PERFORMANCE ANALYSIS OF A WATER SUPPLY SYSTEM OFA DAIRY COMPANY BY MEANS OF ADVANCED SIMULATIVE METHODS

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ABSTRACT
This following work presents the result of a research project, that concerns the development of a simulation model of the water supply system of a dairy company, located in Parma, Italy. The reduction of water consumption is a very topical issue in many industrial fields. The approach developed aims to investigate, through process simulation, the areas of the plant where the efficiency of the water supply system can be significantly improved by means of simple modifications.

At first, the simulation model was used to reproduce the current system, so as to reach a precise knowledge of the water flows in the plant. In the second part of the work, a series of alternative scenarios was investigated, and the related performance was assessed, thus identifying the best plant configuration. The process simulator was designed under Microsoft Excel, using the potential of VBA (Visual Basic for Applications). Thanks to the study implemented, a final scenario of the water supply system was identified, which allows savings up to 30% of water compared to the original configuration.

Keywords: water consumption savings, process simulation, process optimization, layout modeling

1. INTRODUCTION

The amount of water consumption in industrialized countries is continuously increasing: it has doubled in about the last two decades, and in several countries the depletion of underground sources and/or their increasing level of contamination has become a central question. Therefore, rational use of water resources is a key issue for sustainable growth. Water consumption, especially nowadays, faces significant competing forces for change from decreasing water resource availability, stricter water quality regulations, decreased federal subsidies, increased public scrutiny, decreased financial health, and increased infrastructure replacement costs (Rogers and Luois, 2008). Consequently, the reuse of water has become an important issue within industry. Process water is used for many purposes in the food industry, i.e., as an ingredient, as part of the manufacturing process and in direct contact with the foodstuff, or in any indirect contact with the food product (Poretti, 1990).

In several industries, large amounts of water are used in cleaning and process applications. Recycling this water can be an opportunity to combine a reduction in the costs of industrial water with improved control of water management and a better environmental impact on natural resources (Centi and Perathoner, 1999). For instance, consider the cleaning-in-place (CIP) operations in a food industry. Generally speaking, cleaning is a key process in the food industry to assure safe products of high quality. However, the cleaning operations, besides the an economic impact, have environmental impacts.

Solutions for water savings always generate economic benefits related to lower procurement and energy cost, as well as to the lower cost for the treatment and discharge of waste water. For all the above reasons, the rational use of water resources has been an important research topic for many years and in different contexts. Among them, the main ones are the service processes, such as the cleaning operations (Centi and Perathoner, 1999) and the heat exchange processes (Lee and Cheng, 2012; Rezaei et al., 2010). But the topic was deepened also for the food industry, in general terms (Casani and Knochel, 2002; Casani et al., 2005), and for more specific food sectors, such as the sugar industry (Bogliolo et al., 1996), the dairy industry, etc. Among all these fields, for sure the dairy sector is one of those that could receive more contributions from the research.

Looking, for instance, at the cleaning operations, in the dairy industry the time of nonproduction dedicated to CIP is very high, ranging from 4 to 6 h per day. Moreover, the cleaning operation leads from 50 to 95% of the waste volume sent to the purification station (Marty, 2001; Sage, 2005). At present, the industrial CIP procedure mainly lies on practical experience imposed with relevant safety margins in terms of duration and chemical consumption (Alvarez et al., 2010). A further large amount of discharge water, affecting industries operating in the Parmigiano-Reggiano production, comes from the buttermilk concentration, the first operating step for obtaining the whey proteins.

All these factors lead easily to the conclusion that the exploitation of water resources by dairy industry can be greatly improved. According to Pagella et al. (2000), a strategic approach to water reuse must be based on a systematic analysis and on the principle that water users must not use more water of a higher quality than that strictly needed. A punctual and precise knowledge of the flows that run in a production plant is obviously of great help to identify those areas, devices or processes that offer the greatest optimization potentials in terms of water savings. This paper aligns precisely with this need. Indeed, its objective is to optimize the layout and the piping of an existing water supply line, in order to avoid wastes and recover and reuse the water that has been already used in the process, but is still poorly contaminated.

The first part of the study, therefore, focused on the analysis of the piping of the whole plant of the dairy company chosen as case study. The aim of this phase was to achieve a precise knowledge of the existing system and to reproduce it exploiting advanced design and simulation tools. A numerical, discrete events model of the plant was created, exploiting Microsoft Excel and Visual Basic for Applications (VBA). Once the system was re-created, we proceed with the evaluation of different innovative scenarios ("WHAT IF" analysis), obtained by varying the basic layout, to optimize the plant and water consumption. In particular, two different "WHAT IF" analysis were performed and compared to the "AS IS" configuration of the plant. From the simulations, it emerged that, through some changes to the water distribution and storage system, it is possible to get to significant savings both in terms of water demand from wells, and of the amount of waste water discharged.

2. MATERIALS AND METHODS

2.1. Initial layout of the water supply line

The work presented in this paper refers to a dairy company located near Parma, Italy. This company has been active for decades in the production of Parmigiano-Reggiano cheese and butter and is one of the greatest Parmigiano-Reggiano producer of the area, with a production volume of about 60 wheels of cheese and more than 10 tons of butter per day.

The approach followed in the study has focused initially on the detailed understanding of the operating conditions of the plant lines, as they were ("AS IS" configuration). The "AS IS" scenario includes two independent water circuits, one for the cheese and the other one for the butter production line. The layout of the whole factory is shown in Figure 1. In the left side of the picture, the water supply system is represented, with three wells. After extraction, the water is purified and stored in the main tank, named TK901. From this reservoir, all the processes of dairy and creamery plants will be fed. The two distinct sections of the factory are highlighted, in Figure 1, by the two dashed rectangles: the upper one delimits the water service facilities of the cheese production plants, while the lower one delimits the facilities of the butter production plants.

Regard the "cheese section", detailed in Figure 2, water withdrawals are basically associated with two main processes: the fermenters and the washing cycles. The fermenters installed are three, but, when simulating the system, they were considered as a single machine. Such a choice does not modify the water flows management, since the three fermenters always work in parallel.

