

ELECTRICAL EQUIPMENT CENTERS

INSTALLATION ECONOMICS

Abstract

The concept of pre-assembling power distribution and control into a shipable enclosure was first introduced in the mid-50's. The concept has experienced a great acceleration in popularity in the last few years. Equipment Centers, also known as Power Houses, Power Control Assembly (PCA), Power Distribution Center (PDC), Power Control Room (PCR), Packaged Power Center (PPC), etc. This method of delivering power distribution to the job site has been recognized for some time as an excellent method of helping control construction project costs. More widely recognized in the past for cost control of overseas projects, EC's are gaining popularity domestically for some of the same reasons that created their demand overseas and perhaps a few more.

The purpose of this paper is to examine the reasons for the growth of this concept. The economics of on-site construction versus the use of the packaged Equipment Center concept is to be compared.

Equipment Center Definition

For some of the same reasons that mobile homes meet a need in the housing market, power control assemblies fill a need in the industrial/petrochemical market. The equipment center is also as complete inside and out as can be delivered complete to the jobsite. The mobile home comes complete with kitchen, plumbing, lighting, heating and air conditioning, etc. Similarly, an EC is complete with switchgear (primarily low and medium voltage) installed and interconnected to low or medium voltage motor control centers, programmable control, process instrumentation, etc., The internal environment may be controlled by ventilation or pressurization fans, heaters and air conditioners. The external atmosphere may be filtered out with a variety of filters such as sand or chemical filters. Accessories such as annunciators, batteries and chargers, panel boards, transformers, Busway, Halon or other fire protection systems, are interconnectable to the greatest extent practical within the equipment center..

Beyond the mobility, and completeness within, the comparison to mobile homes ends. Most industrial applications require a construction that is much more rugged, fire resistant and permanent than the 2"x2" wood frame of a mobile home. In general steel construction is offered by the various companies that build Equipment Center structures.

Most produce an all steel welded base structurally designed to provide support for lifting the completed assembly onto a tractor trailer for transport to the job site in as few shipping pieces as is practical. Single shipping sections are, in general, limited to 50' L x 14' W x 12' H and weights to about 80,000 pounds. The base usually has 3/16" or 1/4" plate steel for a walkway surface. The load on this walkway surface may be as concentrated as an 800 lb. medium voltage circuit breaker with its weight distributed onto four rollers, each with a small bearing surface. Adequate structural support is essential.

The exterior walls and roof are primarily steel, as light as 18 gauge (.0478") or as heavy as 3/16" plate, most offer a double wall sandwich construction with inner walls and ceiling of 18 or 16 gauge steel. Insulation within the floor, walls and ceiling cavity is usually included. The insulation material can range from a relatively low R-value fiberglass to the maximum R-value polyurethane. An enclosure may be required to withstand winds to over 120 mph; snow loads vary from no snow to over 100 lbs./square foot. The jobsite may be a seismic zone 4 area. It may range from the tropics to a desert area to the North Slope, unlike mobile home construction, the equipment center can be designed to meet the requirements of the client and jobsite conditions.

An equipment center is specifically designed for the equipment that it is to enclose, as well as the jobsite where it is to be installed. Removable conduit plates are provided where needed, coordinated to the equipment and the floor structural members. An equipment center can be mounted on the type of foundation that suits the customer's needs. It can be installed on a flat concrete slab, on piers up off the ground, or on top of a basement foundation, forming a cable entrance vault.

EQUIPMENT CENTER PURCHASE AND ERECTION PROCESS

When the need for additional modernized power, control or instrumentation arises, an engineering team is chosen to design and supervise the project. This happens whether an equipment center is used or a building is erected at the jobsite. First, the mechanical/electrical requirements are determined, thus determining: (a) what equipment is to be enclosed, (b) whether the equipment is enclosed in an equipment center or erected on-site in a block building. In either case the layout and cost of the equipment are similar.

The differences come from the following factors:

1. The cost / number of hours of the purchasers :
 - a.) Engineering
 - b.) Purchasing
 - c.) Expediting and scheduling
2. Method of future extensions.
3. Handling of necessary rear access to switchgear
4. Requirements of conduit entrance.
5. Foundation floor considerations.
6. The number of different union crafts, onsite supervision, bonding and insurance.
7. Equipment receipt and storage control.
8. Coordination of busway, equipment transformers, annunciators, relay panels, battery systems, etc.
9. Equipment mounting, leveling, bus splicing.
10. Interconnection/interwiring.
11. Jobsite traffic flow.
12. Weather delays.
13. System testing.
14. Planned payment.
15. Building permits, inspections.
16. Depreciation.
17. Jobsite delays due to late equipment arrival.

