- REPOWER INSTEAD OF RETIRE - A FOURTH ALTERNATIVE FOR DECOMMISSIONING COMMERCIAL NUCLEAR POWER STATIONS IN THE UNITED STATES

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INTRODUCTION

The three traditional alternatives for decommissioning commercial nuclear power stations in the United States (U.S.) are as follows (1):

- Decontamination (DECON) - the immediate dismantlement, in which the equipment, structures, and portions of the facility and site containing radioactive contaminants are removed or decontaminated permitting release for unrestricted use shortly after cessation of operations.
- Safe Storage (SAFSTOR) - the station is placed and maintained in such a condition that it can be safely stored and subsequently decontaminated (i.e., deferred decontamination) permitting release for unrestricted use.
- Entombment (ENTOMB) - the radioactive contaminants are encased in structurally long-lived material and then maintained under surveillance for an indefinite period of time.

Of the three options provided, the primary reason for deferring the start of decommissioning is to allow the overall radioactivity to decrease by decay, which in turn, will reduce worker risks, costs of dismantling radioactive components, and shipping large volumes of low-level radioactive waste (LLW). Previous evaluations suggest that a 50-year SAFSTOR deferment provides optimum material and radiation reduction benefits (2). However, during this period of deferment, a utility may need to consider replacement power to accommodate its projected electricity demand profile (EDP). Power generators in the U.S. are expected to order 140 Gigawatts (GW) of new generating capacity and put 100 GW into operation by the year 2003 (3). In addition, the average ages for fossil fuel stations and nuclear power stations are approximately 30 years and 16 years, respectively, with an expected useful life of only 30 to 40 years. Therefore, the projected EDP, compounded with the aging base-load capacity, including the untimely premature closing of a commercial nuclear power station will require the utility to address these concerns concurrently through new construction, life extension, or by repowering an existing station. Surprisingly, the concept of repowering was first recognized in 1974 (4), and is receiving more attention than in the past because of the inherent nature of life extension (e.g., equipment replacement and refurbishment) combined with the benefits of repowering (e.g., reduced emissions, an increase in generation capacity). For the purpose of this paper, repower (REPOWER) is defined as adding a new source of fuel to the existing steam-cycle system of a reconfigured commercial nuclear power station to ensure sufficient electrical generation capacity during the SAFSTOR deferral scenario. This paper reviews the various considerations for repowering, such as previous repowering projects, the gas turbine/heat recovery steam generator (GT-HRSG) repowered station, and the evolution of the non-nuclear station.

PREVIOUS REPOWERING PROJECTS

The W.H. Zimmer Station and the Midland Co-generation Station, both designed initially as commercial nuclear power stations and never operated, were reconfigured as a coal-fired station and a natural gas co-generation station, respectively (5, 6). In 1994, the Fort St. Vrain Generating Station was authorized to repower as a gas-fired combined-cycle steam unit consisting of two GT-HRSGs. Initially, this station operated as a 330 MWe high temperature (helium) gas-cooled reactor (HTGR) from January 1979 until August 1989 (7), and after repowering, is expected to generate approximately 471 MWe. A similar combined gas-steam cycle design has also received particular attention in Europe (8).

THE GT-HRSG REPOWERED STATION

Currently, the most common and cost-effective repowering approach is to use natural gas as a source of fuel, add modern GT-HRSGs, and make use of the existing site and internal components of the steam-cycle system (e.g., turbine-generator, condenser, and cooling water systems). Also, as natural gas prices have declined, utilities have taken advantage of several coinciding market trends to further enhance the rise in the application of gas turbines for electric power generation (9):

- favorable construction economics and environmental benefits provided by gas-turbine-based stations;
- achieving very high combined-cycle efficiencies of 54% to 58% using commercially available technology;
- reliability and availability figures of 98% and 95%, respectively, from gas turbine manufacturers; and
- an EDP requiring large blocks of peaking power; i.e., gas-fired stations are more attractive for peaking applications because low-capacity utilization such as peaking service is often best served by a low capital-cost power station.

The common denominator in these projects is to replace the reactor vessel and coolant system by adding several 100-150 MWe GT-HRSGs (Brayton cycle) to a refurbished nuclear steam-turbine-based (Rankine cycle) station. A gas-turbine-based station consists of a compressor, combustion chambers, and a turbine section. This method of GT-HRSG combined-cycle repowering can improve overall plant thermal efficiency by more than 20%, and in some cases triple the total Megawatt output of the original station (10).

