**OPERATING EXPERIENCE AND EVALUATION OF THE EBR-II
EMERGENCY POWER SYSTEM**

by

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EBR-II Project

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ABSTRACT

This report presents the history, growth, and operating experience associated with the emergency power system for Experimental Breeder Reactor II (EBR-II). For the purposes of this report, the EBR-II emergency power system includes the reactor plant, power plant, sodium boiler plant, Fuels and Examination Facility, laboratory and office building, and miscellaneous yard facilities. The general arrangement of the system, the present load, and the anticipated load growth are described.

Evaluation of the EBR-II emergency power system indicates that portions of the system subject to anticipated load growth are loaded to capacity. Modifications to provide overload relief and to improve system reliability are proposed.

I. BACKGROUND

In the original planning for the EBR-II electrical system, the entire distribution of 480-V emergency power was from one power source, a diesel-fired engine-generator set rated at 500 kVA (400 kW), 480 V, 3 phase. As backup, in the event this primary source of emergency power failed to operate, a separate supply, a diesel-fired engine-generator set rated at 125 kVA (100 kW), was arranged to automatically assume critical emergency loads associated with reactor safety. The ratings selected for the equipment of the emergency power system were based on the information on emergency loading available at the time the equipment was sized. To expedite completion of the EBR-II facility, many long-delivery items, including the engine-generator sets mentioned above, were ordered before engineering was completed.

As design progressed, the contemplated load on the emergency system increased. To take full advantage of the emergency power supplies, the philosophy of operation was revised to permit simultaneous starting and loading of both generating units. If the 100-kW unit failed to start under this mode of operation, the 400-kW unit would automatically assume the critical reactor loads.

All the 480-V power loads on the emergency power system are full-voltage start. Furthermore, most of the equipment is automatically started (since it is critical) and theoretically would have loaded the generators simultaneously. Such a condition would cause an excessive drop in generator-terminal voltage and a resulting possible dropout of motor starters during the starting periods. To prevent this occurrence, a time-delayed step loading of the generators was incorporated into the design. Further study revealed that certain loads initially assumed to require emergency power were not critical. A load-shedding feature was added to prevent starting of these loads under emergency operation.

The final design addition was inclusion of a 250-kVA (200-kW) diesel-generator set (from surplus) to supply emergency power for the Fuels and Examination Facility (FEF, then called the Fuel Cycle Facility), suspect-exhaust fans, and other miscellaneous yard facilities. Figure 1 shows a simplified single-line diagram of the 480-V emergency power system as it now exists.

II. DESCRIPTION OF SYSTEM

A. General Arrangement

The emergency power system consists of the 480-V emergency switchgear E-1, motor control center R2 (MCC-R2), emergency bus sections of four motor control centers (MCC-R1B, -P1B, -S1B, and -F1B), and the automatic-starting 400-kW, 100-kW, and 200-kW diesel-driven emergency generators. All the equipment is physically located in the power plant except: emergency bus MCC-S1B, which is in the sodium boiler plant; emergency bus MCC-F1B and the 200-kW generator and its associated automatic transfer switch (ATC), which are in the FEF; and another ATC in the laboratory and office (L&O) building.

Fig. 1. Simplified Single-line Diagram of EBR-II Emergency Power System

B. Normal Power Operation

Normal power is supplied to the 480-V emergency switchgear E-1 from feeder circuit breaker 3B in the 480-V main switchgear. The 400-kW, 100-kW, and 200-kW diesel generators are in standby condition, with automatic controls positioned to start the units on loss of normal power. MCC-R2, L&O emergency loads, and emergency buses MCC-R1B, -P1B, -S1B, and -F1B are supplied through the appropriate feeder circuit breakers in switchgear E-1.

Emergency buses MCC-R1B, -P1B, and -F1B are connected to their respective normal power buses by normally open tie breakers. Automatic controls close the bus tie breaker if power is lost on the emergency bus and the normal bus remains energized. This feature protects against loss of an individual emergency-system feeder. MCC-S1B uses contactors to accomplish the same purpose.

