

## Smart Technology and its Impact on New Plant Construction

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### Abstract

The advent of “Smart Technologies” using fully digital instrumentation and Fieldbus networks offers significant opportunity for cost and schedule savings in new plant design, construction, and commissioning as well as numerous benefits in on-going plant operation and maintenance. A recent study demonstrates the incorporation of these “Smart Technologies” within a new project management approach could save as much as \$20 million in procurement, construction, commissioning and start-up costs on a new 600 MW coal-fired unit. To fully realize these benefits it is important to understand these technologies and consider them in a systematic approach from the beginning of the plant development schedule. This paper will provide an overview of the basic technologies, their application, impact on design, areas of cost savings, and specific project recommendations that should be considered.

Areas covered include:

1. Review of expected improvements in project cost and risk from the application of “Smart” technologies.
2. Project development considerations such as schedule, planning, design, and execution as well as a review of the Construction Industry Institute’s (CII) PEPc model to optimize Owner, Contractor, and Supplier relationships to assure successful implementation of large, complex projects.
3. The benefits of network connectivity via “Smart” systems in support of new plant development from an enterprise-wide information perspective.
4. Review of various bus technologies and their applicability to power plant processes.
5. Field device capabilities and application benefits as they apply to revised plant development approaches.
6. Financial results and analysis of savings identified during the study, including associated metrics.

## **Introduction**

The primary objective of this paper is to compare the construction cost of a Traditional hardwired control system with a digital Bussed control system. Both construction estimates are framed within a typical power plant development process, which identified overall scope, schedule, and budget boundaries. In both approaches, the research process identified and broke down progressively smaller components until detailed construction estimates were completed.

The development process is complex and lengthy, and many of the assumptions in this report can be affected by activities outside the control system area. A few key observations to consider are:

- The owner's participation in the development process can vary widely. If a developer is used, the owner may only assign one person to track the entire process. The owner can also act as the developer, creating a large team to facilitate stakeholder interaction.
- Major stakeholders in the development process can include the owner's team, one or more plant operating entities, a developer, federal, state, and local government regulatory agencies, one or more engineering firms, a general and numerous subcontractors, several major equipment suppliers and their subcontractors, and any number of specialized consulting firms.
- Many of the stakeholders in a development project will have significantly more scope and power than the control system supplier.
- Suppliers can number more than 100 for a major development project, with more than a thousand people involved on site through the course of a project.
- The U.S. regulatory process can dictate technology use, performance, and other project variables affecting the development process significantly.

The number of development process variables can vary results significantly. Applied consistently, the Bussed methods specified in this report will yield consistent savings over Traditional utility implementation practices and identify several ways to simplify an important part of the power plant development process.

## **Scope**

Two potential implementations of a DCS on a Greenfield 600 MW supercritical power plant installation were identified. The "Traditional" installation utilizes dedicated cables to connect non-intelligent field devices to I/O cards, based on a typical Engineer-Procure-Construct development process.

The Bussed installation uses high speed field communications networks and intelligent field device technology to simplify construction. The Bussed I/O approach utilizes a new development process from the Construction Industry Institute (CII) called "PEpC". This revolutionary new model helps to optimize Owner, Contractor, and Supplier relationships to streamline the development process, providing for lower overall project costs when compared

with EPC methods. Costs were estimated for both implementation approaches in five categories: system selection, engineering, construction, startup, and overheads. Potential operating and maintenance cost savings were estimated as well.

The Bussed concept is multi-faceted and includes not only physical but also development and engineering process changes as well. Where a Traditional control system is engineered after major equipment selection and must be responsive to multiple technologies, the Bussed approach is controlled and planned to deliver the best value for the owner or operator. It is a completely integrated concept, not assembled later from a collection of add-ons to larger mechanical systems. The Bussed approach uses the latest in field technology and adheres to a concrete design criteria created very early in the development process.

