8 ELECTRICAL SYSTEMS

8005300721

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8 ELECTRICAL SYSTEMS

8.1 DESIGN BASES

The plant is designed to be electrically self-sufficient with adequate auxiliary equipment and standby power to assure the safe handling of all emergency situations.

To prevent the concurrent loss of all auxiliary power, the various sources of power are independent of and isolated from each other. The power supply and control of equipment providing engineered safeguards will be arranged to minimize the possibility of a loss of their operating functions due to physical damage.

8.2 ELECTRICAL SYSTEM DESIGN

8.2.1 NETWORK INTERCONNECTIONS

The unit will generate electric power at 22 kV which will be fed through an isolated phase bus to the unit main transformer bank, consisting of three single-phase transformers, where it will be stepped up to 500 kV transmission voltage and delivered to the station switchyard. The 500 kV substation design will be a ring bus scheme with provisions for future expansion to breaker and a half. The 500 kV station switchyard will include one line to the Mabelvale 500 kV substation and one line to the Ft. Smith 500 kV substation. The 161 kV switchyard at the generating station will also be of ring bus design and will include one line to South Russellville 161 kV substation and one line to Morrilton 161 kV substation. A bus tie autotransformer bank consisting of three single phase autotransformers will interconnect the 500 kV and 161 kV systems in the station switchyard. The 22 kV tertiary of the autotransformer bank will supply Start-Up Transformer No. 1 which will be identical to the Unit Auxiliary Transformer. Start-Up Transformer No. 2 will be supplied from the 161 kV ring bus. 3

One spare single-phase main transformer and one spare single-phase autotransformer will be provided to replace any single-phase unit in the main transformer bank, or autotransformer bank, respectively in case of a transformer failure.

8.2.1.1 Single Line Diagram

Figure 8-1 is a single-line diagram of the station buses and circuits.

8.2.1.2 Reliability Considerations

Reliability considerations to minimize the probability of power failure due to faults in the network interconnections in the associated switching are as follows:

(a) Each 500 kV line will be capable of carrying the full plant output.

(b) The 500 kV transmission lines will be single circuit and the towers will be designed as recommended by ASCE page No. 3269.

(c) 500 kV and 161 kV system stability will be maintained on tripping of the main generator. 3

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An additional measure of auxiliary power reliability for the plant will be achieved by providing for quick replacement of Start-Up Transformer No. 1 by the Unit Auxiliary Transformer in the event of failure of Start-Up Transformer No. 1. The changeover will be by means of reconnection of overhead swing leads and isophase bus links without a physical relocation of the transformers. 3

8.2.2.2 6900-Volt Auxiliary System

Two 6900-volt buses will be provided for the operation of the four reactor coolant pumps. This will provide the necessary flexibility and reliability during normal plant operation, start-up and shutdown. During normal operation, each bus will be fed from the 6.9 kV winding of the Unit Auxiliary Transformer. During start-up and shutdown, the buses will be fed from the 6.9 kV secondary winding of the Start-Up Transformer No. 1 or of the Start-Up Transformer No. 2. 3

Normal transfer of the 6900-volt auxiliary system between the three sources will be initiated by the operator from the control room, while emergency transfer from the Auxiliary Transformer to one of the Start-Up Transformers will be initiated automatically by protective relay action. Normal bus transfers used on start-up or shutdown of a unit will be "live bus" transfers, i.e. the incoming source feeder circuit-breaker will be closed onto the energized bus section and its interlocks will trip the outgoing source feeder circuit breaker which will result in transfers without power interruption. After closing of 6 the circuit breaker of the incoming transformer, the supply breaker of the other transformer that was connected to the bus before the manual transfer was initiated will be automatically tripped when the operator releases the control switch handle of the incoming breaker. Paralleling sources which are out of phase will be prevented by the use of synchronism check relays.

Emergency bus transfers which will be used on the loss of normal unit sources will be rapid bus transfers, i.e., the normal source feeder circuit breaker will be tripped and simultaneously the emergency standby circuit breaker will close the incoming power source which will result in a transfer within a maximum of four cycles. The selection of one of the two start-up transformers 3 for emergency standby duty will be by means of a duty selector switch in the control room. The duty selector switch determines which start-up transformer 6 transfers first on loss of normal unit source. When one of the start-up transformers is in service, the other start-up transformer will automatically be available for rapid bus transfer emergency standby duty.

