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PROCEEDINGS

8th UBT ANNUAL INTERNATIONAL
CONFERENCE

26-28
OCTOBER

UBT Innovation
Campus

INTERNATIONAL CONFERENCE ON
ENERGY EFFICIENCY ENGINEERING



Proceedings of the
8th Annual International Conference

International Conference Energy Efficiency Engineering

Edited by
Edmond Hajrizi

October, 2019

Editor Speech of IC - BTI 2019

International Conference is the 8th international interdisciplinary peer reviewed conference which publishes works of the scientists as well as practitioners in the area where UBT is active in Education, Research and Development. The UBT aims to implement an integrated strategy to establish itself as an internationally competitive, research-intensive institution, committed to the transfer of knowledge and the provision of a world-class education to the most talented students from all backgrounds. It is delivering different courses in science, management and technology. This year we celebrate the 18th Years Anniversary. The main perspective of the conference is to connect scientists and practitioners from different disciplines in the same place and make them be aware of the recent advancements in different research fields, and provide them with a unique forum to share their experiences. It is also the place to support the new academic staff for doing research and publish their work in international standard level. This conference consists of sub conferences in different fields: - Management, Business and Economics - Humanities and Social Sciences (Law, Political Sciences, Media and Communications) - Computer Science and Information Systems - Mechatronics, Robotics, Energy and Systems Engineering - Architecture, Integrated Design, Spatial Planning, Civil Engineering and Infrastructure - Life Sciences and Technologies (Medicine, Nursing, Pharmaceutical Sciences, Psychology, Dentistry, and Food Science),- Art Disciplines (Integrated Design, Music, Fashion, and Art).

This conference is the major scientific event of the UBT. It is organizing annually and always in cooperation with the partner universities from the region and Europe. In this case as partner universities are: University of Tirana – Faculty of Economics, University of Korca. As professional partners in this conference are: Kosova Association for Control, Automation and Systems Engineering (KA – CASE), Kosova Association for Modeling and Simulation (KA – SIM), Quality Kosova, Kosova Association for Management. This conference is sponsored by EUROSIM - The European Association of Simulation. We have to thank all Authors, partners, sponsors and also the conference organizing team making this event a real international scientific event. This year we have more application, participants and publication than last year.

Congratulations!

Edmond Hajrizi,

Rector of UBT and Chair of IC - BTI 2019

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THE PHOTOVOLTAIC SYSTEM AND EFFICIENCY OF DC TO AC BuNa INVERTER

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Abstract. Background/importance of research topic: Solar energy nowadays is considered being one of the renewable resources that has the highest rate of growth.

Purpose/hypothesis (thesis or statement of problem): BuNa inverter efficiently transforms a DC power source to AC source, with better characteristics in comparison with other inverters. The purpose of this inverter is to supply the LED bulbs only with the same power, more efficiently than other inverters.

Procedures/Data/Observations: The input voltage is 12 Volt from battery and output is 220 Volt AC pure sine wave without loads. The consumption of inverter without loads is 0.1 A from battery or 1.2 Watt.

Conclusions/Applications: This type of inverter has many advantages: no electrical shock hazard, protected input from wrong connection, output is protected from short circuit, after disconnected from short circuit the LED bulbs will light again without causing any damage. Moreover, it can be a great device for hospitals, countries without electricity, schools etc.

Keywords: BuNa inverter, electrical shock, LED bulbs, photovoltaic system, short circuit.

Introduction

Using the technology of the renewable power sources is very popular in modern world. One of the most common ways to generate renewable energy is solar energy conversion to electrical power by photovoltaic (PV) panels. The photovoltaic panel is an implementation of photodiode technology developed for gain of the maximum output power out of the solar irradiance.

The photovoltaic modules are the power sources with the large capacitance. The characteristic of the photovoltaic module depends on the irradiance level, the temperature and the value of the output current very much. The photovoltaic module is close to the non-linear voltage source at the lower irradiance levels and non-linear current source at the high irradiance level. Therefore, the maximum power point (MPP) can be achieved only by controlling converter by maximum power point tracking (MPPT) device or control strategy (Jahn, 2003). Energy can be directly and indirectly obtained from solar energy. Serial and/or parallel-connected solar cells form the PV modules. Depending on the semiconductor material of the panel, the PV converts solar energy to electrical energy with 6%-24% efficiency. There are many factors affecting the efficiency of PV panels with low efficiency. These are panel slope angle, shading, temperature, solar radiation intensity, PV temperature, wind velocity, humidity, and other losses (Bholr, 2015). Among these factors, solar radiation intensity, temperature, wind velocity, humidity, and module temperature are the most important parameters affecting panel efficiency. Changes in atmospheric conditions such as solar radiation intensity and temperature during the day considerably affect panel efficiency. Grid-connected photovoltaic systems for potential use in all countries. Small grid-connected systems for use in detached or semi-detached houses are especially promising developments. Also, the energy produced by a grid-connected

photovoltaic system depends on (i) inverter characteristics (yield, working point and operation threshold, define as the minimum required power to connect the inverter to the grid) and (ii) the coupling system to the grid, which depends on the characteristics of the energy produced by the inverter and on grid stability and availability (Chenlo, 1996). Also, in this paper is introduced efficiency of DC to AC inverter. A high frequency inverter operating at a soft switching mode can be constituted without snubber circuits, though its circuit constitution becomes rather complicated. Accordingly, highperformance ,low losses and decreased EMI noise can be attained for the inverter.

Characterization of the photovoltaic panels

In the manufacturer's manual, the nominal power of the photovoltaic modules is referred to standard conditions: temperature of cell equal to 25°C, irradiance to 1000 W/m², and solar spectrum. It is well known that manufacturers classify modules within the same model according to their nominal power referred to standard conditions +/- 5%. As a result, it is difficult to know, in practice, the real installed power and, hence, to quantify the mismatch losses which are due to the dispersion of the module electrical characteristic parameters (Sidrach, 1996). The steps follow to obtain the real installed power have been: (i) measurement, under outdoor conditions, of the characteristic I-V curve for the modules, (ii) correction of the curves to standard conditions and determination of their electrical characteristic parameters, and (iii) following the laws of modules association, determination of both the real peak power installed and the losses due to dispersion of parameters. Summary data are given in Table 1 for standard conditions. The mean value of the power of the modules is 9.4% lower than the nominal power. The standard deviations of parameters are shown in Table 1.

Table.1 Electrical characteristics of the photovoltaic modules under standard conditions

Parameter	Mean	Maximum	Minimum	STD
Short circuit current Isc (A)	3.1	3.2	3.0	0.04
Open circuit voltage Voc (V)	21.5	22.1	21.2	0.22
Peak power Pm (W)	48.1	50.8	46.5	0.93
Peak-power voltage Vm (V)	17.3	17.8	17.0	0.19
Peak-power current Im (A)	2.8	2.9	2.7	0.04
Fill factor FF (%)	71.5	73.5	70.2	0.79

The daily photovoltaic array yield is given by $\eta_{PV} = E_{PV,d}/E_{r,d}$, where $E_{PV,d}$ is the daily energy (kWh) supplied by the modules and $E_{r,d}$ the available daily energy, defined as the daily irradiation on the plane of the array surface during the time when the inverter is connected to the grid. Here,

$E_{r,d} = \sum_{i=1}^n (E_i * C)$ where $C=0$ if the inverter is out and $C=1$ if the inverter is operating ; n is the total number of values recorded daily and E_i the total energy received on the plane of the array surface during one measurement interval. Therefore, $C = 0$ for ' $E_i <$ the inverter threshold' and ' $E_i \geq$ the inverter threshold, while the inverter is disconnected from the grid'. For each month, the mean daily value of the daily photovoltaic array yield is $\eta_{PV,m} = \sum_{d=1}^D \eta_{PV,d}/D$,

where D is the total number of days with data. Similarly, the monthly mean daily inverter yield is $\eta_{inv,m} = \sum_{d=1}^D \eta_{inv,d}/D$, where $\eta_{inv,d}$ is the inverter daily yield, defined as the ratio between the daily active energy at the output of the inverter and the daily energy at the input of the inverter (Sidrach-de-Cardona, 1997). The monthly average daily system yield is

$\eta_{sys,m} = \sum_{d=1}^D \eta_{sys,d}/D$, where $\eta_{sys,d}$ is the daily system yield, computed as $\eta_{sys,d} = E_{grid,d}/E_{i,d}$, where $E_{grid,d}$ is the daily active energy at the output of the inverter and consequently, to the grid.

If the whole incident energy is considered, global yields can be defined. The global photovoltaic array yield ($\eta_{G,PV,m}$) is the yield of the generator, using all the daily energy ($E_{i,d}$) received on the plane of the array surface, that is $\eta_{G,PV,m} = \sum_{d=1}^D (EPV, \frac{d}{E_i}, d)$, where d stands for daily value and m stands for daily monthly average. Hence, the global system yield is computed as: $\eta_{G,sys,m} = \sum_{d=1}^D (E_{grid,d}/E_{i,d})$.

Solar Radiation Effect on Photovoltaics Cells

The energy radiated directly from the sun is 174 petawatt (PW), and 10 PW of it is reflected from the atmosphere, 35 PW from the clouds, and 7 PW from the surface of the earth back into space. The part absorbed by the atmosphere is 33 PW, and the part absorbed by the land and sea is about 89 PW. Solar radiation has the greatest effect on power output in Photovoltaic system. Photocurrent (PV short-circuit current) amplitude varies in direct proportion to solar radiation. Photoconversion efficiency in the practical working range of the Photovoltaic cell is not affected much by changes in solar radiation. However, this does not mean that the same power will be obtained, since the accumulated energy during a cloudy day will be low-i.e., since the input power decreases (output is constant) the output power also decreases. Additionally, the current generated in the PV panel increases with the sunlight intensity and radiation (R. Mayfield, 2012). Although the significant change in radiation considerably changes the current, the voltage remains nearly constant (Fig.1).

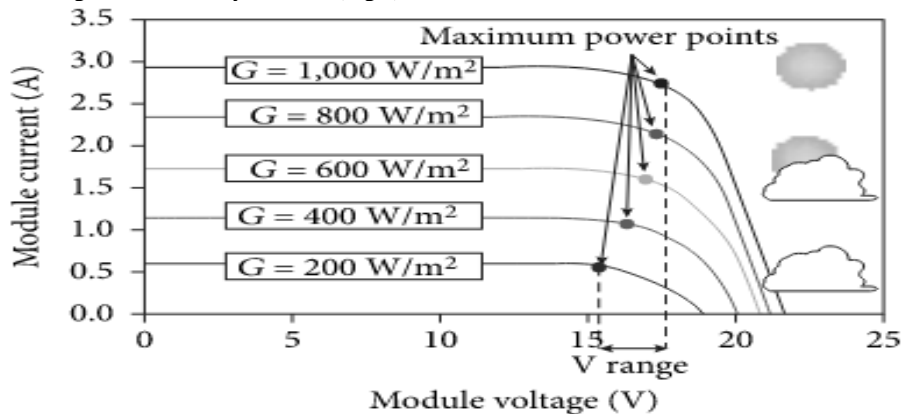


Fig. 1 The effect of solar radiation on PV cells(Mayfield, 2012)

Temperature and humidity effect on PV cells

The operating temperature of the photovoltaic cells varies in a wide range, depending on the various usage areas. Therefore, the effect of temperature on the efficiency of the photovoltaic cell should be known. The photovoltaic cell short-circuit current tends to increase slightly as the temperature increases. The reason is that with the increase in temperature, the semiconductor forbidden gap is reduced and consequently it is increased with radiation absorption (Bilgin, 2013). Because the change in temperature affects the open-circuit voltage more, high-operating temperatures negatively affect power and efficiency in photovoltaic systems. The efficiency of the cell decreases with increasing temperature.

