CURRENT SENSOR –
Power Line Monitoring for Energy Demand Control

1. INTENTION

Based on EnOcean STM devices the aim is to create a simple concept for a self-powered, insulated current sensor to monitor power lines. Basic requirements:

- Autonomous, isolated measurement
- Measurement range 1 to 60 A (AC)

In fact, with an STM module you cannot continuously monitor line current in the same way as with an ammeter because you can only read it at discrete moments, periodically. Therefore, knowing the exact current value at a random measurement instant (it could be a transient peak for example, or zero crossing) it would not make much sense. The only alternative is to read an effective, averaged current value or even only to sense if a current flows or not.

2. CHALLANGE

An AC line usually works at 50/60 Hz, meaning that the sinusoidal voltage varies within about 10 ms between zero and peak. On the other side, the drawn current will not usually have even a sinusoidal waveform (think of the modern switch-mode power supplies in so many consumer devices or of ballasts). Beside, due to external sources of interference the waveforms can be even more "dirty". As result, except for very simple loads, the waveform of the current drawn by a load does not resemble the voltage waveform. Besides phase shift and power factor, current flows in pulses, causing different harmonics and sub-harmonics in the power line.

On the other hand, the STM device can monitor the current only periodically, and the measurement time is typically limited to 2 ms, for energy budget reasons. STM and its additional circuitry have therefore no time to "form" or read an "averaged" current value. This would result in randomly different current values, depending on the individual sampling time within any mains period of about 20 ms (corresponding to 50 Hz.)

One way of avoiding this, is to measure a ready integrated and averaged effective value delivered by a self-powered current transducer for example. The same monitored line should also safely deliver the (low) power needed for the current sensor itself.

As described in following a wireless transmitter is powered by a current transducer to measure and send the current values every time current flows.

3. SOLUTION – USING A SELF-POWERED CURRENT TRANSDUCER

The only suitable, passive ultra-low-power or self-powered current sensor is a current transducer (CT). CTs are generally used to measure AC amperage in electrical circuits. They are accurate, safe, easy to implement and reliable in tough environmental and thermal conditions. CTs are installed insulated around an energized conductor and sense the magnetic field generated by the primary current flowing in the circuit. Unlike other transducers, the primary winding current in a CT is independent of the secondary winding load. This primary winding current depends only on the circuit into which the primary winding is connected. The idea is not new.

For example, a self-powered current transducer can also be loaded with a LED as a discrete current indicator to monitor the circuit condition in a remote location. When the remote circuit current flows, the current transducer will generate enough "harvested" current to illuminate a LED, which indicates the current flowing. When the remote current ceases to flow, the LED turns off. Such solutions are also available on the market (e.g. LCS10T12 AC Current Go/No Go Indicator from ABB).

4. DESIGNING A DISCRETE LINE-POWERED ENERGY HARVESTER

In the home wall distribution box you usually have access to the central wire you want to monitor but no light, for example, to use standard solar panel as a means of powering your STM device. The following circuitry concept uses a second, low-cost 50/60 Hz CT as an external current source. A burden resistor (very important) to convert the current into voltage, a voltage limiter, a rectifier circuit and some additional components to generate a continuous, filtered output voltage between about 3 and 4 V to power the transmitter module as soon as the monitored current exceeds 1 A for example, are additional required.

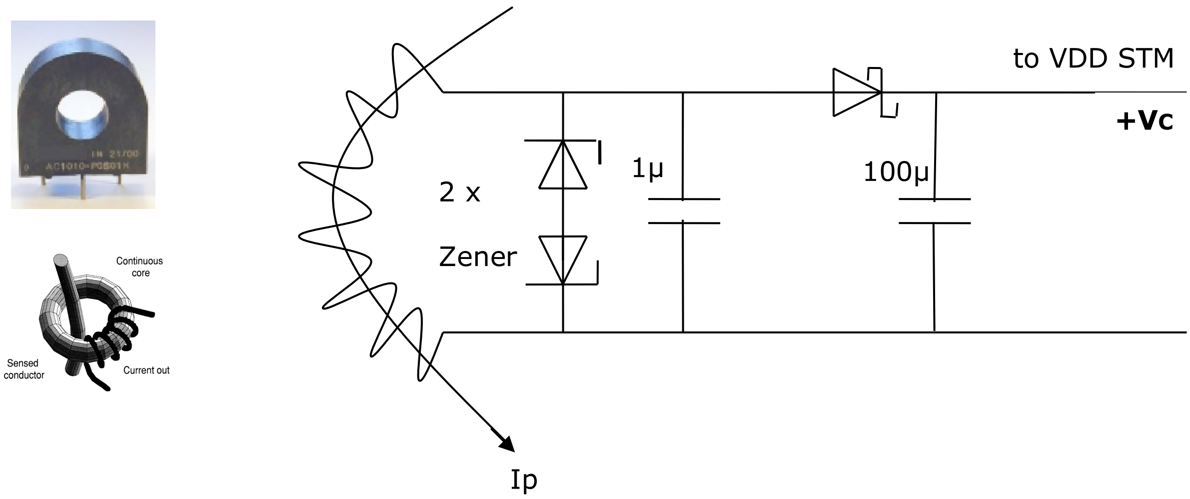

Fig. 1: Energy harvester concept

Select a discrete CT type with an opening size large enough to fit around the single monitored wire, and that could deliver at least 2 V/A @5 kΩ load, e.g. AC1005 from Talema. The CT output (V/A) can be increased or decreased linearly over quite a wide range by adjusting the burden resistor (current sink) value.