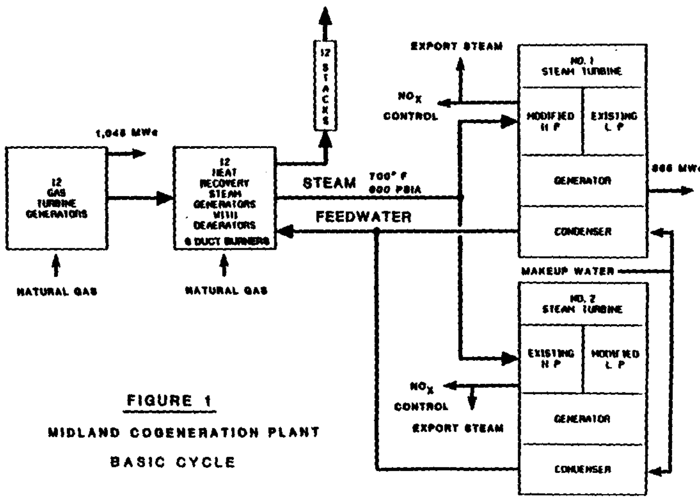

FIGURE 1

MIDLAND COGENERATION PLANT

BASIC CYCLE

Figure 1 represents a general configuration of the Midland Co-generation Venture that was successful in converting two large nuclear steam turbines into a GT-HRSG combined-cycle arrangement (6).

EVOLUTION OF THE NON-NUCLEAR STATION

The containment building will be isolated from the repowered side of the station by installing permanent physical boundaries within the nuclear power block, thereby, enclosing the areas and systems that contain essentially all of the significant radioactive contamination and activated components. The potential of nuclear criticality will have been precluded by transferring the fuel assemblies from the reactor vessel to either the spent fuel pool or an Independent Spent Fuel Storage Installation (ISFSI) (11). Depending on the thermodynamic nature of the repowered system, it may be cost effective to "eliminate and replace" rather than "decontaminate and refurbish" certain components (e.g., pumps, valves, moisture separators). In all practicality, consideration should not be given to decontaminating the small bore piping used for sampling radioactive liquid effluents. In addition, instrument sensors, transducers, and seals having been in contact with steam or condensate containing residual radioactive materials (RRM) will be removed, characterized, and discarded as LLW. Because of the complex geometry of components like the turbine, piping, and associated steam and condensate systems, there will, in all likelihood, be hidden pockets of RRM present creating high radiation dose rate "hot spots" or "crud traps," even following extensive decontamination (12). System perturbations could displace the RRM, that is analogous to a "crud burst" in an operating commercial nuclear power station. Therefore, to ensure that such potential releases are contained, as well as ensure boiler feedwater quality, full-flow condensate ion-exchange polishing capabilities should be maintained for the repowered station. To alleviate stakeholder concerns regarding the potential release of RRM still residing in the steam-cycle system following decontamination, a modified in-house and environmental monitoring program will be maintained throughout the repowering period. The environmental program will consist of monitoring gaseous, particulate, and liquid effluents continuously, which is no different than monitoring other system parameters (e.g., water chemistry). Nevertheless, the radiation dose to the public from a postulated release of RRM remaining on inaccessible work surfaces (e.g., interior of pipes, drain lines) is expected to be indistinguishable from background levels. Additional station systems foreseen to be required, but downgraded during repowering could include, but are not limited to radiological and security access, the management of LLW, AC and DC electrical power systems, and fire protection/suppression systems.

CONCLUSION

The fourth alternative for decommissioning (REPOWER) focuses on replacing an existing fuel source with GT-HRSGs, and reusing the internal non-nuclear components to yield a combined-cycle power station. In addition, the inherent benefits of modifying the serviceable steam cycle improves efficiency, expands electrical generating capacity up to three times the original station output, while maintaining a favorable environmental profile. Repowering is especially well-suited for stations that satisfy mid-range power demands (e.g., 400-700 MWe), and is expected to have a design life similar to that of a new station (e.g., 40 years). Therefore, the REPOWER alternative allows the utility to accommodate its projected EDP, and reduce the need for new construction by using an existing site already dedicated to the generation of electricity.

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