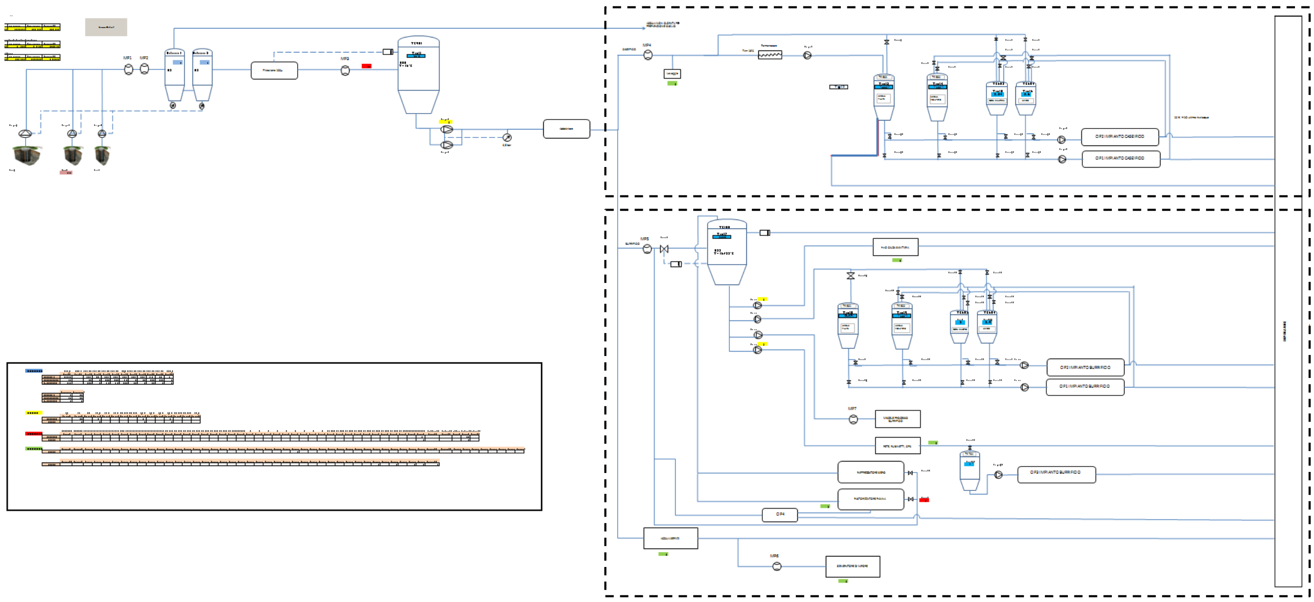

Figure 1 - Schematic layout of the water circuit of the two parts of the plant

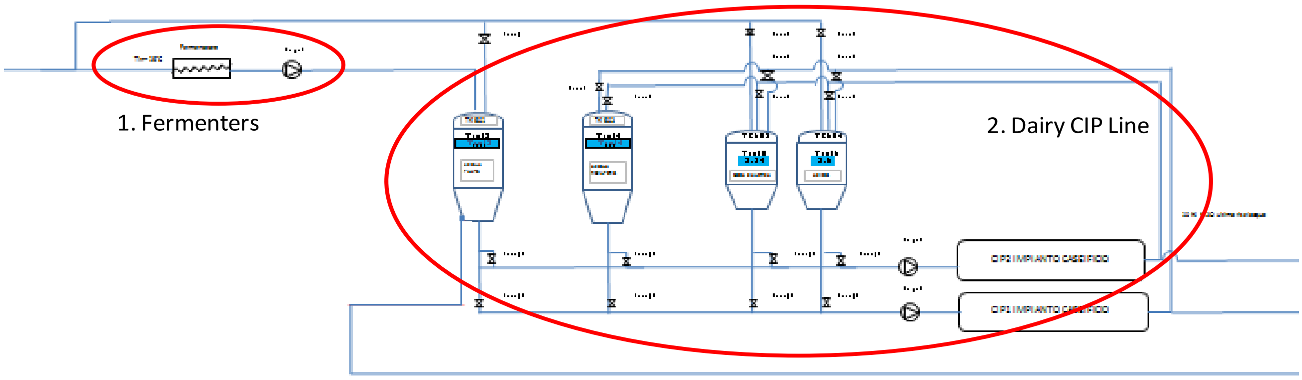

Figure 2 – Detail of Figure 1: layout of the service water line of the cheese production section of the factory

Within the fermenters, the plant reprocesses part of the whey left from the processes of the previous day; this is done because the re-fermented whey has the property of promoting the formation of cheese. The water absorbed by the fermenters is used to cool the whey.

The further relevant amount of water consumption in this part of the factory is generated by the washing cycles. The dairy section consists of 2 different CIP circuits, that operate on different elements of the plant. Specifically, they can operate simultaneously because they are equipped of two different and independent lines. In general, each washing is composed of different sequential phases, which can be combined in different way: (1) first rinse, (2) basic phase, (3) middle rinse, (4) acid phase and (5) final rinse. Washing can be carried out by means, for instance, of simple rinse cycles, or cycles of washing with soda, or combined cycles of soda and acid. Moreover, each washing cycle is characterised by a particular receipt in terms of duration and flow rate of each phase. The four tanks shown in Figure 2 are therefore essential for providing water and other cleaning solutions to both lines of the cleaning-in-place circuit. Each tank has a specific function, only the first one on the left, named TK605, contains pure water. The other ones store different kinds of cleaning solutions. The tank TK605 is fed by two sources: the general tank TK901, or the cooling water, from the fermenters. Overall, the global volume of water absorbed daily by the cheese production line of the company accounts for about 50 m^3. This data refers to the measured daily water discharge in the sewerage system.

