

# THE NEW I&C SYSTEM OF THE TRIGA MARK II REACTOR VIENNA

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## ABSTRACT

The TRIGA Mark-II reactor was installed by General Atomic (San Diego, California, U.S.A.) in the years 1959 through 1962, and went into operation for the first time on March 7, 1962. The TRIGA Mark II reactor in the Viennese Prater is part of Atominstitut which was founded in 1958 as an inter-university institute for all Austrian universities and started operation in 1962, when the TRIGA Mark II research reactor of the institute was officially opened. As part of the reform of the university system, the Atominstitut was integrated 2002 into the Faculty of Physics at the TU Wien. The operation of the reactor since 1962 has averaged 220 days per year, without any long outages. During the last 50 years 3 different I&C systems were in use to control the reactor power and safety related parameters. From 3 different vendors, Skoda, Invap and GA, the Skoda company located in Pilsen was chosen in November 2013. The main work is done together with the subcontractor dataPartner.

## 1. Introduction

The TRIGA Mark II research reactor of the Vienna University of technology is in operation since the 7<sup>th</sup> March 1962. When TRIGA reactors were developed in the mid-fifties, the typical state of the art of I&C systems was based on vacuum tubes. At the Atominstitut this type of I&C systems produced by the company General Atomic (GA) was in use until 1968. Towards the end of the sixties transistors replaced electronic tubes also in I&C systems, and a new type of TRIGA instrumentation based entirely on transistors were marketed. Therefore, during the seventies many TRIGA reactors converted to such types of I&C systems which in a few cases are still in use. At the Atominstitut this replacement took place in 1968. This type of reactor instrumentation produced by the company AEG was easy to maintain and spare parts could easily be replaced for about 20 years until they slowly disappeared from the market. As a result, a new type of digital and modern software based I&C systems were developed and available from the early nineties onward. As software based I&C systems were usually not accepted by the regulatory authorities, a hard-wired back up system for safety related parameters were required and, therefore, a combination of both was the state-of-the-art I&C system in most of TRIGAs world-wide for long time. In 1992 the old transistor

based I&C system was replaced by a new digital software based I&C system produced by the company GA. Nowadays, after use for more than 20 years of software/hardwired digital I&C systems various components of those have again reached their end of life-time. Therefore, the University decided the fourth time to replace the old I&C system by a new one. This new generation 4-digital I&C systems are capable to monitor and control variables and parameters of physical and other processes, component and system statuses, as well as to react on predefined project limits and safety conditions. The details of this new I&C system produced together by the Skoda Company located in Pilsen and dataPartner located in Ceske Budejovice, both Czech Republic, are presented in this paper.

## 2. System Architecture

Generally, system and equipment architecture follows the existing concepts. The whole system consists of SCRAM logic, neutron flux measurement channels (OPM - Operational Power Measurement, IPM – Independent Power Measurement, and PPM - Pulse Power Measurement), I&C field instrumentation, control system, new operator’s console and data acquisition system.