## **Methodology**

Costs associated with each step in the construction process were evaluated for each approach. A typical development framework was laid out to “simulate” the entire process from concept to commercial certification to determine what savings might be available using new technologies and methods. The Traditional and Bussed development processes were examined carefully to determine what savings might be obtained in hard construction in addition to optimizing the development process itself.

To complete the construction estimate, a comprehensive budget model was built to document critical assumptions regarding the Traditional and Bussed approaches. The primary objective is creation of an accurate construction estimate with appropriate granularity to defend the results against rigorous analysis.

Installing a control system is only part of the total effort required to build a plant. This report compares two distinctly different approaches to installation of a DCS framed within the overall development process. The two approaches were not treated as choices, but as unique concepts to be followed in the extreme, where application of each concept was followed rigorously.

## **EPC**

The Traditional approach utilized an Engineer, Procure and Construct (EPC) model used extensively since the peak of central station plant construction in the 1970’s. Once the development process provides for a complete financial model, a large engineering firm designs and specifies a complete plant (E). Major components are put up for bids according to a detailed specification, usually based on a conservative and well tested set of technologies. Capable suppliers respond to the bid package with the usual list of exceptions, and through a detailed selection process, a provider is selected and a contract conformed (P). At this point, exceptions to the original design often result in a detailed re-engineering effort. Finally, after multiple iterations to fully integrate the combined group of low bidders, construction takes place (C).

## **PEpC**

In the Bussed approach, the PEpC model is utilized for a number of reasons. The PEpC process was developed by the Construction Industry Institute, Bureau of Engineering Research in Austin, Texas. The acronym PEpC stands for:

- P – Procure Strategic Suppliers
- E – Engineer
- p – procure Balance of Plant
- C – Construct

In the PEpC model, early knowledge of the higher level system components can save re-engineering revision time after the Procurement stage in the EPC model. The DCS is pre-selected, eliminating the specification, bid, and selection process. Hardware, software, and instrumentation are also pre-selected for applications and major equipment packages. The construction contract for instrumentation and electrical may also require modification for field selection of pre-manufactured cables and other flexible equipment supply methods.

Utilized at the front end of the entire development process, PEpC alone saves time and money through standardization and optimization as shown throughout this report. The primary objective is to meet not only the specification but the intent of the larger business plan through the development process. The PEpC process offers flexibility unavailable through the traditional EPC approach, delivering more value for less money.

