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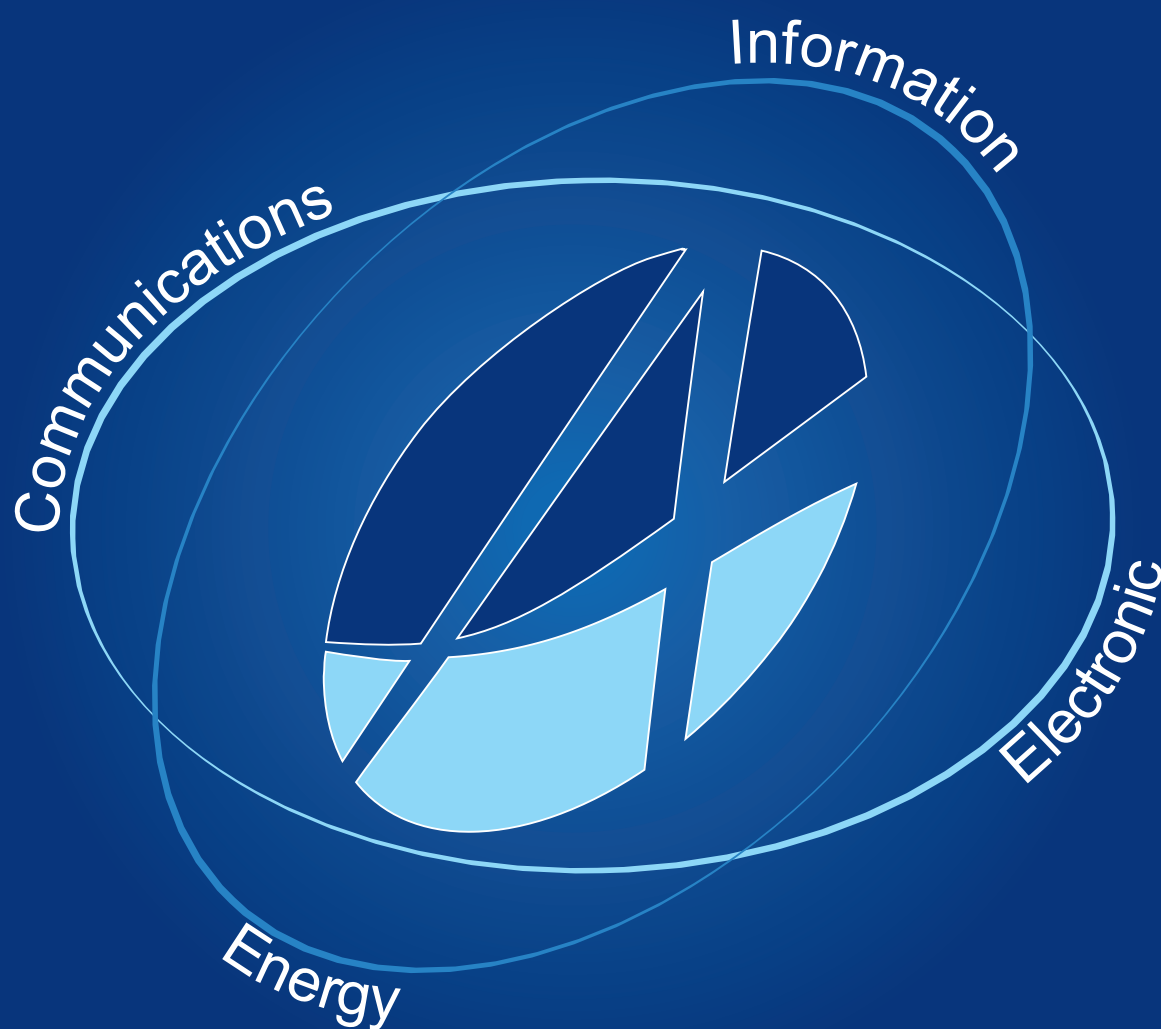
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Editorial

As a result of widening the spectrum of communication, dissemination and implementation of scientific research results, in 2020 was founded the association journal (magazine), issued under the name The Journal of CIEES appearing both in print (ISSN: 2738-7283), and online (ISSN: 2738-7291) format with DOI: <https://doi.org/10.48149/jciees>.

The Journal of CIEES is published in English and it is open access, peer-reviewed international scientific journal publishing papers submitted by authors themselves for publishing and invited by the Editorial Board. The Journal of CIEES covers all the essential branches of theories, technologies, systems, tools, applications, work in progress, and experiences on all theoretical and practical issues arising in telecommunications, electronics, signal processing and applications, information technologies, energy systems and etc.

As always, many people have contributed to this issue including all authors, the anonymous reviewers, the Associate Editors, the Editorial Advisory Board and, of course, our outstanding production team. We wish to acknowledge each individual's contributions, and to also express our gratitude for everyone's commitment. We hope you enjoy this first issue of The Journal of CIEES.

We have had the privilege to publish truly outstanding, quality manuscripts that, judging by the response of our reviewers and readers, are important contributions to their respective fields of research. We want to take this moment to thank all of our reviewers and authors for entrusting us with their discoveries.

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Trend Detection in Seasonal Inflows and the Influence on Energy Generation in Golești Hydropower Plant

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Abstract: Among the multiple water uses, electricity generation is a factor strongly affected by alterations in the water cycle due to climate change. Long periods of drought followed by rainy periods lead to significant changes in the natural regimes of water flow in rivers. This paper aims to determine the long-term trends of seasonal inflows (spring, summer, autumn, winter) in Golești reservoir using daily data recorded over an 11-years period with the non-parametric Mann-Kendall test. The influence of tendency of increasing or decreasing was analyzed for the inflows in the Golești reservoir on the energy produced in associated hydropower plant.

Keywords: time series, seasonal trend, Student-t, Mann-Kendall test, hydropower generation.

1. Introduction

In Romania, most of the river courses are developed for electricity production, irrigation, water supply and flood protection, as well as for industrial water-use in some towns and villages. To be able to perform all these functions at the same time, must be created a system by which will be managed the required demands and, in many cases, a multi-purpose reservoir can be a relatively simple solution for this.

To analyze the trend detection in seasonal inflows and the influence on energy generation using a multi-purpose reservoir, in this study were considered data regarding Golești reservoir and associated hydropower plant.

As is known, energy generation of hydropower plants is directly influenced by the rivers discharges, having seasonal sinusoidal variation, corresponding to the four seasons.

The quantity of water into the river is mainly influenced by precipitations (liquid and solid), falling on the surface of the river basin from which the river collects its water. Other factors influencing rivers discharges are the evapotranspiration (which depends on air temperature, insolation, wind), the storage capacity of the catchment, the management of water resources, etc.

The effects of global climate change have led to extreme phenomena such as flooding in some areas and drought in others, large or sudden variations in temperatures, very high wind intensification in some regions, which have also influenced and modified the natural river flow regimes.

In the field of hydrology, many papers have taken a statistical approach for the long-term variation of

variables such as: precipitation, air temperature, water temperature, river flows, air humidity, etc. [1, 2, 3].

In Europe, in most countries, these types of analyses regarding the trend of flow rate increase or decrease have been carried out. For example, in [4] the authors observed an upward trend of river flows in southern and Central Germany and insignificant trend in Northern Germany. In [5] it was demonstrated that the river flows tend to decrease in the northern part of Poland. Following the study carried out in paper [6] it was concluded that clear decreasing trend in low flows throughout the northern half of Spain negatively influences the Atlantic and Mediterranean regions. For Italy, in paper [7], hydrological data of 23 flow gauges were considered for the analyses, to observe if the river flows show a decreasing trend in terms of global change. All the obtained parameters have indicated a substantial decrease of water resources. Some papers present the correlations between the trend of flows and precipitations [8, 9].

In Romania, the rise in global temperature (estimated at 0.5 °C in the last century) has led to changes in the spatial and temporal distribution of the amount of rain and snow precipitation on the country's territory. The variations of the temperature using time series for winter (1922-1998) and for all seasons (1960-1998) in Romania were analysed from trend and shifts point of view using the Pettitt and Mann-Kendall in [10] and precipitation for period 1962-2006 in [11]. For the period 1976-2005, was made in [12] an analysis of the mean monthly streamflow applying the Mann-Kendall nonparametric test. The main result of the authors was that in the summer months there are decreasing trends and on the winter months the streamflow rate values have a positive trend. Therefore, the same results were also obtained in [13] for the period 1961-2009, where was made an analysis regarding hydroclimatic dynamics for Romanian drylands and aimed the tendency of the streamflow that is directly



influenced by climate change. The climatic water deficit involves a streamflow reduction.

This paper presents the analysis of the trend detection in seasonal inflows in Golești multi-purpose reservoir and the influence on energy generation in the associated hydropower plant.

2. The analysed time series

The analysis focuses on the Golești reservoir and associated hydropower plant, using data from the period 2006-2016. The two analyzed variables consist of the daily average values of the inflows in the Golești reservoir and the daily energy generation in Golești hydropower plant. As the seasonal trend is being detected, both the inflows and the energy generation have been grouped into four series of values corresponding to the four seasons: the series Q_{sp} contains all the daily inflows into the reservoir in the 3 months of spring (March, April, May) of all 11 years analyzed and E_{sp} contains the daily values of energy produced during these periods (Fig. 1). Similarly, the Q_{su} and E_{su} strings were built from the flows and energies corresponding to the 3 months of summer (June, July, August). The Q_{au} and E_{au} series were built for the autumn months and the Q_{wi} and E_{wi} series being made up for the winter months (December, January, February).

The recorded values for the flows for the spring months, March (31 days), April (30 days) and May (31 days), were concatenated for the 11 years of analysis shall form the time series called Q_{spring} which is represented in Figure 1 (a) and the values of energy produced in the Golești hydropower plant Figure 1 (b).

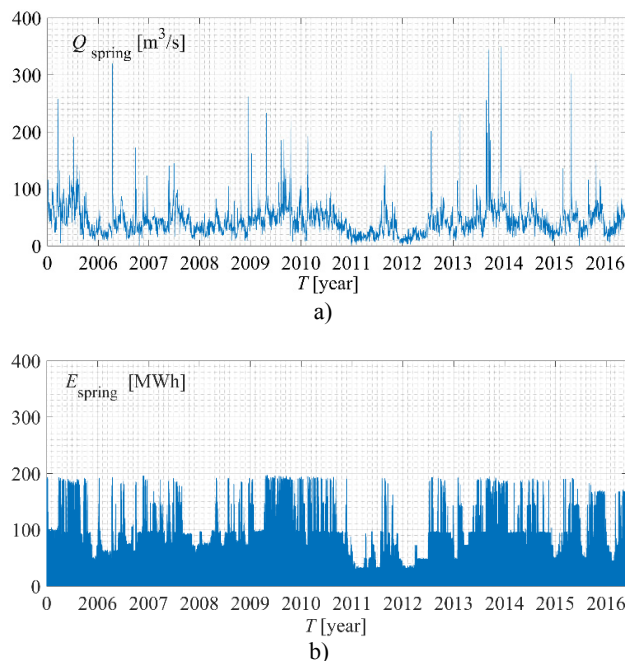


Fig. 1. Spring daily inflow (a) and recorded energy generation (b) in the period 2006-2016.

The main characteristics of these time series are listed in Table 1 and Table 2.

From the analysis of the values in Tables 1 and 2, it can be observed that the average flows are higher in spring and autumn and correspondingly, the energy

generation in hydropower plants is higher in spring and summer than during the rest of the year.

Table 1. Basic statistics of seasonal inflow series [m^3/s].

Reservoir inflow	Average	Standard deviation	Minimum value	Maximum value
Spring	51.44	30.96	4.13	343.82
Summer	48.19	29.31	3.86	348.33
Autumn	35.66	24.03	0.45	301.78
Winter	39.85	21.80	0.16	233.39

Table 2. Basic statistics of seasonal energy generation [MWh].

Daily hydro-electricity produced	Average	Standard deviation	Minimum value	Maximum value
Spring	119.40	46.58	29.65	195.74
Summer	118.42	46.45	33.79	195.09
Autumn	94.79	47.96	8.55	196
Winter	98.10	43.51	17.73	196.83

3. Time series homogeneity tests

3.1. The student-t test

In the method of statistical tests for trend detection, the original series is divided into two subseries of unequal numbers, having n_1 and n_2 components, respectively, such that $N = n_1 + n_2$.

The homogeneity of the mean values of the two subseries shall be checked by means of the Student-t test. The t-test statistic [14] is defined as:

$$t_{obs} = \frac{|\bar{X}_1 - \bar{X}_2|}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}, \quad (1)$$

where s_p is the series variance, calculated as:

$$s_p = \sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}}. \quad (2)$$

The null hypothesis $H_0: \mu_1 = \mu_2$ (the averages of the two subsets are equal) is accepted if:

$$|t_{obs}| < t_{1-\frac{\alpha}{2}}, \quad (3)$$

in which $t_{1-\frac{\alpha}{2}}$ is the distribution quantile t with

$n_1 + n_2 - 2$ degree of freedom. The alternative hypothesis is $H_1: \mu_1 \neq \mu_2$ (the averages of the two subsets are significantly different).

If H_0 is accepted at the level of significance α , it can be allowed that the differences between the two averages are due by chance and the original series is homogeneous on average and it could be affirmed that the series don't have significant trend.

3.2. The Mann-Kendall test

This test is frequently used to detect monotone trends in a series of data such as hydrological or climatic dataset [15]. The null hypothesis is H_0 : the components of the time series shall be independent and uniformly distributed so that there is no trend in the analyzed data series.

The alternative hypothesis is H_1 : the trend in the analyzed data series exists and it is significant. To choose one of the two hypotheses, the following statistical value [16] is calculated as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sgn}(X_j - X_i), \quad (4)$$

where:

$$\text{sgn}(\theta) = \begin{cases} +1, & \text{if } \theta > 0 \\ 0, & \text{if } \theta = 0 \\ -1, & \text{if } \theta < 0 \end{cases}. \quad (5)$$

Under the hypothesis of independent and randomly distributed random variables, the S statistic is approximately normally distributed, with zero mean and variance as follows:

$$\sigma^2 = \frac{N(N-1)(2N+5)}{18}, \quad (6)$$

where N is the number of set values.

In this case, the standardized Z statistics follow a normal standardized distribution:

$$Z = \begin{cases} \frac{S-1}{\sigma} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sigma} & \text{if } S < 0 \end{cases}. \quad (7)$$

The null hypothesis that there is no trend is rejected when the absolute value of Z is greater than the critical value Z_α , at a chosen level of significance α . An upward or downward trend is indicated by a positive or negative Z statistics value.

4. Results and discussion

Table 3 shows the values obtained for the estimators applying the Student- t test for mean trend testing for seasonal flow rate and table 4 for the daily average energy generation in hydropower plant Golești.

Table 3. Estimators with Student- t test for seasonal flow rate.

Q	t_{obs}	$t_{1-\alpha/2}$
Spring	1.056	1.962
Summer	5.426	1.962
Autumn	1.633	1.962
Winter	3.223	1.962

Table 4. Estimators with Student- t test for the daily average energy generation.

E	t_{obs}	$t_{1-\alpha/2}$
Spring	2.133	1.962
Summer	7.170	1.962
Autumn	1.676	1.962
Winter	2.505	1.962

After applying the Student- t test, it can be observed that there is a trend both for flows and for the energy produced during the summer and winter months. Tables 5 and 6 contain the estimator's values for the seasonal inflows and energy production obtained by Mann-Kendall test.

Observing the results from Tables 5 and 6, it can be concluded that for the summer season, both in terms of flow rates and energy, there is a decreasing trend. Also, negative values of Z for flow rate values show a decreasing trend in spring and summer, as can be seen from the linear regression equation found from the recorded values (Table 7).

Table 5. Mann-Kendall test's estimators for seasonal inflows series.

Stream flow	S	Z	Z_α
Spring	-919	-0.085	1.64
Summer	-81768	-7.61	1.64
Autumn	29435	2.786	1.64
Winter	16033	1.543	1.64

Table 6. Mann-Kendall test's estimators for energy generation series.

Energy generation	S	Z	Z_α
Spring	37432	3.48	1.64
Summer	-87124	-8.11	1.64
Autumn	-6201	-0.58	1.64
Winter	16075	1.547	1.64

Table 7. Regression coefficient equations for stream flow and energy generation in Golești and the increasing ($\nearrow$) or decreasing tendency ($\searrow$)

Season	Q [m^3/s]	E [MWh]
Spring	$Q_{sp} = 52.09 - 0.0013t \searrow$	$E_{sp} = 112.77 + 0.013t \nearrow$
Summer	$Q_{su} = 59.17 - 0.0217t \searrow$	$E_{su} = 137.53 - 0.03t \searrow$
Autumn	$Q_{au} = 32.704 + 0.0059t \nearrow$	$E_{au} = 95.87 - 0.0022t \searrow$
Winter	$Q_{wi} = 39.645 + 0.0004t \nearrow$	$E_{wi} = 91.85 + 0.012t \nearrow$

From Figure 2 it can be observed that, except the year 2014 which was rainy, the trend over the last years analyzed was to decrease the streamflow rate values, while the energy produced on spring is oscillating slightly around the mean values.

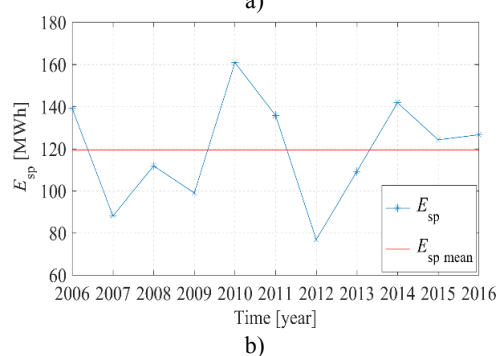
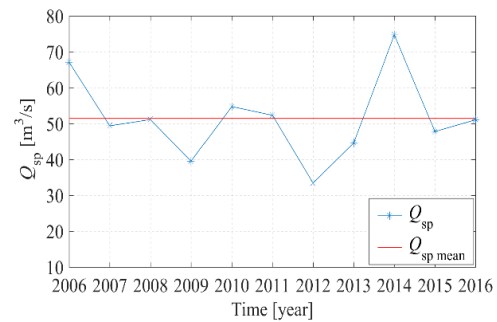


Fig. 2. Spring seasonal average flow rates (a) and seasonal average energies (b).

From Fig. 3 the decreasing trend in both the flows values and the energy generation during the summer period are observed, as shown by the two statistical tests (Student-t and Mann-Kendall).

It is also noted that between 2011 and 2016 in only one year (2014), the mean flows values and the energy generation exceeded the average values of the flows and the energy generation, respectively.

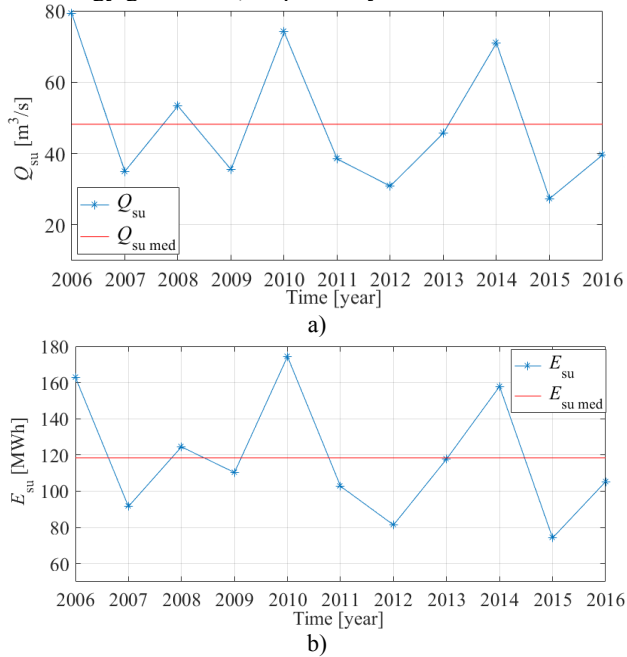


Fig. 3. Summer seasonal average flow rates (a) and seasonal average energy generation (b).

Figure 4 presents autumn seasonal average flow rates and seasonal average energies.

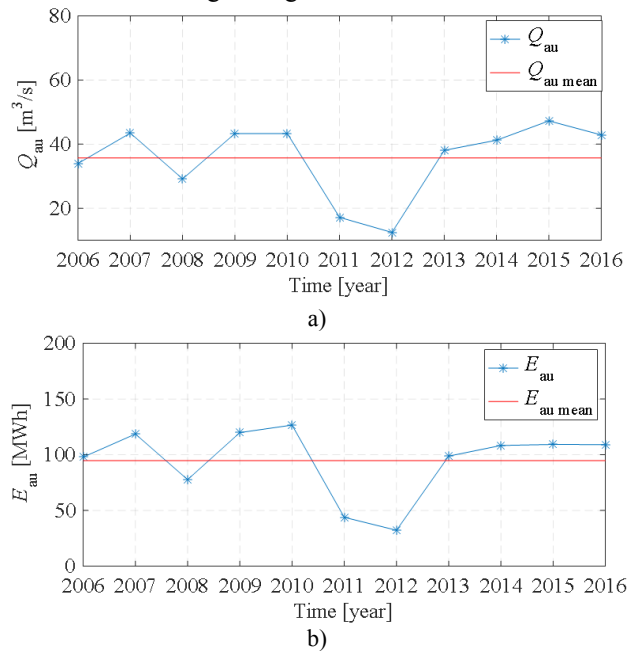


Fig. 4. Autumn seasonal average flow rates (a) and seasonal average energies (b).

Although the Mann-Kendall test suggested a trend of increasing flows and decreasing energies produced in autumn, in accordance with the regression equations obtained, from Figure 4 it can be observed that the two series do not deviate from the average value, except for 2011 and 2012. For this season, the trend is insignificant.

Last figure, Fig. 5, presents values for winter seasonal flow rates and the variation of seasonal average energies. From this figure it can be observed that for winter months, when the mean streamflow rates value is lowest, the energy graph produced accurately follows the graph of all streamflow rates values in the reservoir.

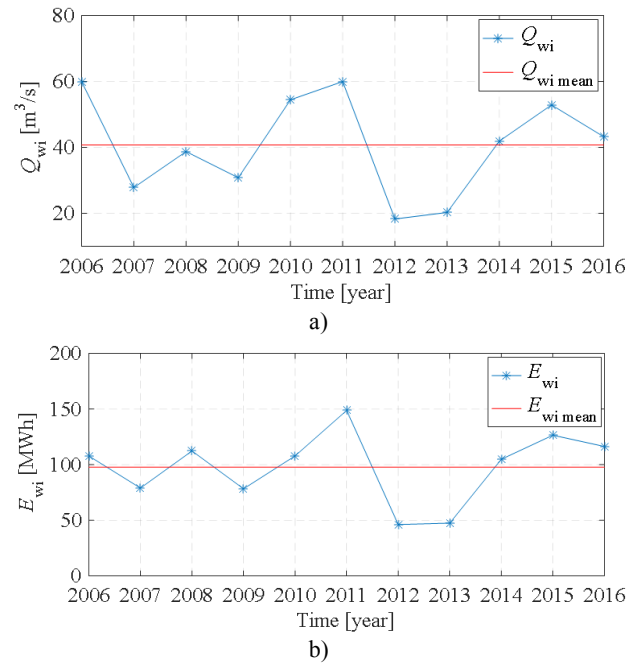


Fig.5. Winter seasonal average flows (a) and seasonal average energy generation (b).

For this season, the Student-t test shows an increase in trend for inflows and energy generation but, from the coefficients of the linear regression it can be observed that the slope of this line is small, so that the tendencies are insignificant.

