Recent and Upcoming Innovations to Support the Transition to Industry 4.0 for Customer's satisfaction

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Today, advances in automation and information technology make it possible to reach a high degree of digitization in production processes by employing large amounts of data collected through sensors and instruments. Continuus-Properzi has always been committed to providing quality and innovation, taking care of customer's specific needs. For Industry 4.0, the company has developed features for new plants, and upgrading options for existing ones, that respond to the specific needs of managers to be updated in real time, and put in condition to react with incisiveness toward the best obtainable results.

Industry 4.0 is the term that identifies the fourth industrial revolution, the evolution currently underway that leads the factories to transform themselves into the so-called *Smart Factories*, or entities that are increasingly digitalized and interconnected with each other. Conceptually, the *Smart Factory* consists of three parts. *Smart productio*n, which is realized where new production technologies create collaboration between all the elements present, namely essentially operators, machines and tools. *Smart services*, where all the "IT infrastructures" and the systems integration techniques are used to make the company interact in a collaborative way with those that interface it (eg. in supplier-customer relations, or collateral ones like logistics, public bodies, etc.) *Smart energy*, which occurs when the two previous parts create more performing systems that reduce energy consumption, according to typical paradigms of sustainable energy.

Cyber Physical Systems, Principles and Enabling Technologies

Essential elements to realize the transformation of companies in Smart Factories are the *Cyber Physical Systems (CPS)*, physical systems closely connected with computer systems that can interact and collaborate with other *CPS*. The development of *CPS* has been made possible by an increasingly wider use, in the world of *OT* (*Operation Technology* or automation), of communication technologies and data exchange developed in *IT* (*Information Technology*). These technologies have constituted the instrument through which the interconnection and collaboration of the systems were and are realized according to the design *Principles* of Industry 4.0. These *Principles* are not univocal and vary depending on reference sources and studies made; here for example we can cite in simplification:

- Machine interconnection
- Data transparency
- Technical assistance
- Decentralized decisions

Still according to studies made, and still evolving, the fourth industrial revolution focuses on the adoption of the so-called *Enabling Technologies*, or technologies developed in accordance with the aforementioned *Principles*, which mainly aim to increase productivity and efficiency, and to reduce time to market. Examples of *Enabling Technologies* that resonate with the media are: Advanced Manufacturing Solutions, Cobot or collaborative robots, Additive Manufacturing, Augmented Reality, Twin Digital, Industrial Internet, Cloud Computing, IT Security, Big Data Analytics, Industrial Analytics, Industrial Internet of Things, Advanced Automation, Artificial intelligence, Cognitive Computing.

This vast and articulated panorama of principles, Enabling Technologies and proposed solutions, moreover constantly evolving, understandably poses to those who approach them for the first time, or to those who are in front of choices to make for a plant to buy or modernize, more than a few doubts. On the one hand, these new technologies appear a bit like a fashion; and on the other, they undeniably present themselves as interesting opportunities for raising their level of competitiveness. In order to deepen the consistency of these opportunities, the search for solutions and Enabling Technologies of greatest potential for their business sector, and the classification of these according to their own priorities and availability of resources to invest, can be challenging. Once the above would be done and choices made, in some cases it is also possible having to choose within different market standards (eg. about type of components) and, in the case of a plant to be modernized, to make compromises with respect to parts that cannot be easily or immediately replaced.

The "Properzi Road Map" toward Industry 4.0

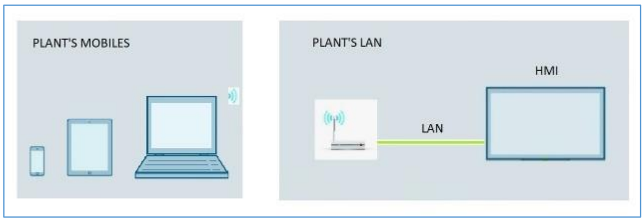
Continuus-Properzi has always been attentive to innovations and new solutions as opportunities to be seized to raise the quality of the plants, to consolidate its experience and know-how, and to put this at the service of users in relation to their specific needs. Consistently with this approach, it has been outlined a way to offer support to users who find themselves having to make implementation choices for their plants. The approach which followed consisted in identifying and selecting the solutions that are prioritized since they are able to bring greater benefits against lower investments in terms of components, number of functions to implement and, for existing plants, invasiveness of the changes to be made.

