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Acquisition of Operational Data in Industrial Laundry Facilities

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Acquisition and continuous evaluation of the operational data is a key factor to effective course of every industrial process. Laundry care services with various process media (water, steam, natural gas, electricity, detergents, etc.) are described in this paper as a model process. Consistent measurements of these operational commodities are often neglected, as we observed in many European laundry facilities. However, no process can be evaluated and efficiently controlled on a long-term basis without operational data. Impact of changes of process parameter setting cannot be identified then, either. This paper deals with professional laundry facilities, and their technical equipment in the area of operational data acquisition. Process media which are worth monitoring are described here as well as the required measurement equipment and its integration into the process.
This paper aims to inform laundry facility operators that integration of field instrumentation into the process must be performed during the facility construction and/or reconstruction phase(s). Investments into rudimentary measurement system greatly outweigh cost of technology equipment. And advantages of data acquisition are numerous. Case study presents several options for monitoring in a laundry facility with given technology equipment, and tries to guide through the measurements.
Paper also describes a sophisticated system of measurement and data processing which may serve for detailed analysis of laundry care process. This system was designed and implemented within the scope of the NETME Centre project, Brno University of Technology, which allowed for creation of a unique facility researching laundry processes (washing, drying). A database of measuring instruments is part of this system, and allows the user to interconnect information about the measurement instruments with measured data. It makes creation of system output report much easier. We expect that the system may be applied in other industrial areas.

1. Current situation in data acquisition at industrial facilities

Rising requirements on operation of energy intensive processes push the operators to search for new savings measures. At the same time, there is a strong emphasis that any changes in the operations should be environmental friendly. Increasing number of scientific papers on energy savings proves that the topic has become subject to researchers' interest (Klemeš and Varbanov, 2013). Research papers mostly focus on efficient use of energy sources (steam, electrical energy, natural gas), and water and waste treatment.
Precise measurements of operational data using relevant methods is an integral part of any energy audit, and serves for subsequent savings measures proposals. In terms of paper processing industry, Saidur et al. (2012) and very recently Kong et al. (2013) researched this topic. Precise measurements are not conducted for the single purpose of energy audits since they also help operators of the facilities to obtain relevant information about their facilities. Main advantage of the contemporary data acquisition (DAQ) systems is the option for subsequent data processing in superordinate control systems. SCADA system provides the operator with process visualization, time-stamped data storage, and alarm notifications. The operator is then able to assess whether a particular machine is working in a standard regime, or if there has been a major accident. Enterprise Resource Planning (ERP) is another level of a control system which

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calculates operational costs, plans future purchases and evaluates total productivity of the business using consumptions of particular commodities (Wagner and Monk, 2008).
Measurements methodology must be relevant to unique properties of an individual process (Vondál and Hájek, 2013). Every process requires a specific method of data acquisition, as proved by Milfelner et al. (2005) for manufacturing technologies and by Walaszczyk and Batog (2013) for assessment of energy consumption of buildings. Measurements data are later integrated in a single database that helps to control the process on a higher-level - e.g. decision support system (Bai et al., 2014).
Industrial laundry care facility has been selected as a model process in this paper to present an up-to-date approach to data acquisition. Benefits of research of industrial laundry care services include the fact that there is a wide spectrum of operational media in the facility operations (water, electrical energy, steam, natural gas, compressed air, detergents), and specific process steps are easy to comprehend for laymen. Despite that, there have scarcely been any papers dealing with laundry care so far (Máša et al., 2013a).

2. Data measured in industrial laundry facilities

Industrial laundry facilities denote facilities which professionally process linen (washing, drying, and ironing) in large amounts (ranging from several hundreds of kilograms to several tons). A well-designed laundry data acquisition system may warn the operator about potential scaling of electrical heaters, and wear-out of motor bearings in washing machines. Both of these malfunctions are manifested via higher consumption of electrical energy. Following paragraphs summarize units which are worth measuring in individual laundry machines.

2.1 Washing machines

Washing machines represent the most important part of the whole laundry process. Water is an exclusive process medium used in washing machines, and is heated in the machine itself by default. Therefore there are several types of washing machine heating (electrical, steam, and natural gas heating). Particular meters are employed in data acquisition depending on a type of heating technology and water management system. Main units monitored in washing machines are mentioned in Table 1.
Measurements of steam are rather expensive. Therefore, consumption of natural gas burnt in steam generator/natural gas boiler is monitored instead. Contemporary industrial washing machines have an integrated advanced control unit which communicates with the computer, and informs the operator about start-up time, selected washing programme, water temperature and/or water level in the machine drum.

