UNIVERSITY OF TWENTE.

BSc Thesis Electrical Engineering

Modeling Milk Cooling Within A Dairy Farm To Minimize Electricity Costs

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Abstract

Cooling milk directly after milking is essential for the shelf-life of milk because bacteria grow rapidly in raw milk above 7°C. Milk cooling accounts for more than 30% of total electricity costs within a dairy farm. This thesis aims to test cooling systems in different configurations to reduce electricity costs within a dairy farm. The models formulated for this research provide predictions about the behaviour of the milk cooling process. Solutions such as pre-cooling and cold storage are considered in this thesis along with detailed modeling of the same. The simulation results shows that there is reduction in electricity cost by 82% in winter and 39% in summer with the help of variable electricity prices, PV panels, water storage and groundwater.

1 Introduction

Cow milk is collected at an average temperature of about 37°C and cooled to below 4°C within 3 hours. Cooling milk improves shelf-life since bacteria develop rapidly in raw milk above 7°C[12][7]. This milk cooling typically accounts for over 30% of the total electricity costs within a dairy farm[20]. To lower these electricity costs, many cooling processes and technological components can be used in various configurations. Since the milking process in a dairy farm is highly predictable, a model is developed to test different configurations and their efficiency in order to cut electricity expenses.

Installing energy conservation techniques can reduce the milk cooling electricity costs. Such a technique is a pre-cooler that can heat water while cooling milk with a heat exchanger. A battery can also be used to reduce electricity costs. The battery can store cheap electricity throughout the day and then be used to handle the milk cooling load. The relatively cheap electricity can come from renewable energy sources or variable electricity prices. The battery can be in the form of a cold storage, a thermal mass that is cooled and later used to cool down milk. How these techniques work and can be used to reduce electricity costs within a dairy farm are researched in this thesis with the following research question and three sub-questions:

How can cooling components and electricity sources be modelled to test various milk cooling configurations to reduce electricity prices within a dairy farm?

- How can cooling components such as the pre-cooler, cold storage and milk cooling tank be modelled?
- What is the effect of using variable electricity prices on the milk cooling electricity costs?
- Do different configurations of the pre-cooler and cold storage affect electricity costs?

There are three steps in the research process. The first phase entails modeling the various cooling techniques and technological elements used to cool and store milk, as well as determining the parameters that specify the test setup. In order to establish a reference for these criteria, a Dutch dairy farm with around 90 cows is visited for this study and is referred to as "the Farm". In total, 5 possible model configurations are examined in the second step, which involves designing the methodology. Drawing conclusions after comparing, analyzing, and evaluating the results is the last phase.

2 Model

A model for the cooling system in a dairy farm provides predictions about the behaviour of the milk temperatures and cooling costs. To get an better understanding of the process each cooling component is modeled individually as a sub-model. The benefit of this is also that each component can be attached or detached to test different configurations and scenarios of the cooling process. First, some common definitions are introduced. These definitions are used throughout the modeling process and provide a fundamental grasp of heat modeling. The second step explains the components used in the model, these are the pre-cooler, cold storage, milk cooling tank and electricity sources. The paragraph concludes with an overview of the parameters, which can later be changed to vary the test arrangement.

To analyse the model's summer and winter behaviour the shortest and longest days in the Netherlands are used. These are: 20, 21 and 22 December 2021 for the winter and 20, 21, and 22 June 2021 the summer.

2.1 Definitions

Definitions are necessary as a starting point for the model because they serve as a base. Understanding how temperature changes is crucial because this study is focused on milk cooling. Equation (1) describes how a system's rate of temperature changes over time.

$$\frac{dT}{dt} = \frac{1}{m * cp} * (\frac{dQ_{gain}}{dt} - \frac{dQ_{loss}}{dt}) \tag{1}$$

$\frac{dT}{dt}$ in the above equation is the change in temperature over time. All measurements are done in degrees Celsius and time is set in hours. m in equation (1) is the mass of the temperature system in kg, and cp is the heat capacity of the system. Heat capacity is the amount of heat that must be applied to an object to change its temperature. The unit of heat capacity is joule per Kelvin J/K, which is unique for every material. Heat flow is the amount of heat energy leaving or added in a system per unit of time. The equation for heat flow is defined as $\frac{dQ}{dt}$. The term $\frac{dQ_{gain}}{dt}$ is the heat added to the system and $\frac{dQ_{loss}}{dt}$ is the heat flow that is lost to the environment.

The heat flow that is lost to the environment is proportional to the temperature difference outside and within the system and is defined with the equation (2).

$$\frac{dQ_{loss}}{dt} = \frac{T_{env} - T_{out}}{R_{eq}} \tag{2}$$

The thermal resistance equivalence R_{eq} in this equation can be defined as the resistance in heat flow. This can be derived from Fourier's Law for heat conduction which is shown in equation (3).

$$R_{eq} = \frac{\delta x}{A * q} \tag{3}$$

In the above formula δx is the thickness in m, A is the area m^2 and q is the thermal conductivity $K * m/W$.

Using equation (1) and (2), a heat model of a system can be developed. Figure 1 shows an implementation of this in Matlab [9].