What are the differences economically between construction utilizing an equipment center versus on-site construction? The starting point is, what electrical equipment is to be enclosed, i.e., what voltage, current and interrupting ratings are required? What motor starters and programmable control are required? After this, a very rough equipment layout is developed to determine an approximate amount of land necessary. These primarily engineering decisions have to be made with either type of construction. Cost, scheduling and installation are the central differences. The following is a step-by-step comparison:

Differences will be broken down into two categories and will be redundantly labeled "Onsite" and "EC".

1. Purchaser's Engineering Participation (Pre-bid)
 - A. Onsite and EC
The electrical engineering department lays out electrical requirements in detail.
A specification is tailored to fit the need .

B. Onsite

An approximate equipment layout is made, maximum space to be covered by the equipment is defined. Vendors are contacted for literature. Due to diversity in vendor design respecting conduit entrances, breaker removal and required clearances, necessary dimensions are too elusive for design purposes. At this point, building design must be delayed pending choice of vendors and equipment drawings received.

C. EC

An equipment center specification, a preferred equipment layout sketch and maximum site space available, or building size limitations are delivered to the vendor. The EC vendor is then responsible for meeting NEC, local and other applicable code requirements, proper aisle and breaker handling space. If an end breaker compartment door requires a 1200 or more opening for breaker removal the vendor is aware of the requirement, hence oversights due to unfamiliarity are reduced.

2. Purchaser's Purchasing Participation

A. Onsite

Bids are requested for electrical equipment. The building design is still holding pending equipment selection and drawings. Bids must be received from sources dealing with numerous items of equipment such as switchgear, bus duct, annunciators, battery systems, and even light fixtures.

B. EC

Bids are requested for the equipment center, complete with equipment fastened to the floor; equipment shipping splits are connected; all internal wiring complete; busway connected to the equipment and coordinated with external transformer busway. The key is "complete".

C. Onsite

Few items are likely to share the same purchase order, some items may have to wait for information from one selected vendor before final selection. Such an item may be final sizing of a control battery system pending breaker tripping and closing power requirements. The amount of coordination between engineering and purchasing is a factor in the cost of such a project.

D. EC

A single purchase order is written for a complete package; building and internal equipment. The complete package is purchased except site work, foundation, conduit and cable connection to remote equipment.

3. Purchaser's Post-bid Engineering Participation

A. Onsite

Final building design is dependent on receipt of electrical equipment drawings. These drawings usually arrive four (4) to twelve (12) weeks from receipt of purchase order.

B. EC

The purchaser normally assigns an engineer and an assistant engineer, part time, to oversee technical aspects of the project.

C. Onsite

Electrical together with architectural or structural engineering study approved equipment drawings and brochures. Electrical prepares a layout, for final building design, with clear space requirements that meet applicable codes and allows for proper removal, servicing and replacement of parts, often handling of breakers requires greater aisle space than that which is necessary to meet codes. The engineering team must be aware of: door swing to breaker removal relationships, rear access and fire escape regulations. The foregoing factors are influenced by vendor choice.

EC

Approximately six (6) to eight (8) weeks after a purchase order is issued, all equipment outlines and arrangement drawings are ready for an engineering review and acceptance.

C. Onsite

With completed electrical layout, the final building design is ready to be finalized. In an air conditioned building block walls are normally furred with studs, insulation and drywall. This produces an eight (8) to twelve (12) inch wall thickness resulting in a twelve (12) to eighteen (18) inch overall increase in both length and width. It is often necessary to increase the size of the building to allow rear aisle space, an aisle behind the equipment also requires fire egress at both ends of the equipment.

EC

An equipment center vendor's arrangement drawings are submitted to the purchaser's electrical and structural departments for foundation design. Wall thickness is normally two (2) to three (3) inches. Rear access to electrical equipment lineups is achieved with panels bolted directly to the equipment or doors mounted behind the lineup. Enclosed space is thereby reduced.

D. Onsite

Future expansion must be considered. When future expansion is planned, the following points are applicable: future conduits should be stubbed in; they are difficult to add under a concrete slab. Building demolition and addition construction are dirty, awkward to handle under pressurization requirements and subject to weather conditions.

