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EVALUATION OF ONE YEAR OF OPERATION OF THE BIOGAS PLANT IN SUCHOHRDLY U MIROSLAVI

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Abstract

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The manner of designing biogas plants is eagerly described by each and every seller or supplier of the respective technology. Numerous feasibility studies comprising forecasts of future operation featuring different quality levels have been written. However, it is rarely possible to obtain information comparing the anticipated future numbers and real values. Nevertheless, an evaluation of past operation of BGP is of utmost importance for calibration of the calculation methods used for designing of future BGPs. Information obtained on the basis of an evaluation is also useful for the purpose of verification of correct functionality of the equipment as well as optimisation of its operation with the objective of achieving the planned (or even better) values of profitability of each respective project. A comprehensive analysis of a biogas plant is a project sensitive to accuracy of inputs. Measurements of amounts and quality of the feed substrate throughout the whole year, which comprises numerous criteria, is highly demanding and complicated, and therefore the objective of this evaluation is to analyze the performance, production and consumption of the biogas plant in the course of a calendar year (Schulz *et al.*, 2004). Power measuring tasks are performed using calibrated gauges (which are mostly used for invoicing purposes), thus ensuring accuracy and credibility of the input data.

biogas, anaerobic fermentation, biogas plant

Functionality of our society is currently dependent on exploiting of the limited amount of non-renewable resources of energy. The ever-increasing energy demands force us to look for a replacement of the non-renewable resources of energy by other (renewable) resources. One of the available alternatives pertains to use of biomass within the process of anaerobic fermentation resulting in creation of biogas that may be further used for energy-related purposes. Anaerobic technologies offer an attractive manner of use of biomass resources for the purpose of partial satisfying of the energy needs of our society (Yadvika *et al.*, 2004). Anaerobic fermentation is a process typical for decomposition of organic matter without in an environment in which air is not present. The total production of biogas comprises mainly transformation of acetic acid to methane and carbon dioxide (70%) while 30% represents transformation of hydrogen and carbon dioxide to methane and water (M. Kaltschmitt *et al.*, 2009; Tirumale and Nand, 1994; Tatar *et al.*, 1998).

The analyzed BGP represents a construction project completed on a green field located in the close vicinity of a former livestock production premises. The premises were vacated at the time of construction (2007). At the time of designing of BGP the farmer was fully aware of the synergies pertaining to interconnection of the operation of BGP with livestock production. Therefore, following construction of BGP, he performed construction and reconstruction of barns with the principal objectives of modernizing and extending his own livestock production The agricultural premises located beside BGP are currently used for breeding of pigs with a closed turnover of the herd. The livestock production provides the feed material for BGP – liquid manure – with the average daily production of 27 m^3. Other components of the feed substrate comprise maize silage, sugar extraction residue, grains and GPS. BGP consists of two concurrently operated reactors (unit reaction volume: 1 500 m^3), each of them being equipped with its own solid substrate dosing feeder (volume: 16 m^3), two liquid substrate (manure) tanks (volumes: 70 m^3 and 90 m^3) and a central pumping unit. The technology was supplied by Weltec BioPower. The energy core comprises three (originally two) cogeneration units featuring the installed power capacity of 2 × 175 kW and 1 × 180 kW. The cogeneration units were supplied by TEDOM, which was also the general supplier of the whole BGP.

Considering the fact that BGP is, rather untraditionally, equipped with three engine-type generators, the evaluation of its operation is more complicated than in case of installations consisting of only one cogeneration unit. On the other hand, as regards the analysis of data, it is also advisable to pay attention to advantages and disadvantages of the selected solution. An obvious advantage of installing several engines is the possibility of controlling BGP output between approx. 90 kW and its maximum performance of 530 kW. The aforementioned control range is not achievable – due to technical reasons – in case of a one-engine alternative. The respective advantage proves to be even more significant in case of existence of a peak demand period requirements or insular operation of the cogeneration and adjacent units. The insular unit provides power even at the time of a power network failure. This principle is applied here as one cogeneration unit is equipped in a manner allowing for the insular mode operation, thus serving as a backup power source. Another advantage of the multilevel installation pertains to operation of the engines in the ideal mode (i.e. maximum output) while one of the machines controls its operation depending on a selected value (gas container condition, temperature, time, etc.). Machines operated at the maximum level of performance reach the best possible efficiency values while saving operating costs and exploiting the technical potential to the maximum extent. Furthermore, it is quite obvious that in case of failure of one machine out of three, the outcomes are not as catastrophic as in case of failure of a single machine. On the other hand, the scope of disadvantages of several cogeneration units comprises higher investment costs, lower power efficiency as well as more complicated BGP regulation and control procedures.

