TO: G. Bawden
FROM: W. Biebesheimer

SUBJECT: REVISION OF TITLE I REPORT FOR THE 220 KV MASTER SUBSTATION
        ABA-61 MARCH 19, 1963

REFERENCE: Memorandum Biebesheimer to Bawden March 6, 1963

Forwarded herewith are 30 copies each of the revised cover and
page 15 for the subject Report. Please distribute in accordance with
the Reference memorandum with instructions to replace these pages only in
the report issued March 6, 1963.

W. B. Biebesheimer
Project Engineer

WBB/dr
Attachments
cc: R. L. Sharpe
    L. W. Swanson (6)
    G. C. Edwards (3)
    File 616
TO: G. Bawden
FROM: W. Biebesheimer
SUBJECT: Title I Report for the 220 KV Master Substation
ABA-61 March 6, 1963

Forwarded herewith are 20 copies of the finished
subject report for transmittal to SLAC and 10 copies
for distribution to the Technical Board and ABA
Operations Division. Full sets of drawings are also
furnished herewith to accompany each copy of the
report.

W. B. Biebesheimer
Project Engineer

WBB/dr
cc w/Report

R. L. Sharpe
L. W. Swanson (6)
G. C. Edwards (3)
File 616
TITLE I REPORT
FOR THE
220 KV MASTER SUBSTATION
AND
ASSOCIATED SITE IMPROVEMENTS

REPORT TO STANFORD LINEAR ACCELERATOR CENTER - NO. ABA - 61
STANFORD UNIVERSITY SUBCONTRACT S - 136
UNDER AEC CONTRACT AT(04-3) - 400

Submitted by W. B. Biebesheimer
Approved by R. L. Sharpe

AETRON-BLUME-ATKINSON
A Joint Venture
Architect-Engineer-Manager
Palo Alto, California

March 6, 1963
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INTRODUCTION

This report presents the Title I design for the 220 KV Master Substation. Included is information on the Architectural design of the Switch-House, yard layout and improvements, fire protection, cost estimates and schedules as well as a technical description of the electrical apparatus and system operation. The associated Site Improvements for the A.C. yard was outlined and its costs included in a previous report, ABA-57.

BASIS FOR DESIGN

The location chosen for the substation is compatible with the incoming supply lines, the electrical load-center and topographical requirements. The preliminary design described herein is based on previously issued report ABA-51 and certain requirements of the Pacific Gas and Electric Co. Authorization for Title I work is contained in a memorandum from K. Copenhagen to G. G. Bawden dated September 18, 1962.
ELECTRICAL DESCRIPTION AND SPECIFICATIONS

The Master Substation receives the 220 kv PG & E power service, transforms this to the 12 kv distribution voltage, and provides circuit protection and control for the project 12 kv distribution system. The substation consists of an outdoor 220 kv yard and equipment, step-down transformers, and a switch-house containing the necessary 12 kv circuit-protective equipment.

Design Criteria

The substation will be engineered, designed, and constructed to insure maximum safety to personnel, maximum reliability of service in keeping with the project requirements, and minimum probability of operating errors. The substation equipment will be full rated for the ultimate Utility System interrupting capabilities. The protective devices will be coordinated for fast removal of faults with minimum loss of service time. These criteria are defined and applied in line with economic considerations and tolerable down time of the project.

General System Design

The substation receives power from PG & E over a double-circuit, 220 kv, overhead transmission line. The initial installed nameplate capacity of the substation is 80 mva with space for expansion to an ultimate nameplate capacity of 180 mva. The general location and approximate equipment sizes are shown on Drawing D-616-703. Drawing D-616-701 is the Master Substation Primary Single-Line Diagram. Drawing D-616-702 is the 12 kv System Single-Line Diagram.
A 60 to 12 kv, 15 mva substation is located south of the Master Substation. This 60 kv substation is covered on ABA Contract 617. Initially the 60 kv substation provides 12 kv power on temporary overhead pole-lines for construction facilities, early occupancy of the Klystron Gallery, and the Support and Service Area Buildings. Ultimately the 60 kv substation 12 kv power will feed into the Master Substation Switch-House through underground cables. A weatherproof 12 kv air circuit-breaker will be installed in the 60 kv substation yard. The breaker will be interchangeable with the units in the switch-house. The connections are shown on Drawing D-616-702, 12 kv System Single-Line Diagram.

General Arrangement

The general arrangement of the major pieces of equipment is shown on the General Area Arrangement Plan, Drawing D-616-703. This equipment arrangement offers the optimum of area utility and accessibility for maintenance. Space is provided for future expansibility and flexibility. The PG & E 220 kv service arrangement simplifies the bussing and adds greatly to the symmetry of the station. Future extension of the Master Substation and 220 kv service to the east is readily accomplished with the arrangement shown.

