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Communication and control system for fleet maintenance management of the DBAG locomotive BR101

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Abstract

The concept of the new high performance locomotive BR101 for the DBAG is based on the modular system design of the ECO2000 family. This article describes the design of its communication and control system with respect to the requirements of cost effective and efficient maintenance measurements, which are implemented in order to manage the short delivery times without major teething trouble obstacles and in order to achieve the guaranteed LCC values. The on-board diagnostic system is designed in accordance with the experiences of the ICE diagnostic system and the standards defined by UIC leaflet 557; it is supported by a central fleet mangement system connecting each locomotive via GSM. Thereby a big portion of preventive maintenance is no any longer dependend on limited flexibility of fixed installations for error detection and allocation.

1 Introduction

Modern-day control systems in rail vehicles are expected to provide more functionality and enhanced performance at reduced cost and in more compact dimensions. Rail vehicle designers are under exigent pressure to cut the costs involved. This applies also to the control and diagnostic system, as a meaningful contribution to overall optimization. When calcualting the total cost of any control system, the cost of the entire service life involved have to be taken into consideration, too. Longterm stability and reproducibility, simple handling, and a high standard of quality, which ensures reliable operation under all specified operating conditions - these are some of the crucial requirements for modern generations of control systems.

2 Control system structuring

The growing quantity of vehicle funtions involved is reflected in a rising number of signals requiring to be processed. Besides the processing width entailed the processing depth is increased as well, both trends resulting unsurprisingly in overall systems of ever-higher complexity. Clear structuring of processing functions and communication paths are the appropriate answere here as implemented within the loco BR101. Powerful communication paths are provided by the Train Communication Network, TCN, proposed as IEC standard IEC61375, currently at FDIS status. The TCN establishes a hierarchical system of control levels (Fig. 1), supporting real time tasks as well as diagnostic functions [1] .

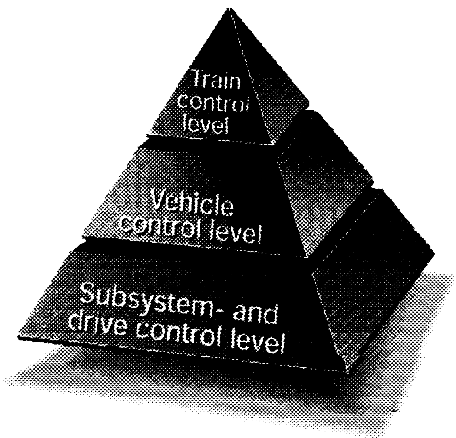

Fig. 1: Layer structured control system design supported by TCN

The demand for high levels of both reliability and availability can hardly be over-stressed when it comes to rail vehicles and their control systems. The vehicles have to clock up enormous daily mileage in networked intermeshing timetables with ultra-short connection times. The requirement is being met by upgrading the vehicles duty performance in terms

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of trouble-free running, and by reducing the permissible downtimes for unscheduled work. For the control system itself, this means effective diagnosis for the entire vehicle, ergonomic operator handling of the man-machine interface of the displays, and low failure rates across the board for the hardware components concerned, complemented by appropriate structural redundancies to minimize the effects of any failure actually occurring.

Standardization in the diagnostic behaviour of level-structured control systems [2], the acquisition and advance reporting of diagnostic and service data to depots and maintenance facilities has long since been state-of-the-art engineering, and is already being reflected in the relevant standardization specifications, like UIC leaflet 557 [3]. This is geared to a concept featuring an integrated, can-do infrastructure for operating and servicing of the traction vehicles involved, safeguarding our customers′ capital investment. While the ICE uses fixed locations for transmission of diagnostic data, the locomotive BR101 is now enhanced by mobile radio technology using a standard GSM interface within each locomotive.

