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Automation, Software und Informationstechnologie

**Report on the type approval of the
Adjustable Frequency AC Drives
PowerFlex 753 and 755
of Rockwell Automation Inc.**

Bericht-Nr.: 968/EZ 334.00/08

Datum: 2008-12-08

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Pages: 9

Test object: Adjustable Frequency AC Drive PowerFlex 753 and 755
Frames 2-7, 400V- 480V

Customer: Rockwell Automation
6400 West Enterprise Drive
USA-Mequon, WI 53092
United States of America

Manufacturer: Rockwell Automation
6400 West Enterprise Drive
USA-Mequon, WI 53092
United States of America

Order-No./Date: Email dlstewart@ra.rockwell.com
3061225 (TRNA number) dated 2007-05-31
3061218 (TRNA number) dated 2007-06-11
TUV36669 ((TRNA number) dated 2008-06-11

Test Institute: TÜV Rheinland Industrie Service GmbH
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Department: Automation, Software and Information Technology (ASI)

TÜV-Offer-No./Date: 968/32/07 dated 2007-02-05

TÜV-Order-No./Date: 9027938 dated 2004-04-20
9760428 dated 2007-06-11
9760481 dated 2007-06-12
9994548 dated 2008-06-11

Inspector: Dipl.-Ing. Thomas Steffens

Test location: see Test Institute

Test duration: October 2007 to November 2008

The test results are exclusively related to the test samples.

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1. **Scope**

This report documents the type approval of the Adjustable Frequency AC Drive PowerFlex 753 and 755 of Rockwell Automation Inc.

On this way the comprehensible proof shall be established, that the devices under test meet the functional and safety related requirements of the product specification and fulfils the requirements up to PL e and category 3 according to EN ISO 13849-1 as well as SIL 3 according to IEC 61508/ EN 62061 / EN 61800-5-2 for the integrated safety function "Safe Torque OFF" (STO).

2. **Standards forming the basis for the requirements**

- [N1] EN ISO 13849-1: 2008
Safety of machinery - Safety-related parts of control systems
Part 1: General principles for design
- [N2] EN 60204-1: 2006
Safety of machinery - Electrical equipment of machines
Part 1: General requirements
- [N3] EN 61800-5-1: 2007
Adjustable speed electrical power drive systems
Part 5-1: Safety Requirements - Electrical, thermal and energy
- [N4] EN ISO 13850: 2006
Safety of machinery; Emergency stop, Principles for design
- [N5] EN 62061: 2005
Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems
- [N6] IEC 61508 Part 1-7: 2000
Functional safety of electrical/electronic/programmable electronic safety-related systems
- [N7] EN 61800-5-2: 2007
Adjustable speed electrical power drive systems
Part 5-2: Safety requirements-Functional
- [N8] EN 61800-3:2004
Adjustable speed electrical power drive systems -
Part 3: EMC product standard including specific test methods

3. **Test object**

3.1 **Identification of the test object**

All technical data of the devices under test can be found in the belonging instruction sheets and the below listed documents.

The Adjustable Frequency AC Drive PowerFlex 753 and 755 are from the safety point of view technically identical. The only difference between PF753 and PF755 is control capabilities. The PF753 represents a subset of the function of the PF755. Therefore all testing was performed with the PF755.

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3.2 Documents

- V&V-Plan, DE 1005-007 Validation and Verification Plan.doc, 2008-07-29, 4 pages
- Firmware Functional Verification Test, DE 1005-006 SafeOff Firmware Functional Verification.doc, 2008-07-29, 7 pages
- Fault Insert Test, DE 1005-005 Safe Torque Off Fault Insert.doc, 2008-07-31, 7 pages
- Functional Verification Test, DE 1005-004 Safe Torque Off Func Verif.doc, 2008-07-31, 7 pages
- Product Requirements Specification, PF753_755_SIL-3_Design_Spec revision RP Final 6.doc, 2008-05-14, 21 pages
- Rhino Spacings, Rhino Spacings 4.doc, 2008-02-10, 3 pages
- Schematic, FMEA1.pdf, 2008-03-28, 5 pages
- EMC Test report, No.:30781469.004-NBO dated 2008-10-31
- LVD Report No. 30771465.004, dated 2008-11-10
- Determination of safety parameters, STO_FMEA_V0p10_081027.xls
- Installation Instruction, preliminary 2008-11-04, 750-IN001A_11-04-08.pdf, 94 pages
- User Manual, preliminary 2008-10-06, 750-UM001A_10-06-08.pdf, 249 pages

3.3 Test sample, test set-up

The judgment of the realized safety function “Safe Torque Off” has been carried out by means of an analysis of the provided documents and partly in common reviews together with the developer.

