to be implemented in a real-time planning tool with interactive feedback.

[0117] Another advantage of the cascaded optimization performed by energy plant optimizer **328** is that the energy plant optimization problem can be split into two cascaded subproblems. The cascaded configuration provides a layer of abstraction that allows high level optimizer **330** to distribute the energy loads across subplants **202-210** without requiring high level optimizer **330** to know or use any details regarding the particular equipment configuration within each subplant. The interconnections between equipment **340** within each subplant may be hidden from high level optimizer **330** and handled by low level optimizer **332**. For purposes of the subplant level optimization performed by high level optimizer **330**, each subplant may be completely defined by one or more subplant curves **342**.

[0118] Low level optimizer **332** may generate and provide subplant curves **342** to high level optimizer **330**. Subplant curves **342** may indicate the rate of utility use by each of subplants **202-210** (e.g., electricity use measured in kW, water use measured in L/s, etc.) as a function of the subplant load. In some embodiments, low level optimizer **332** generates subplant curves **342** based on equipment models **320** (e.g., by combining equipment models **320** for individual devices into an aggregate curve for the subplant). Low level optimizer **332** may generate subplant curves **342** by running the low level optimization process for several different loads and weather conditions to generate multiple data points. Low level optimizer **332** may fit a curve to the data points to generate subplant curves **342**. In other embodiments, low level optimizer **332** provides the data points to high level

optimizer **330** and high level optimizer **330** generates the subplant curves using the data points.

[0119] High level optimizer **330** may receive the load and rate predictions from load/rate predictor **322** and the subplant curves **342** from low level optimizer **332**. The load predictions may be based on weather forecasts from weather service **324** and/or information from building automation system **308** (e.g., a current electric load of the building, measurements from the building, a history of previous loads, a setpoint trajectory, etc.). The utility rate predictions may be based on utility rates received from utilities **326** and/or utility prices from another data source. High level optimizer **330** may determine the optimal load distribution for subplants **202-210** (e.g., a subplant load for each subplant) for each time step the prediction window and may provide the subplant loads as setpoints to low level optimizer **332**. In some embodiments, high level optimizer **330** determines the subplant loads by minimizing the total operating cost of energy plant **200** over the prediction window. In other words, given a predicted load and utility rate information from load/rate predictor **322**, high level optimizer **330** may distribute the predicted load across subplants **202-210** over the optimization period to minimize operating cost.

[0120] In some instances, the optimal load distribution may include using thermal energy storage to store thermal energy during a first time step for use during a later time step. Thermal energy storage may advantageously allow thermal energy to be produced and stored during a first time period when energy prices are relatively low and subsequently retrieved and used during a second time period when energy proves are relatively high. The high level optimization may be different from the low level optimization in that the high level optimization has a longer time constant due to the thermal energy storage provided by thermal energy storage. The high level optimization may be described by the following equation:

$$\theta^*_{HL} = \operatorname*{argmin}_{\theta_{HL}} J_{HL}(\theta_{HL})$$

where θ^*_{HL} contains the optimal high level decisions (e.g., the optimal load for each of subplants **202-210**) for the entire optimization period and J_{HL} is the high level cost function.
[0121] To find the optimal high level decisions θ^*_{HL}, high level optimizer **330** may minimize the high level cost function J_{HL}. The high level cost function J_{HL} may be the sum of the economic (e.g., monetary) costs of each utility consumed by each of subplants **202-210** for the duration of the optimization period. In some embodiments, the high level cost function J_{HL} may be described using the following equation:

$$J_{HL}(\theta_{HL}) = \sum_{k=1}^{n_h} \sum_{i=1}^{n_s} \left[\sum_{j=1}^{n_u} t_s \cdot c_{jk} u_{jik}(\theta_{HL}) \right]$$

where n_h is the number of time steps k in the optimization period, n_s is the number of subplants, t_s is the duration of a time step, c_{jk} is the economic cost of utility j at a time step k of the optimization period, and u_{jik} is the rate of use of utility j by subplant i at time step k.

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[0122] In some embodiments, the cost function J_{HL} includes an additional demand charge term such as:

$$w_d c_{demand} \max_{n_h} (u_{elec}(\theta_{HL}), u_{max,ele})$$

where w_d is a weighting term, c_{demand} is the demand cost, and the max( ) term selects the peak electricity use during the applicable demand charge period. Accordingly, the high level cost function J_{HL} may be described by the equation:

$$J_{HL}(\theta_{HL}) =$$
$$\sum_{k=1}^{n_h} \sum_{i=1}^{n_s} \left[\sum_{j=1}^{n_u} t_s \cdot c_{jk} u_{jik}(\theta_{HL}) \right] + w_d c_{demand} \max_{n_h} (u_{elec}(\theta_{HL}), u_{max,ele})$$

[0123] The decision vector θ_{HL} may be subject to several constraints. For example, the constraints may require that the subplants not operate at more than their total capacity, that the thermal storage not charge or discharge too quickly or under/over flow for the tank, and that the energy loads for the building or campus are met. These restrictions may lead to both equality and inequality constraints on the high level optimization problem.

[0124] In some embodiments, the high level optimization performed by high level optimizer **330** is the same or similar to the high level optimization process described in U.S. patent application Ser. No. 14/634,609 filed Feb. 27, 2015 and titled "High Level Energy plant Optimization," the entire disclosure of which is incorporated by reference herein. High level optimizer **330** may include some or all of the features and/or functionality of the high level optimization module described in U.S. patent application Ser. No. 14/634,609.

[0125] Still referring to FIG. **4**, low level optimizer **332** may use the subplant loads determined by high level optimizer **330** to determine optimal low level decisions θ^*_{LL} (e.g. binary on/off decisions, flow setpoints, temperature setpoints, etc.) for equipment **340**. The low level optimization process may be performed for each of subplants **202-210**. In various embodiments, the low level optimization process may be performed by centralized low level optimizer **332** that performs a separate low level optimization for each of subplants **202-210** or by a set of subplant level controllers that operate within each subplant (e.g., each subplant controller running an instance of low level optimizer **332**). Low level optimizer **332** may be responsible for determining which devices of the subplant to use and/or the operating setpoints for such devices that will achieve the subplant load setpoint while minimizing energy consumption. The low level optimization may be described using the following equation:

$$\theta^*_{LL} = \operatorname*{argmin}_{\theta_{LL}} J_{LL}(\theta_{LL})$$

where θ^*_{LL} contains the optimal low level decisions and J_{LL} is the low level cost function.

[0126] To find the optimal low level decisions θ^*_{LL}, low level optimizer **332** may minimize the low level cost function J_{LL}. The low level cost function J_{LL} may represent the total energy consumption for all of equipment **340** in the applicable subplant. The low level cost function J_{LL} may be described using the following equation:

$$J_{LL}(\theta_{LL}) = \sum_{j=1}^{N} t_s \cdot b_j \cdot u_j(\theta_{LL})$$

where N is the number of devices of equipment **340** in the subplant, t_s is the duration of a time step, b_j is a binary on/off decision (e.g., 0=off, 1=on), and u_j is the energy used by device j as a function of the setpoint θ_{LL}. Each device may have continuous variables which can be changed to determine the lowest possible energy consumption for the overall input conditions.

[0127] Low level optimizer **332** may minimize the low level cost function J_{LL} subject to inequality constraints based on the capacities of equipment **340** and equality constraints based on energy and mass balances. In some embodiments, the optimal low level decisions θ^*_{LL} are constrained by switching constraints defining a short horizon for maintaining a device in an on or off state after a binary on/off switch. The switching constraints may prevent devices from being rapidly cycled on and off. In some embodiments, low level optimizer **332** performs the equipment level optimization without considering system dynamics. The optimization process may be slow enough to safely assume that the equipment control has reached its steady-state. Thus, low level optimizer **332** may determine the optimal low level decisions θ^*_{LL} at an instance of time rather than over a long horizon.

[0128] In some embodiments, the optimal low level decisions θ^*_{LL} are constrained by an equipment staging coordinator **344** that prevents two or more of subplants **202-210** from reacting to a change in the subplant load too quickly after a change in another of subplants **202-210** has occurred. For example, equipment staging coordinator **344** is shown receiving equipment status information from BAS **308**. Equipment staging coordinator **344** may use the equipment status information to determine when the equipment **340** within a given subplant has been staged (e.g., turned on/off). Equipment staging coordinator **344** may prevent multiple subplants from staging their equipment **340** simultaneously or within a predetermined time period after another subplant has staged its equipment **340**. Advantageously, this functionality reduces the peak energy consumption for energy plant **200** at any instant in time and results in a lower demand charge.

[0129] In some embodiments, equipment staging coordinator **344** causes low level optimizer **332** to halt its efficiency calculations and hold the optimal low level decisions θ^*_{LL} for a given subplant at previously-determined values shortly after the equipment **340** for another subplant has been staged (e.g., by providing a freeze signal to low level optimizer **332**). Once a threshold time has passed since the equipment **340** for the other subplant has been staged, equipment staging coordinator **344** may allow low level optimizer **332** to resume its efficiency calculations and to determine new values for the optimal low level decisions θ^*_{LL} (e.g., by withdrawing the freeze signal).

[0130] Low level optimizer **332** may determine optimum operating statuses (e.g., on or off) for a plurality of devices of equipment **340**. According to an exemplary embodiment, the on/off combinations may be determined using binary optimization and quadratic compensation. Binary optimization may minimize a cost function representing the power consumption of devices in the applicable subplant. In some embodiments, non-exhaustive (i.e., not all potential combinations of devices are considered) binary optimization is used. Quadratic compensation may be used in considering devices whose power consumption is quadratic (and not linear). Low level optimizer **332** may also determine optimum operating setpoints for equipment using nonlinear optimization. Nonlinear optimization may identify operating setpoints that further minimize the low level cost function J_{LL}. Low level optimizer **332** may provide the on/off decisions and setpoints to building automation system **308** for use in controlling the energy plant equipment **340**.

