LBNL Fault Detection and Diagnostics Data Sets: Fan Coil Unit

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September 1, 2022

Please cite as:
Lawrence Berkeley National Laboratory, LBNL FDD Data Sets. DOI: https://dx.doi.org/10.25984/1881324

DISCLAIMER

ACKNOWLEDGEMENT

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Office, of the U.S. Department of Energy (DOE) under Contract No. DE-AC02-05CH11231. The authors thank all data providers and partners who helped to develop and evaluate the data sets.

CONTACT INFORMATION

Website: https://faultdetection.lbl.gov/data/

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This documentation describes the curated fan coil unit (FCU) fault detection and diagnostics data set (LBNL FDD Data Sets_FCU). In this documentation, the system information, data points specifications, and input scenarios for faulted and fault-free conditions represented in the data are detailed. The dataset and associated brick model ttl file can be downloaded from https://faultdetection.lbl.gov/dataset/simulated-fan-coil-unit-data-set/.

1 Building and system information

1.1 System type and diagram

A vertical four pipe hydronic fan coil unit (FCU) is modeled in the HVACSIM+. The equipment configuration is illustrated in Figure 1. The FCU has a vertical four pipe hydronic configuration with a fan that has three stage speeds: high, medium and low. The FCU is controlled to maintain room air temperature to the thermostat heating and cooling setpoints.

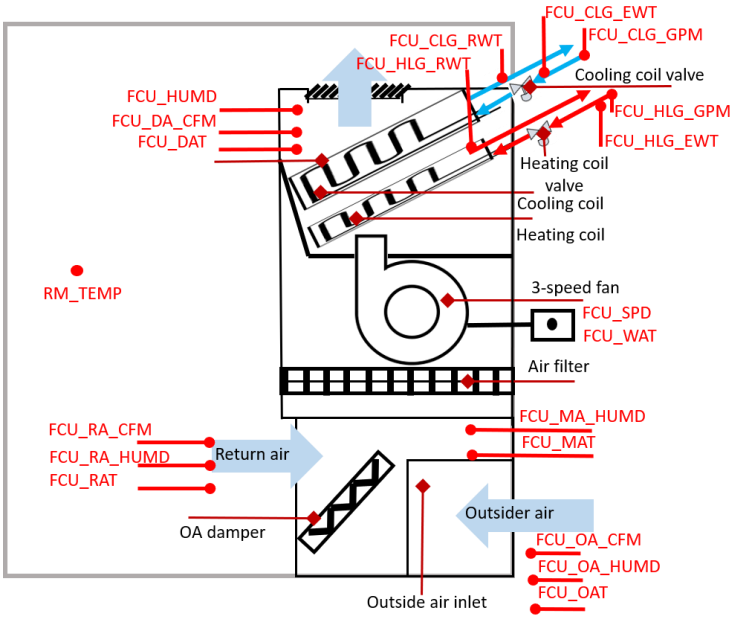

Figure 1 Schematic of a fan coil unit serving a room

1.2 Description of control sequence

This section describes the control sequence settings. The control sequences were set according to the occupied hours and unoccupied hours.

1) Occupied hours (Mon-Fri 6:00AM-6:00PM)
During these hours, the system is in Operate Mode**.** Five control sequences such as fan control, outdoor air damper control**,** cooling coil valve control, heating coil valve control sequence, and zone temperature setpoints were set during the simulation.

