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## 1 Scope

This document introduces an updated version of the IBM EcoGrid Direct-Price Agent v2 as described in [1].

The functional principle of the updated direct-price agent, hereafter referred to as version 2.1, is the same as in version 2.0. However, the heat pump runtime constraints have been changed for the different flexibility levels so as to allow for more potential for demand response.

## 2 Heat Pump Operational Constraints

The heat pump runtime constraints we had implemented in the previous version 2.0 of the direct-price agent are summarized in Table 1.

| <i>User-set Aggressivity Level</i> | <i>Min. Off-time</i> | <i>Max. Off-time</i> | <i>Min. On-time</i> | <i>Max. total Off-time per day</i> |
|------------------------------------|----------------------|----------------------|---------------------|------------------------------------|
| Low                                | 15min                | 15min                | 120min              | 15min                              |
| Medium                             | 15min                | 30min                | 60min               | 30min                              |
| High                               | 15min                | 60min                | 30min               | 60min                              |

Table 1 Heat pump operational constraints for different user settings as implemented in previous price agent version 2.0.

The updated runtime constraints used in the new price agent version 2.1 are provided in Table 2. Note that in new version, the maximum cumulative daily off-time constraints are removed. Moreover, both the minimum and maximum off-times have been increased. Consequently, the heat pump and direct electric heating is now allowed to be throttled for time periods that are longer.

To summarize the new v2.1 behavior, note that, regardless of the user-set flexibility level, the time between the start times of two subsequent heat pump off-periods is guaranteed to be *at least 4 hours (=240min)*.

| <i>User-set Aggressivity Level</i> | <i>Min. Off-time</i> | <i>Max. Off-time</i> | <i>Min. On-time</i> | <i>Max. total Off-time per day</i> |
|------------------------------------|----------------------|----------------------|---------------------|------------------------------------|
| Low                                | 30min                | 30min                | 210min              | -                                  |
| Medium                             | 30min                | 60min                | 210min              | -                                  |
| High                               | 60min                | 90min                | 180min              | -                                  |

Table 2 Heat pump operational constraints for different user settings as implemented in the price agent version 2.1.

## 3 Heat Pump Model

The version of the direct-price agent described in this document uses a very simple heat pump model. It is assumed that the heat pump consumes a constant amount of power  $P_{ON}$  when in operation, and a constant amount of power  $P_{OFF}$  when idle.

The numeric power level values can be identified for every house individually. Table 3 provides a set of typical values.

| <i>Heat Pump Operation State</i> | <i>Constant Power Consumption</i> |
|----------------------------------|-----------------------------------|
| ON                               | 4000W                             |
| OFF                              | 130W                              |

Table 3 Example of heat pump power levels.

## 4 Energy-Procurement Cost Minimization

Given a price forecast for a fixed planning horizon, the IBM direct-price agent computes a heat pump ON/OFF schedule that (i) minimizes the total energy-procurement cost accumulated over the planning horizon and that (ii) simultaneously satisfies all runtime constraints as specified in Table 2.

## 5 Security Features

In addition to the heat pump constraints discussed in Section 2, the following security features are implemented to guarantee participant freedom and an indoor air temperature higher or equal to the user-set minimum temperature at all times.

As soon as at least one of the following conditions is true, *any* planned minimum procurement-cost optimization schedule will be pre-empted and the heat pump is unconditionally enabled to operate according to its native parameters.

- i. The indoor air temperature as measured by the GreenWave temperature sensor is below the user-set minimum temperature.
- ii. The indoor air temperature is below minimum User Comfort Setting established in UI.
- iii. The latest indoor air temperature sample from the GreenWave temperature sensor was received more than 4 hours ago.
- iv. The communication between server and GreenWave gateway in house is lost for more than 30 minutes.
- v. Oestkraft or the participant operationally bail out the household from automation by unchecking the flag in GreenWave user interface.
- vi. The IBM administrative automation state for the household is set to disabled (example as done over Xmas 13/14).

## References

- [1] Mueller, F., Sundstroem, O., & Gantenbein, D. (2014). *IBM EcoGrid Direct-Price Agent Implementation Status v2.0*. IBM Research Zurich.