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THE DEVELOPMENT OF A COGENERATION POWER PLANT FOR SYSTEM SERVICES TAKING INTO CONSIDERATION ENVIROMENTAL PROTECTION

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Abstract

The current work represents the continuation of a two-part study regarding the analysis of the energy market and system services in Romanian environmental protection as well as the role of cogeneration in countering the problems in the national energy system. This article presents the solution of a cogeneration plant and its usefulness in the national energy grid. As it is expected, the solution has to be environmentally friendly and as efficient as possible, and at the same time, taking into consideration the area where it will be installed so that the thermal energy produced can be efficiently exploited.

***Key words**: National Energy System, system services, balancing market, cogeneration power plant, environmental protection.*

INTRODUCTION

The expected evolution of the structure of the energy sector shows that in a few years Romania will base its electricity production mainly on hydropower capacities and wind and photovoltaic resources, which will put more pressure on the transport system operator (CNTEE Transelectrica SA) to ensure the safety and operational stability of the National Energy System (NES) (EGR, 2019; ANRE, 2021) - approximately 1900 MWh/h is the power reserve contracted by Transelectrica on the system services market (Transelectrica, 2022; ANRE, 2021; TEL 04.05, 2022; ANRE, 2007; ANRE 2011).

Currently, over 90% of system services are provided by state-owned companies, mainly Hidroelectrica and some coal-fired power plants. There are only a few private manufacturers who have technically qualified for such services.

The unpredictability of electricity production from renewable energy sources (RES) (Dragomir et al., 2016) has determined a change in the structure of energy delivered to the balancing market depending on the type of reserve that ensures balancing, thus increasing the need for fast tertiary reserve.

It is expected that the european balancing energy exchange platform (PICASSO, MARI) (PICASSO, 2022; MARI, 2022) to be fully operational by the end of 2022. As a result, all existing manufacturers wishing to participate in the European balancing market will go through a new qualification process.

Taking into account the technical requirements, it is unlikely that any manufacturer will be able to meet the qualification conditions for system services without additional investment to upgrade the equipment or even completely replace it.

Thus, the perfect conditions are created for the implementation of cogeneration solutions. The cogeneration process has become more and more used both for efficiency and for the footprint on the environment, polluting much less than solutions with fossil fuels. Of all the solutions in cogeneration, the one most desired by the European countries and not only is the one with biomass because it also allows a high degree of recycling. The study carried out in Turkey by Kulcu and Cihanalp in 2017 reinforces the idea (Kulcu & Cihanalp, 2017).

The presented project represents a new investment in a dispatchable unit with an installed electrical capacity of approximately 20 MW, using cogeneration engines that use natural gas and which will meet the new technical requirements and ensure the flexibility required by Transelectrica on the system services market.

The estimated cost of this investment is 13.9 million euros.

The average annual EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization) will be around 3.2 million euros/year and the average annual net profit will be around 1.7 million euros/year.
The investment recovery period will be around 5.6 years, project IRR (Internal Rate of Return) - 16.3%.
If the installation will also provide heating services in the winter season, provided that the specific regulations allow it and / or a new High Efficiency Cogeneration Support Scheme is implemented, the project could have an EBITDA and a period of similar or improved investment recovery.

The purpose of the project

The project consists in the construction and operation of a cogeneration power plant with a total installed capacity of 20 MWel.
The chosen technical solution consists in the installation of 6 natural gas engines manufactured by INNIO Jenbacher of 3.358 MWel each, with an electrical efficiency of 44.73%.
The estimated cost of the investment is 13.9 million euros, which can be further adjusted according to the company's final project. Of this value, 500 thousand euros was estimated for purchasing the necessary land. The specific investment (excluding land) is 665 thousand euros/MW.
The company will only provide system services and will record revenues from:

a) System Services – fast tertiary backup adjustment as follows:
   - 95% of the year, the plant will supply 18 MWh/h, tertiary regulation reserve;
   - 5% of the year, during the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the Next-Day Market (NDM) (OPCOM 2022) also offering a fall adjustment reserve;

b) Balancing services - fast tertiary adjustment. At the request of Transelectrica, the plant will supply electricity:
   - 15% of the time when the upward adjustment reserve is contracted;
   - 30% of the time, energy is supplied for downward regulation – period in which the down regulation reserve is contracted;

