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Summary
Although multi-variable control is now a well-established technology, new applications are still being found on which to apply it. The BP Amoco group has made extensive use of multi-variable control upon its refineries, however, the application of multi-variable control to the upstream operation is a new approach.

In this paper, details will be presented on how Honeywell’s robust multi-variable predictive control technology was found to be particularly applicable to the offshore production process. The paper will detail the installation on BP Amoco Norway’s Ula Field. This field became one of the first offshore platforms in the world to implement advanced control optimisation in March 1999. The project has been a great success and not only given a sustained production increase of some 2% but has also enabled Ula to maintain optimal fuel gas to their turbines, which has resulted in a saving of CO$_2$ tax of some 1 million $/yr.
Abstract
Although multivariable control is now a well-established technology, new applications are still being found on which to apply it. The BP Amoco group has made extensive use of multivariable control upon its refineries, however, the application of multivariable control to the upstream operation is a new approach.

In this paper, details will be presented on how Honeywell’s robust multivariable predictive control technology were found to be particularly applicable to the offshore production process. The paper will detail the installation on BP Amoco Norway’s Ula Field. This field became one of the first offshore platforms in the world to implement advanced control optimisation in March 1999. The project has been a great success and not only given a sustained production increase of some 2% but has also enabled Ula to maintain optimal fuel gas to their turbines, which has resulted in a saving of CO$_2$ Tax of some 1 million $/yr.

Background
First oil was found on the Norwegian Continental shelf in 1971. Since then Norway has moved on to become the second largest oil producer in the World after Saudi Arabia, with some 37 offshore fields in production. The BP Ula field, which is located in the South-western corner of the Norwegian Continental shelf, was commissioned in 1986. At it’s peak Ula achieved crude oil production figures of 150,000 bbls/day. The field is now in decline and today produces some 30,000 bbls/day.

However, with new production and reservoir techniques plus tiebacks from surrounding fields, Ula is expected to be still economic in 2010. One of the features of late life operation is that produced water that comes up from the reservoir with the oil and gas has to be cleaned and disposed of. The Ula field is today producing some 120,000 bbls/day of produced water. Previously the only way to dispose of this was to clean it as best possible and dump it overboard. However, BP Amoco Norway wished to make a major contribution to improving the environment. Therefore, Ula became one of the first offshore operations in the World to begin re-injecting produced water back into the reservoir in 1995.

In the early 90’s the Norwegian Government decided to impose an environmental tax based on emissions of CO$_2$ to the atmosphere. The tax is levied on the volumetric measurement of fuel and flare gas. This tax has today risen to a level which makes it a significant part of the operating budget costing around 8 million $/yr.

The above factors create complex interactions between process and environmental goals, which are difficult to control using conventional techniques. To help improve productivity a new integrated control and safety system was installed on Ula in 1995 supplied by ABB. Although this system helped it was felt, by the control and production engineers, that still more could be achieved by using advanced control techniques.

In 1996 the then BP Group launched a major technology leavers programme aimed at finding new technologies that could help the Up-stream Businesses. One of the programmes, was aimed at promoting the opportunities presented by advanced control. This initiative was spearheaded out of the BP Research Centre located in Sunbury, England. Ula was identified as an ideal test bed for advanced control and a feasibility study was performed in 1997. This identified opportunities to increase the oil production rate and hence the profitability of the platform, by using advanced control. It was believed that the application of multivariable predictive control, would allow the process to be run closer to the limits set by the complex interactions in the process. In addition it was thought that the project could contribute to reducing the cost of CO$_2$ tax paid on fuel gas.

An international tender was sent out in 1997 which resulted in Honeywell Hi-Spec Solutions being awarded the contract to deliver advanced control solutions to BP Norge (which later became BP Amoco Norway). The project teams consisting of engineers from Norway and Sunbury and offshore staff have been working together, Honeywell Hi-Spec Solutions for over a year to develop the system and interfaces.

Process Description
The producing wells on Ula are connected to the well head manifold and thus to either the Test Separator or the HP Separator since, for the majority of the time, the Test Separator is used.
as a normal production vessel. The majority of the separation of the produced water from the oil occurs in the HP Separator with the water being routed through the hydrocyclones (to reduce the oil levels further) to the Degassing drum. The oil separated in the hydrocyclones flows back to the Closed Drain drum, from where it is pumped back to the MP Separator.

The oil from the HP Separator flows under level control to the MP Separator. Again, any emulsified or entrained water is separated at this point and is passed through the MP hydrocyclones to the Degassing drum. The oil separated in these hydrocyclones also flows back to the Closed Drain drum. The oil then flows to the MOL Booster pumps from where it is pumped to Ekofisk.

The produced water in the Degassing drum then passes through a set of coolers and is mixed with de-oxygenated sea-water, subject to a temperature constraint, before being re-injected back into the wells.

Gas evolved in the HP Separator passes through a cooler and into the HP Scrubber. Condensate knocked out at this point flows back under level control to the MP Separator. The gas then passes through the dehydration unit and onto the HP Compressor from which it is either used to top up the Fuel Gas main, used for Gas lift or is passed onto the WAG (Water Alternate Gas) compressor for re-injection back into the well.

