The use of microcontrollers in modern solutions of power electronics

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***Abstract*— The role of modern power electronics is to provide reliable and uninterruptible power supply for the consumers. Electric power stations are the most commonly used primary sources of energy. That energy is distributed to the consumers by large power distribution grid. Secondary power sources are usually some sort of alternative power sources or batteries. All power sources have to be controlled all the time. There have to be a system of power electronic devices that provides reliable and continuous power supply operation. Modern power electronic devices are switching type. The basic elements of a switching power supply are power electronics and control electronics. The control electronics are suitable for controling with logical circuits. Because of that, microcontrolles are now part of every modern power electronic devices. If the system has more than one power electronic devices controlled by the microcontroller then multiply microcontroles have to be coordinated to work as one. This paper describes an implemented solution of uninterrupted power supply for telecommunications equipment that uses either power distribution grid either alternative power source either storage battery. The microcontroller is a part of every power source that equipment uses. Also it controls and adjust all the power sources so that equipment has reliable and continuous power supply.**

Keywords- alternative power sources, microcontrolles, batteries

I. INTRODUCTION

The application of a switching mode in power electronic devices has enabled an achievement of the efficiency level over 95% as well as reduction in size of devices. In addition, it has enabled easy monitoring and control at the digital level [1]. Microcontrollers have become an integral part of power electronic devices. In the beginning they were used only in the specific solutions and when microcontrollers become widely available they become an integral element of any complex power electronic device. There are different approaches to the use of a microcontroller. It is common that the microcontroller only monitors the operation of power electronic devices. There are solutions where the microcontroller, in addition to monitoring, is used to define the mode of power electronic devices (source of constant voltage or source of constant current, setting the output size value, setting the level of protection, etc.). There is also a third group of power electronic devices, in which a microcontroller is used for generating signals for control of the power switches. In the third group of solutions, power electronic devices, different in function, could be generated by the same power electronic assembly. The system of power electronics consists of more power electronic devices which together provide the necessary electricity for operation of a consumer. If the individual elements of the system have a microcontroller, it is logical that there is a system microcontroller which would control and direct the operation of each power electronic device as well as the entire system of power electronics. This paper presents a solution for supplying telecommunication facility from multiple power sources. Each energy source has an associated power electronic device, and the system microcontroller adjusts the operation of all elements in the system according to the given operation algorithm.

II. ORGANIZATION OF UNINTERRUPTED SUPPLY OF A MODERN TELECOMMUNICATION FACILITY

Uninterruptable power supply of telecommunication facilities is based on the principle of parallel operation of a chemical power source (batteries) and DC voltage obtained from the electric power distribution grid. The nominal value of the DC voltage is 48V. This value can be changed in the range from 42 to 56V. The device which generates DC voltage from AC voltage is called a rectifying unit. In modern solutions of power supply organization in addition to the voltage obtained from electric power distribution grid alternative energy sources are also used as power sources. These are solar panels, wind turbines and fuel cells. Figure 1 shows a block diagram of the organization of continuous operation of the modern telecommunication facilities. The energy system has to provide reliable power for telecommunication and IT equipment, with the well-defined electrical characteristics and precisely defined the autonomy of operation. The system has to be able to optimize the power consumption, in order to maximally extend the autonomy of the most important devices at a given time. Power system has to efficiently use the energy from alternative energy sources. The solution has to be configurable, in order to could be applied for different types of telecommunication centers.

A. Power sources

It is accepted that the main voltage for power supply of stationary and mobile telecommunications devices is DC voltage. Energy sources could be:

- electric power distribution grid,
- electric power unit (aggregat) and,
- storage batteries (DC voltage).

The voltage of a electric power distribution grid and a aggregat is an AC voltage whose nominal value is 230 V.

Rectifying unit is a power electronic device which generates DC voltage, needed to power telecommunications devices, from the AC voltage. In addition, the rectifying unit has a possibility to charge a storage battery. The most common solutions of uninterrupted power supply of telecommunication systems use all three energy sources (electric power distribution grid, electric power unit and storage battery). There are also solutions that rely on two sources, one of which is always storage battery. Switching power supply from power distribution grid to power supply from the aggregat is not immediate, and in the transitional period storage batteries are used. Telecommunication centers are usually installed in stationary objects, but often users such as the military and police, have telecommunication centers installed in vehicles (mobile telecommunication centers). Stationary telecommunication facilities are often located in urban areas where the voltage from electric power distribution grid is available. The main power source is the voltage from electric power distribution grid. Storage battery and power unit are backup power sources. In the telecommunication facilities in which the power supply from electric power distribution grid is reliable, they do not use power unit as a backup power source. They use storage battery as a backup power source. Of course, the capacity of batteries has to be sufficient to achieve the required operation autonomy of telecommunication station. For the stationary telecommunication facilities, the nominal value of the power supply voltage of telecommunications center is 48V. This means that the voltage changes in the range from 42V to 55V, depending on the level of charge in the storage battery, and temperature. It is standardized that positive pole of the DC voltage to be grounded. In the Figure 1 block diagram of the organization of uninterrubtable power supply for stationary telecommunication facilities is shown.