[0131] In some embodiments, the low level optimization performed by low level optimizer **332** is the same or similar to the low level optimization process described in U.S. patent application Ser. No. 14/634,615 filed Feb. 27, 2015 and titled "Low Level Energy plant Optimization," the entire disclosure of which is incorporated by reference herein. Low level optimizer **332** may include some or all of the features and/or functionality of the low level optimization module described in U.S. patent application Ser. No. 14/634,615.

Automatic, Advisory, and Manual Operating Modes

[0132] Referring now to FIGS. **5-10**, several block diagrams and flow diagrams illustrating the operation of energy optimization system (EOS) **302** in an automatic operating mode (FIGS. **5-6**), advisory operating mode (FIGS. **7-8**), and manual operating mode (FIGS. **9-10**) are shown, according to an exemplary embodiment. In brief overview, EOS **302** may determine optimal subplant loads and optimal equipment setpoints in each of the operating modes. In the automatic operating mode, EOS **302** may provide the optimal equipment setpoints to energy plant **200**. In the advisory operating mode, EOS **302** may provide the optimal subplant loads and equipment setpoints to a user interface as recommended setpoints for energy plant **200**. A user may view the recommended setpoints and provide user-defined setpoints for building automation system **308**, which may or may not be based on the recommended setpoints. In the manual operating mode, EOS **302** may control energy plant **200** based on manual (i.e., user-defined) subplant loads received via a user interface of EOS **302**. EOS **302** may use the manual subplant loads to generate recommended equipment setpoints and equipment control signals that achieve the manual subplant loads. The equipment control signals may then be provided to energy plant **200**. Each of these operating modes is discussed in greater detail below.

Automatic Operating Mode

[0133] Referring now to FIG. **5**, a block diagram illustrating a system **500** for monitoring and controlling an energy plant in an automatic operating mode is shown, according to an exemplary embodiment. In the automatic operating mode, EOS **302** automatically determines optimal subplant loads for each of subplants **202-210** and optimal equipment setpoints for the energy plant equipment **340**. EOS **302** provides the optimal equipment setpoints to energy plant

200, which uses the optimal equipment setpoints to control the energy plant equipment **340**. EOS **302** monitors actual subplant utilization via subplant monitor **338** and stores planned and actual subplant utilization data in a subplant utilization database **502**. A dispatch GUI generator **506** uses the planned and actual subplant utilization data to generate a dispatch GUI **902**. Dispatch GUI **902** may be presented to a user via a user interface **504** to allow the user to monitor the operation of energy plant **200**.

[0134] System **500** is shown to include high level optimizer **330**, low level optimizer **332**, and energy plant **200**, which may be the same or similar as described with reference to FIGS. **2-4**. For example, high level optimizer **330** may perform an optimization process to generate a set of optimal subplant loads for each of subplants **202-210**. In some embodiments, the optimal subplant loads include a total cold requested load and a total hot requested load. In some embodiments, the optimal subplant loads include an unmet heating load and/or an unmet cooling load. The unmet heating load may be defined as the amount by which the total requested heating load exceeds the sum of the heating loads produced by subplants **202-210**. Similarly, the unmet cooling load may be defined as the amount by which the total requested cooling load exceeds the sum of the cooling loads produced by subplants **202-210**. In some embodiments, the optimal subplant loads include an optimal amount of one or more resources (e.g., water, electricity, natural gas, etc.) consumed by subplants **202-210** to generate the optimal subplant loads.

[0135] High level optimizer **330** may determine the optimal subplant loads for a plurality of time steps between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). The optimal subplant loads may be updated with each iteration of the high level optimization process. High level optimizer **330** may provide the optimal subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the optimal subplant loads as planned subplant utilization data in a subplant utilization database **502**.

[0136] Low level optimizer **332** may use the optimal subplant loads to generate a set of optimal equipment setpoints for the equipment of subplants **202-210**. The optimal equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of the subplants **202-210**. The optimal equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the optimal subplant load. In some embodiments, low level optimizer **332** performs an optimization process to generate the optimal equipment setpoints. Low level optimizer **332** may provide the optimal equipment setpoints to energy plant **200** and to subplant monitor **338**. Subplant monitor **338** may store the optimal equipment setpoints as planned subplant utilization data in subplant utilization database **502**. In various embodiments, subplant utilization database **502** may be a component of EOS **302** (e.g., memory **312**) or a separate database outside EOS **302**.

[0137] Energy plant **200** may use the optimal equipment setpoints to operate the equipment of subplants **202-210**. Energy plant **200** may monitor the utilization of subplants **202-210** and generate a set of actual subplant utilization data. The actual subplant utilization data may include actual values (rather than optimal values) for each of the subplant

loads optimized by high level optimizer **330**. In some embodiments, the actual subplant utilization data include a total cold requested load and a total hot requested load. In some embodiments, the actual subplant utilization data include an actual unmet heating load and/or unmet cooling load. In some embodiments, the actual subplant utilization data include an actual amount of one or more resources (e.g., water, electricity, natural gas, etc.) consumed by subplants **202-210** to generate the actual subplant loads.

[0138]   Energy plant **200** may report the actual subplant utilization data to subplant monitor **338**. In some embodiments, energy plant **200** reports the actual subplant utilization data at regular intervals (e.g., once every fifteen minutes, once per hour, etc.) Subplant monitor **338** may store the actual subplant utilization data in subplant utilization database **502**. In some embodiments, subplant monitor **338** overwrites or replaces the planned subplant utilization data for a given time step with the actual subplant utilization data for the time step once the actual subplant utilization data for the time step is available (e.g., once the current time advances to the time step). Similarly, subplant monitor **338** may overwrite or replace the planned subplant data for a given time step with an updated optimal value for the time step each time a new set of optimal subplant utilization data is generated by high level optimizer **330**. In other embodiments, subplant monitor **338** supplements the existing planned subplant utilization data with the updated optimal subplant utilization data and/or the actual subplant utilization data without replacing or overwriting the exiting subplant utilization data. For example, the existing subplant utilization data may be stored as a first version of the subplant utilization data and the updated subplant utilization data may be stored as a second version of the subplant utilization data.

[0139]   Still referring to FIG. **5**, system **500** is shown to include a dispatch GUI generator **506**. Dispatch GUI generator **506** may access the data stored in subplant utilization database **502** and use the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the actual subplant utilization data (e.g., past and current subplant loads) and the planned subplant utilization data (e.g., future subplant loads) in a graphical format. Exemplary dispatch GUIs which may be generated by dispatch GUI generator **506** are described in greater detail with reference to FIGS. **11-37**. Dispatch GUI generator **506** may provide dispatch GUI **902** to a user interface **504** for presentation to a user.

[0140]   In various embodiments, dispatch GUI generator **506** and user interface **504** may be components of BAS **308** or components of EOS **302** (e.g., monitoring and reporting applications **336**). Dispatch GUI generator **506** may generate dispatch GUI **902** and provide dispatch GUI **902** to user interface **504** via a communications network. In other embodiments, dispatch GUI generator **506** and user interface **504** are components of a user device (e.g., a computer terminal, a workstation, a laptop, a tablet, a smartphone, etc.). For example, dispatch GUI generator **506** may be a web browser or a specialized application running on the user device. In some embodiments, dispatch GUI **902** is rendered using specialized viewing software (e.g., an energy plant monitoring application) installed on the user device. In other embodiments, dispatch GUI **902** is provided via a web interface which allows dispatch GUI **902** to be rendered and

viewed using a web browser without requiring any specialized applications or software to be installed on the user device.

[0141]   Referring now to FIG. **6**, a flow diagram illustrating a process **600** for monitoring and controlling an energy plant in the automatic operating mode is shown, according to an exemplary embodiment. Process **600** may be performed by one or more components of energy plant system **300** and/or system **500** as previously described. For example, process **600** may be performed by EOS **302**, BAS **308**, dispatch GUI generator **506**, and/or other devices of energy plant system **300** or system **500**.

[0142]   Process **600** is shown to include determining optimal subplant loads for a plurality of subplants of an energy plant (step **602**). Step **602** may be performed by high level optimizer **330**. Step **602** may include determining the optimal subplant loads for a plurality of time steps between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). The optimal subplant loads may be updated with each iteration of the high level optimization process. High level optimizer **330** may provide the optimal subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the optimal subplant loads as planned subplant utilization data in a subplant utilization database **502**.

[0143]   Process **600** is shown to include determining optimal setpoints for equipment of each subplant to achieve the optimal subplant loads (step **604**). Step **604** may be performed by low level optimizer **332**. The optimal equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of the subplants **202-210**. The optimal equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the optimal subplant load. Low level optimizer **332** may provide the optimal equipment setpoints to energy plant **200** and to subplant monitor **338**. Subplant monitor **338** may store the optimal equipment setpoints as planned subplant utilization data in subplant utilization database **502**.

