Building loads are primarily controlled through thermostatic temperature setpoint variations. Building electrical loads display nonlinear interactions with thermostatic setpoints, ambient temperature and electrical bus voltages. Standalone software packages such as DOE-2 are primarily used for building design purposes and are not easily integrated into electrical grid studies. The present work discusses a model that captures the building electro-thermal and building-grid coupling to improve understanding of grid connected building load operation.

Introduction and Motivation

- Building electrical loads display nonlinear interactions with thermostatic setpoints, ambient temperature and electrical bus voltages.
- It is imperative that an adequate representation of this nonlinear behavior be incorporated into load models to effectively control buildings under demand side load management.
- Building load modeling traditionally focuses on electric heating with cycling and aggregate load variations which fail to effectively capture inherent electrical-thermal coupling.
- Operating without regard for such behavior could bring about inefficiencies and even have potential detrimental effects on the power system.
- The following discussion will present a building load model that incorporates the efforts in [1,2,3] to capture the necessary temperature-load-voltage relationships.

Methodology

- The building-grid energy interaction is described through an Energy Hub [2], E2MT, with building controllable and uncontrollable load components (1).
- The thermistorically controllable load portion, primarily the HVAC equipment load, is presented with a corresponding conversion efficiency \( \psi_{electric} \) .
- Building operators should consider neighboring building operation as well as the electric grid.

Discussion of Results

- The results in Figure 4 were obtained through a load flow analysis of the network in Figure 3 by including building temperature as a state and using (4) and (5) to describe the loads.
- The circuit model parameters in Table 1 were estimated from actual building data while the ZIP parameters in Table 2 were obtained from [3] for large commercial and industrial buildings.
- The results displayed are for a unidirectional loading of the buildings with the same \( \psi_{set} \), while the ambient \( \psi_{set} \) was held.
- As the results indicate, building internal and ambient temperature have a direct influence on load behavior.
- Building - grid operation should consider thermal operating points as well as electrical.

Problem Formulation

- Building loads are primarily controlled through thermostatic temperature setpoint variations and are subject to operating limits determined by the HVAC equipment capacities.
- Load variations correspondingly cause variations in the electrical bus voltages, and hence, form a temperature-load-voltage coupling that constrains the building – grid operation.
- Load variations cause variations in the electrical bus voltages, and hence, form a temperature-load-voltage coupling that constrains the building – grid operation. For the example network with given parameters, the bus voltages vary within allowable limits as shown in Figure 1 (b).
- The building thermal load sensitivity is subject to P\(\psi_{set}\) and P\(\psi_{set}\) limits that are sensitive to temperature conditions as shown in Figure 1 (a).
- The thermostatically uncontrollable load portion, lighting, appliance load, etc., is represented through a ZIP load (2), where the coefficients can be estimated from meter data as in [3].
- The building load equation (1) can be written as (4) for real power and (5) for reactive power, with a constant power factor assumption.
- The multiplication \( k_{load}=\tan(cos(\psi_{set})\cdot FF) \) is defined for each building.
- The building load equation (1) can be written as (4) for real power and (5) for reactive power, with a constant power factor assumption.
- For the example network with given parameters, the bus voltages vary within allowable limits as shown in Figure 1 (b).
- In heavily loaded cases, however, it is possible that the bus voltage will violate the low voltage limit as shown in Figure 1 (c).
- Building operators should consider neighboring building operation as well as the electric grid operation to avoid grid constraint violations.
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Conclusions

- The presented model captures the temperature-load-voltage relationship that exists between buildings and the electric grid.
- For the example network with given parameters, the bus voltages vary within allowable limits as shown in Figure 1 (b).
- In heavily loaded cases, however, it is possible that the bus voltage will violate the low voltage limit as shown in Figure 1 (c).
- Building operators should consider neighboring building operation as well as the electric grid operation to avoid grid constraint violations.
- The results displayed are for a unidirectional loading of the buildings with the same \( \psi_{set} \), while the ambient \( \psi_{set} \) was held.
- As the results indicate, building internal and ambient temperature have a direct influence on load behavior.
- Building - grid operation should consider thermal operating points as well as electrical.

References