Abstract: This paper presents a design of a hybrid energy system with renewable resources. Hybrid system can better cover the energy demands of small energy objects in comparison with the classic photovoltaic (PV) or wind energy system. Combination of different sources in cooperation with energy accumulation requires sophisticated control system. The paper describes the intended design of the hybrid system from the point of view of control and system elements. Possible benefits of the designed system are further discussed.

Key–Words: Hybrid, System, Renewable, Off-Grid, Design, Control System.

1 Introduction

With massive development of PV power plants in Czech Republic (CR) and legislative changes large systems became no longer interesting for investments. This is partially caused by the low purchase price of the produced electricity. This results into focusing the following research on the smaller energy sources and their application.

On the other hand small PV system on the family house can’t fully cover energy demands due to the dynamic changes of the sunlight. This causes the discontinuity between the production and consumption which can be solved by accumulation of energy.

Another renewable source of energy which can be used with these systems is a wind turbine. With combination of the solar and wind energy standalone off-grid hybrid energy system can be made.

This solution also solves the problematic of the missing power output from the PV panels during the night and cloudy days. The missing energy is obtained from the wind turbines.

The result from mutual connection of these two energy sources is the improvement of the total efficiency of the energy system.

The research described further is aimed to define the individual parameters of such hybrid system.

2 Description of the system

The 3.6kWp hybrid system is designed as an experimental system for measuring the operational performance of photovoltaic panels and wind turbines and its behavior during dynamic loads. It is intended to be situated on the roof seen on the Fig. 2 of the Department of Electrical Power Engineering at FEEC BUT.

The department’s location is 49°13’38.413”N, 16°34’26.217”E. That gives the annual solar irradiance between 1085 – 1111kW/m². And the average wind speed is between 3 – 3.5m/s measured at 10m above the surface.

The system will combine PV panels and two different wind turbines with following details. Construction of the system will be divided into two stages. The first one will consist from installing PV panels and three-blade wind turbine on the desired location.

Assembled energy system will be used primarily for research in the field of design, operation and management of hybrid power systems. As already mentioned, an important part of the whole system is the accumulation system.
In connection with the requirements for the operation of these resources and in line with legislative and operational conditions was initiated a research which goal is to specify and typify accumulation system for individual energy systems with a view to maximizing energy profits and economic efficiency. It is assumed the use of various types of batteries, which will be tested in real operating conditions to verify its parameters and its suitability.

Described energy system has designed a modular load that corresponds to the operating characteristics of the house constructed in the low-energy standard.

After successful configuration of this first stage, additional wind turbine will be connected to the system in the second stage. Subsequently, new types of batteries that have the potential to be used in conjunction with systems with renewable energy sources will be tested.
Fig. 2: Location of the system

System is designed to use 48 V bus from all the sources. Exceed energy will be accumulated into two battery banks 48 V/200 Ah each. Two power invertors will be connected to the 48 V bus and will maintain converting DC voltage to AC voltage with grid parameters (230 V, sine-wave, 50 Hz).

For purposes of simulating different load and dynamic system changes an AC bus will be created in the solar laboratory, which is situated directly under the roof. Using control system based on PLC (Programmable Logic Controller), different load schemes with various parameters can be created. The aim of creating different types of loads is to simulate the operating conditions and test the system’s functionality.

2.1 Description of the system elements

Design of the hybrid system is shown on the Fig. 1. Further are described the basic components of the hybrid system.

2.1.1 Photovoltaic panels

System will be equipped with nine monocrystal PV panels (Solarwatt M250-60 GET AK), each with peak power 250 Wp and nominal voltage equal to 30.4 V and current 8.2 A.

These panels will be connected to three strings, each containing three panels in serial connection.

This PV grid will provide energy supply for the Tristar MPPT-60 which works as a voltage DC/DC converter and a battery charging regulator. It contains overload and short-circuit protection, high-voltage protection, thermal and transient current protection.

PV panels will be installed on the supporting structure which can be seen on Fig. 2. It is basically the net of galvanized piles, on which will be placed aluminium consoles. This structure will provide the opportunity to set the elevation angle of the PV panel to the different levels.