[0144]   Process **600** is shown to include automatically providing the optimal equipment setpoints to the energy plant to control the equipment (step **606**). Step **606** may include providing the optimal equipment setpoints from low level optimizer **332** to energy plant **200**. Energy plant **200** may use the optimal equipment setpoints as control inputs for individual devices within each subplant (e.g., individual chillers, individual hot water generators, individual thermal energy storage tanks, etc.). In other words, energy plant **200** may operate controllable devices within energy plant **200** (e.g., equipment **340**) in accordance with the optimal equipment setpoints. For example, energy plant **200** may activate a device, deactivate a device, change a setpoint for a device, or otherwise control individual devices of the energy plant equipment **340** based on the optimal equipment setpoints. Energy plant **200** may provide actual subplant utilization data to subplant monitor **338**. Subplant monitor **338** may store the actual subplant utilization data in subplant utilization database **502**.

[0145]   Process **600** is shown to include presenting planned and actual subplant utilization data to a user via a graphical user interface (step **608**). Step **608** may be performed by dispatch GUI generator **506**. In some embodiments, step **608** includes accessing the data stored in subplant utilization

database **502** and using the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the actual subplant utilization data (e.g., past and current subplant loads) and the planned subplant utilization data (e.g., future subplant loads) in a graphical format. Dispatch GUI generator **506** may provide dispatch GUI **902** to a user interface **504** for presentation to a user.

[0146] In the automatic operating mode, the optimal subplant loads and equipment setpoints are used to control energy plant **200**. The optimal values determined by EOS **302** may be automatically provided as inputs to energy plant **200**. For example, low level optimizer **332** is shown providing the optimal equipment setpoints directly to energy plant **200**. In other embodiments, the optimal equipment setpoints may be provided to BAS **308**, which may use the optimal equipment setpoints to generate control signals for the energy plant equipment **340**. Advantageously, the automatic operating mode allows EOS **302** to control energy plant **200** without requiring user intervention by automatically providing the optimal equipment setpoints to energy plant **200**.

Advisory Operating Mode

[0147] Referring now to FIG. **7**, a block diagram illustrating a system **700** for monitoring and controlling an energy plant in an advisory operating mode is shown, according to an exemplary embodiment. In the advisory operating mode, EOS **302** determines recommended subplant loads for each of subplants **202-210** and recommended equipment setpoints for the energy plant equipment **340**. The recommended subplant loads and recommended equipment setpoints may be the same or similar to the optimal subplant loads and optimal equipment setpoints as previously described. However, unlike the automatic operating mode, EOS **302** does not automatically provide the recommended equipment setpoints as control inputs to energy plant **200**. Instead, energy plant **200** receives equipment control signals from BAS **308**, which may generate the equipment control signals based in part on user-defined setpoints received from a user **702** via a BAS user interface **309**.

[0148] System **700** is shown to include high level optimizer **330**, low level optimizer **332**, energy plant **200**, subplant monitor **338**, subplant utilization database **502**, dispatch GUI generator **506**, and BAS **308**, which may be the same or similar as described with reference to FIGS. **2-6**. For example, high level optimizer **330** may perform an optimization process to generate a set of recommended subplant loads for each of subplants **202-210**. High level optimizer **330** may determine the recommended subplant loads for a plurality of time steps between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). High level optimizer **330** may provide the recommended subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the recommended subplant loads as recommended subplant utilization data in a subplant utilization database **502**.

[0149] Low level optimizer **332** may use the recommended subplant loads to generate a set of recommended equipment setpoints for the equipment of subplants **202-210**. The recommended equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of subplants **202-210**.

The recommended equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the recommended subplant load. In some embodiments, low level optimizer **332** performs an optimization process to generate the recommended equipment setpoints. Low level optimizer **332** may provide the recommended equipment setpoints to subplant monitor **338**. Subplant monitor **338** may store the recommended equipment setpoints as recommended subplant utilization data in subplant utilization database **502**.

[0150] Energy plant **200** may monitor the utilization of subplants **202-210** and generate a set of actual subplant utilization data. The actual subplant utilization data may include actual values (rather than recommended values) for each of the subplant loads produced by subplants **202-210**. The actual subplant utilization data may also include actual equipment operating states (e.g., on/off states, load production, operating capacities, etc.) for individual devices of energy plant equipment **340**. Energy plant **200** may report the actual subplant utilization data to subplant monitor **338**. In some embodiments, energy plant **200** reports the actual subplant utilization data at regular intervals (e.g., once every fifteen minutes, once per hour, etc.) Subplant monitor **338** may store the actual subplant utilization data in subplant utilization database **502**.

[0151] Dispatch GUI generator **506** may access the data stored in subplant utilization database **502** and use the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the actual subplant utilization data (e.g., past and current subplant loads) and the recommended subplant utilization data (e.g., future subplant loads) in a graphical format. Dispatch GUI generator **506** may provide dispatch GUI **902** to EOS user interface **704** for presentation to a user **702**.

[0152] In system **700**, EOS **302** and energy plant **200** may be decoupled such that the output of EOS **302** (i.e., recommended subplant loads and equipment setpoints) is not automatically provided as an input to energy plant **200**. User **702** can view the recommended setpoints (e.g., recommended subplant load setpoints, recommended equipment setpoints, etc.) and monitor actual subplant operation via EOS user interface **704**. In some instances, user **702** may use the recommended setpoints to generate the user-defined setpoints provided to BAS **308**; however, such use is not automatic or required when EOS **302** is operated in the advisory operating mode. Instead, EOS **302** may provide the recommended setpoints as suggestions or advice, which the user **702** can choose to accept or reject when generating the user-defined setpoints.

[0153] Referring now to FIG. **8**, a flow diagram illustrating a process **800** for monitoring and controlling an energy plant in the advisory operating mode is shown, according to an exemplary embodiment. Process **800** may be performed by one or more components of energy plant system **300** and/or system **700** as previously described. For example, process **800** may be performed by EOS **302**, BAS **308**, dispatch GUI generator **506**, and/or other devices of energy plant system **300** or system **700**.

[0154] Process **800** is shown to include determining recommended subplant loads for a plurality of subplants of an energy plant (step **802**). Step **802** may be performed by high level optimizer **330**. Step **802** may include determining the recommended subplant loads for a plurality of time steps

between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). The recommended subplant loads may be updated with each iteration of the high level optimization process. High level optimizer **330** may provide the recommended subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the recommended subplant loads as planned subplant utilization data in a subplant utilization database **502**.

[0155] Process **800** is shown to include determining recommended setpoints for equipment of each subplant to achieve the recommended subplant loads (step **804**). Step **804** may be performed by low level optimizer **332**. The recommended equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of the subplants **202-210**. The recommended equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the recommended subplant load. Low level optimizer **332** may provide the recommended equipment setpoints to energy plant **200** and to subplant monitor **338**. Subplant monitor **338** may store the recommended equipment setpoints as planned subplant utilization data in subplant utilization database **502**.

[0156] Process **800** is shown to include presenting recommended and actual subplant utilization data to a user via an EOS user interface (e.g., EOS user interface **704**) (step **806**). Step **806** may be performed by dispatch GUI generator **506** and/or EOS user interface **704**. The recommended subplant utilization data may include the recommended subplant loads generated by high level optimizer **330** and/or the recommended equipment setpoints generated by low level optimizer **332**. The actual subplant utilization data may include data describing the actual operation of energy plant **200** (e.g., actual subplant loads, actual equipment setpoints, etc.), which may be collected by subplant monitor **338** and stored in subplant utilization database **502**.

[0157] In some embodiments, step **806** includes accessing the data stored in subplant utilization database **502** and using the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the actual subplant utilization data (e.g., past and current subplant loads) and the planned subplant utilization data (e.g., future subplant loads) in a graphical format. Dispatch GUI generator **506** may provide dispatch GUI **902** to EOS user interface **704** for presentation to a user **702**.

[0158] Process **800** is shown to include receiving user-defined setpoints at a BAS user interface (e.g., BAS user interface **309**) (step **808**) and generating control signals for the subplant equipment based on the user-defined setpoints (step **810**). In some embodiments, BAS user interface **309** is separate and distinct from EOS user interface **704**. For example, EOS user interface **704** may be coupled to EOS **302** and configured to present information stored in subplant utilization database **502**, whereas BAS user interface **309** may be coupled to BAS **308** and configured to allow user **702** to provide control inputs to BAS **308**. In some embodiments, user **702** is the only link between EOS user interface **704** and BAS user interface **309**.

[0159] In some instances, user **702** may view the recommended setpoints provided via EOS user interface **704** and generate the user-defined setpoints provided to BAS user interface **309** based on the recommended setpoints. In other instances, user **702** may generate the user-defined setpoints independent of the recommended setpoints. Advantageously, the advisory mode allows user **702** to exercise a greater level of control over energy plant **200** relative to the automatic mode by allowing user **702** to choose whether to use the recommended setpoints to control energy plant **200** or provide different user-defined setpoints.

Manual Operating Mode

[0160] Referring now to FIG. **9**, a block diagram illustrating a system **900** for monitoring and controlling an energy plant in a manual operating mode is shown, according to an exemplary embodiment. In the manual operating mode, EOS **302** determines recommended subplant loads for each of subplants **202-210** and recommended equipment setpoints for the energy plant equipment **340**. The recommended subplant loads and recommended equipment setpoints may be the same or similar to the optimal subplant loads and optimal equipment setpoints as previously described. However, EOS **302** does not automatically provide the recommended equipment setpoints as control inputs to energy plant **200** when operating in the manual mode. Instead, EOS **302** receives manual (i.e., user-defined) subplant loads from a user via EOS user interface **704**. EOS **302** uses the manual subplant loads to determine recommended (e.g., optimal) equipment setpoints to achieve the manual subplant loads. EOS **302** may generate equipment control signals for subplant equipment **340** based on the recommended equipment setpoints to achieve the manual subplant loads.

