The life extension process: Considerations for power companies

Introduction

The business environment continues to be challenging for power plant operators, whether it be navigating the unlocking of economies in the aftermath of the pandemic, managing feedstock price fluctuations, the recent geopolitical shifts impacting supply chains caused by the ongoing conflict in Ukraine or the pressures the industry is under to evolve into a low-carbon economy.

In particular:

- **On the demand side**, there is an ever-increasing need for electrical power, together with an increased focus by national governments on energy security. This has increased their demand for the availability of generating assets that can provide a reliable power supply, which has made this demand more acute.
- **On the supply side**, existing assets continue to age and operators are increasing looking more favourably at extension projects to meet this demand gap. There have even been instances where national governments have requested operators to have specific assets continue operating beyond their planned decommissioning dates.

Taken together, these two factors have made future investments in conventional power generating assets extremely uncertain in the near term, CCGT plant construction somewhat mitigates the problem but there has been a general slowdown on new conventional power plants being constructed. In turn, this is putting pressure on operators to extend the life of ageing assets. This increased interest in extending operating assets beyond the original operating life presents several risks that need to be carefully assessed and controlled.

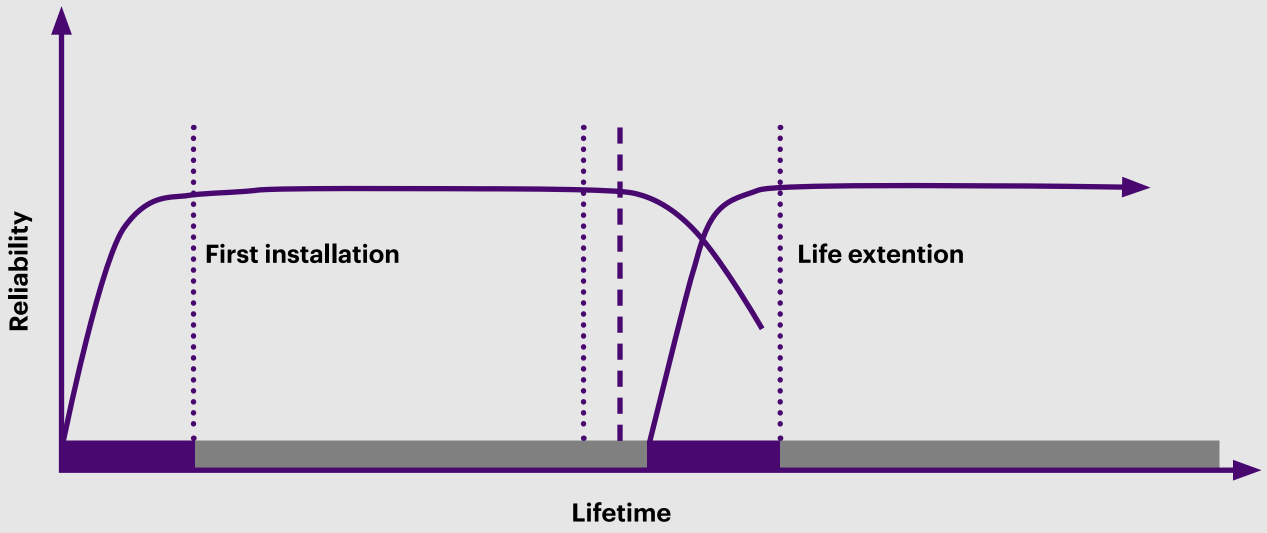
This is why robust life extension processes — and independent analyses of these processes by qualified engineers — need to be undertaken by power companies to ensure that the assets that continue to operate do so in a safe manner and are considered to be “fit for service”. Failing to do so could, and probably will, result in losses that no one wants to experience, either as an operator or insurer. It’s little wonder that insurers are paying closer attention to this issue and will no doubt penalise insurance programmes where assets over a certain age have not undergone this process.

The standard life extension process

The ultimate objective of life extension processes is to determine the duration that assets can operate safely and profitably beyond their specified design lives, and the investment required to secure this outcome. The investment budgets supporting life extension programmes comprise capital funds (Capex) to replace or upgrade equipment, together with estimated future operating expense (Opex), necessary to cover maintenance expenditure and spare parts requirements for the extension period.

