Device Flexibility Generation and Configuration Manual

March 2021

1. Supported Device Categories

Currently, FOA supports and generates FlexOffers for 3 types of devices:

i) Wet Devices (Washer, Dryer, and Dishwasher)

These devices remain idle until a user initiates the device (e.g., putting dirty clothes in washing machine and pressing the start button). We detect that there is a demand for device operation (i.e., a user has started the device) and the operation must be completed within a user-defined time window.

Note: Some Wet devices do not remember operation state when interrupted by the system. Therefore, users will have to go back and restart the device to resume its operation when the system/market sends a schedule.

ii) Thermostatically Controlled Devices (Heat Pump, Boiler, Freezer, Refrigerator, and Air Conditioner)

These devices continuously operate and governed by their own internal cycle (these are typically automated thermostatically devices). The FOA monitors their energy consumption and based on market requirement and user-defined parameters may turn on/off the device for a certain duration.

iii) Devices with Battery Charging (Electric Vehicles, Electric Bikes)

These devices remain idle until a user initiates the device charging. The FOA detects that there is a demand for device operation (i.e., a user has started device charging) and the operation must be completed within a user-defined time window depending on the battery level.

2. Flex Offer Parameters:

A user must specify different parameters depending on the device type:

i) Maximum Start Delay: This defines the time duration by which a user is willing to delay the operation of the device. For example, if a user sets a value of 2 hours for this parameter, then the device must be started within 2 hours. This represents the time flexibility of a device.

ii) Latest Notification Time: Defines the time by which the user must be notified of when the FOA will start the device. This parameter value cannot be greater than the *Maximum start delay*.

iii) Daily Control Window: Defines a daily time window (consisting of start time and end time) such that the FOA will take control of the device only within the time window. For example, if the daily control window is (10am-7pm), then any system-forced control will only occur during this time window.

iv) Max Number of Controlled Periods (Interruptions) Per Day: Defines the maximum number of times the FOA may interrupt (i.e. take control of) a device during a day. For example, if a user sets a value of 4 for this parameter, then the device may be interrupted max 4 times a day.

v) Max Duration of an Interruption: Defines the maximum time duration up to which each interruption may last. For example, if this is set to 30 minutes for an air-conditioner, then the FOA may turn off the air-conditioner for maximum 30 minutes before turning it back on.

vi) Min Distance Between Two Consecutive Interruptions: Defines the minimum time that the FOA should wait from the end of the current interruption before starting next interruption. For example, if this is set to 2 hours for the air-conditioner and the current interruption ends at 12:00 pm, then the next interruption cannot start before 02:00 pm.

vii) Start Battery Charging In: This defines the time by which the battery charging must be started. For example, if a user sets a value of 3 hours for this parameter, then the device charging must be started within 3 hours.

Table 1: Devices types and applicable parameters

	Maximum Start Delay	Latest Notification Time	Daily Control Window	Max Number of Controlled Periods Per Day	Max Duration of an Interruption	Min Distance Between Two Consecutive Interruptions	Start Battery Charging In
Wet Devices	x	x	x	-	-	-	-
Thermostatically Controlled Devices	-	-	x	x	x	x	-
Devices with Battery Charging	-	-	x	-	-	-	x

3. Flex Offer Generation and Device Control:

3.1 Wet Devices:

The FOA continuously (every minute) monitors the power consumption from the smart plug but takes no action until the user interacts with the wet device connected to the smart plug (e.g., putting dirty clothes in a washer dryer or dishes in a dishwasher and pressing the start button). As the user presses the start button on the wet device, the FOA notices a spike in consumption from the device connected to smart plug, upon which the FOA immediately switches off the plug (stopping the device) and generates a FlexOffer according to the user-defined parameters applicable to wet devices (see Table 1).

