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Energy Consumption of Bitcoin Mining

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ABSTRACT

Blockchain is one of the most popular terms associated with changes in the technological paradigm-taking place within the framework of the so-called “fourth industrial revolution.” The Proof of work algorithm is used for process transactions and ensure security in the Bitcoin network. The paper aims energy consumption of bitcoin mining. It implies the need for a network participant to solve a certain cryptographic task with energy consumption and predetermined final time for its completion. The methodology includes the analysis of relationship between active, reactive and apparent power is determined by the phase angle between the current and voltage in the network, more precisely, with the cosine of this angle - cosφ (power factor news). A correctly solved task is accepted by the network and included in the public transaction register. The participant who first provided such a solution receives a block reward. The main finding is that the solution of the energy consumption problem by other network participants, an order of magnitude less time is required.

Keywords: Industrial Mining Farms, Bitcoin Mining, Power Factor Reactive Power, Reactive Power Compensators
JEL Classifications: C30, D12, Q41, Q48

1. INTRODUCTION

With the popularity of Bitcoin, the number of people wishing to become a member of the network and receive an award is growing. The number of active mining participants determines the complexity of the network, the dependence is direct. With increasing complexity, the power requirements of the equipment used also increase, and as a result we get an exponential increase in electricity consumption.

The purpose of this work is to apply the developed method for calculating the energy spent on the operation of the Bitcoin network and correlation with world energy consumption.

A sharp increase in the value of cryptocurrencies in 2017, especially from the beginning of December 2017 to the end of January 2018, when the Bitcoin exchange rate did not fall below the $ 10,000 mark, caused a mining boom in Russia - the extraction of digital assets using computing power (Nyangarika et al., 2019b; Nyangarika et al., 2019a).

However, if only a few years ago every owner of a powerful computer could do mining, then today the situation is radically different. Virtual coin mining without significant investment is simply not possible.

At this stage, computing power is realized with the help of farms, representing as the plurality of a large number of video cards connected to computers (usually no more than 6-8 per motherboard Finnish board), as well as a large number of computing modules using ASIC – integrated special purpose scheme. At the same time, specialized software provides parallel computing processes.

It should be noted that the performance of ASIC is hundreds of times higher than the performance of the best graphics cards and has a higher performance/power ratio. The main disadvantage is the high cost and the fact that they can produce, as a rule, only one currency, while video cards can easily be converted to mining any currency, or can be sold to use in other needs.

2. LITERATURE REVIEW

Due to the excitement around virtual money, mining equipment is growing rapidly in price, as well as the difficulty of getting new coins increases. As a result, the payback of acquiring mining is farms are constantly declining. Many private individuals prefer mining new crypto currencies, the complexity of which is still not very large, and the profitability of the process is very decent (Branch, 1993).

In the event of a currency take-off, users who have managed to mine coins will have a huge profit, but only in isolated cases, such assets can be sufficiently developed. In particular, if we take for example, ethereum, which is the second most popular and promising cryptocurrency. Despite the profitability of acquiring equipment for the extraction of crypto coins, the payback period is increased significantly, while profit declined. Private users today can pool and receive, thus, personal profit (Cameron, 1985).

But over time, entry requirements will increase, equipment will rise in price or as a result of the influence of other external factors, loners will still have to leave the market and reorient to cloud services that are gaining in popularity (Mikhaylov, 2018a; Mikhaylov, 2018b).

Already in Russia, according to various sources, more than 80% of the computing power of concentrated in specialized computing centers engaged in industrial mining with the number of computing modules 300-5000 units. 10% of the computing power is a small business organized in small rooms with the number of computing modules up to 300 units, the rest are amateurs with the number of modules up to 20 units (Lopatin, 2019a; Lopatin, 2019b).

One of the factors restraining the development of industrial mining is a large energy consumption of computing modules. So, a single farm of six video cards consumes from 1 to 1.5 kW of electricity, a single ASIC module has similar performance. In this regard, one of the largest mining farms in Russia, containing more than 3000 modules (Meynkhard, 2019a; Meynkhard, 2020).

For its functioning, it has a power capacity of 4.5 MW. At the same time, 20 bitcoins are mined in day and 600 bitcoins/month. A mining farm being created on the premises of the factory will consume 20 MW (Balestra and Nerlove, 1966; Davis, 2008; Davis, 2011).

After the launch of all capacities, this farm is projected will occupy up to 10% of the global hash rate. Digiconomist publication published the energy consumption data of bitcoin at the beginning of December 2017. It turned out that bitcoin miners spend more than 31 TWh/year on production, which is 0.14% of all energy costs in the world. If the pace continues, then by February 2020 there will be bitcoin mining go all the electricity in the world (Mikhaylov, 2019a; Mikhaylov et al., 2019; Blanchard, 1983).

