Modernization justification

Technical and financial justification to convert a legacy DCS to a new modern automation system

Table of contents

Many industrial manufacturers have older legacy Distributed Control Systems (DCS) running their process. These legacy DCS may work fine today at their plants, yet as time goes on, there are increased potential for exposure to a variety of risks which may prevent them from capitalizing on productivity benefits which come from state-of-the-art technologies. As a DCS reaches the end of its useful life, conversion to a new automation system is required. Before this happens, internal plant personnel must provide both technical and financial justification to their management and often to their corporate offices.

This justification must compare the collective costs of continued operation with the existing DCS with the costs and technical benefits of converting to a modern automation system. Cost and benefits for each option consist of many factors that together comprise the Total Cost of Ownership (TCO).

Comparing the TCO of an existing DCS with that of the new automation system is the most comprehensive way to analyze and justify a DCS Modernization project. TCO is the preferred metric as it considers all relevant financial factors including, but not limited to, initial capital expense, on-going maintenance costs, energy consumed, downtime and product quality.

Once TCO for the existing legacy DCS is quantified, then cost and benefits for converting to a new, modern automation system must be identified and quantified. New automation system costs are generally easier to identify as they consist of the expected expenditures to perform the conversion, potential revenue lost from downtime (if required) during the conversion, and training expenses. Financial benefits are harder to quantify as they consist of many factors, most of which are projected future values.

Many benefits are particularly hard to quantify; these include:

- Less unplanned downtime
- Lower chance of safety-related incidents
- Increased operator efficiency with new high-performance Human Machine Interface (HMI)
- Improved cyber security
- Other benefits are easier to see:
    - Less required maintenance
    - Increased production
    - Reduced labor requirements

When TCO for the existing DCS is compared to the TCO for a new automation system, a true picture emerges to show if a conversion is financially viable. Since it is not common for plant personnel to go through the process of upgrading their DCS, outside assistance is often required to help with developing financial justification through improved technical benefits.

This assistance can be provided by consultants, system integrators and automation suppliers. It's an imperative that the selected trusted partner have experience converting from the existing legacy DCS to the new modern automation system, and that the partner is able to provide quantitative data that can be used to prepare a financial justification for the DCS conversion.

Once all quantitative data is gathered, these data can be assembled into a document that analyzes the DCS conversion in preferred internal corporate financial terms, showing justification for the conversion if warranted. At some point, every DCS will require replacement, and financial analysis will show just when this point has been or will be reached.

But before financial analysis is undertaken, a basic question must be answered; why should we replace our working DCS? A DCS does not have moving parts and isn't subject to normal wear and tear, so reasons for conversion must often transcend basic loss of functionality and extend to other more complex areas as detailed below.

Excessive maintenance and support costs

An existing DCS is typically controlling and monitoring various process plant operations daily without overly excessive downtime or frequent safety-related incidents. But, depending on years of service and vendor support, the DCS may be very expensive to own and operate in terms of TCO. When TCO becomes excessive, then conversion to a new automation system should be considered.

The main components that make up TCO are listed in Table 1. The first three components — purchase price, cost to integrate and training — are not relevant to an analysis of an existing system, but the other factors in Table 1 are germane to determining TCO for an existing DCS.

Table 1: Automation system total cost of ownership components

Purchase price
Cost to integrate into balance of plant
Training
Required maintenance
Spare parts acquisition and stocking
Downtime, planned and unplanned
Changeover time
Off spec product due to quality issues
Energy to run the system
Throughput less than optimal
Cybersecurity compliance
Integration to other plant automation/information systems
Long term support

Required maintenance and spare parts are significant factors in any conversion decision and can be quantified in most cases. An older DCS can become very expensive to maintain for three primary reasons.

First, various electronic components of the DCS may be reaching the end of their useful life, and may be failing at an excessive rate.