The output from this analysis will be a series of different combinations of operating durations versus investment budgets, with operators needing to select the combination range that suits their desired operating period and investment appetite. Typically, operators will seek to maximise the extension period while minimising (or optimising) their total investment, which will bear in mind whether the equipment can continue to operate safely, with accepted levels of reliability and within good industry practice.

Figure 1: **Graph showing typical reliability of generator controls vs age, and the 'reset' due to upgrade**



Sources: WTW

What does a good life extension process look like?

In particular, companies need to establish whether this objective can be achieved:

- without any component changes and no (or minor) increases in future maintenance/spare parts budgets
- with like-for-like replacements of some components
- with upgraded components, or whole equipment modules that do not change facilities' generating capacities — these upgrades may either improve reliability, future maintenance costs or required investment — or all three
- with upgrades required to address equipment and/or spare parts obsolescence — technology suppliers' support through this period is also important
- with upgraded components or whole equipment modules that upgrade facilities' generating capacities

Using a life extension processes to upgrade facility generating capacity may look appealing, but caution needs to be exercised in order to avoid re-verification of regulatory operating licences which could well introduce significant additional overheads to complete, in terms of costs and time.

Tracking asset ageing

For life extension projects to be successful and economically viable, operators first need to track asset ageing in a comprehensive and consistent manner. This requires the monitoring and collation of many operating parameters and the results of specific equipment inspections that can be used as inputs into various mathematical models that are used to establish plant ageing.

While not an exhaustive list, several key operational factors to be monitored include:

- Maintenance costs and whether or not they are increasing or decreasing over time
- Equipment reliability data obtained from maintenance and overhaul programmes — for example, wear, fatigue and performance degradation
- Programmed overhauls or component replacements which also introduce new equipment
- Availability/equivalent availability factors
- Forced outage/equivalent forced outage rates
- Equipment obsolesce and spare parts availability
- Past upgrades in assets which can increase performance/reliability but also introduces new equipment

Targeted equipment inspections will also provide crucial inputs in determining the extent of degradation, in terms of wear and stress, experienced by equipment components from past operations.

Non-standard life extension processes

Mothballed assets

Another area where life extension projects are being considered are mothballed assets, which may have been taken out of service for a variety of reasons. Here the analysis needs to be more detailed, given the condition of equipment may well be conditional on the mothballing methods employed — meaning that some methods are more effective at preserving asset condition than others. Detailed inspections are therefore normally required to evaluate the mothballing impact, in addition to the operational data outlined above.

Given this additional factor, life extensions on mothballed assets are considered potentially riskier than extension of operating assets. In the rest of this article, considerations will be given to the challenges of and life extensions for electrical generators and associated equipment.

Electrical generator life extensions

The main issues arising from generator stator ageing are:

- Main stator bar insulation degradation, leading to decreased insulation resistance
- Stator end-winding looseness, causing fretting and wear of the main stator bar insulation
- Stator wedge looseness, causing stator bar insulation wear
- Stator cooling water manifold and brazed joints issues, causing hydrogen leaks and insulation problems
- Stator core issues, causing core laminations shorting and overheating

Generally, generator stator bars last anything between 20-30 years, depending on the operating regime, operating excursions, insulation type, maintenance regime (cleaning, testing, wedge tightness etc.), oil ingress, cooling water temperatures, load cycling, specific OEM design pertinent issues and so on. Utilizing new insulation materials, stator life could be extended by another 20+ years, providing the stator core is healthy and in good condition.

Stator life extension projects

Simple life extension of stators often result in like for like rewinds. However, usually stator slot portion analysis is also undertaken to decide whether utilizing modern insulation materials could fit into the cross section, usually involving more copper. This potentially provides generator uprating as a bonus in life extension projects which is only possible if rotors can be uprated, shafts/couplings can take the additional load and boiler-turbine life extension studies establish that upgrades are possible to output additional generating power. Plus, capacity expansion on dispatching equipment.