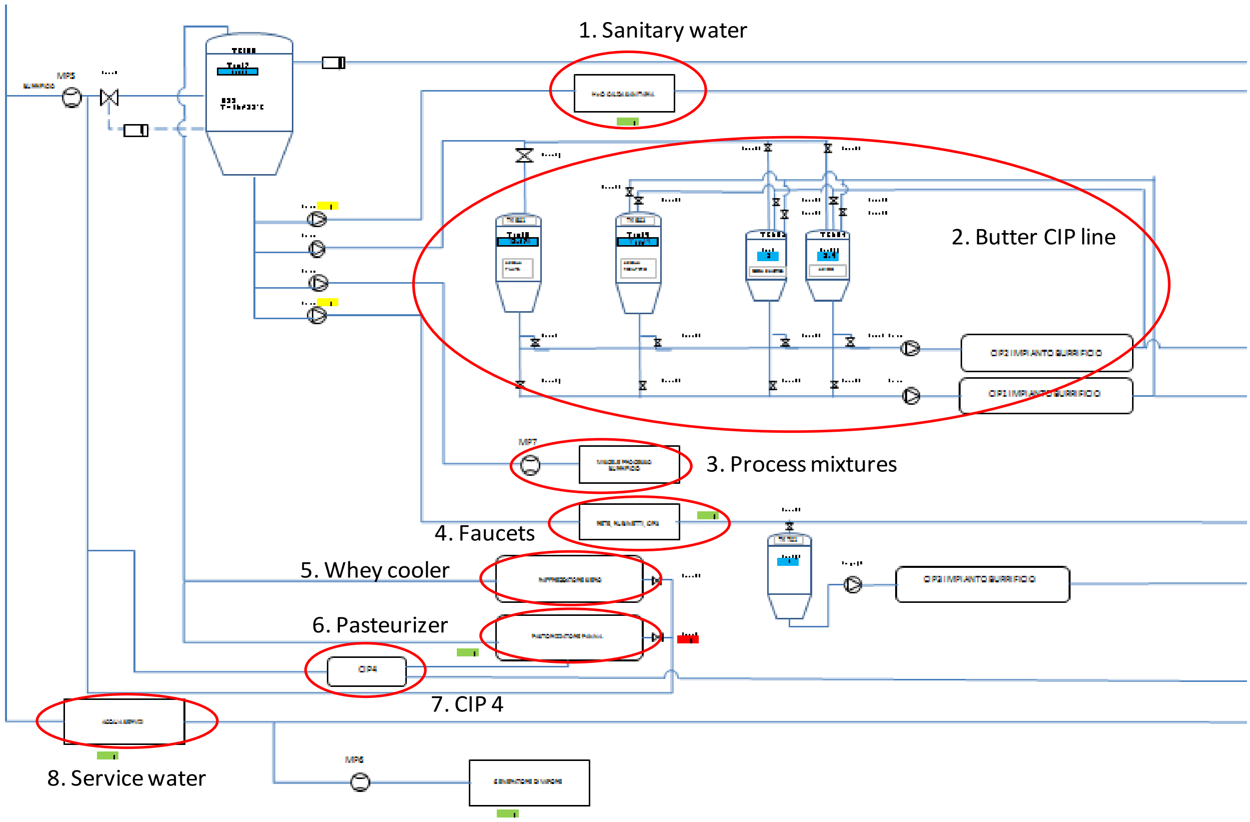

Figure 3 - Detail of Figure 1: layout of the service water line of the butter production section of the factory

The situation is slightly different with respect to the "butter section" of the factory, as can be seen in Figure 3. In fact, in this case there are eight main water withdrawals.

1. The first, small claim, is sanitary water.
2. The second withdrawal is due to the CIP circuit of the butter plants. Even in this case, the CIP circuit consists of 4 tanks: it is structured and works exactly as the CIP system of the "cheese section".
3. There is a certain amount of water that is used as an ingredient to be added to the raw materials, to create appropriate mixtures in the first phases of the process of buttermaking.
4. A further water consumption is related to the use of faucets, for rinsing and washing of floors and surfaces. This supply line feeds also a small secondary CIP circuit, named CIP3, responsible for the cleaning of the churning machines, that require a particular washing cycle.
5. Another point where there is a call for water is the whey cooling system. In fact, the whey comes out from the butter production plants, after being separated from the milk cream, with a temperature higher than 50°C. Before being concentrated and stored, it must be cooled up to 16°C.
6. The milk cream, before the process of churning, must be pasteurized. This process brings the milk cream up to a temperature of 90°C. To avoid organoleptic damage to the product, however, this temperature must be lowered rapidly after the treatment.
7. The pasteurizer machine is washed by means of CIP4, which is equipped of an independent line and requires clean water from tank TK901.
8. A certain quantity of water is finally used as service water, i.e. to feed all the service devices of the factory, such as, for instance, the steam generator.

All the lines of the butter production section are supplied by a single central tank, the TK105 (at the top left in Figure 3), except for CIP4, service water, cooler and pasteurizer. The water which exits from the pasteurizer and cooler is not contaminated at all; it only has a temperature slightly higher than the initial one. For this reason it can be reused and is sent back to the tank TK105. The global daily water consumption of the butter production line of the company amounts to approx. 160 m^3. 110 m^3 pass through the tank TK105 and are destined to the users connected to it, while the remaining 50 m^3 are taken directly from the wells and mainly converted in service water.

2.2. Simulation settings

As previously mentioned, the overall water consumption of the dairy company was studied using a simulation model, developed under MS Excel™.

Specifically, discrete event simulation has been used to reproduce the flows within the water supply system, in order to develop a useful tool to analyze the current performance of the company. The system is represented as a chronological sequence of events, each of them modifying the state of the whole system.

A main parameter of a discrete events simulation is the "time step" between two subsequent calculation steps of the simulator (clock setting). Obviously, the clock setting implemented in the simulator must be selected as a compromise between the accuracy of the results and the computational time. Moreover, in the current scenario, two particular CIP cycles are launched only once every 2 weeks. That forced us to set the overall simulation duration to 14 complete days (i.e., two complete weeks, from Monday to Sunday), and thus 336 hours. After a series of attempts, a time unit of 1 minute turned out to be appropriate for the analysis. Consequently, for the different configurations of the line, the simulator has computed the state of the system for 20160 steps overall.