For better highlighting the results obtained after the application of the two tests, in all presented figures 2, 3, 4 and 5 were represented graphically the seasonal values corresponding to each year together with the seasonal average value calculated for eleven years of analysis.

5. Conclusion

In this paper it was made a statistical analysis in order to determine the trends of seasonal inflows (spring, summer, autumn, winter) in Golești reservoir using daily data recorded over an 11-years period using the non-parametric Mann-Kendall test.

In good agreement with other studies carried out for hydrological parameters in Romania, this paper shows a significant correlated decrease in summer flows and energy generation in Golești hydropower plant. For the other seasons, due to very small values of regression coefficients of time (t) the correlation between flows and energy generation is weak.

References

- [1] Longobardi, A. & Villani, P. (2010). Trend analysis of annual and seasonal rainfall time series in the Mediterranean area", *Int. J. Climatology*, vol. 30, no. 10, 1538–1546. <https://doi.org/10.1002/joc.2001>
- [2] Jaiswal, R. K., Lohani, A. K. & Tiwari, H. L. (2015). Statistical Analysis for Change Detection and Trend Assessment in Climatological Parameters", *Environ. Process.* 2, 729–749. <https://doi.org/10.1007/s40710-015-0105-3>
- [3] Birsan, M.-V., Zaharia, L., Chendes, V. & Branescu, E. (2013) Seasonal trends in Romanian stream flow, *Hydrological Processes*, vol. 28, no. 15, 4496–4505, <https://doi.org/10.1002/hyp.9961>
- [4] Bormann, H. & Pinter, N. (2017). Trends in low flows of German rivers since 1950: comparability of different low-flow indicators and their spatial patterns, *River Research and Applications*, vol. 33, no. 7, 1191–1204. <https://doi.org/10.1002/rra.3152>
- [5] Piniewski, M., Marcinkowski, P. & Kundzewicz, Z. W. (2018). Trend detection in river flow indices in Poland, *Acta Geophysica*, vol. 66, 347–360. <https://doi.org/10.1007/s11600-018-0116-3>
- [6] Coch, A. & Mediero, L. (2016). Trends in low flows in Spain in the period 1949–2009, *Hydrological Sciences Journal*, vol. 61, no. 3, 568–584. <https://doi.org/10.1080/02626667.2015.1081202>
- [7] Billi, P. & Fazzini, M. (2017). Global change and river flow in Italy, *Global and Planetary Change*, vol. 155, 234–246. <https://doi.org/10.1016/j.gloplacha.2017.07.008>
- [8] Uddin, M., Akter, S., Uddin, M.J. & Diganta, M. (2018). Trend Analysis Variations and Relation Between Discharge and Rainfall: a Study on Kushiya River, *Journal of Environmental Science and Natural Resources*, vol. 10, no. 2, 121–132. <https://doi.org/10.3329/jesnr.v10i2.39025>
- [9] Abghari, H., Tabari, H. & Talaei, P.H. (2013). River flow trends in the west of Iran during the past 40 years: Impact of precipitation variability, *Global and Planetary Change*, vol. 101, 52–60. <https://doi.org/10.1016/j.gloplacha.2012.12.003>
- [10] Tomozeiu, R., Busuioc, A. & Stefan, S. (2002). Changes in seasonal mean of maximum air temperature in Romania and their connection with large-scale circulation, *International Journal of Climatology*, vol. 22, no. 10, 1181–1196. <https://doi.org/10.1002/joc.785>
- [11] Zaharia, L. & Beltrando, G. (2009). Variabilité et tendances de la pluviométrie et des débits de crue dans la région de la courbure de l'arc carpatique (Roumanie), *Geographia Technica*, Numéro special, 471–476.
- [12] Birsan, M.-V., Zaharia, L., Chendes, V. & Branescu, E. (2012). Recent trends in streamflow in Romania (1976–2005), *Romanian Reports in Physics*, vol. 64, no. 1, 275–280.
- [13] Prăvălie, R., Zaharia, L., Bandoc, G., Petrisor, A.-I., Ionuș, M. O. & Mitof, I. (2016). Hydroclimatic dynamics in southwestern Romania drylands over the past 50 years, *Journal of Earth System Science*, vol. 125, 1255–1271. <https://doi.org/10.1007/s12040-016-0730-x>
- [14] Popa, R. & Neagoe, A. (2008). Elemente de statistică și prelucrarea datelor (Elements of statistics and data processing), *Printech Publishing house*, Bucharest.
- [15] Yue, S., Pilon, P. & Cavadias, G. (2001). Power of the Mann–Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series, *Journal of Hydrology*, vol. 259, no. 1–4, 254–271. [https://doi.org/10.1016/S0022-1694\(01\)00594-7](https://doi.org/10.1016/S0022-1694(01)00594-7)
- [16] Kendall, M. G. (1962). *Rank Correlation Methods*, Hafner Publishing Company: New York.

Sentiment Analysis from Tweets using Convolutional Neural Networks

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Abstract: By current improvements of web technology nowadays, usage of social media has increased. Twitter is a web site where millions share their opinions. Political parties, firms and other establishments has been examining data at these social media sites to learn person's opinions about themselves. Reporting the sharing of millions of persons instantly is done more easily by using machine and deep learning techniques. In this work, sentiment analysis is done by the Convolutional Neural Network which has wide-spread usage in deep learning. Besides other known works, improvements in feature selection have been applied in order to meet higher success rate. Model has been trained by the different data sets and tested in other data sets. The model has reached to 97% success rate by the training data. 90% and 89% success rates have been achieved on the tests applied to other data sets.

Keywords: Sentiment Analysis, Twitter Sentiment Analysis, Deep Learning, Convolutional Neural Network.

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1. Introduction

User-based "social media", which emerged with the development of Web 2.0, one of the new communication technologies, offers many feedback opportunities to individual users such as instant notifications, comments, and complaints. In addition to micro blogs such as Facebook, Twitter, LinkedIn, Instagram, many platforms, including web-based news sites and even shopping sites, enables the user with instant messages and comments. In these user-based platforms that enable versatile message sharing and interactive interaction, there is a fast data flow with the messages created by the user, and these data turn into analysis objects. The platforms can analyse the analysis of the stored data on their own or through different companies.

Deep learning is a popular technique of machine learning nowadays and it is an application of artificial intelligence. Deep learning methods have been developed over the studies of artificial neural networks [1]. Deep learning includes computational models with multiple processing layers to represent the available data at multiple abstraction levels [2]. Deep learning methods, also known as deep networks, have different layers overlapping for the representation of data. Deep learning methods can create automatic feature sets by making an efficient high-level abstraction from raw data, thus enabling the automatic extraction and use of features that are usually determined by humans [1]. The learning phase of some deep learning algorithms can take quite a long

time, and different studies have proposed semi-supervised learning approaches to shorten the learning processes of deep neural networks [3]. In some studies, approaches to gain skills of deep learning to non-deep but widely used machine learning methods such as support vector machines have been presented [4].

Deep learning methods have yielded very successful results in processing many types of data such as video, audio, and text [5]. Often a method can be successful in text data processing such as natural language processing [6], while a different method can give more successful results in processing video and audio data. In some studies, the proposed deep learning approaches can be successfully used to learn different data types (video, audio, and text simultaneously) [7]. One of the subjects of natural language processing, which has been studied for a long time and has been an important field of application, is text classification. Deep learning is also used for text classification and there are various current studies on this subject [8, 9].

First deep learning using neural networks (deep learning) concept was introduced in 2000 with the work being done [10]. In [11], the authors showed that a multi-layer feed forward neural network can be adjusted by a controlled back propagation method in each training it does. After this stage, various application models have been proposed. Yoon used a single layer convolution neural network in his emotional analysis (positive / negative customer reviews) on different data sets, with very successful results [8]. In another study, researchers used an iterative evolutionary neural network model for text classification. In the proposed model; iterative structure for contextual information and evolutionary neural network for text representation [9]. Hinton et al. used GPU in deep learning and implemented a



normalization method called “dropout” to reduce memorization [11]. In another study performed with Naive Bayes, 81% success rate was observed [12]. The success of the dropout method has been proven by the high results obtained in the ILSVRC-2012 ImageNet competition [10]. On the other hand, Ciresan et al., using CNN, one of the deep learning methods, achieved a high success rate with only 2% error rate on the MSIT dataset [13] and reported that they found the result fastest with CNN. In another important study, a CNN-based recommendation system has been developed [14]. They analysed millions of data on the web and matched source-target document pairs using vectors. Thus, they tried to group documents of interest. Although this model was not successful enough in determining the related documents, it produced good results in the subject modelling field. Akgül et al. worked on Turkish tweet messages from Twitter. They added Turkish words to the dictionary by hand. They shared that the model they developed gave successful results [15]. A Multidimensional Convolutional Neural Network (MI-CNN) model was proposed for two large-scale investigation of incident systems (ICEWS and GDELT) in the field of political science, a series of experiments were performed with the world protest activity data set to evaluate the model, and successful results were obtained [16]. Larsson and Nilsson created a CNN model for sentences in a field, using vectors. In their work, they applied a test optimization to resemble the word vectors of emotions. They used a Recurrent Neural Network (RNN) to decode the vector structure and for new sentences. 80% accuracy was achieved in emotion classification [17].

There are also studies using machine learning algorithms other than deep learning. Singh et al., collected on the Twitter platform tweeter Donald Trump and applied support vector machine algorithm in Weka. The algorithm was successful and predicted that Donald Trump won the results. In a different study, CNN was used to determine the gender of Russian copywriters and an accuracy of 86% was achieved [18]. Şeker and Yeşilyurt collected data from Twitter with a software called Knime, pre-processed the data set and saved it in CSV format. They wanted to express the emotions they guessed by processing the recorded data with emojis. In their work, they applied various machine learning algorithms in Rapid Miner data mining program. Naive-Bayes algorithm gave the best result with 52% in their studies. KNN, support vector machines and decision trees algorithms could not be used due to lack of hardware [19]. Bari and Saatçioğlu used different data set of Amazon, Cornell, IMDB, Twitter, Yelp, Reviews and Kaggle in their emotion analysis studies. They conducted tests with Textblob, Opinion Finder and Stanford NLP algorithms. Textblob and Stanford had good results with NLP, but Opinion Finder did poorly [20]. Yang et al. achieved a 72.2% success rate in their study [21]. Liao et al. achieved an average success rate of 75.39% in a study they conducted using Twitter data and CNN. In the emotion analysis study performed with emojis found on Twitter, it was observed that the success rate was very low [22].

Many studies have been conducted in the literature on emotion analysis. Machine learning methods were used in the studies and the best results were used Convolution neural networks as a continuation of the study with Naive Bayes [12]. In the author's study, a maximum of 81% results were found with Naive Bayes. It is aimed to find better results with the algorithm and method we propose. In order to increase the result value, the parameters in Convolution neural networks are arranged. In the study, a 97% success rate was found by applying a different algorithm to the reference study. This result achieved 16% more success than the previous study.

2. Method

A string (type) is what defines or matches with a set of strings, arranged according to certain spelling rules. Regular expressions are used by many text editors, search tools, and tools for expressing specific text-based patterns. Many languages support the use of regular expressions. Regular expressions are used in data validation, data cleaning, data transformation and many other fields. Data cleansing is an important process that must be done for the model to learn well. By clearing unnecessary words and expressions in the data set, the model can be provided with a better result. With regular expressions, the URL (www, http, https), username, tag (hashtag), signs (- and /) can be cleared and the text converted to lowercase. For example: if there are tags such as @mesut in the tweet, if the model is trained without data cleaning, the model will have the possibility of misclassification and the success rate will decrease. The list of regular expressions used is shown in Table 1. The next pre-processing step is to convert the words that take the construct-inflection-possessive suffixes into a single form. For this study, which is of great importance in frequency calculation, stemming algorithms are used. For this purpose, PorterStemmer root finding algorithm, which is the most widely known of the algorithms developed for the English language, was applied.

Table 1. List of regular expressions.

Regular expressions
Replace URL
Replace Username
Replace Hashtag
Replace With Space

The structure diagram used when making emotion analysis from tweets with machine learning is shown in Figure 1 and the system model suggested in the intermediate stages is shown in Figure 2.

The words in the data set are first passed through the data cleaning stage. It includes data cleaning, parsing URL, name, tag, and converting all to lowercase. With the conversion to lowercase, the words that are separated by normalization are ensured to be calculated accurately. If the data cleaning step is not implemented, the success rate of the system decreases, and runtime increases because the model cannot be properly trained. The success rate increases when you remove ineffective words and names.

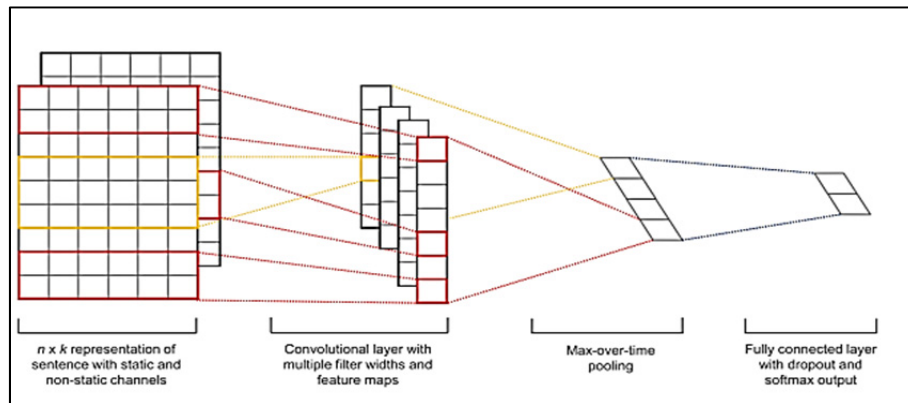


Fig. 1. CNN Model Used.

We tried many parameters for the model to find the best values and CNN parameters, for which we reached the best success rate experimentally, are given in Table 2. After the model is trained, tests can be performed according to any data set.

Table 2. CNN Parameters.

Parametre Adı	Parametre Değeri
embedding_dim	128
filter_sizes	3
num_filters	128
batch_size	64
num_epochs	200
fc hidden size	1024

3. Data sets

Kaggle is a platform where data sets used in machine learning are available and competitions are held. Both data sets used in the study were taken from this site. There are two main pieces of information that we will use in the data set: emotion and tweet content. The first data set is used to train our model and the second data set is used for testing. The data set used for educational purposes contains 100.000 tweets.

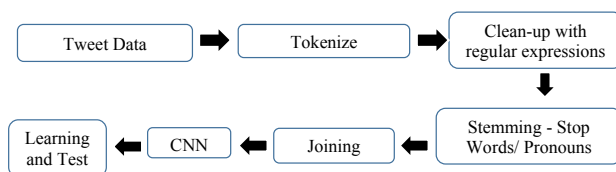


Fig. 2. Proposed system model.

The structure and sample data of the data set we used when training the system for the first time are shown in Figure 3.

ItemID	Sentiment	SentenceText
1	0	it is so sad for my API friend.....
2	0	I missed the New Moon trailer..
3	1	omg its already 7:30 :O
4	0	... Omigaga. Im soooin im gonna Crÿ. I've been at this dentist since 11.. i was suposed 2 just get a crown put on (30mins)...
5	1	i think muf is cheating on me!!! T_T
6	0	or jst worry too much?
7	1	JAAAAAAAAAAAAAHHHHHSSSSSS Chillin!!
8	0	Sunny Again Work Tomorrow :-:) TV Tonight
9	1	I handed in my uniforms today . i miss you already
10	1	hemmm... i wonder how she my number @_@
11	1	I atleast think about you lol

Fig. 3. Learning data set.

The structure and sample data of the data set we use to test the model are shown in Figure 4 and Figure 5.

HamID	Sentiment	SentimentText
146781369	0	switchfoot http://twitpic.com/2y1d - Awww that's a bummer. You shoulda got David Carr of Third Day to do i
146781062	0	is upset that he can't update his Facebook by texting it... and might cry as a result. School today also. Blah!
1467810917	0	@Kenichan i dived many times for the ball. Managed to save 50%. The rest go out of bounds
146781184	0	my whole body feels itchy and like its on fire
146781193	0	@nationalwax no it's not behaving at all. I'm mad. why am i here? because i can't see you all over there.
1467811372	0	@Kwesidini not the whole crew
1467811592	0	Need a hug
1467811594	0	@LOLfish hey long time no see! Yes... Rains a bit only a bit LOL I'm fine thanks
1467811795	0	@Tatiana. K nope they didn't have it
1467812025	0	@druvitra que me muerza ?
1467812415	0	spring break in plain cidra. it's snowing

Fig. 4. Test data set.

ItemID	Sentiment	SentimentText
1		i am actually the rd corey feldman and haim got nothin on me
2	1	is giving twitter go see what happens
3	1	thanks replacement disc arrived just now have checked it front back
4	1	woot woot for being cute gets you on the plane first las vegas here we come
5	1	i happy doughnut day
6	1	i hehehe good sides you need rest
7	1	er actually it makes me stay
8	1	i thank you everyone kind enough to ff me xx hello to new followers
9	1	i whoo hoo eat lots of junk food then run around and chase everyone sounds like so much fun
10	1	i welcome back to myspace

Fig. 5. Test data set.

The structure and sample data of the data set we use to test the model are shown in Figure 4 and Figure 5.

While the model is being trained, stopwords and nouns are removed from sentences to increase the success rate.

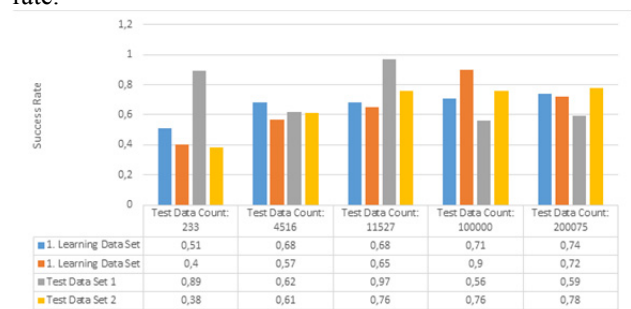


Fig. 6. Learning rate while training model.

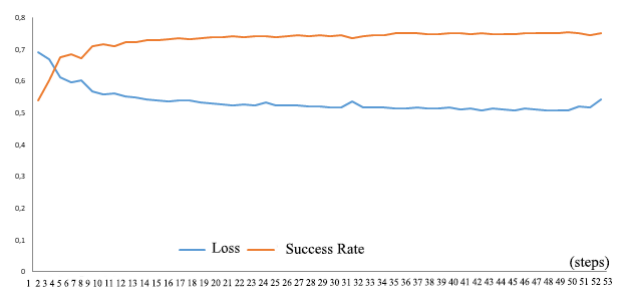


Fig. 7. Success rate of test using the trained model.

As can be seen in Figure 6, in the tests performed while training the model, the success rate was low, and the loss value was at the maximum level in the first training phase.

It was observed that when the training time of the model increased, the success rate increased, and the loss value decreased. A 97% success rate was observed in the tests performed during the training by downloading a different data set from the Kaggle site.

An example of the tests performed can be seen in Figure 7 and the graph in Figure 6 had the highest success rate of 97%. In [23], 71% success rate was observed in the first stage and then 72%.

4. Conclusion

While training the model, the number of layers, hidden layers and linked layers are arranged for performance and hardware upgrades have been made to increase the performance on the computer. In the training, the model was trained using the first data set. In the trained model, 74% success rate was achieved in the tests performed with the first data set and data not used in learning. When the training time was reduced, it was seen that the success rate of 90% was obtained in the tests performed with the 1st data set. In the tests, different data sets and our CNN model were tested and the success rate in the first data set we used gave the best result. When the success rates in our study were examined, it was seen that Salur's work was successful as a success rate [23]. According to a study in the literature, it has been observed that our study with convolutional neural networks gave the best result [24]. When the success rate is examined, success rates close to 75% have been shared in the studies in the literature. In our study, a success rate of % was observed in studies performed with different tweet data sets.

References

- [1] Ravi, D., Wong, C., Deligianni, F., Berthelot, M., Andreu-Perez, J., Lo, B., & Yang, G. Z. (2007), Deep learning for health informatics, *IEEE Journal of Biomedical and Health Informatics*, vol. 21, no. 1, 4-21, doi: 10.1109/JBHI.2016.2636665
- [2] Bengio, Y. (2009). Learning Deep Architectures for AI. *Found. Trends Mach. Learn.* Vol. 2, no. 1, 1-127, <https://doi.org/10.1561/22000000006>
- [3] Lee, D. H. (2013). Pseudo-label: The simple and efficient semi-supervised learning method for deep neural networks. *CML 2013 Workshop: Challenges in Representation Learning (WREPL)*, Atlanta, Georgia, USA, 1-6.
- [4] Cho, Y. & Saul, L. K. (2009). Kernel methods for deep learning. *22nd International Conference on Neural Information Processing Systems (NIPS'09)*. Red Hook, NY, USA, 342-350.
- [5] LeCun, Y., Bengio, Y. & Hinton, G. (2015). Deep learning. *Nature* vol. 521, 436-444, <https://doi.org/10.1038/nature14539>
- [6] Collobert R. & Weston, J. (2008) A unified architecture for natural language processing: Deep neural networks with multitask learning", *25th international conference on Machine learning (ICML '08)*, Helsinki, Finland, 160-167, <https://doi.org/10.1145/1390156.1390177>
- [7] Ngiam, J., Khosla, A., Kim, M., Nam, J., Lee, H. & Ng, A. Y. (2011). Multimodal deep learning, *28th International Conference on Machine Learning*, Washington, USA, 689-696.
- [8] Kim, Y. (2014). Convolutional neural networks for sentence classification. *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing*. DOI: 10.3115/v1/D14-1181
- [9] Lai, S., Xu, L., Liu, K., Zhao, J. (2015). Recurrent convolutional neural networks for text classification. *Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence (AAAI'15)*. AAAI Press, 2267-2273.
- [10] Hinton, G.E., Srivastava, N., Krizhevsky, A., Sutskever, I., & Salakhutdinov, R. (2012). Improving neural networks by preventing co-adaptation of feature detectors. *ArXiv*, abs/1207.0580.
- [11] Aizenberg I., Aizenberg N. & Vandewalle J. (2000). *Multi-Valued and Universal Binary Neurons: Theory, Learning and Applications*. Springer-Verlag, <https://doi.org/10.1007/978-1-4757-3115-6>.
- [12] Pek M. & Turan M. (2019). Sentiment Analysis of Tweets Using Machine Learning, *International Conference on Data Science, machine Learning and Statistics*, Turkey, Van, 85-87.
- [13] Ciresan D., Meier U. & Schmidhuber J. (2011). Flexible, High Performance Convolutional Neural Networks for Image Classification. *International Joint Conference on Artificial Intelligence IJCAI-2011*. pp. 1237-1242. DOI: 10.5591/978-1-57735-516-8/IJCAI11-210.
- [14] Gao J., Deng L., Gamon M. & He X. (2014). Modeling interestingness with deep neural networks. *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, Doha, Qatar, 2-13, <https://doi.org/10.3115/v1/D14-1002>
- [15] Akgül E. S., Ertano C. & Diri B. (2016). Sentiment analysis with Twitter. *Pamukkale University Journal of Engineering Sciences*, vol. 22 no. 2, 106-110. (in turkish).
- [16] Chen T., Xu R., He Y., & Wang X. (2016). Improving sentiment analysis via sentence type classification using BiLSTM-CRF and CNN. *Expert Systems with Applications*, Elsevier, Vol. 72, 221-230, <https://doi.org/10.1016/j.eswa.2016.10.065>
- [17] Larsson, M., & Nilsson, A. (2017). Manifold Traversal for Reversing the Sentiment of Text.
- [18] Singh P., Sawhney R.S. & Kahlon K.S. (2017). Forecasting the 2016 US Presidential Elections Using Sentiment Analysis. In: Kar A. et al. (eds) *Digital Nations – Smart Cities, Innovation, and Sustainability. I3E 2017. Lecture Notes in Computer Science*, vol. 10595. Springer, Cham. https://doi.org/10.1007/978-3-319-68557-1_36
- [19] Şeker, Ş. E., Yeşilyurt A. (2017) Twitter Sentiment Analysis using Text Mining Methods. *YBS Encyclopedia*, vol. no.2, 26-36. (in turkish).
- [20] Bari A. & Saatçioğlu G., (2018). Emotion Artificial Intelligence Derived from Ensemble Learning, *17th IEEE International Conference On Trust, Security And Privacy In Computing And Communications/ 12th IEEE International Conference On Big Data Science And Engineering (TrustCom/BigDataSE)*, 1763-1770, doi: 10.1109/TrustCom/BigDataSE.2018.00266
- [21] Yang X, Macdonald C., Ounis L. (2018). Using word embeddings in Twitter election classification. *Inf Retrieval J*, vol. 21, pp. 183–207. <https://doi.org/10.1007/s10791-017-9319-5>
- [22] Liao S., Wang J., Yu R., Sato K. & Cheng Z. (2017). CNN for situations understanding based on sentiment analysis of twitter data. *Procedia Computer Science*, Vol. 111, 376-381, <https://doi.org/10.1016/j.procs.2017.06.037>
- [23] Salur M. U. & Aydın İ. (2018). The Impact of Preprocessing on Classification Performance in Convolutional Neural Networks for Turkish Text. *International Conference on Artificial Intelligence and Data Processing (IDAP)*, Malatya, Turkey, 1-4, doi: 10.1109/IDAP.2018.8620722.