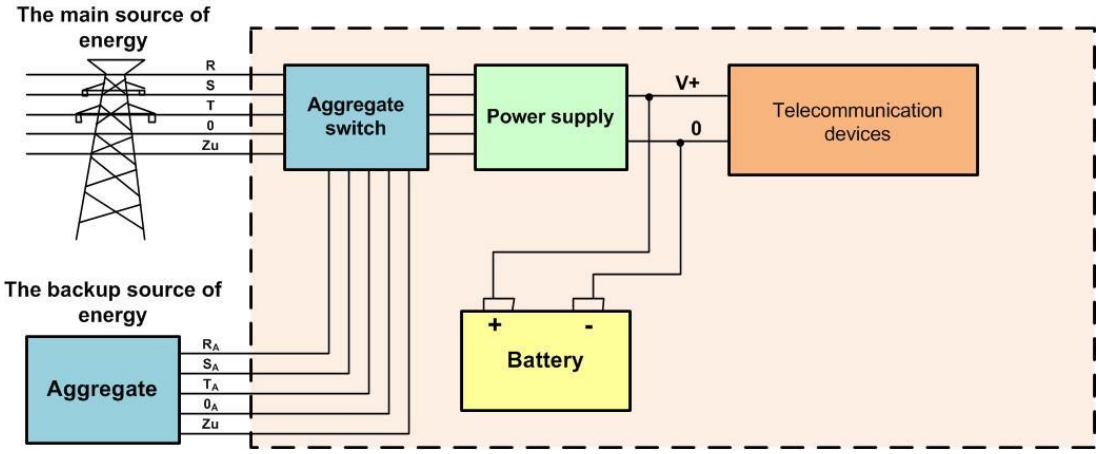

Figure 1. Organization of uninterruptable power supply of stationary telecommunication center

B. Organization of power supply of telecommunications device

In practice, there are two ways of organizing of uninterruptable power supply of telecommunications device:

- centralized,
- distributed.

The Figure 2 presents the solution of centralized power supply. A rectifying unit and a set of storage battery powers a greater number of telecommunications devices. The advantage of this implementation is simple realization and maintaining. The lack of this conception is that one failed power electronic device can cause cancellation of all consumers. In addition, the rectifying unit has to be dimensioned for the potential consumers who will be installed in the future. This means that the rectifying unit and battery are oversized which increases the cost and difficulty of the power supply. It also reduces the efficiency of power electronic devices. That is why these solutions are mainly used in stationary telecommunication facilities. DC distribution enables connection of a larger number of consumers to the same rectifying unit [2].

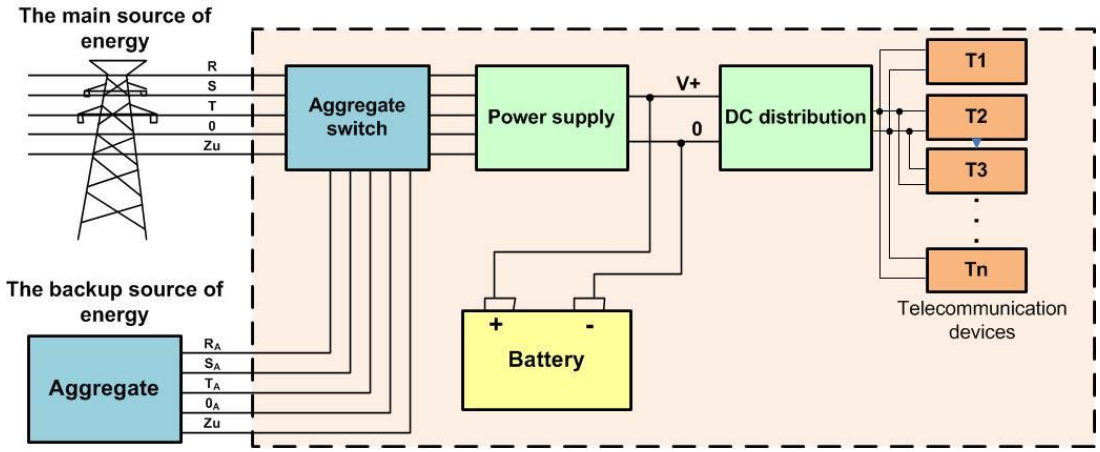

Figure 2. Centralized power supply of telecommunications devices

In a distributed solution, each telecommunications device has its own rectifying unit and own battery as shown in Figure 3.

