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BLUETOOTH BASED TRANSMISSION SYSTEM FOR SUPERCONDUCTING SYNCHRONOUS GENERATOR

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Abstract: *Bluetooth based transmission system, for measurement and control in superconducting synchronous generator where transmission is carried out between stationary and rotating parts, is the topic of this paper. Signals of temperature and coils voltage are transmitted from rotor. Signals controlled rotating converter are transmitted to rotor. The system has been tested under conditions similar to the real ones confirming its advantages.*

Key Words: ***Electronic Measurement Systems, Communication, wireless***

1. INTRODUCTION

The advent of superconductivity have given the possibility to reduce conducting power losses and thus to build smaller electrical devices. Currently superconductivity is very promising in synchronous generators where the excitation is made of superconductor. It results in smaller losses decreased volume and reduced mass. The excitation system has to have measurement of temperatures and voltages across its coils. It is due to possible phenomenon – quench that can occurs when temperature, current and magnetic field density goes outside safe region. Quench means extra losses that leads to generation of heat in superconducting wire. It is dangerous for superconducting coils of excitation as well as to the cryosystem. To prevent machine from being damaged the detection of the quench is necessary. For detection of the inappropriate operation of superconducting coils the temperature and voltage across the coils sensing is needed. These measurements also need to be distributed throughout the superconducting coil. One of the major problem with this measurements is the data transmission from rotating shaft into the stationary host system which can control an excitation coil current. One can see that there is a need for a contactless (wireless) data transmission between rotating and stationary parts of the system.

This data transmission can be carried out by using: i) magnetic coupling (high frequency transformer), ii) capacitive coupling, iii) optical transmission, iv) radio wireless transmission (ie. Bluetooth, ZigBee).

First three solutions need to be placed directly on the axis of rotation [1, 2] but the last one can be placed in other places. What is more, the first three ones have to be tailor-made what can reduce its reliability. The latter transmission - Bluetooth is the best choice [3] as it is fabricated mass-production process and commonly used. It is the standard characterized by low power consumption, low cost and there is no need that transmitter and receiver are in line of sight.

Nevertheless it needs to be examined for rotational motion with relatively long distance between Bluetooth parts, especially that the rotor of it is subjected to vibration that can cause improper operation or even its damage. Such a test when reliability of data transmission is the objective is the subject of this paper.

2. MEASUREMENT SYSTEM

The measurement system described in this paper is a system for measuring temperatures (Fig.1) and voltages (Fig.2) in generator rotor. The measurement system consists of 8 temperature and 7 voltage channels. One single temperature channel is presented in Fig. 1 while in Fig. 2 there is one single voltage channel. The frequency of measurements are rather low of few hertz.

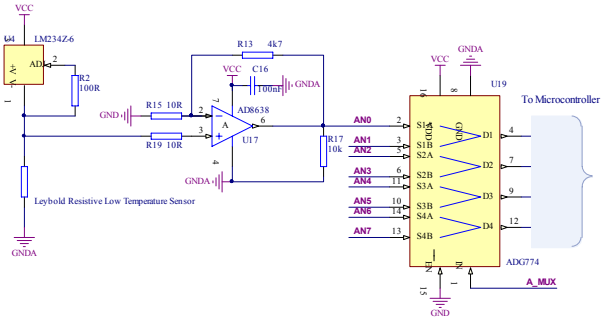

Fig 1. *One single temperature channel with current source low temperature sensor , amplifier and mux*

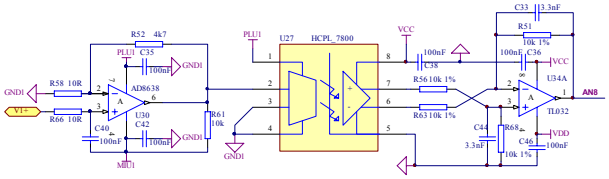

Fig 2. *One single channel of voltage measurement part: embracing zero-offset amplifier, isolation amplifier and low-pass filter*

The temperature measurement part of the system is based on Cernox resistive Low Temperature Sensor CX-1080 supplied with 10 µA current. This current is generated in high precision current source LM334. In this circuit there is also ultra low offset amplifier AD8638. The main part of the measurement system is a microcontroller H83048. Because each temperature sensor has separate current source there is no need to use galvanic isolation between each temperature measurement channel.