The FlexOffer contains the average historical consumption and cycle duration as an estimate of the device flexibility. For example, let's consider that the user presses the start button at 12:11 PM. Let's then assume that the user has set *Maximum Start Delay* to 4 hours, and *Latest Notification Time* to 30 minutes. In FlexOffer format, the ordinary time duration is expressed as 15-minute slices. Thus, 4 hours are expressed as 16 slices (16x15 = 240 minutes = 4 hours), and 30 minutes are expressed as 2 slices. The parameters are summarized in Table 2. Based on these parameters, the FOA sets the FlexOffer *earliest start time* to 12:15 PM and the *latest start time to* 4:15 PM (as *Maximum Start Delay* is 16 slices or 4 hours). The number of slices in the FlexOffer is automatically estimated by the FOA from device consumption history (let's assume it's estimated to be 90 minutes or 6 slices), where the energy consumption for each slice is the average of historical energy consumption. Please note that interruption will occur only if the user presses the start button during *Daily Control Window*.

Table 2: Wet Device Flexibility Parameters

Daily Control Window	08:00 AM - 08:00 PM
Maximum Start Delay	16 slices (4 hours)
Latest Notification Time	2 slices (30 minutes)

After sending the FlexOffer, the FOA waits for a time period as defined by *Latest Notification Time* to receive a decision (i.e. schedule) from FMAN. In our example, the FOA waits for a decision until 12:45 PM (as FlexOffer is generated at 12:15 PM and *Latest Notification Time* is 30 minutes). There are three possible outcomes:

a)- **FlexOffer accepted:** The user starts the device (step 1 - Fig1). The FOA receives an acceptance notification from the market at 12:40 PM (step 2). The notification is accompanied by a schedule which dictates the system to start the device at 01:00 PM. The user will need to resume the device operation at 01:00 PM according to the received schedule. The user starts the device again (step 3), which last till 02:30 PM (step 4). The user is paid for deviation from their normal schedule (activated flexibility) and could be rewarded for willingness to provide flexibility (offered flexibility).

Fig 1: Accepted

b)- **FlexOffer rejected:** The user starts the device (step 1 - Fig2). The market sends a rejection notification at 12:28 PM (step 2). Upon receiving the rejection, the user starts the device operation again at 12:30 PM (step 3), which lasts till 02:00 PM (step 4). The user could be rewarded for offered flexibility.

Fig 2: Rejected

c)- **No response:** The user starts the device (step 1 - Fig3). The FOA receives no notification from the market until 12:45 PM (step 2). The user starts the device operation again at 12:45 PM (step 2), which lasts till 02:15 PM (step 3). The user could be rewarded for offered flexibility.

Fig 3: No response

Once the device resumes operation, no further schedules are accepted until the device completes its cycle.

Note: In all three cases (acceptance, rejection, or no response), the user will need to go back and again press the start button on the device to resume its operation (unless it's a smart device that remembers its last state).

3.2 Thermostatically Controlled:

The FOA continuously (every minute) monitors the status of the device using the smart plug. Once a device is in operation without interruption for a certain duration of time as defined by the *Min Distance Between Two Consecutive Interruptions* parameter, the FOA generates a new FlexOffer. The FlexOffer is composed of **n** number of slices, where **n** is equal to *Max Duration of an Interruption* parameter. For example, if *Max Duration of an Interruption* is set to 60 minutes, then **n** is 4 (60/15 minutes). The default value of **n** is 1 (or 15 minutes).

The FOA waits until the start time of the first slice in the FlexOffer to receive a schedule from FMAN. If no schedule is received, FOA will continue normal operation for the device (leave it ON). In this case, flexibility is not traded but the user could still be reimbursed for willingness to provide flexibility.

