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CONTENTS

CONSUMERS OF ANCILLARY SERVICES IN THE ELECTRIC SUBSTATIONS

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Keywords: fuel cells; ancillary services;

Abstract*:* *The paper aims to identify the current state of ancillary services consumption in power station. In order to replace current methods of supply internal services with, modern solutions based on renewable, clean solutions that exceed current system performance at the lowest cost.. In addition, it has been identified the main consumers of power stations in order to approach the implementation phase of a hybrid system in substations.*

1. INTRODUCTION

Today the availability of the utility grid is of great importance. The society needs electric power to function, and a power outage can have a severe impact [1], [2].

Transients and short interruptions on the utility grid can also have effects on industrial and commercial power systems [3].

The ancillary services represent a vital consumer for the power systems. Their good operation sustains the functionality of the power plants and substation within the power system [4].

Ancillary services are support services within the power system, those that are necessary to support the transmission capacity and are essential in maintaining power quality, reliability and security of the grid. Considering these facts the supply method of the ancillary services is a key feature for the appropriate operation of the power system.

The consumers of the ancillary services are supplied at 400/230 V a.c. (except specific consumers, where considering the work security aspects, are supplied at smaller values) and some of them, at 24 V d.c., (48/60) V d.c., 110 V d.c., 220 V d.c.

2. CURRENT STATE OF ANCILLARY SERVICES CONSUMERS

2.1 Conventional Sources for Electric Substation Ancillary Services Power Supply

According to [5] the consumers of ancillary services are divided into the following categories:

- Category 1 (main services), which includes the receivers on which a power interruption lasting more than a few minutes lead to disruption of transit of electric energy.

From this category are: oil pumps from the (auto)transformers with an oil forced circulation, cooling fans batteries of the (auto)transformers, heaters which start the diesel group, etc.

- Category 2 (secondary services), which includes receivers on which a power interruption lasting longer than those in category 1, lead to disruption of transit of electricity.

To critical importance electrical stations, these receivers are divided into two groups, namely:

- Group A – receivers whose power is assured also by the source of security feeding, namely: electromotors and heating resistance of the tap changer device, motopumps electromotors, heating resistances and lighting lamps of the MOP device, loading chargers of the batteries, compressors, hydrophore and ISI related pump, lighting installation (control room, diesel group), Tc equipment, etc.
- Group B – the other receptors from category 2, namely: heating resistances of clamp boxes, relays cabins, electric heating installation from control room, lighting installation from relays cabins and the control room block without control room, heating installations in all places where it is necessary to ensure a microclimate for the equipment from categories 1, 2 or of similar importance.

- Category 3 (ancillary self services), including receivers that do not fall within the category 1 and 2 and whose power can be interrupted for a period of time longer, such as: disconnecting switch's heating resistance and electromotor, heating resistance and lighting plugs for portable lamps in connection boxes, lighting installation and power plugs from outdoor station, oil centrifugation installation, etc.

From ancillary services DC category of consumers may be noted: circuit breakers and disconnecting switches operating devices, protections, automatization, blocking and signalization circuits, remote installations, telecommunications and safety lighting. Ancillary services DC consumers have a special importance in the normal functioning regime of the installations and are vital in case of crash of primary installations. They are, by their nature, very different and in terms of power supply application, we have:

a) **Long term consumers in permanent regime**, for which the power source is a permanent task both in the normal functioning and in the crash regime.
b) **Long term consumers in crash regime**, which in normal operating regime are fueled by AC ancillary services, but are switched on DC power throughout the lack of AC voltage.
c) **Short term consumers**, entering into service in certain maneuvers ordered manually or automatically, which can enter into service in both the normal and crash regime of the primary installations.

DC power supply is a battery, which operates as a buffer with a RUT series rectifier unit (rectifier with universal application that uses on the recovery only thyristors). The battery unit provides power for consumers only during the total fall of AC power sources. In normal functioning regime, DC SP consumers are supplied from the same source as AC consumers.

Electric energy feeding of the ancillary service consumers is made from multiple sources, namely:

- **normal power supply**, which serves to supply receivers in the normal operation, being in operation as long as the parameters are reached;
- **backup power supply**, which under normal operating is not participating in the receivers powering, but can automatically replace the normal power supply, if it is unavailable;
- **safety power supply**, which takes over as soon as possible receiver's supply when the normal and backup sources of supply went out of service.

Normal and backup feeding sources are designed to be able to provide, each, full power required by ancillary services consumers, and the safety source is designed to provide power only to the consumers who need a high level of safety, namely: consumers of the in categories 1 and 2 and DC consumers.

According to [6], the power stations SP consumers' feeding is ensured:

▪ for power stations of special importance, from three independent sources (normal, backup and safety);

▪ for stations with a higher voltage then 220kV, which are not included in the special importance category and for the stations of 110kV, from two independent sources (normal and backup).

Normal and backup sources are conventional sources of energy and represent:

- a system or a section of bus-bars collectors at medium voltage (6-20kV) from that electric station or from a power station nearby;
- a system or a section of bus-bars collectors at low voltage for distribution of electricity in that electric station or in a power station nearby;
- a line of medium voltage in the station area;

- a third coil of medium voltage (10-20kV) of a (auto) transformer that provides transit of power between the networks of high voltage (110-750kV).

In the stations of particular importance, as a safety source, there is used a diesel electrogenic group.

The traditional SP feeding system from electrical stations is represented in *fig. 1*.

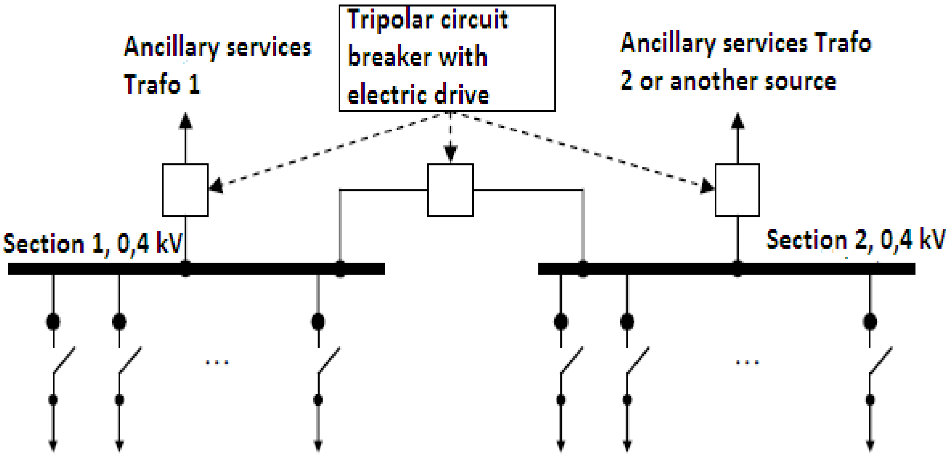

Fig. 1 – The principal scheme for self-services supplying in current situation.

For stations with the highest voltage of 750kV or 400kV, the regulations provides that the normal (basic) power supply to be made, preferably, from AT third coil, through transformers with burden taps and increased security against short-circuits between phases, and backup feeder by medium voltage lines, connected directly to 110/MV stations in the area. In regulations there are no indications on stations with the highest voltage of 220kV, where there are 220/110kV autotransformers, having a tertiary medium voltage coil. Nevertheless established that where we meet 220/110kV autotransformers with an accessible tertiary medium voltage coil, the self-services in the station can be fed from the third coil.

2.2. Unconventional Sources for Electric Substation Ancillary Services Power Supply

Fuel cells offer a clean, quiet and efficient power generation.

Like most new technologies, fuel cells are faced with the challenge to penetrate the market in a very large number of applications, due to the maturity of the product, the engineering system complexity and the durability and sustainability. Many advantages of fuel cells suggest that they may be the main driver in the future for certain applications and products.

Sir William Grove, the inventor of fuel cell technology, proved their operation in London, in the year 1830. Fuel cells have a higher „power density”, efficiently „packing” the power in a reduced space. This property allowed their use in Gemini and Apollo space programs.

In the present, fuel cells include o large variety of technologies and technical solutions. A growing number of investors are involved in developing fuel cells for both stationary and mobile applications.

Five types of fuel cells are usually used in practice:

PEMFC (Proton Exchange Membrane Fuel Cell / Polymer Electrolyte Membrane; AFC (Alkaline Fuel Cell); PAFC (Phosphoric Acid Fuel Cell); MCFC (Molten Carbonate Fuel Cell; SOFC (Solid Oxide Fuel Cell) [7].

The components of a fuel cell are as follows

- the fuel cell itself;
- the gas processor, converting the natural gas in hydrogen rich gas;
- the equipment used for processing electrical energy, converting it in a.c. or d.c.

Internationally, research, renewable and alternative energy have resulted in a variety of wind generator hybrid systems - fuel cell. In the literature there are several papers, which deal with the supply of electricity from renewable resources using hybrid and alternative [8-9], given current conditions: depletion of fossil fuels in the not too distant future and reduce greenhouse gas emissions.

Research in this area is done in various ways:

- Modeling and simulation of renewable energy sources and fuel cells;
- The optimal choice of components and subassemblies systems;
- The problem of energy storage in the form of hydrogen;
- Co-generation of fuel cell;
- Optimal management of resources in order to increase efficiency;
- Integrating distributed system resources - smart electricity networks;
- Development of experimental stands that allow validation of theoretical training and further development;

The main advantage of hybrid systems is the character offsetting variable renewable Offset the variability of renewable can be done only through use of energy storage. For low power are used as storage devices for the most common electrochemical battery. Batteries have the disadvantage that they are very expensive and have a relatively short life. Energy from renewable sources can be stored as hydrogen. This way of storing energy is the most promising storage technology, knowing a huge development in recent years in the field of fuel cells. The applicability of these systems to service internal service power stations is due to the fact that low-maintenance (low defect rate), increasing supply safety of ancillary services. This is particularly important if we consider that the power plants in the near future, will have no operating personnel, will be monitored and remotely controlled from the remote control and remote management centers.

Due to their properties in recent years, fuel cells have been considered as feasible solutions to replace conventional energy sources.

Currently, fuel cells are used to power vehicles, commercial buildings, apartments and even small electrical devices (e.g. mobile phones, laptops); Fuel cells can be constructed to generate power from 1 kW to several tens of megawatts. Some systems can achieve efficiencies (overall) more than 80%, when working in co producing heat and electricity to our communities.

3. ANCILLARY SERVICE CONSUMERS FROM POWER STATIONS

In the following will present the estimated consumption consumers supplied from domestic services of a 400/110 kV power substation.