The effect of temperature on the current voltage (I-V) curve of crystalline silicon cell PV modules is shown in Fig. 2. Each 1°C increase in temperature reduces the power obtained by 0.5%. The excess water vapor in the atmosphere causes the radiation to be screened. When the water in the air is condensed in the form of rain and snow, the atmosphere is clearer and the radiation is blocked at the minimum level (K. M. Aksungur, 2013).

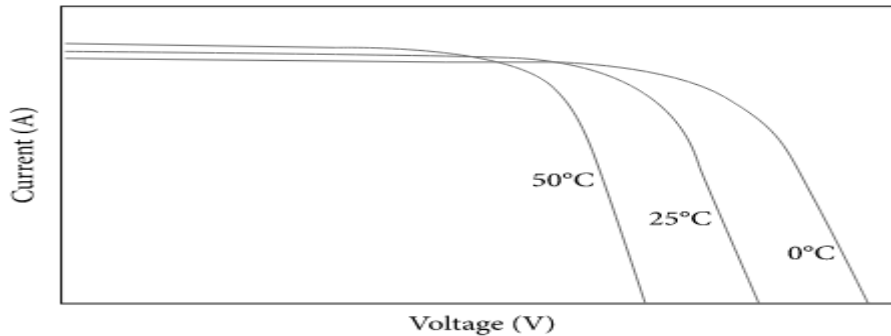


Fig. 2 The effect of temperature on PV cells

Wind velocity effect on PV cells

Weather conditions affect power output in energy production. Module temperature is affected by ambient temperature, cloudiness, wind velocity and position of the photovoltaic system. Since the wind velocity will decrease the temperature of the PV panel, the PV cell temperature is highly sensitive to wind velocity and lowly sensitive to wind direction (Kaldellis, 2014). To increase the efficiency of the photovoltaic panels, generally the methods of Perturb & Observe (P & O), Hill Climbing, Incremental Conductance (IncCond), Fractional VAD, and Fractional IKD are used to monitor the maximum power point of a PV system usually under the same sunshine conditions (Onat, 2009). However, the mentioned maximum power point monitoring methods are the methods that can be applied to homogenous operating conditions, where all of the photovoltaic modules and cells have the same radiation. The rapid changes in solar radiation and the effects of other environmental factors disturb this and reduce efficiency.

Solar Photovoltaic (PV) System Components

Solar photovoltaic (PV) energy systems are made up of different components. Each component has a specific role. The type of component in the system depends on the type of system and the purpose. Fig. 3 shows system components of photovoltaic system.

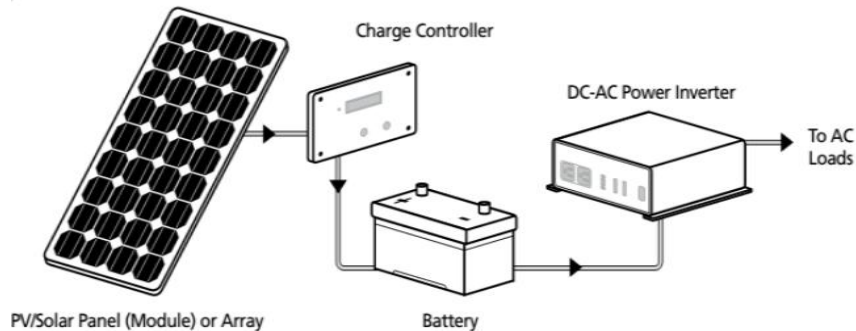


Fig. 3 Block Diagram of a typical off-grid Photovoltaic (PV) System

Solar charge controller

A charge controller or alternatively a charge regulator is basically a voltage and/or current regulator, to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels and going to the battery. Most "12 volt" panels produce about 16 to 20 volts, so if there is no regulation, the batteries will be damaged from overcharging (James and Dunlop, 2012). The obvious question then comes up - "why aren't panels just made to put out 12 volts?". The reason is that if you do that, the panels will provide power only when cool, under perfect conditions and full sun. This is not something you can count on in most places. The panels need to provide some extra voltage so that when the sunlight is low in the sky, or you have heavy haze, cloud cover or high temperatures, you still get some output from the panel, so the panel has to put out at least 12.7 volts under worst case conditions. The primary function of a charge controller is to maintain the battery at highest possible state of charge. The charge controller protects the battery from overcharge and disconnects the load to prevent deep discharge. Ideally, charge controller directly controls the state of the battery. The controller checks the state of charge on the battery between pulses and adjusts itself each time. This technique allows the current to be effectively "tapered" and the result is equivalent to "constant voltage" charging (Samlex, 2014). Without the charge control, the current from the PV module will flow into a battery proportional to the irradiance, whether the battery needs to be charging or not. If the battery is fully charged, unregulated charging will cause the battery voltage to reach exceedingly high levels, causing severe gassing, electrolyte loss, internal heating and accelerated grid corrosion. Therefore, charge controller maintains the health and extends the lifetime of the battery.

Types of solar charge controllers

The two types of charge controllers most commonly used in today's solar power systems are pulse width modulation (PWM) and maximum power point tracking (MPPT). Both adjust charging rates depending on the battery's maximum capacity as well as monitor the battery temperature to prevent overheating (Noor and Ayuni, 2009).

Pulse width modulation (PWM) charge controller

Pulse width modulation (PWM) charge controller is the most effective means to achieve constant voltage battery charging by adjusting the duty ratio of the switches (MOSFET). In PWM charge controller the current from the solar panel tapers according to the battery's condition and recharging needs. When a battery voltage reaches the regulation set point, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery; yet charging continues to return the maximum amount of energy to the battery in the shortest time. The voltage of the array will be pulled down to near that of the battery (Victronenergy, 2014).

Maximum power point tracking (MPPT) charge controller

Nowadays, the most advanced solar charge controller available is the Maximum Power Point Tracking (MPPT). It is more sophisticated and more expensive. It has several advantages over the PWM charge controller. It is 30 to 40 % more efficient at low temperature. The MPPT is based around a synchronous buck converter circuit. It steps the higher solar panel voltage down to the charging voltage of the battery. It will adjust its input voltage to harvest the maximum power from the solar panel and then transform this power to supply the varying voltage requirement of the battery plus load (Victronenergy, 2014). It is generally accepted that MPPT will outperform PWM in a cold temperature climate, while both controllers will show approximately the same performance in a subtropical to tropical climate.

Charge cycle of a charge controller

Most quality charge controller units have what is known as a 3-stage charge cycle as follows:

(i) **Bulk:** In this stage, the battery will accept all the current provided by the solar array. The value of this current will be equal to the Short Circuit Current I_{SC} of the solar array. During the bulk phase of charge cycle, the voltage gradually rises to the bulk level (usually 14.4 to 14.6volts) while the batteries draw maximum current. When bulk voltage level is reached, the absorption stage begins.

(ii) **Absorption:** During this phase, the voltage is held constant (maintained at bulk voltage level) for a specified time (usually an hour) while the current gradually tapers off as the batteries charge up. This is to avoid over-heating and over-gassing the battery. The current will taper off to safe levels as the battery becomes more fully charged.

(iii) **Float:** When a battery becomes fully charged, dropping down to the float stage will provide a very low rate of maintenance charging while reducing the heating and gassing of a

fully charged battery. When the battery is fully recharged, there can be no more chemical reactions and all the charging current is turned into heat and gassing. The purpose of float is to protect the battery from long-term overcharge. After the absorption time phase, the voltage is lowered to float level. This is typically (usually 13.4 to 13.7volts) for a 12V battery and the batteries draw a small maintenance current until the next cycle (Samlex, 2014). The relationship between the current and the voltage during the 3-phases of the charge cycle is shown in Fig. 4 .

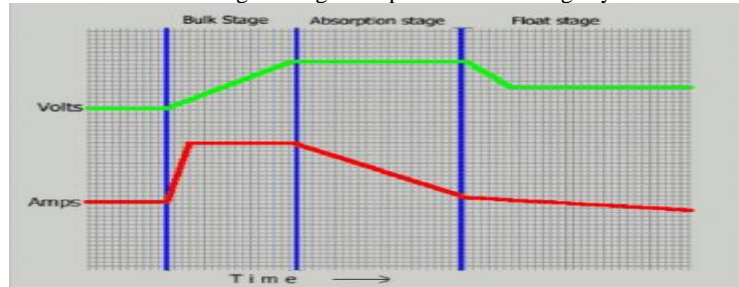


Fig. 4 The relationship between the current and voltage during the 3 phases of the charge cycle

Batteries

Battery is an electrochemical device that converts chemical energy into electrical energy and electrical energy to chemical energy by oxidation-reduction reactions as in Fig.5 .

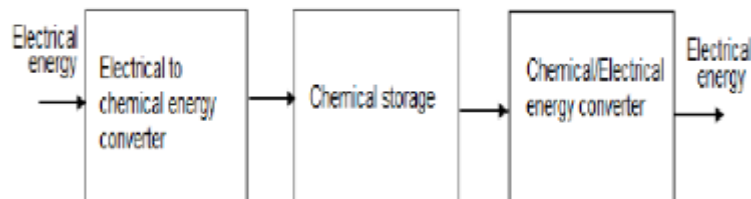


Fig. 5 Principle of battery

Battery parameters

Battery capacity

The storage capacity of the battery is represented in Ampere hour or Ah. If V is the battery voltage than the energy storage capacity of the battery can be $Ah \times V = \text{Watt-hour}$. Usually battery capacity will be specified for a given discharge/charge rating or C rating. The actual capacity depends on operating conditions such as load, temperature, etc.

Battery voltage

The terminal voltage during operating condition is known as nominal voltage or working voltage. This voltage will be specified by manufactures. It may be 2V, 6V, 12V, 24V, etc.

Depth of discharge (DOD)

It gives a measure of energy withdrawn from a battery as a percentage of its full capacity. The state of charge of a battery is the difference between the full charge and the depth of discharge of the battery in percentage. If the DOD is 25% then the state of charge is $(100-25)=75\%$.

Battery life cycle

It is the number of complete charge-discharge cycles a battery can work before the nominal capacity decreases less than 80% of its rated initial capacity. After the specified life cycle, the battery will work with reduced capacity. It can be used but the capacity will be lower.

Types of batteries

Lead acid batteries

Lead acid batteries are the common energy storage devices for PV systems. Lead acid batteries can be either 6V or 12V type in tough plastic container. The batteries can be flooded cell type or sealed/gel type.

Flooded cell type battery

This is the most commonly used type of battery for renewable energy systems today. Flat and Tubular plate type are the versions of flooded batteries. In flooded batteries the electrodes are completely submerged in the electrolyte. During charging of flooded batteries to full state of charge, hydrogen and oxygen gases produced from water by the chemical reaction at negative and positive plates pass out through vents of the battery. This necessitates the periodic water addition to the battery.

Gelled batteries

The addition of silicon dioxide to the electrolyte forms a warm liquid which is added to the battery and becomes gel after cooling. The hydrogen and oxygen produced during charging process are transported between positive and negative plates through the cracks and voids in the gelled electrolyte during the process of charge and discharge (DivyaK.C, 2009).

Inverter

Inverter changes DC input to a symmetric ac output voltage of desired magnitude and frequency. The output frequency is calculated by switching on and off the semiconductor devices by control circuit. The output voltage of an inverter is fixed or variable at fixed or variable frequency. By varying the input DC voltage and maintaining gain of inverter constant we can get variable output voltage. Selection of inverter is depend upon following factors: (i) Current rating, (ii) Voltage rating, (iii) Power handling capacity (Vijaya, 2012). For low power application the half bridge inverter can be selected and for high power application the full bridge inverter can be selected.

Design of single-phase full bridge inverter

Frequency=12kHz

(i) Switching period: $T = \frac{1}{f} = \frac{1}{12 \times 10^3} = 83 \mu\text{s}$

(ii) Maximum duty cycle is: $t'_{on}=0.5*T=41.5*10^{-6}s$

(iii) $D_{max}=0.9*\frac{t'_{on}}{T} = 0.45$

Primary turns: $N_1=30$ Turns, Secondary turns: $N_2= 300$ Turns.