All bus feeder circuit breaker control switches, bus synchronizing switches, 6 and emergency standby duty selector switches for 6900-volt, 4160-volt, and 480-volt buses will be located in the control room.

8.2.2.3 4160-Volt Auxiliary System

Four 4160-volt buses will be provided. Two of the buses will provide power to 3 non safeguards 4 kV auxiliary motors, feeders to 480-volt non safeguards double-ended load centers and feeders to 4160-volt Engineered Safeguards Buses.

Normally these buses will be fed from a 4160-volt winding of the Unit Auxiliary Transformer. During start-up and shut-down, the buses will be fed from 4160-volt winding of the Start-Up Transformer No.1 or Start-Up Transformer No.2. 3 Normal and emergency bus transfers of the 4160-volt auxiliary system between the three sources will be similar to the 6900-volt system bus transfers described in 8.2.2.2 above.

The two 4160-volt Engineered Safeguards Buses will each supply equipment essential for the safe shutdown of the plant. These buses are capable of being supplied from the Unit Auxiliary Transformer 4160-volt winding or Start-Up Transformer No. 1 or Start-Up Transformer No. 2, 4160-volt winding via the 4160-volt Bus No. A1 or Bus No. A2. 3

Upon loss of normal and standby power sources the two 4160-volt Engineered Safeguards Buses will be energized from their respective diesel generator. Bus load shedding, bus transfer to the diesel generator, and pickup of critical loads will be automatic.

8.2.2.4 480-Volt Auxiliary System

The 480-volt system is divided into three load centers with two bus sections each. Power for each bus section will be supplied from a separate load center transformer. The transformers will be fed from the 4160-volt system and arranged so that each transformer of a double-ended load center unit is fed from a different 4160-volt bus. The capacities of the load center transformers and the 480-volt bus tie breakers are sufficient to permit plant operation with one transformer out of service. A spare load center transformer, interchangeable with any of the six load center transformers in service, will be provided. 3 The system will be arranged so that multiple pieces of equipment with a common function are fed from opposite buses; thus, the loss of any 480-volt bus or the failure of any single component of the 4160-volt or 480-volt systems would not deprive the plant of all equipment associated with that particular function.

A 480-volt preferred emergency ac bus, capable of being supplied from either bus section of the 480-volt engineered safeguards load center by automatic changeover of the supply breakers, will be arranged to supply such loads as emergency lighting, standby battery charger and emergency bearing oil pump. 3

Various 480-volt motor control centers will be located throughout the station to supply power to the equipment within the related area.

8.2.2.5 Dc System

A dc system will be designed to provide a source of reliable continuous power for control. Instrumentation, reactor safeguard actuation system, and other loads for normal operation and orderly shutdown.

The dc system will consist of two banks of 125 volt batteries, battery chargers, dc motor and valve control center, and power and distribution panels. A spare battery charger connected to the 480 volt preferred emergency ac bus, will be arranged to standby the battery charger connected to either bank of batteries. Dc bus low voltage and other troubles will be annunciated in the control room. The two banks of batteries will be installed in separate rooms, within Class 1 structure, above the maximum flood level. 3

8.2.2.6 120/208 Volt Instrument Ac System

A 120/208 V ac switchboard with two bus sections will be provided for normal station service and non-essential reactor auxiliary control instrumentation and instrument cooling fan power supply.

These buses have alternate supplies from two engineered safeguard motor control centers via one of two 480 - 120/208 V step-down transformers each rated to carry the full load of both bus sections. Upon the loss of one source or transformer, automatic transfer will maintain the supply from alternate source via the second transformer. Both engineered safeguard motor-control centers supplying the 480 - 120/208 V transformers are capable of being supplied from either of the two diesel generators in the case of plant emergency.

8.2.2.7 120 Volt Vital Ac System

A 120 volt uninterruptable ac power system will be provided to supply the
reactor protection and engineered safeguards control channels. This power | 3
supply system will consist of four inverters (480 volt ac and 125 volt dc input | 17
with 120 volt ac output) and four distribution panels which will provide an independent power source to each protective channel.

