UTILITIES & ENERGY SERVICES
TEXAS A&M UNIVERSITY

Design Standard

Capacitor Bank

Detailed specifications follow.

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Assemblies of outdoor metal-enclosed capacitor bank including:
   1. Foundations.
   2. Receiving, unloading, and storage.
   3. Final placement.
   4. Exterior cable connections.

1.02 INFORMATIONAL SUBMITTALS.

A. Quality assurance data:
   1. Ratings of switching device calculations showing need for reactors and size.
   2. Certified test reports of ground switch.
   3. Capacitor unit tank rupture curve.
   4. Capacitor unit watt losses performance data.
   5. Certified copies of test data and reports.
   6. Calculations for neutral voltage shift from ground or current flow for unbalance protection relay coordination.
   7. Calculations of peak in-rush, RMS inrush current and inrush frequency and duration.
   8. Calculations verifying need for inrush current limiting reactors, and that rating selected is sufficient to protect capacitor unit fuses and switching devices.
   9. Time-current fuse curves for fuses provided, including manufacturer and model numbers.

1.03 ACTION SUBMITTALS.

A. Product Data: Component material lists.

B. Shop Drawings:
   1. Certified complete and accurate Data Sheets.
   2. Certified outline and general arrangement drawing including dimensions, weight, and shipping sections.
   3. Floor plan drawing showing locations for anchor bolts and leveling channels.

4. Elementary diagrams including 3-line diagrams of potential and current secondary circuits showing device terminal numbers and internal diagrams.
5. Schematic control diagrams.
6. Complete wiring diagrams showing connections of component devices and equipment.
7. Interconnection diagrams shall include control cable numbers.
8. Maximum load ampacity requirements for external 120 volt ac control power source.
9. Clear indication of logic state (de-energized vs. energized state with description of each) for all contact signals sent to external controller.
10. Manufacturer recommendations for protection and control of capacitor banks, including (but not limited to):
    a. Recommended alarm or trip setpoints and time delays (i.e. power factor, harmonics, overvoltage, temperature, etc.) for safe operation of overall capacitor bank and individual capacitor stages.
    b. Recommended logic and/or permissives for safe operation of overall capacitor bank and individual capacitor stages.
    c. Recommended logic and/or permissives to avoid conflicting operation or “hunting” where multiple capacitor banks are supplying reactive power in parallel.

1.04 CLOSEOUT SUBMITTALS:

A. Operation, maintenance and instruction manuals containing at a minimum:
1. Instructions for receiving, inspection, storage, and handling.
2. Assembly drawings.
3. Complete installation and maintenance instructions for equipment components.
4. Parts identification for replaceable parts and assemblies.
5. Statement of equipment warranty.

1.05 MAINTENANCE MATERIALS.

A. Provide 3 spare current-limiting fuses for each size required.

1.06 QUALITY ASSURANCE.

A. Design, manufacture, and test in accordance with applicable requirements of:
1. IEEE Std 18 – IEEE Standard for Shunt Power Capacitors.
2. NEMA CP 1 – Shunt Capacitors.
3. NFPA 70 – National Electrical Code.
4. OSHA – Occupational Safety and Health Administration.
5. Applicable standards for auxiliary equipment.

6. Standards of foreign organizations shall not be used without written approval from Engineer.

B. Perform design and routine tests in accordance with NEMA CP1. Test results shall indicate that equipment meets standards prior to shipment.

1.07 DELIVERY, STORAGE, AND HANDLING.

A. Provide suitable crating, blocking, and supports so equipment withstands normal domestic shipping and handling shocks and vibration.

B. Weatherproof equipment as required for shipment. Cover openings to prevent entrance of foreign material during shipment and storage.

