TELEKOMUNIKACIONI HIBRIDNI SISTEMI ZA NAPAJANJE U "SMART GRID" MREŽAMA
TELECOMMUNICATION HYBRID POWER SYSTEM IN "SMART GRID"

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Sadržaj – *Sistemi za napajanja koji se koriste u telekomunikacijama moraju da ispune zahteve bezbednost i dugotrajnosti, kao i da obezbede neprekidan napon za opremu koju napajaju. Sistemi bazirani na obnovljivim izvorima energije, takođe moraju da zadovolje navedene kriterijume. Efikasno i pouzdano rešenje za napajanje telekomunikacione opreme predstavlja sistem kombinovan od obnovljivih i „tradicionalnih" izvora energije. Hibridni sistemi kombinuju najbolje od navedenih izvora energije i obezbeđuju napajanje opreme na nivou elektrodistributivne mreže. Predmet rada je uticaj ICT-a na životnu sredinu, sistem za napajanje baziran na obnovljivim izvorima energije, „inteligentana" kontrola takvog sistema sa fokusom na stvarnim vremenskim uslovima i stanjem baterija, kao i upravljanje radom sistema kao elementa „smart grid" mreže.*

Abstract – *The basic requirements for telecommunication power systems are related to their safety, long life and uninterruptible power (voltage). Power system based on renewable energy, design for power feeding of telecommunication equipment has to fulfill same requirements. An efficient and reliable solution in telecom application is to combine renewable and "traditional" energy sources. Hybrid power system capture the best features of each energy resource and provide "grid-quality" electricity. Hybrid power system design on such way can present element of "smart-grid". The subject of this paper are ICT impact on environment, power system based on renewable energy requirements and "intelligent" control with focus on weather condition and battery status, and system controlling as element of "smart grid".*

KEYWORDS: telecommunication, ICT, renewable energy, CO_2 emission, smart grid, smart meter.

INTRODUCTION

The European Commission today called on Europe's information and communication technologies (ICT) industry to outline by 2011 the practical steps it will take to become 20% more energy efficient by 2015. ICT equipment and services alone account for about 8% of electrical power used in the EU and about 2% of carbon dioxide emissions. But using ICT in a smart way could help reducing energy consumption and CO_2 emission in energy-hungry sectors such as buildings, transport and logistics [1].

Due to new power and energy context such as greenhouse effect and other environmental issues, fuel depletion and electricity cost increase, new regulation and standards, telecom operators have to make efforts for using renewable energy solution [2].

Renewable energy and energy efficiency solutions can present significant investment costs, which mean that Governments have to make efforts and create regulatory frame to stimulate investments in this area. Because of ICT impact on environment, telecom operators have to use renewable energy solutions wherever is possible.

Such renewable energy sources are: Fuel Cells, Photovoltaic cell, Wind Turbine Generators, Micro hydro Generators, Stirling machine, fresh air cooling, etc.

In telecom application an efficient and reliable solution is to combine renewable and "traditional" energy sources. Hybrid power system capture the best features of each energy resource and provide "grid-quality" electricity.

To achive uninterruptible power feeding of telecommunication equipment with quality power, hybrid power system includes energy storage system. Becouse of that, hybrid power system used in telecomm applications can be used as reliable element of "smart grid".

"Smart grid" are being promoted by many governments as a way of addresing energy indepedence and global warming issues.

For hybrid power system design, the cites reliability studies play an important role, because it is necessary to keep the system at its best performance level [3].

This work will present requirements, design, calculation, sizing and "inteligent"control of hybrid system, which is used as element of "smart grid".

REQUIREMENTS

The basic prerequisites imposed to telecommunication power systems are related to their safety, long life and uninterruptible power [4,5].

Hybrid power system design for power feeding of telecom equipment has to provide quality uninterruptible voltage (AC, DC or both). In order to avoid very high costs, an optimization method should be used and good one is described in [6]. One of the major requirements is to design hybrid system cost effectly, with minimum exploitation costs.

