MONITORING OF HYBRID POWER SUPPLY SYSTEM FOR PUBLIC LIGHTING

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ABSTRACT

Supplying of separate isolated load systems such as street lighting can be realized by combination of wind and solar power. Hybrid power supply system consists of a number of independent and different sources of electrical energy with different operating times during different seasons and with energy storage system. Deployment of a hybrid power system is expected in places outside the normal distribution network. Such hybrid power supply system has been realized in the VSB- Technical University campus. For the further research is necessary to know in detail the power flow from various sources to the load or to accumulation battery depending on different seasons. The autonomous monitoring system with remote data transmission system has been developed to monitor the power flow between different blocks of the hybrid power system. The monitoring system also allows efficiency evaluation during various operating modes. The article describes among others the design and implementation of modular and open monitoring system based on National Instruments cRIO. The main goal of the article is to describe practical results that can be used to optimize the hybrid power system design in the near future.

INTRODUCTION

Hybrid power supply system is a parallel combination of wind and solar power plants. Outputs of the individual sources are used for accumulator charging that supplies subsequently the power to a separate insulated voltage system. Combination of different power sources utilizes time different dependences of individual sources. It simply means that accumulator charging from wind power plant is a prevailing mode during winter time, while the photovoltaic power plant is mainly used during summer period. The combination of operation of the individual power sources increases and stabilizes significantly an interval of the electric power supply. The hybrid power supply systems can be used at the places, where the construction of electric connection to the public electric network could be problematic or difficult.

DESCRIPTION OF HYBRID POWER SUPPLY SYSTEM

The hybrid power supply system consisting of two photovoltaic power plants and two wind power plants has been constructed at VSB-Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science. See Fig.1. Two power plants jointly charge NiCd accumulator battery with the capacity of 340 Ah and voltage 12V. The battery is used for feeding of two public lighting lamps. The capacity of the accumulator battery is sufficient for 14-day consumption without charging input from the individual power plants.

Fig. 1 Picture of half of the hybrid power supply system

Block diagram of the system can be seen on the Fig. 2. The hybrid system uses two photovoltaic panels: polycrystalline with the capacity of 130Wp / 17.6V (FV1) and monocrystalline with the capacity of 200W / 17.6V (FV2). NiCd accumulator charging from photovoltaic panels is controlled by control unit (REG). The same control unit also protects the accumulator against discharge by the appliance. The wind power plant VT1 with the capacity of 200 W / 31V is equipped by in-built regulator of charging and it is therefore connected directly to the accumulator. The wind power plant VT2 with the capacity of 200W contains synchronous three-phase generator with permanent magnets. Output of the generator is connected to the rectifier. The rectified electricity from VT2 is used for the accumulator charging via regulator. Two lamps of public lighting are used as appliances in the system (VO1 and VO2). VO1 contains LED lighting fitting with the electric input of 40W. VO2 contains sodium lamp with input of 50W. Both lamps work with 230VAC voltage that is secured by DC/AC converter.

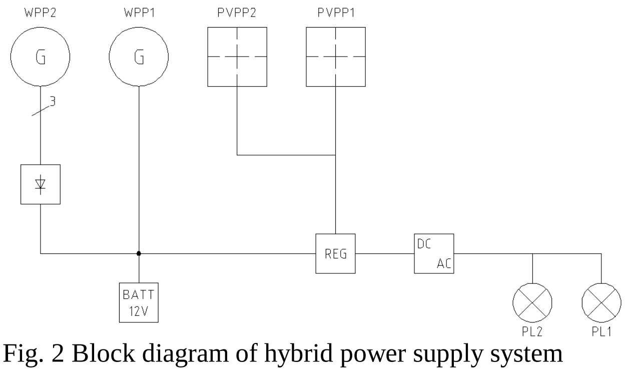

Fig. 2 Block diagram of hybrid power supply system

ANALYSIS OF EEFFECTIVENESS

Investigation of effectiveness of sun or wind power transformation to the electric power is not an objective of this article. Output level and waveform shape of FVE and VTE voltages cannot be used for direct power supply of the appliances. Various conversion devices are used for modification as for example rectifiers, DC/DC converters and DC/AC converters for modification of output voltage according to the requirement of load or requirement of device for the accumulation of electric power. Choice of suitable conversion components must be adapted first of all to V-A characteristic of a separately working electric power source. Detailed information related to this problem can be found in [1] for example.