It is a path similar to what the company did in entering into the paradigms and principles of I4.0. In view of the wide range of new technologies available, it was first studied which functionalities were already substantially present and required only small extensions to be completed, and later, how to develop more advanced ones for a greater productivity, lower reaction time in decisions and cost containment. From the earliest stages, it was evident that to implement these functions it was first essential to adapt the automation system to the specific needs of each of them, in terms of architecture, quantity of sensors and implemented logic. So it was studied, and then introduced, an automation architecture aimed to provide a modular infrastructure, open to the future development of new functions, which were later gradually implemented.

Indeed, in describing this Road Map, we will present here not so much a "full-optional" solution, nor even an examination of Enabling Technologies, but rather a series of *functions* definitely adhering to the operational needs of this type of system. We will start from the most fundamental functions, also contained in the investments, and move gradually towards those more advanced and capable of wider benefits. We will also disregard the type of standards and components to adopt, since these are linked to individual choices of convenience and of eventual compatibility with existing standards.

Visibility of plant data via Intranet

A first feature from which to start, is to equip the plant's PLC/controller and HMIs with a local digital communication network and a Wi-Fi Access Point, which allow the wireless connection of external mobile devices such as notebook PCs, Tablets and mobile phones.



Access to HMI pages via LAN

By the use of mobile devices, operators can move along the system and position themselves at the most appropriate point to carry out inspections, and where foreseen also operations, facilitated by a closer view than would be possible from the HMI station. The functionalities made possible by the local network and wi-fi access point are two:

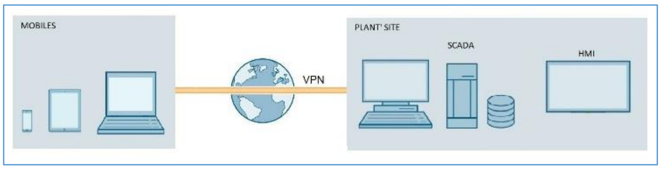
- Access to the pages, and where foreseen to the commands, of the HMI installed in the plant

HMI pages on a mobile phone

- Access to the programming of PLC/controllers, HMIs and other programmable devices present on the network (eg. drives, supervision PC, instruments). In this case the access is executable from a notebook PC having installed the programming software of the devices to which is desired to access. This type of access is useful for maintenance operations, such as monitoring the program execution, making small changes/extensions, or adjusting parameters.

Visibility of plant data via Internet

Through the installation of some additional components, essentially a LAN-router and a connection to an Internet provider, the two features described above are made accessible even remotely via the Internet.



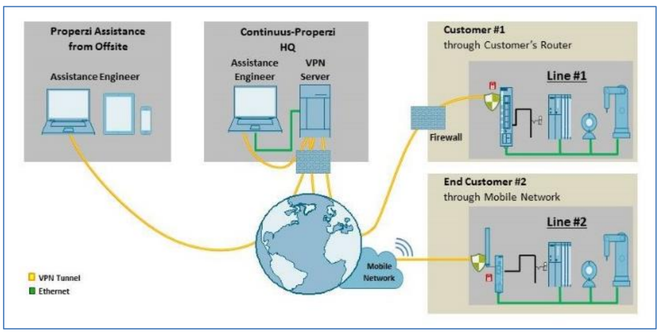
Access to HMI and SCADA pages via Internet

The pages of the SCADA supervision systems can also be made accessible via PCs, tablets and mobile phones, similar to what has just been described for HMIs. Remote access allows users to consult the status of the system, as well as from inside, also from outside the production site, by accessing the pages of interest (eg. synoptic, recipes, reports, etc.) of HMIs and SCADA. This remote access also allows electronic assistance engineers to perform Technical Assistance services from the company's headquarters.

Technical Assistance from Remote

The remote technical assistance to the automation systems consists in the ability to access via Internet to the programmable devices present in the plant, to be able to monitor the operating parameters and the status of the program in execution. It also allows engineers to make changes or add features when requested by the user. Compared to the direct intervention of a technician on the plant's site, this type of assistance allows a decidedly superior timeliness at lower costs, thanks to the fact that it avoids the time for travelling, as well as the time for eventual visa and flight booking issues; furthermore the waiting time for service engineer's availability is normally shorter.

To allow Remote Technical Assistance connection, from the side of the plant the aforementioned Internet access components must be installed, while on the side of the company headquarters a dedicated server is used. Service technicians, whether they are in-house or off-site, connect with their account to this server, and from the server to the plants to provide assistance, all through communications protected by firewalls, VPNs and modern security systems.



Remote Assistance Service

The great advantage of this type of solution is a greater flexibility of service, because it offers the opportunity to perform assistance even by a technician temporarily out of the office. This can happen, for example, where a particular technician would be required who already knows the plant and the customer needs, or if there is a time difference that requires assistance during hours that go beyond normal working time.

