Value Proposition for Smart Retrofit Solutions

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Abstract: Smart retrofitting can include automation, simulation, data collection and optimization of manufacturing processes. It is strongly coupled with the concept of Industrial Internet of Things (IIoT). The adoption of smart retrofitting in manufacturing is found to be modest despite their benefits. Lack of structured value proposition approach by application is suspected as one of the major reasons for lower adoption. This paper provides a value proposition matrix and applies the same to ten low-hanging fruit smart retrofit applications. This would provide a framework for understanding the full value a smart retrofit applications can provide. The matrix can also be used to rank the smart retrofit solutions.

1 INTRODUCTION

Smart retrofitting in manufacturing is defined as "the integration of new technologies and sensors into legacy systems, supporting the transition towards smart manufacturing. It can extend the life cycle of machinery and equipment in a way that is feasible, time-saving, and requires comparatively low investments" (Jaspert et al., 2021). (Kusiak, 2018) suggests that smart manufacturing goes beyond shop-floor automation and involves autonomy, evolution, simulation, optimization of the manufacturing enterprise. IIoT (Industrial Internet of Things) plays a significant role in achieving these. IIoT consists of collecting and integrating process data; and finding patterns to achieve better quality control, productivity, and the speed of operation(Vrana, 2021). IIoT also allows for augmented controls, meaning that the alarms and setpoints for the control mechanisms can be made dynamic based on the data collected(Smith, 2017).

In the full-text analysis of existing literature (Jaspert et al., 2021), ensuring competitiveness and increasing equipment efficiency are identified as the most mentioned contextual drivers of smart retrofitting and limited resources, high complexity, diverse requirements, and cultural restraints are identified as key challenges in the decreasing order of occurrences in the dataset. The paper also categorizes benefits of smart retrofitting into four categories: sustainability, practicability, functionality, and compatibility. The benefits in each category that are mentioned most often are maintaining legacy systems, providing low-cost solution, enabling asset transparency, and upgrading to new technologies. However, the analysis also suggests that there is a gap in understanding "strategic advantages of smart retrofitting" and "potential benefits to the end customer". The authors conclude that "functional and value-creating benefits are rarely addressed".

Similar observations were made after analyzing several Industrial Assessment Center (IAC) recommendations. IACs carry out energy audits at small and medium sized manufacturers to give recommendations around improving energy and production efficiencies. The IAC recommendations show that the adoption of smart retrofit solutions is modest despite their benefits. Lack of structured value proposition approach by application, and higher payback period are speculated as the major reasons for lower adoption. This paper intends to address these challenges by developing a matrix for value proposition of smart retrofit solutions and applying it to rank ten "low hanging fruit" applications. Further high value applications involving variable frequency drives is discussed in more detail.

2 VALUE PROPOSITION CATEGORIES

Smart retrofit solutions can be ranked by using the below mentioned categories (Fantana et al., 2013):

1. **Visibility** into the manufacturing process perfor-

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mance by collecting the operating condition data.

2. **Performance Improvement** by optimizing and utilizing the equipment better, optimizing flows, reducing production losses.
3. **Quality Improvement** using a feedback loop which would measure the product quality and then tweak the operating conditions to improve the same.
4. **Reduced Energy Consumption** by operating the equipment with minimum energy use.
5. **Improved Maintenance** by condition-based monitoring, data collection on system operating condition and subsequent data analysis.
6. **Robustness/Reliability** includes clear and unambiguous parameter measurement, less false positives, fewer or no re-calibrations required and the solution that allows for continuous operation of industrial processes.
7. **Reasonable Cost** includes the cost vs. benefit analysis rather than the absolute cost of the IIoT solution.