Second, it may be very expensive to find replacement parts, and excessive spare parts inventory of these parts may need to be maintained. For older DCSs, eBay often becomes the preferred supplier for spare parts, as spares are no longer available from the original DCS vendor (which may not even exist any longer). The quality expectation from buying used spare parts will always be suspect as well.

Third, it is difficult to find personnel qualified to troubleshoot and repair older systems, particularly if they are proprietary and do not use well-known or current technologies. As plant personnel familiar with the existing DCS leave or retire, it may become necessary to seek outside support. The older the DCS, the harder and more expensive it is to find qualified outside support personnel, both from suppliers and system integrators.

Excessive failure rates, difficulty procuring spare parts and lack of qualified maintenance personnel may result in relatively high levels of unplanned downtime, a significant expense for any manufacturing facility, but particularly for a process plant.

Unlike discrete part manufacturing facilities, plants running continuous processes frequently take hours or even days to restart after a process upset. For example, a large-scale coal-fired power plant has many disparate systems that must all be restarted in correct sequence after a trip including but not limited to the coal supply system, the steam generator and the steam turbine. Due to thermal effects and other factors, it can take hours to restart each system, and cumulatively more to bring the entire plant back online.

For plants running batch processes, the effects of downtime can be even worse. Consider a pharmaceutical plant running a batch process with a 30-day period. If unplanned downtime occurs on the 29th day, then the batch process must often be restarted from scratch, in effect causing 29 days of downtime and lost production.

Downtime is also caused by product changeovers. Many older plants were originally built to produce just a few products, with infrequent required changeovers. The DCS was often specified accordingly, with little built-in flexibility to accommodate changeovers.

But in today's world, product changeovers tend to be much more frequent, and the automation system must be designed to react accordingly. If product changeovers require excessive manual operations, then downtime is often excessive, greatly increasing production costs.

Excessive maintenance and support costs along with relatively high levels of downtime are perhaps the most visible reasons to convert from a DCS to a new automation system and are also the easiest to quantify. Much harder to analyze, but often more important, are the costs associated with poor process control.

Poor process control

Poor process control results in excess costs because of poor quality, excessive energy use and reduced throughput. When processes are controlled near setpoints, quality is maximized. Deviations from setpoints, particularly for long periods of time, can directly impact quality in a negative fashion.

For example, adding too much of one ingredient to a batch can result in an unacceptable product, necessitating scrap. Even if the batch is acceptable, costs may be higher than needed if the ingredient is added in excess quantity.

The closer control is to setpoint, the less energy consumed. Heating a product to 0.1 degrees over setpoint consumes less energy than heating it to 2 degrees over setpoint. It is particularly important to minimize energy use as these costs are predicted to continue to rise, often in a volatile fashion.

Throughput can also be greatly affected by poor process control. In general, the more automated a process, the greater the throughput and the less variation in product quality. Newer automation systems often allow more parts of the process to be automated and may allow tighter control of existing processes.

A common method for improving process control is to add new features to the existing automation system. With an older DCS, this may not be possible. With a new automation system, needed features may be built-in, or comparably simpler to add or integrate.

In some cases, the desired level of advanced process control (APC) is most readily available from a specialist third-party vendor. Common APC technologies include fuzzy or rule-based control, and model-based predictive control (MPC).

Many of these APC technologies run on separate platforms from the main automation system. Integrating such third-party hardware and software into an older DCS can be challenging, as older DCSs generally don't support modern open communication standards.

A very effective method for improving process control is to analyze data using tools such as asset management systems. Other popular data analysis tools push process data to remote locations for analysis using Excel and other software programs.

In the above cases, it becomes necessary to distribute data to other computing platforms, a relatively easy task for modern automation systems, but often very difficult to accomplish with an older DCS.

In summary, it is often difficult to improve process control with an older DCS, particularly as compared to a modern automation system. Substandard process control results in poor quality, excessive energy use and reduced throughput — and these costs can be very substantial.

Once it is determined that existing DCS TCO is currently excessive or quickly increasing to an unacceptable level, the next step is examining costs and benefits of a new automation system.