The set of network interconnection functions described so far constitutes the basic infrastructure to be able to implement further more advanced functions, aimed at satisfying the aforementioned I4.0 design *Principles*.

Key Performance Indicators (KPIs) for plant managers

The managers and people who are part of the management team of the plant, in order to make quick and effective decisions, need to know in real time a set of process variables and parameters, selected in relation to the specific role of each of these people. These are the so-called KPIs, indicators significant of the plant's status and performance for each role. The most typical roles are those of managers in charge of *Production*, *Quality*, *Energy Consumption*, *Maintenance* and the entire *Plant*. Of course, they may differ depending on the specific organization of each user.

To summarize the desired KPIs, the data must be acquired through the automation system network and be stored in a centralized database, so that they can be taken, processed and re-aggregated as needed, and stored in specific sub-databases. The resulting indicators are summarized in so-called *dashboard* pages made individually accessible to each manager, both by the respective company PC and by mobile devices (PCs, tablets and mobile phones) in order to guarantee continuous access to this information. With the purpose of making this functionality even more effective and timely, it is added the option to set up email messages to be automatically sent by the system when a process variable, or a set of these, exceeds a critical threshold.

Beyond what may be the implementation solution chosen among those possible, for the database it is clear that the automation system, as a necessary condition, must be structured with the capability to acquire data in digital form from sensors and devices, and to transmit / exchange them via local network and Internet. In addition, it has to be provided with the software for processing the indicators and sending the messages.

Below is an example of the types of data and information that are with more generality summarized for the plant management team to give them better support on the decision-making processes. For each type of plant then, there will be specific KPIs depending on the type of production made.

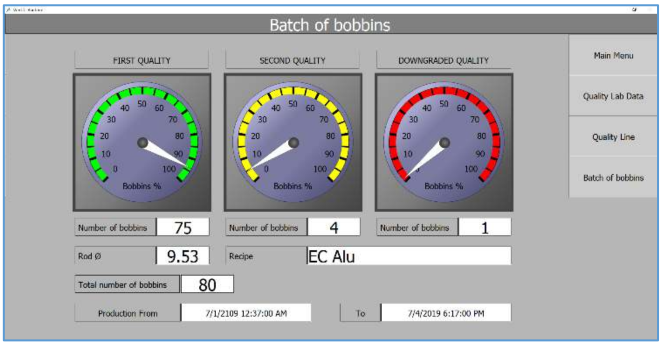
Product quality: Those who manage continuous casting and rolling plants, for aluminium or copper for example, know that quality is not achieved solely through automation, but also that operating practices well-tuned and followed with care are indispensable. The reason why automation can anyway be valuable to give support is in selecting among all the data that pass through it those related to quality, and in summarizing them in indicators useful for the continuous monitoring of the conditions necessary to guarantee it.

This obviously has the objective of being in a position to quickly recognize the possibility that a significant deviation occurs on a parameter, to accelerate the return of production to the optimal parameters and to limit scrap or second-choice products.

The summarization work of the indicators is performed in synergy with that of the reports normally made in the SCADA of the plant. Starting from the database, the data of the *process variables* significant of the quality, with average values and deviations, and the *results of the laboratory tests* are summarized in *Casting* and *Coils* report pages. In correspondence with each process variable and test's result, it is then provided the pre-setting of tolerance ranges for classifying products in *First Quality*, *Second Quality* and *Downgraded Quality*. In case for one or more of these variables, a maximum deviation along the coil is registered, that significantly deviates from the recipe value and comes out over the preset limits, it is possible to set the issue of an *automatic email* to the manager, so that a notification is immediately sent to him. The issue of an automatic email is also settable depending on the occurrence in production of a number of *Second* or *Downgraded Quality* coils that exceed an assigned percentage threshold.

To monitor the progress of the quality produced by the plant, the manager then has access, via fixed and mobile devices, to pages where they are summarized:

- a graph showing, for the last *Coil* or for a selected one, the values of the *deviations* of all the process variables and of the laboratory tests, with a different colour coding depending on the classification tolerance range of the product to which it belongs,
- a graphical dashboard that, by current *batch of coils*, or by set time interval, shows the number of coils produced and the *production percentages* obtained within and outside the tolerances of the quality classes.

