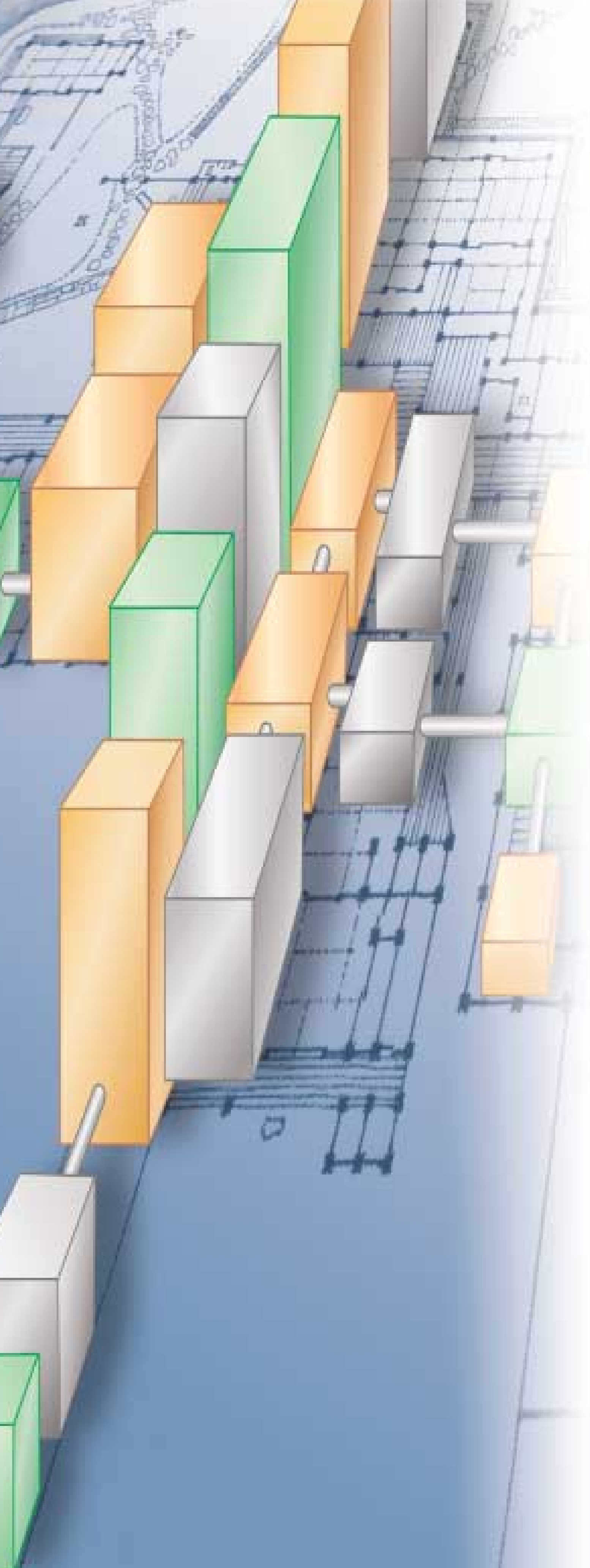

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Power Plant Design

Taking Full Advantage of Modularization

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Modular power plants offer a quicker, cheaper path for new generation.

With the advent of higher gas and oil prices, solid fuel is making a comeback. Solid fuel plants must overcome several obstacles, however, including higher capital costs, longer construction periods and higher emissions. While emissions control technology is sufficiently well advanced that permitting should not be constrained, the longer construction periods and associated higher capital costs still need to be addressed. Modular design represents one promising approach. The concept of modularizing pulverized coal-fired and fluidized-bed power plants has been around since the mid-1980s, but the use of modular or skid designs has not been fully exploited. By maximizing the use of modular design and construction, significant cost and schedule savings can be realized. This article will discuss modular plant design and how it differs from conventional stick-built design, including cost and project schedules. Modularization in this article refers to the use of shop assemblies, sub-assemblies and full-scale modular packages.

For the sake of comparing modular and stick-built power facilities, a 300 MW net size installation has been selected. The reason for this size selection is that the fluidized-bed boiler manufacturers are comfortable with this size for a single-unit design. Larger solid fuel plants are possible, of course, but a single-unit case is the objective of this analysis. The two plants are coal-fired installations, one a pulverized coal-fired facility and the other a circulating fluidized-bed boiler plant. Both plants are designed to meet all environmental requirements while burning a subbituminous coal. The pulverized coal plant will employ a dry scrubber, while the fluidized-bed plant will use limestone in the combustor for sulfur capture. NO_x control for both cases will be accomplished by a selective noncatalytic reduction (SNCR) system.