2.2 Dryers, ironers and finishers

Equipment for secondary processing of the linen is located in one group since their function and working media are similar. Dryers and finishers use heated air whereas ironers utilize heat-exchanging surface. Water bound in the linen interacts with air and/or heat-exchanging surface, and evaporates. In case of European laundry facilities, dryers and finishers employ natural gas heating, but steam and electrical heating are also common. Steam heating prevails in ironers. Therefore, same recommendations apply as for washing machines (Table 1). Dryers and ironers are categorized as the most energy intensive pieces of equipment in the whole laundry facility.

2.3 Specific technologies

Specific technologies concern systems for detergents dosing and systems for linen folding. Dosing of detergents uses compressed air and water distribution methods. Linen folding system is most frequently powered by electricity and pneumatic drives. Measurements of compressed air consumption are performed with specialised flow meter and/or indirectly, as in the case of steam consumption measurements. In terms of compressed air consumption, an indirect method is based on consumption of electrical energy in air compressor. Amount of detergents may be acquired by monitoring rotations of dosing pumps and/or by regular manual recordings, if the detergents are dosed manually.

Table 1: Overview of units measured in industrial washing machines

Physical quantity	Basic meter	Advanced meter
Water consumption (recycled, too)	Mechanical flow meter	Induction flow meter with pulse output
Electricity consumption	Electrometer	Electrical network analyser with communication via Modbus
Natural gas consumption	Gas meter	Gas meter with pulse output
Steam consumption	(Indirect measurement)	Orifice plate flow meter with communication via custom protocol

2.4 Monitoring of material flow as an auxiliary data source

Main purpose of weighing and identification system is to measure total amount of linen and/or to archive the detailed information of every piece and to trace the linen in process. Depending on the acquired information about the amount and type of the linen, linen is inserted into particular machines which are switched on that specific day. This is the basic control system helping the continuous flow of materials in the facility.

3. Approaches to data acquisition in laundry facilities

Although purchase costs of basic meters barely equals the purchase costs of new machinery, most European laundry facilities are not equipped with secondary measurement instruments. Following overview tries to summarize three scenarios most common in European laundry facilities.

3.1 Category I – lowest level of data acquisition

Several energy audits proved that even operators of large-scale laundry facilities try to save money on measurements instruments. Data acquisition is mostly limited to manual reading of meters once in a billing period. This provides the operator with consumptions of electrical energy, water, and natural gas only for the whole billing period, and the operator is thus forced to work with average values only. Laundry facility commonly archives at least the basic data about the processed linen. Description in the archive is restricted to information about the amount of linen (pieces, kg), and/or type of linen.

Disadvantages of this approach are obvious. There are no data about individual machines available and the operator has no information about:

- Deterioration of a particular machine due to wear-out
- Long-term load and productivity of a machine and its service personnel

On the other hand, operator does not have any expenses concerning measurements system (especially expensive up-to-date meters). There is no support of high-level control here whatsoever.

3.2 Category II – data acquisition in selected machines

Many laundry facilities, which have undergone certain kind of retrofit and/or revamping, fall into this category which means the operator usually installs secondary measurements instruments in newly purchased machines. These types of instruments usually concern gas and water flow meters which are installed in heavily used machines (key technology of operation). System of weighing and identification of linen is quite common in this category. Reading of important values is conducted manually and on daily basis. This procedure provides the operator with better understanding of the process and machines consumptions, and allows the operator to run the facility without any significant losses of energy or water and with better information about specific machines.

3.3 Category III – measurement instruments integration

This category is represented by the most advanced laundry facilities, and reference laundry facilities of worldwide manufacturers of laundry machinery. Every type of consumption (water, natural gas) of individual pieces of equipment is measured. Measurements system often consists of a data logger which acquires data, and SCADA system responsible for the visualisation. Facilities also commonly employ the RFID technology for linen identification, which is an advanced technology of contactless identification. All of this provides the operator with extensive knowledge about consumptions of the particular machines at any given time. Complex measurements system of this kind is rather expensive compared to other types of control mechanisms.

