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KPI for PID Fleet Report

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Introduction

In continuous production plants, the use of Proportional Integral Derivative (PID) controllers is widely implemented. This report has been focused in that type of industry and specifically in the possible Key Performance Indicators (KPIs) to be used in a PID fleet.

It is recognized that some of the KPIs designed by the Standard 2204 are better suited for discrete industry processes and others are better suited for continuous process industry. The main problem is that a large amount of KPIs for discrete processes have been defined while the study of possible indicators for continuous processes has been mostly neglected. This issue is reflected in the procedure that continuous industry production follows in order to apply key performance indicator to their processes, using the standard most of the time. The scarcity of reference to continuous processes has also been addressed at the time of defining appropriate KPIs in our study.

A performance indicator or key performance indicator is one of the types of performance measurement. KPIs evaluate the success of an organization, particular activity, or a simple work unit.

The KPIs, for Manufacturing Operations Management (MOM), are defined in the standard ISO 22400. This standard shows, providing guidelines and regulations, how to perform in order to be successful in a company.

An international ISO standard has been developed according to a well-defined procedure, and, through voting, accepted by a majority of the word-wide countries that participate.

In this case standard 22400 defines a KPI by giving its content and its context:

- Content: a quantifiable element with a specific unit of measure (including the formula that should be used to derive the value of the KPI).
- Context: a verifiable list of conditions that are met.

As it has been mentioned previously, Standard 2204 focuses more on discrete processes than continuous processes, so one of the challenges has been translating these definitions into equivalent definitions for the continuous processes.

Interview with Krister Forsman

As described, the aim of this report is to show KPIs that can be useful when overlooking the PID fleet at a continuous production plant. The master thesis *KPIs for Asset Management: A Pump Case Study* (Chapter 6.3) by Matthieu Lucke has been used as inspiration. This section covers the topic on how to use KPIs to overlook the pump fleet at a plant and gave an idea on where to start for the KPIs in this project. The greatest inspiration for possible KPIs came, however, from our interview with Krister Forsman working at Perstorp**.** From Krister Forsman's guest lecture in this course we learned that Perstorp is a company producing chemicals using mainly continuous and batch processes. The company have several plants and uses KPIs to communicate within the company and to manage production at each individual plant.

Perstorp works with many different kinds of KPIs, which depending on their nature, will be used for different situations. As for any other company financial KPIs are of great importance to keep track of the company costs but as this course is aimed to future engineers the interview was focused on the technical KPIs. Among the ones Krister mentioned were number of tons produced of a certain product, variable cost per ton and loss versus plan. These technical KPIs are example of KPIs used to determine the everyday running of a plant. Engineers will have access to relevant KPIs and can every morning use them to decide what needs to be done based on discrepancies in the data. Of course there are many other KPIs used at Perstorp but these where some of the mentioned ones.

A KPI Krister mentioned as one of the more important ones is steam usage. As steam consumption is a large cost it is important to keep a close look at this KPI to see that there is no unnecessary steam usage that will cause the costs to increase. A high steam usage can also indicate that some other part of the production is malfunctioning. If a certain unit of the process suddenly increases its steam use it could be this unit needs maintenance in order to bring the steam level back to normal.

For a continuous plant it is not always easy forming KPIs using the standard. In many ways the ISO standard is aimed more at discrete production and some KPIs is hard to translate to the continuous plant. One example of this is the OEE. For a discrete plant this can be a measure using unit time as it is easy to define how much product is produced per time but for a continuous plant one cannot state how much product is produced per time as the product is often in a continuous flow. It becomes too hard to sort out what in the flow is actual product and what is a different product or even what is waste. To work around this problem Perstorp is developing an alternative to the OEE, which we will refer to as the Perstorp OEE (this is not the official name which is still to be determined). This KPI uses tons as unit instead of time and looks at the quote between how much is actually produced and what is the theoretical maximum production. This KPI is meant as an overseer of the entire plant and a low quota could indicate that there is something not working as it should in the production. The lower than max production rate could be due to market, perhaps there is not enough possible buyers to have the plant at maximum production and by producing less you are avoiding unnecessary costs such as storage costs. However, it could also be something else, problems in the plant that are causing the low production rate. If a machine is not working properly or if there have been unexpected restarts at the plant this would show in the Perstorp OEE and the low quota would then indicate a problem that needs to be fixed in order to improve the production rate. The development of the Pertsorp OEE has been ongoing for about one year and as it is not a standard KPI it is not offered by suppliers and the software needs to be developed from scratch. There is still some work that needs to be done but Perstorp hopes to be able to incorporate this into their production and use it as a succesfull example of a continuous plant KPI.

Another commonly used KPI that can be difficult to measure in a continuous plant is yield. It is not always easy to tell exactly where the yield should be measured and the concentration in a flow is not always known or is too difficult to measure. Perstorp uses this measure in some plants but for the more complicated plants it becomes too difficult to decide how to measure the yield. For those plants that do use it works as a measurer for the entire plant and not for specific units. Since the yield can be very difficult for a continuous plant it is not always that the measures are correct, sometimes all other KPIs indicate that the plant is running perfectly fine but the yield is still off. This is most likely an indication of how difficult the yield is to measure and not that there is something faulty with the production.