The project can be implemented in 12-15 months. The life of the project is assumed to be 15 years, although the number of operating hours on each engine at the end of this period, when the overhaul would take place, is 36660 hours, since the average annual number of operating hours per engine is 1,556 hours. This number of hours corresponds to a demand of 15% for the increase adjustment from the total time slots and 5% electricity delivered at the peak on the NDM minus 30% demand for the tertiary decrease adjustment.
As an alternative to system services, the plant can also provide thermal energy to the local distribution operator in the winter season, if the specifics and/or conditions allow this and/or if the new support scheme for the cogeneration production of high-efficiency electricity will be approved.

Location

Constanta is one of Romania's cities with the highest price for thermal energy (331.84 Ron / MWh for consumers connected to the transport network and 482.73 Ron / MWh for consumers connected to the thermal energy distribution network) and the City Hall grants substantial subsidies for the population.
The main local producer - Electrocentrale Constanța produces inefficient and polluting thermal energy (Nedelcu et al., 2019) with hot water boilers that can only operate until the end of 2022, with a derogation for CO2 emissions.
One of the operating scenarios of the plant would be the delivery of system services, balancing services, the sale of electricity on NDM during the winter and the sale of thermal energy to the RADET thermal energy distributor.
In this scenario, the plant will operate and record revenues from:

a) System Services - fast tertiary regulatory reserve - during the summer season (6 months), as follows:
   - 95% of the period, the power plant will supply 18 MWh/h, the upward adjustment reserve;
   - 5% of the period, during the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the NDM, also providing a fall adjustment reserve;

b) Balancing services - fast tertiary adjustment - at the request of Transelectrica, the plant will supply electricity:

- 15% of the time when the upward adjustment reserve is contracted, according to the upward adjustment request;
- 30% of the downward adjustment time, during the period in which the downward adjustment reserve is contracted;

c) Sale of electricity produced in cogeneration - during the winter season (6 months), on NDM or through bilateral electricity contracts;
d) Sale of thermal energy, heat and hot water - during the winter season (6 months), to the local thermal energy distributor (RADET).

During the winter season, the plant could choose to partially provide a secondary regulation reserve. If a new scheme to support high-efficiency cogeneration will be approved, the power plant will also request its qualification to benefit from the scheme.

Technical characteristics of cogeneration engines

The cogeneration plant is equipped with 6 INNIO-Jenbacher manufacturing cogeneration modules of the JMS 620 GS-N.LC type with an installed electrical power of 3358 kWel and an installed thermal power of 2101 kWth. The technical specification engine JMS 620 GS-N.LC – J02 are presentet in Table 1.

Table 1. Technical specification engine JMS 620 GS-N.LC – J02

Thermal engine type	JMS 620 GS-N.LC – J02	
Electric power	3.358	kWel
Recoverable thermal power (180°C at basket) - tolerance ± 8%	2.101	kWt
Hourly fuel flow at PCI = 9.5 kWh/Nm3 - tolerance + 5%	791	Nm3/h
Electrical efficiency - tolerance ± 8%	44.7	%
Thermal efficiency - tolerance ± 8%	28.0	%
Total yield - tolerance -13% - +3%	72.7	%
Generator voltage	10.5	kV
Frequency	50	Hz
Fuel gas pressure	22.01	bar
Engine cooling water circuit temperature	80	°C
Engine cooling water return temperature	44	°C
Engine noise level	65 dB at 10 m	

Investment

The main elements of the investment are: land, equipment - 6 cogeneration engines, construction and installation works, connection to electricity networks (including the power station), natural gas, water and thermal energy, obtaining approvals and authorizations and other expenses. The elements of the investment are presented in Table 2.

