Modeling and Calibration of a Variable Refrigerant Flow (VRF) System with a Dedicated Outdoor Air System (DOAS)

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Abstract

With increased use of variable refrigerant flow (VRF) systems in the U.S. building sector, there have been gaining interests in capability and rationality of various building energy modeling tools to simulate VRF systems. **This paper presents modeling and calibration of a VRF system with a dedicated outdoor air system (DOAS) by comparing to the measured data from a real building and system.** Modeling and calibration of a VRF-DOAS model were performed using the whole-building simulation, U.S. DOE's EnergyPlus version 8.1, with the measured data collected from an occupancy emulated research building, Flexible Research Platform (FRP), at Oak Ridge National Laboratory (ORNL). The initial building model was built, and the original EnergyPlus code was modified to model a specific DOAS installed in the FRP. **The VRF-DOAS model can reasonably predict the performance of the actual VRF-DOAS system based on the criteria from ASHRAE Guideline 14-2014. The calibration results show that hourly CV-RMSE and NMBE would be 15.7% and 3.8%, respectively, which is deemed to be calibrated.**

1 Literature Review

Im and Munk [1] evaluated the energy performance of a multi-split VRF system in comparison to a typical RTU-VAV system installed in the Oak Ridge National Laboratory's Flexible Research Platform (FRP).

Aynur et al. [2] analyzed a comparative study between VRF and VAV systems and evaluated the energy savings potential of VRF systems. Their simulation results showed that VRF systems could consume about 38%-83% less energy usage for cooling season.

Raustad [3] validated against field data measured at an multi-zone building. It was found that about 72% of all the simulated energy use fall within 25% of the measured data, and a coefficient of variation of the root mean square error, CV (RMSE), was about 21% between measured and simulated total energy use.

Hong et al. [4] developed a new VRF simulation module based on physics in EnergyPlus version 8.4. With their comparison between measured and simulated results, normalized mean bias errors (NMBEs) were 2.8% and 4.5% for cooling and heating operations.

2 Target Building Description

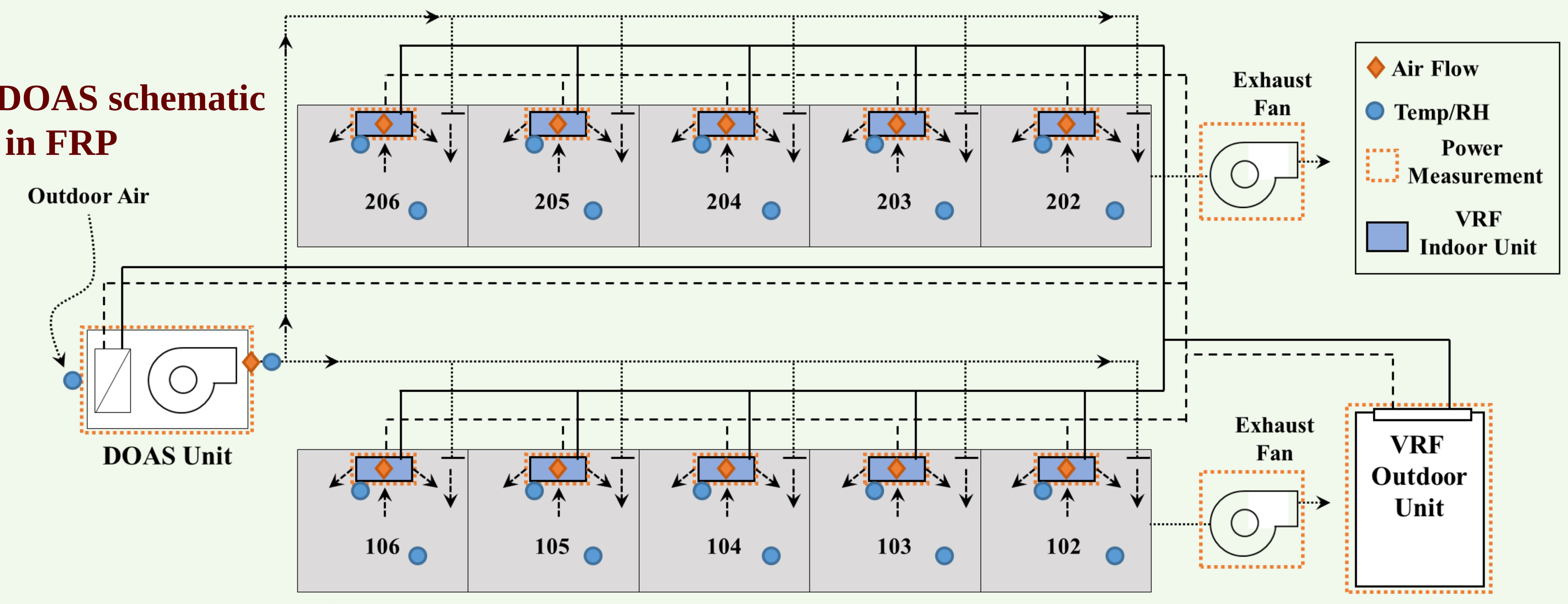
(a) Two-story flexible research platform (FRP)

