NEW TECHNOLOGICAL CHALLENGES OPERATING THE 110 KV, 16.7 HZ GRID FOR RAILWAY POWER SUPPLY IN GERMANY

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ABSTRACT
The liberalization of the energy and railway sector changed regulatory and economic boundaries, and posed new requirements for the topology and the operation of the 110 kV grid supplying the German railway system. Procurement of traction energy had to comply with the rules of regulated energy markets. Technical facilities are linked to the EEX markets for peak power, and thus require highly efficient and dependable connections to the public grid. The ongoing consolidation within supplier markets for technical components stipulates the use of standardized components in generation and transmission. The advances in power electronics and modern control systems open a way to utilize the opportunities of our present economic environment. State-of-the-art static converter stations, highly integrated control technology, and station automation tailored to railway needs facilitate an attractive access to the energy markets for railway systems.

The paper will illustrate the application of modern components in the railway energy supply system, and illustrates new opportunities to operate and improve the 110 kV, 16.7 Hz grid. A technology that will enhance operations also for international partnerships.

INTRODUCTION

During WWI, the shortage of coal supply forced train operators to develop electric traction schemes. At that time, DC drives were the choice for controllable speed; however, DC lacks the possibility of transformation and thus the capability for long distance transmission. This was different for the standard 50-Hz AC grid in Europe, but contemporary motor technology, i.e., series-wound universal motors, could not cope with collector stresses imposed by standard AC frequencies. Three-phase systems allowed for simple induction motors, but were complex and quite uneconomic. Hence a compromise was developed to go for single-phase systems of one-third of nominal frequency, i.e., 16 2/3 Hz, at a 15 kV catenary. For transmission purposes, an overlaying grid of 110 kV has been chosen. For stability purposes, the frequency has been altered slightly to 16.7 Hz during the nineties.

Modern technologies in control and power electronics open new ways to operate such a grid. In particular, it is much easier to establish additional couplings to the public grid.

RAILWAY POWER SUPPLY IN GERMANY

The 110 kV, 16.7 Hz grid supplying German railways includes 7750 km distribution line (length of routes) connected by 180 substations with the overhead contact line of the railway system. The installed power is app. 3000 MW. Though the railway and the public grid are coupled, they are not synchronized.

The region northeast of Berlin is supplied in a decentralized structure coupling the public 110 kV grid directly with the 15 kV, 16.7 Hz catenary wire in a synchronized mode. The 110 kV grid is controlled by central supervisory control and data acquisition (SCADA) system with two redundant control and dispatch centres in Frankfurt and Hannover. This System includes the control of power plants and conversion links with the public grid.

The operation of the 15 kV catenary grid is controlled by seven regional control centres (RCC) throughout Germany.

NEW TECHNOLOGY IN RAILWAY POWER SUPPLY

Static Converter Stations

Since middle of the nineties, static converter stations are used in the 16.7 Hz grid in Germany, initialized with the advent of semiconductors capable of switching currents above 2 kA. Because of the asynchronous mode of the 16.7 Hz and 50 Hz grid, converters employing an intermediate DC circuit were required.

The control equipment supervising the operation of the converters uses standardized IEC protocols. All control centres are supplied the same graphics and state information of those stations. Hence, the operator staff doesn’t realize the difference between the manufactures and the technical generations.

All static converter stations are remotely controlled using a frequency – power – function. In sparse traffic regions in the north east of Germany, DB does not employ a transmission grid, but uses power converters to supply the 15 kV catenary directly. Modern static converters feature operation modes in both fixed frequency ratio to the public grid, or synchronized with the central 110 kV 16.7 Hz grid. In synchronized mode the converters can take care at the phase angle of neighbour
substations. The forced-outage availability of the current generation of static power converters exceeds 98%, and overall efficiency is higher than 97%. Low losses even during partial load operations allow a high flexibility using the converters in load sharing mode and for and balancing the grid. Another new feature is the active compensation of harmonics, using filters in intermediate circuit.

Grid control
In addition to a well tuned primary control embedded in all generating equipment (generators and converters), the 110 kV grid is stabilized by a secondary controller that uses a classic PI characteristic. Like in a conventional transmission grid, the secondary controller balances the 110 kV network.