The ATC in the FEF is connected to the switchgear E-1 feeder with controls positioned to transfer the load to the 200-kW diesel generator on loss of normal power. The L&O automatic transfer switch operates connected to the emergency feeder, with controls positioned to transfer to the normal power feeder on loss of emergency power when the normal feeder remains energized. Switches are provided to isolate the automatic transfer switch for maintenance.

C. Emergency Power Operation

Loss of site electrical power initiates the following automatic response in the emergency power system.

The 400-kW, 100-kW, and 200-kW diesel generators start and come up to speed. MCC-R2 is isolated from the total system and supplied directly by the 100-kW diesel generator. The ATC in the FEF transfers the emergency load to the 200-kW diesel generator and isolates the FEF from the total system. All remaining loads are supplied by the 400-kW diesel generator through emergency switchgear E-1, which is isolated from the normal power system by the automatic opening of breaker 3B in the 480-V main switchgear. The system will continue to operate in this mode until site power has been restored and the system is manually converted to the normal operating mode in accordance with operating procedures.

If the 100-kW diesel generator fails to start or shuts down after starting, the critical loads on MCC-R2 will be automatically transferred to the 400-kW diesel generator through MCC-R1B.

A more extensive description of operation of the emergency power system during various partial failures of normal power is given in Volume 5 of the EBR-II System Design Descriptions and in ANL-7202,* which discusses electrical design of EBR-II.

III. LOADING AND OPERATIONAL EVALUATION OF SYSTEM

A. Loading

As discussed in Sec. I, several modifications of the basic emergency system were initiated to assure proper load distribution and reliability of operation. Studies indicated that some loads connected to the system did not require emergency power. These loads (listed in Table I) are disconnected from the system during emergency operation.

TABLE I. Loads Automatically Disconnected from Emergency Power System during Power Outage

<u>Load No.</u>	<u>Nameplate Description</u>	<u>Load, kVA</u>
PM-10	Htg. & Vent. Unit Fan (North)	5
PM-11	Htg. & Vent. Unit Filter (North)	1/6
PM-12	Htg. & Vent. Unit Fan (South)	5
PM-13	Htg. & Vent. Unit Filter (South)	1/6
PM-36	Data Logger Refrigeration Compressor	1-1/2
PM-75	Vapor Extractor	3/4
PF-33	Cooling Tower	10
PM-171	Silicone Pump No. 1	15
PM-172	Silicone Pump No. 2	15
PM-56 ^a	Auxiliary Boiler Feed Water Pump	40
PF-30	Fuel Cycle Facility Emergency Feeder	120

^aAdministrative control of PM-56 permits manual standby operation if required.

*F. Verber and H. L. Schmidt, The Electrical Design of the EBR-II, ANL-7202 (June 1966).

The emergency system is arranged to automatically start the diesel generators whenever a power failure occurs and to transfer the essential services to emergency power after the generators have stabilized at operating speed. Time-delayed step loading of the generators was incorporated to prevent excessive terminal voltage drop caused by simultaneous starting of motors. The delay sequences resulted from a series of field tests conducted in 1961 and 1962.

The loads automatically applied to the 100-kW diesel generator are listed in Table II. If that generator fails to start or shuts down after starting, these loads are transferred automatically to the 400-kW diesel generator.