Table I. Estimated consumption of AC consumer:

No.	***Consumer name***	**Consumption**
		kW
1.	Power distribution panel (GIS)	39,5
2.	Power Body Control overview	40
3.	Rectifier	35
4.	Transformer electric switch box	50
5.	Utilities AC services	0,6
6.	Power control AC internal services	0,1
7.	Heating cabinets counters	1,5
8.	Switch tap changer	2
9.	Hydrophore supply	1,5
10.	Pumps power supply	5
11.	Inverter	4
12.	Diesel group panel	1,5
13.	Surveillance system	1
14.	Fire system	1
15.	Phone system	1
16.	Outdoor lighting panel	6,5
17.	Utilities DC services	0,5
18.	SCADA panel supply	1,1
19.	Heating the panel from central room	1,6
20.	Heating of protection panel	1,7
21.	PT1+2 supply	4
	TOTAL	199,1

To supply internal services must ensure as normative PE 111-8/88 normal power supply and backup power supply.

In this case taking into account the values of the table as a normal power supply and backup power supply that will choose each internal service transformer with an output of not less than 250 kVA. Also be a source of safety chooses a generator with a power greater than 199.1 kVA

Table II. Estimated consumption of DC consumer:

No.	***Consumer name***	**Consumption** ***kW***
1.	Power distribution panel (GIS)	0,1
2.	Inverter	4
3.	PT-TSI supply	0,2
4.	SCADA panel supply	1
5.	Safety Lighting	2
6.	Metering panel	0,13
7.	BCU	0,05
8.	Ancillary service command (AC)	0,05
9.	AAR 0.4 kV supply	0,05
10.	Protection cabins supply	4,48
	TOTAL	12,06

Regarding the choice of batteries, taking into account a discharge for 3h and a correction factor takes into account the capacity of the battery discharge time of 1.25 can choose a battery with a minimum capacity of 250 Ah.

4. CONCLUSION

Ancillary services are a very important consumer for power systems, the proper functioning of the power substations and plants depend on the operation of this service.

Regarding the supply schemes for the ancillary services there are several variants, the idea being that power to be supplied from two independent sources that can each provide the power required by the ancillary services.

Since the fuel cell can be built to generate power from 1 kW up to several tens of megawatts, and the use of renewable energy sources meets unprecedented growth, supplying the ancillary services from hybrid system based on renewable energy source and fuel cell is a realistic solution.

In future must be investigated how these systems can be implemented in power substations.

REFERENCES

1. U.S.-Canada Power System Outage Task Force, *Final report on the august 14, 2003 blackout in the united states and Canada: Causes and recommendations*, Report, Apr. 2004.

2. G. Andersson, P. Donalek, R. Farmer, N. Hatziargyriou, I. Kamwa, P. Kundur, N. Martins, J. Paserba, P. Pourbeik, J. Sanchez-Gasca, R. Schulz, A. Stankovic, C. Taylor, and V. Vittal, *"Causes of the 2003 major grid blackouts in north america and europe, and recommended means to improve system dynamic performance,"* IEEE Trans. Power Syst., vol. 20, no. 4, pp. 1922-1928, Nov. 2005

3. M. Bollen, *Understanding power quality.* Piscataway, NJ: IEEE Press, 2000.

4. N. Chiosa, *Contributions regarding the autotransformer tertiary winding ancillary services power supply,* Ph.D. Thesis “Politehnica” University of Timisoara, Romania, 2005.

5. Ilie Ardelean, Vasile Dusa, Bucur Lustrea, Ioan Borlea, Dan Jigoria , *Technical and economic arguments for using fuel cells in RET power station’s self services feeding,* EUROCON '09. IEEE , vol., no., pp.480,485, 18-23 May 2009

6. Regulation PE 111-8/88, *Instructiuni pentru proiectarea statiilor de conexiuni si transformare, servicii proprii de current alternativ*

7. O. Prostean, St. Kilyeni, C. Barbulescu, Gh. Vuc, and I. Borlea, *Unconventional Sources for Electric Substation Ancillary Services Power Supply,* Proceedings of the 14th International Conference on Harmonics and Quality of Power ICHQP2010, Bergamo, Italy, 2010

8. S. RABIH, *Contribution à la modélisation de systèmes réversibles de types électrolyseur et pile à hydrogène en vue de leur couplage aux générateurs photovoltaïques,* PhD thesis, l’institut National Politechnique de, 2008;

9. M.J. Khan, M.T. Iqbal, *Analysis of a small wind-hydrogen stand alone hybrid energy system,* Applied Energy, 86 (2009) 2429-2442, 2008;

ANALYSIS OF THE INFLUENCES OF GRID-CONNECTED PV POWER SYSTEM ON DISTRIBUTION GRIDS

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Keywords: photovoltaic, inverter, distributed generation, drop voltage.

Abstract: *This paper presents the analysis of producing an electric power of 2.8 MW using a solar photovoltaic plant. The PV will be grid connected to the distribution network. The study is focused on the influences of connecting to the grid of a photovoltaic system, using modern software for analysis, modeling and simulation in power systems.*

1. INTRODUCTION

The concept of a sustainable and efficient energy start to materialize through number of installations of renewable energy around the world. In last years, engineers and investors helped and supported by governments start to develop power plants using renewable energy (e.g. wind farm, photovoltaic plant, hydro plant). Grid – connected solar PV continued to be the fastest growing power generation technology.

In Romania the installations of PV systems starts to increase in last few years stimulated by green certificates.

Power installed in PV systems grid-connected an evolution is described below [1]:

- 0,009 MW at the end of year 2010;
- 1,011 MW at the end of year 2011;
- 18, 88 MW at the end of year 2012;
- 78.72 MW at the end of March 2013;

In 25 March, a power of 78.72 MW is installed in grid-connected PV systems in Romania, and all PV systems obtain six green certificates [1].

2. GRID OVERVIEW

The grid (in Romania) is a layered system defined by the voltage level (high medium and low-voltage) and designed to cover a region. The inter-connection is made in electric substations. The high-voltage substations including the substation connecting to the medium lager or highly automated [2].

The PV analyze will be integrated in medium voltage layer of the grid, which is a part of the distribution network. The distribution systems are usually regulated through tap changing at substation transformers and by the use of voltage regulators and capacitors on the feeders. This form of voltage regulation assumes power flows circulating from the substation to the loads [3]. Major of these sources generate electricity in a distributed way, as their number growth will change the situation and require a much higher automation degree in the low and medium voltage level.

The substation analyzed has a single distribution transformer with several feeder lines, and the voltage for these lines is adjusted in a block. PV system is situated at a distance of 9 km away from substation.

3. MATHEMATIC MODEL OF CELL PHOTOVOLTAIC SOLAR CELL- SCIENCE DEFINITION

A photoelectric cell designed to convert sunlight into electrical energy, typically consisting of layers or sheets of specially prepared silicon. Electrons, displaced through the photoelectric effect by the Sun's radiant energy in one layer, flow across a junction to the other layer, creating a voltage across the layers that can provide power to an external circuit [10]. The principle is detailed in figure 1.

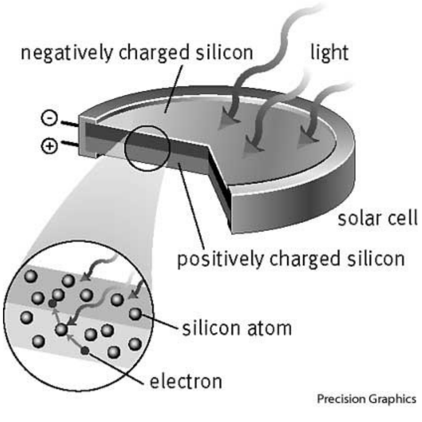

Fig. 1. The principle of solar cell.

When light penetrates a solar cell and reaches the lower charged layer, its energy causes atoms there to release electrons, which drift to the upper layer, giving the upper layer a net negative charge and the lower layer a net positive charge. This voltage difference can be used as a source of electrical energy [10].

Mathematic model of photovoltaic cell photovoltaic can be obtained starting form p-n junction. At this a current noted I_{ph} which is proportional with solar irradiance is added and a term who represent intern phenomena of cell [11].

Current I produced by cell and current crossing the equivalent diode can be evaluated by equations:

$$I = I_{ph} - I_d \times \left(e^{\frac{\mathrm{q}\times(U+R_S\times I)}{\mathrm{k}\times T}} - 1\right) - \frac{U+R_S\times I}{R_{sh}} \tag{1}$$

$$I_d = I_d \times \left(e^{\frac{\mathrm{q}\times(U+R_S\times I)}{\mathrm{k}\times T}} - 1\right) \tag{2}$$

Where:

I_{ph}= electric current generated by solar irradiance;

I_d= electric current of saturation;

R_s= equivalent series resistance;

R_{sh}= equivalent parallel resistance

k= Boltzmann constant ($k=1.3806504\text{x}10^{-23}$ J/K)

q=electron charge ($q=1.602\text{x}10^{-19}$ C)

T= cell temperature

The equivalent scheme of a solar cell is presented in figure 2.

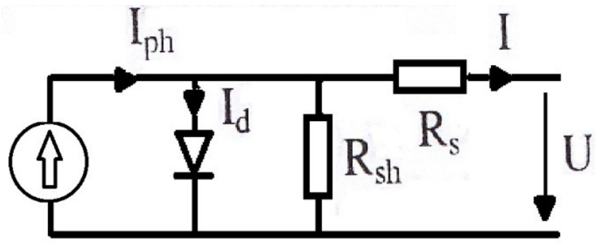

Fig. 2. Equivalent scheme of a PV cell.

Diode is modeling cell behavior in the absence of light (dark). The current source is modeling current generated by lighting. Electrical resistances is modeling internal energy losses in solar cell: series resistance correspond to losses in the cell material and parallel resistance R_{sh} is modeling transverse currents (parasites) flowing through solar cell [11].

4. GRID-CONNECTED PHOTOVOLTAIC SYSTEMS

Currently interconnected photovoltaic system is being used as a complement to a conventional generation in many countries [4]. In this study is analyzed a photovoltaic system with a storage and all energy produced will be delivered to the system, using distribution system existing in the local area.

This type of photovoltaic system does not use storage for energy produced. The energy is injected into the grid. Figure 1 shows schematically a block diagram of a typical PV system grid-connected with no storage of energy.

The functional blocks are described below:

a) photovoltaic generator;
b) inverter;
c) point of common coupling;
d) transformers;
e) bi-directional meter of AC power;
f) electric grid.