Since CTs are current transducers, a burden resistor is required to convert the output current into an appropriate voltage level. The CT rectified output voltage (+Vc) should be limited to around 4 V for instance (< max. rated supply voltage for the STM). According to manufacturer's data sheets and assuming a minimum of 2.6 V as the secondary output DC voltage at the minimum primary current of 1 A, the burden resistor would be Ro = 5 to 10 kΩ. Low-drop Schottky diodes should be used as a rectifier. To prevent any damage caused by over current, an additional overvoltage protection circuit like two 3V3/0.5 W Zener diodes shown above are used. Alternatively, use the VDDLIM path of STM 300 therefore (connected to VDD it can sink up to 50 mA current, limiting potential overvoltage). In this case, the burden resistor is no longer necessary.

If the intention is only to send a Go/No Go signal, this current transducer working as an energy harvester would be enough to power the STM to send a message periodically every time and as long as a primary current > e.g. 1 A flows. For current value monitoring however a second current transducer acting as a sensor as shown below is additionally needed.

5. CURRENT MEASUREMENT, FIRST APPROACH (P&P, PREFERRED SOLUTION)

Fig. 2: Current Transducer (CT)

Use a ready available "calibrated" device, e.g. H922 from Flex-Core (Fig. 2) as a current transducer.

The H922 is a low-cost, self-powered current transducer with switch-selected 30, 60 or 120 A settings and integrated electronic circuitry. It uses swing-open jaws to clamp round a current-carrying wire. Note that only one wire must be used for current measurement.

This transducer is manufactured by Flex-Core and further specifications can be found under http://www.flex-core.com.

Some manufacturer specifications

The mentioned transducer requires no external power supply; the device is "parasitical" powered from the monitored line current through its integrated current transformer.

- Range: 0 to 30, 60, 120 A, switch-selected (H922)
- Output: 0 to 5 Vdc, proportionally to primary current
- Accuracy: better ±2% or ±1% FS
- Size: 2.9 x 2.58 x 1.04 in (LxWxH)
- Approvals: UL listed E150462

The delivered output voltage between 0 and 5 Vdc is available as long as the primary current flows and it only needs to be divided by 3 (i.e. about 0 to 1.7 V range) and applied at the STM AD input. This will detect the current flow and its changes and transmit the information. An overvoltage protection, realized e.g. by two 3V3 Zener diodes connected between the corresponding STM AD input and GND, see Fig. 1 is recommended in order to prevent any damage. Additional protection could be provided by STM 3xx device itself, through connecting VDDLIM and VDD together.

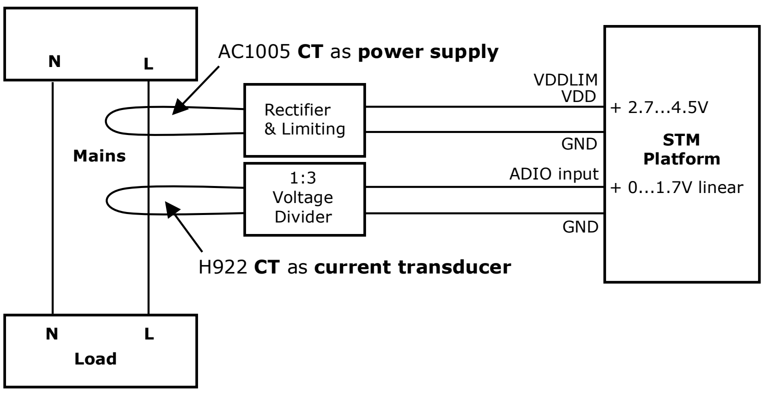

Fig. 3: Principle of Current Sensor

Caution! A CT should never be open-circuited while main current is passing through the primary winding. If the load (burden resistor or overvoltage protection) is removed from the secondary winding while the main circuit current is flowing, the flux in the core shoots up to a high level and a very high voltage appears across the open secondary circuit. Due to the high turns ratio usually found in these transformers (e.g. 1:1000), the voltage can reach under this condition a dangerously high level, which can break down the insulation and damage the circuitry. It also becomes a hazard to personnel. It is strongly recommended to put a "short" or other overvoltage limitation device on the secondary winding before removing the secondary load while the main current is flowing through the primary winding.

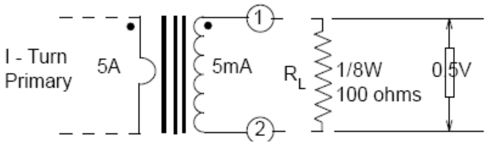

Fig. 4: CT Equivalent Schematic

Some Notes about CTs

Current transducers provide a simple, low-cost, nevertheless accurate method of sensing current flow in power conductors. They are available mostly in two basic configurations:

- Ring-core CTs with holes (power conductor-opening size).
- Split-core CTs have one end removable so that the load conductor or bus bar does not have to be disconnected in order to insert the CT.

The ring-core style is the most readily used core geometry for current transducer application. There is no air gap in the core, so the magnetizing current will always be small. Ring-core geometry fits perfectly with flux flow in the core; therefore, the core material can be utilized efficiently giving you a small core and small core loss as a result. They are the primary choice for new installations. However, to retrofit an existing installation, a split-core style could be the better alternative. Split-core CTs are very popular and suitable for fast retrofitting. The split-core CT is smaller than the clamp-on probe style CT and is considerably less expensive. It works best in a crowded electrical panel where space is often limited.