[0161] System **900** is shown to include high level optimizer **330**, low level optimizer **332**, energy plant **200**, subplant monitor **338**, subplant utilization database **502**, dispatch GUI generator **506**, EOS user interface **704**, and BAS **308**, which may be the same or similar as described with reference to FIGS. **2-8**. For example, high level optimizer **330** may perform an optimization process to generate a set of recommended subplant loads for each of subplants **202-210**. High level optimizer **330** may determine the recommended subplant loads for a plurality of time steps between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). High level optimizer **330** may provide the recommended subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the recommended subplant loads as recommended subplant utilization data in a subplant utilization database **502**.

[0162] Low level optimizer **332** may use the recommended subplant loads to generate a first set of recommended equipment setpoints for the equipment of subplants **202-210**. The first set of recommended equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of subplants **202-210**. The first set of recommended equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the recommended subplant load. In some embodiments, low level optimizer **332** performs an optimization process to generate the first set of recommended equipment setpoints. Low level optimizer **332** may provide the first set of recommended equipment setpoints to subplant monitor **338**. Subplant monitor **338** may store the first set of recom-

mended equipment setpoints as recommended subplant utilization data in subplant utilization database **502**.

[0163] Low level optimizer **332** may also receive manual subplant loads from EOS user interface **704**. The manual subplant loads may include user-defined loads for each of subplants **202-210**. A user can specify the manual subplant loads via EOS user interface **704** (e.g., by entering values for the manual subplant loads, by adjusting sliders or dials, etc.). The manual subplant loads may be provided from EOS user interface **704** to low level optimizer **332**. The manual subplant loads may also be provided to subplant monitor **338**. Subplant monitor **338** may store the manual subplant loads as manual subplant utilization data in subplant utilization database **502**.

[0164] Low level optimizer **332** may use the manual subplant loads to generate a second set of recommended equipment setpoints for the equipment of subplants **202-210**. The second set of recommended equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the manual subplant load. In some embodiments, low level optimizer **332** performs an optimization process to generate the second set of recommended equipment setpoints. Low level optimizer **332** may provide the second set of recommended equipment setpoints to subplant monitor **338**. Subplant monitor **338** may store the recommended equipment setpoints as manual subplant utilization data in subplant utilization database **502**.

[0165] In some embodiments, low level optimizer **332** uses the second set of recommended equipment setpoints to generate equipment control signals for energy plant **200**. The equipment control signals may include on/off signals, load production signals, power consumption signals, or other types of control signals which may be used to control individual devices of subplant equipment **340**. The equipment control signals may cause each of subplants **202-210** to operate the individual devices of the subplant in a manner that achieves the manual subplant load for the subplant. For example, the equipment control signals for a chiller subplant may specify that a first chiller of the subplant operate at 75% capacity, a second chiller of the subplant operate at 40% capacity, and a third chiller of the subplant operate at 60% capacity. In some embodiments, the equipment control signals are provided directly from low level optimizer **332** to energy plant **200** (as shown in FIG. 9). In other embodiments, the equipment control signals may be provided to energy plant **200** via BAS **308** or generated by BAS **308** based on the second set of recommended equipment setpoints.

[0166] Energy plant **200** may monitor the utilization of subplants **202-210** and generate a set of actual subplant utilization data. The actual subplant utilization data may include actual values (rather than recommended values) for each of the subplant loads produced by subplants **202-210**. The actual subplant utilization data may also include actual equipment operating states (e.g., on/off states, load production, operating capacities, etc.) for individual devices of energy plant equipment **340**. Energy plant **200** may report the actual subplant utilization data to subplant monitor **338**. In some embodiments, energy plant **200** reports the actual subplant utilization data at regular intervals (e.g., once every fifteen minutes, once per hour, etc.) Subplant monitor **338** may store the actual subplant utilization data in subplant utilization database **502**.

[0167] Dispatch GUI generator **506** may access the data stored in subplant utilization database **502** and use the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the recommended subplant utilization data (e.g., recommended subplant loads and the first set of recommended equipment setpoints, etc.) manual subplant utilization data (e.g., manual subplant loads and the second set of recommended equipment setpoints), and actual subplant utilization data (e.g., actual subplant loads and actual equipment setpoints) in a graphical format. Dispatch GUI generator **506** may provide dispatch GUI **902** to EOS user interface **704** for presentation to a user **702**. A user can view dispatch GUI **902** and provide the manual subplant loads via EOS user interface **704**.

[0168] In some embodiments, EOS user interface **704** is a comprehensive monitoring and control interface that allows the user to monitor the operation of energy plant **200** and provide control inputs (e.g., manual subplant loads) that affect the operation of energy plant **200**. In addition to displaying dispatch GUI **902** generated by dispatch GUI generator **506**, EOS user interface **704** may be configured to receive input from the user via dispatch GUI **902**. For example, dispatch GUI **902** presented via user interface **504** may include interface options that allow a user to change the load setpoints for subplants **202-210**, change the on/off states or operating setpoints for equipment **340**, activate or deactivate entire subplants or individual devices of equipment **340**, adjust the configuration of BAS **308** or energy plant **200**, or otherwise monitor and control the operation of energy plant **200** and/or equipment **340**. EOS **302** may control energy plant **200** and/or equipment **340** (e.g., via actuators, power relays, etc.) in accordance with the user input received via EOS user interface **704**.

[0169] In some embodiments, the user input received via EOS user interface **704** overrides automated control decisions made by EOS **302**. For example, the manual subplant loads provided via EOS user interface **704** may override the recommended subplant loads determined by high level optimizer **330**. In some embodiments, EOS **302** determines whether the manual subplant loads would cause EOS **302** to violate an optimization constraint (e.g., building temperature out of range, thermal energy storage tank fully depleted or filled to capacity, etc.). If the manual subplant loads would not cause EOS **302** to violate an optimization constraint, EOS **302** may override the recommended subplant loads determined by high level optimizer **330** with the manual subplant loads. However, if the manual subplant loads would cause EOS **302** to violate an optimization constraint, EOS **302** may not override the recommended subplant loads determined by high level optimizer **330**. In some embodiments, EOS **302** causes dispatch GUI **902** to display a warning for the user if the manual subplant loads would cause EOS **302** to violate an optimization constraint within a predetermined time window. The user can then choose to override the recommended subplant loads and violate the optimization constraint or use the recommended subplant loads and satisfy the optimization constraint.

[0170] In some embodiments, dispatch GUI generator **506** updates dispatch GUI **902** based on the manual subplant loads before the manual subplant loads are used to affect the operation of energy plant **200**. For example, dispatch GUI generator **506** may display the second set of recommended equipment setpoints that would result from the manual

subplant loads before the manual subplant loads are used to generate the equipment control signals. In some embodiments, EOS **302** uses the manual subplant loads to calculate an amount of time before the manual subplant loads would cause EOS **302** to violate an optimization constraint (e.g., time until thermal energy storage tanks are filled or depleted). Advantageously, this allows the user to view the predicted effects of the manual subplant loads before the manual subplant loads take effect.

[0171] Referring now to FIG. **10**, a flow diagram illustrating a process **1000** for monitoring and controlling an energy plant in the manual operating mode is shown, according to an exemplary embodiment. Process **1000** may be performed by one or more components of energy plant system **300** and/or system **900** as previously described. For example, process **1000** may be performed by EOS **302**, BAS **308**, dispatch GUI generator **506**, and/or other devices of energy plant system **300** or system **900**.

[0172] Process **1000** is shown to include determining recommended subplant loads for a plurality of subplants of an energy plant (step **1002**). Step **1002** may be performed by high level optimizer **330**. Step **802** may include determining the recommended subplant loads for a plurality of time steps between the current time and a future time horizon. Each of the time steps may have a defined or predetermined duration (e.g., fifteen minutes, one hour, etc.). The recommended subplant loads may be updated with each iteration of the high level optimization process. High level optimizer **330** may provide the recommended subplant loads to low level optimizer **332** and to subplant monitor **338**. Subplant monitor **338** may store the recommended subplant loads as planned subplant utilization data in a subplant utilization database **502**.

[0173] Process **1000** is shown to include determining recommended setpoints for equipment of each subplant to achieve the recommended subplant loads (step **1004**). Step **1004** may be performed by low level optimizer **332**. The recommended equipment setpoints may include on/off states, operating setpoints, and/or other setpoints defining the utilization of individual devices of the subplants **202-210**. The recommended equipment setpoints may include setpoints for individual devices of subplants **202-210** in order for each subplant to meet the recommended subplant load. Low level optimizer **332** may provide the recommended equipment setpoints to energy plant **200** and to subplant monitor **338**. Subplant monitor **338** may store the recommended equipment setpoints as planned subplant utilization data in subplant utilization database **502**.

[0174] Process **1000** is shown to include presenting recommended and actual subplant utilization data to a user via an EOS user interface (e.g., EOS user interface **704**) (step **1006**). Step **1006** may be performed by dispatch GUI generator **506** and/or EOS user interface **704**. The recommended subplant utilization data may include the recommended subplant loads generated by high level optimizer **330** and/or the first set of recommended equipment setpoints generated by low level optimizer **332**. The actual subplant utilization data may include data describing the actual operation of energy plant **200** (e.g., actual subplant loads, actual equipment setpoints, etc.), which may be collected by subplant monitor **338** and stored in subplant utilization database **502**.

[0175] In some embodiments, step **1006** includes accessing the data stored in subplant utilization database **502** and

using the stored data to generate a dispatch GUI. Dispatch GUI **902** may include various graphics (e.g., graphs, charts, flow diagrams, etc.) that illustrate the actual subplant utilization data and the recommended subplant utilization data in a graphical format. Dispatch GUI generator **506** may provide dispatch GUI **902** to EOS user interface **704** for presentation to a user **702**.