EC

Complete end walls are often designed for removal by unbolting and lifting off. A mating section, containing future equipment, is then moved into place and attached to the existing structure. This procedure often is accomplished in a matter of hours, minimizing interruption of service and providing early start-up of new processes.

E. Onsite

Conduit and cable entry through the house exterior is a key consideration. Basically, entry is only possible through a floor, wall or roof. Floor access, once cast in concrete, becomes somewhat inflexible, resisting change or addition. Wall entry is unsightly but functional and relatively simple. It is common that electrical equipment is most easily accessed through the top or bottom, therefore, simply getting through the wall does not completely solve the problem. Roof access is also easy to penetrate but difficult to seal from moisture, an enemy to electrical equipment and should generally be avoided.

EC

A metal building particularly one on a raised foundation or piers, becomes readily accessible through the bottom, Wall penetrations are much the same as in conventional construction. Roof entry, while still not desirable, is accomplished with sealing hubs or welded bushings.

F. Onsite

Foundations are prepared with substantial footings to support walls and roof. A concrete slab floor may be poured on compacted fill for equipment surface.

EC

The self-supporting base structure may be secured to piles, piers, curb, a foundation or a slab. An equipment center can be set on top of existing structures or platforms including offshore locations-

G. Onsite

Weather and geographic conditions are always serious considerations in building design. Conventional construction designers are accustomed to beefing up for snow and wind load factors. Most designers agree that concrete block is

not the ideal building material for resisting high winds and moderate to heavy seismic activity, under these conditions, a standard roof becomes dead weight and exerts strain on the walls where it is attached.

EC

The above conditions are met in EC design and construction quite readily with only minor modifications. Stringent snow, wind and seismic conditions are usually met with very small increases in the cost of the structure to compensate for additional steel members, fasteners or weldments. Fully welded structures are able to meet these requirements with relative ease.

4. Purchasing Participation

A. Onsite

A completed building design, when received, is distributed for bids to general contractors, who, in turn, take bids and select concrete trades, masons, carpenters, electricians, heavy equipment operators and on and on. Contractors are selected.

EC

Quotes are received for foundation, site and electrical work. Because fewer contracts are required, few contractors are selected.

B. Onsite

Purchase orders are issued; supervision is selected, usually in the form of an engineering project manager, a general contractor, or both. From this point on, coordination, weather and labor coverage such as bonding and insurance for each craft increases this work load.

EC

Purchase orders are placed with those involved. Work is scheduled to coincide with the arrival of the equipment center. Due to the decreased number of trades involved, the coordination effort should be less burdensome.

5. Erection

A. Onsite and EC

Both types of construction share in fundamental preparations, site work and preliminary electrical work. Concrete work, however, becomes decidedly less involved in equipment center construction unless it is placed on a basement type foundation.

B. Onsite

With foundations, floors and electrical conduits in place, walls are ready to be erected. It becomes a matter of preference here as to whether it is best to set the electrical equipment before or after wall construction. In either case, it is preferable to set this equipment prior to roof construction for ease of handling. A crane is preferred for equipment handling.

EC

The equipment center can be coordinated to arrive at the completion of the foundation. A crane is used to lift the EC from the truck to the foundation. The base is then welded or bolted to the foundation. This process is estimated to take half day or less.

C. Onsite

Materials are constantly received and stored in the process of normal construction. This factor increases problems with traffic, storage, breakage, vandalism and theft.

EC

All the above are either reduced or eliminated.

D. Onsite

With equipment set and the walls erected, the roof may be built; interior framing, wiring, insulation, drywall and painting may proceed. During this process, it is desirable to keep the equipment covered so as to avoid damage to components and keep out construction dust and debris.

EC

Cables and interconnecting wires to remote equipment may be pulled and terminated. Bus splices may be completed and the EC is ready to be commissioned to service.

A comparison of on-site concrete block construction vs. Equipment Center construction was run through the estimating process with the following results:

	Man Hours	
	<u>Onsite</u>	<u>EC</u>
<u>Preliminary Engineering</u>		
Single line diagrams	180	180
Equipment arrangement	120	120
Power Control equipment layout	<u>80</u>	<u>80</u>
Subtotal	380	380

	Man Hours	
	<u>Onsite</u>	<u>EC</u>
<u>Specifications</u>		
Pre-fab buildings	--	80
Switchgear	40	120
MCC	40	40
Battery and battery charger	40	40
HVAC	80	80
Drywall construction	40	--
Concrete masonry units	40	--
Built-up roofing	40	--
Metal doors and frames	40	--
Suspended ceiling	40	--
Flooring	40	--
Painting	40	--
*Concrete foundations	40	40
*Steel structures	<u>40</u>	<u>--</u>
Subtotal	560	320

*If project includes other foundation and steel work, the same specs can be utilized.

