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Currents' Physical Components and Renewable Energy Sources. Observations and Questions

Składowe Fizyczne Prądu oraz odnawialne źródła energii elektrycznej. Obserwacje i pytania

Abstract: *The development of power theory and numerous observations and questions related to renewable energy sources and the reasons behind climate warming are described in the article. It shows the contrast between results that can be obtained by empirical methods and results where these methods cannot be applied due to human opinions and decisions. It is demonstrated that, despite general opinion, where climate warming is traced to carbon dioxide emission, some climatologists think, on the basis of their own research, that these changes are caused by variations in Sun activity, while the increase in carbon dioxide content in the atmosphere results from the increase of Earth's temperature, and it is not the reason behind this increase.*

Streszczenie: *Esej ten przedstawia stan rozwoju teorii mocy oraz liczne obserwacje i pytania dotyczące odnawialnych źródeł energii i przyczyn ocieplania klimatu. Ukazuje on kontrast między wynikami, które można osiągnąć metodami nauk empirycznych, a wynikami, w których, ze względu na ludzkie opinie i decyzje, metody takie nie mają zastosowania. Esej ten pokazuje, że pomimo powszechnej opinii, która ocieplanie klimatu wiąże z emisją dwutlenku węgla, pewni klimatolodzy, na podstawie swoich badań, uważają, że zmiany te powodowane są zmianami aktywności Słońca, wzrost zawartości dwutlenku węgla w atmosferze jest zaś skutkiem wzrostu temperatury Ziemi, a nie przyczyną.*

Keywords: *CPC, renewable energy*

Słowa kluczowe: *teorie mocy, energia odnawialna*

1. INTRODUCTION

The current article consists of two seemingly disjointed parts. The first one is related to power theory and compensation, the other to renewable energy sources. There is, however, a common factor: They are both related to the cost of electrical energy consumed by humans. The juxtaposition of the two illustrates the contrast between results that may be obtained by empirical methods (such as in the case of power theory) and results of research, where these methods cannot be used (such as in the case of investigation of renewable energy sources). Different factors influencing the development of RES, for instance, the impact on the natural environment or human decisions/opinions, are not measurable and cannot be described quantitatively – therefore, the application of empirical methods is very limited. In this part the author will present multiple observations and questions without answers.

The first part of the paper is devoted to power theory based upon Currents' Physical Components (CPC). This is a crowning achievement of electrical engineering research conducted for more than a century; results of resolving of the most controversial problems of electric circuit theory are presented.

The second part of the article is devoted to renewable energy sources (RES), energy transformation issues, and motivation for the proposed change traced to global Earth warming.

The transformation of energy, which consists of the replacement of fossil fuel power plants with renewable energy sources such as wind or solar power, is unfortunately clearly reflected in our electricity bills. Wind or solar energy does not cost anything, so the social expectation is that these bills should go down – and this does not happen. The development of renewable energy sources is funded by the public budget, whereas the consumers avail themselves of tax relief, so that the increase of electricity bills may be just a tip of the iceberg as far as real costs of the transformation are concerned. How much does the transformation really costs, what are its reasons and consequences are, seems therefore a reasonable issue. The increase in electricity prices reduces the competitiveness of the industry and may lead to the impoverishment of the economy.

One of the leitmotifs of energy transformation is the battle against global warming; according to the general opinion, this is caused by carbon dioxide emission leading to the greenhouse effect. However, we may find there are climatologists who point out that the change in climate is not due to the greenhouse effect, but to variations in Sun activity, while the increase in carbon dioxide content in the atmosphere results from the increase in Earth's temperature and is not the reason behind this increase.

Part A: Currents' Physical Components

A.1. Introduction.

The soundness of the generally used power equation

$$S^2 = P^2 + Q^2 \tag{1}$$

was challenged by Ch. Steinmetz [1] at the end of the nineteenth century, when he measured the current and voltage RMS values together with the active power P/the reactive power Q in the circuit containing an arc lamp supplied from a variable voltage source. Steinmetz's observations initiated a scientific discussion that has been ongoing for more than a century about how to describe the flow of energy in circuits with non-sinusoidal waveforms and how to improve the power factor under such conditions. Thousands of scientific papers were published on this subject, several different descriptions and interpretations of energy properties of the electrical circuits emerged (so-called schools of Power Theory). The founders of the consecutive schools were as follows:

(1923): M.A., Illovici, Rumunia

(1927): A.I. Budeanu, Rumunia

(1931): S. Fryze, Poland

(1970): W. Shepherd, UK

(1980): N. Kusters, Canada

(1976): M. Depenbrock, Germany

(1983): A. Akagi, Japan

(2010): P. Tenti, Italy

Within the framework of these schools or their combinations, hundreds of scientists and engineers tried to explain and describe the energy flow in electrical circuits with non-sinusoidal current/voltage waveforms and to develop compensation methods. Several of these concepts eventually found their place in standards.

A.2. Currents' Physical Components

The author of the current paper began work on the development of this concept back in 1983, starting with the description of the energy properties of linear single-phase circuits. This work was continued and evolved in the description and physical interpretation of the energy flow in three-phase, four-wire circuits, with non-sinusoidal and asymmetrical voltage, with unbalanced, nonlinear and periodically switched (power electronics) loads.

In this circuit (see Fig.1), with supply voltage

$$\boldsymbol{u}(t) = \begin{bmatrix} u_R(t) \\ u_S(t) \\ u_T(t) \end{bmatrix} = \sum_{n\in N} \boldsymbol{u}_n(t) = \sqrt{2}\,\mathrm{Re}\sum_{n\in N} \begin{bmatrix} \boldsymbol{U}_{Rn} \\ \boldsymbol{U}_{Sn} \\ \boldsymbol{U}_{Tn} \end{bmatrix} e^{jn\omega_1 t} \quad , \tag{2}$$

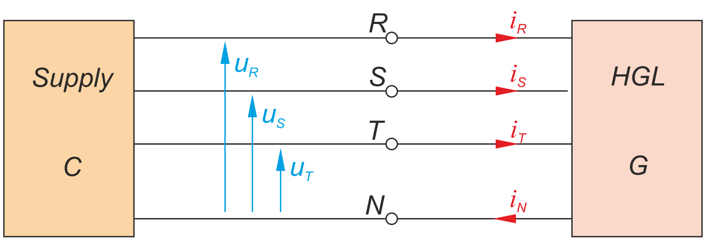

Fig.1. Three-phase, four-wire circuit

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load current

$$\boldsymbol{i}(t) = \begin{bmatrix} i_{\mathrm{R}}(t) \\ i_{\mathrm{S}}(t) \\ i_{\mathrm{T}}(t) \end{bmatrix} = \sum_{n\in N} \boldsymbol{i}_n(t) = \sqrt{2}\,\mathrm{Re}\sum_{n\in N} \begin{bmatrix} \boldsymbol{I}_{\mathrm{R}n} \\ \boldsymbol{I}_{\mathrm{S}n} \\ \boldsymbol{I}_{\mathrm{T}n} \end{bmatrix} e^{jn\omega_1 t} \,, \tag{3}$$

may be decomposed into seven components

$$\boldsymbol{i} = \boldsymbol{i}_{\mathrm{aC}} + \boldsymbol{i}_{\mathrm{sC}} + \boldsymbol{i}_{\mathrm{rC}} + \boldsymbol{i}^{\mathrm{z}}_{\mathrm{uC}} + \boldsymbol{i}^{\mathrm{p}}_{\mathrm{uC}} + \boldsymbol{i}^{\mathrm{n}}_{\mathrm{uC}} + \boldsymbol{i}_{\mathrm{G}} \,, \tag{4}$$

and each component is associated with a single physical phenomenon or circuit property. These components were therefore called Currents' Physical Components. Definitions and interpretations of these components can be found in publications [2] and [4]. All CPC are mutually orthogonal, which means that each of them will increase the three-phase RMS value of the supply current $||\, i \,||$

$$||\boldsymbol{i}|| = \sqrt{||i_{\mathrm{R}}||^2 + ||i_{\mathrm{S}}||^2 + ||i_{\mathrm{T}}||^2} \,, \tag{5}$$

Independently of the others, i.e.

$$||\boldsymbol{i}||^2 = ||\boldsymbol{i}_{\mathrm{aC}}||^2 + ||\boldsymbol{i}_{\mathrm{sC}}||^2 + ||\boldsymbol{i}_{\mathrm{rC}}||^2 + ||\boldsymbol{i}^{\mathrm{z}}_{\mathrm{uC}}||^2 + ||\boldsymbol{i}^{\mathrm{p}}_{\mathrm{uC}}||^2 + ||\boldsymbol{i}^{\mathrm{n}}_{\mathrm{uC}}||^2 + ||\boldsymbol{i}_{\mathrm{G}}||^2 \,. \tag{6}$$

A.3. CPC and compensation.