The simulation model consists of 4 MS Excel™ files, that reproduce: (1) the layout of the whole system, (2) the input setting of the model, in terms of the relevant raw data collected from the company, (3) the elaborated input data, and (4) the final database with the simulation results.

After the definition of the system layout, for each element, a specific cell has been identified as representative of a single object, and easily recognized through the VBA code. After that, the raw data have been grouped in the second spreadsheet: for instance for the tanks, the on/off levels have been derived from the logics of the real system. The "ON" status reflects the call of water from the upstream line, while the "OFF" status interrupts the operation.

For the various components of the system, such as pumps and valves, the punctual flow rate has been measured using a flow meter (model Krohne Optisonic 6300), depicted below (Figure 4). It exploits ultrasonic wave frequencies to determine the rate at which the fluid is moving inside the pipe.

Figure 4 - Ultrasonic clamp-on flow meter

We analyzed the processes and washings cycle listed, with the collection of their relative flow rates, starting times and durations. Moreover, these pieces of information has been inserted in the second spreadsheet, to be then elaborated in the third one by means of a VBA macro, able to reproduce the logic of the system.

The last spreadsheet contains the final results obtained from the simulations: for each time step, all the data related to the water volume inside each tank and the on/off state and the flow rate passing through the various pumps and valves.

However, even though the use of VBA allows great flexibility in programming and writing a specific code, some simplifications had to be introduced to model the original system configuration. The main simplification regard the pumps and valves functioning, as follows:

- The flow rate provided by each pump is equal to the sum of the flow rates required from any process or washing fed by the pump itself (a great operative flexibility of the pumps was assumed). Therefore, to simplify the model, the behavior of the centrifugal pumps has been assumed as comparable to the one of volumetric pumps.
- On the other hand, the behavior of the valves was considered similar to that of gate valves: they are assumed to be unable to act on flow regulation, but only to act as on/off systems.

The remaining simplifications have a really negligible impact on the whole system. An example could be the truck washings: in the real system, trucks are washed in sequence, so the washing cycle phases (called, for simplicity, P1, P2 and P3) are repeated 3 times. In the simulation model, conversely, only one single washing cycle is launched. This means that the washing phases of the trucks are grouped, and their durations are summed up: 3 generic "macro-phases" are carried out. The Figure 5 below can well clarify such change.

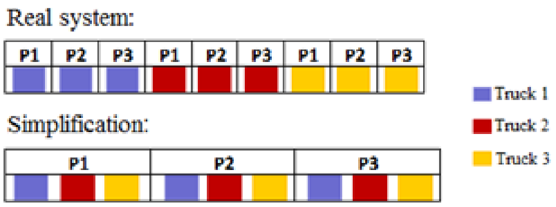

Figure 5 – Truck washing simplification

3. SIMULATION RESULTS

3.1. Limitations of the initial water supply line

Once defined the layout, the logical connection and the system simplifications, it was possible to launch the simulation process. The most interesting outcomes from the simulation concern the performance of the tanks of the plant. In particular the limitations emerged were two:

1. The tank TK605, with a volume of 9.5 m^3.
2. The tank TK105, with a volume of 32 m^3.

From the simulations, we found that the capacity of the two tanks is not sufficient. This is mainly due to the scheduling of the production and washing phases of the company. There is a deep difference between the time distribution of the processes, which the filling and emptying of the two tanks depend upon. By the very nature of the business activities, it cannot be guaranteed the simultaneity of the operations, and this implies the need of higher buffering volumes.

3.1.1. Cheese factory analysis

Considering the tank TK605, it can be fed by both wells water and by the water in output from the fermenters. Therefore, the two water users of the cheese producing plants (the fermenters and the CIP line), could be reduced to only one (the tanks of the CIP cycle), since the water that exits the fermenters could be entirely reused. The working cycle of the fermenters is spread over the whole day, with a variable flow rate of cooling water, shown in Figure 6. As a result, by these machines, an almost constant stream of water arrives to the tank. The overall daily amount of water that passes through the fermenters is 20.2 m^3, equal to 20200 liters.

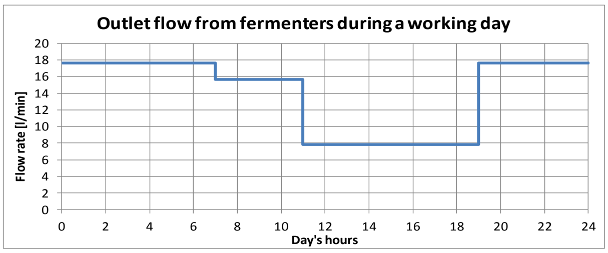

Figure 6 - Outlet flow from fermenters (inlet flow of the tank TK 605) during a working day

A different evaluation has to be done for the outlet of the tank TK605, which feeds the rinses of the CIP cycles of the dairy plants. The washing cycles change from day to day. The absorption of water from the tank TK605 will, therefore, be variable as a function of the day of the week, with a cyclicality of all the various CIP operations every 2 weeks, as explained in the previous paragraph. Moreover, in evaluating the outputs from the tank, it should be taken into account that, during the final rinse of each CIP cycle, the water used during the last 10% of the time, is recycled and used for the following cycle. Therefore, this amount of water should not be considered when quantifying the global water consumption. As an example, Figure 7 shows two graphs, with the water withdrawals from the tank TK605 during the days of Monday (in blue) and Tuesday (in red). By adding up the data of punctual consumption, the global daily quantity of water in outlet from the tank can be derived. On Monday, we obtained a total consumption of about 37000 liters (36925), on Tuesday 39500 liters (39414).

It is evident that the processes of cleaning of the cheese factory are concentrated in rather limited time windows, with large flow rates required in a short time. Considering the whole week, day by day the differences in the absorption cycle from the tank are not so deep, but there is nonetheless a variability, which had to be taken into account. By integrating the output flow rates from the tank TK605 during 24 hours, the volume of water daily emitted by the tank can be computed. The data are collected in the graph of Figure 8.