C. Ship equipment in one complete unit without further assembly required at destination.

PART 2 - PRODUCTS

2.01 SYSTEM DESCRIPTION.

A. Type: Outdoor, 3-phase, single line up in NEMA 3R enclosure.

B. Construction: Metal-enclosed complete with equipment, relays, instruments, wiring and all accessories as specified.

C. Service conditions: See **Appendix A Data Sheets**. Equipment will be located outdoors inside fenced substation yard.

D. Ratings: See **Appendix A Data Sheets**.

2.02 DESIGN REQUIREMENTS.

A. Single assembly shall be comprised of following section types:
1. Incoming disconnect.
2. Capacitor.
3. Control.

B. Assembly shall contain switching and fuse protection functionality necessary for full operation of capacitor bank.

C. Overall outside dimensions of length and width, as well as power cable entry location, shall be in accordance with dimensions given on Detail “A”. Provisions for bottom-fed conduit into control box shall accommodate two 2-inch conduits as indicated on Drawings.

D. Environmental requirements:
1. Ambient conditions: See **Appendix A Data Sheets**.

2. Design equipment in accordance with relevant sections of most recent local building code.

2.03 INCOMING DISCONNECT SECTION EQUIPMENT.

A. Terminal lugs:
   1. Copper, 2-hole NEMA spacing.
   2. Provide for termination of power cables from below.
   3. Provide 36” (900 mm) minimum space from bottom of compartment to terminal lugs for spreading cables and installation of stress cones.

B. Disconnect switch:
   1. 3-pole, gang-operated, nonload break.
   2. External operating handle with padlock and key interlock provisions.
   3. Viewing window for visual indication of blade position.

C. Grounding switch:
   1. 3-phase, gang-operated.
   2. Manually-operated with fully insulated handle to ensure stored energy has been discharged from capacitors while providing safety and visual ground indication.
   3. Provide key interlocked with isolating disconnect switch and compartment access doors to obtain proper operating sequence and operator safety.
   4. Grounding switches that require use of control power to ensure grounding of capacitors not acceptable.
   5. Use of multi-position switch for Disconnect Switch and Grounding Switch is acceptable.

D. Main in-line fuses:
   1. 3 fuses for short-circuit protection of bank.
   2. Type: Nonexpulsion, clip-style.
   3. Size and rating: As determined by manufacturer.
   4. Locate behind hinged access door with screen protector. Fuse may serve as means of isolating bank.
   5. Blown fuse indication (by way of dry contact or other means) shall be provided on main fuses to alert maintenance personnel of a blown fuse condition.

E. Surge arresters: Metal-oxide. Ohio-Brass “Dyna Var,” or equal.

F. Main bus: Electrical grade copper, full round edge, 3-phase.

G. Provide interlock mechanism to prevent opening capacitor housing before source power is disconnected.

2.04 CAPACITOR SECTION EQUIPMENT.

A. Reactors:
1. Inrush current-limiting reactors, single-phase, air core.
2. Provide single-phase, varnish-encapsulated reactor on each phase to limit high-frequency inrush current to values below I^2T rating of fuses as well as below kA x kH.
3. Size: As determined by manufacturer.

B. Vacuum switches:
1. The capacitor bank stages shall be controlled by single phase motor/solenoid operated vacuum switches that have been tested for capacitor switching.
2. If single-phase switches are used, switches must be operated by a single contact, to ensure simultaneous command delivery to all three phases. Separate contacts from one relay not acceptable.
3. While in remote, the capacitor bank stages shall be controlled by magnetically-held switches, such that one signal provides both “on” and “off” command. Thus, capacitor stage shall be “on” when incoming run signal is logical “0”, and “off” when incoming run signal is logical “1”.
4. Capacitor switches shall be tested in accordance with ANSI Standard C37.66.
5. The vacuum switches/contactors shall be controlled by a local/remote switch. In the remote position, the switches shall accept control from an external power factor controller (SEL-351-7). In the local position, , the vacuum switches will be forced on or off, regardless of the external controller output signal.
6. The vacuum switches shall be interlocked with the bank’s air-disconnect switch and ground switch.

C. Power capacitor units:

1. All-film type and stamped with BIL rating consistent with voltage class of tank.

2. Externally fused. Individually fuse each capacitor to protect against case rupture with current limiting fuse.

3. Low loss design with losses of each capacitor unit shall not exceed 0.07 watt/kilovar, measured at 1.1 times rated voltage and 46ºC ambient temperature.