Among the previously listed Power Theory schools, none provided the grounds for the construction of compensators for loads supplied with non-sinusoidal voltage. The first solution (within the CPC framework) for linear single-phase circuits emerged only in 1983. Nowadays, when CPC-based power theory has fully developed, it provides the basis for:

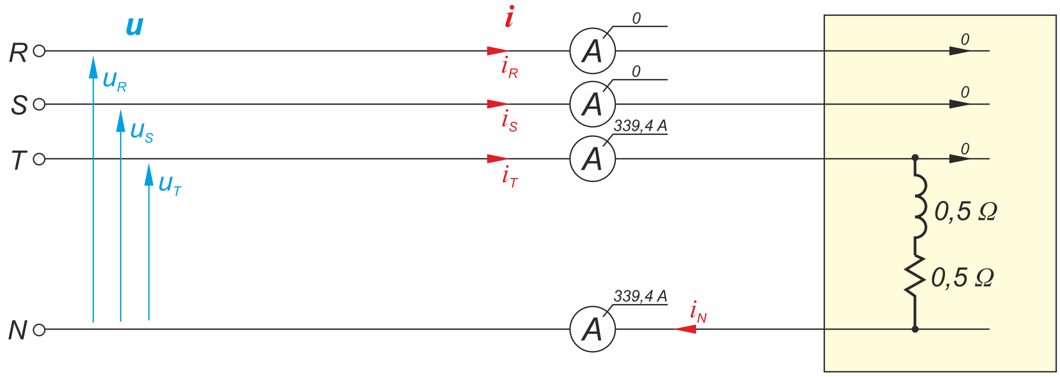
- reactance,
- switched,
- hybrid

compensation in three-phase, four-wire circuits with linear and non-linear loads and periodically variable parameters and arbitrary configuration.

The CPC power theory determines how each component may be reduced by a compensator. It also shows how to identify the compensator structure and calculate its parameters. Details may be found in [3] and [4].

The example below shows an unbalanced linear load, supplied with a symmetrical distorted voltage. The relative values of the voltage harmonics are as follows:

$$U_3 = 2\%U_1, \quad U_5 = 3\%U_1, \quad U_7 = 1{,}5\%U_1$$



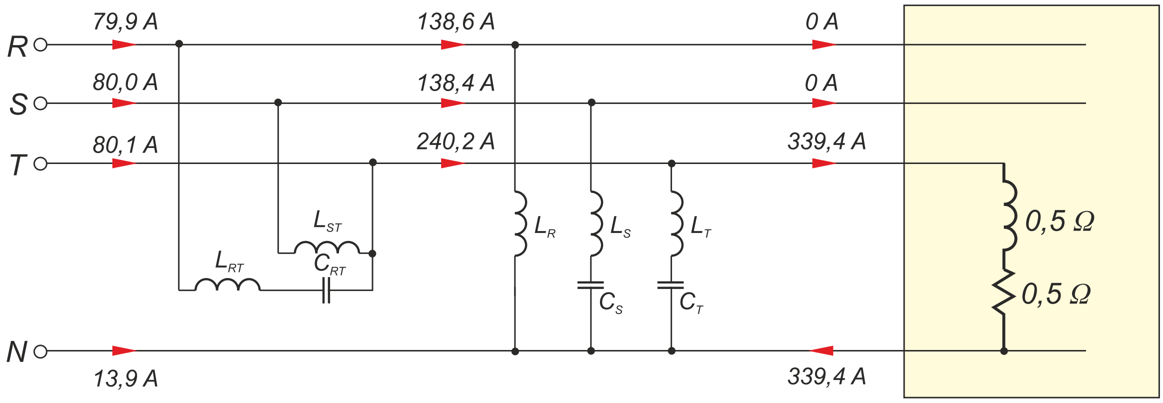
$||\boldsymbol{i}||$ = 339,4 A $||\boldsymbol{i}_a||$ = 138,5 A $||\boldsymbol{i}_s||$ = 4,9 A $||\boldsymbol{i}_r||$ = 138,6 A

$||\boldsymbol{i}_u||$ = 277,1 A $||\boldsymbol{i}^z_u||$ = 196,0 A $||\boldsymbol{i}^p_u||$ = 2,4 A $||\boldsymbol{i}^n_u||$ = 196,0 A

Fig. 2. Circuit with unbalanced load and RMS values of supply CPC

In this load we do not find the generated current i_{G}, since this is a linear load. Therefore, there is no need to use the subscript "C" in the current distribution, because there is no other current supply than the supply source shown as "C" in Fig.1. The power factor for this load is $\lambda = P/S = 0.408$.

The identical load together with the reactance compensator is shown in Fig.3. In general, each harmonic in the supply voltage doubles the number of elements in the compensator. The compensator in Fig.3 has a reduced number of elements so that no branch holds more than two elements. This reduced compensator can only minimize the RMS value of the supply current; it cannot compensate this current fully. The scatter current is not compensable by reactance. This type of compensator symmetrizes the load and improves the power factor up to $\lambda = 0.994$.



$||\boldsymbol{i}|| = 139{,}3\ A$ $\quad ||\boldsymbol{i}_a|| = 138{,}5\ A$ $\quad ||\boldsymbol{i}_s|| = 4{,}9\ A$ $\quad ||\boldsymbol{i}_r|| = 11{,}9\ A$

$||\boldsymbol{i}_u|| = 8{,}0\ A$ $\quad ||\boldsymbol{i}_u^z|| = 3{,}1\ A$ $\quad ||\boldsymbol{i}_u^p|| = 5{,}9\ A$ $\quad ||\boldsymbol{i}_u^n|| = 4{,}4\ A$

Fig. 3. Circuit with reactance compensator and RMS values for CPC of the supply after compensation

Traditionally, compensation was only related to reactive power. Today, modern loads may also be a source of harmonics, asymmetry, power fluctuations, or different disturbances: sporadic ones at low or high frequency. All of these components may be identified with CPC and reduced with switching compensators of different hybrid structures. An example of an unbalanced load, which is connected in parallel with a power electronics load of variable active power, is shown in Fig.4.

