DCS modernization strategy and implementation

Defining strategies for converting an existing distributed control system to a new automation system

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Many industrial manufacturers today have aging Distributed Control Systems (DCS) currently in place. These legacy systems may work fine today, yet as time goes on, there is increased potential for exposure to a variety of risks which may prevent you from capitalizing on productivity benefits from state-of-the-art technologies. As a DCS reaches the end of its useful life, modernizing to a new automation system is appropriate.

Once the decision is made, the strategy must be defined. In most cases, it is necessary to execute with as little downtime and risk as possible, and these requirements determine much of the Modernization strategy.

There are four main strategic decisions that must be made:

- Hot cutover vs. Cold cutover
- Rip and Replace vs. Phased migration
- Horizontal approach vs. Vertical approach
- Replication vs. Innovation

The first decision (hot versus cold cutover) is a key tipping point, since it sets the tone for the entire scope of the modernization effort; it sets the strategic focus for all conversion activities. With hot cutover, the legacy DCS and the new automation system operate concurrently (in parallel), with individual control loops cut over serially, one by one or in small groups, from the old DCS to the new at an I/O level. With cold cutover, the legacy DCS is essentially completely displaced by the new automation system, with the entire process shutdown, and then restarted after completion of the replacement.

The hot cutover choice may seem more expensive in terms of pure upgrade costs, but when you consider TCO (Total Cost of Operations), which includes the cost of lost production due to the extensive downtime, increased risk during startup, etc., it is generally the best choice.

The second key decision (Rip and Replace vs. Phased) is related to the first since a full rip and replace essentially is a cold cutover. However, with proper planning, users can choose a subset of the legacy DCS to replace completely, if it can be done so independently of the remainder of the DCS controls using the rip and replace strategy (see horizontal below). With a Phased approach, users have the flexibility to choose specific subsets of the legacy system to replace, and this often means replacing HMI, controllers and I/O separately, as we will show later. Most users will naturally conclude that a phased conversion strategy will work best for them, as described later. The phased approach clearly takes longer to complete but requires less downtime and incurs less risk.

The third decision (Horizontal vs. Vertical) is again related to the above. The user must determine if the conversion or upgrade will be done vertically or horizontally. A vertical upgrade means that one specific process area slice is converted at one time, including the Human Machine Interface (HMI), controllers, and I/O. For example, one entire boiler is converted. Conversely, a horizontal upgrade means similar DCS equipment is all replaced at one time across multiple (some or all) process units. For example, a plant could replace all the HMI stations for all 20 boilers (or the entire set of HMIs), leaving all the controllers, etc. in place and running.

The final decision (Replication vs. Innovation) might be considered more philosophical but can be crucial to provide financial justification to move forward with modernization. Replication is simply doing a bare minimum replacement-in-kind of the legacy DCS, copying whatever is required into the new automation system. Conversely, innovation means moving forward with the up-front notion to improve the existing system to perform better with a new automation system in place. This includes improvements that may mean increased production and throughput, quality of product, increased safety performance, etc. Replication is cheaper up front but is clearly more expensive over the entire life cycle of the new automation system, as many of the benefits of a modern DCS are forfeited.

This white paper discusses strategies for modernizing an existing DCS to a new automation system, and will show how to implement the chosen strategies while maximizing uptime, while minimizing cost and risk. Project management is covered to ensure project schedules are met, for minimizing downtime, and for controlling costs — all at acceptable levels of risk.

Pure replication — good or not?

A legacy DCS can be replicated by the new automation system, or you can choose to improve it by modernizing. Replication is less expensive at first, but will usually have a much higher life cycle cost as operational improvements will be minimal.

Replication is simply a replacement of existing automation hardware with new components, keeping all functionality identical to the greatest extent possible. The new HMI screens simply mimic the old, with no attempt made to improve the operator experience. Any existing HMI-related problems with poor process adjustments, alarm handling, and identification and resolution of issues will still exist.

In many cases, the intent is simply to import old HMI displays into the new HMI using some type of translation software. Issues arise because such translation software is often not available, and even when available considerable work is still required to correct the bugs that inevitably arise during translation.