4. Design mounting frame and connecting bus work to permit replacement of one unit without disturbing adjacent units.

5. Tank: Stainless steel, light gray finish for resistance to severely corrosive environments.

D. Individual capacitor fuses:
   1. Each individual capacitor shall be protected by single, dedicated current limiting fuse.
   2. Type: Nonexpulsion, capacitor-rated, current limiting, with blown fuse indication.
   3. Provide viewing window for visual indication of fuse status.
   4. Mount fuses in manner that will permit replacement of individual fuse without disturbing adjacent units.
   5. Size and rating: As determined by manufacturer to ensure protection against case rupture.

E. Interlocks: As required to prevent entry into bank while energized.

F. Auxiliary contacts: (2 NO and 2 NC) for each switch and alarm. Wire from relays and indicators to terminal blocks for remote status and control.

G. Blown fuse detection shall be provided at every stage using fuse sensing.

H. Tank: Stainless steel or aluminum, with light gray finish for resistance to severely corrosive environments.

I. Bushings:
   1. Light gray, wet-process porcelain material, glazed for high-strength and durability.
   2. Hermetically sealed to capacitor tank.

J. Mounting brackets:
   1. Stainless steel, with industry standard mounting centers for unit interchangeability.
   2. Underside of each bracket shall be unpainted for allowing positive grounding to mounting surface.

K. Bushing terminals:
   1. Provide complete with parallel-groove, stud-type terminal on each bushing.
   2. Parallel groove terminals shall accommodate No. 8 solid to No. 1 stranded aluminum or copper conductors.

L. Provide with internal discharge resistor to reduce terminal voltage to less than 50 volts or less, within 5 minutes after capacitor has been disconnected from source of supply.

M. Nameplates: Stainless steel, listing required NEMA and ANSI/IEEE data.

N. Each capacitor shall contain no PCB contaminates and be labeled with blue "non-PCB" decal.

2.05 CONTROL COMPARTMENT EQUIPMENT.

A. Protection: Provide sensing and stage isolation for neutral unbalance and blown fuse detection. Capacitor bank shall continue to operate upon isolation and loss of a single stage to match reactive power requirements of system as closely as possible.

B. Selector switches.
1. One “Local/Remote” 2-position.
2. One “On/Off” 2-position per stage.

C. Indicating lights (LED).
1. One green (open) and one red (closed) for the status indication of the following:
   a. Each individual stage vacuum switch.
   b. Main disconnect switch.
   c. Grounding disconnect switch.
2. One red per fuse (main and individual stage) for blown status indication.
3. One green (healthy) and one red (alarm) for health status of capacitor bank (provided by external controller).

D. Segregation: Controls shall be completely isolated from medium-voltage compartment allowing access while capacitor bank is energized.

E. Provide 120V GFI convenience outlet.

2.06 ENCLOSURE.

A. Construction: Totally enclosed, NEMA 3R, 11-gage steel assembly with 4” (100 mm) (minimum) welded structural steel channel base. Hinged doors shall be provided for all maintenance requiring internal access.

B. Lifting lugs:
1. Reinforce base at each corner with 1/4” (6 mm) steel plate welded to web of channel. Provide with bolted, removable steel lifting lugs in reinforced portion.
2. If enclosure exceeds 9’ (2.7 m) in length, provide additional reinforcement and lifting lugs at centerline on each side.
3. Enclosure shall be capable of being lifted, skidded or sledded into position on concrete pad without damage to any portion of enclosure or contents.

C. Anchor bolt holes: 3/4” (19 mm) diameter at each corner of enclosure.

D. Conduit access: Provide opening in floor of enclosure with removable cover plate drilled to accommodate 6" (150 mm) conduit with bushing.

E. Doors:
   1. Flush design. Extended door sills which can trap water or debris not acceptable.
   2. Provide padlockable, 3-point latching (top, bottom, and center).
   3. Hinges: Welded to door and to enclosure in configuration to allow removal of doors in open position only.
   4. Provide automatic sliding stainless steel door stays so doors hold open in approximately 140º position.