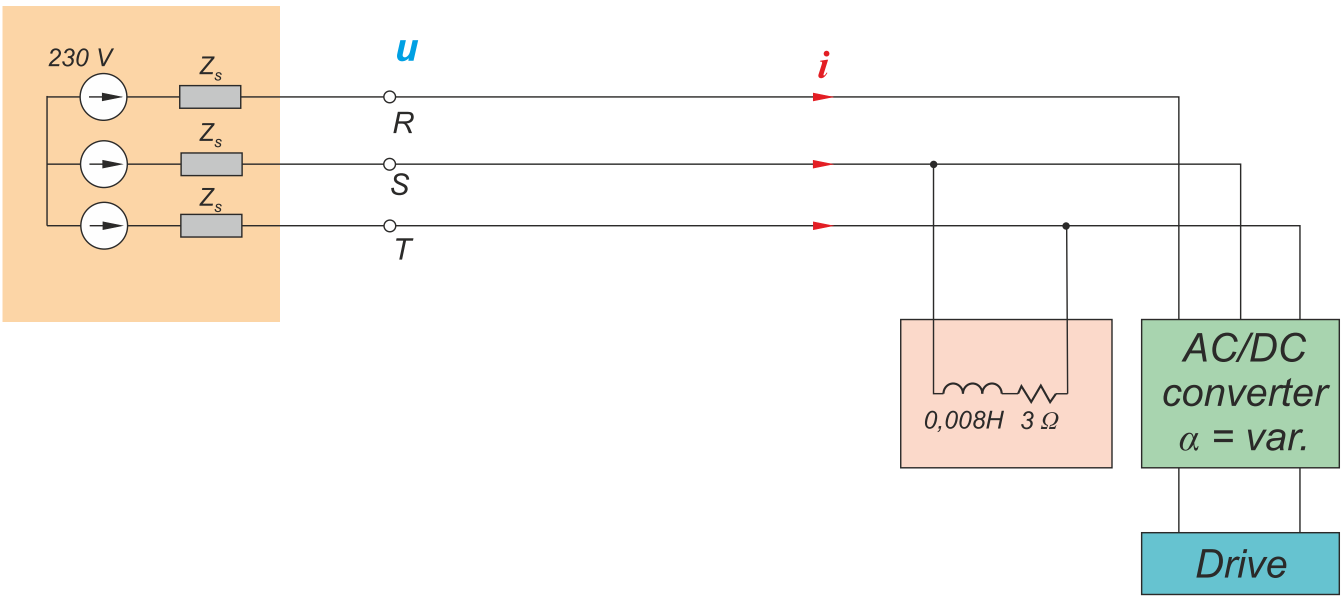


Fig. 4. Circuit with unbalanced load and power electronics load

Voltage, line currents and active power waveforms for this load are shown in Fig.5.

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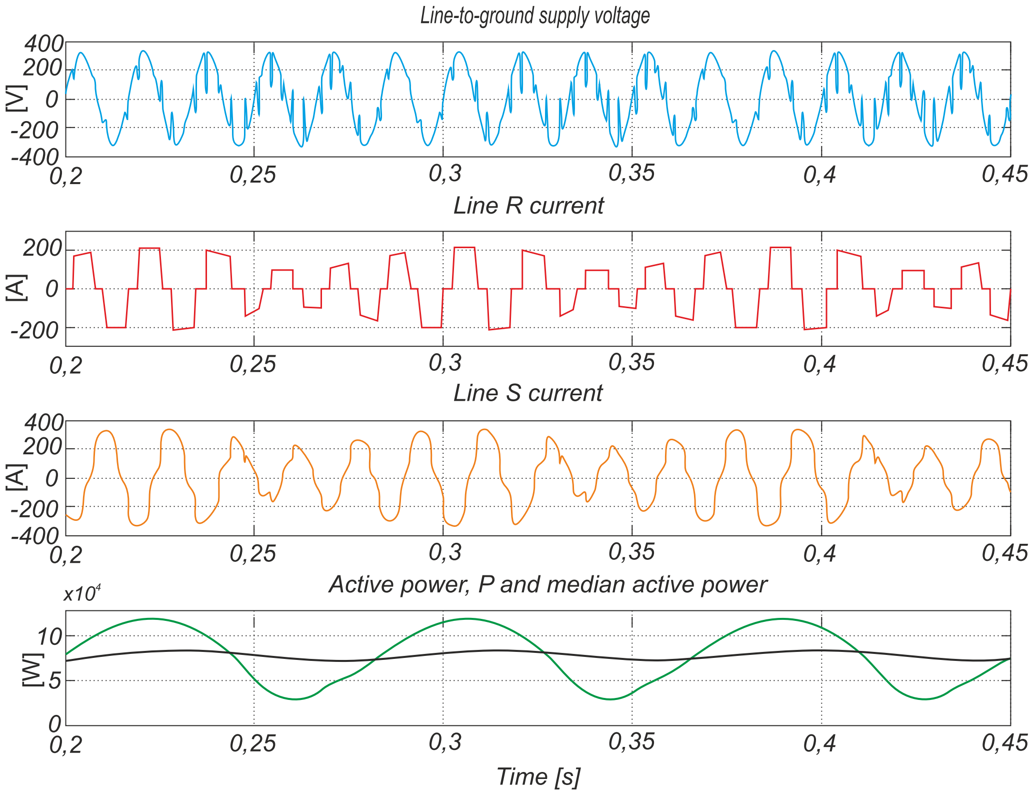

Fig. 5. Voltage u_R, R and S line currents and active power waveforms for load shown in Fig. 4

The compensator for this load must reduce reactive current, unbalance current, and fluctuations in active power. The currents contain slow-varying and fast-varying components. These functions may be fulfilled by a hybrid compensator with a flywheel that acts as energy storage for the compensation of the active power changes of the load. The compensator structure is shown in Fig. 6.

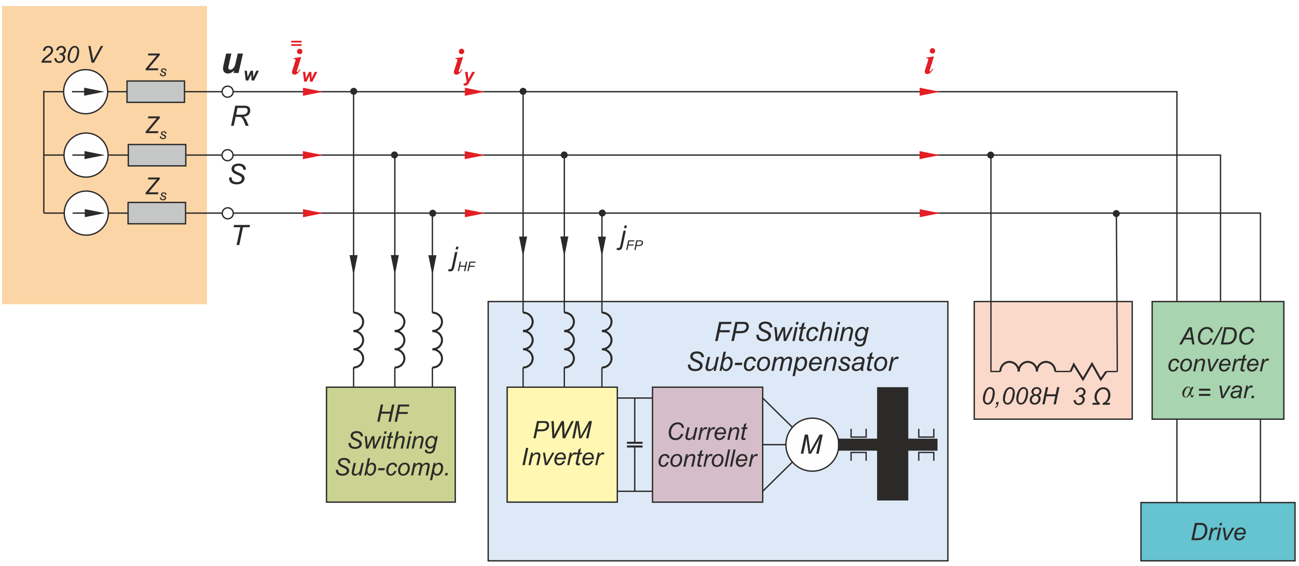

Fig. 6. Circuit with load and switching hybrid compensator

The compensator currents and compensation results are shown in Fig.7. They demonstrate that compensator has eliminated the commutation impulses from the voltage, asymmetry of the supply currents, and reduced the active power variability. This variability after compensation is shown in Fig.7 (the fourth graph counting from bottom to top) as "median active power".

Generally, both examples show the effectiveness of CPC-based power theory in resolving compensation problems even for most complex circuits. At present, CPC is the only Power Theory with such potential.

