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# Remote Control and Monitoring of a Small Hydro-Power Plant

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***Abstract:*** *The presented distributed system consists of three microcontrollers and is intended for the control and monitoring of the waterwheel of a small hydroelectric power station. The small power station is located in a remote area and works in autonomous mode. Specialized software is developed, realizing "PEAK POWER TRACKING" algorithm for automatic control. Every 10 seconds, reports of measured data are sent to the personal computer (base station) via GPRS/ Internet. The used communication protocols are: TCP/IP; GPRS; SMS; ZigBee; USB.*

***Keywords:*** *GPRS, TCP/IP, remote metering, control block, Ad-hoc Wireless Networks.*

## I. Introduction

The general idea of this work is to develop hardware and software for control and monitoring of a small hydro-power plant. The hydro-power plant consists of a waterwheel, a hydro-generator and an electronic block. A rotary torque sensor is used to measure the rotational speed and rotary torque of the water wheel.

The whole system consists of two parts: (1) a water wheel, a generator and an electronic block to the generator and (2) a control system. The block-diagram is shown in Fig. 1. The first part is called **Powerful Electronic Energy Converter Governor** (PEECG), the other part is called **Control system**.

The paper presents some basic parts of the hardware and software tools for the second part of the block-scheme in Fig. 1 – the Control System.

The Control System consists of 3 modules – a control module, a camera (or monitoring) module and a communication module.

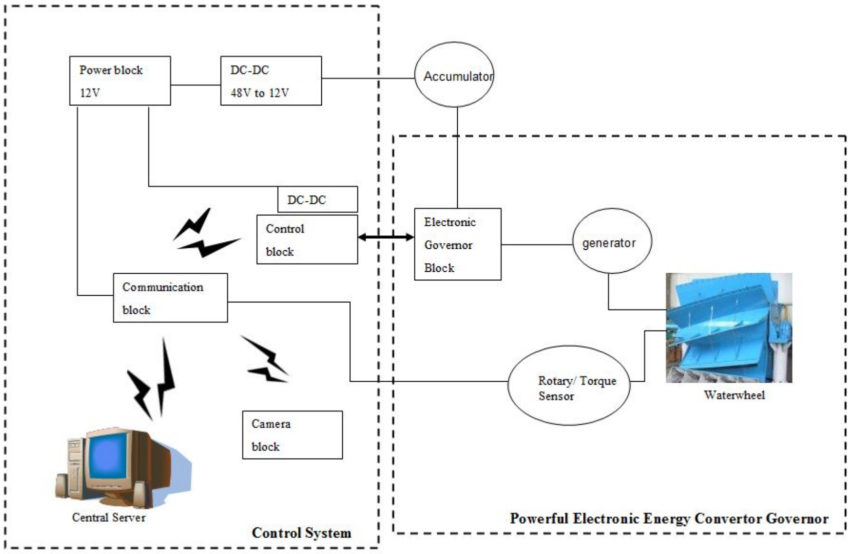


Fig. 1. Block-scheme of the whole system

The control module is directly connected to the object – to the block Powerful Electronic Energy Converter Governor. The module supports short-range wireless communication (IEEE 802.15.4) to the communication module and sends information about the measured values and data every ten seconds.

IEEE 802.15.4 technology is used in the so called Wireless Personal Area Network (WPAN), where the typical length between the nodes is a few meters.

The communication module also supports long-range wireless communication and sends all the data to the remote personal computer using GPRS communication, with access to a standard TCP/IP server.

All modules in the Control system are based on wireless modules JN5139/48. This is a family of surface-mounted modules produced by Jennic Ltd., which enable an IEEE 802.15.4 implementation [1, 2, 3]. In addition, the wireless communication extremely improves the system's abilities and flexibility.

The control system allows PEECG to work in automatic and manual mode. In automatic mode the control system serves as an autonomous controller, realizing the algorithm **Peak Power Tracking (PPT).**

This algorithm forms an output value for the load current of the generator, in dependence of the measured momentary values for current and voltage of the generator, rotary torque, rotational speed and water level.