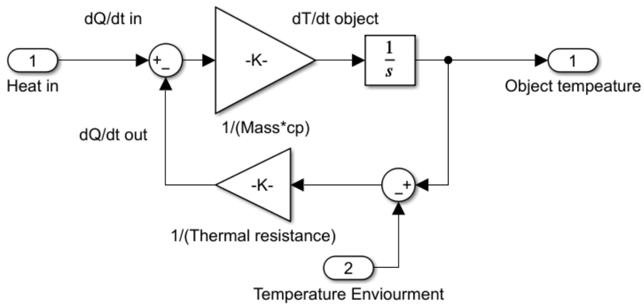

Figure 1: Model of equation (1) and (2)

The model in Figure 1 can be used to make a heat exchanger in Figure 3. In this model, the environment temperature is the temperature of another heat model.
Adding heat to the system is also needed for the model. Formula (4) defines heat gain. T_{cooler} is the temperature of the cooling liquid, T_{system} is the temperature of the system that is cooled, and $\frac{m}{t}$ is the flow rate in $\frac{kg}{h}$.

$$\frac{dQ_{gain}}{dt} = \frac{m}{t} * cp(T_{cooler} - T_{system}) \tag{4}$$

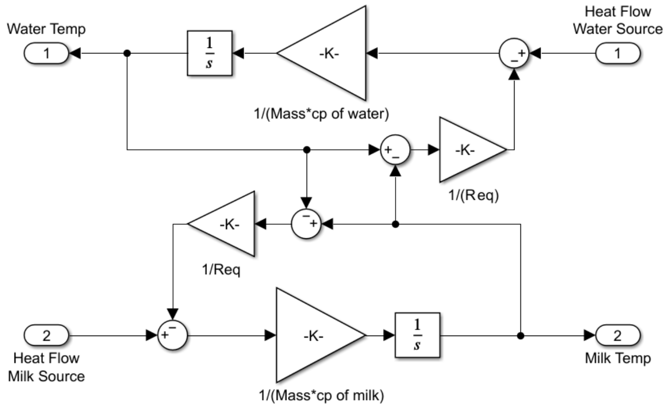

Figure 2: Model of heat exchanger

2.2 Pre-Cooler

The first component that can optimise the cooling process is the pre-cooler. The initial milk temperature straight from the cow is around 37°C. Active milk coolers would take the maximum amount of electricity to cool this directly. An efficient way to reduce this electricity consumption is to let the milk heat dissipate into the surrounding environment through a radiator. Consequently, the active cooler will need to expend less electricity to get the milk to storage temperature.

This heat, however, is lost to the environment while the heat from the milk can be reused. A heat exchanger can be used to heat water using the heat from the milk. The heat exchanger decouples the milk from the cooling liquid, but maximizes heat transfer. The ratio of water to milk flowing through the heat exchanger can be modified to maximise cooling. A heat exchanger for this use is manufactured by Mueller, and it is utilized in the model [13]. The Mueller heat exchanger recommends two liters of water for every liter of milk. The pre-cooling component can be treated as a closed or open-loop system. A water storage tank is used in a closed-loop system. The tank's water is used in the heat exchanger and then pumped back into the tank. The open-loop system uses water directly from a source on the heat exchanger, which is then stored, utilized, or pumped back into the earth. For both systems, ground or tap water can be used. The groundwater in the Netherlands is around 10°C [3].

The following section explains the modeling of the water tank needed for the closed-loop system. The water tank installed for this model was a Remon RV3000 (3000L) tank made from polyethylene (PE) material [17]. The tank has a height of 2.075 m and a diameter of 1.470 m with a weight of 70 kg. The density of polyethylene is 960 kg/m$\hat{3}$ [15]. The thickness of the tank can be calculated by dividing the weight by the surface area multiplied by the density of polyethylene. This yields a thickness of 0.39 cm. The thermal conductivity of PE is around 0.5 W/mK [19]. Using this information, the thermal resistance can be calculated with equation 3 and is found to be 1.515E-7 K/W. Using Figure 1 the model of the water tank can be made.

For the open-loop system, the energy for the pump is taken into account. This is because for the open-loop system, the water needs to be pumped up from the ground. For this model, the water is pumped from a water source 50 meters deep [5] with a "Pluriject 4/130" pump [16]. This pump is also utilized on the Farm and has a flow rate of 4.8 m3/h and can pump up water from 50 meters deep. The pump consumes 1.5kW of power. It can be calculated that for every liter 1125J is needed.

