Software Defined Buildings

Building Application Stack

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Buildings: 41% U.S. Energy Use

U.S. energy consumption by sector, 1960 and 2010

Source: U.S. Energy Information Administration, State Energy Data System 2010
Huge Sensor Networks

151 Temperature Sensors
50 Electrical Sub-meters
12 Variable Speed Fans
138 Air Dampers

> 6,000 Sense and Control Points

312 Light Relays
6 Variable Speed Pumps
121 Controllable Valves

Sutardja Dai Hall
Built in 2009
140k sq. ft.
Controls are Widely Available

Bancroft Library:
  – Built in 1949
  – 100k sq. ft.
  – 5,000 points

>70% of large buildings have digital controls

U.S. Energy Information Administration, 2009
Applications

Occupant Controls

Automated Fault Detection:
10 - 40% energy savings

Ventilation Optimization:
17% energy savings

Challenge: Portability

Buildings are custom designed
$LOC1  = BOTH CHILLERS RUNNING EVAPORATOR BUNDLE DELTA T LOAD CALCULATION

$LOC2  = CONDENSER WATER PUMP 1/2 PROOF OF RUNNING TRIGGER

C *** POWER FAILURE AND DEFINE STATEMENT CONTROL ***

ONPWRT(1020) GOTO 1040
SET(0.0,SECNDS) LOCAL(LOC16)
DEFINE(A,"SDH.CHW1.")

$LOC16 = "SDH.CH1.CHW.FLOW"

IF("SDH.CH1.CHW.FLOW" .OR. "SDH.CH2.CHW.FLOW") THEN ON("SDH.CHX.CHW.FLOW") ELSE OFF("SDH.CHX.CHW.FLOW")

"SDH.CHW_BYPASS_VLV_LOOPOUT" = $LOC13

C IF("!PXCMO3:BATT" .EQ. DEAD) THEN ON("MBC03.BATTERY") ELSE OFF("MBC03.BATTERY")

C *** CHILLER EMERGENCY POWER LOAD STAGGER CONTROL ***

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "SDH.CH1.START.STOP" .EQ. @OPER) THEN RELEAS(@OPER,"SDH.CH1.START.STOP")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "SDH.CH2.START.STOP" .EQ. @OPER) THEN RELEAS(@OPER,"SDH.CH2.START.STOP")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CH_SEQ" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP1_SS")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CHP1_SS" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP2_SS")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CHP2_SS" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP3_SS")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CHP3_SS" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP4_SS")

IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CHP4_SS" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP34_LEAD")

C IF("SDH.ATS_E01.NORM" .EQ. OFF .AND. "%A%CHP34_LEAD" .EQ. @OPER) THEN RELEAS(@OPER, "%A%CHP2_SS")

C IF("SDH.ATS_E01.NORM" .EQ. ON .AND. "SDH.CH1.START.STOP" .EQ. @EMER) THEN RELEAS(@EMER,"SDH.CH1.START.STOP")

C IF("SDH.ATS_E01.NORM" .EQ. ON .AND. "SDH.CH2.START.STOP" .EQ. @EMER) THEN RELEAS(@EMER,"SDH.CH2.START.STOP")

C IF("SDH.ATS_E01.NORM" .EQ. ON .OR. "SDH.ATS_E01.EMER" .EQ. ON) THEN RELEAS(@EMER,"SDH.CHP2_SS")

C IF("SDH.ATS_E01.NORM" .EQ. ON) THEN RELEAS(@EMER,"SDH.CH2.START.STOP")

C *** CHILLER SEASONAL SEQUENCE CHANGE CONTROL ***

IF(MONTH .GE. 4.0 .AND. MONTH .LE. 9.0) THEN ON("%A%CH_SEASON") ELSE OFF("%A%CH_SEASON")

IF("%A%CH_SEASON" .EQ. ON .AND. "%A%CH1_FAIL" .EQ. OFF) THEN "+%CH_SEQ" = 12.0

IF("%A%CH_SEASON" .EQ. OFF .AND. "%A%CH1_FAIL" .EQ. OFF) THEN "%CH_SEQ" = 21.0
“Assembly Language”

Today app programmers must understand:

– Building architecture
– HVAC design
– Control system connectivity and function

For each building

Goal: write once, run anywhere
Building Model
# Using direct BACnet

```python
import bacnet

damper_setpoints_for_each_outside_air_damper = {
    'SDH.PXCM-01 SDH.AH1A_OAD': [
        'SDH.PXCM-04 SDH.S1-20:CTL FLOW MIN',
        'SDH.PXCM-04 SDH.S1-19:CTL FLOW MIN',
        ...],
    'SDH.PXCM-01 SDH.AH1B_OAD': [
        'SDH.PXCM-11 SDH.S2-04:CTL FLOW MIN',
        ...],
    'SDH.PXCM-08 SDH.AH2A_OAD': [
        'SDH.PXCM-11 SDH.S4-03:CTL FLOW MIN',
        ...]
}

for oad in damper_setpoints_for_each_outside_air_damper.keys():
    device = bacnet.find(name=oad)
    oad_airflow = bacnet.read_prop(device, object_type=bacnet.OBJECT_ANALOG_OUTPUT, \  
        instance_number=device.instance_number, property=bacnet.PROPERTY_PRESENT_VALUE)

    for dmp in damper_setpoints_for_each_outside_air_damper[oad]:
        damper = bacnet.find(name=dmp)
        old_setpoint = bacnet.read_prop(device, object_type=bacnet.OBJECT_ANALOG_OUTPUT, \  
            instance_number=damper.instance_number, property=bacnet.PROPERTY_PRESENT_VALUE)
        new_setpoint = old_setpoint / oad_airflow
        bacnet.write_prop(device, object_type=bacnet.OBJECT_ANALOG_OUTPUT, \  
            instance_number=damper.instance_number, property=bacnet.PROPERTY_PRESENT_VALUE, \  
            value=new_setpoint, value_type=bacnet.BACNET_APPLICATION.TAG_REAL)
```

Code: BACnet
```python
# Using BAS
import appstack
api = appstack.Appstack()
ah_dampers = api('#OUT_AIR_DMP > #AH')
for dmp in ah_dampers:
    for vav in api('#VAV < %s' % dmp.name):
        vav.set_min_airflow(vav.min_fresh_air() / dmp.get_percent_open())
```
Energy Savings

RMSE = 5.6%
Savings: 16.52%
25.4 kW

Energy Savings

Savings: 16.52%
25.4 kW

Power (kW)

Measured
Baseline

RMSE = 5.6%
Thank You