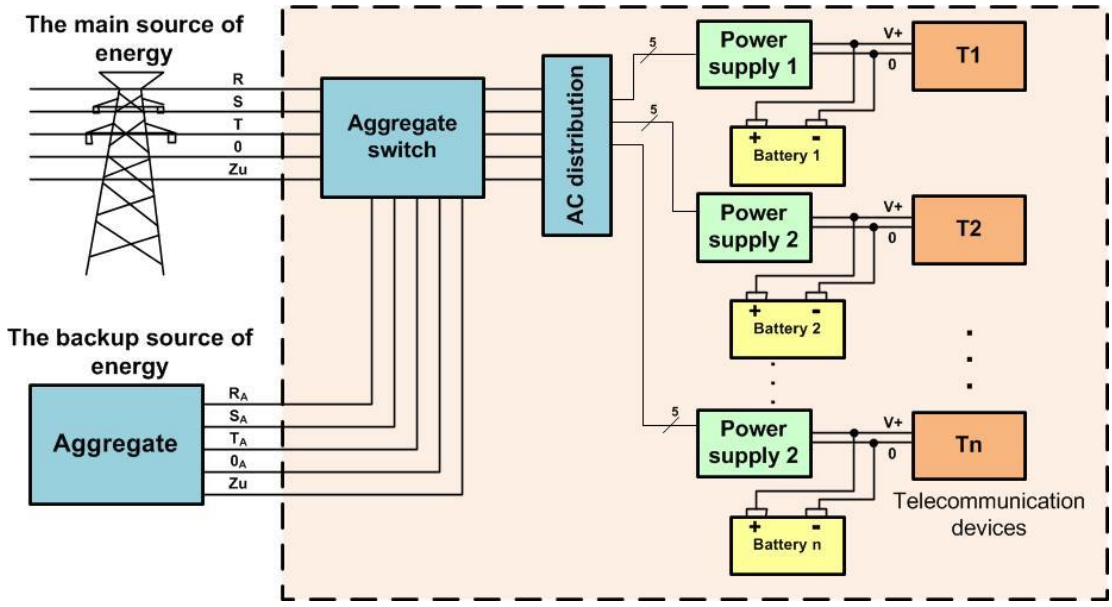

Figure 3. Distributed power supply of telecommunications devices

Distributed solution of organizing of power supply of telecommunication systems eliminates the disadvantages of centralized solution. Cancellation of a rectifying unit will cause interruption of operation of only one telecommunications device. However, the price of power supply from distributed concept is much more than the cost of centralized power supply, which also applies to maintenance costs.

Having in mind the disadvantages of the previous two configurations, the solution shown in Figure 4 was created. It is a modified version of distributed power supply. Only one set of batteries is used. AC/DC converters are used instead of rectifying units. These converters generate stable DC voltage with a nominal value of 48V. They are simpler and less expensive than rectifying units. The value of the output voltage is adjustable through a microcontroller that is an integral part of the converter. In addition to setting the value of the voltage microcontroller can set the mode so that the converter can operate as a constant voltage source and a constant current source. The same converter is used to charge the battery - battery chargers. Then they operate as a constant current. This approach for solving the problem of uninterruptable power supply can be applied in both stationary and mobile telecommunication systems. However, it is better to use it in mobile telecommunication centers as it allows optimization of power to the consumers. The voltage converters supply groups of consumers. To charge the battery the same converter is used, but it is set to operate as a battery charger (IU characteristic). Only one set of batteries is used. The configuration in Figure 4 is configurable. The number of voltage converters is defined by the real needs.

Figure 4 The modified configuration of distributed power supply optimized for mobile telecommunication centers

