APPLICATION OF THE OBJECT ORIENTED APPROACH IN THE RESEARCH OF AUTONOMOUS POWER SUPPLY SYSTEMS

Vitālijs Osadčuks, **Ainars Galiņš**
Latvia University of Agriculture, Faculty of Engineering, Institute of Agricultural Energetics
vtl@tvnet.lv, ainars.galins@llu.lv

Abstract. Possibilities of using autonomous hybrid power supply systems in individual household have been examined using system analysis methods. Based on the gathered information about the attributes of the system and its components an object model has been developed. The obtained model consists of diagrams describing the structure of classes and can be used in the further development of a control system. The working scenarios of the system have been examined, too.

Key words: hybrid power system, object oriented modelling, object model, class diagram.

Introduction

The aim of the research is to develop object model of a hybrid power supply system, which can be used in an individual household.

The main tasks are to examine possibilities of using alternative energy sources to define the general case of combined power supply consisting of power generators, accumulators and power consuming devices, and to describe particular example based on the general structure. In the composition of the object model strategies and patterns discussed in [3] have been used. The object model has been developed taking in consideration its expansion potential by adding new components.

The individual hybrid power supply system of an individual household is an electrical grid including number of electrical energy sources greater than one with total power output 3 – 4 kW, assuming that at least 10% of it is created by each generator. The power consumers are daily use electric and electronic devices like irons, vacuum cleaners, water pumps, TV sets, etc., with total monthly electrical power consumption of about 250 kWh.

Alternative power sources, advantages and disadvantages of using in the individual household autonomous energy supply

There are several definitions of alternative energy and its sources. The alternative is energy that is not very widely used nowadays and in opposition to fossil is extracted from renewable resources [1]. Alternative renewable energy sources are wind, flow of water, solar radiation and biomass. All of these resources do not have bad influence on environment like in the case of fossil fuel [2].

In several cases nuclear power is considered as alternative resource, which in fact is non-renewable. Recently adapted sources of energy like hydrogen (in fuel cells), fusion power, etc., are energy sources that are limited due to geographical (geothermal energy) and seasonal conditions (high/low water level).

The advantages and disadvantages of renewable alternative energy should be analyzed in the context of the study – individual household combined (hybrid) autonomous power supply system. The main reason of narrow use is that fluctuations of the power supplied by them.

So the advantages and disadvantages of using renewable alternative energy are derived from their definition: the depleted alternative resources will renew in the natural way sooner or later; they do not harm environment, they are freely available, and the costs of exploitation are related only to installation and maintenance of equipment used. Disadvantages are relatively small efficiency, unavailability of possibility of using the alternative resources in certain places or periods of time, and relatively high costs of system installation. The main reason, why alternative energy is not popular and makes it difficult to base on it purely autonomous power supply systems, is the instability of such energy sources over time.

Practically availability of all alternative renewable resources used today is highly depended of environmental conditions. It is hard to deliver necessary power to the individual consumer with the system which is relaying only on one type of the renewable resources.

Where with in the small autonomous power supply different energy sources are used in combination making a system called hybrid. A number of interchangeable energy sources in one system in selected combinations can provide a good power supply. As an example to be mentioned is combination of wind and solar power. While one is available other is not and vice versa. In addition to it a reliable backup generator must be used to power the system for the periods of time when none of alternative resources are available. A battery backup can be used to increase overall system stability (to smooth the pikes and falls in the supply voltage due to changing loads from the consumer activities) and to power the system for short periods of time when the operation of backup generator is not efficient.

System design

In the general case the autonomous power supply system is an electrical grid consisting of one or more power generators, balancing elements or short-time backups (accumulators) and consumers. All the components are connected to a common bus with common electrical characteristics. Each generator can use either its own energy source to produce electricity or share it with other generators. For example all wind turbines in the system use the same wind power. Generators supply the electrical power to the grid, consumers use it, but accumulators depending of their working state can act as power generators and consumers as well.

Typical example of autonomous power supply system is the electrical equipment of vehicles. It consists of a alternator, an accumulator and number of consumers – lights, ignition system, signals, etc.

The main goal of the studied autonomous hybrid power supply system is to provide consumers with stable electrical power by monitoring the electrical characteristics of the common bus and controlling the components to ensure normal operation conditions.