Calculation of the core Geometry Transformer:

Select ETD 59/31/22 Ferrite Core Transformer $K_g=(w_A*A_c^2*K_u)/(MLT)$, where K_g is the core geometrical parameter constant, w_A is core window area, A_c^2 is cross sectional area and MLT is length per turn. So for this transformer are this parameters: $w_A=5.17cm^2$, $A_c=3.68cm^2$, $MLT=13.9cm$, $K_u=0.2$.

$K_g=(5.17*(3.68)^2*0.2)/(13.9)=1.007$.

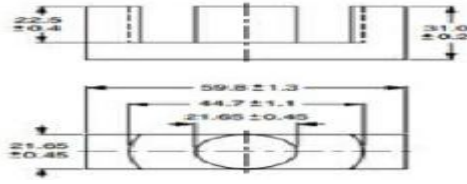


Fig. 6 ETD Core 59/31/22

Skin depth: $\sigma = \frac{6.62}{\sqrt{f}} = 0.06$

Resonant circuit

In RLC series circuit the resonance is occur when the capacitive and inductive reactance are equal in magnitude. When resonance occur the amount of energy stored in inductor is transferred to capacitor and capacitor transferred the energy to inductor, so total energy stored in circuit remains same. At condition of resonance in RLC circuit the resonance frequency is $f_0 = \frac{1}{2\pi\sqrt{LC}}$. The primary inductance is $L_{prim}=20\mu H$ so at 10kHz $L_{coil}=65\mu H$ (Grandi G and Kazimierczuk, 2004).

Waveform of output voltage of BuNa inverter

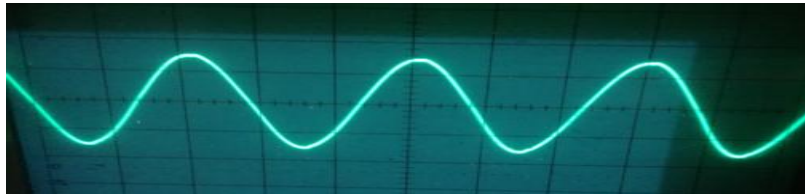


Fig. 7 Output waveform of BuNa Inverter

Conclusion

One of the biggest problems in photovoltaic panel applications is that they are not cost-efficient in the initial installation stage. Despite serious declines in recent years, the amount of energy these systems generate is not high compared to the plant costs. The amount of electric energy produced by photovoltaic panels depends on air temperature, humidity rate, wind velocity and photovoltaic module temperature, and particularly solar radiation. Also, it is concluded that this inverter has many advantages: no electrical shock hazard, protected input from wrong connection, output is protected from short circuit, after disconnected from short circuit the LED bulbs will light again without causing any damage. It is tested for 5 LED Bulbs with 6W

(5*6W=30W) input current from 12V battery is 2.1A/h. Other types of inverter draw from battery 7.5A/h or more.

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Energy Performance Certificate – Belgium-Wallonia example

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Abstract. The Energy Performance Certificate (EPC) is based on following EU Directives: The EU Directive 2010/31/EU of 19 May 2010 on the Energy Performance of Buildings (amended by Directive 2018/844 of 30/05/2018) requires the Member States, the establishment of a measurable system of Buildings Energy Performance (BEP) or a Certification of Energy Performance (CEP). This Directive requires that each EU member state must set up a specific calculation method to achieve the BEP requirements and to certify the energy performance of buildings.

The energy efficiency EU Directive 2012/27/EU of 25/10/2012, in particular the article n°5. The EU Directive 2009/28/EC of 23/04/2009 on the use and promotion of the energy produced from renewable sources.

The PEB certificate expresses the energy performance of a PEB unit (public buildings, residential and industry buildings, apartments, etc...) by means of several indicators such as energy class, global and specific consumption of primary energy, renewable energy, CO2 and other greenhouse gas emissions and contains recommendations for improvement.

The Belgian Energy Performance Certificate is the perfect example helping Belgium as a Member State to achieve its energy efficiency targets. It can inspire the authorities in Kosovo, whose ultimate goal is to join the EU, to prepare the legislation that would incorporate the entire EPC in the procedures for new construction or renovation of buildings. This would be one much appreciated way to prepare at best to reduce greenhouse gas emissions and improve the energy performance of the residential, tertiary and public buildings in Kosovo.

Keywords: Energy Performance Certificate, Energy Efficiency, European Directive, Belgium

Introduction

The certification of Buildings Energy Performance (BEP)

The certification of the building energy performance (BEP) consists in evaluating globally and according to a defined calculation method, the energy performance of a building.

The European Directive 2010/31/EU requires from member states to adopt a lot of measures to improve the energy performance of buildings:

- establish a calculation method
- define the BEP requirements for buildings to be built (new buildings) or renovated (old buildings)
- organize the certification of BEP during the construction, sale or rental as well as to display the issued certificate for public buildings only;

Advertisements for sale or rental must mention the energy performance of buildings, so that prospective purchasers or tenants can compare the energy performance of goods placed on the market.

What are the main goals?

- Climate and energy package 2020 (adopted in 2009): -20% greenhouse gas, + 20%, renewable energy, + 20% energy efficiency compared to 1990
- Framework for Climate and Energy 2030 (adopted in 2014): -40% greenhouse gas, + 27% renewable energy, + 27% energy efficiency compared with 1990
- Low carbon economy roadmap: -80 to 90% greenhouse gases by 2050 (60% in 2040) compared to 1990

The EPC (Energy Performance certificate) assesses the Energy Performance of Buildings (EPB) under standardized conditions of use and climate. The applicable calculation method evaluates the performance of the building envelope (thermal insulation) and systems (heating, domestic hot water, ventilation ...).

Some important EPB notions and definitions

(The decree of 28/11/2013 relating to the energy performance of buildings = "EPB Decree" – transposition into the Wallonia EPB Directive)

- **energy performance of a building (EPB)** (Art 2, 1): quantity energy actually consumed or calculated to meet the different energy needs related to a standardized use of the building, which includes, among other things, the energy used for heating, domestic hot water production, the possible cooling system, ventilation and lighting;
- **building** (Art 2, 2): any construction with a roof and walls in which energy is used to regulate the indoor climate;
- **total usable area** (Art 2, 12): sum of the surfaces of the different levels of the building calculated between the external walls or walls; the thickness of these walls or walls is not taken into account in this sum;
- **protected volume** (Art 2, 13): volume of all spaces of a building which is protected, from the thermal point of view, from the external environment (air or water), soil and all adjacent spaces;
- **envelope** (Art 2, 14): all the walls of the building which determines the protected volume;
- **System** (Art 2, 15): technical equipment for heating, cooling, ventilation, domestic hot water production, lighting, electricity generation or combining several of these functions;
- **primary energy** (Art 2, 18): energy from renewable and non-renewable sources which has not undergone any process of conversion or transformation;
- **energy performance certificate (EP certificate)** (Art 2, 22) : a certificate recognized by Europe (Wallonia) which indicates the energy performance of a building or building unit calculated in accordance with the predefined calculation method;

EPC (Energy Performance Certificate) - definitions

The EPB certificate expresses the energy performance of EPB unit (public buildings, residential buildings, apartment, industries etc...) by means of several indicators such as energy class, total and specific consumption of primary energy, renewable energy, CO₂ and other greenhouse gas emissions, etc. and contains recommendations for improvement.

The obligation to mention the EPB indicators in the sales and rental advertisements makes it possible to provide the best information to prospective purchasers or tenants.

The EPB certificate is a document that allows to determine the amount of consumed or estimated energy in normal building use conditions.

The indicators mentioned in the EPC report make possible to compare the energy performance of the various buildings with each other, and therefore the energy cost for the same use as well as their CO₂ and other greenhouse gases.

The most important indicators mentioned in first page of the Certificate:

- performance level expressed in kWh/m² x an
- annual CO₂ emissions expressed in kgCO₂ / m² x year
- histogram of consumptions/productions over 3 years
- the label of global energy performance
- the recommendations
- the entered data

If sale, leasing, rental or advertising: buildings **must** have and/or display their Energy Performance Certificate.

The EPC is valid 5 years. An annual update is required (only the energy consumption data, Art. 52.).

Scope of the EPC

Public Buildings

WHEN should we have a BEP Certificate?

- All Buildings with a total usable area of more than 250 m² occupied by a public authority and frequently visited by the public must be certified.
- The public authority must display the EPC in a way that is legible and visible to the public, except for the part relating to recommendations.
- The Government determines under which conditions a building is considered frequently visited by the public.

A building is **frequently visited** by the public when its public access is free without conditions other than a possible inclusion of payment or of an entrance fee/ticket. (Art. 51.)

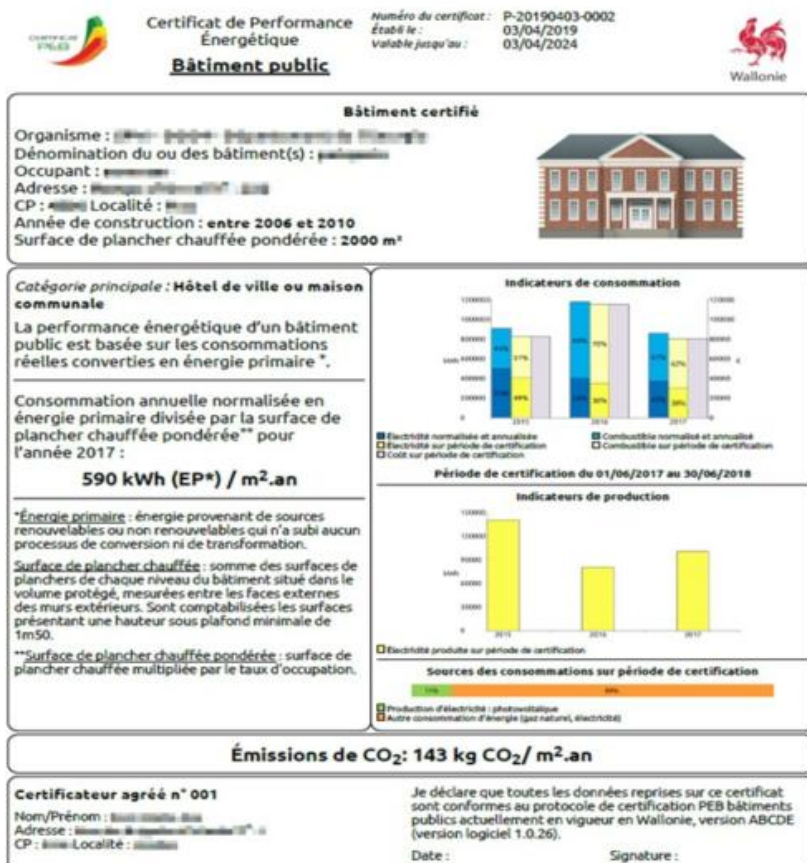


Figure 1: Example of EPC (public building)

WHO are the public authorities?

- federal authorities, regional authorities, community authorities, provincial authorities, municipal authorities, public interest organizations, public or private legal entities offering public services, (ex: intermunicipal public bodies, CPAS, police zone, emergency zone, ...), NGOs offering public services or associations formed by one or more public authorities or similar, European institutions, International organizations...Extensive list of occupancy categories where 100% of the building area is considered as frequently visited by the public:
- Municipal Offices or Town Hall, Parliament, judicial or administrative jurisdiction, Nursery home, Hospital - health centre or similar services, Rest home – revalidation - care or similar services, Museum, theatre, cultural centre, Library - media library or similar services, Detention centre - penitentiary centre - Prisons or similar services, school, Sports Centre, Swimming pool, Train or Bus Station.

Exceptions:

- PEB units used as a place of worship for religious activities or to provide moral assistance in a confessional or philosophical conception;
- industrial units, workshops and agricultural non-residential units, which are very low energy consumers;

Non Public Buildings

WHEN should we have a BEP Certificate?