At the same time, the cost of electricity on a particular farm is from 10% to 30% of the received currencies and depend not only on the equipment used, but also on tariffs. As noted in the above report, now Bitcoin is generating $ 7.2 billion a year in profit with energy costs of about $ 1.5 billion (Meynkhard, 2019b). In this regard, the problem of ensuring the quality of power supply mining farms both in terms of energy efficiency of power sources, and taking into account the protection of used expensive equipment of mining farms (Brown, 2001).

3. METHODS

The input impedance of power supplies of mining farms is active-reactive, due to with which the current and voltage at their inputs do not coincide in phase, which leads to the reflection of part of the energy from consumer to the source.

An energy source for powering a mining farm (power plant, power shield) can last but to give, without the risk of an accident, only a well-defined power *S* equal to the product of its strength nominal current *I* to the nominal voltage *U*. The product of the effective current and voltage is called apparent power:

$$S=UI \tag{1}$$

Gross power is the highest value of active power at given values of current and voltage. It characterizes the greatest power that can be obtained from AC current transducer, provided that there is no voltage between the current flowing through phase shift (Denisova, 2019; Denisova et al., 2019).

The relationship between the active power *P*, reactive power *Q* and apparent power *S* can be determined from the power triangle (Dayong et al., 2020).

The relationship between active, reactive and apparent power is determined by the phase angle between the current and voltage in the network, more precisely, with the cosine of this angle - cosφ (power factor news).

From the power triangle it follows that for a given apparent power *S*, the greater the reactive power *Q*, which passes through an alternator or transformer, the less active power *P*, which he can give to the receiver.

So, with cos φ=0.95, reactive power is 33% of the consumed active power. In fact, at cosφ=0.7 the value of reactive power is almost equal to the value of active power, and at cosφ=0.5 it exceeds 1.7 times, significantly increasing the active losses in the network.

Increased reactive network utilization current also leads to a decrease in voltage in the network, and sharp fluctuations in reactive power to voltage fluctuations in the network.

This is especially true when deploying mining farms in the areas of former warehouses and enterprises whose electrical networks (wires) were not originally designed for the flow of such currents, which often leads to emergencies and even fires.

In addition, the phase mismatch of the current and voltage at the input of the computational power sources.

Mining farm equipment, made in the vast majority of transformerless scheme leads to a decrease in the efficiency of their functioning due to a reduction in the time of row of the input capacitor during the period and, as a result, to a decrease in the output current supplying terminal computing equipment.

To compensate for reactive power, special compensating devices are used, being sources of reactive energy of the opposite sign.

The reactive power must be compensated locally, in order to prevent negative impact on energy supply. Currently, most reactive power compensators used in industrial enterprises, are capacitor units or controlled denser installations, which are sources of negative reactive power, which due to this circumstance cannot be used to compensate for reactive power when powering computing equipment of mining farms.

Food of industrial mining farms is carried out, as a rule, by three-phase sources nutrition, the functioning of which is largely affected by symmetry phase (linear) voltages. However, due to various circumstances, including due to unequal phase load measurements by single-phase mining auxiliary equipment consumers farms, this ratio is violated, which leads to an increase in instability and a significant higher ripple output voltage supplying the final computing equipment mining farms, which can lead to malfunctions. The elimination of this drawback is possible, example, by means of quick automatic connection to special power supply buses phase shifting reactivity.

When you turn on uninterruptible power supplies that feed a mining farm, due to with a charge of the input capacitance of the sources, inrush currents arise that significantly exceed rated. Although this process is short-lived, it can cause increase in the cost of electricity for the enterprise. Depending on the tariff used energy supply companies may charge a monthly fee not at the nominal but at the maximum power consumption. Excess can be up to 30% of the monthly cost of electric energy.

On the reliability of the operation of equipment of mining farms, primarily sources power supply, are affected by transients in the power supply network, which result in short temporary excesses (usually within a few milliseconds) of currents and voltages relative but nominal values that may be due to external and (or) internal causes.

Such causes may include lightning, switching at supply substations and loads. Because of transients, voltage changes can reach from several volts up to tens of kilovolts, and current surges - a dozen kiloamperes.

The heating and energy consumption of mining farms is largely dependent on the availability of higher harmonic components in the curves of currents and voltages in the supply networks. In addition, short-term power outages, defined as total absence, are possible.

All the initial data is public, as the blockchain is redistributed database, maintained by all the participants.