On the other hand, FMAN may respond with a schedule for one or more slices. A slice schedule with 0 value means "turn OFF the device for that slice" while a schedule > 1 means "turn ON for the slice". In case of a 0-schedule, the FOA will power OFF the device even if the device is sleeping and the user will be reimbursed

for the duration of adaptation. After FlexOffer execution, at the end of *Max Duration of an Interruption*, the FOA always returns the device to default state (ON) and waits for time duration as defined by *Min Distance Between Two Consecutive Interruptions* parameter, before generating a new FlexOffer for the device. Please note that the total number of generated FlexOffers (i.e., interruptions) can't exceed *Max Number of Controlled Periods (Interruptions) Per Day*. Also, all interruptions must occur during *Daily Control Window*.

Let's assume that the FOA operates a device (e.g., heat pump) based on the flexibility parameters in Table 3.

Table 3: Thermostatically Controlled Device Flexibility Parameters

Daily Control Window	08:00 AM - 08:00 PM
Max Number of Interruptions Per Day	4
Max Duration of an Interruption	1 (15 minutes)
Min Distance Between Two Consecutive Interruptions	4 (60 minutes)

Every time the FOA generates a FlexOffer, there are three possible outcomes:

a)- **FlexOffer accepted:** At 12:11 PM (step 1), the FOA generates a FlexOffer with 1 slice (as *Max Duration of an Interruption*=1) for the period 12:15-12:30 PM. The FOA receive a schedule of 0 for the slice at 12:14 PM from FMAN (step 2). Based on the schedule, the FOA switches OFF the device at 12:15 PM, and switches it back ON at 12:30 PM (step 3-4). The user will be paid for deviation from their normal schedule (activated flexibility) and also could be rewarded for offered flexibility. The FOA must wait until 01:30 PM to generate another FlexOffer (as *Min Distance Between Two Consecutive Interruptions* = 4).

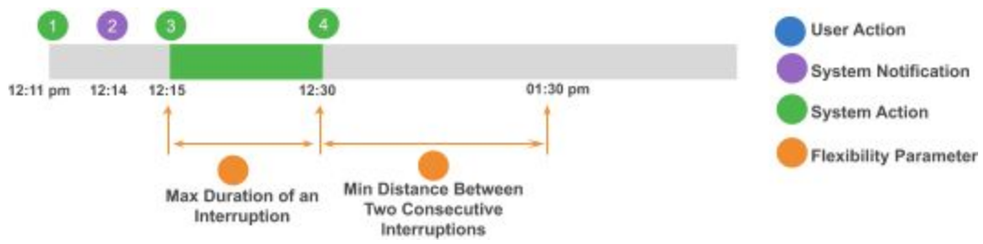

Fig 4: Accepted

b)- **FlexOffer rejected:** At 12:11 PM, the FOA generates a FlexOffer with 1 slice for the period 12:15-12:30 PM. The FOA receive rejection at 12:14 PM from FMAN. In this case, the FOA sends no signal to the device. The user could be rewarded for offered flexibility. The FOA still waits until 01:30 PM to generate another FlexOffer because currently we count *Min Distance Between Two Consecutive Interruptions* from the end time of the last slice in the current FlexOffer regardless of whether the current FlexOffer is accepted or not.

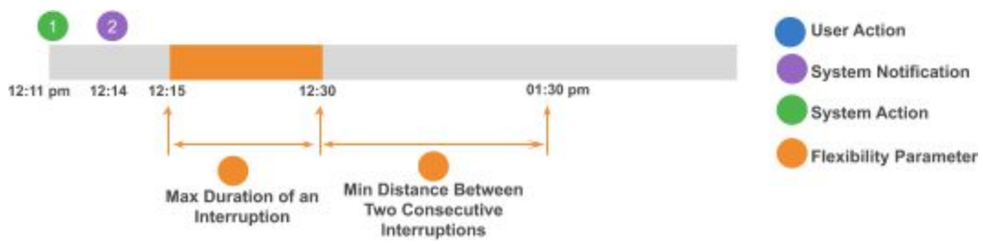

Fig 5: Rejected

c)- **No response:** At 12:11 PM, the system generates FlexOffer with 1 slice for the period 12:15-12:30 PM. The system receives no response until 12:15 PM from FMAN. In this case, the FOA sends no signal to the device. The user could be rewarded for willingness to provide flexibility. The FOA still waits until 01:30 PM to generate another FlexOffer because currently we count *Min Distance Between Two Consecutive Interruptions* from the end time of the last slice in the current FlexOffer regardless of whether the current FlexOffer is accepted or not.