3 SMART RETROFIT: LOW HANGING FRUIT OPPORTUNITIES

The potential smart retrofit benefits range from higher equipment effectiveness to achieving better performance. These benefits depend heavily on the application for which smart retrofit solutions are implemented. Some potential smart retrofit applications that fall under the "low hanging fruit" category, meaning applications for which smart retrofit IIoT solutions are more easily implemented, are as described below:

- **Adjustable Speed Drives in Industrial Mixing:** The central idea is to operate the industrial mixing motors by reducing the initial speed to avoid power spikes. One of the methods to accomplish this is to use a variable frequency drive to control the speed of motor based on a maximum power requirement. As the speed of mixing increases, the mixture warms up reducing the viscosity and thereby the torque requirement, which in turn would reduce the power required from the motor. There is also a possibility of measuring and assessing the product quality through its viscosity and temperature as represented by the required torque.
- **Compressed Air Energy Management:** Installing pressure, air flow rate and current transducer sensors on compressed air system can help analyze and report performance of the system. This data can be used to assess air leaks, optimize multiple compressor part load performance, and avoid short cycling and flow spikes. In addition, compressed air dryer system performance can be monitored by measuring the overflow water collected in downstream tank and/or air outlet dewpoint. This detects water pass through and reports performance to create trends and support troubleshooting procedures.
- **Intelligent Bag House Fan Control:** This application consists of implementing an on-demand system for baghouses. The system would maintain the required suction pressure based on the activity of the workstations and use a variable frequency drive to adjust the speed of the baghouse blower. Such an operation would result in running the blower at lower than full-load capacity as required. The blower speed is efficiently controlled by changing the frequency of voltage provided to the motor instead of using other methods such as valves and dampers.
- **Energy Storage Intelligence:** The application consists of measuring and reporting the equipment performance for energy storage units like batteries or ice storage. These measurements can be used to charge (e.g. solar) when the energy is available or inexpensive and discharge to reduce electricity demand and TOU charges
- **Cooling Tower "Free Cooling" Intelligence:** Using the cooling tower water to cool the process fluid helps reduce the load from the chiller system partially or completely depending on the ambient temperature. Performance can be optimized by adjusting the parallel free cooling and chiller loops.
- **Smart Condensate Return Tank:** By measuring the make-up and feed water flowing through a boiler condensate tank, condensate return and boiler loads can be tracked and steam trap problems can be detected to reduce water treatment costs and leaks. Boiler performance can also be visualised for better troubleshooting and performance optimization.
- **Production Line "Quick Change" Monitoring:** The goal is to minimize product change-out time. IIoT solutions can be used to know the changeover/change out time from machine load data. This data can also be used to provide insights around overall equipment effectiveness in

addition to improving product sequencing, productivity, changeover times and energy use per unit delivered product.

- **Motor-driven System Performance:** Avoid failures, downtimes and resolve problems before they happen by monitoring temperature, vibration, and/or electric motor pattern. This would be applicable to any motor driven system which is critical for plant operation
- **15-minute Demand Data Analysis:** Energy spikes can be assessed and better sequencing can reduce demand charges by monitoring 15-minute interval data. Correlation between demand data and shifts, operations, seasons etc. can also be obtained.
- **Coordinating HVAC Compressor Loads:** The idea is to adjust setpoints with IIoT thermostats for coordinating multiple HVAC compressors. This can not only save on energy demand and energy use but can also provide automated response to failures and degradation.

4 VALUE PROPOSITION MATRIX FOR LOW-HANGING FRUIT OPPORTUNITIES

The value proposition of the above-mentioned smart retrofit "low-hanging fruit" applications is ranked as shown in Table 2 below. The value categories are considered having equal weights. The boxes in value proposition matrix are checked when that value is achieved by the application. The ease of quantifying the benefits each value category provides is another factor, which is considered, and the classification is shown in Table 1

Table 1: Ease of Quantification.

Value Categories	Quantification		
	Easy	Medium	Hard
Visibility			x
Performance Improvement		x	
Quality Improvement		x	
Reduced Energy Consumption	x		
Improved Maintenance			x
Robustness/Reliability		x	
Reasonable cost	x		

5 DISCUSSION

The value proposition matrix provides a potential approach towards understanding the value provided by an IIoT solution, categorize the same and rank the ideas based on how many boxes are checked. In the figure, the application with more than 75% boxes checked is categorized as a high value proposition, the one with more than 50% but less than 75% boxes checked is categorized as a medium value proposition and the rest as a low value proposition solution. Variable speed drive applications and coordinating HVAC compressor loads have most boxes checked.

Implementing IIoT retrofit solutions for all the applications listed above would enable visibility into the process as the control action is coupled with operating parameters, for instance: Motor driven system performance measures various parameters like temperature, vibration, electric current or power etc. Compressed air management measures datapoints such as pressure, air flow rate and water pass through.

