

BUILDING MANAGEMENT SYSTEM PROMOTED AT “THE ADVANCED RESEARCH CENTER FOR INNOVATIVE MATERIALS, PRODUCTS AND PROCESSES” - BUCHAREST POLYTECHNICAL UNIVERSITY

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Abstract: The notion of BMS (Building Management System) means a hierarchical management system, with a distributed structure, that should include as components all the installations corresponding to the building. It is based essentially on a quick efficient data exchange among different components and involved devices. The main aims for the introduction of BMS system in a building are decreased power consumptions and the costs necessary for operating the installations, improving the quality of the services and managing the installations, the increase in the degree of security of the building, equipment and personnel in the building. The BMS represents a management destined to the control and monitoring of the control system and of all the installations (the

electric part, thermal installation, lighting, air conditioning, water management and sewerage system), the security system (against breaking-in, access control, closed circuit television) and fire alarm system.

The control systems with which are provided the utilities for which we intend to carry out the coupling to a BMS must perform monitoring, control, command and protections. The BMS is formed by hardware and software. The software uses protocols, such as C-bus, Profibus, protocols using the Internet and open standards (BACnet, LonWorks, Modbus). The hardware component has three functional levels: the that of the controllers, and the communication level (webservers, calculators with dedicated software).

Key words: *BMS, intelligent building, building control*

Abbreviations:

AHU – Air Handling Unit

AI – Analog Inputs

AO – Analog Outputs

BACnet – Building Automation and Control networks

BMS - Building Management System

C-Bus – communication protocol for the automation of the houses and buildings, the protocol belongs to the Clipsal company

DALI – Digital Addressable Lighting Interface

DI – Digital Inputs

DO – Digital Outputs

EIB – European Installation Bus, communication protocol belonging to the standard KNK

GSM – Global System for Mobile Communications

HTTPS – Hyper Text Transfer Protocol Secure

HVAC – Heating, Ventilating and Air Conditioning

IT – Information Technology

KNK – standard communication protocol, administered by the KNK Association

LonWorks, LON – network platform built on a protocol developed by Echelon Corporation, used for the automation of various functions in the buildings

M-Bus – Meter Bus, main path used for reading from a distance different meters

Modbus – serial communication protocol published by Modicon

MSSQL – Microsoft Structured Query Language

PC – Personal Computer

Profibus – Process Field Bus

SMS – Short Message Service

UPS – Uninterruptible Power Supply

1. Introduction

The goal of a “building management system” is to centralize and simplify the monitoring, operation and management of a building.

The main advantages to be carried out by implementing the BMS are:

- a quick response to the requirements of the users and in case of the conditions;
- decreasing maintenance costs (power, gas, water) by their centralized management;
- reducing the personnel necessary for managing these services;
- easy maintenance and operation by the facilities provided (archiving, automatic alarm, operation and maintenance programs);
- the possibility of extending easily;
- the possibility of connecting the software and hardware to the other systems in the building (fire alarm, lighting etc).

2. Describing a building management system

A building management system is designed by taking into account the following principles:

- **simplicity** – the control stations and the PC type operation will use the same system bus bar, and the data exchange will carry on and a reliable operation will be ensured;
- **rapidity** – data transmission optimized by the free network topology and the direct communication system, oriented to events among participants on the busbar;
- **reliability** – due to the distributed intelligence, the control stations will be able to operate on fully autonomous bases and independently from a main central computer;
- **flexibility** – the system has a modular structure that take into account the installation and operation conditions of the equipment in its structure and that allows the step by step extension;
- **communicative** – network communication capacity and the use of standard interfaces allow the centralized building management system to native integrate the local automation;

- open – the subsystems will be able to integrate on the horizontal or vertical on the automation level, or on the centralized management level.

The building management system “The Advanced Research Center For Innovative Materials, Products and Processes” has the following functions:

- Controls and monitors the thermal module;
- Controls and monitors the cooling station (chillers and distribution circuits);
- Controls and monitors the air handling unit;
- Controls and monitors the interior ventilation;
- Controls and monitors the lighting;
- It monitors the technical alarms (power panels, elevators, UPS, pumping, etc);
- It monitors power consumptions (power, gas, hot water, cold water);
- It interfaces with weak currents systems (fire detection);
- Control, monitoring functions, alarms, events, cost efficiency, reports, graphics.

The building management system is hierarchized as follows:

- data collection elements (sensors and transducers) and driving elements;
- input / output interfacing modules on each local application;
- control stations for HVAC installations (heating, ventilation and air conditioning);
- automation substations for heating, ventilation and air conditioning installations (HVAC)

The sensors used for data collection:

- temperature sensors, thermostats;
- humidity sensors;
- light sensors and the presence of solar rays;
- proximity sensors;
- pressure sensors and the pressure difference, presostats;
- level sensors;
- flowing detectors.

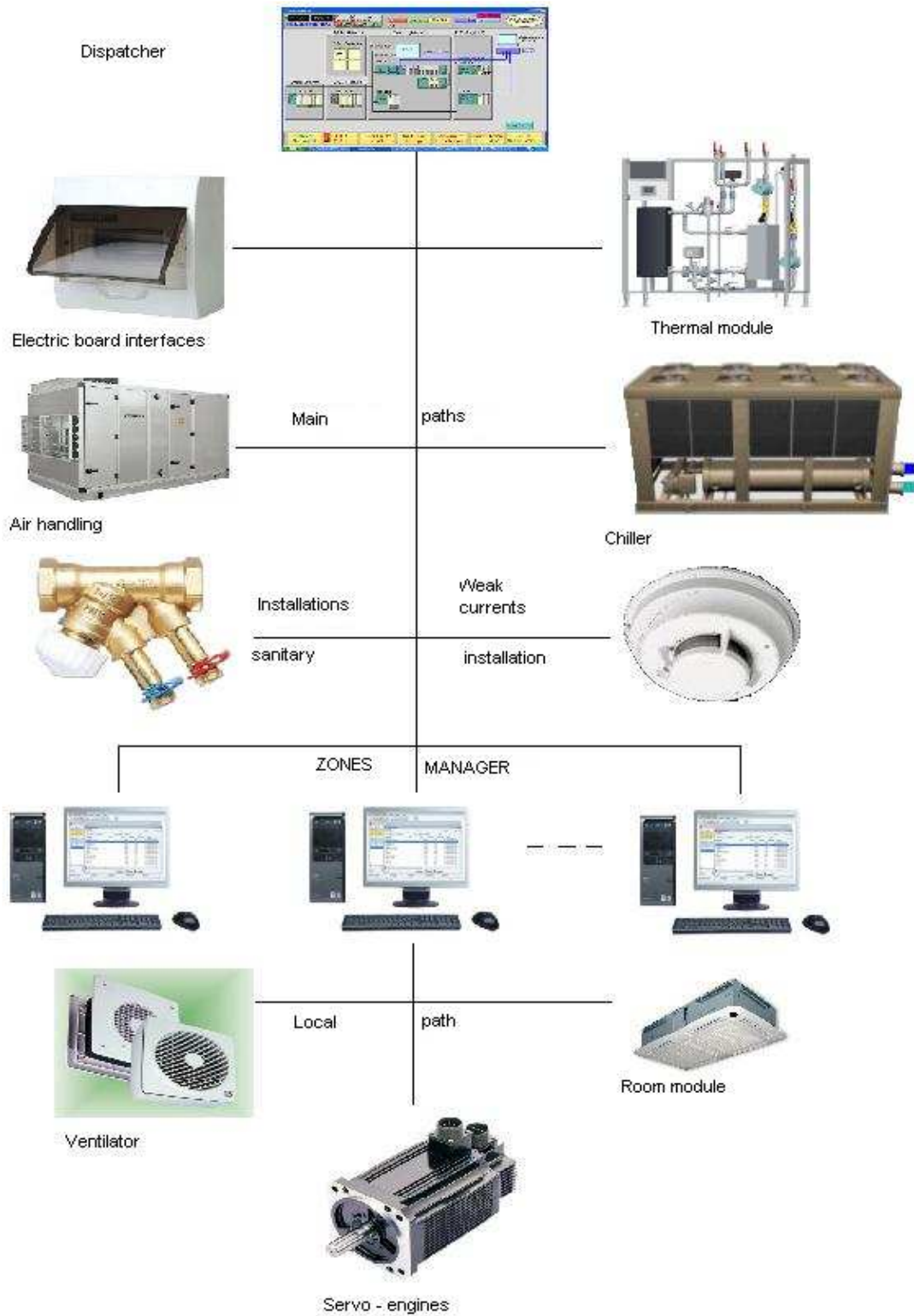


Fig. 1 – BMS fundamental circuit

The BMS uses ways of checking the system operations, for example, the data taken over by the interior temperature sensors will confirm the righteousness of then automatic actions of the system.

The system has to contain standard controllers, able to operate in an open system architecture and has the possibility to be integrated with equivalent systems or equipment.

The design of the control system has to allow the coexistence and interoperability of primary controllers for HVAC, elevators and lighting, within the same network.

The system has to be designed so that all the building management functions be carried out in a single control point, with the possibility of duplicating these functions, with specific access levels.

The working station for the operator, the PC type, allows the communication with the standard controllers. That allows the centralized system operation of the HVAC installations and the lighting of the building.

The controllers are provided with local or passing operator consoles with lighting for operation and parametrization, with clear text menus, easy to understand, with access levels. The control is achieved according to the type and requirements of the application.

3. System architecture

3.1 Component elements

They are sized according to the quantity and structure of the monitored and managed data, respectively digital input – DI (representing alarms or states), analogue input AI (for instance, temperature measurements), digital output – DO (engine commands, other driving elements), analogue output – AO (standard signals in current or voltage), metering.

For rendering consumption efficient, the best sizing of the installations, the lifetime of the equipment, in the BMS architecture are provided the frequency converters for the pumps in the thermal power plant, the chiller, the pumping groups and for the ventilators in the air handling units or interior ventilators.

3.2 The interconnection component elements

The interconnection of the component elements is carried out by a communication protocol of the command-response type, thus ensuring a permanent dialogue with the components installed in order to confirm the performing of the commands as well as to provide data on their condition.

All the local controllers communicate and are configured by means of a communication protocol, with the central server in an open system. The monitored parameters are displayed locally and modified in the application loaded on the controller by means of an operator console, but may be, at the same time, modified also by means of the software on the central station, where the operation of all equipment is monitored.

The field equipment are mounted in electric board. The control of the connected elements can be carried out both automatically and by hand through selection keys on the front side of the electric board, so that the electric board should not open.

4. Monitored and controlled installations

4.1 Thermal module

The controller of the thermal module has to ensure the control and data acquisition for control valves, turn/return temperature sensors, operation point control, heating circuits operation, that of the air treatment units, domestic hot water circuit.

4.2 Chiller

The controller for the chiller has to ensure the control and data acquisition for two chillers with their own automation (cascade connected), control valves, turn/return temperature sensors, operation point control, chiller start/stop controller, depending on the cooling agent demand.

The following signals are taken over:

- the water temperature at the chiller outlet;
- chiller operation state;
- chiller alarm;
- pump control – frequency converter;
- pump unit failure;
- chiller compressor operation time – set software.

4.3 Air handling unit (AHU)

The controller for the air handling unit, central air conditioning unit of the “rooftop” type, ensures the data acquisition and the control for a number of control valves, driving engines for the control flaps, turn/return temperature sensors, operation point control,

start/stop depending on the cooling thermal agent demand, on the external temperature sensor for summer/winter operation compensation.