- The BEP certificate is mandatory only in case of sale & rental. An exception is when the building is acquired for demolition. In this case, the acknowledgment of receipt of the demolition permit application must be attached to the agreement of sale.
- The PEB certificate must be established BEFORE the sale or lease, in order to respect the obligations related to advertising:
- All kinds of sale & lease advertising and displays must MENTION the energy performance of building offered for sale or lease.
- The PEB indicators to be mentioned in advertisements are extracted from the PEB certificate:
 - the unique code which is the identification number of the EPC
 - total primary energy consumption, in kWh per year
 - the specific consumption of primary energy, in kWh / m² per year
 - the energy class or "label" (table 1 below)

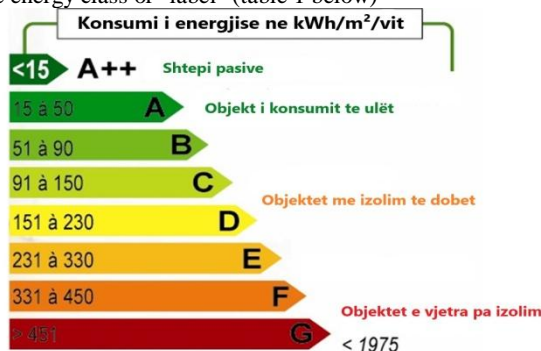


Table 1: Energy consumption label

- The PEB certificate must be communicated to the purchaser in original form or to the tenant (copy of the certificate) BEFORE the signing of the agreement of sale or lease. The agreement must mention the completion of this formality.

HOW to obtain an EPC and WHO can deliver it?

The EPC must be delivered by specialized and licensed persons who establish the EPC according to a specific calculation method.

License conditions (art 42):

- must have a degree or diploma : energy engineer, architect, architectural engineer, civil engineer, bio-engineer, industrial engineer, energy manager, graduate in construction, or have at least two years of experience in the energy managing of buildings;
- have completed certification training and achieve successfully a final exam;

The certifier's role:

- ensure the reproducibility of the on-site data collection process and their encoding in the ECUS software which consists to use a specific standardization protocol;
- complete and follow strictly the regulatory texts to reduce the risk of personal interpretation by the certifier.

The specific tools to accomplish his mission:

- the ECUS software: a mandatory online tool to encode information and generate the certificate;
- the protocol: includes the rules relating to the collected data and their integration into the ECUS software.

Sanctions:

- the absence of a PEB certificate valid at the time of sale or rental is sanctioned by a flat-rate administrative fine in the amount of 1,000 €.
- the non-respect of the obligation relating to the publicity is sanctioned by a flat-rate administrative fine of 500 €
- failure to comply with the obligation relating to the transmission of the PEB certificate is sanctioned by a flat-rate administrative fine of 500
- Sanctions aimed at the certifier (Art 54):
 - When a EBP certifier fails to fulfil his obligations, the Government may sanction him by suspending or withdrawing its license.

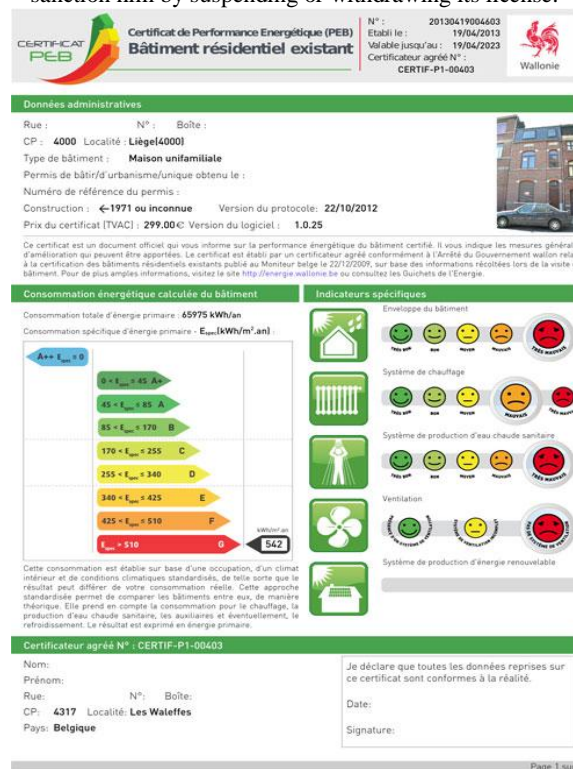


Figure 2: Example of EPC (residential building)

Conclusion

The Belgian Energy Performance Certificate as a perfect example helping Belgium as a Member State to achieve its energy efficiency targets, can inspire the Kosovo authorities whose ultimate goal is to join the EU, to prepare the legislation that would incorporate the entire EPC in the procedures for new constructions or renovation of buildings.

The EPC Belgian-Wallonia case could be perfectly integrated into Kosovo's energy legislation. Beginning from the moment when the Urbanism Permission is submitted, the EPB indicators would be included in the new construction projects. For the existing buildings, the EPC display must be mandatory for public buildings in order to set an example for industries and residential buildings to follow this example.

This would be one much appreciated way to prepare at best the Kosovo to reduce greenhouse gas emissions and improve the energy performance of the residential, industries and public buildings in the youngest country of Europe.

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Project Proposal for the Picoidraulica Laboratory

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Abstract. This project-oriented work, is a pre-feasibility study of a pico-hydraulics plant, which has to be installed on an appropriate structure in UBT- University for Business and Technology at Pristina, the capital of Kosovo. It begins with the structural analysis of the designed laboratory, moving on through to the technical-economic study of the individual components, concluding with the definition of its effectiveness, based on the actual data of the plant. The purpose of the plant comes from the idea of fully exploiting the energy available in a public building, with special regard to what is daily discarded without being exploited. It will be analyzed the feasibility and the convenience of the recovery of the grey water potential energy from buildings of considerable height (100 – 200 meters) through a hydraulic turbine.

Keywords: Energy Efficiency, Pico Hydraulics, Green Energy, Architecture and Design, Reduction of Carbon Dioxide Emissions, Water Consumption Management.

Introduction

Architectural and engineering studies are increasingly involved in the design of so-called sustainable skyscrapers: structures that combine the high density of urban centers with the need to contain the energy needed and the integration of renewable energies.

"The densest cities, with less suburban development, fewer roads and more public rail transport, are the only solution to support the impact of the rapid turbulence of the population," says Ken Shuttleworth, an English engineer who, along with Norman Foster, realized the Gherkin (the seventh highest building in London), the new City Hall, the Millennium Bridge and still directs London towards the so-called "vertical design". Building vertically means to reduce soil consumption and this in itself is an element of sustainability. But the height is not enough to declare the low environmental impact of a structure. Skyscrapers, due to their size, are very complex structures, and to ensure high energy performance, become necessary a close collaboration between architecture and engineering.

With the adoption of the European Directive (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 which amends Directive 2010/31 / EU on energy performance in buildings and Directive 2012/27 / EU on energy efficiency, the new EPBD - Energy Performance Building Directive, it was introduced the concept of "Nearly Zero Energy" for new (or even old) public or private buildings. With nZEB - Nearly Zero Energy Buildings – that means highly energy-efficient buildings characterized by very low or almost zero power requirements that have to be significantly covered by energy from renewable sources. Particularly interesting is EPBD art. 9, which states that all newly constructed buildings from December 31 in 2020 are almost zero, while for public buildings the deadline is anticipated on the 31 of December in 2018.

P60 – nZEB for the UBT

The central subject of this study will be the construction of the laboratory of a P 60 nZEB, a 60 floors structure with renewable energy systems, low impact technologies and a complete energy efficiency. This structure will be located in Prishtina, Kosovo, particularly within an area of the Campus UBT, University of Business and Technology: the aim of the final project is to test the possible energy independence of this area through the use of renewable sources and technologies with almost zero impact. The technology introduced is Pico Hydraulics system, a technology for the exploitation of hydroelectric potential of grey water to produce electricity. This energy transformation system, introduced in the P60 buildings, aims at achieving three fundamental objectives: the first is the energy recovery of the water supply of the building, the second is the reduction of CO2 emissions, and the third is the reduction of primary energy consumption from the network, planning to build in the same university area also a photovoltaic PV creating a smart grid with the building.

This study, reported in the following chapters, deals with the preliminary laboratory phase: it consists in describing the design choices and in the analysis of the components of the simulation structure of the plant with final design and economic feasibility study.



Fig. 1. The Gherkin, London

Pico Hydraulic Plant

Purpose of the residential hydroelectric plant

The purpose of the plant comes from the idea of fully exploiting the energy available in a public building, with special regard to what is daily discarded without being exploited. It will be analyzed the feasibility and the convenience of the recovery of the grey water potential energy from buildings of considerable height through a hydraulic turbine.

Storage system analysis

In order to overcome any problems linked to the structural resistance of the residential floor and at the same time maximize the electricity production, an innovative configuration of the hydroelectric plant has been devised. This provides two types of storage tanks: secondary tanks and a primary collector.

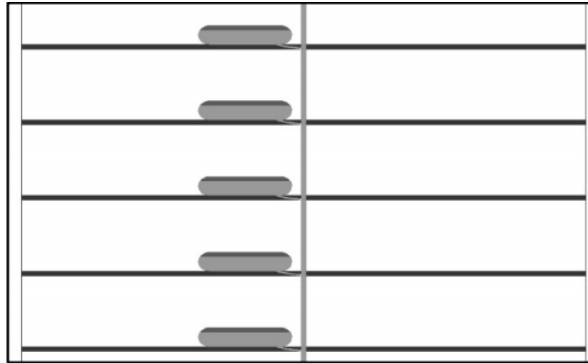


Fig. 2. New type of storage tanks

The first are placed on each floor of the building, with the exception of the first ones that are too low and have a capacity of 450 liters, the other is a single vertical cylindrical tank having a diameter comparable to that of the exhaust pipe of the gray water, closed below this by a valve. The latter, controlled by the electronic control unit, regulates the opening and closing of the connection between the primary tank and the Pelton turbine distributor. Other valves are required on each floor, placed between a secondary tank and a primary, as well as a filter that is laid out in each floor to remove the impurities from the gray water that will accumulate in the secondary reservoir. This type of plant has the obvious advantage, beyond the feasibility, of maximizing the flow of turbine liquid: it will in fact contribute to the gray water of each floor of the building (excluding the first ones for a reason related to low potential energy) and not only those placed above a large reservoir, as previously thought.

The laboratory

Starting from a preliminary description of the studied structure, we examine in detail each component necessary for the life simulation cycle of the P60 structure. With subsequent energy analyzes, the feasibility criteria of the laboratory are reported and the economic weight of the possible implementation is determined.

Structure

Elevating small laboratories at different rates, how many are the plans of the building in question, it is evident that it would be complicated and difficult, both in terms of construction itself and economically. As a result, it is decided to create a single, smaller size structure that can estimate the reliability of the total plant.

It is a simple and practical configuration that can highlight problems arising from a continuous flow of the turbine water, and thus simulate the life cycle of the building over a given period of time. Consider the following closed simulation system (see Figure 3):

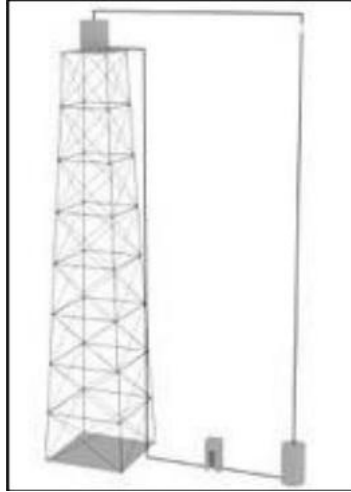


Fig. 3. System Work Simulation System P60 obtained using the Rhinoceros 3D application software

Components and devices:

- Tanks A:
 - Material: PVC (type NANA 3000S);
 - Capacity: 3000 l;
 - Diameter: 1650 mm;
 - High: 1720 mm.
- Tanks B:
 - Material: PVC (type CLYVER 3000S);
 - Capacity: 3040 l;
 - Diameter: 1450 mm;
 - High: 2520 mm.
- Pipe/conducts C:
 - Material: Polyethylene;
 - Section diameter: 80 mm.
- Turbine-generator unit and technical compartment (D);
- Submersible Electropump in sommersione (inside B) (E);
- Lifting work chosen.

