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This document appeared in

Detlef Stolten, Thomas Grube (Eds.):

18th World Hydrogen Energy Conference 2010 - WHEC 2010

Parallel Sessions Book 5: Strategic Analyses / Safety Issues / Existing and Emerging Markets

Proceedings of the WHEC, May 16.-21. 2010, Essen

Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-5

Institute of Energy Research - Fuel Cells (IEF-3)

Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010

ISBN: 978-3-89336-655-2

# Fuel Cells as Back-up DC Power Supply for Substations

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Continued reliable operation of substations is essential if the high voltage grid should fail. A battery with a high but finite capacity supplies the auxiliary power required in such a case. A sustainable redundancy concept also suitable for longer grid failures is required, in particular for strategically important substations. An innovative and promising solution is the application of fuel cell systems. Amprion, the plant operator and the Dortmund-based H&S system vendor have implemented this concept in a pilot plant for an existing high voltage substation. The following article describes the specific construction of an innovative emergency power supply for an application with particularly high demands.

## 1 DC Power Supply in High Voltage Substation

Switches and control systems in high voltage substation must remain operational without restrictions even if the high voltage has a fault or fails completely. The required auxiliary energy stems from stationary lead-acid cells – pooled into a battery using cell connectors – with a nominal voltage, e.g. 220 V DC, and a very high capacity that can sustain switching operations for several hours. Accordingly, all devices and systems are rated for an operating voltage of 220 V DC. During normal system operation, a rectifier constantly charges the battery in the “stand-by parallel mode” via the grid. To dimension the DC supply of a system, great care must be taken not only to ensure a sufficient stand-by time in case of an error but also that the peak currents the switchgear draws can be provided during switching. The battery system must be able to supply such peak currents in particular when the end of the rated stand-by time is near.

## 2 Limits of Conventional Redundancy Solutions

The concept of an emergency power supply using a battery with a large capacity has proven its worth for many years. But in case of an error such as a longer power outage or a defective charge rectifier, time is always pressing because the only energy source of the substation is the battery with its restricted capacity. A sustainable redundancy concept is of major importance, in particular with strategically vital substations representing a nodal point for the reliable large-area power supply of a region. Determining factors are, for example, typical failure probabilities and associated failure times or replacement and installation times of defective rectifiers or other defective devices. The operators are constantly testing new alternatives in order to keep the system operable in a reliable manner and for an extended period of time or to optimize repair assignments or the storage of spare devices should a power outage occur. An innovative and technically feasible solution is the use of fuel cells to be described in detail below.

### **3 Application of Fuel Cell Systems as DC Power Supply**

Fuel cells convert the energy stored in hydrogen to heat and electrical current. Commercially available systems [1] feature an electric power of 5 kW at a DC voltage of 48 V. A downstream DC/DC converter [2] provides the operating voltage of 220 V DC required in this area of application. A nest of, for example, 12 hydrogen cylinders in a skeleton container ensuring a load-dependent operating reserve for one day supplies the “refillable” energy. Even longer system failures can be bridged without being put under any time pressure since organizing the supply of hydrogen is easy. When an agreement with a reliable supplier of hydrogen and an appropriate defined lead time are in force, this supply could even be automatically triggered by a direct request from the system.

Relatively budget-priced PEM fuel cells with a rated service time of approx. 1500 operating hours per stack are especially suited for this kind of emergency power supply. A single test run for a few minutes each month is sufficient to ensure its operability and also to prevent dehydration of the stack. The service life of such a solution is more or less equal to the 15 years of stand-by service life specified by the manufacturer.

With a reliable supply of hydrogen and independent of the installed battery capacity, this new type of a compact and, above all, emission-free and silent emergency power supply for large scale switchgear ensures a nearly unlimited supply in case of a malfunction. A practical dimensioning example: a 5 kW PEM stack supplied by a nest of 12 hydrogen cylinders (200 bar) can run for approx. 24 hours at 220 V DC and a rated consumer load of 20 A. The regular and almost wear-free test runs give rise to high expectations with regard to reliability and long-life cycle. In addition to major maintenance scheduled at longer intervals, the fuel cell system starts its test runs fully automatically and reports detected errors to the remote control center.

### **4 Integration into Existing High Voltage Substation**

For many years, the H&S system vendor headquartered in Dortmund [3] has been a partner of renowned electric power companies, also focusing on designing and marketing DC systems providing auxiliary power to switchgear. At present, H&S is engaging in the innovative field of fuel cell technology and assessing the field utility in the described area of application. Being a cooperation partner, Amprion GmbH [4] commissioned the installation of a fuel cell system with necessary peripherals for existing high voltage substation.

A fully-featured test installation on the company's premises comprising hydrogen cylinder nest, 5 kW fuel cell system, DC/DC converter (48 V/220 V), rectifier, station battery, infeed/isolation cabinet, simulated secondary devices and monitoring technology made it possible to determine a great numbers of operating parameters and installation prerequisites beforehand. Examples: Adjustment of the messaging and start-up behavior of the fuel cell, specification of suitable redundant DC/DC converters with defined harmonic wave characteristics, connection to an existing alarm and warning system, adjustment of pressure sensor switching points, compliance with common operating and installation regulations, etc.

The rectifier converts the grid supply voltage (400 V AC) to 220 V DC during regular, trouble free operation. This direct current provides power to the secondary devices in the switchgear and also charges the station battery connected parallel as energy buffer. When an error such

as a grid failure or a rectifier fault occurs, a second redundant DC infeed via the fuel cell and the DC/DC converter is available, which takes over the supply of the secondary devices via an existing low-voltage high-power fuse within the rated limits. The battery is still providing current peaks occurring when several switches start up at the same time.

In an article to follow, the authors will report on practical experience with the installed system and give a preliminary assessment of the solution's cost-effectiveness and the definite prospects.

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