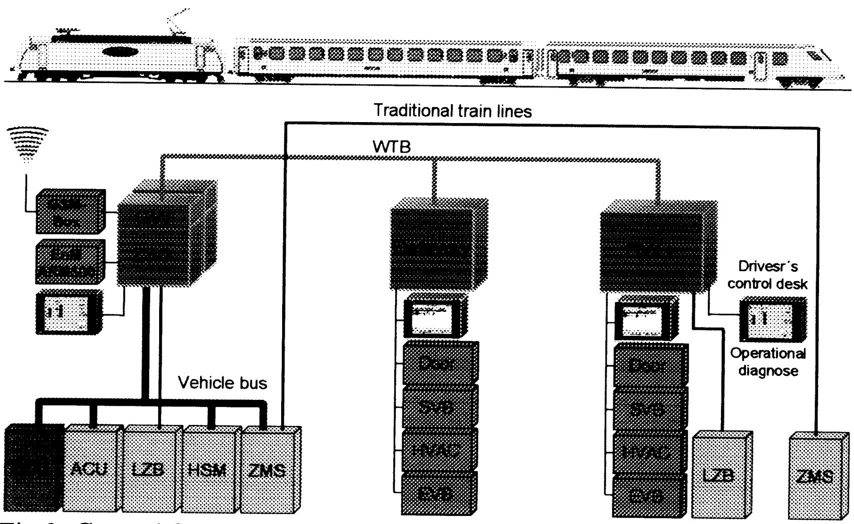

Fig 2: Control System of BR101 and Metropolitan Train

Thereby, fleet service management becomes independend from location of vehicle operation in order to increase availability by shortening down-times for repair and service. Fig 2 shows the processing stations and communication paths in the BR101′s control system imple-mented by the

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MICAS-S resp. MITRAC decentralized control system [4] as it is designed for the Metropolitan Trains of DBAG. Metropolitan is modern and comfortable train design for IC connections. MICAS-S was premiered in 1985 as the first traction control system to feature digital processing for all tasks throughout: train, drive and vehicle control. MITRAC is the successor of the MICAS-S system, based on 32bit processor technology.

3 Key elements of the control system of BR101

3.1 Drive control system

High-performance locomotives like BR101 are equipped with an individual-axle drive. This firstly optimizes utilization of the friction values involved. Secondly, it ensures minimized restrictions on the traction program by means of structural redundancy even in the event of a fault. Only through systematically modularized design [5] of converters and associated control technology platform, it was possible to gain standardiz-ation and scalability for the full range of traction applications and all the different classes of performance (Fig 3). The drive control unit (DCU) comprises the control system for the four-quadrant controller (4-qC), the control for the inverter, the link to the vehicle bus, and the diagnostic routines of the DCU. The proven torque control method called Direct Self-Control (DSC) combines low torque ripple control with the high dynamic response to any requirements regarding antislip/antislide protection. The 4-qC control ensures an optimized power factor and minimum perturbation on the supply network under any conditions.

The core of the DCU is the traction motor controller (TMC) which is upward compatible to the preceeding model in both its hardware and its software. It can be used for IGBT applications as well as for GTO applications like BR101 or S-Trains BR423 thereby providing a standardized and uniform platform. In parallel to the dramatic simplification of hardware an expanded funtionality was implemented, represented by a list of few examples:

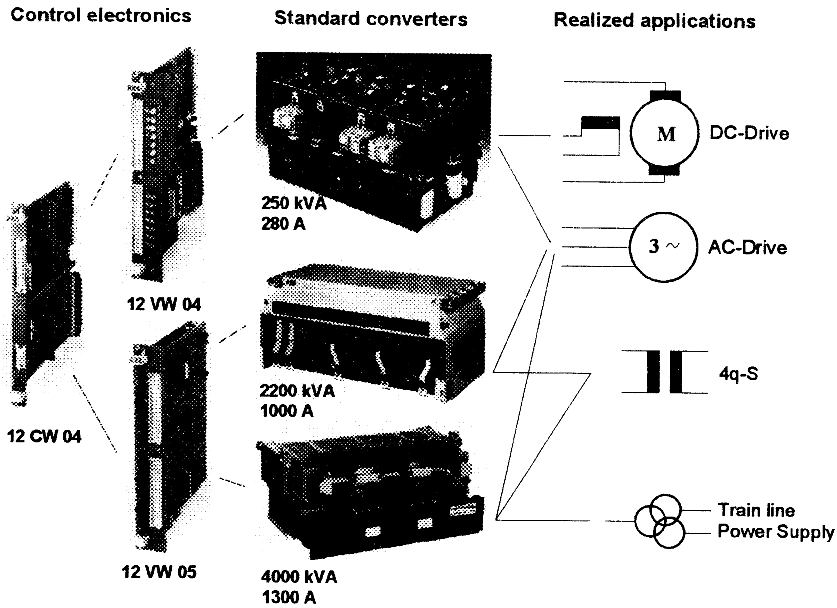

Fig. 3: Standardized platform for all classes of traction drive control

- Active filtering and damping of the critical harmonics in the input current for the line inverter and for the machine-side converter as well
- Expansion of the control system selftest to the power section, all sensors and to any interfaces of the inverters
- Precise setpoint control by using a combined real-time model of GTO switching times in addition to the machine model, both computed every 40us periodically
- Central service access and program download to all CPU's and controllers over the vehicle bus by using the TCN functions

The latter is an important feature in order to achieve information transparency for the entire control system of the loco BR101 by using the functinality of the TCN for transmitting diagnostic data. For the a.m. train called Metropolitan, which will be hauled by the BR101, this feature can be used within the loco as well as within the complete train.

3.2 Sensor bus IFZ for distributed I/O implementation

The concept of the BR101 reflects the strong competition of loco suppliers on the central European market. Only standardized and modular designs and products can provide the commercial benefits which

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are enforced by price reductions in the order of 30% compared to earlier railway vehicle orders [6]. In addition the order for the BR101 locos requires a delivery of 145 vehicles within 3 years; regular service of the loco's was requested appr. after 6 month of the first delivery for service of IC- and IR-trains.

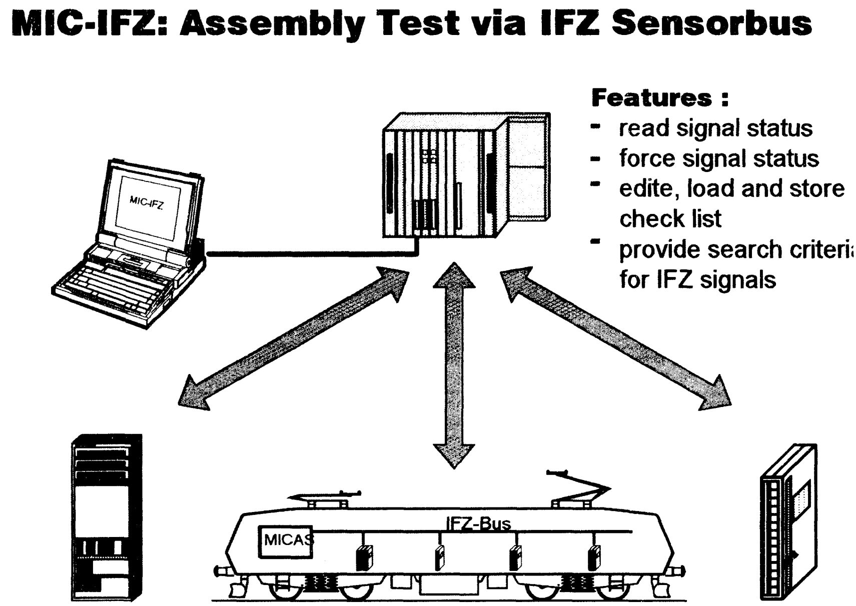

Fig. 4: Preassembly testing via sensor/actor bus IFZ

This lead to the conclusion that all functions must be implemented in pretestable subsystems or preassembled units. Easy and flexible configuration of the system must be possible, resulting in some useful design requirements for interfacing standard electrical sensors and actors. The loco BR101 is based on the proven I/O-system of the IFZ bus which was introduced on the Metro DT4 for Hamburg and the ICE trains since 1988. Simple and robust sensor and actor modules support easy and cost efficient assembly and cabling. The feasability for testing of preassembled units is used to implement a decentralized production for preassembly units while final assembly of the locomotive is performed only at one place. Testing the I/O-interfaces of the preassembled units can simply performed by interconnecting the IFZ bus interface to an test ZSG-station, controlled by a special service program MIC-IFZ on a PC based work station, Fig 4.

