Improvements in Power Efficiency and Energy Storage for Energy Harvesters

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ENERGYMAN Project

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- TSB Funded : “Energy Harvesting for Autonomous Sensing”
- Address two inter-related critical areas of managing energy extraction and storage to achieve sufficient available energy for more applications
- Existing systems are both inefficient and impractical.
  - Limitations in the charge/discharge cycle life, storage life , capacity, leakage and temperature range of available energy storage devices.
  - Many situations where vibration energy is either variable frequency and low level (industrial motors), or high amplitude and stochastic(rail)
- Objectives
  - Improvements in power output from vibration harvester systems in industrial and rail applications by developing
    - novel designs in power management
    - novel energy storage

    to achieve the higher levels of energy required.

Perpetuum Overview

- Rail Systems powered by Vibration Energy Harvesters
  - More power for greater functionality e.g. gearbox, track monitoring
  - More power for freight for Communications
- Energy Harvesters and Power Modules for Industrial applications
  - More power for higher reporting rates for vibration monitoring
  - Greater machine coverage

Performance Assessment

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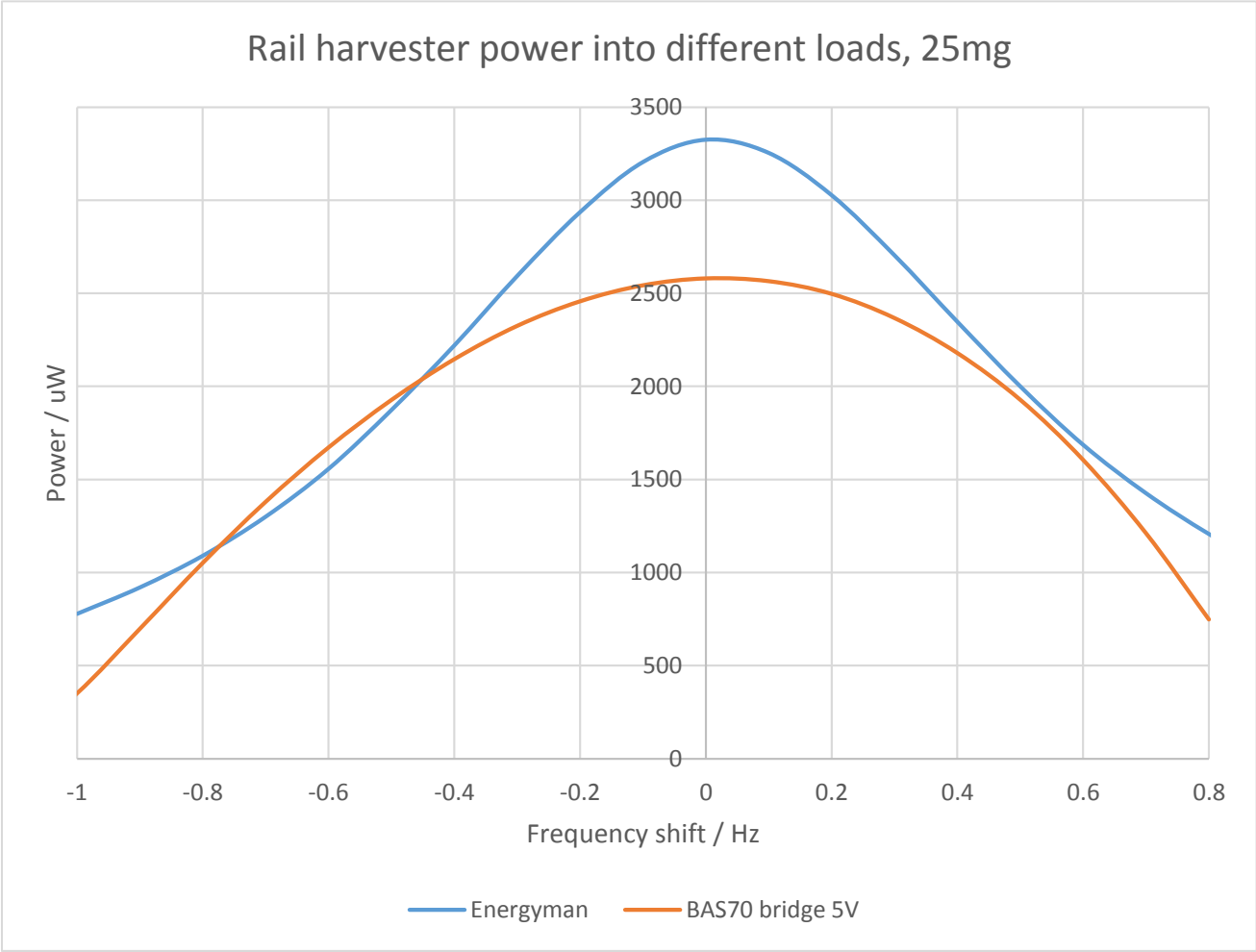
Intermediate assessment of early approach to boost convertor design.