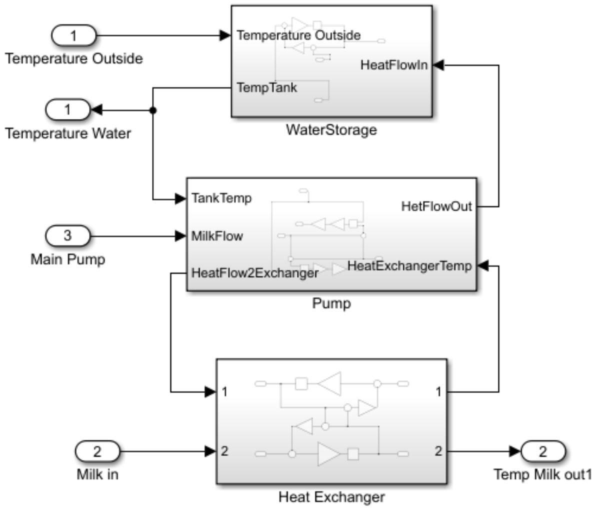

Figure 3: Model of the pre-cooler, closed loop

2.3 Cold Storage

The second component that could reduce electricity costs in milk cooling is an active cooling component. With a buffer, cheap energy can be stored and used when needed. Relatively cheap energy can come from PV panels, wind turbines or variable electricity prices. Cold storage could be a cheap and efficient technique to store this energy. This cold storage is a thermal mass that is well insulated and cooled down at any time. A heat exchanger within the cold storage can cool down the milk passing through it. This is represented by two thermal masses, as seen in Figure 1 and connected with a heat exchanger illustrated in Figure 3. The first thermal mass is the buffer of cold storage, and the second thermal mass is the milk within the heat exchanger. The following requirements define the model. The first requirement is that the system fits into the farmer's space.

The size requirements are the same as a Remon RV1000 water tank [17]. The water tank is a 1000L tank similar to the Remon tank on the Farm. The second requirement is that the tank must be well insulated. The latter-mentioned milk cooling tank specifies the isolation requirements. It states that the isolation is chosen such that the temperature rise is 1 °C in 4 hours with an initial temperature of 4 °C and an outside temperature of 38 °C. Water is taken as a thermal mass for the cold storage because of the availability, relatively high heat capacitance and environment friendliness [2]. Using equation (1) and (2) the thermal resistance R_{eq} of the water tank can be calculated which results in 3.252E-5 (K/W).

The electricity costs for the cold storage are lower than that for the milk cooling tank. This is why the heat exchanger within the cold storage uses a high thermal energy exchange rate. Transferring as much relatively cheap energy to the milk ensures that the milk is cooled with the cheapest electricity and stored with the best insulation. This is because the milk goes to the milk cooling tank, which is better insulated because of the relatively smaller surface area, see equation 3). The cold storage cooler is designed to meet the same requirements as the milk tank cooler discussed later.

2.4 Milk Cooling Tank

The final stage of the milk within the model is the milk cooling tank. This is where the milk is stored and cooled before transport. The milk tank is generally emptied every 72 hours and is filled every 12 hours at 5 am and 5 pm. An external cooler cools the milk cooling tank. The NEN5708 standard and "Leerboek melkwinning" state that the cooler has to turn on when the milk cooling tank is filled to 10% of the maximum volume of the milk cooling tank [1][7]. This is to prevent the milk from freezing, as the cooling elements can freeze the milk when not enough milk is inside the tank. Mueller has a Milk Level Detection (MLD) sensor that can measure the milk level inside the tank [14]. The MLD sensor is not mandatory and the farmer can turn on the milk tank after the first milking session, however, for this thesis this sensor is used because of the definition in the NEN5708 and simplicity.

The NEN5708 standard [1] also sets the requirements for the milk cooling tank, and can be used to calculate the thermal resistance of the milk cooling tank. The NEN5708 states that the tank must have sufficient thermal insulation so that at a specified outside performance temperature (PT) and with the rated volume of milk, the rate of rising of the mean temperature of the milk at an initial temperature of about 4°C must not exceed 1°C in 4h. The setpoints of the PT use three classifications, A, B and C, which are 38, 32 and 25 degrees, respectively. The temperature differential between the tank's interior and exterior increases with higher categorization. With equation (2) it can be seen that higher isolation is needed to comply with the 1°C per hour rule.

For the milk tank the Mueller P10000 (10.000L) is used for the model and is the same model that the Farm used [14]. Meuller complies to the NEN5708 so the thermal resistance can be approximated. With the density of milk, the weight of the full tank can be calculated, which results in 10.000* 1.035 = 10.350 kg. Using this information the thermal resistance can be calculated using equation 1 and 2 which results in an R_{eq} of 3.343E-6 (K/W).

The set points for the cooling are used from the "Gebruikershandleiding" of the Mueller P10000, which states that the cooler cools down the milk to 3.7°C and then turns off. The cooler turns on again at 3.7°C+ 0.5°C = 4.2°C. This is also similar to what is specified in "Leerboek melkwinning"[7]. Glycerol, which is also utilized in the model, was the cooling liquid used by the Farm. The coolant temperature is estimated to be -10°C because turning on the milk cooler could freeze the milk with a milk cooling tank filled with milk under 10%. Coolant flow is estimated by the fact that milk is cooled to 4°C within 3 hours after milking [7].

2.5 Electricity sources

PV panels produce relatively cheap and clean electricity from solar radiation, which the farm can use. This solar radiation is not continuous and depends on a number of variables, including the presence of clouds, the location, the caliber of the equipment, and the position of the sun.

For this paper the electricity generation of the solar panels was not measured, however, a model is made based on the global radiation (in J/cm2) data from the KNMI in Twente [8] with a resolution of 1 hour as seen in Figure 4. The PV panels convert the radiation to electricity. The model multiplies the radiation data with an efficiency constant of the PV panels to calculate the electricity output. The peak power of the PV panels is taken to be 250W which defines the efficiency [6].