4. Measurements system in our laboratory

Research and development facilities fall into a special category. A unique laboratory researching various parts of the laundry processes, and the process as a whole as well, has been established within the scope of the NETME Centre (Máša et al., 2013b). The Laboratory of energy intensive processes has a measurement system with far wider range of measurable quantities than common laundry facilities. In addition to the consumption monitoring, there are following meters installed in our laboratory:

- Prandtl tubes, thermometers, and sensors for relative humidity at the exhaust from dryers and ironers (i.e. measuring of loss due to heat in flue gas of the machines)
- Orifice plate flow meter at the steam system inlet – measuring steam consumption
- Thermo-couples located in ironer cylinders – measuring temperature along the cylinder
- Strain gauges installed in selected machines – measuring stress state in machine design
- Conductivity sensors in washing machine drums – measuring water bath conductivity

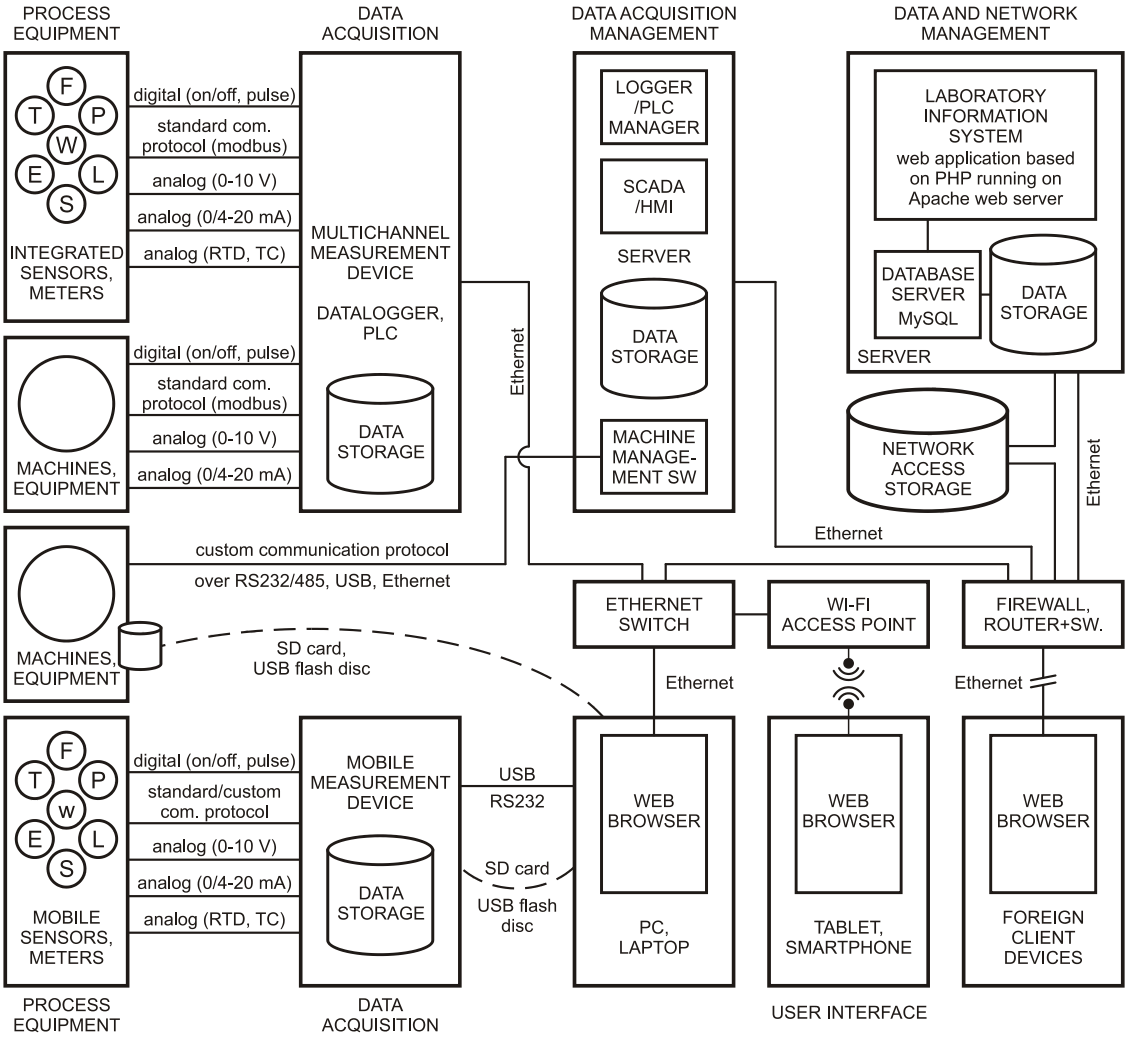

Figure 1: Topology of data acquisition and management system

In addition to specific meters, there is also a centralized data acquisition system in our laboratory. All measured units are processed in a data logger which collects data from all meters and logical signals (up to 250 signals) with 2 Hz frequency. Data acquisition automatically starts with start-up of any piece of equipment. Data logger stores the processed data into a protected database and distributes them into the SCADA system which is responsible for data visualization and subsequent data processing. Visualisation of current data is a great feature of the process control as it allows the service personnel to prevent any emergencies or at least deal with them quickly. SCADA system is interconnected with a PHP application which processes commands from a web user-interface. Service personnel are thus equipped with current information at any given time. Web application allows to control the process and its history, and further process the data in portable computers, tablets and touch screens which may serve as a communication interface for the service personnel. System of linen weighing and identification is integrated into this system. Information about each piece of linen is interconnected with information about consumption and conditions. Therefore, every piece of linen has its history stored. Collecting of data from multiple sources into one database is the biggest contribution to the measurement system development. Availability of every type of data in single place makes the whole system user friendly and well-arranged. Topology of data acquisition and management system in our laboratory is shown on Figure 1.

Advantages of this system follow

- Complete overview about current situation in the facility and current consumptions
- Prevention of accidents and mitigation of their impact
- Strengthening of superior level of process control, e.g. ERP systems

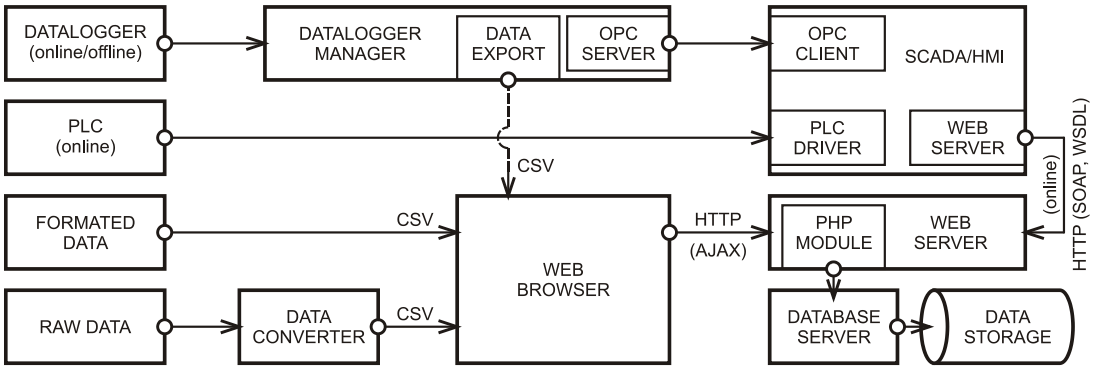

Figure 2: Collecting of measured data in central database (data flow)