Modular Plant Design

Modular plant designs (Figure 1) are very unique compared to stick-built facilities in that the amount of property required for a modular design is approximately one-third more than for a stick-built design. By removing the verticality from the conventional plant, congestion during construction is significantly minimized. The total modular design also relies extensively on modular fabrication at off-site facilities, where labor is generally two-thirds less costly than field labor and quality can be controlled more accurately.

The most significant difference between backbone modular and conventional plant designs is in the full use of modular or skid-mounted mechanical and electrical equipment. The design involves locating nearly all equipment modules at grade, and connecting them to a common "backbone" pipe rack that runs the length of the plant. The modular components include major mechanical and electrical equipment as well as minor equipment of different systems grouped together, i.e., control rooms, HVAC, etc.

All major equipment skids are sub-assembled in offsite fabrication facilities and shipped to the site for placement along the backbone. Even large items such as the steam generator can be broken down into subassemblies and shipped to the site in large modular pieces. In the case of a PC boiler, subassemblies could include entire low-NO_x burner fronts completely assembled with all piping, electrical and instrumentation complete and routed to a single interface point.

The selected turbine-generator has a guaranteed nameplate rating at the generator outlet of 325 MW, with a net plant rating of approximately 300 MW. The turbine-generator has been lowered from the conventional 40 foot elevation to approximately the 25 foot elevation. This allows the entire turbine bay structure height to be reduced. Further, instead of using a typical turbine pedestal approach, the modular design uses a steel pedestal much lower to grade and a side exhaust with complete condenser in two pieces. The turbine deck or operating floor and the mezzanine floor have been eliminated.

Another change is that the deaerator has been moved to a lower elevation to eliminate the typical enclosure on top of the turbine building. While this arrangement requires the addition of a booster pump to the feedwater system, it is considered to be more economical. The extra operating costs associated with the booster pump are less than the additional annualized structural costs associated with positioning the deaerator at a higher elevation. High and low pressure feedwater heaters are modularized and vertically stacked in a conventional cascading formation and will sit very close to the turbine-generator and backbone pipe rack to interface with their connecting systems.

The circulating water is cooled in an evaporative eight-cell mechanical draft-cooling tower, which is modularized and constructed from aluminum and fiberglass, with synthetic fill. The overall plant water balance is based on a conservative zero discharge station design.

The flue gas exiting from the steam generator passes through a dry SO_2 removal system for the PC case, while SO_2 removal for the fluidized-bed case is accomplished via the limestone bed. The dry scrubber is modularized in several sections, including the inlet and outlet ducts, the spray dryer assembly, and the vessel assemblies for each parallel system. The flue gas finally passes through either one or two modular baghouses and clean gas is extracted via two induced draft fans, where it exits up the chimney. The baghouse modules are fabricated into modular compartments with pulse jet headers, controls, hoppers/hopper heaters and ash discharge valves attached.

Feedwater heater skid for modular plant design.

Much of the materials handling systems and equipment is amenable to modularization because of its repetitive, consistent design. Fuel for the boiler is delivered to the site by rail car and is unloaded in a continuous car dumper. Coal is moved automatically by belt to concrete live storage silos with an alternate route to inactive or dead storage. Mobile equipment is used to reclaim coal from inactive storage. For the most part, all coal handling and conveying equipment is modularized into individual structural cages that include rollers, idlers, emergency trip switches, and electrical and instrumentation hardware. The conveying equipment will be shipped in 60 to 80 foot lengths, depending on site and local conditions.

The lime reagent or limestone for the SO_2 collection processes is delivered either by truck or rail cars, unloaded into a transfer tank, and then conveyed to lime/limestone storage silos by a pneumatic transport system. All lime/limestone equipment – blowers, silos, feeders – is skid-mounted, while transfer lines or conveyors are modularized in shippable lengths.

Bottom ash from the economizer section of the boiler and ash from the fabric filters is collected and conveyed to holding silos, from which it is transported to an off-site disposal area. The bottom ash conveyor and ash conveying systems are completely modularized, delivered on-site with blowers/vacuum pumps, valves, motors and instrumentation pre-installed.

The plant water/wastewater treatment systems, including fire water, are all modularized onto skids complete with piping, structural, valving, electrical, and instrumentation and controls. The water treatment system (demineralizer system) is fabricated into four modules (regeneration/degasifier, anion, cation, polisher) that will plug directly into the backbone pipe rack, which in turn feeds the boiler make-up system.

The major advantage of modularizing the control and instrumentation for equipment comes from moving the instrument modules out of the field. Time and cost savings are achieved by shipping split assemblies of control panels; pre-wiring from control panel to direct digital controller, printers, relay and recorder board, logic cabinets, and data logger; installing in-line instruments and sensors on the modules; and pre-wiring to instruments from the DDC.