[0176] Process **1000** is shown to include receiving manual subplant loads at the EOS user interface (step **1008**) and determining recommended setpoints for equipment of each subplant to achieve the manual subplant loads (step **1010**). The manual subplant loads may be user-specified subplant loads and may override the recommended subplant loads determined by high level optimizer **330**. Step **1010** may be the same or similar to step **1004**, with the exception that the manual subplant loads are used instead of the recommended subplant loads to determine the recommended setpoints for the subplant equipment. In some embodiments, dispatch GUI **902** is updated to include the manual subplant loads and the set of recommended setpoints that result from the manual load setpoints.

[0177] Process **1000** is shown to include generating control signals for the subplant equipment based on the recommended setpoints to achieve the manual subplant loads (step **1012**). The equipment control signals may include on/off signals, load production signals, power consumption signals, or other types of control signals which may be used to control individual devices of subplant equipment **340**. The equipment control signals may cause each of subplants **202-210** to operate the individual devices of the subplant in a manner that achieves the manual subplant load for the subplant. In some embodiments, the equipment control signals are provided directly from low level optimizer **332** to energy plant **200**. In other embodiments, the equipment control signals may be provided to energy plant **200** via BAS **308** or generated by BAS **308** based on the recommended equipment setpoints determined in step **1010**.

Dispatch GUIs

[0178] Referring now to FIGS. **11-37** several drawings of a dispatch GUI **902** which may be generated by dispatch GUI generator **506** are shown, according to an exemplary embodiment. Dispatch GUI **902** may present the recommended (i.e., optimal) subplant loads, manual subplant loads, and actual subplant loads in a variety of visual formats (e.g., diagrams, charts, graphs, etc.) that illustrate the operation of energy plant **200**. Dispatch GUI **902** may also present the first set of recommended equipment setpoints (i.e., the setpoints that result from the recommended subplant loads), the second set of recommended equipment setpoints (i.e., the setpoints that result from the manual subplant loads), and the actual equipment setpoints to provide details regarding the operation of each subplant. Dispatch GUI **902** may include past dispatch data (e.g., past subplant loads, past equipment setpoints) and current dispatch data (e.g., current subplant loads, current equipment setpoints) to allow a user to view a history of energy plant operations. Dispatch GUI **902** may also include future dispatch data (e.g., planned subplant loads, planned equipment setpoints) to allow the user to view planned energy plant operations into the future.

Plant and Subplant Summary Interfaces

[0179] Referring particularly to FIG. **11**, a plant summary interface **1100** is shown, according to an exemplary embodi-

ment. Plant summary interface **1100** may include graphics depicting each of the subplants within energy plant **200**. For example, plant summary interface **1100** is shown to include a plurality of chilled water loops **1102-1106** (i.e., Loop A **1102**, Loop B **1104**, and Loop C **1106**). Chilled water loops **1102-1106** are configured to provide cold thermal energy (e.g., measured in tons) to satisfy the cooling load of campus **1108**. Similarly, the steam subplant **1111** within plant B is configured to provide steam (measured in KPPH) to satisfy the heating load of campus **1108**. The cogeneration subplant **1110** within plant B can be configured to provide electricity (measured in MW) to satisfy the electric load of campus **1108**.

[0180] Plant summary interface **1100** is shown to include paths **1112-1120** connecting each of the chilled water loops **1102-1106** and subplants **1110-1111** to campus **1108**. If a subplant or chilled water loop is currently providing energy to campus **1108**, the path connecting the subplant or chilled water loop to campus **1108** may be highlighted or otherwise marked to indicate the flow of energy along the path. For example, path **1120** may be colored red to indicate the flow of steam along path **1120**, whereas paths **1112-1116** may be colored blue to indicate the flow of cold thermal energy along paths **1112-1116**, path **1118** may be colored orange to indicate the flow of electricity along path **1118**, or a path may be colored green to indicate the flow of gas along the path. In some embodiments, paths **1112-1120** are animated to indicate the flow of thermal energy. For example, the arrows along each of paths **1112-1120** may move along each path **1112-1120** to indicate the flow of thermal energy. Similarly, plant summary interface **1100** is shown to include paths **1122-1124** connecting electricity supply **1126** and gas supply **1128** to campus **1108**. Like paths **1112-1120** connecting the subplants to campus **1108**, paths **1122-1124** may be highlighted or otherwise marked to indicate the flow of electricity or gas energy along each path. The values below each of paths **1112-1124** within campus **1108** indicate the amount of each resource (i.e., electricity, chilled water, steam, and gas) being provided to campus **1108** by the corresponding subplant or supply.

[0181] Percentage indicators next to subplants **1110-1111** and chilled water loops **1102-1106** indicate the percentage of utilization for each subplant **1110-1111** or chilled water loop **1102-1106** (i.e., the percentage of the total subplant or chilled water loop capacity being utilized). For example, FIG. **11** is shown to include a 37% indicator next to Loop A **1102**, a 37% indicator next to Loop B **1104**, a 37% indicator next to the Loop C **1106**, a 37% indicator next to the plant B cogeneration subplant **1110**, and a 37% indicator next to the plant B steam subplant **1111**. This indicates that each subplant and chilled water loop is being utilized at 37% of its maximum capacity. The utilization rings associated with each subplant and chilled water loop may be filled to visually indicate the utilization percentage.

[0182] Referring now to FIG. **12**, a chilled water loop summary interface **1200** for Loop B **1104** is shown, according to an exemplary embodiment. Interface **1200** illustrates the percent utilization of each chilled water subplant within Loop B (e.g., chilled water subplant **1202**, chilled water subplant **1204**, and chilled water subplant **1206**) as well as the utilized capacity for the entire Loop B **1104**. The values below each of the paths **1208**, **1210**, and **1212** connecting

chilled water subplants **1202-1206** to campus **1108** indicate the chilled water production of each chilled water subplant **1202-1206**.

[0183] Referring now to FIG. **13**, a chilled water loop summary interface **1300** for Loop A **1102** is shown, according to an exemplary embodiment. Interface **1300** illustrates the percent utilization of each chilled water subplant within Loop A (e.g., chilled water subplant **1302**, chilled water subplant **1304**, and chilled water subplant **1306**) as well as the utilized capacity for the entire Loop A **1102**. The values below each of the paths **1308**, **1310**, and **1312** connecting chilled water subplants **1302-1306** to campus **1108** indicate the chilled water production of each chilled water subplant **1302-1306**.

[0184] Referring now to FIG. **14**, a plant summary interface **1400** for Loop C **1106** is shown, according to an exemplary embodiment. Interface **1400** illustrates the equipment within Loop C **1106** and provides key performance indicators (KPIs) for each of the equipment. For example, interface **1400** is shown to include a plurality of electric chillers (i.e., electric chiller **1**, electric chiller **2**, electric chiller **3**, and steam chiller **1**). The KPIs may include efficiency (e.g., COP, kW/ton, etc.), cooling production (tons), and rate of electric consumption (kW). Interface **1400** may display the percent utilization and cooling production of each device within Loop C **1106** as well as the overall percent utilization and cooling production of Loop C **1106**. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0185] Referring now to FIG. **15**, an equipment information page **1500** for the equipment of Plant F within Loop A **1102** is shown, according to an exemplary embodiment. Interface **1500** illustrates the equipment within Plant F and provides KPIs for each of the equipment. For example, interface **1500** is shown to include a plurality of steam chillers (i.e., steam chiller **1** and steam chiller **2**). The KPIs may include efficiency (e.g., COP, KPPH/ton, etc.), cooling production (tons), and rate of steam consumption (KPPH). Interface **1500** may display the percent utilization and cooling production of each device within Plant F as well as the overall percent utilization and cooling production of Plant F. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0186] Referring now to FIG. **16**, an equipment information page **1600** for the equipment of Plant E within Loop B **1104** is shown, according to an exemplary embodiment. Interface **1600** illustrates the equipment within Plant E and provides KPIs for each of the equipment. For example, interface **1600** is shown to include a plurality of electric chillers (i.e., electric chiller **1** and electric chiller **2**). The KPIs may include efficiency (e.g., COP, kW/ton, etc.), cooling production (tons), and rate of electric consumption (kW). Interface may display the percent utilization and cooling production of each device within Plant E as well as the overall percent utilization and cooling production of Plant E. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0187] Referring now to FIG. **17**, an equipment information page **1700** for the equipment of Plant D within Loop A **1102** is shown, according to an exemplary embodiment. Interface **1700** illustrates the equipment within Plant D and provides KPIs for each of the equipment. For example, interface **1700** is shown to include a plurality of chillers (i.e., electric chiller **1** and steam chiller **1**). The KPIs may include