F. Main bus: Copper, ASTM hard drawn, electrical grade; silver-plated joints, uninsulated.

G. Ground pads:
   1. Two 1/4" (6 mm) steel pads, diagonally located at opposite ends of capacitor bank enclosure. Weld to base channel or sheet steel.
   2. Provide with 2, horizontally oriented, 9/16" (14 mm) holes at 1-3/4" (44 mm) NEMA spacing. Ground pads shall be free of paint.

H. Ground bus: 1/4" x 2" (6 mm x 50 mm) continuous copper ground bus for entire length of enclosure. Bus shall be silver-plated at each joint position.

I. Control power: Provided by external 120 volt ac source. Control power shall provide all wetting voltage for incoming/outgoing signals between capacitor bank and external power factor controller, as well as power for space heaters, convenience receptacle, local LED lights, etc.

J. Ventilation:
   1. Provide adequate ventilation including permanently embossed louvers with baffling screens welded to enclosure interior to prevent insects, protrusions, or entry of No. 14 wire into enclosure while increasing airflow.
   2. Heat-rise:
      a. Determine additional ventilation requiring forced air (fans) for increased air circulation based on heat-rise calculations by manufacturer.
      b. Calculations shall be based on mVAR rating.
   3. Fans shall be rated to operate on ac volts.
   4. Unit filters shall be replaceable without de-energizing equipment.

K. Heaters and thermostats:
   1. Include proper number of heaters and thermostats to reduce effect of condensation within bank.
   2. Heater shall be rated to operate on ac volts.

L. Paint:
   1. The enclosure shall be prepared and painted with a high-solid epoxy coating as specified below. The paint shall be ANSI gray 61 – Munsell No. 8.3G 6.10/0.54.
   2. **Surface Preparation**: All steel surfaces shall be prepared per SSPC-SP2, 3, 6, 7, 10, 11 or the paint manufacturer's recommendations. Exceptions to the manufacturer's requirements shall be approved by the paint manufacturer and provided with the submittal documents.
   3. **Inaccessible Surfaces**: Prepare and coat steel surfaces inaccessible to preparation and coating after fabrication with all coats before fabrication. Inaccessible surfaces shall be considered Zone 2A per SSPC specifications..
   4. **Paint Specification**: All surfaces, inside and out, shall be coated with a High-Solid Epoxy Siloxane Marine paint with a dry film thickness of 2 to 3 mils.
   5. The paint utilized shall have the following properties:
      - Salt Spray (ASTM B117) 5500 Hours with no face blistering.
      - Humidity (ASTM D2247) 5500 Hours with no face corrosion or blistering.
      - Gloss retention (ASTM G53) QUV-B bulb: Greater than 50% gloss retention at 26 weeks.
      - Elongation (ASTM D5222) 14%.
      - Abrasion resistance (ASTM D4060) 1kg load/1000 cycles, CS-17 wheel: 53 mg weight loss.
      - Impact resistance (ASTM D2794): Direct 24 in.lb and Reverse 6 in.lb.
      - Adhesion, elcometer (ASTM D4541): 2700 PSI.
      - NFPA Class A Qualification.

      Paint shall also provide excellent chemical resistance to splash, spillage, fumes and weather for acidic, alkaline, salt solutions (acidic, neutral, and alkaline salt solutions), fresh water, solvents and petroleum product environments.

   6. Upon request, the manufacturer shall provide supporting documents (surface preparation procedures as well as paint manufacturer's paint specifications) showing the above requirements are met. Failure to comply with this request will be cause for cancellation of order.

M. External welds except roof welds shall be ground and sanded; internal welds shall be wire-brushed.

N. Labeling and markings:
   1. Mark and label enclosure in accordance with IEEE/NEMA standards.

2. Affix labels identifying component compartments to exterior of enclosure. Labels shall be clearly visible with doors in open or closed position.
3. Labels shall meet ANSI/IEEE guidelines for extended exposure to elements.
   a. "Danger High Voltage" sign shall be attached on each door of capacitor bank enclosure.
   b. "Caution - Before Compartment Entry, Allow At Least (factory recommended time with minimum safety factor of 2) Minutes After De-energization for Capacitors to Discharge.”.
   c. "Ground Switch - Allow (factory recommended time with minimum safety factor of 2) Minutes For Capacitors To Discharge Before Operating".
   d. “Warning – Line-Side Energized When Switch Open” sign shall be attached on door of incoming disconnect section.
   e. “Danger - Equipment Supplied by Two (2) External Sources”.
   f. “Danger - Equipment Switching Controlled by External Source”.