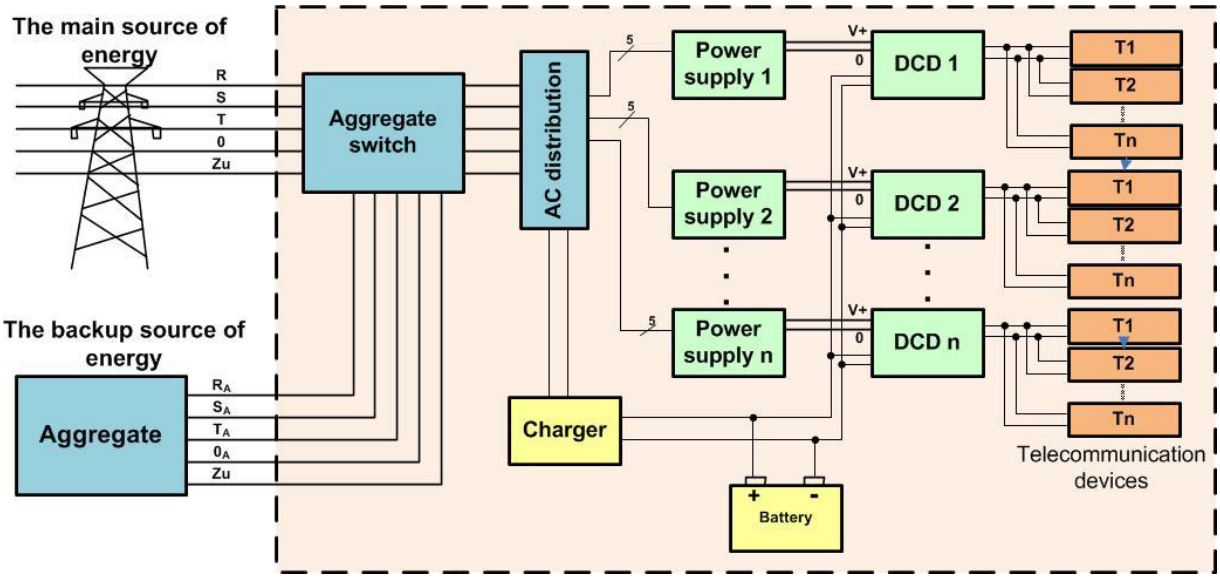

Figure 4. The modified configuration of distributed power supply optimized for mobile telecommunication centers

The configuration shown in Figure 4 is suitable for connection to alternative (renewable) energy sources. Solar panels are DC sources and they can be used to charge the system battery without conversion to AC voltage. The same is true for less power (up to 10kW) wind turbines. Reducing the number of voltage conversion the efficiency of use of alternative sources increases.

The occurrence of renewable energy sources telecommunications companies are interested in implementation them primarily in remote, inaccessible telecommunication facilities. The use of fuel cells, solar panels and wind turbines has started. The aim is to avoid the power units, reduce operating costs of renewable energy sources, and certainly reduce environmental pollution. Simultaneous use of energy sources based on fossil fuels and renewable energy sources can achieve the desired goal.

III. CONNECTION OF ALTERNATIVE ENERGY SOURCES

A usual configuration for connecting renewable energy sources is shown in Figure 5. Electricity produced from solar or wind is connected in parallel with existing energy sources: power generator, power unit and storage battery. It is not realistic to expect that renewable energy sources at once completely replace energy sources based on fossil fuels, primarily due to the low efficiency. Interruptions in the power supply of telecommunication facilities cause disruption of telecommunications traffic, and that means big losses for the telecommunications companies. It is realistic to expect that in the first phase of the implementation of renewable energy sources, renewable energy sources will be connect in parallel with the existing power systems. Renewable energy sources will supply telecommunication system, and if there is not enough energy from renewable energy sources in that case power supply from the resources based on fossil fuels will be used. In following stages the sources based on fossil fuels will be slowly replaced with renewable energy sources [3-5].

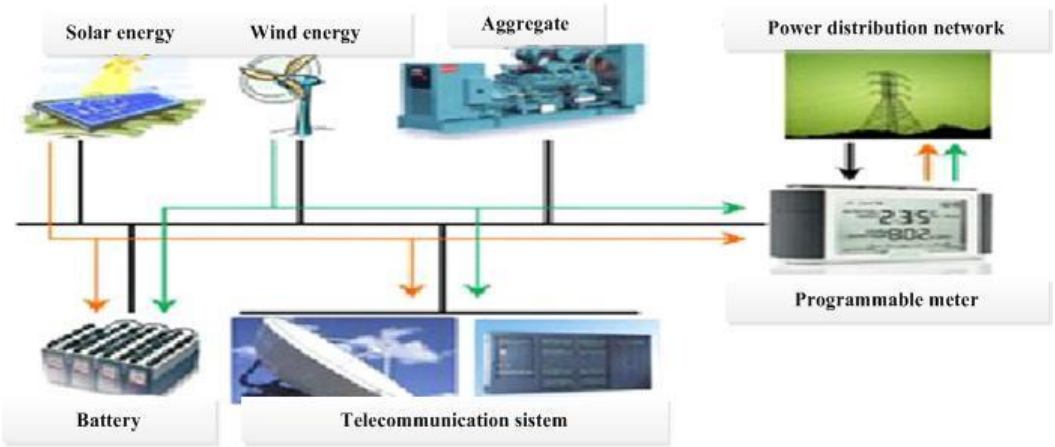

Figure 5. Connecting and control of telecommunications consumers power supply

A. Distribution at the AC voltage level

Figure 6 shows the connection of unconventional sources of energy and electric power distribution grid for power supply of consumers. Switch P1 is the power unit relay, which in the case of power failure in the electric power distribution grid includes power unit and connects it with consumers. Switch P2 enables parallel connection of voltage generated by the solar panels, fuel cells and wind turbines, with energy sources based on fossil fuels. Thus, adding is at AC voltage level. To achieve this, inverter is a necessary element. Inverter generates AC voltage from the DC voltage from the output of renewable energy source generated based on fossil fuels. There are two possible operation modes of configuration shown in Figure 6.