Photovoltaic cell

Sunlight may be used to generate electricity directly via photovoltaic cells. Problem is still high price per Watt. One of the major requirements in hybrid power system design is to optimize size of cell. Many parameters have influence on photovoltaic cell design as: micro location, weather condition, technology of photovoltaic cells, financial, etc.

Wind Turbines

The output power depends of wind velocity. If the wind speed changes smoothly, the output power of wind turbine will also change very. On the other hand, wind turbulence causes the output power to fluctuate [7]. Requirements for wind turbines is to give constant power as much as it possible in wide range of wind velocity. In Serbia, problem for wind turbine appliance is missing of correct data for wind parameters as wind velocity and wind potential. Authors opinion is that project of wind mapping in Serbia has to be managed by Government institution. Suggestion is to perform measurement at 30, 50 and 70 meters from the ground.

Energy Storage

There are different types of energy storage (flywheel, battery, etc.). The energy storage behaves like a buffer to accommodate the unequal instantaneous energy in power system [7]. Basic requirement for the battery is ”high” number of cycling. Opposite, replacing of battery can present significant exploitation costs, which is not environment friendly. Critical point is choosing of battery technology. Different technology means different price and parameters as: life time, number of cycles, resistivity to depth discharged…

Diesel back-up generators

Conventional back-up generators are normally diesel engine directly coupled to synchronous generators. In hybrid power system which is subject of this work, diesel back-up generator has to ensure uninteruptibility of the system. One of the requirements is to optimize size of generator and to minimize fuel consumption and carbon dioxide emissions.

Hybrid power system as element of “smart grid”

A “smart grid” is a form of electricity network utilising digital technology. In telecom appliance, for telecommunication equipment has to be provide quality uninterruptible voltage. In proposed system energy can be provide from hybrid power system elements (photovoltaic cell, wind turbine generators, diesel back-up generators and storage battery) or from the utility grid. In some situation, energy from hybrid power system can be “delivered” to utility grid, which means that quality of voltage must be “grid quality”.

Smart meters

A smart grid replaces analog mechanical meters with digital meters that record usage in real time. A smart meter is usually an electrical meter that records consumption in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Smart meters enable two-way communication between the meter and the central system.

In this work, authors proposed smart meter which measure delivered energy from the utility grid and energy deliver from hybrid power system to the utility grid. For delivered energy to the utility grid, proposed smart meter has to measure separately energy from photovoltaic cell and wind turbines. Reason for that is different price for energy deliver from “sun” or “wind”. Proposed smart meter, also has to be monitor by telecom operator (owner of hybrid power system). Becouse of large number of telecom sites which can be equiped with renewable energy sources, delivered energy to the utility grid can be significant.

SYSTEM DESIGN

Many methods and algorithms are developed for hybrid power system modeling, design and components sizing. For optimal modeling, design, calculation and components sizing is essential to have precise micro location meteo data and to define system reliability in power feeding. A detailed study of the above factors is the first step to choose the required system topology and to make the best of the local potentialities to supply the telecommunication equipment [3].

Optimization in hybrid power system present focal point. Optimization for system describe in this paper, means that system is design cost effectly and exploitation costs, maintenance costs, replacing costs of system components are minimize in exploitation period. Appeal for system reliability has impact on the system price and system optimization.

For example, hybrid power system can be modeled with a high degree of accuracy considering the highly complex working of actual systems. Optimization algorithms change the values of decision variables of an underlying in model in such a way as to optimize the resulting value of the model’s objective function [8].

Calculation and sizing has to be done according next basic parameters and requirements: geographical location, meteo data, temperature range, period of insulation per year, period of insulation per day, required autonomy of diesel generator back-up, required autonomy of battery back-up, etc.

Price of electrical energy also present important parameter. Under consideration are prices for: delivered electrical energy in different period of the day from the utility grid and energy produced by different renewable sources (solar, wind,…) delivered to the utiliti grid. For optimize system design and system control is necesarly to have this date for long term period, which means that govermant strategy (depends in which country system has to be instaled) has to be take in consideration.

CALCULATION AND COMPONENT SIZEING

In this work calculation and component sizing are based on DC current and 48VDC nominal voltage (tipical telecommunication load). Converters efficiency will be not taken in consideration, it is not essentially for this work.