O. Nameplate: Affix permanently stamped, noncorrosive nameplate to enclosure indicating:
1. Nominal system voltage.
2. Maximum design voltage.
3. Basic insulation level.
4. Continuous current rating.
5. Fuse type.
6. Fuse rating maximum.
7. Fuse symmetrical ampere interrupting rating.
8. Interrupting rating for each switch type.
9. Maximum capacitance rating.
10. Customer code number.
11. Date of manufacture.

2.07 CONTROL AND SECONDARY WIRING.

A. Wire: Stranded, tinned copper. Flame-resisting switchboard type, SIS No. 12 AWG minimum.

B. Accessories: Terminals, auxiliary devices, wiring troughs, and miscellaneous materials as required. Use ring-tongue or locking fork terminals.

C. Wiring termination shall facilitate connection of control, potential, and power supplies to high-side circuit breaker, transformer, and protective relaying.

D. Terminal blocks:
1. Washer-head connecting screw type; General Electric EB-5, Westinghouse KCE, Cutler-Hammer 10987, or equal.

2. Mount terminal blocks on vertical surfaces; provide legible, permanent marking on terminals; plug-in or stab-type terminal blocks not acceptable.
3. Terminate current transformer secondary leads on short-circuiting type terminal blocks.

2.08 MIMIC BUS.

A. Provide on front of segregated control compartment section.

B. Type: 3/8" (10 mm) wide, phenolic, fastened with screws.

C. Color: Red.

D. Show disconnect switch, vacuum switch, reactors, capacitors, ground switch, and fuses.

2.09 SUPERVISORY CONTROL EQUIPMENT.

A. Power factor controller shall be SEL-351-7, externally located in 12.47kV switchgear cubicle supplying capacitor bank (controller supplied by switchgear manufacturer).

B. Provide switching controls on capacitor bank enclosure to allow capacitor bank to be locally or remotely controlled. In "Remote" operation, control will be by external controller. In "Local" operation, control will be by switching controls on capacitor bank enclosure.

C. Provide switching controls on capacitor bank enclosure to allow capacitor bank to be automatically or manually controlled, via Local/Remote switch. In "Remote" operation, control will be by external controller. In "Local" operation, control will be by selection of "On" or "Off" control. Local On/Off control shall be prohibited while in "Remote" operation and Remote control shall be prohibited while in "Local" operation.

D. Blown fuse detection of an individual stage shall immediately open and block closing of Vacuum Switches for that stage, regardless of "Remote/Local" control status. This shall be done by means of interlocking connections.

E. Provide terminal blocks to accommodate all incoming conductors between external controller (SEL-351-7 relay) and capacitor bank, in accordance with cable schedule. External wiring connections shall include:
1. Outgoing signals to external SEL-351-7 power factor controller:
   a. 89G ground switch "a" status.
   b. 89D main disconnect "a" status.
   c. Stage 1 blown fuse indication.
   d. Stage 2 blown fuse indication.
   e. Stage 3 blown fuse indication.

f. Main blown fuse indication.
g. Key interlock status.
h. Stage 1 “on” indication.
i. Stage 2 “on” indication.
j. Stage 3 “on” indication.
k. Over temperature indication.
l. Local/remote status.
m. Note: Items a-l above shall all share a single “common” conductor routed to external controller.

2. Incoming signals from external SEL-351-7 power factor controller:
   a. Stage 1 open/close.
   b. Stage 2 open/close.
   c. Stage 3 open/close.
   d. Common alarm (to local red LED).
   e. Healthy indication (to local green LED).

F. Locate terminal blocks in auxiliary compartment.

G. Provide 24 spare terminals for future supervisory functions.

2.10 NAMEPLATES.

A. Material: White plastic engraving stock, 1/16" (2 mm) thick with black core.

B. Lettering: Engraved approximately 3/16" (5 mm) high.

C. Wording: Prepared by manufacturer, subject to review by Engineer.

D. Locations:
1. Front of each unit.
2. Each control switch.
3. Each relay.
4. Each set of low voltage fuses.
5. Each ac circuit protective device.