All other mentioned tests, performed by Rockwell or by TRNA, were performed on representative models.

The test sample will be kept by Rockwell Automation.

4. Tests and test results

4.1 General

The measuring and test equipment, which has been used by the TÜV Rheinland Group in the tests described in the following, is subject to regular inspection and calibration. Only devices with valid calibration have been used. The devices used in the various tests are recorded in the inspector’s documentation.

All considerations concerning uncertainty of the measurements, so far applicable, are stated in the inspector’s documentation, too.

In cases where tests have been executed in an external test lab or in the test lab of the manufacturer and where the results of these tests have been used within the here documented approval, this has occurred after a positive assessment of the external test lab and the achieved test results in detail according to the Quality Management procedure QMA 3.310.05.

4.2 Description and judgement of the safety structure

The adjustable frequency AC Drive PowerFlex 753 and 755 provides the safety function “Safe Torque Off”.

The integrated safety function “Safe Torque Off” has to fulfil the requirements for Performance Level e (PL e) and safety category 3 according to EN ISO 13849-1 and SIL 3 according to IEC 61508, IEC 62061 and IEC 61800-5-2.

As the safety function “Safe Torque Off” provides only a coast-to-stop capability, in application where coasting to a standstill may result in a hazard, additional protective measures, as mechanical brakes, are required.

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The safety structure of the safety function consists of a dual channel structure. Both independent safety inputs are used for disabling the logical control signals for the output IGBTs that are responsible for motor rotation and torque. All necessary signals to turn the output IGBTs on or off are routed through a buffer line driver. The first safety input is used for switching off the power supply of the driver and of the pull-up resistor of the PWM signal lines. The second safety input is used to disable this driver.

A diagnostic processor is used for monitoring the input signals for plausibility. A fault detection takes place by demand of the safety function. A monitoring of the concurrency of the signals is not realized.

In case of a detected fault, the diagnostic processor turn off both safety circuits and prevents a release and the system remains in the safe torque off.

Most of the faults can be detected on demand of the safety function but not all faults.

By organizational measures or by the application it must be ensured that the safety function is requested at least once the year.

Measures for fault detection are implemented in the diagnostic processor in order to ensure proper function of the processor. By means of these measures a few failure can be detected but not all. The measures are described in detail in the "Product Requirements Specification".

The firmware of the diagnostic processor has been developed according to the quality standards of Rockwell.

For the realization of the safety function STO following boards are involved:

- Control board with among others the Driver chip used to control the IGBT gate signals
- Safe Torque Off option board
- Back Plane as interface between the Control board and Safe Torque Off option board

The Safe Torque Off option board can be used in two different slots of the drive. The other slot can be used by any other board (i.e encoder board).The safety signals as well the signals of the other none safety relevant option boards are routed through the Back Plane.

Due to this it must be excluded that faults in the none safety relevant option boards do not cause a bridging of the safety signals. Hence the existing option boards have been analyzed in order to exclude this fault. For future boards the corresponding safety pins will not be fitted.

For using the Safe Torque Off option board a jumper on the control board must be removed to prevent that the driver will be supplied by the control board.

The necessity of removing this jumper for the operation of the Safe Torque Off option board must be described in the user manual. The jumper can only be reach by means of a tool.

A fault message at the drive will be indicated, if the option board is installed and the jumper is not removed.

The procedure how to remove the jumper is described in user manual.

The STO option board is supplied by the drive mounted power supply with +24 VDC and +/- 12 VDC (PELV).

With this described safety structure, the integrated safety function "Safe Torque Off" fulfils the requirements for safety category 3 and PL e according to EN ISO 13849-1 and can be used in application up to safety integrity level 3 according to IEC 61508, EN 62061 and EN 61800-5-2.

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4.3 Results of the functional and safety analyses

In a common review together with the developer the safety of design of the Hardware has been discussed and analysed.

Base on the reviews a failure mode and effect analysis (FMEA) has been performed by Rockwell for providing the evidence that no single fault results in the loss of the safety function.

The FMEA has been verified by the Test Institute by a theoretical analysis and selected parts have been tested by Rockwell supervised by an inspector of TÜV Rheinland.

Following conditions have to be considered:

- Both safety inputs have to be used in parallel independent to each other.
- Due to the fact that a short circuit in the external wiring of the safety inputs will not be revealed by the system a fault exclusion according to DIN EN ISO 13849-2 has to be made. This is possible for example, when the cable is protected against external damage by cable ducting or armouring.
- The correct function of the safety function has to be verified periodically by requesting the safety function at least once a year.
- Additional measures must be foreseen, if external forces are effective on the motor axis, such as mechanical brakes.

