Master thesis project: Feasibility Study on the implementation of Steam Injectors in the Emergency Feed Water System (EFWS) of Pressurized Water Reactors (PWR) nuclear plants

**Context**

Jet pumps are liquid-handling device that make use of the momentum of one fluid to move another. The steam injector is a special type of jet pump, operated by steam and used for boiler feed and similar services, in which the fluid being pumped is discharged against a pressure higher than either motive or suction pressure (see Figures 1 & 2). The steam injector is driven by steam and is therefore a totally passive thermo-hydraulic system (apart from instrumentation and valves).

Within the framework of the Post Fukushima era, the need of alternate feedwater injection systems has been identified by many nuclear plants since the loss of electric power and the subsequent failure of the feed water pumps led to the total loss of emergency feed water to contain reactor overheating in the Fukushima event.

In particular, the necessity of installing an additional passive Emergency Feed Water System (EFWS) train has been relevant for several existing nuclear power plant to assist in beyond design management of reactor cooling by supplying emergency feed water to the steam generators. As a result of the above requirements, there is an opportunity to develop the steam injector concept and study its application in the EFWS of Pressurized Water Reactors (PWR).

**Objectives of the thesis**

The main objective is to determine if the steam injector technology could be used in PWR nuclear plants on a technical point of view. From given defined technical specifications and boundary conditions, this thesis aims at realizing a technical feasibility study on the implementation of a steam injector in the EFWS of PWR nuclear plants. The consideration of economical aspects is also important with the realization of a business plan depending on the foreseen costs for the development and industrialization of the steam injector as well as the market potential forecast.

The technical analysis first consists in performing a literature review to gather all the information related to steam injectors used to feed boiler-type vessels. It is then possible to extract the typical operating conditions already explored, simulated and/or tested in the scientific community. All these thermo-hydraulic parameters can afterwards be analyzed and compared to the operation conditions and related parameters of a reference PWR plant. From this point, a first conclusion on the feasibility of implementing steam injectors in the EFWS will come up: can the required conditions of the EFWS be matched by using steam injectors (single or multiple stages)? The performance of a 0-Dimension analysis using thermodynamic equations is expected to get to this preliminary conclusion.

The second step of the study consists in realizing a 1-Dimension and/or a 2-Dimension analysis to simulate the displacement of the fluid in the steam injector and the heat exchange that occurs by the water-steam direct contact. The impact of using two stages of steam injectors in series will also be explored.
Depending on the student background and his availabilities as well as on the timeframe, the scope of the thesis can be adapted.

This thesis would allow the student to have the opportunity to work on real industrial subject involving creativity, innovation and technical skills. Furthermore, it is a unique occasion for the student to build a network with engineers from a company as strongly implanted in the nuclear energy sector as Westinghouse.

Figure 1: Operating principle of the steam injector

Figure 2: Typical pressure evolution along the steam injector axis