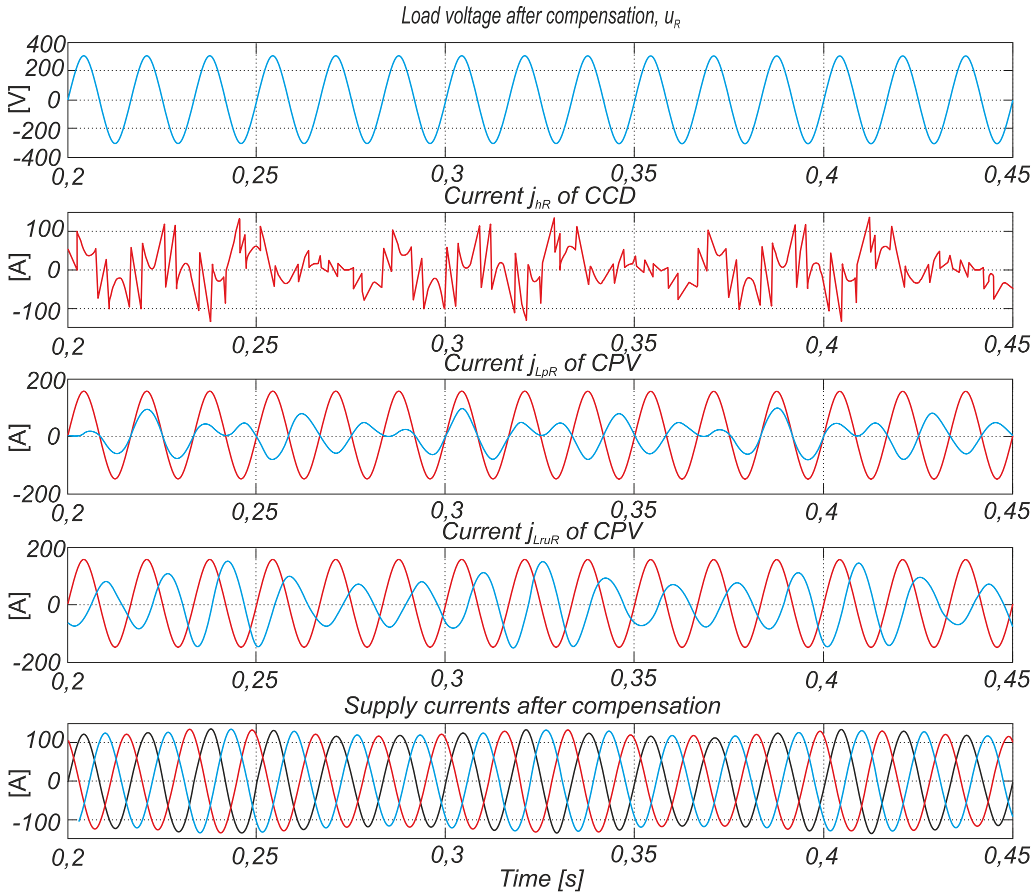

Fig. 7. Waveforms of supply voltage u_R, compensator distortion current CCD (HF), compensator current for active power variability, CP V(FP), reactive and unbalance current, line currents. All waveforms after compensation

A.4. Discussion of the existing Power Theory schools.

The Power Theory schools enumerated above have introduced many erroneous concepts and interpretations into electric circuit theory. These errors have been disseminated by standards, publications and teaching. Moreover, the introduction of another power theory by the author of this article was justified provided that it could be shown that the existing power theories do not fulfil expectations as to the interpretation of effects accompanying energy transfer and creating grounds for compensator construction. That is why the development of CPC had to be interspersed with work discussing the soundness of the existing theories. The main results of these investigations are listed below.

It was shown [5] that there are no circuit phenomena associated with reactive and deformed power defined according to the Budeanu theory. In [6] it was shown that the same applies to the reactive current according to the Fryze definition and that the Fryze theory does not constitute grounds for compensation. Shepherd's theory was analyzed in [7]. The proposed capacitative compensation was shown to not be effective under industrial conditions. The same applies to the Kusters' concept [8]. Depenbrock's Power Theory extends the Fryze theory to three-phase circuits but does not eliminate its existing shortcomings [6]. Interpretation flaws in the Akagi theory of instantaneous reactive power were indicated in [9, 10], while the incorrectness of the compensation algorithm in the presence of deformed or asymmetric voltage was proven in [11, 12]. Tenti's Power Theory is very similar to Budeanu's PT, and while it is formulated in the time domain, it is still burdened by all the faults of its predecessor [13].

Part B: Renewable energy sources: Observations and questions

B.1. Introduction.

The development of renewable energy sources (RES) seems to be in opposition to the optimization approach, as the motivations for this development appear to be vague and rarely expressed in economic terms.

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The cost of 'harvesting' energy from renewable sources consists of multiple components. Among them, we may name the cost of harmful impact on the natural environment, cost of used Earth resources, cost of standard components (such as construction cost, running costs, taxes, and profits or utilization of the worn-out devices). We may also point out the costs (or benefits) of the social nature (social resistance or support) or political nature (e.g. dependence/independence of the state economy on the availability of some raw materials).

Of course, some of these costs cannot be determined in the economic sense. Therefore, the question arises: to what extent is the expansion of RES based on economic foundations? Observing discussions about renewable energy sources, one gets the impression that media opinions and political decisions are the dominating factors settling RES development. In this article, I show several situations justifying this impression. This is also supported by the observation that government grants available to the developers of RES and different financial incentives for the end users disrupt the market mechanisms. In these conditions, economical optimization of different decisions related to the RES development may lose all meaning and lead to an increase in electricity prices.

The government grants provided to the RES construction and financial incentives for the consumers mean that the rise of the electricity bill may be just a tip of the iceberg as far as real costs of the energy transformation are concerned. The query is: How much does the 'harvesting' of free renewable source energy transformation really cost? It seems reasonable to ask this question and may prove useful in the development of RES.

The author of the article does not claim to be an expert on the problems presented in part B (as opposed to the subject matter in part A). Therefore, the above questions cannot be answered. However, as a layman, the author may share some personal observations, based on commonly available data and information (media, scientific publications) and the data received by courtesy from other researchers. At any rate, the composition of part B is not the outcome of the author's own research. Some observations are commented upon; the reader is welcome to draw his/her own conclusions.

B.2. Anti-nuclear crusade.

Not far from my home university (Louisiana State University-LSU), we may find two power plants situated on the Mississippi River: one is oil-driven, the other is a nuclear power plant. Once I took my electrical energy students on a field trip to an oil-driven electric power plant. The Chief Electrical Engineer drew a bar chart on the board (see Fig.8), showing the fuel cost of the oil-driven plant versus the cost of the nuclear-driven plant.

Now, if power plants driven by fossil fuels were not to be eliminated from the electricity market, the nuclear plants had to be forced to equalize their energy prices to the level of market prices by increasing investment and service/maintenance costs. It seems that this was enforced under the pretext (possibly rightly so) of reducing the risk of nuclear hazard in these plants.

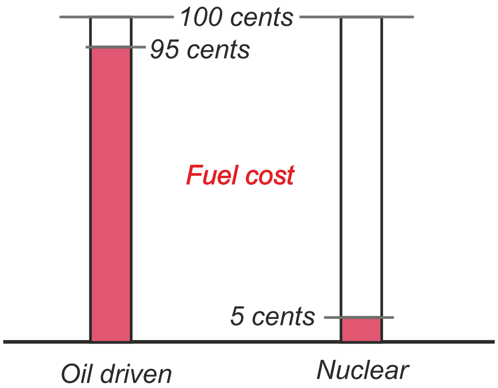

Fig. 8. Fuel cost per $1 of the electricity price; oil- driven versus nuclear- driven power plants

Until the 1970s, more than 90 nuclear power plants were built in the US. Today, they provide c.16% of the energy to the national grid. However, long before the failure of the Three Miles Island power plant in 1979 and disasters in Chernobyl (1986) and Fukushima (2011), the media were flooded with the descriptions of hazards of nuclear power engineering and how difficult (almost impossible) it is to safely store radioactive waste from nuclear plants. Radioactivity was said to be emitted by everything imaginable. This propaganda appeared to be a sort of 'Anti-Nuclear Crusade'.

This crusade proved to be very effective. American society has been so negatively attuned to nuclear power engineering that even before 1975, and in spite of the total absence of mortal casualties in the US, the construction of 130 out of 180 proposed nuclear plants was either not initiated or interrupted (this information is provided by Robert F. Gilkeson [14], President of Edison Electric).). Gilkeson judged this to be a huge strategic error that led to the dependence of the US on imported gas and oil. He said that replacing a 1000 MW power nuclear power plant with an oil-driven plant requires burning 10 million barrels of oil with an approximate market value of 1 billion dollars.