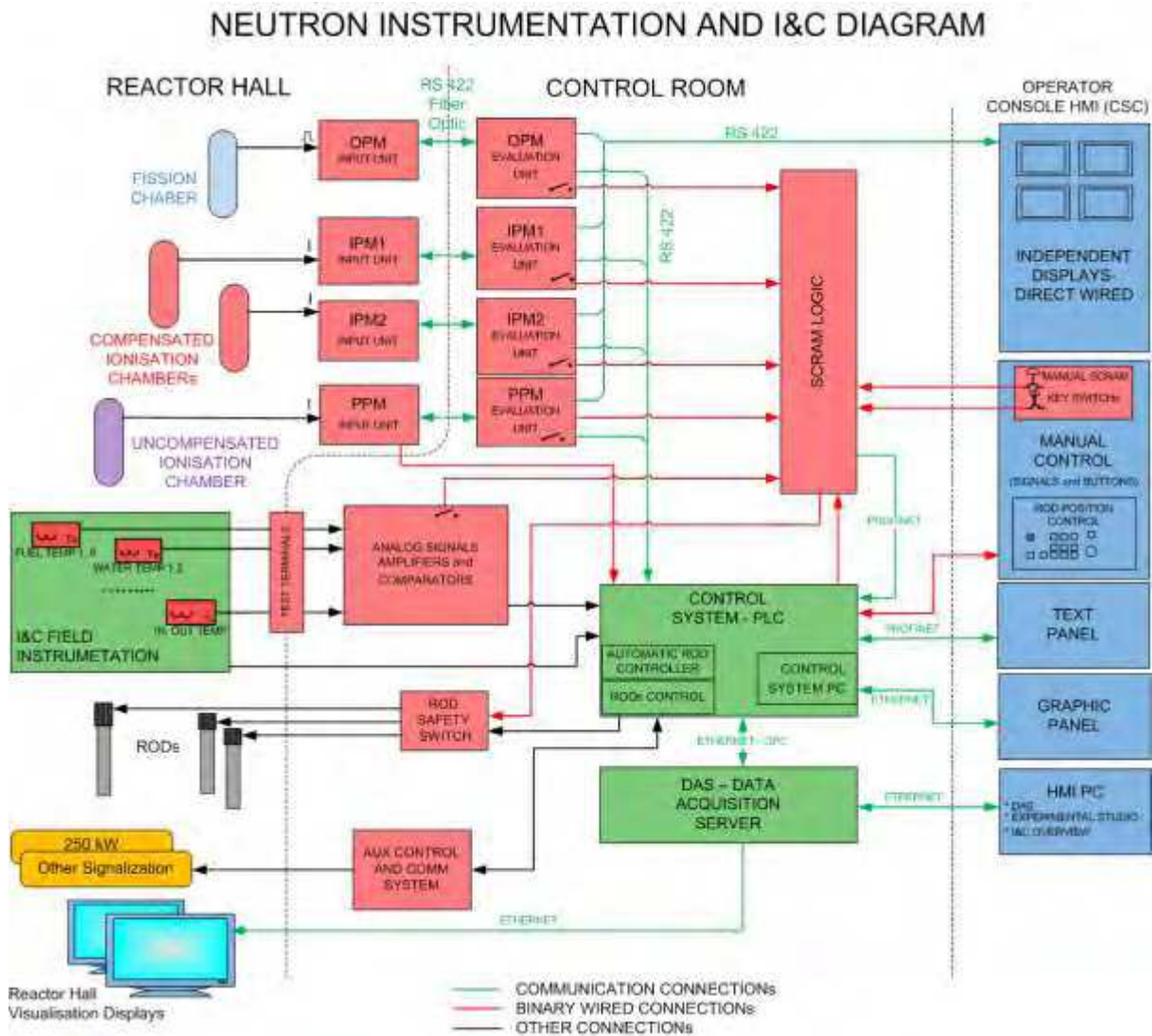


Figure 1: I&C Overview Diagram

### 3. Neutron Detectors

The following three different types of detectors for neutron flux measurements are used on the TRIGA® reactor:

- 1 pc of fission wide-range chamber for neutron flux measurements and for reactor control from source range (about 5 mW) to nominal power (250 kW). It works in Campbell mode – Photonis type CFUL08.
- 2 pcs of compensated ionization chamber for reactor control and especially for safety functions from source range to nominal power – Centronic type RC6
- 1 pc of non-compensated ionization chamber for measurements in pulse mode (peak till 250 MW, energy till 12 MWs. It measures amplitude, length and shape of pulse) – Centronic type RC7.

### 4. Neutron Flux Measurement Channels

- 1 pc wide-range operational channel – Operational Power Measurement (OPM)
- 2 pcs wide-range safety channels – Independent Power Measurement (IPM)
- 1 pc wide-range pulsing channel – Pulse Power Measurement (PPM)

Signals read from chambers are directly numerically processed to reactor power value and reactor power change rate – period in wide-range channels. The power value is converted to common units and can be expressed in %, cps, A or W. Actual values are updated every 100 ms and are sent via optical serial line to an independent display and via second optical interface to a control system. These channels open Safety Relay contacts in the Scram Logic loop if measured values exceed the preset protection setpoints or in the case of any system internal failure is indicated.