The main aim pursued for the design of this laboratory is to optimize energy, in order to minimize installation and management costs. The selection of the best turbine for each particular hydro site generally depends on the features of the site itself: the dominant factors are the head available and the power required. This selection also depends on the speed at which the generator or other devices driven by the turbine.

In this case, the features considered are:

Table 1. Characteristic of the lab.

Structural characteristic of the lab	Characteristic of the device to fed
Available head $H=25\ m$	Power required by the pump

Pump

With the ideal goal of creating an auto-efficient system, the first energy analysis concerns the pump.

The best configuration that minimizes the H_p prevalence of the machinery, is characterized by the presence of reservoir tank downstream of the turbine. Within the same reservoir, it was assumed to place an electric pump to further reduce leakage.

This component brings the fluid into a quiet state, thereby eliminating the losses that would have occurred at the suction with the fluid at high speeds.

It is more advantageous not to take into account the high concentration losses due to the strong impact on the outlet and at the entrance of the two machines, considering the high kinetic high of free falling water.

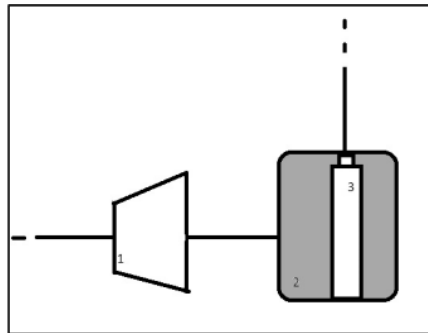


Fig. 4. Reservoir tank downstream of the turbine

Here are the calculations made and the values of the parameters considered for estimating the hydraulic loads in inlet and outlet of the pump:

- Hydraulic load outlet:

$$H_{2 \text{ mand}} = \frac{P_{atm}}{\rho g} + \frac{V_2^2}{2g} + z_2 + \Delta H_2 \quad (1)$$
- Hydraulic load inlet:

$$H_{1 \text{ asp}} = \frac{P_{atm}}{\rho g} + \frac{V_1^2}{2g} + z_1 + \Delta H_1 \quad (2)$$

Table 2. Factors for calculating the hydraulic loads in suction and delivery

Inlet/Suction		Outlet/Delivery	
$z_1 = 0$		$z_2 = 25 \text{ m}$	
$P_1 = P_{atm} = 10^5 \text{ Pa}$		$P_2 = P_{atm} = 10^5 \text{ Pa}$	
$V_1 = \frac{Q}{\pi \frac{D^2}{4}} = 1 \text{ m/s}$	$Q = 5 \text{ l/s}$ $D = 8 \text{ cm}$	$V_2 = \frac{Q}{\pi \frac{D^2}{4}} = 1 \text{ m/s}$	$Q = 5 \text{ l/s}$ $D = 8 \text{ cm}$
$\Delta H_1 = \Delta H_{1 \text{ distributed}} + \Delta H_{1 \text{ concentrated}}$		$\Delta H_2 = \Delta H_{2 \text{ distributed}} + \Delta H_{2 \text{ concentrated}}$	

It follows that the value of the prevalence, that is, the maximum lifting difference expressed in meters is:

$$H_p = H_2 - H_1 = 25 \text{ m} \quad (3)$$

Known this parameter, the characteristics of the submersible pump that best meet the needs of the laboratory have been evaluated, Submersible electropump SERIES S4 della DAB PUMPS.

Table 3. Constructive characteristics of the electropump

Technical data		
Rated power required: 3 kW		
Minimum fluid temperature: 0 °C		Maximum fluid temperature: 40 °C
Rated flow rate: 5,5 l/s	Rated head: max 31 m	Efficiency 52 %

Table 4. Constructive characteristic of the motor

Technical data			
Rated power: 3 kW	Rated voltage: 400 V (Trifase)	Rated current: 7,9 A	Frequency: 50 Hz
Power factor: 0,73	Efficiency: 75%		Functioning with the inverter: Allowed-min 30 Hz.
Number of poles: 2		Rated velocity: 2840 rpm	

Characteristics of the electric devices:

- Electronic control panel for motor protection, control and command with direct starting;
- Electric accessory for command and control: Active Driver Plus.

Turbine-generator unit

On the one hand, with the aim of balancing the structural requirements of the laboratory (exploitable head) and, on the other hand, with the external imposition of the devices powered by the turbine (in particular the power of the pump), the choice of the machine group fell on the following set:

- Turbine Group - ECOWATT Generator (IREM Module TPD24 / www.irem.it) Composed of:

Table 5. Micro Pelton turbine: main characteristics

Technical data		
Type: Pelton		Type blades: Blades fixed to the disk by TIG welding
Useful head: 25 m	Flow rate used: 3 l/s	Material: Steel INOX AISI 316L (type 24-75)
Generated electric power: 350 W	Rated voltage: 24 V (DC)	

Table 6. Generator (type.G503/B)

Dati tecnici			
Type: Synchronous with permanent magnets	N° Poles: 8	Out voltage: 3-phase 18-20 Vca (260 Vca)	Rpm: 2500/3000
Protection level: IP54	Full load efficiency: 0,8		
Insulation: Class F	Bearings: Stagni (tipo 6204 2 Z)		
Operating position: Vertical	Electric power: 500 W		
Ventilation: Natural			

The characteristics of other devices are here omitted; there are:

- Turbine-generator housing;
- Power supply unit;
- Electronic regulator with heat dissipation in the air.

Lifting work

In order to have an available head exploitable by the hydraulic turbine of the value of about 25 meters, two alternatives for lifting the tank have been evaluated. Use existing buildings or hills on the university campus. Construction of a permanent tower with support platform at the top. The first option would be the most risky from the point of view of security: the positioning of the tank system and piping on the top of a pre-existing structure could go undo its normal operation. Incidental events such as water leakage from piping with consequent flooding or mechanical stress given by the weighing of the plant would cause enormous damage, especially since the facilities inside the campus are mainly equipped with very delicate electronic machinery and equipment subject to easy deterioration. On the other hand, the simple placement of the tank would only require lifting costs, by crane machinery in the order of a few hundred euros. The second option presents the evaluation of two technologies compared: - Steel tower on reinforced concrete foundation - Tower and foundation in reinforced concrete with burglars. As opposed to the first, this alternative for both technologies has high construction costs: the cost is around € 25,000, considering both the foundations and the structure. This is a preliminary estimate as, for the construction of that type of works, a soil study is required, with a geological and geotechnical report that may highlight weight incurrence problems: the possible design of piles, due to the presence of clayey or friable terrain obviously represents an additional burden.

5. Work cycle

The previous analysis of the components of the laboratory was not based on the concept of continuous flow: the type of work cycle that is considered is the intermittent cycle based on the charge-discharge of the reservoir upstream of the turbine:

- The drainage takes place with a tank discharge time equal to:

$$t_{svuotamento} = \frac{3000 \text{ l/s}}{3 \text{ l/s}} = 16,7 \text{ min (4)}$$

- The charging take place with a tank filling tima equal to:

$$t_{riempimento} = \frac{3000 \text{ l/s}}{5 \text{ l/s}} = 10 \text{ min (5)}$$

This is a particularly advantageous solution both from an energy point of view and from the point of view of the life of the turbine itself. In this way, it is not necessary to balance the flow rates and powers of the plant machinery, but mostly, the stresses to which the turbine is subjected are not dynamic due to a frequent load, but are cyclic-static, resulting in a lower risk of damage to all shaft or other parts of the machine, ensuring a longer working life.

Cost analysis

The following economic assessment analyzes the cost of realizing and installing each alternative considered.

Table 7. Pump and annexes devices

Component	Price €
Submersible electropump SERIES S4	€ 821,00
Electric panel for protection/control/command	€ 258,00
Active Driver Plus	€ 60,00
TOTAL	€ 1.139,00

Table 8. Turbina-Generator unit e annexes devices. Certification of IREM: based on standard ISO 9001, ISO 14001, BS OHSAS 1800

Component	Price €
Turbine-generator unit ECOWATT	€ 3.550,00
Electronic regulator with heat dissipation in the air	€ 1.380,00
TOTAL	€ 4.930,00

Table 9. Polyethylene reservoir tank

Component	Price €
Tank (A)	€ 950,00
Tank (B)	€ 1.100,00
TOTAL	€ 2.050,00

Table 10. Pipe and conducts

Component	Price
Pipe in PVC of D= 80 mm	5,78 €/m
Connection cruve 87° in PVC of D=80 mm	2,67 €/pezzo
Therefore, considering a total length of pipes of about 52 m, and 4 connection curves:	
TOTAL	€ 310,67

Table 11. Lifting work

Alternative	Price €
(1)	Intorno ai € 400
(2)	€ 25.000,00
Laboratory plant	Total price € 8.500,00
+ Lifting work chosen	+ Price of the option chosen

The results are a general cost of the simulation system of € 8,496.00, to which the additional weight of the option chosen for the lifting work must be added.

Conclusions

This work describes the design of the picohydraulics laboratory to be realized at UBT, in an area located in the university campus.

Summing up the considerations made above, the project provides:

- The construction of a picohydroelectric plant consisting of the basic mechanical components described above and related electrical control devices;
- The possible creation of a supporting structure for the tank at high altitude.

With regard to energy sustainability, the future wastewater recovery plant will certainly be more interesting if integrated with other renewable technologies. Following the energy analysis of the planned plant, the "PV-pico hydroelectric" connection is convenient, providing the energy needed to cover the energy delta between the output power available from the hydraulic turbine and the greater input power consumed by the pump to close the cycle.

This project has low implementation and maintenance costs, due to the particular type of "intermittent" lifecycle assumed, so that the lifetime is significant, considering the low risk of damage of the machinery.

In conclusion, the plant described above can boast a high level of reliability and safety combined with limited implementation costs.

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Reformed Methanol Fuel Cells: Proposed Plant for Vehicular Applications

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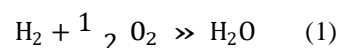
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Abstract. Among the various possible applications for a reformed methanol fuel cell, in addition to the portable generation in remote areas and military use, the use in the automotive field is interesting and promising. RMFC is used as "range extender" in battery-powered electric vehicles. This would increase the driving autonomy of the electric vehicle making it no longer strictly dependent on the capacities of today's batteries, eliminating the problems associated with them, such as the battery pack weight and overall dimensions. Besides, they need for recharge to short-term and are characterized by very high hazard in the event of a car accident (today's lithium ion batteries - if heavily damaged - tend to generate fires difficult to extinguish). In this paper the possibility to design and realize an onboard plant has been studied and evaluated. The various characteristics of the cells are analyzed and a first preliminary system is studied in all its components. The next steps, in addition to optimizing the plant, will be to evaluate the economic feasibility and the various systems of methanol supply.

Keywords: RMFC, onboard power plant, range extender, thermal feasibility, energy efficiency, reduction of carbon dioxide emissions.