This massive negative propaganda present in the media raises the question: 'Who engineered this Anti-Nuclear Crusade?' Most likely, there is no cut-and-dry answer to this question, since different actors might be present and with different intentions: from the cynics to the deluded. The first answer which springs to mind is the competitors; in other words, that the factor behind this crusade is fossil fuel plant operators. However, this does not seem to be right. The suppression of nuclear power engineering by traditional power plants would mean an increase in the demand for oil and gas, and an increase in the prices of the fuel needed in these plants would follow. Such a price rise would be beneficial to the oil and gas mining industry and countries where the state budget depends on the sale of raw materials. Since it does not seem possible in view of Gilkeson's statement [14] that the American mining industry could want to harm the state economy, the possible agents behind this crusade could be countries that rely heavily on the sale of oil and gas as the main source of state income. -Examples of such countries are Saudi Arabia, Libya, Venezuela, Nigeria, or the Soviet Union.

This crusade required the media of international scope. The countries listed above, with the exception of the Soviet Union, did not possess such media. That is why it seems most possible that the Soviet Union, with its enormous oil and gas resources, constituting virtually its sole source of income in international trade, could be a probable agent behind this anti-nuclear crusade.

The leakage of radioactively contaminated cooling water from the reactor of the Three Miles Island nuclear power plant in 1979 and the public reaction to this event stopped the development of nuclear power engineering in the United States. The Anti-Nuclear Crusade prevailed won. If the hypothesis that this crusade was backed by Soviet propaganda is true, then the Chernobyl disaster in 1986 was a real godsend to this crusade. Before the Chernobyl catastrophe (and afterwards as well), the nuclear power plants in the US did not record a single fatal accident.

In March 2011, a fourteen-meter high tsunami caused by the earthquake in the Pacific destroyed the protective walls of the Fukushima power plant. At the same time, the reactor cooling supply system was destroyed and the cores of three out of six reactors melted; the hydrogen containers exploded, destroying buildings and exposing the reactors. Radioactivity rose rapidly; tens of thousands of residents were evacuated.

A second tsunami overtook the Earth, that was a tsunami of fear of nuclear power engineering. The German power engineering experts recommended the closure of all nuclear power plants (total power c. 25000 MW). This was significant if we consider that replacement fuel cost (i.e., oil cost) might attain 25 billion dollars annually.

However, reactions to the Fukushima disaster were diverse. After a few weeks, Barack Obama, the then President of the United States, stated that, according to his experts, the nuclear power plants are:

– the safest,

– the cheapest,

– the least harmful to the natural environment.

Therefore, 31 new nuclear power plants should be built in the States.

Since there are no grounds for inference that the professional expertise of American experts may differ from that of their German colleagues, the question arises as to the reliability of these opinions. They were, after all, drawn on the basis of identical facts. So what were the grounds for these opinions on both sides?

– Research results?

– Political impact?

– Media Impact?

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It must be noted here that the Anti-Nuclear Crusade was directed outward of the Soviet Union. At the time when the development of nuclear power engineering was totally stopped in the US, about 150 nuclear power plants were built in the Soviet Union/Russian Federation.

The readers of this text are aware that the author is not competent to answer these questions; however, as any observer of the real world, he may pose these questions, and the readers may try to answer them.

B.3. Fascination with the wind.

Fear of nuclear power engineering and concern about the degradation of the natural environment caused by burning fossil fuels (coal, oil, and gas) and subsequent carbon dioxide emissions have focused attention on wind energy. The perspective of free energy generated by windmills engendered a kind of public fascination with the wind. My students and university colleagues succumbed to this fascination. They are convinced that everything possible (starting naturally with nuclear power plants) should be replaced with wind farms. This fascination spread to government officials in many countries who prepared to offer financial support to such farms.

However, not everything is as straightforward as it seems. I watched a television interview with the owner of a wind farm. The journalist asked a question about what the owner would do if government support were cut one day. The answer was that the farmer should sell the plant the next day. Does this mean that his wind farm, with free 'fuel' but without government funding, would not generate any profit? So, the question arises: How much does it cost to 'harvest' wind energy?

Obviously, I am not competent to answer this question. However, to the amusement of my students, I conducted an 'intellectual' experiment, replacing a River Band Nuclear Plant operating close to the university (1500 MW power) with a wind farm of identical power.

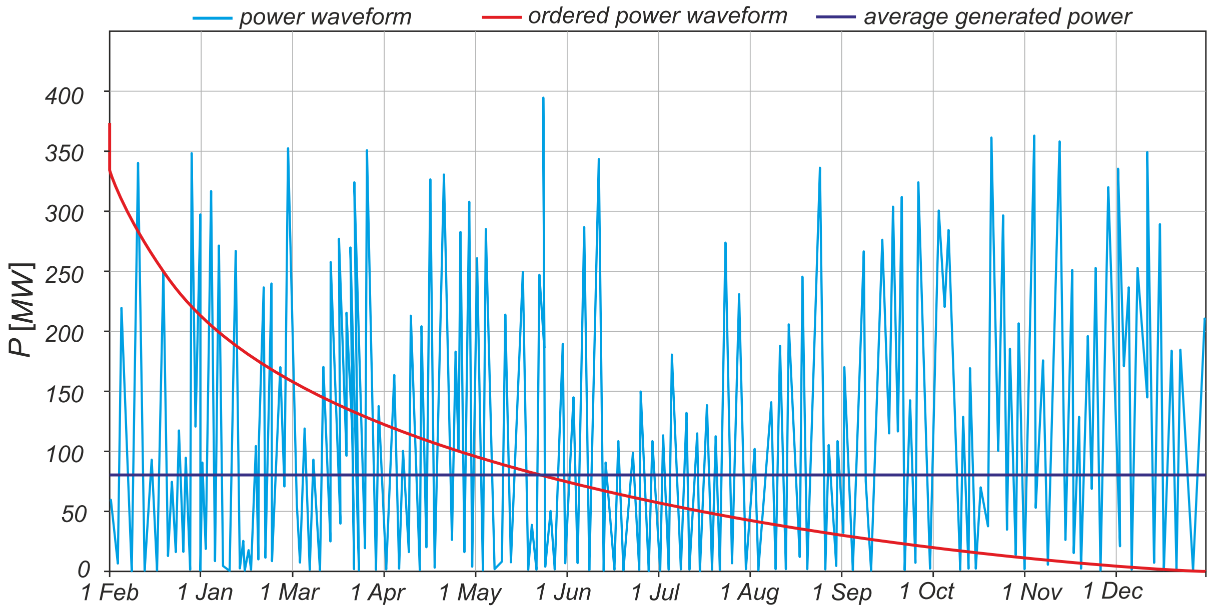

Fig. 9. Annual variation of the power in Polish wind farms (total installed power 455 MW)

Assuming that the wind turbines are rated at 3 MW, the farm would have to contain 500 turbines. Courtesy of Prof. Lubośny of Gdańsk University of Technology, I was able to obtain the results of power measurements in Polish wind farms [15] (see Fig.9). In this chart, the black line represents the annual average power of the farms, and the red line in the chart shows the average ordered power, i.e. total time over a year when wind farms operate at a definite power level, from maximum to nil.

These measurements show that with installed wind power of 455 MW, the average annual power is equal to only 85 MW, so the effectiveness of 'harvesting' wind energy in these farms is 18.7%. This means that 500 wind turbines will not be able to reproduce the power of the River Band Nuclear Plant. The number of wind turbines would have to be raised to 2676.

The number of these turbines certainly makes a statement. Furthermore, another question arises: What amount of Earth's resources – aluminum, iron, copper, cement, water, different chemicals (not counting human work) – is necessary to construct 2676 turbines and generators?

Still, supposing that the farm is already constructed, it will operate with power equal to or greater than that of the simulated electric power plant just for 5 months in a year (see Fig.5). During the remaining 7 months, the level of installed power is not attained; in one month, the generated power is practically nil.