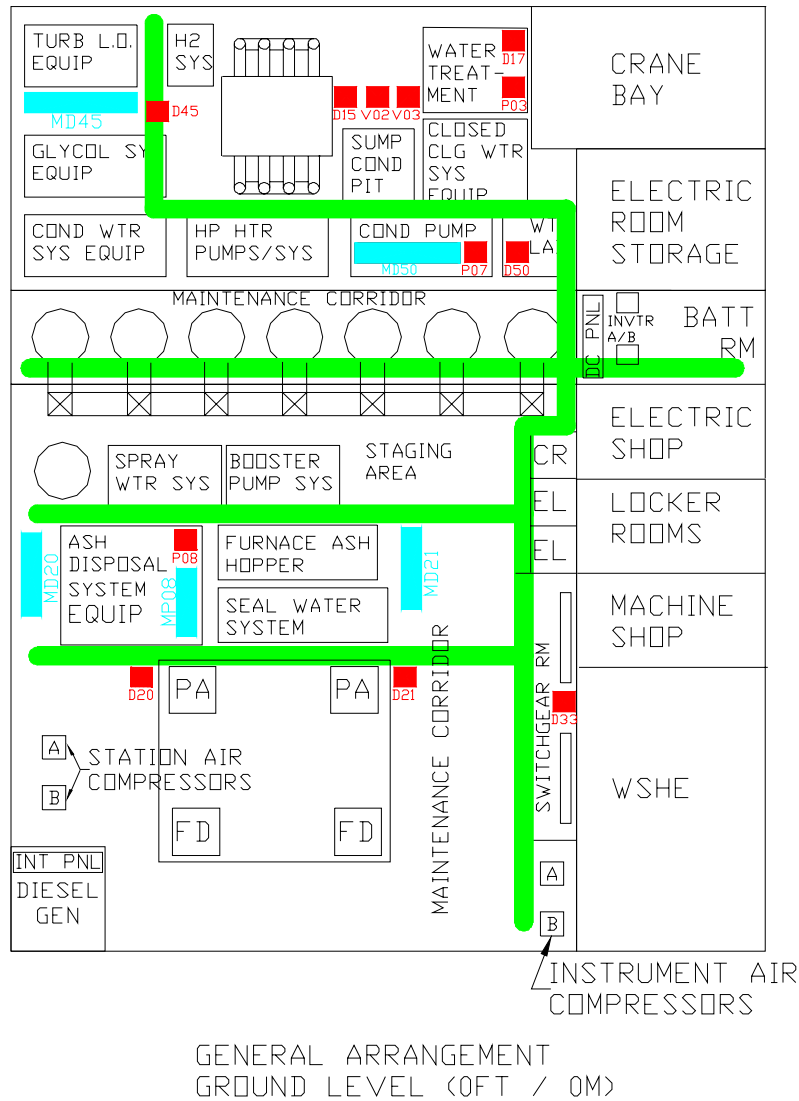
### **Physical Plant Layout**

Typical supercritical plant layouts and design criteria were researched to create a proposed plant. The plant was physically defined by plan, elevation and several general arrangement (GA) drawings. Remote buildings containing auxiliary systems were also dimensioned. The plant was logically defined by an existing DCS specification with approximately 5200 hard and 4250 soft I/O partitioned into typical power plant system designations. Appropriate systems were placed on GA drawings to complete the physical plant definition, as demonstrated by Figure 1.

### **System Selection**

Control system procurement provided the first opportunity for cost savings in the development process. The PEpC selection process eliminated the expense of a complex specification, bid, evaluation, and conformation process. Costs associated with the EPC selection process were identified and estimated, for owner, engineer, and supplier activities.

Figure 1. Sample plant general arrangement drawing.



The PEpC approach eliminates a significant portion of the Traditional specification and bid process by pre-selecting the central DCS platform and field technologies such as I/O busses and instrumentation. The AE is responsible for assembling a “construction specification” containing an I/O list, details regarding installation, specific local code requirements, construction, startup, and long term operational needs. The plant concept is developed into a working model around strategic suppliers to create the best value.

There are significant logistic savings in pre-selection as well. In new plant construction, all system suppliers are given a specific standard for instrumentation up front. A disadvantage of this approach is that equipment suppliers are forced to use a pre-determined standard. If this standard differs from their usual product offering, a surcharge may result from equipment charges or re-engineering efforts, which are minimal in comparison to potential savings.

As a result of pre-selection standardization, less support engineering time is required for overall plant construction. There will be fewer variations on installation details, support documentation, and interfacing requirements. General engineering support for grounding, conduit, tray, and isolation requirements become simpler to apply and manage. Construction standardization reduces training costs, repetitive installation quality is higher, and interface problems with multiple suppliers are reduced. Plant construction staffing is reduced at all levels, fewer workers means less supervision, which leads to lower overall project overheads.

Pre-selection leads to plant standardization, which has numerous benefits. There are savings in spares and warehouse space, leading to smaller buildings with less construction cost. Additional savings are found in training and support, including less time for startup and commissioning, as well as fewer technicians and electricians on support staff. Inter-system integration is more standardized, rather than having multiple systems talking to multiple systems, there is one central system talking to a few specialized systems such as vibration monitoring, excitation, and switchyard control.