Curve shows response at resonance.

30% power increase



New Design - Coil

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- Fewer turns on harvester coil:
  - lower coil resistance
  - much more robust coil
  - possibly cheaper to produce
- BUT:
  - Rectifier diode bridge forward voltage drop becomes more significant
  - Could lose half the available input ac voltage from the harvester
- SO:
  - Very low power active rectifier circuit needed
  - Precision Shunt Regulator

Energy Storage

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- "Hybrid Layer Capacitor" (lithium rechargeable) –
  - Supercaps - limited lifetime, especially at high temperatures
  - HLC - much better performance/lifetime at high temperatures
    - acceptable performance at low temperatures
  - HLC 25 year lifetime
  - HLC - 45 X the amount of energy of the electrolytic capacitor bank for volume
  - HLC Limitations are that
    - Cannot be charged higher than 3.9V
    - Cannot be allowed to discharge below 2.5V (permanent damage will result). Solution needed.

New Design Results

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- What has been achieved:
- 10-40 x energy storage/volume
- 30-40% power improvement
- More robust Harvester coil

ENERGYMAN Results

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- Project successful in achieving two key objectives
  - Increased Energy Storage
  - Increased power output
- Both are important for product/application evolution
  - IPM for Emerson Vibration Monitor
  - New Rail systems (Gearbox/Motor/ Track/ Freight wagons)

Using Harvesters

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- Need to choose Energy Source (Vibration, Thermal, etc)
- Leading wireless instrumentation suppliers have chosen universal system
- Generic Energy Harvester Adapter Module – GEHAM
- Enables Plug and Play Interchangeability:
  - Vibration Harvester
  - Thermal Harvester
  - Solar etc.
  - 24V DC

Battery Pack to IPM - Emerson

Standard OEM Battery Module

GEHAM Circuit

Integrate GEHAM into OEM Battery Module

Intelligent Power Module (IPM)

- Wide range of input voltage levels: 8V – 24V.
- Integrated robust capacitive storage for duty cycle
- Intelligent Power Management circuitry
- Hazardous Zone 0, Class 1 Division 1
- Same form, fit & function as original OEM battery module
- Reduce or eliminate battery change costs & logistics
- Add energy harvesting now or later

Example GEHAM: Emerson IPM

- Emerson Intelligent Power Module accepts
  - Perpetuum Vibration Harvester
  - Micropelt Thermal Harvester
  - Perpetua Thermal Harvester
  - 24V DC
- Others to be added
- ATEX, IECEx, FM approved
  - (Not all power sources)

Honeywell Power Module

- Allows much faster update rates and extends battery life
- Replaces the standard IS Battery Pack in Honeywell XYR 6000 transmitters
- Accepts many external power sources
- Batteries included as normal pack but only necessary for network joining
- Internal energy storage capacitor powers normal radio transmissions
- ATEX, IECEx, FM approved
  - Baseefa13ATEX0063X / IECExBAS 13.0037X