Generally is very important to predict all converters in system with higher efficiency. In total, it present significant reduction of energy. Converter design means more or less quality of convertor parameters (e.g. output voltage, disturbance, ripl, peaks, harmonics). This is very important in system which work parallel with utility grid and part of energy from renewable sources is deliver to the utility grid. Figure 1 shows hybrid power system described in this work.

Capacity of battery

Required minimal capacity of battery can be calculated according formula:

$$Q_{min} = (I_{DC} \text{ x } T \text{ x } \kappa_1) \text{ (Ah)} \qquad (1)$$

where I_{DC} is telecommunication equipment DC current, T is required authonomy, κ_1 is coeffitient for battery capacity increasing depend of plate sulfatisation and low temperature (1,15).

In this system, required autonomy will be ensured with two parallel Lead-acid 48V batteries in GEL technology. GEL technology present balans between price, number of cycles and deep discharge resistivity. Important characteristic of GEL battery is higher charging current. Higher charging current means shorter charging time. Opposite, higher charging current means decreasing of battery life time and increasing of operational costs. In this work is described “intelligent” control. Battery current is usually set on fix value. System “intelligent” control change this value depends of battery status and “real” meteo condition.

Area of photovoltaic cell

Many authors developed different methods and algorithm for optimizing of photovoltaic cell. In hybrid power system, sizing of photovoltaic cell present critical point because of its price.

Principe is to provide energy from photovoltaic cell for load feeding and battery charging. In some situation energy will be deliver to the utility grid.

The other solution is to instal solid area of photovoltaic cell which can provide energy for load feeding, battery charging and delivering to the utility grid.

Day (24h) will be split in two periods. First period, with maximum insulation (in this period photovoltaic cell provide maximum power), second period totally black out, no energy from photovoltaic cell.

Requirements for photovoltaic cell in first period are to provide energy for telecommunication equipment power feeding and energy for battery charging. In period of insulation, battery must be charged with enough energy to provide back-up autonomy in pre-defined period with no sun (e.g. 2 days). Energy can be provided from diesel generators also, but the target is to reduce fuel consumption of diesel generators. Bigger area of photovoltaic cell means more energy during other season also, not only summer. Final results are total operation cost and CO_2 emission decreasing and more energy deliver to the utility grid.

For optimal photovoltaic cell sizing is necessary to have “real” insulation data in period for micro location where system will be install.

Calculation will determine energy from photovoltaic cell in period of insulation during summer season, for telecommunication equipment power feeding and for energy storage in battery [9]. Energy stored in battery is determined for pre-define required autonomy.

$$E_{PV} = I_{DC} \text{ x } U_{DC} \text{ x } T_{ins} + I_{DC} \text{ x } U_{DC} \text{ x } T_{back\text{-}up} \qquad (2)$$

where I_{DC} is telecommunication equipment DC current, U_{DC} is nominal voltage (48V), T_{ins} is period of insulation and $T_{back\text{-}up}$ is required time for battery back-up.

Required power from photovoltaic cell in period of insulation is:

$$P_{PV} = E_{PV} / T_{ins} \qquad (3)$$

For optimal area of photovoltaic cell calculation is important to have technical characteristics of photovoltaic cell. Different technologies means different characteristics and price. E.g. monocristal photovoltaic cell has higher energy (power) density per m^2 than polycristal, but price is also higher.

In this example where day is split in two period necessary parameter is peak power per m^2 (P_m^2) of photovoltaic cell.

$$S_{PV} = P_{PV} / P_m^2 \qquad (4)$$

Conclusion for photovoltaic cell area

Decision for choosing photovoltaic cell area is based on different facts as price, real meteo micrlocation condition, operational costs, price of the energy from and to the utility grid, etc.

Authors proposed photovoltaic cell with bigger area then calculated. Reason is reduction of diesel generator fuel consumption and CO_2 emission, decreasing of logistic costs and benefites from energy deliver to the utility grid.

Power of wind turbine

In hybrid power system with solid area of photovoltaic cell, price of wind turbine is minor compared with the price of the other system component.