Table 2. Investment elements of the project

Investment		
Land acquisition	EUR	500,000
Cogeneration engine equipment	EUR	6,951,060
Construction and installation	EUR	3,223,680
Connection to the power grid	EUR	2,719,980
Authorizations, approvals, design	EUR	200,000
Other	EUR	302,220
Total	EUR	13,896,940

As it has been shown above, the main elements of the investment refer to:

- Land acquisition.
- Purchase of the main equipment – 6 cogeneration engines. They come equipped with all auxiliary installations and equipment - cooling, ventilation, heat exchangers on the burned gas circuit, the glycol circuit and the cooling water circuit. After their installation, only the connection to the energy utilities is made - electricity, natural gas, water.
- The construction works consist of the construction of the building where the cogeneration engines are located, the foundations on which the engines are installed (according to the technical specification of the equipment supplier, the creation of access roads, etc.).
- The works regarding the connection to the power grid refer to the construction of a connection station (in the case of energy capacities over 10 MW it is mandatory), the realization of the electricity network between the motors and the power station, and the connection works to the power lines of the distribution operator.
- Costs related to the preparation of technical documentation, approvals and authorizations necessary for the achievement of the objective and its operation, design, obtaining the cogeneration energy production license and registration in the energy markets.

HYPOTHESES FOR PROJECT OPERATION AND ANALYSIS

Technical data of the plant

As it was previously presented, the plant is equipped with 6 INNIO-Jenbacher cogeneration engines of the JGS 620 GS NLC J02 type.

Currently, the legislation does not mention the granting of the cogeneration bonus. For this reason, the operation of the plant premise started from delivering only electricity, with the aim that in the future, in the event of a change in legislation, thermal energy will also be delivered to the local thermal energy distribution operator. This pessimistic scenario of service provision can demonstrate the reliability of the project; the future delivery of thermal energy bringing even more feasibility.

Fuel consumption efficiency, electrical energy supply efficiency and thermal efficiency supply efficiency were determined. Thus, to establish the efficiency of fuel consumption, the transition from the lower calorific value of natural gas to the higher one (HCV/LCV=0.9) and the tolerance given by the equipment supplier regarding fuel consumption deviations of 2.5% were taken into account compared to the standard consumption given by the technical specification of the engine. As it is known, technical calculations are made taking into account the lower calorific value of the fuel (LCV), but the fuel costs are determined taking into account the higher calorific value of the fuel (HCV).

To determine the efficiency of electricity supply it had to be taken into account:

- the internal consumption of the plant -2.5% of the production.
- the losses in the transformer - 2.5%.
- the losses in the line (from the engine to the settlement point with the energy distribution operator electrical) of 2%.

According to the data provided by the supplier INNIO-Jenbacher, the lifetime of the engine is 60,000 hours of operation until the overhaul, and preventive maintenance is carried out every 2000 hours of operation. The technical operating data of an engine and power plant are presented in Table 3.

Table 3. Technical operating data of engines

Engine		
Type		JGS 620 GS NLC J02
Number of engines	No	6
Electric energy produced	kWel	3,358
Thermal energy produced	kWth	0
Fuel consumption	kW PCI	7,507
Fuel efficiency	%	87.75%
Efficiency of electricity supply	%	93.64%
Efficiency of thermal energy supply	%	95.00%
The electrical efficiency of the motor	%	44.73%
Thermal efficiency of the motor	%	0.00%
Number of hours of operation until the capital overhaul	Hours	60,000
Maintenance intervals	Hours	2,000
Annual average number of operating hours / engine	Hours/ year	1,648

Assumptions regarding the operation of the plant

In order to establish the operating forecasts of the plant, the structure of the energy market, the statistics of System Services offers, the activation of the tertiary reserve of increase or decrease and NDM were analysed (Andrei et al., 2019).

Thus, the plant will provide electricity for:

a) System Services – Fast Tertiary Backup Adjustment as follows:
   - 95% of the year, the plant will supply 18 MW, the tertiary regulation reserve.

b) Delivery of electricity on NDM for 5% of the time. In the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the NDM, also providing fallback regulation reserve.