- [24] Zhao, L., & Zeng, C. (2017). Using Neural Networks to Predict Emoji Usage from Twitter Data.
- [25] Tantıđ, A. C. (2012). *Metin Sınıflandırma*, Türkiye Bilişim Vakfı Bilgisayar Bilimleri ve Mühendisliği Dergisi.
- [26] Şeker, A., Diri, B. & Balık, H. (2017). Derin Öğrenme Yöntemleri ve Uygulamaları Hakkında Bir İnceleme, *Gazi Mühendislik Bilimleri Dergisi*.
- [27] Salakhutdinov, R., Mnih, A. & Hinton, G. (2007). Restricted Boltzmann machines for collaborative filtering, in *Proceedings of the 24th international conference on Machine learning – ICML*.
- [28] Pek, M. & Turan, M. (2019). *Evrişimli Sinir Ağları Kullanarak Imdb Film Yorumlarından Duygu Analizi*, Akademisyen Kitabevi A.Ş.
- [29] Pek, M. (2019). *Ağlarda Saldırı Tespit Ve Önleme Sistemleri*, Akademisyen Kitabevi A.Ş.
- [30] Boynukalın, Z. (2012). *Emotion Analysis of Turkish Texts by Using Machine Learning Methods*, MSc Thesis, Middle East Technical University.

Analysis and Estimation of the Field Strength of Digital Terrestrial Television Broadcasting

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Abstract: DVB-T is the most widely used standard for digital television broadcast. With its introduction in 1997, it is used in more than 70 countries. Almost all of these countries adopted the new standard for digital terrestrial television broadcasting – DVB-T2. DVB-T2 is the best technology for digital television broadcasting, which offers better signal robustness, flexibility and more than 50% more efficiency, compared with other digital terrestrial television broadcast systems. This paper focuses on ways to deliver MPEG TS to transmitters and estimation of the field strength.

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1. Introduction

The system of digital terrestrial television broadcasting is realized on the basis of the Orthogonal Frequency Division Multiplex (OFDM). In terms of the number of the carrier frequencies, two modes of operation are applied [1, 2]:

2k mode, which supports 1705 OFDM carrier frequencies (of which 1512 with useful information and 193 for data and synchronization) with useful time slot of 224 μ s, which under the rate of information flow 7.608 Mb/s means data transmission speed about 4462 b/s;

8k mode, which supports 6817 OFDM carrier frequencies (of which 6048 with useful information and 769 for data and synchronization) with useful time slot of 896 μ s, which under the rate of information flow 7.608 Mb/s means data transmission speed about 1116 b/s.

The following modulation schemes are applied: QPSK; 16-QAM and 64-QAM. 16-QAM and 64-QAM [3]. These can be realized simultaneously in combination under some rules, allowing specification of hierarchical model of the transmission of data, namely:

A – low-speed data transmission with a higher degree of error protection, which provides basic video quality, guaranteeing a playable television in more adverse conditions, as is the case of mobile reception;

B – high-speed data transmission at a lower degree of error protection, providing a higher quality of the video image.

The introduction of the hierarchical model of transmission apparently determines the necessity of realization of the hierarchical model in terms of encoding quality of manufactured TV products [4].

With a modulator parameter α is defined the

magnitude of the ratio of the spacing of two adjacent constellation points from two neighboring quadrants at the magnitude of the spacing of two adjacent constellation points in one quadrant. For the modulator parameter α are defined three values: 1 (for non-hierarchical model), 2 and 4 (for hierarchical model).

For the avoidance of interference caused by echo signals and with other signals of adjacent transmitters in SFN networks (Single Frequency Network) among OFDM symbol period fits guard interval, during which no information is broadcasted.

In order to protect the channel from errors for transmission channel coding applies OFDM (COFDM-Coded Orthogonal Frequency Digital Modulation), which includes defensive coding procedures in and out of the transport structure [5, 6].

2. Approaches to deliver MPEG TS to transmitters

2.1. Using RTP / UDP / IP to deliver MPEG

In fact, there are two such possibilities: terrestrial communication networks and communication networks using the space segment. In some cases, a version of gap filler cascading can be used, but this option will lead to gradual degradation of the signal, due to the accumulation of errors [7]. In the case of using terrestrial networks, it is most rational to use data networks capable of transmitting multicast streams using RTP/UDP or only UDP protocols. These networks can be implemented using a variety of technical means: via relay links, using various data transmission technologies [8, 9].

At this point, we should pay attention to that it is necessary to provide data transmission in real time, synchronously, which is impossible with the help of TCP/IP protocols. That's why the choice of UDP or RTP / UDP for use in multicast mode seems to be the most rational.



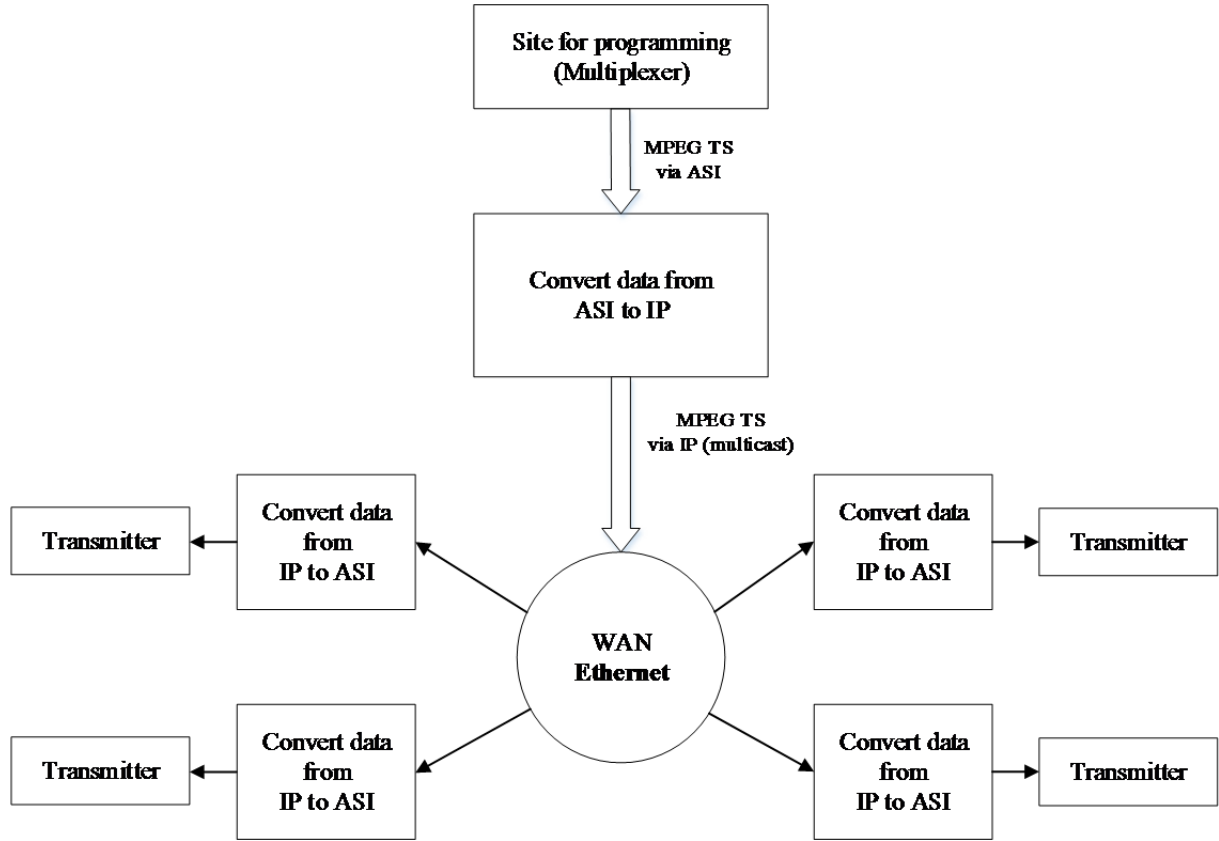


Fig. 1. Structure of the DVB network using IP transmission.

The RTP protocol is inherently an add-on over the UDP protocol, several additional data fields for giving information about the contents of the package. In particular, RTP allows the sequence number of the frame to be transmitted in a sequence and a timestamp indicating the time at which the packet was generated. Frame number field and time stamp field can help in the control of the integrity of the flow, as well as in the measurement by the variation of speed when transmitted over a network. In particular, if the packet numbering sequence is violated, the RTP protocol will indicate that one or more packets have not been transmitted.

In the case of using data networks using multicast traffic, it must be taken into account that the network will always introduce some delays, with non-permanent delays. The size of the memory allocated for buffering is limited, so the technical data always indicate how much jitter can handle a particular device. As a rule, devices can handle jitter of 100-200 msec.

Time stamps of RTP are generated using an internal clock device that generates RTP packets. Such a device can be an ASI-IP converter or a multiplexer. In standard RTP (RFC 3550), the frequency of the internal clock (timebase) is equal to 90 kHz [10]. Thus, the time stamp of the RTP is equal to the base portion of the MPEG TS. Some multiplexers generate temporary stamps based on 27-MHz clock, which is accepted for full PCR (i.e., the base part plus the extension). If the receiving equipment requires the presence of temporary RTP stamps generated by a clock of a certain frequency, this need to be taken into account in order to avoid synchronization errors.

When configuring ASI-IP conversion hardware, it must be considered change the speed of the digital stream by adding network packet headers, as shown on Figure 1. Because the MPEG TS transport stream is (encapsulated) within RTP / UDP / IP network packets, the overall speed of the digital stream will be greater. Because the payload size of the Ethernet frame is 1518 bytes, and the packet size of the transport stream is 188 bytes, then an RTP packet containing up to 7 MPEG TS packets can fit into one Ethernet frame. When encapsulating 7 packets, the speed change will be minimal. Since the delivery of traffic to the transmitters always requires the most reliable communication channel with the minimum number of errors, it is rational to choose the number of encapsulated packets to be maximal, i.e., equal to 7.

Otherwise, it should be taken into account that if one RTP packet will not be delivered in any way, then all packages will be "lost" MPEG TS, which are encapsulated in it. Thus, if there is a probability of RTP packets being lost on the network, then the number of encapsulated MPEG TS packets should be selected as minimal (1-5). However, once again I will focus your attention to the fact that in a properly configured network, the delivery of packets must be 100%. Otherwise, the network is simply not suitable for delivering the signal to the transmitters [11].

Recalculate the transport stream speed of MPEG TS and MPEG TS over IP can be as follows:

$$S_{UDP} = S_{MPEGTS} \left(1 + \frac{224}{1504N} \right) \quad (1)$$

$$S_{RTP} = S_{MPEGTS} \left(1 + \frac{320}{1504N} \right), \quad (2)$$

where N is the number of MPEG TS packets in one RTP packet; 1504 is the number of bits in one MPEG TS packet $1504=188 \times 8$; 320 is the header size RTP / UDP in bits; 224 is the header size UDP in bits.

2.2. Using satellite communication

The second possibility of signal delivery to local repeaters is use of the satellite segment (Figure 2) This scheme can be more expensive than the use of terrestrial networks. In addition, this scheme may not be suitable for the organization networks of digital television, limited to small regions, due to the limited orbital-frequency resource [12].

The standard bandwidth of the transponder of the television satellite is 32 MHz, and when using QPSK modulation, a digital stream with a speed of 32 Mbit / s, which is approximately equal to the maximum flow rate that DVB can provide (in the mode 64QAM with FEC = 7/8 and a guard interval of 1/32). On the one hand, it can allow the organization of digital television networks without resorting to the transformation of the traffic flow on repeaters [13]. As a rule, such transformation is always required within the region, due to the different broadcasting policies of the channels, the size of the required zones radio coverage, the need to use conditional access systems, etc. In any case, the use of these or other means of delivery is a complex task and should be addressed within the overall network structure [5, 6].

The satellite transmitting station is necessary for organizing and distributing program packages from the main multiplexing station to the local transmitting stations located throughout the country. The satellite station is most often located in an area remote from the main station. Multiplexes transmit to the satellite transmitting station over an IP network or other telecommunication channels. Decoder receivers with IP-inputs and ASI-outputs accomplish acceptance of transport flows. For optimal use of leased satellite capacity, it is advisable to merge multiple multiplexes into one transponder. The modulated signal is transferred to the required bandwidth by means of an up converter, then amplified by amplifiers and emitted to a satellite with a transmitting antenna with a diameter of 9 m.

3. State of digital terrestrial television in Bulgaria

In order to ensure the quality and reliability of the transmission of the television signal to the main broadcasting sites for digital broadcasting on the territory of Bulgaria, the NEC Company's iPASOLINK radio-relay platform has been selected.

The topology of the transmission network consists of 6 main radio relay rings connecting the main sites in the country. An XPIC solution is used to more efficiently use the frequency resource by operating two polarizations, both horizontal and vertical, at the same carrier frequency.

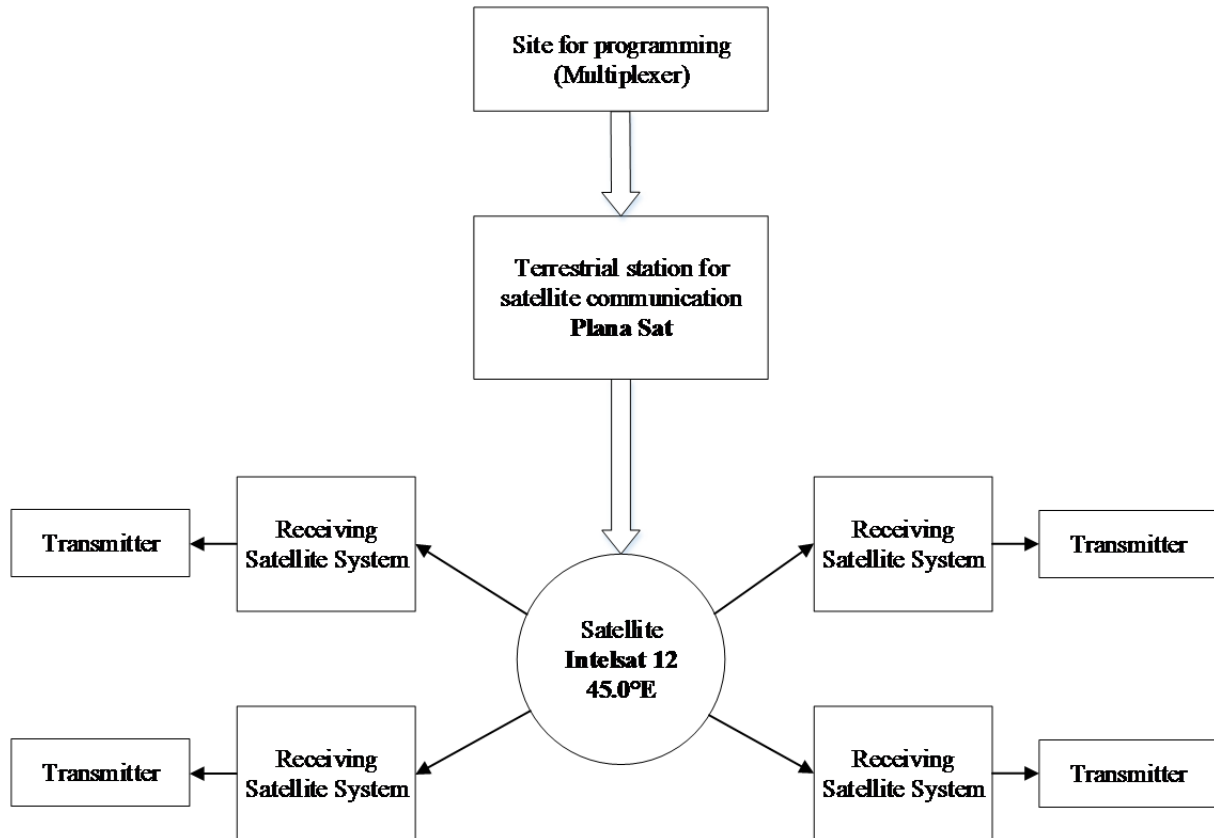


Fig. 2. Structure of the DVB network using satellite communications.

The system maintains adaptive modulation (AMR) and automatic output power control (ATPS) to achieve higher line reliability in adverse weather conditions. At each point, a back-up power supply is provided. The NURTS radio network provides the transmission of a television signal through a set of 1 Gb Ethernet interfaces, both electrical and optical, enabling quick and easy connection of the equipment to different types of devices [14].

When building the network are used antennas with a high degree of separation of the two polarizations (XPD > 34 dB) of the ANDREW company.

Low latency and synchronization are essential for the functionality of relay networks, and QoS and traffic distribution are a prerequisite for the efficient operation of the system. With link aggregation support and iPASOLINK connectivity, an increase in network capacity and reliability, and a reduction in the amount of hardware used, are achieved.

Advantages of the digital radio relay network:

- full independence from external suppliers;
- complete control and network management at every point;
- IP based solution allowing flexible traffic management and provision of different types of services;
- modular platform architecture with the ability to quickly and easily upgrade the network and increase capacity;
- low signal latency, synchronization, high capacity utilization of the network.

4. Measurements

4.1. Measurements of the transmitted signals

Bit error rate is regulated in the relevant standards and in designing the transmitters, measures have been taken to reduce the influence of a variety of distortions on this parameter. For good reception of signals for digital television broadcasting in UHF is necessary to ensure the field strength not less than 900 $\mu\text{V}/\text{m}$. 1 μV corresponding to 59 dB [11, 12].

The radiated power of the transmitter is the product of the average power of the transmitter and the coefficient of amplification of the transmitting antenna:

$$P_R = P_{AVR} * G_{ANT} \quad (3)$$

The most significant factors affecting the field strength at the point of adoption are as follows:

- The relief of the Earth's surface and shadowing obstacles;
- Interference losses, caused by reflected signals;
- Absorption of radio waves from water vapor and fogs;
- Losses as a result of refraction in the atmosphere;
- Losses from natural and artificial origin.

On Tables 1 to 3 are shown the of acceptance in percentages at different PAVR and coefficient of amplification of the transmitting antenna $G = 10 \text{ dB}$, $G = 5 \text{ dB}$ and $G = 0 \text{ dB}$ respectively.

Table 1. Probability of acceptance in percentages at $P_{AVR} = 100\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99	98	94	91	85	78
G=5 dB	95	93	88	78	70	50
G=0 dB	92	85	72	55	45	30

Table 2. Probability of acceptance in percentages at $P_{AVR} = 200\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99.5	99	97	94.5	91.5	78
G=5 dB	97	95	82	88	78	75
G=0 dB	95	91	88	72	60	50

Table 3. Probability of acceptance in percentages at $P_{AVR} = 500\text{W}$.

Distance to the antenna r, km	10	12	14	16	18	20
G=10 dB	99.8	99.5	99	98	94	85
G=5 dB	99	98	96	93	90	85
G=0 dB	98	95	91.5	85	77	70

4.2. Measurement of television transmitter

To carry out the experimental research was used the following equipment: Rohde & Schwarz ETL TV analyzer and power meter Rohde & Schwarz NRP-Z22 [15, 16].

The measuring of video signals broadcasted through the DVB-T system in Bulgaria shall be performed in compliance with the requirements of ITU and ETSI standard EN 300 744 [5, 6, 17]. The objective assessment of the quality of the broadcasted digital signal shall be determined by measuring and analyzing the following technical parameters:

- values of the field strength at points located on the border of the theoretically determined service area, in order to analyze the actual coverage with a normal digital signal;
- BER (bit error ratio) - evaluation of the quality of the demodulated signal;
- MER (modulation error ratio) - quality assessment of each carrier of the complex OFDM signal;
- delay in signal propagation between two transmitters, part of an SFN network, at a corresponding reception point;
- monitoring the synchronization of the complex OFDM signal;
- Minimum average field strength - for territories (settlements) with over 30,000 inhabitants - 85dB $\mu\text{V}/\text{m}$; for other settlements - 56dB $\mu\text{V}/\text{m}$.

All performed measurements are for SFN zone in south-west Bulgaria, for channels 29, 31 and 33.

The Figure 3 shows the measurement of the synchronization of one transmitter with another, it is necessary that their levels are significantly above the threshold "Echo Detection Threshold").

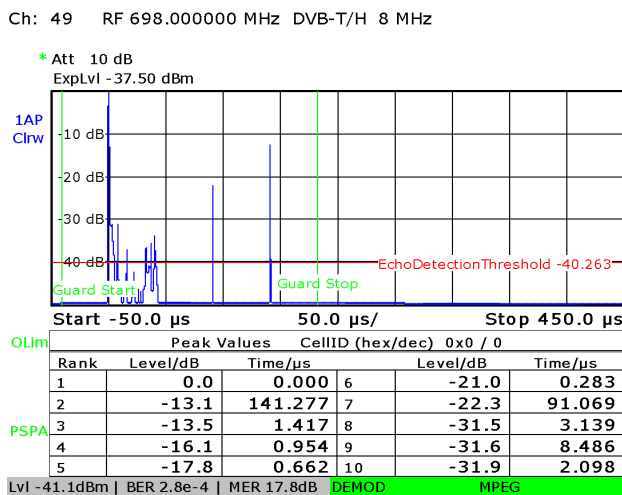


Fig. 3. Transmitter synchronization.

On Figure 4 is showed the out of band emissions and the I/Q imbalance on Figure 5, respectively.

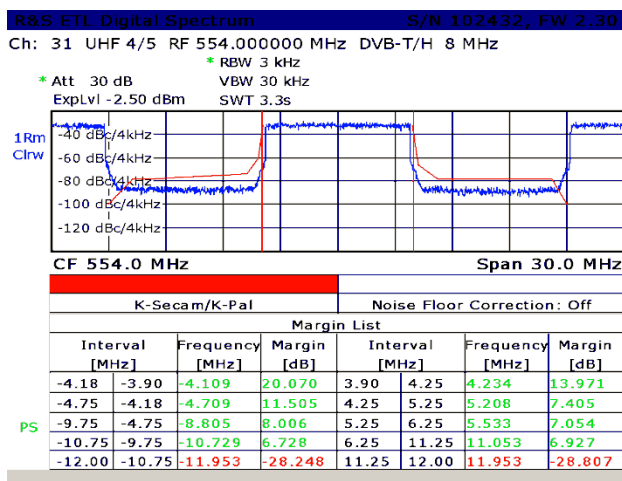


Fig. 4. Out of band emissions.