## **Engineering**

Engineering requirements differ significantly between the Traditional and Bussed approach. Use of database and drawing methods not typically used with the Traditional approach saves time for the engineer and drafter, and cuts down on the number of total “drawing touches”. A typical Traditional engineering approach includes several discrete tasks for engineering, design, and drafting support staff:

- Compilation and entry of database information for all I/O points
- Selection of appropriate field device and entry of device information into database
- Initial design sketch with specific I/O information, field device information, and required field wiring
- First draft of drawing completed from template
- Reviews of first drafts in conjunction with second pass database review
- Drawing revision changes

For the Bussed approach, instrumentation and field devices are pre-determined due to the early selection process. Most field devices require no further research or modification from any standard template due to mechanical or system supplier inconsistencies. A standard template is developed for smart devices, allowing reduction in drawing complexity, higher I/O density on drawings, and fewer and simpler revision cycles.

An example of this technology is cable estimates. Traditional work flow allows for creation of the cable tabulation during the second drawing revision. Using the Bussed model, cabling is done with the partitioning of the system. The reduction in hardwired cabling further simplifies the process. The Traditional approach offers many opportunities to choose the number of conductors, type, size, color code, etc. With the Bussed approach, an electrician can select the appropriate drop cable length from a pre-ordered stock and install it. They are all the same except for the length, and extra cables are returned at the conclusion of construction.

Once partitioning of the system is completed, drawings are extremely repetitive. Many construction drawings are easily replaced by a formatted text document showing pertinent cabinet, interface card, field device, and any other information required. Since every field device is routed directly into the DCS, there is little or no “field logic” performed with relays or complex system interconnects. This simplifies drawings and reduces field-troubleshooting time during checkout or during operating equipment failures.

## **Construction**

The most critical part of any plant development process is calculation of an all-inclusive construction labor rate buildup. A typical contractor rate buildup includes base labor rate and benefits, site insurance, federal and state taxes, subsistence, fringes, and equipment rental as a percentage of the total rate.

After development of a construction rate, progressively more detailed physical models for electrical and instrument construction were assembled. Time and material models were developed for tray networks, conduit drops, cabling, and terminations. Tray networks were defined for all elevations and overlaid on available GA’s to link major systems and clusters of I/O. Drop methodologies were defined, including piping, cabling, tray usage, terminating, and other details.