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This approach covers the functions status request of I/O signals, status forcing of I/O signals, edite ,load and store of check lists for I/O signals and criterias for searching interface signals out of an interfrace listing. Thus testing and commissioning can be performed cost effective within two steps, first after production of the preassembled modules, second after complete assembly within the loco.

3.3 Energy consumption meter for BR101

By means of the railway meter ARM500 [6] it is possible to measure and to account the energy of any vehicle operated within the power supply network of DBAG. Using an integrated memory storing the average value of 15 minutes of the load profile it is possible to cover the samples of the complete energy consumtion of 90 days. Remote access to the load profile of any loco BR101 is available via GSM. The ARM500 supports the necessary interfaces functions in order to compute the load profile results. It is possible to elaborate a complete energy accounting system for the DBAG, i.e. there is the possibility to quantify and account each run of a train separately (Fig. 5).

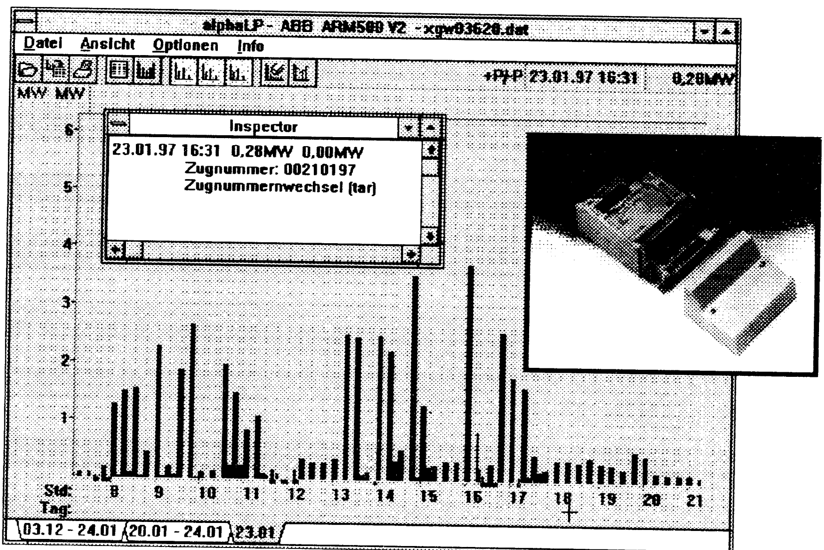

Fig. 5.: Load profile and energy meter of the loco BR101

The energy meter is integrated into the high voltage assembly of the loco. The analog input values are converted by an 21 bit-A/D-converter using the sigma-delta-approach taking 2400 samples per second. A signal processor evaluates effective, reactive and apparent power respectively energies. The sampling rate is selected to enable energy metering even for the energy which is included in the harmonics of input voltage and input current in order to meet the requirements of energy metering of the PTB (PTB = Physikalisch Technische Bundesanstalt, which is responsible administration for approval of energy meters for accounting purposes in Germany).