The block diagram of the system in general case is shown in Fig. 1. The arrows show the direction of power flow.

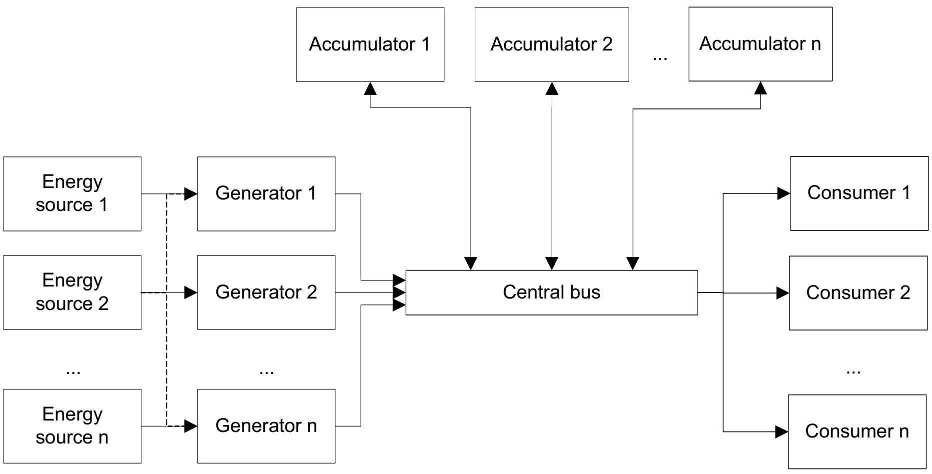

Fig.1. **Common structure of an autonomous power supply system**

Object model composing

In the development of control systems an object model can be used not only for better understanding of properties, functionality, working states of the system components themselves and the system entirely, but also for creating of the control system directly from the object model keeping its idea and structure. A wide range of CASE tools and object-oriented programming languages may be used.

A class and an object are the main concepts in the object-oriented modelling. The class is an entity that brings together a set of objects focusing on their properties and functionality (set of functions or methods), in other words – attributes. The object is a particular instance of the class. Each object has all attributes of the corresponding class [4].

There are two mostly used types of relationships between classes: inheritance and aggregation. Inheritance is used to arrange classes in hieratical structures. In the highest level of the hierarchy there are the most general classes with properties and methods that are common to all the other inherited classes. If a class is inherited from other class, it inherits all attributes of it and also may contain its own properties and functions. In such way it is possible to localize objects in the system to the required level of detail.

The main class called Device with the basic functionality common for all the devices in the system (turn on, turn off, read state of the device, etc.) can be inherited, for example, by class Generator. Now the class Generator has all attributes typical to device and also can implement its own functionality, such as electric properties, their current and critical values, and so on. Of course, it is acceptable to add another intermediate class between the Device and the Generator. It can be Electrical Device class that represents all electrical devices with their respective attributes; it inherits Device functions and passes them to Generator together with its own functionality. But for the class diagram creation of it is necessary to set up the problem domain of the inspected system. So if all the devices are electrical such intermediate class would be excessive and all electric related functionality could be added to the basic Device in order to avoid complicated diagrams. On the other hand, it could limit the possibilities of extension of the system in the future. Therefore the object model should be detailed to find compromise between compact structure and extensibility [3].

Aggregation allows a class to be encapsulated in another class or to make as component (field) of it. It is assumed, that every component can be detailed further and can become a system itself. Such mechanism can be very helpful in complex systems with a lot of classes. It becomes possible that class using another complex class may not know about its subsystems. It also helps to organize diagram, make it layered by level of interaction with hardware, software or user or by another criteria, reduce number of relationships and reduce overall complexity of the model. As example in this case, the system does not know are transducers and technologies used to measure and calculate current maximum possible power output of a wind turbine.

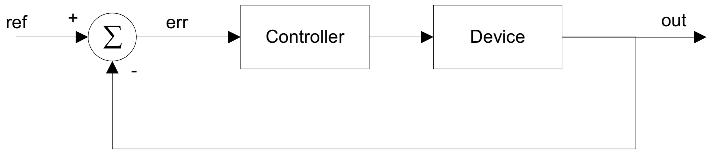

Fig. 2. **The control problem in the functional blocks notation**

Special structures called interfaces also can be used to compose the object model. The interface is a special case of the class, which has no properties, but only definitions of functions, without body. Interfaces are used as frames that show what functionality should implement a class to meet a particular interface. Between classes and interfaces there is relationship “implements” – a class implementing an interface which contains bodies all functions defined in the interface[1] [4]. As interfaces cannot contain properties (fields), only inheritance relationship can appear between them, no aggregations.