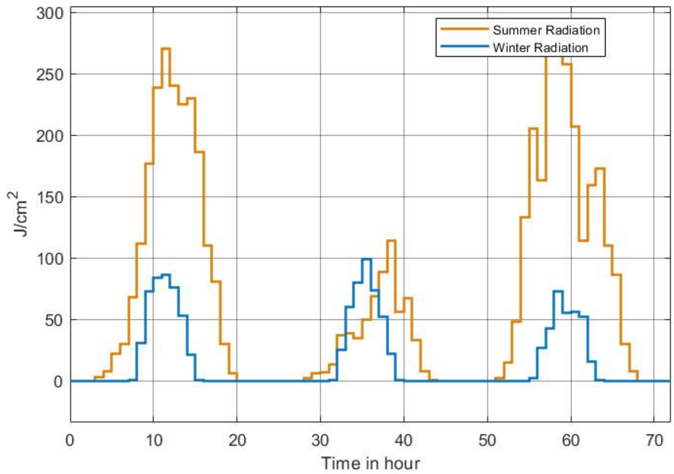

Figure 4: Radiation 20, 21 and 22 December and 20, 21, and 22 June 2021

In addition to PV panels, grid electricity can be used to charge the model's cold storage. In the model, the grid energy price depends on day-ahead prices. The day-ahead prices are the electricity prices for the next day. For the model, price data from ENTSO-E Transparency Platform [4] was used and is shown in Figure 5 for the summer and winter. Low electricity prices are wanted for the cold storage to reduce cooling costs. Because the electricity price is around four times as much in the winter as in the summer, the average price of the electricity as a threshold can not determine if the price is relatively low or expensive. A moving average could do this because the sliding window property only looks at a local time period and is used in the model. The cold storage only charges when the price of electricity is below this running average.

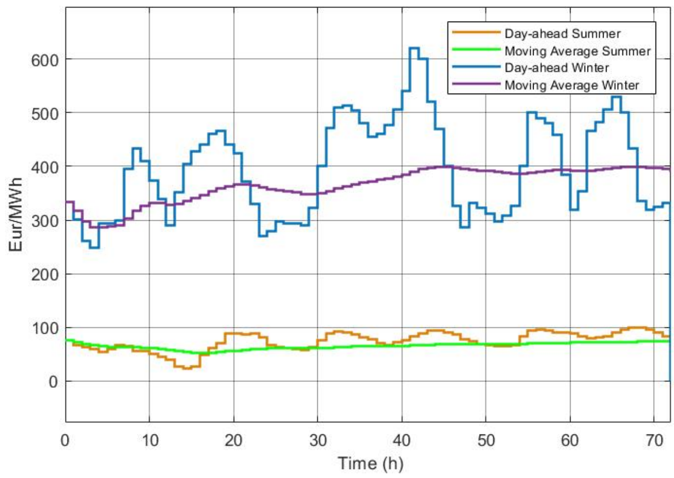

Figure 5: Day-ahead prices 20, 21 and 22 December and 20, 21, and 22 June 2021

2.6 Parameters

Setting the parameters defines the farm's test setup, which is needed to test the model with the different components. The model can simulate multiple scenarios, but for the scope of this research, most parameters are taken as constants. The reference to these parameters is from a combination of sources. The reference to the parameter and the parameters themselves can be found in Table 1.

Parameter List				
Name	Value	Unit	Description	Ref.
StartTempMilk	37	°C	Initial temperature milk	[12]
Cows	90	Cows	Number of cows that give milk	Farm
AvgMilkProduct	12	L	Production of milk per cow per milking session	Farm
MilkstartTime	5	h	Time the first milking should start	Farm
PVPanels	10	Panels	Number of PV panels on farm	Farm
SizePV	1.6	m2	Size of PV panels	Farm
SizeWaterStorage	3000	L	Watertank size for pre-cooler	[17]
ReqWaterStorage	1.52E-7	K/W	Thermal resistance of water tank	[17]
InitTWaterStorage	10	°C	Initial temperature in water storage	[3]
pumpMultiplier	2	Water/Milk	Heatexchanger ratio	[13]
TempOpenLoop	10	°C	Temperature ground water	[3]
HeightTank	2.08	m	Height of watertank	[17]
DiameterTank	1.47	m	Diameter of watertank	[17]
PumpEnergy	1125	J/L	Powerconsumtion pump	[16]
ReqColdStorage	3.25E-5	K/W	Thermal resistance cold storage	
VolumeCS	1000	L	Volume of cold storage	[17]
InitCS	10	°C	Inital temperature cold storage	[3]
RHeatExCS	2E-7	K/W	Thermal resistance cold storage	-
ReqMilkTank	3.34E-6	K/W	Thermal resistance milk tank	[14]
SetPointCooler	3.7	°C	Setpoint cooler	[7][14]
Hysterse	0.5	°C	Switchpoint cooler	[7][14]
TankVolume	10000	L	Size of milk tank	[14]
CoolFlow	500	kg/h	Heatflow from cooler	[1][7]
CoolTemp	-10	°C	Tomparture from cooler	[1][7]
CpWater	4186	J/(kg K)	Thermal capacity water	[2]
CpMilk	3930	J/(kg K)	Thermal capacity milk	[18]
CpGlycerol	2350	J/(kg K)	Thermal capacity glycerol	[21]
DensityWater	1	Kg/L	Density of water	-
DensityMilk	1.035	Kg/L	Density of milk	[10]

Table 1: Table of parameters used in the model

3 Approach

Various component combinations can be examined using the model. This is done to find how every configuration affects the electricity costs and temperatures in the system. For summer and winter the temperatures, electricity costs and radiation vary significantly. This is why for every configuration, the summer and winter scenario are tested. Four setups are tested in order of increasing complexity.