Similarly, replication attempts to use the same controller programming, simply importing the configuration to the new controller hardware. Again, a substantial amount of work is often required to translate the old configuration to the new. Any existing problems with the controller configuration, such as poorly organized and understood constructs, will be retained with the new controllers. Some improvement is usually realized, as the new controllers often have superior algorithms for loop control, and new hardware certainly brings more memory and CPU power, so some consolidation is possible.

I/O may be replaced one for one, with no upgrade to distributed I/O via digital networks. Changes are only made to I/O to resolve any compatibility issues among I/O and field devices.

The main benefit of replication is that the new automation system components will be supported by the supplier for decades, particularly important when the DCS is reaching the end of its useful life, which is often the case in an upgrade.

Improvement/innovation — surely better!

In stark contrast to replication, improvement involves more investment, but in almost all cases a superior return. With improvement, each upgrade area is examined strategically, with investments made where return is greatest. Table 1 lists some of the benefits of improvement over replication, and these benefits are explained in detail below.

Superior ROI
Easier to maintain the software and configuration code
Tighter process control
Better quality — less scrap and re-work
Improved operator interface screens
Better alarm handling
Faster troubleshooting and identification of root causes of alarms
Increased throughput

Table 1: Reasons for improvement rather than replication

For example, new high-performance HMI screens are developed to fix existing challenges such as poor alarm handling or difficult recognition of root cause issues. Fixing these problems will decrease downtime, improve safety, and reduce risk. HMI configuration is performed with the supplier's latest version of HMI programming software, easing maintenance and ongoing support.

New controller configuration and code can be written to automate existing manual operations, and to improve and optimize process control. These changes result in better quality, less scrap, and more throughput. The new controller code can be written using current programming techniques such as the S88 batch process control standard, providing code that is much easier to understand and support.

Substantial return-on-investment (ROI) can often be made by upgrading to smart and distributed I/O and high speed digital networks, particularly as modern digital I/O networks accommodate both smart I/O and smart field instruments.

In most cases, improvement is a superior strategy when compared to simple replication, as ROI is faster, and improved operations and consequent benefits will be ongoing.

In addition to readily quantifiable benefits — such as better quality, increased production and less unplanned downtime — plants can also expect to experience fewer safety-related incidents, and substantially improve security and regulatory compliance.