Perstorp have plants with different kind of processes, a process might start as a batch production but then become a continuous process and as packing is included the product will be in discrete entities. Krister believes there are no models that are able to handle this type of mixed process plant very well which lead to problems when it comes to KPIs and following the standard. Many companies with other than a discrete production still follow the standard but when looking beneath the numbers the definition of KPIs differs between companies. This is of course a problem when it comes to communication since the same name of a KPI can have two different definitions depending on the company. There can even be different definitions between two plants within the same company that claim to measure the same KPI which, naturally makes it hard for management to compare the production of the two plants. In theory it should be easy to follow the standard and avoid this kind of problems but as previously mentioned the standard is in many ways directed to the discrete industry and Krister believes that the standard has in a way left the continuous industry behind. There is not always a clear translation of a discrete KPI into a continuous one and companies therefore need to find their own definitions which lead to the type of problems described above. According to Krister a standard more suitable for non-discrete production process would be a good future improvement for Perstorp as well as the continuous development of the Perstorp OEE.

Presentation of KPIs

Output at limit

KPI Definition	
Content	
Name	Output at limit
ID	
Description	Measure of output at maximum production over a certain time period
Scope	Work unit, process
Formula	In specification Output / Time
Unit of Measure	m^3/time or tonnes/time
Range	min=0, max=to be defined
Trend	The higher the better
Context	
Timing	On-demand or periodically
Audience	operator, supervisor
Production Methodology	continuous
Effect Model Diagram	
Notes	See below

At a continuous plant with a PID fleet there are bound to be some controllers that are limited in their maximal output. Some of these limits will be difficult or unnecessary to change but it might be that a limited controller indicates a bottleneck in the process. If this limit is due to, for example, a tank that is too small following the output or even a badly placed measurer, improving or even removing the cause of the limit could improve the process. The two mentioned problems could be fixed by using a better tank or perhaps by reassigning an already existing tank that is not using its full capacity. By moving a badly placed measurer the controller in question would get a different value for the maximum output, which might improve or remove the limit and there would be no need for any other adjustment.

Continuous OEE

KPI Definition	
Content	
Name	Continuous OEE
ID	
Description	Overall equipment efficiency for a continuous plant. The measure in tonnes and the theoretical max is measured during a certain time period.
Scope	
Formula	In specification production in tonnes /Theoretical max production in tonnes
Unit of Measure	%
Range	min=0%, max=100%
Trend	The higher the better
Context	
Timing	Periodically, on-demand, real time
Audience	operator, supervisor
Production Methodology	continuous, discrete, batch
Effect Model Diagram	
Notes	See Below

As mentioned previously, Krister Forsman talked about a KPI used at Perstorp that is somewhat similar to OEE. The following KPI is inspired by this and tries to model an OEE KPI more suitable for the continuous plant. For a discrete plant the OEE can be used in terms of time since it is relatively simple to calculate product produced per time unit. In a continuous plant however, the product is not necessary a discrete entity but rather a continuous flow of product and it can be difficult to measure the concentration of product in such a flow. The standard OEE is therefore difficult to translate to the continuous plant but by instead formulating a similar KPI that measures the product in tons the KPI becomes more suitable for a continuous process. Measuring tons produced of the product during a certain time interval will be a lot more meaningful for a continuous plant. This measurement would be an indication of the plant overall but also how well the PID fleet is working to keep the process at its maximum capacity.

Steam usage

KPI Definition	
Content	
Name	Steam usage
ID	
Description	Current steam consumption is compared with the consumption predicted by the model.
Scope	Work unit, process
Formula	(actual steam consumption-theoretical steam production)/unit produced
Unit of Measure	tonnes of steam /ton of product
Range	min=0, max=to be defined
Trend	The lower the better
Context	
Timing	Real time or on-demand
Audience	operator, process engineer
Production Methodology	Continuous
Effect Model Diagram	
Notes	See Below

During the interview with Krister Forsman, when he was asked about the KPIs that he considered the most important in the running of a continuous process, he talked about the steam consumption as one of the main KPI to look into.

Controlling the usage of steam in the process we can minimize variable costs in the plant. However, as it is mentioned in the slides of the course, minimizing the variable costs can come up with scenarios where the maximum total profit is not reached. Thus, in order to avoid a reduction of the production due to this KPI and to be able to define a range of appropiate values, the steam consumption is compared with the theoretical consumption from a model of the plant at the actual production. In this way, the variable cost related with steam usage is minimized according to the current production.

One important aspect of this measurement to take into account in its use, which has already been mentioned, is that in continuous processes the calculation of steam consumption is related to the amount of product generated and not with a time period.