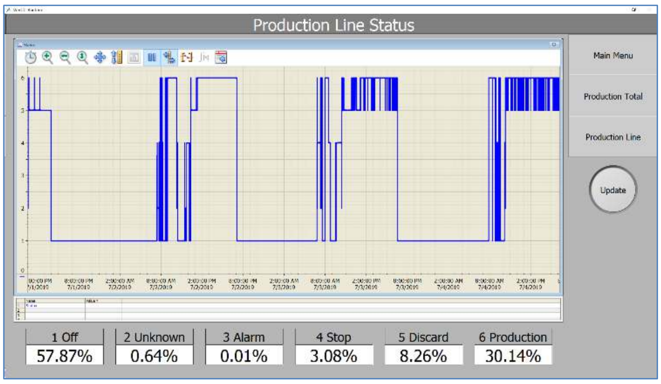


Batch of Bobbins - quality KPI

Therefore, as we have seen above, the email fulfills the task of a timely notification, while the access to the pages makes available, to the person in charge, an information summary at all times, and first-aid information with respect to situations to be resolved.

Production Manager: To this role the attention is normally centred on achieving a given production budget, and on the yield of the plant. To monitor the progress, summary pages are available, with graphs showing on the selected time span, the trend of the Ton per hour produced, the gross, net, discarded production, and the budgeted one, the yield efficiency, and the plant's utilization rate.

To then give useful information for better understanding the events that can cause productivity deficiencies, there is also a graph that represents, along the time, the plant's states among the various possible (for instance off, running, stopped, in alarm, etc.), and a table with the description, date, time and duration of the last alarms that caused the plant to stop.



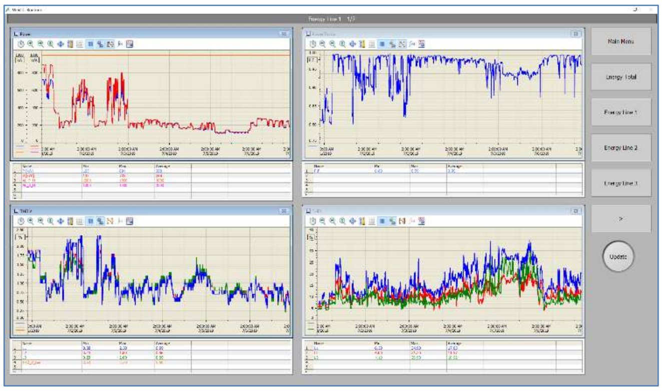
Plant's states graph

For a timely notification of eventual situations critical for the production, it is foreseen for instance an automatic e-mail transmission when a plant's stop continues beyond a pre-set duration.

Maintenance Manager: Here the main information is the monitoring about the duration of the most important parts of the plant and those most subject to wear, and the signalling of the components that are close to a foreseeable end of life compared to the available information. The relative data are summarized in table form where for each significant component, or homogeneous groups of them (eg. motors, reducers, important bearings, belt and casting wheel, pumps) the hours of operational life foreseeable before the next planned ordinary and extraordinary maintenance are set up. At the same time, the following are calculated: the hours of operational life from the last maintenance executed, the time remaining until the next maintenance deadline will be reached, and a warning, which can also be set by e-mail, when the expected residual life is nearly reached. For significant discrete components, such as large contactors, the same type of table is made available with the same settings, but calculating the number of cycles instead of operating hours.

In addition to this information, it is also possible to acquire and summarize some other ones, more specialized, aimed to recognize in advance those situations coming to an early or unexpected deterioration. For example: analysis of the motors' torque at no-load and on-load, temperature measurements, vibration measurements.

Energy Manager: For this purpose, they are primarily available features for measuring gas and electricity consumptions. For the latter, in addition to the energy consumed in kWh, significant variables can also be acquired for the type and quality of consumption in terms of: absorbed power in both kW and kVA, supply voltages, absorbed currents, power factor, quantity of harmonics in THD V and THD I (Total Harmonic Distortion of voltage and current). The values are graphed and processed by calculating the minimum, average and maximum values, over a selected period of time.



Energy graphs

Compared to the most critical variables it is then possible to set an alarm value, and provide for the automatic issuance of emails. Examples of application are the parameters that normally originate penalties in the electricity bill, such as exceeding the maximum power in kVA of the plant or lowering the Power Factor below the minimum allowed, or deviations of the supply voltage over the tolerance range around the nominal value.

Plant Manager: In this case, the information in evidence is deduced by summarizing the data from that of the previous managers, making it even more essential with respect to the overall results; if there are more lines or systems on the site, their data will also be available.