GE Insight.mesh

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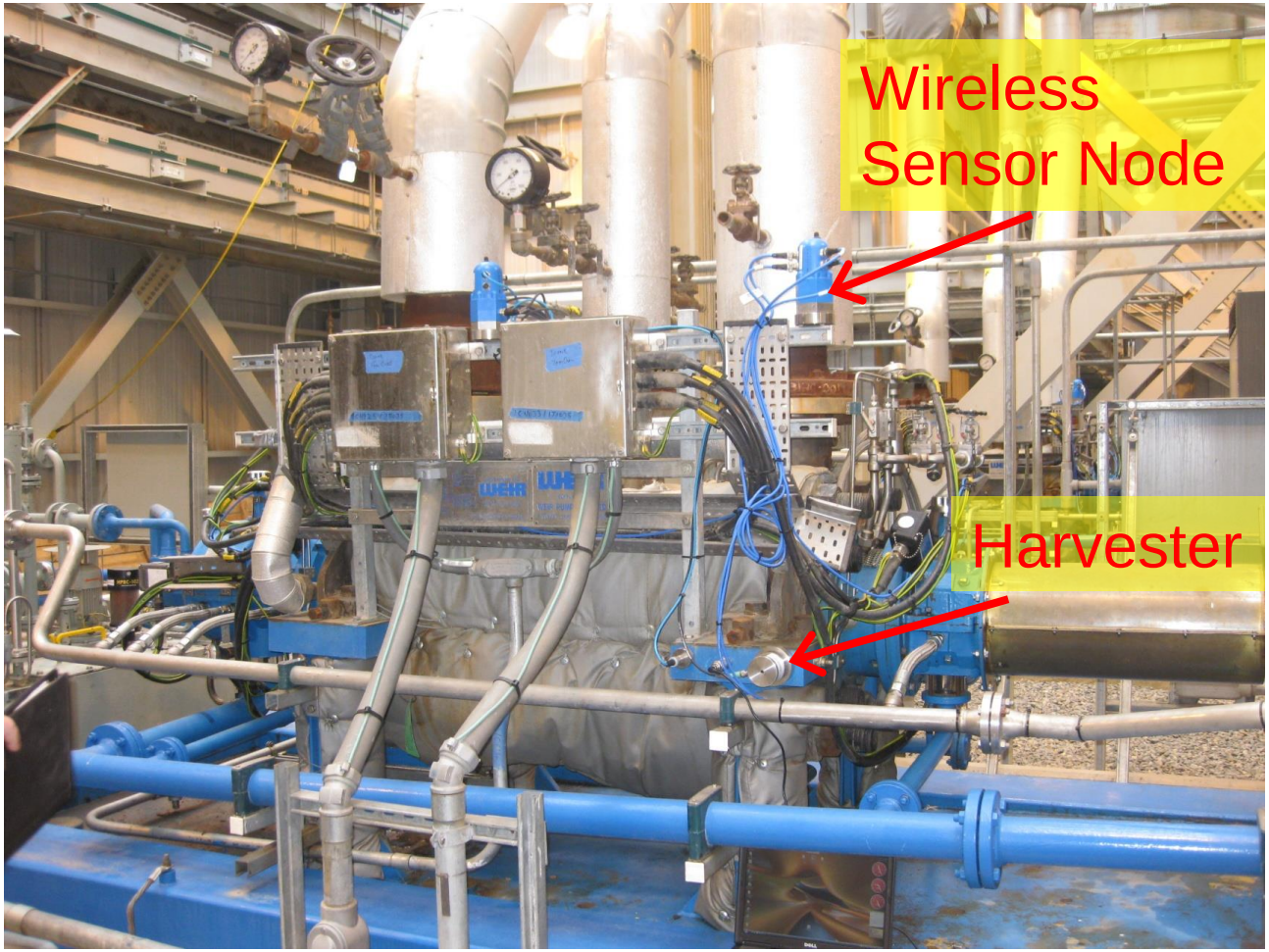

GEHAM designed into WSN Body

Energy Harvesters

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- Perpetuum Energy Harvester on suitable vibration source
  - Extends battery life to >10years
  - Allows 4 second transmitter update rate
- Fully certified (Zone 0)
- Very high reliability
- Simple connection to Power Module
- Batteries still available to power normally
- Emerson and Honeywell Power Modules and GE Insight.mesh will **also** accept
  - Thermal Harvesters eg Micropelt, Perpetua
  - DC Power up to 20V
  - Other suitable types of Energy Harvester

Process Plant using GEHAM's

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Oxea and Firestone

ENERGYMAN Progress

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- Existing IPM's are fine for WSN's with
  - Low data transmission requirements
  - High frequency reporting
  - Pressure, Temperature, Flow
  - GE High data/low frequency with batches
- Vibration Monitors (e.g. Emerson 9420, Perpetuum Rail) require
  - Much higher energy to transmit large data volumes
  - Some Applications – near continuous sensing/processing
- ENERGYMAN Project
  - much greater storage capacity
  - more power from Harvester.