In Fig. 2 there is presented voltage measurement part of the electronic system. Because the measurement system has to allow measuring voltage at different parts of the excitation coil there is a need to separate voltage channels from each other. In the final paper the method of measuring voltages across coil windings will be presented (it attenuates influence of induced voltage caused by current changes).

The measurement system can detect quench by measuring low voltages i.e. 10 µV. In this part there is also popular industrial isolation amplifier HCPL7800 which can transfer analog signals by means of optical digital sigma-delta method. For filtering high frequency components at the end of measurement part there is a low-pass filter.

3. WT 11 BLUETOOTH MODULE

Bluetooth module WT11[5] was used to test transmission. WT11(Fig 3) is a highly integrated Bluetooth module, containing all the necessary elements, including antenna, to Bluetooth wireless communication. This module is the class 1 with power consumption of 100 mW and ~100 m range.

Fig 3. *WT11 Bluetooth module*

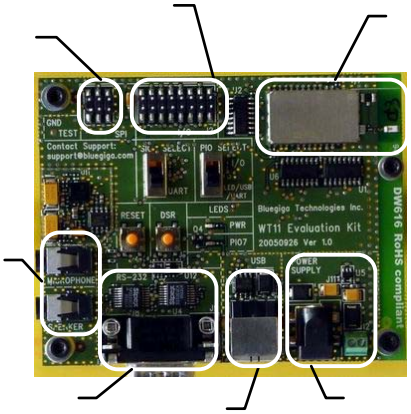

Fig 4. *WT11 Evaluation Kit*

WT11 Evaluation Kit (Fig. 4) was used to easy connect Bluetooth module to PC and µP. This kit except WT11 consist:

- RS-232 and USB interface to communication between WT11 and external devices,
- SPI interface for upgrading firmware and parameters,
- 3,5 mm jack for speaker and microphone connection for audio transmission,
- GPIO interface to connect power supply, transmission, reset etc.

4. DATA TRANSMISSION

4.1 Voltage measurement test

Block diagram of data transmission is depicted in Fig. 5. Signals from voltage channels are fed to microcontroller H83048 A/C converters and are stored in memory. The microcontroller H83048 includes eight a 10-bit A/D converter. The analog voltage conversion range can be programmed by input of an analog reference voltage at the V_{REF} pin. The minimum conversion time is 7.45 µs per channel. That high speed conversion, and good accuracy allow to used integrated A/D convertor to measure voltage.

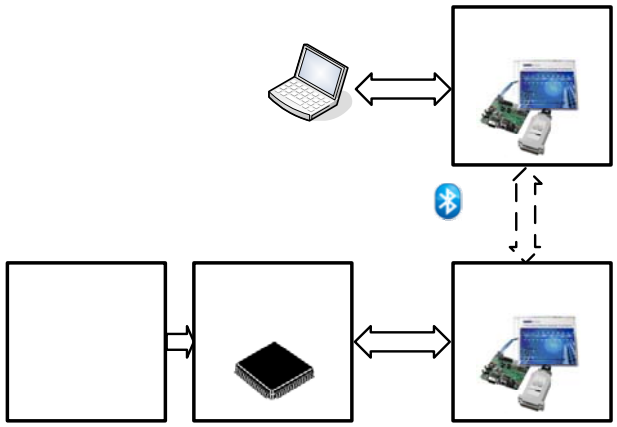

Fig 6. *Voltage measurement test*

During laboratory tests 8 measurement signals were sent from microcontroller by Bluetooth, serial port (RS232 - UART) to stationary computer. Serial data transmission is organized in MODBUS protocol and data is sent in ASCII version [4]. One measurement of all channels has lasted ~80 ms what is enough for described generator operation.