TABLE II. Loads Automatically Applied to 100-kW Diesel Generator during Power Outage

<u>Load No.</u>	<u>Nameplate Description</u>	<u>Load, kVA</u>	<u>Delay, sec</u>
RM-50	Shield Cooling Exhaust Fan 2	30	20
RM-51 ^a	Shield Cooling Exhaust Fan 1	30	20
RM-52	Thimble Cooling Compressor 1	60	b
RM-53 ^a	Thimble Cooling Compressor 2	60	b
RM-67	Pilot Light Transformers	2	b
RM-68	Emergency Instrument Air Compressor	1.5	b
RF-13	Shield Cooling Supply Fan Dampers		
	RM-99	0.25	b
	RM-100	0.25	b
RF-13C	Shield Cooling Supply Filters Dampers		
	RM-101	0.25	b
	RM-102	0.25	b

Total connected load (net), 94.5 kVA

^a Standby operation--only one motor for this service will operate at one time.

^b No intentional delay.

The loads automatically applied to the 200-kW diesel generator in FEF are listed in Table III. On loss of normal power, circuit breaker 1A in switchgear E-1 opens and locks out to isolate the FEF emergency loads.

The remaining emergency power loads are applied to the 400-kW diesel generator. Table IV lists the loads that are automatically connected to

TABLE III. Loads Automatically Applied to 200-kW Diesel Generator during Power Outage

<u>Nameplate Description^a</u>	<u>Load, kVA</u>
Stack Exhaust Fan 1	60
Stack Exhaust Fan 2 ^b	60
Emergency Instrument Air Compressor	3
Instrument Power	10
Sodium Cleanup Exhauster	40
Suspect Exhaust Fan 1	60
Suspect Exhaust Fan 2	60
Sodium Cleanup Pump	2
Freight Elevator	5
Emergency Lighting	15
Stack Feeder	4.5
Total connected load (net), 200 kVA	

^aNone of the listed loads has an intentional delay.

^bStandby operation--only one motor for this service will operate at one time.

TABLE IV. Loads Automatically Applied to 400-kW Diesel Generator during Power Outage

<u>Load No.</u>	<u>Nameplate Description</u>	<u>Load, kVA</u>	<u>Delay, sec</u>
None	Pump Pit Sump Pump	0.5	a
PM-77	Turning Gear Oil Pump	5	a
PM-90	Instrument Air Compressor No. 1	50	a
PM-91	Instrument Air Compressor No. 2	50	a
PM-94	Continuous Power Supply	115	a
PG-383	Annunciator	10	a
PF-74	Control Power System (PG-1)	10	a
PM-74	Hydrogen Seal Oil Pump	2	a
PM-119	Duplex Condensate Pump	3	a
PM-120	Duplex Condensate Pump	3	a
RF-11	Emergency Panel RE-1	5	a
PF-63	Sodium-Boiler Plant	0.3	a
PM-64	Demineralizer Service Pump No. 1 (make-up)	7.5	a
PM-65	Demineralizer Service Pump No. 2 (make-up)	7.5	a
RF-14	Refueling Machine (RE-3)	10.75 & 5.2 kW	a
RM-45	Argon Blower No. 1	5	a
RM-46	Argon Blower No. 2	5	a
PF-11	Guard House & Fire House Emer. Feeder	11.5	a
PM-59	Emergency Instrument Air Compressor	2	10
PM-96	Station Battery Charger	5	10
PM-115	Cooling Water Pump No. 1	15	10
PM-116	Cooling Water Pump No. 2	15	10
RM-48	Shield Air Recirculating Fan No. 1 (Supply Fan)	20	10
RM-49	Shield Air Recirculating Fan No. 2 (Supply Fan)	20	10
RM-54	Refrigeration Compressor No. 3	40	20
RM-62 ^b	Refrigeration Compressor No. 1	20	20
RM-63 ^b	Refrigeration Compressor No. 2	20	20
	Compressors No. 1, 2, 3 Auxiliaries and Heaters	7.5 & 20 kW	a

Table IV (contd)