An example of algorithm depending on the external temperature sensor is presented in Table 1 below:

Table 1

Mode	General temperature	External temperature	Heat recovery	Heating
Heating level 2	$T_G \leq 21.5$ pentru 15 min.		Yes	Yes
Heating level 1	$T_G < 21.5$		Yes	No
Ventilation only	$21.5 < T_G < 22.5$		No	No
Cooling level 1	$T_G > 22.5$	$T_E < T_Z$	No	No
Cooling level 2	$T_G > 22.5$	$T_E > T_Z$	Yes	No
Night cooling	$T_G < 23$	$T_E \leq (T_G - 2)$	No	No

T_G = General temperature ; T_E = Exterior temperature T_Z = Zonal temperature

At the air treatment plant, mainly the following signals are pursued:

- analogue outputs for flap engine
- flap engine position reading
- filter state monitoring
- thaw protection
- heating valve command
- cooling valve command
- ventilator command – frequency converter
- air introduction ventilator
- pressostat signals
- signals from the air exhaustion ventilator
- air temperature sounding
- exterior temperature sounding
- general reset signal.

4.4 Fan coil units (air conditioning unit mounted in false ceiling)

The controller for fan coil units has to ensure the data acquisition and the control for a number of control valves, control flap driving engines, turn/return temperature sensors, operation point control, start/stop depending on the cooling thermal agent demand. The pursued signals are the on-off signals, the fan coil unit control signals and the digital signals for the hourly scheduling of the fan coil unit operation in the building.

4.5 Elevators

The controller delivered in the accessories of the elevators will be able to start/stop independently each elevator depending on the command received by the Central Station. Whenever these are endowed with a “Energy Efficient” mode its activation can be commanded.

In the BMS the following signals are monitored:

- operating/out of operation lift state
- fireman mode operations
- engine failure
- blocked lift
- cabin alarm.

4.6 Illumination

The controller for light circuits control their opening/closing as well as the variation of the intensity wherever the case.

The gradual control by dimming is efficient from the point of view of the expenses.

From the power installation are monitored also signals from the meters in the electric board for power distribution. At the same time, also the UPS units are monitored.

4.7 Central Station for the system monitoring and controlled

The real time interactive monitoring of the BMS is possible from a central point, by means of the graphical presentations of the installations that are carried out on the computer by the dispatcher.

The control and command of the installations or the modification of the parameters can be performed both locally and centrally (from the PC to the dispatcher).

At the dispatching are available all the data on the substations in the network connected to it, it is possible to intervene and transmit commands to all these substations and, besides, it is possible to achieve a graphical image of the installation in question.

The graphical representations of the whole system occupy several successive windows on the screen of the dispatcher point monitor. The images representing parts in the system are interactive, in the sense that all the parameter values displayed next to the elements in question are updated permanently, and those representing settings can be modified on the display, by using the facilities of the operating system. Thus due to the configuring software we can reconfigure the various operating curves (temperatures, pressures, humidity, etc).

From the central dispatcher we can require data at any moment on the state of each field element connected to this system (start/stop, operation/failure).

The central station is a computer configured with inputs for interfaces with the controllers, by means of which data can be acquired and with a certain access level.

The software allows signalling alarms in certain cases of failures and their transmission by telephone by direct calling, SMS (GSM) and/or by e-mail.

5. Compatibility of the equipment in the control system

Typical optimization functions between the individual systems, like for example, the central hourly scheduling or simple transmissions of the values prescribed from one subsystem to another, constitute simple but very effective measures for reducing the costs and save energy. Recording data between systems is an irreplaceable tool for optimizing the consumption of an installation.

To access all the parameters made available by the producer, all the HVAC aggregates, of the chiller type, electric power meters, thermal power meters, gas, water meters, generators unit, elevators, lighting installations likely to be taken over/monitored in the BMS, must be provided with an extra communication card by an open protocol (LonWorks, BACNet, MODBUS, M-BUS, C-BUS, EIB, KNX, DALI, etc).

Because the systems work with different communication protocols (for example, heating and ventilation with BACnet, the control of the individual spaces with LON, chill production with ModBus, the meters with M-Bus), the integration of these protocols is carried out by a gateway that in a supplementary way may take over for the user also central functions such as recording the measured values and their saving, the takeover and transmission of the alarms.



Fig. 2 – Gateway using several protocols

The central data archiving is carried out in databases such as MSSQL, MySQL or Oracle that are later taken over by the software responsible for centralizing gateways.

The data archiving has an important role in simplifying and choosing rightly the control strategy and the controls.

The alarms in the systems are transmitted to a distance by the adequate utilities to be analyzed. At the same time, by the access from a distance only one expert is necessary that monitors the system and triggers actions necessary in case of emergency. The automatic informing of the corresponding contact person by SMS or e-mail are standard functions of the system. The operators can view and control by means of a usual browser the technical systems of the building, the system has to bear the standards for the Internet such as “https” thus to be integrated in the typical IT infrastructure.

The gateway is responsible also with carrying the various access levels for various users (the administrator of the building, technician, etc).

6. Case study: The Advanced Research Center For Innovative Materials, Products and Processes

The building “The Advanced Research Center For Innovative Materials, Products and Processes” within the Bucharest Politehnica University, will include ten storeys (basement, ground floor and eight storeys),

and the BMS is going to manage all the storeys of the building.

At the ground floor of the building “The Advanced Research Center For Innovative Materials, Products and Processes” is provided a room for the BMS.

The BMS will monitor and control the following installations:

- Thermal module
- Chillers
- Air handling unit
- Fan coil units
- Lighting bodies
- Consumption monitoring (electric power meters, thermal power meters, water, gas meters)
- Technical alarm monitoring (fans, electric board, UPS, pumping units, etc).

The thermal module will be provided with automation controller and the following field equipment: temperature, pressure ones, flowing one, valves and servo-engines.

The building “The Advanced Research Center For Innovative Materials, Products and Processes” will contain 2 chillers that will be endowed each with an automation controller and corresponding field equipment: temperature sensors, pressure ones and flowing ones.

Within the building there will be 5 air handling units (AHU):

- 2 AHU for laboratory offices;
- 1 AHU for the conference hall;
- 2 AHU for clean rooms.

We will provide automation controllers for 525 fan coil units with 4 pipes, respectively about 240 controllers grouped by zones (laboratories/working halls/conference hall). A controller regulates 1-3 fan coil units.

Lighting installation will contain the following bodies:

- 2900 normal lighting bodies;
- 340 safety lighting bodies for the discharge and marking of the interior fire hydrants;
- 40 exterior lighting bodies.

The normal lighting installation will be carried out by using lighting bodies equipped with compact fluorescent sources.

The lighting installation will be controlled ON/OFF locally and centrally (from the control panel of the BMS) by lamp groups.

The lighting installation will be controlled according to the working schedule – in the common spaces and according to the requirements specific of certain rooms (driving scenarios). The exterior lighting installation will be controlled according to the natural lighting level.

The lighting system control will be carried out gradually by dimming, with the possibility of setting the light intensity stages (valid for the image/multimedia takeover laboratories and for the conference hall).

We carry out the monitoring/reporting of the state of the batteries included in the safety lighting bodies for the discharge and marking of the interior fire hydrants.

The system will offer the possibility of monitoring/viewing the state of the installation and the transmission of error messages to the control panel of the BMS.

For the lighting bodies we will provide the automation controllers.

We will monitor the consumptions from the electric power meters, thermal power ones, water, gas ones by the automation controller.

The monitoring of the technical alarms from the ventilators, electric boards, UPS or

pumping units will be carried out by automation controller.

Later, the BMS can integrate also other systems, such as the elevators, as well as other data gathering elements.

The BMS room at the ground floor of building will be endowed with a dispatcher computer-server, two client stations, a color printer and a UPS. The three computers will be provided with software and adequate interfaces.

7. Conclusions

The implementation of a BMS brings about multiple advantages. The integration of all the installations in the building by a computerized system and the bringing of all the data on a single computer, permanently offers an overall image of the whole building and an easy management. Another advantage of such a system is reducing the energy consumption of the building by supervising all the consumers. Flexible from the point of view of the structure, the BMS solution can be configured for any operating state, with preset scenarios, and a subsequent extension can be performed very easily.

Following the implementation of the BMS in the building "The Advanced Research Center For Innovative Materials, Products and Processes" within Bucharest Politehnica University, the energy saved in the first year is expected to be 40%÷ 50% of the standard, at the same time ensuring also the increase in the comfort of the occupants. During the following years the percentage of the energy used can decrease depending on the experience gained by the users of the building, thus increasing the degree of efficiency.

Although the building management system is complex by the diversity of the systems and protocols it uses, it is very transparent for the users.

References

- [1] Building Control Systems – CIBSE Guide H (2000)
- [2] <http://www.sustainablelearning.info>
- [3] <http://www.centraline.com>
- [4] <http://www.buildingplatform.eu>
- [5] Levermore G.J. Building management systems, 2nd ed. (2000)

CONSIDERATIONS REGARDING THE APPLICATION OF THE TECHNICAL STANDARD “TECHNICAL CONDITIONS FOR CONNECTING THE OVERHEAD TRANSMISSION LINES FOR THE WIND PLANTS” IN THE NPS

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Abstract: The integration into the overhead transmission lines (OHTL) and the distribution lines (DL) of the WPP made it necessary to review the operating conditions both of the new sources and of those already installed in the NPS. In this sense we proposed the supplementary technical conditions for connecting these power

sources with random operating state, reflected in the current ANRE technical standard (Order 51/2009). In the current paper we analyze the real possibilities of applying these standards, mainly referring to the participation in the frequency control, the influence upon the transient states.

Key words: *Wind power plants (WPP), delimitation point (DP), common coupling point (CCP), busbar (BB), wind generating unit (WGU), dispatching wind power plant (DWPP), non-dispatching wind power plant (NWPP)*

1. Introduction

A wind power plant (WPP) differs from the conventional power plants by three important aspects: uncontrollable electric power production, dispersed location of the wind units and the type of used generators. These differences imposed – for the operating reliability of the system and ensuring the quality of the electric power supplied to consumers – specific technical standards for connecting the public overhead transmission lines.

In the first stage, wind generators of low unitary power (0.2MW up to 1MW) grouped in power plants with limited powers (1MW – 5MW) and connected to the mid voltage networks (20kV), do not pose special problems in the overhead transmission lines. The main connecting condition consist in ensuring the automatic tripping under insulating operating conditions and at voltage variations generated by faults in the overhead transmission lines.

At the same time, with a gradual increase in wind source power (in 2008 65933 MW installed in European WPP [1], in turning from distributed generation to wind parks of high installed powers connected to the overhead transmission lines, their impact upon the electric power systems increased, determining the network operators to impose more and more restrictive connecting technical conditions, close to those imposed

to conventional generators. The increase in the performance of wind power plants with a view to ensuring quality and electric power supply security, based especially on power electronics, determined also the increase in the costs per installed kW.

In 2008 C.N. Transelectrica S.A. worked out, together with a group of specialists, a proposal for technical standard with reference to the connecting conditions of the wind power plants to the system that was submitted for approval to ANRE. With the approval of the European Union, this standard was approved, is currently obligatory and can be found on the ANRE site: “Technical conditions for connecting the overhead transmission lines for the wind power plants, ANRE Code: 51.1.017.0.00.03/04/09” [2].

2. Possibilities of applying the Technical Standard approved by ANRE by the order 51/2009 for connecting the wind power plants in the NPS

A wind power plant can be formed by tens or hundreds of wind power units, connected by tens or even hundreds km of collecting networks. In spite of all that, most connecting conditions imposed by the network operators in each country refer to the electric network connecting point.

Of all the conditions present in order 51/2009, referring to the delimitation point of

the power plant from the rest of the system, there are a few that might raise a series of problems and we refer especially to the voltage control, frequency control, power factor and reactive power control, the decrease in the active power produced upon the command of the transmission operator, aspects presented further on and that are tackled in the current paper.

For the beginning, it is important to point out that in connecting of a WPP to the network there are three specific points:

- LV terminals (ex., 400V, 690V) or MV (ex., 20kV) at the level of each wind unit, where the producer presents the operating characteristics;
- busbars (BB) to which are connected all the wind generators;
- the common coupling point (CCP), where are connected several users and where “feels” the local impact of the wind power plant.