New automation system costs

Excessive TCO for an existing DCS is the main reason for any migration, but financial justification for any such conversion also requires a quantification of a new automation system costs and benefits.

New automation system costs can be broken down into three main categories: installed cost of the new automation system, cost to train employees on a new system, and downtime incurred while installing the new system. Installed cost includes all costs to purchase, test, install and start up the new automation system. In addition to these three main cost categories, there are other costs as referred to and summarized in Table 1.

The first two costs are straightforward to quantify as suppliers will provide fixed-price quotes for each. The cost of downtime incurred while installing the new system is harder to quantify, but it can be minimized by following certain conversion methods. We call this a Phased Migration approach.

A common conversion method is called "Rip and Replace", where the plan is to replace the entire DCS at once — including the HMIs, controllers and I/O. This method is simple to execute, and often results in lowest overall purchase and installation costs, but downtime can be excessive, with all downtime occurring in one period.

Starting up from a complete shutdown of a system can also be a significant challenge, since you might be battling process startup issues as well as learning how to ramp up the new DCS.

Phased conversion overview

Breaking up the total required downtime into multiple stages is often advantageous, and this is accomplished with a multi-phase conversion strategy. This strategy also spreads conversion costs out over a longer period, which may also be desirable. All these phases are not required, but rather useful choices made with the user and project team inputs during FEL studies.

Viable multi-phase conversion options:

- HMI layer replacement
- Controller layer replacement
- I/O module replacements
- Full I/O device re-wiring

Since the HMIs are typically the “most obsolete” component, that layer is often converted first. This is done with minimal downtime, and in some cases no downtime.

The next phase might be replacement of controllers. This dictates some downtime but is kept to a minimum as explained below.

In later phases, the I/O is replaced. Again, there are methods to minimize required downtime during this time, and these methods are explained below.

Ultimately, the time comes to go full circle and replace the wiring from the field devices to the marshalling panels or from the panels to the I/O terminations.

Phased conversion details

Once the new HMIs are configured, they can be tested using software that simulates connection to an actual automation system. There are many ways to perform this simulation, with benefits and costs generally increasing with the accuracy of the simulation.

Virtually all modern HMIs are PC-based, as are most simulation systems. In many cases, the simulation software can be installed on the same PC as the HMI, minimizing cost and required footprints.

Once the HMIs are configured and the simulation software is active, the HMIs can be installed in the process plant control room. Viewing these simulated HMI screens next to existing HMIs can be a low-risk and low-cost method to train plant operators on the new HMIs.

Once the operators are comfortable with the new HMIs, the simulation software can be uninstalled from the HMI PCs, and the PCs can be connected to the existing controllers. Depending on the DCS, this may necessitate some downtime, and may also require some engineering to integrate the new HMIs with the existing controllers.

The next phase in a multi-phase conversion strategy might be the replacement of the controllers. To minimize downtime, the new controllers are configured, and logic is tested in a simulated environment. As the new HMIs are already in place, the HMI software can often be installed on the same PC as the simulation software, adding to the integrity of the simulation.

As with the HMIs, benefits and costs of simulation increase with the accuracy of the simulation. But unlike with HMIs, controller simulation is much more critical as mistakes in controller configuration can cause downtime, and it is much harder to change controller configuration online as compared to HMI configuration.

For these reasons, it is generally a good idea to invest in controller simulation to the greatest extent possible, as this will go a long way towards ensuring a smooth switchover from the old DCS to the new automation system.

Once the controllers are configured and tested via simulation, they must be installed and connected to the HMIs and the I/O. Connection to the HMIs is very straightforward as both sets of components will typically be supplied by one vendor, or by two vendors adhering to a standard open communications protocol such as EtherNet/IP.

However, connections from the new controllers to the existing I/O can be more problematic as it is unlikely that the existing I/O will support modern communication protocols. Fortunately, many automation suppliers have I/O scanners or other interface components that enable communications between current model controllers and older I/O systems, minimizing required engineering effort and downtime.