	Man Hours	
	<u>Onsite</u>	<u>EC</u>
<u>Final Engineering</u>		
A. Review vendor prints (equip.)	120	120
Design equipment layout	120	---
Review equipment layout	---	40
Design lighting & grounding	80	---
Review lighting & grounding	---	20
Design HVAC system (ducting)	120	---
Review HVAC system	<u>---</u>	<u>20</u>
Subtotal	440	200
B. Design building & foundations		
Foundations	80	80
Architectural floor plan, roof plan & exterior elevations	150	---
Architectural sections and ceiling plan	120	---

Architectural & structural details		<u>120</u>	<u>---</u>
	Subtotal	470	80
			Man Hours
<u>Erection at Jobsite</u>		<u>Onsite</u>	<u>EC</u>
Foundations		280	150
Building		770	80
Lighting & ground System		200	---
Switchgear		385	---
Motor Control Center		50	---
Battery & Charger		100	---
HVAC & Ducting		520	---
Annunciator Panel		20	---
Bus duct, interior		60	60
Bus duct, exterior		60	---
Conduits		70	---
Termination of internal wiring		40	---
Start-up and testing		<u>80</u>	<u>40</u>
	Subtotal	2635	330
<u>Purchasing</u>			
P.O. Switchgear		80	---
P.O. Motor Control Center		80	---
P.O. Battery and Charger		40	---
P.O. Annunciator		40	---
P.O. Bus Duct		40	---
P.O. HVAC		80	---
P.O. Lighting & Ground Material		60	---
P.O. EC Complete		<u>---</u>	<u>160</u>
	Subtotal	420	160
	Total Labor Hours	4905	1470
	@ \$30 per man-hour	\$147,150.00	\$44,100.00
			Costs
<u>Materials</u>		<u>Onsite</u>	<u>EC</u>
Foundation		\$ 3,200	\$ 1,000
Building		20,000	510,000
Lighting & grounding		5,000	(included)
Switchgear		400,000	(included)
MCC		10,000	(included)
Battery and charger		6,500	(included)
HVAC and ducting		20,000	(included)
Annunciator panel		4,000	(included)
Bus duct, indoor		10,000	(included)
Bus duct, exterior		10,000	(included)
Conduit		3,300	(included)
Termination and internal wiring		<u>6,500</u>	<u>(included)</u>
	Material Total	\$498,500	\$511,000
	Labor Total	<u>147,150</u>	<u>44,100</u>
	Difference in Cost: <u>\$90,550</u>	\$645,650	\$555,100

There are many factors that influence the above tabulations. Some clarifications should be noted:

- 1) This comparison is made for an actual project under construction in California during this writing.

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- 2) The above direct cost estimate is based on industry average costs. Excluded are indirect costs for: temporary storage, construction management, field supervision, crane and other equipment fees, the costs of project overhead and profits. These costs actually weight project expense in favor of the equipment center concept.
 - 3) The switchgear for this project is rather complex and somewhat more expensive than normal and in this case, the cost of the switchgear alone tends to overshadow the cost of either structure.

This breakdown of the project cost indicates that construction costs 16.3% more than the equipment center. If the switchgear price of \$400,000 is deducted from both columns, we see a more dramatic increase of 58% over the equipment center. The truth is that, depending on the project, the difference will lie between 16% and 58%, normally estimated at around 30%.