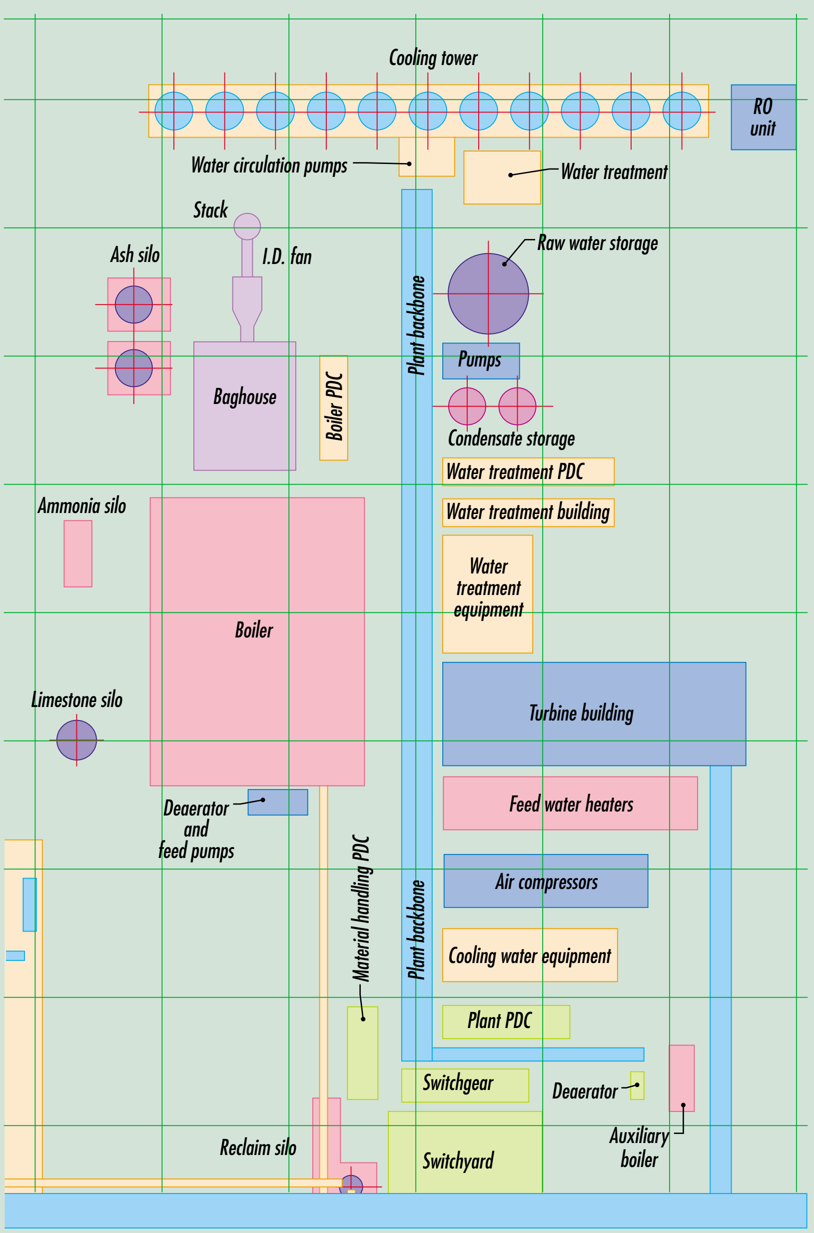
The electrical switchgear, motor control centers and power distribution centers are skid-mounted into modules to support the systems that each electrical system supplies. For example, the power distribution center for the ash handling system is located near the ash handling equipment itself and is fed from a main switchgear center close to the main auxiliary transformer. Even though the main power distribution center is in two modules instead of one, this approach results in a net loss in wiring because of the close proximity between the equipment and the power distribution center.

Warehouse, administration building, machine shop and electrical shop space has been removed from the power building block. Space for these functions can be more economically provided in a separate structure.

The same building codes and design load criteria apply for the backbone design. The main difference is that the structure for the main power block and individual modules is much different as a result of the unique layout.

Shop assembly of the critical piping module provides better access for the heat

FIGURE 1
MODULAR PLANT LAYOUT (300 MW FLUIDIZED BED DESIGN)



treatment and radiographic inspection of main steam and hot and cold reheat piping welds. This permits better quality control for assembly of critical piping since field welding and inspection will be reduced. The piping engineering and design involved with this type of plant consists of assembling spool pieces on appropriate modules at a central facility and then shipping the modules to the plant site for erection.

Foundations will be similar for both cases, i.e., spread footings, mats or pile and caisson supports if required. The building column foundations will be smaller due to the smaller building profile and lighter loads. The floor slab may require additional thickening due to the numerous floor mounted pipe supports, movement during installation of the skid mounted equipment modules, and the profusion of equipment on the grade slab.