The requirements for the integrated safety function "Safe Torque Off" according to EN ISO 13849-1 category 3 and PL e and according to IEC 61508, EN 62061 and EN 61800-5-2 SIL 3 are fulfilled.

All the required information for a safe use can be found in the user manual.

4.4 Determination of the Safety parameters

The architecture of the safety circuit of the safety function "Safe Torque Off" is entirely redundant. Therefore the Hardware Fault Tolerance (**HFT**) is determined to **1**. That means without the consideration of any diagnostic measures any single fault will not cause the system to fail to danger. The Common Cause factor β has been determined to **2 %**. The system provides no **online** diagnostic. A diagnostic will be carried out on demand of the safety function.

Due to the fact that the safety circuit is realized by discrete hardware, the system is considered as a low complex system (Type A System) according to IEC 61508.

For the determination of the safety parameters PFD_{Av} and PFH following assumptions have been made:

- The safe state is the de-energize state.
- The failure rates are constant over the whole time.
- The reference condition of the SN29500 are kept.

The following results have been determined under an assumption of a proof test interval of 20 years:

$$PFD_{Av} \approx 3.29 \cdot 10^{-5}$$

$$PFH_D = 1,36 \cdot 10^{-9} \text{ calculated according to IEC 62061}$$

$$PFH \approx 3.75 \cdot 10^{-10} \text{ 1/h calculated according to IEC 61508}$$

$$MTTF_D = 1952 \text{ years}$$

$$DC_{av} = \text{High}$$

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The details for the determination of the safety parameters are described in the document "STO_FMEA_V0p10_2008-11-13TUV.xls".

The safety function "Safe Torque Off" fulfils the safety parameters for the safety integrity level 3 according to IEC 61508 and PL e according to EN ISO 13849-1.

4.5 Judgement of the measures for the fault avoidance

The developing of the integrated safety function of the PF753/PF755 has been carried out according to the requirements of IEC 61508. The required documents to the different phases of the life cycle have been produced and the relevant measures for fault avoidance according to IEC 61508 have been applied.

These documents are present at the Test Institute.

Furthermore the Quality Management System of Rockwell is certified according to ISO 9001 for design, manufacture, distribution and service of automation components and systems. The certificate is present at the Test Institute.

The measures for the fault avoidance which have been carried out by Rockwell for the developing of the integrated safety function of the PF753/PF755 are sufficient to fulfil the requirements for SIL 3 according to the IEC 61508.

4.6 Electrical safety

TÜV Rheinland of North America (TRNA) has performed the electrical safety certification according to EU Low Voltage Directive (LVD) and to EN 61800-5-1. The results are documented in the summary report-no.: 30771465.004 dated 2008-11-10 and confirm, that the PF753/PF755 fulfils requirements according to the EU Low Voltage Directive (LVD) and to EN 61800-5-1 for the above mentioned models.

The results are accepted by the Test Institute.

4.7 Environmental tests

The environmental tests according to EN 61800-5-1 have been carried out by TRNA. The results of these tests are documented in the summary report: 30771465.004 dated 2008-11-10 and confirm, that the requirements according to EN 61800-5-1 are fulfilled.

The results are accepted by the Test Institute.

4.8 EMC/EMI contemplation

The results of the EMC tests are documented in the summary report-no.: 30781469.004-NBO and confirm, that the requirements for EMC conformity according to EN 61800-3 are fulfilled. Further increased levels according to EN 62061 have been applied.

The results are accepted by the Test Institute.

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5. Summary

The type approval of the safety function "Safe Torque Off" within the adjustable frequency AC Drives PF753 and PF755, manufactured by Rockwell Automation, Inc., came to the result, that the requirements of the applicable standards, which are listed in clause 2, are met.

Furthermore the inspection of the safety function "Safe Torque Off" of the adjustable frequency AC Drives PF753 and PF755 came to result that the safety function fulfils the requirements for safety category 3 and PL e according to EN ISO 13849-1 and Safety Integrity Level 3 according to IEC 61508, EN 62061 and EN 61800-5-2 under the following prerequisites:

- Both safety inputs have to be used in parallel independent to each other.
- Due to the fact that a short circuit in the external wiring of the safety inputs will not be revealed by the system, a fault exclusion according to DIN EN ISO 13849-2 has to be made. This is possible for example, when the cable is protected against external damage by cable ducting or armouring.
- The correct function of the safety function has to be verified periodically by requesting the safety function at least once a year.
- Additional measures must be foreseen, if external forces are effective on the motor axis, such as mechanical brakes.

The above listed conditions and the user manuals must be considered.

Cologne, 2008-12-08
TIS/ASI/Kst 968 stf-ta

The expert



Dipl.-Ing. Thomas Steffens