In this research interfaces are used to describe the functionality of a device in order to meet the system requirements. For example, interface IWindGenerator is used to define methods, which can be used on a wind turbine, no matter of model or manufacturer.

The main advantage of an object model against block diagram (see Fig. 2.) is easy extendibility in terms of adding new functions to existing devices and adding or replacing existing devices by completely new devices.

By using the object-oriented approach there can be several solutions for the control problem. In [6] each block of the control system is simply implemented as a class. Controller knows which device(s) it controls (it encapsulates devices or receives them as parameters in its own methods) and

[1] In particular cases interface can contain properties, too, as it is in Microsoft .NET environment. There is a terminology issue. In the .NET environment class has fields (not definable in the interfaces), properties and functions. In fact the property is a function, which returns an internal field value. Both functions and properties defined in the .NET interfaces should be implemented in classes.

according to control algorithm calls functions of the device class. While [3] describes a model where functionality of the controller is included instantly into devices. Benefit of such approach is freeing of centralized controller and number of hardware and software communication lines with it, as well as no doubling of functionality in the controller and the device, because control functions and the control algorithm are included into the device and must not be called from controller class object.

As particular example of system to be modelled authors used an autonomous electric power supply system with such components: the wind turbine, the accumulator battery, the inverter and the back-up power source – diesel generator (see Fig. 3.). The centralized 24V DC bus is used to connect power generating and power consuming devices together. Such solution is used in context of issues that appeared in the process of system analysis. For example, it is possible to connect diesel generator to the AC grid on the other side of the inverter (diesel generator uses AC machine). It would save up on double inverting, but also causes voltage-frequency synchronization problems between the inverter and the AC generator.

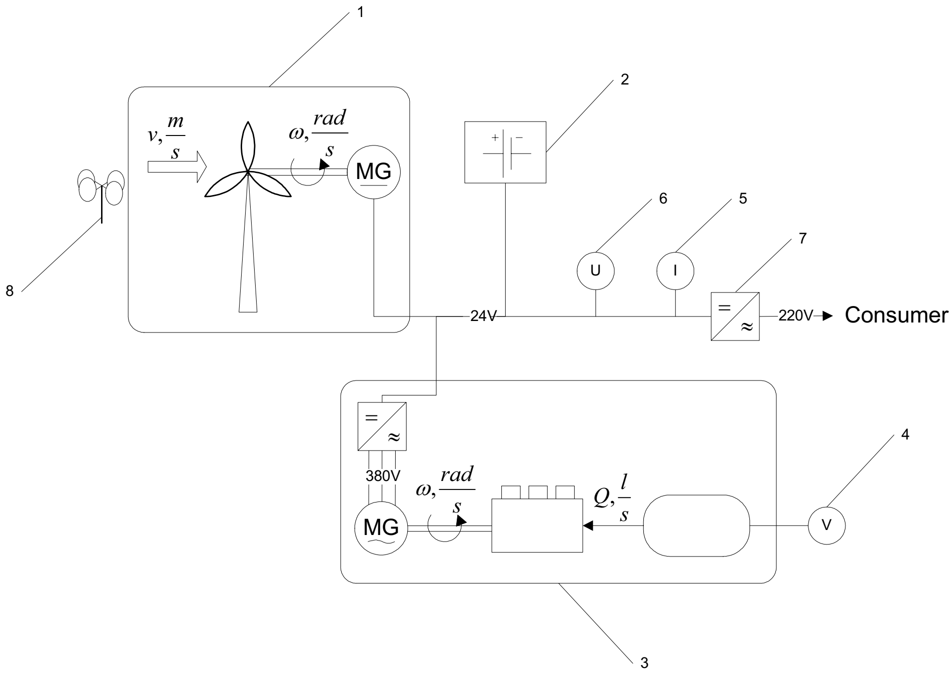

Fig. 3. **Components of example autonomous electric power supply system**: 1 – the wind turbine, 2 – the battery, 3 – the diesel generator, 4 – the fuel capacity meter, 5 – the current transducer, 6 – the voltage transducer, 7 – the inverter, 8 – the anemometer