With this possibility, the elevation angle can be changed and its effect on the operational efficiency can be calculated.

2.1.2 Wind turbines

The potential of the wind energy is acquired by two different wind turbines. The first is three-blade wind turbine WHISPER 200 with nominal power 1 kW at wind speed equal to 11.6 m/s and the minimal start-up speed is 3.1 m/s.

The second is the combination of the Savonius and Darrieus types CXF–400 with nominal power output 400 W at wind speed equal to 12 m/s and...
the minimal start-up speed is 1 m/s. It is shown on the Fig. 3. Power from the turbines will lead to the Tristar MPPT-60, which are connected to the 48V DC bus.

These invertors will work in master-slave mode. It means that the "slave" invertor will be automatically connected and disconnected depending on the actual power output.

2.2 Measurements and control system

Measuring and control system will be based on Unitronics PLC Vision V1040. The possibilities of using industrial PLC and its suitability for application in controlling of small power plant have been studied in literature [1]. Selected PLC is shown on Fig. 4.

Between its benefits belongs, that it combines the logic controller and HMI (Human Machine Interface) which is ensured by a touch sensible color display. This PLC offers enough inputs and output, including analog inputs used for measuring continuous variables.

It can be equipped with GSM modem for remote control or connected via RJ45 to ethernet. It can cooperate with multiple devices such as motion controllers, another PLCs and power analyzers using MODBUS and ASCII protocol.

Fig. 4: Unitronics Vision V1040

The PLC is equipped with the Unitronics V200-18-E3XB snap-in module with following inputs and outputs:

- 18 x DI DC 24 V
- 4 x AI DC 0–10 V, 0–20 mA, 4–20 mA
- 2 x DO DC 24 V
- 15 x DO 30 V, AC 250 V/3 A
- 4 x AO DC 0–10 V, 4–20 mA
In order to measure desired values, the PLC will be equipped with additional modules for measuring the following:

- voltages from the system on:
  - individual strings,
  - outputs from the wind turbines,
  - the DC bus and battery Banks,
  - the AC bus (needs additional module capable of measure voltages up to 250 V).

- currents from the system in:
  - individual strings,
  - outputs from the wind turbines,
  - each battery bank,
  - each power invertor,
  - each load
    will be performed with current converters with 4–20 mA outputs.

- informations from the weather transmitter are acquired through the RS485 port on the PLC and the ASCII protocol,

- radiometer data acquisition,

- up to four temperatures monitoring due the PT100 thermocouples can be connected directly to the snap-in module,

- wind turbines speed monitoring with high-speed inputs

For the purposes of measuring the values described higher, the following modules have been chosen.

- expansion module EX-A2X – needed for connecting additional measuring modules,

- measuring modules IO-DI8ACH – each measures up to 8 x 250 V AC channels

- measuring modules IO-ATC8 – each modules adds AI DC 0–10 V, 0–20 mA, 4–20 mA

This is necessary for detailed information about the working conditions.

Weather transmitter WXT520 measures barometric pressure, humidity, precipitation, temperature and speed and direction of the wind.

The CMP 21 is a high performance research grade pyranometer designed for measuring the irradiance (W/m²), which consists from the direct solar radiation and from the diffuse radiation.

These values will be stored to a database which will provide the complex background about the system location and weather conditions.

3 Conclusion

The described hybrid system presents a variable off-grid energy system with renewable sources suitable for family houses.

The research associated with this system is aimed to evaluate the suitability of various system elements with different parameters. The intention is to find a solution which is suitable for application in similar systems. This research will be realized in cooperation with Czech companies fgForte and SUNLUX.

As the main results from this research should be mentioned preparation of the project specification and defining the conditions for connecting the hybrid systems into the electric distribution network. Next step is the preparation of the philosophy of the accumulation system design according to the characteristics of production and load and testing new technologies suitable for application in hybrid systems.

Application of the hybrid systems results into higher energy self-sufficiency of the objects and reduces the actual usage of the distribution networks.

The hybrid system described higher is planned to start its run in the first stage until the end of the year 2013. Therefore, we can expect the first results from the measurements in the spring of 2014.

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