IIoT environment and multi criteria decision making systems

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Abstract — This paper describes the design and development of a LabVIEW based SCADA (Supervisory Control and Data Acquisition) for temperature control system using the features of the Industry 4.0 standard. Remote monitoring and control of industrial processes is the need of today’s automation industry. SCADA system is useful in monitoring, controlling and accessing the performance of remotely situated systems by acquiring and controlling the physical parameters such as temperature, humidity, level etc. Data communication is achieved using the popular Modbus and onewire protocol. Various features like database, data logging, secured login, waveform graphs, trends, history and multi-user functionality are also incorporated. The developed system will be an independent tool since LabVIEW supports the generation of executable file which can practically run on any computer without having LabVIEW software package. Sensors monitoring the operating temperature in mechanical components of the IoT based device can track any abnormalities or deviations from an established baseline to proactively address undesired behavior as predictive maintenance before crippling system failures.

Keywords – Cloud computing, Industry 4.0, Internet of Things, FAHP.

I. INTRODUCTION

The IoT (Internet of Things) is one of the major factors in new communicative and interactive developments. With the concept of Industry 4.0 spreading from its German origins across the world, it is worth examining the extent to which Industry 4.0 and the Internet of Things are connected. The concept of the Internet of Things dates back to 1999 and was coined by British technology pioneer Kevin Ashton. Physical objects are made “smart” by connecting them to the Internet utilizing ubiquitous sensors; a factor leading to the gradual replacement of conventional computers and major changes in, amongst other areas, everyday life[1][3][4]. The IoT will also have an effect on the way things are produced triggering another industrial revolution (it should be noted that, seeing as changes in production processes historically take longer to be fully implemented, one might rather use the term evolution instead). With the first revolution being the introduction of the steam engine, the second bringing assembly line mass production and the third establishing automation via electronic controllers, it is now time for the fourth industrial revolution [2]. The term Industry 4.0 was coined by the German government (as Industrie 4.0) and stems from a project set out to prepare German industry for the future of production. This future, according to the German Federal Ministry of Education and Research, “will be characterized by the strong individualization of products under the conditions of highly flexible (large series) production, the extensive integration of customers and business partners in business and value-added processes, and the linking of production and high-quality services leading to so-called hybrid products”. Industry 4.0 operates on several technological concepts, including the aforementioned cyber-physical systems and the already familiar Internet of Things. The IoT facilitates the communication and cooperation processes of cyber-physical systems. Common IoT technologies used in Industry 4.0 and, consequently, Smart Factories are, inter alia, wireless networks, intelligent or “smart” objects, sensory technology, and actuating elements[6][7][8].

II. RELATED WORK

The German government’s next major steps to secure the manufacturing footprint within this high labor-rate region, to further enhance the competitive position of its local manufacturing companies [11][13][9]. Remarkably, the US-based Industrial Internet Consortium (IIC)—with key players such as GE, IBM, Cisco and Intel—is also aligning with this platform, so expect further global collaboration in the future around this topic[12][10][14]. The Industry 4.0 platform is operated by governments, companies, business associations and trade unions to support the digitization of industrial and electronics manufacturing[15][16][17][18][19]. ABB showed its brand-new, leading-edge dual arm, small-parts assembly robot solution YuMi. The smartFactory KL is a network of partners with various industrial companies (for example, BASF, Festo, Hirschmann, Siemens, Bosch, Continental, Phoenix Contact, John Deere, Flextronics, IBM, SAP and others) showcasing the intelligent factory of tomorrow in an Industry 4.0 mindset toward lot size one[20][21]. With standardized interfaces and the very latest information technology, it enables highly flexible, automated production in keeping with the idea of “plug and produce”.

III. EXPERIMENTAL SETUP

IIoT (Industrial Internet of Things) devices should work to bring about Industry 4.0 manufacturing in five ways [22].

- Decentralized intelligence
- Rapid connectivity
- Open standards and systems
- Real-time context integration
- Autonomous behavior

Putting this into practice for industry, IIoT, devices or assets connect to the cloud or local information technology (IT) infrastructure to collect and/or transmit data [23][24][25]. This data can be analyzed, providing insight about the device or asset. Sensors monitoring the operating temperature in mechanical components can track any abnormalities or deviations from an established baseline [26][27]. This allows the company to proactively address undesired behavior as predictive maintenance before crippling system failures can develop, which would otherwise lead to plant downtime and lost production revenue.