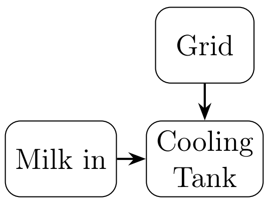

Figure 6: Configuration 1

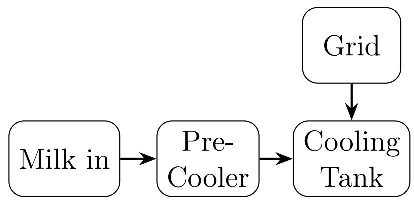

Figure 7: Configuration 2

Figure 6 shows the most basic configuration. The milk is emptied into the milk cooling tank directly after milking. This scenario is used as a reference so that other configurations can be compaired against it. For configuration 2 shown in Figure 7, the pre-cooler is added before the milk cooling tank. The pre-cooler is set to a closed-loop system in the standard configuration because that is what the Farm utilized. However, for this configuration, both the open and closed-loop systems are tested. This is done to compare the performance of the open closed-loop system.

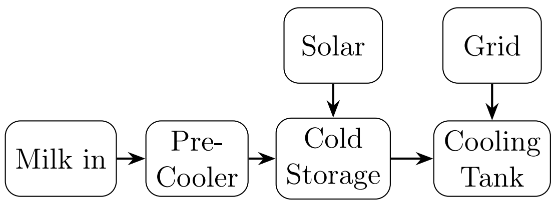

Figure 8: Configuration 3

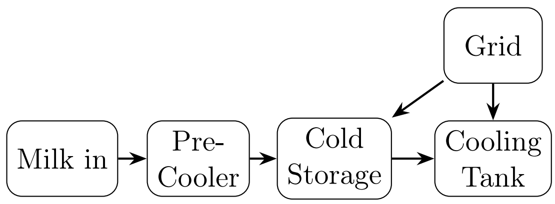

Figure 9: Configuration 4

In configuration 3 and 4 shown in Figure 8 and Figure 9, the cold storage is added. Since a higher temperature difference leads to more heat transfer to the pre-cooler water, the cold storage is placed after the pre-cooler, see equation (2). As a result, the active cooling components use less energy and the water in the pre-cooler is warmer, which is desirable for heat reuse. Due to the cold storage's ability to be powered by solar and grid power, both options are tested. In configuration 3 the system is tested with 10 PV panels and in configuration 4 the grid is used when the electricity price drops below the running average.

4 Results

The configurations mentioned above are simulated for 72 hours for the winter and summer scenarios and the results are given in this section. For every scenario the running electricity costs for cooling (Costs in Euro) as well as the temperature of the milk going into and the temperature in the milk tank are plotted. The volume of the milk in the final milk cooling tank is also plotted to see when the milk is added to the system. The commutative totals of the electricity price and usage are given in tables below. For the configuration with the pre-cooler the temperature of the milk going into the exchanger is plotted and for the configurations with the cold storage the temperature of the water within the cold storage is added to the plot. This is to see how these systems react to the outside and milk temperatures.

4.1 Configuration 1

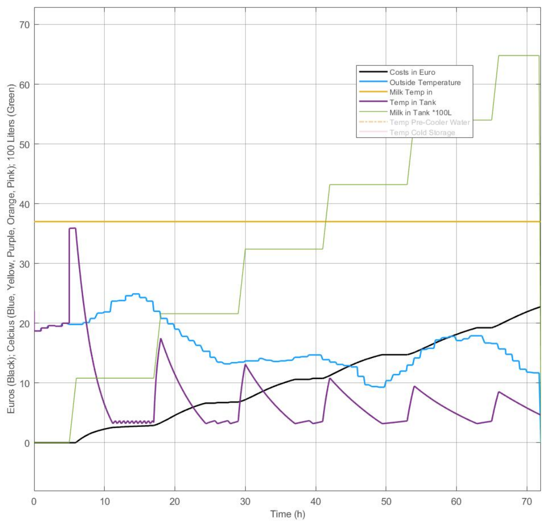

Figure 10: Config. 1, Summer
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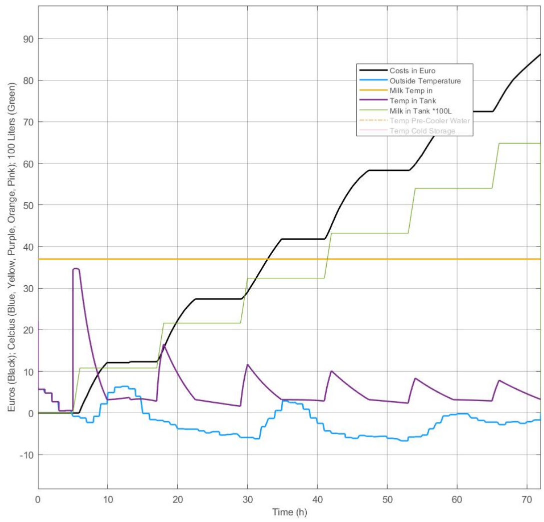

Figure 11: Config. 1, Winter

	Total electricity costs	Total electricity usage
Summer	23,05 Euro	0.291 MWh
Winter	87,92 Euro	0.205 MWh

Table 2: Config. 1, cumulative values after 72h

As can be seen in the results of configuration 1 in Table 6 the price to cool the milk in the winter is almost four times as much as in the summer. It can also be seen that the energy consumption in the winter is less. In Figures 10 and 11 it can be seen that storing milk in the winter at 3.7°C does not take any electricity costs, while in summer the opposite is true. Finally it can be seen that cooling milk to storage temperatures takes longer in summer.