Now, what about the transmission line cooperating with a nuclear power station generator of 1500 MW? Our wind farm may generate power 5-6 times greater – this will come in gusts lasting hours or days. The transmission line would not be able to cope. Therefore, it would have to be modernized (increasing its transmission capacity). The same principle applies to unit transformers. They would have to be exchanged for transformers with higher rated power, otherwise the installed power of the wind farm would have to be reduced.

Moreover, if the nuclear power plant is exchanged for a wind farm, something else is eliminated from the grid: kinetic energy of the rotor and steam turbine (this plays an important role in the frequency stabilization of the system). On account of very low rotational speeds (several rotations per minute) and small moment of inertia, the rotors of wind generators are devoid of such capabilities.

We must also remember that the expected lifetime of the wind farm is significantly less than that of the nuclear power plant, which may be as long as 60-80 years. During the lifetime of the nuclear plant, the wind farm must be constructed several times anew; each time, a huge pile of worn towers, blades, and generators must be utilized (2676 wind plants!). The cost of this utilization and its impact on the natural environment would be substantial.

Anyway, when my students became aware of all the points involved in the replacement of the nuclear power plant by a wind farm, they lost enthusiasm for the exchange. Most likely, their previous knowledge on the 'harvesting' of wind energy came from the media. And there you will rather not find the answer to the crucial question: How much does 'harvesting' wind energy cost? The media message is usually focused on positive and not negative issues related to harvesting and its costs. Public opinion is thus manipulated.

B.4. Zero-emission hydrogen cars.

Fascination with 'wind energy' is similar to California's fascination with 'ideal green', that is, zero-emission hydrogen cars. This fascination demonstrates the effectiveness of media propaganda.

People are concerned with global warming, which, in general opinion, is caused by the greenhouse effect, resulting from the excessive presence of carbon dioxide and other greenhouse gases (such as methane) in the atmosphere.

Hydrogen fuel cells do not emit carbon dioxide; therefore, electric cars equipped with these cells are dubbed by the media 'zero-emission cars' or 'ideal green' cars. According to reports in the media, the transformation of these cars may slow the dangerous global warming process and climatic change.

This opinion was supported by the California Energy Commission (CEC), which decided [16] 'the adaptation of zero-emission hydrogen fuel cell electric cars', through extension of hydrogen car changing stations. The set goal was to have 1.5 million zero-emission cars on California roads by 2025.

The possibility of 'Saving the Planet' by buying 'zero emission' or 'ideal green' hydrogen cars, which was intensely promoted in the media, helped sell tens of thousands of such cars in California.

Hydrogen fuel cells are, in fact, 'zero emission', since they do not emit carbon dioxide. However, what about hydrogen production? According to Wikipedia, 98% of hydrogen worldwide was obtained (2021) through the process of methane (CH4) reforming. Hydrogen may also be obtained by water electrolysis or another process. Still, approximately only 2% of the hydrogen in the market is produced by processes other than reforming.

Methane reforming progresses as follows. At c. 10000 °C, mixture of methane and water is transformed into hydrogen and carbon monoxide:

$$CH_4 + H_2O >> 3H_2 + CO.$$

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These compounds mixed with water at 3600 °C, are transformed into hydrogen and carbon dioxide:

$$3H_2 + CO + H_2O >> 4H_2 + CO_2.$$

This means that from one kmole of methane, which weighs:

$$m_{CH4} = 12 + 4 \times 1 = 18 \text{ kg}$$

we obtain hydrogen weighing

$$m_{H2} = 4 \times 2 = \mathbf{8\ kg}$$

and emit carbon dioxide weighing

$$m_{CO2} = 12 + 2 \times 16 = \mathbf{44\ kg.}$$

So, we get a 'zero emission' car, but while hydrogen is produced as it is done today, its production is absolutely not 'zero emission'. One mole of methane, in the process of engine combustion:

$$CH_4 + O_2 >> CO_2 + 2H_2$$

emits 44 kg of carbon dioxide, i.e. the same quantity as the one obtained during hydrogen production by reforming.

Despite these facts and thanks to the support of the media, tens of thousands of hydrogen cars were sold in California as 'zero emission' or 'ideal green' vehicles. The author is not aware whether the California government goal, i.e. 1.5 million hydrogen cars on the roads by 2025 has been attained.

B.5. Is mankind warming the Earth?

NASA scientists have revealed the measurements of Earth's average temperature recorded from 1880 to 2018 (see Fig.10). They concluded that human activity is responsible for global warming. This was published as front-page news by The New York Times journal on 7 February, 2019. Each point representing Earth temperature is really an annual averaged temperature from several thousand measurement points located around the world.

The process of averaging the measurement results over one year duration and meter locality helps to reduce random measurement errors. Therefore, the obtained average global temperature (AGT) is a very reliable value. This varies over time (see Fig.10), and there are no premises to question this variability. Since the values themselves may depend, for instance, on the density of measurements in Arctic and tropical regions or on lands and oceans, the variability of average temperature is less dependent on such conditions.

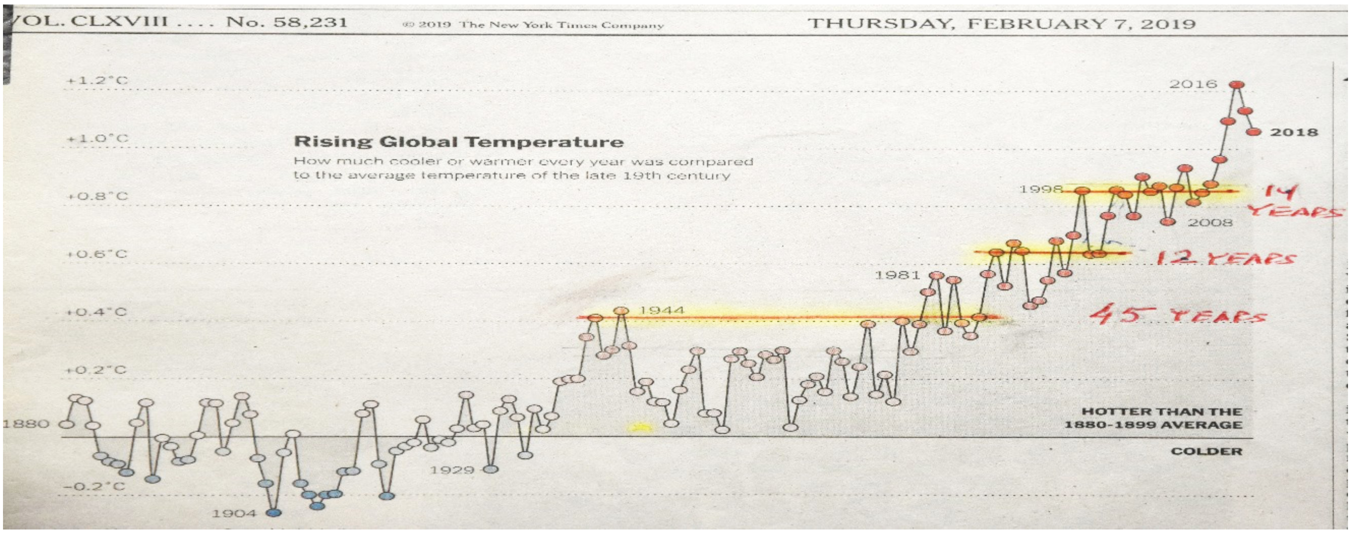

Fig. 10. Changes in average global temperature, from 1880 to 2018

The graph shows that annual changes in global temperature did not usually exceed ± 0.10 °C, sometimes up to ± 0.20 °C. The changes over several years could be greater; between 1900 and 1904 the temperature decreased by 0.40 °C, between 1935 to 1941 it increased by 0.40 °C, and then during 1944 to 1950 it again decreased to 1935 level. The 0.20 °C changes in temperature, in two-year intervals, may be observed after 1979, 1984, 2000; after 2013, the change occurred over three years and was equal to almost 0.40 °C. The increases in temperature were spread out in time by multiyear intervals, when no constant temperature rise was observed.