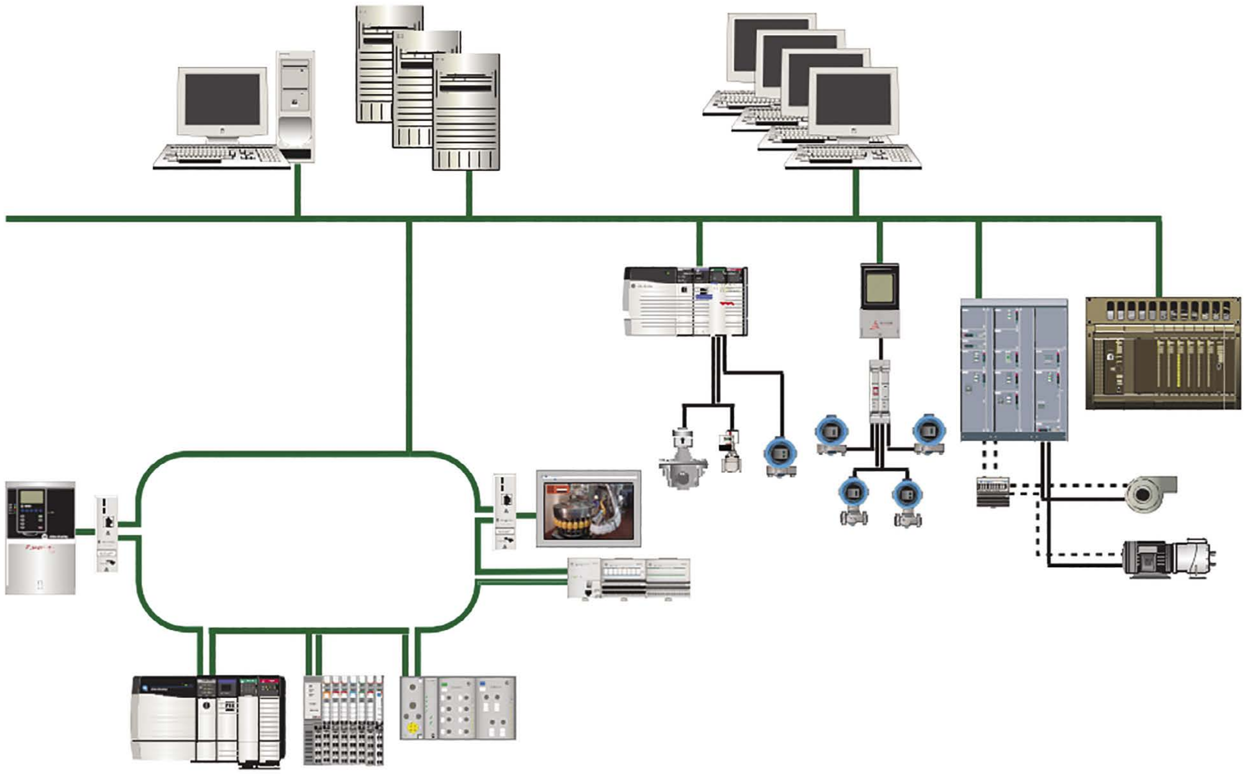

Diagram 1: A modern automation system provides tight integration among various controllers and computing systems, allowing for integrated monitoring and control of the entire plant.

Vertical versus horizontal

Many process plants have multiple similar subsystems that operate across one or more process areas. For example, a plant might have ten boilers, with each one supplying process steam to a process area.

In a horizontal upgrade, the automation system for each boiler would be replaced in a sequential fashion over a single period. In a vertical upgrade, the automation system for the boiler would be replaced in conjunction with the upgrade to its associated process unit's automation system.

Horizontal versus vertical upgrade decisions are often driven by specific plant process configurations. For example, two boilers might supply steam to five process areas each, necessitating a horizontal upgrade approach.

In another case, each process area might have its own automation system, meaning that the boiler's automation system would be upgraded in conjunction with its associated process unit's automation system in a vertical fashion.

In still another case, one automation system might control the entire plant, making the vertical versus horizontal decision purely strategic, as either option would be feasible.

Either vertical or horizontal upgrades can be executed with a phased approach, minimizing downtime and risk when managed properly.

Phased approach mitigates risk

One conversion method 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 the downtime coming in one continuous period.

Breaking the total required downtime up into multiple periods is often advantageous, and this can be accomplished with a multi-phase conversion strategy. This strategy also spreads conversion costs out over a longer period and minimizes risk for each phase.

With multi-phase conversion, the most obsolete components — generally the HMIs — might be converted first, usually requiring little or no downtime.

In the next phase, the controllers are replaced. This will usually necessitate some downtime, but it can be kept to a minimum by using the methods explained below. In a later phase, the I/O is replaced. Again, there are methods to minimize required downtime during this phase, and these methods are explained below.

In the HMI phase, the old HMIs are replaced with modern PC-based HMI components. 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 in the same PC as the HMI, minimizing costs and required footprint.

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 is 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. This may require some downtime and may also require configuration to integrate the new HMIs with the existing controllers.

In the controller phase, legacy controllers are replaced with modern controllers featuring higher speed, more memory, and process optimization technologies such as multi-variable control, model-based control, and other advanced process control methodologies.

Depending on the vintage of the old DCS and other factors, new controller configuration may be generated from scratch or imported from existing DCS programs. If imported, the code can be converted automatically using engineering conversion utilities, assuming such utilities are available for the old DCS and the new automation system. Even with the best conversion utilities, some manual re-effort will be required. If no conversion utilities exist, then manual conversion is an option, and this is often best performed by a third-party service firm familiar with both the old DCS and the new automation system.

Once the new automation system controller code is generated, the new controllers and software can be run and tested in a simulated environment to minimize issues when the new controllers go live on actual plant processes. 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 veracity of the simulation.