- Fan control

        - 3-speed fan with “Automatic On/Off” (Auto) mode: the fan on/off and speed change is based on the cooling proportional-integral-derivative (PID) output and heating PID output. The 10% dead band is given at each speed switchover level.
            - Low speed condition: the PID outputs (the cooling/heating coil valve position) are >0% and < 40%
            - Medium speed condition: the PID outputs (the cooling/heating coil valve position) are >= 40% and < 80%
            - High speed condition: the PID outputs (the cooling/heating coil valve position) are >= 80% and < 100%
            - Off: no heating or cooling demand
- Outdoor air (OA) damper control
    - The OA damper maintains minimum damper position 30%
- Cooling coil valve control sequence
    - The PID control is used to adjust the cooling coil valve position. The setpoint dead band is 1 °F. If the actual room temperature is beyond 1 °F of the cooling setpoint, the FCU is in the “cooling” mode, and the cooling coil valve PID loop is enabled and the cooling valve position will be controlled by the cooling coil valve controller PID output. When the room temperature falls below within 1 °F compared to the cooling setpoint, the cooling PID is disabled and valve fully closed
- Heating coil valve control sequence
    - The PID control is used to adjust the heating coil valve position. The setpoint dead band is 1 °F. If the actual room temperature is beyond 1 °F of the heating setpoint, the FCU is in the “heating” mode, and the heating coil valve PID loop is enabled and the heating valve position will be controlled by the heating coil valve controller PID output. When the room temperature falls below within 1 °F compared to the heating setpoint, the heating PID is disabled and valve fully closed
- Zone temperature setpoints
    - Zone cooling setpoint: 72 °F
    - Zone heating setpoint: 68 °F

2) Unoccupied hours (Mon-Fri 6:00PM - 6:00AM, Sat-Sun 24-hour)

During these hours, the system is in Setback Mode. The operation is similar to operate mode except two addition settings as

- Outdoor air damper: The OA damper is fully closed
- Zone temperature setpoints
    - Zone cooling setpoint: 85 °F
    - Zone heating setpoint: 55 °F

3) Shutdown mode

The shutdown mode is only triggered by the low temperature protection described below. Under the shutdown mode, the fan is constantly off, and the OA damper is fully closed.

4) Low Temperature Protection

When the FCU mixed air temperature is below 35°F and persists for 300 seconds, the system will switch to shutdown mode to prevent freezing coils. The shutdown mode will last until the end of the current day, and the system will be turned back on at the beginning of the next day.

2 Data point summary

A total of 29 data points were included in the data sets. The data point descriptions are summarized in Table 1. In the table, the "Basic point" column indicates if the data point is commonly employed in the existing building automation system to monitor the system.

Table 1 Data points summary of the fan coil unit

NO.	Data point name	Description	Unit	Basic point?
1	FCU_CTRL	FCU control modes (operate/setback/shutdown)	0-Shutdown, 1-Operate, 2-Setback	Y
2	FAN_CTRL	FCU fan operation mode (Auto/Cycle/ON)	1-Auto, 2-Off	N
3	RM_TEMP	Room temperature	°F	Y
4	RMCLGSPT	Room cooling setpoint	°F	Y
5	RMHTGSPT	Room heating setpoint	°F	Y
6	FCU_MAT	FCU mixed air temperature	°F	N
7	FCU_DAT	FCU discharge air temperature	°F	N
8	FCU_RAT	FCU return air temperature	°F	N
9	FCU_CVLV	FCU cooling coil valve position	Open(0-1)	N
10	FCU_CVLV_DM	FCU cooling coil valve control signal (command)	Open(0-1)	Y
11	FCU_CLG_GPM	FCU cooling coil water flow rate	GPM	N
12	FCU_CLG_EWT	FCU cooling coil entering water temperature	°F	N
13	FCU_CLG_RWT	FCU cooling coil return water temperature	°F	N
14	FCU_HVLV	FCU heating coil valve position	Open(0-1)	N
15	FCU_HVLV_DM	FCU heating coil valve control signal (command)	Open(0-1)	Y
16	FCU_HTG_GPM	FCU heating coil water flow rate	GPM	N
17	FCU_HTG_EWT	FCU heating coil entering water temperature	°F	N
18	FCU_HTG_RWT	FCU heating coil return water temperature	°F	N
19	FCU_DA_CFM	FCU discharge air flow rate	CFM	N
20	FCU_OA_CFM	FCU outdoor air flow rate	CFM	N

21	FCU_DMPR	FCU mixed air damper position	Open(0-1)	N
22	FCU_DMPR_DM	FCU mixed air damper control signal (command)	Open(0-1)	N
23	FCU_SPD	FCU fan speed	rev/s	Y
24	FCU_OAT	FCU outdoor air temperature	°F	N
25	FCU_WAT	FCU fan power consumption	Watt	N
26	FCU_MA_HUMD	FCU mixed air humidity	%RH	N
27	FCU_OA_HUMD	FCU outdoor air humidity	%RH	N
28	FCU_DA_HUMD	FCU discharge air humidity	%RH	N
29	FCU_RA_HUMD	FCU return air humidity	%RH	N

It is noted that, for sensor related faults (i.e., Zone air temperature sensor bias fault), the value of the faulty sensor logged is the faulty value.