Introduction

The H₂ fuel cells was initially presented in 1843 by sir William Grove, published in the December 1838 edition of The London and Edinburgh Philosophical Magazine and Journal of Science. This technology has become immediately of interest for the possibility of producing energy in a continuous and high efficiency way. Moreover, the H₂ can be produced through different renewable processes. The most common hydrogen fuel cells are of Polymer Electrolyte Membrane (PEM) type. In these devices, the hydrogen and oxygen react by generating water and electricity, which can be used for specific functions. A PEM fuel cell consists of two electrodes, the negative anode and the positive cathode, separated by a membrane (PEM) that only allows the transport of positive ions. Hydrogen is supplied to the anode where it is distributed through a Gas Diffusion Layer (GDL). The anode is composed of metals that act as a catalyst (usually platinum) which facilitate the separation of molecular hydrogen into ions. The positive hydrogen ions migrate through the membrane until they reach the cathode, where they react with oxygen, supplied or in the form of pure O₂ molecular oxygen or air. The reaction is catalyzed by the cathode and produces water (see figure). The overall operation reaction is:



As shown in Figure 1, the PEM membrane, anode and cathode and GDL are combined into the Electrode Assembly (MEA) membrane. The latter is compressed between two bipolar plates that

serve as conductors for electrons, so that they can flow between contiguous cells, but also as a field flow that distributes the reagents on the GDL. Usually the bipolar plates are graphite-polymer composite made. The assembly of the various parts of the cell in a single component allows reducing the space occupied and maximizing the efficiency. There are two types of PEM fuel cells:

- high temperature PEFC (HTPEFC);
- low temperature PEFC (LTPEFC).

The main difference is that LTPEFC operate at temperatures below 100°C and their membranes, in Nafion, need to be constantly humidified by water. HTPEFC operate at temperatures above 100°C and the membrane is Polybenzimidazole (PBI) made, doped with phosphoric acid. As they do not require cooling or dehumidification, the main advantage is the high tolerance to impurities such as CO. The CO is a poison for catalysts, due to the high selectivity of the membrane against the H₂. The disadvantage is that they need to be heated up to the operating temperature before they can be considered "enabled" and, generally, their efficiency is lower than the LTPEFC.

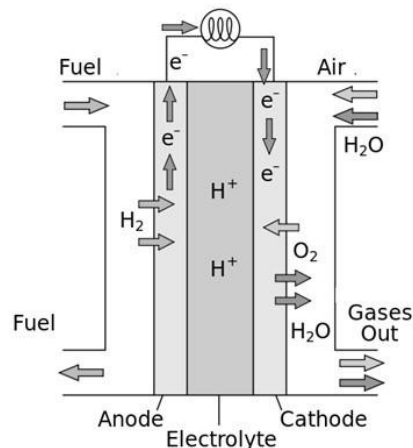


Fig. 1. Hydrogen fuel cells structure

A fuel cell typically has a maximum voltage of about 1V in open circuit conditions. However, the voltage decreases as the cell current density increases (see figure 2). In the case where the cell is used in applications where the electric load is not constant, for example in the automobile field, it requires intervention to mitigate this problem. In fact, a load increase would lead to a current increase, necessary to maintain the voltage at nominal rate. Excessive load leads to a voltage drop that stops the cathodes reaction and, then, blocking the operation of the cell. Considering that is not possible to increase the cell surface too much, to produce more current, the energy efficiency is increased by placing more fuel cells in series. In addition, to avoid any energy demand peaks, the cell works in parallel with a DC battery, that is recharged at low level and discharged at high power demand.

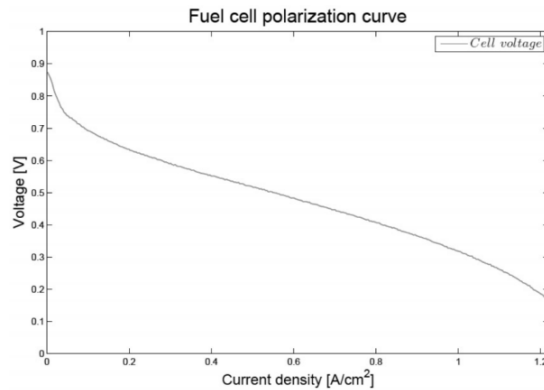
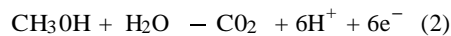


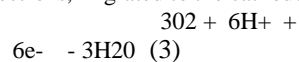
Fig. 2. Polarization curve Hydrogen

Direct Methanol Fuel Cells DMFC

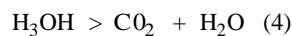
Continuous research into alternative energy generation methods has led to the development of other types of fuel cells which. These devices use a different fuel or ion exchange systems, but, do not differ from the PEMFC for the operating principles. In this scenario, the fuel cells with direct methanol can be considered. A DMFC (Direct Methanol Fuel Cell) operates at temperatures between 70 and 100°C and is directly powered by CH₃OH, oxidized electro-chemically to the anode [6.7.8]. The possibility to use, as fuel, directly in the cell, makes DMFC particularly suitable as portable generators. In this case, the methanol is not pure, but it is present in a mixture containing water. The water is necessary to initiate and develop the anodic oxidation reaction. The methanol/water mixture can be used as refrigerant of cell stack too. Moreover, the accumulation of methanol, liquid at temperature and ambient pressure, is of considerable practical simplicity compared to hydrogen (it has to be compressed at very high pressures). The global reaction is the following ones. The methanol is supplied to the anode where ionic catalyzed splitting occurs:



Hydrogen protons and electrons, migrated to the cathode, reacts with oxygen:



The final reaction will be:



The process produces water, electric current and CO₂. For these reasons, the reaction is not completely "clean" as in the case of hydrogen. Such a cell has efficiencies of 25%. The efficiency reduction is due to the strong heat dissipation correlated to the reaction (of about 75% energy loss) and the so-called "crossover" phenomena of methanol. This efficiency decrease is due to the methanol leakage, through the membrane (not very selective), that reaches the cathode, directly reacting with oxygen. The crossover is characterized by two main disadvantages:

- Reduction of the production of H⁺ ions and consequent reduction of transported electrons to the cathode;
- Increase of the electrochemical potential to the cathode due to the reaction of CH₃OH with oxygen, resulting in a decrease in the potential difference

between anode and cathode and, consequently, a lower electron transport gradient.

The solutions focus on new, more selective membranes. These membranes almost completely screen methanol, optimizing the ratio $\text{CH}_3\text{OH}/\text{H}_2$ and generating a complete methanol consumption. Consequently, a higher efficiency is achieved. However, DMFC are very attractive if is applied to small portable electronic devices and in the case of backup power generation plants, where battery storing is insufficient. The strong point of DMFC is the high methanol energy density, about

30-40 times higher than lithium ion (Li-ion) batteries. In fact, even considering their low efficiency, it is experimentally obtained an energy density 10 times more. Low efficiency is not necessarily a problem if the project goal is the extension of the device/object/vehicle operative life. In fact, the DMFC are widely used in military applications, in the remote energy generation for computers, satellite phones and emergency kits.

The proposed Reformed Methanol Fuel Cell Plant

The proposed technology bases its operation on the use of reformed methanol to provide hydrogen to be used in a fuel cell. A small practical plant is proposed to ensure a wider use in different applications. This type of cell compared to DMFC has several advantages. First, the highest energy efficiency due to the non-direct use of methanol thus avoiding the problems associated with it. The efficiency of the proposed system is strictly dependent on the temperature in each stage. For this reason, it is necessary to ensure a precise control of the operating conditions. Then, the liquid fuel must be vaporized before entering into the reforming reactor. This particular need leads to the coupling of the two phenomena. The liquid fuel controls the plant operating temperature. In this manner, a preheating and vaporization of the reactor supply current is obtained.

The methanol supplied to the plant is not pure but in mixture with water. This is necessary for the steam reforming reaction development and is supplied in a slightly higher stoichiometric ratio ($\text{H}_2\text{O}/\text{CH}_3\text{OH} = 1.2:1.5 \text{ mol}/1 \text{ mol}$). The methanol quantity is higher than necessary for the reaction, but an almost complete conversion of methanol can be obtained. The steam reforming reactions are:

In the WGS reaction, water is necessary. The water is already present in the plant thanks to the excess water flow rate supplied at the reformer inlet. There are several possibilities of the reformer-fuel cell plant configuration:

- ATR (Auto Thermal Reforming) reactor. In the reactor both reactions (steam reforming and the methanol partial oxidation) occur. The total energy balance is positive. The system needs a strong control over the temperatures generated by the partial oxidation. In fact, a sudden increase of the temperature improves the reaction of methanol decomposition and a consequent greater production of carbon monoxide. From eqt. (6) the total hydrogen production is lower;
- Reactor where only the steam reforming reaction takes place, avoiding the partial oxidation by a reduction of oxygen quantity in the vacuum system. The heat needed to the reaction is provided through an electrical resistance that wraps the catalytic bed, guaranteeing optimum distribution of heat flows. The production of hydrogen is higher and temperature sensors can control the bed temperature.

To limit the adverse effects of CO production, different solutions can be used:

- Use a high-temperature (HTPEFC) fuel cell, more tolerant of carbon monoxide poisoning. On the other hand, higher operating temperatures and lower

efficiencies characterize this system. This choice allows removing the water gas shift treatment from the system, decreasing the initial dimensions and costs. It should be recalled that, however these cells are more tolerant to poisoning; they require scheduled maintenance in the short/medium term. Not recommended in long-term applications.

- Insert a catalytic functioning WGS (water-gas shift reactor) reactor for the reduction of carbon monoxide using a lower temperature fuel cell (in this case a PEFC). The disadvantage is due to the presence of an additional system parts that also require constant temperature controls.

Methanol Reforming

The methanol reforming is realized through selective catalysis for the production of hydrogen alone. The objective is to achieve a reactor where both the oxidative methanol steam reforming for H₂ production and the CO concentration reduction (< 30ppm CO). Several studies have demonstrated the efficacy of Cu ZnO/Al₂O₃ catalysts for the selective production of H₂ and of Pt/Al₂O₃ catalysts for the conversion of CO. Combinations of different types of catalysts lead to better efficiencies in terms of conversion of methanol, hydrogen production, lower production of carbon monoxide or higher consumption through its catalytic conversion. The reaction takes place in a fixed down-flow bed reactor. Moreover, the methanol reforming requires the lowest temperature for the reaction (operating temperature between 180 and 275 °C). The most interesting aspect is that the CO-formation varies depending on the temperature. With the temperature decrease from 275°C to 180°C, its production decreases from 1.5% to 0.05%. This is due to two reasons, the low reaction temperature can suppress the methanol decomposition reaction (that produces CO), and the WGS, at low temperatures, converts CO into CO₂ and H₂.

Experimental evidence has shown that all Cu ZnO-based commercial catalysts have high conversions compared to methanol. At 275°C All Cu ZnO-based catalysts lead to 100% conversions, but significant traces of carbon monoxide can be found within the product. At 230°C, catalysts reach conversions between 93 and 98% with lower CO production. For the methanol oxidative reforming, for portable applications, air can be used as an oxidizing. The variation of molar ratio O₂/CH₃OH influences on the progress of the methanol reaction and conversion, on carbon monoxide and hydrogen production.

Table 1. The variation of molar ratio O₂/CH₃OH

Ratio O ₂ /CH ₃ OH	Conversion CH ₃ OH	Production CO (ppm)	Production H ₂ (mol%)
0	60.8	848	70.4
0.1	74.6	2602	66.6
0.2	86.9	3125	69.2
0.3	97.4	3371	54.4
0.5	98.4	3642	49.4

With the ratio increase, the conversion of methanol increases. This increase is apparently related to the partial oxidation reaction that generates a decrease of relative hydrogen production and an increase of carbon monoxide production. Note also that lower values of the O₂/CH₃OH ratio cause a reduction of the transport gas (inert N₂) and a consequent worsening of the thermal transport conditions. These conditions changes generate strong thermal gradients due to the different natures of steam reforming (endothermic) and partial oxidation (strongly exothermic) reaction. It is necessary to find a compromise. Always respecting the constraint of the smallest possible overall dimensions (for onboard applications), it can try to unite two catalysts with base copper-zinc and with platinum base. The aim is to simultaneously initiate

the two reactions (SR and WGS). Several experiments have been carried out and the obtained results are based on two main specifications:

- Hybrid Catalyst with 1% Pt/Al₂O₃ in mechanical mixture with a catalyst CuZnO/Al₂O₃ with weight ratio between the two catalysts equal to 1:3;
- Two-layer catalytic bed of which in one is present only 1% Pt/Al₂O₃ and in the only response Cu-ZnO/Al₂O₃, always in relation in weight 1:3.

