Setting the Standard for Automation™

ISA100.18
Power Sources Working Group

Energy Harvesting 2011

Feb 7th 2011

Standards
Certification
Education & Training
Publishing
Conferences & Exhibits

Introduction

- Energy Harvesting companies discussed need for standards to promote the EH industry
  - Enable rational decisions on power source selection
  - Stop wild claims
  - Meet key end user requirements
  - Facilitate adoption by systems integrators
  - Interchangeability
- Looked at several possible “homes”
- Selected ISA
  - Open process
  - End User driven
  - Public Meetings and No fees to join
- Aim is to be inclusive of all relevant wireless protocols

Mission

The ISA100.ps Working Group mission is to develop standards to enable users and suppliers to compare, specify and interface power/energy sources for “non line powered, low power, wireless sensor nodes (WSN)”.

- **Objectives:**
  - –Develop and Publish standards that permit interchangeability of Power Modules for WSN’s.
  - –Develop and publish standards for specifying performance of power/energy sources

Scope of Work

The Power Sources WG will provide informative guidelines and standards for interfaces and the test, comparison, and compatibility of various autonomous power sources with various classes of low power wireless devices used in industrial settings. Power sources in this context could include but are not restricted to Energy Storage devices (such as batteries and fuel cells), Energy Harvesting sources (such as vibration, thermal and solar) and mains power sources including transmitted power.

As a natural outcome of this effort this group may make recommendations for existing standards and recommended practices which will aid in the compatibility and better utilization of existing power sources. The goal of this effort being to provide the necessary resources such that available energy is not the limiting factor in device mission time.

Specific work is likely to include

- Test criteria and comparisons of Power Source performances
- Use in/with wireless sensors in industrial settings
- Process sensors, RTLS devices, discrete sensors, machinery sensors
- Low power (order 1 mW P_{av}), long lifetime use cases
- End nodes, and maybe routers, but less on gateways
- Requirements of low power wireless systems such as ISA100.11a, WirelessHART™, ZigBee®, etc
- To determine and recommend any desirable changes to those standards to improve operating power performance
- Energy harvesting including Thermal, Solar, Vibration, Chemical, RF / EM fields, and others
- Energy storage mode applications include short and long term
- Lexicon
- Primary & secondary batteries and fuel cells
- Power Management systems
- Signal protocols, input=WSN, output=PS
- Mechanical and electrical interfaces

Deliverable

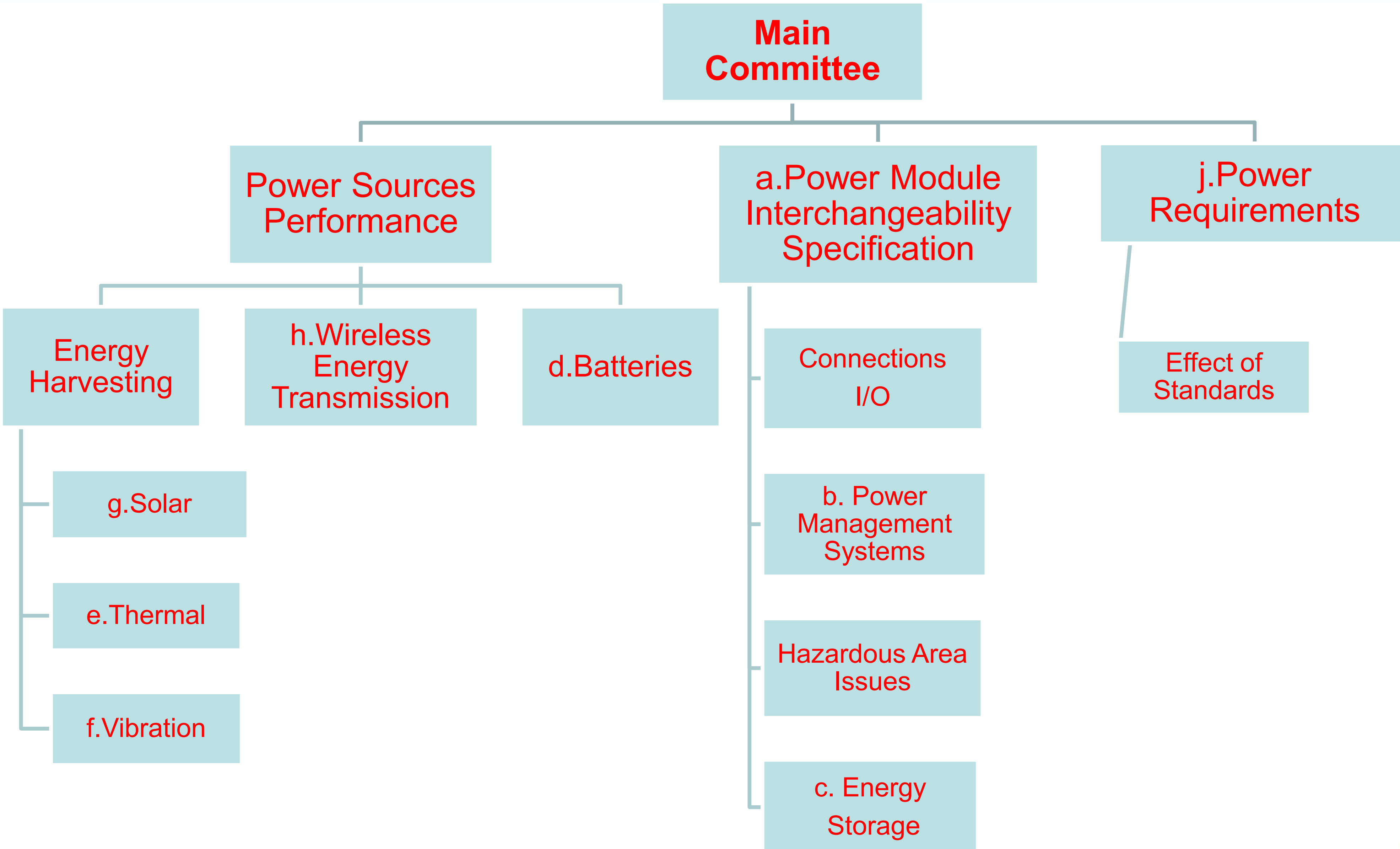
Descriptive standard documents on how to write:

- Power sources output performance documentation for PS supplier data sheets
- Power sources input requirements documentation for WSN supplier data sheets

Prescriptive standard documents that bring:

- Power module *interchangeability* *(at the connector interface)*: documents that ensure that a Wireless Sensor Device from supplier A can be powered with either a thermal, vibration, EM, solar or primary cell battery from B, C, D, E or F.

Working Group Structure



Use Cases

PART 1 – Generic

It has been proposed that standards for Power Sources should be based on 3 use cases.

The Use Cases are based on the average power typically consumed by Wireless Sensor Nodes to power the sensors, microprocessors, RF transceivers and other electronics typically used in Wireless Sensor Nodes using **802.15.4 (eg ISA100.11a, WirelessHART, Zigbee, 6LowPan,) and other low power wireless systems such as 802.15.1 and 802.11.**

The preliminary suggestion is that the three use cases should cover typical **low, medium and high power** requirements. The considerable variation in power used by different systems and sensors and by different reporting frequencies results in a wide range of power requirements. However it is believed that these use cases will cover the range of average power requirements of most systems currently being deployed.

The proposed use cases are average power consumption of

Case A 0.3mW

Case B 1.0mW

Case C 25mW

Battery Life Comparison for typical Lithium Thionyl Chloride Cells

A “D” cell in Use Case C (25mW) will last about 4 months

A “C” cell in Use Case B (1.0mW) will last about 3 years

“AA” Cell in Use Case A (0.3mW) will last about 3 years.

Use Cases

PART 2 – Example Wireless Sensor Application use cases

Following list of narratives outlines envisaged target use of energy harvester powered wireless sensors.

1. Machine condition monitoring, wireless sensors – vibration powered - industrial processing plants like oil & gas processing facilities or wastewater plants can benefit from on-line monitoring of rotating equipment: machinery wear from bearings, gearboxes, misalignment etc. Batteries would last a year or so, so would demand regular replacement that may be cost prohibitive. Vibration levels of > 20 mg can be used as alternative to battery power.
2. Thermal harvesting for process instruments – heat flux powered – industrial processing plants, sensors for temperature, pressure, flow, level can be made battery-less, so that their lifetime spans several decades.
3. Sealed for life, embedded for life wireless sensors – it is unpractical, and often infeasible to swap batteries is wireless sensor nodes that sit deep inside machines in nuclear power plants, submarines, on aircraft, on offshore rigs, at sea beds, or subsurface. Thermal, vibration and RF powered sensors enable battery-less solutions with near infinite lifetimes.
4. EM harvesting – high voltage and high current electrical power distribution systems can benefit from easily clamped on, non-contact current, voltage, frequency, temperature, phase measuring wireless sensors. Batteries can be eliminated if clamp-on transformers or capacitive coupled scavenging methods are used to power the wireless sensors.
5. RF harvesting – emerging technology that captures and stores high frequency electromagnetic waves so that sensors that employ an IEEE 802.15.4 radio can be powered.
6. Marine seabed harvesting, solar panels, wave energy, ocean currents, wind, electrochemical active algae, tapping of impressed current cathodic protection voltages – are examples of energy sources that can all be exploited to deliver power supplied to wireless sensor nodes.
7. Mesh repeater-router, ZigBee FFD – range extender for wireless mesh network, typically needs more power than leaf sensor nodes (often sleepy, hence Case A), does not have a sensor necessarily (more Case B,C). Could be solar cell powered, sit on a lamppost, or inside luminaries.

