

Modular Test Equipment – Flexible Application Test Bench for Fuel Cell Power Systems

P. Jung, A. Henne, M. Strohmaier

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Modular Test Equipment – Flexible Application Test Bench for Fuel Cell Power Systems

Peter Jung*, **Andreas Henne**, MOEHWALD GmbH, Germany

Manfred Strohmaier, Engineering und Anlagenbau GmbH, Germany

1 Introduction – Modular Test Equipment

A complete fuel cell power system consists of various components like fuel cell stack, heat exchanger, humidifier, compressor, expander or control valves. Acceptable test results can only be achieved by using an efficient test design taking into account the complexity of interaction between different components. The detailed investigation of these components requires tests with real system components as well as tests with test bench components.

For such tests a flexible and fast exchange of components is required. The supply of all components in a modular and optimised design allows such testing concepts. The modules must be well maintainable and safely exchangeable. Furthermore, only precise control and accurate data acquisition allows precise investigation of complex processes in the system.

2 Flexible Test Bench System – Concept

Test equipment for technical systems requires the same development standard as the prevailing system. Due to the changing demands in testing fuel cell systems - more system and component testing rather than 'stack'-testing - a flexible solution is required to perform a larger variety of tests. MOEHWALD GmbH has developed a suitable concept for an innovative test bench meeting such requirements.

2.1 Standard test equipment for stack-test

Actually, state of the art test benches for 'stack'-testing consist of the following components described in the block diagram below.

All components like the medium supply, humidifier, cooling system, pressure control, loading and controlling, data recording and software are 'hard wired' and cannot be replaced with other components. Figures 1 and 2 show a MOEHWALD GmbH standard stack test bench with fast steam humidification. The test bench provides a basic standard of gas circuits for anode and cathode gases, an exhaust unit, a cooling circuit and an electronic load. Optionally, additional gas circuits for mixing noxious gases are available.

* Corresponding author, email: p.jung@moehwald.de

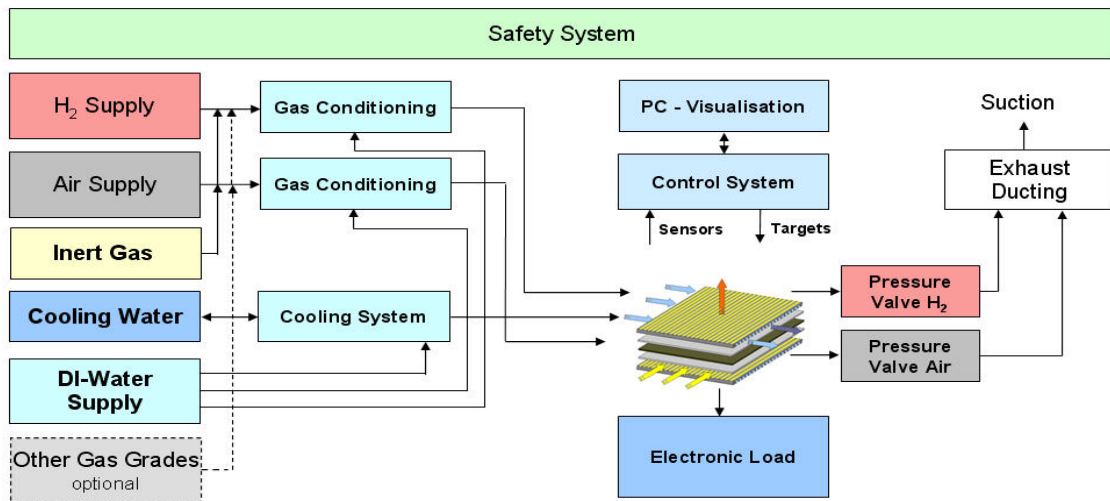


Figure 1: block diagram of standard stack test equipment – hard wired.