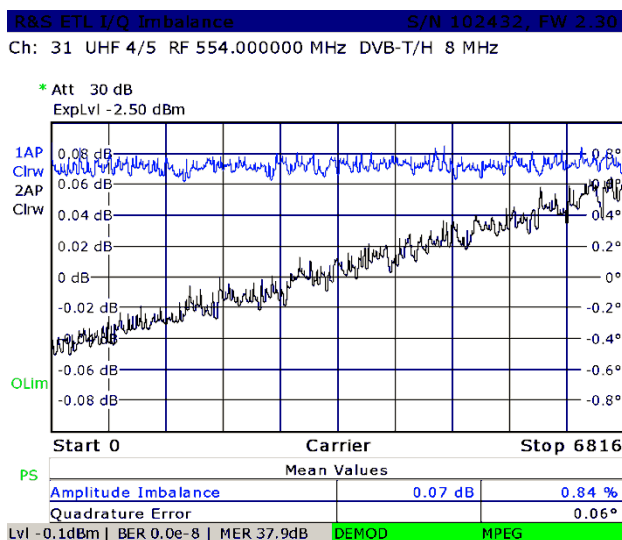


Fig. 5. I/Q imbalance.

The measurements showed that the television transmitters provide above the minimum average field strength of 56dB μ V/m and work in synchronization in the same SFN network.

5. Conclusion

In recent years, significant attention has been paid in Europe to the development and deployment of digital television broadcasting on a terrestrial, satellite and cable ways, based on DVB-T, DVB-C and DVB-S standards. In Bulgaria, the market for digital terrestrial, cable and satellite radio and television broadcasting is liberalized. The national radio spectrum allocation plan shall determine the authorized frequency bands for satellite and terrestrial television broadcasting. The development of national digital television broadcasting networks should be as a combination of single-frequency networks forming a multi-frequency network.

References

- [1] Alencar, M. (2009). *Digital Television Systems*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511609732
- [2] Serov, A.V. (2010). *Digital video broadcasting DVB-T/H*. BHV Petersburg, St. Petersburg, (in russian)
- [3] Song, J., Yang, Z. & Wang, J. (2015). *Digital Terrestrial Television Broadcasting: Technology and System*. Wiley-IEEE Press
- [4] Iliev, T. B., Mihaylov, G. Y., Bikov, T. D., Ivanova, E. P. and Stoyanov, I. S. (2018). An approach for more effective use of the radio-frequency spectrum in DVB-T single frequency networks. *41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, Opatija, Croatia, 0445-0448, doi: 10.23919/MIPRO.2018.8400084.
- [5] ITU-R (2016). *Handbook on Digital Terrestrial Television Broadcasting Networks and Systems Implementation*, https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-63-2016-R1-PDF-E.pdf
- [6] ITU-R SM.1875-3 (08/2019) *DVB-T coverage measurements and verification of planning criteria*, https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.1875-3-201908-1!PDF-E.pdf
- [7] Angelov, K. K., Sadinov, S. M. and Kogias, P. G. (2020). Development of a Simple SDR-based System for Monitoring of VHF and UHF Radio Frequency Bands. *XXIX International Scientific Conference Electronics (ET)*, Sozopol, Bulgaria, 1-4, doi: 10.1109/ET50336.2020.9238302.
- [8] Siebert, P. (2019). Digital Video Broadcasting in 2019. *SMPTE Motion Imaging Journal*, vol. 128, no. 8, 87-88, doi: 10.5594/JMI.2019.2924813.
- [9] Martinez, A. et al., (2009). Analysis of the DVB-T Signal Variation for Indoor Portable Reception. *IEEE Transactions on Broadcasting*, vol. 55, no. 1, 11-19, doi: 10.1109/TBC.2008.2006657.
- [10] RTP (2003). *A Transport Protocol for Real-Time Applications* (RFC 3550). <https://tools.ietf.org/html/rfc3550>
- [11] Singhal, C. & Anubhav (2019). Efficient Mobile TV Broadcast in DVB-T Network. *22nd International Symposium on Wireless Personal Multimedia Communications (WPMC)*. 1-6, doi: 10.1109/WPMC48795.2019.9096116.
- [12] Iliev T. B., Mihaylov, G. Y., Ivanova, E. P., Stoyanov, I. S. and Radev, D. I. (2017). Experimental study of the basic parameters and the field strength of a television transmitter in the single frequency network (SFN). *27th International Conference Radioelektronika (RADIOELEKTRONIKA)*, Brno, 1-4, doi: 10.1109/RADIOELEK.2017.7936640.
- [13] RRC-06 (2006). *Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz*. <http://handle.itu.int/11.1004/020.1000/4.129>

-
- [14] ITU-R, (October 2009). *Case Study on transition from analogue to digital terrestrial TV (DTTV) broadcasting in the Republic of Bulgaria*, https://www.itu.int/ITU-D/tech/OLD_TND_WEBSITE/digital-broadcasting_OLD/Bulgaria_Assistance_Transition/Bulgaria/Bulgaria_Web.pdf
- [15] Data Sheet Rohde & Schwarz (2018). *Rohde & Schwarz ETL TV Analyzer*, (Version 24.00). https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_common_library/dl_brochures_and_datasheets/pdf_1/ETL_dat-sw_en_5213-7748-22_v2400.pdf
- [16] Data Sheet Rohde & Schwarz (2019). *Rohde & Schwarz NRP and NRP-Zxx Power Meter and Power Sensors*, (Version 12.00). https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_common_library/dl_brochures_and_datasheets/pdf_1/NRP-Family_dat-sw_en_5213-5539-22_v1200.pdf
- [17] ETSI EN 300 744 (2015). *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television*. (V1.6.2). https://www.etsi.org/deliver/etsi_en/300700_300799/300744/01.06.02_60/en_300744v010602p.pdf
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Feasibility of Small Wind Turbine via Net Metering in Greek Islands

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Abstract: The evaluation of a small 3kW wind turbine through the net metering scheme is studied in this article. 14 near to sea locations in Greece examined with the help of the RetScreen expert software. The simulations based on electrical, financial and environmental criteria. Siros with average wind speed of 6.93 m/s is the most attractive area while Iraklion is the least attractive location. According to the results the simulated project is already economically sound and a small wind turbine in the Greek islands will become a progressively an even more financially source of electricity in Greece. Finally, yet importantly is the fact that the use of small wind turbines has as a result that significant amount of Greenhouse gases do not reradiate into the topical atmosphere.

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Keywords: Small wind turbine, RetScreen software, GHG emission, Net metering.

1. Introduction

Net metering in electricity section is a method of trading electricity from renewable energy sources. This method offers to customers' future credit when they have an energy system which based on renewable energy sources. Of course there are rules according to how long and in which way someone can take the advantages of this credit. In Greece the net metering system has operated from 2014 in consistence with Law 3583/2014 while from 2006 the Greek government has announced and the "virtual net metering" a billing plan which allows a customer to credit energy from one meter to another (Law 3468/2006) [1, 2]. In Greece the net metering scheme permits many renewable energy sources such as photovoltaic panels, small wind power turbines, biomass, biogas, small hydroelectric power plants and combined heat and power systems. The Greek net metering program foresees that the electricity produced by a renewable energy power plant is offset with self-consumed energy in an annual base. If there is surplus this energy is fed into the grid without remuneration. Now very soon there will be two new categories:

- Installations with wind turbines up to 60 kW after bids for the category of small wind turbines.
- Installations with small wind turbines up to 2-3 kW for self-generation and self-consumption, in homes and businesses, according to the decentralized production scheme of net metering and virtual net metering, as well as related facilities from energy communities.

The second category which will have a really small

bureaucracy has interesting for many consumers especially in the "windy" Greek islands. The purpose of this article is to evaluate both the financial and the environmental analysis of a small 3 kW wind turbine in 14 island areas. All the simulations realized using the RetScreen Expert clean energy management software system version 6.0 [3-6].

2. Case study

The power transmission grid in Greece divided in the 2 part, the first is main-land national grid and the second is a mixed of thousands small networks in the Greek islands. The electricity cost in these small networks is really high and based in autonomous power stations with natural gas as a fuel. In these islands owing to the fact that there is a very good wind resource the use of small wind turbine through the net metering program it seems attractive [7].

The electricity production in Greece today based mainly in Natural gas (with contribution more than 43%) and in renewable energy sources with significant reduction in the use of lignite. In 2005 the lignite covered more than 59% of the electricity production; the oil contribution was approximately 14% while Renewable Energy Sources (RES) and Hydro energy together offered less than 12% [8, 9]. During the 2020 lignite is the fuel for only of the 14% for energy production but RES production contributes to the national grid more than 36% (Figure 1).

Without doubt the potential for wind energy in Greece is really high. Figure 2 shows the cumulative installed capacity and the Electricity production (according to Euroobserver) during the years 2009-2019 in Greece [10]. During 2020, the installed capacity of wind power in Greece exceeded the 4,000 MW, reached 4,114 MW and



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meets approximately the 12% of electricity demands in country.

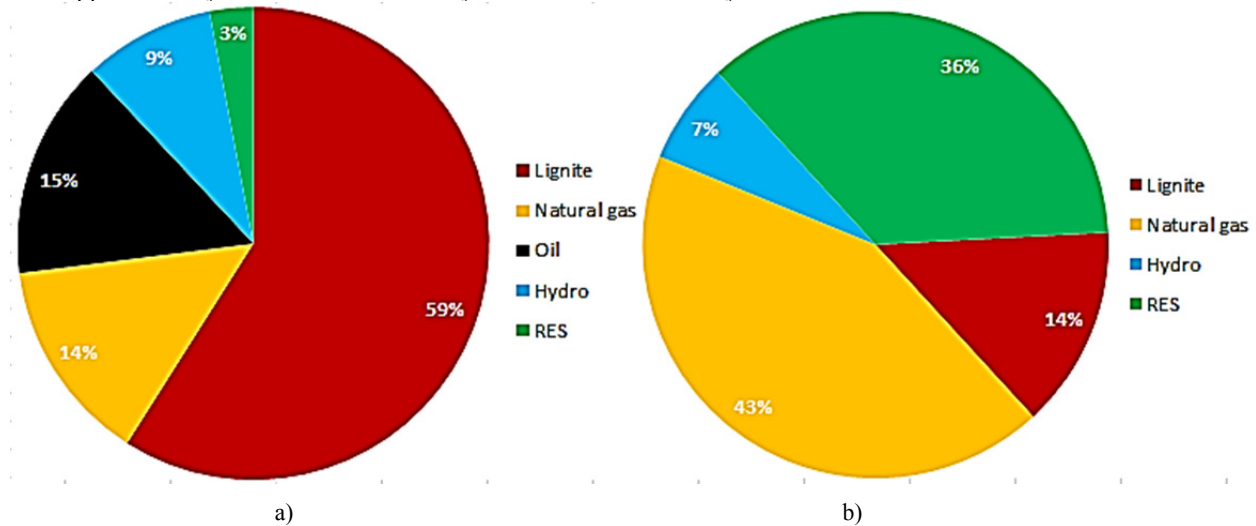


Fig. 1. The electricity production in Greece for every fuel a) in 2005, b) in 2020.

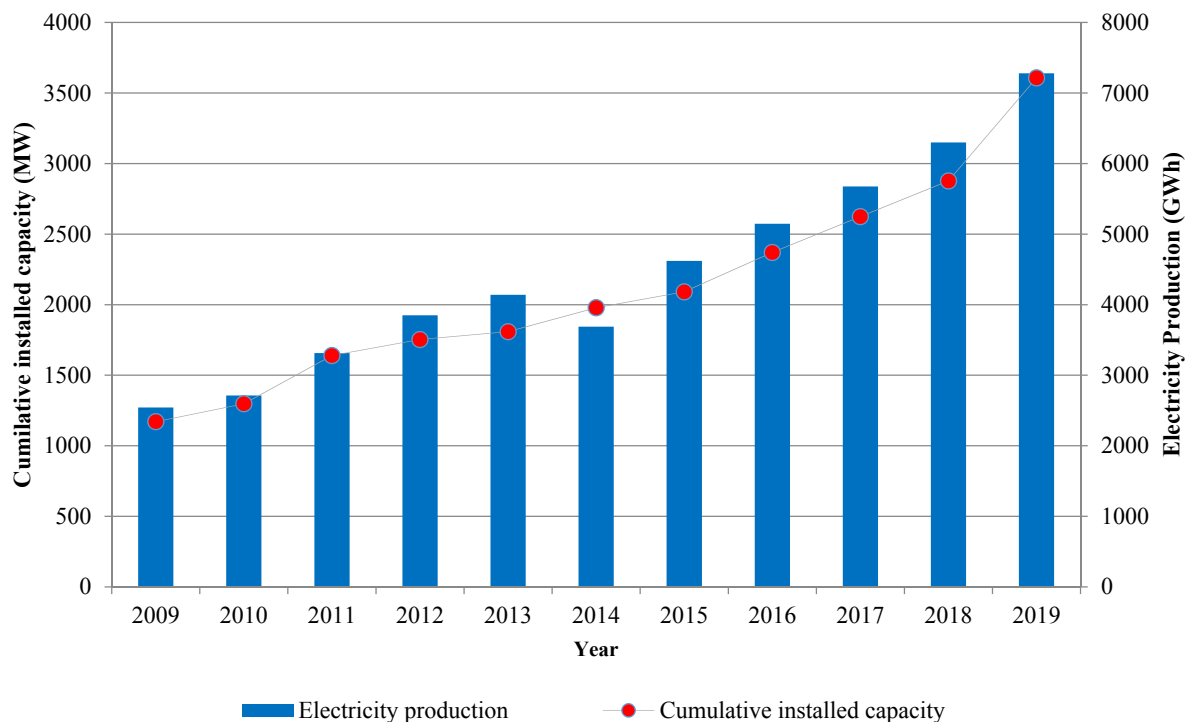


Fig. 2. The wind power installed capacity and the electricity production during the years 2009 - 2019 in Greece.

Is really a matter of peculiar interest that all this energy is installed onshore because in Greece there are not offshore wind turbines!

In this article based on the long-term official data from Technical Chamber of Greece (Table 1) a small 3 kW wind turbine was evaluated in 14 cities (Fig. 3) near to the sea with good wind potential [11]. These areas include 13 cities in Greek islands (Iraklion, Ierapetra, Kithira, Limnos, Milos, Mitilini, Naxos, Paros, Rhodes, Samos, Skiros, Siros, Chios) and 1 city which belong to the main-land (Methoni).

The project presumes a small 3 kW wind turbine at each of the 14 locations to simulate with the help of the RetScreen expert software, the electricity production, the Capacity Factor (CF), the financial viability and the Greenhouse gases (GHG) emission reduction due to the use of the wind turbine. The selected wind turbine is a 3 kW model from ReDriven Power Inc..

RetScreen is easy handle software based on a well-known Microsoft Excel and can be used in order to evaluate the viability of renewable energy projects. In order to calculate the energy production in each area the necessary energy model and the characteristics of the

selected wind turbine model illustrated in Figure 4. The project lifetime has been considered to be 25 years.

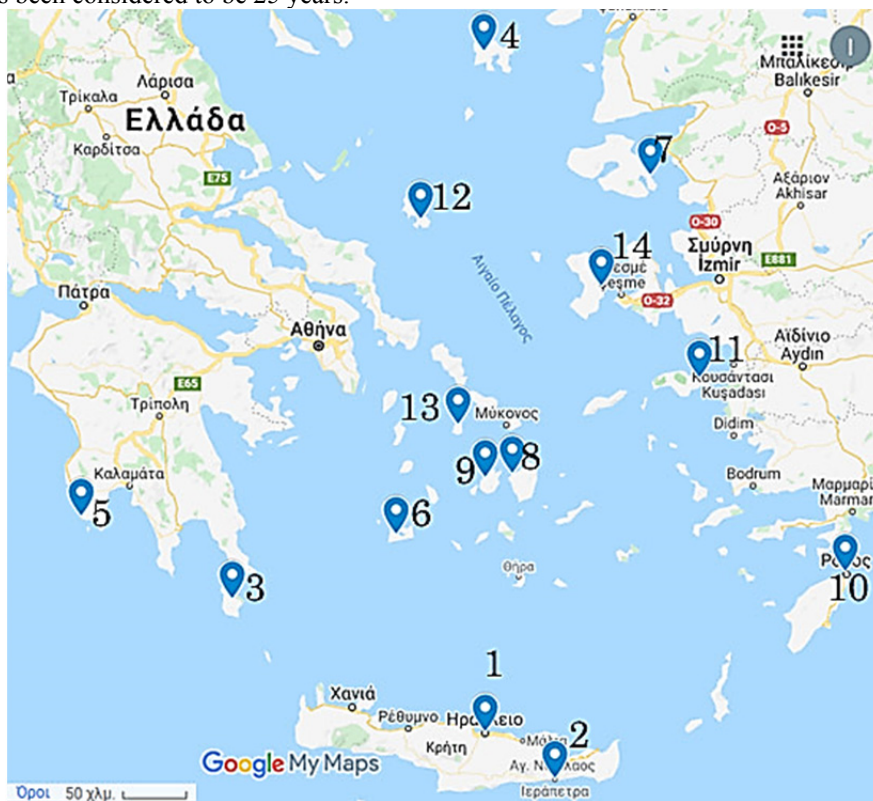


Fig. 3. The 14 simulated areas: 1. Iraklion, 2. Ierapetra, 3. Kithira, 4. Limnos, 5. Methoni, 6. Milos, 7. Mitilini, 8. Naxos, 9. Paros, 10. Rhodes, 11. Samos, 12. Skiros, 13. Siros, 14. Chios.

Table 1. Long-term mean values of wind speed for the 14 simulated area.

Month	Location													
	Iraklion	Ierapetra	Kithira	Limnos	Methoni	Milos	Mitilini	Naxos	Paros	Rhodes	Samos	Skiros	Siros	Chios
1	4.8	4.7	7.1	5.8	5.5	7.9	5.5	7.9	7.5	3.9	6.0	6.8	8.1	5.2
2	5.1	4.9	6.8	6.3	5.7	8.0	5.8	8.1	7.5	4.4	6.2	6.9	8.1	5.9
3	4.7	4.6	6.8	5.7	5.5	7.1	5.1	7.6	6.5	4.4	5.5	6.2	7.6	4.8
4	4.1	4.0	5.7	4.2	5.3	5.7	4.3	5.9	5.4	4.5	4.3	4.9	5.8	3.4
5	3.2	3.7	5.0	3.9	4.8	4.4	3.5	4.9	4.5	4.3	4.2	4	5.4	3.1
6	3.5	4.4	4.4	3.7	5	4.1	3.8	5.0	4.0	5.2	4.7	4.2	4.9	3.5
7	4.6	6.4	4.4	4.4	5.1	5.7	4.9	6.6	5.2	6.0	7.0	4.8	7.0	5.2
8	4.6	6.0	4.5	4.8	4.9	5.9	4.7	6.9	4.9	5.8	6.6	5.1	7.2	5.2
9	4.0	5.1	5	4.4	4.6	5.9	4.4	7.0	4.9	4.9	5.7	5.1	6.5	4.4
10	3.8	4.4	6.3	5.3	4.5	6.3	4.3	7.4	5.5	3.4	5.1	6.0	7.5	4.3
11	4.2	3.9	5.8	5.3	5.1	6.3	4.7	6.7	6.3	3.1	5.5	5.6	7.2	4.5
12	4.8	4.6	6.8	5.7	5.5	7.4	5.6	7.5	6.8	3.8	6.0	6.4	7.8	4.8
Average	4.28	4.73	5.72	4.96	5.13	6.23	4.72	6.79	5.75	4.48	5.57	5.50	6.93	4.53

Energy model includes six subsections: Resource Assessment, Wind turbine, Power and energy curves, Losses, Summary and Other information. Resource assessment comprises all the data associated to wind potential. Wind turbine contains all the related parameters of the selected wind turbine. Power and energy curves

subsection depicts the corresponding power curve value of the selected wind turbine. Losses subsection includes the availability of the wind turbine and three types of losses, array losses, airfoil losses and miscellaneous losses. Summary section gives the initial and O&M costs, the electricity export rate and the RetScreen calculates the

capacity factor and the electricity exported to the grid [12].

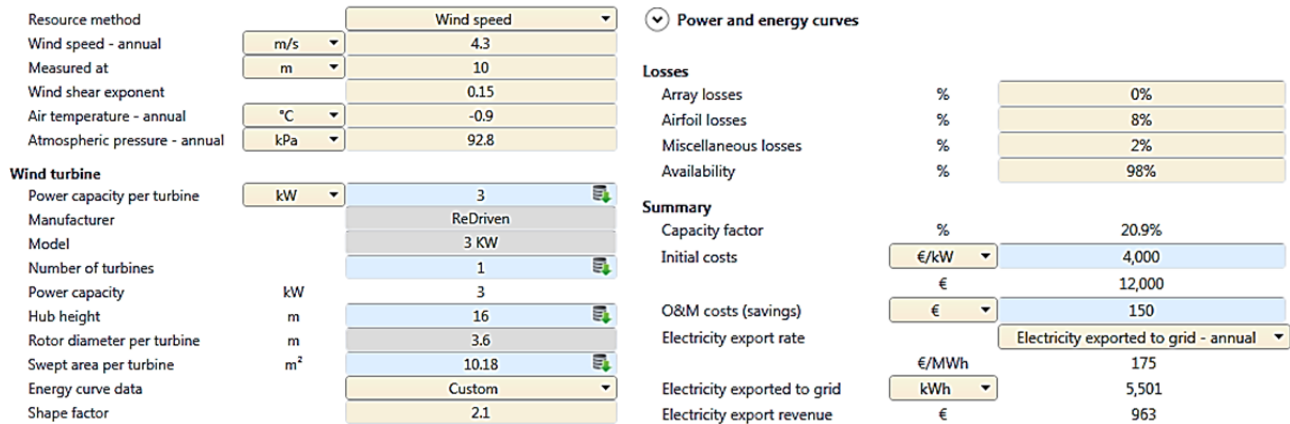


Fig. 4. Energy model and the technical characteristics of the selected wind turbine model.

3. Results and discussion

According to the estimations of RetScreen the electricity derived from the wind turbine and the CF for each of the 14 locations are given in Figure 5. According to fig. 5 the maximum energy production and CF take place in Siros with values 11883 kWh and 45.2% correspondingly, while the minimum yield occurs in Iraklion with values 5519 kWh and 21% respectively.

Based on the costs which depicted in fig. 4 (Initial cost 12,000€, O&M costs 150€ per year and electricity price for the produced energy to grid equal to

175€/MWh) from financial point of view Siros has the maximum IRR (Internal Rate of Return) on equity and the minimum payback time and as presumable result Iraklion with the lowest wind capacity provides the minimum IRR on equity and the maximum payback time. Figure 6 shows the IRR and the payback time for each area correspondingly. In all cases both the inflation ratio and deb ratio was 0%. Based on the fact that the lifetime of a project is 25 years the investment is attractive in each of the investigated area.

