Ten Years Of NEK MOV Program

Matija Balić
Enconet d.o.o.
Miramarska 20, HR-10000 Zagreb, Croatia
matija.balic@enconet.hr

Bogoljub Sember, Vladimir Butković
NE Krško
Vrbina 12, SI-8270 Krško, Slovenia
bogoljub.sember@nek.si, vladimir.butkovic@nek.si

ABSTRACT

In the mid-90's Nuclear power plant Krško (NEK) has initiated activities to address NRC concerns regarding potential failures of motor operated valves (MOV) that could cause them to fail to perform their safety function intended by the plant’s design. These concerns were addressed in IE Bulletin 85-03, General Letters 89-10, including subsequently issued supplements, GL 95-07 and GL 96-05. At the time, NEK has decided to establish a dedicated plant program (MOV program) that shall organise all necessary engineering and testing activities which will ensure safe and reliable operation of the NEK’s safety related MOVs (important for safe shut down of the plant in case of the postulated plant accidents).

NEK MOV program documents were initially developed based on the VECTRA Technologies methodology for prediction of MOV behaviour, but later on, as a result of use of the CRANE MOVATS testing equipment, their testing support and based on their well known and by the industry accepted testing approach, initially developed testing program documents (thrust/torque calculation procedure) were accordingly revised.

In cooperation with NUTEC (now ENCONET d.o.o.), a software tool was developed, able to store all data relevant for the program and calculations of the valve operating margins. This tool is the NEK MOV Database and includes all important valve data needed for calculation of both targets and thresholds as a prerequisite for field testing, and testing data needed for evaluation of the valve status after the test. Both Test Setup Window calculations and Post-Test Engineering evaluations are achieved using software's in-built mathematical algorithms.

Out of the whole NEK MOVs population, only safety related MOVs were screened out and included in the program. Currently, 124 valves are included in NEK MOV program, 120 of which have been comprehensively analysed and documented through the NEK MOV Database.

MOV program has been established in 1999, and divided into three phases:
- Phase1: Design Basis Review (finished)
- Phase2: Static test of all MOVs included in the program (finished as of 2009.)
- Phase3: Periodic Verification, Dynamic Tests, Trending&Maintenance (in progress)

This paper presents experience gained during first 10 years of the MOV program, its results, lessons learned and expected developments.
1. REGULATORY BACKGROUND

Industry-sponsored organisations, the US NRC (Nuclear Regulatory Commission), and many utilities have recognized the importance of MOV performance for a safe and reliable power plant operation. As a result, several industry and regulatory documents have been issued that stress the need for additional emphasis on activities that affect MOV operability. These documents include: Bulletin 85-03, "Motor-Operated Valve Common Mode Failure During Plant Transients Due To Improper Switch Settings" [1], Generic Letter 89-10, "Safety-Related Motor-Operated Valve Testing And Surveillance" [2], Generic Letter 95-07, "Pressure-Locking and Thermal-Binding of Safety Related Power Operated Gate Valves" [3], Generic Letter 96-05, "Periodic Verification of Design Basis Capability of MOV" [4] and SOER 83-9, "Valve Inoperability Caused By Motor Operator Failures" [9]. Each of these documents serves to underscore the necessity of a comprehensive program designed to assure MOV operability.
2. **NE KRŠKO APPROACH TO THE MOV PROGRAM IMPLEMENTATION**

After several incidents in other NPPs and generic Letters issued by the NRC, NPP Krško recognized the importance of a MOV program and decided to start with its implementation. On the basis of VECTRA approach, NEK MOV Team implemented activities on the NEK MOV program for an initial scope of 128 MOVs, as follows:

- Engineering judgement of appropriate selection of MOVs included in Krško MOV program in accordance with the following requirements:
  - Affected system and its parameters (fluid, diff. pressure, temperature etc.)
  - Control devices type (Torque Switch, Limit Switch, Bypass etc.)
  - Postulated plant accidents (worst-case) scenarios for performance of MOV intended safety function by the plant design
  - EQ (Environmental Qualification) zone requirements for all possible scenarios
  - Importance of the MOV to overcome the possible abnormal conditions

- Engineering verification of the appropriate adjustment of the control switches based on the engineering calculation and evaluation (Torque and Limit Switches) and readjustment if necessary.

- Performance of static diagnostic tests on each MOV within the NEK MOV Program to establish torque/limit switch settings and verify some of the assumptions used in engineering calculations (packing load, stem factor, torque-switch repeatability)

- Performance of dynamic diagnostic tests to simulate the design basis differential pressure. In the event these system conditions are not achievable, dynamic testing is performed at the maximum achievable conditions. It is to be performed on valves where it is practical and meaningful. As with static testing, dynamic tests verify some of the assumptions used in engineering calculations (valve factor and load sensitive behaviour).

