Objectives and contributions

# Objectives

This work is focused on measuring the energy flows in the railway system

The aim of this work is to improve the energy efficiency in the railway transportation system (RTS) and reduce the maintenance cost of RTS power systems.

The implementation of smart meters (SM) in RTS promote a better overview of power flow and, based on the information of SM, algorithms focusing on energy efficiency can be implemented.

The SM requires sensors such as voltage and current sensors. The level of intrusion as well as the level of electric <<valor da grandeza electrica>> of such sensors implies considerable costs of the sensors.

Therefore, the implementation of complex processing on smart meters is of added value. This complex processing can be the implementation of fault monitoring algorithms in SM based on the energy measurements.

Framed in the shif2rail, the work is focused on the implementation of a smart meter demonstrator for the RTS. To embrace the entire railway system, the power flow should consider the energy flux from and to the catenary. Therefore, the key point should be the measurement of the energy in the **traction substations** and in the train **power transformer**

Based on this thesis proposal, the objectives are the following:

1. Research on high-voltage and high-current measurement systems
2. Research of train power transformer and implementation of a simulation model of a train power transformer.
3. Development and implementation of a measuring system with high acquisition and processing capabilities.
4. Research on communication systems and development of a network model in a simulation environment.
5. Research, development and implementation of a fault monitoring system.
6. Research, development and implementation of an energy flow monitoring system.
7. Implementation and validation of SM in a pilot project through real tests.

# Contributions

1. Increase of energy flow information of RTS
2. Reduction of transmission costs of information (no need of LTE, the data are concentrated and transmitted from trains to stations, during passenger exchange, with a high throughput link)
3. Decrease of the Life Cycle Cost (LCC) of

State of the art

# Section 1: Smart metering

1. Smart grids and the need for smart meters
2. Metering systems – overview
3. Metering systems in railways
4. Wireless sensor networks – overview
5. Smart metering with WSN in Railway Transportation System (RTS)

# Section 2: Wireless networks

1. Network technologies – historic overview
2. Current technologies
3. Emerging technologies and standards
4. Network simulators

# Section 3: Energy sensors

1. Sensor overview – historic perspective
2. Current transducers and voltage transducers
   1. Commonly used technologies and principles
   2. New breakthroughs
3. High power measurement challenges in RTS
4. Energy measurement technologies in RTS

# Section 4: Power system of RTS

1. Overview of existing worldwide power systems
2. Overview in the perspective of production-distribution-consumption
   1. Traction substation (Production)
   2. Catenary (Distribution line)
   3. Rolling stock (Consumption/load)
3. Traction substation transformer overview
4. Catenary (?)
5. Train power transformer
6. Train motor and power converter
7. Auxiliary loads

# Section 5: Decision Support Systems (DSS)

1. Overview/definition
2. Eco-driving – driving assistant
3. Timetable scheduling
4. Maintenance support

# Section 6: Outlier detection in RTS energy measurement

1. Definition of outlier detection in RTS energy measurement perspective
2. Literature review of Outlier detection in WSN
   1. Motivation
   2. Research areas
   3. Challenges
3. Taxonomy of outlier detection techniques
   1. Classification based
   2. Statistical based
   3. NN-based
   4. Clustering based
   5. Spectral decomposition-based

Methodology and work plan

Note: not in chronological order

# RTS wireless network

1. **Purpose**: model and simulate a WSN for energy measurement of RTS rolling stock, with an advanced network infrastructure (englobing both train WSN and station AP’s)
2. **Contribution**: An energy measurement system in rolling stock does not require a broadband real-time/continuous communication (such as LTE), being possible to collect and store data in train data concentrator and, while the train is waiting at station for passenger exchange (which lasts for less than one minute), the data is transferred between train and station AP (and then to a remote server). Therefore, the contribution will be the **cost reduction of information transmission** of energy sensor network data
3. **Methodology**:
   1. Modeling of energy sensor network of rolling stock: sensor nodes and data concentrator
   2. Modeling of infrastructure: train concentrators, station AP, station data “buffer” and station internet connection
   3. Implementation in simulation environment of such models, using NS3 simulator or similar
   4. Definition of “sensor data rate” as function of the line length-between-stations ()

# Non-intrusive self-powered sensor node

1. **Purpose**: In the scope of Shift2Rail, is expected to develop a smart meter for railways. The purpose is to model, simulate and implement a series of sensor nodes for current measurement in the transformer´s secondary windings. Assuming that the railway environment requires non-intrusive measurement devices and, if possible, self-powered, a set of requirements is then identified for the sensor node:
   1. Electrically non-intrusive (using hall-effect, rogowsky or current transformer principles; without the need for mechanically changing the windings)
   2. Self powered, if the current transformer has sufficient power capabilities
   3. With high processing capabilities, high acquisition frequency and sufficient amount of memory
      1. Variable acquisition in tens of samples per second (according to the power quality standard of 15kHz <?>)
      2. Frequency analysis capability
      3. Capable of implement outlier detection algorithms
2. **Contribution**: new advanced sensor node for high current measurement
3. **Other Contribution**: given the measurement characteristics, a self powered wireless sensor node can implement features of high processing.
4. **Methodology to be defined**

# Rolling stock traction transformer model

1. **Purpose**: model the train transformer with two perspectives:
   1. Efficiency estimation based on secondary measurements
   2. Evaluation of transformer operation towards fault detection
2. **Possible contribution**: an accurate model for train transformer, capable of efficient estimation of energy consumption based on secondary windings current measurements
3. **Possible contribution**: assuming that the influence of transformer in the power life cycle cost is relevant (see note), the contribution will be the operation monitoring towards maintenance cost reduction.
4. **Methodology**:
   1. Study failure rates of trains/transformers
   2. Model in a simulation environment the power transformer
   3. Identify and model transformer failures
   4. Implement in sensor nodes an energy estimation mechanism based on the loss model of the transformer and sensor nodes measurements
   5. Implement in sensor nodes a frequency analysis towards operation monitoring
   6. Prepare and implement results in field operation