(b) VRF HP outdoor unit

(c) Dedicated outdoor air system (DOAS) unit

(d) VRF HP indoor unit

(d) VRF-DOAS schematic installed in FRP



(e) Building characteristics of two-story FRP

Location	Oak Ridge, Tennessee, USA
Building size	Two-story, 12.2×12.2 m (40×40 ft), 4.3 m (14 ft) floor-to-floor height
Exterior walls	Concrete masonry units with face brick, RUS-11 (RSI-1.9) fiberglass insulation
Floor	Slab-on-grade
Roof	Metal deck with RUS –18(RSI –3.17) polyisocyanurate insulation
Windows	Double-pane clear glazing, 28% window-to-wall ratio
Baseloads	9.18W/m² (0.85 W/ft²) lighting power density, 14.04W/ m² (1.3 W/ft²) equipment power density
VRF system	42 kW (12 ton) VRF system with a DOAS

3 Calibration Approaches

***Step1*: EnergyPlus source code modification**

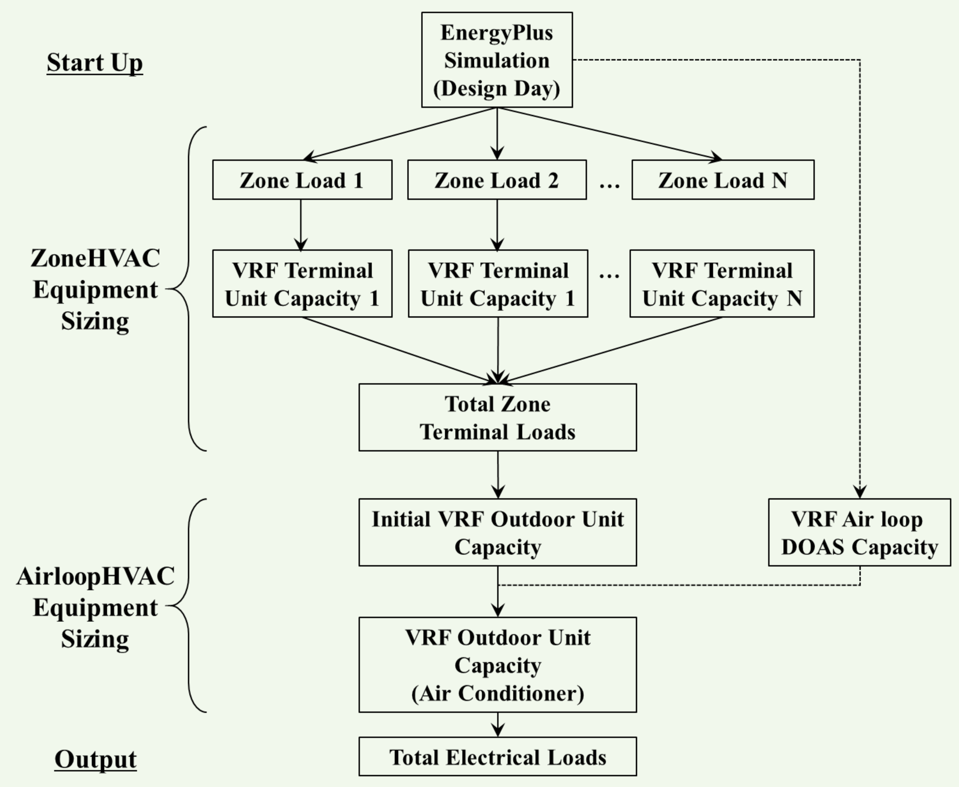
***Step2*: Building load calibration**

- Weather data update
- Infiltration update
- Interior light intensity and schedule update
- Plug load intensity and schedule update

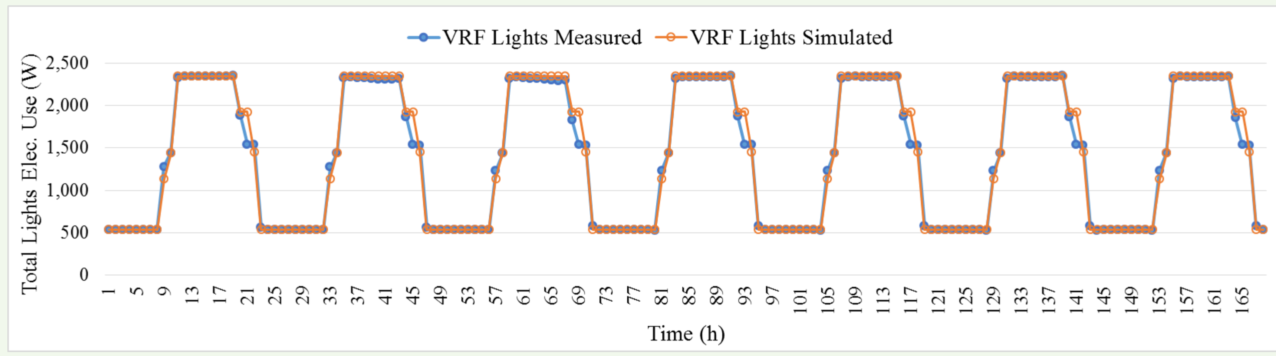
***Step3*: VRF-DOAS system calibration**

- DOAS using the modified version of EnergyPlus 8.1
- DOAS outdoor air (OA) set point temperature
- VRF operation schedule update
- Heating and cooling COPs of the VRF system update

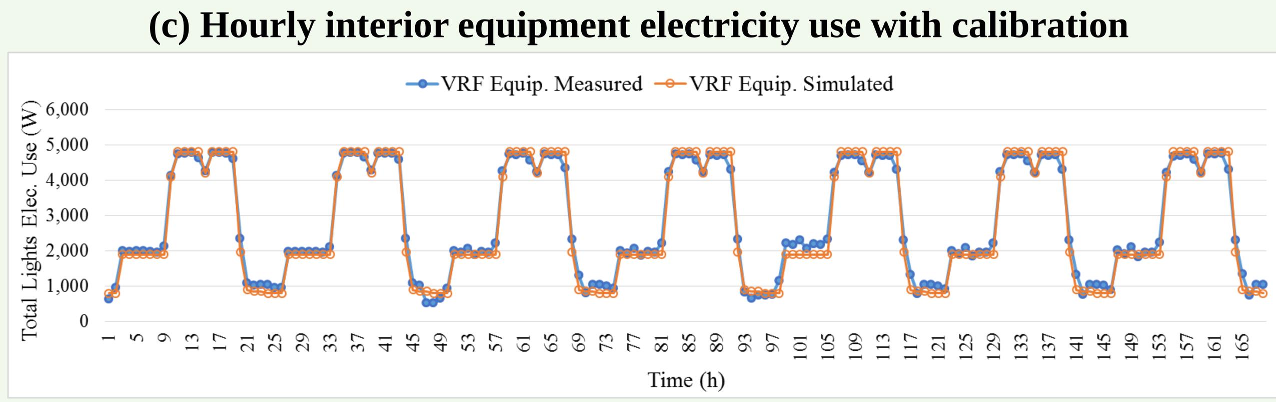
(a) Process of the modified EnergyPlus version 8.1 for VRF-DOAS