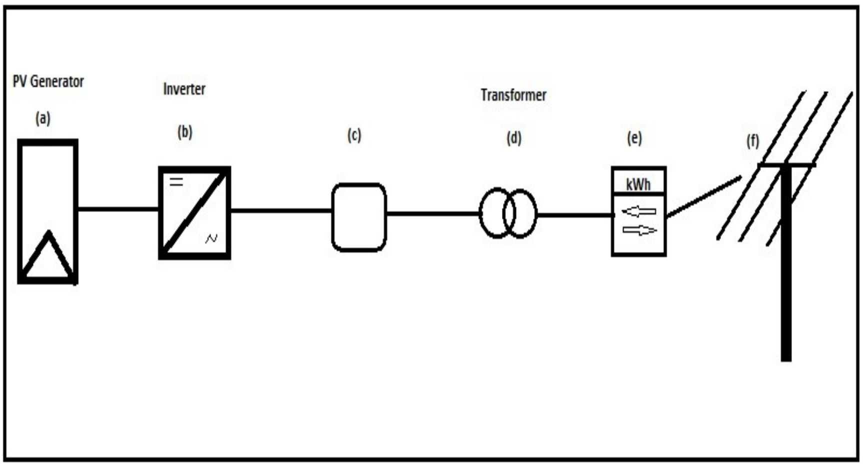

Fig. 3. Grid-connected PV power system with no storage.

5. DISTRIBUTED GENERATION TECHNOLOGIES

The power plant will be connected directly to the distribution network at a distance of 9 km fare away from electric substation and the maximum power delivered is limited by the local network conditions.

A general definition for distributed generation suggested here is "Distributed generation in an electric power source connected directly to the distribution network or customer site of the meter" [3].

The maximum power of 2.8 MW installed considering different ratings of distributed generation include this PV system as small distributed generation, which is rated between 5KW-5MW.

Distributed generation takes place on two levels: the local level and the end-point level. Local level generation plant often include renewable energy technologies that are site specific such as wind turbines, geothermal energy production, solar systems (photovoltaic and combustion), and some hydro-thermal plants. They are also more energy and cost efficient and more reliable. Since these local level distributed generation produce often take into account the local context, the usually produce less environmentally damaging or disrupting energy than the larger central model plants.

At the end-point level, the individual energy consumer can apply many of these same technologies with similar effects. At this level, distribution technology can operate as isolated "islands" of electric energy production or they can serve as small contributors to the power grid. Most studies confirm, however, that the penetration of distributed generation up to a level of 10-15% of maximum load can be easily be absorbed by the electricity network without major structural changes [3]. The PV system analyzed is one of the first PV systems in the local area; the only disadvantage is the length to the substation.

The distribution generation allows producing, store and managing the energy in the same place of consumption. This brings many benefits for distribution companies. Within these advantages, it is worth nothing the following:

- It avoids or defers s investments in transmission and distribution by location generation close to consumption.
- Depending on network configuration and the load and generation location, the decentralized energy produced prevents an equivalent amount from being transported over long distances, with the added looses. Similarly, it reduces congestion in transport system to the final consumer.
- It improves the supply reliability. It reduces the chance or failures when outages occur in the high voltage transport lines by decreasing the percentage of its use. This is essential in applications that require continuous service for health and safety reasons.
- Receive power control and voltage regulation in distribution network: One of the ways to regulate the tension using transformers with taps or the known buster. Distributed generation may inject a reactive quantity, which improves the distribution network voltage levels.
- Flattening on the demand curve: distributed energy production may coincide with peak demand, avoiding the use of electrical power from distant power plants that operate only during those hours, at a very high price, compared with electricity of the

off-peak hours. For example, PV systems have their peak production in hours where consumption is increasing due to the use of air conditioning system in warm climates.

- It gives a choice of self-supply in areas where network infrastructure does not exist, or is very expensive which opens markets in remote areas without access to the mains or with high environmental restrictions.
- It increases the options of power supply for users.
- Its location is more flexible due to its small size.
- In case of contingency, it is possible to operate the system provisionally, giving a greater support to the affected region.
- It allows minimizing the risk and capital exposure due to its size, easiness of location and short installation time.
- It allows the risk and capital exposure due to its size, easiness of location and short installation time.
- It allows to use cheaper fuels that otherwise would be used as agricultural residues, biogas from landfills, waste heat, etc.
- Incentives from renewable energy sources: Many renewable generation technologies operate at scales of small generation and can be adapted by the smallest users. This opens a possibility for the use of resources that reduce environmental pollution. [9]

6. SHORT DESCRIPTION OF PV SYSTEM ANALYSED

The study is focused on the influences of connecting to the grid of a photovoltaic system with a rated power of 2.8 MW.

The type of solar modules used for the PV system is poly-crystalline solar modules with a nominal power of 230 W and a number of 12.172 of panels will be installed. The solar modules will delivery energy using 12 inverters with a power of 250 kW each.

A short list with technical specifications of solar panel is presented in table 1.

Table 1 Specifications of solar panel 230 W at Standard Test Conditions

Rated power	230 W
Type of cells	Poly crystal Si
Tolerance	±3%
Rated current	7,78 A
Rated voltage	29,8
Short circuit current	8.3 A
Open circuit voltage	37,3 V

Solar Panel manufacturers use what is called Standard Test Conditions (STC). This means they put the solar panels in a flash tester in their factory that has been calibrated to deliver the equivalent of 1000 watts per square meter of sunlight intensity, hold a cell temperature of 25'C (77'F), and assume an air mass of 1.5. This flash test gives them their STC ratings. Air mass is the optical path length through the Earth's atmosphere for light from a celestial source. As it passes through the atmosphere, light is attenuated by scattering and absorption; the more atmosphere through which it passes, the greater the attenuation. Consequently, celestial bodies at the horizon appear less bright than when at the zenith. An air mass of one is looking straight up from sea level at the sun when it is directly overhead [8].

Because of this, when utilities and municipalities are trying to calculate real available wattage on an average day (in order to issue tax credits, etc.) they use what is called Normal Operating Cell Temperature (NOCT) ratings. NOCT recognizes a bit of reality and assumes the following: 800 watts per square meter of Sunlight Irradiance, an average of 20'C (68'F) Air Temperature, an average wind velocity of 1 meter per second (2.24 miles per hour), with the back side of the solar panel open to that breeze (as opposed to being on a roof where heats builds up under the panels) [8].

The PV system will be connected to the distribution system, which has a nominal voltage of 20 KV. The inverters works at low voltage (0.4 KV) so two transformers with a power of 1600 kVA each will be required. From transformers will be created an electric line using a cable of medium voltage to connect the PV system to the electric line existing in the area.

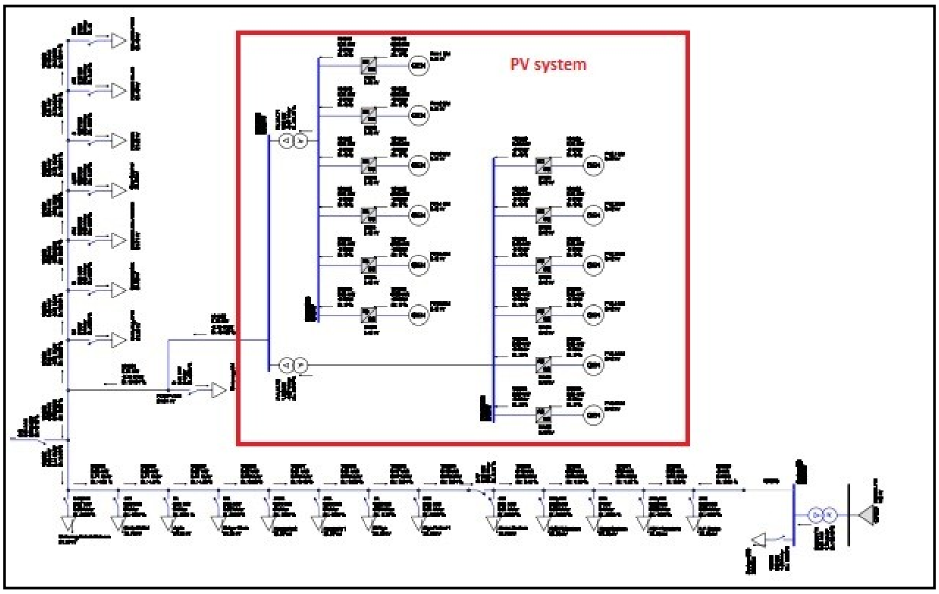

Fig. 4. PV system analyzed.

The system PV analyzed is presented in above figure (Figure 4) and local consumers connected to the distribution system, on the electric common line with the PV system. The local consumers connected on the same electric line with the PV system are influenced by the photovoltaics.

7. STUDY OF THE INFLUNECES OF CONNECTING THE PV SYSTEM TO THE GRID DISTRBUTION

To limit the influences and ensure the optimal conditions to produce and delivery all electric energy to the local consumers from the PV system, is necessary to analyze all operating modes of the grid and specially the grid distribution. The study is focused on the influences caused by connecting the PV system to the grid distribution.

To obtain the accurate results, all the local consumers have been identified with all electrical characteristics (installed power, absorbed power, electric line, protections).

The major problem required to be analyzed is the voltage levels. The new PV system changes the voltage profile of the local distribution network because of the change in the magnitudes of power flow. Usually the voltages profile will tend to rise, which is not a problem in congested networks with low voltage problems, as would be in the contrary. The design and configuration of the distributed network is to operate with the power flow in one direction. Connecting the PV system will cause the reverse of power direction, and it can cause malfunctions of protection circuits as they are configured. The installation of the PV system changes the flow into bidirectional.

The PV system analyzed is situated at a distance of 9 kilometers far from electric substation. An electric line of medium voltage cross the emplacement of the PV and the point of connection to the grid will be realized by building a new electric line using a cable with a length of 250 meters and connect it to the existing electric line.

Integration of the PV system into the medium voltage layer of the grid imposes to adapt the PV system to the distribution system. Here are few major conditions: voltage fluctuations, frequency, flow, and the reverse flow on the electric feeders used.

8. PROBLEMS REVEALED BY THE STUDY

Based on real measurement and characteristics of grid and respectively of local consumers the PV system power is limited by the electrical characteristics of the grid and especially by the electric line used to delivery the energy.

Creating a new electric line increases the cost of PV system. One of the biggest problems to create a new electric line is obtaining the permit to cross with the line all private properties to the transformer station for a length of 9 km.

Another problem revealed is the level of voltage. Generally, a simple distribution transformer, which is our case, has several feeder lines and the voltage for the line is adjusted in a block. The level of medium voltage for distribution system is set between values of 20.1 kV to 20.9 kV.

To produce energy the PV system require solar energy, which means that night the system is unable to produce energy so the scenario of the grid working night is not necessary to be analyzed.

In distribution system are two severe conditions: working with maximum load and minimum load. For an accurate analysis has been used information from the grid owner for the maximum load of the grid, and also the minimum load connected to the grid, and the level of voltage used to work the distribution in this two situations in safe electrical parameters.

For scenario with the PV system connected and producing at rated power with distribution system at maximum load at the local consumers, the drop voltage is situated at value of 5 % of nominal voltage at the point of connection of PV system. In this scenario a part of local consumers are sustained by the PV system and the difference of power required is covered by the electrical substation. The loss on feeders rises with 48% by loses in scenario without system PV, and the direction flow is changed. The value of fault current rises only with 6%.