The Switch-House arrangement is shown on Drawing D-616-703. This arrangement allows ready access to the operating areas from the Klystron Gallery level. The lower level provides the means of getting the outgoing feeder cables into the underground distribution system in the most expeditious manner.
The arrangement of the 220 kv yard is shown on Drawing D-616-703. It should be noted that the elevation of this yard is depressed approximately 14 feet below the level of the adjacent Klystron Gallery area. This minimizes the sky-lining of the structures in the yard and makes possible a simpler construction for the lower level of the Switch-House. The yard arrangement allows for the future addition of transformers as the project load dictates. This expansion will necessitate some down time for one transformer bank and its bus work. The proposed arrangement utilizes a suspension-type 220 kv bus, not the low-profile tubular-bus design. Suspension busses are proposed because of lower cost and a far better resistance to damage by earthquake. The suspension bus is simple and uncluttered and offers a thinner silhouette than the tubular-bus, low-profile type.

PG & E Service

The PG & E 220 kv dual-circuit transmission line will be able to supply SLAC with about 300 mwa. The calculated ultimate short-circuit capability of the service is 5000 mwa for one circuit, and 9080 mwa for the two circuits operating in parallel. PG & E's service voltage regulation is from $\pm 4\%$ to $\pm 5\%$. Present understanding is that PG & E will supply the necessary current-transformers, potential-transformers, and meters for revenue metering on the 12 kv bus. The metering will be totalized for the two 220 kv services and the 60 kv service.
The breakers afford a means of disconnecting either or both 220 kv lines, and an interrupting means of clearing a fault on the 220 kv bus or a fault within a 220 kv transformer. The scheme will, if required to operate because of a 220 kv bus fault or an internal transformer fault, cause about a 10-second delay in restoration of service and will perform as indicated below:

a. The two 220 kv circuit-breakers will open.

b. The motor-operated bus-tie sectionalizing switch opens.

c. The circuit-breaker reclosing on the faulted section of bus will lock open and will cause the main 12 kv secondary circuit-breaker to open.

d. The circuit-breaker reclosing on the good section of bus will remain closed and will supply power to the project.

e. The time delay from the 220 kv fault to the restoration of power to the project will be from 7 to 10 seconds.

In case of an internal transformer fault, two sets of relays act, the sudden-pressure relays and the differential-current relays. The differential relays will initiate the relay system to perform as indicated below:

a. The two 220 kv circuit-breakers will open.

b. The 220 kv disconnect switch ahead of the damaged transformer and the associated 12 kv main secondary circuit-breaker will open. The damaged transformer is isolated.

c. The two 220 kv circuit-breakers will reclose and seeing no fault will remain closed and supply power to the project.

d. The time delay from the initiation of the differential relays to restoration of power will be from 7 to 10 seconds.
The project is to supply and install the carrier-current relays and wave-traps to PG & E specifications. PG & E will make the 220 kv connections to SLAC's terminal structure. All other equipment and facilities are furnished and installed by the project.

Major 220 kv Equipment

The initial construction of the Master Substation will consist of the following major devices, equipment, and structures:

2 - 220 kv line termination structures
2 - 220 kv circuit breakers
1 - 220 kv sectionalized strain type bus
3 - Bus support structures
2 - 220 kv motor-operated gas-blast switches
1 - 220 kv motor-operated bus-sectionalizing switch
2 - 24/32/40, OA/FA/FOA oil-cooled transformers
1 - Switch-House containing the 12 kv indoor switchgear assemblies, relays, control and metering panels, control battery and charger.

Space is allocated and electrical provisions are made for the future installation of a 12 kv tie bus and reactors, 12 kv switchgear assemblies, additional 220 kv transformers, and extension of the 220 kv bus.

Primary Protection System

The Primary Single-Line Diagram, Drawing D-616-701, shows two 220 kv circuit-breakers, one on each PG & E service line.
220 kv Breakers

The 220 kv circuit-breakers will have an interrupting capacity of 10,000 mva. Although the ultimate fault duty for each line is 5000 mva, 10,000 mva circuit-breakers were selected as there is no price differential between the two classes.

220 kv Switches

The 220 kv motor-operated gas-blast switches are proposed for transformer primary disconnect-devices. The gas-blast feature permits interruption of the magnetizing current of the transformer. The 220 kv bus-tie disconnect switch is the air-break motor-operated type. Motor operators are used to enable switch operations to be tied into the protective relaying as outlined above. The circuit-breaker disconnect switches are the manual group-operated type and are used only for isolating the circuit-breakers for maintenance and inspection.