In addition for controlling purposes several transducers are included into the system: current and voltage transducers on the centralized bus, fuel level meter on diesel generator fuel tank and anemometer for current maximum power estimation of the wind generator. Besides the transducers may not be separated from physical devices in particular case. They are added in order to gather information for control of corresponding devices and as it is shown later in the object model are logically encapsulated into controlled devices. So, transducers may be a part of the controlled devices physically, too.

The wind generator is used as a basic power source. It is connected to the DC bus all the time and gives as much power as it can in the given moment of time (if its control algorithm allows). The accumulator battery serves as a limited time back up and a buffer element to eliminate power fluctuations in the bus caused by transitional processes of consumer devices (turning on and off large loads – irons, vacuum cleaners, etc.). The diesel generator can be operated when voltage in the centralized bus falls below the charging voltage of the battery, i.e., in cases of the wind generator output power falling and/or substantial load rising on the consumer side.

The first step in the creation of an object model is to define the problem domain. What objects (devices) are in the system, what are the functions they perform. An example of defining the problem domain is shown in the system description above.

Based on the gathered information the class (interfaces) diagram of the system has been created (see Fig. 4.). The class diagram shown in Fig. 5 represents the described example. Each class in it implements an interface from the first diagram.

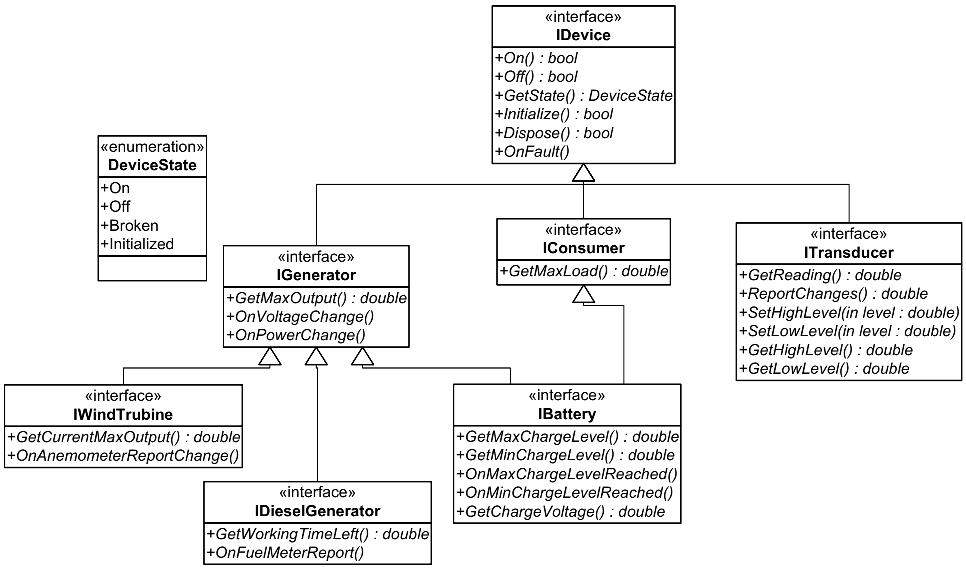

Fig. 4. **Interfaces of autonomous electric power supply system**