All channels consist of the two following units:

- Input unit for processing neutron chamber signal and converting the analog signal into digital domain for transmission to the evaluation unit.
- Evaluation unit for comparison of the neutron flux measured values against the safety system setpoints.

The hardware platform is based on Texas Instruments Hercules safety microcontrollers. These microcontrollers are based on ARM Cortex-R dual-lockstep IP cores and are designed specifically for IEC 61508 safety critical applications.

The software is developed in C programming language using Texas Instruments ARM compiler and tools. The software development respects recommended practices and guidelines, e.g. MISRA standard or NUREG CR-6463 guidelines.

Channels are equipped with test signal generators, which allow auto diagnostics and safety function check every time before the reactor is started up.

### 5. Scram System

The TRIGA type reactor is the only nuclear reactor in this category with worldwide excellent safety record of over 50 years due to inherent features such as the intrinsic characteristic of the standard reactor U-Zr-H fuel. It results in safe and reliable self-shutdown while the temperature coefficient acts independently of any external controls in the event of an accidental reactivity insertion. That offers true "inherent safety," rather than relying on

"engineered safety" features. Nevertheless the new I&C System provides additional external means to assure that the TRIGA reactor safely shuts down in unexpected power or temperature deviations.

### Scram Logic Circuit

The entire SCRAM circuitry is hardwired and is not affected by any software based systems or the Control or Data acquisition system.

Automatic SCRAM logic is implemented on relay logic, consisting of certified safety relays. The design allows for 100% testability features and accurate analysis of the safety function reliability. The safety relays are capable to perform self-diagnosis. Power relays are continuously diagnosed at every contact switching. Diagnosis is mainly focused on sticking relay control (checks and evaluates the time till contacts open). The diagnosis consists of two redundant computation branches. If at least one of the branches evaluates the safety condition failure, it opens the output contactor contacts (reactor trip).

Output contactors disconnect power to magnets and pneumatic valve resulting in drop of control rods (reactor trip).



*Figure 2: SCRAM Module Example*

Specifically SCRAM Logic boards use:

- Safety category relays. These are compact, slim relays conforming to:
  - EN Standards (EN50205 Class A, certified by VDE),
  - EN61810-1 (Electromechanical non-specified time all-or-nothing relays)
  - UL standard UL508 Industrial Control Device,
  - CSA standard CSA C22.2 No. 14 Industrial Control Devices

## 6. Reactor Control System

The Reactor Control System (RCS) is a modular distributed control system with PLCs in different locations. The fast industrial bus Profinet facilitates interfaces among the PLCs, displays, inverters, and other components. Profinet commands can implement requested rod position including maximum rod motion speed. RCS has the capability to self-diagnose status and failures of inverters and motors. The Siemens Simatic S7 PLC system, a widely used industrial control system in Europe, was selected for TRIGA reactor control.