There are characteristic curves of output voltage of the photovoltaic panel in case of various loads that will further change depending on the sunlight intensity.

The output voltage for synchronous generator with permanent magnets is directly proportional to the generator rotation speed. The output voltage must be rectified and stabilized to the value that is suitable for the accumulator battery charging with respect to the load characteristic of the generator.

If semiconducting devices are used for the above-described conversions and stabilizations, deformation of voltage as well as current signals must be always taken into account. The deformation is caused by the switching character of function of converters and regulators. Example of instantaneous values of voltage and current on the DC/AC output of converter can be seen in the Fig.3. The deformation of voltage as well as current signal by the influence of the switching frequency of DC/AC converter is obvious.

The deformation of the monitored quantities in case of application of semiconducting devices is not the only negative aspect of the conversion devices. Each conversion device works with certain effectiveness that has an influence on the evaluation of total effectiveness of the hybrid system.

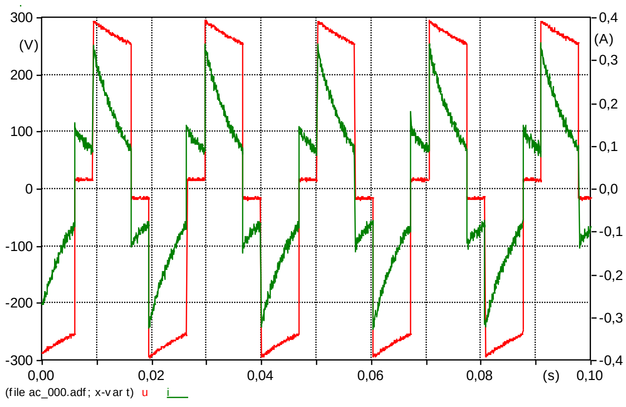

Fig. 3 Shape of instantaneous voltage (V) and current (A) at the DC/AC converter output

Total system effectiveness is calculated as a product of individual effectiveness of the system components. The effectiveness of the components is not constant, but it changes according to the operation state of the whole installation.

MONITORING SYSTEM

Monitoring system has been designed and implemented in order to obtain a complete picture of output and effectiveness flows of the component of the hybrid power supply system. Monitored voltages and currents were defined for the securing of monitoring of all flows of outputs and effectiveness of various components at different operating conditions – see Fig.4

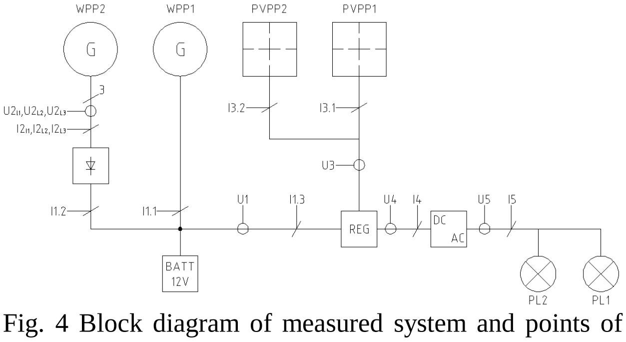

Fig. 4 Block diagram of measured system and points of measurement

Single-purpose microprocessor device has not been selected as the base of monitoring system in order to ensure a fast development and flexibility of the system in case of necessary future modifications. cRIO system supplied by National Instruments Company has been selected.