Electricity producers are obliged to offer electricity for Balancing Services - Fast Tertiary Regulation. The plant will supply electricity at the request of Transelectrica. It was considered that in this market the activation orders given by the National Energy Dispatcher for the activation of the rapid tertiary adjustment reserve will be:

- 15% of the time the growth adjustment reserve is activated;
- 30% of the time energy is supplied for down regulation.

The analysis of the project is done over a period of 15 years of operation (or 180 months) plus the implementation period which lasts approximately 1 year. To be on the safe side it was considered the starting point of operation is the second month of the third year.

The plant starts operating from year 2 – March until year 17, the tenth month.

Only the production of electricity was considered, although in the winter months, when the city needs larger amounts of thermal energy, both electricity in the NDM and thermal energy for heating in the centralized system could be delivered.

It was also considered that 2% of the bids submitted for system services are lost.

Offering system services through monthly and weekly auctions, it was estimated for each time interval the quantitative and financial offer submitted and how much of it is won. Also, when establishing the operating schedule, the availability of the engines, 92% (8200 hours/year), and their planned overhaul periods were taken into account.

Thus, the 6 engines, out of the total of 49200 hours available, will operate a total of 18048 hours delivering a total of 185231 MWh. The situation of operating hours and the amount of electricity delivered annually from the plant is presented in Table 4.

Table 4. Hours of operation and quantities of energy delivered from the plant annually

Typeof service provied	Functioning hours	Energy delivered
	h	MWh
Increase adjustment	7500	22,500
Decrease adjustment	131	2,477
NDM	1,836	5,778
Total	9,467	30,755

The annually amount of electricity delivered from the plant is presented in Figure 1. It is noted that 83% of the amount of electricity is delivered for System Services, 14% on the Balancing Market (BM) and 3% on NDM.
As shown, the revenues of this project are provided from the system services and implicitly from the Balancing Market.
Thus, the income will be from:

- System services – fast growing tertiary reserve.
- System services – fast growing tertiary reserve.
- Balancing market – increase adjustment.
- Balancing market – decrease adjustment.
- NDM – peak price (7.00-23.00).

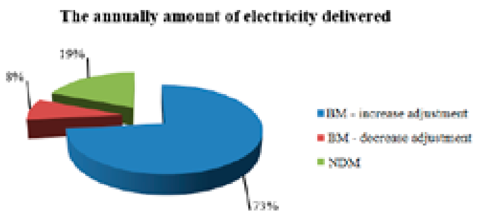

Figure 1. Share of the quantities of electricity delivered annually

Revenues from System Services represent revenues from contracting system services (the obligation to make available to National Energy System (NES) the quantities of electricity contracted for the rapidly increasing and decreasing Tertiary Reserve).
The revenues from the Balancing Market represent the revenues obtained from:

- the increase adjustment, at the National Energy Distributor (NED) order, when NES is in deficit.
- the decrease adjustment at the NED order, when NES is in surplus.
- from the NDM where it must deliver to secure itself on the market balancing decrease ordered by NED.

CONCLUSIONS

The plant implementation will increase the stability of the NES, while following and fulfilling the European and national environmental and energy efficiency legal provisions. This were stipulated in Romania's National Energy Strategy as well as in the legal measures established for its fulfilment.
In conclusion, the project of the cogeneration plant 20 MWel takes advantage of the existing opportunities by solving some of the current problems.
The plant is equipped with 6 cogeneration engines with an installed electrical power of 6x3358 =20148 MWel and an installed thermal power of 12606 MWth.
The electrical efficiency is 44.7% and the thermal efficiency is 28%.
Being specially designed to provide system services, The engines were chosen with a high electrical efficiency.
The plant can provide system services, electricity on the centralized market (bilateral contracts), NDM, Intraday Market (IM) and can provide thermal energy to the centralized thermal energy supply system of the city.

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