Frequency of startups of the fleet

KPI Definition	
Content	
Name	Frequency of start-ups of the plant
ID	
Description	Number of start-ups of the plant
Scope	Process, Plant
Formula	Frequency of start-ups of the fleet=number of start-ups/time period
Unit of Measure	Time period $^{-1}$
Range	min=0, max=infinite
Trend	The lower the better
Context	
Timing	On-demand or periodically
Audience	
Production Methodology	operator, supervisor
Effect Model Diagram	Batch process
Notes	See below

For the definition of this KPI the master thesis "KPIs for Asset Management: A Pump Case Study "(Chapter 6.3) by Matthieu Lucke has been used as inspiration. In this paper the frequency of startups is referred as an information that can be useful to define the state of the fleet.

This indicator can define as well if the functioning of the plant is adequate or the set points of the process are not well defined. This KPI provides also information about the PID controlling such that an excessive number of startups of the fleet will indicate a bad tuning of the controller.

Nevertheless, as a general indicator, it is difficult to define a number of maximum dnumber of startups in a regular functioning and also it is important to study in each case the cause of the incident to relate it or not with controlling issues.

Percentage Yield

KPI Definition	
Content	
Name	Percentage Yield
ID	
Description	The amount of in specification product that is actually produced (Actual Yield) compared to the calculated amount that could be produced based on raw material consumption (Theoretical Yield).
Scope	Work Unit, Product
Formula	Percentage Yield = Actual Yield / Theoretical Yield
Unit of Measure	%
Range	min=0%, max=100%
Trend	The higher the better
Context	
Timing	Periodically
Audience	Operator, Process Engineer, Supervisor, Management
Production Methodology	Batch, Continuous
Effect Model Diagram	
Notes	See Below

This is certainly one of the oldest and most well established KPIs for chemical reactions, and is probably tracked in most continuous processes and plants around the world. This KPI represents a huge portion of the variable costs. If the percentage yield is low there are raw materials being wasted and not converted into product, and since raw materials are a large factor in variable costs, a low percentage yield can be a very costly but avoidable mistake. It is avoidable because unlike fixed costs, varible costs are proportional to how much you are producing, which means you can control your variable costs while your fixed costs will always remain the same. Therefore, maximizing your yield is one way to reduce your variable costs.

This is similar to effectiveness, but for a continuous / batch chemical process. Unlike effecctiveness it does not address time contraints at all, but rather addresses raw material waste in a similar way to effectiveness addressing time wate.

We also felt that this addressed the PID fleet because often PID performance, maintaining levels or temperatures etc., is crucial in a process' yield.

Labor Requirement

KPI Definition	
Content	
Name	Labor Requirement
ID	
Description	Amount of labor required to produce one unit of product.
Scope	Product, Work Unit, Worker, Work Group
Formula	Work Requirement = Labor Time / Unit of Product
Unit of Measure	Time Unit / Quantity Unit
Range	min=0, max=infinite
Trend	Lower equates to more automation, which, in many cases is good. However, in some industries hours of labor are unavoidable, and not necessarily bad.
Context	
Timing	Periodically
Audience	Operator, Supervisor, Management
Production Methodology	Discrete, Batch, Continuous
Effect Model Diagram	
Notes	See Below

In this KPI we wanted to look at labor as a variable cost. In many situations labor can be a large expense and is something that should be carefully kept track of. We felt that this was an important situation for similar reasons to yield being important. Again we kept our focus a little more general to KPIs that could be used in many situations, but sacrificed a little bit of specificity. The specificity sacrificed comes from defining the KPI using product produced.

Krister pointed out that many of their plants operate and the legal minimum of labor (2 people at the plant at any given time) because the plant is entirely automated. This clearly indicates that Perstorp has invested heavily in their PID fleet. He did say, however, that in the packaging and certain post production situations this may be applicable to Perstorp, but these are more discrete processes than continuous. We thought that this was still a relevant and important KPI because not all companies have invested so much in a proper PID fleet. However, in a continuous facility it is very likely that automation using a PID fleet is preferable.

Discussion

Throughout this Project we focused more on KPIs that could be used for most continuous processes, and could definitely be used at Perstorp, rather than focusing on more specific KPIs for individual work units or process units that exist at Perstorp. In our conversations with Krister it became clear that there were many KPIs defined for individual pieces of equipment, and any sort of real study of these would be mostly exhaustive, especially because much more specific knowledge of each given process and what exactly should be happening in each process is required to come up with relevant KPIs. However, we felt that we addressed how well the smaller work units and process units were operating with percentage yield, output at limit, and steam usage as these can be analyzed one piece of the process at a time to gather important information on process limitations and weaknesses.

We also realize that many of our KPIs call for measurements that may be very difficult or very costly, and perhaps even prohibitively expensive or impossible. Krister was quite good at pointing this out in our second conversation with him, when he was reviewing the KPIs we had come up with. For example, although it may be useful to know your processes bottleneck by using output at limit for each part of a process, actually gathering this information may not be practical. If yield is low it is probably a good idea to find the major sources of loss, but again in a many stage process this could easily become far too complicated and require far too many measurements (which might in themselves be impossible to measure) to be a real possibility. Having said this, we still feel that in many circumstances our KPIs have vital and versatile uses.