9.5.6 Diesel Generator Starting Air System

The EDG starting air system, diesel generator starting air system (DGSAS), is designed to start the EDG by using compressed air to rotate the engine until combustion begins and it accelerates under its own power. The DGSAS is divided into two parts, a safety-related portion, which is that portion downstream of and including the starting air receiver tank inlet check valves, and the remainder of the system which is non-safety related.

9.5.6.1 Design Basis

The safety-related portion of the DGSAS is required to function following a DBA and to achieve and maintain the plant in a safe shutdown condition.

- The DGSAS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles by its location within the Seismic Category 1 EPGB (GDC 2).
- The safety-related portion of the DGSAS remains functional after an SSE and performs its intended function following the postulated hazards of fire, internal missiles, or pipe break (GDC 3 and 4).
- No portion of the DGSAS is shared with any other division or unit (GDC 5).
- Safety functions can be performed, assuming a single active component failure coincident with the LOOP due to the 4 X 100 percent redundant design structure of the EDG (GDC 17).
- The active components are capable of being tested during plant operation. Provisions are made to allow inservice inspection of components (GDC 45 and 46).
- The safety-related portion of the DGSAS is designed and fabricated to codes consistent with the quality group classification assigned by RG 1.26 and the seismic category assigned by RG 1.29. The power supply and control functions are in accordance with RG 1.32.
- The capability to isolate components, systems, or piping is provided, where possible, so that the system safety function is not compromised. This includes isolation of components to deal with leakage or malfunctions and to isolate non-safety-related portions of the system (GDC 44).
- The safety-related portion of the DGSAS is capable of storing sufficient air to allow for at least five consecutive crank cycles of approximately three seconds or two to three revolutions of the diesel engine without recharging the receivers, or the air start requirements per engine start as specified by the engine manufacturer; whichever air start requirement is larger.
- The non-safety-related portion of the DGSAS performs no safety-related function and is designed non-safety-related and Seismic Category NSC.

The non-safety-related portion of the DGSAS performs the following functions:

- The DGSAS air compressors supply the starting air receivers for the diesel engines with compressed air.
- Additionally, each compressor is equipped with an air dryer which reduces the moisture content of the compressed air supplied to the starting air receivers.

9.5.6.2 System Description

9.5.6.2.1 General Description

The DGSAS is shown schematically in Figure 9.5.6-1—Emergency Diesel Generator Starting Air System. This schematic shows valve arrangements to provide component isolation capability in the event of system leakage. The starting air receiver inlet check valves provide isolation between the safety-related and non-safety-related portions of the system.

Each EDG has its own starting system. The starting system for each diesel engine is a dedicated and independent starting air system. Each starting air system consists of two electrically driven compressors, two air dryers and filters, two starting air receivers, compressed air piping, valves, controls, and instruments. Each engine has its own engine-driven air start distributor with a pilot air connection to each cylinder for operating air starting valves.

Starting air pressure is also used to operate the governor servo rack booster which opens the fuel injection pump racks to provide adequate fuel at startup. For emergency shutdown, the governor shutdown solenoid internal to the governor operates which causes the governor to close the fuel racks.

The layout of the piping and main components (i.e., compressors, air dryers, air receivers, valves and filters) provides the space required to permit inspection, cleaning, maintenance, and repair of the system.

The pressure transmitters associated with the pressure indicators on the local control panel are supplied with air from the starting air system.

9.5.6.2.2 Component Description

The major components of the DGSAS are described in the following paragraphs. The safety classification and seismic design classification for these components, along with their design and fabrication code, are provided in Table 3.2.2-1—Classification Summary.

Electrically driven Compressors

The air compressors are driven with an electric motor and receive power from the associated EDG switchgear. Each compressor is equipped with an air intake filter and intercooler. The intercooler of each compressor is equipped with an automatic blowdown device that operates during compressor operation and a manual drain to remove any accumulated water. The compressors start/stop functions are automatically controlled by a pressure switch monitoring the starting air receiver pressure. The compressors are non-safety related. Each compressor has a non-safety-related air cooled aftercooler to cool the compressed air. The compressors are designated as primary and backup. The backup compressor will start on a falling pressure in the receivers if the primary compressor fails to start or is unable to maintain system pressure. Both compressors start upon an engine start to minimize the time required to restore receiver pressure.