- Parallel operation of electric power distribution grid and inverter power generated from renewable energy sources,
- alternative operation - telecommunication facility is supplied from the electric power distribution grid or from the voltage generated by the inverter.

The first method allows the excess of energy produced by renewable energy sources to be placed in power distribution grid. However, in order to connect two sources of AC voltage in parallel a necessary condition is to have the same effective value, the same frequency and the same phase angle. Of course, it is feasible, but economically difficult profitable. Due to its complexity, parallel operation is less reliable and it is not really to be used for supply of telecommunication facilities.

An alternative manner of power supply is easier for realization, and therefore it is more reliable. The voltage at the output of the inverter does not have to be synchronous and have the same phase to the voltage in the power distribution grid. When switching from one to another source of energy, the power interruption appears. Interruption is necessary because the voltage of the power distribution grid is not synchronous and it does not have the same phase to the voltage at the output of the inverter. The storage battery will power supply consumers in commuting time. This approach saves energy, which is supplied by the electric power distribution company, hence energy from renewable energy sources will be used and when there is a voltage from power distribution grid. The requirement for supply from alternative sources is to produce enough energy to power supply consumers. Lack of this concept is that the lack of energy from renewable energy sources cannot be recovered from the electric power distribution grid. Telecommunication facility is supplied from the electric power distribution grid or from renewable energy sources. There is no possibility to operate in parallel.

The advantage of the processes described is a simple realization. The use of energy sources based on fossil fuels is reduced, but it has many disadvantages. First of all, it has a low degree of efficiency. Inverters are devices that generate DC voltage from the input AC voltage. Voltage conversion is not lossless. It consumes the energy of renewable energy sources. Then rectifying unit generates DC voltage from AC voltage at the output of the inverter and thereby also consumes some energy. Any conversion of energy consumes a part of the energy from the renewable energy sources. Overall efficiency of energy use of renewable energy sources (1) is the product of efficiency of individual converters (2). The efficiency of renewable energy sources can be calculated as the ratio of power required to telecommunications equipment and the total power of renewable energy sources (1).

$$P_{OI} = P_{VG} + P_{SP} + P_{GC}. \tag{1}$$

$$\eta_{OI} = P_{TU} \Big/ P_{OI} = P_{TU} \Big/ P_{OINV} * P_{OINV} \Big/ P_{OSS} * P_{ISS} \Big/ P_{OI}$$

$$= \eta_{ISP} * \eta_{INV} * \eta_{SS}, \tag{2}$$

where in:

P_{TU}, - Power required for operation of telecommunications devices,

P_{OI}, - Available capacity of renewable energy sources,

P_{ISS}, - Power from the output of serial stabilizer,

P_{OINV}, - Power at the output of the inverter,

η_{INV}, - Inverter efficiency,

η_{SS}, - Serial stabilizer efficiency,

η_{ISP}, - Rectifying unit efficiency.

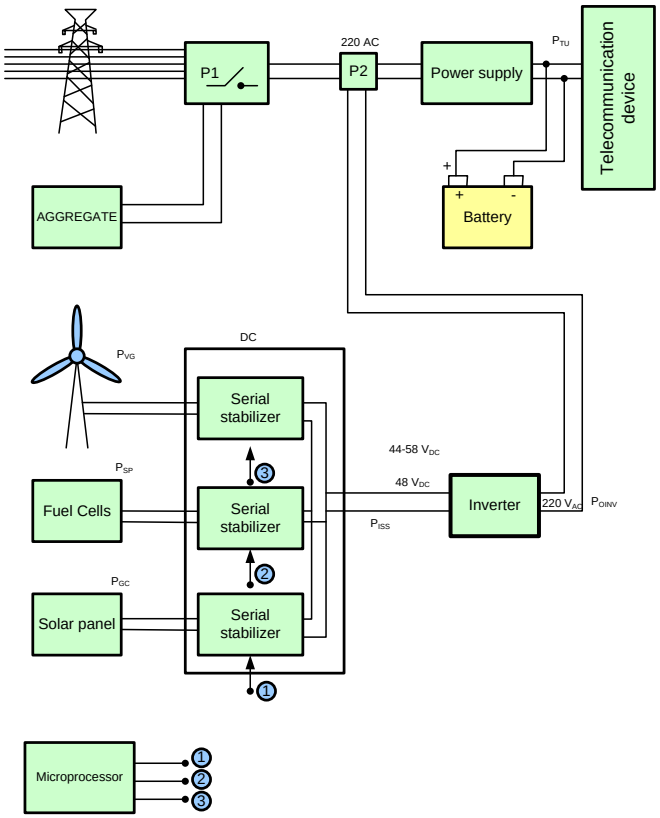

Figure 6. Using of inverter for generating an AC voltage from voltage of renewable energy sources

