A Guide to On-Time and On-Budget Plant Commissioning of Industrial Control Systems

Mitigate the Risk of your Next Plant Commissioning Project Over Running.

The First Law of Industrial Control Systems
“Plant Commissioning always takes 2-10 times longer than the original estimate.”

Does this tally with your experience of projects involving industrial control systems? How much time, stress and financial loss has your company been exposed to due to overrunning projects?

No one wins in this situation. If you are a systems integrator on a fixed price job, the losses are obvious. Even if you managed to negotiate a Time & Materials contract, the short term gain of extra work is far outweighed by the loss of reputation with an angry and out of pocket customer. And if you are the end user, the cost of downtime will be enormous. Even a small scale plant’s cost of downtime is $1000’s per hour.

“We’ll fix it in commissioning”

This paper will show you that this law can now be consigned to history. Here and now there is a way to be 100% confident in the operation of your control system and the integrity of the logic in your PLC code, all before it is installed on site. There is no longer any excuse for control system bugs to be found during commissioning.

A new control strategy, commissioned in less than one day.

The aim of the control system was to control the moisture content of coal being loaded onto ships. This was done by sensing the moisture content of the coal in real time, with a microwave based analyzer and then spraying water onto the coal if the coal was too dry.

This may sound simple enough, but as always there were complicating factors. Firstly, as can be seen in Figure 1, there were a lot of different nozzles, of many differing sizes, all spraying differing amounts of water onto the coal as it passed underneath, on a conveyor belt. This would require some relatively sophisticated logic to work out which nozzles to switch on, in order to generate the desired water flow.

Secondly, the moisture analyzer was 40 seconds down the conveyor, introducing a nasty time delay into any loop tuning.

Finally the conveyor belt speed was constantly changing, which added a significant disturbance to the control loop.

Figure 1 – Moisture Addition System
We decided to use a cascade control strategy. Its purpose was to:

- decide how much water to spray on the coal
- decide how many valves to open to deliver the desired flow of water onto the coal.

The control strategy is shown as a block diagram below.

![Control Strategy Block Diagram](image)

**Two Approaches to Commissioning a Control System**

**Approach #1: 20th Century Commissioning**

The usual procedure, once the control strategy is decided upon is:

1. Implement the strategy in the PLC: i.e. code it up in ladder logic
2. Look at the code and hope that it works as well in practice as it does in theory
3. Go to site
4. Shut down the process
5. Install the code
6. Start debugging
7. Don’t have any lunch: there’s no time
8. Carry on debugging
9. Finish off debugging
10. Repeat steps 6-9 for far too many 10-12 hour days
11. When it is looking good, try out lots of scenarios as per your test-plan
12. Continue debugging as more unexpected behavior is found
13. Finally end up with a system that works, but could have been a lot better if you had more time and a bit of space to think.
14. Get sign off from the plant representative
15. Start the plant back up and monitor the performance

**Approach #2: 21st Century Commissioning**

1. Implement the strategy in the PLC: i.e. code it up in ladder logic
2. Create a low-medium realism model of the plant you are going to be controlling in a join-the-dots modeling package
3. In your office, connect the PLC to the model via OPC (10 minutes)
4. Debug the code on your desk
5. Don’t worry if it doesn’t work first time. Have a coffee and think at leisure about how to make it work. Or ask a colleague.
6. When you come up with a solution that looks good, pat yourself on the back and have another coffee.
7. Run through the test plan and take plots of the plant response.
8. Send these off to your client for approval.
9. Leave the controller controlling over the weekend, to ensure it is robust.
10. Have a nice relaxed weekend (I suggest going surfing)
11. Come back on Monday morning. Check the logs to be happy that everything went OK.
12. Go to site, Install code
13. Fine tune the controller settings to match the real plant response
14. Get sign off
15. Monitor the performance, confident that you have a robust solution

The key point of building a model is that it is low-medium realism. With modern software that is designed for this purpose, almost any plant can be easily modeled. It simply involves configuring a standard block and then joining it graphically to other blocks to create a model that is has enough realism to debug the code.
Outline of a Stress Free, Under Budget Project. Moisture Control Job Methodology.

1. The implementation of a control strategy in the PLC as ladder logic.
2. Build the plant model with Control Performance Optimizer. Usually this process takes less than a day. See illustration below.

Control Performance Optimizer is Powered by Matrikon, which represents vendor neutrality. This product works with third-party control systems and applications.

![Control Performance Optimizer](image)

**Figure 3 – The modeled plant using Control Performance Optimizer**

Figure 3 illustrates that building the plant model need not be a very complex task. For example, the 40 second delay between the nozzles and the moisture sensor is simply modeled by dropping in the grey “Delay” block and configuring the delay to 40.