The worst scenario for the PV system is the minimum load at local consumers (e.g. summer weekend) when as is well known that the level of voltage in substation increases and the PV is generating at maximum power create also a bigger value of drop voltage on the electric line, a value which is situated at 5.3 % of nominal voltage. The loss on feeders rises with 71% by loses in scenario without system PV, and the direction flow is changed.

It is possible by fluctuations to the locally voltage to achieve bigger values than 7.5% over nominal voltage and cause disconnection of the PV system through an overvoltage protection required by the grid owner.

Distribution utilities have reported challenges in regulating voltage in areas with high penetration of solar PV [5]. Locally, the voltage can fluctuate as a response to fluctuating solar irradiance, ass well as other factors such as load transients or the existence of multiple solar PV inverters (12 inverters in this case) on a distribution circuit. When the PV system is grid-connected, the connection impedance between that system and the grid naturally drives up the nominal voltage at the point of interconnection. This voltage rises is, among other things, proportional to the amount of current generated by the PV system and this current it itself proportional to the solar irradiance fluctuations throughout the day directly create grid voltage fluctuations [6].

The owner of the grid required a recloser integrated in SCADA (Supervisory Control and Data Acquisition) and a network analyzer for harmonics in the point of grid connection.

The recloser will have installed overvoltage and undervoltage protection required by the grid owner to protect the local consumers. A solution to avoid overvoltage protection and disconnect the PV system is to limit the power in the moments when a set value is reached in timing steps and if is necessary by restricting the power by stopping one or two inverters by case until system became stable.

9. CONCLUSIONS

Concerns about voltage variations and reverse power flow are expected to rise as PV systems installations are increasing. With the existing technologies and best practices for managing those technologies, can minimize voltage fluctuation and reverse power flow effectively.

REFERENCES

1. *www.transelectrica.ro/pdf/piata/unitatiproductie.pdf* accesed on 27 March 2013.

2. Antonello Gaviano, Karl Weber, Christian Dirmeier, *Challenges and Integration of PV and Wind Energy Facilities from a Smart Grid Point of View*, Energy Procedia, Volume 25, Pages 118-125, 2012.

3. Rajkumar Viral, D.K. Khatod, *Optimal planning of distributed generation systems in distribution system: A review,* Renewable and Sustainable Energy Reviews, Volume 16, Issue 7, Pages 5146-5165, September 2012.

4. Markrides G, Norton Matthew, Schubert Markus, Werner Hj, *Potential of photovoltaic systems in countries with a solar irradiation. Renewable and Sustenable Reviews,* Renewable and Sustainable Energy Reviews, Volume 14, Issue 2, Pages 754-762, February 2010.

5. J. Bebic, *Power System Planning: Emerging Practices Suitable for Evaluating the Impact of High-Penetration Photovoltaics,* Subcontract Report, NREL/SR-581-42297, February 2008

6. Mohamed A. Eltawil, Zhenming Zhao, *Grid-connected photovoltaic power system: Technical and potential problems- A review,* Renewable and Sustainable Energy Reviews 14, pp.112–129, 2010.

7. Samuel Wolfe, Adje Mensah, *Overcoming Challenges to High Penetration of Solar PV: Using Optimized Energy Storage and Distribution Grid Controls,* The Electricity Journal, Volume 25, Issue 9, Pages 43-47, November 2012.

8. *http://www.amsolar.com/home/amr/page_164* accesed on 28 March 2013.

9. J.A Hernandez, D. Velasco, C.L Trujillo, *Analysis of the effect of the implementation of photovoltaic systems like option of distributed generation in Colombia,* Renewable and Sustainable Energy Reviews, Volume 15, Issue 5, Pages 2290-2298, June 2011.

10. *http://science.yourdictionary.com/solar-cell.* accesed on 29 March 2013.

11. Vatra Fanica, Postolache Petru, Vatra Cristiana Andreea, Poida Ana, *Intergrarea si functionarea centralelor eoliene si a instalatiilor fotovoltaice in sistemul electroenergetic*, Ed SIER, 2012.

IMPACT OF INTERNET OF THINGS AND CLOUD COMPUTING TO SMART GRID

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Keywords: Smart grids, Decentralized control, Semantic Web, Intelligent sensors, Multi-agent systems

Abstract*: The grid of most countries is set up to be centrally controlled, but in last decade more researches explores solutions to gradual reorganization the power system to resemble the Internet. In this paper we discuss about emergent technologies for smart grids deployment with the focus on middleware for Internet of Things in the Cloud.*

1. INTRODUCTION

The electric utilities have to regulate the grid's frequency and voltage by maintaining a balance between power generation and changing demand, but the grid of most countries is set up to be centrally controlled and is more and more difficult to manage this complex system in the advent of Distributed Energy Resources (DER) and increasing amount of data supplied by recent devices.

If Smart Grid focus on idea of data flow and information management, one of the most important changes in the power systems architecture will be two-way power (and data flow) due to the usage of more renewable sources of energy [1],[2]. Also, a new term "*prosumer*" emphasizes the combination of the terms "producer" and "consumer", and refers to the dual role of an energy entity by being both an energy generator and an energy user [1]. The Smart Grid Dictionary [3] define the term prosumer as "a term coined by Alvin Toffler to describe a producing consumer. From a Smart Grid perspective, it would apply to distributed energy resource situations in which the owner of electricity production or storage assets may also have a consumer relationship with a utility, aggregator, or other energy services provider".

It is considered that Smart Grid relies on the design, development, and deployment of information networks to allow data exchange between devices, applications, consumers and grid operators. For this desire, communication and networking seems to be key technologies for achieving automation and interactivity [4].

In last decade researchers started to explore solutions to gradual reorganization of the power systems so that it resembles the Internet functionalities [5]. Bob Metcalfe, co-inventor of the Ethernet, in his ***Enernet***(Energy-Internet) concept stated that the future power grid should have its own TCP/IP stack of protocols, as well as be highly distributed and asynchronous in nature [6]. In other words, there is a growing interest of taking lessons from the Internet and applying them to the future power grids [7].

2. STANDARDIZATION ACTIVITIES IN SMART GRIDS

There is a considerable effort in the standardisation activity for Smart Grids and part of them related with Internet technologies, some examples will be given.

The document RFC6272 [8] provides an overview of the Internet Protocol Suite (IPS) and the key infrastructure protocols that are critical in integrating Smart Grid devices into an IP-based infrastructure.

The Organization for the Advancement of Structured Information Systems (OASIS) is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. „OASIS promotes industry consensus and produces worldwide standards for security, Cloud computing, SOA, Web services, the Smart Grid, electronic publishing, emergency management, and other areas." (OASIS) collaborative energy standards are designed to address information exchange across the smart grid [9] such as Energy Interoperation - an information model for demand response (DR) and distributed energy resource (DER) event information, as well as messages for DR, market interactions, and price quotes.

Open Automated Demand Response (OpenADR) provides a non-proprietary, open standardized DR interface (based on OASIS) that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet.

Another examples are IEC61850-a standard for electrical substation automation and inter-substation communication (the abstract data models defined in IEC 61850 can be mapped to a number of protocols running over TCP/IP, support XML and Web Services) or IEC61970 - Common Information Model (CIM) providing a semantic layer in an enterprise architecture. The IEC61499 [10]function blocks architecture is a convenient abstraction for modeling *distributed multi-agent control* system. IEC 62351 is a standard developed for „handling the security of a series of IEC protocols, include authentication of data transfer through digital signatures, ensuring only authenticated access, prevention of eavesdropping, prevention of playback and spoofing, and intrusion detection”.

The European Telecommunications Standards Institute (ETSI), „produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.” ETSI standards relative to Smart Grids includes Machine-to-Machine communications (M2M); Applicability of M2M architecture to Smart Grid Networks; Impact of Smart Grids on M2M platform; Open Smart Grid Protocol (OSGP) [11].

3. MIDDLEWARES FOR INTERNET OF THINGS

It is commonly agreed that smart grid networks will rely on a wide scale monitoring and sensor infrastructure in addition to the ongoing deployments of smart metering infrastructures [11]. Therefore, there is a global effort to incorporate pervasive sensors, actuators and data networks into national power grids. [12].

The term Internet of Things (IoT) describes a "world in which physical and virtual objects are networked together, enabling them to “talk” to each other to exchange data and services"[13]. As identified by Atzori et.al.[14], Internet of Things can be realized in three paradigms: *things oriented* (sensors, actuators), internet-oriented (*middleware*) and *semantic-oriented* (knowledge).

The idea of abstraction layer – to interoperation of heterogeneous devices with a common protocol is actually a trend in pervasive computing and IoT applications. With the advent of sensor-cloud and sensor-grid architecture, appear the concept of *sensor network virtualization*, where multiple, heterogeneous, wireless sensor networks can be controlled as a single, unified, virtual sensor network [15].

In [16] are identified *Virtual Sensor* (VS) as a software entity serving as “an aggregation point for multiple sensors, using physical sensor entities and a computational model to combine their measurements”, and *Sensor Network Virtualization* as collaborative wireless sensor networks providing the common layer to the interaction of the “Things” with processes and people, rather than just connecting the things. The Knowledge-Aware and Service-Oriented Middleware (KASO Middleware) presented in [17] aims to integrate embedded networks in the future Service Cloud, to provide access to pervasive services related to sensors and actuators. KASO Middleware introduced Perceptual Reasoning Agent (PRA) programming model providing REST services to register, expose and discovery, composition and orchestration of services; the model has been validated through a real healthcare tele-monitoring system.

4. SMART GRID CLOUD APPLICATIONS

The most common cloud computing service models that vendors can offer are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). By IaaS the physical infrastructure(storage, hardware, servers and networking components) are provided by the vendor, in a scalable manner. The users are responsible for providing and managing the operating system, middleware and application stack. PaaS is a paradigm for delivering operating systems and associated services over the Internet without installation. In SaaS distribution model the applications are hosted by a vendor (service provider) and made available to customers over the Internet.

Applications like Advanced Metering Infrastructure (AMI) Energy management is expected to be available as SaaS model [18]; soon, perhaps will be also, distribution management system (DMS), volt/VAR optimization, outage management, or asset management. General Electric (GE) already offers advanced metering, data management and demand response applications via it’s GridIQ Service.

Big Data is the term currently being used to describe the situation a company faces when the size and/or complexity of their data make it difficult for traditional data management technologies to handle. The advent of AMI has increased the level of data collection dramatically. Data set that are terabytes to exabytes in size and come from a range of sources puts the management and analysis beyond the scope of traditional IT tools. In a pilot project [19] meters can provide more than 43,000 data points per customer per month. Distribution automation is another source of Big Data in utilities: real-time monitoring and control requires much more granular readings than those taken by smart meters. A GridSim simulation used a sample rate of 30 samples per second, per sensor [19].