(b) Hourly interior light electricity use with calibration



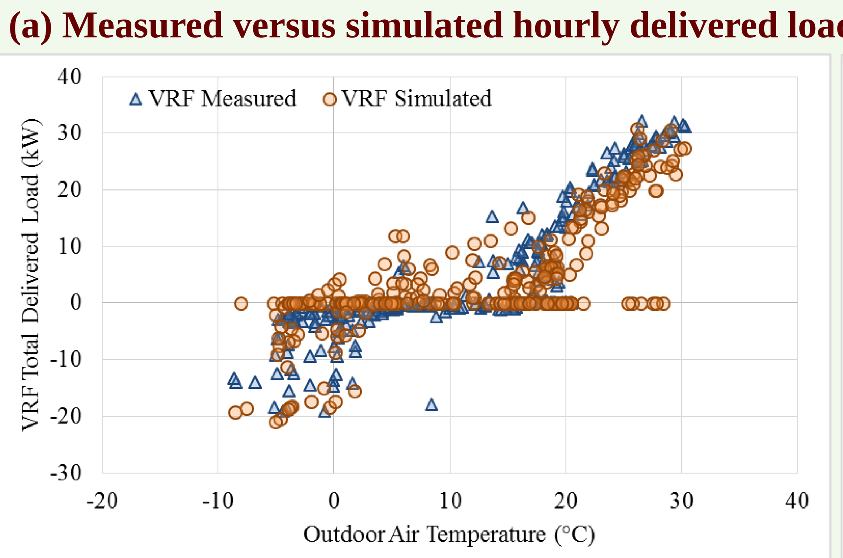
(c) Hourly interior equipment electricity use with calibration