The popularity of Bitcoin correlates with number of miners, Figure 1 represents continuous growth of network difficulty. Figures 2 to 4 represent charts for power consumption of bitcoin mining for the period 2017-2019. We see correlation between difficulty growth and increasing of power consumption. Except situation in the end of 2018 when BTC price started decrease. Much criticism has been rushed at the electricity consumption expenditure of Bitcoin network, but this expenditure keeps the system secure.

Obviously, that growth causes increasing of electricity consumption by miners. There are two different competitive areas within the mining sector, one for industry-miners and another for pure miners. When using application specific integrated circuits (ASICs), average amount of electricity needed to provide hashrate of 1 Th/s is 100W/h, for the period 2017-2019.

4. RESULTS AND DISCUSSION

From the above it follows that the task of energy conservation when creating farms for industrial mining is very relevant and requires the development and creation of unique equipment, under connected to the power supply system of the mining farm. This will ensure solution to all the problems raised above. As for mega-farms, immersion-cooling systems are considered the most effective. They consume less energy than traditional cooling systems, such as fans and air conditioners. There are two types of immersion systems: with modules immersed in liquids with low temperatures. After heating, the liquid evaporates; taking with it the excess heat, then condenses and drains back to the tank.

The use of Peltier elements for effective selection is also of great interest heat from fuel elements to increase the performance of mining farms (An et al., 2019a; An et al., 2019b; An et al., 2019c; An et al., 2019d).

An increase in the temperature of the equipment leads to a decrease in the efficiency and reducing their service life.

Figure 1: Difficulty of bitcoin mining, BTC

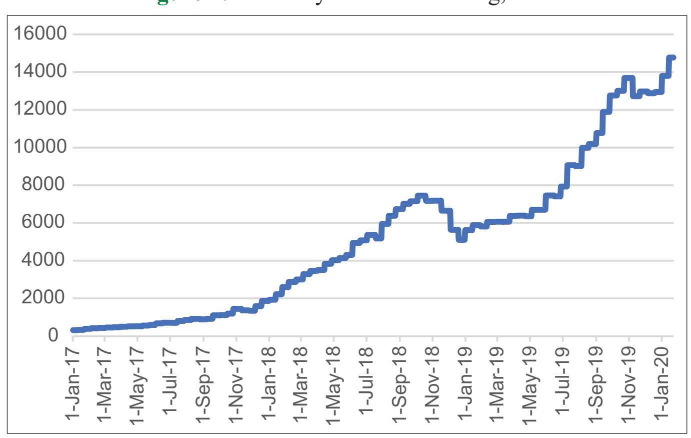


Table 1: Electricity consumption of bitcoin network worldwide

Year	Power bitcoin mining consumption, TWh	Worldwide power consumption, TWh	Share, %
2017	5.027	22 190	0.02
2018	31.34	22 964	0.14
2019	55.27	23 290	0.24

Table 2: Regional power consumption

Year	Asia consumption, TWh	Africa consumption, TWh	Americas consumption, TWh	EU and CIS consumption, TWh
2017	3.0	0.3	1.0	0.8
2018	18.8	1.6	6.3	4.7
2019	33.2	2.8	11.1	8.3
Renewables penetration, %	22.40	17.80	50.55	36.40
Ktoe equal	9406.25	830.32	1998.02	1927.31