By choosing high-quality serial stabilizer configuration the effectiveness of 95% may be achieved. It is not possible to achieve such a performance when using inverter. The efficiency of inverters for which a condition of galvanic separation satisfied (necessary in relation to telecommunications equipment) is less than 90%, realistic about 80%. Efficiency of rectifying unit according to applicable telecommunications regulations cannot be less than 90%. The total efficiency of this solution is the product of the efficiencies of all three devices, and it is smaller than 75%. So, we should strive for solutions with minimum number of conversions. [6]

B. Distribution at the DC voltage level

Qualitative solution for connecting various sources is shown in Figure 7. Renewable energy sources are connected in parallel with rectifying unit. Thus, the distribution of energy is at the DC level. Between telecommunications devices and energy sources, there is only one converter - serial stabilizer. Thus, with this configuration maximum efficiency of use of energy of renewable energy sources is achieved.

The parallel operation of renewable energy sources and energy sources based on fossil fuels is enabled. The same microcomputer can control serial stabilizer and rectifying unit. Microcomputer should be programmed so that the voltage at the output of the serial stabilizers is greater than the voltage at the output of rectifying unit. Telecommunications device will be powered from renewable energy sources. If the amount of energy from renewable energy sources is insufficient to supply telecommunications equipment (a measure is the value of the output voltage), a microcomputer will increase the voltage of rectifying unit. In addition, the current value of all energy sources is controlled. By changing the value of the reference voltage, it is possible to realize parallel operation of both types of energy sources. It should seek to make maximum use of renewable energy sources, and minimum energy of sources based on fossil fuel and/or electric power distribution grid. [6]

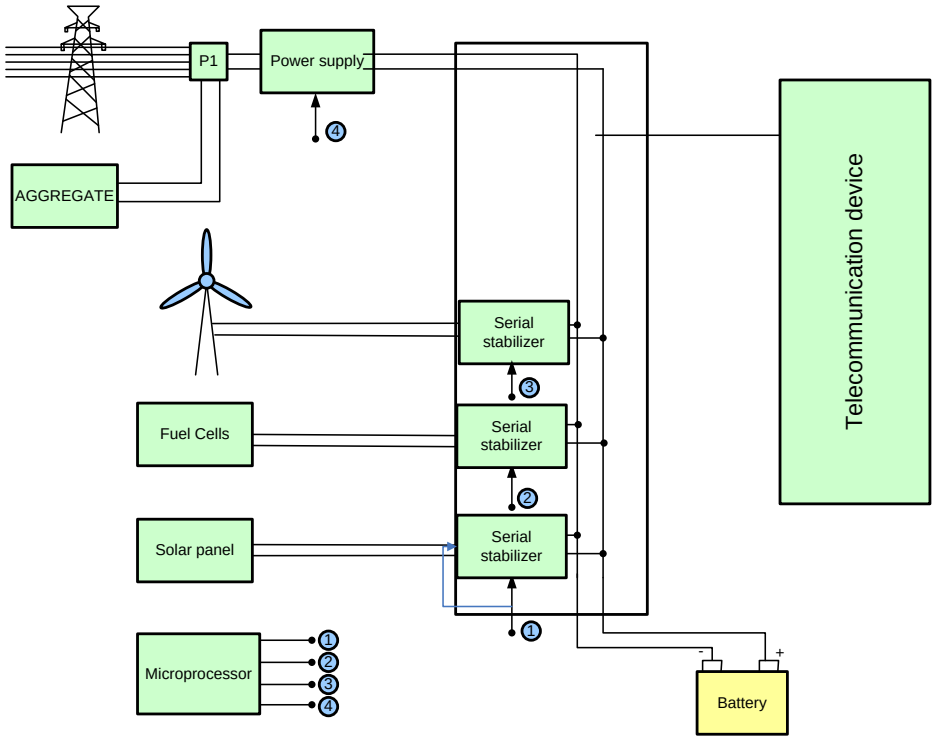

Figure 7. The distribution of energy of the DC level

IV. THE SYSTEM OF POWER ELECTRONIC DEVICES

In the previously described concept, a common feature of all power electronic devices is to provide uninterrupted power supply of telecommunications device. The power sources that are available at the moment of decision will be used. Nevertheless, additional criterion could be included as for instance the lowest price of energy. Therefore, there has to be coordination between power electronic devices. The choice of energy source which powers consumers depends on the availability of energy resources and the needs of consumers. Thereby, the only energy source that is completely controlled is storage battery. The presence of voltage of power distribution grid and energy of alternative sources are not under the control of power electronic devices. Because of that, the batteries are heart of the system. However, chemical energy sources are sensitive to external conditions; their capacity depends on the temperatures, and they have to be maintained by well-defined procedures. This means that it is necessary to develop special power electronic devices that would control the storage battery. Starting from the described concept, three groups of devices were developed:

- voltage converters (rectifying modules and serial converters)
- voltage distribution (DC and AC)
- control devices for batteries

All devices that are used to provide uninterruptable power supply are the parts of the system of power electronic devices. Each unit of power electronics have to be manageable. That basically means that it must have a microcontroller. In addition to measuring the parameters of energy sources microcontrollers control an operation of the voltage inverter. They can include it or exclude it as needed. In this way, the energy source for supplying consumers is defined. Of course, in such a way parallel operation of the various energy sources is enabled. Thereby, the power sources which operate in parallel do not have to provide the same amount of energy. The goal is to set maximum power from the alternative sources at their disposal at any given moment. Figure 8 shows the block diagram of the organization of uninterruptable power supply of mobile telecommunication center. The solution was implemented and characteristics are tested. The roles of some elements are:

- Programmable AC distribution connects the individual consumer with voltage from power grid. Connection is through a switch and, if necessary, the link with power grid could be disconnected. Practically, if there is enough energy in alternative sources, consumers will be disconnected from the power grid and they will be power supplied from alternative energy sources. Of course, it is possible to use the combined solution - the part of consumers uses power grid and the other part uses alternative sources.
- Rectifying modules are controllable AC/DC converters. At the implemented solution nominal value is 24V. Rectifying modules power supply telecommunication devices in the case when the voltage from power grid is present. Rectifying modulus -charger has the same configuration as the other rectifying modules, but it is set to charge the battery optimally from the power grid

- Programmable serial converter controls alternative source and on the basis of the measured parameter values sets the output voltage of the converter in order to maximize use of alternative energy sources. Practically, it is non-insulated DC/DC converter controlled by a microcomputer.
- DC distributions provide uninterrupted power supply of telecommunications equipment. Possible sources of energy are electric power distribution grid and storage battery. It is possible that the modules operate in parallel.
- A system for controlling the storage battery is a circuit that controls the correctness of each cell of the storage battery. It has the ability to correct the value of the voltage of each cell and thus it allows optimal charging and discharging of the storage battery.