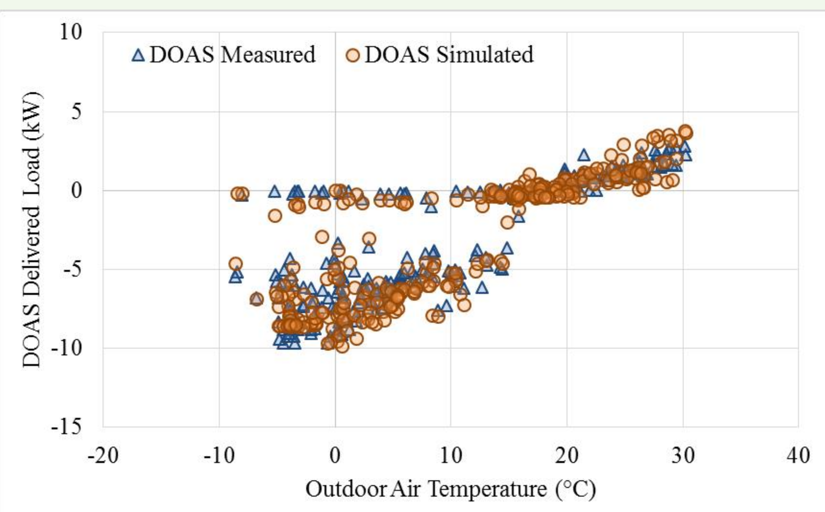


4 Results Analysis

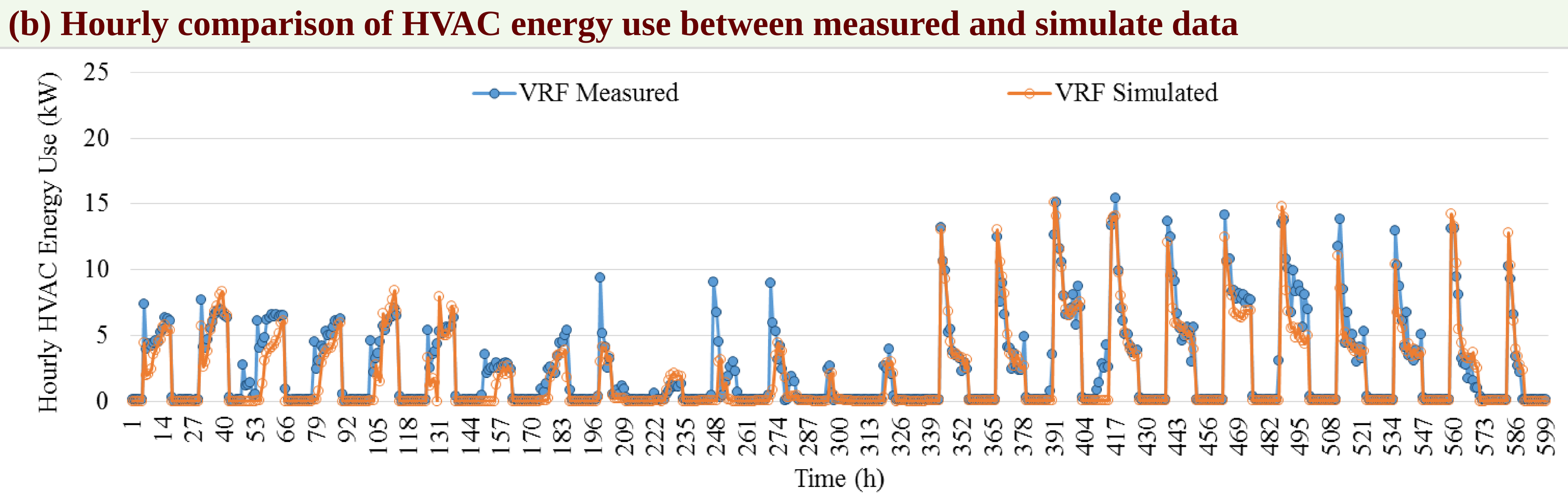
$$Load_{Delivered} = \dot{m}_a \times (h_{return} - h_{supply}) \quad (1)$$

