University of Central Florida
Building Automation System Specification

Prepared by the Department of Utilities and Energy Services

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1. General

1.1. Description

A. General: The intent of this specification is to optimize building performance and standardize building automation controls.
B. Communications: All controls systems and devices shall be compliant with ANSI/ASHRAE Standard 135, BACnet and BTL listing requirements.
C. Platform: The control system shall consist of an enterprise-level, web based front end management application. The web interface shall be available on PC, MAC, and mobile platforms without use of additional software.

1.2. Products Furnished but Not Installed Under This Specification

A. Hydronic Piping
    1. Control Valves
    2. Flow Switches
    3. Temperature Sensor Wells and Sockets
    4. Flow Meters except where defined in 1.2
B. Ductwork Accessories
    1. Automatic Dampers
    2. Airflow Stations
    3. Terminal Unit Controls

1.3. Products Installed but Not Furnished under This Specification

A. Refrigeration Equipment
    1. Refrigerant Leak Detection System
B. Package DX Equipment
    1. Thermostats – Coordinate with UES for determination of stand-alone vs BAS integration
C. BTU Utility Meter
    1. Chilled water meters furnished under Division 33 will be installed under this division.

1.4. Products Not Furnished or Installed under but Integrated with the Work of This Specification

A. Heat Generation Equipment
    1. Boiler Controls
B. Refrigeration Equipment
    1. Chiller Controls
C. Rooftop Air-Handling Equipment (for package, stand-alone single-zone systems)
    1. Discharge Air Temperature Control
    2. Economizer Control
    3. Volume Control
D. Unit Ventilators and Fan Coil Units
    1. Set Point Reset
    2. Day and Night Indexing
E. VAV Terminal Units
    1. Cross-Flow Velocity Sensor
F. Variable Frequency Drives
    1. Energy Data

2. Alarms
3. Internal BACnet points

G. CRAC Units
1. Status/Alarms

H. Lighting Controls
1. Occupancy
2. BACnet points

I. Utility sub-Meters (This does not include the meters for UES billing)
1. Energy Data

1.5. Related Documents

A. UCF Design, Construction, and Renovation Standards http://fp.ucf.edu
B. Building Construction and Renovation Requirements
http://energy.ucf.edu/forms-and-procedures
C. Maintenance and Operations Requirements
http://energy.ucf.edu/forms-and-procedures

1.6. Approved Control System Primary Manufacturers

A. The following are approved control system manufacturers and product lines:

Manufacturer	Product Line
Automated Logic	OptiFlex/ME/SE/ZN Products
Trane	Tracer Ensemble/Synchrony/UC Products
Delta Controls*	3.4 and enteliBUS
Siemens*	APOGEE Products

B. Newer product lines shall be evaluated for approval by the Department of Utilities and Energy Services. New product lines must comply with ANSI/ASHRAE Standard 135, BACnet, be BTL listed, and comply with the minimum standards set forth in this specification.
C. Systems with an * are only approved where the project must match existing building incumbent BAS. All other instances must be pre-approved by UES.
D. Equipment and / or software that has an obsolescence window within the next 5 years shall not be submitted to be installed or included in any project without pre-approval by UES.

1.7. Quality Assurance

A. The LEED Enhanced Commissioning credit for Building Design and Construction is used in conjunction with the latest published version of ASHRAE Standard 202 and Guideline 1.1 to provide quality assurance for all new renovations and construction projects.
B. All projects that include the addition of or modification to any BAS controller shall be commissioned. The BAS vendor is to coordinate with the T&B contractor and CxA regarding testing times and allocate labor hours for both activities.
C. The BAS contractor is required to prove functional performance of the sequence of operations, to be witnessed by the CxA and UES.
1. All functional performance testing shall be performed on UCF network.
a. UES to approve any testing that cannot be performed on UCF's network.
D. The contractor will be responsible for coordinating with other trades on the prime contractor's construction schedule and the commissioning schedule.

E. A complete Point-to-Point checkout report for every controller shall be furnished before Cx functional performance testing phase begins.
F. As-built documentation must be uploaded to and linked within the front-end graphics at the respective floor plans and equipment graphics.

1.8. Codes and Standards

A. Work, materials, and equipment shall comply with the most restrictive of UCF, local, state, and federal authorities' codes and ordinances or these plans and specifications.

1.9. System Performance

A. Systems specified above are predetermined to meet basic performance requirements.
B. Engineer shall design and Contractor shall program the sequences of operations to incorporate the latest version of ASHRAE Guideline 36 as a minimum level of adjustability, data visualization and energy-saving programming.
C. Building and HVAC system performance metrics and energy data shall be included in the system graphics. Graphics package to be reviewed by UES for each project.

1.10. Submittals

A. Contractor shall provide shop drawings or other submittals on all hardware, software, and installation to be provided. No work may begin on any segment of this project until submittals have been reviewed and approved for conformity with the design intent.
B. In addition, Shop Drawings and Submittals must meet the requirements set forth in the Division 1.
C. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawings shall clearly reference the specification and/or drawing that the submittal is to cover.
D. Submittals shall include:
    1. A complete bill of materials of equipment to be used indicating quantity, manufacturer, model number, and other relevant technical data
    2. Manufacturer's description and technical data, such as performance curves, product specification sheets, and installation/maintenance instructions for the items listed below and other relevant items not listed below:
        a. Direct Digital Controller (controller panels)
        b. Transducers/Transmitters
        c. Sensors (including accuracy data)
        d. Actuators
        e. Valves
        f. Relays/Switches
        g. Control Panels
        h. Power Supply
        i. Wiring
    3. Wiring diagrams and layouts for each control panel. Show all termination numbers.
    4. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware.
    5. Complete and accurate riser diagrams showing control network topology, routing, layout, locations, firewall penetrations, network addresses (TCP/IP and BACnet), and wire types.

6. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
7. A schematic wiring diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, it shall be labeled with the same name. All terminals shall be labeled.
8. An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number.
9. A mounting, wiring, and routing plan-view drawing. The design shall consider HVAC, electrical, and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.
10. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
11. A point list for each system controller including both inputs and outputs (I/O), point naming, point numbering, the controlled device associated with the I/O point, and the location of the I/O device. Software flag points, alarm points, whether it is shown on the graphics, and high/low limits. Point that are trended, need to be indicated with their COV or polling interval. See Naming Convention section.
12. Front-end Graphics screens shall be submitted to UES for approval for each project. To include but is not limited to the following examples.
    a. Building Overview
    b. Equipment Overview
    c. Chilled Water
    d. Hot Water
    e. AHU (With and Without Heat)
    f. CTU (With and Without Heat)
    g. FCU (With and Without Heat)
    h. VTU (With and Without Heat)
    i. Chilled Beam
    j. Exhaust Fan (Hood and General)
    k. VTU Summary Page (Broken down by AHU)
    l. ERV
    m. DOAS
    n. Floorplans showing room numbers, temperature, (humidity and CO2 if applicable)

13. BACnet PICS (Performance Interoperability Conformance Statement) for each third-party device, and plan for integration (integration components detailed on network riser will suffice).