We considered this remark to be important to make from the beginning because:

- the performance of the wind units are specified (most often incompletely) by the producer and can be analyzed and for sure determined only at the common busbar (BB);
- the capacity of participating in the frequency control is constructively determined and given in the technical characteristics of the units, as it cannot be corrected, the units that do not respect the building technical conditions cannot be selected to be installed;
- the voltage control capacity can be continued or not, the operation can be between the limits given by the power factor (inductive, capacitive) or at a certain constant power factor that can be chosen in a certain domain; the factors characterizing the voltage fluctuations (c – flicker coefficient, k_u – voltage variation factor, k_u - flicker step factor, N_{10} – the highest number of switching operations at an interval of 10

min, N_{120} – the highest number of switching operations at an interval of 2 hours) are given constructive, being made available by the producer;

- a deforming state carried out at the busbar is determined by the characteristics of the inverters, a.s.o.

and these characteristics can ensure or not the conditions imposed in the CCP depending on:

- the voltage in the network to which the WPP is connected;
- the level of the power / short-circuit current in the CCP (NPS input in the CCP);
- the electric distance from BB to CCP;
- the supplementary endowment for the automation and control provided by the producer.

Further on we present a series of aspects requiring discussion if not all the types of wind power units meet the connecting technical conditions in order 51/2009.

To better understand these conditions we present in Figure 1 an example of a case: a WPP formed of three components 80MW each, connected to the overhead transmission line (400kV) by means of a new substation equipped with a 250MVA 400/110 kV transformer.

According to the document “Principles regarding the setting of the delimitation point between the CNTEE Transelectrica SA and the installations of the producers in the process of connecting to the overhead transmission lines of the new users”, the delimitation will be carried out at the high voltage terminals (400kV) of the 400/110kV transformer, in the new substation, at the 400 kV clamp of the transformer separator, towards the bay connecting to the overhead transmission line.

Consequently, the conditions in the order 51/2009 referring to the delimitation has to respect at the level of the 400kV separator of the 400/110 kV transformer.

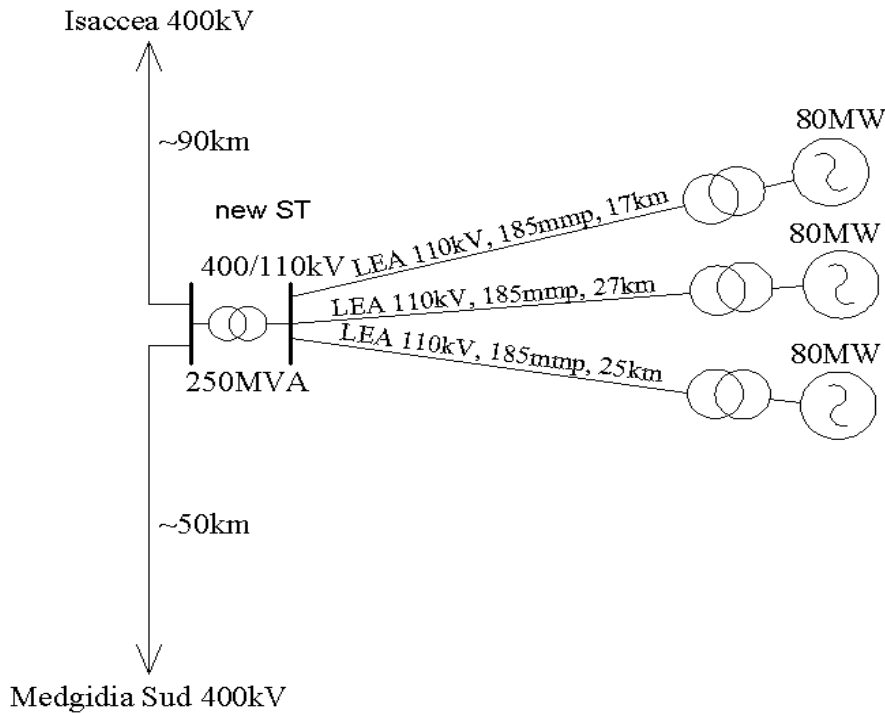


Fig. 1 - Example of diagram for connecting a 240MW power WPP to the transmission line

2.1 Voltage control and reactive power

2.1.1 The provision in the Technical Standard item 5(d) for CEED (also CEEND) to operate continuously at voltage in the connecting point in the range $0.90 \div 1.10 U_n$ is not necessary.

In the overhead transmission/distribution line the voltage in the connecting point is imposed by the NPS/NDS operation overall and, with or without WPP, has to respect the inclusion into the allowable band: MV, 110kV, 220kV ($0.9 \div 1.1 U_n$), respectively at 400kV ($0.95 \div 1.05 U_n$).

For example, it results that for a wind power plant connected to the OHTL like the one in Figure 1, with delimitation point at the level of the 400kV voltage, WPP does not have to operate within the band $U_n \pm 10\%$ but $U_n \pm 5\%$. What should be specified?

The WPP connection to the connecting point is permanent, even if the WPP does not produce power. Under these circumstances, if the connection is carried out by a high voltage cable network (110kV, 220kV, 400 kV), the capacitive reactive power input might lead to a higher voltage in the CCP over the allowable limit. The situation can be the same also in the 20kV network.

The condition might be for the WPP, by the reactive power control, not to determine getting out the allowable voltage band.

2.1.2 In the following we present article 16 in the Technical Standard approved by ANRE by the order 51/2009:

- (1) At voltage values in the connecting point situated within the voltage allowable band, the reactive power produced/absorbed by a CEED has to be able to continuously control in an adequate way a power factor ranging at least from 0.95 capacitive to 0.95 inductive;
- (2) The CEED has to be able to carry out the voltage – reactive power automatic control in the CCP in any of the ways:

- (a) voltage control;
- (b) reactive power control exchanged with the NPS;
- (c) power factor control.

Two important aspects can raise problems: the voltage control in the CCP and the reactive power band corresponding to a power factor ranging from 0.95 capacitive and 0.95 inductive. The second aspect involves a reactive power production /absorption of about a third of the active power in the CCP.

Taking into account that in the Technical Code of the OHTL it is necessary for the conventional generators should carry out the control voltage (to “keep” the voltage at values imposed by the modification of the produced/absorbed according to the capability diagram of the generator), it was

considered opportune to impose this condition also to wind power plants.

Obviously, a WPP cannot be achieved a voltage control but in the case of a “weak” network (with the short-circuit power in the CCP low) and under the conditions of a relatively important reactive power.

The voltage variation can be determined by:

$$\Delta U \% = \frac{\Delta Q}{S_k} \% \quad (1)$$

where:

$\Delta U \%$ - the percentage voltage variation

ΔQ - the reactive power variation carried out by control (MVar)

S_k - the short-circuit power in the CCP – MVA (in its turn between S_{kmin} and S_{kmax} depending on the structure of the networks and of the sources at the respective moment).

Thus, even wind generators that can achieve a voltage control at the terminals cannot have too high a contribution in this sense if they are connected in a “strong” network node.

To carry out the voltage control at the level of the CCP, it is necessary to have a control system that should control all the wind units so that their response be unitary, similar to a single power source. This control system, usually located at the level of the power plant, has to perform the voltage control by means of the reactive capability both of each turbine (if that is possible) and of some compensation equipment in the power plant, such as condensers, shunt reactors and / or devices based on power electronics.

It should be remarked that this voltage control is imposed on wind power plants in few European countries, and besides, a series of wind turbines on the market cannot achieve it. For that reason, in these countries (for example, Scotland, England [4], Ireland), currently they design wind power plants equipped with supplementary equipment meant to carry out that (SVC STATCOM, etc.) continuously.

The provision of minimal variation limits of the power factor in the CCP between 0.95 inductive (overexcited) is convenient for TO / DO. However, the issue is in what way the WPP can control the compliance with this condition? The large part of the turbines have as a power factor in the standard

construction the value 1 (zero reactive power absorption / production).

For WPP that include turbines without reactive production capabilities or wherever they do not suffice, developers used initially condensers to correct the power factor to the value 1, but this solution does not determine a dynamic response to the frequency changes and system voltage. Due to the fact that this equipment is slow, they cannot carry out a fine continuous control and cannot react to small fine voltage changes, usual in weak networks.

For example, in the USA FERC (Federal Energy Regulatory Commission) requires a power factor interval ranging between 0.95 inductive – 0.95 capacitive that is not compulsory only if the system impact study considers that it is necessary. Also this study determines if it is necessary to have supplementary equipment based on power electronics for a dynamic control of the reactive power or if condensers do not suffice [3].

The reactive power produced/consumed in the delimitation point has to range between certain imposed limits, a condition many types of turbines cannot meet unless they improve the standard wind generators or without supplementary equipment.

The reactive power production or absorption of the power plant in the example mentioned, as it is seen in the delimitation point, does not depend only on the reactive injection/production of each turbine or on the reactive power injection / absorption of a possible compensation equipment, as well as the reactive power injection / absorption of the power collecting system of each wind unit, on the reactive power losses on the 110kV (overall 62 km) of connection to the new 110/400kV and on the reactive power losses at the 400/110kV 250MVA transformer for connecting to the 400kV busbar.

In Figure 2 we present the way in which the total reactive power issued/absorbed by the WPP ranges at the terminals of all the units, at the 110kV busbar, in the new 400/110kV substation and on the 400kV side of the 400/110kV transformer.

The calculation presupposed that the turbines used have the possibility to carry out a voltage control at the terminals ranging between 0.95 inductive – 0.95 capacitive.

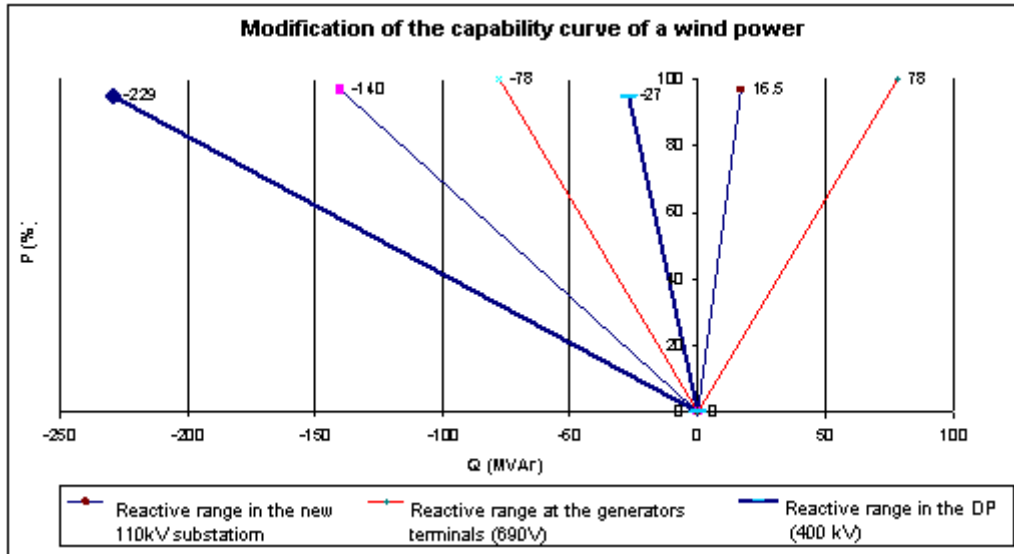


Fig. 2 – Evolution of the wind power plant capability diagram starting from the terminals of the generators up to the delimitation point, on the 400 kV side of the 400/110 kV 250 MVA transformer

From the figure it can be noticed that in the connecting point (on the 400kV side of the 400/110kV transformer in the connection substation) the WPP operates only under a capacitive (subexcited) state, without the possibility of producing reactive power. To meet the Transselectrica conditions, the beneficiary has to acquire an equipment that performs the reactive power compensation up to the value corresponding to a 0.95 inductive power factor.