To initiate the reaction, air is used with a ratio of O₂/CH₃OH equal to 0.3 at a temperature of 230°C. The process path follows the direction of CuZnO > Hybrid > Two layers catalysts.

These results led to the development of series reactors systems. A first reactor, where steam reforming and methanol partial oxidation take place, is based on a catalyst copper-zinc, maintained at 230 °c with a molar ratio H₂O/CH₃OH = 1.4 and molar ratio O₂/CH₃OH = 0.3

In the second reactor takes place the preferential oxidation of carbon monoxide through a 1% Pt/Al₂O₃ catalyst, maintained at a temperature of 150 °C with an extra air supply between the first and the second reactor within 11 and 53% of air delivered to the first reactor.

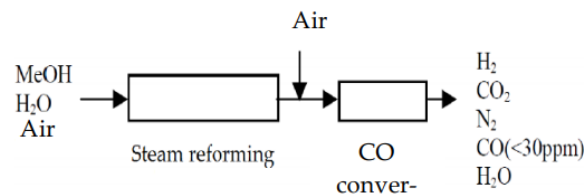


Figure 3. Example of an integrated reactor for the production of hydrogen from methanol

The proposed plant

The system is composed by an ATR reactor system with WGS bottoming purification systems. A LTPEM type fuel cell is considered. Initially, the methanol/water mixture is stored into a reservoir. Successively, a pump (P) delivers the mixture to the system. From the tank, the mixture enters a vaporizer, where it reaches the necessary conditions to start the reforming. The vaporizer must reach a temperature of 80°C for the considered H₂O/CH₃OH mixture. This vaporization can be implemented in three (3) ways:

- Through the heat produced by the combustion of part of the mixture in a dedicated component;
- The heat produced by the combustion of the unreacted gas inside the fuel cell;
- By exchanging heat with the hot parts of the system, exploiting the dual function of temperature control.

In our case, it is considered more efficient, to "compose" the vaporizer with all these three modules. When the system is switched on, due to the absence of heat in the system and unreacted gases, it is necessary to use the methanol combustion to vaporize the mixture, and achieve the operative temperature (230 °C). Once the system reaches the stability conditions, the vaporization is obtained by thermal exchanges with the plant parts and by the combustion of the not-reacted H₂.

Once entered the reactor, the charge follows the reactions described in the previous section by transforming into synthetic gas ready to be sent to the fuel cell. The reactor is realized by placing the two chambers, OXSR and WGS, in close contact, concentrating the hot parts of the system in a single point. Some blowers supply the air to these hot parts. The reaction chambers are built by inserting flow breakers inside them. On the walls, it is positioned the specific catalyst, forcing the charge to enter into contact with them. This system

guarantees a good mixing and an easier limitation of the reactor overall dimensions. The produced synthesis gas, with a low carbon monoxide concentration, is delivered to the anode of the LT-PEFC. In combination, the air is sent to the cathode. So, the reactions can be initiated. At anode outlet, the retention valve will be opened very frequently (it was also considered the option of not inserting it at all). The procedure is necessary to avoid the large accumulation of carbon dioxide and oxide that do not participate to the reaction, preventing the entrance of the synthesis gas. The purged gas presumably contains unreacted hydrogen that can be burnt to provide necessary heat for the mixture vaporization. The exhausted gases are delivered into the atmosphere or, in a green scenario, to a CO₂ storage system for its reuse in the sustainable production of methanol. The fuel cell outgoing water is vaporized and released into the atmosphere or stored.

Onboard RMFC plant

Currently, the interest of many manufacturers is to optimize the use of fuel cells in the automotive sector. In our case, the considered fuel cell and the plant studied could be a good compromise solution. There are reformed methanol fuel cell with reduced dimensions and weights, compared to a commercial ICE. The downside is the start-up period, about 30 minutes, which are incompatible with the automotive application. For these reasons, the opportunity to use a low temperature cell has been investigated. In addition the reformer can be warmed by the methanol combustion, decreasing the time of initialization. During this period, necessary for the start-up of the entire device, the vehicle is moved by a battery package. The battery nominal power is lower than the currently used on the hybrid vehicles. The purpose of the package is to compensate the energy peaks required by providing energy, and to store the excess energy produced by the cell.

In the case of an onboard application, modifying commercial vehicles, the following results could be achieved:

- Complete integration and sustainability of the vehicle
- Increase in vehicle range
- Use of excess heat for the heating of the vehicle
- No particulate production.

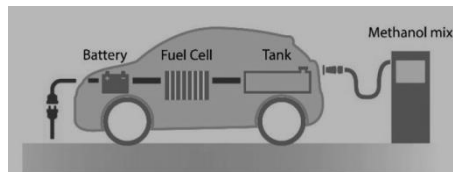


Figure 5. A RMFC on board plant

Conclusions

The RMFC have, therefore, several advantages and different aspects that require further development and research. They are to be considered a viable alternative to the traditional generation systems. The use of methanol is interesting because it is considered to be "liquid electricity", since it is a hydrogen carrier among the best on the market with the possibility of being used in energy generation at low cost. In addition, the malleability of methanol

production, i.e. the possibility of being produced by both traditional and innovative methods, greatly facilitates the energy transition. This factor could entice fuel companies to invest in its use.

In addition, methanol compared to fossil fuels is a green alternative in many respects, whether they are productive or emission-related. As far as the proposed plant is concerned, a further study and optimization of the components, necessary for the assembly of the system, is necessary. In addition, an economic feasibility analysis is needed to make this solution competitive. Once the technical and economic feasibility has been demonstrated, a careful analysis of the system security will be mandatory.

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Use of adsorption thermal storage for conservation and reuse of energy at living homes

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Abstract. Use of zeolite type of long term thermal storage and reuse of energy at our homes. The goal is to create future completely self-sufficient energy independent living homes and residential buildings. Integration of heating cooling and refrigeration for everyday use by lowering energy waste and increase of overall energy efficiency management. Description of idea of integration of three household appliances, air conditioner, refrigerator and water heater, into unique system

without need of thermal energy irradiation into external ambient. Conservation of thermal energy during hot summer and reuse of such energy for heating on days with low temperature.

Keywords: Energy conservation, adsorption heating, thermal long term energy storage, energy efficiency. Use of adsorption thermal storage for conservation and reuse of energy at living homes

Introduction

Today we abuse in use of energy and especially in reuse. We don't learn from nature and the way how living beings consume resources with high efficiency. Goal of this paper is to demonstrate practical way of energy management and storing for reuse at living houses and residential buildings.

Three main household appliances at our homes are air conditioning (cooling and heating), refrigerator and water heater. All of them use more than 80% of total energy consumption at our living house. Today we pump thermal energy from inside of refrigerator and dissipate this energy into house air volume than we take this heat from internal ambient and expel it with air conditioner into outside environment. In such way we create thermal waste increasing street temperature in cities that is becoming serious problem during hot summer months. Not less important that this external units generate heat pollution they are visually unpleasant.



Photo of buildings in center of Prishtina. Circled are external air condition units

The main problem is energy storage. Typically water boiler of 80 liters consume 5 kWh and depending on insulation quality lose 75% of stored thermal energy in 48 hours. The main idea here is to unify refrigerator, air conditioner and water heater into unique device equipped with thermal storage that allows energy reuse.

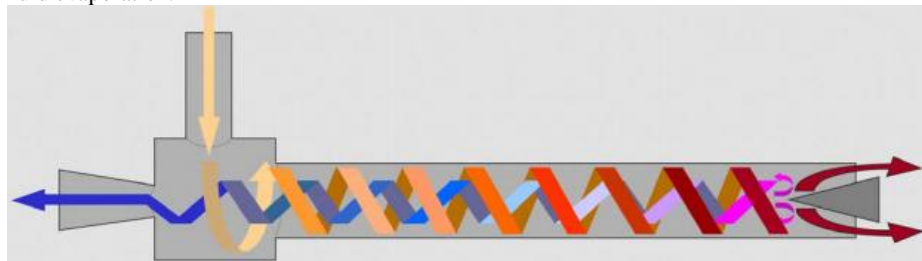
Thermal storage

Long term thermal storage was not feasible because of thermal losses. Because of second law of thermodynamics the sum of entropies in the interacting systems increases. With discovery of adsorption thermal storage and specially zeolite ability to store thermal energy at room temperature new ways are opened. Zeolite pellets can store thermal energy for long time without dispersion. On other side this kind of storage has very high heat capacity, four time more than water. (Scapino, Zondag, Bael, Diriken, & Rindt, 2017) (Energy, 2015) Water has one of the highest specific heat capacity $4.2 \text{ kJ/kg}^{\circ}\text{K}$ and for zeolite this is around $16.42 \text{ kJ/kg}^{\circ}\text{K}$.

Proposed solution

Idea is to integrate solar thermal collectors, photovoltaic panels and air compressor with specially built refrigerator and zeolite adsorption thermal storage presented on schematics in Figure 3.

Solution is based on vortex tube known as Ranque-Hilsch vortex tube invented in 1931 and is used in industry for cooling and heating using only compressed air. Vortex tube is not used in refrigeration because has lower performance and efficiency than standard solution based on fluid evaporation.



Principle of vortex tube functioning (Wikipedia public domain picture)

In this paper we will not concentrate on explanation how vortex tube works because it is explained in many sources and books. (Vortex tube, n.d.)

The presented solution overcome lower efficiency of vortex tube because in this case both functions (cooling and heating) are used. Cooling for refrigerator and air conditioner on one side and heating for water heater and thermal storage on other.

In our solution compressed air is created with electric motor and Tesla turbine. Choosing this solution eliminate need for additional air compressor. Vortex tube separates hot and cold air. Hot air is used to regenerate (thermally charge) zeolite and cold air goes to refrigerator and air conditioner.

Exploded view of modified vortex tube with BLDC Motor and Tesla turbine is presented on Figure 1. (This picture is original work and can be published only with copyright notice referring to this paper.) Solution with BLDC Motor and Tesla turbine gives optimal results with

small dimensions and low noise because the system works at very high speed of 60 to 120 thousand rpm.

Modified vortex tube is inserted into drum (Figure 2) which hosts inside zeolite pellets and heat exchange tubes. This drum rotates slowly powered with small electric motor to achieve zeolite pellets mixing to maximize heat exchange. Tubes for heat exchange are connected to hot water installation used also for house heating with standard floor or radiator installation. Excess of heating goes to seasonal heat storage and can be conserved for indefinitely long period of time.

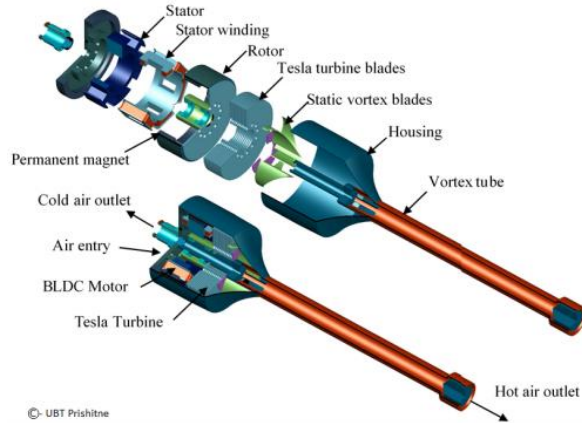


Figure 1

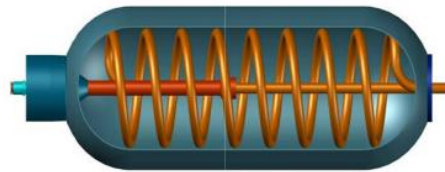


Figure 2

A solution for typical living house use combined system with solar thermal collector 2.5 kW, solar photovoltaic panels 2.5 kW and battery in range from 6 to 10 kWh storage capacity with corresponding inverter 2.5 kW. Seasonal storage capacity is scaled depending on climate zone and efficiency of building insulation. From 2 to 5 vortex tubes with drums can be used in normal house where minimum one is used for refrigerator and at least one for air conditioner. All energy in excess will be stored in seasonal storage and all system can be connected to smart home equipment and control.