The essential equipment such as nuclear instruments, nuclear auxiliary instruments, integrated control devices, and control rod drive position indicating lights will be distributed and will be connected to these four panels. The computer data-logger which is non-essential for the reactor
protection system will be connected to a separate inverter unit. | 17

Inverter trouble and bus low voltage will be annunciated in the control room.

8.2.2.8 Evaluation of the Physical Layout of Electrical Distribution System Equipment

The physical locations of electrical distribution system equipment will be such as to minimize vulnerability of vital circuits to physical damage as a result of accidents. The proposed locations are as follows:

(a) Unit Auxiliary Transformer and Start-Up Transformers will be located
out of doors with sufficient physical separation from each other or | 3
separated by the fire walls. Lightning arresters will be used where applicable for lightning protection. All transformers will be covered by automatic water spray systems to extinguish oil fires quickly and prevent the spread of fire.

(b) The engineered safeguard 4160-volt switchgear and 480-volt load | 17
centers will be located within Class 1 structure area so as to | 3
minimize exposure to mechanical, fire and water damage. This equipment will be properly coordinated electrically to permit safe operation of the equipment under normal and short circuit conditions.

(c) 480-volt motor control centers will be located in the areas of electrical load concentration. Those associated with the turbine-generator auxiliary system in general will be located below the turbine-generator operating floor level. Those associated with the nuclear steam supply system will be located in areas so as to minimize their exposure to mechanical, fire and water damage.

(d) Within practical limits, nonsegregated, metal-enclosed 6900-volt and 4160-volt buses will be used for all major bus runs where large blocks of power are to be carried. The routing of this metal-enclosed bus will be such as to minimize its exposure to mechanical, fire and water damage.

(e) The application and routing of control, instrumentation and power cables will be such as to minimize their vulnerability to damage from any source. All cables will be applied using conservative margins with respect to their current carrying capacities, insulation properties and mechanical construction. Cable insulations in the Reactor Building will be selected so as to minimize the harmful effects of radiation, heat and humidity. Appropriate instrumentation cables will be shielded to minimize induced voltages and magnetic interferences. Cables related to engineered safeguard and reactor protective systems will have special red colored identification markers and will be routed and installed in such manner as to maintain the integrity of their respective redundant channels and protect them from physical damage. | 3

8.2.3 EMERGENCY POWER

The emergency power sources are designed to provide a dependable supply of power for critical services in the unlikely event of simultaneous loss of normal and standby power.

8.2.3.1 Emergency Diesel Generators

The two Engineered Safeguards Buses, each supplying equipment essential to the shutdown of the plant, are capable of being supplied from the Unit Auxiliary Transformer, or Start-Up Transformer No. 1 or Start-Up Transformer No. 2, or from either of the two emergency diesel generators. | 3

Two full capacity size diesel generator units will provide station emergency power and satisfy engineered safeguard loads for essential auxiliaries. Each generator will be supplied with a high speed voltage regulator designed to return generator voltage to rated value within a minimum delay after starting of the largest motor. The rating of each of the diesel generators and the tie breakers of the Engineered Safeguards buses is sufficient to carry the vital simultaneous load of both bus sections. If a fault occurs on one bus, that bus will be isolated. Either bus can feed the power to the equipment necessary to shut down the unit in a safe condition. | 3

Both diesel generators will be started automatically by under-voltage relays on Engineered Safeguards buses #A3 or A4 or by a safety injection signal. | 3

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In addition to starting the diesel generators the undervoltage relay on the bus will isolate the bus from its normal supply source and trip all outgoing feeder breakers.

A voltage relay connected to the potential transformers at the diesel generator terminals will detect generator rated voltage condition and provide a permissive interlock for the closing of the respective generator circuit breaker. Thus, if both diesel generators start, Engineered Safeguards buses 3
#A3 and #A4 will be supplied separately from each of the two generators with the bus tie breakers open. No automatic closing of the tie breakers between the 4160-volt engineered safeguards buses will be provided. Manual closing of these circuit breakers will also be prevented by an interlock when both emergency diesel generators are in service.