The best solutions use SVC or STATCOM equipment that compensates the reactive power demand in the delimitation point, however, due to high costs, a series of solutions use lower power STATCOM equipment combined with condensers.

Any supplementary reactive power compensation at the busbar of the power plant up to the remote coupling point to the network must be identified during the process of granting the consulting by the TO/DO before obtaining the connecting authorization by the WPP.

The sizing of such an equipment cannot be carried out but after finding out all the electric characteristics of the turbines, of the turbine connecting cables to the busbars, of the 110kV lines/cables, of the 400/110kV transformer.

Another aspect is the fact that some 110 kV or 400kV substations can be considered to be CCP for 2 – 4 WPP with various

beneficiaries. Under the circumstances we should consider carrying out the reactive power compensation for each WPP separately, individually or we should carry out a common compensation system.

Relating to this paragraph, in the opinion of the authors, it is indicated to maintain the requirement for the wind power unit / wind power plant of continuous reactive power control, but without establishing beforehand the power factor range achieved in the CCP.

2.2 Overcoming the voltage dips and variations

The capacity of overcoming the fault or behaviour of a power plant during the fault is the ability of the generator to remain connected to the network during faults (short-circuit) in the network and to resume the normal operation after eliminating the fault. Although initially wind generators had to be disconnected from the network at voltage dips, today this capability is compulsory for the WPP in most countries, especially for the connected to the OHTL.

According to article 9 [2]:

(1) The power generator has to remain in operation upon the occurrence of voltage dips and variations on one or all the phases, in the connecting point, of the type of those in Figure 3.

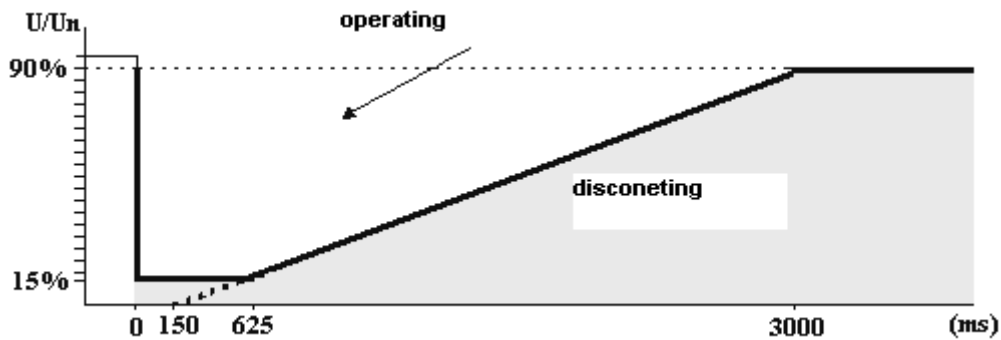


Fig. 3 - Shape of voltage dips at which the power generator has to remain in operation

(2) During the voltage dips CEED has to produce active power corresponding to the level of the remaining voltage and maximize the injected reactive current, without exceeding the operating limits of the CEED. The CEED has to be able to generate maximum reactive current for at least 3 s. This provision (art. 9) is obviously, absolutely necessary in case of a high power installed in wind power plants to avoid blackouts, for ensuring the transient stability in their operation.

This condition is valid also for non-dispatching power plants ($P_{inst} < 10\text{MW}$). However, the following issue occurs: many WPP with powers of 1 – 8MW are connected in derivation in mid voltage electric lines (20 kV). These lines – usually long distribution “axes” - supply a high number of transformer posts and, given the high frequency of transient faults on these lines, they are provided with three-phase tripping, which acts after relatively long pauses (1.5s – 3s, respectively 5s – 7s in cycle 2). The presence of a power plant that might remain connected (without an explicit provision for disconnecting from the distributed power line upon fault) does not allow keeping this extremely important automation for ensuring the continuous supply to consumers. Therefore, it appears necessary – in the opinion of the authors – to complete for the non-dispatching wind power plants connected to the power distribution line – the disconnection upon fault in the network. By this provision, given the low power of the WPP in this situation (even if 3 – 7 wind units would be on the same axis) it would not endanger the NPS stability or that of the area extended by the network.

2.3 WPP returning after restoring the voltage within normal limits

This provision (art. 9, paragraph 3) needs to be specified:

(3) From the moment the electric network voltage was restored within the normal operating limits, CEED has to produce the whole active power available as soon as possible, with a degree of load variation of at least 20% of the installed power per second (MW/sec.).

The current editing of the present form of the current standard might generate blackouts. Let us presuppose that in a 400/110kV transformer substation with two transformers, the cause of the failure was the faulting of a transformer unit and that the transformer remained in operation might have the capacity surpassed upon returning to the power plant connected to the 110kV busbar system. Obviously, also the second transformer might disconnect, with the respective consequences for the whole area. It appears necessary – in spite of all the risk of a period with a virtual lack of generated power – the CEED return to the power available only with the approval from the STO/DO.

Such a completion of the technical standard might avoid a large blackout, whenever the failure that determined the voltage deviation might have led to the reduction in the capacity of the power exhausted from the WPP.

Along the same line of thought, art. 15 provides the automatic connection of the CEED when the speed of the wind returns to normal operating values. The provision for the WPP is absolutely correct.

The system transmission operator, taking into account the distribution of the CEED on various areas, the concentration of the CEED and the possible short term variation of the

generated power will analyze the impact upon the frequency control in the NPS and will establish whether this provision can remain in the current editing or for quick increases in the power generated over a certain value, the approval from the STO is necessary.

2.4 Avoiding the network congestion

Some technical standards for network connection to the WPP explicitly provide the obligation of producers to reduce power, at the request of the network operator, without penalizing the operator. CN Transelectrica SA has the practice that in the authorizations for the solution studies regarding the WPP connection to the public overhead transmission lines to specify: "CNTEE Transelectrica SA, as System and Transmission Operator, has the right, in case the entire NPS operating reliability makes it necessary, to order the disconnection and / or performing of installations likely to ensure

the tripping of the wind power plants by criteria dictated by the NPS reliability". It should be analyzed if these provisions should be introduced also in the order 51/2009.

2.5 Active power control depending on the system frequency

In article 10 [2] it is specified that: CEED will be provided with an automatic system control of the active power depending on the value of the frequency (f/Pautomatic control). That will act according to a frequency/active power response curves exemplified in Figure 4. At the same time, at the same paragraph it is specified that if the network frequency grows or decreases, the power plant must have the capacity to decrease, respectively to increase, the active power produced. For a power plant to increase the power produced means that it must operate initially under the maximum power value available which has high economic implications, as it might decrease the power production.

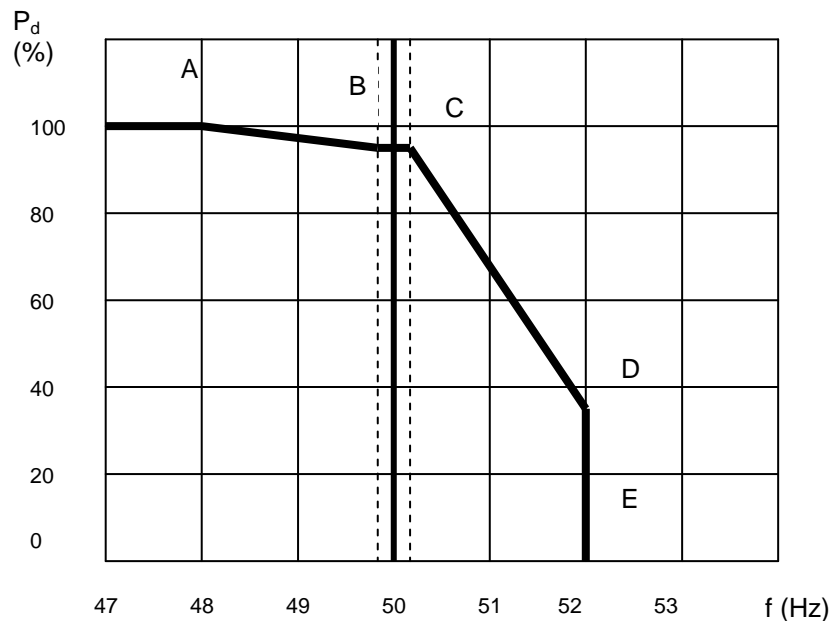


Fig. 4 - CEED power variation depending on the frequency

2.6 Designing the connecting installations to the public overhead transmission lines of the WPP

Relating to that aspect, the current technical standards do not have any reference. The existing technical norm (PE 026/92) and the current Technical Codes do not refer to wind power plants so that the network connection studies were carried out initially

- by pursuing the compliance with the standards for conventional power plants:
- checking the steady states for the network with all the operating elements (N) and (N-1) operating elements (the inclusion within the capacity limits and those of the voltage range);
 - compliance with the short-circuit stress limits;
 - compliance with the static stability limits;

- checking the transient stability, as well as the checks relating to the quality of electric power (flicker, harmonics).

Currently, taking into account the approach to the problem also in other systems, CN Transelectrica SA, on the basis of studies carried out in Romania, established the following approach to analyzing the wind power plants for sizing states.

- the analyzed WPP will be considered for the states with N elements loaded at the rated power and at 70% of the rated power in states with N-1 operating elements;
- the rest of the wind power plants in various analyzing hypotheses will be considered to be loaded at 70% of the rated power in the analyzed area and 30% of the rated power in the rest of the NPS.

These indications are not currently "regulations" and are contested by some distribution operators, however, without having a scientific technical argumentation. Therefore, it is obvious that during the next period, it is necessary to complete the Technical Standard with clear criteria for sizing/designing the connecting installations of the WPP to the system.

3. Conclusions

The technical standard approved by ANRE by Order 51/2009 makes it necessary for the wind power plants to behave like conventional power plants and, sometimes, even more rigorously than these, under the conditions in which these units differ to a large extent from the conventional generators.

The paper presents a series of aspects included in the technical standard that, in the opinion of the authors, requires revision. Taking into account the restrictive conditions imposed at present, most wind power plants might actually be connected to the system

References

- [1] http://www.ewea.org/fileadmin/ewea_documents/documents/statistics/2008_wind_map.pdf
- [2] Condiții tehnice de racordare la rețelele electrice de interes public pentru centralele electrice eoliene, Cod ANRE : 51.1.017.0.00.03/04/09
- [3] Zavadil R., Miller N., Ellis A., etc - 2007 Queuing UP. Interconnecting Wind Generation into the Power System, IEEE Power & Energy, Volume 5, No. 6, November/December, 2007
- [4] The grid code, Issue 3, Revision 22, 17th September 2007, NATIONAL GRID ELECTRICITY TRANSMISSION, Great Britain

only with major investment into supplementary equipment in the common coupling point, that should compensate the behavior of the WPP different from that of conventional power plants, in order to meet the technical conditions.

We consider that to carry out a dispatching operation of the WPP in which the power factor continuously ranges from 0.95 capacitive to 0.95 inductive in the connecting point requires in many cases high supplementary investment in comparison with the total investment, especially in case of connecting to the overhead transmission line. Relating to this paragraph it might be indicated, in the opinion of the authors, to maintain the requirement for wind power plants to continuously control the reactive power, but without establishing beforehand the range of the power factor carried out in the CCP.

From the point of view of the authors, non-dispatching power plants connected to the 20kV voltage must not have the obligation to pass through the voltage dips in the network but to be disconnected upon the occurrence of faults in the network.

The provision in the Technical Standard item 5(d) for CEED (also CEEND) to operate continuously at voltage in the connecting point in the range $0.90 \div 1.10 U_n$ is not necessary, as in the Technical Codes the voltage in the connecting point is imposed by the NDS/NPS overall, and, with or without WPP, should comply with the inclusion in the allowable band: MV, 110kV, 220kV ($0.9 - 1.1)U_n$, respectively at 400kV ($0.95 - 1.05)U_n$. The condition might be that the WPP by the reactive power control, should not determine the getting out of the allowable voltage band.