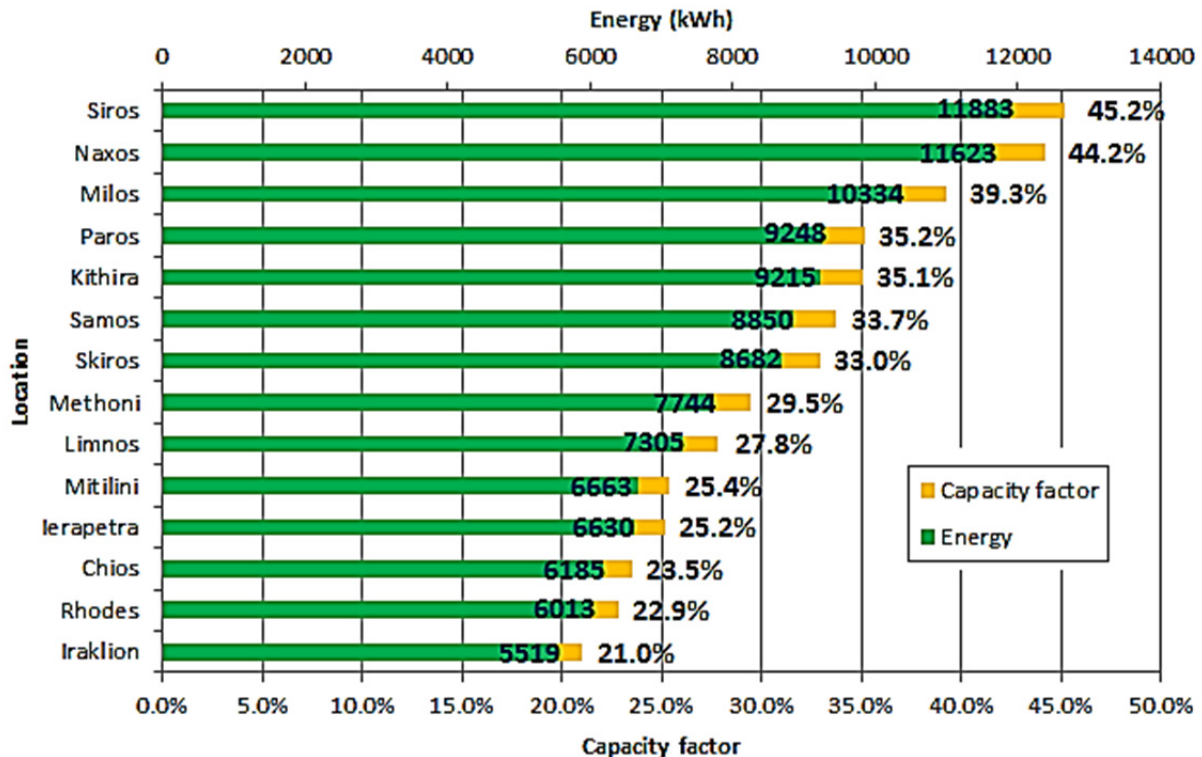


Fig. 5. Yearly energy production and the capacity factor for the 14 simulated areas in Greece.

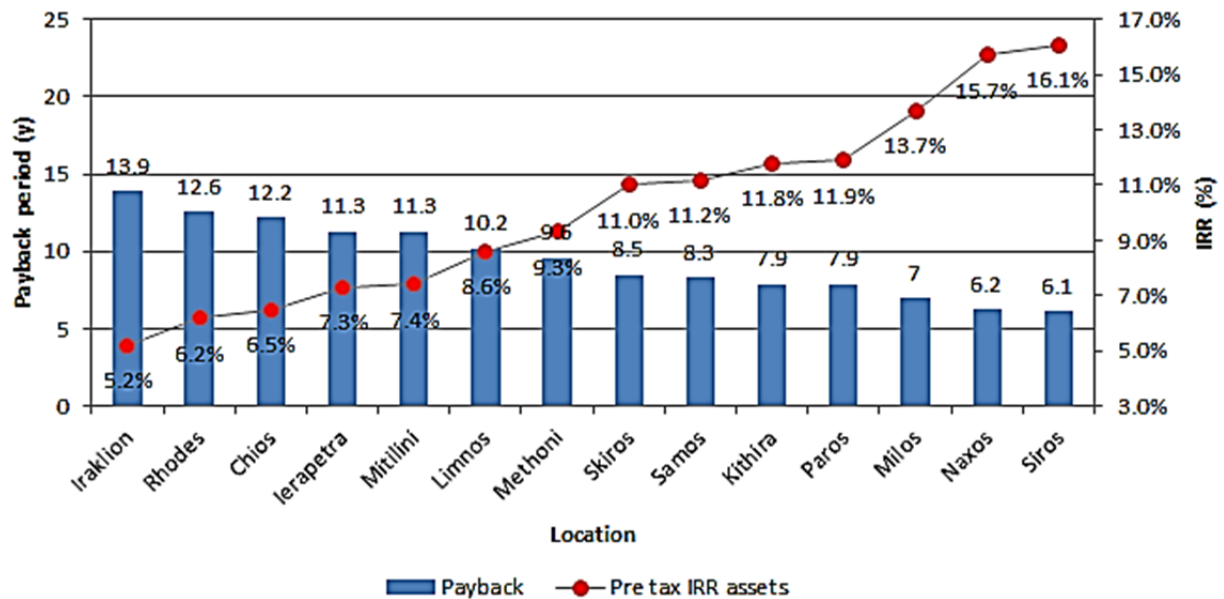


Fig. 6. Internal return rate for the 14 simulated areas in Greece.

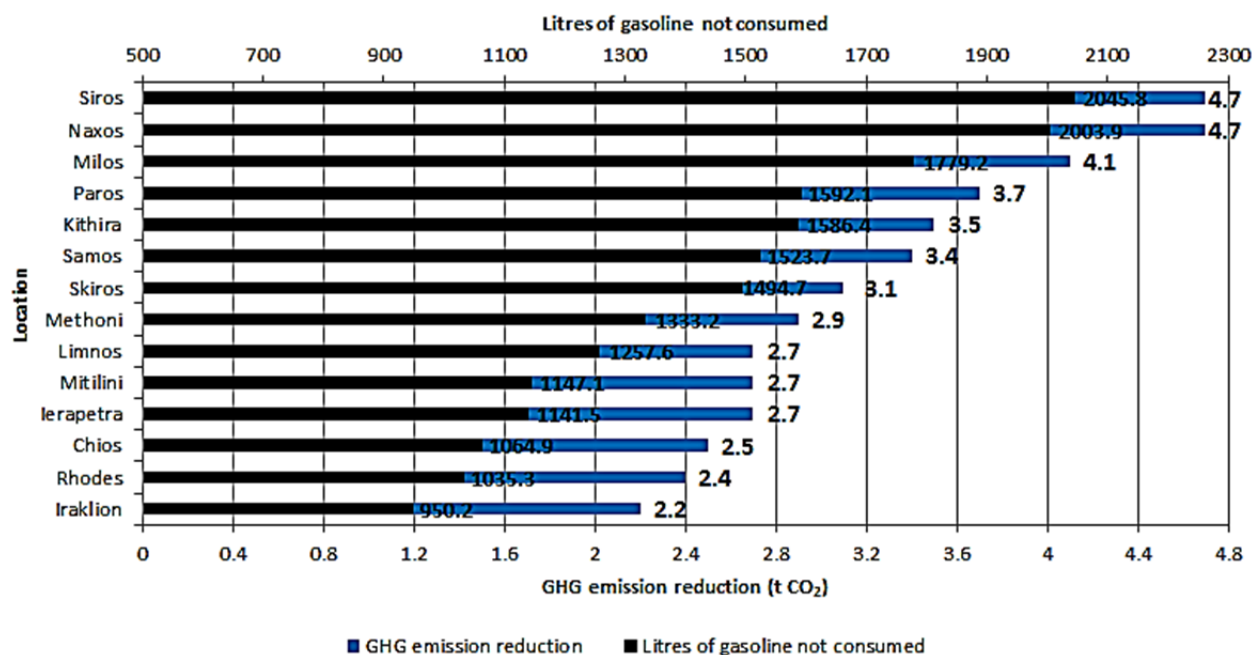


Fig. 7. Greenhouse gases reduction and the equivalent in litres of gasoline do not consumed owing to the use of the simulated wind turbine project for the 14 different locations.

The use of a small wind turbine instead of conventional fuels such as lignite, natural gas or diesel offers significant benefits in the reduction of the emitted GHG. Based on the fact that today natural gas is the most common fuel in Greece in order to produce electricity the GHG reduction based on the comparison between natural gas and wind turbine energy. The emission worksheet is used for this purpose. For GHG emission factor equal to 0.401 tCO₂/MWh, the algorithm of the RetScreen calculates the total annual reduction of GHG emissions for each of the 14 areas. The maximum GHG emissions

reductions of 4.7 t per year were estimated in Siros and Naxos while the lowest reduction was occurred for Iraklion with values 2.2 t per year. Figure 7 shows both the GHG reduction and the equivalent in litres of gasoline that not consumed for each simulated area.

4. Conclusion

Greece as a country with very long coastline and numerous islands Greece has high wind energy potential. This work based on real long-term wind speed data presented a study for evaluation of an installation of a

small wind turbine in 14 different areas. The average annual wind speed in these areas fluctuates from 4.28 – 6.93 m/s. The electricity production varies between 5519 and 11883 kWh/year while the Capacity Factor varies between 21 and 45.2%. The internal rate of return diverges from 5.2 up to 16.1% while the payback time fluctuates from 6.1 up to 13.9 years. From an environmental point of view the use of a small wind turbine instead of natural gas minimize the Greenhouse gases emission at least of 2.2 t CO₂ every year. Bearing in mind the fact that the price of natural gas is steady rising is obvious that the financial benefits will be even more attractive during the next years.

References

- [1] Official Journal of the Hellenic Republic. 3468/A/27.06.2006. pp. 1405-1428 Access online on 02 February 2021 http://www.et.gr/search_publication.
- [2] Official Journal of the Hellenic Republic. 3583/A/31.12.2014. pp. 41235-41250 Access online on 02 February 2021 http://www.et.gr/search_publication.
- [3] Owolabi, A. B., Nsafon, B. E. K., Roh, J. W., Suh, D., & Huh, J. S., "Measurement and verification analysis on the energy performance of a retrofit residential building after energy efficiency measures using RETScreen Expert." *Alexandria Engineering Journal* 59 (6), 2020, pp. 4643-4657.
- [4] Himri, Y., Merzouk, M., Merzouk, N. K., & Himri, S.. "Potential and economic feasibility of wind energy in south West region of Algeria." *Sustainable Energy Technologies and Assessments*, 38, (2020) 100643.
- [5] Torres, E. (2020). Work in progress: Using RETScreen Expert Software for Authentic Assessment, *2020 IEEE World Conference on Engineering Education (EDUNINE)*, 1-3. doi: 10.1109/EDUNINE48860.2020.9149494
- [6] Turgali, D., Kopeyeva, A., Dikhanbayeva, D. & Rojas-Solórzano, L. (2021). Potential impact of global warming on wind power production in Central Asia. *Environ Prog Sustainable Energy*, e13626. <https://doi.org/10.1002/ep.13626>
- [7] Fantidis, J. G., Bandekas, D. V., Potolias, C., & Vordos, N. (2013). "Cost of PV electricity—Case study of Greece", *Solar Energy*, 91, 120-130.
- [8] Papanicolaou C., Typou J., Ioakeim J., Kotis Th. and Foscolos A. "The prospect of using greek lignite in an energy portfolio related to power generation." *Bulletin of the Geological Society of Greece*, vol. XLVII Proceedings of the 13th International Congress, Chania. 47.4 (2013): 2121-2130.
- [9] IPTO (Independent Power Transmission Operator S.A.), "Monthly Energy Report, December 2020 Access online on 02 February 2021 at www.admie.gr/sites/default/files/attached-files/type-file/2021/01/Energy_Report_202012_v1_0.pdf
- [10] EurObserv'ER, Access online on 02 February 2021 at <https://www.eurobserv-er.org/>
- [11] Technical Chamber of Greece, 2010. "Climatic data on Greece", First ed., T.O.T.E.E. 20701-3/2010. Athens July 2010.
- [12] Psomopoulos, C.S., Ioannidis, G.C., Kaminaris, S.D. et al. (2015). A Comparative Evaluation of Photovoltaic Electricity Production Assessment Software (PVGIS, PVWatts and RETScreen). *Environ. Process.* 2, 175–189. <https://doi.org/10.1007/s40710-015-0092-4>

Modelling and Simulation Analysis of Routing Algorithms in Multichannel Optical Communication Networks

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Abstract: In this paper, it is considered the broadband backbone optical networks with wavelength routing and circuit switching used to build long-range wide area networks. In this type of network, if there is an available and acknowledged connection request, it is necessary to determine the optimal path between the optical communication nodes in the network. This also requires the assignment of an optimal set of wavelengths along the selected route between these nodes. This paper takes into account the multichannel optical communication networks with spectral multiplexing. Four different routing algorithms are modeled and analyzed for which their weight functions are determined to take into account various factors, such as the total distance of the individual routes, the total number of available wavelengths for a given route and how many of them are available for use. It is studied and compared the performance of the proposed algorithms in a multichannel optical network in terms of blocking probability.

Keywords: multichannel network, spectral multiplexing, blocking probability, routing algorithms, weight functions.

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1. Introduction

The multichannel optical communication networks with spectral multiplexing combine the advantages of high-speed single-channel optical networks and signal multiplexing in classic communication networks. [1, 2]

This paper examines an optical wavelength routing network. The routers in the network have the ability to convert the wavelength, which allows them to convert data from one input wavelength to another output wavelength in a given operating optical range. The physical device and the state of the network determine the range to which the wavelengths can be converted (in whole or in part). [2, 3, 7]

In this paper, a channel-switching model, where a transmission path is set for the entire duration of a session, will be considered as an example. The set of connections through the intermediate nodes from start to end point determines the transmission path with the wavelength specified for each connection. When the wavelength conversion option is not available on the network, its continuity is mandatory - this means that the same wavelength is used for all consecutive connections. [4,6]

In order to build a transmission path, a route and wavelength decision must be made. Given the existence of a set of connections, the problem of establishing a transmission path by routing and setting the wavelength

for each connection has gained popularity in the literature as a routing and wavelength-assignment (RWA) problem [6-8]. One of the main parameters of interest in the analysis of this problem is the blocking probability (due to lack of free wavelength) [9, 10].

The main purpose of this work is to analyze and investigate the blocking probability using four different routing algorithms through modeling and simulation analysis of a multichannel optical communication network.

2. Routing algorithms based on the shortest path

One of the main tasks is to determine the path from the start node to the end node, which is with the shortest length, using a certain algorithm and a given wavelength which is the responsibility of the medium access control protocols [3,7].

Each path in the network could be unambiguously defined with specific weight functions. Specific information for a multi-channel optical network can be incorporated into these weight functions to improve performance. They must take into account the number of wavelengths that are available for use and the total number of wavelengths for a certain path.

The model of formation and establishment of a transmission path (Figure 1) when requesting a session is based on a routing method depending on the status of the transmission lines. Here each router sends periodically to all other routers information about its adjacent lines. This amount of data is used to learn the network topology with the corresponding weight functions of the lines.



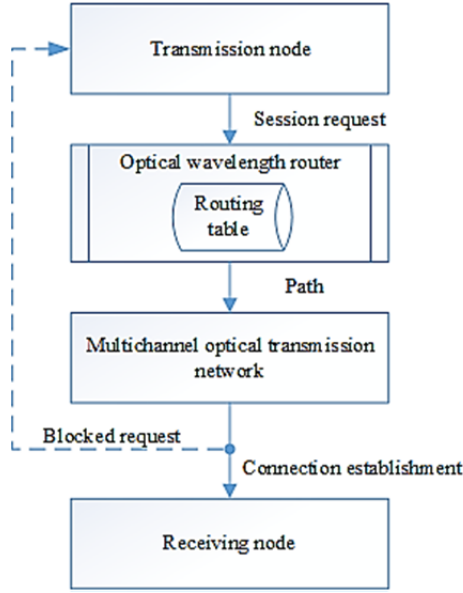


Fig. 1. Model of formation and establishment of transmission path when requesting a session.

Hereupon each router could calculate independently the shortest path connecting it to each available destination, forming a routing table.

When a session request is received, the router determines the shortest path based on the existing records in its routing table, and this is repeated in each network node along the entire path from the source to the destination. The router then assigns a specific wavelength for the given path and declares its assignment to all routers on that path.

The initial choice of wavelength can be random or based on a specific rule or available information (as it is shown in [11-13], for example). If the network allows wavelength conversion, then the transmission path is established by determining and assigning different wavelengths in the different lines along the path. If this request cannot be fulfilled, another wavelength should be selected, which can be determined by feedback from the nearest node on the selected path. It is necessary to find at least one free wavelength by repeatedly performing this process. If not, then this request is blocked, i.e. transmission path cannot be built.

3. Routing algorithms and weight functions for multichannel optical networks

A graph $G(V, E)$ can be used to represent the network topology, where V represents the set of vertices (network nodes) and E – the set of edges (lines) [15-17]. Each connection $(i, j) \in E$ is uniquely defined by a weight function w_{ij} that represents the cost of using the line. The implementation of the shortest path algorithm ends when each router has recorded in its routing table information about the full range of possible paths to each destination.

In multichannel optical networks, the line status information will contain specific parameters that include the total number of wavelengths and the number of available ones [11,13]. Furthermore, lines along which the available wavelengths are already utilized can be tagged as unusable until the next refresh of the table.

Weight functions considering these factors are described below.

For a given connection $(i, j) \in E$, λ_{ij}^a denotes the number of available wavelengths in a line when line status information is collected, λ_{ij}^T is the total number of wavelengths in a line, d_{ij} is metrics equivalent to the physical distance or propagation delay.

Four algorithms for calculating weight functions (w_{ij}) will be considered and modeled here:

3.1. Based on the number of hops (NHWF)

The hop refers to the transition from one node to another. The shortest distance between two nodes in the hops will give the number of transitions required to pass the packet from the starting node to the final one. A basic case is presented where $w_{ij} = 1$ and $\forall (i, j) \in E$. Through this function, the shortest path selection is based on the smallest number of hops.

3.2. Based on the distance (DWF)

Here, $w_{ij} = d_{ij}$ and $\forall (i, j) \in E$. d_{ij} represents the physical distance by the equivalent propagation delay, expressed in microseconds (ie, the propagation time). This function will select the shortest path with the least propagation delay.

3.3. Based on the available wavelengths (AWWF)

The weight function w_{ij} is defined as:

$$w_{ij} = \begin{cases} -\log\left(1 - \frac{1}{\lambda_{ij}^a}\right), & \lambda_{ij}^a > 1, \forall (i, j) \in E \\ 1, & \lambda_{ij}^a = 1, \forall (i, j) \in E \end{cases} \quad (1)$$

where $1/\lambda_{ij}^a$ is the reciprocal of the number of available wavelengths in the line, i.e. it models the possibility of the line to reject session establishment. This parameter will be as small as the number of available

wavelengths is greater. Therefore $\left(1 - \frac{1}{\lambda_{ij}^a}\right)$ determines

the probability of line to accept the session request. The purpose is to maximize this probability. This metric ignores the physical distance as well as the number of hops and it has a dynamic weight function which will change when the network status changes.

3.4. Based on the total number of wavelengths and the available wavelengths (TAWWF)

The weight function w_{ij} is defined as:

$$w_{ij} = -\log\left(1 - \left(1 - \frac{\lambda_{ij}^a}{\lambda_{ij}^T}\right)^{\lambda_{ij}^T}\right), \quad \forall (i, j) \in E \quad (2)$$

where λ_{ij}^a and λ_{ij}^T are respectively the number of available wavelengths and the total number of wavelengths. $p^{\lambda_{ij}^T}$ determines at a given time what is the

probability that all wavelengths will be utilized, where p is the probability that the wavelength will be utilized. For a given status, the probability can be calculated as:

$$p = \left(1 - \frac{\lambda_{ij}^a}{\lambda_{ij}^r} \right) \quad (3)$$

4. Results

The algorithms presented above were modeled in MATLAB environment. An analysis of their behavior in multichannel optical networks was performed by simulation testing. Because these types of networks are with losses, system failure may occur due to a lack of resources. In this type of network, multiple paths share the same lines. The developed model makes it possible to find an answer to how different paths with different traffic utilization interact and what is the blocking probability for each of the given paths. The module offers functions for calculating the blocking probability for different types of networks: a network with, without, and with a partial redistribution of wavelengths. Scripts are also available to define the network structure (user-defined and randomly generated) and traffic matrices. The purpose of the study is to use the weight function modeling approach to determine the total network load, to compare the network performance using the different routing algorithms, and to determine the blocking probability in these cases.

4.1. Input parameters

By using the developed m-functions, a network topology with 20 nodes. This topology is arbitrarily generated and the maximum number of wavelengths/channels varies between 8, 16 and 40 at the 1550 nm band. Network traffic is modeled by a number of requests for transmission from the source to the final destination. The received transmission requests in each optical node is modeled with a Poisson distribution with an average of λ connection requests per unit time. The transmission duration is modeled with an exponential distribution with an average value of 3 units of time.

The system parameters that are variable are as follows:

- L – the total number of wavelengths for each line;
- λ – the intensity of transmission requests at each node;
- γ – wavelength conversion factor – it is determined based on what part of the total number of wavelengths can be converted for a node.

When there is no wavelength conversion, it is denoted as $\gamma = 0$, while $\gamma = 1$ indicates a complete conversion of the wavelengths. If the value is between 0 and 1, this indicates a partial wavelength conversion.

The parameters to be evaluated are the following:

- P – the blocking probability (that the transmission request will be rejected/blocked due to the lack of transmission path or available wavelength);

- U – the link utilization (it is determined by the time during which all network lines are utilized);
- D – average delay (the average traffic delay per session; it includes the sum of the mean values of the propagation delay and the wavelength conversion delay in the intermediate optical nodes).

All simulations were performed for two different values of the total number of wavelengths/channels per line, 8 and 16, respectively.

4.2. Blocking probability (P) analysis

Figures 2 to 5 present the results of the dependence of the blocking probability a function of traffic per node for a total number of 8 and 16 wavelengths/channels and respectively at two different values of the wavelength conversion factor $\gamma = \{0.5, 1.0\}$. The results are presented for each of the routing algorithms considered: NHWF, DWF, AWWF, and TAWWF.

The NHWF algorithm minimizes the number of hops in the selected route. It gives the best results in terms of the minimum value of the probability of blocking

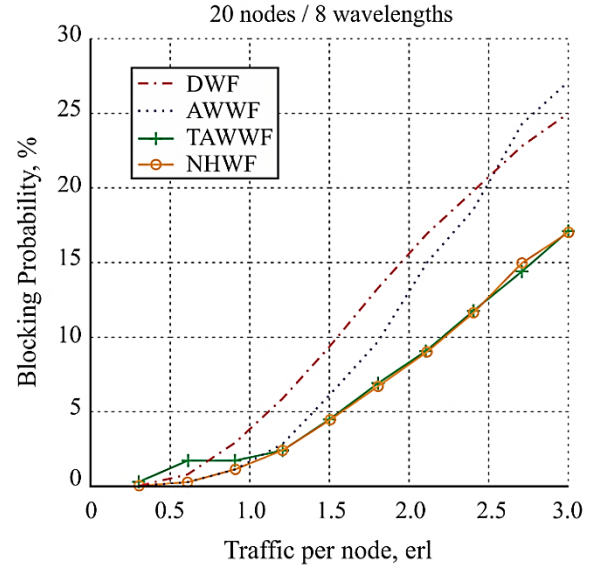


Fig. 2. Dependence of the blocking probability as a function of the traffic per node at $\gamma = 0.5$ and 8 wavelengths/channels.

The DWF algorithm provides relatively poor performance since the shortest path only takes into account the distance as a factor. If there are several different paths between two nodes, the path with fewer hops is assumed to provide a better result. The reason is that the probability of blocking will increase as the number of lines along which an available wavelength is found is increased.