Once the new HMIs and the new controllers are in place, the final step in a multi-phase conversion strategy, I/O replacement, can take place. In this case, software simulation isn't required, but hardware simulation often is.

Hardware simulation for I/O consists of connecting new I/O modules to field sensors, actuators, and instruments of the same models found in the existing plant. For discrete inputs and outputs, these simulations are quite simple and may not need to be performed.

For analog inputs and outputs, these simulations can be more complex, particularly when an instrument output is connected to an automation system input via a 4-20mA current loop. If a digital fieldbus is used to connect smart instruments to a controller, testing becomes even more important.

Once hardware testing is performed, the new I/O can be installed and connected. As with HMI/controllers connections, the connection between the new I/O and the controllers is very straightforward as both sets of components will typically be supplied by one vendor, or by two vendors adhering to a standard open communications protocol such as EtherNet/IP.

Connections among I/O points and existing field sensors, actuators, and instruments are more complex, but many automation suppliers have wiring solutions that minimize downtime when replacing and connecting I/O.

Whatever modernization method is chosen, certain benefits will be realized, and these benefits can be quantified with varying degrees of certainty.

New automation system benefits

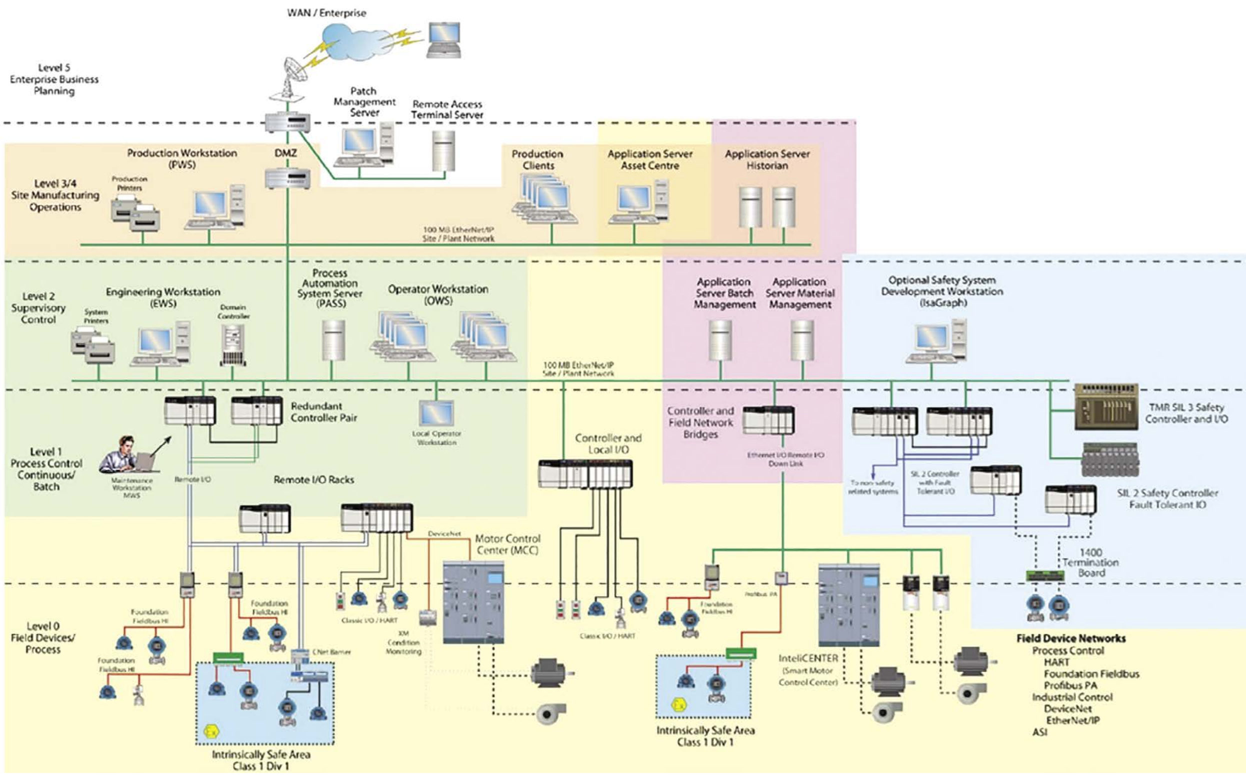
Once the new automation system is installed and operating, and plant personnel are trained in its operation, maintenance should be very minimal. Virtually all modern automation systems are very reliable, and most include tools that can proactively identify problems with field devices before they occur, further reducing maintenance costs.