Fig. 1 shows the holistic system approach for temperature control of the microclimatic environment. The control model is realized using FAHP multi-criteria decision making approach to choose the best possible control algorithm [28].

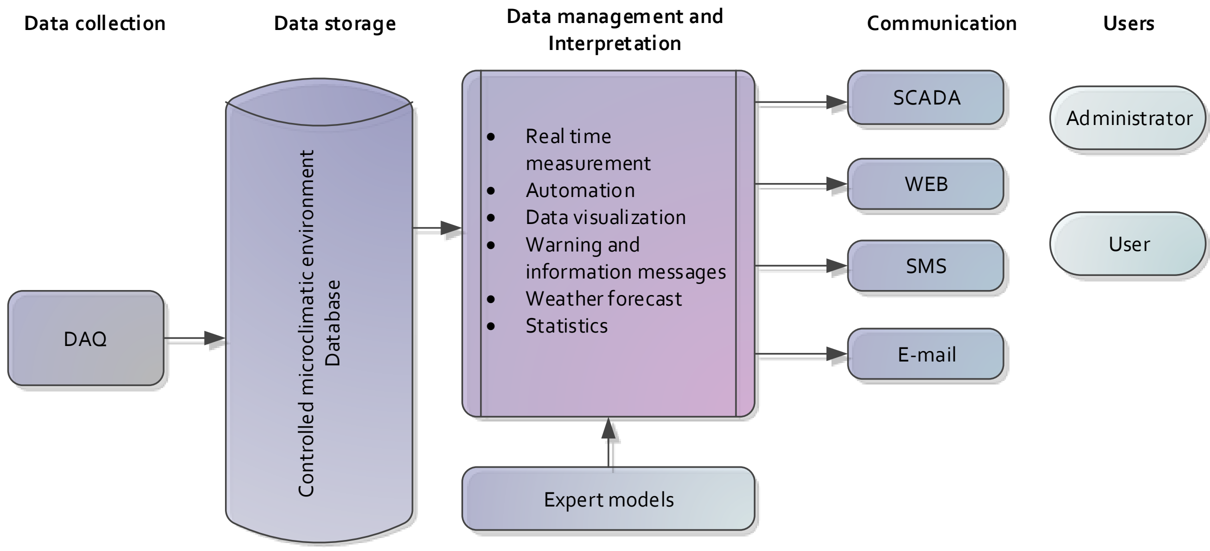

Figure 1. Holistic system approach

The FAHP method is a systematic approach to the choice of alternatives and justification of the problem using the concepts of fuzzy sets and analysis of hierarchical structures [22][5]. The decision maker can specify the settings in the form of the natural language or a numeric value on the importance of each attribute [29][30]. The system combines these settings with existing data using the FAHP method as depicted in fig 2. In the FAHP method, pairwise comparisons in the matrix are fuzzy numbers and fuzzy arithmetic operators.

Table 1 shows the fuzzy numbers required by the FAHP algorithm, table 2 presents the values of the first hierarchy level, tables 2 and 3 gives the evaluation matrix of the A and B criteria. Table 5 gives the linguistic evaluations of alternatives according to criteria and table 6 presents the fuzzy rules for the temperature [31][32].

The first level is the goal itself. In this case, the goal is to determine the optimal control strategy. The goal is divided into the following three main criteria: A - outdoor weather station, and B - indoor stationary measuring point [33][31]. The third level includes system parameters.

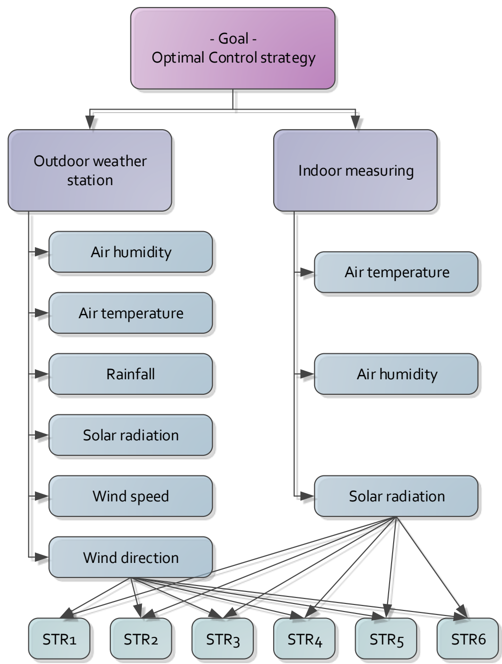

Figure 2. FAHP hierarchy

Table 1. Fuzzy numbers

Fuzzy language	Fuzzy values	Meaning
VB	(1,1,2)	Very Bad
VP	(1,2,3)	Very Poor
P	(2,3,4)	Poor
F	(3,4,5)	Fair
G	(4,5,6)	Good
VG	(5,6,7)	Very Good
I	(6,7,7)	Ideal