In accordance to demands of NEK MOV Program implementation, NEK MOV Team divided all necessary activities into three phases, as follows:

- **PHASE I**
  - Preparation of NEK MOV Program including position papers, procedures and attachments (made by VECTRA)
  - NEK MOV Program independent verification (made by ERIN)
  - Krško MOV Database Software (made by NUTEC)
  - PSA Analysis for Krško MOV Program ("NEK ESD TR-08/97 Risk Importance Ranking Analysis for Krško MOV's" [10]) (made by NEK)
  - Performance of the "Weak Link" analysis (made by Crane Valve, Velan, Fisher, NUTEC, Borg-Warner, etc.)
  - Creation of valve files and providing every valve file with related valve drawing, B-201 and B-208 electrical drawings, flowchart, MECL Walkdown Data, isometric drawing, conduit and cable layout, termination sheets, engineering evaluation, test results collection and evaluationetc.)
  - Development of all postulated plant accidents scenarios for each MOV
  - Performance of preliminary engineering evaluation

Proceedings of the International Conference Nuclear Energy for New Europe, Bled, Slovenia, Sept. 14-17, 2009
**PHASE II**

- Appropriate training to members of the NEK MOV Team on such items as diagnostic test methods, test equipment, test results analysis and methods for setting and controlling MOV switch setting
- Maintenance procedures review and Testing procedure development
- Procurement of testing equipment (includes diagnostic equipment, cables, sensors etc.)
- Static and dynamic testing plan
- Development of static and dynamic testing procedures
- Test performance and prompt in-situ analysis
- Adjustment of control switches
- Performance of "root cause" analysis

**PHASE III**

- Periodic verification
- Post-maintenance testing
- Dynamic testing of preselected valves
- Analysis of periodic and dynamic tests, and post-maintenance testing
- Trending of test results
- Preventive maintenance

At the moment, subsequent to successful completion of Outage '09, Phases I and II have been completed. Phase III is of such nature that it will remain ongoing.

Intention of NPP Krško was to enlist mostly local sources for application of NEK MOV Program. For that reason, NUTEC developed Krško MOV Database as a very strong and comprehensive tool for realization of all implementation phases of the NEK MOV Program. Along with organization improvements (data tracking and systematization of responsibilities) and clear guidelines (based on test and calculation procedures) NEK MOV Database will ensure standardized and reliable testing process that should result in an effective MOV Program at NEK.

The Krško MOV Database was initially created in accordance with VECTRA approach. The purpose of the Database is the storage of basic valve data – both related to valve itself, and to conditions it is to encounter, performing calculations based on this data which gives a "target window" for actual testing data to achieve, and storage of both testing data and it's evaluation.

Since the start of cooperation between NEK MOV Team and CRANE Movats, new requirements have been made on the database. For that reason, the Database has been modified with two new segments, procedures "PR-11a" and "Engineering Evaluation", based on CRANE Movats technology. Mentioned procedure provides the MOV Team with all basic data necessary for periodic verification and trending purposes, as well.
3. MOV TESTING DURING OUTAGE '09 AND ANALYSIS OF TEST RESULTS

During Outage '09 34 MOVs were tested as shown in [Table 1.], 32 of them rising-stem, and two quarter-turn valves. Most were tested with Crane UDS data acquisition and analysis system, only two were tested with the Viper system. Easy Thrust Torque (ETT) strain gages were utilized as well as Torque Thrust Cell (TTC).