Manual closing of the breakers will be possible, only:

(a) if the 4160 volt engineered safeguard buses are being fed from the outside source and both emergency diesel generators are not in service.

(b) If on loss of offsite power only one emergency diesel generator starts or subsequent to both starting one fails in service.

As an additional measure of safety for preventing the two diesel generators from being tied together the control switches for the two bus tie breakers will have key locked handles.

The essential loads will be automatically energized in a predetermined sequence with time intervals sufficient to allow the starting inrush current to decay before proceeding with the starting of next motor. After each motor is given the signal to start the closing of the motor circuit breaker will be checked. If the circuit breaker should have failed to close an alarm window for the respective motor will be annunciated in the control room.

The diesel generator loads and the sequence of starting on emergency shut- 3
down condition are as shown in Table 8-1.

The loads required for operation in the MHA condition will be clearly below the capacity of one diesel generator, rated 2750 kw.

Spare capacity will be available for supplying vital loads not included for MHA operation, such as jockey fire pump, turbine emergency oil pump, turbine turning gear and additional motor operated valves.

One each of the primary make-up pump and service water pump motors can be 17
fed from either Engineered Safeguards Bus. The circuit breakers for the double fed motors are provided with a selector switch in order to assure proper bus selecting, and the closing circuits are interlocked to prevent both closing at the same time. Two reactor building cooler fan motors 17
are connected to each Engineered Safeguard Bus.

Each generator will be equipped with means for starting periodically 3
to test for readiness and means for synchronizing the unit onto the bus without interrupting the service.

8.2.3.2 Station Battery

The station batteries will be sized to provide power requirements for vital auxiliaries, instrumentation, control equipment and minimum amount of emergency lighting for safe plant shutdown and to provide the controls to re-energize the plant auxiliary systems from the start-up source.
The batteries will have sufficient capacity to carry emergency load for 6
a minimum period of two (2) hours without the battery chargers.

The ungrounded dc system will have detectors to indicate when there is a ground existing on either system side. A ground on one side of the dc system will not cause any equipment to malfunction.

Grounds will be located by a logical isolation of individual circuits connected to the faulted system, while taking the necessary precautions to maintain the integrity of the vital bus supplies.

8.3 TESTS AND INSPECTIONS

A program of regular inspections and functional checks of equipment and protective devices common to normal central station practice will ensure the operability of auxiliary distribution system components.

Emergency transfers to the various emergency power sources will be tested on a routine basis to prove the operational ability of these systems. Periodic operating tests will be performed on the diesel generators, the battery chargers, and the emergency lighting.