The continuous operation of a fuel cell stack can be realised through an automation system with a time based load control. The sensors, actors and the control software allow a load conditioned setting of mass flow, temperature, humidity, fuel gas pressure and cooling medium temperature. In addition, the test bench is equipped with an independent and comprehensive safety and alarm-processing system, which allows a comfortable integration into the customer's laboratory safety functions, e.g. a building management system.



Figure 2: MOEHWALD GmbH PEM stack test bench FCP5000-15 (15kW).

2.2 Flexible test bench for stack, components and system testing

The underlying idea of the new test bench concept is to allow a flexible exchange of provided standard test bench elements with components of the fuel cell system. The result is a test

system that combines the capability of stack, components and system testing in only one bench. For stack testing idealised bench components are used to assemble an optimised test environment, for component testing, the stack is part of the test bench system. Like a - construction kit - the concept is realised by several independent test bench components. They can be put together to a complete, functional test system according to the requirements defined by the test engineer. Ideally every single test bench component has got its own integrated controller in order to allow an adaptation to the required process behaviour via software. The system is able to simulate different real components or can be used to develop components that perfectly fit into the overall system. This, in turn, leads to high demands on dynamic behaviour of the applied actors and sensors. An overlaid host computer with appropriate real-time software responding to the varying requirements of such variable machinery provides control over all elements of the ‘construction kit’.

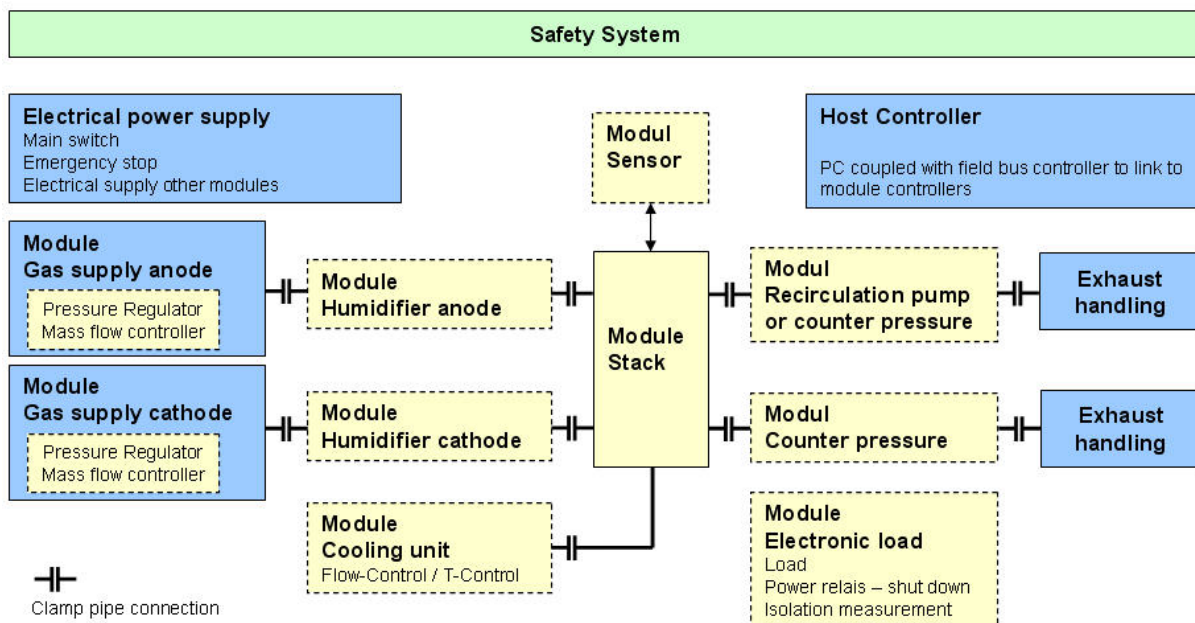


Figure 3: Block diagram - concept modular flexible test bench.

Figure 3 shows a block diagram which exemplifies the new concept on the basis of a test bench for a PEM fuel cell system. Modules in dashed line can be omitted or added, others in solid line are integral part of the system. Essential system parts that must not be omitted are the safety system, the electrical power supply as well as the host controller, gas supply and exhaust handling. Other modules like humidifier, cooling unit, sensor module, stack module, counter pressure, recirculation etc. can be arranged or substituted by system-oriented components achieving the test engineers conception.

