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Dynamic Frequency Regulation Method Based On Thermostatically Controlled Appliances in the Power System

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Abstract

This paper presents a dynamic frequency regulation strategy which uses residential thermostatically controlled appliances (TCA) to alleviate frequency deviations caused by high penetration of renewable energy sources in the power system. Heating, ventilating and air-conditioning (HVAC) load is used as an example of TCA load. With the control strategy, HVAC units respectively collect frequency information locally, based on which their on/off status is dynamically regulated. The simulation is implemented with 1000 HVAC units in a British Grid model. The results demonstrate that the strategy effectively alleviate the frequency deviations caused by renewable energy sources. A frequency response ability assessment method based on a dynamic load-sorting strategy is also presented.

Peer-review under responsibility of the organizing committee of CUE 2015

Keywords: Demand Response, Thermostatically controlled appliances, Dynamic frequency regulation, Frequency response ability assessment

1. Introduction

Expanding implementation of renewable energy in the power system is promising in alleviating the environmental problems caused by extensive usage of fossil fuels. However, frequency instability caused by the intermission and uncertainty of renewable energy sources, such as wind and solar power is a major operation issue for their high penetration into the power grid.

Demand Response is considered as a valuable method to balance the system power and thus restrain frequency instability in future grids. The development of smart grid with advanced communication and control tools will enable DR programs to provide ancillary services to power systems such as frequency regulation. Thermostatically controlled appliances (TCA) can provide large load balancing capacity and are controllable for the ability to change on/off status instantly. Thus, under proper control strategies, TCAs can be a major DR resource for frequency control.

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Nomenclature

Abbreviation

DR	Demand Response
TCA	Thermostatically Controlled Appliance
HVAC	Heating, Ventilating, and Air-conditioning

Symbols

f	Frequency
T_{set}	Thermostat set-point
T_+	Temperature upper limit
T_-	Temperature lower limit
ΔT	Deficit between T_{set} and T_+ (T_-)
Δf	Frequency deviation
k	User comfort parameter
P	Power consumption of a HVAC unit
P_{c}	Controllable power
P_{c_max}	Upper limit of P_c
n	Total number of HVAC units
m_t	Number of controllable units at moment t
s_j	On/off status of unit j

2. HVAC Control strategy

2.1. Thermal behavior of HVAC units

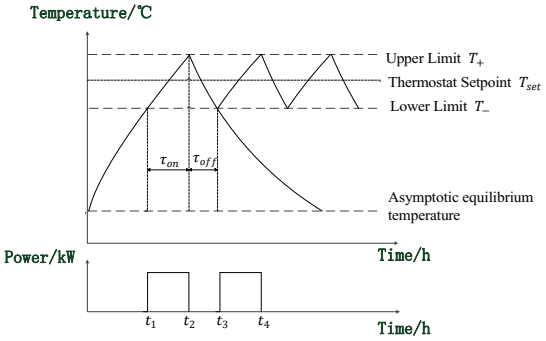

Fig. 1 Thermal behavior of an HVAC unit in winter