<u>Load No.</u>	<u>Nameplate Description</u>	<u>Load, kVA</u>	<u>Delay, sec</u>
PF-31	Laboratory and Office Building		20
	L & O Cond. Pump No. 1	7.5	
	L & O Cond. Pump No. 2	7.5	
	Emergency Lighting Transformer	15	
	EVAC Sirens & Reproduction Machine	1	
	L & O Floor Drain Sump No. 1	0.5	
	L & O Floor Drain Sump No. 2	0.5	
	Annex Cond. Pump No. 1	0.5	
	Annex Cond. Pump No. 2	0.75	
	Sodium Chem. Lab. Exhaust Fan No. 1	15	
	Sodium Chem. Lab. Exhaust Fan No. 2	15	
	Emergency Lighting Transformer	6	
L11M-311A ^c	Main Exhaust Fan (West)	20	a
L11M-311B	Main Exhaust Fan (East)	20	a
LM-707A	Process Water Pump (South)	5	a
LM-707B ^c	Process Water Pump (North)	5	a
RM-52 ^d	Thimble Cooling Compressor No. 1	60	50
RM-53 ^{c,d}	Thimble Cooling Compressor No. 2	60	50
PF-67 ^d	Pilot Transformers	2	50
RF-13 ^d	Shield Cooling Supply Fan Dampers		
	RM-99	0.25	50
	RM-100	0.25	50
RF-13C ^d	Shield Cooling Supply Filters Dampers		
	RM-101	0.25	50
	RM-102	0.25	50
RM-68 ^d	Emergency Instrument Air Compressors (Reactor Plant)	1.5	50
RF-35A	Auxiliary Primary Sodium Pump	50	a
RF-69	Personnel Air Lock	1	a
RM-50 ^d	Shield Cooling Exhaust Fan No. 2	30	70
RM-51 ^d	Shield Cooling Exhaust Fan No. 1	30	70
PF-34	Emergency Lighting Panel PE-1	15	5 minutes
Total connected load (net), 510 kVA			

^aNo intentional delay.

^bCompressors RM-62 and RM-63 will operate simultaneously as a standby for RM-54, but not at same time as RM-54.

^cStandby operation--only one motor for this service will operate at one time.

^dApplied to 400-kW generator if 100-kW generator fails.

this generator, and Table V lists those that can be manually applied as required. An example of the latter type of electrical load is operation of the reactor-building rotary bridge crane to position the hoist for lowering to the floor after normal power was lost.

TABLE V. Loads Manually Applied to 400-kW Diesel Generator during Power Outage

<u>Load No.</u>	<u>Nameplate Description</u>	<u>Load, kVA</u>
RF-10	Rotary Bridge Crane	67
RM-60	Air Supply Fan	30
RM-66	Purge Exhaust Fan	5
RF-71	Equipment Air Lock	1
RM-73	Equipment Air Lock Cart	0.75
RF-14	Large Rotating Plug Seal Heaters	30 kW
PM-50	Auxiliary Boiler No. 1 Forced Draft Fan	10
PM-53	Auxiliary Boiler No. 2 Forced Draft Fan	10
PM-56	Auxiliary Boiler Feed Water Pump	40
PM-57	Diesel Oil Pump	2
PM-58	Fuel Oil Pump	5.25
PM-76	Turning Gear	1.5
PM-94M1 ^a	Continuous Power Supply	50
RF-35A	Auxiliary Primary Sodium Pump	50
None	Evacuation Siren	10
PF-96	Auxiliary Boiler No. 3	7.5 & 20 kW

^aPM-94M1 is standby for PM-94 and will not operate when PM-94 is in service.

The connected load (net) listed for each generator (Tables II-IV) is the total connected load less the standby loads. The gross connected load is considerably greater; however, a more realistic load picture is obtained by using net values.

Table VI represents the actual demand loading on each generator during site power outages since September 1969.

TABLE VI. Measured Demand Loads (in Amperes) on Emergency Generators during Power Outages

Date	Generator Capacity, kW		
	100	200	400
9/26/69	95	180	400-580 ^a
12/8/69	90	135	420
5/20/70	92	150	480
10/24/70	92	170	480
1/20/71 ^b	92	135	295

^a100-kW load was transferred to 400-kW generator to check transfer system.