The air compressors are reciprocating type compressors. Each compressor is capable of recharging the associated receiver tanks within 30 minutes following five EDG start attempts.

Moisture and Oil Separator

The moisture and oil separator removes entrained moisture and oil from the air flow to improve the efficiency of the air dryer. The separator has a temperature, pressure, and flow rating compatible with the compressor rated discharge conditions. The separator is equipped with an automatic drain trap and automatic and manual blowdown valves.

Air Dryer and Filter

An air dryer is provided in each starting air train. The dryer includes a prefilter. The dryer provides moisture-free air with a dew point of not more than 50°F when installed in a normally controlled 70°F environment; otherwise, at least 10°F less than the lowest expected ambient temperature. The air dryer and filter cleans and dries the air discharged from the compressor prior to entering the starting air receivers during recharging. The dryer package is non-safety related.

Starting Air Receivers

The starting air receivers are tanks that have the capacity to allow at least five start attempts of the EDG from the low pressure alarm setpoint of the receiver. A start cycle is defined as an air admission of at least three seconds, resulting in two to three revolutions of the engine. Overpressure protection is provided by safety valves installed on the top of each air receiver. Each tank has an access for internal inspection and cleaning and is equipped with an automatic drain trap with a manual bypass for removing moisture. Each tank is equipped with an inlet and outlet isolation valve to allow for system maintenance upstream and downstream of the tank. Tank

pressure instrumentation provides indication for local and remote monitoring panels, and on local gauges on each receiver. The starting air receivers for the EDGs are safety related.

Control Air Circuit

The control air circuit consists of starting pilot air valves, main air start valves, distribution valve, and injection valves for engine starting; and solenoid operated booster valve to supply control air to the engine governor booster for emergency fast engine starts. Each component in the control air circuit for the EDGs is safety related.

9.5.6.3 System Operation

9.5.6.3.1 Normal Operation

Each EDG is provided with an independent starting air system, consisting of two electrically driven air compressors, two air dryers and air filters, compressed air receivers, monitoring equipment, compressed air piping, and isolation, relief, and starting valves.

Ambient air from within the engine room is compressed, dried, filtered, and then stored in the receiver tanks. The starting air storage capacity for each diesel engine is sufficient for a minimum of five successful engine starts without recharging the receiver tanks.

The start valves are controlled by solenoid pilot valves. The solenoid booster valve controls air to the engine governor boost actuator. An emergency start signal energizes the start valve and the booster valve according to the following sequence:

1. The start valve and the booster valve are energized to setpoint speed of the engine, and the engine speed increases continuously up to the idle speed in the test mode or rated speed in emergency mode.

2. If the setpoint speed is reached within the specified time window, the EDG startup is successful.

3. If the setpoint speed is not reached in the specified time window, the start air valve is de-energized and the start is unsuccessful. If necessary, a new manual start attempt can be performed after an unsuccessful start.

The starting air receivers also provide air to the engine control panel instrumentation.

9.5.6.3.2 Abnormal Operation

In case of abnormal operation during an emergency start, an alarm signal is provided to the MCR. If the failure is one that will jeopardize continued operation, a trip signal is activated. The EDG emergency trips are listed in Chapter 16, B 3.8.1, SR 3.8.1.13.

All other alarmed conditions will require operator evaluation to determine if continued operation is feasible. Operators can activate a manual trip at any time.

In case of abnormal operation during periodic start, an alarm signal is provided to the MCR. If the failure jeopardizes the equipment during a test or surveillance start, a trip signal is activated.

9.5.6.4 Safety Evaluation

- The safety-related portion of the DGSAS is located in the EPGBs. The EPGB is designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other similar natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

- The safety-related portion of the DGSAS is designed to remain functional after an SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. There are no high- or moderate-energy lines in the EPGB whose failure could alter the function of more than one DGSAS. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to make sure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

- The DGSAS for each diesel engine is independent of any other diesel engine system. This precludes the sharing of any systems and components important to safety that could prevent those systems or components from performing required safety functions.

- The four-division design of the EDGs provides complete redundancy. A single failure in one division of the DGSAS safety-related portion will not compromise the EDG safety function. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8. This meets the recommendation of NUREG/CR-0660 (Reference 1).

- The DGSAS is initially tested using the program described in Chapter 14. Periodic inservice functional testing is carried out in accordance with Section 9.5.6.5.