Last but not least we consider it necessary to complete the Technical Standard with clear criteria for sizing/designing the connecting installations of the WPP to the system.

WASTE ENERGY VALORIZATION TECHNOLOGIES

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Abstract: The paper presents the general aspects regarding the municipal waste energy valorization technologies. Waste incineration with or without recovering the flue gas resulted constitutes one of the most important methods for their treatment and elimination applied in the European Union. At the same time, by this procedure also a waste energy valorization is likely. We performed a comparison between 2 waste energy valorization variants, incineration and gasification, respectively.

Taking into account that by the gasification technology one can use only the sorted (packed) waste, the conclusion of the comparative analysis by which it is confirmed the fact that incineration is the most suitable technology for the municipal waste valorization is correct, because by this process the waste in the community can be fired wholly.

Key words: *municipal waste, incineration, energy valorization*

1. General aspects regarding municipal solid waste

Municipal solid waste results mainly from the domestic activity in households. The calorific power of the organic fraction in the municipal solid waste ranges 8000÷12000 kJ/kg, which represents about a third of the calorific power of coal. The decision on the use of waste as an energy source is related to their local and national management policy and the

awareness of the population regarding recirculation and incineration.

The choice of the waste treatment die in a locality is done by taking into account:

- their composition and properties;
- available technologies;
- the market of various recyclable materials.

The whole management process has to be integrated in order to avoid the conflicts between various treatment dies.

Integrated waste management takes into account passing through two distinct phases (Figure 1).

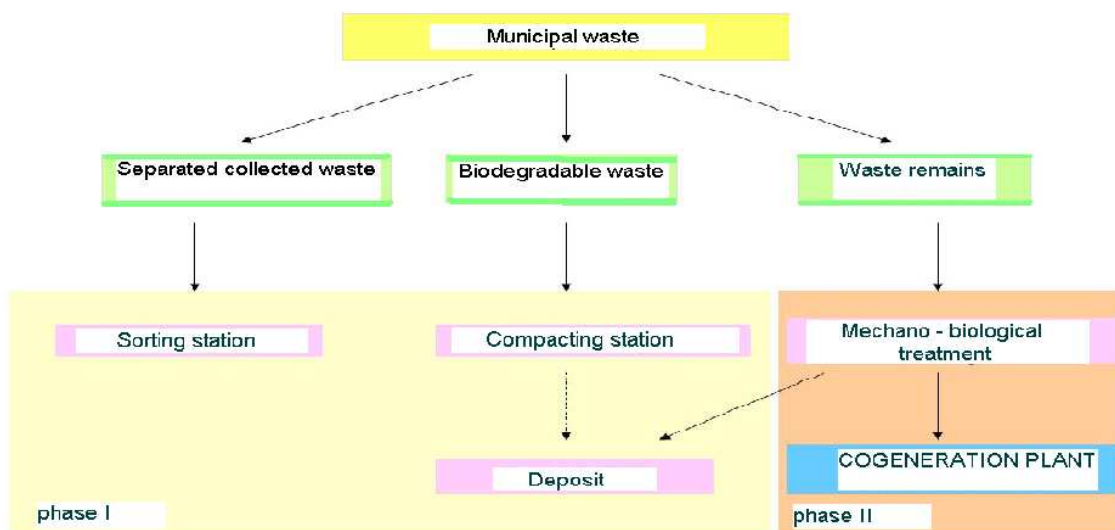


Fig. 1 - Integrated waste management

Phase I aims at stabilizing the separately collected biodegradable waste, efficiently separating the waste fractions for recycling and ensuring a new deposit. In order to achieve this goal there must be basic waste management buildings, the sorting station, the dismantling installation, the composting station, the deposit and precinct infrastructure.

Phase II aims to reduce the quantity and improve the stability of the disposed waste, in order to offer a solution for the waste sludge, that in the water treatment installation and to ensure more power for the heating of the power plant. To achieve this goal there must exist the mechano-biological treatment of municipal waste and the cogeneration plant.

From the integrated waste management diagram it results the following:

- a) the first basic principle is to minimize-recycling of the waste quantity that has to be treated and removed by collecting-sorting and recycling.
- b) depending on the waste characteristics one can use various treatment-removal „dies”, namely:

- b.1.) biological treatment by composting;
- b.2.) thermal treatment by incineration and co-incineration;

- the waste treatment-removal die by co-incineration represents an „industrial installation” for which can be done a global balance, made up of material balance, energy balance and the quantification of the environmental impact by environmental balance.

- the choice of the incineration and co-incineration is based mainly on the quantities produced and the characteristics of waste: i) the specific weight (kg/m^3); ii) humidity (%); iii) the calorific power (kJ/kg or kcal/kg); iv) the carbon/nitrogen ratio (C/N).

b.3.) final disposal.

In general, high calorific power are used for electric and thermal power production. In order to do that, waste is either incinerated, or turned into solid, liquid or gas fuel that can be easier to transport and use for heat and electricity production or for supplying cars. The municipal solid waste treatment and conversion are presented in Figure 2.

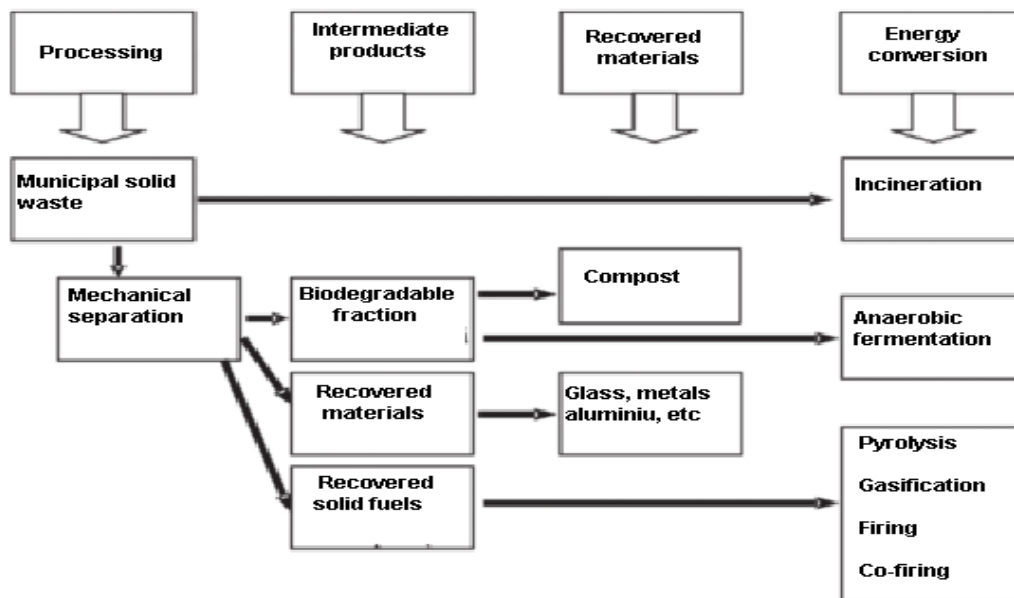


Fig. 2 - Municipal solid waste treatment and conversion dies

2. Waste thermal treatment technologies

In many EU towns where waste thermal treatment is carried out there are firing and gasification installations.

2.1 Firing installations

Firing is the oldest and most used energy conversion method. The electric power transforming efficiency is 20÷25%. Waste can be incinerated directly or fired at the same time with coal (co-firing). Modern boilers are designed to use co-firing to reduce CO₂ emissions.

Upon designing the firing system we take into account the fuel characteristics to be used, the environmental legislation, the cost and performances of the available equipment. The limit waste humidity for maintaining firing does not have to exceed 60% of the mass. Humidity is a very important property on which depend the firing installation design and the firing process unfolding.

The main types of biomass firing installations, to which belong also the municipal waste, are presented in Figure 3, namely:

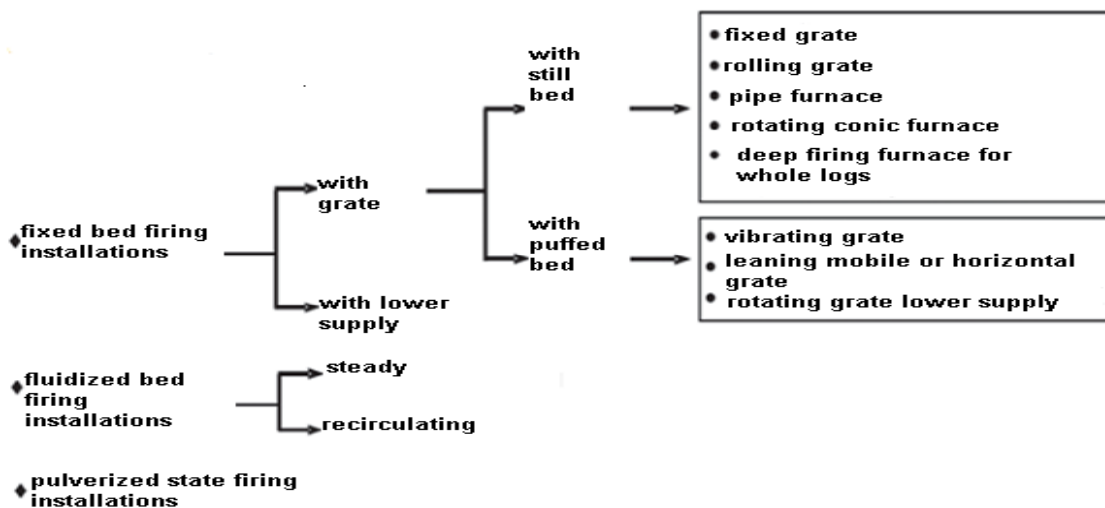


Fig. 3 - The main types of firing installations

Upon choosing the firing technologies the following problems have to be taken into account:

- the dirtiness and corrosion of the heat exchange surfaces;
- reducing the heat exchange of dirtied surfaces as well as their corrosion that determines the shortening the lifetime duration of the equipment.

The most encountered firing (incineration) technologies are those provided with grate furnace, rotating furnace and a fluidized bed furnace.

In a grate furnace, waste is introduced and fired for 2 or 3 hours at a temperature from 750° to 1000°C. We use a grate that allows the air cross the firing bed.

The technologies differ depending on the (fixed or mobile) grate, the waste and air mixture to reach the best combustion (lateral air blast , etc), and to control the unfired and ash waste production. We use rotating furnaces, especially for industrial waste. Metals damage grates, although waste will be introduced into a rotating furnace with longitudinal airing, which allows the optimizing the (waste/air) mixture and higher temperatures (1200°C).

It may be that in fact, energy valorization originates in the simple fact that matter fired at a high temperature generates heat, which can be recovered so much more as waste has a high calorific power.

Waste incineration generates polluting emissions. A ton of domestic waste generates 6,000 Nm³. These gases contain pollutants that have to be captures / retained / treated (for ex., dust, metals and dioxin).

The gas treatment equipment can have several modules: a) dedusting; b) acid gas neutralization; c) dioxin and furan treatment; d) nitrogen oxide treatment.

Out of incineration, the treatment residue are made up of: slag, waste incineration gas residue, ashes, combustion refuse, miscellanea.

The ash deposition on the heat exchange surfaces upon firing waste can take place to a larger or lesser degree than upon firing coal. Upon firing waste and coal mixture, the ash deposition takes place to a lesser degree than upon firing only one of the fuels. The adherence and hardness of the depositions upon waste firing are higher than those upon coal firing.

The tests carried out prove that sodium and potassium decrease the ash melting temperature, and, consequently, the ash deposition on the pipes of the boiler is intensified. Calcium and magnesium increase the ash melting temperature. Silicium can combine with potassium producing silicates with a low melting temperature in volatile particles. This process is important, on the one hand, in order to avoid sintering / agglomeration and melting ash and, on the other, in preventing ash slagging on the heat exchange surface.

