EOL VALVE TEST BENCH AUTOMATIZATION

PETER OBLAK

Poclain Hydraulics d.o.o., Žiri, Slovenia
peter.oblak@poclain.com

The paper shows the process and examples of transition from manual to automatic testing mode on the test bench which was originally designed for manual testing. Test bench was designed for testing smaller batches of products. It is described what had been changed on the hydraulic circuit, electrical scheme and software side. In the first step hydraulic and necessary electrical modifications were made. When first part of modification was done, the software with automatic tests was updated. Third step was to setup communication between controller and server to synchronize test reports and test procedures, data logs, backups, oil cleanliness information, graphs etc. The software enables simple programming extensions with new features. The test procedure is quickly adaptable for new test procedures which comes when new valve is developed and needs to be tested on the test bench.

1   Intruduction

Test bench for EOL (End of line) testing is a machine where valves assembled in the factory are tested under required test procedures. Usually EOL test is located at the end of the assembly line or somewhere close. EOL test bench consists of hydraulic circuit with pumps, valves, hydraulic blocks, tanks, hoses, measurement equipment and connectors. In electrical cabinet all hydraulic and electrical equipment which needs to be wired are connected to get electrical power supply or acquire the measurements. Electrical cabinet include also controller with touch screen control panel with user interface for managing the software and controlling test bench and test procedures. To ensure safety standards test bench include safety cabinet and compact framework which can be seen on the Figure 1.

Figure 1: Test bench for EOL testing
Source: [2]

Test bench which is introduced in this article was originally designed for manual testing of small batches of the valves. Every valve which comes from the production/assembly line is tested on the EOL test bench to check if valve have any hydraulic or electrical dysfunction or any other damage which can lead to potential error on the customer application. With EOL test for every valve is ensured to deliver high quality product and satisfy customer's requirements.

2   The scope of investigation

To ensure highest possible quality of the product, the decision was to make step forward and upgrade the test bench for testing valves to automatic mode with automatic test procedures. In the sections below it is presented which components have been upgraded or replaced with newer to achieve this goal.

The upgrades were made on hydraulic, electrical and software side. During hydraulic and electrical upgrade, the test bench was out of service for one week. Software upgrade was made in parallel and was implemented when test bench hydraulic and electrical upgrades were ready. During start-up some issues were detected and successfully solved.

The software idea was to use blocks (functions) which can be easily build into the test procedure. With simple blocks, technician can build test programs by themselves with stacking blocks together one by one. The steps are executing in the procedure step by step from the first step to the last step (see Figure 2). In principle individual step is independent from all others. It is possible to merge steps to create partial process which could be a part of the main test procedure (Figure 3). Partial process can be used in several places in the test procedure. It could be also used in other test procedures, not just in one.
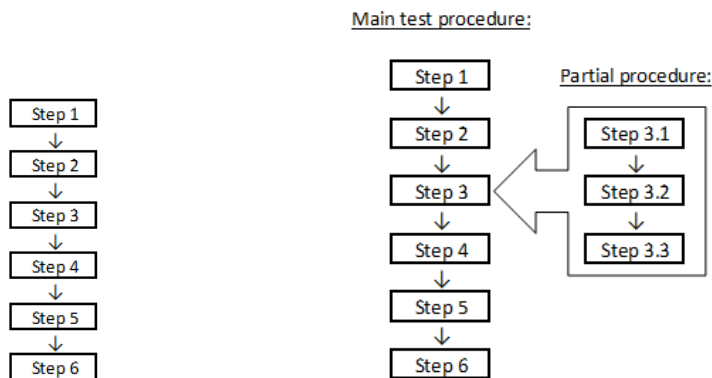
Figure 2: Step by step program execution.
Source: [2]

Figure 3: Step by step test procedure with partial procedures which are included as part of the main test procedure.
Source: [2]

When the requirement for new function arise, the programmer needs to develop new function according to test specifications which are usually given by R&D department. New function could be used in all further test procedures or partial procedures. When all required functions are ready the technologist needs to stack functions to a test procedure and validate test procedure on the test bench to be sure all works fine before test procedure is used in production.

3   Hydraulics modification

For hydraulics upgrades some hydraulic components had to be replaced and some new components had to be added to make possible test in automatic mode. The components which were added are:

- On/off valves instead of manual pipes,
- proportional valves instead of manual settings,
- flow meters,
- particle counter,
- cleanliness measurement (upstream and downstream oil measurement, ISO 4406),
- water cooling system instead of air cooler.