The chart of AGT changes published by NASA scientists in NYT as proof of the impact of human activity on global temperature cannot be treated as such. In empirical sciences (based on measurements), scientists may formulate, according to Popper [19], auxiliary hypotheses only and may adopt the theory that is most probable in light of the available evidence. Therefore, the conclusions of NASA scientists may be taken as a hypothesis only. The chart of changes in AGT (Fig.10) seems to undermine this hypothesis rather than support it. The reasons are as follows:

1. At the end of the 19th century, a three-phase synchronous generator was invented, and global power engineering system was initiated. Until the Second World War, thousands of electric power plants – driven by coal, gas, oil – were built; these emitted carbon dioxide without any limitations. The mining industry grew rapidly on account of the swift increase in demand from the steel industry, chemical industry, and heating. In spite of the huge carbon dioxide emission accompanying combustion of these fossil fuels in electric plants, steel plants, chemical plants, and for heating purposes, average global temperature in 1936 was the same as in 1890.
2. The global population during the Second World War was about 2.5 billion. In 1986, that is, after 45 years, it grew approximately to 5 billion. Doubling the population would be accompanied by doubling the industrial activity, including carbon dioxide emission. This cannot be observed in the AGT chart since AGT in 1986 was the same as in 1944.
3. The increase in population and the associated increase in electricity generation worldwide and human global industrial activity are continuous processes, while changes of average temperature shown in Fig.10 are of stepwise character. The presented measurements show that changes in global temperature took place over relatively short periods that lasted for several years, and then temperature rises were not observed for many years. It is quite improbable that human activity should change in the way shown in the AGT chart (Fig.10).

NASA scientists showed measurements of average global temperature to prove the hypothesis that human activity causes the rise in global temperature. These measurements falsify the presented hypothesis, rather than support it.

The propaganda of the media is consistent with this hypothesis and treats it as the obvious truth. Views on climate change other than the presented hypothesis are usually not found in the media.

B.6. Chicken or egg?

According to popular opinion, global warming can be traced back to the phenomenon called 'the greenhouse effect', that is, the reflection of heat emitted by the Earth by so-called greenhouse gases, such as carbon dioxide or methane (the predominant gas is CO_2).

This opinion was also expressed [17] by W. Gardner, Professor of Geoscience, A&M University, Austin, TX. He supported this view by the chart of global temperature change and carbon dioxide content in the atmosphere over the last 450,000 years (see Fig.11). This chart covers four Ice Age periods, lasting for c. 120,000 years and interglacial periods, including the last and present one, i.e., the Holocene. We may observe from the chart that the Holocene era started with a rise in global temperature by approximately 8-90 °C.

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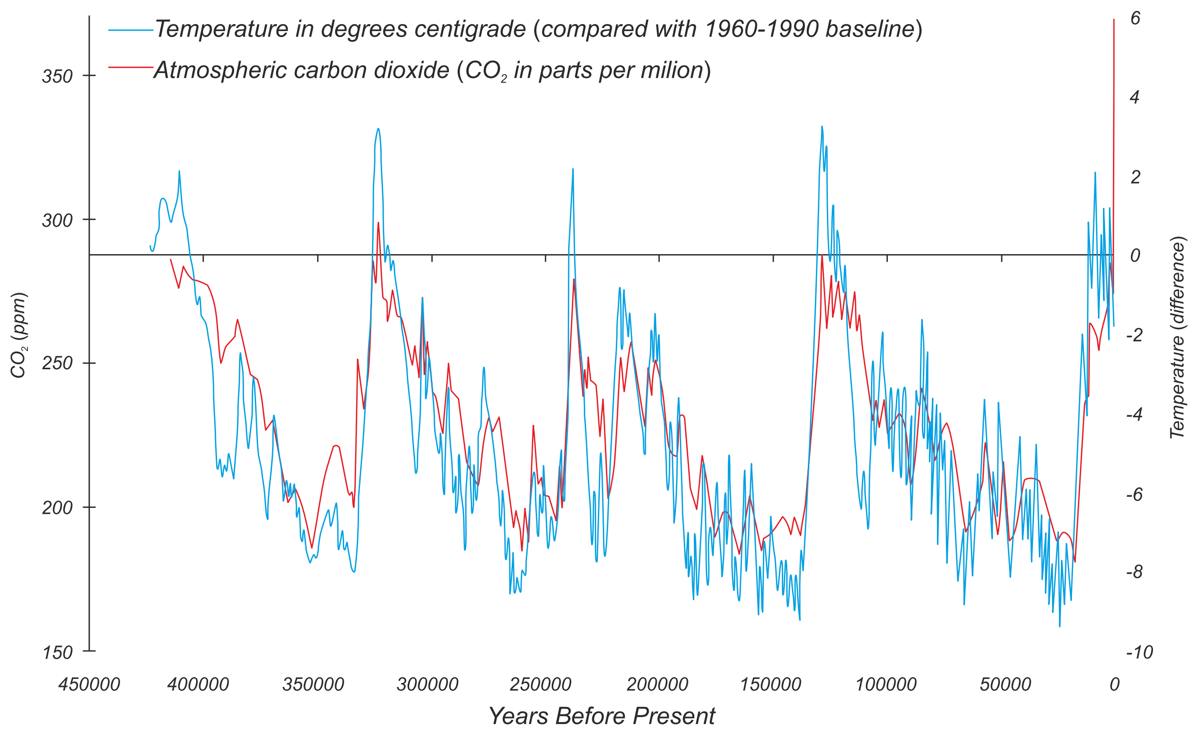

Fig. 11. Earth's average temperature and atmospheric carbon dioxide content over 450000 years

From our standpoint, the most important is the global temperature change in the present era, i.e. the Holocene; this is not easily observed in Fig.11. More precise information may be found in research works devoted only to the Holocene, cited in [18]. The global temperature change calculated as an average from five different locations is shown in Fig.12. However, these values are not as accurate as the AGT measurements shown in Fig.10. The chart of temperature changes (black line) shows a rapid warming over two millennia of the Holocene; 10,000 years ago global temperature was the same as today, 8,000 years ago it was slightly higher and then it dropped on average by some 0.30 °C.

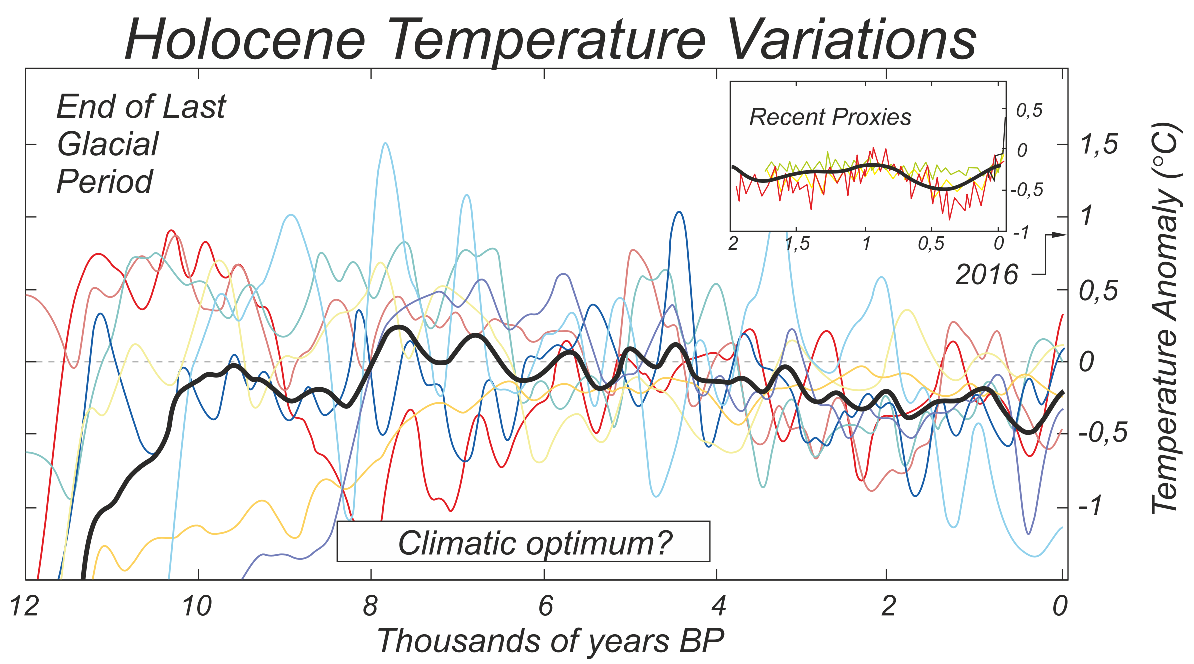

Fig. 12. Changes of global temperature in Holocene era.