The volatility followed by the condensation of volatile metals leads to the formation of flying ash sized less than $1\mu\text{m}$ which is hard to retain the filtration installations.

The diagram of the main flows in a fixed bed firing installation is presented in Figure 4.

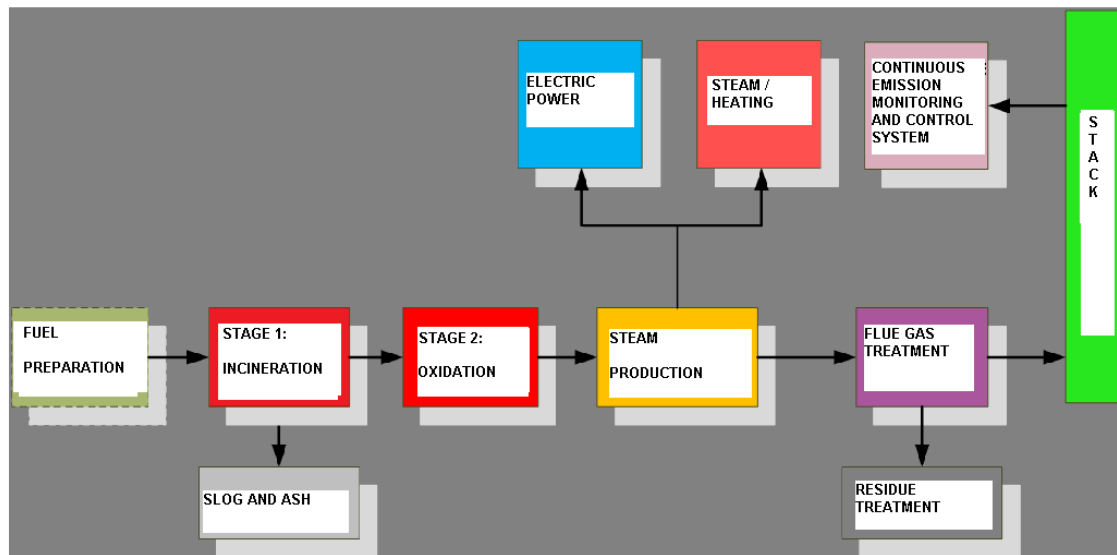


Fig. 4 - The diagram of the main flows in a fixed bed firing installations

The high unfired carbon content in the ash reduces the chemical stability of ash and increases a lot the amount of ash, which increases the ash handling, transport and storage cost. To diminish these effects, ash should recirculate in order to burn it again or the firing process should be improved.

The rotating furnace investment costs are higher than about 10% as compared with the mobile grate furnace due to the storage spaces, the transport means and furnace supply systems. The circulating fluidized bed firing installations are suitable for ash re-firing, because they are flexible at fuel change and produce ash without unburnt

fuel. Ash re-firing leads to a reduction in NOx emission by 20%, but also to the increase in CO emission at about 100-140ppm.

2.2 Gasification

Thermochemical gasification is the conversion process by partial oxidation at a high temperature of the matter containing carbon, like biomass and coal, by forming a gas named gasogen, "medium heat value gas" (MHV gas) or "average quality gas". This gas contains CO, CO₂, H₂, CH₄ and lower quantities of heavier hydrocarbons such as ethane and ethene, water, nitrogen (if we use air as oxidizing agent) and various

contaminants; the small coke particles, ash, tar, and oils. Partial oxidation can be performed by using: air, oxygen, steam and their mixtures.

Air gasification produces low calorific power gas (4000÷7000 kJ/m³N), suitable for using in boilers, engines and gas turbines, but is not suitable for transport by pipes due to a low energy density.

Oxygen gasification produces higher calorific power gas (10000÷18000kJ/m³N), suitable for a limited distribution by pipes and for using as synthesis gas (the mixture formed from CO, H₂ and CO₂ traces obtained by cleaning gasogen gas). This gas can be produced also by pyrolytic or steam gasification, the heat necessary to the process being ensured by firing the auxiliary product - carbon in a secondary reactor.

Gasification can be applied to biomass, including also municipal waste with a humidity content lower than 35%.

Air gasification is the most used technology due to avoiding costs and dangers associated to oxygen production and use corresponding to oxygen gasification, as well as the complexity and cost of the multiple reactors from pyrolytic or steam gasification, where two reactors are necessary.

Currently gasification is considered still to be a pilot phase technology and ensures the processing of only certain types of waste (for ex. Flaff obtained from pack waste). There is a single installation of this type in Finland and also in Germany a similar installation was put into operation, but that due to operation and maintenance problems was closed down in 2004.

3. Comparative analysis of the municipal waste valorization technologies

To perform a comparative analysis of the municipal waste valorization we consider an annual quantity generated by municipal waste of 130 688 tons/yr, with P_{ci} average = 9713 kJ/kg.

The comparative analysis takes into account 2 technological variants likely to carry out in the town.

Variant 1 – Domestic and mixture assimilated waste incineration

The main installations within this technology are the following:

- heat recovery and energy valorization system
- flue gas filtering and washing system (dedusting, neutralization, residue treating)
- slag and ash collecting system
- waste water treatment system.

Variant 2 – Sorted (pack) waste gasification

The main installations within this technology are the following:

- waste collecting and homogeneity system
- magnetic metal separation system
- waste treatment system (drying – sterilizing – briquetting)
- gasogen
- flue gas treatment system
- slag collecting system
- waste water treatment system.

In Table 1 we present the technical and economic indicators of the two analyzed variants.

Table 1

	Variant 1 Incineration	Variant 2 Gasification
Waste type	Domestic and mixture assimilated waste	Pack waste
Generated annual quantity (t/yr)	130,688 Available quantity at municipal level	130,688 The quantity is not available but at a regional level
Operating hours/yr	8,000	8,000
Minimum calorific power (kJ/kg)	8,500	10,000
Electric power generated (MWh/yr)	116,000	116,000
Installation investment costs (mil. Euro)	36	41
Installation operation costs (Euro/ton)	55	32
Collecting and transport costs (Euro/ton)	22	22

Due to the comparative analysis of the waste incineration variant and gasification variant from the technical and economic point of view, the domestic and mixture assimilated waste incineration proved feasible.

4. Conclusions

From the analysis of the municipal waste thermal treatment technologies for energy valorization the following result:

- the implementation of a gasification technology – similar to that in Finland that is the only one in the UE – will not comply with

the “energy efficiency” criterion and will valorize energetically only pack waste generated at regional level;

- at the level of the waste pack quantities generated in a town, currently the gasification technology for smaller capacities is not produced (at town level);

- the implementation of a technology by using the fixed bed firing installation (mobile grate furnace) or fluidized bed firing installation will ensure the solution to the waste management problem in town under high reliable conditions in design, construction, operation and maintenance.

References

- [1] McKendry P., Energy production from biomass (part 2) conversion technology, Bioresource Technology 83, 2002, 47-54.
- [2] McKendry P., Energy production from biomass (part 2) gaseification technology, Bioresource Technology 83, 2002, 55-63.
- [3] Ion V. Ion, Energia din Biomasă, Art.7(38)/2006 Universitatea “Dunărea de Jos” din Galați.
- [4] Milka Leskošek, Jure Svetičič, Slavko Marš, Regional waste management centre Celje, Aprilie 2010

URICANI TOWN DISTRICT HEATING BY USING RENEWABLE ENERGY SOURCES

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Abstract: The European Union energy objectives include also the increase in the share of renewable energy sources to 20% of the whole European Union power consumption in 2020. In Romania there is an important potential of renewable energy sources, made up of hydroelectric power, biomass, wind energy, solar energy and geothermal energy.

The use of wood biomass for heating is promoted by many European Union countries, and the European Commission supports financially projects that use biomass in order to produce electric or/and thermal power production.

Following the continuous deterioration of the state of the district heating system of Uricani

town, the local public administrative authority decided to promote a district heating project by using renewable energy sources, respectively biomass in order to access European and governmental funds for its implementation.

Romania has a high wood biomass energy potential, evaluated at about 1700 thousand toe/year, with important reserves found even in the area of Uricani town. That determined the local administrative community to promote the development of a project for the full rehabilitation of the district heating system in: the source, heat transport networks, thermal points and distribution networks.[1]

Key words: *renewable sources, pre-insulated pipes, thermal modules, district heating system monitoring*

1. Introduction

The Council of Europe adopted an action plan that aims to reach the targets of reducing by 20% the greenhouse gas emissions, of using a 20% share renewable energy sources and of increasing the power efficiency by 20% up to 2020.[2]

The European Commission analyzes, promotes and supports financially national plans that reflect this reaching of these targets until 2020.

The use of the renewable energy sources contributes to the reduction of greenhouse gas emissions.

Romania, due to the climate, relief and nature of the soil, has a considerable quantity of wood. Romanian territory was heavily wooded so that, 100 years ago the forests covered up to 88% of the territory. Romania holds 6.3 million ha of forests, representing 26.7% of the area of the country. Besides, there is a supplementary area of about 100 thousand ha of "wooded area" and other land with forest vegetation.

Taking into account the wood resources in Romania the wood processing and furniture

industry developed, resulting in wood waste. The waste quantity resulted depends on the specific consumptions as well as on the processing capacity.

The estimated average price of forest waste depends on a series of factors, namely: the cutting forestry technology, the quantity and quality of wood waste, the transport distance. An approximate calculation resulted in the sum of 32 euro/ton.

According to the renewable resource valorization Strategy, it is estimated that Romanian wood biomass potential is about:

- 1,175 th toe – residue from forest exploitations and fire wood;
- 487 th toe – wood waste – sawdust and other wood remains.

The Hunedoara county has a high biomass potential, evaluated by ARCE in 2006 at 600 – 700 TJ of which about 73% is not yet used. This value includes all the biomass sources, not only those based on wood.

2. Uricani area district heating

The central public thermal power production, transport, and distribution system service of the town of Uricani was conceded to the operator SC GOSCOMLOC SA in 1995.

The Uricani town district heating system is made up of:

- Thermal power sources
- Secondary thermal networks

2.1 Thermal power sources

Thermal power (heating and hot water) supply to Uricani town was at first carried out during the period 1975 – 1978 by means of three Thermal Plants, situated within the territory of the town. These were equipped with hot water boilers, METALICA PAL 15 type, operating on solid fuel – coal.

The distribution of the 3 thermal plants (TP) was the following:

- Town TP 229 apartments
- Bucura 1 TP 1344 apartments
- Bucura 2 TP 1123 apartments

In the area of the old town are 40 blocks built with 949 apartments, 720 of which were

heated with wood and coal stoves and the remaining 229 were supplied from Town TP. The town hall, nursery, hospital and kindergarten have their own thermal power plants operating on light liquid fuel (LLF).

Currently the Uricani town has no district heating system, as since 2006 the used system was given up, because the thermal plants had a high degree of obsolescence, and the level of pollution has risen a lot above the allowable norms, according to the relevant standards.

Thus, the Uricani town district heating is currently performed mainly from individual sources that operate on wood/coal fuel. This district heating system (local sources on wood/coal) is polluting. The local sources are not monitored from the point of view of the environmental impact.

As a result of completing the works for introducing the methane gas in town in 2008, about 40% of the apartments mounted individual plants operating on natural gas. Bucura II TP and Town TP are currently dismantled. The buildings of all the three thermal plants are in a pronounced stage of damage.



Fig. 1 - Bucura 1 Thermal plant 1 before being rehabilitated

2.2 Secondary heat distribution networks

The district heating system for the blocks of flats in the Uricani town was designed of 3 pipes: 2 for heating + 1 for domestic hot water, in the conventional solution having pipes thermally insulated with mineral cotton, mostly mounted underground, in prefabricated reinforced concrete pipes, or in the basements of the blocks. There are also areas where the networks are overhead. The secondary heat networks are 11 km long.