^bPlant down for long shutdown when outage occurred.

The demand load on the 100-kW generator is very constant between 90 and 95 A. Although the 100-kW generator could carry 150 A full load, the type of load (see Table II) and the starting inrush current on the diesel engine effectively load the generator to its capability. Field tests conducted in 1961 to establish the step-loading scheme also confirmed the loading condition. However, 15 kW additional load could be added to the 100-kW generator under strictly time-delayed and controlled conditions, if this additional loading were necessary for reactor safety.

The 200-kW generator, in the FEF, is approximately 60% loaded. The new Fuel Assembly and Storage Building under construction will ultimately increase the load 20 kW. With this addition, approximately 60 kW of growth capacity will remain, and no further increase in emergency requirements is contemplated at present.

Full-load capacity for the 400-kW generator is 600 A. The average loading under emergency operation is 480 A, although indications as high as 550 A have been observed during test runs. During the September-1969 outage (see Table VI), the 100-kW generator was shut down to simulate failure and verify the automatic transfer of the critical loads to the 400-kW generator. With this operating condition, the load current reached 580 A, or 97% of full-load capacity. Since the design philosophy requires the 400-kW generator to have this back-up capability, the generator is considered to be fully loaded.

Because the 400-kW generator does not have spare capacity, 17.5 kW of load in the new Sodium Chemistry Laboratory addition to the L&O building that would ordinarily be connected directly to emergency power is designed for normal power supply with administrative control on transfer to the emergency system.

Proposed additions that will require emergency power are 15 kW for a water chemistry lab addition, 10 kW for a drum-charging and hydrotest pump, and 10 kW for an instrumented-subassembly power supply. With the proposed additions, including the existing administratively controlled loads, the 400-kW system would be overloaded approximately 50 kW. Therefore, only selected additions can be accommodated with the present capacity.

B. Operational Evaluation

The diesel engines are test-run once weekly for a period of 30 min. During the test run, the mechanical features of the engine control circuit and the fuel and exhaust systems are inspected. As necessary, malfunctions are corrected. There has never been a diesel-engine startup failure during emergency operation at EBR-II.

An electrical load test is conducted on each diesel generator twice annually. The exact schedule is subject to plant operational requirements. A failure of the normal power system is simulated by opening the main 480-V switchgear circuit breaker 3B (see Fig. 1), and the automatic actions of the system are observed and recorded. Minor malfunctions in the control circuits of the transfer scheme were prevalent in the early history of the system, but have been eliminated by modifying the circuits. The most difficult problem to eliminate was the occasional failure of the breaker of the 400-kW generator to remain closed after operation. The control relays would operate and the circuit breaker would close; but the breaker would fail to latch in, would bounce open, and thus unload the generator. After much study and test operation, one control relay was replaced in October 1970. Since then, the system has operated satisfactorily.

IV. PLANS FOR MEETING FUTURE NEEDS

To improve the existing load conditions on the 400-kW generator and eliminate the obvious overload that will occur with the proposed emergency power additions, a proposal for FY 1971, entitled "Increased Emergency Generator Capacity," has been initiated. This proposal includes addition of a 100-kW diesel generator to supply all existing loads of the L&O building, including the Sodium Chemistry Laboratory addition and the yard emergency lighting. The total existing load that will be transferred to this generator from the 400-kW generator will be approximately 45 kW.

Because of the many control-circuit malfunctions associated with the use of circuit breakers for transferring from normal to emergency 400-kW power, a plant modification incorporating an automatic transfer switch to replace the breaker transfer scheme has been proposed and is being studied.

The 200-kW generator has ample capacity for all foreseeable emergency requirements in the FEF.....

It is not anticipated that loads will be added to the 100-kW generator, but addition of small critical reactor loads (less than 15 kW) could be considered if required.