A LBNL_FDD_Data_Sets_FCU.ttl file was also developed to present the data points and their relationships according to the Brick Schema[1](version 1.2). Figure 2 shows the FCU data point relations created under the Brick schema model.

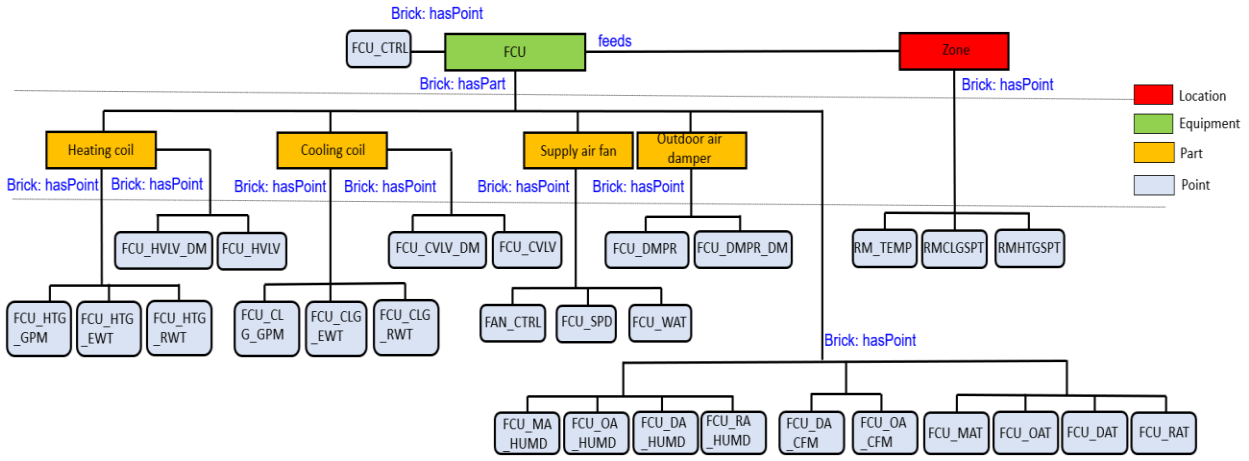

Figure 2 The schematic diagram of FCU Brick model

3 Faulty and fault-free scenarios

Faulty and fault-free scenarios included in the data set are shown in Table 2. There are a total of 48 faulted cases and 1 fault-free case. Each faulted case lasts for one year. The TMY weather data for Des

[1] Ref: Brick Schema website https://brickschema.org/ Access: May 01, 2022

Moines, IA is used as the weather inputs. The internal load density was varied to simulate a typical commercial building occupancy and was similar to those described in [1].