3. The modern solution for district heating

The local authority of Uricani town takes into account to provide to inhabitants a district heating service under the conditions of an

efficient use of the renewable resources and pollution mitigation. [3]

The following are taken into account:

- The provision of a new thermal power supply source;
- The transformation of the existing thermal plants into thermal points supplied from the new thermal plant;
- Heat carrier transport networks;
- Distribution networks for heating, domestic hot water and recirculation;
- 3 new thermal points, with modular equipment in factory.

The maximum hourly heat demand that should be ensured by the source at the level of the end consumers is presented in Table 1:

Table 1

Consumer	Maximum hourly heat demand Gcal/h	Maximum hourly domestic hot water demand Gcal/h	Average hourly domestic hot water Gcal/h	Total maximum hourly demand/TP, MV Gcal/h
PT 1 Bucura	2.44	0.37	0.2	2.81
PT 2 Bucura	1.79	0.27	0.15	2.06
PT 3	2.32	0.6	0.2	2.68
Total consumer demand	6.55	1		7.55
Total demand at the source				8.12

Taking into account the maximum heat demand we adopted the solution of carrying out a thermal plant equipped with 1 hot water boiler (CAF) of 10 Gcal/h operating on natural gas and 1 hot water boiler (CAF) of 1 Gcal/h operating on wood biomass.

For the transport and distribution system we take into account to carry out the thermal networks by using pre-insulated pipes.

We provide 3 new thermal points, respectively TP1 and TP2 resulted from transforming Bucura TP1 and TP2, respectively carrying out a fully new TP3 that will have a new site in the central area of the town.

4. Presenting the proposed investment

4.1 The thermal plant and biomass deposits

The new thermal power production source, located in the Bucura 1 Thermal Plant, will include main equipment:

- 1 hot water boiler of 10 Gcal/h for supplying heat during wintertime;
- 1 hot water boiler of 1 Gcal/h for supplying domestic hot water all year long, about 8000 hours;
- winter district heating water electropumps – 3 items, equipped with a frequency converter each;
- summer district heating water electropumps- 2 items, equipped with a frequency converter each;
- addition and expansion water module, including addition water electropumps (2 items);
- softening – degasifier;
- natural gas supply system;
- wood biomass fuel supply system;
- two stacks, one for each hot water boiler.

The equipment will be mounted in the old building of the thermal plant, a building that will be rehabilitated.



Fig. 2 - Bucura 1 Thermal plant after rehabilitation

On the district heating turn collector will mount a control tap with 3 paths, by which we perform a mixture between hot water going out of the boiler and the district heating return water. The mixture between these fluids leads to the control of the hot water temperature on the district heating turn depending on the environmental temperature.

The 10 Gcal/h hot water boiler is a horizontal boiler with flame tubes and smoke pipes operating on gas fuel, having, in rated operating state the following parameters:

- Input water temperature70⁰C
- Maximum allowable output water temperature110⁰C
- Output water pressure6 bar
- Heat load10 Gcal/h

The 1 Gcal/h hot water boiler operating on wood biomass fuel will be designed for the biomass made available by the client, with the following characteristics:

- 20% sawdust.....max. 35% humidity
- 20% wood chps.....max. 35% humidity
- 60% logs.....max. 35% humidity

We will ensure the transport of wood biomass to the deposit, the rhythmical supply to the power plant with prepared biomass, as well as the wood sizing according to the furnace of the boiler.

The rated operating state parameters are:

- Input water temperature40⁰C
- Maximum allowable output water Temperature110⁰C
- Output water pressure.....6 bar
- Heat load1 Gcal/h
- Fuel flow rate 390 kg/h
- Removed ash quantityabout 100 kg/day
- Operating hours8000 hours/yr

For the continuous fuel supply of hot water boilers we need 3 transporting belts that will bring fuel to the biomass deposit.

The ash produced as a result of firing fuel (estimated quantity at 100 kg/day) will be stored in a closed container and taken over rhythmically by the same company that carries out the biomass supply. The boiler is equipped with a flue gas particle retention system of the multi-cyclone type. On the flue gas stack will provide an exhausting ventilator) that triggers a negative pressure among gases that are sucked from the boiler and exhausted through the stack.

The expansion and addition module, fully equipped and automated, has the following technical characteristics:

- addition water flow rate: 1 m³/h
- addition water pressure: 2 bar
- static pressure in the network: 2.6 bar
- the total volume of the primary network: 25 m³
- feed water temperature: 10 – 25°C.

The expansion and addition module contains at least the following equipment:

- softened water basin;
- addition water electropumps, 2 items: 1 operating and 1 standby.

District heating electropumps for winter: 3 items, (3 x 50%), 2 operating and 1 standby – ensures the circulation of hot water through the district heating network.

District heating electropumps for summer, 2 items (1x100%), 1 operating and 1 standby ensures the circulation of hot water in the district heating network during summer, when the 1 Gcal/h hot water boiler operates.

The water softening system will have the flow rate of $Q = 1 \text{ m}^3/\text{h}$.

The feed water of the softening installation is the drinking water from the drinking water network of the town.

The quality of the softened water according to the technical provision PT C2-2003 is – total hardness = 0.05 mval/l.

The installation is formed of two technological with a rated flow rate of 1 m³/line.

The water softening technology include the following treatment steps:

- the gas chlorine clearing and retention step by filtration through automatic filters with active coal bed
- the water softening step by filtration on Na-cation filters
- the water chemical degasifier step by chemical reagent dosing.

The wood biomass supply system consists of a deposit that will be located in a part of the old building of the thermal plant.

That will be separated from the boiler room by a fireproof construction wall. In the deposit we will ensure room for the transporting belts and for fuel supply.

The transporting belts will ensure the continuous fuel supply to the 1 Gcal/h hot water boiler burner.

The crushed fuel from the deposit is taken over by a supply device and is transported (by means of the 3 transporting belts) in the lower part of the furnace from where it is introduced on the grater located on the entire area of the furnace.

The primary air is blasted upwards, by the valves of the grater, forming a suspended firing, and the secondary air is introduced above the furnace, in order to contribute to completing the firing process. This way we obtain an optimal firing, for low pollutant emissions.

Thermal loading of main equipment in characteristic operating states is presented in the thermal diagram. (Figure 3)

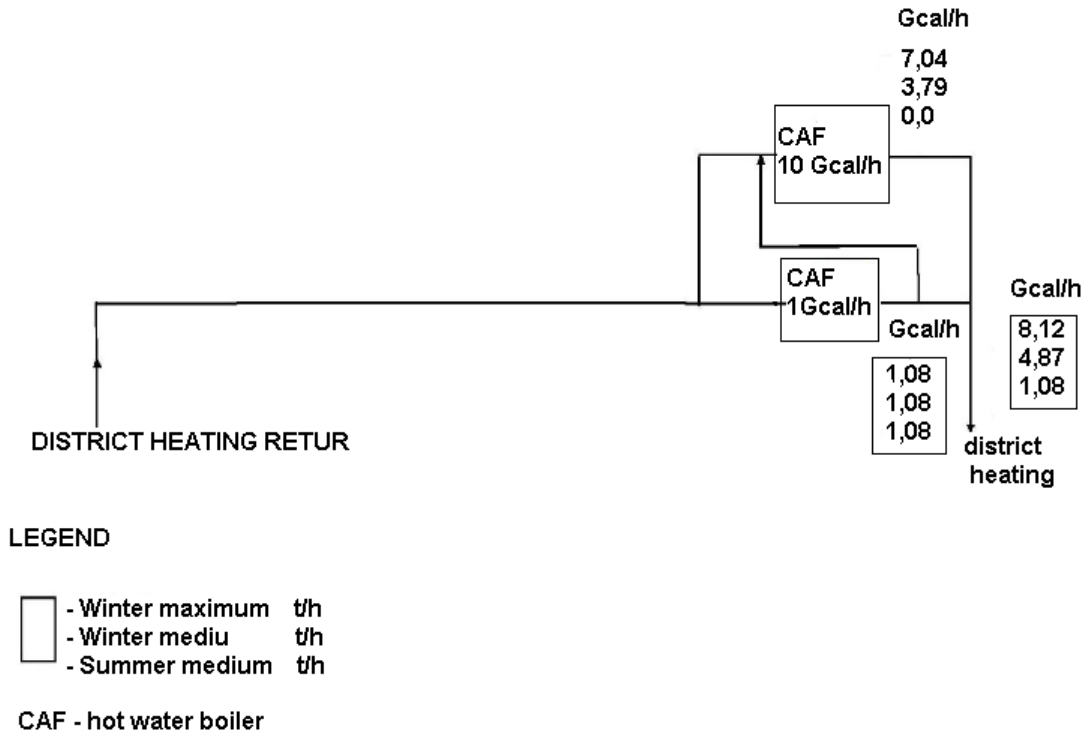


Fig. 3 - Uricani TP Fundamental thermal circuit

4.2 Transport and distribution networks

The transport and distribution networks will be carried out from pre-insulated piping made up of: the operating pipe (through which the heat carrier circulates), the thermal insulation from rigid polyurethane foam (PUR) without CO₂ content having parameters in accordance with the European standard SR EN 253 and the high hardness polyurethane protection cover without sewing, treated inside by the Corona procedure, with technical parameters according to the European standard SR EN 253, ensuring a good protection against the exterior wetness of the thermoinsulating material. These pipes have to guarantee the operation at a long temperature of 140^o C and have to be provided with a system of sensors (electrical conductors) incorporated into the foam, in order to monitor the level of humidity of the insulation and the location of the possible faults.

In order to carry out the district heating networks we provide to use – steel piping without hot welding laminated for high temperatures according to SR EN 10216-2-2003, material P235 GH according to SR EN 10028-2/2004, sized according SR EN

10220-2003, with diameters ranging between Dn 125 and Dn 200.

The length of the track of the primary tracks, located underground is about 670 m.

For the **distribution networks** we take into account the following works:

- dismantling the existing pipes;
- replacing them with earthed pre-insulated pipes, following the existing tracks, except for the situations when these cross under the basements of blocks, a case in which the pipes will be mounted on new tracks;
- the introduction of domestic hot water recirculation pipe along the whole length of the secondary tracks.

The distribution pipes will count 4 (heating, turn-return, domestic and recirculation hot water), and will have diameters ranging between Dn 40/125-Dn 150/250 (heating), Dn 40 (Ø1¼")/110 ÷ Dn 80 (Ø3")/200 (domestic hot water) and Dn 20 (Ø¾") ÷ Dn 50 (Ø2") for recirculation.

The total length of the tracks for the distribution networks corresponding to the three thermal points – that will be connected to the district heating system, is about 6000m.

We will take into account the equipping with monitoring systems for thermal networks in order to detect and locate the faults that may occur at the level of the piping.

To that end, the secondary circuits monitoring system will have the following equipment and main parts:

- the monitoring looping with detection sensors;
- line units that monitor each segment of track and ensure the data collection and transmission to a central unit;
- data supply and amplification units for the communication of the pre-insulated pipe monitoring / surveillance system;
- the monitoring plant unit that centralizes all the data from the surveillance circuits and informs the user on the state of the system;
- accompanying cables / data transfer from multi-wire distance, protected and screened;
- pipe/sensor connectors for the mechanical and electrical connection;
- connection boxes, etc.

The monitoring will be carried out individually at the level of each thermal point for the subordinated secondary networks and centrally by the central centralized monitoring unit located at the level of the dispatching room in TP1 – Bucura.

4.3 The thermal points

The proposed solution pursues the passing from the conventional system of quarter thermal plants, to the district heating system with direct connection to the primary heat carrier network by means of three thermal modules, fully equipped and automated, two located in existing buildings, and one in a new building. Thus, we will carry out primary heat carrier supply to the thermal point, by a network formed of 2 pipes, a solution that has many technical and economic advantages.