The PPT algorithm is commonly used for solar panel control [4] and can be applied to maximize the turbine output power. The main purpose is to maintain the operating point of the generator at maximal power. The algorithm moves the operation point to get closer to the maximal point. This could be achieved by decreasing or increasing the load current.

This work is connected with the joint project between the Institute of Information and Communication Technologies and ISTA-Andreeva Ltd.

## II. System configuration and requirements

There are several basic functions of the control system. Each action and functionality is connected with these five functions.

- *Input signal measurement* – there are 6 input signals that must be measured. These signals correspond to the values of water level 1 (level of the water before the waterwheel), water level 2 (level of the water after the waterwheel), voltage of the generator, current of the generator, load current of the generator, rotary torque and rotational speed of the waterwheel. The last two values are received from a rotary torque sensor.
- *Digital outputs control* – there are two relay outputs. These outputs could be controlled manually – from the personal computer, or automatically – depending on the set points in the control algorithm (Peak Power Tracking). These output signals are sent to the Powerful Electronic Energy Converter Governor (PEECG) and correspond to the option Stop/Start of the governor and Up/Down of the floodgate.
- *Analogue output control* – this is one analogue output (0-10 V), which corresponds to the value of the load current. This output is controlled by means of the Peak Power Tracking Algorithm.
- *Picture of the waterwheel area* – on a request from the personal computer, the system can make a picture and send it via GPRS.
- *Sending of measured data* to the remote PC via GPRS.

As above said, the system works in automatic or manual mode. By default, the system works in automatic mode. There is a digital input to the control module, which is responsible for the mode. This input is controlled from the Powerful Electronic Energy Converter Governor (PEECG).

In automatic mode, the Control module generates an analogue signal (0-10 V) corresponding to the load current of the generator, and consecutively changes the output signal with 0.5 A, or with 103 mV as a voltage signal. The sampling time is 10 s and the ADC is 12 bits. The control of this signal is related to the measured momentary values for current and voltage from PEECG (generator) and the water level. There are two signals for the water level – named Level 1 and Level 2 and the values are in the range from 0 up to 2000 mm.

The values measured by the rotary torque sensor are 0-1800 N.m (for torque moment) and 0-110 tr/min (rotary). For this purpose, an ADC is used – 10 bits (input values from 0-1V), embedded in the communication module.

**The manual mode** is activated at level 1 on input "Mode". In this mode, the control module does not generate an analogue output for the load current of the generator but instead it measures all data for the water level, rotary and torque and the current and voltage of the generator. In the initial set-up and after restart, the control module is set to automatic mode.

The control module sends measured data (via IEEE802.15.4/ZigBee) to the communication module. The communication module sends all data (via GPRS) to the Personal computer (Base station). The specialized software in the Personal computer has a procedure to open a socket, data reading and data storing on the hard drive. A GUI is developed and all measurements are shown in real time. The information is refreshed every 10 s.

The operator of the remote PC may decide (depending on the monitored measurements) to send a command to the control module. The commands are sent to the communication module as SMS. The option "email to SMS" is activated in advance for the SIM card on the communication module.

## III. Hardware of the modules

### IIIA. Control module

This module is responsible for the signal measurement, the controlling algorithm – Peak Power Tracking, and the realization of the wireless network. The module is based on the wireless microcontroller JN5139/48. This microcontroller integrates a 32-bit RISC processor, with a fully compliant 2.4 GHz IEEE802.15.4 transceiver, 192 KB of ROM, 96 KB of RAM, and a rich mixture of analogue and digital peripherals [1, 8].

Jennic Ltd. offers the IEEE802.15.4 protocol stack implemented in the modules. JenNet is a proprietary protocol stack developed by Jennic for short-range wireless networking applications based on the IEEE 802.15.4. JenNet offers a small footprint alternative to the standard based ZigBee protocol stack without fees or certification. A simple API (Jenie) allows easy application development [1, 5].

The block scheme of the Control module is presented on Fig. 2.