Table 1 – Outage '09 Testing Scope

<table>
<thead>
<tr>
<th>Test Date</th>
<th>Test Type</th>
<th>W/O Number</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI-8804B</td>
<td>12-Mar-09</td>
<td>Static</td>
<td>2008-7406</td>
</tr>
<tr>
<td>SI-8804A</td>
<td>16-Mar-09</td>
<td>Static</td>
<td>2008-7404</td>
</tr>
<tr>
<td>SI-8923A</td>
<td>17-Mar-09</td>
<td>Static</td>
<td>2008-6736</td>
</tr>
<tr>
<td>SI-8821A</td>
<td>18-Mar-09</td>
<td>Static</td>
<td>2008-6733</td>
</tr>
<tr>
<td>AF-11002</td>
<td>23-Mar-09</td>
<td>Static</td>
<td>2008-9229</td>
</tr>
<tr>
<td>AF-11003</td>
<td>24-Mar-09</td>
<td>Static</td>
<td>2008-6493</td>
</tr>
<tr>
<td>CC-10374A</td>
<td>25-Mar-09</td>
<td>Static</td>
<td>2008-6583</td>
</tr>
<tr>
<td>CC-10375A</td>
<td>26-Mar-09</td>
<td>Static</td>
<td>2008-6609</td>
</tr>
<tr>
<td>CC-10376A</td>
<td>27-Mar-09</td>
<td>Static</td>
<td>2008-6610</td>
</tr>
<tr>
<td>SI-8923B</td>
<td>28-Mar-09</td>
<td>Static</td>
<td>2008-6737</td>
</tr>
<tr>
<td>CC-10369A</td>
<td>30-Mar-09</td>
<td>Static</td>
<td>2008-7241</td>
</tr>
<tr>
<td>CC-10367A</td>
<td>31-Mar-09</td>
<td>Static</td>
<td>2008-6511</td>
</tr>
<tr>
<td>RH-8701A</td>
<td>6-Apr-09</td>
<td>Static</td>
<td>2008-7403</td>
</tr>
<tr>
<td>CC-10438A</td>
<td>7-Apr-09</td>
<td>Static</td>
<td>2008-7243</td>
</tr>
<tr>
<td>CS-8123</td>
<td>8-Apr-09</td>
<td>Static</td>
<td>2008-7379</td>
</tr>
<tr>
<td>SI-8811A</td>
<td>9-Apr-09</td>
<td>Static</td>
<td>2008-7674</td>
</tr>
<tr>
<td>SI-8808B</td>
<td>10-Apr-09</td>
<td>Static</td>
<td>2008-7678</td>
</tr>
<tr>
<td>CC-10301A</td>
<td>11-Apr-09</td>
<td>Static</td>
<td>2008-7233</td>
</tr>
<tr>
<td>CS-8134</td>
<td>12-Apr-09</td>
<td>Static</td>
<td>2008-7367</td>
</tr>
<tr>
<td>SI-8808A</td>
<td>13-Apr-09</td>
<td>Static</td>
<td>2009-5782</td>
</tr>
<tr>
<td>SI-8801A</td>
<td>14-Apr-09</td>
<td>Static</td>
<td>2009-6577</td>
</tr>
<tr>
<td>CC-10306A</td>
<td>15-Apr-09</td>
<td>Static</td>
<td>2008-8266</td>
</tr>
<tr>
<td>SI-8818B</td>
<td>16-Apr-09</td>
<td>Static</td>
<td>2009-6659</td>
</tr>
<tr>
<td>CC-10305A</td>
<td>17-Apr-09</td>
<td>Static/DP</td>
<td>2008-8186</td>
</tr>
<tr>
<td>CC-10302A</td>
<td>18-Apr-09</td>
<td>Static/DP</td>
<td>2008-8183</td>
</tr>
<tr>
<td>AF-11002A</td>
<td>19-Apr-09</td>
<td>Static</td>
<td>2009-7005</td>
</tr>
<tr>
<td>CC-10439A</td>
<td>20-Apr-09</td>
<td>Static</td>
<td>2008-7245</td>
</tr>
<tr>
<td>CC-10258A</td>
<td>21-Apr-09</td>
<td>Static</td>
<td>2008-7230</td>
</tr>
<tr>
<td>CC-10302A</td>
<td>22-Apr-09</td>
<td>Static</td>
<td>2009-7054</td>
</tr>
<tr>
<td>RC-8000A</td>
<td>23-Apr-09</td>
<td>Static</td>
<td>2008-7381</td>
</tr>
<tr>
<td>CS-8135</td>
<td>24-Apr-09</td>
<td>Static</td>
<td>2008-7907</td>
</tr>
<tr>
<td>CS-LCV112C</td>
<td>25-Apr-09</td>
<td>Static</td>
<td>2008-7368</td>
</tr>
<tr>
<td>SI-8801A</td>
<td>26-Apr-09</td>
<td>Static</td>
<td>2008-7941</td>
</tr>
<tr>
<td>RH-8702A</td>
<td>27-Apr-09</td>
<td>Static</td>
<td>2008-7933</td>
</tr>
<tr>
<td>SI-8801A</td>
<td>28-Apr-09</td>
<td>RL verif.</td>
<td>2009-7096</td>
</tr>
<tr>
<td>CS-LCV665</td>
<td>29-Apr-09</td>
<td>Static</td>
<td>2008-7380</td>
</tr>
</tbody>
</table>

During Outage '09 finally all valves were statically tested, since one last valve needed to have a disc pin replaced to elevate it's stress limit and thus open a Test Setup Window, which marked the end of Phase II of NEK MOV Program. Also for the first time dynamic tests were performed. They were planned on 4 valves but for various reasons only one test was completely successful.