The proposed diagram is the indirect connection diagram of the heating installations to the primary network, by means of a heat exchanger and domestic hot water preparation, into heat exchanger in parallel to the district heating system.

The equipment will be acquired in a module system assembled by the supplier, tested and delivered in subassemblages and wholly according to sizes.

Thus, the **thermal module** will include the following equipment:

- heat exchanger for preparing the heat carrier;
- heat exchanger for preparing domestic hot water;
- pumps for heat carrier circulation in line, with frequency converter;
- domestic hot water recirculation pumps in line;
- the heat carrier temperature control looping according to the exterior temperature, control valves with two paths;
- impurity filters;
- domestic the domestic hot water temperature control looping, control valves with 2 paths;
- electric power supply and automation control board;
- temperature sensors, pressure sensors;
- measuring devices (local manometers and thermometers, primary thermal power meter, secondary heating and acm., cold and recirculation water meter);
- safety valves;
- closing devices: butterfly valves, airing taps, discharging;
- linking pipes;
- addition expansion module;
- water treatment module.

In order to carry out, maintain and control the adequate water chemical qualities we will mount:

- in the heating installation
 - automatic softening station
 - impurity filters
 - sampling bleeding
- in domestic hot water preparation installation
 - magnetic or electronic antitartar device
 - impurity filters sampling bleeding
 - sampling bleeding.

The addition – **expansion module includes:**

- addition pumps;
- open and closed expansion/addition vessel;
- discharging tap, electromagnetic tap with valve for pressure control or supply;

- safety valve;
- supply and control electric board;
- level sensors;
- armature, piping.

The prefabricated thermal modules will be installed on metallic foundations at

manufacturing, and these can be installed on a supplementary concrete foundation at the operating place. We will take adequate measures for ensuring the water discharge from the area where the heat exchangers and pumps were installed.

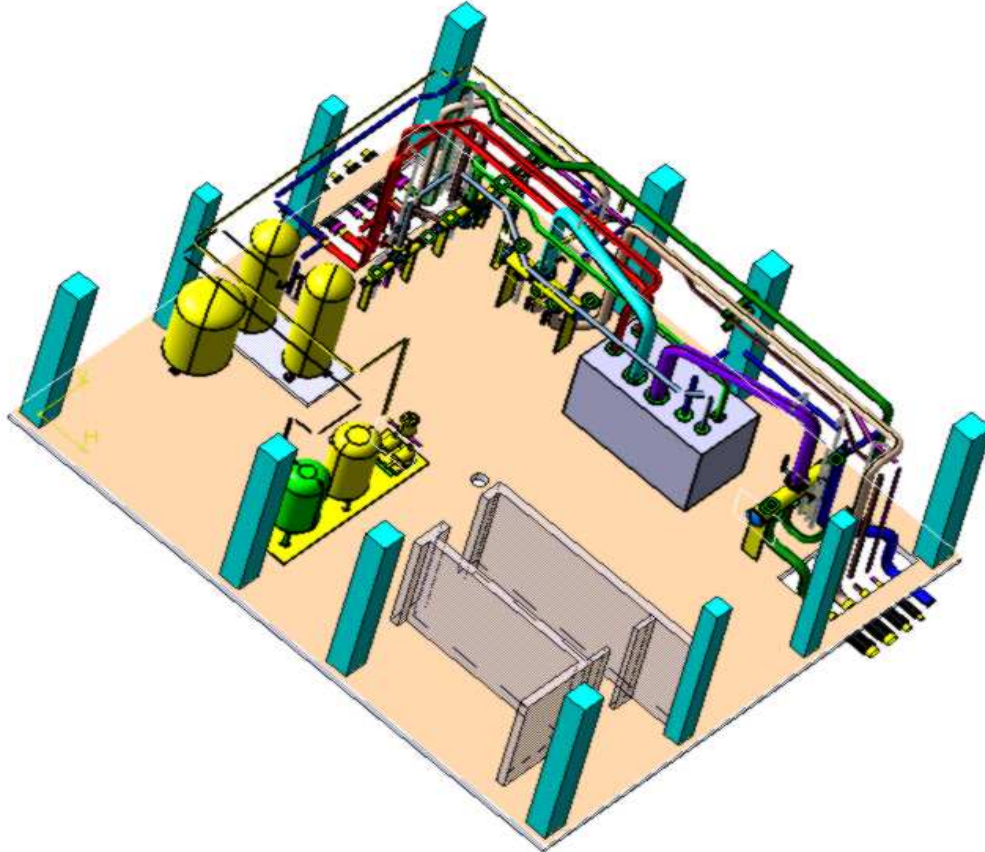


Fig. 4 - New thermal point Uricani PT 3 – a module system

5. Energy analysis

The annual thermal power quantity for the heating to be delivered to the end of the new thermal power, calculated according to SR 4838/97 on the basis of the average monthly temperatures for the town of Uricani is about 18273 Gcal/year, correlated to the classified

curve of exterior temperatures. The total annual hot water demand to the end of the thermal plant, both for heating and for domestic hot water preparation is about 22114 Gcal/year.

Ensuring the thermal power consumption in the 2 production units is presented graphically in Figure 5.

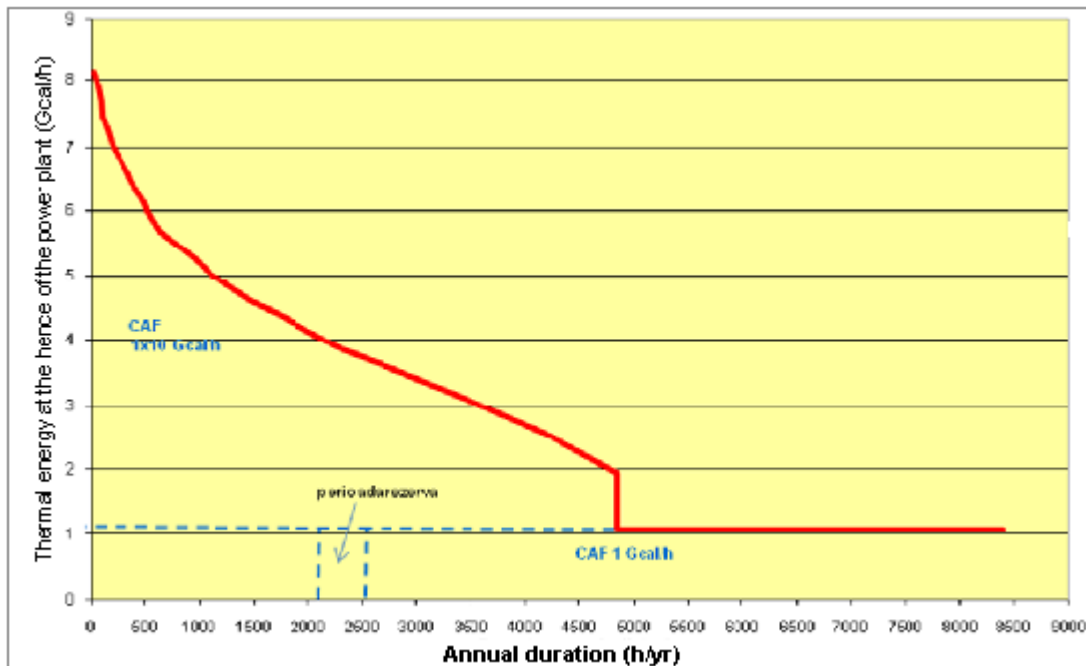


Fig. 5 - Annual variation graphic of thermal power at the fence of the power plant

To establish the average annual performance we took into account the following calculating bases:

- wintertime: 4844 hours/year
- summertime: 3556 hours/year

a. The annual thermal power quantity delivered to the fence of the thermal power was determined from annual variation graphics of the thermal power demand, based on the values of the hourly thermal power demand previously presented and taking into account the data forwarded by the client.

c. Fuel considered in calculating the annual production is:

- for the 10 Gcal/h hot water boiler: the natural gas with Pci = 8050 kcal/mc
- for the 1 Gcal/h hot water boiler: 98% biomass with Pci = 3000 kcal/kg and 2% natural gas with Pci = 8050 kcal/mc;

b. The durations of the characteristic operating states were considered on the basis of the data forwarded by the client, thus:

d. The annual thermal power production and annual fuel consumption we considered for each equipment, in the characteristic operating states.

In Table 2 we present the average annual performance during the lifetime considered in the economic efficiency analysis:

Table 2

Specification	UM	Value
Total operating duration	years	20
Annual operating duration	hours/yr	8400
Annual own electric power services consumption, of which: - pumping	MWh/yr MWh/yr	427.9 176.9
Thermal power delivered to the end of the thermal plant, of which:	Gcal/yr	22114.1
10 Gcal/h hot water boiler	Gcal/yr	14423.3
1 Gcal/h hot water boiler	Gcal/yr	7690.8
Annual fuel consumption, Of which:	MWh/yr	29413.4
For the 10 Gcal/h, of which:	MWh/yr	18232.9
Natural gas	Th mc/yr	1947.5
For 1 Gcal/h hot water boiler, of which:	MWh/yr	11180.5
Natural gas	MWh/yr Th mc/yr	223.6 23.9
Biomass	MWh/yr tons/yr	10956.9 3140.4
Global efficiency (Ql + Ep)/B	%	87.4

The total value of the investment determined by the acquisition and mounting works of the two new boilers of hot water in the Uricani TP and the rehabilitation of the transport and distribution system of the heat carrier of the town of Uricani is:

- 5 278 900 Euro (without VAT), of which:
 - Total values source Uricani TP: 2497 100 Euro
 - Total network values: 2 781 800 Euro

The financing of the investment regarding the rehabilitation of the district heating system of the Uricani town, we propose to be carried out 100% from the sources ensured by the investment program "2006 – 2015 district heating heat and comfort", under the form of grants [4].

6. Conclusions

Following the power efficiency analysis carried out the following resulted:

- The profit of the district heating: 1 hot water boiler of 10 Gcal/h operating on natural gas and 1 hot water boiler of 1 Gcal/h operating on wood biomass (98%) and natural gas (2%)

- The quantity of thermal power under the form of hot water that will be delivered to the end of the thermal plant is estimated at 22114.1 Gcal/yr, and will be covered from two new hot water boilers:

1. Q delivered from the 1x10 Gcal/h: 14423.31 Gcal/yr;
2. Q delivered from the 1 x 1 Gcal/h hot water boiler: 7690.89 Gcal/yr.

From the point of view of the environment, as the equipment is new and modern are provided with installations to reduce the environmental pollution and the compliance with the values of the emissions within the legal limit values.

The total value of the investment determined by the acquisition and mounting works of the two new hot water boilers in Uricani TP as well as the rehabilitation of the heat transport and distribution system in the town of Uricani, is 5 278 900 euro (VAT).

In the end, the following can be asserted:

- Carrying out the new thermal plant will ensure the Uricani town district heating under reliable conditions at the price of 41 euro/Gcal;
- Taking into account that the proposed solution for carrying out the source of thermal power production presupposes the use of renewable sources, respectively, biomass, the efficiency parameters of project can be

improved under the conditions in which in the future we will promote the scheme for sustaining heat production from Renewable Energy Sources, according to the specifications of the European Commission;

- Economic efficiency indicators for the Uricani district heating system:
 - VNA (10% return rate): 305.24 th euro /year.
 - profit rate: 5.48%.

References

- [1] HG 882/2004 – Strategia Națională privind alimentarea cu energie termică a localităților prin sisteme de producere și distribuție centralizate
- [2] Directiva 2009/28/EC privind energiile regenerabile
- [3] Legea nr. 325/2006 – Legea serviciului public de alimentare cu energie termică
- [4] Ordinul MIRA nr.471/2008 privind Regulamentul pentru implementarea programului Termoficare 2006-2015 - căldură și confort

Creăm împreună
energia de mâine.