Basic parametar is power of wind turbine. Output power of wind turbine depends of wind velocity. Based on wind potential in micro location where system will be install, type and characteristics of wind turbine will be determine.

Authors proposed wind turbine which can feed telecommunication equipment, charge battery and deliver some energy to the utility grid.

Diesel back-up generators

Diesel back-up generators will be used in situation without sun, without wind, with no energy from the utility grid, when the back-up battery is discharged.

Diesel back-up generators in this work is defined to feed telecommunication equipment and to charge battery with maximum current.

Positive fact is that already, at many telecommunication location diesel back-up generators are installed, or they are planed for installation at future location.

General authors recommendation is to use diesel back-up generators bigger then 10kVA (cosφ = 0,8), for power feeding of telecommunication equipment or the other critical application. “Smaller” diesel back-up generators have no quality speed and voltage regulator, it cause unstable voltage and frequency. Also, there is no possibility to use sophisticate system for diesel back-up generators control and monitoring.

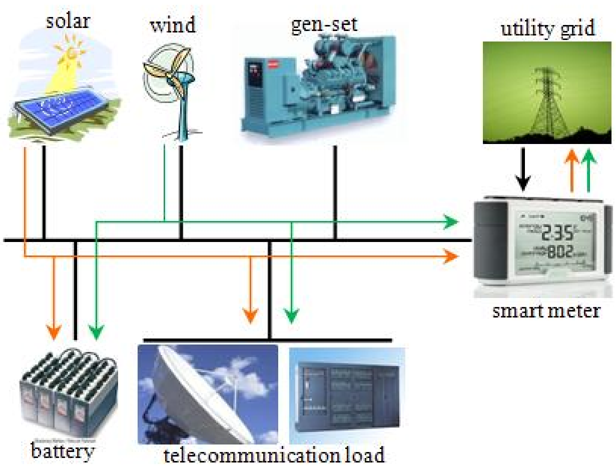

Fig. 1. Hybrid power system

PRINCIPLE OF HYBRID POWER SYSTEM AS ELEMENT OF “SMART GRID”OPERATION

In hybrid power system described in this work, energy for telecommunication equipment power feeding and battery charging can be provide from photovoltaic cell, wind generator, battery cell, diesel generator or utility grid (public mains). Energy from photovoltaic cell and wind generator also can be deliver to the utility grid.

System operating algoritham (system controling) can be define based on next requirements: reduce power consumption from utility gid, reduce diesel generator fuel consumption and CO_2 emmision, reduce of logistic costs, increase energu deliver to the utility grid, optimize system operating, etc. Based on this, many algoritham can be define.

In this work authors proposed next operating algoritham. Primary power source is renewable energy. In situation when energy can be provide from the wind or from the sun, energy from wind is used for load power feeding and battery charging, energy from the sun is deliver to the utility grid (usualy price for delivered energy from the sun is higher then energy from the wind). Generaly, all suficient energy from renewable sources is delivered to the utility grid. If renewable sources can’t provide enough energy for load power feeding, missing energy is provide from the battery. In situation of discharged battery, energy for load power feeding and battery charging is provide from the utility grid. Diesel generator is used in situation if renewable sources and battery can’t provide enough energy for telecommunication load and utility grid is “break off”.

CONTROL OF HYBRID POWER SYSTEM

Principles of hybrid power system control is based on algorithm described in previous chapter. If energy from renewable sources is not sufficient, energy is provided from battery, utility grid or diesel back-up generator.

Battery has to be charge quickly as it possible. Period of battery charging is longer if charging current is ”smaller”. Opposite, period of battery charging is shorter if charging current is ”higher”, but this can cause reduction of battery lifetime. In typical hybrid power system ”real” battery status (battery condition) is not take in consideration.

In this chapter, authors will explain proposed princip of ”intelligent” control in hybrid power system, based on battery status (battery condition) and ”real” meteo condition for location where system is installed [9]. “Intelligent” control also means controlling of energy “flow” from renewable sources to the load, battery and utility grid, and from the utility toward described system.

Parameters important for battery operation as low voltage disconnection and maximum battery charging current are usually set on fix value. In this work, those parameters are programmable (changeable).