4.2 Configuration 2

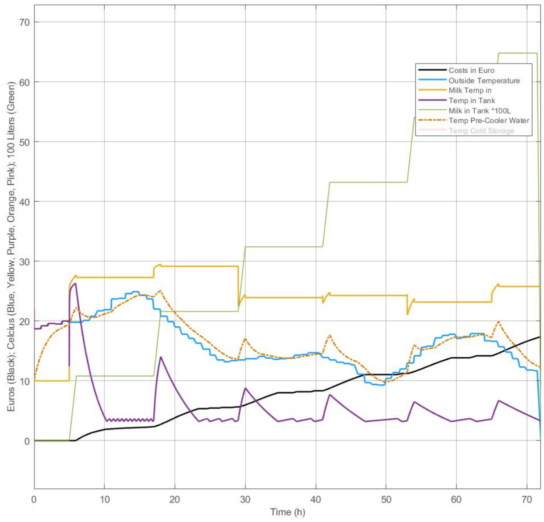

Figure 12: Config. 2, Summer, Closed Loop

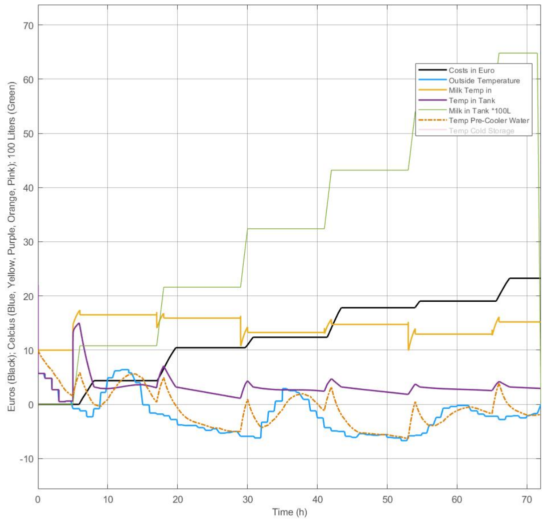

Figure 13: Config. 2, Winter, Closed Loop

	Total electricity costs	Total electricity usage
Summer	17,39 Euro	0.220 MWh
Winter	23,26 Euro	0.0523 MWh

Table 3: Config. 2, cumulative values after 72h, Closed Loop

It can be seen that the temperature of the water storage tank is affected by the outside temperature more than the milk within the milk cooling tank. The milk temperature entering the milk tank is also impacted by the temperature within the water storage tank. In the summer, the milk flowing into the milk cooling tank is around 10 degrees higher than in the winter. Compared to combination 1, the cost of electricity for cooling the milk is now more comparable for the winter and summer scenario. Significant price reductions have also occurred, particularly for the winter scenario.

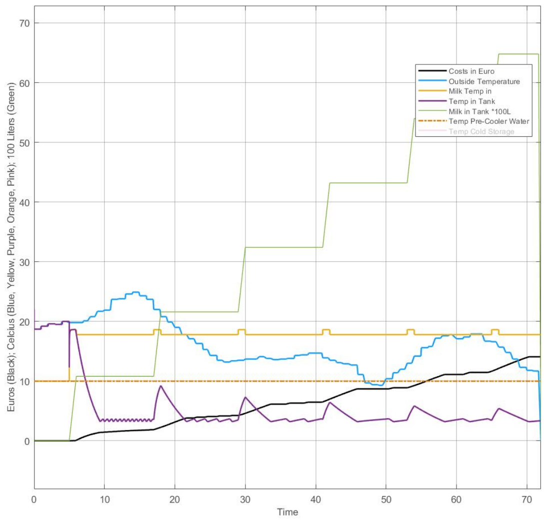

Figure 14: Config. 2, Summer, Open Loop

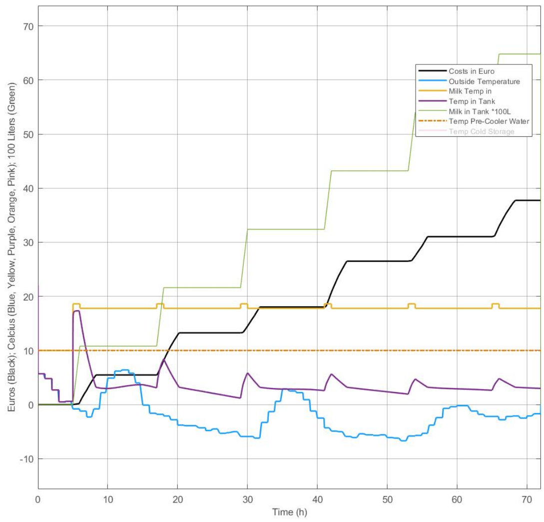

Figure 15: Config. 2, Winter, Open Loop

	Total electricity costs	Total electricity usage
Summer	14,07 Euro	0.180 MWh
Winter	37,75 Euro	0.0852 MWh

Table 4: Config. 2, cumulative values after 72h, Open loop

With the open system, the temperature of the water is not affected by the outside temperature. In the summer, the total price for electricity is less than in the closed loop scenario. In the winter, this difference is opposite.

