Justifying Upgrade Projects in Existing Mills

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Abstract - This paper describes the various potential benefits for upgrading existing mill electrical and control systems beyond the usual justifications of manpower savings, production cost savings and directly measurable operating and maintenance cost savings. Using examples from upgrades of power systems, drive systems, and control instrumentation systems, the authors describe the various ways that reliability, product quality, and other sometimes intangible benefits can be expressed in dollar terms that management understands. The examples include upgrading a plant water supply electrical system justified on improved reliability and shutdown avoidance and the justification of instrument/control upgrades based on increased "on-grade" pulp production.

I. INTRODUCTION AND BACKGROUND

Upgrade projects are done to improve a company's business by making more of a better product with fewer resources and less waste. Also, externally imposed requirements such as government regulations and market changes often create the need for an upgrade project.

For electrical engineers, projects tend to involve power and control systems. These projects are the focus of this paper.

II. TYPICAL CASES FOR JUSTIFICATIONS

A. Increase Capacity to Accommodate Plant Changes

Most upgrade projects increase the capacity of the electrical system or the capability of the control system to accommodate plant capacity increases, new processes, or new products. These projects are driven by their process and mechanical considerations and the electrical/controls system is a support function. The challenge to the electrical engineer, in this instance, is to ensure that these projects carry their share of the cost of using "utility systems" such as the high voltage distribution, transformer capacities, DCS or PLC network and control room costs.

B. Improve Efficiency

The efficiency improvement project assumes no change to the process in the mill. Replacement of fixed speed drives or eddy current coupling drives with variable frequency drives is an example for this type of project. The challenge to the electrical engineer is to look beyond the calculated energy use efficiency gains to see if mill product quality can also be improved by the new drive system.

C. Reduce Maintenance

Reduce maintenance by installing new equipment with less moving parts, wear components, and replace other maintenance items with static, standard systems. Replacement of relay systems with PLCs is a good example for this class of justification. Avoided costs are from reduced repair, system down time and spare part costs. These are offset by the proposed replacement system cost, training costs, and new spares' costs.

D. Reduced Deviation from Set Point Using Advanced Controls

This leads to:

- Reduction of off-grade production at the source. This avoids adding value to a product that may be off-grade further down the process, and have to be abandoned or reprocessed.
- Reduction in off-grade production during grade changes. Less time required for grade changes results in more time for producing the product.
- Better product quality and consistency.
- The ability to make different products.
- Reduce margins of safety for process variables that operate within fixed limits (e.g., saving acid or caustic required to control pH to set limits).
- Elimination of storage elements previously required to average out process variables.
- Simplifying the process.

E. Increased Production

Production increases through improved process control make better use of existing plant assets. Fixed costs do not increase. The cost of producing the additional tons of product only involves variable cost. The additional production has much higher margin of profit than the average ton of product.

III. LESS OBVIOUS JUSTIFICATIONS

There is less direct cost link to some benefits of a project that many electrical engineers know exist but are difficult to define in monetary terms. A good example of this is the justification of PLC and DCS systems over relay logic systems and pneumatic instrumentation in the 1980s. While we all know that software logic is very important to ease of commissioning and documentation of a project, the benefits are rarely quantified accurately in cost or schedule terms at the justification stage of a project.

Another constant concern for electrical engineers is how to justify an upgrade of electrical power system components. They know from experience that these components may become the cause of a future plant down time. While there are seldom any questions in paying for repairs to failed equipment, justifying funds to upgrade the system before the failure is often met with skepticism. The forward thinking engineer needs to quantify the risk of failure in monetary terms so that management can prioritize the project.

The following three projects are examples of how upgrade projects were justified.

A. Better Plant Operations Due to Modern Controls

Benefits such as better product due to better understanding of the process, faster troubleshooting because of better diagnostic help from modern day systems, and uniformity of the system throughout the mill for better maintenance are all real and substantial benefits. These benefits cannot be easily predicted or calculated before the project. However, the mill can miss valuable opportunity to be competitive and profitable by not looking at these considerations.

Experience and statistics can be the basis for identifying and quantifying the value of these benefits. The following example is one set of statistics that the authors hope will be followed by others so that an experience base will be formed for this type of projects and serve as a reference for justifications for others.

In this first example, the pulping operations for this complex consist of two kraft pulp mills in proximity to each other, ***Mill A*** at 700 TPD and ***Mill B*** at 500 TPD. Both mills were built in the 1960s. A control upgrade project to replace pneumatic instrumentation and relay logic at both mills was started in 1988. The project began with the fiber line at ***Mill A*** (digester, chip handling, brown stock washing and screening, bleach plant and chemical preparation, recausticizing and lime kiln) and then the fiber line at ***Mill B*** in 1990. These two lines were upgraded by 1991 and 1993 respectively. New control rooms are constructed to house the DCS and PLC systems consolidating controls from various control consoles and panels to two central pulping control rooms, one for each mill. In total, 2,600 instrument loops and 6,000 discrete input/outputs were implemented on DCS and PLCs using the scheduled mill maintenance shutdown over the period of the project.