Use Cases

PART 3 – Primary batteries for Wireless Sensors use case

Emerging industrial wireless sensors typically use Li-$SOCl_2$ (Li-Thionyl) cells, but each vendor has picked his own cell size, or sometimes made dedicated proprietary battery packs. This leads to unnecessary cost and complexity for users that may want to use more than one vendor's products. Goal thus is to standardize shape, size, capacity, safety and all other relevant electrical and mechanical and safety parameters so that eventually one type of battery fits into any instrument, and so that battery lifetime remains predictable, consistent and comparable – while allowing for freedom and fair open level playing field for battery suppliers.

Use Cases

PART 3 – Primary batteries concerns

From http://en.wikipedia.org/wiki/Lithium_battery

Thionyl chloride	Lithium tetrachloroaluminate in thionyl chloride	3.5 V	3.65 V	290	670

Li-$SOCl_2$	Liquid cathode. For low temperature applications. Can operate down to -55 °C, where it retains over 50% of its rated capacity. Negligible amount of gas generated in nominal use, limited amount under abuse. Has relatively high internal impedance and limited short-circuit current. High energy density, about 500 Wh/kg. Toxic. Electrolyte reacts with water. Low-current cells used for portable electronics and memory backup. High-current cells used in military applications. In long storage forms passivation layer on anode, which may lead to temporary voltage delay when put into service. High cost and safety concerns limit use in civilian applications. Can explode when shorted. Underwriters Laboratories require trained technician for replacement of these batteries. Hazardous waste, Class 9 Hazmat shipment.[2]

Result and Analysis
- Examples of Implementation

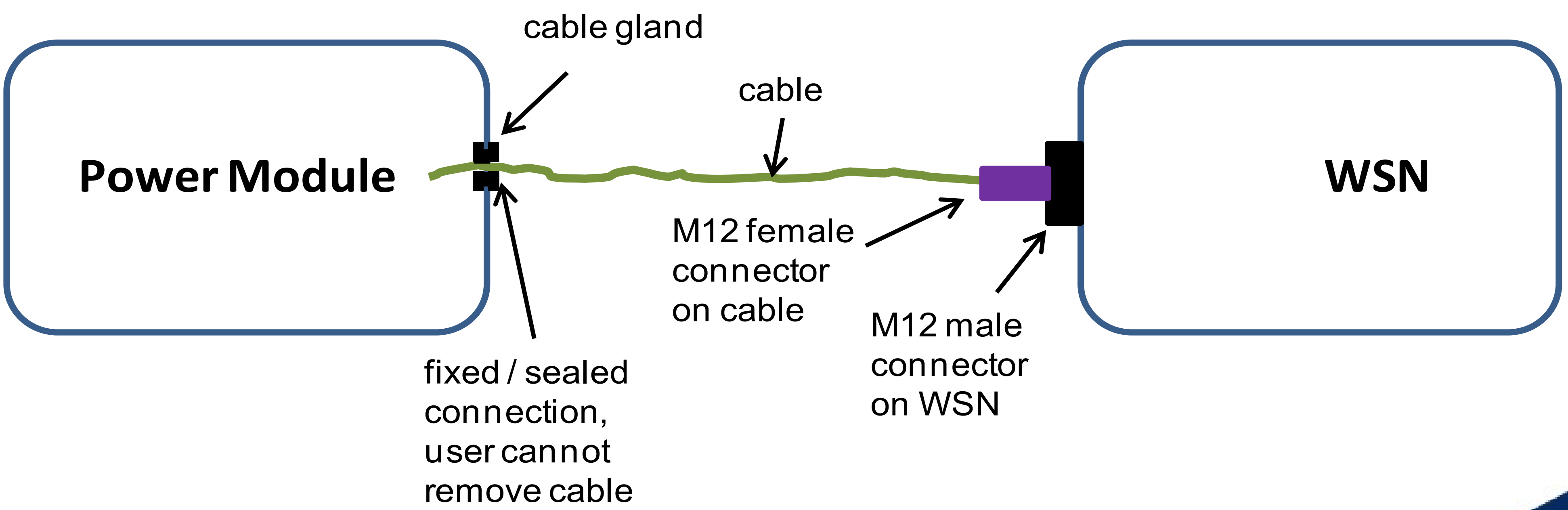
Conditions	Thermal	Vibration	Solar
Harvester	**Peltier** 0.18% (Efficiency) $14cm^2$ *2pcs Heat-sink 40 x 100 x 110 mm 780 cm^2 (Surface)	**Electro magnetic induction** 655g Φ55 x 55(h) mm	**Mono crystal silicon** 15% (Efficiency) 40 cm^2 (Cell size)
Energy Source	Heat source: 70 degC Ambient: 25 degC ΔT: 10 degC	100 Hz 1.0 G 50 µm p-p	Rainy weather 20,000 lx 20 mW/cm^2
Output Power	**43 mW** @0.5 V	**29 mW** @3 V	**55 mW** @3 V