3 Flexible Test Bench System – Main Components

3.1 Test bench – Power feed-in and emergency stop

Electrical power components are placed in a separate cabinet, assuring test bench modules feeding and emergency stop control. Each test bench module is equipped with a terminal

box, containing the required electrical hardware plus an EtherCAT® slave for process I/O. The hardware includes components - connected to the central emergency control unit – to assure, that every single unit is set to a safe basic condition in case of an emergency stop.

3.2 Control system with data acquisition

Control and data acquisition of the system, made up of alterable modules, is performed by a host PC including a field bus controller e.g. EtherCAT® master. Each test bench module contains its own EtherCAT® slave linked to the master.

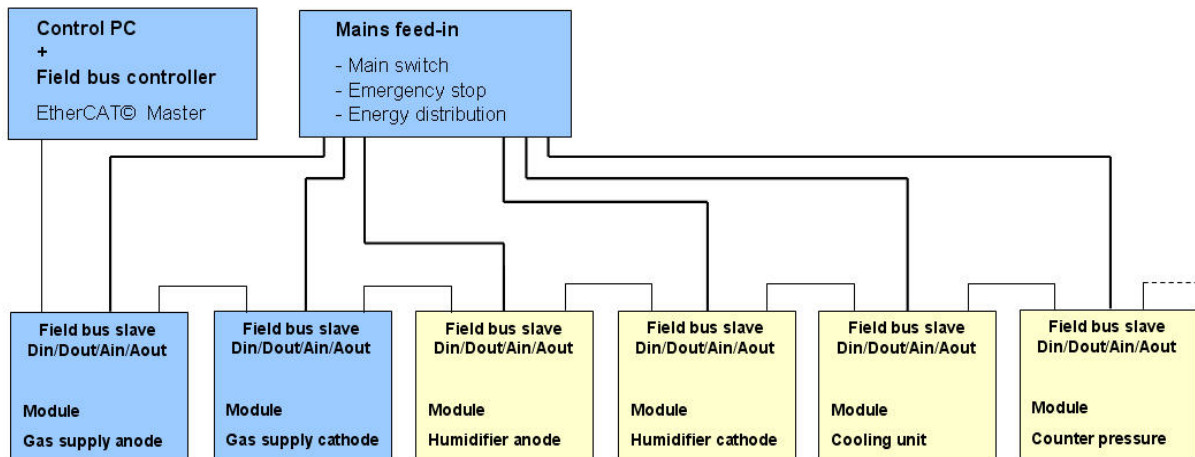


Figure 4: Block diagram – control concept.

The slave unit is in charge of peripherals control and measurement data acquisition. This master/slave system achieves highest flexibility required for the possibility of an incremental increase of process I/Os in each module and the increase of the total amount of slave modules.

3.3 Test bench control software RT-Labor

Applications requiring high performance, fast data acquisition and high flexibility are best suited with Moehwald real-time software system RT-Labor. RT-Labor supplies the test engineer with a comfortable software tool to configure individual test- and measure-cycles by drag and drop without programming knowledge. Together, a standard PC with modern hardware components plus RT-Labor Software, establishes the base for high performance applications in data acquisition and controlling:

- Priority controlled, pre-emptive and multitasking operating system
- Cycle time up to 100µs
- Data acquisition control - time and event triggered
- Integration of Multi I/O PC cards for faster data acquisition (up to 1 MHz)
- Ring buffer for post mortem recording
- EtherCAT® connection to peripherals
- CAN bus support

3.4 Mechanical construction

To fulfil practical requirements concerning safety functions, the modularised equipment must be encased. This includes hard wired components as process media and electrical energy feed-in as well as safety functions for explosion-proof design e.g. suction, gas-warning and prevention of electrostatic discharge.