The results of the AWWF algorithm are also relatively poor. This is due to the fact that AWWF chooses longer paths since the number of available wavelengths decreases for shorter paths.

The results of the TAWWF algorithm are nearly identical to those of the NHWF when the traffic load is above average to high.

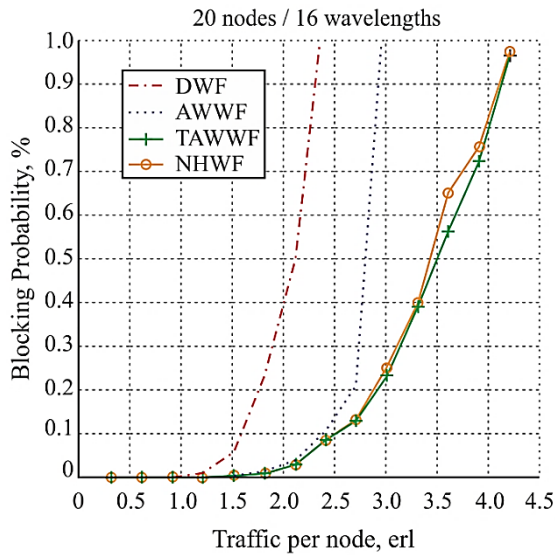


Fig. 3. Dependence of the blocking probability as a function of the traffic per node at $\gamma = 0.5$ and 16 wavelengths/channels.

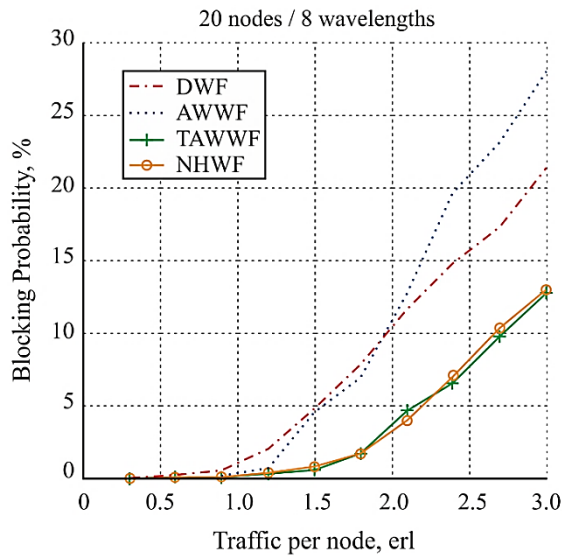


Fig. 4. Dependence of the blocking probability as a function of the traffic per node at $\gamma = 1.0$ and 8 wavelengths/channels.

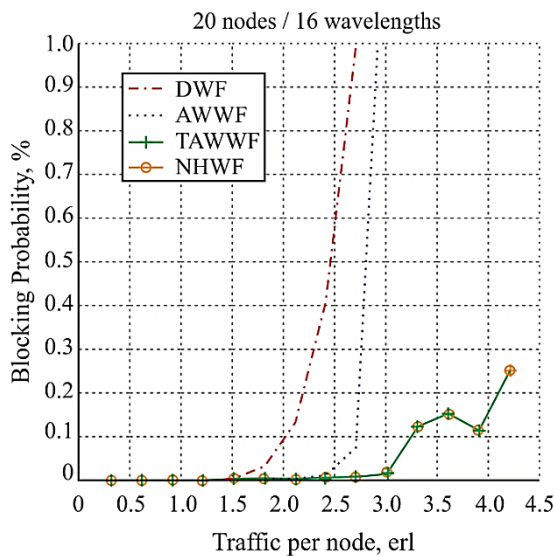


Fig. 5. Dependence of the blocking probability as a function of the traffic per node at $\gamma = 1.0$ and 16 wavelengths/channels.

The reason is that this weighting function attempts to select the connections which are least utilized and have the largest number of available wavelengths.

The probability of blocking is slightly lower for full wavelength conversion (Figures 4 and 5) compared to partial conversion at $\gamma = 0.5$ (Figures 2 and 3). It is noticed that the probability of blocking increases sharply after a certain threshold value of the traffic load, which is exactly as expected. The total probability of blocking decreases at a large total number of wavelengths.

5. Conclusion

A major problem with multi-channel communication networks with spectral multiplexing lies in the efficiency of the methods, algorithms, and protocols on the basis of which the access of network nodes to the transmission medium is managed as well as the processing of session requests and the routing of transmitted data packets.

A model for determining the blocking probability in multichannel optical networks is defined. Determining the shortest path is performed using algorithms with different weight functions that take advantage of the characteristics of the multi-channel network in different ways, i.e. different routing options are modeled on the network.

The weight functions in the model take into account the total number of wavelengths as well as the given number of wavelengths available at a time for s different links through a given path.

Various weight functions and obtained results are considered in terms of probability of blocking, line utilization, and average delay. The analysis shows that the weight functions based on the smallest number of hops and in combination with the available wavelengths and the total number of wavelengths produces the best results in terms of probability of blocking.

Acknowledgements

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References

- [1] Sivalingam K. & Subramanian S. (2000). *Optical WDM Networks: Principles and Practice*. Boston, MA: Kluwer Academic Publishers
- [2] Miliotis K., Papadimitriou G. & Pomportsis A. (2003). Design alternatives for wavelength routing networks. *Optics & Laser Technology*, vol. 35, no.2, pp. 137-154, [https://doi.org/10.1016/S0030-3992\(02\)00165-2](https://doi.org/10.1016/S0030-3992(02)00165-2).
- [3] Li C., Wai P. & Victor L. (2013). On Wavelength-Routed Networks With Reversible Wavelength Channels. *Journal of Lightwave Technology*, vol. 31, no. 9, pp. 1409-1417, doi: 10.1109/JLT.2013.2250481.
- [4] Karasan E. & Ayanoglu E. (1998). Effects of wavelength routing and selection algorithms on wavelength conversion gain in WDM networks. *IEEE/ACM Transactions on Networking*, vol. 6, no. 2, pp. 186-196, doi: 10.1109/90.664267.
- [5] Chen, Y., Bari, A. & Jaekel, A. (2012). Optimal regenerator assignment and resource allocation strategies for

- translucent optical networks. *Photon Netw Commun* 23, pp. 16–24. <https://doi.org/10.1007/s11107-011-0331-1>.
- [6] Yabin Y., Chai T., Cheng T. & Lu C., (2006). Dynamic routing and wavelength assignment algorithms in wavelength division multiplexed translucent optical networks”. *Computer Communications*. vol. 29, issue 15, pp. 2975–2984. <https://doi.org/10.1016/j.comcom.2006.04.013>
- [7] Koganti R. & Sidhu D., (2014). Analysis of Routing and Wavelength Assignment in Large WDM Networks, *Procedia Computer Science*, vol. 34, pp. 71-78, <https://doi.org/10.1016/j.procs.2014.07.047>.
- [8] Sakai T., Hanawa D., Noguchi K., Sakamoto T. & Oguchi K. (2010). Software simulator prototype for wavelength routing network design. *33rd International Conference on Telecommunications and Signal Processing - TSP 2010*, pp. 363-366.
- [9] Birman A. (1996). Computing Approximate Blocking Probabilities for a Class of All-Optical Network. *IEEE Journal on Selected Areas in Communications*, vol. 14, no. 5, pp. 852-857, doi: 10.1109/49.510908.
- [10] Angelov K. & Sadinov S. (2019). Investigation of the Reliability of Service Equipment in Communication Networks”, *27th National Conference with International Participation (TELECOM)*, pp. 58-61, doi: 10.1109/TELECOM48729.2019.8994894.
- [11] Angelov K., Sadinov S. & Kogias P., (2019). Modelling and optimization of multichannel optical communication lines, *International Scientific Conference UNITECH 2019*, pp. I-322-326.
- [12] Sharma R. & Raghuwanshi S. (2018). Computer Model for EDFA Dynamics Over 1525–1560 nm Band Using a Novel Multi-Wavelength MATLAB Simulink Test Bed for 8-Channels”. *IETE Journal of Research*, 64:6, pp. 814-831, DOI: 10.1080/03772063.2017.1369908, pp. 814-831, 2018.
- [13] Sadinov S. (2017). Simulation Modeling and Research of 8-channel WDM System. *International Scientific Conference - UNITECH 2017*, pp. II-108-113.
- [14] Chatterjee B., Sarma N. & Sahu P. (2013). Review and Performance Analysis on Routing and Wavelength Assignment Approaches for Optical Networks. *IETE Technical Review*. vol. 30. pp. 59-70. 10.4103/0256-4602.107335.
- [15] Iliev M., Balabanova I., Kostadinova S. & Georgiev G. (2019). Statistical Processing and Quality of Service for Incoming Traffic in Markov Chains. *29th Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEIE)*, pp. 1-7, doi: 10.1109/EAEIE46886.2019.9000418.
- [16] Ivanova E., Iliev T., Mihaylov G., Kiseev V. & Stoyanov I. (2019). Significant Simulation Parameters for RESTART/LRE Method in Teletraffic Systems of Ultra Broadband Convergence Networks. In: Silhavy R., Silhavy P., Prokopova Z. (eds) *Intelligent Systems in Cybernetics and Automation Control Theory. CoMeSySo 2018. Advances in Intelligent Systems and Computing*, vol 860. Springer, Cham. https://doi.org/10.1007/978-3-030-00184-1_7.
- [17] Sadinov S., Balabanova I. & Georgiev G. (2018) “Statistical models for predicting of teletraffic parameters of Markov chains”, *International Journal 'Information Models and Analyses'*, *ITHEA 2018*, Vol. 7, no.1, pp. 77-88.

Assessment of the Gross Potential of Local Waste Based on Geoinformation Systems for Bioenergy Production

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Abstract: This article analyzes the gross potential of local hydrocarbon waste and biomass using the example of the Republic of Uzbekistan with the aim of producing bioenergy. To calculate the raw material potential, we used official and reference data on the production and consumption of fuel, fertilizers and the formation of organic waste, the accumulation of municipal solid waste (MSW), the amount of saline land where halophytic plantations can be created, which can be considered as biomass. Based on the collected data, mathematical operations and calculations of the potential of biogas technology were performed. A block diagram has been developed that describes the steps of a Geo Information Systems (GIS) map. GIS maps have been created that give a visual representation of the spatial distribution of the gross potential of various types of waste in the regions of the republic and can serve as a tool in planning the distribution of biogas technology.

Keywords: GIS, biogas, solid household waste.

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1. Introduction

There are a number of environmental problems in the Republic of Uzbekistan, such as salinization and soil degradation, air pollution, the accumulation of household waste, food pollution, significant greenhouse gas emissions, etc. To prevent these problems, the Government approved the Concept "On Environmental Protection of the Republic of Uzbekistan for the period until 2030" [1].

On the basis of the concept, approved a roadmap for the implementation of a number of works to improve the environmental situation in the Republic. In environmental pollution, the main problem is accumulated waste. Available types of waste can be divided into the following groups: industrial and municipal waste, human physiological waste, crop by-products, livestock waste. In general, municipal wastes, livestock and plant wastes, solid household waste (solid household waste) can, at least in part, be considered renewable fuels [1].

Obtaining biofuels from various wastes is a very urgent task all over the world. Processing waste into bioenergy, solve problems with environmental pollution and lack of natural energy. The concentration of poultry and livestock, as is known, is associated with the problem of the disposal of farm waste. Modern biotechnology provides for any transformation of the substrate into a feed product and vice versa [2]. After analyzing the

composition of the processed organic fertilizer by the Sanitary and Epidemiological Stations of the Ministry of Health of the Republic of Uzbekistan, the following were determined: organic nitrogen 89.7 mg / l, potassium 586.561 mg / l, calcium 303.0385 mg / l and phosphorus 60.436 mg / l [3]. By this content, processed manure after a biogas plant is suitable for fish feed composition.

2. Materials and methods

In order to assess the potential of raw materials for waste treatment using biogas technologies and the production of energy and biofertilizers, an analysis of the raw material potential is carried out on the example of the Republic of Uzbekistan as a whole. To calculate the raw materials, official and reference information on the production and consumption of fuel, fertilizers and the formation of organic waste were used. From tables 1.2, you can revise the types of resources. Uzbekistan has a high potential for converting various wastes into bioenergy.

In addition to the accumulation of different types of waste, which contribute to air pollution and the release of greenhouse gases, it also poses great risks from the effects of salinization of soil and fresh water, which are widespread and significant. As an increasing number of agricultural land and ecosystems are affected, more attention is being paid to this issue, especially in academia. Salt stress is one of the most important contributing factors to crop loss worldwide. While salinization of the soil reduces crop productivity, intensive agricultural practices can themselves become a source of increasing soil salinity.



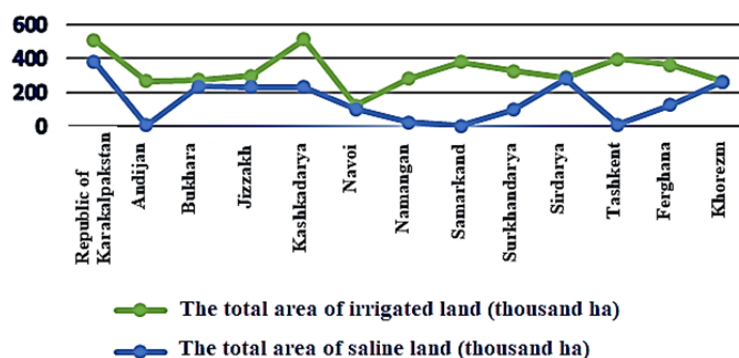
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Table 1. Gross biomass potential from local waste. [4], [5].

Name of region	MSW landfills, ha	landfills for industrial waste, ha	Number of inhabitants, thousand people
Republic of Karakalpakstan	175.7	68.2	1889.8
Andijan region	47.0	7.0	3110.71
Bukhara region	120.3	28.6	1915.9
Jizzakh region	112.7	75.0	1374.4
Kashkadarya region	156.9	124.4	3261.2
Navoi region	76.8	5223.6	992.4
Namangan region	76.2	56.6	2795.6
Samarkand region	92.9	335.6	3857.0
Surkhandarya region	203.4	55.0	2612.3
Sirdarya region	49.5	10.1	841.8
Tashkent region	183.3	3451.8	5484.6
Ferghana region	138.5	25.1	3733.0
Khorezm region	60.2	16.5	1856.4

Table 2. Livestock and poultry by region, on October 1, 2019 [4].

Name of region	The number of cattle, (thousand heads)	The number of cows, (thousand heads)	Sheep and goats, (thousand heads)	Birds, (thousand heads)
Republic of Karakalpakstan	1088.9	318.6	1112.8	4317.8
Andijan region	1048.5	360.1	1430.9	7331.5
Bukhara region	1208.3	397.7	2133.9	4696.1
Jizzakh region	873.6	256.8	2129.0	3474.5
Kashkadarya region	1555.2	512.1	4575.6	6107.0
Navoi region	469.1	201.1	2194.3	2761.9
Namangan region	694.8	226.3	760.1	4911.6
Samarkand region	1583.5	683.0	2486.2	12196.1
Surkhandarya region	906.2	330.4	2280.5	4942.4
Sirdarya region	437.6	154.9	318.4	1823.1
Tashkent region	825.0	388.2	955.9	15229.9
Ferghana region	998.2	360.1	850.3	8280.9
Khorezm region	856.6	334.6	418.1	5724.6

Information on saline lands on a scale of the Republic of Uzbekistan**Fig. 1.** Example for short figure.

Changing practices to reduce the risk or rate of salinization can improve results, but managing saline farmland after it is created is difficult and often leads to land abandonment [6].

According to the diagram shown in Figure 1. Based on the data presented [7], it can be seen that saline lands account for about 50% of irrigated land. By creating artificial plantations on a sufficiently large area, it is possible to combine with other useful halophytic plants or crops to get a sufficiently large crop of raw materials for biogas production and nevertheless to achieve a decrease in soil salinity.

For several years, in collaboration with the National University of Uzbekistan and Kitakiushu University (Japan), experiments were conducted to assess the potential of halophytic plants as a renewable source of alternative energy. It has been shown that the halomite biomass (vaults, salicornia, Caspian Karelia, climaxoptera, atriplex, annual solyanka, etc.) growing on saline lands where it is impossible to grow ordinary crops can be used for biogas production [8]. From 1 ton of dry matter, up to 300-400 m³ of biogas can be obtained [9].

Researchers [10] studied the anaerobic assimilation of halophytic biomass in experiments with a periodic test in a continuous mode: 130–366 ml of biogas was obtained from 1 g of DM of various halophytes at 35 °C; and 269–480 ml - at 55 °C.

In addition, 12-13 million m³ of solid waste accumulates in Uzbekistan annually, of which 6.3 million m³ comes from the population. The total number of

landfills in the Republic is more than 186 landfills and occupy more than 780 ha of land [11].

As a result of the studies [12,13], it was found that the total yield of pyrolysis products in the temperature range 350-600 C⁰ weakly depends on temperature. Therefore, fuel consumption for own needs to maintain the temperature regime is up to 25-30% of standard fuel. Thus, the mass yield of pyrolysis products during slow heating of plant biomass (sawdust) in the range of temperatures studied was: coal - 45.7%, liquid products - 21.7%, biogas - 32.6%.

According to statistics, in 2017, 114.7 million tons of production and consumption wastes were generated in the republic, including toxic waste not recyclable - 41.6 million tons (36.2%) and toxic waste recyclable, - 42.8 million tons (37.3%). At the same time, the volume of non-toxic waste that could not be recycled amounted to 21.1 million tons (18.3%), non-toxic waste to be processed - 9.2 million tons (8%) [1].

Thus, according to the diagram in Figure 2 provided from [11], it can be said that the landfills of the republic have significant potential for landfill methane.

3. Results and discussion

This article is devoted to the study of the development of GIS maps of the gross potential of local waste to ensure the convenience of bioenergy. The map developed by GIS technologies is the best way to attract investors in the development of waste treatment and bioenergy production.

Table 3. Biogas yield from various halophytic biomass [10].

№	Name halophyte	Green crop, t / ha	The output of dry biomass, t / ha	Biogas output, m ³
1	Salsola sclerantha	18.95	4.3	1290÷1720
2	Climacoptera lanata	23.10	5.75	1725÷2300
3	Suaeda paradoxa	25.45	5.33	1599÷2132
4	Kochia scoparia	44.10	11.3	3390÷4520
5	Glycyrrhiza glabra	13.84	5.55	1665÷2220
6	Nitrogen atriplex	42.05	10.55	3165÷4220

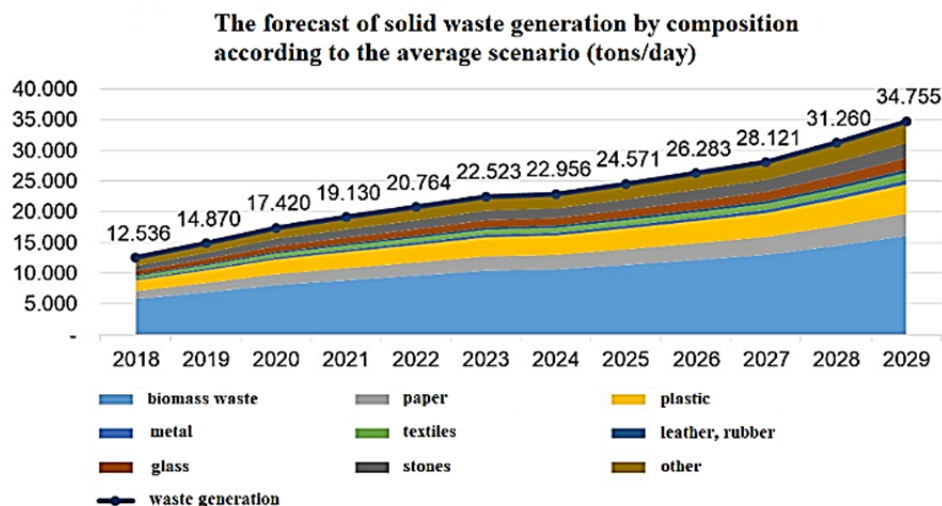


Fig. 2. The forecast of the formation of solid waste by composition according to the average scenario (tons/day).

To develop a GIS map software package for assessing the gross potential of various types of waste for bioenergy production, the following:

- studied the statistical data for the republic;
- - performed mathematical operations and calculations of the potential of biogas technology;
- developed a block diagram describing the stages of a GIS map;
- performed geoprocessing data;
- installed limitations;
- received usable card.

For this purpose, information was collected on the number of livestock for cattle breeding and poultry farming by region [4], the amount of saline land where halophytic plants for biogas production can be grown [7], and the amount of solid waste accumulated in which landfill gas is generated [5].

GIS project is carried out on the basis of the algorithm according to the block diagram presented in Figure 3. The flowchart describes all the stages of the development of GIS maps.

At the next stage of the GIS maps of biomass potential related to various types of waste were superimposed on the main maps. After that, it was necessary to introduce several restrictions.

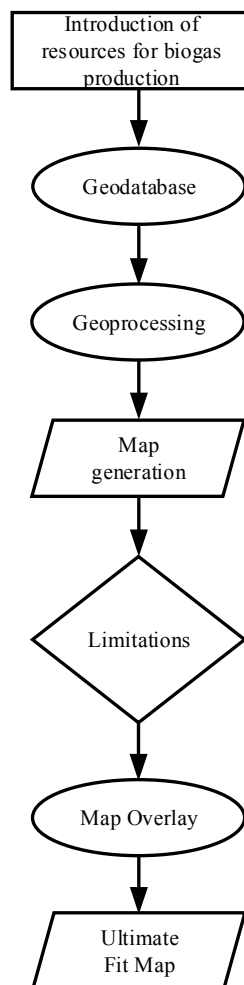


Fig. 3. A flowchart describing the stages of development of a GIS map.

For the specific application of restrictions, it can be taken into account that on a regional scale in the landscape and natural areas of the network, the installation of biogas plants is allowed only if the environmental impact assessment confirms that the territory can withstand the construction of the station.

The gross potentials of different types of waste of each region marked on the map for introducing bioenergy production in many cases reflect the required information much more clearly than dozens of pages of reports with tables. Based on the data in Tables 1 and 2, a GIS project database was created. Based on the map data, the final usable maps are generated and created, which are shown in Figures 4, 5, 6, 7, 8 and 9.

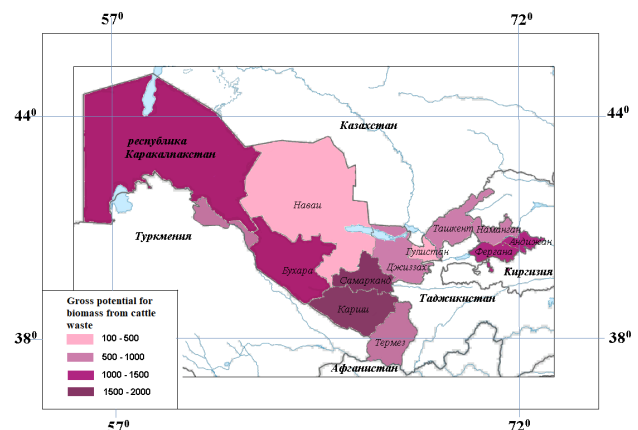


Fig. 4. Gross potential for biomass from cattle waste.