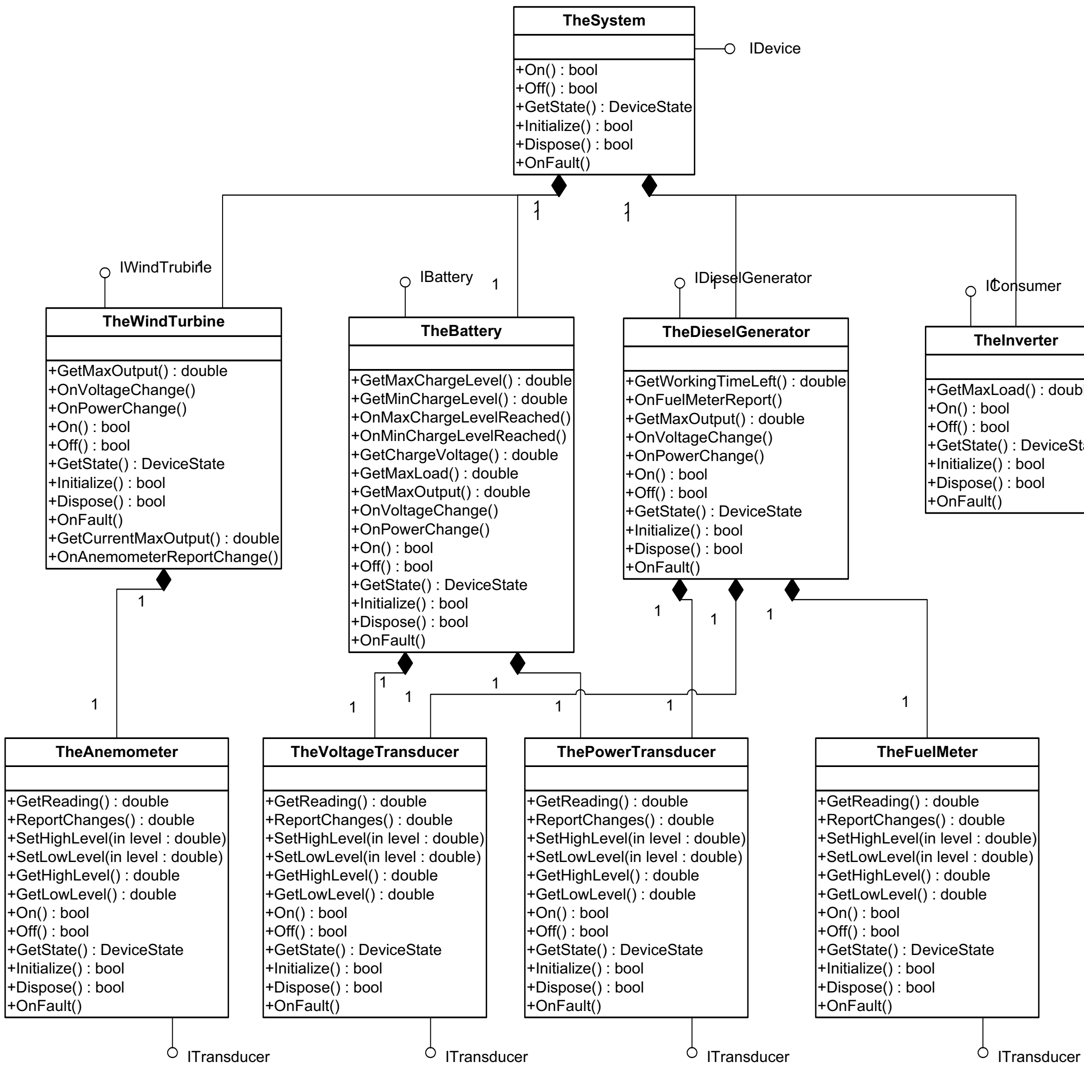

Fig. 5. **Class diagram of concrete components of a power supply system**

Each function of the classes collaborates in at least one working scenario of the system. For example, a scenario where diesel generator is turned on when voltage in the central bus falls below the stated value. The voltage transducer detects change of its state and sends a message to the both battery and diesel generator. In this scenario we discuss the reaction of the diesel generator. The message is handled by function `OnVoltageChange()`. It waits for a defined time of a transition process or arriving of the next message of the voltage change. If the voltage normalizes, the function returns, else it checks the fuel level in the tank by using `GetReading()` method of the fuel meter and depending on it turns on the back-up generator, function `ON()`.

Conclusions

1. An object model gives a clear, systematic view on the functionality and properties of all components and the system generally. It helps in specification of working scenarios and in further development of a control system.
2. System analysis based on methods of object-oriented modelling is an iterative process. Set of tasks and objectives of the system, classes, interaction between them, resources is modified to improve correctness and completeness in each step.
3. In the case of combined power supply system, where each component is a complicated, self-sufficient subsystem itself and physical placement of the components is distributed, the practical realization of object-oriented control system faces with software and hardware deployment issues, in other words where each function of a class to be physically implemented – on periphery or centralized control unit.

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