Table 2 Simulated input scenarios included in the dataset for the FCU

Input scenarios		Method of fault imposition
Fault type	**Fault intensity**	
Heating coil fouling air-side	(1) Severe: increase airflow resistance by 200%, decrease heat transfer rate by 10%; (2) Middle: increase airflow resistance by 50%, decrease heat transfer rate by 5%; (3) Minor: increase airflow resistance by 10%	Increase air flow pressure resistance, decrease heat transfer coefficient
Heating coil fouling water-side	(1) Severe: increase water flow pressure resistance such that the water flow rate decreases by 50% when valve is fully open; decrease heat transfer rate by 50%; (2) Moderate: increase water flow pressure resistance such that the water flow rate decreases by 30% when valve is fully open; decrease heat transfer rate by 30%; (3) Minor: increase water flow pressure resistance such that the water flow rate decreases by 10% when valve is fully open; decrease heat transfer rate by 10%	Increase water flow pressure resistance, decrease heat transfer coefficient
Cooling coil fouling air-side	(1) Severe: increase airflow resistance by 200%, decrease heat transfer rate by 10%; (2) Middle: increase airflow resistance by 50%, decrease heat transfer rate by 5%; (3) Minor: increase airflow resistance by 10%	Increase air flow pressure resistance
Cooling coil fouling water-side	(1) Severe: increase water flow pressure resistance such that the water flow rate decreases by 50% when valve is fully open; decrease heat transfer rate by 50%; (2) Moderate: increase water flow pressure resistance such that the water flow rate decreases by 30% when valve is fully open; decrease heat transfer rate by 30%; (3) Minor: increase water flow pressure resistance such that the water flow rate decreases by 10% when valve is fully open; decrease heat transfer rate by 10%	Increase water flow pressure resistance, decrease heat transfer coefficient
Filter restriction	10%, 20%, 50% flow rate reduction at the same pressure difference (corresponding outlet resistance +23.45%, +56.25%, +400%)	Increase air flow pressure resistance
Outdoor air inlet blockage	Face area -80%	Decrease damper face area
Outdoor air damper leaking	Face area +20%, +50%, +80%	Increase damper face area
Zone air temperature sensor bias	-4°C, -2°C, +2°C, +4°C	Add bias to sensor output

Heating coil valve stuck	Full open, full closed, partial open at 20%, 50%, and 80%	Assign a fixed simulated controlled device position
Heating coil valve leaking	20%, 50%, 80% of the max flow (0.066kg/s)	Assign a water flow rate when fully closed
Cooling coil valve stuck	Full open, full closed, partial open at 20%, 50%, and 80%	Assign a fixed simulated controlled device position
Cooling coil valve leaking	20%, 50%, 80% of the max flow (0.36kg/s)	Assign a water flow rate when fully closed
Outdoor air damper stuck	Full open, full closed, partial open at 20%, 50%, and 80%	Assign a fixed simulated controlled device position
FCU unstable control	NA	Decrease both heating and cooling proportional bands to 10% of normal value respectively
Heating control reverse acting	NA	Modify simulated control strategy to allow reversed action
Cooling control reverse acting	NA	
Fan outlet blockage	A 80% flow rate reduction at the same pressure difference (corresponding to outlet resistance by 2400%)	Increase air flow pressure resistance by 2400%
Fault-free		NA

The data set is provided in a set of the csv files. Each .csv file represents one-year data of a fault with a specific fault intensity or a fault-free case. The data set uses 1-minute measurement frequency so the data sets can be converted into input samples of any time horizon larger than 1 minute. Table 4 lists the csv file description for each faulty case and fault-free case.

Table 3 File inventory

No.	Fault file name	Fault type	Fault intensity
1	FCU_OADMPRLeak_20.csv	Outdoor air damper leaking	20% leakage
2	FCU_OADMPRLeak_50.csv	Outdoor air damper leaking	50% leakage
3	FCU_OADMPRLeak_80.csv	Outdoor air damper leaking	80% leakage
4	FCU_OADMPRStuck_0.csv	Outdoor air damper stuck	Stuck at 0% position
5	FCU_OADMPRStuck_30.csv	Outdoor air damper stuck	Stuck at 30% position
6	FCU_OADMPRStuck_50.csv	Outdoor air damper stuck	Stuck at 50% position
7	FCU_OADMPRStuck_80.csv	Outdoor air damper stuck	Stuck at 80% position
8	FCU_OADMPRStuck_100.csv	Outdoor air damper stuck	Stuck at 100% position
9	FCU_VLVLeak_Heating_20.csv	Heating coil valve leaking	20% leakage
10	FCU_VLVLeak_Heating_50.csv	Heating coil valve leaking	50% leakage
11	FCU_VLVLeak_Heating_80.csv	Heating coil valve leaking	80% leakage