The logics of performance controlling of this specific BGP is set up in a manner ensuring that two cogeneration units are operated permanently while the third one is started up as required, ideally in peak periods. At the same time the operator strives for not regulating the performance rather than disconnecting and starting up individual cogeneration units on the basis of a preset identifying value (most commonly the information about the amount of gas in fermentation tanks). The control scheme affects other possible states as well (control cascade): in case that the amount of gas decreases under the preset limit value, the cogeneration is gradually switched off, resp. two other machines are switched off as well, and its automatic start-up is performed following refilling of the gas tanks.

MATERIALS AND METHODS

Once we name the cogeneration unit using the abbreviations of CU1, CU2 and CU3, we may check how many hours of operation were recorded in 2010 in relation to individual machines, Tab. I.

I: *Operability and average performance per year*

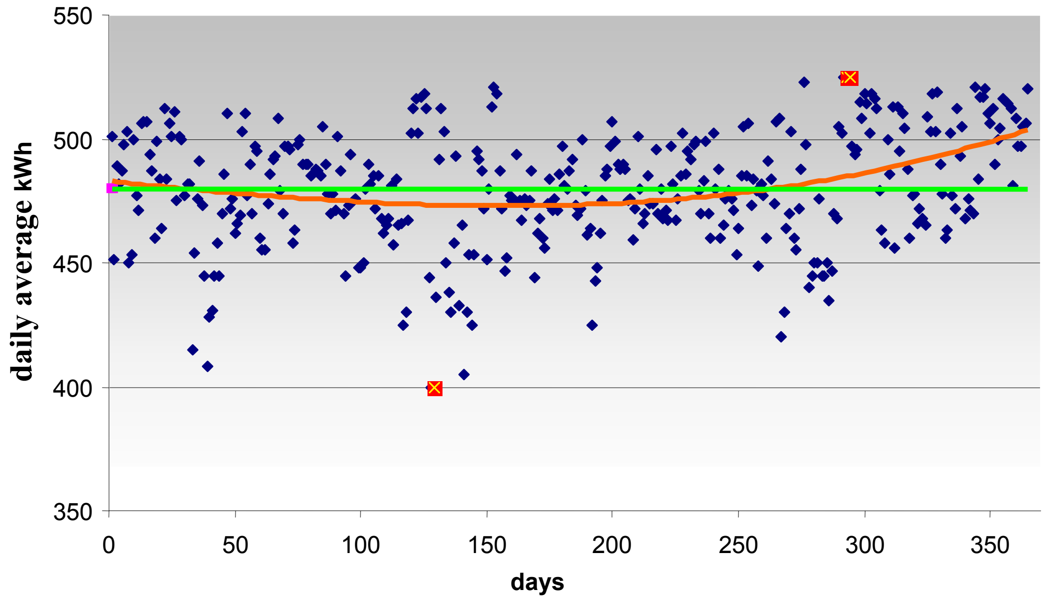
Cogeneration Units	MWh per year	Performance kW/h
CU1	8 630	168
CU2	8 571	170
CU3	7 578	177
Total	4 779	172

Tab. I documents the fact that CU1 was operated permanently while CU2 and CU3 were used as a peak demand power source alternately. It is to be emphasized that the runaway of CU1 was perfect. The cogeneration unit was switched off for only 130 hours (i.e. 5.5 days) in the course of the year. Such a high level of operability documents existence of great work of service personnel and, mainly, devoted work of operators. Such a result would not be achievable without supervising the cogeneration unit even on Christmas day during the dinner party. It is easy to state that operation of the unit is automatic. This, however, means that it requires round-the-clock supervision, even if it is performed only remotely. Once a cogeneration unit encounters a malfunction, it is essential to respond immediately, irrespective of the time or day. On the other hand, great work of service personnel and operators is rewarded by great results.

The exemplary value of exploitation of the average nominal output at the level of 98.3% (average value: 177 kW out of 180 kW) in case of CU3 suggests that the aforementioned source worked in the optimum mode throughout the whole year and it was necessary to control its performance only very rarely. The above-mentioned cogeneration proves to reach the best possible parameters.

Average Output

The average annual output calculated on the basis of daily outputs was 480 kW (standard deviation: 23.7 kW). The average output did not decrease to zero on a single day, which might occur in case of installation of one single cogeneration unit. Such situations result from long-term service periods or,



1: *The daily average performance*

for example, waiting for supply of a spare part, the replacement of which had not been anticipated.