Technologies such as I/O scanners can also be deployed at this point to simulate connections among the controllers and the I/O. Modern I/O scanners can also be deployed early in a project to shadow or capture existing I/O dynamics in real-time. Once captured, these data can be used for debugging the new controller code, greatly reducing risk.

As with the HMIs, benefits and costs 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's 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-phased conversion strategy — I/O replacement — can take place. In this case, software simulation is not 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 as that found in the existing plant. This simulation is generally performed in a test area where it is feasible to stage and interconnect all the required components.

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 4-20 mA 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/controller 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 is more complex, but many automation suppliers have wiring solutions that minimize downtime when replacing and connecting I/O.

With either an all-at-once or a phased approach, a hot cutover of one control loop at a time can be quite advantageous to minimize downtime and risk.

Hot cutover reduces downtime and risk

With hot cutover, some or all of the old DCS and the new automation system operate simultaneously, with one control loop at a time converted from the old DCS to the new automation system.

If a phased approach was selected, hot cutover occurs at the I/O level as the HMI and the controllers have already been replaced. The old and the new I/O systems are both in place and running simultaneously, with old I/O replaced by new I/O as each loop is put into service.

If a phased approach was not selected, then the old and the new HMI, controllers and I/O are kept up and running simultaneously. As new loops are put into service, the associated I/O is moved to the new controller. Old HMI and controllers are retired as the I/O associated with them is converted, until the entire automation system is replaced.

With cold cutover, the old DCS is replaced en masse by the new automation system, with the entire process being restarted at once. There is no simultaneous operation of the old DCS and the new automation system.

As outlined in Table 2, hot cutover has advantages over cold cutover, but with some drawbacks. The chief advantages are decreased downtime and reduced risk. Because the old DCS is kept running while the new automation system is being cutover one control loop at a time, only one control loop at a time is down. In most plants, this can be managed with little or no downtime.

Benefits	Drawbacks
Less downtime	More expensive over time
Reduced risk	Requires more space
Easier to troubleshoot potential issues	Takes longer to complete
Simpler to implement on-the-job training	Both old and new systems must operate concurrently

Table 2: Hot cutover versus cold cutover

Risk is very low as control of each loop can be transferred back to the old DCS in the event of problems controlling the loop with the new automation system. Troubleshooting is very simple as any problems are isolated to one loop. Finally, on-the-job training occurs naturally as each new loop is put into service and tested, all at a manageable pace.

Although a hot cutover has compelling advantages as detailed above, there are also corresponding drawbacks. A hot cutover is more expensive as some or all of both the old DCS and the new automation system have to be up and running simultaneously. More space is required in the control room, adding to the complexity of project management. Finally, the total time for the cutover will generally be much longer.

In summary, most plants opt for hot cutover, unless there are special circumstances that would allow the entire plant to be shutdown for an extended period. These circumstances might include a complete overhaul or replacement of major processing equipment, an anticipated substantial reduction in demand for the plant's output due to seasonal or other factors, or major required changes to plant processes for compliance with regulations.

No matter what strategies are selected for a modernization, project management will be a key factor in determining successful implementation.

Project management plans for success

Project management is an art and a discipline unto itself, and a well-respected vocation with its own professional organization and certification program. Depending on the size and scope of the upgrade project, project management will require varying numbers of staff, with staffing requirements often changing throughout the project.

One individual must be designated as the Project Manager (PM), and the PM must have ultimate decision-making responsibility. The PM must be given the authority to instantly make decisions trading off cost, schedule, and risk. In a large project, there will be hundreds or even thousands of these decisions, and consulting with upper management or a committee on each one will simply add too much time and corresponding cost.

In most cases, the PM is given authority to make on-the-spot decisions up to a certain monetary level, with only decisions above this level requiring upper management approval or consensus among the entire project team. For maximum effectiveness, the monetary level should be expressed in percentage terms. For example, a $1 million upgrade project might include authorization for the PM to make decisions up to the $20,000 level, or 2%.