220 kv Transformers

The transformers will be rated 24/32/40 mva OA/FA/FOA, 220 kv to 12 kv. The connections will be wye-wye with a delta tertiary winding. Because of the project requirement for voltage regulation of ± 2.5%, the transformers will be equipped with standard under-load tap-changing equipment with 32 steps of 5/8% each. Transformer overload capacities can be computed as recommended by ASA Standard C57. The primary winding will be graded insulation rated 750 kv BIL. The secondary winding will be uniform insulation rated 110 kv BIL. The leads of the tertiary winding will not be brought out of the tank. The tertiary winding will be protected against excessive circulating currents through relaying tied into the overall protective relaying system.
The primary line-bushings and the primary neutral-bushing will be provided with current transformers.

The transformer impedance will be 11% on the 24 mva base. This value is selected to permit the use of 500 mva switchgear on the 12 kv side. Short circuit studies indicate that single phase-to-ground and three-phase short circuit currents have approximately the same magnitude, hence reactors or resistors are not required in the neutral-to-ground connections of the transformers. The transformers will be equipped with station type lightning arrestors because of the reduced level of the primary winding insulation.

Primary Protective Relaying

The general plan on protective relaying on the 220 kv side of the substation is shown on Drawing D-616-701, Primary Single-Line Diagram. The system will provide complete protection to the SLAC system and equipment, and will be coordinated with the PG & E system requirements to provide reliable service. The plan utilizing circuit-breakers and motor-operated switches will enable fast restoration of service. The system is designed to utilize maximum emergency or short-time rating of equipment. In general each protective relay scheme will have an additional backup system to assure protection. The major systems on the protective relaying scheme are outlined below:

- Bus differential
- Directional Distance
- Ground Directional
- Ground Directional Carrier
- Ground Current Alarm
Out of step blocking relay
Sudden-pressure relays on transformers
Differential protection around each transformer
Over-temperature relay on transformers
Ground current on transformer primary neutral
Tertiary winding overcurrent relay

Structures

The structures will be designed with flanged steel members. The height will be designed to minimum clearance consistent with acceptable engineering practice. Due consideration will be given to the aesthetic aspect of the overall substation design.

Switch-House

The switch-house will provide housing for the 12 kv switch-gear, metering and relay panels, control console, batteries, tie-bus, and the like. The building is described in Section V of this report. The equipment arrangement in the switch-house is shown on Drawing D-616-703.

Control Console

A control console will be provided in the switch-house. It will be the nerve center of the entire electrical system. The control console will have mimic busses depicting the essential conditions of the 220 and 60 kv supply systems as well as the 12 kv distribution system. Instruments, control switches, and indicating lights provide a means of visualizing the general condition of the entire system and controlling it from a central point.
The relays associated with the incoming lines, high voltage circuit-breakers, and main transformers are mounted on the rear panels of the console. The general features which are to be incorporated into the control console are listed below.

**Control and Indication:**
- 220 kv circuit-breakers
- 220 kv bus-tie sectionalizing switch
- 220 kv transformer primary disconnect switches
- 12 kv main circuit-breakers
- 12 kv bus-tie circuit-breakers
- 12 kv feeder circuit-breakers

**Indication Only:**
- Station power
- Battery charging
- Voltage on each Klystron Gallery Substation
- System Alarms

**12-kv Switchgear**

The metal-clad switchgear shall be of the indoor type with air circuit-breakers, rated 15 kv, 500 mva interrupting capability, and 95 kv BIL. Circuit-breakers are used in lieu of the less expensive fused disconnect switches because of the need for rapid load shedding to meet PG & E's requirements on interruptible power. The circuit-breakers are also needed to shed and select loads to limit the load to 15 mva in case the 60 kv substation is the sole supply to the project.
Reactors

Switchgear of 500 mva interrupting capability can be used regardless of the PG & E system growth with the addition of current-limiting reactors and a tie-bus. Reactors are not required for the present two transformer installation even if the PG & E system short circuit capability increases to its ultimate 9080 mva value. Reactors are required after a third transformer is added and the PG & E system fault capacity for two circuits in parallel exceeds 2000 mva. Reactors must be installed when the fourth transformer is added regardless of the PG & E capacity.

Station Power

The 480 volt power for the station house power and auxiliaries will be supplied from an adjacent Klystron Gallery Substation. A high degree of reliability is needed for the service to the critical loads such as the 220 kv transformer cooling facilities, battery chargers, and the like.