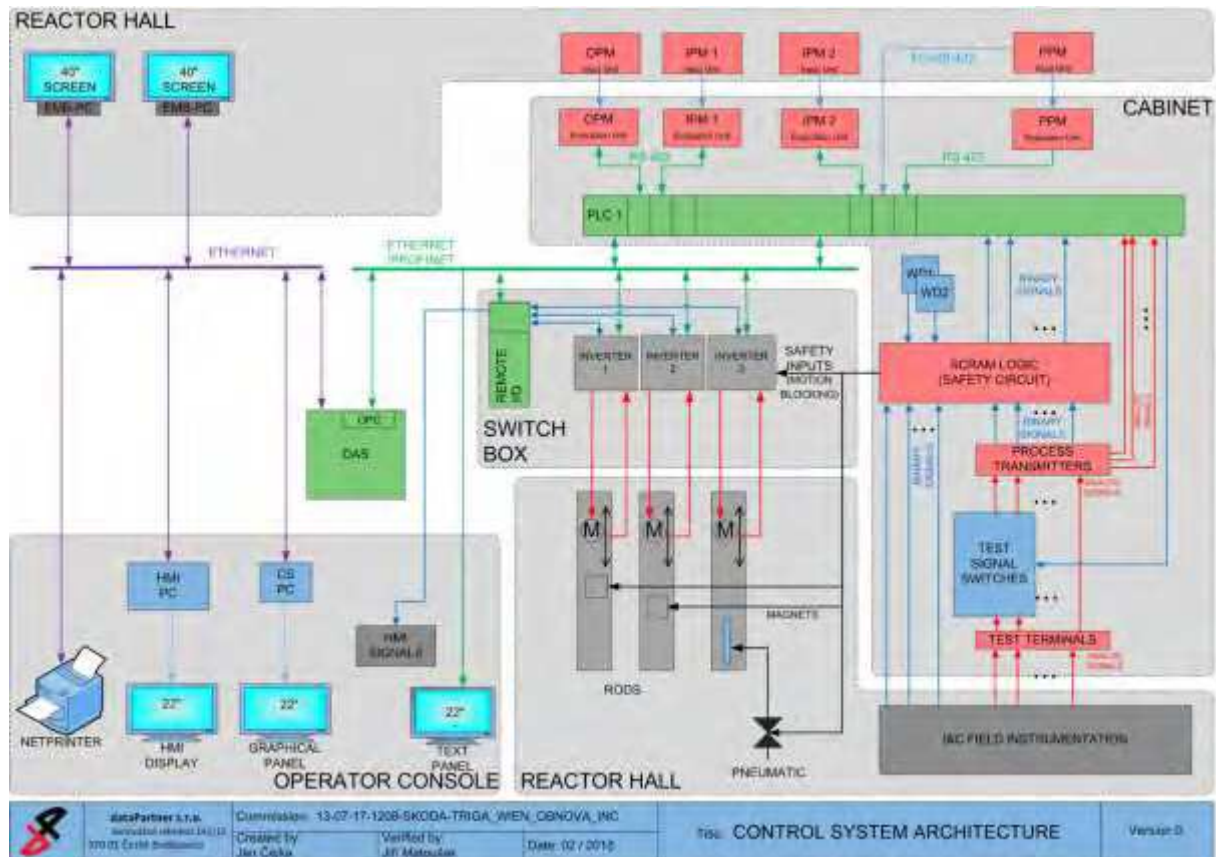


Figure 3: Control System Architecture

## Reactor Control System States

At any moment the reactor control system is in one of four possible states: *Standby*, *Shutdown*, *Pre-start Checks* and *Operation*.

## Reactor Operation Modes

### Manual Mode

In the *Manual* operation mode, the operator controls the drives manually, thus an operator manually controls the power output of the reactor without active automatic intervention of the control system (as long as the reactor power stays below the maximum pre-set levels).

### Auto Mode

The reactor control system, when placed in *Auto* operation mode, will automatically control the position of the regulating rod or the safety rod or any combination of the two to maintain a specific power level. The remaining rods including the transient rod are under manual control.

### Pulse Mode

The *Pulse* operation mode allows to produce a very high power, short duration pulse from the reactor. This pulse effect is accomplished by firing the transient rod upward with compressed air.

## 7. Experimental Studio

The Experimental studio is a SW tool for working with data acquired during experiments and training. It is suitable especially for teaching students to work independently when processing and evaluating data and confirming theory. The Experimental studio allows easy and effective creation of mathematical tasks for acquired data analysis – the batch processing of recorded data as well as online streamed incoming data. The Experimental studio can use online reactor operational data or recorded history data.