The fourth level consists of alternatives. Six control strategies have been developed: STR1 – Day_High_Performance, STR2 – Day_Normal, STR3 – Day_Economic, STR4 – Night_High_Performance, STR5 – Night_Normal, STR6 – Night_Economic.

Table 2. Values of the first hierarchy level

	A	B
A	1	2
B	1/2	1

Category A – Outdoor weather station: To control microclimate conditions, it is necessary to monitor and external climate factors. Data collected from the outside weather stations are also placed in the database. Taking into account external factors, the second criterion is divided into six sub-criteria: B1 - Humidity, B2 - Air temperature, B3 - The amount of rainfall, B4 - Solar radiation, B5 - Wind Speed, B6 - Wind direction [22].

Table 3. The evaluation matrix of the A criteria

	A1	A2	A3	A4	A5	A6
A1	1	1/3	2	1/3	1/5	1
A2	3	1	2	2	1/2	5
A3	1/2	1/2	1	1/2	1/3	1
A4	3	1/2	2	1	1/2	3
A5	5	2	3	2	1	5
A6	1	1/5	1	1/3	1/5	1

Category B – Indoor stationary measuring point: The indoor stationary measuring point is introduced for the purpose of improving control performance. Besides standard internal factors such as temperature, relative humidity, lighting conditions, etc., we measure the soil temperature and soil moisture. The third criterion is divided into five sub-criteria: B1 - Air temperature, B2 - Air humidity, B3 - Solar radiation [22].

Table 4. The evaluation matrix of the B citeria

	B1	B2	B3	B4	B5	B6
B1	1	3	1	1/4	1/3	2
B2	1/3	1	1	1/3	1/2	1
B3	1	1	1	1/2	1	2

One of the six alternative control strategies is chosen as the optimal strategy for the given conditions. Table 6 shows linguistic evaluations linked to specific criteria. After obtaining triangular fuzzy numbers, their priority (geometric mean method) is calculated [22].

Table 5. Linguistic evaluations of alternatives according to criteria

Alternatives	Criteria					
	A1/B1	A2/B2	A3/B3	A4/B1	A5/B2	A6/B3
STR1	G/G	F/G	VG/F	G/F	G/VG	G/VP
STR2	VG/	F/G	F/G	VP/G	F/G	VG/F
STR3	VP/V	VG/F	VG/VP	G/G	VG/VG	VG/G
STR4	F/G	F/G	VP/VG	VG/VG	G/VG	G/F
STR5	VG/G	I/F	G/F	G/F	G/G	VP/F
STR6	VP/G	F/F	VG/G	I/VP	VG/VG	VG/G

For each criterion or alternative, the weighting factor is calculated by using equation in [32]. After defuzzification of fuzzy weights, the new value of weighting factors can be obtained.

Table 6. Fuzzy rules for the temperature

If internal temperature is	And external temperature is	Then thermal system is
Negative low	Negative low	Very high heating
Negative	Negative low	High heating
Zero	Negative low	Medium heating
Positive	Negative low	Very low heating
Positive high	Negative low	Optimum
Negative low	Negative	High heating
Negative	Negative	Medium heating
Zero	Negative	Low heating
High	Negative	Optimum
Positive high	Negative	Very low cooling
Negative low	Zero	Medium heating
Negative	Zero	Low heating
Zero	Zero	Optimum
Positive	Zero	Low cooling
Positive high	Zero	Medium cooling
Negative low	Positive	Very low heating
Negative	Positive	Optimum
Zero	Positive	Low cooling
High	Positive	Medium cooling
Positive high	Positive	High cooling
Negative low	Positive high	Optimum
Negative	Positive high	Very low cooling
Zero	Positive high	Medium cooling
Positive	Positive high	High cooling
Positive high	Positive high	Very high cooling

National Instruments LabVIEW can be used to monitor and control Modbus I/O Modules via an OPC server or an RS-485 interface [32][33]. Modbus protocol is defined as a master/slave protocol, meaning a device operating as a master will poll one or more devices operating as a slave. This means a slave device cannot volunteer information; it must wait to be asked for it. The master will write data to a slave device's registers, and read data from a slave device's registers. A register address or register reference is always in the context of the slave's registers. Fig. 3 presents the DAQ architecture og the developed system.