efficiency (e.g., COP, kW/ton, KPPH/ton, etc.), cooling production (tons), rate of electric consumption (kW), and rate of steam consumption (KPPH). Interface **1700** may display the percent utilization and cooling production of each device within Plant D as well as the overall percent utilization and cooling production of Plant D. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0188] Referring now to FIG. **18**, an equipment information page **1800** for the equipment of Plant A within Loop B **1104** is shown, according to an exemplary embodiment. Interface **1800** illustrates the equipment within Plant A and provides KPIs for each of the equipment. For example, interface **1800** is shown to include a steam chiller (i.e., steam chiller **1**). The KPIs may include efficiency (e.g., COP, KPPH/ton, etc.), cooling production (tons), and rate of steam consumption (KPPH). Interface **1800** may display the percent utilization and cooling production of each device within Plant A as well as the overall percent utilization and cooling production of Plant A. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0189] Referring now to FIG. **19**, an equipment information page **1900** for the equipment of Plant C within Loop B **1104** is shown, according to an exemplary embodiment. Interface **1900** illustrates the equipment within Plant C and provides KPIs for each of the equipment. For example, interface **1900** is shown to include an electric chiller (i.e., electric chiller **1**). The KPIs may include efficiency (e.g., COP, kW/ton, etc.), cooling production (tons), and rate of electric consumption (kW). Interface **1900** may display the percent utilization and cooling production of each device within Plant C as well as the overall percent utilization and cooling production of Plant C. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0190] Referring now to FIG. **20**, an equipment information page **2000** for the equipment of Plant B within Loop B **1104** is shown, according to an exemplary embodiment. Interface **2000** illustrates the equipment within Plant B and provides KPIs for each of the equipment. For example, interface **2000** is shown to include a plurality of chillers (i.e., electric chiller **1**, electric chiller **2**, and steam chiller **1**). The KPIs may include efficiency (e.g., COP, kW/ton, KPPH/ton, etc.), cooling production (tons), rate of electric consumption (kW), and rate of steam consumption (KPPH). Interface **2000** may display the percent utilization and cooling production of each device within Plant B as well as the overall percent utilization and cooling production of Plant B. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0191] Referring now to FIG. **21**, an equipment information page **2100** for the steam equipment of Plant B is shown, according to an exemplary embodiment. Interface **2100** illustrates the steam equipment within Plant B and provides KPIs for each of the equipment. For example, interface **2100** is shown to include a plurality of boilers (i.e., boiler **4**, boiler **5**, boiler **6**, and boiler **7**). The KPIs may include steam production (KPPH), rate of natural gas consumption (MMBtu), and rate of electric consumption (kW). Interface **2100** may display the percent utilization and steam production of each steam production device within Plant B as well as the overall percent utilization and steam production of

Plant B. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0192] Referring now to FIG. **22**A, an equipment information page **2200** for the electric equipment of Plant B is shown, according to an exemplary embodiment. Interface **2200** illustrates the electric equipment within Plant B and provides KPIs for each of the equipment. For example, interface **2200** is shown to include a plurality of combustion turbines (i.e., combustion turbine **1** and combustion turbine **2**). The KPIs may include efficiency (e.g., COP, kW/kW), electric production (MW), and rate of electric consumption (kW). Interface **2200** may display the percent utilization and electricity production of each electricity production device within Plant B as well as the overall percent utilization and electricity production of Plant B. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0193] Referring now to FIG. **22**B, another equipment information page **2210** for the electric equipment of Plant B is shown, according to an exemplary embodiment. Interface **2210** illustrates the electric equipment within Plant B and provides KPIs for each of the equipment. For example, interface **2210** is shown to include a plurality of gas turbines (i.e., gas turbine **1** and gas turbine **2**). The KPIs may include efficiency (e.g., COP, kW/kW), electric production (MW), and rate of natural gas consumption (mcf/hr). Interface **2210** may display the percent utilization and electricity production of each electricity production device within Plant B as well as the overall percent utilization, electricity production, heat rate, and electricity import of Plant B. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

[0194] Referring now to FIG. **22**C, another equipment information page **2220** for the electric equipment of Plant B is shown, according to an exemplary embodiment. Interface **2220** illustrates the electric equipment within Plant B and provides KPIs for each of the equipment. For example, interface **2220** is shown to include a plurality of gas turbines (i.e., gas turbine **1** and gas turbine **2**). The KPIs may include efficiency (e.g., COP, kW/kW), electric production (MW), and rate of natural gas consumption (mcf/hr). Both the actual and target values of the electricity production and rate of natural gas consumption may be indicated when operating in the automatic mode. Interface **2220** may display the percent utilization and electricity production of each electricity production device within Plant B as well as the overall percent utilization, electricity production, heat rate, and electricity import of Plant B. In some embodiments, the equipment images will appear dimmed if the equipment is out of service.

Dispatch Schedule Interface

[0195] Referring now to FIGS. **23**A-**23**B, a dispatch schedule interface **2300** which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. Dispatch schedule interface **2300** may include detailed dispatch information for each of the subplants within energy plant **200**. For example, dispatch schedule interface **2300** may include detailed dispatch information for each chiller subplant **202-206**, steam subplant **208**, and cogeneration subplant **210**. Dispatch schedule interface **2300** may also include detailed dispatch information for each of the individual devices within each subplant **202-210**. For example, dispatch schedule interface **2300** may include

detailed dispatch information **2302** for each of chillers **218-228** within each chiller subplant **202-206**, each of boilers **232** within steam subplant **208**, and each of combustion turbines **230** within cogeneration subplant **210**.

[0196] Detailed dispatch information **2302** for each chiller may include the chiller's status (e.g., on or off), the amount of cooling energy (i.e., "Cooling Q") produced by the chiller (measured in tons), the power consumption of each chiller (measured in kW), the temperature of the cold water produced by each chiller, the flow rate of the cold water produced by each chiller, and the dispatched condenser flow setpoint for each chiller. Detailed dispatch information **2302** for each boiler may include the boiler's status (e.g., on or off), the amount of heating energy (i.e., "Heating Q") produced by the boiler (measured in mmBTU/h), the amount of fuel usage of each boiler (measured in mmBTU/h), the power consumption of each boiler (measured in kW), and the temperature of the hot water or steam produced by each boiler. Detailed dispatch information **2302** for the cogeneration subplant may include the amount of electricity produced by each of the combustion turbines.

[0197] In some embodiments, dispatch schedule interface **2300** includes multiple values for each of the variables included in detailed dispatch information **2302**. For example, dispatch schedule interface **2300** may include an optimal value **2304** for each variable (i.e., the "EOS" value), a building automation system (BAS) value **2306** for each variable (i.e., the "BAS" value), and an actual value **2308** for each variable. Optimal values **2304** may be determined by EOS **302** as previously described. In some instances, optimal values **2304** are based on the optimal or recommended subplant loads determined by high level optimizer **330**. In other instances, optimal values **2304** may be based on the manual subplant loads received via EOS user interface **704**. When EOS **302** is operated in the automatic mode, optimal values **2304** may be the same as the BAS values **2306** since optimal values **2304** are automatically provided as inputs to the BAS. However, when EOS **302** is operated in the advisory mode, optimal values **2304** may be different from BAS values **2306** since optimal values **2304** are provided as recommendations but not automatically applied as inputs to the BAS. Actual values **2308** may represent measured or observed values of the variables obtained from energy plant **200**, as indicated by the actual subplant utilization data collected by subplant monitor **338**.

[0198] In some embodiments, dispatch schedule interface **2300** presents snapshots of detailed dispatch information **2302** for multiple different dispatch intervals. For example, FIG. 23A shows a snapshot of detailed dispatch information **2302** for the present dispatch interval **2310**. Other pages of dispatch schedule interface **2300** may show snapshots of detailed dispatch information **2302** for a past dispatch interval or a future dispatch interval. A user can navigate between the past, present, and future dispatch intervals by selecting arrows **2312-2314** located on the sides of each window. For example, clicking arrow **2312** may cause dispatch schedule interface **2300** to transition from displaying the snapshot for the present dispatch interval **2310** to the snapshot for the past dispatch interval. Similarly, clicking arrow **2314** may cause dispatch schedule interface **2300** to transition from displaying the snapshot for the present dispatch interval **2310** to the snapshot for the future dispatch interval. Advantageously, this allows a user to navigate between past, present, and

future snapshots of detailed dispatch information **2302** to view subplant loads and equipment setpoints for a series of dispatch intervals.

[0199] Referring now to FIG. **23**C, another dispatch schedule interface **2350** which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. Dispatch schedule interface **2350** is shown displaying dispatch information for several devices of equipment. In some embodiments, the equipment are grouped into corresponding plants and/or loops in dispatch schedule interface **2350**. A user can expand or collapse various sections of dispatch schedule interface **2350** to show or hide information for equipment of each plant and/or loop. For each device of equipment, dispatch schedule interface **2350** may indicate whether EOS **302** is on or off, whether the device is out of service, and whether no dispatch is provided for each time interval. These status indications may be provided in the form of colored bars, where each color represents a different status indication.

Dispatch Chart Interfaces

[0200] Referring now to FIGS. **24-28**B, several dispatch chart interfaces **2400-2850** which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. Dispatch chart interfaces **2400-2850** show high-level energy flows for past, present and future dispatch schedules in stacked bar charts **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860**. The lines **2402**, **2502**, **2602**, **2652**, **2702**, **2752**, **2802**, and **2852** that span vertically across each chart **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860** represent the last dispatch time. When a new dispatch schedule is generated, each chart **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860** is updated and shifted to the left.

[0201] To hide or unhide specific data on each chart **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860**, a user can click the checkboxes **2404**, **2504**, **2604**, **2654**, **2704**, **2754**, **2804**, and **2854** in the legends **2406**, **2506**, **2606**, **2656**, **2706**, **2756**, **2806**, and **2856**. To focus on a specific area of data, a user can click a point on charts **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860** and drag to the right. The chart **2410**, **2510**, **2610**, **2660**, **2710**, **2760**, **2810**, and **2860** then zooms in on the selected range. The user can continue zooming in until the desired area of focus is reached. To pan, the user can use chart controls **2408**, **2508**, **2608**, **2658**, **2708**, **2758**, **2808**, and **2858** below each chart. To return to the original view, the user can select Reset zoom. The user can point to any point of data for more information about the date, time, and energy output flows.

