Health-aware operation and control of a subsea gas compression station

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Unplanned maintenance interventions for subsea oil and gas production systems are usually very costly, due to the loss of valuable production. Fast intervention is desired to reduce these losses, but this is usually not possible due to the need for specialized lifting vessels, unavailability of spare parts or inaccessibility due to harsh climate conditions. Consequently, unplanned production stops caused by component or system failure cannot be tolerated. In direct opposition to this requirement, however, is the need for high efficiency and small margins, caused by the low oil price. Oil companies have to push the limits in order to stay profitable. A systematic approach is therefore needed to ensure optimal operation without compromising the system integrity.

Proactive maintenance strategies such as prognostics and health monitoring (PHM) systems are used to minimize the risk of unplanned breakdowns. The systems provide the decision makers with information about the health state of the system, so that they can schedule maintenance. However, this information is often not considered when deciding on the optimal production strategy. Consequently the proposed strategy might threaten the integrity of the system. Operators will then typically choke back production until the estimated remaining useful life (RUL) is well inside the acceptable range. This approach might lead to sub-optimal operation, especially when the system is complex and many degrees of freedom are available.

In recent years, some authors have attempted to combine PHM and control to obtain a control structure which not only ensures optimal operation, but also safeguards the system integrity. (Escobet, Puig, & Nejjari, 2012) propose a reconfigurable control scheme which keeps the RUL bounded by adjusting the set-point of a PI controller. While it is shown that the method works for a conveyor belt test-bed, concerns were expressed regarding the ad-hoc inclusion of health information. They highlight the need for a more systematic approach. Additionally, the set-point selection algorithm can propose set-points which are either sub-optimal or infeasible.

A model predictive control (MPC) framework allows for a more systematic inclusion of health information by including additional constraints in the optimization. Furthermore, MIMO systems can be handled effortlessly. This approach was explored in (Pereira, Galvão, & Yoneyama, 2010) and (Salazar, Weber, Nejjari, Theilliol, & Sarrate, 2016). Pereira et al. consider a linear system subject to degradation which is proportional with the input usage. Due to input redundancy, the controller is able to relieve degraded actuators by redistributing the control efforts. Salazar et al. consider a similar case, but include a dynamic Bayesian network for reliability assessment.

Our contribution is to develop a health-aware control structure for a subsea production and processing systems. As a case example, we consider a subsea gas compression system. The results of Pereira and Salazar and corresponding coworkers are extended by considering a stochastic evolution of the RUL in combination with a nonlinear process model. The resulting bi-level optimization problem is solved by linearizing around worst case realizations, resulting in a robust control structure (Diehl, Bock, & Kostina, 2006). Furthermore, we consider the case where the maintenance horizon is not known a priori, but is a decision variable in the optimization. That way, we combine maintenance and production scheduling to ensure optimal operation.

References

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