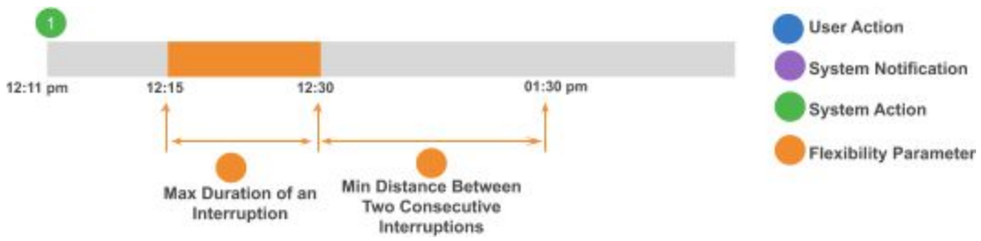

Fig 5: No Response

3.3 Devices with Battery Charging:

The FOA continuously (every minute) monitors the power consumption from the smart plug but takes no action until the user presses the "start charging" button on the device connected to the smart plug. As the user presses the start button, the FOA notices a spike in consumption from the device, upon which the FOA immediately switches off the plug (stopping the device) and generates a FlexOffer according to the user-defined parameters applicable to devices with battery charging (see Table 1).

Let's consider that the user presses the start button at 12:11 AM. Let's then assume that the user has set *Start Battery Charging In* parameter to 4 hours (16 slices). The parameter is also listed in Table 2.

Table 2: Wet Device Flexibility Parameters

Daily Control Window	08:00 AM - 08:00 PM
Start Battery Charging In	16 slices (4 hours)

Based on the parameter, the FOA sets the FlexOffer *latest start time to* 4:15 PM (as *Start Battery Charging In* is 16 slices or 4 hours). The number of slices in the FlexOffer is automatically estimated by the FOA from device consumption history (let's assume it's estimated to be 6 hours or 24 slices), where the energy consumption for each slice is the average of historical energy consumption when device is being charged. Please note that interruption will occur only if the user presses the start button during *Daily Control Window*.

After sending the FlexOffer, the FOA waits for a time period as defined by *Start Battery Charging In* to receive a decision (i.e. schedule) from FMAN. In our example, the FOA waits for a decision until 4:15 AM. There are three possible outcomes:

a)- **FlexOffer accepted:** The user starts the device at 12:11 AM (step 1 - Fig 7). The FOA receives an acceptance notification from the market at 12:40 AM (step 2). The notification is accompanied by a schedule which dictates the system to start the device at 01:00 AM. The FOA starts charging the device at 01:00 AM according to the received schedule which lasts till 07:00 AM (step 3-4). The user is paid for deviation from their normal schedule (activated flexibility) and could be rewarded for offered flexibility.

Fig 7: FlexOffer Accepted

b)- **FlexOffer rejected:** The user starts the device (step 1 - Fig 8). The market sends a rejection notification at 12:28 AM (step 2). Upon receiving the rejection, the FOA starts the device charging at the start of next slice (12:30 AM), lasting till 06:30 AM (step 3-4). The user could be rewarded for offered flexibility.

Fig 8: FlexOffer Rejected

c)- **No response:** The user starts the device (step 1 - Fig 9). The FOA receives no notification from the market until 04:15 AM (step 2). The system starts charging the device at 04:15 AM, lasting till 10:15 AM (step 2-3). The user could be rewarded for willingness to provide flexibility.

Fig 9: No response