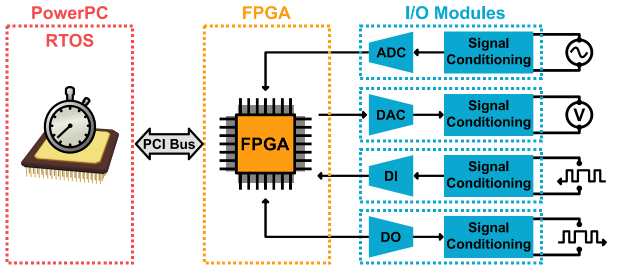

Fig. 5 Block diagram of the cRIO

CompactRIO combines an embedded floating point processor (PowerPC) with real-time operating system VxWorks, a high-performance FPGA and hot-swappable I/O modules. Each I/O module is connected directly to the FPGA, providing low-level customization of timing and I/O signal processing. The FPGA is connected to the embedded real-time processor via a high-speed PCI bus, see Fig.5. This represents architecture with open access to low-level hardware resources. Both PowerPC processor and FPGA are programmed in graphical programming language LabVIEW. LabVIEW contains built-in data transfer mechanism to pass data from the I/O modules to the FPGA and also from the FPGA to the embedded processor for real-time analysis, post processing, data logging, or communication to a networked host computer.

CRIO system combines an open embedded architecture with small size, extreme ruggedness, wide operating temperatures (-20 to 55°C) and hot-swappable industrial I/O modules, see Fig.6. Versatility and flexibility of the selected hardware platform and technology of virtual instrumentation enable development of demanding monitoring devices during a very short period, see for example [2].


Fig. 6 Physical appearance of the cRIO system

CRIO input modules that can measure directly all required ranges of voltages and currents within the measured system are not available on the market. Altogether 10 current signals and 7 voltage signals are monitored. Each signal has different level and moreover there are also combinations of DC and AC signals. LEM LA 25-NP was selected as converter for the currents. It has adjustable ranges within the scope from 5 to 25A and zone width from 0 to 150kHz. The converters LEM AV100-50 are used for the voltage measuring points. They provide an input voltage range of 50V rms with zone width 0-11kHz. The voltage at the level of 230V rms is measured by the converter – LEM LV 25-P/SP2. All LEM converters ensure a galvanic separation of measuring circuit from the measuring system and they have nominal current output 25 or 50mA. Although that theoretically there are no other signals than DC and AC with the frequencies up to 50Hz in the hybrid system, the selected components of the measuring chain must respect the signal frequency spectrum of the components with switching elements, because of presence of such components like inverters and regulators.

Complete HW of the monitoring system is installed in the existing outdoor switching cabinet that also contains complete electric equipment of the charging hybrid system. The switching cabinet provides protection against climatic effects, but it is not equipped by thermal insulation. It is therefore more demanding from the standpoint of operating temperatures of the individual components.

No permanent electricity is available within switching cabinet. Only electric power for public lighting is available here, but the power supply is active only during night. It was therefore necessary to secure a permanent supplying of the measuring system even during the day by means of UPS created from a suitable battery and charger. These components have been selected with the respect to the climatic conditions of the outdoor switching cabinet. Battery discharging up to minimum value is not suitable, because it shortens its service life. The best solution is to discharge the battery to 70% of rated capacity, because it extends its service life from 200 to 2,500 cycles and it means nearly seven years of operation.

Communication between the measuring system and remote PC is carried out on the internal network of the university. The measuring system is interconnected with the university communication network by means of wireless connection.

OBSERVED RESULTS

The principal parameters of the hybrid system have been verified by the measuring system within the scope of the existing testing operation. Effectiveness of the individual components of hybrid system as well as effectiveness of the complete hybrid system was monitored. Curves of effectiveness of the wind power plant for different levels of loads are shown in the Fig. 7.