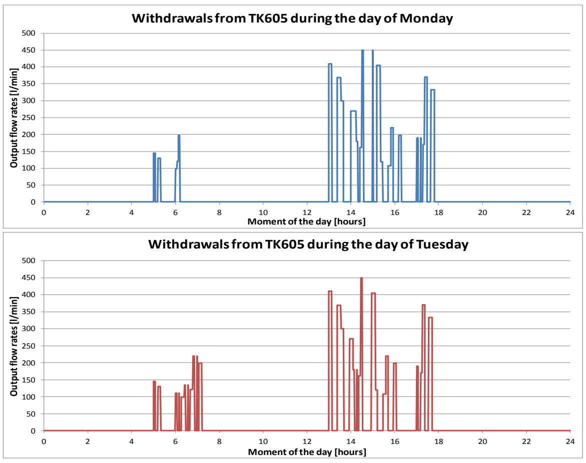

Figure 7 - Water output from the tank TK605 during the days of Monday and Tuesday for the CIP cycles

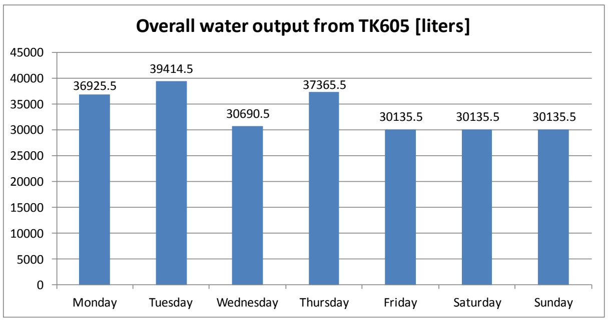

Figure 8 - Daily water output from tank TK605, used for the rinse phase of the CIP cycles

By computing the average consumption over the 7 days, it is found that approximately 33,500 liters (33543) of water are processed every day by TK605. This is more than the 20200 liters arriving each day to the tank from the fermenters, that, consequently, could be entirely reused, avoiding to take it from the wells. The only limitation to the reuse of this water is related, as anticipated, to the current volume of the tank (9.5 m^3), that is not sufficient to this purpose. Therefore, during the night, when the CIP are off, the tank reaches the filling level and the water that continues to arrive from the fermenters is discharged to the ground. This is evident from the graph in Figure 9.

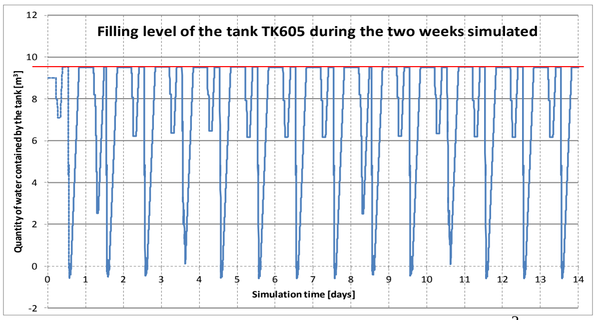

Figure 9 - Water contained in the tank TK605 (in m^3) during the two weeks simulated

In the picture, the red line represents the tank capacity. Once this limit is reached, the tank cannot accept further water and is forced to discharge it. This is even more evident analyzing the behavior of the drain valve of the tank, which opens when the limit capacity is reached (Figure 10).

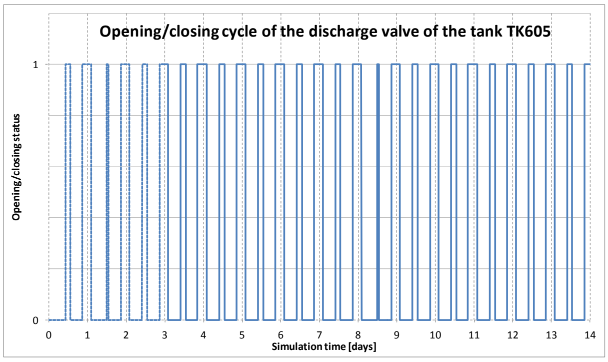

Figure 10 - Cycle of opening and closing of the discharge valve of the tank TK605. When the status is on 1, the valve is open and vice versa.

From the AS IS simulation, it emerged that the valve remains open for 34.36% of the global time. Averaging the results on the fourteen simulated days, this generates 10.57 m^3 (10570 liters) of water wasted daily, that, conversely, could be saved. This account for 52.33% of the water potentially recoverable (i.e. the 20200 liters in output from the fermenters' cooling). Moreover, by comparing the quantity of wasted water with the daily global absorption of water of the cheese factory (50 m^3), this quota represents the 21.14%.

It is obvious that avoiding to discharge more than 10000 liters per day of potentially reusable water would result in a significant economic savings. This, in turn, would justify an investment to increase the storage capacity of the tank TK605.

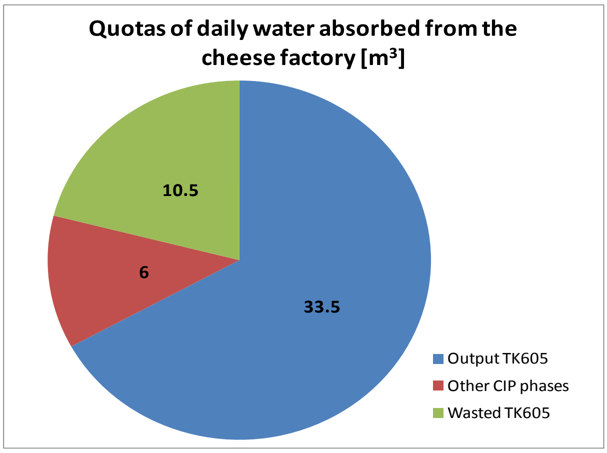

Figure 11 - Pie chart with the use distribution of the total daily amount of water absorbed from the "cheese section" of the company (50 m^3)

3.1.2. Butter factory analysis

As previously mentioned, from the analysis of the butter production line, we were able to identify that the critical point is the tank TK105, i.e. the central tank that feeds the line of the service water, the CIP circuits, the faucets and the line that brings water directly to the product to generate the correct mixtures. Also in this case, the tank can be fed in two ways: directly from the wells, or by the water in output from the pasteurizer and cooler.