The combination of Cloud Computing and Smart Grid was investigated also in [20]; here it is considered that data processing can be provided as a pure IaaS service. Data processing services can be used for analyzing energy consumption patterns in the area of demand response or forecasting. Demand response is a technology to intelligently switch off devices at peak consumption levels, but can influence the consumption by price corrections. Based on continuous data analysis and grid monitoring, the cloud or service provider can send signals or change customer prices by web services. In contrast to demand response, demand forecasting is not reacting on consumption but predicting the future demand by processing various data like grid control data and consumption data.

Process analytics is the multivariate analysis of a process to develop a statistically based understanding, leading to process improvement and/or optimization. A process analysis can be used to improve understanding of how the process operates, and to determine potential targets for process improvement [12].

High Performance Computing (HPC) applications tend to migrate into the cloud, and obviously SCADA systems can be instances of HPC applications. However, in [21] are identified three styles of power computing: applications with weak requirements, Real-time applications, Applications with strong requirements. Today's cloud is well matched just to first category of applications (by example - applications that maintain maps of the physical infrastructure).

Recently SmartCloud company has developed a technology that unify stream, processing, Semantic Web, and multi-agent architectures - intended to improved the real-time data processing in Big Data environments. The company implemented „first situation awareness system" to monitor power system and alert staffs about emerging situations that could impact reliability. „The system takes real-time data from 30,000 data points and identifies and displays critical trends."

Semantic Web technologies applied for IoT are a fundamental approach in the problem of interoperability of the "things". By linking Semantic Web technologies with sensor networks has emerged Semantic Sensor Web and the main features of it are ontologies. In [22] Context-Aware Sensor Configuration Model (CASCoM) provides context discovery functionalities by using semantic knowledge and fusing raw sensor data. Susel et. al. presented in [23] „a system for ontology alignment in the Semantic Sensor Web which uses fuzzy logic techniques to combine similarity measures between entities of different ontologies."

5. CONCLUSIONS

In this paper we have tried to figure a trend in energy systems in close cooperation with Internet technologies, offering possible directions for multidisciplinary research. Few important arguments presented are standardizations such as IEC61850, IEC61970 or IETF6272 and recent development of the first applications in this field.

The Internet and the Cloud Computing appear to be the natural trend in power grids evolution and first changes have quickly appeared, despite of some compatibility issues.

REFERENCES

1. D. S. Markovic, D. Zivkovic, I. Branovic, R. Popovic, D. Cvetkovic, *Smart power grid and cloud computing*, Renewable and Sustainable Energy Reviews, **24**, pp. 566–577,2013.

2. P.G.D. Silva, S. Karnouskos,D. Ilic, *A survey towards understanding residential prosumers in smart grid neighbourhoods*, Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition on, vol., no., pp.1-8, 14-17, 2012.

3. C. Hertzog, *Grid resiliency as a social benefit,* 2013, www.smartgridlibrary.com

4. Cisco, *Internet protocol architecture for the Smart Grid*, http://www.cisco.com/, 2009.

5. J. Boyd, *An Internet-inspired electricity grid*, Spectrum, IEEE, Vol.50, Issue 1, pp.12-14, 2013.

6. R. Metcalfe, "*Enernet:Internet Lessons for Solving Energy*," in ConnectivityWeek, Santa Clara, 2009.

7. T. Shibata, *Power routing switches toward energy-on-demand home networking*, ConsumerCommunications and Networking Conference (CCNC),pp. 844-845. IEEE, 2011.

8. RFC6272, *Internet Protocols for the Smart Grid*, IETF, http://tools.ietf.org/html/rfc6272, 2011.

9. D. Holmberg, W. Cox, D. Sturek, *OASIS Collaborative Energy Standards, Facilities, and ZigBee Smart Energy*, Proceedings of 2011 Grid Interop, Phoenix, AZ, Dec 5-8, 2011.

10. G. Zhabelova, V. Vyatkin, *Multi-agent Smart Grid Automation Architecture based on IEC 61850/61499 Intelligent Logical Nodes*, IEEE Transactions on Industrial Electronics, 59(5), pp.2351-2362, 2011.

11. ETSI, *The European Telecommunications Standards Institute*, http://www.etsi.org/

12. Y. Simmhan, S. Aman, A. Kumbhare, R. Liu, S. Stevens, Q. Zhou and V. Prasanna, *Cloud-Based Software Platform for Big Data Analytics in Smart Grids*, Computing in Science and Engineering, vol. 15, no. 4, pp. 38-47, July-Aug., 2013.

13. A. Crapo, R. Piasecki, Xiaofeng Wang, *The Smart Grid as a Semantically Enabled Internet of Things*, Grid-Interop Forum, 2011.

14. L. Atzori, A. Iera, G. Morabito, *The Internet of Things: A survey*, Computer Networks, **54**, pp. 2787 – 2805, 2010.

15. Md. Motaharul Islam, Md. Mehedi Hassan, Ga-Won Lee and Eui-Nam Huh, *A Survey on Virtualization of Wireless Sensor Networks*, Sensors, 12, pp.2175-2207, 2012.

16. A. Merentitis, F. Zeiger, M. Huber, N. Frangiadakis, K. Mathioudakis, K. Sasloglou, et.al., *WSN Trends: Sensor Infrastructure Virtualization as a Driver Towards the Evolution of the Internet of Things*. In UBICOMM 2013, The Seventh International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies, pp. 113-118, 2013.

17. I. Corredor, J.F. Martínez, and M. S. Familiar, *Bringing pervasive embedded networks to the service cloud: A lightweight middleware approach*. J. Syst. Archit. 57, 10 (November 2011), pp. 916-933, 2011.

18. G. Deshpande, Smart Grid Applications go on Cloud, Technology Trends,2012.

19. J. Deign, C.M. Salazar, *Data management and analytics for utilities*, smartgridupdate.com, 2013.

20. O. Ruf, *The Appliance of Cloud Computing in a Swiss Smart Grid*, master thesis,University of Applied Sciences and Arts Northwestern Switzerland, 2013.

21. K. P. Birman, L.Ganesh, and R. van Renesse. *Running Smart Grid Control Software on Cloud Computing Architectures*, Workshop on Computational Needs for the Next Generation Electric Grid, Cornell University, 2011.

22. M. Compton, P. Barnaghi, L. Bermudez, R. Garca-Castro, O. Corcho, S. Cox, et.al.,"*The SSN ontology of the W3C semantic sensor network incubator group,*" Web Semantics: Science, Services and Agents on the World Wide Web, vol. 17, no. 0, pp. 25 – 32, 2012.

23. F. Susel, Ivan Marsa-Maestre, J. R. Velasco, B. Alarcos, "*Ontology Alignment Architecture for Semantic Sensor Web Integration*," Sensors, 13, 12581-12604, 2013.

MODELING AND SIMULATION OF A SMALL WIND TURBINE USING MATLAB SIMULINK

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Keywords: Wind energy, Modeling, Simulation, Matlab

Abstract*: In this paper, a small wind turbine is analyzed. Because usually the manufactures don't provide enough information about the turbine (especially for small turbines), the steps for obtaining this parameters are presented. A Matlab program was written to fulfill this steps and then the whole turbine was simulated in Simulink. The resulted performance curve from simulation was compared with the performance curve from the manufacture's datasheet for validation*

1. INTRODUCTION

In recent years, the demand for renewable energy increased due to environmental problems, high conventional fuels prices and shortage of traditional energy sources in the near future. [1] [2] Of all available renewable resources, solar and wind energy are attracting the most attention due to its abundant, inexhaustible potential and its increasingly competitive cost. Wind technologies have been developing rapidly over the last few decades being considered one of the most important sustainable energy resources and one of the best technologies today to provide a sustainable electrical energy supply to the world development. [3] [4]

The utilization of wind energy has a very long tradition, being used first to move ships. Later, the Persians invented the windmill to pump water and grind crops. Nowadays, wind turbines are used to convert wind energy into electricity. The main problem of wind energy is that its availability depends on climate conditions and terrain. Also, the "quality" of the wind is very important because even if the speed it's good, turbulences produced by trees or hills (in cities by buildings) will affect the energy production and can damage the turbine. [5] [6]

In terms of the generators for wind-power application, there are two big concepts: fixed-speed and variable-speed wind turbine generators. Permanent magnet synchronous generators (PMSG) are increasingly popular due to their advantages of small size, high energy density, low maintenance cost, and ease of control. [2] [3] Large wind turbines are complex in operation, deploy multitude of control methods and operate in grid-connected mode. On the other hand, small wind turbines can be used for grid-connected system as well as stand-alone system for remote places where grid based electricity is not available. [7] [8]

In order to simulate a wind turbine, some information about it must be known. Unfortunately, the manufactures don't provide enough specifications in their data sheets, especially for small scale turbines. Usually, they provide only the power curve (with respect to wind speed) and some information about rotor diameter and weight. This paper will present a method to obtain the parameters needed for simulations using Matlab Simulink.

2. WIND ENERGY CONVERSION

The kinetic energy of the wind is given by the following equation:

$$E = \frac{m \cdot v^2}{2} \text{ [Nm]} \tag{1}$$

where v is the wind speed (m/s) and m is the air mass determined by air density ρ and volume that crosses a certain surface A in time t:

$$m = \rho \cdot A \cdot v \cdot t \text{[kg/s]} \tag{2}$$

The wind power P_w has the following expressions:

$$P_w = \frac{\rho \cdot A \cdot v^3}{2} \text{ [W]} \tag{3}$$

The power extracted from the wind by a wind turbine is given by:

$$P = C_p \cdot P_v = C_p \cdot \frac{\rho \cdot A \cdot v^3}{2} \text{ [W]} \tag{4}$$

where C_p is the power coefficient and it's given as a function of the tip speed ratio λ and the blade pitch angle. The pitch angle is the angle between the plane of rotation and the blade cross section chord. [9] The tip speed ratio of a wind turbine is defined as:

$$\lambda = \frac{u}{v} = \frac{\omega R}{v} \tag{5}$$

where: u is the tangential velocity of the blade pitch, ω is the angular velocity of the rotor (rad/s), R is the rotor radius (m), and v the wind speed (m/s).

In Fig. 1 the approximation of the real rotor power curve by various theoretical approaches is presented. [1]. Usually three-blade airflow wind turbines are used for electric energy generation because, they have the highest power coefficient.