3.4 Diagnosis control system

Each processing station of any subsystem inside the loco is designed in accordance with the specifications of the UIC leaflet 557. This leaflet defines for diagnostic purposes the categories of faults, their meaning and the consequences during vehicle operation. Any subsystem control unit provides a complete set of diagnostic information reflecting the process controlled and the control station itself; typical examples are auxiliary inverter controller (ACU), drive control, traditional train line control (ZMS) and brake control (HSM). For example, each of the 4 independant drive controllers provides the standard diagnostic features like fault status messages including time stamp, error location, error counters, error codes and suited environmental data. In addition to these features in accordance with UIC557, the different MICAS controllers include the so called fault pattern diagnosis, which operates like a controller internal data logger. It is perfectly suited to perform the error analysis of transient faults. Having the fault pattern diagnosis in stand-by throughout the entire operation of the loco minimizes the necessity of dedicated test runs of the vehicles in case of transient failures. Thereby, the availability of the loco BR101 can be increased significantly.

All of the subsystems are supervised by the redundant central vehicle computer (ZSG1, ZSG2) and interconnected via the vehicle bus. The central vehicle computer collects and stores all the diagnostic messages

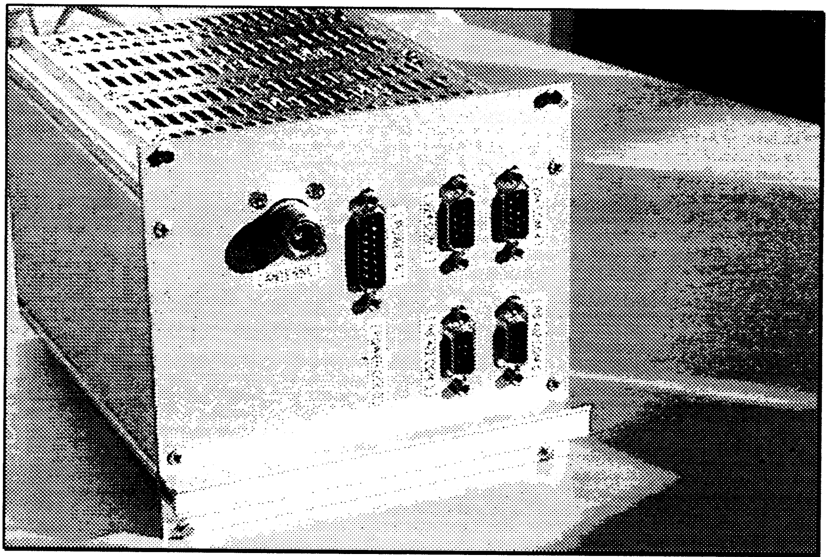

Fig. 6: GSM-Box 12KD01 for loco BR101

of the locomotive and if reqired of the entire train. Depending on the position of the driver one of these units acts as a master station. This master station is able to feed the related drivers desk panel with all relevant data about the status of the train and its subsystems. In case of changing the drive direction of the train, i.e. if the driver moves from one end to the other of the train, the position of the related master ZSG is switched to the same position. At the same time, the diagnostic data based of the ZSGs involved is replicated at the new position. Replicating the data base is supported by standard functions of the TCN.

Any diagnostic information is available on a colour display at the drivers desk. During regular operation, the display information reflects the status of loco and train as suited for drivers purposes. Error messages of any subsystem are prioritized with respect to the consequences of train operation. Each error message is to be acknowledged by the driver. The display also provide hints for error recovery if requested by the operator. For maintenance inside the workshop, the driver's display can be configured as a data base viewer, presenting all the diagnostic messages in different catagories by filtering selectable attributes, i.e. to list all the messages of one subsystem or all the messages of a certain time span etc. The diagnostic system of the loco BR101 is completed by a GSM interface (GSM = Global System for Mobile Communication), Fig 6.

The GSM-Box acts as digital teleservice system. It enables the user to communicate with any MICAS-S system initiated from a remote PC-based work station. For data transmission, the commercial network GSM (D1 or D2) may be used. The GSM-Box is designed for use on rail vehicles even though it uses some commercial of-the-shelf available components. It is composed out of a DOS-based PC station and an additional GSM-Module which is restricted to pure data communication. Interconnection to the loco control is performed by several point-to-point interfaces acc. RS232. By using standard PC software components like `PC anywhere`, the remote control by a centralized way side work station is performed; this central diagnosis station becomes fleet management funtionality by having access to all loco's BR101 type independent from the location of operation. Considering the distributed operation of the fleet of loco's for IC-, EC- and IR-services the centralized teleservice access is a very useful feature for in-time comissioning of the vehicles as well as for future operation.