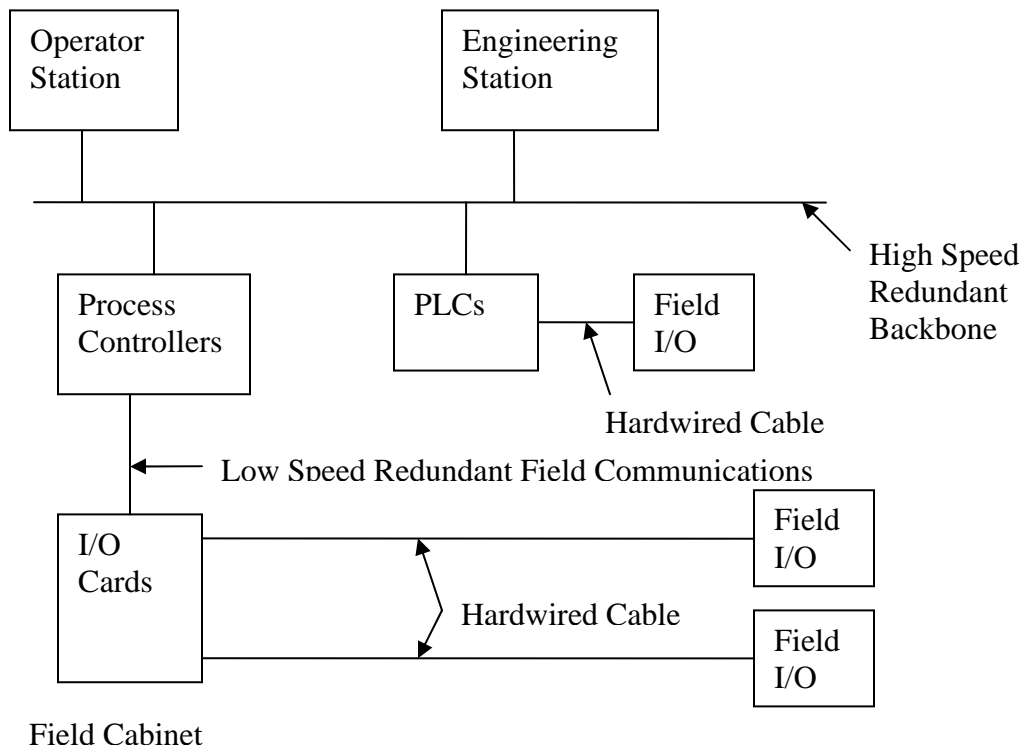
## **DCS Configuration**

DCS implementation strategies were developed for both approaches, including system configuration and field I/O interface methodologies. The Traditional strategy used a system of tray and conduit to route individual I/O cables from non-intelligent field devices to field mounted DCS cabinets. In the case of multiple signal devices such as motor switchgear, multi-conductor cable was assumed. The Traditional system configuration is shown below in Figure 2.

The Bussed approach used three types of field I/O busses and a combination of hardwired I/O to interface with smart field devices. The buss types include Analog, Temperature, and Digital I/O segments. Wherever possible, signals were brought into the system via one of the three buss methods. The only exceptions were for Sequence of Events (SOE), non-smart analog devices, and critical, high-speed process loops. Hard wired signals were brought into the bussed system using I/O cards and the same assumptions as the Traditional approach. A Bussed system configuration is shown in Figure 3. Bussed instrumentation upgrade costs were estimated for analog devices, including transmitters, controllers, and temperature clusters. Digital buss segment devices were also estimated as required.

Analog buss segments include smart devices such as transmitters, control valves, analyzers, and other Foundation Fieldbus compliant hardware and terminate directly to the central DCS in field cabinets. Digital buss segments include devices such as switches, solenoids, starters, breakers, switchgear, and other smart digital I/O packages. Digital device buss segments can terminate with equal ease to the central DCS or PLC based processors linked to the central DCS via a gateway or other high speed connection.

Figure 2. Traditional system configuration.