Figure 4: Additional flow meters which are easily to grab and plug into the tested valve.
Source: [2]

Due to lack of space inside the test bench frame it was a challenge to make all required upgrades. When test bench was designed (more than 10 years ago), it was not foreseen that big upgrades would be needed in the future and it was optimized for the current needs. The upgrade required quite a bit of adaptation from the teams which were involved in the upgrade.
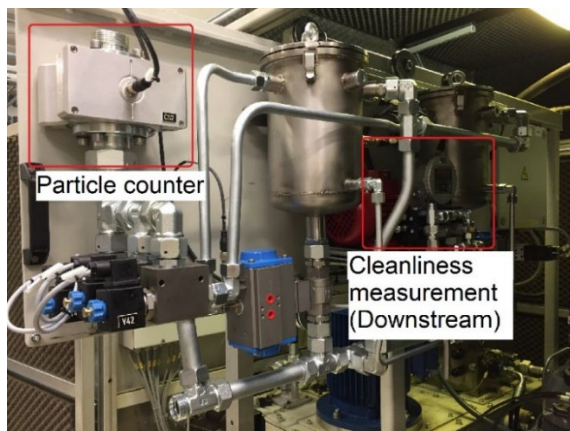
Figure 5: Particle counter and oil cleanliness measurement.
Source: [2]

Figure 6: Flow meter mounted on the rail in front side of the test bench.
Source: [2]

4   Electrical modification

Electrical cabinet dimensions were defined for the current needs at the time when test bench was designed. Usually, electrical cabinet is designed to have some additional free space for the future upgrades. In our case there was some additional space, but not enough for all components which were needed to be installed. It was chosen the solution to mount the components on the electrical cabinet door (Figure 7).

Figure 7: New components mounted on the electrical cabinet door.
Source: [2]

5   Software

Software LabVIEW was chosen because it offers many possibilities to adapt the software to specified requirements and needs. For acquiring measurement NI (National instrument) hardware was chosen. It is well known as the best ones and is often chosen for this kind of projects in our company.
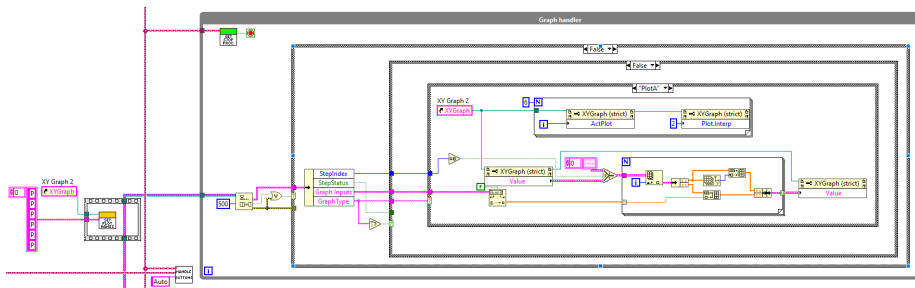

Figure 8: LabVIEW - block diagram example.
Source: own.

5.1   User interface

Basic user interface was made to communicate with operator. It has several options to login/logout, automatic testing, manual testing, maintenance mode, basic settings, turn on/off the main motor. Furthermore, the main screen shows essential

information about test bench status such as oil temperature, oil cleanliness, hardware status, log status, reporting status, monitoring, server synchronization etc.
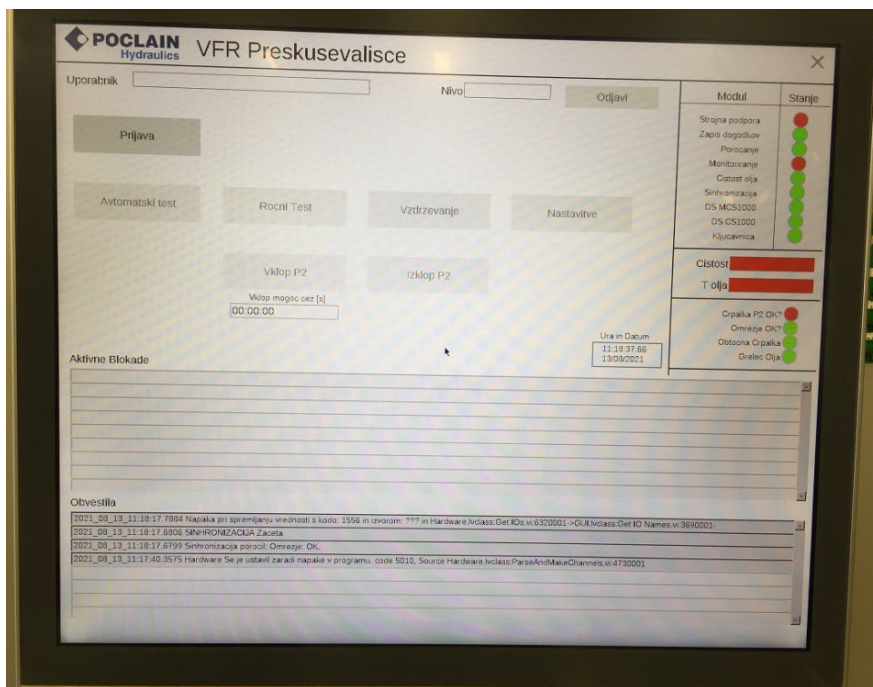

Figure 9: User interface - main screen.
Source: [2]

When click to each key, sub screen appears to operator to manage with test bench and test procedure. To manage with the program, operator can use touch screen, shortcuts on the keyboard, mouse and keypad.