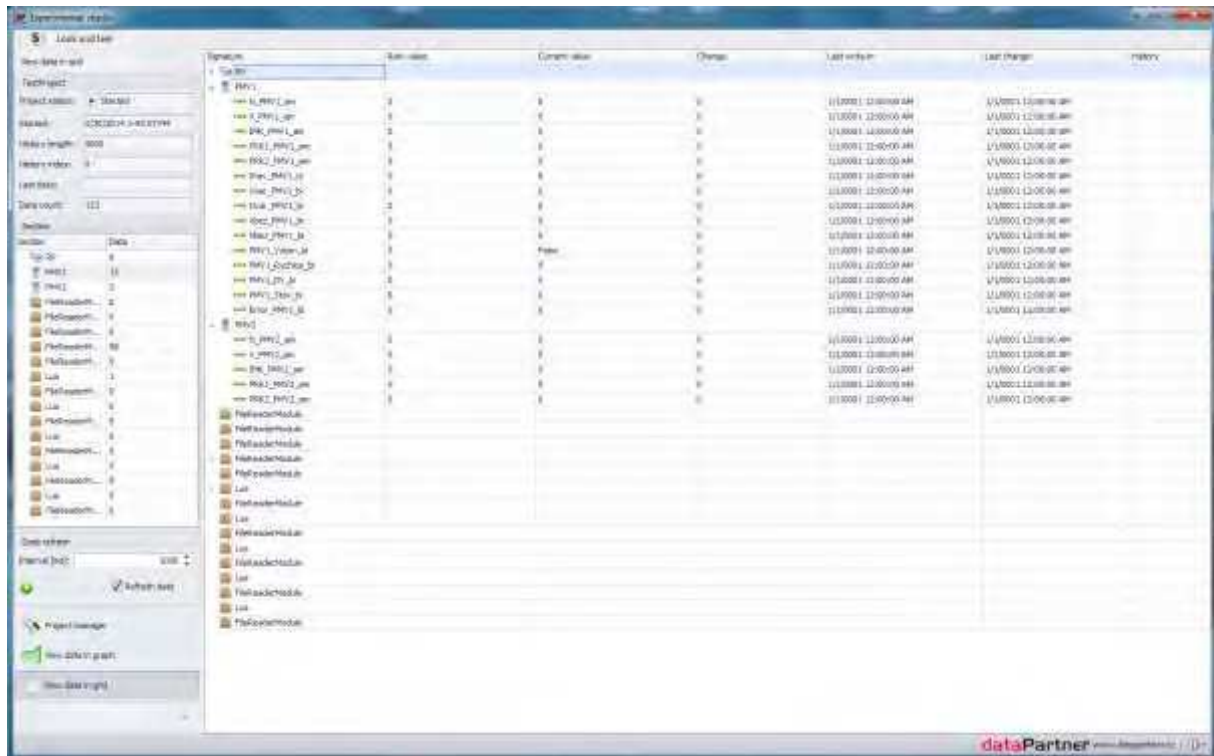


Figure 4: Experimental studio screenshot

## 8. Data Acquisition System

For storing all measured and computed variables at the operator console, a dedicated data acquisition and logging system (DAS) is used. DAS is based on industrial PC architecture, the data is stored on hard discs. It gathers data from the control system and stores it to the database for later recall, analysis or playback.

## 9. Safety Systems Qualification

All I&C structures and components are designed so that they can perform reliably their functions under the environmental conditions they will be submitted to during their mission time. The operability of I&C structures and components under the related environmental conditions was demonstrated by tests, analysis, operation experience, etc. The supplier's qualification procedures are established to confirm that the equipment is capable to meet the requirements for performing safety functions while subjected to environmental conditions existing prior to and at the time when it is required throughout operational life.

Qualification includes the following:

- Functional Tests
- EMC Tests
- Accelerated Ageing Tests
- Seismic Tests

## Seismicity

The equipment is designed, manufactured, and tested on the basis of the general dataPartner qualification procedures for seismic resistance which should also be valid for the actual realization site per Reference [11].

The tests have been performed according to [11] IEC 980: 1993 with acceptable results. The applied test earthquake intensity exceeds required seismicity criteria in the document ATIB1010 Sicherheitsbericht 2013 [19].

## Equipment Lifespan

The reactor site integrated radiation dose is so low that it does not significantly impact ageing of the equipment outside of reactor, thus neutron flux measurement modules and SCRAM relays are tested for at least 15 years qualified lifetime by accelerated ageing methodology.

## SW qualification

The system SW is developed and tested by standards, methodology, and QA procedures required by the Czech State Authority for a 10 MW research reactor LVR-15 in the Czech Republic. Safety System SW development follows Reference [14] including Graded Approach. Safety Related System SW development follows Reference [15] as it is documented accordingly.

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