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800-MWe HTGR-GAS-TURBINE
TWO-LOOP
ELECTRIC PLANT

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Gas-Cooled Reactor Associates
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800 MWe HTGR-GAS TURBINE TWO-LOOP ELECTRIC PLANT

Introduction

The design and development of the electric plant for the HTGR-Gas Turbine (GT) present a radical departure in accommodating the electrical requirements of the nuclear heat system and the balance of plant. To address not only these requirements but also codes and standards (for power plants and safety-grade systems), the evolution of the design dictates the application of innovative and unique solutions. The complexity of the GT plant and the criteria for nuclear power stations are substantial restraints and limit the availability of alternatives normally present in the development of a design and configuration.

The objective of this report is to acquaint the reader with the electric design and to highlight those aspects of the electric plant which are unique. In addition, some insight will be presented on the impact of the plant configuration evolution on electric systems.

Description

A number of switchyard variations can be readily adapted to the GT plant without impacting the integrity of offsite power or presenting unnecessary equipment arrangements. Switchyards accommodating the independence of power sources associated with standard LWR requirements are directly applicable. Voltage levels at any of the standard ranges can be employed to match plant requirements with existing grid/transmission arrangements.

A bank of four single-phase-generator step-up transformers rated at 990 MVA connect the main generation equipment with the switchyard. Two three-phase unit auxiliary transformers rated 30 MVA and 15 MVA are provided for normal and safety-grade station service, respectively. Two three-phase reserve auxiliary transformers rated 30 MVA and 15 MVA are connected directly to the switchyard and provide a separate offsite preferred power source for startup, shutdown, and emergency conditions. Table 1 describes all high-voltage transformation equipment.

Table 1

Generator Step-Up Transformer (GSU)

Four (4) - one (1) $\emptyset$, 60 Hz (one installed spare)
65°C FOA
990 MVA
500 KV Wye - 24 KV delta

Unit Auxiliary Transformer (UAT-1)

One (1) - three (3) $\emptyset$, 60 Hz
OA/FA/FOA
H-18/24/30 MVA, 24 KV Δ
X-9/12/15 MVA, 4.16 KV Y
Y-9/12/15 MVA, 4.16 KV Y

Unit Auxiliary Transformer (UAT-2)

One (1) - three (3) $\emptyset$, 60 Hz
OA/FA/FOA, 65°C
H-9/12/15 MVA, 24 KV Δ
X-9/12/15 MVA, 4.16 KV Y

Reserve Auxiliary Transformer (RAT-1)

One (1), three (3) $\emptyset$, 60 Hz
OA/FA/FOA, 65°C
H-18/24/30 MVA, 500/230 KV Y
X-9/12/15 MVA, 4.16 KV Y
Y-9/12/15 MVA, 4.16 KV Y

Reserve Auxiliary Transformer (RAT-2)

One (1) - three (3) $\emptyset$, 60 Hz
OA/FA/FOA
H-9/12/15 MVA, 500/230 KV Y
X-9/12/15 MVA, 4.16 KV Y

Main generation consists of two 3600 rpm generators, each rated 490 MVA, and a shaft coupled to independent turbine-compressor units. While sustained single-loop generation is not readily achievable due to reverse-flow complications, separate generator operation under reduced power conditions is provided to accommodate startup, low power testing, and loop trip. Each generation train is arranged with a main generator circuit breaker (rated 250 KA interrupting) for electrical isolation and a 5000 MW static frequency converter to motor the generator for plant startup. This innovative arrangement, shown in Figure 1, is necessitated by the unique starting requirements of the turbomachine and the sustained parallel operation of both generators.

Station auxiliary service under operational conditions is provided at a primary voltage level of 4.16 KV supplied from both unit auxiliary transformers. At this distribution level, definite distinction is made between non-safety-grade and Class IE power supplies. Absent in this GT configuration is a higher (7 KV-13.8 KV) distribution voltage normally provided in LWR designs to accommodate large rotating apparatus.

A redundant, non-vital, 4.16 KV switchgear lineup is connected to both the reserve and the auxiliary station transformers to achieve a high availability. Both busses are also connected to a BOP diesel generator (non-Class IE) for emergency power to protect equipment. While load quantities and types are different, the arrangement and the inclusion of an emergency power source are typical for a large power station design. Table 2 identifies connected loads at the 4.16 KV, non-vital level. Of some significance is the application of two power circuit breakers in series for loads inside containment. This ensures that substantial fault currents are cleared in the interruption of high energy circuits, which could compromise the containment pressure boundary if a single failure occurred.