1.11. Warranty

A. Warrant work as follows:
   1. Warrant labor and materials for specified control system free from defects for a period of 24 months after final acceptance or duration specified in Standards or contract. Control system failures during warranty period shall be adjusted,

repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.

2. Contractor shall provide labor and materials to resolve system performance issues resulting from lack of optimization or "dialing in" of sequence routines. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period. The start of warranty period will be rejected if systems have known performance deficiencies discovered during the T&B and / or Cx phase until resolved.
3. If Engineer and UES determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
4. Provide updates to operator workstation software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
5. Contractor may reuse existing devices, wiring, etc. with prior approval from UES. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance. Any devices found inoperable UES is to be notified and the contractor shall either submit a change order for repair or UES will replace the faulty device.

1.12. Ownership of Proprietary Material

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:
   1. Graphics
   2. Record drawings
   3. Database
   4. Application programming code
   5. Documentation
   6. Administrator Access to all controllers and systems

1.13. Definitions

A. **BAS Utility Meter** – Refers to a commodity meter which ties into the BAS to monitor and trend commodity consumption intended for use in conjunction with the M&V Plan.

B. **Billing Utility Meter** – Refers to a commodity meter used for utility billing, typically connected immediately at the line side of a building. Utility Meters will accommodate the M&V requirements for monitoring and logging commodity data where tied into the **UCF Fixed Network**. See Division 33 for more details

C. **BACnet Interoperability Building Blocks (BIBB)** – A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.

D. **BACnet/BACnet Standard** – BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.

E. **BACnet Testing Laboratories (BTL) –** Association of the BACnet International organization which supports compliance testing and interoperability testing activities.
F. **BTL Listed** – Refers to the approval of a device from the BACnet Testing Laboratories that the device is verified to comply with BACnet and interoperability standards.
G. **Protocol Implementation Conformance Statement (PICS)** – Protocol Implementation Conformance Statement are a written document that identifies the particular options specified by BACnet that are implemented in a device.
H. **Primary Equipment – Refers to major building equipment:**
   1. Air Handling Units
   2. Chilled Water Systems
   3. Hot Water Systems
   4. Computer Room Units (CRU, CRAC, etc.)
   5. Rooftop Units (RTU)

2. Product Standards

2.1. Materials

A. Use new products that the manufacturer is currently manufacturing and that have been approved for commercial or industrial application. Do not use this installation as a product test site unless explicitly approved in writing by UES. Spare parts shall be available for at least five years after completion of this contract.

2.2. Communication

A. Buildings will network into the existing enterprise IP infrastructure.
B. All buildings will have at least one point of connection to the IP network, and the only devices allowed at the IP level shall be those that meet or exceed the minimum BIBB requirements of the latest BTL listed B-BC class PICS.
C. UES will coordinate with UCF IT to provide all necessary network connections nearby or inside controls panels. No dedicated IP network switching or routing equipment is permitted to be installed by contractor. If local IP connectivity is required, additional network connections are to be requested at the time of submittal.
D. All network configuration to be assigned by the Department of Utilities and Energy Services, through Owner, including IP addresses, subnet masks, gateways and broadcast distribution tables.
E. Control devices on all tiers of the building network must natively support communication a BACnet network. All BACnet devices shall be BTL listed.
F. Integrated third party devices related to this specification shall be connected to BAS through native BACnet interface.
G. **Contractor will be responsible for providing and configuring a BTL listed BACnet gateway for third party equipment furnished by other trades, when designed for integration into BAS, including but not limited to CRAC units, lighting controls, boilers and chillers.**
H. All data points and information required by the sequence of operation, graphics, trends or alarms must be accessible, adjustable and command-able where applicable, through BACnet. **No setpoints or analog configuration points shall be hard-coded into any sequence of operation program**. **All analog and digital hardware and software points shall be adjustable.**
I. BACnet devices must be addressable to the full range of BACnet device instance numbers (1 to 4194303). See section 3.17.B for more details.
J. MS/TP devices must communicate at a minimum of 76.8kbaud.

1. If exception is given to a lower baud rate device it must not be attached to a network with devices that could otherwise support 76.8kbaud.

K. All controllers shall be configured for US customary units, at all levels of architecture.

2.3. Operator interface

A. Operator Interface must support the latest full release version of Microsoft Windows which has been publicly released for at least one year.

B. System software shall be based on server/thin-client architecture, designed around the open standards of web technology. The control system server shall be accessed using a web browser over the Owner's local area network.

C. The system must meet all of the feature requirements of a BACnet Advanced Operator Workstation (B-AWS) profile.

D. Contractor as part of base bid shall include cost to implement the latest version of the server and/or workstation software, including any licensing to add new controllers.

1. If upgrades to the existing BAS software will cause issues with existing controllers, contractor will coordinate with the Department of Utilities and Energy Services, through Owner, to determine phasing in process.
2. System server software will be installed on a Virtual Machine provided by the Department of Utilities and Energy Services, all software must be copied to the server remotely and able to be installed from the remote copy.
3. Unless already owned and installed at the enterprise-level, all projects shall include a licensed copy of required software and service tools needed to view, configure, command, and monitor BAS.

2.4. General Controller Requirements

A. Controllers must comply with ASHRAE Standard 135 BACnet.

B. Controller memory must exceed the demand of the project, by at least 25%, to allow for additional logic and programming in the future.

C. Controllers that perform scheduling shall have a real-time clock with alternate power source.

D. The building controller shall maintain all BIOS and programming information in the event of a power loss for at least 90 days.

E. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1m (3 ft).

F. Controllers shall be powered by 24VAC.

G. Controllers for primary equipment shall be provided with a UPS system for up to 1 hour of service without building power.

H. Controllers shall have a service communication port for connection to the portable laptop service tools.

2.5. Building controllers

A. Building controllers must meet at minimum the requirements of the BACnet Building Controller (B-BC) profile.

B. Building controllers may reside on BACnet/IP, MS/TP, or ARCNET LANs.

2.6. Custom application controllers

A. Custom application controllers must meet at minimum the requirements of the BACnet Advanced Application Controller (B-AAC) profile.

2.7. Application specific controllers

A. Application specific controllers must meet at minimum the requirements of the BACnet Application Specific Controller (B-ASC) profile.

2.8. Input and output interface

A. Controllers must be able to accept input signals from the following:
   1. 0-10 VDC
   2. 0-20 mA
   3. Contact closure
   4. Pulse input
   5. Resistive inputs

B. Controllers must be able to provide output signals of the following:
   1. 0-10 VDC
   2. 4-20 mA (where long distance signaling is necessary)

C. Binary inputs shall allow the monitoring of On/Off signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.

D. Pulse accumulation input objects. This type of object shall conform to all the requirements of binary input objects and also accept up to 10 pulses per second for pulse accumulation.

E. Analog inputs shall allow the monitoring of low-voltage (0 to 5 or 10 VDC), current (4 to 20 mA), or resistance signals (thermistor). Analog inputs shall be compatible with— and field configurable to— commonly available sensing devices.