4.1 Bluetooth transmission test

In this case reliability of Bluetooth wireless transmission was tested. The receiver rs232 interface were connected in loop-back configuration (Fig. 7). This allow to eliminated microcontroller from rotating module. To test transmission number 0-9 was sent periodically.

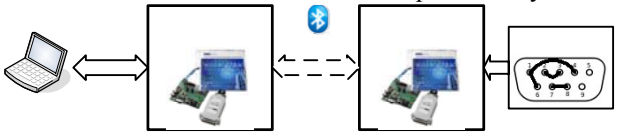

Fig 7. *Bluetooth loop-back configuration*

The Bluetooth transmission using module WT11 was tested at 500 rpm and at 0,5 m arm in the test system shown in Fig. 8. Tests were done with rotating Bluetooth module mounted for iron grounded sheet that was intended to simulate iron housing of the synchronous machine.

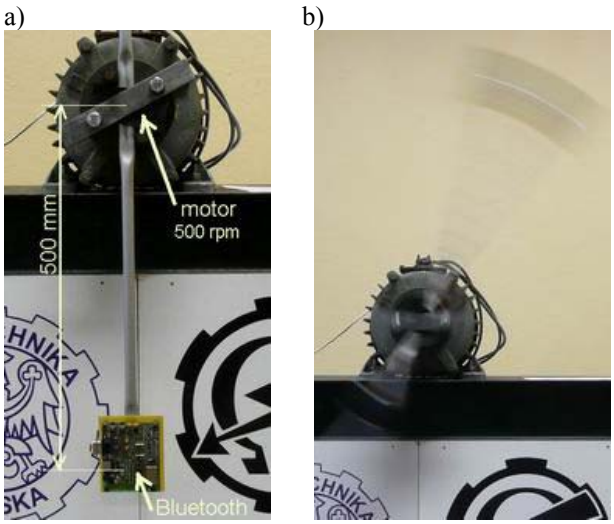

Fig 8. *Bluetooth module mounted on 0,5 m arm and asynchronous machine to test influence of rotation on transmission: a) stationary, b) module during rotation*

The two distance between transmitter and receiver was tested 25cm and 100m (Fig. 9). This represented the worst case of Bluetooth transmission operation. In the first case the distance between transmitter and receiver was most quickly changed. In the second one Bluetooth operated nearly on maximum range.

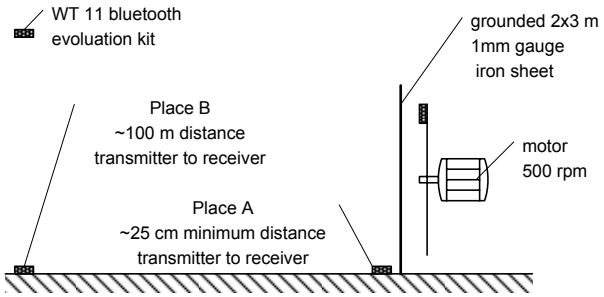

Fig 9. *Bluetooth reliability transmission test*

First tests using 1mm grounded metal sheet (Fig. 9) shows no influence on radio transmission. No transmission error was detected during these tests. There is also no influence of rotation and the distance between transmitter and receiver on transmission.

5. CONCLUSION

All tests that have been done show that Bluetooth transmission is suitable for rotating applications. Performed in this work tests allows to draw following conclusions:

1. Data transmission using Bluetooth satisfies demands for monitoring system of superconducting machine.
2. The WT 11 Bluetooth device enables transmission of sufficient number of data for monitoring voltages, temperatures and additional quantities, i.e. vacuum level.
3. The microcontroller conversion of analog data to proper protocol of digital data is needed.
4. Because of high frequency data transmission (2.4 GHz) rotation with tested speed does not influence on transmitted data.
5. Tests of transmission with barrier shows that transmission is possible to distance up to 100 m with barrier of 2 m of height.

6. REFERENCES

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