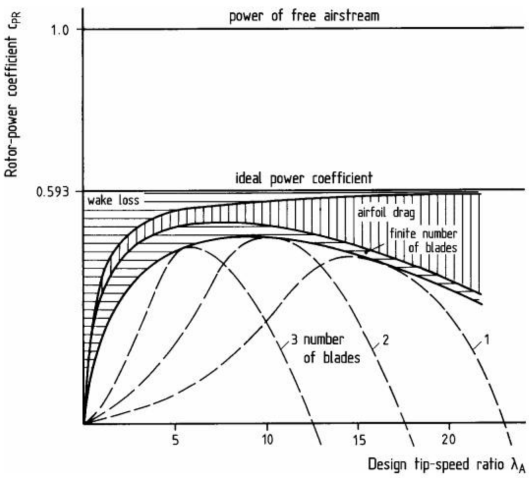


Fig. 1 – Approximation of the real rotor power curve by various theoretical approaches [1]

3. SIMULATION AND RESULTS

In this paper a wind turbine fabricated by Southwest Windpower Inc. is analyzed. Table1 presents the specifications of the wind turbine, model AirX 400, and in Fig. 2 the power curve with respect to wind speed.

Table1. Parameters of wind turbine AirX 400

Power	400 W
Voltage	24V
Rotor diameter	1.15 m
Cut in wind speed	2.5 m/s
Cut out speed	13 m/s
Weight	5.85 kg
Blades	3

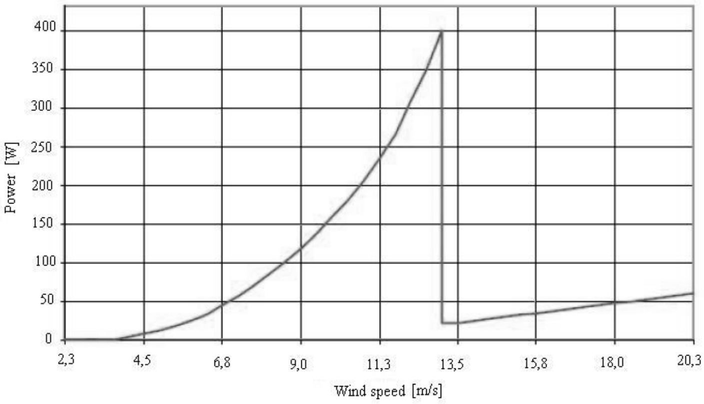
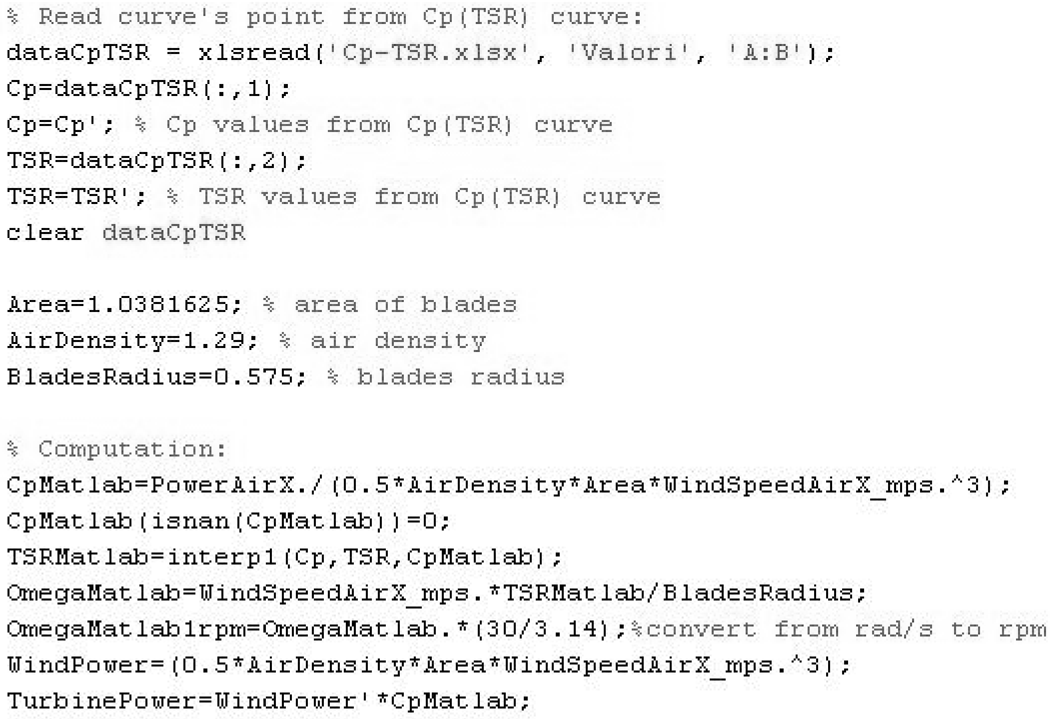


Fig. 2 – AirX 400 performance curve

This wind turbine was analyzed using Matlab. It must be specified that the analyze was made for the interval between no wind speed and cut-out wind speed, i.e. for wind speed ranging between 0 to 13 m/s. In order to find the parameters needed for simulations these steps were made:

- the values of power in respect with wind speed were extracted from Fig. 2;
- the *Cp* values in respect with *λ* were extracted from Fig. 1 (for a 3 blade wind turbine);
- from eq. (4), Cp was computed for every value of power;
- with eq. (3) we computed the power of the wind;
- with eq. (4) we computed the power of the wind turbine.

In order to fulfill these steps, a Matlab program was written. A screenshot with a part of this program is presented in Fig. 3.



```
% Read curve's point from Cp(TSR) curve:
dataCpTSR = xlsread('Cp-TSR.xlsx', 'Valori', 'A:B');
Cp=dataCpTSR(:,1);
Cp=Cp'; % Cp values from Cp(TSR) curve
TSR=dataCpTSR(:,2);
TSR=TSR'; % TSR values from Cp(TSR) curve
clear dataCpTSR

Area=1.0381625; % area of blades
AirDensity=1.29; % air density
BladesRadius=0.575; % blades radius

% Computation:
CpMatlab=PowerAirX./(0.5*AirDensity*Area*WindSpeedAirX_mps.^3);
CpMatlab(isnan(CpMatlab))=0;
TSRMatlab=interp1(Cp,TSR,CpMatlab);
OmegaMatlab=WindSpeedAirX_mps.*TSRMatlab/BladesRadius;
OmegaMatlab1rpm=OmegaMatlab.*(30/3.14);%convert from rad/s to rpm
WindPower=(0.5*AirDensity*Area*WindSpeedAirX_mps.^3);
TurbinePower=WindPower'*CpMatlab;
```

Fig. 3 – Screen shoot with a part of the program written in Matlab

After running the Matlab program, the parameters needed for the simulation are loaded in Matlab's workspace. In Fig. 4 is presented the differences between the theoretical *Cp(λ)* and the obtained curve after simulation. Also, from Fig. 4 we can see that the power coefficient is ranging from 0 to 0.27 for this wind turbine. In Fig. 5 we can see the output power of the wind generator in respect with wind speed and angular speed of the rotor.

In Fig. 6 is presented the wind turbine system implemented in Matlab Simulink. This model has as input parameter the wind speed (the "Ramp" block from Simulink library). The permanent magnet synchronous machine block has a negative input in order to act as a generator (positive for motor and negative for generator).

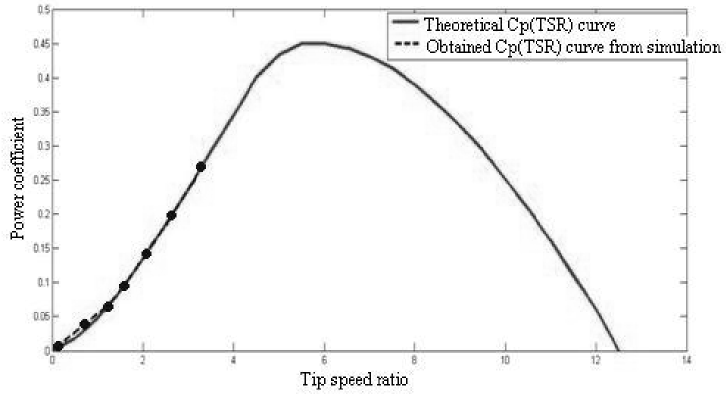


Fig. 4 – Differences between the theoretical Cp(λ) and the obtained curve after simulation

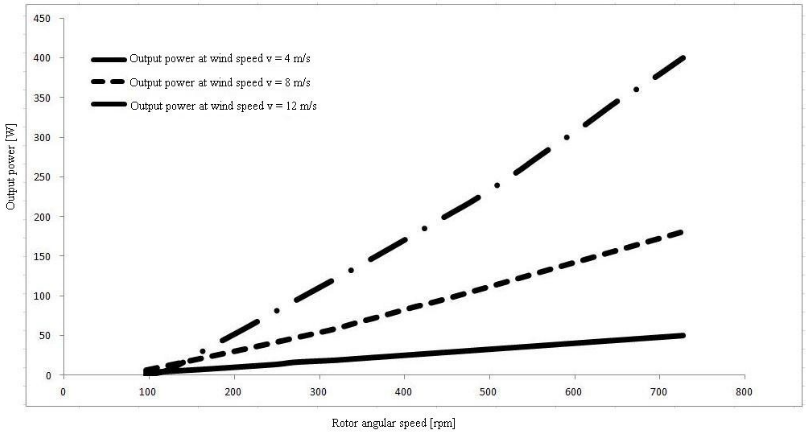


Fig. 5 – Output power of the wind generator in respect with wind speed and angular speed of the rotor