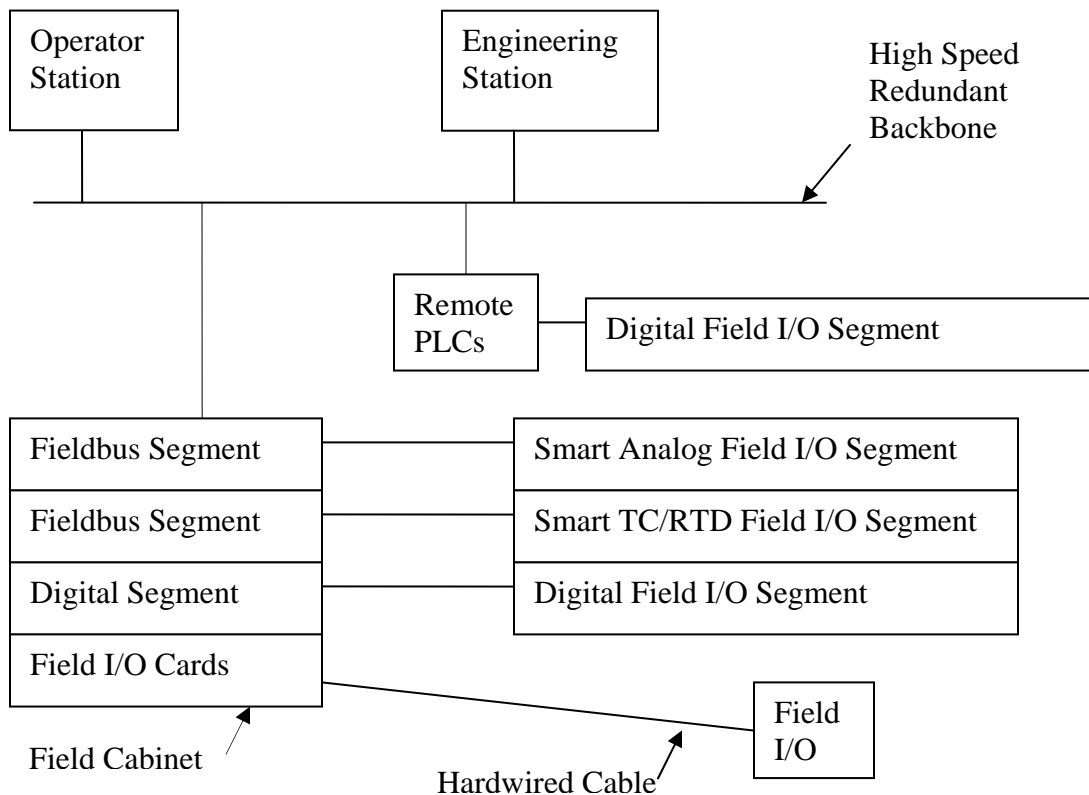


### Motors, Starters, and Switchgear

Motor I/O was defined in three separate classes for both the Traditional and Bussed approach. Traditional Class 1 motors include reversing starters and breakers up to 100 HP at 480 VAC, which require three digital I/O points. Class 2 devices are 480 VAC and range from 100 to 400 HP, including four digital I/O and three analog temperature measurements. Class 3 devices include medium and high voltage switchgear, relays, and other switching equipment with up to eight digital I/O and four or more temperature I/O. Most services fit into one of many variations of the three basic classes.

The Bussed approach to the three classes is similar, with all I/O requirements the same. However, there is no hard wiring to the cubicle or switchgear lineup. Rather, a single or redundant high-speed multi-drop digital buss soft controls all Classed devices (partitioned properly), eliminating a high percentage of DCS field cabling. Software interlocks and heartbeats ensure appropriate security and safety is maintained. For intrinsic systems and Sequence of Events monitoring, a single I/O cable usually fulfills needed requirements. Perhaps the largest benefit to a digital starter, relay, or switchgear is the amount of data available. Digital software packages offer dozens of available points, most of which would be unavailable using the Traditional approach, or cost prohibitive due to analog instrumentation requirements to obtain the same information.

Figure 3. Bussed system configuration.



### Checkout, Startup, and Commissioning

For the Traditional approach, the DCS is powered up and loop checkout begins more or less when construction is completed. A major issue becomes schedule, as much of the checkout and startup process are critical path activities. Field checkout can involve wire checking, calibrations, screen verification, and simulated operations testing.

For the Bussed approach, the DCS is powered up as soon as possible, perhaps months ahead of the same event in the Traditional approach. Digital and analog instrumentation is terminated through connection of prefabricated cables and “awakens” upon connection to the buss, completing self-configuration and testing automatically. Field checkout consists of actuating field mechanics as required, yielding a significant time savings over Traditional requirements. Time estimates for various point types, instrumentation groups, and complex devices were developed for both development approaches. Owner or operator cost estimates were also applied to create a total savings for checkout.

At the conclusion of checkout, the sequential process of startup begins. Traditional systems have limited equipment diagnostic capability since only control and critical monitoring points are connected. Using smart devices, systems, and bussed connections, a much denser monitoring capability is available through the Bussed approach. This translates into more information about

the process and better analysis tools, resulting in quicker resolution with higher quality systems. Up to two months of checkout time and one month of startup time, all of which is critical path, have been estimated as possible reductions in the overall development process.

## Overheads

Two types of overheads are typically involved with a major construction project, including fixed and variable. Fixed overheads are usually budgeted as a straight percentage of the total project cost. Variable overheads are a compounded interest calculation applied to ongoing cash expenditures on a monthly basis.

Fixed overheads are defined as cost items linearly proportioned to the size of the project, and therefore are only a fixed percentage of base plant cost. The percentage can change slightly based on project setup and site or specific variables, but in general are a fixed percentage of monthly costs through the entire project, and include items such as administrative support, construction management, contingency, freight, project management, sales tax and other items.