(a) Measured versus simulated hourly delivered loads

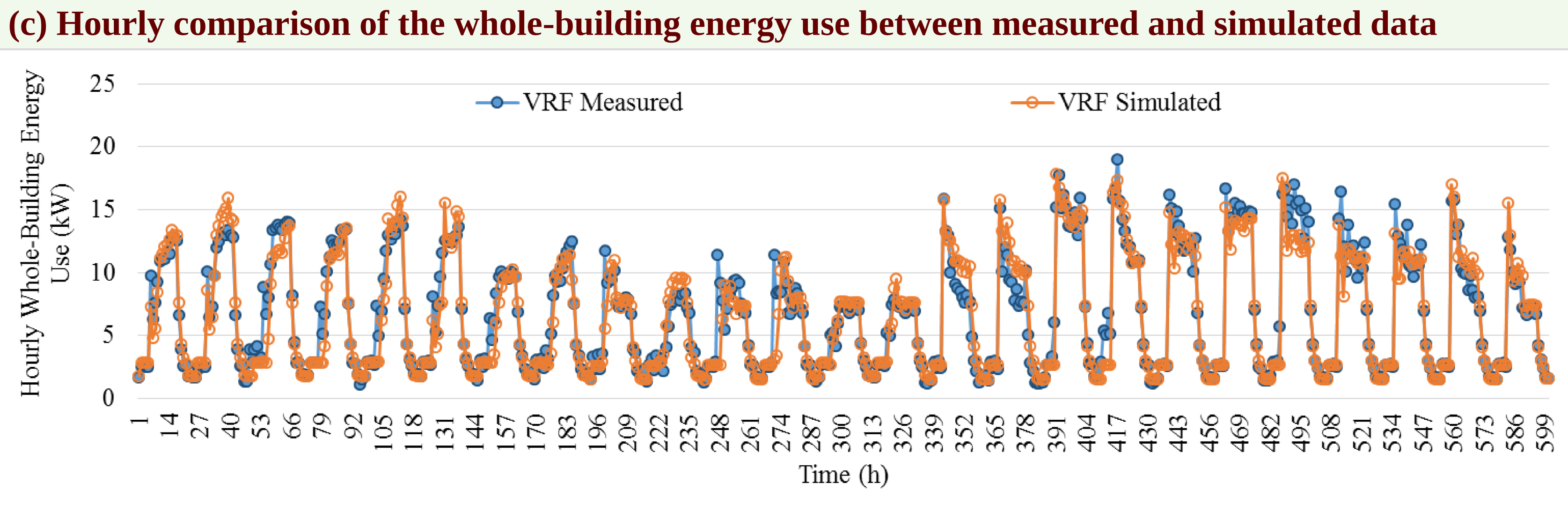




(b) Hourly comparison of HVAC energy use between measured and simulate data



(c) Hourly comparison of the whole-building energy use between measured and simulated data



(d) The whole-building energy use of the VRF-DOAS model with and without calibration

	Lights	Equip.	Cooling & Heating	Fan	Total
Measured (kWh)	795.0	1,674.8	1,521.7	68.2	**4,059.7**
Simulated without calibration (kWh)	864.3	1,483.4	1,203.1	132.8	**3,683.6**
Simulated with calibration (kWh)	861.1	1,798.6	1,249.7	71.5	**3,980.9**
Diff. without calibration	8.7%	11.4%	20.9%	94.6%	**9.3%**
Diff. with calibration	8.3%	7.4%	17.9%	4.8%	**1.9%**

(e) Statistical evaluation of the VRF-DOAS model with and without calibration

		Without calibration (%)	With calibration (%)
Daily	CV (RMSE)	20.1	8.7
	NMBE	9.6	0.2
Hourly	CV (RMSE)	32.3	15.7
	NMBE	10.9	3.8

5 Conclusion

Modeling and calibration of a VRF system with a DOAS were performed using a modified EnergyPlus program based on the measured data from FRP. The calibration processes in three main stages: (1) VRF-DOAS source code modification of EnergyPlus 8.1, (2) building load calibration, and (3) VRF-DOAS system updates for final calibration until the statistical comparison shows acceptable match under the criteria defined in the ASHRAE Guideline 14-2014.
The calibration results show that hourly CV-RMSE and NMBE would be within 15.7% and 3.8%, respectively. The results also show that the whole-building energy usage after calibration of the VRF-DOAS model is 1.9% (78.8 kWh) lower than that of the measurements during comparison period.

Reference

[1] P. Im and J. D. Munk, "Evaluation of Variable Refrigerant Flow (VRF) System Performance Using an Occupancy Simulated Research Building : Introduction and Summer Data Analysis Compared with a Baseline RTU System," ASHRAE Annu. Conf., pp. 1–9, 2015.
[2] T. N. Aynur, Y. Hwang, and R. Radermacher, "Simulation comparison of VAV and VRF air conditioning systems in an existing building for the cooling season," Energy Build., vol. 41, no. 11, pp. 1143–1150, 2009.
[3] R. Raustad, "A variable refrigerant flow heat pump computer model in energyplus," ASHRAE Trans., vol. 119, no. PART 1, pp. 299–308, 2013.
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