12	FCU_VLVStuck_Heating_0.csv	Heating coil valve stuck	0% position
13	FCU_VLVStuck_Heating_20.csv	Heating coil valve stuck	Stuck at 20%
14	FCU_VLVStuck_Heating_50.csv	Heating coil valve stuck	Stuck at 50%
15	FCU_VLVStuck_Heating_80.csv	Heating coil valve stuck	Stuck at 80%
16	FCU_VLVStuck_Heating_100.csv	Heating coil valve stuck	Stuck at 100%
17	FCU_VLVLeak_Cooling_20.csv	Heating coil valve leaking	20% leakage
18	FCU_VLVLeak_Cooling_50.csv	Heating coil valve leaking	50% leakage
19	FCU_VLVLeak_Cooling_80.csv	Heating coil valve leaking	80% leakage
20	FCU_VLVStuck_Cooling_0.csv	Cooling coil valve stuck	Stuck at 0%
21	FCU_VLVStuck_Cooling_20.csv	Cooling coil valve stuck	Stuck at 20%
22	FCU_VLVStuck_Cooling_50.csv	Cooling coil valve stuck	Stuck at 50%
23	FCU_VLVStuck_Cooling_80.csv	Cooling coil valve stuck	Stuck at 80%
24	FCU_VLVStuck_Cooling_100.csv	Cooling coil valve stuck	Stuck at 100%
25	FCU_SensorBias_RMTemp_+2C.csv	Zone temperature sensor bias	+2°C
26	FCU_SensorBias_RMTemp_-2C.csv	Zone temperature sensor bias	-2°C
27	FCU_SensorBias_RMTemp_+4C.csv	Zone temperature sensor bias	4°C
28	FCU_SensorBias_RMTemp_-4C.csv	Zone temperature sensor bias	-4°C
29	FCU_Fouling_Cooling_Airside_Minor.csv	Cooling coil fouling air-side	Minor
30	FCU_Fouling_Cooling_Airside_Moderate.csv	Cooling coil fouling air-side	Moderate
31	FCU_Fouling_Cooling_Airside_Severe.csv	Cooling coil fouling air-side	Severe
32	FCU_Fouling_Cooling_Waterside_Minor.csv	Cooling coil fouling water-side	Minor
33	FCU_Fouling_Cooling_Waterside_Moderate.csv	Cooling coil fouling water-side	Moderate
34	FCU_Fouling_Cooling_Waterside_Severe.csv	Cooling coil fouling water-side	Severe
35	FCU_Fouling_Heating_Airside_Minor.csv	Heating coil fouling air-side	Minor
36	FCU_Fouling_Heating_Airside_Moderate.csv	Heating coil fouling air-side	Moderate
37	FCU_Fouling_Heating_Airside_Severe.csv	Heating coil fouling air-side	Severe
38	FCU_Fouling_Heating_Waterside_Minor.csv	Heating coil fouling water-side	Minor
39	FCU_Fouling_Heating_Waterside_Moderate.csv	Heating coil fouling water-side	Moderate
40	FCU_Fouling_Heating_Waterside_Severe.csv	Heating coil fouling water-side	Severe
41	FCU_FilterRestriction_10%.csv	Filter restriction	10% blockage
42	FCU_FilterRestriction_20%.csv	Filter restriction	15% blockage
43	FCU_FilterRestriction_50%.csv	Filter restriction	50% blockage
44	FCU_OABlockage.csv	Outdoor air inlet blockage	NA
45	FCU_FanOutletBlockage.csv	Fan outlet blockage	NA
46	FCU_Control_CoolingReverse.csv	Cooling control reverse acting	NA
47	FCU_Control_HeatingReverse.csv	Heating control reverse acting	NA
48	FCU_Control_Unstable.csv	FCU unstable control	NA

49	Fault_free.csv	Fault free	NA

References

[1] Jin Wen, Shokouh Pourarian, Xuebin Yang and Xiwang Li. NIST 10D243 Tools for Evaluating Fault Detection and Diagnostic Methods for HVAC Secondary Systems of a Net Zero Building. National Institute of Standard & Technology. U.S. June 2015