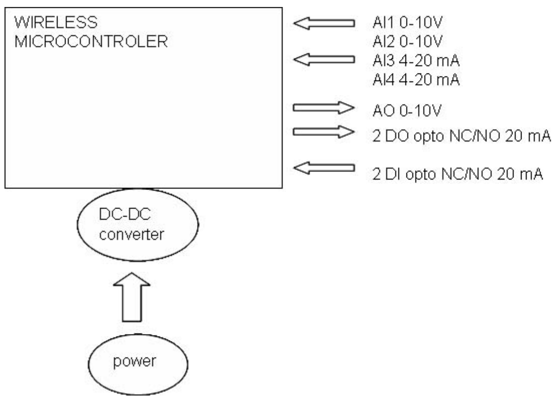


Fig. 2. Block-scheme of the Control module

The first two inputs – AI1 and AI2 (0-10 V) correspond to the momentary values of the current and the voltage of the generator. The value of the current ranges from 0 to 48 A, and the voltage value is between 0 and 525 V.

The inputs AI3 and AI4 are used for water level measurement. There are two measurement points – before the waterwheel and after the waterwheel. The water level ranges from 0 mm up to 2000 mm. All ADC channels are 12 bits, embedded in the wireless microcontroller. One of the digital inputs is used for the signal "Mode" from the PEECG. Two digital inputs are used for the signals Start/Stop to the governor block and Up/Down to the floodgate.

Every 10 seconds the Control module sends measured data to the Communication module via 802.15.4, using the JenNet network.

IIIB. Communication module

This module is intended to work as an autonomous device in heterogeneous networks and to serve as a communicator in the data transfer between wired and wireless devices. One of the main advantages lies in the possibility for data exchange with a remote server via GPRS/ Internet (TCP/IP)

The communication module is designed as a multifunctional microcontroller for data collection.

The module is based on microcontroller ATMega 2560 and a set of slave devices with different functions. For storing different data – measurements and initializing data and tables, the module has 128 Kbytes (2×64 K) external memory EEPROM. For different procedures and interpreters, the module has 512 Kbytes external memory RAM.

The power supply is 12 V. In the module, there is a circuitry for power conversion to 5 V and 3.3 V for different internal devices. The consumption of the module is about 150 mA in active mode.

A simplified block scheme of the Communication module is presented in Fig. 3.

The communication module supports Short range communication (communication with the control module and the camera module and reading of the measured data) and Long range communication – communication to the remote server.

The short range communication is ZigBee and it is based on the wireless microcontroller JN5139/48. For long range communication, a GPS/GPRS module is used, which is produced by Telit Ltd. – GE 863.

GE863 is the smallest GPS/GPRS module available on the market. It combines a GSM/GPRS modem with a single-chip GPS receiver. An additional feature of the modules is the integrated TCP/IP protocol stack. This feature allows access to a standard TCP/IP server. It is possible to create a standard networking structure – "client-server", for communication between the communication module and remote standard personal computers.