All the applications would save energy as well. By monitoring motor driven system performance and HVAC compressor loads, it is possible to improve maintenance as they enable condition-based monitoring. Applications such as compressed air energy management, smart condensate return tank, cooling tower free cooling allows for performance improvement opportunities as well. In the case of compressed air management, multiple compressor part loads can be optimized whereas in case of smart condensate tank return leaks can be detected and fixed to improve the boiler performance. Free cooling loop in cooling tower gives an opportunity to optimize the operation between chiller and free cooling loops based on the ambient temperature and process requirements.

The applications like smart condensate return and HVAC compressor loads use simple and cost-effective sensors to monitor the parameters. Since the motor driven system performance application involves more sensors and complicated data analysis it is subject to more false positives. Hence in the value proposition matrix robustness is not considered as the value proposition for the same.

5.1 High-value Retrofit IIoT Solutions

5.1.1 VFDs

Variable Frequency Drive is a type of motor drive that controls the speed and torque of an AC motor by varying the motor input frequency. The two applications discussed here are using VFDs for industrial mixing and smart baghouse systems. In both these

Table 2: Value Proposition Matrix.

High-value IIoT Applications	Visibility	Performance Improvement	Quality Improvement	Reduced Energy Consumption	Improved Maintenance	Robustness/ Reliability	Reasonable Cost	Overall Value	
Adjustable speed drives in industrial mixing	x		x	x	x	x	x	86%	High
Compressed air energy management	x	x		x			x	57%	Medium
Intelligent bag house fan control	x	x	x	x	x	x	x	100%	High
Energy storage intelligence	x			x				29%	Low
Cooling tower "Free Cooling" Intelligence	x			x		x		43%	Low
Smart condensate return tank	x	x		x		x	x	71%	Medium
Production line "Quick Change" monitoring	x	x		x				43%	Low
Motor-driven system performance	x			x	x		x	57%	Medium
15-minute demand data analysis		x		x				29%	Low
Coordinating HVAC compressor loads	x	x		x	x	x	x	86%	High

applications visibility into the process is obtained. In Industrial mixing application the speed of motor is controlled based on power requirement which in turn is based on mixture viscosity and temperature. In Smart baghouse the speed of suction fan is controlled by sensing the pressure requirement at each station which in turn indicates how many stations are running.

Performance improvement can be obtained in case of baghouse by optimizing the suction required at different stations. Other process improvements in the form of saved conditioned air can also be achieved. In absence of a VFD, the baghouse suction would also remove the conditioned air from the space in turn increasing the load on the HVAC system. For processes like paint sprays booths and furnaces, implementing a VFD on baghouse suction would enable optimization of process parameters like furnace temperature and paint spray pressure to achieve process fuel savings.

Quality improvement can be achieved in industrial mixing by tightly controlling the viscosity and temperature of the mixture by controlling the speed of motor. In the baghouse application, as soon as the workstation is sensed to be active, the baghouse suction would start to remove any dust, mist, gases and maintain product quality. Energy consumption is reduced when partly loaded motors are retrofitted with a VFD.

Smart baghouses measure the differential pressure across the workstations and the filters. This would allow for condition-based monitoring and maintenance. In the case of industrial mixing since the operating parameters like viscosity, temperature, torque and/or velocity are monitored, they can be used to detect anomalies. The baghouse VFD solution is robust since the parameters like pressure and/or air flow can be measured with high accuracy, and the relation to other process parameters is well defined. For VFDs in baghouse a payback period of lower than 1 year can be achieved (ref,).

6 CONCLUSION

A lack of structured approach towards value proposition of smart retrofit solutions was suspected as the reason for their lower adoption. Hence, in this paper, a value proposition matrix was presented and applied to ten “low-hanging fruit” smart retrofit solutions. Variable frequency drive applications were discussed in detail as one of the high-value smart retrofit applications. The applications were evaluated without considering the limitations of smart retrofits /IIoT such as cybersecurity. All the categories in the value proposition matrix were considered having equal weights. However, based on application certain benefit categories may out-weigh the other and more studies are required to understand the same.

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