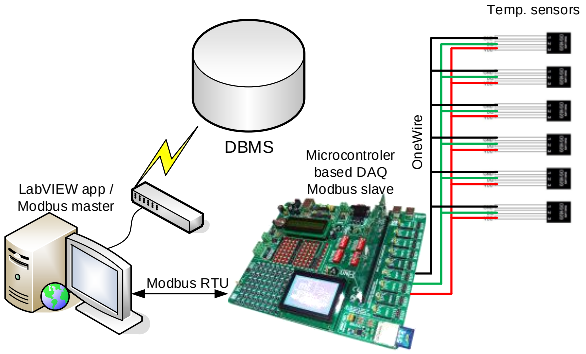

Figure 3. DAQ architecture

The following example will introduce a simple LabVIEW application that will communicate with an UNI-DS3 board. The front panel of the application will have an indicator to read an input Modbus message and a measured temperatures from the sensors as shown in Figure 4.

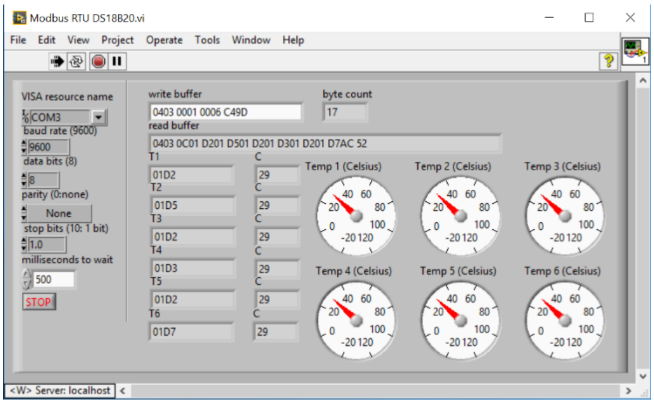

Figure 4. LabVIEW environment

The software programming and implementation of logic of the system has been designed in LabVIEW. The controlling of the remote process is through LabVIEW Programming via port interfacing. The system has been programmed in such a way that no human intervention at the process site is necessary once the system has been initiated [31][36]. As the system is started, controller starts receiving the feedback signal, it will take corrective action and sends an ON or OFF signal back to the process such as heater and fan to start and stop. LabVIEW receives the Data of controller and the HMI contains the START/STOP buttons, the status indicators, and GUI of the system. The current value of temperature, read through the instrument driver, is displayed. Depending on these conditions, the outputs are switched.

IV. DISCUSSION

IIoT data comes from: switches and buttons, sensors and actuators, and drives and vision systems. IIoT extends into controllers, such as PLCs, distributed control systems (DCS), or programmable automation controllers (PACs). Combining data from different devices creates actions. From this point the data turns into information to be communicated to human-machine interfaces (HMIs), historians, and analytics packages using OPC Unified Architecture (UA) [34].

Software in today's converging AT and IT permits machine control programming in multiple languages, facilitating a wider range of engineering tools to complete necessary tasks. Protocol selection should be considered in controls platforms primed for Industry 4.0 connectivity. Many traditional PLCs offer fieldbuses, but machines need a faster, more flexible communications protocol, such as EtherCAT, Profinet or Modbus, for deterministic communication to sensors, servos, and other motion hardware [35][28].

V. CONCLUSION

This research has shown that it is necessary to develop a robust model for microclimatic control and to upgrade to the new Industry 4.0 standard in order to improve the system efficiency. It also led to new knowledge in the field of control methods under microclimatic environment. A control algorithm has been developed for this application using FAHP method. The process of data fusion has been proposed for microclimatic environment in real-time for collecting data from the environment. A model of expert system has been developed for microclimatic environment control based on multi-criteria decision making and the implementation of fuzzy rules.

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