Looking at the cooler and pasteurizer, their working cycles are shown in Figure 12, that shows the water absorbed (and then transferred to the tank TK105) by the two machines.

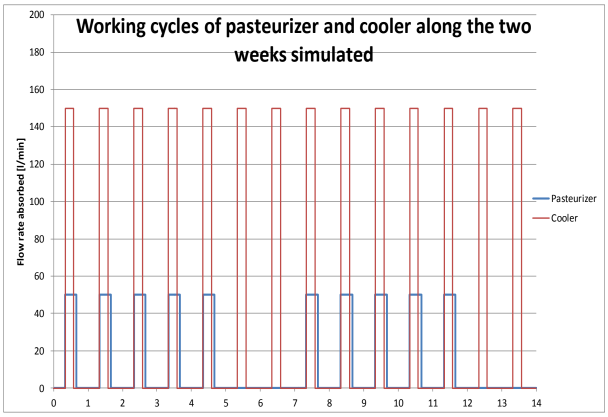

Figure 12 - Working cycles of cooler and pasteurizer of the butter section of the plant factory

While the duty cycle of the cooler is distributed across the fourteen days, the one of the pasteurizer is limited from Monday to Friday, while the machine remains turned off during weekends. Both machines start working at 8 a.m. The cooler works for the next 6 hours absorbing a water flow of 150 liters per minute, while the pasteurizer continues to work for 8 hours absorbing 50 liters of water per minute. It should be remarked that the production cycle of the butter factory is active from Monday to Friday: indeed, during the weekend the company does not manufacture butter, and the water absorption is, therefore, minimal. Conversely, when the production of butter is active, the water requirements of the various lines is considerably higher (Figure 13). In particular the daily water needs of the users connected with the tank TK105 amounts to 110 m^3 on average. Therefore, in these days the total water output from pasteurizer and cooler (72200 liters, equal to approximately 72 m^3), is fully used from the downstream processes, and an additional withdrawal from the wells is generated.

The main problems are concentrated in the weekends. The water needs, on Saturday and Sunday, are respectively of 37.8 and 41 m^3, the 34% and the 37% compared with the average of the other days of the week. Therefore, even if the pasteurizer does not operate, the incoming water from the cooler cannot be fully exploited, and must be discharged to the ground. In particular, Figure 14 depicts the filling level of the tank TK105 during the two weeks simulated. The red line represents the maximum capacity of the tank (32 m^3). When the maximum capacity of the tank is reached, the discharge valve opens, and the inlet water is discharged to the ground. The state of opening and closing of the valve is depicted in Figure 15. The valve remains open for a total of 318 of the total 20160 minutes simulated, i.e. for the 1.58% of the time. This data may seem to be very small, but, nonetheless, it results in a significant loss of water, reaching 63.6 m^3 during the two weeks, with a maximum value of 23.2 m^3 registered on the first Sunday. These value are even more significant when compared with the 110 m^3 of water that are absorbed daily from the butter production line.

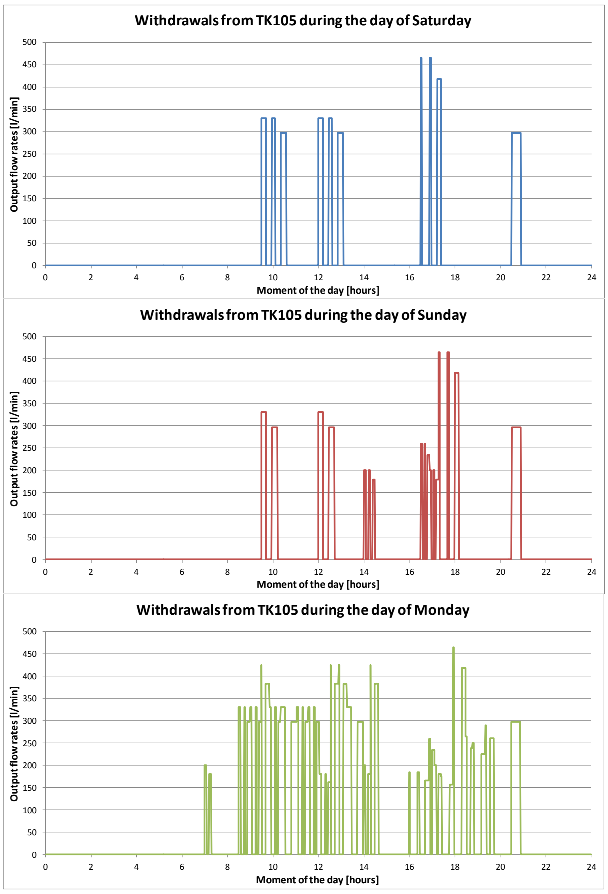

Figure 13 - Water absorbed from TK105 during the days of Saturday, Sunday and Monday

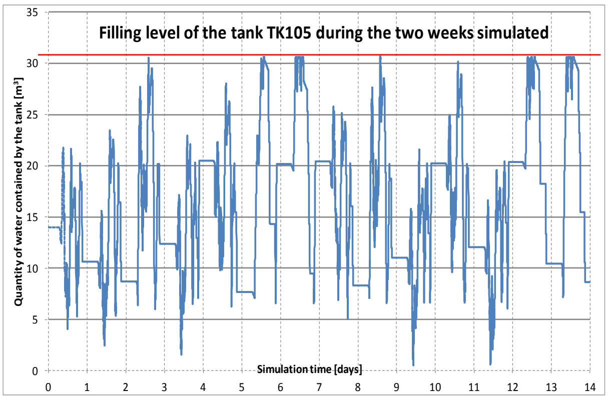

Figure 14 - Filling level of the tank TK 105 along the simulated two weeks

The valve remains open for a total of 318 of the total 20160 minutes simulated, i.e. for the 1.58% of the time. This data may seem to be very small, but, nonetheless, it results in a significant loss of water, reaching 63.6 m^3 during the two weeks, with a maximum value of 23.2 m³ registered on the first Sunday. These value are even more significant when compared with the 110 m³ of water that are absorbed daily from the butter production line.