1. Now connect the model to the PLC using OPC which is available in any PLC with a network connection. This takes only about 10 minutes to configure.

OPC allows the controller to drive the model as if it was connected to the real plant, as shown in figure 4.

![How the PLC talks to the model](image)

**Figure 4 – How the PLC talks to the model**

1. With a connection established you must now debug the code. Because you can run the control system on your desk interfaced to a simulated plant, you can run the controller in debug mode and iron out all those logic errors that would typically be ironed out on site.

Within 4 hours all the logic that switched the nozzles on and off had been fully commissioned - without leaving the office. We could be confident that the logic was 100% because we could give the PLC a water flow setpoint, watch on the laptop as it switched the correct nozzles on and then check that the resulting simulated water flow was the correct number.

An hour in the office is worth 10 hours on site. The cost of this commissioning was:
- 1 engineer’s office hourly rate times half a day.

The cost of debugging this logic onsite would have been:
- At least 2 engineers (one to drive the PLC and one out on the plant watching the solenoid valves and communicating via wireless device.
- The cost of the plant being down for half a day
- The cost of the operators’ wages who would enjoy half a shift in the tea room
- The commissioning engineers’ expenses
- And it always seems to be more difficult to debug logic when you are on site and under pressure.
Commissioning the Moisture Control Loop

With the nozzle controller logic behaving nicely, it is time to test the outer loop; the moisture control PID.

It becomes apparent that the transport delay of 40 seconds between the nozzles and the moisture analyser is going to be problematic. With a standard PID loop we just can’t tune it to get the desired response and disturbance rejection. It is clearly time to rethink our control strategy. We try a Smith Predictor algorithm instead of the PID, as these are designed for large time delays.

The next day was spent coding and commissioning the Smith Predictor. We got some reasonable responses from it, but we struggle to get it to robustly reject the disturbance of coal feed rate.

We were now at the end of the second day of our ‘on-desk’ commissioning and very happy that we are not on site.

The nature of the problem means that we don’t actually need a ‘tuneable’ controller. We just need to look at the moisture error (analyzer reading – moisture setpoint) and multiply this by the coal flow. This gives us a moisture correction in the form of a water flow setpoint that we need to ask the water flow controller for. Offsets are removed by adding the moisture correction to the old water flow setpoint.

If we have been spraying 100 l/s of water onto the coal and the coal moisture is too dry by 2%, then work out how much extra water we need to spray on the coal (using the current coal flow rate) to get the coal 2% wetter. Add this extra water flow rate to the 100 l/s to get the new flow rate.

A flow chart of this simplified moisture controller is given in figure 5.

This code was implemented in the PLC and tested in the office. After some tweaks to the code it showed proper control and robust disturbance rejection and most importantly it performed to the client’s spec.

Figure 5 – The new moisture control logic

With client approval, we go to site and have the new system installed and commissioned in under a day. If we had left it until plant commissioning to test our code fully, we would have had to change our control strategy halfway through. Plant commissioning would have lasted at least a week, with all the associated costs that entails.
Training Your Operators on the Plant before it is Built

Another big win with this approach is that once you have a model of the plant you will be controlling, you have a valuable training tool. Your HMI can plug straight into the simulation and can control the model via the PLC. Your operators can practice controlling the simulated plant before the plant has been commissioned. When the plant is ready, the operators will already feel familiar with the controls and the plant’s response. So the time it takes for the operators to get the plant up to optimum operation will be substantially reduced.

If you are wondering how much work is involved in hooking up the HMI screens to the simulation, the answer is “almost none”. When building your model you will have put a simple software switch in the PLC code that switches between the real world IO and the simulated IO. Because the HMI talks to the PLC and the PLC talks to the model, no modifications are required to the HMI code. Figure 7 illustrates how it all works.
The New Law of Industrial Control Systems

“Plant Commissioning should never again overrun due to control system debugging.”

When you can commission your control systems in the office, you can remove most of the risk of commissioning overruns. It is a classic case of spending a dollar at the beginning of your project to save 10 at the end of the project. What are the real costs of a project that delays the start-up of the plant by weeks or months?

If you are hiring a firm to do your control systems work, ask them how they test the system in their factory. If they aren’t using simulation technology to ensure an error free system is delivered to your site, then they are exposing you to a large risk. Think carefully about how much any overruns in plant commissioning will cost you over and above what you are paying for the control system.

What to Do Next

If your next plant commissioning project needs to be on time and on budget, then implementing medium-realism simulation will reap tremendous benefits for you and reduce plant commissioning time, typically by weeks.

Don’t let poorly tested control systems expose you to high risk.