Table 2: Benefits of conversion to new automation system

Reduced maintenance
Less downtime
Enhanced data collection and analysis capabilities
Ability to integrate other control/information systems
Quicker product changeovers
Fewer manual operations required
Increased operator efficiency
Improved quality
Less energy required
Increased throughput
Advanced process control capability
Built-in cyber security features

For example, an existing transmitter connected to the new automation system via a digital fieldbus such as EtherNet/IP will send a host of information about the process to the automation system. The new automation system can easily be connected to asset management software specially designed to analyze this information. Diagram 1, Multidiscipline Control System Architecture, shows how a modern automation system uses standard open communication protocols to connect to a wide variety of other control and information systems, including asset management systems.

Diagram 1: Multidiscipline control system architecture



Most modern automation systems use Ethernet to provide reliable and high-speed communication system connections among controllers, motor drives, motor control centers, operator interface stations, engineering workstations, process safety systems and higher-level applications such as ERP systems.

Once analyzed, this information can be used to alert plant personnel of impending problems, allowing maintenance to be performed on an as-needed basis rather than on a calendar basis, or in response to a failure. Changing maintenance schedules from annually to only-as-needed can result in substantial maintenance savings, as well as reduced unplanned downtime as replacement and repair can be planned.

Costs for performing maintenance proactively as opposed to reactively can be quantified by first estimating maintenance costs for the existing DCS. Maintenance costs for the new automation system can then be quantified, with some savings added for avoiding unplanned downtime due to proactive maintenance.

Estimates for maintenance and spare part stocking costs for a new automation system can typically be provided by the selected supplier. Alternately, these costs can be identified with greater certainty by entering into a maintenance agreement with the supplier.

For those processes where product changeovers occur, quicker changeovers are expected, and time saved can be quantified by comparing changeover time with the existing DCS to that anticipated with the new automation system. Most plants have a lost production value for each hour of downtime, and that number is used to complete the calculation.

With a new automation system, there may be existing manual operations that can be automated. This should result in direct labor costs savings which can be quantified, as well as estimated cost savings for the greater accuracy and repeatability of automatic as opposed to manual operations.

Many process plants are faced with costs to comply with cyber security mandates. In addition, many plants want to improve their cyber security to lessen vulnerabilities. Most new automation systems will have built-in cyber security tools, reducing compliance costs, with added savings from increasing overall automation system security.

Perhaps hardest to quantify are savings due to improved process control. As previously mentioned, a new automation system can be expected to provide tighter process control and thereby help a plant reduce energy use, increase throughput, and improve quality. These improvements are often realized through implementation of advanced process control technologies such as model-based control.

One method to quantify these savings is to estimate percentage improvements. For example, the new automation system might be expected to reduce energy use by 1% due to improved process control. Scrap and rework might be cut by 2%, and throughput might be increased by 1.5%. Adding the savings from these improvements can result in a quantifiable and substantial number.

Now that the main factors comprising TCO for an existing DCS and a new automation system have been discussed; financial analysis can be undertaken to determine if conversion can be justified.

Financial analysis

Previous sections of this white paper showed how to calculate the factors comprising TCO for an existing DCS and a new automation system. Summing up the numbers for each will allow comparison of the two. If the TCO for the new automation system is lower than the TCO for the existing DCS, then conversion is justified. If the TCOs are roughly equal, but if the TCO for the existing DCS is increasing, then conversion may be justifiable soon.

