Energy Monitoring (EM)

This note presents an overview of the data collection process employed by Energy Monitoring Start-up (EM). The objective is to provide a scientific reference for EM's clients.
EM offers an innovative technology that integrates three key functionalities:

1. Breakdown of electricity consumption for individuals.
2. Preventive maintenance solutions for businesses.
3. Behavioural monitoring for elderly care.

1. Sensor's logic and the electrical features

1.1 Steps of firmware computations

EMS's sensor is sampling the current wave on the electrical circuit at a frequency of about 7 kHz. For the voltage, a single phase sensor measures the magnitude of voltage at every peak of the wave. These current and voltage measurements are analysed in real time by the firmware. Here we describe the logic operated by the firmware.

Event detection. The sensor is measuring in real time the magnitude of the current wave. When a persistent change is observed in the magnitude of the current, the sensor computes a data point that we call an *event*. An event is described as a *ON* event (respectively *OFF* event) if the change in current is positive (respectively negative). The threshold for the event detection in the firmware is of 195mA. A change in current magnitude has to be persistent for more than 2 seconds to be considered as an event. When no persistent change is detected in current magnitude for 160 seconds, the sensor
computes a data point that is called *KEEP ALIVE* event.

Energy metering. In parallel to the event detection logic, the sensor is running an energy meter counter. In other words, the sensor integrates in real time current multiplied by voltage. Although the energy counter is incremented in real time, the energy metering is only transmitted with the other electrical features when an electrical event is detected. In particular, this happens at most every 160 seconds. An important consequence of the independence of energy metering with event detection can be found in section **3** where it describes the behaviour of the sensor with bad internet access.

1.2 The features in a standard data file

Here we describe the list of features, contained in each data point sent by the sensor. We include units, format, range of values and comments necessary to understand some subtleties of the computations. We refer to Wikipedia for introductions about AC power and discrete Fourier analysis.

Notation and terminology. Lets consider an event EVT. We designate by

- T the timestamp of EVT,
- T_{-1} the timestamp of the event preceding EVT,
- $\Delta T = T - T_{-1}$.

We observe that:

$$\Delta T \neq 1\text{s},$$

in fact:

$$1\text{s} \leq \Delta T \leq 160\text{s}.$$

In the rest of this note we also use the following notations:

Feature name	Notation	Feature name	Notation
evt	$Type$	active _power _delta	ΔP
active	P	reactive _power _delta	ΔQ
reactive	Q	energy	E
current	I	energy_delta	ΔE
voltage	U	transient_i	$Transient_i$
phase	φ	fft _real _i, fft_img_i	$FFTR_i$,$FFTI_i$
appearant	$\|S\|$	fft _delta _i	ΔFFT_i

Transient and steady state. A switch ON or OFF on an electrical circuit is followed by a *transient* state and by a *steady* state (see figure ??). The transient state can be characterized by the values of $Transient_i$ and the steady state can be characterised by the values of FFT. In the case of an OFF event or of a resistive ON event, the transient state is usually very short and cannot be observed.

The features.

- *sensor_ timestamp*: The UTC time of the event in the format

  `yyyy-mm-dd T hh:mm:ss+00:00.`

  The internal clock of the sensor is reset every 24 hours to an on-line clock.In general the clock is precise up to 30 seconds.

- *device*: the sensor id (integer).
- *firmware*: the firmware version (integer). As of October 2018 the last official firmware release is 41.
- *active power*: active power P at the beginning of the steady state following EVT in W (integer).
- *reactive power*: reactive power Q at the beginning of the steady state following EVT in W (integer).
- *current*: magnitude of current I at the beginning of the steady state following EVT in A (float).
- *voltage*: magnitude of voltage U at the beginning of the steady state following EVT in V (float).
- *phase shift*: power phase shift φ at the beginning of the steady state following EVT in ° (float between -90 and +90 °).
- *apparent power*: apparent power $|S|$ (*Be aware of the typo*) at the beginning of the steady state following W (integer).
- *active_power_delta*: active power variation ΔP of the event EVT in W (integer). Note that because the sensor is not considering some small or short current transitions as an event, one has:

  $$\Delta P(T) \neq P(T) - P(T_{-1}).$$

  More precisely if we designate by P_{-} the value of active power right before the event EVT then:

  $$\Delta P(T) = P(T) - P_{-}.$$

- *reactive_power_delta*: reactive power variation ΔQ of the event EVT in W (integer). The same comment as the one for active_power_delta applies here.
- *energy*: the energy metering E at the moment of the event EVT in W h (integer).
- *channel*: the channel of the event in case of a 3 phase sensor (integer). In case of a single phase sensor this value is uniformly equal to 1.
- *transient_i for* $i = 1, \ldots, 10$: the first 10 transients of the current wave of the transient state of EVT in A (float). These values characterise the transient state of an appliance switched ON.

- *fft_real _i and fft_img _i for $i = 1, \dots, 9$*: the real and imaginary part of the result of the discrete Fourier transform applied to a 1 second window located 3 seconds after EVT in mA (integer). These values characterise the steady state of the circuit after the event.

- *fft_ratio _i for $i = 1, \dots, 9$*: the module of variation of the discrete Fourier transform ΔFFT_i in mA (integer).The same comment as the one for active_power_delta applies here. More precisely, let FFT^- be the result of the FFT performed on the samples collected right before EVT and let FFT^+ be the result of the FFT performed on the samples collected in steady state. Then for $i = 1, \dots 9$:

$$\Delta FFT_i = \|FFT_i^+ - FFT_i^-\|_2.$$

  Then

$$FFTRatio_i = \frac{\Delta FFT_i}{\Delta FFT_1}$$

- *coilreversed* This boolean variable describes if the coil has been installed in the positive direction (then it is equal to TRUE) or in the negative direction then it is equal to FALSE. Note that when the value of current is very small (< 1A), the boolean value can change and is not reliable.

- *hz*: frequency of the current wave in Hz. In the case of a single phase sensor, this value is extrapolated by firmware and is either 50 or 60 Hz (integer). In the case of a 3 phase sensor, this value is measured by the firmware (float).

$$NormTransient_i = \frac{Transient_i}{\sqrt{\sum_{k=1}^{9}(Transient_k)^2}}$$