Above, a Woodward operator interface similar to one used as part of a complete plant control package at Conowingo, left.

Providing a stable influence

Woodward Governor's latest hydro turbine control systems are becoming more modular as it pushes for increased generation efficiency and promotes greater grid stability. Patrick Reynolds reports from Wisconsin, USA.

Generation efficiency can increase from 1% to 3% from changing from mechanical to digital governing of Kaplan turbines.

Woodward Governor told power utility delegates of the efficiency bonus at its most recent Hydro Power Control Conference - or 'governor school' - held last month in Wisconsin, the company's centre for hydro turbine controls. Maybe not a claim to merit banner headlines, but it won the attention of many utility operators and managers, some of whom were in charge of control systems more than 70 years old.

The efficiency improvement comes from measuring the position of a Kaplan unit's adjustible blades more accurately, allowing finer adjustments. For any combination of net head and gate position there is a blade position for optimum efficiency - the relationships form a three dimensional mathematical surface, or algorithm (3D-Cam), for each unit.

To convince powerplant operators, the company is putting its money where its mouth is. Application specialist Jerry Runyan says that Woodward is looking for a client which would let the company - at its own cost - install its 3D-Cam, digital control system on a Kaplan unit. As Woodward would take some financial risk to prove its claim, the deal is that the company and the client would share any profits accrued from extra energy being generated per unit volume of water through the turbine.

The efficiency improvements by digital controls, though, are not limited to Kaplan units. Impulse turbines can be digitally governed by algorithms for needle controllers similar to the Kaplan blade controllers. In this case the net head is assumed to be constant. The efficiency of a nozzle of an impulse turbine is a function of the power level at which it is operating. Sequencing nozzles according to the desired power level can improve efficiency.

More effective sequencing of the nozzles pairs by this technique improves the overall efficiency of a unit, reducing the power drop during the switch between the number of nozzle pairs in operation. Power drops can be about 10% of the output, unacceptable to grid operators. The digital sequencing system can reduce the drop to about 1%, says Woodward.

With Kaplan units, automated index testing to establish the 3D-Cam relationships is becoming more common, says Terry Bauman, a systems analyst with Woodward. The index testing system has been designed specifically to [illegible] it collects data on gate position/blade angle relationships and making adjustments to a unit's attitude, if necessary, to complete the database needed to describe the mathematical efficiency surface. The test takes about 20 minutes per data point, he says, but the data are only valid if the power output has been constant.

Index testing - the next generation

'We're getting close to the point where the test is almost off the shelf,' says Bauman. The first couple took nearly five days to set up, the last only a few hours. 'We're achieving more of a standardised system of installation.'

Bauman has his sights set on the next development phase of the index testing system, which he hopes to bring out within a few years. He wants to avoid the need for constant power output during the test.

'I'm at the conceptual stage,' he says, but is looking for a fixed index test system which could be run at any time, without restrictions, and could automatically reprogramme a turbine's digital control software with an updated 3D-Cam efficiency surface. It would be 'an intelligent system,' he says, able to test at suitable intervals and make control changes if the efficiency was deemed to have changed enough.

Apart from developing intelligent index tests, Bauman is looking into making smarter governors. 'You're going to see more integration,' he says of the different parts of a governing control system. He points to greater use of standardised modules and their interfacing systems to create the governors of the future.

'I don't think the idea of standardising governors is necessarily good. It's better to standardise modules and customise the modular arrangement. That would allow the flexibility that customers are looking for. The client gets what it wants, more cost effectively.' He says that the modular governing system would benefit clients by lower cost, better performance and system integrity. 'They would have greater confidence in the proven modules.'