[0202] In some embodiments, dispatch chart interfaces **2400-2850** include some or all of the features described in U.S. patent application Ser. No. 14/815,845 filed Jul. 31, 2015, and titled "Systems and Methods for Visualizing Equipment Utilization in an energy plant." The entire disclosure of U.S. patent application Ser. No. 14/815,845 is incorporated by reference herein.

[0203] Referring particularly to FIG. **24**, dispatch chart interface **2400** is shown displaying the chilled water production for Loop B. The total chilled water production of Loop B consists of the production **2412** of the Plant A, the production **2414** of Plant B, and the production **2416** of Plant C. The chilled water production of each plant at each time step is indicated by the height of the corresponding stacked bar in stacked bar chart **2410**. The total height of the

stacked bars at each time step indicate the total chilled water production of Loop B at that time step.

[0204] Referring now to FIG. 25, dispatch chart interface 2500 is shown displaying the chilled water production for Loop A. The total chilled water production of Loop A consists of the production 2512 of Plant D, the production 2514 of Plant E, and the production 2516 of Plant F. The chilled water production of each plant at each time step is indicated by the height of the corresponding stacked bar in stacked bar chart 2510. The total height of the stacked bars at each time step indicate the total chilled water production of Loop A at that time step.

[0205] Referring now to FIG. 26A, dispatch chart interface 2600 is shown displaying the chilled water production for Loop C. The total chilled water production of Loop C consists of only the production 2612 of Plant G. The chilled water production of Plant G at each time step is indicated by the height of the stacked bar in stacked bar chart 2610, which is equal to the total chilled water production of Loop A at that time step.

[0206] Referring now to FIG. 26B, dispatch chart interface 2650 is shown displaying the production and storage of Loop C at each time step. The total production of Loop C consists of the production 2662 of electricity and steam within Loop C and the amount of electricity and steam discharged from storage within Loop C. Line 2664 indicates the load on Loop C. The difference between the total production of Loop C and the load on Loop C signifies the unmet load. The storage of Loop C consists of the amount of return water stored within Loop C at each time step, designated by line 2666.

[0207] Referring now to FIG. 27A, dispatch chart interface 2700 is shown displaying the total steam production and consumption for energy plant 200. The total steam production of energy plant 200 consists of the production 2712 of the boilers of Plant B and the production 2714 of the cogenerators of Plant B. The steam production of each of the boilers and the cogenerators at each time step is indicated by the height of the corresponding stacked bars 2712 and 2714 above the horizontal axis (i.e., KPPH=0) in stacked bar chart 2710. The total height of the stacked bars 2712 and 2714 above the horizontal axis at each time step indicate the total steam production at that time step.

[0208] The total steam consumption of energy plant 200 consists of the consumption of Plant A, campus 1108, Plant F, Plant G, Plant B, and Plant D. The steam consumption of each of the plants at each time step is indicated by the height of the corresponding stacked bars 2716, 2718, 2720, 2722, 2724, and 2726 below the horizontal axis (i.e., KPPH=0) in the stacked bar chart. The total height of the stacked bars 2716-2726 below the horizontal axis at each time step indicate the total steam consumption at that time step.

[0209] Referring now to FIG. 27B, dispatch chart interface 2750 is shown displaying the total steam production and consumption of Plant B at each time step within a selected time period. The total steam production of Plant B consists of the production 2762 of the boilers of Plant B, the production 2764 of a first set of cogenerators of Plant B, and the production 2766 of a second set of cogenerators of Plant B. The steam production of each of the boilers and the cogenerators at each time step is indicated by the height of the corresponding stacked bars 2762-2766 above the horizontal axis in stacked bar chart 2760. The total height of the stacked bars 2762-2766 above the horizontal axis at each

time step indicate the total steam production at that time step. Line 2768 represents the total load on Plant B. The difference between the total load on Plant B and the total production of Plant B represents the unmet load.

[0210] The total steam consumption of Plant B consists of the consumption 2770 of Building A, the consumption 2772 of Building B, the consumption 2774 of Building C, the consumption 2776 of the chillers within Plant B, and the consumption 2778 of Building D. The steam consumption of each of the buildings and chillers at each time step is indicated by the height of the corresponding stacked bars 2770-2778 below the horizontal axis in stacked bar chart 2760. The total height of the stacked bars 2770-2770 below the horizontal axis at each time step indicate the total steam consumption at that time step.

[0211] Referring now to FIG. 28A, dispatch chart interface 2800 is shown displaying the total electricity production and consumption for energy plant 200. The total electricity production of energy plant 200 consists of the production 2812 of Plant B. The electricity production at each time step is indicated by the height of the corresponding stacked bar 2812 above the horizontal axis (i.e., KPPH=0) in stacked bar chart 2810.

[0212] The total electricity consumption of energy plant 200 consists of the consumption 2814 of Plant A, the consumption 2816 of campus 1108, the consumption 2818 of Plant F, the consumption 2820 of Plant G, the consumption 2822 of Plant C, the consumption 2824 of Plant E, the consumption 2826 of the cooling equipment of Plant B, the consumption 2828 of the electric equipment of Plant B, the consumption 2830 of the steam equipment of Plant B, and the consumption 2832 of Plant D. The electricity consumption of each of the plants at each time step is indicated by the height of the corresponding stacked bars 2814-2832 below the horizontal axis (i.e., KPPH=0) in stacked bar chart 2810. The total height of stacked bars 2814-2832 below the horizontal axis at each time step indicate the total electricity consumption at that time step.

[0213] Referring now to FIG. 28B, dispatch chart interface 2850 is shown displaying the total electricity production and consumption of Plant B at each time step within a selected time period. The total electricity production of Plant B consists of the production 2862 of a first set of cogenerators of Plant B, the production 2864 of a second set of cogenerators of Plant B, and amount 2866 of electricity imported by Plant B. The electricity production of each of the cogenerators and the amount of electricity imported at each time step is indicated by the height of the corresponding stacked bars 2862-2866 above the horizontal axis in stacked bar chart 2860. The total height of the stacked bars 2862-2866 above the horizontal axis at each time step indicate the total electricity production at that time step. Line 2768 represents the total load on Plant B. Line 2868 represents the total electric load on Plant B. The difference between the total electric load on Plant B and the total production of Plant B represents the unmet load.

[0214] The total electric consumption of Plant B consists of the consumption 2870 of Building A, the consumption 2872 of Building B, the consumption 2874 of Building C, the consumption 2876 of Building D, the consumption 2878 of Building E, the consumption 2880 of the chillers within Plant B, the consumption 2882 of the steam generators within Plant B, and the consumption 2884 of Building F. The electric consumption of each of the buildings, chillers, and

steam generators at each time step is indicated by the height of the corresponding stacked bars **2870-2884** below the horizontal axis in stacked bar chart **2760**. The total height of the stacked bars **2870-2884** below the horizontal axis at each time step indicate the total electric consumption at that time step.

Input Data Interfaces

[0215] Referring now to FIGS. **29-34**, several input data interfaces **2900-3400** which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. In some embodiments, input data interfaces **2900-3400** allow a user to manage inputs used by high level optimizer **330**. Such inputs can include, for example, campus electric and thermal energy load forecasts, utility pricing forecasts, weather forecasts, campus schedules, equipment out-of-service schedules, and manual utility pricing. Manual inputs can be maintained solely by the user, whereas forecast inputs give the user the ability to override weather, pricing, loads, etc. forecasted by EOS **302**.

[0216] Referring particularly to FIG. **29**, a weather forecast input interface **2900** is shown, according to an exemplary embodiment. The weather forecast inputs may predict the weather in the geographic region in which the building or campus **1108** is located for each of the plurality of time steps. Weather forecasts may include, for example, cloud coverage, dry bulb temperature, wet bulb temperature, humidity, precipitation, wind, or any other type of weather forecast. In some embodiments, weather forecast input interface **2900** includes a graph **2902**, **2904**, and **2906** for each of the weather variables. Each graph **2902-2906** may illustrate the predicted values for the corresponding weather variable over time. Weather forecasts can be predicted for the duration of the optimization period. In some embodiments, EOS **302** uses the weather forecasts to predict the thermal and electric energy loads of campus **1108**.

[0217] Referring now to FIG. **30**, a dry bulb temperature forecast input interface **3000** is shown, according to an exemplary embodiment. Dry bulb temperature forecast input interface **3000** is shown to include a graph **3002** of the predicted dry bulb temperature as a function of time. Interface **3000** is also shown to include a table **3004** of the predicted dry bulb temperature values. Table **3004** may include a cell for each hour of the optimization period. For example, table **3004** is shown to include a row for each day and a column for each hour. The cells at the intersections of the rows and columns contain the predicted dry bulb temperature values for the corresponding days and hours.

[0218] Referring now to FIG. **31**, an override interface **3100** is shown, according to an exemplary embodiment. Override interface **3100** may be displayed in response to a user clicking override button **3006** in forecast input interface **3000**. In some embodiments, a user can override the predicted values by selecting override button **3006** and entering a manual value for the corresponding variable. The manual override can be applied to a user-defined time period beginning at a start time/date and ending at an end time/date. The forecasted values can be changed by a user defined offset (e.g., increased or decrease by a user-defined amount) or set to a specific user-defined value. In some embodiments, override interface **3100** prompts the user to specify a reason for the override.