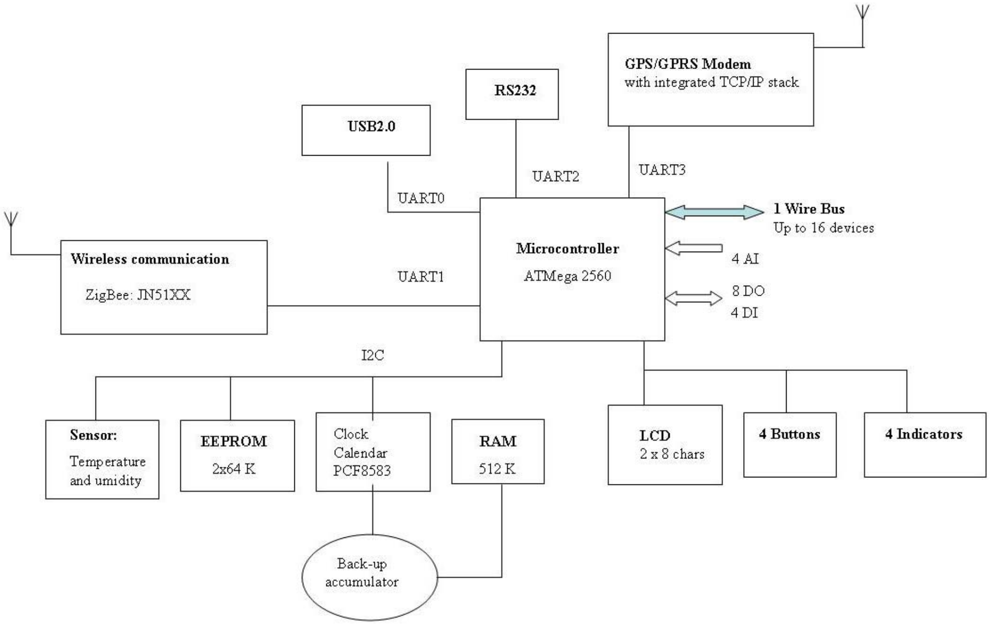


Fig. 3. Block-scheme of the Control module

Table 1 summarizes the basic features of the Communication module.

To produce real data about the time and date, independent on the general power scheme, the module has the same device clock-calendar (PCF8583) as a sensor node.

Table I. Basic features of the Communication module

| | |
|---|---|
| Microcontroller | ATMega 2560 |
| Clock Frequency | 16 MHz |
| External memory | 512 K RAM<br>128 K EEPROM |
| Wireless communication | **ZigBee**:Jennic:JN51XX<br>**GPRS:** GE863 (Telit Ltd) |
| Power | 12 V AC-DC<br>Or accumulator |
| Consumption | < 150 mA |
| Additional devices | Clock-calendar,<br>GPS/GPRS modem<br>1 Wire Bus<br>LCD (2×8 chars) |
| Inputs/Outputs | 4 Analogue inputs<br>8 Digital Inputs<br>4 Digital Iputs/Outputs<br>1 Wire Bus |

A special feature of the Communication module is the possibility to support at the same time three independent communication interfaces: (1) wired connection RS 232 and USB (for PC, Laptop or PDA); (2) communication device for short range communication (ZigBee); (3) communication device for long range communication and access to the remote Personal computer or server – GPS/GPRS modem.

IIIC. Camera module

This module is based on the wireless microcontroller JN5139/48. The block scheme of the Camera module is presented in Fig. 4.

The module supports an embedded camera. The module includes a heating control system and a temperature/humidity sensor. The camera communicates with the microcontroller by a serial channel with a baud rate of 115200 bits per 1 s. The camera transmits a picture to the microcontroller and the microcontroller sends this picture to the communication module in packets of 64 bytes. The picture is compressed by the JPEG engine and transferred to the wireless controller JN5139 through the serial port [6]. There are 11 AT commands for communication and management of the camera functionality.

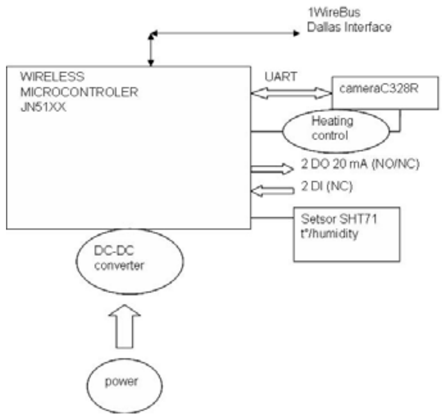


Fig. 4. Block-scheme of the Camera module

## IV. Software architecture of the system

There are two types of software developed for tests and work – software for the modules and software for monitoring and GUI in the PC. Each of the modules is programmed to serve as a coordinator in the wireless network. The modules are programmed in ANSI C.

Fig. 5 shows a brief schematic connection of the software modules.

For two of the modules, based on the wireless microcontroller JN5139, a Software Development Kit (SDK) is used with regard to the JenNet protocol stack provided free of charge by Jennic Ltd. [1, 7]. The JenNet provides a simpler alternative to ZigBee PRO protocol and simplifies and streamlines the application development [5].