When equipment is purchased or a building is constructed, a deduction is allowed by the government to determine taxable income in the form of a depreciation allowance. The nature of the investment determines the rate at which the depreciation allowance is calculated; i.e., equipment, such as electrical switchgear would be amortized over a five (5) year life. If this equipment is housed in a concrete block building, the building would be depreciated over a fifteen (15) year period. The rate of depreciation for the portion of the investment allocated to the building is taken from the following table:

**ACRS Cost-Recovery Percentages for
Real Estate Except Low-Income Housing**

The applicable percentage is (use the column representing the month in the first year the property is placed in service):

If the Recovery Year Is:	1	2	3	4	5	6	7	8	9	10	11	12
1	12	11	10	9	8	7	6	5	4	3	2	1
2	10	10	11	11	11	11	11	11	11	11	11	12
3	9	9	9	9	10	10	10	10	10	10	10	10
4	8	8	8	8	8	8	9	9	9	9	9	9
5	7	7	7	7	7	7	8	8	8	8	8	8
6	6	6	6	6	7	7	7	7	7	7	7	7
7	6	6	6	6	6	6	6	6	6	6	6	6
8	6	6	6	6	6	6	6	6	6	6	6	6
9	6	6	6	6	5	6	5	5	5	6	6	6
10	5	6	5	6	5	5	5	5	5	5	6	5
11	5	5	5	5	5	5	5	5	5	5	5	5
12	5	5	5	5	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5	5	5	5	5
14	5	5	5	5	5	5	5	5	5	5	5	5
15	5	5	5	5	5	5	5	5	5	5	5	5
16	--	--	1	1	2	2	3	3	4	4	4	5

Assuming a company is in a 50% tax bracket, as companies with profits above \$100,000 are, the government will, in essence, pay one half the cost of the equipment over a five year life and the building over a fifteen year period. If the investment is made in the fourth month, the percentage of depreciation allowed on the building the first year is 9%, 11%, the second year, 9% the third year then 8%, 7%, 6%, etc.₂

Should a company buy similar equipment at \$400,000 in a \$100,000 enclosure that is capable of being disconnected, picked up and moved, such as a EC, the total enclosure is considered equipment and is personal property, therefore, is eligible to be depreciated on a five year schedule at the rate of 15% the first year, 22% the second year and 21% the three final years. A five year payback on an investment has many economic advantages over a fifteen year payback.₂

Perhaps the most significant advantage springs from another government phenomenon. The investment in equipment qualifies for a 10% investment credit. Therefore, the total EC investment, less foundation cost, qualifies for the credit. Using the preceding example, a \$554,100.00 (the cost of the EC less the cost of a foundation) investment nets the purchaser a \$55,410.00 savings on the EC compared to a \$42,250.00 investment credit for the same equipment in the block building, an additional \$13,160.00 savings. Bringing the total project percentage difference to 18.7% in favor of the EC.²

Other Considerations:

1. Onsite

Expediting - With any single order, a certain amount of expediting must be allowed for. With onsite construction, expediting or job following funds must be allocated for each different brand of electrical equipment involved; annunciators, batter/charger manufacturers, foundation companies, masons, electricians, carpenters, roofers and crane operators.

EC

Expediting may be simplified to a single local EC supplier contact, foundation company and an electrical contractor.

2. Onsite

Jobsite traffic is considerably increased during construction, with the building trades that are involved, not to mention the steady stream of material suppliers. An increase in traffic may have direct relationship to safety and security.

EC

The traffic is significantly reduced, primarily due to fewer trades involved and shorter construction time.

3. Onsite

Delays due to weather are so unpredictable that there is little need to belabor it except to note that water damage to indoor switchgear normally voids all warranties.

EC

The effect of weather on EC construction is seldom significant.

4. Onsite

System testing must be completely carried out at the end of the job. The main difference is the degree of testing. All interconnections within the building and those externally should be tested.

EC

System testing of the interconnected electrical equipment can be accomplished at the EC factory, prior to shipment, away from the confusion of the jobsite. Although it is usually recommended that a final onsite series of thorough system checks be performed, many jobsite problems are prevented by this factory test.

5. Onsite

Payments for invoices submitted are high numbers. Each individual contractor and vendor submits invoices throughout the project. Equipment may have to be paid for long before it is usable.

EC

Payments can be planned from the beginning. A payment is necessary for the foundation work, conduit work, the EC with its related exterior busway and transformers, the crane placement work, and then the final electrical connection work. The invoices are reduced in number and are anticipated.

6. Onsite

Standard building permits and inspections are required.

EC

In many localities, an equipment center is similar to an outdoor switchgear enclosure requiring no local building inspection.

Conclusion:

There are many economic advantages that are measurable in terms of dollars and taxes saved when using an equipment center rather than conventional construction. There are secondary savings in time and freedom from disruption due to construction scheduling, that are not as simple to determine. These more elusive costs are often worth more to a project than the preliminary, more obvious, savings.

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