[0219] Referring now to FIG. **32**, a utility pricing forecast input interface **3200** is shown, according to an exemplary

embodiment. Utility pricing forecast input interface **3200** may include a forecast of utility prices for each time step of the optimization period. The forecasted utility prices can be defined for electricity (e.g., $/kWh), natural gas ($/mmBtu), water ($/L), or any other resource consumed by energy plant **200**. In some embodiments, utility pricing forecast input interface **3200** allows a user to define one or more utility pricing rates by selecting add rate button **3202** and specifying the rate **3204** and time period **3206** during which the rate **3202** applies. In some embodiments, EOS **302** uses the utility pricing forecasts to predict the cost associated with resource purchases over the optimization period.

[0220] Referring now to FIG. **33**, an equipment out-of-service interface **3300** is shown, according to an exemplary embodiment. Equipment out-of-service interface **3300** allows a user to define the time periods during which each of the subplants and/or the pieces of equipment within each subplant will be out-of-service. When a subplant or piece equipment is out-of-service, EOS **302** may exclude that subplant/equipment from the dispatches.

[0221] Referring now to FIG. **34**, a campus schedule interface **3400** is shown, according to an exemplary embodiment. Campus schedule interface **3400** allows a user to define the holiday and out-of-season calendar **3402** for campus **1108**. During holidays, the occupancy of campus **1108** may be lower than usual, which can affect the load forecast. In some embodiments, EOS **302** uses the campus schedule to generate the load forecasts.

Reporting Interfaces

[0222] Referring now to FIGS. **35A-36B**, several reporting interfaces which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. FIG. **35A** is a drawing of a reporting landing page **3500**. Reporting landing page **3500** shows high level KPIs **3502-3510** to provide the most relevant performance data to the user. For example, reporting landing page **3500** is shown to include the total utility cost **3502**, the peak demand **3504**, the performance **3506**, the unmet chilled water load **3508**, and the system efficiency **3510**. KPIs **3502-3510** can include the data for the current week, day, month, or any other time period. In some embodiments, KPIs **3502-3510** indicate a percent change relative to the previous time period (e.g., 14% decrease this week, 9% increase this week) for each of KPIs **3502-3510**. In some embodiments, reporting landing page **3500** allows a user to generate and/or view detailed reports for various dispatch schedules, performance monitoring, and a site summary.

[0223] FIG. **35B** is a drawing of a performance monitoring interface **3550**. Performance monitoring interface **3550** allows a user to visualize various performance measurements over time. The user can select a performance measurement via dropdown menu **3552** (e.g., consumption, production, etc.), a type of energy via dropdown **3554** (e.g., steam, electricity, hot water, cold water, etc.), and a type of equipment via dropdown **3556**. The user can specify a start date **3558** and an end date **3560** and click the "Generate Chart" button **3562** to create a chart **3570** or **3580** that plots the selected performance metric for the selected energy type and equipment for the specified date range. Each of the lines in chart **3570** represents the value of the steam consumption performance metric for the equipment of campus **1108**, Loop A **1102**, Loop B **1104**, or Loop C **1106**. Each of the lines in chart **3580** represents the value of the electricity

consumption performance metric for the equipment of campus **108**, Plant C, Plant B, or Loop B **1104**.

[0224] Referring now to FIGS. **36A-36**B, an example of a site summary report **3600** which can be accessed via the reporting interfaces is shown. Site summary report **3600** may provide information such as utility cost; economic load demand response (ELDR) revenue; production by site, loop, plant, or equipment; and consumption by site, loop, plant, or equipment. Such information can be provided for a user-defined time period.

Audit Log Interface

[0225] Referring now to FIG. **37**, an audit log interface **3700** which may be generated by dispatch GUI generator **506** is shown, according to an exemplary embodiment. The audit log is a running list of user edits and changes to operating mode used by EOS **302**. User edits can include, for example, overrides to forecasted inputs, manual input entries, schedule changes, and other manual overrides. Changes to the operating mode used by EOS **302** can include manually switching among the advisory mode, the automatic mode, and the manual mode. In some embodiments, each edit requires the user to log a reason for their change. Each of these edits and the reason for the edit can be displayed in the audit report.

Configuration of Exemplary Embodiments

[0226] The construction and arrangement of the systems and methods as shown in the various exemplary embodiments are illustrative only. Although only a few embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.). For example, the position of elements may be reversed or otherwise varied and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present disclosure. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present disclosure.

[0227] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of

machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0228] Although the figures show a specific order of method steps, the order of the steps may differ from what is depicted. Also two or more steps may be performed concurrently or with partial concurrence. Such variation will depend on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations could be accomplished with standard programming techniques with rule based logic and other logic to accomplish the various connection steps, processing steps, comparison steps and decision steps.

What is claimed is:

1. An energy plant comprising:

a plurality of subplants configured to serve energy loads of a campus, the plurality of subplants comprising:

a cogeneration subplant configured to generate steam and electricity; and

a chiller subplant electrically coupled to the cogeneration subplant and configured to consume the electricity generated by the cogeneration subplant;

a high level optimizer configured to determine recommended subplant loads for each of the plurality of subplants, the recommended subplant loads comprising a rate of steam production and a rate of electricity production of the cogeneration subplant and a rate of electricity consumption of the chiller subplant;

a low level optimizer configured to determine recommended equipment setpoints for equipment of the plurality of subplants based on the recommended subplant loads; and

a controller configured to operate the equipment of the plurality of subplants based on the recommended equipment setpoints.

2. The energy plant of claim **1**, wherein:

the chiller subplant is fluidly coupled to the cogeneration subplant and configured to chill the steam generated by the cogeneration subplant; and

the recommended subplant loads comprise a rate of steam consumption and a rate of chilled steam production of the chiller subplant.

3. The energy plant of claim **1**, further comprising a user interface configured to receive manual subplant loads specified by a user;

wherein the low level optimizer configured to determine the recommended equipment setpoints for the equipment of the plurality of subplants based on the manual subplant loads.

4. The energy plant of claim **3**, further comprising a dispatch graphical user interface (GUI) generator configured to generate a dispatch GUI and present the dispatch GUI via the user interface, the dispatch GUI comprising the recommended subplant loads and the manual subplant loads.

5. The energy plant of claim **4**, wherein the dispatch GUI comprises an operating mode selector configured to display

a plurality of operating modes and to receive a user selection of one of the operating modes;

the plurality of operating modes comprising an automatic operating mode, an advisory operating mode, and a manual operating mode.

6. The energy plant of claim **3**, wherein the low level optimizer is configured to operate in:

an automatic operating mode in which the low level optimizer determines a first set of recommended equipment setpoints to achieve the recommended subplant loads; and

a manual operating mode in which the low level optimizer determines a second set of recommended equipment setpoints to achieve the manual subplant loads.

7. The energy plant of claim **3**, wherein the high level optimizer is configured to determine an amount of overproduction or underproduction resulting from the manual subplant loads by comparing the manual subplant loads to a campus energy load.

8. The energy plant of claim **7**, wherein:

the plurality of subplants comprise an energy storage subplant; and

the user interface comprises an indication of an amount of time until the energy storage subplant is (1) fully depleted based on the amount of underproduction or (2) filled to capacity based on the amount of overproduction.

9. The energy plant of claim **1**, further comprising a subplant monitor configured to monitor the energy plant and identify actual subplant loads for each of the plurality of subplants.

10. The energy plant of claim **9**, further comprising a dispatch graphical user interface (GUI) generator configured to generate a dispatch GUI comprising the recommended subplant loads and the actual subplant loads.

11. A method for monitoring and controlling an energy plant comprising a plurality of subplants that operate to serve energy loads of a campus, the method comprising:

operating a cogeneration subplant of the plurality of subplants to generate steam and electricity; and

operating a chiller subplant of the plurality of subplants to consume the electricity generated by the cogeneration subplant;

determining recommended subplant loads for each of the plurality of subplants, the recommended subplant loads comprising a rate of steam production and a rate of electricity production of the cogeneration subplant and a rate of electricity consumption of the chiller subplant;

determining recommended equipment setpoints for equipment of the plurality of subplants based on the recommended subplant loads; and

operating the equipment of the plurality of subplants based on the recommended equipment setpoints.

12. The method of claim **11**, further comprising operating the chiller subplant to chill the steam generated by the cogeneration subplant;

wherein the recommended subplant loads comprise a rate of steam consumption and a rate of chilled steam production of the chiller subplant.

13. The method of claim **11**, further comprising receiving manual subplant loads specified by a user via a user interface; and

determining the recommended equipment setpoints for the equipment of the plurality of subplants based on the manual subplant loads.

14. The method of claim **13**, further comprising generating a dispatch GUI and presenting the dispatch GUI via the user interface, the dispatch GUI comprising the recommended subplant loads and the manual subplant loads.

15. The method of claim **14**, further comprising receiving a user selection of one of a plurality of operating modes via an operating mode selector of the dispatch GUI, the plurality of operating modes comprising an automatic operating mode, an advisory operating mode, and a manual operating mode.

16. The method of claim **13**, further comprising:

operating in an automatic operating mode to determine a first set of recommended equipment setpoints to achieve the recommended subplant loads; and

operating in a manual operating mode to determine a second set of recommended equipment setpoints to achieve the manual subplant loads.

17. The method of claim **13**, further comprising determining an amount of overproduction or underproduction resulting from the manual subplant loads by comparing the manual subplant loads to a campus energy load.

18. The method of claim **17**, wherein:

the plurality of subplants comprise an energy storage subplant; and

the user interface comprises an indication of an amount of time until the energy storage subplant is (1) fully depleted based on the amount of underproduction or (2) filled to capacity based on the amount of overproduction.

19. The method of claim **11**, further comprising monitoring the energy plant to identify actual subplant loads for each of the plurality of subplants.

20. The method of claim **19**, further comprising generating a dispatch GUI comprising the recommended subplant loads and the actual subplant loads.

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