F. Binary outputs shall provide for On/Off operation or a pulsed low-voltage signal for pulse width modulation control. Outputs shall be selectable for either normally open or normally closed operation.

G. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide a 0 to 10 VDC as required to provide proper control of the output device.

H. All analog outputs controlled via Proportional, Integral, Derivative (PID) or any subset of P, PI or PD control shall have the span of control set to not overrun the response rate of the controlled device.
   1. For example, a VFD drive programmed to a minimum speed of 15 Hz and a ramp rate of 1 Hz per second has a full span of 45 seconds from minimum to maximum assuming 60 Hz is the maximum speed. The BAS PID loops should not output a signal that has a minimum-to-maximum of less than 45 seconds in this case. Likewise, for a 90 second damper or valve actuator, the PID output full span should be 90 seconds.

I. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no damage to the controller.

J. Controllers shall have at least two analog outputs, two binary outputs and two universal inputs as spare for future capacity.

2.9. Power supplies and line filtering

A. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in both primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
   1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum

peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand a 150% current overload for at least three seconds without trip-out or failure.

a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MIL-STD 810C for shock and vibration.
b. Line voltage units shall be UL recognized and CSA approved.

B. Power line filtering.
1. Provide transient voltage and surge suppression for all controllers either internally or as an external component. Surge protection shall have the following at a minimum:
a. Dielectric strength of 1000 volts minimum
b. Response time of 10 nanoseconds or less
c. Transverse mode noise attenuation of 65 dB or greater
d. Common mode noise attenuation of 150 dB or better at 40 Hz to 100 Hz

2.10. Auxiliary control devices

A. Laboratory Air Supply and Exhaust Valves
1. Pressure independent Venturi style air valves or fast-acting blade-style valves must be provided with all laboratory HVAC systems for supply air, fume hood exhaust air, and general exhaust air.
2. Pneumatic valves are not permitted.
3. Proprietary valve controllers are not permitted without prior approval from UES.
4. Valves must be fully integrated into the BACnet network.
5. Valves must accept an analog 0-10VDC signal (ability to be commanded from the BAS) for setpoint control and reset routines.
6. All control and feedback signals shall be shown as a "%" of span on the BAS graphics.

B. Damper/Valve actuators:
1. Electronic actuators shall be used typically, no pneumatic actuators unless required by atypical design and pre-approval from UES.
2. The actuator shall have mechanical or electronic stall protection to prevent damage to the actuator throughout the rotation of the actuator.
3. Where indicated, for power-failure/safety applications, an internal mechanical, spring-return mechanism or capacitor-based electronic-return shall be built into the actuator housing.
4. Proportional actuators shall accept a 0 to 10 VDC control signal and provide a 2 to 10 VDC operating range.
5. Proportional actuators shall provide 0-10VDC or 4-20mA feedback signal.
6. All 24 VAC/VDC actuators shall operate on Class 2 wiring
7. All non-spring-return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring-return actuators with more than 7 N-m (60 in-lb.) torque capacity shall have a manual crank for this purpose.
8. All control and feedback signals shall be shown as a "%" of span on the BAS graphics.

C. Control Valves:
1. Shall be modulating two-way characterized control valves.

2. If valve controllers include control routines that interrupt the BAS control signal, (example: dT control, etc), valve control must first default to BAS setpoint control (meet DAT setpoint first, then control to dT secondary)
3. All control and feedback signals shall be shown as a "%" of span on the BAS graphics.
4.

D. Temperature sensors:
   1. Accuracy ±0.4 °F
   2. Temperature sensors shall be Type II or III thermistor style
   3. Duct sensors shall be single point or averaging as shown and abide by the following:
      a. Single point sensors in duct shall be at least ½ the depth of the ductwork, up to 12 in
         i. ACI A/AN-D or equivalent
      b. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2 (10 ft^2) of coil cross section
         i. ACI A/AN-FA or equivalent
   4. Immersion sensors shall be provided with the following:
      a. Separable stainless steel well
      b. Pressure rating of well consistent with the system pressure in which it is to be installed
      c. Well that will withstand the flow velocities in the pipe.
      d. ACI A/AN-I or equivalent
   5. Space sensors:
      a. Shall be available with any combination of the following options, blank plate for "common spaces, such as halls and atriums), set point adjustment, occupancy override switch, display, and/or communication port as indicated by UES
      b. ACI A/AN-R2 or equivalent

E. Low-limit thermostats (freeze protection):
   1. Low-limit airstream thermostats shall be UL listed, vapor pressure type, with an element of 6 m (20 ft) minimum length
   2. Element shall respond to the lowest temperature sensed by any 30 cm (1 ft) section
   3. Manual reset only
   4. Kele – TSA-DOP or equivalent

F. Humidity Sensor:
   1. Supply power 24VAC
   2. Outputs signal 0-10VDC
   3. Accuracy ±3% full scale
   4. Typical sensing range of 10% to 90%
   5. Duct sensors shall be provided with a sampling chamber
   6. ACI A/RH2 or equivalent

G. CO2 Sensors:
   1. Supply power 24VAC
   2. Outputs signal 0-10VDC
   3. Accuracy ±5% full scale
   4. Typical sensing range of 0 ppm to 2000ppm
   5. ACI CO2 or equivalent

H. Combination Temp/CO2/Humidity
   1. Combination sensors allowed and recommended to reduce wall footprint

2. Combination sensors must comply with the same requirements for the individual sensors accuracies and ranges
3. Supply power may be of any of the options of the individual sensors
4. ACI CO2-VEN or equivalent

I. Flow Meter
1. Supply power 24 VAC
2. Output signal 4-20mA
3. Accuracy ±1% full scale
4. Pipe Diameter < 3" – Onicon F-3000 Series or equivalent
5. Pipe Diameter ≥ 3" – Onicon F-3500 Series or equivalent

J. Airflow monitoring:
1. Supply power 24 VAC (VA determined by number of sensors)
2. Outputs signal 0-10 VDC
3. Accuracy ±2% full scale
4. Size, number of probes and number sensors per probe to be provided as prescribed by manufacturer for each application
5. Diameter < 12in: ELF /F Series or equivalent
6. Diameter ≥ 12in: Ebtron GTC116-PC or equivalent

K. Dry Pressure Transducers:
1. Supply power 24 VAC
2. Outputs signal 0-10 VDC
3. Accuracy ±1% full scale
4. Typical duct static pressure range: 0-5 inH_2O
5. Typical filter differential pressure range: 0-1 inH_2O
6. Typical building static pressure range: 0-0.25 inH_2O
7. Veris PXULX05S or equivalent

L. Wet Pressure Transducers:
1. Supply power 24 VAC
2. Outputs signal 0-10 VDC
3. Accuracy ±1% full scale
4. Typical Pressure range (minimum 0-100 psi for chilled water)
5. Veris PWLX04S or equivalent

M. Relays:
1. Coil voltage 10-30 VAC/VDC or 120VAC
2. Contact rating beyond 120 VAC
3. Provides LED Status light
4. Shall be UL listed
5. Functional Devices RIBU1C or equivalent