PART 3 - EXECUTION

3.01 EXAMINATION.

A. Verify site conditions.

3.02 PREPARATION.

A. Clean interior and exterior of equipment prior to placing into service.

B. Debris shall be removed an appropriately discarded.

3.03 INSTALLATION.

A. Install in accordance with manufacturer's recommendations.

3.04 FIELD QUALITY CONTROL.

A. Perform filed tests required by manufacturer.

B. Perform installation tests as required by relevant industry standards.

C. Provide necessary testing facilities.

3.05 MANUFACTURER'S FIELD SERVICES.

A. Provide manufacturer's service representative(s) to supervise and/or check installation.

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APPENDIX A
DATA SHEETS: METAL ENCLOSED CAPACITOR BANK

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DATA SHEETS METAL ENCLOSED CAPACITOR BANK		Equipment Name: CAP-108, CAP-102 Qty. Cap. Banks = Two (2)	
DESCRIPTION	**UNITS**	**SPEC DATA**	**VENDOR DATA**
Manufacturer	N/a	GE or equal (must be approved by	
Catalog/Serial No.	N/a		
Ratings:			
Nominal Line-to-Line Operating Voltage	kV	12.47	
Maximum Line-to-Line Continuous Voltage	kV	13.09 (1.05 p.u.)	
System Grounding	N/a	Low-resistance (non-effectively grounded)	
Capacitor Bank Grounding Configuration	N/a	Ungrounded wye	
Total Bank Capacitance	kVAR	4800	
Number of Steps	Qty.	5	
Number of Stages	Qty.	3	
Sequence of Stages to Achieve Steps	N/a	1+2+2	
BIL	kV	95	
Short-Circuit Interrupting	kA	50	
Connection Type	---	3-phase, 3-wire	
Frequency (50 or 60)	Hz	60	
Service Conditions:			
Outdoor Rated	Y/N	Y	
Ambient Temperature Range	°C	-30 to +40	
Altitude Above Sea Level	ft.	350	
Specific local Building Code and specific relevant sections used in equipment design.	---	By Manufacturer	
Incoming Line Section Rating:			
Bus Nominal Current Rating	A	By Manufacturer to support full kVAR capability	
Cable Terminations		Shall accommodate up to 1x750kcmil per phase	
Cable Voltage Rating	kV	15	
Cable Size	-	Shall accommodate up to 1x750kcmil per phase	
Quantity per phase	Qty.	1	
Disconnect Switch Rating:			
Voltage	kV	15	
Current	A	By Manufacturer to support full kVAR capability	
Vacuum Switch Rating:			
Voltage	kV	15	
Current	A	By Manufacturer to support full kVAR capability	
Capacitor Rating:			
Voltage	kV	15	
Current	A	By Manufacturer to support full kVAR	

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DATA SHEETS METAL ENCLOSED CAPACITOR BANK		Equipment Name: CAP-108, CAP-102 Qty. Cap. Banks = Two (2)	
DESCRIPTION	**UNITS**	**SPEC DATA**	**VENDOR DATA**
Quantity of Capacitors	Qty.	By Manufacturer	
Individual Capacitor kVAR	kVAR	0.96, 1.92, 1.92 (1+2+2 sequence arrangement)	
Total Bank kVAR	kVAR	4800	
Grounding Switch Rating:			
Voltage	kV	15	
Current	A	By Manufacturer	
Reactor Rating			
Voltage	kV	By Manufacturer	
Current	A	By Manufacturer	
Inductance	H	By Manufacturer	
Surge Arrester Rating:			
Class (Intermediate or Station)	-	Intermediate	
Type	.	Metal-Oxide Varistor	
MCOV Rating	kV	15.3	
Duty Cycle	kV	18	
Control Compartment Rating:			
Control Voltage (ac or dc)	-	120Vac	
Unit Dimensions:			
Height	ft.	By Manufacturer	
Width	ft.	6	
Length	ft.	12.75	