Generator rotor ageing issues

The main issues arising from generator rotor ageing are:

- Rotor interturn insulation degradation and/or copper shrinking, causing inter-turn shorts
- Rotor end-winding deformation, causing end-winding blocking arrangement migration and inter-turn shorts
- Old type of retaining rings material (i.e. 18% manganese/5% chrome)
- Rotor J-lead (connection lead) brazed joint fatigue
- Slip rings wear
- Rotating rectifier parts obsolesce

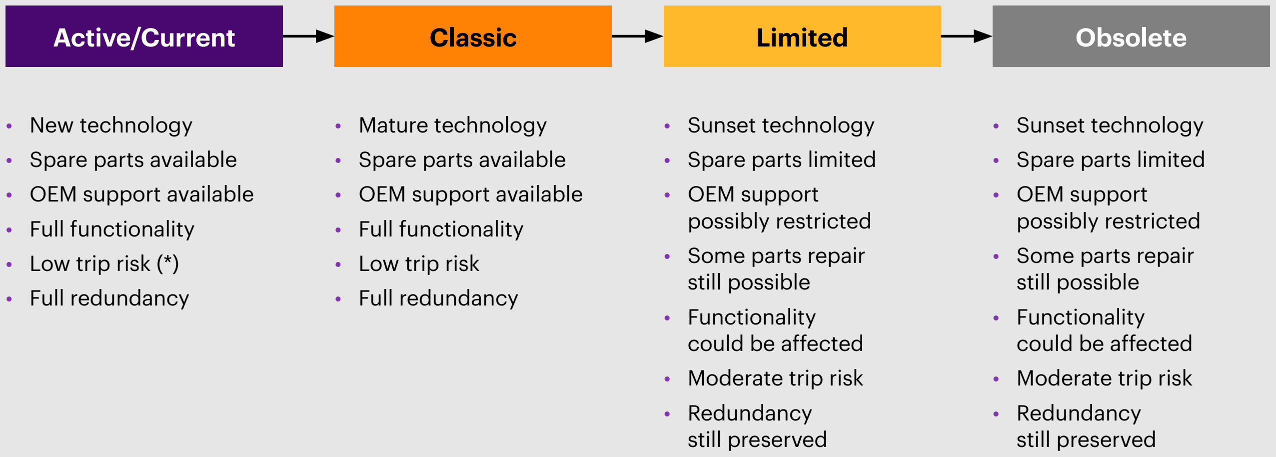
Rotor insulation systems usually last 15-25 years, which will depend on similar conditions outlined for the stator. Life extension projects comprise of a stator life extension study and a rotor life extension study. A testing regime on the generator stator testing with high voltage AC will provide information on the condition of the insulation condition:

- The capacitance, and loss angle of the insulation
- the partial discharge activity on each phase
- the impedance of the winding

A physical inspection of the winding convolute, stator bar supports stator wedges performed to check for loose fitting, dust trails indicating abrasion of insulation, and corona discharge. The stator laminations would be checked with eddy current testing and thermal imaging when magnetised with a test source. From these assessments, it can be estimated how much life the generator has potentially left.

The process of life extension of generators usually considers both the technical assessment, the total cost and duration of the upgrades. A typical stator rewind project is three months (70-90 days breaker to breaker, assuming that the coils have been previously manufactured and are on site). A rotor rewind project is also in a similar time duration. This scenario is assuming that all the rewind materials, tools and accessories are ready at site.

Figure 1: **Graph showing typical reliability of generator controls vs age, and the 'reset' due to upgrade**



Active/Current

- New technology
- Spare parts available
- OEM support available
- Full functionality
- Low trip risk (*)
- Full redundancy

Classic

- Mature technology
- Spare parts available
- OEM support available
- Full functionality
- Low trip risk
- Full redundancy

Limited

- Sunset technology
- Spare parts limited
- OEM support possibly restricted
- Some parts repair still possible
- Functionality could be affected
- Moderate trip risk
- Redundancy still preserved

Obsolete

- Sunset technology
- Spare parts limited
- OEM support possibly restricted
- Some parts repair still possible
- Functionality could be affected
- Moderate trip risk
- Redundancy still preserved

* risk of non-process-related trips due to equipment aging / outdated technology that may require regular calibration because of drifting parameters, which can cause nuisance tripping or even worse prevent proper tripping.