Figure 2: Bitcoin mining electricity consumption in 2017, TWh

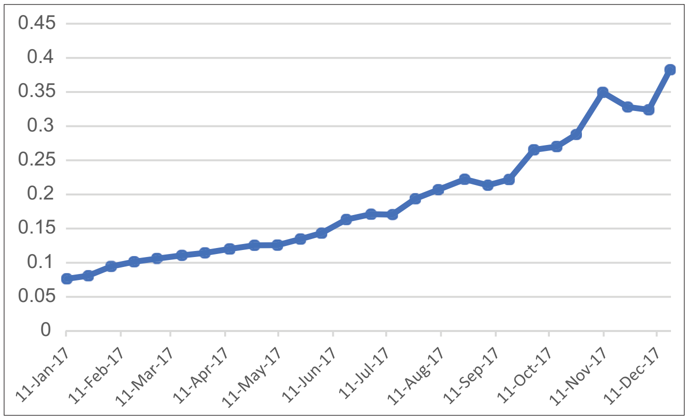


Figure 4: Bitcoin mining electricity consumption in 2019, Twh

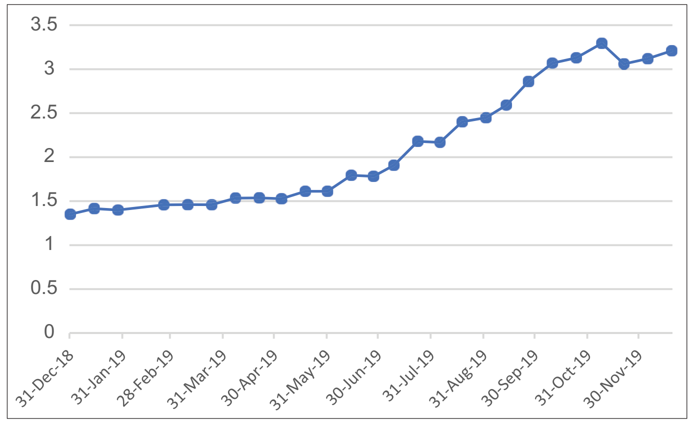


Figure 3: Bitcoin mining electricity consumption in 2018, Twh

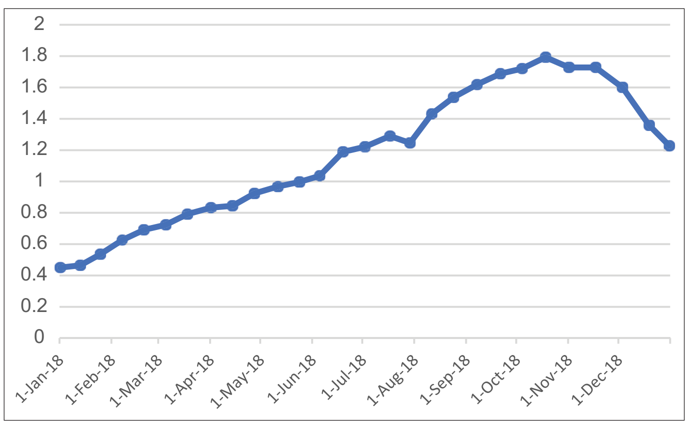
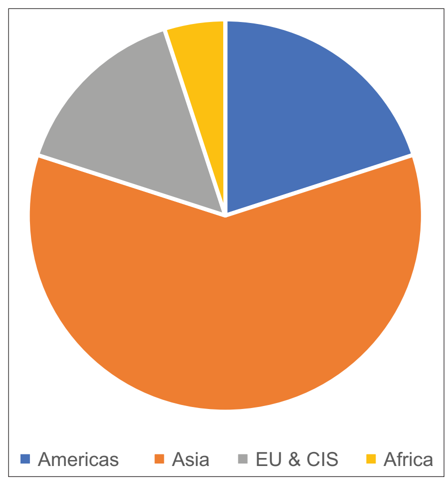


Figure 5: Bitcoin miner distribution



Summarising all the claimed data and comparing it to worldwide electric power consumption presented in Table 1.

It shows significant growth and amount reached in 2019 is huge. For example, entire Czech Republic consumed 56 TWh during this year.

The next step is to calculate how that consumption affects ecology. At first, let's define mining regions (Figure 5).

There is a difference in sources used to generate electricity, so let's divide them into two categories: Renewable (hydro, solar and wind generation) and non-renewables (fossil, nuclear, natural gas, coal and others) sources. As for non-renewables we can calculate ecological impact by transforming them into Mtoe equivalent. The tonne of oil equivalent (toe) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. 1 terawatt-hours is approximately 220,46 ktoe, with average efficiency of non-renewable power plants of 39%.

Table 2 represents electricity consumption by regions separately, renewables penetration in electricity generation by regions and ktoe equivalent.

Totally, world energy consumption, provided by Bitcoin miners for period 2017-2019 is 14,16 Mtoe.

5. CONCLUSION

Bitcoin mining farms consume large amounts of electricity. Their expenses 30% of the received currency for electricity (An et al., 2020). The reliability, efficiency and performance of mining farms directly depend on the quality of the power they receive. To improve the quality of electricity it is necessary (Mikhaylov et al., 2018; Nyangarika at al., 2018):

- Reduce reactive power (increase power factor), which under such loads has a negative character. Negative reactive power compensators for today no day on the market
- Reduce voltage imbalance, which can lead to equipment malfunction. Creature balancing transformers require a break in the supply network, which reduces reliability power supply. In addition, such transformers have large weight and size characteristics and high price (Mutalimov et al., 2020)
- Reduce the level of harmonics in networks leading to increased energy consumption and heating of cable networks and consumers (Lisin, 2020)
- Compensate for short-term voltage drops and surges in the supply networks leading a failure in the operation of mining farms and their failure
- Improve transients in networks associated with switching (switching) in lines and lightning strikes.

The performance of mining farms depends on the efficiency of heat extraction from the heat elements. There are various ways to implement this process (An and Dorofeev, 2019).

These steps will help miners to decrease electricity consumption. Miners society should think about their influence on world power expenditure.

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