Proceedings of the International Conference Nuclear Energy for New Europe, Bled, Slovenia, Sept. 14-17, 2009
The MOV testing should either affirm or disprove MOV capability for safe operation under the design basis conditions (worst-case). Before testing, both targets and limits need to be defined which delimits a Test Setup Window. It is comprised of a lower limit on thrust/torque, a requirement derived from system conditions and valve geometry, an upper limit of motor capability to deliver torque and not stall, and an additional upper limit of structural integrity of both valve and actuator. All three values include conservatively applied uncertainties (uncertainty of force requirement, uncertainty of motor capability, and uncertainty of stress limit).

![Diagram of MOV Test Setup Window](image)

**Figure 1 – Basics of Test Setup Window**

The Total Error (99% probability) is the sum of *Dependent Error* (bias) and *Independent Error* (random).

*Dependent Error* contains degradations such as Load Sensitive Behaviour (LSB), Spring Pack Relaxation (SPR) and Stem Lube Degradation (SLD). Dependent Error uses the most conservative model for determining uncertainty, errors are simply added (99% probability).

*Independent Error* contains Test Equipment Error (TE) and Torque Switch Repeatability (TSR) or Limit Switch Repeatability (LSR). Just TE includes all individual component errors involved in the measurement (transducer, module, A/D board etc). Independent Error uses more realistic estimate for uncertainty based on root-sum-square model (95% probability).
Testing was performed in accordance with the procedure GME-4.206r0, "Postopek za testiranje elektromotorno krmiljenih ventilov s pomočjo 'Movats 3500' in 'Crane Nuclear UDS' testne opreme" [11]. Usually MOV testing consists of the following main steps:

- Preliminary, as-found testing
- In-field analysis
- New torque switch setting (if necessary) and/or new limit switch setting (if necessary)
- As-left testing and In-field analysis

During In-field analysis testing crew evaluates test data considering these issues:

- Thrust/Torque meet requirement
- Thrust/Torque do not exceed any limits
- Stroke time is not exceeded
- Spring pack displacement is not exceeded
- Torque switch bypass covers unseating
- Control switch trip actuates at 50-75% of the MOV Test Setup window (if possible)

In-field analysis was performed on the Data Collection Computer. Then, test data was transferred with a memory-stick to an office-based Data Analysis computer for detailed readout. Results of detailed test trace analysis were finally input into the NEK MOV Database for both storage and Engineering Evaluation calculations.

4. **10 YEARS OF NEK MOV PROGRAM**

Over 10 years, approximately 300 tests were carried out on 120 valves (out of 128 included in the Initial MOV Program scope). Initial scope has shrunk due to plant modifications (valves no longer being used, 9050A and 9050B), and due to realizations that some valves cannot be tested (47000, 47001, 47002, 47003, which were only verified to operate correctly), or need not be included into the program scope (HCV133 and HCV227).

A vast majority of these tests were static ones, only during Outage '09 an attempt was made to perform 4 dynamic tests. During these, valuable lessons were learned, such as:

- It is crucial to anticipate physical practicality of test, and try to avoid situations where for instance one transducer is inside containment while the other is not.
- Only tests where a meaningful percentage of scenario conditions can be achieved are worth doing.
- Prior to test, a walkdown of components is valuable to avoid problems.

All the static tests done were analysed, and these results are now part of NEK MOV Database. They enable the determining of future testing frequency (based on achieved margins and valve significance), point to possible issues with the valve or actuator, and enable tracking and trending of individual valves over the course of multiple tests.

One issue noted for tracking and trending is that if the frequency of maintenance activities is greater than that of testing, trending is no longer very useful since every new test is essentially done on a "new" valve. Also, for a meaningful trend to become visible, a number of tests should be done – and if the frequency of valve testing is low, e.g. 6 cycles = 9 years, it is virtually impossible to identify ANY supposed trend over the lifetime of the plant.

The NEK MOV Database has shown itself to be an especially useful and robust tool for MOV Program, with its data storage and analysis functions.
5. REFERENCES

[1] Bulletin 85-03, "Motor-Operated Valve Common Mode Failure During Plant Transients Due To Improper Switch Settings",
[9] SOER 83-9, "Valve Inoperability Caused By Motor Operator Failures"
[10] "NEK ESD TR-08/97 Risk Importance Ranking Analysis for Krško MOV's"
[11] GME-4.206r0, "Postopek za testiranje elektromotorno krmiljenih ventilov s pomočjo 'Movats 3500' in 'Crane Nuclear UDS' testne opreme"