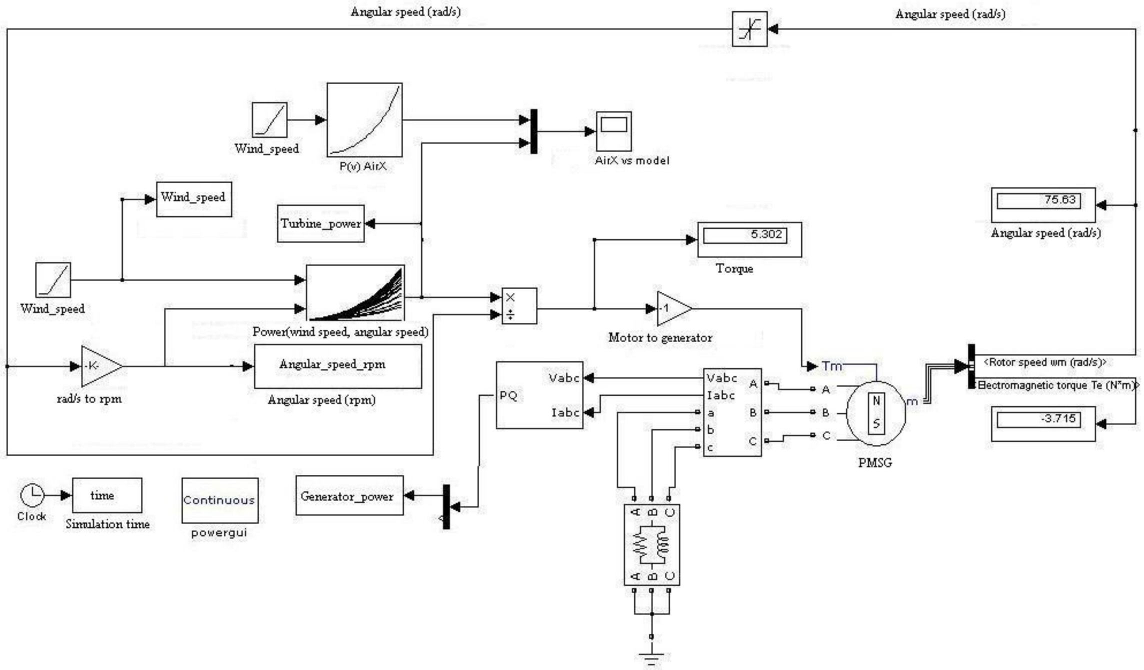
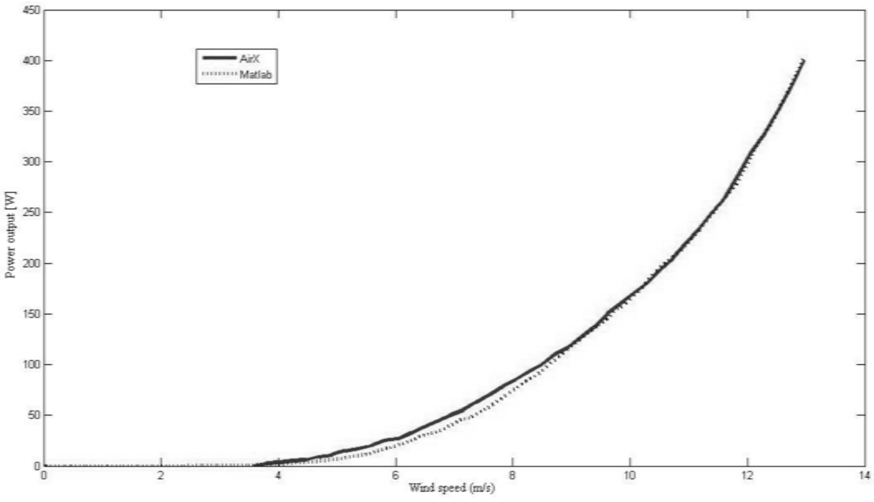


Fig. 6 – The wind turbine system implemented in Matlab Simulink

The “Power (wind speed, angular speed)” block (“Lookup2D” in Simulink library) outputs a power value using interpolation-extrapolation method with respect to the input values of wind speed and angular speed. The data needed for this block were obtained after running the Matlab program presented in Fig. 3.

For the validation, the power curve obtained after simulations was compared with the curve from the manufacturer (Fig. 7). As it can be seen, there is a good match between those two curves.



3. CONCLUSIONS

In this paper, a small wind turbine was analyzed. Because usually manufactures don’t provide enough information about the wind turbine, a Matlab program was written in order to find out some parameters needed for simulation. Then, using blocks from Matlab Simulink library, a wind turbine was implemented. The resulted performance curve from the model was compared with the curve from the manufacture’s datasheet for validation.

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REFERENCES

1. H. Erich, *Wind turbines: Fundamentals, Technologies, Application, Economics*, 2nd Edition, Springer, 2005.

2. M. Yin, G. Li ; M. Zhou, C. Zhao, *Modeling of the Wind Turbine with a Permanent Magnet Synchronous Generator for Integration*, Power Engineering Society General Meeting, 2007. IEEE, pp.

1 - 6, Tampa, FL, 2007.

3. Z.M. Dalala, Z.U. Zahid, et. al., *Design and Analysis of an MPPT Technique for Small-Scale Wind Energy Conversion Systems*, IEEE Transactions on Energy Conversion, pp. 756 - 767, 2013.

4. A. Rolan, A. Luna, G. Vazquez, D. Aguilar, G. Azevedo, „*Modeling of a variable speed wind turbine with a Permanent Magnet Synchronous Generator*, IEEE International Symposium on Industrial Electronics, pp. 734 - 739, Seoul, 2009.

5. A. Luque, P*erformance of a Small Scale Turbine in an Urban Environment*, Master thesis, University of Strathclyde, Glasgow, 2009

6. A. Soetedjo, A. Lomi, W.P. Mulayanto, *Modeling of Wind Energy System with MPPT Control*, International Conference on Electrical Engineering and Informatics (ICEEI), pp. 1 - 6, Bandung, 2011

7. M. Arifujjaman, M.T. Iqbal, J.E. Ouaicoe, M.J. Khan, *Modeling and control of a small wind turbine*, Canadian Conference on Electrical and Computer Engineering, pp. 778 - 781, Saskatoon, 2005.

8. M. Örs, *Maximum Power Point Tracking for Small Scale Wind Turbine With Self-Excited Induction Generator*, Control engineering and applied informatics (CEAI), vol.11, pp. 30-34,2009

9. M. Sarvi, S. Azarbara, *A Novel Maximum Power Point Tracking Method Based on Extension Theory for Wind Energy Conversion System*, International Journal of Computer Science & Engineering Technology (IJCSET), Vol. 3, 2012

A METHOD FOR CHOOSING THE OPTIMAL POWER SUPPLY FOR A REMOTE HOUSE

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Abstract: *The electrical power required by a house can be obtained either by producing it locally from various sources but also by connecting to the main grid. This article wants to provide a method to calculate the cost in the two situations, in order to choose the best option.*

1. INTRODUCTION

It is difficult to imagine the existence of a house without electricity. Usually, this is obtained at a reasonable price from the main grid. But if a house is built at some distance from this grid, the cost to connect it can significantly increase. In such cases there is a viable alternative, that of producing electricity locally from renewable primary sources and/or internal combustion generators.

Knowing the value of initial investment, operating costs for certain periods (eg 20 or 40 years) and the energy price in the main grid, we can calculate and compare the total cost per KWh of electricity produced in both situations. Thus, it can be estimated depending on the distance to the main grid which of these options would be more economical.

2. THE CONDITIONS UNDER WHICH THE COSTS WERE COMPARED

- Date on which the calculations were made: 6.01.2013
- Exchange Rates : 4,4251Ron = 1Euro

- The price of electricity from the main grid: 0,627Ron/KWh = 0,14 Euro/KWh, at 6.01.2013
- The calculations were made taking into account the costs of the two variants, on two periods, one of 20 years and another of 40 years and introducing them in the final price of the energy.
- The results of the calculations and the conclusions obtained can be affected by how it will come true or not the estimates of the following:
- The evolution of electricity prices provided by the main grid
- Fuel price evolution (for internal combustion generator)
- Lifetime of equipments, especially batteries

3. ESTIMATION OF ELECTRICITY NECESSARY FOR THE LOCATION

Is taken into consideration a household with the following consumers (*table 1.*):

Table 1. Electrical consumers from the household

Electrical appliance	Electrical power [W]	Operation hours per day [h/day]	Daily energy consumption [KWh]	Monthly energy consumption [KWh]
Energy saving bulbs	5x20=100	5	0.5	15
TV	100	5	0.5	15
Computer	300	5	1.5	45
Refrigerator	200	5	1	30
Washing machine	300-800-3,000	a cycle	1	30
Iron	1,000	0.2	0.2	6
Central heating	100	12	1.2	36
Vacuum cleaner	1,000	0.2	0.2	6
Other appliances			0.9	27
The total energy consumed			7	210

It requires an amount of energy of 7KWh/day, 210KWh/month, 2,520KWh/year

4. OBTAINING ELECTRICITY FROM THE SOLAR ENERGY USING PHOTOVOLTAIC PANELS

The system is made up of:

- The production of energy: photovoltaic cells (PV)
- The electric power conditioning
    - Charging regulator with MPPT tracking
    - 3KVA Inverter
    - Electrical panel, protections switches
    - Scheduling and monitoring system
- The electrical energy storage: batteries
- 3KVA Diesel generator and automation
- Electrical appliances with low power consumption

A. System sizing:

1. The photovoltaic cells

According to the data provided by suppliers, a photovoltaic panel with 100W rated power has a daily electricity production of approx. 400Wh , ie 0.4 KWh [1] [2].

The number of panels needed to produce the required daily energy of 7KWh daily is Np,

$$Np=7KWh/0.4KWh=17.5 \tag{1}$$

If we denote by Pp the total power of these photovoltaic panels, then

$$Pp=100W \text{ x } Np=1.75KW \tag{2}$$

Therefore to produce the 7KWh every day, we need panels with a total power of Pp=1.75KW;

If we need a reserve of energy from photovoltaic sources for bad days, we need to increase the PV power. Considering one unfavorable day for every three favorable days, in each of these three favorable days the energy produced shall be 33% higher than the daily consumption. The recalculated PV panels power Ppr becomes:

$$Ppr=1{,}75KW \text{ x } 1{,}33=2{,}327KW \tag{3}$$

We choose 13 photovoltaic panels of 185W each, which will have a total power Ppv of:

$$Ppv = 0{,}185KW \text{ x } 13=2{,}4KW \tag{4}$$

2. The chosen electric power conditioning system (controller, inverter, electrical panel) will provide a power of 3KVA.

3. 3KVA Diesel generator [3][4] and automation [5].

4. Sizing the storage battery:

The batteries need to store up energy required for at least one day of operation without input of energy from panels (7KWh); if there are consecutive days without input of energy from the PV panels we use the diesel generator.

We choose 12V 200Ah batteries each with energy storage capacity W of:

$$W= 200Ah \text{ x } 12V = 2{,}400 \text{ Wh} = 2.4KWh \tag{5}$$

In order to store the amount of 7KWh energy, we need 3 batteries.

Considering a maximum depth of discharge (DOD) of 50% in order to protect the battery, we need 6 batteries.

Batteries have a limited useful life, both in time and in number of full charge/discharge equivalent; according to the manufacturer, the life of the batteries will be 3-8 years, depending on operating conditions[6].

Consider a battery service life of 5 years, after that they will be replaced

B. Finding the annual cost and the specific price per KWh:

The system components can be found in *Table 2*:

Table 2. The system components

The component	Quantity	Unitary price 2013 [Euro]	Initial value 2013 [Euro]	Lifetime [years]	Annual cost (for 20 years) [Euro]	Annual cost (for 40 years) [Euro]
[1]	[2]	[3]	[4]	[5]	[6]	[7]
			[2]x[3]		[4]/20	[4]/40
180W Photovoltaic panels	13	332	4,316	20	216	216
3KVA Electric power conditioning system	1	4,397	4,397	40	220	110
3KVA Diesel generator and automation	1+1	843+505	1,348	20	67	67
Fuel for internal combustion generator (liters per year) (20 days per year x 7kwh/day x 0,33liters/KWh)	46	1,4	64	1	72	80
12V 200Ah batteries, 5 years lifetime	6	280	1,681	5	336	336
Total initial investment / annual investment			11,806		911	809
Price from photovoltaic sources if the consumption is 2,520 KWh/year (Euro/KWh)					Pret_f20 = 0.36	Pret_f40 = 0.32

For the first 20 years, the conditioning system value is divided by 20, although it can last 40 years.