4.3 Configuration 3

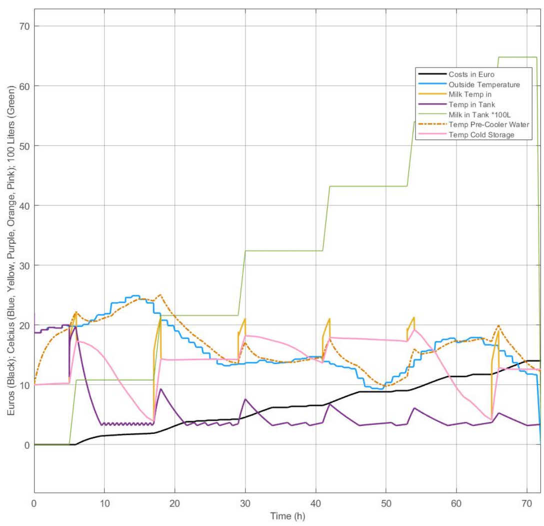

Figure 16: Config. 3, Summer

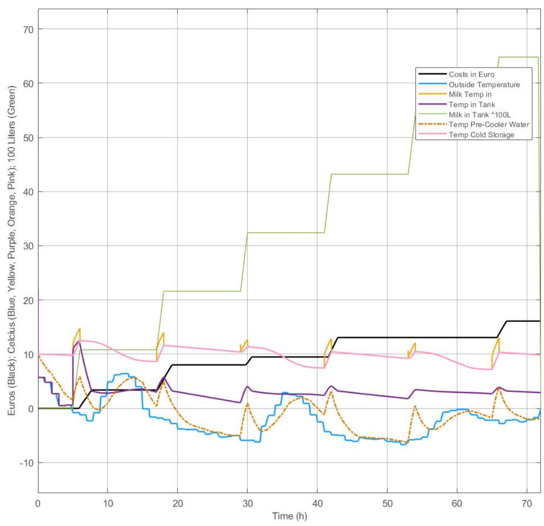

Figure 17: Config. 3, Winter

	Total electricity costs	Total electricity usage
Summer	14,02 Euro	0.179 MWh
Winter	16,09 Euro	0.0361 MWh

Table 5: Config. 3, cumulative values after 72h

It can be seen in the results of combination 3 that the cold storage charges according to PV power output which is dependent on the solar radiation, see Figure 4. This is more in summer than in winter. However, the average temperature of the cold storage is lower in winter. The price of the total electricity usage is almost the same, while the electricity usage in summer is more than five times higher. It can also be seen that in winter the fifth milk cooling does not cost any electricity.

4.4 Configuration 4

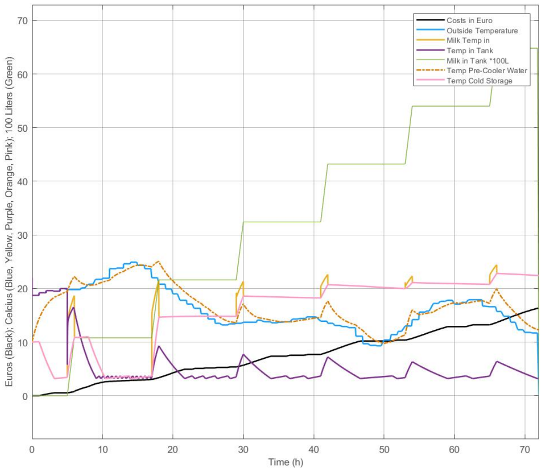

Figure 18: Config. 4, Summer

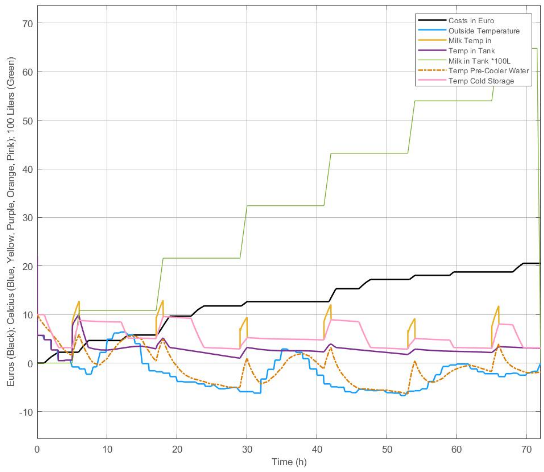

Figure 19: Config. 4, Winter

	Total electricity costs	Total electricity usage
Summer	16,30 Euro	0.211 MWh
Winter	20.54 Euro	0.0577 MWh

Table 6: Config. 4, cumulative values after 72h

This configuration uses the pre-cooler and cold storage connected to the grid. It can be seen that the cold storage cooler only turns on a few times in the beginning for the summer scenario. This is more common in the winter, and the electricity price moves more frequently throughout the simulation.