N. Safety Alarm Logic Board:
1. Supply power 24 VAC
2. Accept up to 6 N/C contacts for safety interlock
3. Functional Devices RIBLB-6 or equivalent

O. Current Transducers:
1. Outputs signal 0-10 VDC or 4-20mA
2. Accuracy ±2% full scale
3. Range depends on application
4. Split core
5. UL Listed
6. Veris H923 or equivalent

P. Electric Energy Meter:
1. Accuracy ±1% full scale

2. Scale depends on application
3. Must include BACnet communication option
4. Veris E50H5 or equivalent, with appropriate split core or rope style CT's

Q. Thermal Fluid Energy Meter
1. See Division 33 Chilled Water Meter specification.
2. **NOTE: BTU Meter for main service from UCF chilled water district will be provided by UCF, with appropriate BACnet/IP option for communication with BAS to be integrated by contractor. Contractor responsible only for other Thermal Fluid Energy Meters specified**

R. Variable Frequency Drives:
1. Analog input signal of 0-10V speed reference
2. Analog output signal of 0-10V for frequency output 0-60Hz
3. Binary input to accept dry contact closure to initiate run command
4. Analog output signal of VFD current in Amps
5. BACnet communication must be integrated into the VFD
6. ABB ACH580 or equivalent integrated controls
7. All other requirements set forth in Division 26 of this document

2.11. Wiring and Raceways

A. The following cable types should be used for their respective purpose:
1. I/O - Yellow Jacket, 18/2awg, Plenum Rated
2. Power, AC - Orange Jacket, 18/2 Plenum Rated
3. Power, DC - White/Orange Stripe Jacket, 18/2 Plenum Rated
4. Comm. MS/TP - Blue Jacket, 24/2 Plenum Rated Shielded Low Capacitance
5. Comm. OTHER - Purple Jacket, 24/2 Plenum Rated Shielded Low Capacitance

B. Enclosure
1. Controller enclosures shall be mounted indoors, except factory installed controls integral to outdoor equipment and designated for outdoor use by the manufacturer
2. Enclosures shall be sized to accommodate all devices and cable management with room to work. Typically, 24"x24"x9"
3. Size appropriate wire duct shall be used for cable of lengths greater than 1', such that the duct is no more than NEC prescribed maximum fill level.

C. Cable troughs
1. Each Primary Equipment control enclosure shall be provided with a cable trough for excess cable storage, typically 24"x9"x9", or proportional to the controls enclosure.

D. Terminal blocks
1. All incoming cables to controls enclosure shall be terminated to din rail mounted blocks at the top of enclosure as follows:
   a. I/O Common: Gray Terminal Block
   b. I/O Signal: Yellow Terminal Block
   c. 24VAC/DC Common: Gray Terminal Block
   d. 24VAC/DC Power: Orange Terminal Block
   e. 120VAC Common: Gray Terminal Block
   f. 120VAC Power: Single Pole, Din Rail Mountable, Low Voltage Circuit Breaker.
2. Terminal Blocks shall be grouped to rows of similar cable (I/O, 24VAC, 24VDC, and 120VAC) and alternating terminal wires (Signal/Common, Power/Common).

2.12. Fiber Optic Cable System

A. Fiber optics shall not be used in typical applications.

2.13. Compressed Air Supply—Pneumatic

A. Compressed air systems and pneumatic control equipment shall not be used.

3. Execution

3.1. Examination

A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to UES and the architect/engineer for resolution before rough-in work is started.

B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to UES and the engineer for resolution before rough-in work is started.

C. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to UES and the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

3.2. Protection

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3. Coordination

A. Site:
   1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
   2. Coordinate and schedule work with all other work in the same area, or with work that is dependent upon other work, to facilitate mutual progress.

B. Submittals: Refer to the "Submittals" article in Part 1 of this specification for requirements.

C. Test and Balance
   1. The contractor shall furnish all tools necessary to interface to the control system for test and balance purposes.
   2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.

3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process to match the Cx sampling rate. Additional sampling thresholds based on testing failure rates related to the BAS will be the responsibility of the contractor.
4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

D. Life Safety
1. Duct smoke detectors required for air handler shutdown are supplied under Division 26. The contractor shall interlock fire alarm system to air handlers for shutdown as described Division 26.
2. Smoke dampers and actuators required for duct smoke isolation are not provided under this Division..

E. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
1. All communication media and equipment shall be provided as specified in Part 2, "Communication" of this specification.
2. Each supplier of a control's product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequences of operation described in this section.
3. The Contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this section and those provided under other sections or divisions of this specification.
4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4. General Workmanship

A. Installations shall conform with section 110 of the National Electrical Code
B. Install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.
C. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
D. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100, Part A of the National Electrical Code (NEC).
E. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
F. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.
G. All equipment installations shall be square, plumb and level with their supporting structure.

3.5. Field Quality Control

A. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this specification.

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
C. Contractor shall have work inspected by local and/ or state authorities having jurisdiction over the work.

3.6. Existing Equipment

A. Materials not reused shall follow guidelines to be recycled or salvaged in accordance with Division 1.
B. Equipment and sensors may not be reused unless otherwise noted. Terminal device wiring may be reused but the contractor warranty is to cover any pre-existing issues with wiring that is reused.
C. Temperature Sensor Wells: The contractor may reuse any existing wells in piping for temperature sensors. These wells shall be modified as required for proper fit of new sensors.
D. Indicator Gauges: Where these devices remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy. Maintain the operation of existing pneumatic transmitters and gauges.
E. Fittings, wells and gauges may be reused if condition is like-new, or will be refurbished to like-new condition, and must meet current standards or project requirements.
F. Unless otherwise directed, the contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the contractor find existing equipment that requires maintenance, UES and the engineer is to be notified immediately.
G. The mechanical system in occupied buildings must remain in operation between the hours of operation for that building. No modifications to the system shall cause the mechanical system to be shut down for more than 15 minutes or to fail to maintain space comfort conditions during any such period without prior outage coordination with UES and the Building Manager, at a minimum. Perform cut-over of controls that cannot meet these conditions outside of those hours.
H. The scheduling of equipment through existing or temporary control systems shall be maintained throughout the DDC system installation until brought under full control by the contractor and documented on the Systems Usage Plan.
I. Modify existing starter control circuits, if necessary, to provide hand/off/auto control of each starter controlled. If new starters or starter control packages are required, these shall be included as part of this contract.
J. Patch holes and finish patches to match existing walls.
K. Patch holes in existing ductwork where any equipment was removed.

3.7. Wiring

A. All control and interlock wiring shall comply with national and local electrical codes and Division 26. Where the requirements of this section differ from those in Division 26, the requirements of this section shall take precedence.
B. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Division 26 requirements.
C. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current limit.)
D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL Listed for the intended application. For example, cables used in ceiling plenums shall be UL Listed specifically for that purpose.