Safety-grade, Class IE systems and components are physically and electrically separated from all non-vital apparatus and other safety-grade systems and components of a different channel or alignment. Three of these

Figure 1
Main Generation Arrangement

Table 2

Non-Essential 4.16 KV Loads

<u>Identification</u>	<u>Quantity</u>	<u>Size</u>
Main Cooling Tower L/C	2	1000 KVA
Containment Penetration Building L/C	2	1333 KVA
Auxiliary Reactor Service Building L/C	1	1333 KVA
Non-IE Switchgear Building L/C	2	1333 KVA
Turbine Maintenance Building L/C	1	1333 KVA
Administration Building L/C	1	1000 KVA
Fuel Storage Building L/C	1	1333 KVA
Circulating Water Pumps	4	1000 HP
Site Heating Boiler	1	1260 KVA
Helium Transfer Compressor	2	600 HP
Fire Pumps	2	250 HP
RCB Chillers	2	600 HP
Makeup Water Pumps	2	200 HP
RPCW Pumps	2	350 HP
Service Water Pumps	3	800 HP
Administration Building Chiller	1	250 HP
Bypass and Auxiliary Valves	4	350 HP
Static Exciters, Main Generator	2	200 KVA
Static Frequency Converters	2	5000 KVA

independent channels have been configured such that any one channel is capable of sustaining plant shutdown under emergency conditions. Two independent sources of offsite power, through the reserve and the auxiliary transformers, are connected to each of the three busses and represent a preferred power source. Emergency power is provided by three independent diesel generators of sufficient size to support and start Class IE loads. Table 3 identifies the loads and acknowledges the redundancy for each respective channel. Because of the safety classification, GT Class IE components and systems are qualified using comparable criteria and compliance standards employed in the nuclear industry.

An LWR standard 480 V, 3 $\emptyset$ distribution voltage level (non-vital and safety-grade) and 120 V, 1 $\emptyset$ service level for control and instrumentation have been provided. Also, an integrated 250 V/125 V DC system and UPS AC system have been applied for critical control room and plant protective functions.

Observations

The most significant difference between the GT electric plant and other plants is the disparity in auxiliary loads. Expressed as a percentage of gross MWe output, station electrical requirements are nominal:

<u>GT</u>	<u>LWR-PWR</u>	<u>LWR-BWR</u>	<u>SC</u>
5.6%	6.3%	7.1%	11.6%

The steam cycle differential accounts for approximately 45 MWe of electric drive circulators.

Extensive use of isolated phase bus is made to accommodate multiple generators. Depending on the relative location of the plant to the switchyard, the majority of this bus will be self-cooled.

Technology Demonstration Facilities

This task was set up during the second quarter of FY 1980 and was in support of the application studies. The objective of this task was to obtain an initial design for the Nuclear Heat Source Demonstration Reactor (NHSDR). This work represented a major effort under the Technology Transfer Program for this fiscal year. This topic will be described in detail in the subsequent NHSDR applications report and, therefore, will not be discussed here.

EPRI Liaison and Umbrella Agreement Liaison

Only a small effort was devoted to these two technology transfer tasks this year, with this effort being maintained through GA's Program Management and Support activities. EPRI liaison was handled primarily through GCRA, with GA providing support when necessary.

Table 3

Engineered Safety-Grade 4160 V Loads

Each of the connected loads or sources is typical for three independent Class IE channels.

<u>Identification</u>	<u>Quantity</u>	<u>Size</u>
Ultimate Heat Sink Fans	4	250 HP
Main CACW Pump	1	400 HP
Auxiliary Circulator Controller	1	900 HP
UHS Building L/C	1	500 KVA
CAD Building L/C	1	1333 KVA
Main Diesel Generator	1	3300 KW

Because the GT is essentially a turbine-compressor, motive power is required to elevate the power train to self-sustaining levels. The application of static frequency converters to motor the generator is an innovative concept not associated with traditional power plant practices. The major feasibility aspects have been found acceptable; however, assessment of the long-term operability impact is necessary in the conceptual design phase.

This review and the reviews of the turbomachine maintenance facility and containment building will be consolidated with an Integrated Design Report and Cost Estimate which will address the overall plant layout and associated costs which were developed during Phase I, Phase II, and Phase III design stages and capital cost reduction efforts. The major factors established during the phases were the relocation of the electric generators from inside containment to outside containment, the reduction in PCRV diameter, and development of the canted turbomachine cavities.