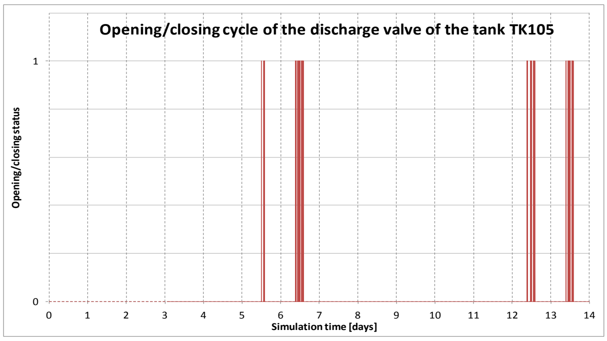

Figure 15 - Cycle of opening and closing of the discharge valve of the tank TK105. When the status is on 1, the valve is open and vice versa.

3.2. What if analysis: layout variations

After identifying the critical points of the AS IS system, we tried to identify some corrective actions, with the aim of decreasing (or eliminating) the waste identified. In this section, two different alternatives to the current layout of the lines of water supply will be analyzed, exploiting the simulator already prepared for the AS IS analysis.

3.2.1. CASE 1: Enlargement TK605 and introduction of cooling tower

In this scenario, we tried to optimize individually the two productive sections of the factory, keeping them separated. In particular, with respect to the "cheese section", we evaluated the effect of an enlargement of the tank TK605, which feeds the rinse phases of the CIPs, and which receives water from the fermenters. Looking at the "butter section", we evaluated the introduction of a cooling tower that would feed the cold water circuit of both the pasteurizer and the cooler. The tower would provide the two machine with a colder water than that withdrawn from the wells, thus generating interesting water savings.

Analyzing separately the two changes, replacing the tank TK605 (volume 9.5 m³) with a tank of 30m³, would allow to recover all of the water discharged on the ground by the cheese production lines in the current configuration (i.e., more than 10 m³ per day).

The introduction of the cooling tower, instead, implies more complex considerations. First of all, the inclusion of such a system has been suggested to the company by a plant engineer, who has proposed a tower of a defined potential, namely 500 kW. The manager of the company wanted to understand if such investment was actually profitable. The behavior of the manufacturing system, in fact, changes depending on the seasons, as the performance of the tower depends on the environmental temperature. Beginning from the analysis of the AS IS scenario, the pasteurizer absorbs 240 m³ of water over the two weeks simulated, while the cooler 756 m³. The cooling tower would reduce these requirements. In particular, during Summer, considering an average temperature of 25°C, the tower would let to save about 100 m³ of water every 2 weeks. In fact, the pasteurizer could be entirely fed with the tower water, and, as the water coming from the tower would be cooler than that of the wells, it would be sufficient to use 140 m³ instead of 240.

During Winter, considering an average temperature of -1°C, the efficiency of the plant would increase, and water savings could reach 728 m³, out of the 996 currently required. The pasteurizer and the cooler could be both fed with 268 m³ of water from the tower.

Averaging over the year, the pasteurizer and the cooler would have their water needs reduced by approximately 414 m³ every two weeks, equal to 41.6%. Hence, the amount of water saved would be relevant, but it must be considered that all the wells water used by pasteurizer and cooler can be reused, while it is not possible to recover the tower water. Consequently, with respect to the butter production line, the overall water absorption of the system would actually increase rather than decreasing (Figure 16).

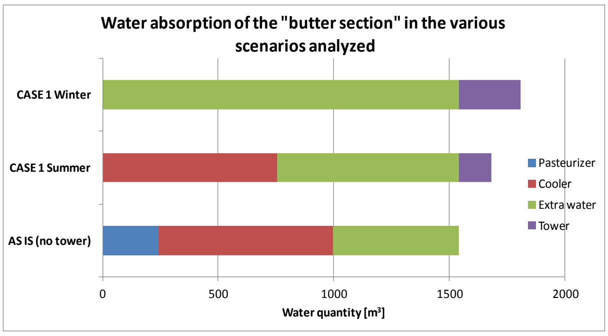

Figure 16 - Water absorbed by the butter factory during the two weeks simulated in the different cases analyzed: the total quantity are subdivided according to the users

3.2.2. CASE 2: Introduction of a new tank, parallel to the TK901

In this scenario, we assume to increment the total storage capacity of the central tank of the whole plant, the TK901. In the current configuration, the tank has a capacity of approximately 10 m³, that has been kept constant in this analysis. Instead of enlarging it, we pondered the introduction of a new reservoir, named TK902, that would work in a complementary manner to the first one.

This tank would allow to avoid water waste, recovering the outputs from the fermenters of the "cheese section", and the discharge water downloaded by the TK105 (in the "butter section") when it reaches its maximum capacity. Therefore, it would work as an inter-operational buffer, with the purpose to decouple water recovery and the water withdrawals from the various lines. A schematic representation of the line with the insertion of the tank TK902 is depicted in Figure 17. The new part of the line is highlighted in red. The red continuous lines represent the piping in output from TK902, while the dashed lines are the inlets, that allow the tank to fill, recovering water from other processes. By introducing the new tank, the operating conditions of the plant would not be altered, but the two sections would have a preliminary point of contact, exactly the tank itself. In fact, inside the TK902, the recirculation water of both the cheese and the butter productive lines would be recovered. The volume of the tank was not defined *a priori*; rather, it has been derived from simulations, identifying the maximum filling levels achieved. The volume of water that the tank TK902 would contain along the two weeks is represented in the diagram of Figure 18. As can be seen, the maximum level is reached on Sundays, when the cheese production lines work normally, while the production of butter is off. This leads to an accumulation of the water coming from the cooler of the serum, that increases the level of water within the tank TK902.