System Studies

Two system studies have been made by ABA. The first or preliminary study was made on a small dc board. The results of this study determined the general magnitude of the short circuit currents. This study also definitely pointed out the need for a more detailed analysis beyond the capability of a dc analyzer. A more thorough system analysis was made on a suitable ac network board. This study was based on the best available information at the time and resulted in a more detailed understanding of the basic electrical system requirements. The results of these studies are incorporated in the design as presented in this report.
The detailed records of these studies are not included herewith, but they are available in the Electrical Engineering Files.

The next step in the system study program must be carried out jointly with PG & E. As mentioned in Paragraph 11, it is essential that close coordination must be maintained with them. Preliminary work between PG & E and ABA Engineers has laid the basis for further mutual studies. These studies will finalize the details of the system and set the specific requirements of the major equipment items for the present and the ultimate configuration.

FOUNDATIONS AND SITE IMPROVEMENTS

The area within the outdoor substations will be surfaced with six inches of aggregate base material with additional gravel filled pits to contain the transformer oil in the event of a tank failure.

Edge of pavement returns for the entrance drive will be provided with forty foot (minimum) radius. The access road will be paved with asphalt concrete surfacing, and will have grades not in excess of six percent.

The substation finish grade will be at elevation 270 + which will provide a 14 foot differential in elevation between the switchyard and the Klystron roadway.

Storm drainage will be accomplished by grading the surface of the yard so that runoff can be collected in open ditches and swales. A culvert will be provided under the entrance drive.
The area will be surrounded by a 6-foot chain link fence with a barbed wire extension arm and with the necessary equipment and man-gates.

Concrete Foundations will be provided for the equipment.

SWITCH HOUSE DESIGN

   a. **Occupancy** - Group G
   b. **Type of Construction** - Type IV (N)
   c. **Number of Stories** - 1 story and basement
   d. **Location on Property** - Separated on four sides
   e. **Area Limitations** - (per UBC)
      
      | Type IV (N)               | Fire Zone III          |
      | Basic Area (One Story)   | 13,500 square feet allowable |

2. Footings, Foundations, and North Wall of Basement - Reinforced Concrete

3. First Floor Framing - Steel Girders and Beams with Concrete Slab over Basement

4. Live Loads:
   
   Floor Areas  125 psf
   Roof Area    20 psf
   Wind & Seismic .2 D.L.

   Wind and seismic loads to be taken in the first story by rigid frame bents in the transverse direction, and by knee braced bents in the longitudinal direction. In the basement story these loads will be taken by the concrete retaining wall on the north.

5. Roof -
   
   4 ply built up tar and gravel (colored granular material) on 1 inch rigid insulation.
6. Exterior Walls -

First Floor: Metal siding
           Metal louvres, sash and doors.

Basement:  Metal siding, metal louvres, and rolling steel
door.

7. Partitions - None

8. Flooring -

Exposed hardened concrete slab

9. Lighting and Power -

60 foot candles on the first floor
25 foot candles in the vault space. Convenience outlets
as required.

10. Ventilation -

Natural gravity ventilation from exterior.

11. Area Analysis

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<td>Basement</td>
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Total Area 4,200

FIRE PROTECTION

The fire protection system will be designed to provide sufficient
building equipment protection. The system includes automatic fixed
temperature detection for the upper and lower levels, manual alarm stations,
and horns. Portable hand extinguishers will be purchased and installed
by SLAC.

COMMUNICATIONS PROVISIONS

Conduit only will be run underground from the sub-station to the
Klystron Gallery. The number and size of conduits are a SLAC responsibility
as outlined in ABA-56. The estimate figures used are based on two 2-inch
conduits.
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<td>60 KV Substation Alterations</td>
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*Covered in ABA-57

Revised March 19, 1963
DESIGN AND CONSTRUCTION SCHEDULE

Title I Draft Submittal
Title I Report Submittal
Start of Title II (Bid Package #1)
Title II - 50% Submittal
Title II - 90% Submittal
Title II - 100% Submittal
Bid Opening
Notice to Proceed
Start of Title II (Bid Package #2)
Title II 90% Submittal (Bid Package #2)
Award of Contract Bid Package #2
Foundations and Building Complete
Start Erection & Installation of
Bid Package #1
Activation of Substation

November 30, 1962
March 6, 1963
March 27, 1963
June 11, 1963
July 26, 1963
September 11, 1963
October 11, 1963
November 8, 1963
November 8, 1963
November 8, 1963
February 14, 1964
May 15, 1964
September 15, 1964
September 23, 1964
March 23, 1965
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<tr>
<td>D 616-702</td>
<td>12 KV Single Line Diagram</td>
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<td>D 616-703</td>
<td>Master Substation - General Area Arrangement Plan</td>
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<td>Master Substation Site Plan</td>
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<td>Switch House Elevations &amp; Sections</td>
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