For the purposes of essentiality required by the Plant Manager, for the Quality for example, there is normally only one page with the graph of the percentage of coils within the tolerances for each of the quality classes. For the Production there are only the graphs showing the net Ton per hour trend produced with respect to the budget, the yield efficiency and the utilization index. For the Maintenance there will be the number of components whose expected residual life expires shortly or expires. For the Energy there will be indicators of exceeding the maximum power in kVA or the fall of the Power Factor below the minimum.

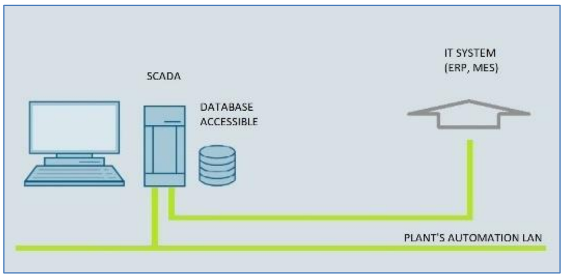
As anticipated, the one exposed so far is only a general example of possible choices of information to be processed and summarized for the managers and of the benefits that this allows to achieve. In relation to each specific user/plant, the solutions are normally developed specifically according to the type of product, where they would be submitted, and to the organizational requirements of the customer/user. In order to address the choices in the most profitable way it is important that the users have clear ideas about the functional objectives they wish to achieve, and that they interact with the plant's manufacturer on these issues from the very first stages of defining a project.

Data exchange between automation and IT

A very useful function is the interface between the automation of the plant and the IT information systems of the user. This in fact allows both to exchange data of instantaneous type, and to share with the IT the data acquired by the automation, by means of a network connection that provides to IT an access to the SCADA supervision system.

The instantaneous data exchange serves to implement functionalities that require data processing to be performed partly in the IT of the user and partly in the automation, and which require an execution to be completed within the timeframe of a specific production phase. As an example, we can consider the insertion of a quality code within the printing of a label to be applied to the product. The quality code must be processed by the automation, in order to be able to classify it according to the tolerances on the process variables, and also by the IT of the user to be able to comply with other possible requirements connected to the customer such as, for instance, a classification or coding out of standard.

The transmission of the data acquired from the automation to the IT, of interest to the latter, requires then to set up in the SCADA, starting from its main database, one or more specialized databases, by type of data and relative scan-rate, and accessible. From this/these open database(s) the IT, where typical features of MES (Manufacturing Execution System) and ERP (Enterprise Resource Planning) are implemented, reads the useful data for the elaborations to carry out.



Interface between SCADA and customer IT

With this solution, they are brought to the IT of the customer two types of data bases, or data:

- those already elaborated according to functions envisaged in the project of the plant, and therefore significant of the manufacturer's knowledge on the machines and process,
- and those from the process variables, only scaled in engineering units, to give the user the possibility to implement in his IT system and to adjust over time the necessary production management functions depending on the evolution of market.

Industrial IoT (Internet of Things)

Industrial IoT is the Internet of things applied inside an industrial line or plant, where a series of devices, in particular sensors and actuators, are connected to the Internet in order to facilitate and improve the production process. The Industrial IoT allows to bring all the data of these devices towards the upper levels of the automation, that is to the SCADA systems, to the IT of the user and to other CPS through a unique addressing scheme which is the Internet's own.

Advanced features generally also characterize the IoT devices. They are the so-called *Smart transducers*, i.e. analogue or digital transducers, or actuators, equipped with a processing unit and a digital communication interface. The ability to communicate through a digital protocol allows them both to exchange data with the automation, and to be directly accessible via the Internet. It is then the process unit that makes them *Smart* since it allows them to read or modify the operating parameters and to associate other data to the measurement, such as: the status of the transducer, diagnostic data, additional measures such as temperature and vibrations.

To date a single standard is not yet available which is applicable to all the devices of interest for the transmission of the multiple data of the *Smart transducers* to the controllers/PLCs and to the Internet, and this for the moment forces to accept some limitation of use or complication coming from the coexistence of several standards. On this front, the company is committed to following market developments in search of the best opportunities to unify and standardize the communication protocols in use as much as possible.

In parallel to making available a wider quantity of data, it is associated the development of software and analysis algorithms, aimed at developing an ever deeper knowledge of the production process and its dynamics. From this knowledge arises the opportunity and interest to implement more advanced decision-making models that are capable of ever more intelligent processing through deductive algorithms (such as predictive maintenance, efficiency optimization, better production planning, etc.) up to implementing artificial intelligence algorithms. This is with the aim to increase the ability to adapt the production process to the needs of the market in real time and to exploit new business models. On this front the company is engaged in studies and developments that are foreseeably expected to find application in the near future.

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