E. All wiring in mechanical, electrical, or service rooms—or where subject to mechanical damage— shall be installed in raceway.
F. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
G. Do not install wiring in raceway containing tubing.
H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.
I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork or duct supports, electrical raceways, piping, or ceiling suspension systems.
J. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
K. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
L. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
M. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
N. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on flexible duct strap or tie rods. Raceways shall not be run on or attached to ductwork.
O. Adhere to the requirements found in Division 26, for situations where raceway crosses building expansion joints.
P. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
Q. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms and cooling tower yards, liquid-tight, flexible metal raceways shall be used.
R. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
S. Size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
T. Include one pull string in each raceway.
U. Conduit fill should not exceed NEC limitations at any point in cabling system.
V. An additional 2' of cable shall be provided and neatly coiled where a cable trough is provided.
W. Cable sheath shall be stripped back no further than 1" from the end of the cable.
    1. Exception given when sensor or terminal connections require additional length stripped to reach terminations.
X. There shall be no more than ¼" of conductor exposed at the end of cable for termination purposes.

3.8. Communication Wiring

A. The contractor shall adhere to the items listed in the Wiring article in Part 3 of the specification.

B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
C. Do not install communication wiring in raceway and enclosures containing Class 1 wiring.
D. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
E. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to the manufacturer's instructions.
G. All runs of communication wiring shall be of continuous length when that length is commercially available. Use of communication repeaters shall be coordinated with UES in advance.
H. All communication wiring shall be labeled to indicate origination and destination data.

3.9. Fiber Optic Cable

A. Fiber optic systems shall not be used.

3.10. Control Air Tubing

A. Pneumatic systems shall not be used. Control air tubing shall be limited for use in remote locating of duct static pressure sensors, filter differential pressure sensors, and duct pressure limit switches only.

3.11. Installation of Sensors

A. Install sensors in accordance with the manufacturer's recommendations.
B. Mount sensors rigidly, square, plumb, level and adequately for the environment within which the sensor operates.
C. Dissimilar metals shall be appropriately isolated.
D. Room temperature, humidity and /or carbon dioxide sensors shall be installed on concealed junction boxes properly supported by the wall framing and mounted at a height that complies with ADA clearances.
E. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.
F. Sensors used in mixing plenums, hot and cold decks, and after any heating and cooling source shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct or coil such that the entire surface area has been traversed across the vertical plane of sensed area at least once by the averaging sensor element. Each bend shall be supported with a capillary clip.
G. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m of sensing element for each 1 m^2 (1 ft of sensing element for each 1 ft^2) of coil area.
H. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
J. Differential air static pressure:
    1. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.

a. Locate Supply Duct Static Pressure sensor probe approximately ½ to 2/3rd down the main duct trunk, away from any transitions, reductions or taps, in a straight section of duct and indicate location of the probe with a label on the ceiling grid as well as on the as-builts and BAS floor plan graphics. If a suitable downstream location is not possible, UES may approve the use of reading duct static pressure closer to the discharge of the fan, but each case will need to be determined on a case by case basis.

2. Return Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
3. Building Static Pressure: Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
5. All pressure transducers shall be mounted in the associated BAS control panel or in a location accessible for service without use of ladders or special equipment if the pneumatic sensing tubing exceeds 150' in length.
6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shutoff valves installed before the tee.

3.12. Flow Monitor Installation

A. Use manufacturer's recommended depth probe for size of duct or pipe.
B. Install with manufacturers recommended distances of pipe/duct work.

3.13. Actuators

A. Mount and link control damper actuators according to manufacturer's instructions.
   1. To compress seals when spring-return actuators are used on normally closed dampers, power actuators to approximately 5° open position, manually close the damper, and then tighten the linkage.
   2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
   3. Provide all mounting hardware and linkages for actuator installation.
   4. Dampers: Actuators shall be direct-mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° available for tightening the damper seals. Actuators shall be mounted following manufacturer's recommendations.
   5. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.14. Warning Labels

A. Warning labels as described in Division 26

3.15. Identification of Hardware and Wiring

A. All wiring and cabling shall be uniformly labeled at both ends with 1" long label, 0.1" font, center-top aligned, with 3 repeated rows minimum as specified by Cable Name.
B. Permanently label or code each point of field terminal strips and refer to terminal block interface in as-built drawings.

C. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates: Minimum 4 cm by 10 cm (H by W) (1 ½ in by 4 in.) nameplates.
D. Identify all other control components with permanent labels. All plug-in components shall be labeled such that removal of the component does not remove the label.
E. Identify room sensors relating to terminal box or valves with nameplates.
F. Manufacturers' nameplates and UL or CSA labels are to be visible and legible after equipment is installed.
G. Identifiers shall match record documents.
H. All wiring and sensors need to be labeled with what they are and not just an ID number. Example: Discharge Air Temp. Wire label in panel, in sensor and the sensor itself should say 'DAT'.

3.16. Controllers

A. Provide a separate controller for each AHU, FCU, VAV or other HVAC system except where system integration or interlocks should be more reasonably accomplished from one controller (interlocked exhaust fans with the AHU controller, or CHW pumps associated with air-cooled chillers, or CHW tertiary pumps as a unified system, for examples). Points used for area wide control loop reset, such as outside air or space temperature, are exempt from this requirement.
B. Points shared between lab or life safety equipment must be on the same sub-network.

3.17. Programming

A. Controller Naming
   1. All BACnet devices shall support writing to Object Name property of the device unless otherwise specified by the Department of Utilities and Energy Services.
   2. All BACnet device Object Name properties shall follow the conventions:
      a. BLDG-***NNN***/***AAA***/***EEE*** (Primary equipment controllers) [1]
      b. BLDG-***NNN***/***AAA***/***EEE***_RM-***RRR*** (Zone level equipment) [1]
      c. Where:
         i. ***NNN*** is the final UCF building number. [1]
         ii. ***AAA*** is the building abbreviation. [1]
         iii. ***EEE*** is the equipment symbol/name [1]
         iv. ***RRR*** is the room number primarily serviced by equipment, typically location of the thermostat or equipment. [1]
      d. Example:
         i. BLDG-1/MH/AHU-1
         ii. BLDG-150/UPD/VAV-1-1_RM-101

   [1] Note: Length shall not be padded with zeros.

B. BACnet Device Addressing
   1. All BACnet/IP devices will reside on BACnet Network 1, UDP Port 47808/0xBAC0
   2. Sub-network numbers shall be sequentially assigned by contractor, beginning with the 3-digit building number followed by a 2-digit network sequence number.
      a. Network #: BBBNN
      b. Where:
         i. BBB is the building number
         ii. NN is the network sequence number
   3. Devices ID's shall be constructed by using the network number, followed by 2-digit device sequence number. Effort should be made to ensure that MS/TP MAC Address dip switches match the 2-digit sequence number of device ID.
      a. Device ID: BBBNNMM

b. Where:
i. BBB is the building number
ii. NN is the network sequence number
iii. MM is the device MAC address

4. Example:
a. Building 123 first building controller will be part of the first network number 12301, and therefore has device ID 1230100. The first MSTP device (or ARCNET), on network 12301 will have device ID 1230101; the fifteenth device will have device ID 1230115, etc.
b. The fifth building controller will have network number 12305, and device ID 1230500. The second device attached to its sub-network will be 1230502

5. Final UCF building number shall be used for the device addressing, and may not match the original design designation. Contact the UCF project manager for final building number, and approval of device addressing. For building numbers greater than 400, submit and RFI for review by the Department of Utilities and Energy Services.