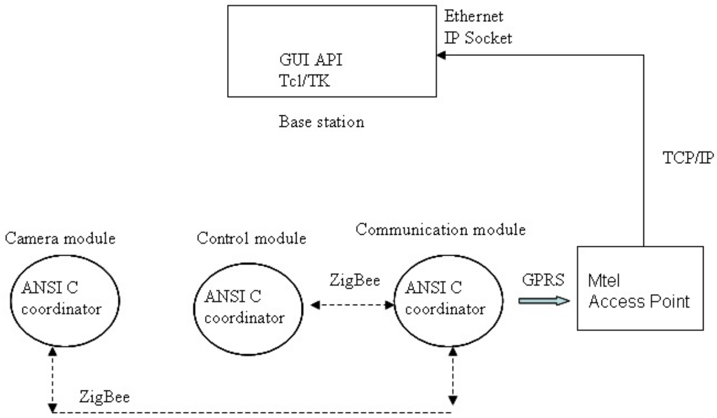


Fig. 5. Software modules – block-diagram

The software tools provide an Integrated Development Environment (IDE) – Eclipse or Codeblocks, and a Linux-like Command Line Interface (CLI), both of which can be used to carry out full software development for Jennic's wireless products [5].

The GUI and monitoring functions in the Base station are developed using the Open source Script language Tcl/Tk.

The communication module sends all measurements in block. There are two types of information – reports (all measured data) and pictures (pictures of the area activated by a user request from the base station). The reports are sent by the Communication module every ten seconds. The GUI reads the data and stores it in files (each report named according to the receiving time – yy-mm-dd-HH-MM-SS-R.txt) in the directory "Reports". The structure of each block is shown in Fig. 6.

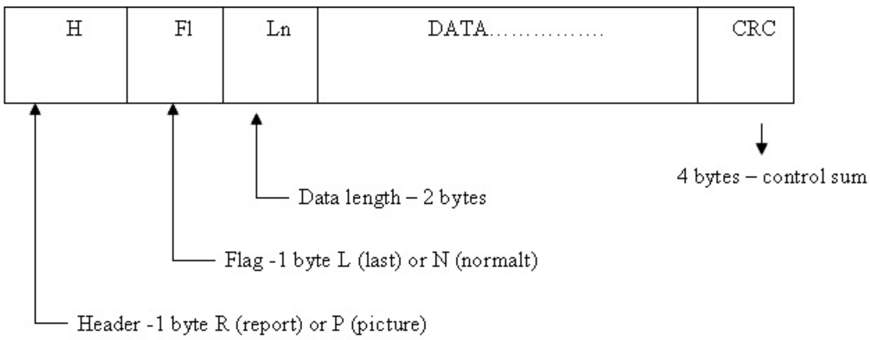


Fig. 6. Structure of the data blocks

## V. Conclusion

Module BTnode [7] is the first one which supports a combination of two wireless interfaces in one module. BTnode supports Bluetooth and ZigBee. The advantage of the Communication module, presented in this paper is the possibility to combine long- range and short-range wireless communication (GPRS and ZigBee).

The presented work has two main purposes: to investigate the control mechanism and principles for small hydro-power plants and to investigate the possibilities for implementation of wireless communication. The general idea is to develop a flexible and innovative solution to control and monitor hydro-power plants. The solution presented could be used for small-sized hydroelectric stations.

In the paper, a complete solution is described, but each of the presented modules could be used independently.

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## Дистанционное управление и наблюдение малых гидро-электрических станций


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(Р е з ю м е)

В работе предложена система, которая состоит из трех микроконтроллеров для дистанционного управления и наблюдения малых гидро-электрических станций. Станция находится в отдаленной области и работает в автономном режиме. Разработано специализированное управление, реализирующее алгоритм “Peak Power Tracking” для автоматического управления. Каждые десят секунд посылаются отчеты измеренных данных к персональному компьютру (базовой станции) при помощи GPRS/Internet. Коммуникационные протоколы, которые применяются: TCP/IP, GPRS, SMS, ZigBee и USB.