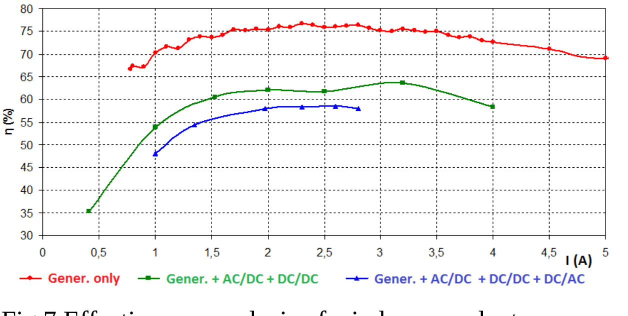

Fig.7 Effectiveness analysis of wind power plant

Graph legend for Fig.7: red – generator, green – generator + AC/DC + DC/DC, blue – generator + AC/DC + DC/DC + DC/AC. Condition of the accumulation device – NiCd accumulator battery with total capacity of 340Ah – has been monitored by means of measuring system utilization (except information on energy flows and time courses of required quantities in the individual components of the hybrid system). The results of accumulation device capacity analysis within the scope of day cycle are shown in the Fig. 8.

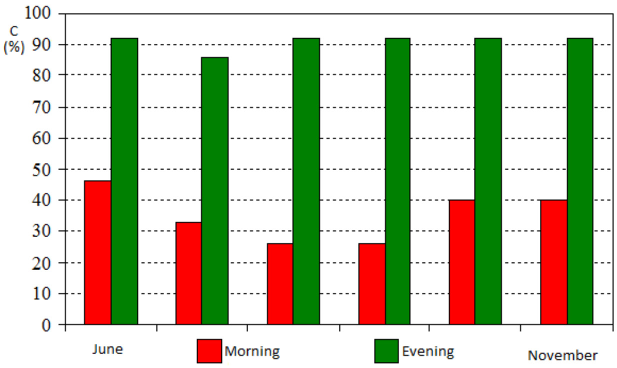

Fig. 8 Accumulation device capacity during daily cycles

Characteristic trend of capacity state for the hybrid system is obvious from the Fig.8. The capacity of battery reached nearly 95% of total disposable capacity in evening during summer months, when previous amount of energy for the accumulation device charging was secured by photovoltaic power plant. Decreasing of the amount of sunlight in combination with gradual shortening of day and change of sun trajectory at the beginning of autumn caused a decreasing of the amount of energy coming from the photovoltaic power plant. It was necessary to shorten the operation time of the public lighting from 8 to 6 hours in order to enable charging of the accumulation device of the hybrid system for supplying of the light sources. The original duration of the public lighting operation can be restored again during autumn, when gradually increasing amount of energy for the accumulation device was secured by the wind power plant.

CONSLUSION

Utilization of so-called hybrid systems is becoming more important at time, when higher and higher emphasis is given to energy independence. The hybrid systems combine cooperation of two mutually independent renewable sources of electricity. Some remote areas, for which the construction of public connection would be very expensive, can be supplied from the hybrid systems. Also the supply points that must be independent on the distribution network can be supplied from these sources. Many criteria must be taken into account during selection of the individual components of the hybrid system in order to achieve the highest possible effectiveness of the system. The analysis of effectiveness of the hybrid power supply system that has been constructed at the VSB-Technical University of Ostrava has shown within the scope of this publication. The hybrid system utilizes cooperation of two most widely used renewable energy sources; it means cooperation of wind turbine and photovoltaic power plants. Demandingness of the selection of the individual components of the system is a complex task, because it is quite complicated system and requirements and needs of the accumulation device, characteristics of output capacity of wind turbine as well as photovoltaic power plant and also the investment costs must be included and taken into account during the component selection. Therefore it is necessary to start with determination of the accumulation device capacity for given consumption during the preparation of the hybrid system implementation. Subsequently we have to proceed with selection of a suitable source of electric power with the respect to the climatic conditions of given locality. We have to consider carefully also the selection of suitable conversion devices in the electric power chain of the hybrid system. The present operation of the monitoring system lasting several months provides initial information on effectiveness of the individual components as well as the whole system. Used concept on the basis of cRIO platform and virtual instrumentation will enable a quick modification of the monitoring system with minimum costs in case of necessity. Collection and evaluation of data continues and provides some new results.

Acknowledgments

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