The plant design has not compromised the good engineering practices of generous equipment laydown and maintenance areas throughout the facility. This includes pull areas for heat exchanger tubes, pumps, compressors and electrical equipment.

Ease of equipment maintenance is also enhanced by this approach since significantly fewer pipes need be routed around equipment, thereby increasing available access area to any particular component.

SCHEDULE

As depicted in the schedule shown in Figure 2, a modularized power plant from the start of engineering and design through completion of plant start-up will require 34 months for completion. This is compared to a standard stick-built power plant that would require 43 months for completion, or a savings of nine months in the total project duration. The bulk of the time savings comes from three significant items:

- *Use of pre-fabricated and pre-tested modules that only require installation and final piping and electrical hookup.*
- *Reduced amount of field labor associated with assembly and construction.*
- *Reduced time required for plant start-up since the modules will have been shop-tested prior to shipment.*
- *The modular assembly approach displaces 40 percent of the stick-built field manhours, which can be expended more efficiently in a shop environment than in the field.*

The engineering schedule will be different for the backbone case. The main power block is fairly independent of the equipment details, and design may proceed after initial size requirements are established. Module designs may proceed after initial size requirements are established. The pipe rack modules may be designed as general design, prior to final print layouts, thereby shortening the structural design schedule. In addition, the logistics effort for setting modules into the building will be minimized. The backend facility design will be similar to the conventional case.

The construction schedule for the main power block in the modular design approach will also be different from that of the conventional case. Underground utilities will either be in standard trenches and ducts or will be run overhead on racks. The building foundations and buildings are smaller than in conventional designs and can be installed at an early date. The module mat foundations can be oversized and poured, enabling the concrete foundation contractor to leave the site early. Modules can then be supplied and installed on their own completion schedule.

FIGURE 2
SCHEDULE COMPARISON: STICK-BUILT VS. MODULAR (PC OR CFB)

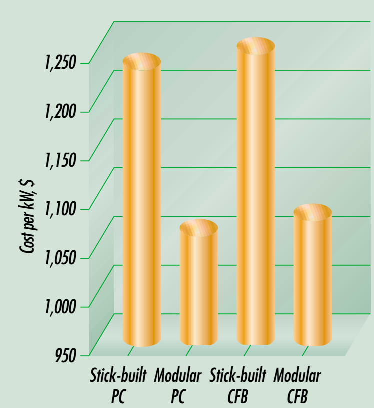
Stick-built 300 MW plant

Task	Duration	Start	Finish
Process equipment procurement	390 days	Monday 4/30/01	Friday 10/25/02
Plant design	390 days	Monday 4/30/01	Friday 10/25/02
Plant material procurement	400 days	Monday 11/12/01	Friday 5/23/03
Plant construction	550 days	Friday 1/18/02	Friday 2/27/04
Plant checkout and startup	280 days	Monday 11/10/03	Friday 12/3/04

Modular 300 MW plant

Task	Duration	Start	Finish
Process equipment procurement	345 days	Monday 4/30/01	Friday 8/23/02
Plant design	390 days	Monday 4/30/01	Friday 10/25/02
Plant material procurement	400 days	Monday 11/12/01	Friday 5/23/03
Plant construction	400 days	Friday 3/29/02	Friday 10/10/03
Plant checkout and startup	180 days	Monday 7/7/03	Friday 3/12/04

FIGURE 3
CAPITAL COSTS FOR STICK-BUILT AND MODULAR PLANT DESIGNS



Cost

Current cost estimates for a stick-built solid fuel-fired facility are in the range of $1,250-$1,360/kW, while the modular plant costs are in the range of $1,080-$1,190/kW (Figure 3). Specific cost savings for a modularized power plant over a stick-built power plant come in a number of areas:

- *The total labor cost savings for a modularized plant are driven by the displaced stick-built field hours, at an improved efficiency of 15 percent and a bare wage rate at 20 percent less than the field labor rate. The resulting labor savings are in the range of $15-20 million.*
- *Equipment rental, small tools, expendable supplies and temporary facilities for the stick-built portion of the plant are significantly reduced due to the lower amount of field labor expended and the shorter overall duration in the field for both direct construction and plant start-up. These savings amount to $5-8 million.*

Water treatment skid for modular plant design.

- *The construction staff cost savings, which are due to the overall shorter duration in the field for construction and plant start-up, are in the range of $2.5-4 million.*
- *The two offsets to the above savings are increased home office and engineering costs due to the modular design, and increased structural costs for the modules and modular logistics and transportation costs. The increased costs are in the $1.5-2.5 million range.*
- *Other savings associated with modularization of the piping, electrical, buildings and structures equate to $23-28 million.*

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