C. Point Naming:
1. Additional points required for programming shall follow similar formatting and submitted for approval to the Department of Utilities and Energy Services, through Owner.

D. Alarms:
1. All alarms shall be created using BACnet Event Enrollment objects or through BACnet compliant intrinsic alarming of objects. If additional programming logic is created that signal an alarm, information about the alarms triggers shall be included in the BACnet "object's description".
2. Use of proprietary language to transitions alarms is not recommended…i.e. creating a binary point that is transitioned based on internal code on the controller that signals alarm/normal.
3. Notification Classes will be used to direct alarm. The following Notification classes shall be used for the associated alarm types.
a. Notification Class 1 - Critical Equipment:
i. Critical equipment failures, including, AHU, pump, boiler, lab exhaust fan, and chiller failures, or anything with potential life safety issues
ii. Alarm Priority 80
b. Notification Class 2 - Critical Notification:
i. Status, control, and performance alarms, including, FCU and CRAC failures, or critical environmental conditions.
ii. Alarm Priority 110
c. Notification Class 3 - Notification:
i. Status, control, and performance related alarms, including, but not limited to AHU SAT, PUMP DP and CHW TEMP alarms
ii. Alarm Priority 150
d. Notification Class 4 - Maintenance
i. Maintenance or work order related alarms, including, but not limited to Zone Temps, Filter DP, VFD speeds
ii. Alarm Priority 230
e. Notification Class 5-9 (Vendor Specific) – Archival
i. Used for transfer of trends/buffer ready notifications for archival purposes.

ii. Alarm Priority 230

4. Priority Assignments shall be established as follows
   a. Off-Normal Transition shall be assigned associated priority range
   b. Fault Transitions shall be assigned associated priority 254
   c. Return to Normal Transitions shall be assigned priority 255
5. All alarms from Class 1 through Class 4 shall be sent to the Broadcast network (65535) and require acknowledgement for Alarm conditions.
6. Class 5- Archival shall be used for buffer ready notifications and shall include the device used for archival by vendor
   a. Automated Logic – Device 2499
   b. Delta Controls – Device 996
   c. Trane – Device 125
   d. Siemens – Device 9998
7. Third-Party devices which do not support the creation of the above notification class definitions shall be mapped to alarms on an associated higher tier controller.
8. All alarms shall include a time/date stamp using the standalone control module time and date.
9. Each alarm can be configured in terms of level, latching (requires acknowledgement of a Return to Normal / does not require acknowledgement of a Return to Normal), entry delay, exit deadband, and post suppression period.
10. An operator shall be able to sort alarms based on level, time/date, and current status.
11. All alarms shall be reported with the following information:
    a. Date and time of the alarm
    b. Level of the alarm
    c. Description of the alarm (in clear, easy to understand terminology)
    d. Equipment tags for the units in alarm
    e. Possible causes of the alarm of provided by fault detection routines
    f. The source that serves the equipment in alarm
12. Maintenance mode:
    a. Operators shall have the ability to put any device in/out of maintenance mode.
13. All alarms associated with a device in maintenance mode will be suppressed. Exception: Life safety alarms shall not be suppressed.
14. If a device is in maintenance mode, issue a daily Level 3 alarm at a scheduled time indicating that the device is still in maintenance mode.
15. Entry delays:
16. All alarms shall have an adjustable delay time such that the alarm is not triggered unless the alarm condition is TRUE for the delay time. Default entry delays are as follows:
    a. Level 1 alarms: 1 second
    b. Level 2 alarms: 10 seconds
    c. Level 3 alarms: 1 minute
    d. Level 4 alarms: 5 minutes
17. Exit Hysteresis:
    a. Each alarm shall have an adjustable time-based hysteresis (default 5 seconds) to exit the alarm. Once set, the alarm does not return to normal until the alarm conditions have ceased for the duration of the hysteresis.

b. Each analog alarm shall have an adjustable percent-of-limit-based hysteresis (default: 5% of the alarm threshold, i.e. alarm exits at a 5% differential to NORMAL from the ALARM condition that triggered ALARM state). Alarm conditions have ceased when the alarmed variable is below/above the triggering threshold back to normal range by the amount of the hysteresis.
c. Examples of Exit Hysteresis:
    i. If a high-temperature alarm is triggered at 100°F and has an exit hysteresis of 5% for 1 minute, the alarm will remain active unit the alarmed temperature drops below 95°F (100°F minus 5%) continuously for 1 minute.
    ii. If a low-pressure alarm is triggered at 0.5 in. of water and has an exit hysteresis of 20% for 10 seconds, the alarm will remain active until the alarmed pressure rises above 0.6 in. of water (0.5 in. of water plus 20%) continuously for 10 seconds.

18. Latching:
    a. Latching alarms require acknowledgement from the operators before it can return to normal, even if the exit dead band has been met. A non-latching alarm does not require acknowledgement. Default latching status is as follows:
        i. Level 1 alarms: latching
        ii. Level 2 alarms: latching
        iii. Level 3 alarms: non-latching
        iv. Level 4 alarms: non-latching
    b. Acknowledging an alarm clears the alarm, the exit dead band, and suppression period. A device can go right back into alarm as soon as the entry delay elapses. Only Level 1 and Level 2 Latching Alarms related to "Source" equipment that require acknowledgment shall be annunciated. All other non-suppressed alarms shall be logged as noted within this section. General or restroom exhaust fans, for example, are not considered "source" equipment and therefore even under equipment failure should not email an alarm; logging it is sufficient. Process exhaust systems, however, such as those that serve laboratory hoods, explosion-proof rooms, or other areas of critical concern, are considered "source" equipment and as such should generate alarm annunciation via email if Level 1 or Level 2 alarms occur.
    c. Post-exit Suppression Period:
        i. To limit alarms, alarms shall have adjustable suppression periods such that if the alarm is triggered, its suppression timer is triggered and the alarm may not trigger again until the post suppression timer has expired. Default suppression periods are as follows:
        ii. Level 1 alarms: 0 minutes
        iii. Level 2 alarms: 5 minutes
        iv. Level 3 alarms: 24 hours
        v. Level 4 alarms: 7 days
    d. Note that post suppression only applies to a particular instance of an alarm; e.g. a high SAT alarm on AHU-1 will suppress more high SAT alarms on AHU-1 but not on AHU-2.
19. Equipment Staging and Rotation:

a. If the lead device has a fault condition or has been manually switched OFF, a Level 2 alarm shall be generated and the device shall be set to the last-stage position in the staging order until the alarm is reset by an operator. A device in alarm can only automatically move up in the staging order if another device goes into alarm.
b. This sequence does not lock out a device that is in alarm. It moves all devices in alarm to the end of the rotation sequence such that they will be the last devices called to run. The sequence will only call for these devices in alarm if all of the devices not in alarm are already enabled and there is a call for a stage-up. A device in alarm will respond if called to run only if it capable of doing so (e.g., not locked out on internal safety, locked out on a Hand-Off-Auto (HOA) switch at the starter, or otherwise disabled). It is important to note that this staging does not override the devices internal safeties, so it will not damage equipment.
c. Note that some alarm conditions could be triggered when the underlying equipment is fully operable. For example, a status point not matching the ON/OFF command could be triggered by a faulty status signal. The same is TRUE for a supervised HOA at a control panel; the operator might have been testing the equipment and simply forgot to turn the HOA back to AUTO.