For this approach, two requirements have to be fulfilled:

-Battery has to be monitored, and 2 capacities have to be calculated based on monitor information, actual capacity and capacity of fully charged battery. If capacity of fully charged battery is nearby nominal capacity, higher charging current and lower level of LVD allowed.

-Weather parameters as air temperature, relative humidity, barometric pressure, wind velocity have to be measured, at present micro location. Now days technology enable, based on this value, to have very precise short term weather forecast. With measurement of these parameters, few days weather forecast is accurate too.

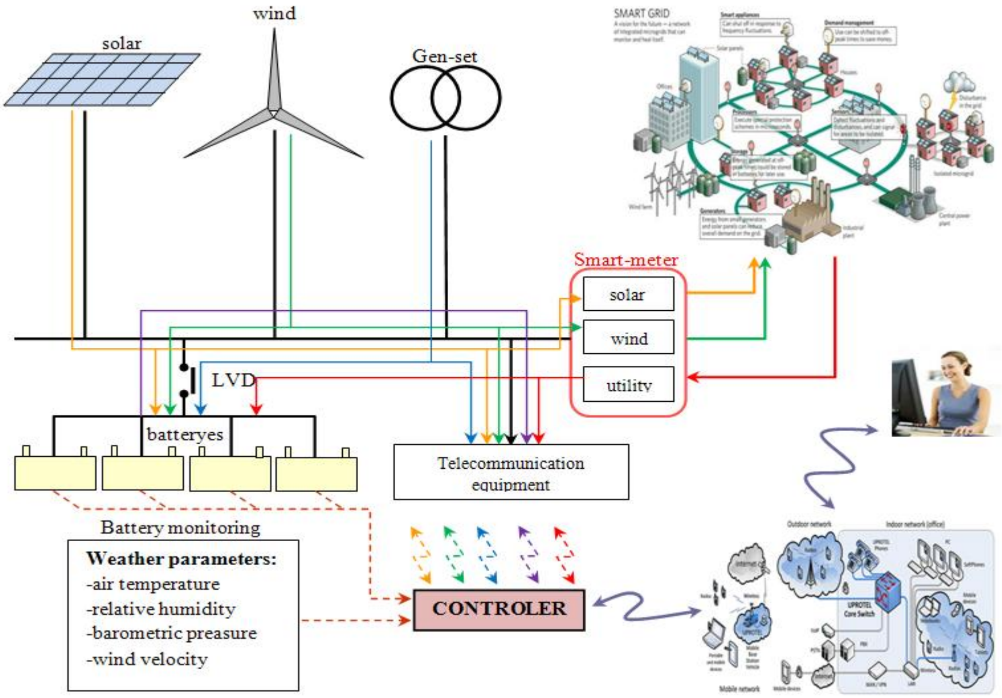

Figure 2. ”Intelligent” control of hybrid power system

System controling can be realize automaticly, or remotely. Remote monitoring and control can be done by “smart grid” operator, or by telecom operator. This is crutial for energy “flow” controlling. “Smart grid” operator don’t have any influence on system parameters changeing, as battery current and level of LVD. At the other side, telecom operator for the energy “flow” control must get permition from “smart grid” operator (it has to be realized as automatic proces).

Figure 2. shows ”intelligent” control of hybrid power system described in this chapter, without central battery charger.

CONCLUSION

In now days consensus has been reached among the scientists, energy engineers and economists as well as political communities all over the world that there is a need to supply energy for all sectors, including ICT without a detrimental impact on ecology and environment.

In this work, for telecommunication application has been suggested to use renewable energy in combination with traditional, to provide stable and reliable energy sources.

After presenting of the components of described hybrid power system and their sizing, authors present idea of ”intelligent” control of hybrid power system as element of “smart grid”.

Presented idea of ”intelligent” hybrid power system control, for target has reducing of fuel consumption and CO_2 emission, reducing of used energy from utility grid, decreasing of logistic and operational costs and cost effective component sizing.

Future work will be focused on new working algorithm development, based on real meteo data, which means number of variety and system adoption for short term and long term period, with consideration of energy price and benefites from delivered energy to the “smart grid”.

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