Initially, the project was justified purely on the poor condition of the existing 23 to 25-year old instrumentation and their decreasing reliability.

The project also included new field instrumentation such as magnetic flow meters, level, pressure, and flow transducers, and temperature control devices. There was also replacement of eddy current couplings on washer drum drives by variable frequency drives, lime kiln mid zone temperature controls, and "one button" sequence starts for chip screens, bleach plants, and other areas.

At the same time, the mill established the principle that any mechanical or process upgrade such as a boiler upgrade or a new burner management system should include a modern control system, ensuring a coherent move towards a mill DCS and PLC standard and minimizing any "re-upgrading" in the future.

Results from the Upgrade

There are many positive comments on the results of the upgrade; these include:

- Mill personnel changed from "emergency response mode" before the upgrade to "anticipation and problem prevention mode" after the upgrade. The operators and process engineers have a much better understanding of the process and have the tools to explore ways of improving the mill production.

- Operators no longer have to remember interlocking sequences when starting processes; these are programmed in.

- The mill is now coming up to production target much faster with the preprogrammed sequence start and better information at the control room.

TABLE I
PERCENTAGE CHANGE OF "ON-GRADE" PRODUCTION OVER YEAR ZERO

	Year 1	**Year 2**	**Year 3**
Mill A	-4.09	3.32	3.87
Mill B	1.46	2.99	4.04

However, in addition to these comments, the real measurable benefits are illustrated in the Mill "on-grade" production improvements over this time as shown in Table I. The improvements range from 3 to 3.5% for each mill.

The project could have been easily justified based on 1.5% improvement in "on-grade" production, without the original instrument replacement case. This "on-grade" improvement is a measure of the benefits that, so far, are impossible to quantify individually. If industry statistics from other control upgrade projects can be compiled to show that this is not an isolated incident, then improvement in "on-grade" production can be the main justification for control upgrade projects instead of instrument replacement.

B. Better Plant Operations Due to Advanced Model-based Process Controls

One of the major benefits of advanced process controls is to reduce the variation of the process variable from the desired control set point. A stable process variable results in better product quality and cost reductions from better operation of steam and power utilities, and process chemistry.

Kraft Continuous Digester Control in Mill C. The objective in optimal control of a continuous pulp digester is to achieve maximum pulp production at a specified Kappa number with a minimum of chemicals and energy input. Reducing the variability of parameters like effective alkali results in smoother digester operation and reduced Kappa number variations. In this mill, a three month trial with an advanced adaptive controller reduced the standard deviation of the Kappa number from 3.76 to 3.40 with Kappa = 32.

Using the economic evaluation based on [1], it was projected that the saving per ton of pulp is $0.60 (US). Multiplying the annual production of the digester results in the annual savings which can then be compared with the cost of implementing the advanced controls for either a gross payback period or a rate of return calculation. In this case, the payback was less than five months! [2]

C. Improving Reliability of Power Systems

Power systems, like other utility and support systems, are often taken for granted by mill personnel as part of the infrastructure that will always be there and available on demand. Electrical engineers, however, are well aware of the differences in power system reliability and the associated costs to provide that reliability. Fortunately, technical bodies have compiled statistics and published standards so that power systems can be analyzed. Equipment failure is a fact of life; it will happen. Using industry-wide reliability figures and methods outlined in the standard, system failure rates can be predicted. Together with the cost of power interruption to the mill, a real probable cost per year can be derived that will show a rate of return for improving the power system to reduce the predicted probability of failure. This is investing money in a planned fashion rather than waiting for a failure to occur and then using the failure to justify the repair cost.

This analytical approach will also remind mill management that there are no "fail-safe" solutions and retrain the engineer from over promising the results of a power system upgrade.

This example is for an aluminum smelter, producing aluminum ingots from alumina. The main electrical power is from their generation plant about 80 km away, by two 230 kV circuits for about 600 MW of power. The bulk of the power is used in rectifiers converting ac to dc power for the electrochemical reaction. The major concern with a power failure to the plant is that the molten aluminum in the process will freeze in several hours, and thereafter it is a major cost ($100 million) to restart the process. Apart from the reliability of the main power system to deliver power to the rectifiers, the rectifiers themselves are water cooled and any prolonged failure of the water system can cause a shutdown of the rectifiers. This is comparable to pulp and paper mills that are all completely dependent on their water system for the mill process and generally have short storage times before the process will be directly affected. The typical power system failure rates for a pulp and paper mill will be higher while the loss cost will be lower. However, the analysis is the same.