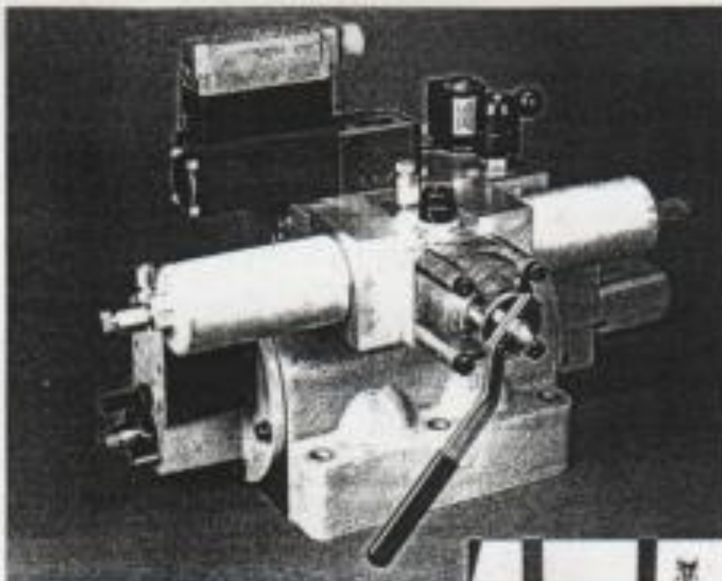
David Bishoff, a member of Woodward's development team, agrees that modularisation, and using the latest market technologies, is the way forward. As such, the company's new ModuFlo governor distributing valve, which he designed, has just been launched onto the turbine controls market. As well as looking quite different from the traditional assembly - the new valve's technical details have also markedly changed.

New modular distributing valve

Says Bishoff: with only 10 moving parts, the new valve has 80% less than the old. Where the traditional design has 200 parts in its assembly, the new has 70. The ModuFlo valve costs less than half the price of the previous distributing valve, takes only one day to assemble compared to the two weeks needed for the older model, and its parts orders only need a quarter of the lead time. At 1gallon/minute (4.5litres/min), its oil consumption is three times more efficient, its frequency response is 10Hz instead of 1Hz, and the pressure rating is one and a half times the previous valve's, at 1500psi (104 bar).

First field use of the distributing valve is scheduled for early next year. Two ModuFlo valves - one for the gate position and the other for the blade angle - are to be installed in the governor of a vertical, adjustable blade Kaplan turbine at Montana Power's Thompson Falls powerplant. As the valve is a mix of Woodward designed parts and modules bought on the market, the latter will have some 'fine tuning' tests over the next few months, says Bishoff, to classify them in terms of radio frequency immunity - crucial in some tender specifications.

The market-resources parts include the ModuFlo's three DO-3 size control solenoid valves, the primary transducer valve and the internal components of the pilot valve filter - the body of which is designed by Woodward. Other Woodward designed parts include the hydraulic rate limiters and shutoff plunger, the final valve spool, the valve base casting, endcaps and upper manifold.



Above, Woodward has just launched its new ModuFlo governor distributing valve

The rate limiter's modular design allows it to be attached to either end of the the valve, and so operate in open or closed limiting mode. Likewise, the endcaps can swap sides, allowing the valve closing direction to be changed - a good solution to problems such as pipework having been installed the wrong way.

Part of the attraction of the new valve is the proportional valve on the upper manifold - 'a smart solenoid' - he says, which drives the pilot valve, and therefore the distributing valve below. Powered by a 24V source with a +/-10V signal, it has an LVDT feedback which senses partial valve movement with zero lap.

'The valve is the result of 25 years of my design, operation and manufacturing experience. To do something like this takes a lot of talking with a lot of people,' says Bishoff. He talks of 'team concept engineering', getting a multi-disciplined team together at the start of the design process.

Part of the new slimline valve was put though its paces in front of the 'governor school' delegates when, in less than 40 minutes, Woodward technicians converted one of

Foreground, gateshaft governor converted with parts of modular new ModuFlo distributing valve, replacing the mechanical column [illegible]

Replacing a governor at Philadelphia Electric's Conowingo hydropower plant.

their ubiquatous, mechanical gateshaft governors to run with some of the new modular parts.

First, the old mechanical control column was removed. That was followed by the relay restoring link and the gate servomotor link, which were replaced by an LVDT, linked to the proportional valve, and an MLDT, respectively. A shuttle valve with a shutdown solenoid was then added. This safety interlock valve allows the proportional valve to work, but allows the shutdown solenoid to act when de-energised, locking out the proportional valve. Oil can then flow to move the distributing valve in the base into shutdown mode.

The whole new assembly fits onto the existing boltholes which had held the mechanical column with the pilot valve. For the demonstration, the new arrangement was controlled by a Summit 517.