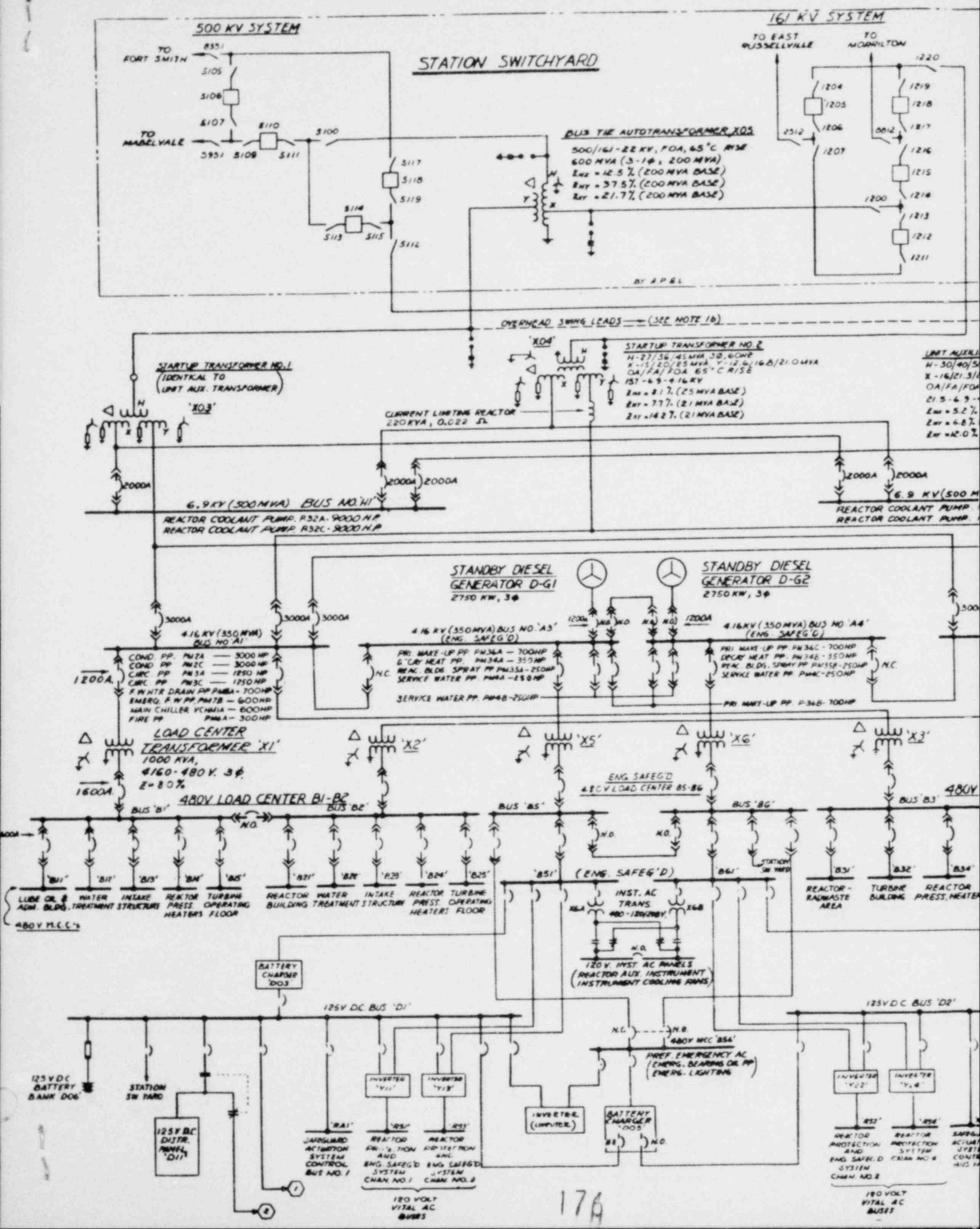
TABLE NO. 8.1

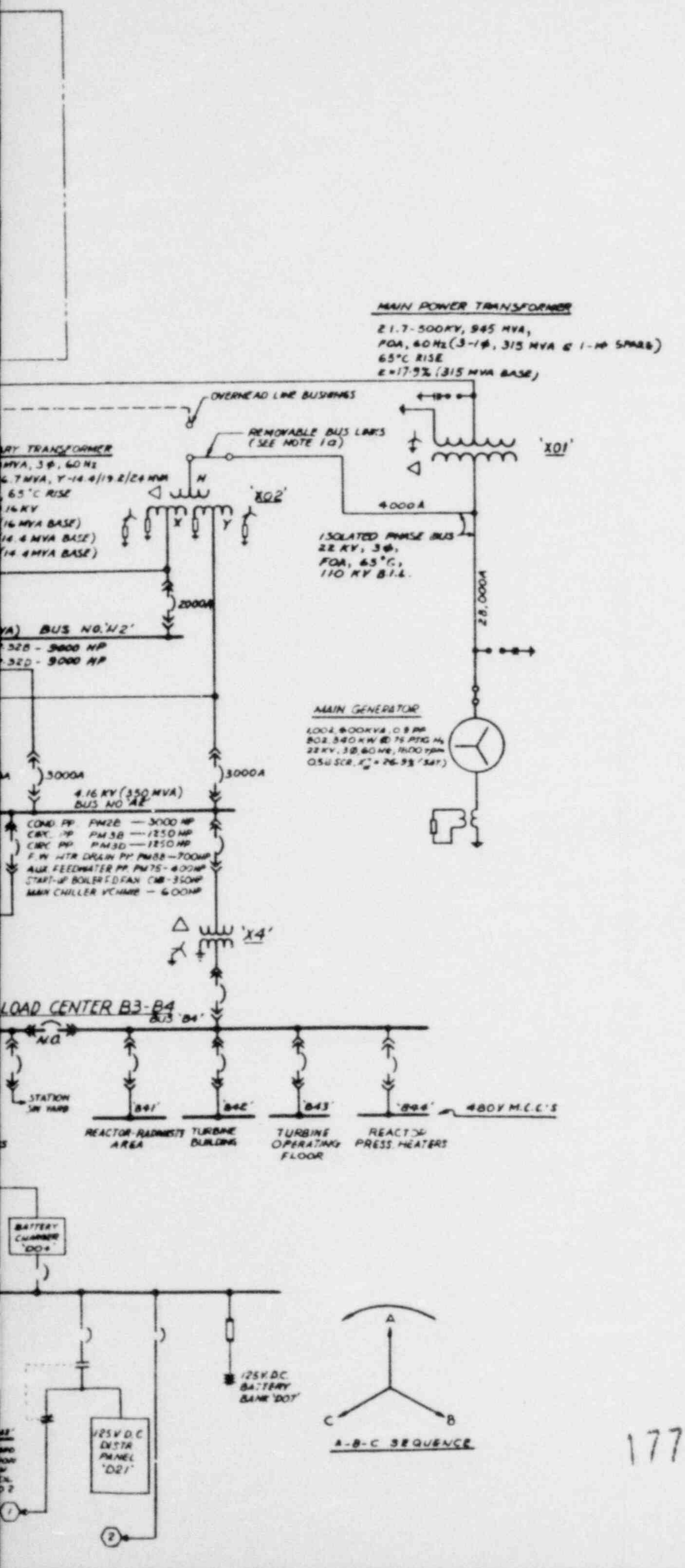
EMERGENCY DIESEL GENERATOR LOADS

EQUIPMENT	No.	H.P. Each	Load on Either Bus: Connected No.	Load on Either Bus: Connected H.P.	Load on Either Bus: For MHA No.	Load on Either Bus: For MHA H.P.	Simultaneous Load With One Diesel Gen. Oper.: Connected No.	Simultaneous Load With One Diesel Gen. Oper.: Connected H.P.	Simultaneous Load With One Diesel Gen. Oper.: For MHA No.	Simultaneous Load With One Diesel Gen. Oper.: For MHA H.P.	Starting Sequence	Time From Safety Inject Signal
Load Center Transf. Supplying:											1(1)	15
Reactor Bldg. Cooler Fans(2)	4	75	2	150	2	150	2	150	2	150		
H.P. Injection MOV's	6	5	3	15	3	15	3	15	3	15		
L.P. Injection MOV's	6	3	3	9	3	9	3	9	3	9		
Spray System MOV's	4	3	2	6	2	6	2	6	2	6		
Service Water Syst. MOV's	20	2	6	12	6	12	14	28	6	12		
Cont. Rm. Air Conditioner	1	15	1	15	1	15	1	15	1	15		