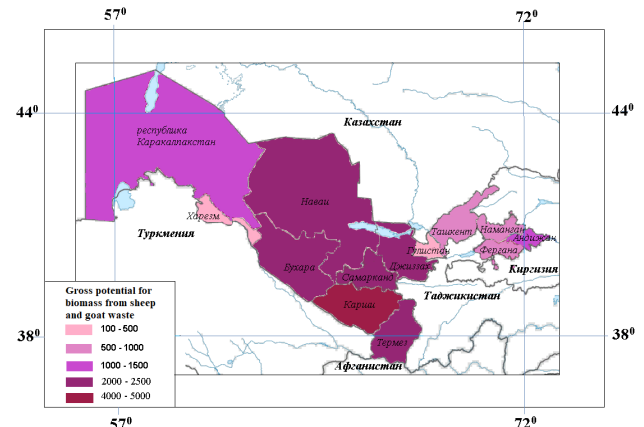


Fig. 5. Gross potential for biomass from waste sheep and goats.

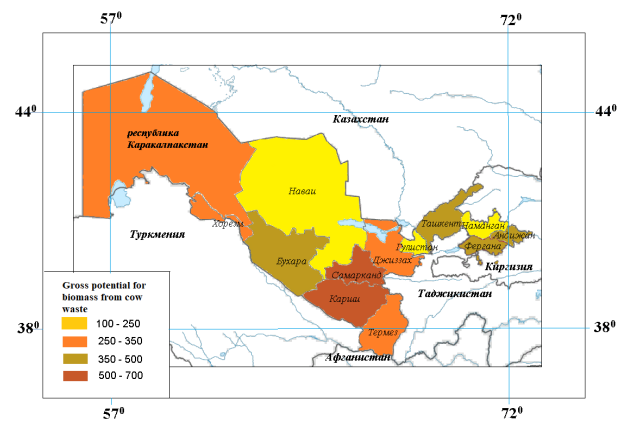
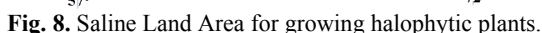
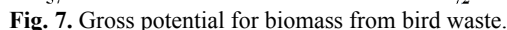


Fig. 6. Gross potential for biomass from cow waste.



Although the Republic of Uzbekistan is rich in natural resources, the time has come to take care of environmental pollution. If waste disposal is not carried out at a high level with state support, the accumulation of solid waste every year, the area of saline land will increase from year to year.

4. Tashkent and Samarkand region have a high potential for the production of bioenergy from bird biomass, since the number of birds exceeds that in other areas.

[7] Ministry of Agriculture of the Republic of Uzbekistan. Available at: <http://agro.uz/uz/information/statistics/>

- [8] Toderich, K., Popova, V., Khujanazarov, T., Shoaib, I., Hasan, B., Mukimov, T., Zhapayev, R., & Shaumarov, M. (2016). Tests and best practices of bio-farming on saline soils in Central Asia and South Caucasus. <https://hdl.handle.net/20.500.11766/11331>.
- [9] Zavyalova, L. & Salihov, P. (2012). *Road map on development of biogas technology market in Uzbekistan*, UNDP, Tashkent. <https://mineconomy.uz/biogaz3.pdf>.
- [10] Akinshina, N., Azizov, A., Karasyova, T. & Klose E. (2016) On the issue of halophytes as energy plants in saline environment, *Biomass and Bioenergy*, vol91, 306–311, <https://doi.org/10.1016/j.biombioe.2016.05.034>
- [11] Appendix to the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan (2017). *On measures to expand the production and implementation of biogas plants in the republic in the period 2017 - 2019*. (June, 2017, No. 338)
- [12] Uzakov, G. N., Davlonov, H. A. & Holikov, K. N. (2018). Study of the Influence of the Source Biomass Moisture Content on Pyrolysis Parameters. *Appl. Sol. Energy*, vol. 54, 481–484. <https://doi.org/10.3103/S0003701X18060178>.
- [13] Uzakov, G. N., Davlanov, H.A. & Rabinov, R. (2017). Research of thermal processing of biomass for production of alternative fuel, *Geliotekhnika*, vol. 3, 34–38 (in uzbek).

Starting Processes in Electric Drive of a Passenger Elevator

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Abstract: During the operation of electric induction motors used to drive passenger elevators, electro-mechanical transient processes occur, which can cause unacceptable dynamic loads and vibrations. In this regard, research is needed both at the design stage and for operating elevator systems to determine the arising impact currents and torques, in order to propose solutions for their limitation within pre-set limits. Paper deals with starting processes in a two-speed induction motor drive of a passenger elevator. The equations for the voltages of the induction motor are presented in relative units in a coordinate system rotating at a synchronous speed. The values have been obtained for the torques, the rotational frequencies and the currents when starting at a high speed and passing from high to low speed.

Keywords: induction motor, machine model, electric drive, transient analysis, elevator.

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1. Introduction

Elevators are stationary lifting systems with periodic action, intended for lifting or lowering people or loads in a cab or platform moving between two or more permanent stops in a specially built shaft on fixed metal rails used to guide the travel of an elevator car in an elevator shaft. These are steel profiles with smooth guide surfaces, the cross section of the profile is usually T-shaped (machine drawn, cold drawn or rolled) [1].

There is no uniform classification of elevators. Different types can be distinguished depending on the type of drive, load, speed, design, etc. The electric elevator is a classic version of a lifting mechanism with tow ropes and a motor. Electric elevators are a tried and tested technical solution for more than 100 years. They are suitable for all types of buildings with heavy traffic. Passenger elevators are the most common type of elevator systems, constantly encountered in our daily lives. The rated speed of electric elevators is usually 1.0 or 1.6 m/s. The drive is carried out by means of a lifting mechanism of gear type with two-speed electric motor or with frequency regulation. In this design, the motor power is transmitted to a friction washer through a gearbox (hence the name - gear drive). Reduction-driven machines use worm gears to control the movement of the elevator by 'rolling' steel tow ropes located above a friction drive pulley that is attached to a gearbox. In addition to electric drive in elevators, it is also found hydraulically, as it is suitable for elevators with a travel of up to 12000 mm and for freight elevators with a capacity of several tons.

For the safety of passengers, a system is usually

provided for moving the elevator down to the nearest stop and opening the automatic doors when the power supply is stopped. Variants of earthquake-resistant elevators with electric drive are also available.

All modern elevators are equipped with the so-called speed limiters that stop the cab when the speed is exceeded at 15%. The probability that the ropes or suspension elements will break and the elevator will 'fall' is reduced to zero. The safety of elevators is regulated by state regulatory documents and controlled by relevant authorities. Elevators are supervised facilities with increased danger of operation and are under the supervision of inspections for state and technical supervision. The maintenance, repair and reconstruction of elevators is carried out by persons (companies) who have received permission to carry out such activity from the state agency for metrology and technical supervision or from authorized officials. The specialist elevator maintenance company must provide 24-hour continuous emergency service.

Elevators are complex technical objects. Today there are many manufacturers of electric motors for them, control units and complete technical solutions - some of them are world-famous elevator companies. It is a fact of elevator traffic that every three years, elevator cabs transport the equivalent of the entire population of planet. As part of the *NowWeMOVE* campaign, April 24 has been declared *Elevator-Free Day* as a global initiative. It can take place anywhere - in offices, shopping malls, public buildings, parking lots, universities and other public or private buildings. The purpose of this event is to draw attention to physical activity for health and to show that in order to move, we do not need to spend time and money.

The main indicators of elevators are: load capacity, speed, productivity and braking accuracy. Other specific definitions related to elevators are: machine room - a



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room where the lifting group (motor and gearbox) and some components of the electrification and control system are located. It is usually located above the elevator shaft; ultimate floor - the top or bottom stop, served by an elevator cab [1].

Motor technologies developed rapidly from the time when in 1889 a directly connected electric elevator appeared, suitable for servicing tall buildings [2]. Later, with the development of technology, multi-speed motors replaced single-speed motors and allowed greater efficiency and conditions for movement. Electromagnetic technologies are replacing manual control and braking. The button control and various complex signaling systems contribute to the further modernization of the elevators. Various security systems are also being introduced, as elevators are the so-called high risk facilities.

Today, sophisticated regulators and switching circuits exist and are used, ensuring precise speed control at all times. Literally all public elevators are automated and have the ability to precisely control and adjust through processor devices with maximum efficiency and security [3]. The development of technology leads to rapid progress in the development of elevator equipment. This contributes not only to increase the comfort and safety of people, but also to reduce the space required for elevator facilities and give aesthetic appearance and durability to the architecture of buildings. The classic shape of the elevators has an electric cable drive with an upper machine room. Recently, electric elevators with machine room with gearless mechanisms with synchronous motors are preferred. [4].

There is a huge interest in the purchase and installation of elevators in recent years. Most orders come from hotels, new housing, shopping malls and business buildings. Prices range widely, depending on three main factors - domestic or imported production, size and load capacity, luxury interior design, degree of automation. According to the standards of the European Union, for example, the elevators must have automatic doors and have access to the relevant symbols for the disabled.

2. Technical considerations

The electrical equipment includes motors and devices for selecting the direction of movement, starting and stopping, reducing the speed before stopping, precise stopping, opening and closing the doors, stop during a call, locks and protections, lighting, alarms, etc. Electric motors for elevators are manufactured in special series in order to meet the increased requirements for them, namely: to have a high starting torque; to provide transient processes for the shortest possible time; to be able to adjust the speed, etc. The two-speed induction electric motors with constant torque for both speeds are used in cranes, elevators, metalworking machines, etc. When switching the winding to a larger number of pole pairs (lower synchronous speed), the motor rotates in the direction of the rotating field, due to which the electric machine works as a generator and gives energy to the mains. The low energy consumption meets the latest energy efficiency requirements, and the choice of an optional regenerative drive (braking energy is used)

allows the carbon footprint and elevator operating costs to be further reduced.

In view of the precise braking and the need for low speeds for a more comfortable ride for mass elevators, two-speed induction motors with a squirrel cage rotor are used [5]. The high speed is used for starting and moving with a set speed between the floors, and the low speed - for deceleration and precise stopping. Usually the high speed winding of these motors is dimensioned for cycle duration factor (CDF) 50% and for low: CDF 10%. In some cases, frequency control is used to ensure smoothly dynamic movements - the ideal solution for new and modernization of old elevators [6]. When upgrading, the replacement option with high-efficiency electric motors of a higher energy class should also be considered.

Most electric motors are designed to run at maximum efficiency at full load, but in practice this is rare. Controllers, often called 'voltage regulators', constantly regulate the voltage at the motor terminals so that it corresponds to the instantaneous load. In this way, losses of power and energy are minimized.

Sometimes in practice the question is whether to use a simple induction motor with a frequency regulator or to apply a two-speed electric motor. In many cases, the relatively complex and more expensive frequency inverter can simply be replaced by a two-speed electric motor. This 'trick' applies when the only requirement for the machine is to run at high and low speeds [7]. The electronic component base constantly lowers its price, but with the entry of electronic components to a new higher level with improved technology leads at the same time to the fact that the control device for an electric motor is always more expensive than the price of the object controlled.

Another option is to use an electric motor with forced cooling. This allows to achieve number of switches per hour 240 sw/h for inverter-controlled motors or number of switches per hour 180 sw/h for two-speed motors [8].

The determination of the static and dynamic loads in the elevators has a lot in common with that of the lifting mechanisms in the cranes, but there are features related to the presence of counterweight - a component which provides tension between the towing pulley and the suspension ropes and which consists of a set of weights. The counterweight reduces the amount of force (and hence the required torque and power of the electric drive motor) required to drive the cab, is positioned in the elevator shaft and moves on a separate rail system. The weight of the counterweight is usually equal to the weight of the cab plus 40-50% of the elevator's load capacity. This equalizes the loads during lifting and lowering. The efficiency of elevators has lower values than those of crane lifting mechanisms because it includes additional friction losses in the guide metal rails. When raising an empty cab, in fact, the counterweight will lift the empty cab, and the motor will operate in generator (braking) mode.

The analysis of the mathematical expressions of the static loads in the presence of counterweight shows that the large loads during lifting and lowering of nominal load decrease in comparison with those without counterweight, and the small loads during lifting and

lowering of empty cab increase. Obviously, the value of the weight of the counterweight is important for choosing the power and will depend on the mode of operation of the elevator. If the elevator is constantly being raised and lowered fully loaded, a value must be selected, when lifting at full load and lowering an empty cab - another value and in another operating mode a corresponding value.

The highest values of the total resistance forces and corresponding torques arise in two cases - lifting a nominally loaded cab, standing at the lowest stop and lowering an empty cab from the top stop. The required moment of inertia is determined depending on the minimum time for starting (or stopping) the elevator with passengers in the cab for the two heaviest modes for acceleration during the operation of the elevator - raising one passenger and lowering a full cab.

When choosing an elevator, the drive mechanism must also be taken into account. When determining the power of the electric motors driving elevator systems, it is necessary to know: the kinematic scheme, the load capacity, the weight of the cab and the counterweight, the speeds of movement, the admissible accelerations and decelerations, the number on the floors, the distance between the floors, the operating duty of the elevators and other parameters. The operating duty is determined by the purpose of the elevator and the conditions under which it operates. The lifting elevators, included in current technological lines, have a uniform load schedule with cyclically arriving loads. In the case of passenger elevators, the working conditions largely depend on the purpose of the building in which the elevator operates. In all buildings the peak load is in the morning and in the evening (before and after the end of working hours). In residential buildings and hotels the largest flow of passengers is in the morning directed downwards, and in the evening - upwards, and in administrative buildings it is the opposite - in the morning upwards and in the evening downwards. In case of intensive passenger traffic, it is recommended to build several elevators operating with common control (duplex, triplex). [9].

The power of the electric motors is calculated for peak operating modes, and only in some specific cases a calculation for normal daily operating mode is required.

The calculation of the required power of the electric motor is reduced to pre-selection of the electric motor according to the simplified load diagram, drawing of the exact load diagram taking into account the transient modes and checking the selected electric motor by the methods of equivalent current or torque for cycle of operations that the motor is correctly selected and will not heat up unacceptably at high and low speeds. In addition to this, it is necessary to check for short-term overload at the torque - the multiplicity of the maximum load torque and the permissible multiplicity for overload at the torque of the selected electric motor are compared. When checking the accelerations during starting of the elevator has been done, and with already selected electric motor and brake, the satisfaction of the permissible values can be ensured by changing the flywheel of the system.

Elevator solutions with various applications are currently available in Bulgaria. Some of them are made in

Bulgaria, others are developments of foreign companies, which are also available on our market. The focus of the various product offerings is energy efficiency, safety and optimality of the elevator solution - important factors for choosing products and technologies for implementation in new buildings and for replacement of obsolete facilities with the development of modernization solutions. In essence, modernization can be partial or complete. The partial modernization consists in the replacement of individual components of the elevator in order to improve some of its characteristics.

The choice of control mode for frequency drives strongly depends on the application. The three main control modes are scalar (volt / frequency V / Hz), vector or with field orientation control. For drives using V / Hz control, an operating flow is directly involved in the formation of the operating shaft of the motor shaft. There are regenerative inverters on the market that return the regenerative energy back to the power supply network, without the need for braking resistors, with an electric meter for regenerative and motor mode of operation to record the efficiency of the regenerative system. Vector frequency drives have precise torque control over a wide speed range without having to use speed feedback. Frequency drives with field orientation control use a feedback encoder to obtain information on motor speed and possible travel faults. The choice depends entirely on the tasks to be performed and the type of equipment. It often takes a lot of time and effort to install an encoder on older machines, and in some cases this is not even possible. In this case, the best and easiest solution is to operate the machine without feedback.

When controlling hoists, the frequency regulators show clear advantages, but the use of a combination of a frequency converter and a regenerative module can save up to 70% in individual cases compared to elevators with standard two-speed electrical or hydraulic technology. If a large load needs to be slowed down quickly, a dynamic braking resistor or regenerative module must be used to return the regenerative current back to the mains. Also, the smooth start provides comfort in the elevators.

3. Factors and decisions influencing final energy consumption

About a third of energy consumption in European countries is accounted for by residential buildings. Due to the increased needs and requirements of users, energy consumption in buildings has recently increased significantly. For this reason, it has become one of the main reasons for the increase in carbon emissions and the continuous efforts of the countries to improve energy efficiency and the use of renewable energy sources [10]. For this reason, it has become one of the main reasons for the increase in carbon emissions. Therefore, the untapped potential for energy savings exists in terms of energy efficient equipment, investment decisions and behavioral solutions in these sectors. This fully applies to elevators [11].

Research shows that around 4.8 million elevator facilities are in operation within the European Union. The number of elevators operating in Bulgaria is over 70,000, and about 60,000 of them are obsolete, over 20 years old.

Understandably, along with the important issue of their safety, the issue of their energy consumption is also relevant. Other studies show that elevators account for about 3 to 5% of final electricity consumption in a building. Their annual consumption is determined by three main factors: the volume of energy consumed at rest; the necessary energy in the process of work; frequency of use of the facility. Energy consumption while a facility is in operation and during the idle period is determined mainly by the technical characteristics of the system components and their energy efficiency. This means that these factors are determined at the level of design and actual construction of elevators, as well as in the stages of its installation, which, once set, as a rule should not undergo significant changes during the operation of the system. Alterations can occur in the process of aging and wear (which contribute to increased friction, for example). The consumption values in the two operating modes of the facility are largely independent of each other. Low energy consumption during the transport of passengers and cargo does not always mean low consumption at idle, and vice versa.

What determines the frequency of travel, along with the location, is the purpose for which the elevator is used (providing an accessible environment, opportunities to transport goods, etc.), as well as the nature of the groups using the facility. Elevators in residential buildings are in most cases not as frequently operated as those in public buildings such as hospitals. It is these differences in frequency of use that can mean a wide range of energy consumption on an annual basis, even in the case of facilities of similar design.

According to estimates based on international research, the results of measurements of consumption at idle present data in a very wide range. Experiments show that in the residential and commercial sectors, there are very different values of consumption. This dispersion can be explained by the different energy efficiency of the components used and by the choice of specific equipment. With regard to energy consumption in the process of moving passengers and goods, monitoring of absolute values shows that there is no basis for any definitive comparison of the different elevators. Here the comparisons would be based on the technologies used by the manufacturer.

Although all elevators consist of similar elements, there are varieties into which they are divided, depending on different structural elements. The most common division is according to their drive. The direct comparison between the two main types of elevators by this criterion - hydraulic and electric, certainly gives an advantage to the second technology. Hydraulic elevators, however, are suitable for servicing buildings with no more than 6 or 7 floors. In this case, they are the most profitable solution. As the height of the building increases, electric elevators are indicated as more suitable.

4. Potential for energy saving and their implementation

Based on numerous research, scientists conclude that if efforts are made to exploit the potential of elevators through the consistent use of the best available

technologies (including high-performance devices and components, such that allow the inclusion of standby mode when the facility is not in operation) about 60% of the energy consumed for the operation of elevator facilities in European countries could currently be saved [11].

An important issue concerning the use of energy efficient solutions in elevator technologies is the fact that their choice is in most cases part of the obligations of construction companies, which after completion of construction, rent or sell the building, along with the implemented solutions. Here comes the question of the lack of motivation of the builder to implement highly efficient technology, costing more, instead of focusing on a more cost-effective financial solution, which in the future will generate higher costs for its users.

Two of the trends in the development of energy efficiency of elevators encourages innovation in the development of drive systems. Increasingly, consumers are demanding systems that take up less space and therefore stop choosing equipment without a machine room. In this case, the advantages are in terms of drive modes. There is also a positive trend in the development of the systems themselves towards innovative solutions and new design. Such compact solutions are already available on the market, as well as the replacement of steel ropes with other options that are more durable and also reduce the need for additional lubrication.

Some manufacturers offer state-of-the-art software control systems. The basic elements of such a system are considered to be the possibilities for fixing certain rules, such as the exclusion of certain elevator facilities at night and on weekends. In order to reduce costs, it is possible to add additional features as well as increase operational flexibility. For example, in some systems, the cabs are set to be positioned at a certain point in time, such as all elevators returning to the ground floor in the early morning hours to accommodate the increased volume of passengers. This reduces the waiting time. Some manufacturers offer passenger flow control solutions that allow the optimization of the used equipment by floors and the reduction of the energy used.

5. Characteristics of electric drives for elevators

Elevator controls are available in the power range from 2.2 to 32 kW and are a reliable choice for many of the newly built elevator systems and in the modernization of older elevators. Some of their more important features are the following, and the purpose of all functions is to meet the needs of the market [12]:

- Four quadrant intelligent elevator control system (adjustable parameters of the elevator - times for acceleration / reduction of speed, set of speeds, etc.) and rapid response to process changes due to dynamic vector control; regenerative solutions as option, and hence reduced energy costs, as the regenerative power supply returns excess braking energy back to the grid; highly efficient vector control algorithm - controls the orientation of the field (FOC); optionally sensorless motor control for operation without feedback;

- Flexible digital torque control - preset torque (torque limit - parameters setting allow separate limits in four quadrants); smooth release and application of the brake, without the need for additional measurement of the weight of the load;
- Inertia monitoring (inertia compensation) – speed optimization; overshoot and anti-vibration control;
- Integrated safety functions - initial phase check, motor protection (temperature monitoring via electronic thermal overload relay), overvoltage/under voltage protection;
- Drive control in the event of an trouble; smoothly reduction of speed in case of power loss; increased tolerance in the permissible variation of the supply voltage: $\pm 15\%$;
- Full range of protection functions: precise current measurement, multi-level overload protection, current overload, short circuit; built-in EMI-filter; Built-in data black box function, record the elevator running state data before fault to help analysis fault cause;
- Control algorithms: the purpose of these algorithms is to optimize the movement of the cab and provide reduced depreciation of mechanical parts, reduce electricity consumption and reduce passenger service time.

In connection with the use of electronic devices for elevator control it is necessary to pay attention to the so-called indicators for the quality of electricity. In other words, whether these devices do not influence in any way the parameters of the electrical network from which they are powered. In this regard study of the impact of various parameters of the physical environment on the design and

operational indices of energy efficiency has been carried out in [13]. The results obtained make it possible to identify specific measures to improve the indices and bring them into regulatory norms.

6. Determination of the mechanical characteristics of the electric motor

The electromechanical transient processes in a two-speed passenger elevator powered by an AC200M-24/6 electric motor are studied. The static mechanical characteristics obtained are presented in Fig. 1. The mechanical characteristics of the motor are calculated for high and low speed, using the expression:

$$M = \frac{M_m (2 + 2s_m)}{\frac{s}{s_m} + \frac{s_m}{s} + 2s_m}, \quad (1)$$

where M_m , s_m are maximum torque and slip values, and M , s – going values.