Bishoff aims to link the MLDT to one of the company's model 700H - a basic speed governor developed for gateshaft conversions to compete against gate limit operators, which offer no speed control and deal only with gate positioning. The company says the ModuFlo system will work with all its digital controls, allowing it to offer a complete, new generation conversion package for its gateshafts.

Commenting on the conversion trial - the first, and in front of the industry - Bishoff says: 'It's fun to create new things.'

But all that said - why use a speed governor? It appears that many powerplant operators have been happy without, using gate limit operators and relying on the grid for stability. The US Electric Power Research Institute warned in its 1992 report - 'Impacts of Governor Response Changes on the Security of North American Interconnections' - that too many such governing systems soften the grid, giving a greater threat of instability. Further, if a lot of such non-speed control powerplants were islanded from the system, they would probably be unstable and it would be difficult to resynchronise them and get the grid back up. The warning is also valid for growing energy markets, which by their nature will have relatively softer grids.

A solution to the problem comes from the stabilising influence of the 'feed forward' algorithm, says David Kornegay, Woodward's engineering manager. It allows rapid power dispatching, a key commercial concern to sell power, without the need for higher forward gains when connected to the grid. The higher gains, used for faster dispatch, can cause a governor relying on the grid for stability to overcorrect to the grid's frequency variations. Enough governors in this situation can threaten the power pool with instability. If plants with stable speed gains are islanded, they would remain stable.

The speed control issue is controversial, says Kornegay. The feed forward allows gains to be set lower, so a powerplant could contribute to grid stability. 'But for many utilities, this is not a priority concern at present.' As already happens in the US northwest power pool, he says that this issue may come to the fore if more power pools demand that plants can contribute to grid stability before they are allowed to join, or continue in, a pool.

Once your powerplant is accepted into a pool, being competitive is not simply a question of getting things right at the unit level. As [illegible] control to improve efficiency and satisfy power dispatch calls becomes more important. Woodward project engineer, Tom Steber, explains that clients are increasingly looking for turnkey plant control systems, such as performed for Philadelphia Electric at its Conowingo plant.

Woodward designed a system at the heart of which was its NetCon 5000 controller, handling neutral breakers and turbine vent valves, as well as linking with the turbine governors by fibre optics and the operator control interfaces by serial links. Each of the plant's seven turbines had a Summit 517 governor installed, replacing four Allis Chalmers and three IP Morris governors which had been operating for more than 60 years. By managing the plant under this tighter regime, Steber says that its capability to go on peaking status for the grid meant the plant control system paid for itself within a year.

Governor training

Interactive computer training is becoming more popular with industry, and the hydropower sector is no exception. To this end, Woodward brought out the latest version of its mechanical turbine controls training system in March.

The software package, developed with training consultant CAE-Link for mechanical cabinet actuators (MCA), grabbed the attention of 'governor school' delegates last month.

Simple entry menu for the interactive computer training package ...

The MCA package offers nine modules - including a functional overview, cabinet controls and indicators, over and under frequency operation, and troubleshooting. The first module allows all modules to be accessed automatically sequencing. Although governing has moved on to digital controls, and sections of the system can be easily converted to suit, a dedicated version awaits industry demand.

The roots of the MCA training package lie with the US Bureau of Reclamation. It wanted a computer-based training package for the Hoover dam, CAE-Link got the contract, and the speciality governing section was developed with Woodward. The basic premise of the system was to create a computerised version of the company's MCA maintenance manuals.

In addition to being an interactive tool, it offers trainers or staff doing quick refreshment courses the opportunity to take tests. The company points out the tests are not designed to be part of any staff assessment system. It offers no record keeping facility or printouts after each test - a random selection of 20 questions out of 93.

More than 30 training packages have been sold to a dozen North American clients, and enquiries from Europe are increasing.

... which gets progressively more detailed on the hows and whys of mechanical governing.

With water turbines accounting for a fair share of downtimes and running costs of hydro-electric plant, improvements in automation control systems are continually being sought. Martin Hindley reports from Tampere.

Taking control

Modern advances in digital electronics coupled with the challenges of production technology, have galvanised efforts among designers to develop cheaper and more effective process automation equipment.

