Power generation

Power station feedwater pumps

Proven satisfactory operating experience together with the lessons learned from the past provide a sound basis for commercial specifications. In this article, Dr Edward Grist reviews experience gained over a number of years applying this approach to the specifications for power station feedwater pumps.

Feedwater pumps are the heart of a power station steam generation cycle. Experience based on pumps in a number of different designs of main plant rated above 500 MW shows that some main plant/feedwater pump layouts are more advantageous than others. New specifications for feedwater pumps, often the most costly and the most powerful pumps in a power station, need to take into consideration this hard-won experience. Feedwater pumps with cartridgeized internals and a vapour-lock running capability installed in a 3 × 50% pump set layout are the preferred option.

In the 1960s, the Central Electricity Generating Board (CEGB), the power utility for England and Wales, engaged in an ambitious programme of support for the development of radically new designs of high-speed feedwater pumps for 660 MW main plant. These pumps, running at a higher speed and being physically much smaller in size than their predecessors, had a very stiff shaft and an external axial thrust balancing arrangement. The machines had large internal hydraulic clearances that enabled them to run for a limited period fully vapour-locked, the most onerous condition feedwater pumps can meet in power station service.

All the feedwater pump designs used by CEGB subsequently were of a cartridgeized design; that is, one where the internals could be withdrawn from the pump casing and removed in one piece for maintenance elsewhere. Operational records for these pump designs showed a significant improvement in reliability compared to previous generations of pumps serving main plant of 500 MW and above.

Many boiler feedwater pumps are high-energy pumps. The adequacy of support systems for these pumps requires special attention. The term ‘high-energy’ applies

Table 1. A summary of feedwater pump availability records

<table>
<thead>
<tr>
<th>660 MW 100% feedwater pumps – cartridge design; able to run vapour-locked</th>
<th>500 MW 100% feedwater pumps – non-cartridge design; not able to run vapour-locked</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designation of group of pumps</strong></td>
<td><strong>Survey period (years)</strong></td>
</tr>
<tr>
<td><strong>Designation of group of pumps</strong></td>
<td><strong>Number of pumps</strong></td>
</tr>
<tr>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
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<td>C</td>
<td>9</td>
</tr>
</tbody>
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*All pumps more than two years in service before commencement of availability survey.*
Pumps to the new CEGB specifications were first produced by G & J Weir Ltd (Glasgow, UK) and by Sulzer Bros (UK) Ltd (Leeds, UK). Both manufacturers’ designs of pressure-stage pump and a 50% stand-by pump – 100% main plant it is inevitable that an event will occur that will lead to it being out of maximum revenue-generating service for a significant unplanned time if it is dependent upon a single 100% feedwater pump.

Examples of the kind of question needing to be addressed in a risk assessment are:
1. When a cartridge change is suddenly needed are staff immediately available?
2. When cartridge changes are very infrequent – perversely because of the improved pump reliability – are staff ‘up to speed’ with the training needed to remove this very heavy and very hot hardware safely in a short time?
3. Is a pump casing forced cooling system installed quickly?
4. Is the ‘less than robust’ cartridge withdrawal carriage available undamaged?
5. Can the carriage and its sub-systems be removed this very heavy and very hot hard

A vapour-lock requirement necessitates limiting shaft deflection within internal hydraulic clearances. A shaft stiff is essential. It is unlikely that a pump with more than three impeller stages will meet the requirement. A 1965 design study, carried out by the author, of a single-impeller, pressure-stage pump running at a much higher speed showed that, whilst this arrangement was mechanically feasible, the pressure at the pump inlet required to suppress cavitation necessitated being preceded by a second, high-head, multistage pump. The single-impeller pressure-stage pump set adds unacceptable complexity. A two-stage or three-stage pump is the most suitable option.

Making a choice
A feedwater pump set specification should be written around a preferred option that is compatible with main plant requirements. However, the engineering design of pumps and prime movers must never be regarded as fixed. Wherever practicable, a specification should allow the merits of innovative offers to be tendered and evaluated against the preference.
There are significant benefits in choosing a 3 × 50% pump arrangement as the preferred option. Foremost, it is likely to be the most cost effective over the life of the plant whilst at the same time ensuring that electricity generation by the main plant is given maximum protection from being hostage to the availability of a feedwater pump.

A 3 × 50% arrangement incorporating a pressure-stage pump that has a vapour-lock capability and cartridge-ized internals gives full back-up with maximum availability. On the debit side, this maximum availability is achieved by the inclusion of increased internal clearances at impeller neck rings and at the balance drum. This in turn gives rise to a reduction in pump efficiency of about 0.5%. However, all the associated energy is not lost to the plant thermal cycle. It appears as an inefficient way of preheating feedwater on its way to the boiler/steam generator.

Selecting a 3 × 50% pump set arrangement fixes the duty (the flow rate and generated head) for individual pumps. The pump speed is then chosen. This is primarily determined by two considerations: (i) the net positive suction head provided by the inlet storage tank height, operating pressure and associated pipework geometry; and (ii) the improvement in reliability achieved by choosing the simpler construction associated with the high-speed pump.

A pump set design based on fixed-speed, electric motor technology is the simplest mechanical and hydraulic arrangement, especially where a suction-stage pump is unnecessary. Avoiding the use of a suction-stage pump does, however, bring the risk of unacceptable cavitation when the proven better reliability of high-speed machines is chosen, but methodologies exist for ensuring cavitation does not put high availability at risk.

The 3 × 50% pump set arrangement, shown in Figure 1, has proved effective in many installations. However, choosing this arrangement brings a need to re-evaluate the commercial worth of specifying a requirement to have cartridge-ized hydraulic internals.

The time to access hydraulic internals, inspect/replace and return to service in a non-cartridge-ized pump is put, optimistically, at three days. The time to replace a defective cartridge is put at 24 hours. So, setting aside the other benefits of being cartridge-ized and assuming a single-pump operation can run-out to 60%, the financial risk can be quantified if, as seems probable in the life of the plant, a second pump fails when a non-cartridge-ized pump is out of service then a cartridge design is justified. The cost of a failure far exceeds the additional cost of the cartridge design.

The energy source for the pump prime movers is fixed during the outline planning stages of power station design. Usually three options are considered: (i) steam turbines, (ii) variable speed (slip-ring) electric motors, and (iii) fixed-speed (squirrel-cage) electric motors. The final choice results from an optimization of these and other factors, many of which are particular to local constraints. These include maximizing station efficiency, maximizing station output from given turbine-generator plant, accommodating the cost of providing high starting-current electrical systems, adding complexity by including a suction-stage pump driven from the same prime mover, adding complication by adopting mixed steam-turbine/electric-drive combinations and the need to provide an electric starting pump for systems employing all-steam-turbine pump drives.

**Type testing**

Design features that are new to a particular manufacturer can produce unexpected problems. It is necessary to evaluate the potential risk these features pose and decide whether or not it is prudent to require type...