We estimate an increase of the fuel price in the next 20 years of 25% and in the next 40 years of 50%; the fuel cost from columns 6 and 7 is calculated at an average price of diesel in the 20 and 40 years, reflecting the estimated price increases; the specified amount of fuel will be purchased annually.

The annual costs of the battery pack were calculated by dividing their value to 5 years (the estimated service life)

5. OBTAINING ELECTRICITY FROM THE MAIN GRID (NATIONAL POWER SYSTEM, SEN)

In the following we will calculate the energy costs in the version that we decide to connect to the main grid.

We take into consideration the following data :

The cost of connection to the main grid:

- Between 1,500Ron and 2,500Ron, depending on the distance to the first pillar, if the grid is in proximity; we consider an average cost of 2,000Ron = 452Euro;
- If the main grid is at a certain distance from our location, the connection cost increases with the cost of the power line as follows:

For an overhead power line (LEA) 0.4KV the cost is 90,000 Ron/Km (6)

and

For underground power lines (LES) 1KV the cost is 120,000 Ron/Km (7)

We consider a connection with LEA 0.4KV with a cost of 90,000 Ron/Km = 20,338Euro/Km.

The current price of a KWh of electricity from SEN, Pret_a, is :

$$\text{Pret\_a} = 0.627 \text{ Ron/KWh} = 0.14 \text{Euro/KWh} \quad (8)$$

Annual amount of electricity purchased, Cant_an, is:

$$\text{Cant\_an} = 210 \text{ KWh/month} \times 12 \text{ month} = 2{,}520 \text{ kWh} \quad (9)$$

The cost of annual purchased electricity will be calculated based on the current price, making an estimation of its future price trends.

We estimate a 50% increase in electricity prices in the first 20 years, and 100% in the first 40 years, from the current level due to the increase in price of primary resources, to the support granted to producers of electricity from renewable sources, retrofitting power plants in order to decrease pollution, building nuclear power plants and environmental taxes paid by polluting plants.

So the average price of electricity from the main grid will be:

For the first 20 years we have Pret_ret_20:

$$\text{Pret\_ret\_20} = \{[0.627 + (150/100) \text{x} 0.627]/2\}\text{Ron/KWh} = $$
$$= 0.784\ \text{Ron/KWh} = 0.177\ \text{Euro/KWh} \quad (10)$$

And for the first 40 years we have Pret_ret_40:

$$\text{Pret\_ret\_40} = \{[0.627 + (200/100) \text{x} 0.627]/2\}\text{Ron/KWh} = $$
$$= 0.94\ \text{Ron/KWh} = 0.212\ \text{Euro/KWh} \quad (11)$$

By measuring the distance in Km, we specify the cost of the connection to the main grid, in Euro, Cost_racord by:

$$\text{Cost\_racord} = 452\text{Euro} + (20{,}338\text{Euro/Km}) \text{ x distance} \quad (12)$$

We denote by distance20 the distance to the power line if the calculation is made for the first 20 years.

We denote by distance40 the distance to the power line if the calculation is made for the first 40 years.

By introducing this cost in electricity prices, we get a recalculated price per KWh.

For the first 20 years we have Pret_ret_rec_20 :

$$\text{Pret\_ret\_rec\_20} = \text{Pret\_ret\_20} + [\text{Cost\_racord} / (20\text{years x Cant\_an})] \quad (13)$$

$$\text{Pret\_ret\_rec\_20} =$$
$$= 0.177\ \text{Euro} + [452\text{Euro} + (20{,}338\text{Euro/km}) \text{ x distance20}]/(20\text{years x } 2{,}520\text{kWh/year}) \quad (14)$$

And for the first 40 years we have Pret_ret_rec_40:

$$\text{Pret\_ret\_rec\_40} = \text{Pret\_ret\_40} + [\text{Cost\_racord}/ (40\text{years x Cant\_an}) \quad (15)$$

$$\text{Pret\_ret\_rec\_40} =$$
$$= 0.212\ \text{Euro} + [452\text{Euro} + (20{,}338\text{Euro/Km}) \text{ x distance40}]/(40\text{years x } 2.520\text{kWh/year}) \quad (16)$$

6. CALCULATION OF THE DISTANCE TO THE MAIN GRID AT WHICH THE TWO PRICES ARE EQUAL

In each of the two versions, 20 or 40 years, we have an estimated price of energy from the photovoltaic (Pret_f20 and Pret_f40) and from the network energy prices, Pret_ret_rec_20 respectively Pret_ret_rec_40.

Since the recalculated price of electricity taken from the SEN depends on the distance between the location and the network, we calculate the distance at which the two prices are equal.

For the first 20 years we have:

$$\text{Pret\_f20} = \text{Pret\_ret\_rec\_20} \quad (17)$$

therefore

$$0.36\ \text{Euro/KWh} =$$
$$= 0.177\ \text{Euro} + [452\text{Euro} + (20{,}338\text{Euro/Km}) \text{ x distance20}]/(20\text{years x } 2.520\text{kWh/eyar}) \quad (18)$$

Hence, the distance at which the two prices are equal:

$$\text{distance20} = 0.431\text{Km} = 431\text{m} \quad (19)$$

For the first 40 years we have :

$$\text{Pret\_f40} = \text{Pret\_ret\_rec\_40} \tag{20}$$

therefore

$$0.32\ \text{Euro/kWh} =$$
$$=0{,}212\ \text{Euro} + [452\text{Euro} + (20{,}338\text{Euro/Km}) \times \text{distance40}]/(40\text{years} \times 2{,}520\text{KWh/year}) \tag{21}$$

Hence, the distance at which the two prices are equal:

$$\text{distance40} = 0.513\text{Km} = 513\text{m} \tag{22}$$

7. RESULTS AND CONCLUSIONS

From the above results analysis, we find that on an average consumption of 7KWh/day:

- For the first 20 years, if the main grid is at a distance of less than 431m the connection to the main grid is advantageous and for a longer distance photovoltaics version becomes more advantageous.
- For the first 40 years, the distance where the photovoltaic variant becomes advantageous is of 513m. If we take into consideration that low voltage lines are designed with a length of less than 500m and beyond this distance a transformer is required (cost about 20.000 Euro) it is obvious that for more than 500m, the photovoltaic solution becomes more advantageous.

In addition to these comparisons, the price of energy obtained in the two variants, the national network and its own plant, each of them has some advantages and disadvantages to each other:

Connecting to the main grid has the advantage of increased security of supply, the malfunctions are solved by the supplier, no further expenses other than the payment of energy, lack of constraints on appliances use. The disadvantage is the high price of the connection, the fact that all the money should be given at the beginning and the risk of unfavorable evolution in electricity prices

Own photovoltaic installation comes with the advantage of much lower initial cost, of being clean, of providing energy even under critical circumstances, and also with the disadvantages caused by operational limitations, the risk of failure that will bring additional costs.

REFERENCES

1. http://www.lpelectric.ro/ro/support/solar_estim_ro.html

2. http://customer.lpelectric.ro/doc/Outback_profesional_solar_pack_ver1.pdf

3. http://www.clickbox.ro/Generatoare-pentru-uz-general_176/Generator-diesel-Kipor-KDE-3500X_p3664.html

4. http://www.depozit-online.ro/shop/generatoare-diesel-monofazate/generator-kipor-open-frame-kde3500x-2-8-kva

5. http://www.depozit-online.ro/shop/generatoare-diesel-monofazate/automatizare-generator-kipor-

6. **Sabou, D., Tîrnovan, R., Ştefănescu, S.**, *Considerations Regarding the Choosing of Battery Types for Energy Storage in an Isolated Microgrid*, Acta Electrotehnica, Volume 52, Number 5, Proceedings of the 4th International Conference on Modern Power Systems, Cluj-Napoca, ISSN 1841-3323, pag. 428-433, 2011,

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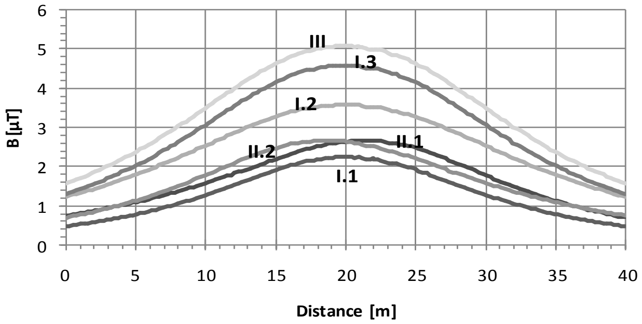

Fig. 4 - Magnetic flux density at 1 m above the ground

Table1. Transposing principle

	Circuit											
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	***1***	***2***
1/3 line length	*R*	*T*	***R***	***R***	*R*	*S*	*R*	*T*	*R*	*S*	***R***	***R***
	S	***S***	*S*	*T*	*S*	*R*	*S*	*R*	*S*	*T*	***S***	***S***
	T	*R*	*T*	*S*	***T***	***T***	*T*	*S*	*T*	*R*	***T***	***T***
1/3 line length	*T*	*S*	***T***	***T***	*T*	*R*	*T*	*S*	*T*	*R*	***T***	***T***
	R	***R***	*R*	*S*	*R*	*T*	*R*	*T*	*R*	*S*	***R***	***R***
	S	*T*	*S*	*R*	***S***	***S***	*S*	*R*	*S*	*T*	***S***	***S***
1/3 line length	*S*	*R*	***S***	***S***	*S*	*T*	*S*	*R*	*S*	*T*	***S***	***S***
	T	***T***	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*R*	***T***	***T***
	R	*S*	*R*	*T*	***R***	***R***	*R*	*T*	*R*	*S*	***R***	***R***
Name	***I.1***		***I.2***		***I.3***		***II.1***		***II.2***		***III***	

3. EQUATIONS

Equations are centred on page and are numbered in round parentheses, flush to right margin. In text respect the following rules: all variables are italic, constants are regular; the references are cited in the text between right parentheses: [1], the list of references has to be arranged in order of citation.

REFERENCES

1. International Commission on Non-ionizing Radiation Protection, *Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (Up to 300 GHz)*, Health Physics, **74**, pp. 494-522, 1998.

2. A. Marincu, M. Greconici, *The electromagnetic field around a high voltage 110 KV electrical overhead lines and the influence on the biological systems,* Proceedings of the 5th International Power Systems Conference, pp. 357-362, Timisoara, 2003.

3. Gh. Hortopan, *Compatibilitate electromagnetică,* Ed. Tehnică, 2005.