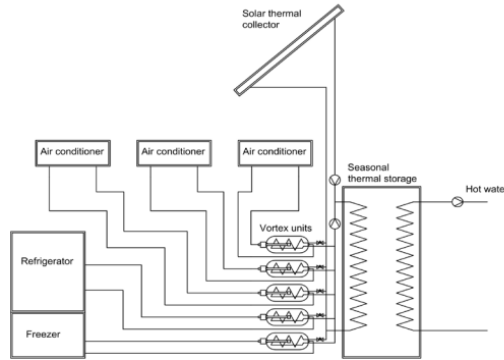


Figure 3

Figure 3 represents schematic view of described system of energy management and Figure 4 shows the integration in energy efficient home building. The solar photovoltaic system is optional and will not be described in this paper.

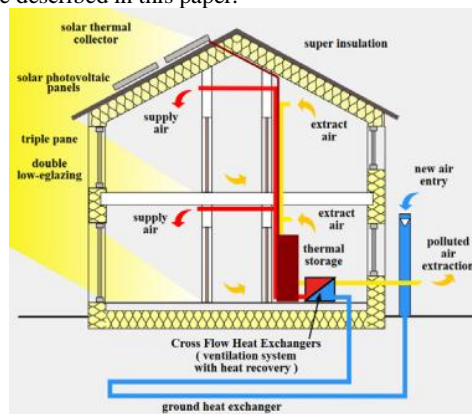


Figure 4

Conclusions

Constructing more efficient building is not only trend but is a must. Humanity on developed countries is going toward self-sufficient buildings that generate all energy they need. Today we are using more energy that is needed and we produce this energy on big plants consuming oil, gas, coal or nuclear fuel with big impact on climate changes and global warming. The main problem today is that systems that efficiently use adsorption zeolite thermal storage are complex and not yet developed. The second problem is the cost of zeolite that is around 2\$ per kilogram. This paper is just a small step in direction to achieve the goal of 2000 W consumption per capita which is 48 kWh daily. (Wilke, Papadopoulou1, & Robinson, 2011)

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The performance of the renewable energy sources in the power distribution systems — case study

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Abstract. Renewable energy resources, among other things, play a significant role in the safe and clean supply of electricity consumers. Also, their impacts are reflected in the proper functioning of the transmission, generating and distributing system. Their integration into the topology of power systems and balance between production and consumption, also planning requires a detailed analysis so that the energy balance to be under allowed limits and has no consequences in impairing the safety margin of the power system parameters. For this, analysis and study coincide with the analysis of the indicators and their performance on the integration of these resources into a power system by building a structure and combining the hybrid variety of these resources. Thus, the study deals with some aspects of the analysis of the parameters of these sources into the power system, respectively in the one substation and performances of the electrical parameters.

Keywords: Power system, renewable energy, solar and wind energy, energy balance, production and consumption, electric substation.

Introduction

Renewable sources in the power system play a very significant role, affecting the supply of clean energy to consumers, as well as their positive environmental impacts. Given the European policies for meeting the standards for renewable energy production, then the need for discussion and treatment in this area relies on the capacity of each country to achieve its objectives.

Another aspect of renewable resources is their treatment in terms of the performance of their parameters. Given that many factors are reflected in the performance of reproductive systems in the first place are climate factors and then their impacts on energy balance. But, of course, they also have other negative impacts, such as the unexpected power flows they produce, the harmonics, which are reflected in the quality of the voltage and system parameters respectively and the frequency of the system. In the case study, performance indicators of some types of renewables are shown, such as wind and solar.

Renewable energy sources and power systems

Renewable sources in the case study, such as water, wind and solar constitute a diversity in clean energy. Therefore, the construction of these concepts and their treatment for the proper functioning of the power system constitutes a good basis for evaluation.

Considering the importance of the voltage quality in power system [1], and other parameters are more important in achieving the standard of renewable resources.

This constitutes a structure of consumer as well as a step towards achieving standards for the integration of renewable resources.

The connection of the generators has affected in the voltage profile, power flow, losses, stability, short circuit currents, and radial distribution network. The influence will depend on the number, type, location, and size of generators. The distributed generators are mainly designed to be connected directly to the distribution network near load centers.

Regarding the utilization of alternative renewable energy sources, Kosovo is not in the appropriate levels. Approximately only 9 % of the electricity produced in Kosovo is from renewable energy sources [2].

Combining the solar and wind turbine systems

in the suggested solar and wind turbine systems the output from the solar part depends on the incoming solar radiation and is obtained during sunshine. On the other hand the output of the wind turbine depends on the wind speed at the location of the installation and is obtained any time of the day or night that the speed is over a lower limit. Therefore the photovoltaic and wind turbine systems can supplement each other, being primarily used to cover building electrical load and secondary to increase the temperature of the existing thermal storage tank of the photovoltaic system [3]. The proper combination of photovoltaic and wind systems is of great importance in small distribution systems, to cover consumption and lack of production especially in places where water generation systems are lacking. Thus combining them over different periods of time and properly coordinating other generating systems helps in the production and consumption balance. Electric energy that will be obtainable from the wind and solar energy differs depending on seasons. In winter months, electric energy generation from the sun may not be possible for the day's time. Similarly, electric energy generation from wind in the spring and summer months remains very low [4].

Performance indicators of renewable energy in power systems

The core set of energy indicators, now called Energy Indicators for Sustainable Development (EISD), has been designed to provide information on current energy related trends in a format that aids decision making at the national level in order to help countries assess effective energy policies for action on sustainable development.

The indicators can help to integrate energy into socioeconomic programmes, to combine more renewable energy, energy efficiency and advanced energy technologies to meet the growing need for energy services, to increase the share of renewable energy options, to reduce the flaring and venting of gas, to establish domestic programmes on energy efficiency, to improve the functioning and transparency of information in energy markets, to reduce market distortions and to assist developing countries in their domestic efforts to provide energy services to all sectors of their populations. The indicators should identify what energy statistics need to be collected as well as the necessary scope of regional and national databases [5].

The evaluation of the indicative parameters regarding the status of transformers during their operation is essential regarding continuity of operation for different cases and loading regimes. These indications of the mode operation are determined for a specified period. The monitoring and assessment of such components like; P, Q, F, W, T, and C are essential to achieving better reliability of the power transformers and lines [6]. Other specific parameters in

the performance are the voltage quality and losses in the electricity distribution networks, also are a significant part of the overall losses in the electric power system [7].

The amount of wind and solar PV that can be installed in a distribution system without violating the reliability and performance of the system depends on the design of the distribution system and on the load profile. Systems with a high mismatch between the electricity generation and demand will have more difficulties to cope with large penetration levels while systems with better load matching can facilitate larger shares. Similarly, systems designed for high peak demand can facilitate more PV and wind power than systems designed for a low peak demand since the system is designed to cope with higher power levels. Other concerns relate to the length of the distribution grid where long distances between the customer and the substation will likely experience increased voltage fluctuations and voltage rises during the day compared to a grid with shorter distances [8].

Cost and in particular the capital outlay remains the main challenge in the dissemination of small wind energy systems. These viability parameters, however, are also relevant to solar PV systems, resource inconsistency and technology cost and associated technical limitations [9].

An analysis of the renewable energy sources- case study

Power systems consist on the diversity generation, such as solar, wind, water and other sources. Also, one factor is the performance of these sources and their impact on the power system. Power systems play a significant role in providing reliable and quality customer service. Nowadays, the integration of renewable energy systems, especially wind and solar, poses a challenge and a necessity for countries where these two resources can be developed and integrated into the overall development of energy production. In the case study, a 110/10 / 0.4 kV electrical substation is included in the transmission system, with integrated photovoltaic and wind systems operating. The substation consists of two sources of wind turbines with an installed power of 40 MW, as well as 6 photovoltaic systems with an installed power of 11.49 MW. While the 110 kV side is equivalent to the power system as a strong balancing bus of the active and reactive power balance, the 10 kV side is designed for lines and transformers, and the 0.4 kV side for customers [Figure 1]. Cases are analyzed when operating integrated photovoltaic and wind systems, as well as when operating separately.

Through the analysis and simulation results achieved through the ETAP program, the performance aspects of solar and wind panels and their impacts on the electrical substation are addressed.

Fig. 1. Substation of 110/10/0.4 kV level as integrated with wind turbines and photovoltaic panels

In the first case, the substation performance is analyzed when the wind turbines and photovoltaic panels are integrated into operation in aspects of power flows, voltages and voltage safety band. Where shown through the graphs as in Figure 2, the active and reactive power flows in an energy balance of 50 MW. The data shows the power flows in the distribution lines in busbars (18 busbars), which may indicate the importance of determining the location of the construction of renewable sources and their operation in view of security and electricity flows (active and reactive power).

Fig. 2. Electricity flows (active and reactive power) in the substation (wind turbine and solar panels operates as integrated)

Also, the performance of factors and indicators except of energy flows, such as losses, voltage safety margin at 10 kV and 0.4 kV levels, when operates only wind turbines or solar panels, and when working as integrated is also analyzed.

Fig. 3. Losses in substation elements 110/10 / 0.4 kV, respectively on power lines and transformers, when renewable sources operate like the integrated and separately

Figure 3 shows the active power losses of the elements in both transformers and distribution lines. It shows that active power losses are expressed when wind turbines or photovoltaic panels are not integrated. In the first case when wind turbines and photovoltaic panels are integrated, the losses are 1.0157 MW, whereas when the photovoltaic panels are integrated only the losses are 1.9403 MW, and when the wind turbines are integrated only the losses are calculated to be 1.3983

MW. So, this implies that the integration of renewable sources, among other things, affects the performance of electrical parameters as well as the reduction of electrical losses.

Another important factor is the voltage fluctuations, namely the safety margin.

The analysis includes their impact when integrated and when working separately. The simulation results are shown in Figure 4 and Figure 5, which also show the behavior of the electrical parameters, respectively the performance of the renewable sources and their impact on the safety margin in terms of voltages at 10 kV and 0.4 kV levels.

Fig. 4. Safety margin of solar panels and wind turbines as integrated operate at 10 kV level

Also in Figure 5 are shown the simulation results of the renewable sources and their impact on the performance of busbars at 0.4 kV level.

However, security performance depends both on the performance of integrated or isolated systems as well as on network configuration, and the climatic conditions that result especially on the performance and efficiency of renewable resources.

Another important factor is the lines and transformers, their design in terms of construction and types of construction. Such factors together with the renewable resources installed in the proper locations and with efficient parameters affect the performance of the power systems.

Fig. 5. The safety margin of solar panels and wind turbines as integrated operate at 0.4 kV level

By analyzing the simulation results shown in Figures 4 and 5, it can be seen that the impacts of the renewable sources are important for the safety margin of the voltage fluctuations and have a positive effect on joint integration. However, the operation of wind turbines and solar panels greatly depends on the climatic conditions at their location, so their coordination concerning the balance of generation and consumption plays a crucial role as well as the safe operation of the distribution system as a whole.

Conclusions

From the simulated results obtained, some conclusions can be drawn in terms of operation and integration of renewable sources and their role in the performance of the power system. From this, it can be concluded that renewable sources also have their role in improving the performance of the parameters of the integrated power system or even of isolated substations. Thus, they affect the security of supply of consumers as well as the quality of tensions and reduction of losses. This is also shown in the results obtained, which shows their role in the performance of the substation. An important factor is also the design of the program and the revision of climatic conditions so that the security of the systems is at a higher level and the security margin is increased so that the supply of customers is uninterrupted and the quality of the electrical parameters is at a high level and acceptable margin.

Thus, the construction of renewable sources in addition to electrical performance plays an important and increasing role in the efficiency and positive climate impacts, with particular emphasis on reducing greenhouse gases released mainly from fossil fuels.

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