20. Alarm condition examples include the following:
    a. Variable speed fans:
        i. Status point not matching its ON/OFF point for 3 seconds after a time delay of 15 seconds while the device is commanded ON.
        ii. Hand Operation:
    b. If a device is ON-in-hand (e.g., via an HOA switch or local control of VFD), the device shall be set to the lead device, and a Level 4 alarm shall be generated. The device will remain as lead until the alarm is reset by the operator. Hand alarm conditions are determined by the following:
    c. Status point not matching its ON/OFF point for 15 seconds while the device is commanded OFF.
21. Hierarchical Alarm Suppression:
    a. Hierarchical alarm suppression is a technique for suppressing extraneous or nuisance alarms based on the principle that if a fault occurs both at a source (e.g., AHU), and a load (e.g., VAV box), then the fault at the load is likely caused by the fault at the source and is, at any rate, a lower priority than the source fault; as such, the alarm for the load fault is suppressed in favor of the alarm for the source fault, so that the operator's attention is focused on the problem at the source.
    b. This principle can be extended up the hierarchy, e.g., a fault at the chiller system would suppress faults at the AHUs it serves, which would in turn suppress faults at the VAV boxes served by the suppressed AHUs.
    c. Alarm suppression is based on the "OK" or fault state of upstream systems, rather than individual pieces of equipment. For example, in a plant with multiple redundant chillers, a single chiller failure would not necessarily impede the ability of the chiller plant to serve the load, so suppression of downstream alarms would not be appropriate in this case. It will necessarily be up to the designer to determine the appropriate threshold for setting a system fault based on the number of component faults (e.g., two out of three chillers must be OFF or in alarm before a system-level fault is set, triggering suppression of downstream alarms.)

d. Note that this logic is intended to suppress alarm visual and audible displays, notifications (e.g., email or SMS), listing in primary alarm logs, and other actions that can distract the operator or make it more difficult to diagnose and respond to alarms. The alarm should still be generated and recorded to a database.

22. For each piece of equipment or space controlled by the BAS, the relationship to other equipment in terms of source or load must be defined (e.g., cool source, heat source, airflow source).
    a. For equipment that include a T&R loop, the equipment generating the requests will always be the load component, and the equipment receiving and responding to the request will be a source component.
    b. A component is "source" if it provides resources to a downstream component, such as a chiller providing chilled water (CHW) to an AHU. A component is a "load" of it receives resources from an upstream component, such as an AHU that receives CHW from a chiller. The same component may be both a load and a source (e.g., an AHU that serves the load at a VAV but itself is a load to the CHW system).
    c. A set of components is a "system" if they share a load in common (collectively act as a source to downstream equipment, such as a set of chillers in a lead/lag relationship serving AHUs). For each system, there shall be a SystemOK flag, which is either TRUE or FALSE.
    d. SystemOK shall be TRUE when all of the following are true:
        i. The system is proven ON
        ii. The system is achieving its setpoints for at least 5 minutes
        iii. The system is ready and able to serve its load
    e. The SystemOK shall be FALSE while the system is starting up (before reaching setpoint) or when enough of the system's components are unavailable (in alarm, disabled, or turned OFF) to disrupt the ability of the system to serve its load.
    f. By default, Level 1 through Level 3 component alarms (indicating equipment failure) shall inhibit SystemOK. Level 4 component alarms (maintenance and energy efficiency alarms) shall not affect SystemOK.
    g. The BAS shall selectively suppress alarms related alarms for load components if SystemOK is FALSE for the source system that serves the load, and only annunciate the Level 1 and Level 2 alarms at the source.
    h. If SystemOK is FALSE for a cooling water system, then only high-temperature alarms from the loads shall be suppressed.
    i. If SystemOK is FALSE for a heating water system, then only low temperature alarms from the loads shall be suppressed.
    j. If SystemOK is FALSE for an air-side system (AHU, FCU, VAV box, etc.), then all alarms from the loads shall be suppressed.
    k. This hierarchical suppression shall cascade through multiple levels of load-source relationships such that alarms at downstream loads shall also be suppressed.
    l. The following types of alarms shall never be suppressed by this logic:
        i. Life/safety and Level 1 alarms
        ii. Failure-to-start alarms
        iii. Failure-to-stop/HAND alarms
    m. Time Based Suppression:
        i. Time based suppression is used to suppress reset request and alarms after a change in setpoint. This includes automatic changes in

setpoint such as occupancy sensor status, as well as changes made by occupants.

ii. The BAS system shall calculate a time-delay period after any change in setpoint based on the difference between the controlled variable (e.g., zone temperature) at the time of the change and the new setpoint. The default time delay period shall be as follows:

iii. For thermal zone temperature alarms, 10 minutes per °F of difference but no longer than 120 minutes.

iv. For thermal zone temperature cooling or heating requests: 5 minutes per °F of difference but no longer than 30 minutes.

23. Zone Alarms:

a. High Temperature alarms: If the zone is 3°F above the cooling setpoint for 10 minutes, generate a Level 3 alarm. If the zone is 5°F above the cooling setpoint for 10 minutes, generate a Level 2 alarm.

b. Low Temperature alarms: If the zone is 3°F below the heating setpoint for 10 minutes, generate a Level 3 alarm. If the zone is 5°F below the heating setpoint for 10 minutes, generate a Level 2 alarm.

c. For zones with CO2 sensors:

i. If the CO2 concentration is less than 350 ppm, or the zone is in unoccupied mode for more than 2 hours and the zone CO2 concentration exceeds 600 ppm, generate a Level 3 alarm. The alarm text shall identify the sensor and indicate that it may be out of calibration.

ii. If the CO2 concentration exceeds setpoint plus 10% for more than 10 minutes, generate a Level 3 alarm.

d. Low airflow:

i. If the measured airflow is less than 70% of setpoint for 5 minutes while setpoint is greater than 0, generate a Level 3 alarm. If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm. If a zone has an importance multiplier of 0 for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

e. Airflow sensor calibration alarm:

i. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow setpoint, generate a Level 3 alarm.

f. Leaking damper alarm:

i. If the damper position command is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow setpoint for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

g. AHU Fault Condition Alarms:

i. The following Table 2 indicates the alarm variables and fault conditions that should result in Level 4 alarms for AHUs:

Variable Name	Description	Default Value
ΔT_{SF}	Temperature rise across supply fan	1°C (2°F)
ΔT_{MIN}	Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)	6°C (10° F)
ε_{SAT}	Temperature error threshold for SAT sensor	1°C (2°F)
ε_{RAT}	Temperature error threshold for RAT sensor	1°C (2°F)
ε_{MAT}	Temperature error threshold for MAT sensor	3°C (5°F)

Variable Name	Description	Default Value
ε_{OAT}	Temperature error threshold for OAT sensor	1°C (2°F) if local sensor @ unit. 3°C (5°F) if global sensor.
ε_{F}	Airflow error threshold	30%
ε_{VFDSPD}	VFD speed error threshold	5%
ε_{DSP}	Duct static pressure error threshold	25 Pa (0.1")
ε_{CCET}	Cooling coil entering temperature sensor error. Equal to ε_{MAT} or dedicated sensor error	Varies, see Description
ε_{CCLT}	Cooling coil leaving temperature sensor error. Equal to ε_{SAT} or dedicated sensor error	
ε_{HCET}	Heating coil entering temperature sensor error; equal to ε_{MAT} or dedicated sensor error	
ε_{HCLT}	Heating coil leaving temperature sensor error. Equal to ε_{SAT} or dedicated sensor error	
ΔOS_{MAX}	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend Fault Condition evaluation after a change in Mode	30
AlarmDelay	Time in minutes to that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

All other system alarms in the BAS shall be suppressed to reduce nuisance alarm notifications.

E. Software Programming
   1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. All BAS programming shall be accessible and viewable in the BAS web-based front end. For programming languages that are not graphic or text-based and that do not have a mechanism built-in to the web-browser front end, the program sequence of operations and all adjustable parameters must be documented in .PDF format and hyperlinked to the respective equipment graphic.

F. Operator Interface
   1. Standard graphics—Provide graphics for all mechanical systems and 2d top-down floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point

information on the graphic displays shall dynamically update. Show on each graphic all points indicated by the sequence of operations.

2. All BAS graphics must be included in the submittal package (as defined in the Submittal Section of this document) for review and approval from UES. Only graphics that have been approved by UES may be installed onto the BAS front end.
3. Floor plans shall indicate through static or dynamic colored zones (or other owner approved option), areas served by each VAV box/FCU supply system. Each zone shall also indicate approximate location of controlling sensors (temp, RH, CO2, pressure) and connected terminal equipment. Additionally, if divisions are required for the floor plan, each split shall not require view of a different floor plan to view systems, components, or equipment from the previous floor plan.
4. Show primary equipment information on a "graphic" summary table. Provide dynamic information for each point shown.
5. Show terminal equipment information on a "graphic" summary table. Provide dynamic information for each point shown.
6. No logos
7. No text effects for aesthetics; examples: color change for status/alarm are permitted, unnecessary bevels and shadows are not
8. No background gradients or images, besides a photo of the building on a landing page and floor plans
9. Alarm status indicators should be located by associated equipment points
10. Menus should take up less than 10% of the screen
11. The order and location of menu items should stay consistent between pages
12. Where multiple of the same type of equipment is in parallel, points should be pivoted into a table instead of a list:
    a. Example

SA Fan VFD	Run	Status	Cmd	Fdbk	Alarm
A	Off	Off	0%	0%	Normal
B	Off	Off	0%	0%	Normal
C	Off	Off	0%	0%	Normal
D	Off	Off	0%	0%	Normal

13. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

G. Provide sufficient internal memory for the specified sequences of operation and trend logging. There shall be a minimum of 25% of available memory free for future use.

3.18. Control System Checkout and Testing

A. Start-up Testing: All testing listed in this article shall be performed by the contractor (on UCF's Network) and shall make up part of the necessary verification of an operating control system. This testing, as well as any commissioning checklist provided, shall be completed before the owner's representative is notified of the system demonstration.

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.

2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (VFD, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. A BAS Point-to-Point (P2P) report must be generated verifying that all I/O and software points have been fully verified and validated as operational. This P2P report must be generated for each controller, listing the I/O point name, address, configuration, span, and timestamp of technician's point check.
7. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops and optimum start/stop routines. UES and the CxA will provide the Functional Performance Test scripts for use by the CxA during the FPT phase. This script shall be ran in advance of the Cx FPT phase so that all sequences have been fully tested BEFORE witness of operation by UES and the CxA.
8. Alarms and Interlocks:
    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

3.19. Control System Demonstration and Acceptance

A. The system shall not be accepted until:
    1. All forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."
    2. All commissioning observation log items have been responded to and addressed as necessary.

3.20. Cleaning

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.
B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.
C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.21. Training

A. Provide a minimum of four hours on-site or classroom training for personnel designated by the owner for all minor projects that extend, expand, upgrade or modify the existing BAS in a building.

B. Provide a minimum of eight hours on-site or classroom training for personnel designated by the owner for all whole-building BAS replacements, upgrades or modernization projects.
   1. Provide two additional 4-hour training sessions at 6- and 12-months following building's turnover. Each session shall be coordinated with UES.

C. Train the designated staff of owner's representative and owner to enable them to do the following:
   1. Day-to-day Operators:
      a. Proficiently operate the system
      b. Understand control system architecture and configuration
      c. Understand DDC system components
      d. Understand system operation, including DDC system control and optimizing routines (algorithms)
      e. Operate the workstation and peripherals
      f. Log on and off the system
      g. Access graphics, point reports, and logs
      h. Adjust and change system set points, time schedules, and holiday schedules
      i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
      j. Understand system drawings and Operation and Maintenance manual
      k. Understand the job layout and location of control components
      l. Access data from DDC controllers and ASCs
      m. Operate portable operator's terminals
   2. Advanced Operators:
      a. Make and change graphics on the workstation
      b. Create, delete, and modify alarms, including annunciation and routing of these
      c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
      d. Create, delete, and modify reports
      e. Add, remove, and modify system's physical points
      f. Create, modify, and delete programming
      g. Add panels when required
      h. Add operator interface stations
      i. Create, delete, and modify system displays, both graphical and others
      j. Perform DDC system field checkout procedures
      k. Perform DDC controller unit operation and maintenance procedures
      l. Perform workstation and peripheral operation and maintenance procedures
      m. Perform DDC system diagnostic procedures
      n. Configure hardware including PC boards, switches, communication, and I/O points
      o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
      p. Adjust, calibrate, and replace system components
   3. System Managers/Administrators:

a. Maintain software and prepare backups
b. Interface with job-specific, third-party operator software
c. Add new users and understand password security procedures

D. These objectives will be divided into three logical groupings. Participants may attend one or more of these, depending on level of knowledge required.
E. Provide course outline and materials in accordance with the "Submittals" article in Part 1 of this specification. The instructor(s) shall provide one copy of training material per student.
F. The instructor(s) shall be factory-trained instructors experienced in presenting this material.
G. Classroom training shall be done using a network of working controllers' representative of the installed hardware.