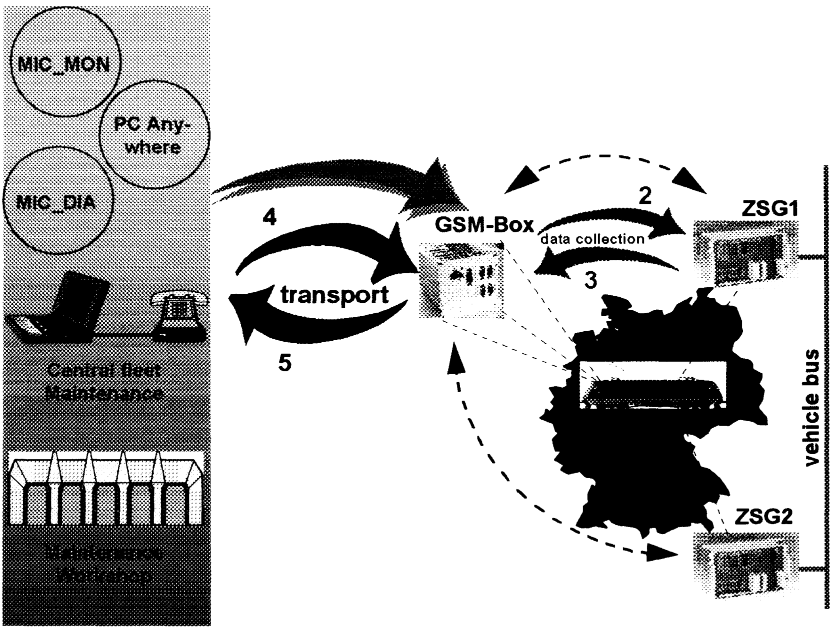

Fig. 7: Teleservice via GSM for BR101 fleet service management

In addition to the use of standard PC software components, there are some useful tailor made modules for service access to the MICAS-S-system (MIC-MON) and for analyzing the data collected (MIC-DIA). MIC-MON is a monitor program in order to read the diagnostic data (or any other) out of the non-volatile memory of the central vehicle computer (ZSG1,2). In addition it allows to initiate the memory after exchange during maintenance or to adjust the real-time clock of the ZSG. MIC-DIA provides any necessary help for analysing the diagnostic data transmitted to the central fleet management service computer. Standard messages deliver direct advices for repair and/or maintence. Further more, comfortable filter options enable the maintenance crew to analyze the dianostic messages together with its history in order to gain hints for error location and identification. Preventive maintenance can be derived from repetition rates of related failure events. MIC-DIA is the first step in direction of an expert system on the basis of a data management system which delivers an immediate recommendation for repair and service directly related to any diagnosis message (Fig. 7).

4 Outlook

The first locomotives of BR101 series went into operation on schedule by August 1996. Since September 1996, they have been undergoing measuring and trial runs for attaining type approval granted in the same year. Careful advance testing of the control system and the control procedures involved has paid off in terms of full compliance with the stringent specifications governing development work and production. A short time into the trials, operating points of up to 280km/h were being achieved, far above the specified requirement of 220km/h. Now one year after delivery of the first locomotices more than 50 locos are operating throughout Germany in regular service. The communication and control system works porperly and successfully under all conditions. Key features of the control system of the loco BR101 like TCN, diagnostic and MMI functions as well as proven drive control solutions are selected for the new generation of Adtranz control technology and are used in further loco´s like BR145 etc. . The technology used in BR101 for teleservice and energy metering represents a new milestone in terms of customer benefits and is making a vital contribution to the success of the migration strategy of a gradualized, upward compatible development approach. In line with this migration strategy the next loco of the ECO2000 family, the BR145, incorporates further steps of the ever moving progress of control systems.

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