Since the PM is responsible for the overall cost and schedule of the project, they are generally best suited to make these decisions, and they should be experienced enough to know what level of consultation with the project team is optimal in each case.

The PM relies on the project management team to handle tasks such as project scheduling, continuous tracking of costs, and monitoring of percent complete for each task. Monitoring percent complete can be quite difficult on upgrade projects, particularly for software-related tasks.

If a task consists of installing a new control room console, percent complete can usually be ascertained by visual inspection. If a task consists of configuring thousands of function blocks for a new controller, other methods must be used.

When monitoring completion of software-related tasks, there is simply no substitute for experience, ideally performing similar development tasks. If the PM does not have such experience, they should designate a person to work on the project team as a technical lead to monitor software configuration. Depending on the size and scope of the project, the PM may require technical leads in other areas also, with these technical leads often loaned to the project on a part-time basis.

As with many complex disciplines, experience is the best teacher for a PM. If a plant routinely manages projects internally, then the required project management expertise may reside in-house. Alternately, many plants rely on corporate personnel that move from plant to plant within an organization to manage large capital projects. If feasible, the provision of a project team comprised of internal resources can be the best solution, as the team will be very familiar with existing plant operations and personnel.

But for many plants and organizations, there's simply insufficient in-house staff and expertise to manage large capital projects internally, particularly for specialized tasks performed infrequently, such as a DCS upgrade or conversion. That is why many plants turn to outside service providers to manage these projects.

If this option is selected, the plant must designate one person to be the chief liaison with the service provider's PM. This liaison, often called the internal PM, must work very closely with the service provider's PM to ensure successful completion of the project.

When selecting a service provider, the main criteria should be experience with the desired upgrade path in terms of strategy, plant processes, and the new automation system hardware and software. Ideally, the service provider will have successfully executed multiple similar upgrades, with an opportunity for plant personnel to speak with past customers to verify service provider claims.

In summary: Making the right decisions

To summarize, four strategic decisions must be made before proceeding with a modernization plan. First, it must be established whether a hot or cold cutover strategy will be used, which guides the rest of the decision points.

Second, choosing a phased approach over a rip and replace strategy is the likely scenario due to the flexibility and long-term benefits.

Third, selecting the horizontal approach to replace like equipment is a viable strategy for some legacy DCS and the user's situation, compared to using the vertical approach. Both have their pros and cons.

Finally, opting for innovation contrasted with simpler replication brings many financial and technical advantages and is often needed to even take the modernization project to management for funding.

For example, there may be situations when an entire plant will be out of service for an extended period. In those rare instances, a cold cutover of the entire automation system in a horizontal fashion is often selected.

More commonly, all or part of the plant must be kept up and running, leading to interrelated strategic decisions. For example, a vertical upgrade strategy may be selected where one process area of a plant is upgraded at a time, leading directly to decisions with respect to a phased approach and to a cutover method.

If a phased approach is selected, then each area can be upgraded via a hot or a cold cutover. For example, it may be decided to upgrade the HMI hot, but the controllers and I/O cold.

In instances where downtime and risk must be minimized — hot cutover with a phased approach to HMI, controller and I/O replacement is usually selected. This strategy is relatively expensive strictly in terms of upgrade costs, but overall costs are generally lower as downtime is kept to an absolute minimum. For most plants, the cost associated with any significant length of downtime will dwarf money saved by using a less expensive upgrade strategy.

This strategy also takes up the most overall time, but there is minimal or no downtime during the entire upgrade period. This contrasts with a strategy such as cold cutover of the entire automation system, a strategy that would minimize upgrade time, but require downtime during the entire upgrade period.

Whatever upgrade strategies are selected, proper management is a must as a good project management team can implement the chosen plan on schedule and budget with acceptable levels of risk. In many cases, a third-party service provider is best placed to provide project management services for an upgrade.

Plants with an aging DCS will require an upgrade to a modern automation system at some point. Selecting the right upgrade strategies and the right project management team are critical to the success of the upgrade. If a third-party service provider is chosen, they can often assist in not only project management, but also in the development of the upgrade strategies.

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