Sources: WTW

Both a stator and rotor life extension project and/or uprating come with substantial cost, typically in a region of 60-70% cost of replacement new equipment. A detailed study of costs is therefore also required from the onset, to decide whether life extension is a better option than the plant replacement.

In the case of old generators, plant replacement would also completely mitigate some of the issues that cannot be alleviated with plant life extension projects. However, a wider design check would also need to consider the new generator design, weight and dynamic forces, the concrete plinth new dynamic load study, the new rotor grid interaction, the inertia of the machine, etc. This would necessitate the approval of the off-taker, together with the Grid Operator whose connection agreements and requirements for generation will have to be met. These regulations will have changed over the life of the generator and will probably be more demanding than at the initial install.

Generator replacement can also reduce the total outage time, presenting a significant saving as the unit could go to grid earlier — for example 30-40 days to completely replace the generator, compared to typically 70-90 days for rewind (i.e. best case: if all the equipment present prior to start and there are well established procedures available).

Excitation life extension system considerations

As part of the plant life extension, the excitation system and Automatic Voltage Regulator (AVR) have to be considered. The electronic control components in the system are ageing and the manufacturers support for a product is limited, resulting in obsolescence.

Electrical components in the excitation system, for example thyristors, capacitors, resistors and electronic components, have limited life and are prone to ageing and performance degradation with possible failure. The OEMs typically discontinue the manufacture of a component after it has been manufactured, for example from 10 to 15 years. The OEMs may not have a direct replacement part, in which case a complete system will need to be replaced and a detailed study produced by the equipment OEM. These studies will have to demonstrate compliance with the country's grid code and will result in proving tests of the new system. The Generator Circuit Breaker (GCB) condition and rating also needs to be checked and considered.

Ultimately, the excitation transformer must also be the part of the lie extension study. Typically, excitation transformers — especially if the dry type — have a longer life expectancy if tested regularly and maintained well, and usually have some reserve.

Automatic Voltage Regulator (AVR) life extension considerations

Synchronous machines excitation systems of are modelled in such way that they regulate their behaviour — they maintain the generator terminal voltage and enhance the power system performance and reliability. Their model must be suitable for the actual excitation of generators in such manner, that it smooths out the large, severe disturbances as well as the small deviations. Excitation control elements include both excitation regulation, stabilizing functions and protection functions (limiters).

In addition, modern excitation controllers include the Power System Stabiliser (PSS) system, which is used to enhance damping of the national power system oscillations using excitation control.

Protection functions (including excitation limiting functions) entail, for example, the over excitation limiter (OEL)[1], as well as the under excitation limiter (UEL)[2]. Whilst modern AVR systems entail a whole array of excitation regulating, stabilizing, and limiting functions, they are usually either not present or are present in a rudimental shape in older systems, which may have been compliant to older standards. In such scenarios, modern Grid Code requirements (which are different in every country/region) usually drive the need for upgrades and/or compliance.

During the commissioning and Grid Tests of the upgraded AVR system, the Grid may require further tuning of the AVR/PSS parameters to suit the local Grid needs.

Conclusion: the need for an independent process oversight

The conventional power sector is increasingly embracing opportunities to extend the operational life of many facilities to meet the ongoing demand for electrical power. We have seen that this introduces potential risks which operators and the insurance community need to fully understand and have a clear path for their evaluation and possible mitigation.

Life extension analyses clearly fit this requirement, and from the outline above regarding electrical generators, it should be recognised they are comprehensive and highly technical in nature. They incorporate all the key factors that are pertinent to operate equipment safely and reliably, offering valuable insights into the most appropriate extension periods to meet the needs of power plant operators.

However, it is also clear that with the complex analysis, there is potential for key aspects to be either overlooked or not given the appropriate priority in the assessment process. A degree of oversight of these assessment processes by qualified engineers could therefore help to ensure that all aspects have been considered and are effectively communicated to stakeholders.

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[1] Under excitation limiter (UEL), which prevents the generator from exceeding its core-end heating limit and/or its stability limit, when it is operating at a leading power factor, i.e., absorbing MVar.

[2] Over excitation limiter (OEL), which prevents the generator from exceeding its field current heating limit, when it is operating at a lagging power factor, i.e., supplying MVar.