Power harvesting for wireless sensor is feasible in principle

Use Case C 25mW for the target power

ISA100 WG18 Connector Subgroup
Draft Proposal ©ISA *EXTRACT 1*

- **Mechanical Details**
- Standard shall accommodate a variety of connection options including connectors on either or both ends of the cable connecting external power source to WSN or a flying lead connection to either or both end. These options are described in the five options below, Figures 1-5.



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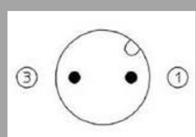
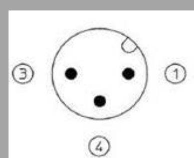
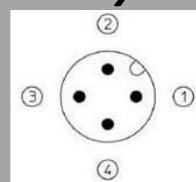
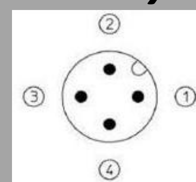
Electrical Details

Cabling between external power module and WSN shall comply with standard conductor color specification as shown below.

	IEC 61076-2-101 M12 A-Coded Connector[NOTE 1]				Flying-Lead Interface			
Signal	***2-Way*** 	***3-Way v1*** 	***3-Way v2*** 	***4-Way*** 	***2-Way***	***3-Way v1***	***3-Way v2***[NOTE2]	***4-Way***
Ground	Pin 1	Pin 1	Pin 1	Pin 1	Black	Black	Black	Black
Comm			Pin 2	Pin 2			Orange	Orange
Power	Pin 3	Pin 3	Pin 3	Pin 3	Brown	Brown	Brown	Brown
Sense		Pin 4		Pin 4		Red		Red

Pin 1 Ground

Black in color.

Pin 3 DC Power (positive)

Brown in color. Non-regulated, DC, voltage limited output. Upper voltage limit specified with tolerance. Power provided may be nominal 5VDC (for a nominal single, 3.6V cell battery load) or 8VDC (for a nominal dual, 3.6V cell battery load). Power module must provide a voltage above the nominal operating voltage in order to charge an intermediate energy storage capacity sufficient to power the device during high- power cycles.

ISA100 WG18 Connector Subgroup
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- **Communications Details**
- Pin 2, Digital Communications Interface intended to provide static and dynamic information from external power module, where applicable. Power module and WSN shall not be precluded from writing to the TEDS memory if technically feasible within the arrangement shown.
- Digital interface shall be powered by the WSN device.
- Digital interface shall be compliant with IEEE 1451.4, Class 2, according a To-Be-Defined Energy Harvester template under the IEEE 1451 standard. (Note: Work to define an Energy Harvester TEDS will be undertaken by ISA100.18 in parallel with review of this specification)
- External Power Source manufacturer shall be responsible for registering IEEE manufacturer ID and any associated fees.
- Maxim DS 2431 recommended as onboard memory chip for TEDS.

Conclusions

- Industrial Wireless Standards nearly ready
  - End Users want ISA100.11a and WirelessHART convergence
- WSN's need Energy Harvesters
  - Peter Harrop, IDTechEx – "90% of WSN's will need Energy Harvesting"
  - Dan Huber, ABB "The success of wireless will depend on wireless power supplies"
  - Oil Companies "We will trial wireless with batteries but volume roll out needs a solution to power"
- Energy Harvester suppliers need to demonstrate
  - Meeting user requirements
  - Performance is properly specified and comparable
  - Different Harvesters and Power Sources are readily interchangeable
- ISA100.18 is working on standards to achieve this

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