Variable overheads are not a fixed percentage of monthly costs, but rather calculated from the total amount of money spent at any given time during the course of a project. The two major factors are inflationary escalation and Interest During Construction, or IDC. Inflation effects, or escalation, can significantly affect expenses in the second half of a long term project. Inflation was estimated at 3%, compounded yearly.

Interest During Construction is the cost to borrow money to build the facility. IDC begins at the start of construction and continues to be charged against construction until commercial operation, at which time long term financing is put in place. At the end of a major development project IDC can be more than \$100,000 per day, showing the true value of unscheduled critical path events. IDC was estimated at 6% for this comparison.

## Analysis

The total construction estimate is summarized in the following table. Approximately \$19.7 million is potentially saved when utilizing the Bussed approach, a 39.4% total reduction in considered costs.

<b>Item</b>	<b>Traditional</b>	<b>Bussed</b>	<b>Total Delta</b>	<b>Percent</b>
System Selection	\$ 459,000	\$ 157,600	\$ 301,400	-65.7%
Engineering	5,353,538	1,851,683	3,501,854	-65.4%
Construction	10,402,980	6,775,638	3,627,341	-34.9%
Startup	834,424	408,533	425,891	-51.0%
Subtotals	17,049,942	9,193,455	7,856,487	-46.1%
Overheads	33,068,487	21,184,242	11,884,245	-35.9%
<b>Totals</b>	<b>\$ 50,118,428</b>	<b>\$ 30,377,697</b>	<b>\$ 19,740,732</b>	<b>-39.4%</b>

The following metrics were developed from costs estimated. Regional construction costs and project specific requirements may have a significant impact on the financial results.

<b>Metric</b>	<b>Traditional</b>	<b>Bussed</b>	<b>Amount</b>
Total Cost	\$ 50.1 M*	\$ 30.4 M	(\$19.7M)
% of Total Plant Cost	5.97%	3.62%	-2.35%
Construction Cost per Point	\$ 5,301	\$ 3,213	(\$ 2,088)

\* (M) = Million

### **Observations**

Use of the PEpC selection process will result in a much earlier entry for parts of the project engineering team, requiring procedural changes to the initial project cycle stages. A strong owner presence and a diligent supplier presence may be required to assist other development process stakeholders to utilize the Bussed approach.

Implementation of the Bussed concept as specified in this report may be affected by other disciplines, suppliers, and entities within the development process. Specifically, development areas with larger investments in equipment scope, tighter schedule deadlines or different contract requirements could change the results outcome. Construction accounting methods and internal owner practices may also have a significant effect on bussed/PEpC project outcomes.

### **O&M Savings**

Use of the Bussed approach can reduce O&M staff due to high levels of automation and ease of troubleshooting. Asset management software can assist in monitoring the health of smart devices, helping prevent forced outages and increasing plant efficiency due to high performance of well-maintained field elements. The ease in which field problems can be identified and corrected not only reduces plant startup time, but shortens typical operations failures as well. Use of predictive maintenance software packages can lead to scheduled “failures” saving time and avoiding costly forced outages. Hardwired field logic is avoided, simplifying troubleshooting and reducing maintenance personnel. At the same time, highly trained technicians proficient at database manipulation and complex computer logic will be required. In a Traditional plant, electricians and instrument repair departments segregate work by skill, creating defined separation between physical and logical work. In a Bussed plant, fewer, highly skilled technicians can care for the plant, saving money by using fewer field personnel for simpler work.

### **Conclusion**

The Bussed implementation concept as specified in this report resulted in nearly \$20 million in selection, engineering, construction, startup, and overheads savings for a typical utility development project. Additionally, plant staffing and forced outage rates may be reduced while plant efficiency is increased. The combination of a bussed system installed using the PEpC

process can benefit the development and construction process by eliminating scope and reducing schedules and budgets. The life cycle of a facility can be improved through use of additional information at all levels of the plant operation, resulting in higher value products for owners and operators.

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