For the average daily values see Fig. 1. It is rather obvious that the average daily values prove to vary significantly. It is essential to focus on the average value (green line on the level of 480 kWh) as well as the respective trend (orange line). The trend documents stabilisation and consolidation of the daily values, which resulted in an increase of the average daily output at the end of the year. The red marks in the Chart show the minimum and maximum values of the average daily output.

The parameters of evaluation of the average output of BGP may comprise another interesting value specific for biogas plants – a recalculation of the annual production to the reactor volume. This value actually defines the performance per a cubic meter of volume and comprises numerous additional operation-related assumptions; therefore, biogas plants featuring lower values may not be regarded as worse and vice versa. The respective value is affected mainly by the energy density and rate of decomposition of the organic part of feed substrate as well as ability of the technology to handle a high amount of average dry mass in the reactor. It also depends on priming of the reactors and condition of the anaerobic process, which represents the limit factor applicable to possible loading of the reactor. This biogas plant produced 1416.6 kWh of gross production per each cubic meter of reaction volume per year. Once again, it is a good result which may be easily compared by individual operators of BGPs with their respective achievements.

The total production and consumption represent the values which attract the maximum attention. An analysis of production-related parameters is essential to be performed (at least generally) every day. More detailed analyses are conducted on a weekly and monthly basis. The yearly analysis is a sole statement pertaining to a year of operation; however, it may not contribute to elimination of contingent production-related shortcomings. Tab. II shows the gross and net production values related to individual CUs. It is rather obvious that the higher the average usage of maximum output is, the lower the percentage of own consumption of CU is. The own consumption is mostly independent of the output of CU. The difference between CU1 and CU2 is approx. 1.7%, which is definitely not a negligible number as far as the annual output is concerned. Considering this parameter, one large cogeneration unit surpasses three small ones, however only in case that it is operated at the maximum performance level.

II: *Gross/Net production and own consumption in the course of the calendar year*

	Gross Production	Own Consumption	Net Production
CU1	1 449 662	5.99	1 362 840
CU2	1 458958	5.88	1 373 220
CU3	1341271	4.29	1 283 760
Total	4 249 891	5.41	4 019 820

The value of own technological consumption of BGP (consumption required for biogas production), which represents a highly favourable value of less than 2% of the gross production in this case, decreases the net production of a CU before the first invoicing measurement. Following deduction of the value of own technological consumption of cogeneration and BGP from the gross production value, we obtain the value of net production on the level of approx. 92.5% of gross production. The net production value represents the basis for invoicing of the green bonus and it may be further used for the purpose of supply of power related to other adjacent consumptions. It is followed by other consumption of BGP (consumption that is not significant as far as production of biogas is concerned) and other consumption of adjacent production premises (pig breeding) – total: 9.2% (including transformation-related losses) of the gross production. Following deduction of all the losses and consumptions, 80.15% of the gross production is supplied to the network.

It is essential to monitor the value of own consumption of cogeneration and BGP technology closely. In this case it represents a highly favourable value of approx. 7.5% of the gross production. It is necessary to focus on the aforementioned value as it represents the consumption which decreases the invoiced amount of power without an entitlement to the green bonus.

RESULTS

The objective of the evaluation was to analyze operability of the source as well as the output, production and consumption of the biogas plant. The project showed to reach very good performance properties. As regards the cogeneration units, the respective values reached top class levels – principally in the area of operability in which CU1 recorded 8630 hours of operation per year. Another great result pertains to reaching of the average output of 177 kW in case of CU3 featuring the installed output of 180 kW. The total average output of 480 kW (standard deviation: 23.7 kW) is to be mentioned as well. The aforementioned value shows a low level of variance of average daily outputs as regards the average value; in addition, it was rather surprising that not a single day with a zero output was encountered. Another value that is interesting as regards its comparison with data from other BGPs is 1416.6 kWh/m^3, which represents the gross production of power per each cubic meter of reaction volume per year. All the above-mentioned results were achieved thanks to the great work of devoted operators who, in case of outages, perform service interventions without delay and who ensure proper maintenance and servicing of the technology. Last but not least, quality of the installed technology and service entity which performs servicing of the equipment also proves to contribute to the success of operation.

SUMMARY

The work is focused to analyze the energy inputs for selected biomas station. These data are very valuable especially as feedback for the investor and supplier of biogas plants as an indicator for comparison with other biogas stations. Assessed biogas station reached great results, the total average power 480kW with the standard deviation of 23.7 kW. Another interesting indicator to compare with other BGPs is the production of electrical energy per m^3 of reaction volume for the year amounted to 1416.6 kWh/m^3 per year. Its share in the successful operation carries no doubt the quality of the installed technology and service organization, providing repairs.

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