E.S. Relay Rm. Air Cond.	1	10	1	10	1	10	1	10	1	10		
Cont. Rm. Emerg. Air Filter	1	2	1	2	1	2	1	2	1	2		
Decay Ht. Removal Rm-Unit Coolers	4	5	2	10	1	5	2	10	1	5		
Emerg. Diesel Gen. Rm. Exh. Fans	4	7.5	2	15	2	15	2	15	2	15		
*Spent Fuel Pool Cooling Pp	2	60	1	60	-	--	1	60	-	--		
*Turb. Emerg. Brg. Oil Pp	1	60	1	60	-	--	1	60	-	--		
*Turbine Turning Gear	1	50	1	50	-	--	1	50	-	--		
Diesel Oil Transf. & Misc. Sump Pumps				60		60		60		60		
NSSS Inst. & Cont. Rod Cont.				7.5		7.5		15		15		
Battery Chgr. Emerg. Ltg.				200		200		300		200		
*T.G. Bearing Lift Oil Pump	1	15	1	15	1	15	1	15	1	15		
Primary Make-up Pumps	3	700	1	700	1	700	1	700	1	700	2	20
Decay Heat Pumps	2	350	1	350	1	350	1	350	1	350	3	25
Service Water Pumps	3	250	1	250	1	250	1	250	1	250	4	30
Reactor Bldg. Spray Pumps	2	250	1	250	1	250	1	250	1	250	5	35
TOTAL MAXIMUM EXPECTED LOAD IN H.P.				2246.5		2071.5		2370		2079		

(1) Load Center Breaker Closes and loads energized in required sequence.