Valmet Automation, one of the leading manufacturers of process instrumentation and automation in Finland, has developed a task-oriented control package for power plants including hydro-electric facilities, which it calls Damatic XD. The system, which owes much to the established open architecture environment, regulates and controls water turbines as well as all sluicegate installations at a plant. It consists of a local network formed from a system network with units performing different functions.

The units are linked to eachother by a system bus, either duplicate coaxial or optic cable, into which the basic modules are connected. Communications in the bus is a name-based, token-passing type, relaying information at a speed of 2Mbytes/sec.

Valmet is currently installing the system at the Inkeroinen hydropower station owned and operated by Finland's Tampella Forest OY.

According to Matti Nyyssonen, sales manager for Valmet's Automation Systems division based in Tampere, two out of the five turbines at the plant have been already been equipped with the system. The three remaining units will be fitted out by the end of this year, he said.

The key driver for any hydro-electric plant is, obviously, to make maximum use of water flow. The operation of the plant is generally regulated by the surface level control of the upper reservoir, which guides surplus water current through the intakes.

The facility is designed to maintain the reservoir level at its maximum operational height during turbine activity, Valmet explains. It does this by controlling the water current ratio with the help of the turbines and the bypass drawing gates, the company says.

For security reasons, the surface level control of the resevoir can be duplicated so that the programs controlling the surface level operate in both stations. However, the process controls can only be received from the active station, which automatically updates the application data in the passive station, while the diagnostics monitors the operation of both active and passive sections.

The protection logistics of the turbines and the surface level control of the reservoir are carried out both in the process stations and using the freely programmable PLU cards at the I/O level of the Damatic XD system.

But, while this forms the basic control principle, Valmet says, there are also other control parameters, most notably, rotational speed control and power control, which the Damatic XD regulates.

The rotational speed control, which is employed in start/stop and isolated usage situations, has a set value controlled by a separate automation synchroniser. This, in turn, is controlled by automation.

When the supply frequency deviates from its nominal value by a certain amount, or when the network connection cuts off, the systems are always set automatically to the rotational speed control, which includes the facility to set the power-rotational speed statics necessary for parallel coupling, the company says.

In the event of a failure, a machine that runs in rotational speed mode can be interfaced with a "dark" network to access reserve power. In this case, level control of the reservoir is performed by the sluice gates.

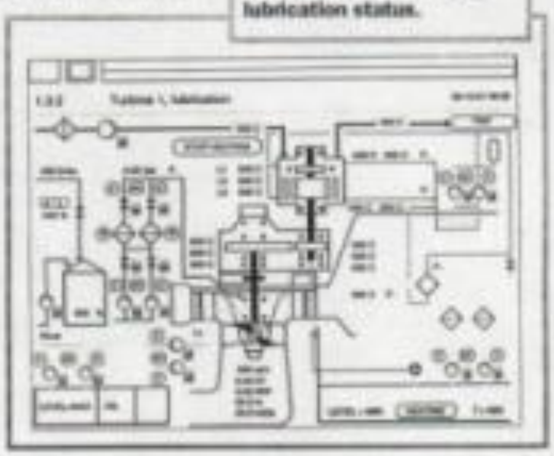
The power control, Valmet points out, is used to control the systems, according to the chosen standard and relative power levels as well as running the system at the desired load condition in the stopping phase. The system that is interfaced to the network can be run either during the starting phase to the desired power level or to an even power level with another machine through a ramp function. In the stopping stage, the automation sets the system unloaded (reverse power) using another ramp function, then opens the switch and sets the rotational speed control of the system to be stopped.

The system can be used either with the standard power level set according to the machine in question or with the balancing control of the power level.

The power level control can always be set without jerking using the ramp functions associated with start/ stop problems and it is not until the control logistics switches the chosen set value on, that a stable running status is achieved, Valmet says. With the balancing control, the set relation for power distribution between generators is reached.

Opening control can be divided into two key sections: leading wheel position control and runner wheel position control using the combination function. The position of the leading wheel is controlled by electro-hydraulic settings located on the turbines. These are set according to the output signal of the setting controller. The position of the moving blades is controlled in relation to that of the leading wheel, in relation to to the combination curves derived from model tests. The user can observe and manipulate the process status by means of a full-graphic video monitor and keyboard, either in a local or remote control room.

Typical Damatic XD screen display revealing turbine lubrication status.



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