As indicated earlier, data acquisition system consists of hardware and software parts. It is primarily a software part, which makes the system unique. Detailed overview of the software solution is shown on Figure 2. Individual parts of data acquisition and management system are usually not compatible with each other. Special PHP application is needed to convert different types of data and save them in one database.

5. Meters database

New feature of the system with a great application potential is the meter database. Sophisticated measurements and acquisition of large volumes of data requires efficient processing of information about particular measurement instruments. Measured values are worthless unless they are measured with meters with a proper range, at a satisfactory temperature, relevant sampling and under other necessary conditions. Laboratories and large-scale industrial laundry facilities work with dozens of measurement instruments. Therefore it is beneficial to create a system to interconnect the measured data with information about the relevant meters.

Laboratory of energy intensive processes employs a combination of MySQL and PHP applications database. Results are processed as a web interface available in any computer connected to the Internet. Particular database session contains information directly linked to the measurement (units, measurement error, measurement range, sampling, etc.) and information about suppliers and manufacturers, complete technical specifications and equipment model designation, too. The database presents expected results: easy handling of data, quick search, random sorting and categorization, and information about technical, service, and warranty supports. Database together with advanced system of data acquisition support ERP (enterprise resource planning), as described by Chofreh et al. (2014). Creation of a sophisticated ERP system for a laundry facility is the key task for the future research.

Advantage of meters database is the interconnection of the database with facility loggers of individual pieces of equipment, and with loggers of individual pieces of linen. This helps analyse the acquired data and easily create output reports. There is no need to process the data, search and enter the relevant information manually.

6. Conclusion

Data acquisition and processing in industrial laundry facilities is a specific task requiring specific procedures, measurement instruments, and systems. Thorough integration of the measurement system results in energy savings and provides the operator with the option to monitor the operations in great detail and thus optimize the facility (e.g. via replacement of existing machinery with new technologies). The most important contribution to the smooth running of the facility is the ability to solve problems proactively. Additional system may evaluate impending failure based on comparison of long-term trends and current data. Innovative measurement system and data processing presented here is a guide for the operators describing how to monitor the facilities. Connection of several database systems brings great potential for business growth and development (in terms of energy intensity and service quality). In addition to that, the operator has all necessary information readily available, anywhere and anytime.

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