Gas evolved in the MP Separator passes through the MP Gas Cooler and into the MP Gas scrubber, where condensate is knocked out and pumped back to the MP Separator. The gas is then compressed and passes, under back-pressure control, to either the Fuel Gas main, or the HP Scrubber. Due to the Norwegian legislation on CO₂ tax, the use of “heavier” gas for the supply of Fuel Gas is preferable, since the tax is levied upon the normalised quantity of gas combusted, not based upon its molecular weight.

The platform is currently well limited and is running with the production chokes wide open on all wells. Choke by-pass valves are also open where provided. The current limitation on the process is not dictated by the topside process capacity, but rather on the ability of the well to produce.

Control Strategy
The control strategy prior to the implementation of the multivariable control was focused on single loop basic control. Primarily, loops had been tuned for load disturbances, with relatively few control cascades. Any optimisation of the process was performed by the operator, in response to his knowledge of the process and conditions at the time.

Reasons for implementing Profit Controller
After a study performed by BP upon the Ula platform, it was felt that there were opportunities to increase the oil production rate and hence the profitability of the platform. The way to achieve this was seen to be by decreasing the overall operating pressure of the process, however, due to the interactions on the process, it was recognised that this would be an ideal opportunity for the application of multivariable control. It was estimated that application of the multivariable control, driving the operating pressure of the process down, would yield increases in oil production rates in the region of 1-2%.

Prior to achieving these benefits, it was recognised that there were process configuration changes required to enable the application of multivariable control to proceed. These changes were made during the Ula platform shutdown during August 1998.

Profit Controller Control Scheme
For the Profit Controller control scheme to be implemented, some changes were required on the basic PID controllers on the DCS. The Ula platform is controlled using the ABB Master DCS. To enable the correct changeover between Profit Controller and operator control, the PIDCON block was utilised, which enabled the operator to have full normal control over the block, but also enabled the use of a cascade mode, to which Profit Controller would write when in control.

The Profit Controller software runs on a 400 MHz Windows NT 4.0 machine. This is interfaced to the Honeywell Process History Database (PHD) which connects via an Ethernet connection to the ABB Master control system using a UNIX based IMS as the gateway.

Implementation
Time was spent tuning the basic controllers and ensuring that the basic control philosophy was correct. Once this was completed, step-testing activities commenced.

The step testing activities were carried out with the operating pressure of
the process manually lowered by the operator. This gave a clear idea of where the constraints on the operation would lie, when the Profit Controller was continually trying to push the operating pressure down.

The step tests were carried out whenever the process was steady enough to identify responses. The Process Historian Database was used to store the data, this was then extracted ready for the model identification at the end of the step-testing period. During the step tests, potential manipulated variables were step tested up to eight times, depending upon the clarity of response observed.

The models were then identified using the Honeywell APC Development Environment and the Profit Controller Identifier Release 170.00. The configuration was then built using the Profit Controller Point Builder and these files were then used to generate the PHD Tagload file.

Once the PHD points were built, the Profit Controller took approximately two days to commission. Models were commissioned in isolation, so that the Profit Controller action on each model could be identified. Having the Profit Controller built onto the Process History Database greatly aided the commissioning activities, since the controller predictions could be compared to the actual process value with no addition configuration work. Tools such as the Honeywell Process Trend package made this task easier and more intuitive.

It was noted during the commissioning of the controller that some of the features of Profit Controller were ideally suited to this application offshore. Specifically, the Range Control Algorithm ensured that the controller was robust and enabled it to handle disturbances such as wells being brought onto production and being taken out of service. Careful use of soft optimisation limits in conjunction with Linear Program (LP) weights enables the controller to optimise the process correctly whilst avoiding control action during known and unavoidable process disturbances which the operators themselves would ignore.

User Interface
Because of the wealth of information generated by the Profit Controller controller, attempting to build succinct meaningful DCS resident schematics was difficult. In the end, it was decided that the information available in the Honeywell Profit Viewer schematics would be much more meaningful and also gave built in features such as access levels and multiple user access.

Because the Profit Viewer schematics are designed around the existing Profit Controller schematic format, the amount of training required for the operators and engineers was minimal. The schematics combine the best of the proven schematic format together with Windows features such as the “Toolips” text box feature, double clicking on fields and as such, users can navigate the schematics with little training. Because the schematics are dynamic (i.e. the change as the controller configuration changes, adding and removing Manipulated or Controlled Variables to the controller is a minor task. This assisted in reducing the commissioning time for the controller.

Actual Results
The advanced controller was commissioned in March 1999 and has proved to be a great success. The project has not only given a sustained production increase of some 2% but has also enabled Ula to maintain optimal fuel gas to their turbines, which has resulted in a saving of CO$_2$ Tax of some 1 million $/yr.

Experience so far is that the technology has been well received by the offshore staff. They find the Honeywell Profit Viewer both intuitive and easy to operate. It has required only minimal training of operators who have no previous experience of advanced control. The Profit Viewer has also given operations staff the opportunity to better understand the process goals possible and which constraints are stopping them achieve these.

Another exciting possibility, that is being actively pursued, is to extend the Profit Viewer to the onshore support office, via a new high bandwidth fibre optical link. This will enable the land based production engineers to monitor the Profit Controllers Performance. Honeywell’s support staff will also be able to maintain and modify the system from shore.

The project team believes the techniques used on Ula are directly applicable to the whole of BP Amoco’s upstream business and therefore, the impact for the Group of the widespread application of this technology are significant.