Many companies prefer different financial metrics than TCO, but these metrics can all be calculated using the numbers gathered in the TCO analysis. Many of the numbers used to calculate TCO will be estimates with varying degrees of certainty but putting some degree of quantification to these numbers is still beneficial and necessary.

Some companies use payback period as a financial metric for new investments, which in this case would simply calculate the number of years it would take to pay back the total cost of the new automation system through annual expected savings.

Payback period is simple to understand but doesn't take into account savings realized from the new automation system after the payback period. For a long-lived asset such as an automation system, the payback period metric understates true benefits.

Another problem with payback period is that it doesn't accurately incorporate the time value of money. For example, an investment of $1,000,000 that saves $200,000 per year would have a payback period of five years, but that assumes that $200,000 five years from now is worth the same as $200,000 today, when in fact it's worth less, with how much less depending on the discount or interest rate.

Varying the acceptable payback period length, increasing it for relatively low interest rates and decreasing it for relatively high interest rates, incorporates the time value of money to some extent — but not as accurately as other financial metrics.

Popular metrics that directly measure return on capital include return on assets, return on net assets, and internal rate of return. These metrics are more accurate for a DCS conversion to a new automation system as they inherently assume a life span of the new automation system after the payback period, and they take into account the time value of money.

For example, a new automation system might cost $1 million and save $100,000 each year, resulting in a 10% return. If the acceptable corporate rate of return is 8%, the new investment would surmount this hurdle. But these metrics are generally more effective for incremental investments, as opposed to comparisons between two different options as with a DCS conversion.

Perhaps the most accurate financial metric for a DCS conversion is net present value (NPV). NPV estimates the value of continuing with the existing DCS as opposed to the new automation system, and it incorporates the interest rate, also referred to as the corporate discount rate.

Net present value can be harder to quantify as it requires annual costs/savings for each option to be listed for the expected life of the shorter-lived option. For example, if the DCS is expected to be totally obsolete and unsupportable in five years, then the annual TCO for the existing DCS and the new automation system would have to be calculated for each of five years, with all values discounted back to the present. Table 3 shows an example of an NPV calculation for a five-year period.

As Table 3 shows, the existing DCS has an annual TCO of $100,000 that's increasing at a rate of 10% the first year, rising by 5% per year to 25% in the fifth and final year as the DCS becomes increasingly unsupportable.

Table 3: Net present value

Net present value		**Existing DCS**	**New automation system**
Interest or discount rate	*6%*		
Net present value		$560,483	$311,542
Year 1 TCO, investment plus savings minus costs		($100,000)	($850,000)
Year 2 TCO, savings minus costs		($110,000)	$150,000
Year 3 TCO, savings minus costs		($126,500)	$150,000
Year 4 TCO, savings minus costs		($151,800)	$150,000
Year 5 TCO, savings minus costs		($189,750)	$150,000

A new automation system would require an investment of $1,000,000 but would save $150,000 per year in TCO as compared to the existing DCS. These savings would reduce the first-year cost to $850,000 and would accrue annually. The interest or discount rate is assumed to be 6%.

The bottom line is that the NPV of the new automation system would be a negative $311,542, while the NPV of the existing DCS would be negative $560,843, making this a good investment.

There are many options for quantifying the value of converting from an existing DCS to a new automation system. But to ensure accuracy, the TCO for each option must be considered. TCO considers all factors related to each option and includes cost savings and benefits from investment in a new automation system.

Conclusion

Comparing the TCO for the existing DCS to that of a new automation system indicates if the conversion is financially justifiable. Outside assistance is often required to evaluate a prospective upgrade — and this assistance can be provided by consultants, system integrators and/or automation suppliers.

The selected partner should have experience converting from the specific DCS in use to the preferred new automation system. This will allow the partner to provide much of the data required for the financial justification, and to also provide technical assistance as required.

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