5 Evaluation and Discussion

The results show that the amount of electricity used and the cost of electricity can be greatly decreased, especially during the winter. With configuration 3 the decrease in electricity price is 39.2% and in winter 81.7% compared to configuration 1. Isolation and variable electricity prices play a big role in the total electricity costs. The pre-cooler with a closed loop performs better in the winter scenario because the water in the water tank is less insulated against the water in the ground. This means that the water in the tank becomes cooler than the groundwater, which is beneficial for cooling milk.

Hot water generation is not considered in this study, however, reusing the heat from the cow milk can have an impact on the total farm electricity costs because warm water is used on the farm in the winter. As the water tank does not have sufficient isolation, it can be seen that the temperature of the water tank adjusts to the outside temperature quickly.

This is why, in the winter, the cold storage can be utilized to store warm water because solar radiation is low and cold water is not scarce. This is not tested because the electricity expenses for heating water are not considered in this model. A simulation of the closed loop system with the cold storage tank instead of the water tank can be found in the Appendix A Figure 20. As water heating is not considered, configuration 1 may be more efficient in winter because the heat from the cooler can be used to heat water [11].

Installation and purchase costs are not considered for this research, however, the cooler can be shared between the cold storage and the milk tank. The initial test was done with two coolers with the identical specifications; this was then tested with one cooler, which did not appreciably impact the results. The simulation was also conducted with two milk batches for 144 hours, but there was no significant difference. It can be seen from the plots that the initial temperatures settled quickly.

6 Conclusion

This research is done to test different configurations of cooling components and electricity sources that can be used to reduce the electricity costs of cooling milk within a dairy farm. To conduct this research, a model of these components is created using a real case scenario. These components are evaluated in various combinations to determine their efficiency. The different components that were modeled are: Pre-cooler (Open and closed loop), Cold storage, Milk cooling tank and electricity sources (PV panels and the grid). It is found that isolation and variable electricity prices play a big role in the overall electricity costs of cooling milk, and that costs can be reduced by 39.2% in summer and 81.7% in winter.

7 Future research

In future research, water from the open system could be pumped back and the effect of this method can be tested on groundwater temperature. Furthermore, how this could be leveraged to one's advantage should be examined. Moreover, the model could be used to find the optimal number of solar panels to be installed to cool the milk, and an algorithm can be found to reduce further costs using day-ahead prices and solar predictions. Since the open-loop pre-cooler system was more efficient in summer and the closed system in winter, finding the optimum day to switch between an open and closed-loop system may be interesting. Additionally, the heat that the coolers may be reused to heat up water and how this impacts electricity prices for the entire farm may be investigated.

8 Limitations

The study has the following limitations. Heatloss from pipes was not considered in this study. This could benefit the model as heat loss would reduce cooling costs. It can be seen in configuration 2 that the milk going into the cooling tank does not change between cooling sessions. In a real world scenario, this would be the case. The water tank is modeled with the outside temperature of the KNMI data [8], however, the location for this tank would usually be indoors resulting in a higher external temperature. The water would also not be able to stay liquid below 0°C as the water would freeze below this point. The total flow resistance of the model was not modeled because no measurements of the pipes where done, so the electricity costs associated with the milk pump are not taken into account. Further, the cost of groundwater purification, which was later determined to be 5 cents per m3 of water, was not taken into consideration [17]. The milk tank was modeled to comply to NEN5708 [1]. However, this is an underestimation of the Mueller milk tank that was installed on the farm and used for this research. In a private conversation with Mueller, it was stated that the company can achieve 1 degree increase every 12 hours using a PT of 38 degree. This is however never tested and no official reference could be found.

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A Appendix

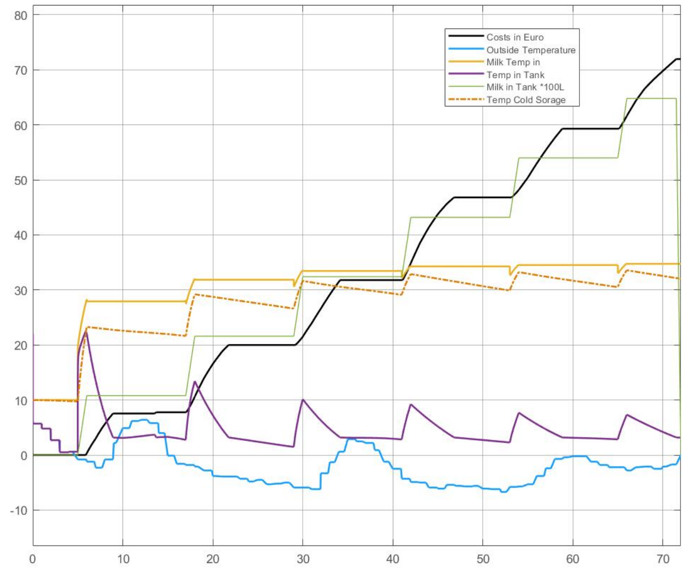

Figure 20: Cold storage tank instead of an water tank