TABLE II
PUMPHOUSE CUT-SETS OF EXISTING ELECTRICAL SYSTEM

Cut Set	λ Failures per year	Critical Demand period months/year	Adjusted λ Failures per year	Annual Probability of Failure F1	30-year Probability of Failure F30
1. Loss of switchgear PDP#401-1	0.01428	6	0.00714	1:140	1:5.2
2. Loss of main and standby transformers	2.0 E-6	6	1.0 E-6	1:1.0 E+6	1:33,333
3. Loss of traveling screen motor	0.0824	1	0.00687	1:146	1:5.4
Pumphouse Totals			0.014	1:72	1:2.9

TABLE III
ANNUAL RISK COST SUMMARY FOR PUMPHOUSE SWITCHGEAR

Description	Annual Probability of Failure	Single Loss Cost	Annual Risk Cost ARC
Existing installation	1:140	$100 million	$714,000
Upgrade Option #1	1:1.25 E+6	$100 million	$80
Upgrade Option #2	1:1470	$100 million	$68,000

The plant engineers are aware of their vulnerability to the water supply and the plant system already has dual 13 kV feeds to the pump houses to ensure a backup source of power. The equipment, however, is a mix of vintages from the 1950s to the 1970s, causing concern for system reliability due to the age of the equipment. On the other hand, the system was originally designed with standby pumps and redundant equipment for system reliability making the overall reliability level of the system difficult to ascertain.

A system reliability study was undertaken for the system. The electrical system was partitioned into a number of "minimal cut sets" connected in series. The components of each "minimal cut set" are in parallel, and all components within the cut set must fail in order to cause a system failure. The failure of any "minimal cut set" will produce a system failure. System analysis is further simplified by reducing the number of "minimal cut sets" to only those with components that will produce a forced down time failure greater than six hours.

Table II summarizes the probability of failure of the system for six hours, the analysis was simplified because the average down time of most component failures is less than the critical six-hour duration needed to constitute a catastrophic failure. Other equipment failure combinations such as the loss of three out of four pump motors is also possible, but have been discounted because there is a 50% redundancy level in the pumping units under normal water usage at both stations, and resultant failure rates become extremely small when more than one standby or redundant pumping unit failure is required to cause a pumping system catastrophe.

The study then establishes a reliability target for the electrical system by comparing it to a civil engineering water supply system risk assessment report, which cited failure ranges of between 1:100 and 1:950. The electrical system probability of failure was then targeted for a range of 1:1,000 to 1:10,000.

Switchgear upgrade options were proposed with their projected probability of failure rates calculated.
The single loss cost was reduced to an annual risk cost based on the probability of failure and then compared to the cost of implementing the upgrade. This reduces the justification into a rate of return analysis familiar to other mill personnel. Table III shows the single loss cost for this project.

Some of the interesting points from the analysis are:

There are large ranges in probability numbers and their accuracy. The accuracy of these numbers is dependent on many variables such as the rules for collecting the probability data and the definition of the equipment and how it fits with the data.

There are other considerations such as mechanical equipment and structural systems besides electrical that can fail. The system cannot be justified based on improvement of the electrical system reliability alone as it may surpass the reliability of the other systems, in which case the capital expenditure should be shared with improving the other systems.

Reliability of old versus new electrical equipment. The IEEE standard makes no differentiation based on the age of the equipment. However, it is noteworthy that there was a comparison between a 1962 survey and a 1973 survey showing a considerable improvement in electrical reliability during that eleven year period. In particular, 600 volt drawout circuit breakers in the 1962 survey had failure rates six times higher than those reported in 1973. Some of this improvement has been credited to improved design and manufacturing of new equipment.

Spare equipment and testing procedures. After estimating the system failure rate, there is the issue of how long it will take for the system to be repaired. The same IEEE standard also offers industry statistics on mean time to repair. The appropriateness and completeness of the spare part will have an important bearing on the time to repair. This time can be reduced by simply having specific spare parts for the part of the system that is more prone to failure. Testing of the spare part is required to reduce the probability of the spare not being functional when required. The more frequent the test, the more reliable the spare part. In general, the availability of the spare part is considered to be half of the testing interval.

IV. CONCLUSIONS

There are many obvious ways to justify projects; we should not overlook the not so obvious. An open mind is required to identify justifications for projects that cannot always be predicted by a standard set of procedures.

This paper describes some examples of indirect returns that rely on statistical analysis but nevertheless are just as convincing as other direct efficiency gain type of justifications.

Productivity gains through better process information and more sophisticated controls are real and more data needs to be collected to help justify control upgrade projects.

Management may have difficulty grasping some technical arguments for better control but they do understand dollars, so express justification in dollars due to increased production, less rejects, reduced energy cost and reduced down time.

Statistics such as overall plant on-grade production improvement after a control upgrade are important in showing some of the real benefits of a modern day control system. We encourage other engineers to come forward to share their experiences with upgrade projects so that these statistics can form the basis for other engineers trying to justify modern controls.

V. REFERENCES

[1] P.O.Tikka, M.J.Kuulela and M.S. Saarenpaa, “New Methods to Master Continuous Digesters”, Control Systems, 1988.

[2] W.A Gough and J.T. Kay, “Kraft Continuous Digester Cooking Control”, Canadian Pulp and Paper Association Conference, January 1995.

[3] IEEE Standard 493-1990, “IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems”.