5.2   Manual testing

To have option to test wide range of valves manual test was required. Also, for some valves automatic test does not have sense because it takes more time than manual test. In manual testing some test blockades are disabled (oil temperature range, oil cleanliness …) to have option of test also in case where all conditions are not valid for production testing. In manual operator have wider range of test options which could be useful.

5.3   Automatic testing

With development of technology and implementation of standard Industry 4.0 the need for EOL test bench automation becomes more and more important and necessary to reach high reproducibility of the test. With the same test procedure there is no deviation between the tests which may occur if test is manually managed by operator.

Test procedure consists of a set of steps (functions). With set of steps it is possible to make setting on the values, measure the values, capture the graph, analyse the graph or do anything else according to the test procedure. With own development of the functions in LabVIEW it is obtained almost unlimited possibilities to develop customized functions to achieve almost any test procedure requirement.

6   Advantages and disadvantages of automatic testing

6.1   Advantages

With test automatization the operator's influence on the test report and measurement results is eliminated and could not change test result during the test.

Test reports are generated at the end of every test and are stored on the controller. Every 5 minutes the synchronization between controller and server is triggered and reports with some other files synchronized to the server. If network connection is unavailable the reports are stored on the controller and are synchronized with the server when network connection is established again. After synchronization the original files are deleted on the controller side to release the space for new reports.

To have traceability of the EOL testing the output file is generated at the start of every month. In the output file all major data about tests and test bench are stored. Data structure of the output file can be seen on the Figure 10. This file is used for further analysis and monitoring in different applications.

Test time is important in the way of time consumption and production planning. It is measured how much time the operator spends to test one valve. During automatic testing operator don't need to stay all the time in front of the test bench, it can do other things such as assemble the valves, squatting holes, packing...

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Preizkusevalisce;Datum;Ura;Operater;Nalog_ID;Sifra;Naziv;Rezultat;Test_Ime;Test_Nacin;Test_verzija;Test_Cas;Olje_Temp;Olje_Nivo;Cistoca
VFR;29/06/2023;11:50:30;Damjan Mohoric;I1R55271621;B55535N;-;GG;B55535N;A;vA1.1;414;52.0°C;12.4/10.1/7.0
VFR;29/06/2023;12:12:34;Damjan Mohoric;I1R55271622;B55535N;-;GG;B55535N;A;vA1.1;437;52.1°C;11.8/9.2/7.0
VFR;29/06/2023;12:21:07;Damjan Mohoric;I1R55271623;B55535N;-;WW;B55535N;A;vA1.1;244;52.6°C;12.7/11.0/7.0
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VFR;29/06/2023;12:44:41;Damjan Mohoric;I1R55271625;B55535N;-;GG;B55535N;A;vA1.1;412;51.8°C;14.0/12.5/8.7
VFR;29/06/2023;12:52:44;Damjan Mohoric;I1R55271626;B55535N;-;GG;B55535N;A;vA1.1;410;52.7°C;13.4/11.7/8.2
VFR;29/06/2023;13:00:43;Damjan Mohoric;I1R55271627;B55535N;-;GG;B55535N;A;vA1.1;409;50.3°C;13.3/11.6/7.0
VFR;29/06/2023;13:08:40;Damjan Mohoric;I1R55271628;B55535N;-;GG;B55535N;A;vA1.1;414;51.7°C;13.5/11.8/7.2
VFR;29/06/2023;12:28:31;Damjan Mohoric;I1R55271623;B55535N;-;WW;B55535N;A;vA1.1;2854;50.5°C;13.5/11.7/7.0
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Figure 10: Output file example.

Source: own.

In manual testing mode operator have focus on the tested valve all the time during the test. For every test step needs to make some clicking on the keyboard or touch panel. He needs to manually turn on/off motors, valves and set the analogue values. Usually this set values are not set to exact value. Automatic test values are set to exact values every test. Values must be in range and are stored in the report at the end of the test.

Safety is provided with safety devices and is not controlled with test bench software. In our case there is no rotating parts or pressing devices. The only potentially danger is high pressure oil inside the hoses, blocks and valves which are located inside the safety cabinet. These components have high pressure lines where the pressure could reach over 300 bar which can be fatal.

6.2   Disadvantages

In case of NOK test results operator must decide what would be the next action with tested valve. In manual test process are some possibilities where the operator may make wrong decision. During the time it turned out that new operators need training on the test bench and induction period to be able to make the manual test in correct way and to make right decisions.

Test time for some test procedures is longer in automatic mode because it takes some time to measure and analyse the steps, but in manual mode operator can visually check the value and confirm or reject the step.

7   Conclusion

Three main upgrades (hydraulics, electric and software) of test bench were done successfully and test bench works in production for some time.

Next step where the focus will be soon is to test more valves with automatic tests. Some test procedures are in validation phase where separate steps are tested if works properly and in if measurement limits are set correct. Especially big interest is from production side. R&D department is interested to make automatic tests with steps which are adopted to their needs. The software allows us flexibility and adaptability to reach wide range of requirements.

With chosen software concept was achieved the agility and fast reaction to the market needs. It was reached short development time of new steps (functions) and consequently short time to develop new automatic tests for the valve.

References

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