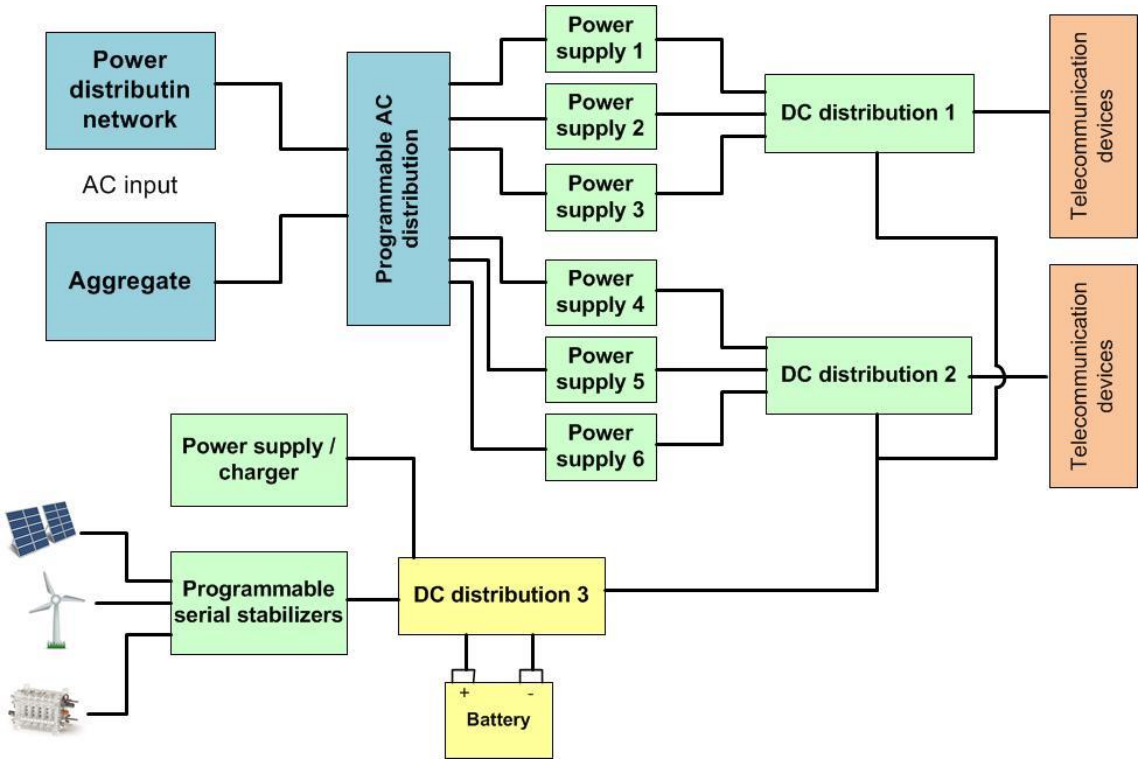

Figure 8. Organization of the power supply of mobile telecommunication center

The coordination of operation of the microcontrollers is accomplished through a microcontroller system. Figure 9 shows how microcomputers of power electronic devices are connected in the solution of uninterruptable power supply of mobile telecommunications center.

The main program is installed on a personal computer. Through the same computer remote monitoring is organized as well as the control of power electronic devices. Thus, PC is at the top of the hierarchy of power electronics system. Via Ethernet computer communicates with the distributions. Power converters communicate with distributions via RS 485 interface. The power converters collect data on energy sources and consumer needs. The data are processed in the distributions and forward to the computer. Based on the collected data and the pre-set algorithm, the computer adjusts which power sources will be used.

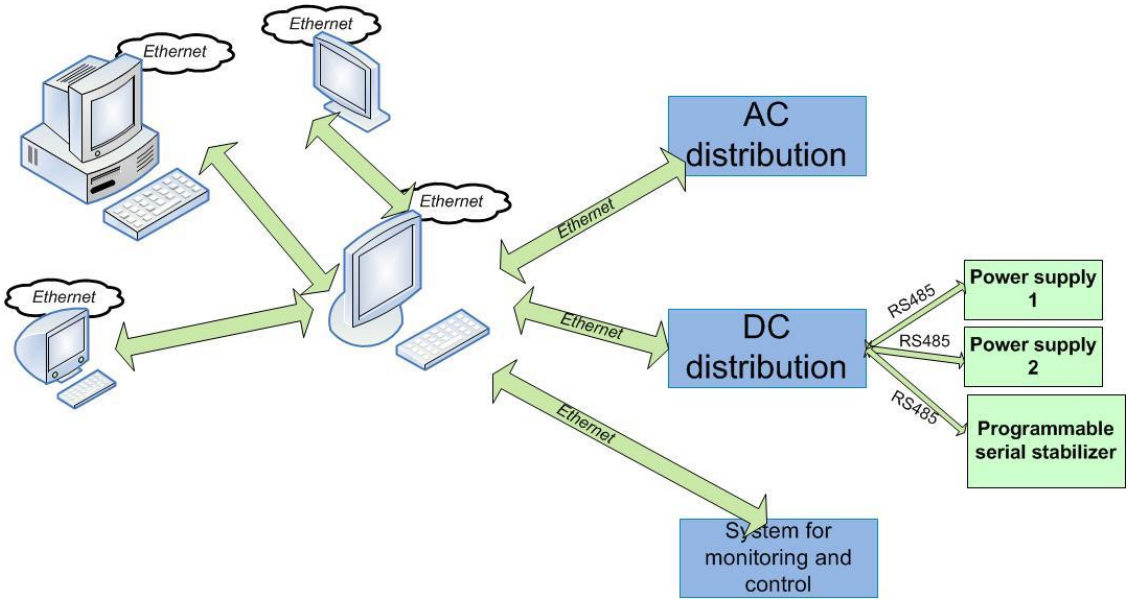

Figure 9. Microcomputers connecting of the power supply of mobile telecommunication center

CONCLUSION

The paper describes the solution implemented for power supplying mobile telecommunication facility. The power electronic devices are connected to each other and together form a system of power electronics. Since microcontrollers have become integral elements of almost every power electronic device a solution n that allows a reliable and uninterruptable operation of the telecommunications device with the maximum use of alternative sources was created. The procedure described is called "DC distribution". In the method described the efficiency of the use of alternative sources increases more than 30%. The storage battery was chosen as basic source of energy. In this way, the operation autonomy of the device in the case of absence of power sources is correctly defined. Also, the solution described allows parallel operation of alternative energy sources and electric distribution power grid.

Until now, a model of the solution described was realized. In the next years it is expected a production of zero series, and later serial production of procedure of the uninterrupted supply of telecommunication facilities.

ACKNOWLEDGMENT

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