(2) Second Cooler Fan manually switched if one diesel fails to start.
*No aut[illegible]tic start signal from Engineered Safeguard System


500 KV SYSTEM
STATION SWITCHYARD
161 KV SYSTEM
TO FORT SMITH
TO MABELVALE
TO EAST RUSSELLVILLE
TO MORRILTON
BUS TIE AUTOTRANSFORMER X05
500/161-22 KV, FOA, 65°C RISE
600 MVA (3-1φ, 200 MVA)
BY A.P.&L.
OVERHEAD SWING LEADS — (SEE NOTE 16)
STARTUP TRANSFORMER NO. 2
STARTUP TRANSFORMER NO. 1
(IDENTICAL TO UNIT AUX. TRANSFORMER)
'X03'
'X04'
CURRENT LIMITING REACTOR
220 KVA, 0.022 Ω
6.9 KV (500 MVA) BUS NO. 'H1'
REACTOR COOLANT PUMP P32A - 9000 H.P.
REACTOR COOLANT PUMP P32C - 9000 H.P.
STANDBY DIESEL GENERATOR D-G1
2750 KW, 3φ
STANDBY DIESEL GENERATOR D-G2
2750 KW, 3φ
4.16 KV (350 MVA) BUS NO 'A1'
4.16 KV (350 MVA) BUS NO. 'A3' (ENG. SAFEG'D)
4.16 KV (350 MVA) BUS NO 'A4' (ENG. SAFEG'D)
SERVICE WATER PP. PM4B - 250HP
PRI. MAKE-UP PP. P36B - 700HP
LOAD CENTER TRANSFORMER 'X1'
1000 KVA,
4160-480 V. 3φ
Z=8.0%
'X2'
'X5'
'X6'
'X3'
480V LOAD CENTER B1-B2
ENG. SAFEG'D 480V LOAD CENTER B5-B6
BUS 'B1'
BUS 'B2'
BUS 'B5'
BUS 'B6'
BUS 'B3'
LUBE OIL & ADM. BLDG.
WATER TREATMENT
INTAKE STRUCTURE
REACTOR PRESS. HEATERS
TURBINE OPERATING FLOOR
REACTOR BUILDING
480V M.C.C.'s
(ENG. SAFEG'D)
INST. AC TRANS.
120 V. INST. AC PANELS
(REACTOR AUX. INSTRUMENT INSTRUMENT COOLING FANS)
REACTOR - RADWASTE AREA
TURBINE BUILDING
BATTERY CHARGER 'D03'
125V DC BUS 'D1'
125V DC BUS 'D2'
125 V DC BATTERY BANK 'D06'
STATION SW YARD
125 V DC DISTR. PANEL 'D11'
INVERTER 'Y11'
INVERTER 'Y13'
INVERTER (COMPUTER)
BATTERY CHARGER 'D05'
480V MCC 'B56'
PREF. EMERGENCY AC
(EMERG. BEARING OIL PP)
(EMERG. LIGHTING)
INVERTER 'Y22'
INVERTER 'Y24'
SAFEGUARD ACTUATION SYSTEM CONTROL BUS NO. 1
REACTOR PROTECTION AND ENG. SAFEG'D SYSTEM CHAN. NO. 1
REACTOR PROTECTION AND ENG. SAFEG'D SYSTEM CHAN. NO. 3
REACTOR PROTECTION AND ENG. SAFEG'D SYSTEM CHAN. NO. 2
120 VOLT VITAL AC BUSES



NOTE

1. IN EVENT OF STARTUP TRANSFORMER No1 FAILURE:
   a. RECONNECT REMOVABLE 1800 AMPERE BUS LINKS FROM GENERATOR BUS TO OVERHEAD LINE BUSHINGS.
   b. SWING OVERHEAD LEADS FROM STARTUP TRANSFORMER NO. 1 TO UNIT AUX. TRANSFORMER.

SINGLE LINE DIAGRAM.

Figure 8-1

Supplement No.17