The graphs shown in Fig.11 indicate a large correlation between carbon dioxide content in the atmosphere and global temperature. Still, there is no evidence of what is the cause and what is the result of these changes. During some periods, temperature and carbon dioxide content change simultaneously and in the same way; there are intervals where temperature changes first and vice versa; there are intervals where temperature changes while carbon dioxide content is relatively constant. So, standard causality dilemma arises: What came first, chicken or egg?

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The global temperature rise, in general opinion, is caused by the greenhouse effect, that is, reflection of heat radiation of the Earth by methane or carbon dioxide present in the atmosphere. So, another query may be formulated: is there a reverse effect, i.e., whether the carbon dioxide content in the atmosphere may change with the global temperature?

Plants grow due to the absorption of carbon dioxide; this goes back to the atmosphere in the process of biodegradation of dead plants by decay and rotting. Animals emit carbon dioxide into the atmosphere in the breathing process. However, the proportion of land animals' weight to plant weight is assessed at 1:1000 [20] and therefore the flora must be self-sufficient due to carbon dioxide; in other words, the atmosphere must recover the gas when dead plants decompose. When the temperature increases, the weight of the plant may increase and the decomposition rate may be faster, so more carbon dioxide may go back to the atmosphere.

In the oceans, this process is different. Photosynthesis, that is, the absorption of carbon dioxide by plants, is possible only in the surface layer of the ocean. The weight of plants in the oceans is estimated to be only 3-5 times greater than that of marine animals, and this in turn is 11 times higher than the weight of terrestrial animals. Therefore, carbon dioxide emission by zooplankton and marine animals may be significant. The rise in ocean temperature may increase the mass of animals and plants in the sea and subsequently carbon dioxide emission into the atmosphere.

Therefore, apart and in parallel to the greenhouse effect, which increases global temperature, there are biochemical processes that, as the temperature goes up, increase carbon dioxide content in the atmosphere. This might explain why changes of carbon dioxide content in the Earth's atmosphere shown in Fig. 11 seem to be delayed in relation to global temperature.

B.7. What changes the global temperature?

The hypothesis that states that an increase in the carbon dioxide content in the Earth's atmosphere is the byproduct of an increase in global temperature generates another obvious question: What is the reason behind the increase in temperature?

The public opinion is convinced that global warming is caused by the said emission and does not voice any doubts. Still, for some climatologists, the greenhouse effect is only one of several phenomena responsible for climatic change. These are:

1. Some heat reaches the Earth's surface from the core; core temperature is estimated at 6000 °C. In the mantle, close to the surface, the temperature decreases at a rate of approximately 1 °C/30 m; this means that we have a constant thermal flux that warms the surface of the Earth. Tectonic movements, volcano activity, or shift in Earth's magnetic poles all demonstrate changes in the intensity of this thermal flux.

2. The main heat source for Earth is the Sun. The radiation activity of the Sun surface, which is hidden behind the heliosphere, is accessible only indirectly to researchers. High-energy Sun radiation generates carbon and beryllium isotopes 14C and 10Be in the upper strata of the Earth atmosphere. These isotopes are found in core materials extracted from Antarctic or Greenland icebergs and from trees. Analyzing changes in isotope content, conclusions may be drawn (see publications [21-26]) on changes in Sun activity.

3. The spatial orientation of the rotational axis of the Earth changes over time. These changes are known as Milankovitch cycles [27] and are made up of four elements:

– axial precession with a period of 25,700 years,

– apsidal precession with a period of 112,000 years,

– axial tilt (obliquity) with a period of 41,000 years,

– orbital eccentricity with a period of 100,000 years.

Lands and oceans differ in their ability to absorb solar radiation. When the axial orientation of the Earth changes, the orientation of the land and oceans also changes (even the distance from the Sun varies), and therefore the amount of absorbed thermal energy also changes.

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4. The transparency of the atmosphere (which may be reduced by the presence of volcanic ash) may affect the quantity of energy travelling from the Sun to Earth. Volcanic activity can be estimated by measuring the amount of ash in different deposits. Examples of dependence of glacier localities on volcanic activity may be found in [28].

5. Reflection of Earth's thermal radiation by carbon dioxide, methane, and other hydrocarbons was discovered in 1824 by Joseph Fourier [29]. It is known as the 'greenhouse effect' and is the most frequently mentioned phenomenon that influences global temperature.

All of these phenomena are involved in global temperature changes. Climate researchers investigate the specific contributions of each one.

It seems that, while public opinion has no doubts on the subject, there are still some climatologists researching the matter. These investigations are very complex. Research aimed at finding the causes of changes in global temperature many thousands of years ago is particularly difficult. It demands advanced knowledge of physics, geology, geomorphology, biology, astronomy and so on. The results and conclusions of the investigation may be very controversial and require continuous scientific verification.

For the public, the reason for global warming is obvious, it is caused by the greenhouse effect brought about by the carbon dioxide emissions. Each attempt to question the accuracy of this conclusion meets with compelling argument: but everyone knows that it is so!

However, some climatologists are rather cautious in their views. For instance, 15 authors of the article 'Holocene climate variability' [26] affiliated with several research centers in Europe and the United States say: 'Of all the potential climate forcing mechanisms, solar variability superimposed on long-term changes in insolation […] seems to be the most likely important forcing mechanism'. They also add that "changes in the concentrations of CO_2 and CH_4 appear to have been more the result than the cause of the RCCs"|(RCC – rapid climate change).

Unfortunately, opinions in social media tend to disseminate in a different way than the results of scientific research (which usually are not published in such media). A certain intellectual activity and precision is necessary to find out and evaluate the correctness of the research. That is why the extent of its influence is incomparably less than that of opinions on social media networks, which spread without any verification. It must be noted that the sources of scientific opinions may be identified, since such is the structure of science; this is completely different from the media opinions, where the sources and their credibility are usually blurred. Worse, usually we do not know who the originator of these opinions is: corporations, parties, governments, or perhaps obsessed dupes (e.g. Ostatnie Pokolenie) overwhelmed by the noble idea of saving the planet. At any rate, the view that it is mankind that ,due to carbon dioxide emission, causes global warming is very profitable to some institutions (as demonstrated by the story of hydrogen-powered cars).

B.8. Conclusions

Today, we are witnessing two processes. One is the rapid devastation of the natural environment of the Earth accompanied by mass extinction of species and warming of the climate. The destruction is due to the exploitation of natural resources and climate warming. This warming may be the result of different causes that climatologists have investigated. Public opinion tends to associate global warming with carbon dioxide emissions. The battle against emission is expensive; this is visible in the electricity bills and in the increase in budget expenses. The countries where energy is expensive become impoverished and have fewer financial resources to use in the fight against degradation of the natural environment.

However, perhaps those climatologists who think that global warming is due to an increase in solar irradiation are right; if so, then the expensive fight against CO_2 will not decrease the climate warming rate.

It is symptomatic that, in spite of huge investments in zero-emission energy sources and coal mine closures, reports on the rate of global warming and glacial decline are becoming more and more dramatic. These reports are more prevalent than information showing results of reduction in emission on warming rate.

However, even if this reduction does not slow global warming, replacement of traditional energy sources with RES might have a very positive impact on reducing the degradation rate of the natural environment. Still, decisions related to the development of RES should be made based on economic aspects and not ideology such as 'Save the Planet' We should also know more about how much 'harvesting' of free renewable energy really costs.

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