- Section 3.2 delineates the quality group classification, seismic category, and design and fabrication codes applicable to the safety-related portion of this system and supporting systems. The power supplies and control functions necessary for safe function of the DGSAS are Class IE, as described in Chapters 7 and 8.

- Section 9.5.6.2 describes provisions to identify and isolate leakage or malfunction and to provide isolation of the non-safety-related portions of the system.

- Each engine starting air system has independent starting air receivers. Each set of receivers has a sufficient capacity to provide at least five diesel engine starts. A start cycle is defined as an air admission of at least three seconds resulting in two to three revolutions of the engine.

- The safety-related function of the DGSAS is to start the EDG. No starting air is required for continued diesel operation once the engine is running.

9.5.6.5 Inspection and Testing Requirements

Tests will be conducted concurrently with the qualification testing of the EDGs to verify the capability of the DGSAS to start the diesel engine. Preoperational testing is described in Chapter 14 and Section 14.2, tests #104, 105, and 106.

The DGSAS will be subjected to preservice inspection and testing in accordance with applicable codes, regulatory requirements, and manufacturer recommendations to prove its design adequacy and performance per RG 1.9. The DGSAS will be subjected to inservice inspections and testing in accordance with applicable codes, regulatory requirements and manufacturer's recommendations to confirm its availability in case of LOOP per RG 1.9.

When the engine is on standby, the starting air system is normally pressurized up to the air start solenoid valves. Instrumentation is provided to indicate and alarm when there is a loss of air pressure.

The safety-related portions of the DGSAS are designed and located to permit required Section XI testing.

9.5.6.6 Instrumentation Requirements

Each diesel engine is provided with instrumentation to monitor the operation of the DGSAS. Alarms are separately annunciated on the local diesel engine control panel which also signals a general diesel trouble alarm in the MCR. The DGSAS is provided with the indicators and alarms as shown in Table 9.5.6-1.

Instrumentation and controls for the DGSAS are designed to provide the following safety-related control functions:

- Control air regulation – The air control pressure is controlled with an autonomous pressure reducing valve. The actuator used to perform this function is as follows:
  - Autonomous pressure reducing valve A.
  - Autonomous pressure reducing valve B.
- Start function – Emergency start signal energizes the start solenoid valve. The start solenoid valve controls the main air starting valve. The actuators used to perform these functions are as follows:
  - Start solenoid valve A.
  - Start solenoid valve B.

- Governor boost – Emergency start order energizes the governor boost solenoid valves. The governor boost solenoid valve controls the governor boost actuator. The actuators used to perform these functions are as follows:
  - Governor boost valve A.
  - Governor boost valve B.
  - Governor boost actuator.

Instrumentation and controls for the DGSAS are designed to provide the following non-safety control functions:

- Automatic compressor control – The air compressors can be controlled in automatic or manual mode from the MCR. The receiver pressure monitors initiate start and stop of the compressors, as necessary, to maintain the required system pressure.
- Manual compressed air supply – The air compressors also can be controlled manually from the MCR.
- Monitoring of compressed air supply – The pressure in the compressor discharge header is continuously monitored during compressor operation. An alarm is issued if the pressure falls below the required limits. The standby compressor will receive and auto start signal on this alarm. Operation of the compressor is also monitored. An alarm is issued if the defined pressure limits are exceeded.
- Monitoring of compressed air storage – An alarm occurring when EDG is in standby warns the operator that low starting air pressure may compromise the function of the EDG in a safety capacity. This alarm will provide a start signal to both compressors.
- Monitoring of compressed air control circuit – An alarm occurs when EDG is on standby, warning the operator that control air pressure may compromise the function of the EDG in a safety capacity.

9.5.6.7 References

1. NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability," University of Dayton Research Institute for the U.S. NRC; UDR-TR-79-07; February 1979.

Table 9.5.6-1—DGSAS Indicators and Alarms

Component	Indication / Alarm
Receiver A Air Pressure	Monitoring w/alarm and control
Header A Pressure	Monitoring w/alarm
Control Air A Pressure	Monitoring w/alarm
Receiver B Air Pressure	Monitoring w/alarm and control
Header B Pressure	Monitoring w/alarm
Control Air B Pressure	Monitoring w/alarm

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