SCADA Systems
From 1998 on, German Railways concentrated the regional control centres for operation of the 15 kV catenary in seven Regional Control Centres (RCC). Prior to that, operations were split among more than 35 RCCs. Today’s seven RCCs were build on identical specification. Therefore, every region uses the same technology for catenary operations. The catenary system can be monitored from at least five operating consoles, with additional projection onto a large-screen display wall. The SCADA solution permits subsequent expansion to incorporate additional workstations for functions like operation of rotary and static converters, or for scheduling fault response activities [1].

A typical RCC is based on the following parameters:

- 200,000 process variables with 1s to 2 s maximum response time within the control system
- 1000 telecontrol connections via a range of different transmission media
- 1000 state variables in a highly dynamic environment
- Hardware slack capacity of approximately 40%, meaning ample reserves even under maximum data traffic conditions
- Safe-Fail concept, i.e., the entire system continues to function if a single component fails [1] The SCADA system is connected to the office network and the SAP – PM system for maintenance scheduling. During the last years, a variety of old fashioned process data connections were replaced by a WAN using transmission control protocol / internet protocol (TCP/IP). The SCADA system uses its own virtual private network (VPN). The RCC sites are able to convert specific data generated by older station automation and field control systems into the format specified in standard IEC 60870-5-104 [2]. The SCADA systems controlling the catenaries are a sound basis for further development in control technology in railway power supply. The possibility to scale up this modern SCADA systems, or the opportunities to connect this systems via standard interfaces to other control systems, pose a wide framework for the modernisation of the 110 kV-SCADA or load allocation system.

Figure 1 architecture of grid control

Figure 2 regional control centre

Automatic feeder test
Compared to the public grid, the catenary has to withstand quite frequent short circuits caused by vegetation and the mechanical stress from the engine’s pantographs. The mechanical construction of a 15 kV catenary can’t support the forces caused by short-circuit currents from the substation transformer. Therefore, in the past test resistors limiting the test current to 5A were used for verifying electric clearance in a previously faulted catenary section. Analysing the voltage drop in this section upon connection of the test current allowed to differentiate the required clearance. This procedure, however, was rather complex and time consuming, and required additional expensive hardware like a spare breaker bay, switches etc. Today, this checks are accomplished through semiconductor systems that limit the voltage and thus the current flow by appropriate switching patterns. The distinction between clear and faulty is derived out of the current – time integration of those test voltages. [3], [4]. The new system is comparatively inexpensive, requires virtually no maintenance, and is connected in parallel to the respective catenary section breaker. Clearing times following short
circuits in catenary sections have been cut by at least a factor of ten, greatly improving service to train operators by cutting down times of the power supply.

PROGRESS IN CONVERSION TECHNOLOGY FOR LINKS TO THE PUBLIC GRID

Static converters account for more than 500 MW or one sixth of the installed power of 16.7 Hz 110 kV grid in Germany, whilst single phase generators became increasingly expensive. This is particularly important for power plant, where DB Energie has contractual access to dedicated generation capacities. These capacities were established via single-phase generators tapping off the medium pressure steam supply in a standard power plant. Apart from the expensive hardware and complex operations of such dual stations, the resulting efficiency was comparatively poor.

Therefore, DB Energie has adopted a new strategy to overcome those deficiencies. Today shares in generation capacity are obtained off a standard 50-Hz three-phase generator, and will be converted to 16,7-Hz power through on-site static frequency converters. This greatly reduces capital expenditure and operating costs, and dramatically enhances the overall energy efficiency and economics. On the system side, one has to develop new schemes for protection and stability control, because static converters do not supply fault currents anymore, and lack the stabilizing mechanical inertia typical for rotating machines. Solutions to these challenges are available and already in operation, though still on a small scale. But simulations show that even a large grid dominantly fed through static converters is inherently stable.

With this as background, today’s technology permits a far higher structural flexibility in the railway transmission grid, permitting expansions based rather on economic considerations and almost no technological limitations. Energy can be imported from virtually any area within Central Europe, thus establishing a degree of liberalization in energy markets for railway utilities in Europe that compare to public markets.

REFERENCES