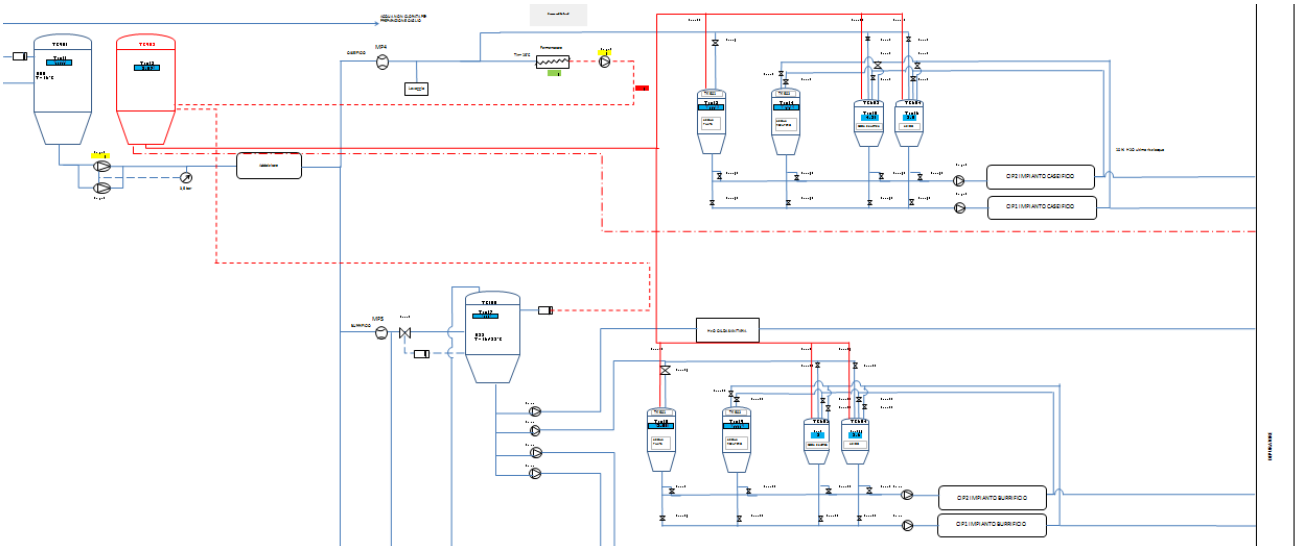

Figure 17 - New configuration of the water distribution system of the factory after the introduction of the tank TK902

It is evident that the tank level has a tendency to grow at night and in the early morning, when the productive and CIP processes are off. Conversely, during the day, the level drops until the tank is empty, when the various CIP cycles and the other utilities connected to the tank require water. However, a tank with a capacity of 30 m^3 seems to be appropriate to face the normal water demand and also in presence of potential peaks of request.

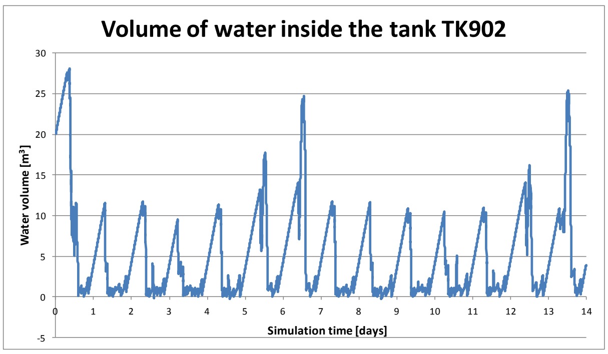

Figure 18 - Volume of water contained by the TK902 along the two weeks

The tank, if correctly dimensioned, could completely avoid the waste of water. The water saved would therefore amount to a total of 211.58 m^3 all along the two weeks. This volume of water is very relevant, even more if compared with the daily water consumption of the whole plant. In fact, the set of cheese and butter production lines and the other services, do absorb every day about 210 m^3 of water. Therefore, the installation of the tank TK902, would bring to save a volume of water equal to that necessary for one day of operation of the entire factory, every two weeks (or, in terms of percentage, the 7.2%).

4. CONCLUSIONS

Due to the increasing costs of water and water discharge, reuse of water in the food industry is becoming more and more important. The work carried out in this paper has allowed, first of all, to identify and quantify the water wastes of a real company, operating in the dairy industry. After the analysis of the current system layout, two alternative configurations of the water supply lines were evaluated, with the purpose of understanding which one would ensure the most performing results in terms of water saving. In this respect, the first plant configuration did not give satisfactory results, so the company management rejected the possibility of installing a cooling tower. Conversely, the second scenario provided interesting results in terms of water saving, by eliminating almost all the water wastes identified in the AS IS scenario. The introduction of a new tank (TK902, with a capacity of 30 m^3), which would work in a complementary way to existing TK901, would reduce the company's water consumption by 7.2%.

This study is a typical example of how discrete events simulation can be a very useful tool from many points of view. In fact, it allows to predict the performance of a new system configuration, before its physical implementation. This is an important advantage for companies, as it can guide strategic decisions through a “WHAT IF” analysis. Once set the basic logic of the simulation model, it is, indeed, very fast and cheap to change some parts of the layout and to assess the corresponding impact on the system performance. Through discrete events simulation, in fact, it is possible to monitor in detail the operating conditions of a water supply line, taking into account of the circulating flow rates, the on/off periods of pumping systems, the filling levels of the storage tanks. This allows a precise knowledge of what is happening on the entire system, as well as to identify those areas where interventions should be planned to improve the system performance.

Discrete events simulation is not an innovative tool by itself, but becomes so when it is applied to contexts hitherto unconsidered. The company with whom we collaborated has realized the benefits potentially arising from the method, and has managed to avoid an unnecessary investment on one hand and to understand how to reduce their water waste on the other.

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