The stack module is mounted in central position of the cabinet, other modules are arranged around to provide short connection paths for high dynamic response. To realise the modular concept – construction kit – the modules are interconnected with appropriate alterable clamp pipe connections shown in figure 5.

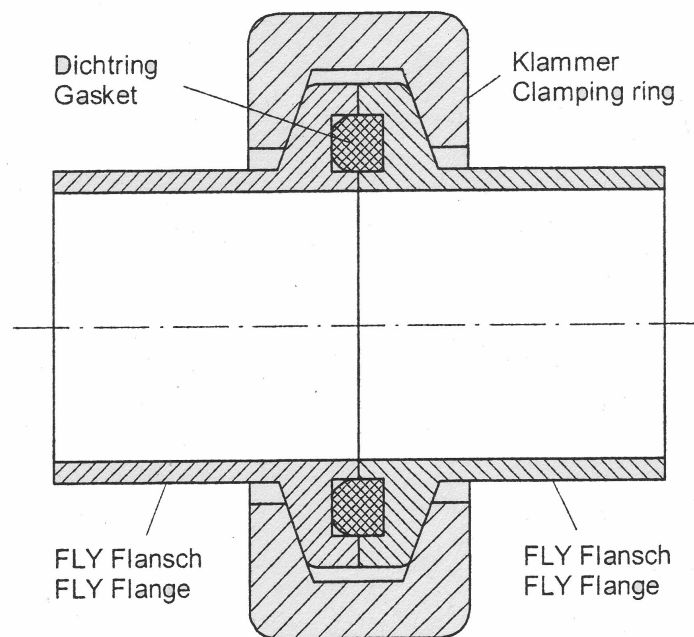


Figure 5: Draft: clamp pipe connection – from Linnemann GmbH.

Using those connectors - flexible and adequate for use with the module-concept, but not pre-defined to assure 'technical tightness' - requires stringent effort to assure leak-tightness, especially regarding the handling of hydrogen. Procedures to assure leak-tightness are air pressure leakage tests followed by a hydrogen sniffing procedure at all interfaces. Tightness checks have to be performed after each retrofitting of the assembly as well as cyclic checks in predefined fixed time intervals.

4 Conclusion

The concept of a modular test bench provides the test engineer with powerful test equipment for fuel cell development. It offers the whole testing range from the stack to a complete system in just one bench. This guarantees high technical flexibility and is a cost-effective solution for the development of future fuel cell components.

5 Moehwald GmbH – Optimal Results for More Than Three Decades

Moehwald GmbH develops and manufactures measurement and testing technology for fuel cells, fuel cell systems, Li-Ion batteries and systems, hybrid drives as well as diesel/gasoline injection systems and hydraulic components. Worldwide, successful customers rely on our testing technology for development and production. We are trusted partner of all global automotive manufacturers.

More than 30 years of experience in the development of test benches and manufacturing systems, as well as the know-how of our interdisciplinary project teams stand behind our customised solutions. As a subsidiary of Robert Bosch GmbH we have access to the latest technology of one of the most innovative industrial companies.



Figure 6: MOEHWALD GmbH customers worldwide.

On the development of fuel cell test benches, MOEHWALD closely cooperates with MS2, a company experienced in design and operation of fuel cell and fuel cell test systems. Jointly, both companies have successfully realized several test systems.

Moehwald has been ISO 9001 certified since 1997.

References

- [1] James Larminie, Andrew Dicks, "Fuel Cell Systems Explained", Second Edition 2003 ISBN978-0-470-84857-9
- [2] Linnemann GmbH, Technical Information, "Clamp Pipe Connection DIN32676", 2009
- [3] BGR 104 - Explosionsschutz-Regeln, Regeln für das Vermeiden der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung, Hauptverband der gewerblichen Berufsgenossenschaften, Fachausschuss "Chemie", März 2005
- [4] Beckhoff Automation, Technical Information, "EtherCAT-Ultra Highspeed Communication"
- [5] MOEHWALD GmbH, "PEM Stack Test Bench FCP5000-15", User Manual, 2009