7. Model of two-speed induction motor electric drive

The study of electromechanical transient processes in an induction motor is performed under generally accepted assumptions [14]. The voltage equations for the windings of an induction motor are presented in relative units in a coordinate system that rotates at the synchronous angular speed of the stator fields. Expressing the full magnetic flows by means of the corresponding currents and presenting the obtained expressions in view of the convenience of solving them in the form of *Cauchy* we get

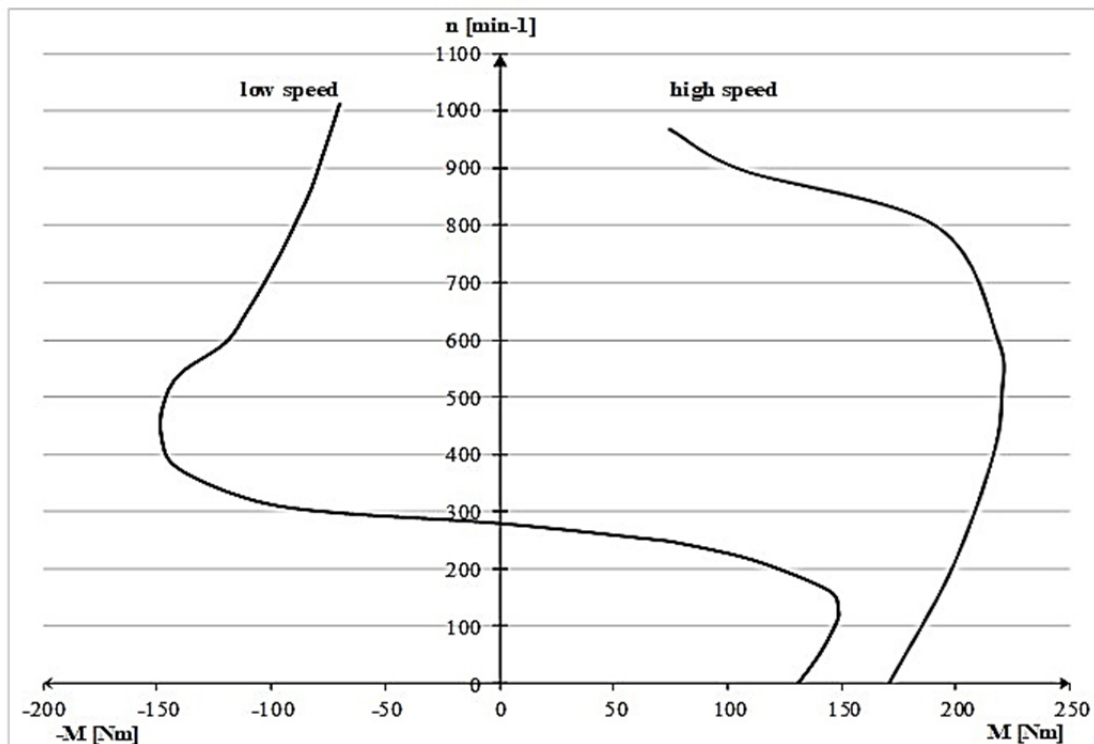


Fig. 1. Static mechanical characteristics for high and low speed.

$$\begin{aligned}
\frac{di_{sx}^*}{d\tau} &= \frac{1}{L_{eq}^*} \left[u_{sx}^* L_r^* - u_{rx}^* L_m^* - r_1^* L_r^* i_{sx}^* + r_2^* L_m^* i_{rx}^* + i_{sy}^* \left(L_s^* L_r^* - s L_m^{*2} \right) + L_r^* L_m^* (1-s) i_{ry}^* \right]; \\
\frac{di_{sy}^*}{d\tau} &= \frac{1}{L_{eq}^*} \left[u_{sy}^* L_r^* - u_{ry}^* L_m^* - r_1^* L_r^* i_{sy}^* + r_2^* L_m^* i_{ry}^* + i_{sx}^* \left(s L_m^{*2} - L_s^* L_r^* \right) + L_r^* L_m^* (1-s) i_{rx}^* \right]; \\
\frac{di_{rx}^*}{d\tau} &= \frac{1}{L_{eq}^*} \left[-u_{sx}^* L_m^* + u_{rx}^* L_s^* + r_1^* L_m^* i_{sx}^* - r_2^* L_s^* i_{rx}^* + i_{sy}^* \left(s L_s^* L_r^* - L_m^{*2} \right) + L_s^* L_m^* (1-s) i_{sy}^* \right]; \\
\frac{di_{ry}^*}{d\tau} &= \frac{1}{L_{eq}^*} \left[-u_{sy}^* L_m^* + u_{ry}^* L_s^* + r_1^* L_m^* i_{sy}^* - r_2^* L_s^* i_{ry}^* - i_{rx}^* \left(s L_s^* L_r^* - L_m^{*2} \right) + L_s^* L_m^* (1-s) i_{sx}^* \right]
\end{aligned} \tag{2}$$

where $i_{sx}^*, i_{sy}^*, i_{rx}^*, i_{ry}^*$ - model stator and rotor currents (p.u.) respectively;

u_{sx}^*, u_{sy}^* - model stator voltages; since the motor is a induction type with squirrel-cage rotor the model rotor voltages $u_{rx}^* = 0$ and $u_{ry}^* = 0$;

$L_s^*, L_r^*, L_m^*, L_{eq}^*$ - stator, rotor, mutual and equivalent inductance (p.u.) respectively;

$\tau = \omega_b t$ - time in relative units.

The electromagnetic moment is obtained:

$$M^* = \frac{M}{M_N} = \frac{3}{2} \cdot \frac{p u_b i_b}{\omega_b M_N} (i_{sy}^* i_{rx}^* - i_{sx}^* i_{ry}^*), \tag{3}$$

where u_b, i_b, ω_b, M_b - basic values of voltage, current and angular speed, respectively.

p - pole pair number;

M_N - rated torque.

The mechanical equipment of the two-speed elevator is presented with a single-mass dynamic model. The equation of motion will be:

$$M^* - M_L^* = \frac{J_\Sigma \cdot \omega_b^2 ds}{p \cdot M_N d\tau}, \tag{4}$$

where M_L^* - torque of the load (p.u.);

J_Σ - total moment of inertia of the electric drive (that of the electric motor and that of the mechanical part of the elevator).

After conversion is obtained:

$$\frac{ds}{d\tau} = - \frac{p \cdot M_N (M^* - M_L^*)}{J_\Sigma \cdot \omega_b^2} = - \frac{p}{J_\Sigma \cdot \omega_b^2} (M - M_L), \tag{5}$$

where u_A^*, u_B^* and u_C^* are phase voltages (p.u.).

The following dependences are used to calculate the phase stator currents:

$$\begin{aligned}
i_A^* &= i_{sx}^* \cos \tau - i_{sy}^* \sin \tau; \\
i_B^* &= i_{sx}^* \cos \left(\tau - \frac{2\pi}{3} \right) - i_{sy}^* \sin \left(\tau - \frac{2\pi}{3} \right); \\
i_C^* &= i_{sx}^* \cos \left(\tau + \frac{2\pi}{3} \right) - i_{sy}^* \sin \left(\tau + \frac{2\pi}{3} \right).
\end{aligned} \tag{6}$$

8. Results obtained

In the studied electromechanical transients, the electric induction motor operates in motor and generator mode, as the slip varies widely. Therefore, the slip-dependent parameters of the equivalent circuits of its windings will also change. If you work with variable parameters, the analysis would be complicated many times. From the comparisons of the results for transient processes obtained by calculation and experimentally in [14] it is found that the best match is achieved when the parameters of the machine are chosen for slip, corresponding to the initial speed of the transient process. Therefore, for modeling the starting processes, it is appropriate to use parameters corresponding to the slip value $s=1$. The studies use the parameters of the equivalent circuits of the electric motor, which are determined by a calculation method for slip $s=1$. In the studies, when the operation of the electric motor changes from one speed to another, the model changes, replacing the parameters of the electric motor and the initial slip for the respective rotational frequency. When studying the transient processes when lowering a full cab, the sign before the load torque ML changes.

It is known from practice that the reduced total moment of inertia J_Σ of the elevator is several times

greater than the moment of inertia J of the electric motor – in research we accept $J_\Sigma = FI \cdot J$ as the coefficient of inertia FI is chosen equal to 2.5.

To solve the differential equations system consisting of (2), (3), (5) and (6) the software MathCad® of Parametric Technology Corporation (PTC®) has been used and specifically laid down therein functional method Rkadapt - method for solving differential equations with adaptive size of approximating step [15]. As a result of the research, the dependences of the rotational speed n^* ,

the torque M^* and currents i_A^*, i_B^*, i_C^* have been obtained for high-speed start-up and switching from high-speed to low-speed when raising and lowering a full cab. Some of the obtained results are given below - Figures: 2 ÷ 13.

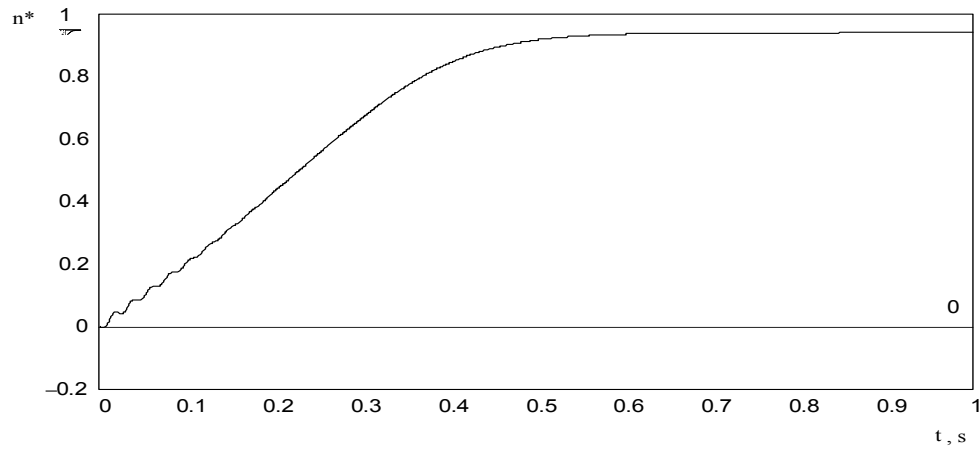


Fig. 2. Variations of the rotational frequency in case of starting at high speed when raising a full cab.

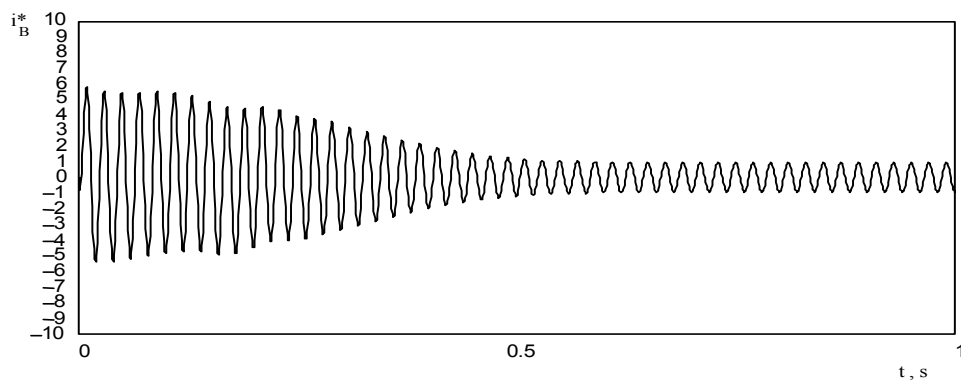


Fig. 3. Variations of the phase stator current in case of starting at high speed when raising a full cab.

Fig. 4. Variations of the rotational frequency in case of starting at high speed when lowering a full cab.

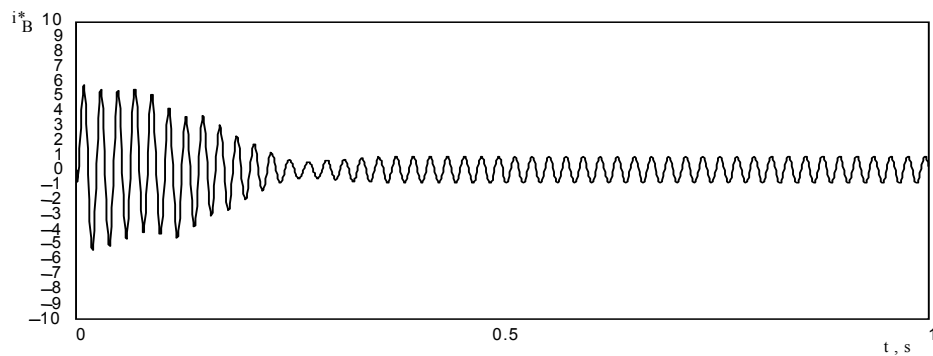


Fig. 5. Variations of the phase stator current in case of starting at high speed when lowering a full cab.

Fig. 6. Variations of the rotational frequency in case of transition from high to low speed when raising a full cab.

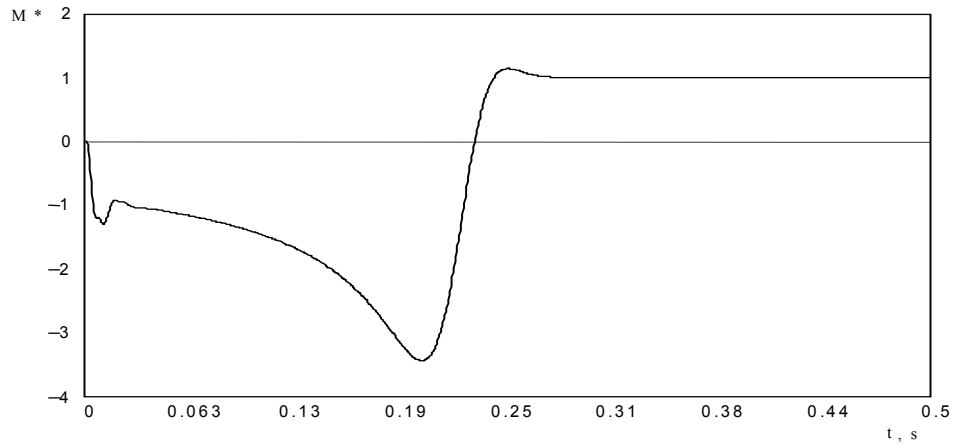


Fig. 7. Variations of the motor torque in case of transition from high to low speed when raising a full cab.

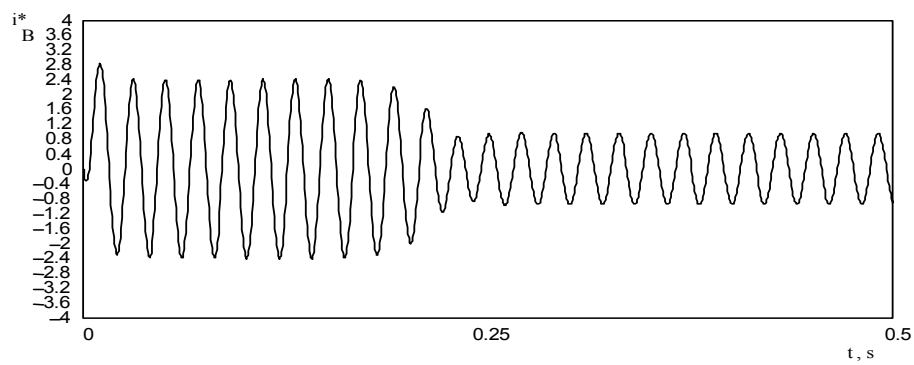


Fig. 8. Variations of the phase stator current in case of transition from high to low speed when raising a full cab.

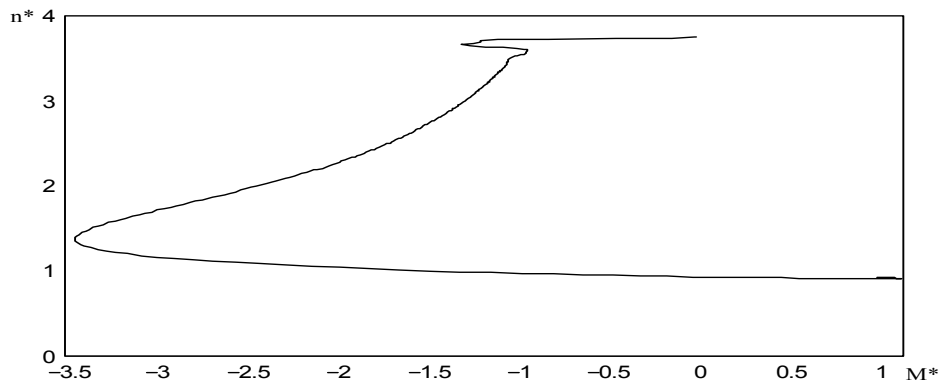


Fig. 9. Mechanical characteristic in case of transition from high to low speed when raising a full cab.

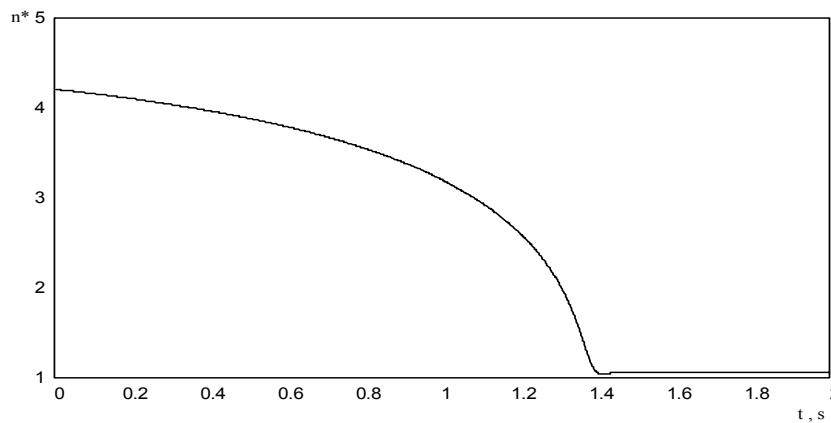


Fig. 10. Variations of the rotational frequency in case of transition from high to low speed when lowering a full cab.

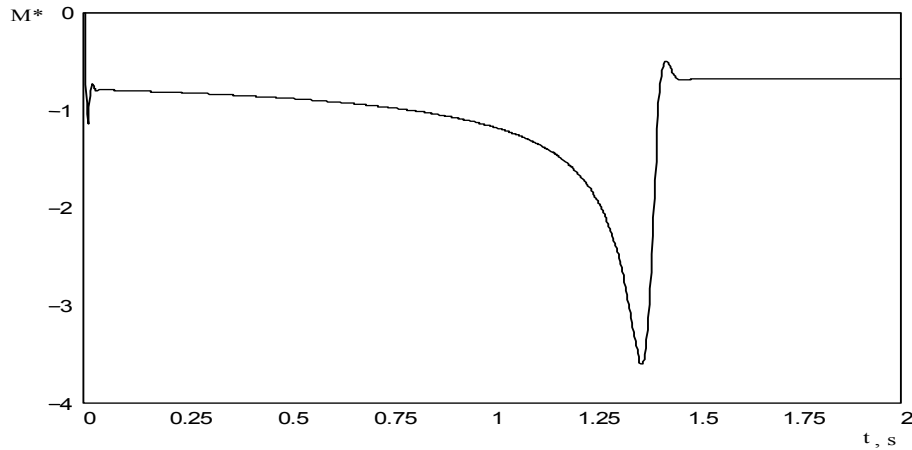


Fig. 11. Variations of the motor torque in case of transition from high to low speed when lowering a full cab.

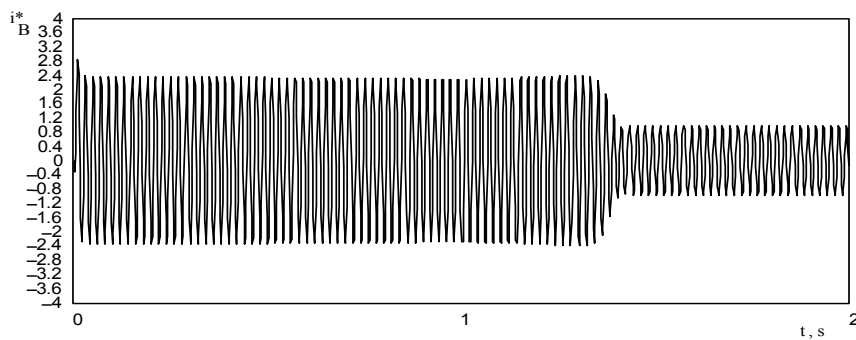


Fig. 12. Variations of the phase stator current in case of transition from high to low speed when lowering a full cab.

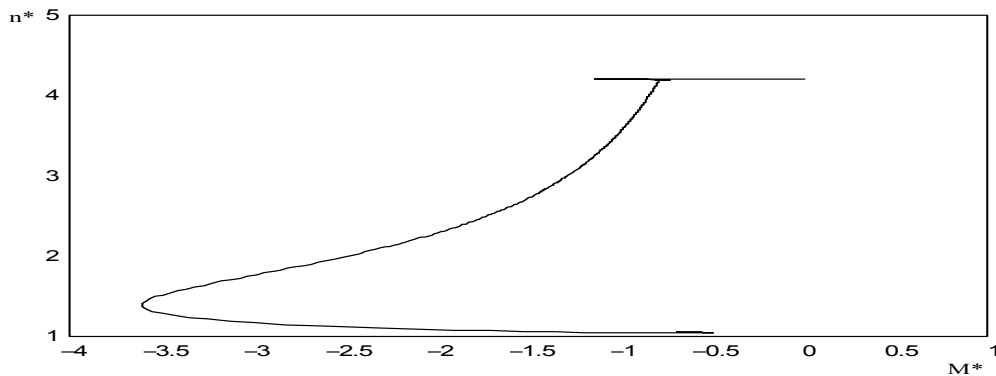


Fig. 13. Mechanical characteristic in case of transition from high to low speed when lowering a full cab.

An important indicator that has a decisive influence on the transient dynamic processes of electric drive is the electromechanical time constant:

$$T_M = \frac{J \Sigma \omega_1}{M_N} s_N \quad (7)$$

In engineering practice, this is considered to be the time required for the electric motor to rotate at angular speed $0.633\omega_1$. Often its predefining is used to coordinate settings and protections.

For the considered motor type AC200M-24/6 the electromagnetic time constant is determined on the basis of its technical parameters and for the most loaded case of operation of the elevator:

$$T_M = \frac{0.29275 \times 1000}{73.84} \cdot 0.03 = 0.119 \text{ seconds.}$$

9. Conclusion

With the help of the developed model the ongoing transient processes in the electric motors and the kinematic mechanical schemes of elevators can be studied. A solution could be sought to the opposite task - the development of an electric drive with parameters that ensure the flow of transient processes under pre-set requirements by the user. The reliability and operability of the proposed model has been tested experimentally in previous studies of the authors for induction motors with different rated power and the match between the computational and experimental results is very good, within 5% discrepancy.

Appendix

Technical data for electric motor AC200M-24/6:

Low speed: $P_{N_1}=1.9$ kW; $U_{N_1}=400$ V; $I_{N_1}=24.00$ A; $n_{N_1}=240 \text{ min}^{-1}$; $I_{START_1}=30.00$ A; $r_1=1.812 \Omega$.

High speed: $P_{N_2}=7.5$ kW; $U_{N_2}=400$ V; $I_{N_2}=17.00$ A; $n_{N_2}=970 \text{ min}^{-1}$; $I_{START_1}=67.00$ A; $r_1=0.617 \Omega$.

$$J=0.1171 \text{ kgm}^2.$$

References

- [1] <https://www.kone.bg>
- [2] <https://eleva.biz>
- [3] <http://delta-electronics.bg>
- [4] <http://www.techpro.bg>
- [5] <https://www.elpromptroyan.com>
- [6] https://comunicatorbg.com/denik_lift.html
- [7] <https://www.eldvigateli.com>
- [8] <https://www.mvtech.bg>
- [9] <http://www.lift-m.eu>
- [10] Stoyanov, I., Ivanov, V., Iliev, T. & Ivanov, H. (2019). Yield and Performance Study of a 1 MWp Grid Connected Photovoltaic System in Bulgaria, *Journal of Engineering Science and Technology Review - Special Issue on Conference in TIEM 2019*, 205-209. <http://www.jestr.org/downloads/SpecialIssue2020/fulltext43SE.pdf>
- [11] <https://www.tech-dom.com/>
- [12] <http://www.tagacom.com>
- [13] Ivanova G., I. Donev & I. Kostova. (2020). Study of the Influence of the Physical Environment on the Design and Operational Indices of Energy Efficiency EEDI and EEOI, *XIIth SCIENTIFIC CONFERENCE Bulef 2020*, 9-12 September 2020, Varna, Bulgaria, IEEE *Xplore*[®].
- [14] Rachev S. (2004). Transient Processes and Dynamic Loads in Induction Machines for Lifting Mechanisms, PhD dissertation, *Department of Electrical Engineering, Technical University - Gabrovo*, Gabrovo, Bulgaria, 2004. (in Bulgarian)
- [15] www.ptc.com

