International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2755-2760

Marketing Prospects for Universal Electric Power Converters

E.A. Buzoverov[1], A.Y. Varaksin[1,2] and K.K. Denshchikov[1]
[1]*Joint Institute for High Temperatures, Russian Academy of Sciences, Moscow, Russia.*
[2]*Bauman Moscow State Technical University, Moscow, Russia.*

Abstract

The prospects of the market of universal electric power converters (UPC), which are an innovative device for improving the quality of energy consumed, as well as leveling its negative impact on the network, are examined in this statement. Consumers interested in using UPC are determined by assessing the damage they incur as a result of poor-quality power supply and power outages. It is shown that consumers of the 1st category of reliability of power supply are most interested in the application of UPC, for which the device can improve the quality of power supply, as well as eliminate short-term power outages associated with switching the load between the supply feeders. Corresponding calculations were performed as part of this study; segmentation of potential device consumers was performed by regions and types of enterprises. Estimated potential volume of the domestic market - 1680 pcs. devices with a total capacity of 5040 MVA. In monetary terms, the market volume is estimated at 956 625.7 thousand USD. It is shown that the markets of developed countries may be less promising for development compared to the domestic market due to the higher quality of power supply in centralized power grids. Promising may be access to the markets of developing countries.

Keywords: Power Supply, Universal Electric Power Converter (UPC), Market Prospects

I. INTRODUCTION

This universal electric power converter (UPC) is designed to compensate for reactive power, actively filtering the higher harmonics of the load current, suppressing harmonic distortion of the voltage at the connection point, balancing the voltage of the network, as well as generating active power during a short-term power failure. UPC is a short-term energy storage device for high-voltage networks (10 kV), capable of supporting up to 3 seconds the rated voltage when it is interrupted. Such characteristics of UPC in combination with its technical and economic parameters determine its competitiveness in the market of devices for similar purposes [1].

The experience in the development of UPC will allow in the future to create scientific and technical foundations for the production of a large range of devices that provide high quality power supply in a wide range of capacities, operating voltage and duration of operation. The basis of such devices is the idea of hybridization, i.e. the joint use of various energy storage devices (short-term and long-term) and power electronics devices that ensure the maneuverability of electric power systems under various influences, as well as the possibility of backup power supply to the most critical consumers and loads powered by long-term dead-end lines [2].

UPC consists of a voltage converter, energy storage and control system. The voltage converter performs the functions of regulating and balancing the voltage of the network, actively filtering the harmonic components of voltage and current, as well as the functions of a rectifier and inverter for servicing the energy storage device. The energy storage device is designed for short-term output of active power in the event of a power failure. The control system manages and protects device components.

The main element in the energy storage is a battery of supercapacitors. The required storage capacity is achieved through the use of original type-setting supercapacitors of our own design, several times cheaper and having much (4 times) more power than the battery of foreign-made supercapacitors on the market [3].

The use of UPC of developed design allows you to:

- reduce the number of shutdowns of three-phase synchronous and asynchronous motors in the reverse sequence caused by an increased level of voltage unbalance;
- prevent accelerated wear of equipment caused by the high content of higher harmonics;
- provide voltage stabilization in the presence of abruptly variable loads;
- reduce damage from disruptions of continuous technological production caused by interruption of power supply.

Thus, the UPC occupies an intermediate position between devices that can only improve the quality of electricity and uninterruptible power systems for a certain class of consumers.

II. PROBLEMS OF THE QUALITY OF ELECTRIC ENERGY IN ELECTRIC NETWORKS

The energy complex of the Russian Federation has a number of problems caused, in particular, by a shortage of energy generating and network capacities in a number of regions of the country; their non-optimal structure with a pronounced lack of semi-peak and peak maneuverable power plants; reduced reliability of power supply due to high wear and tear of fixed assets; insufficient capacity of electric networks and high losses in them. At the same time, modern science and new technological advances make it possible to create conditions for the transition in the field of energy to a qualitatively new level. A fundamentally new quality is achieved by incorporating active elements in existing and created systems that change their characteristics under the influence of external control. This effect is carried out by adaptive control systems that respond to the current state of energy systems and facilities, optimizing their condition in normal mode, as well as preventing emergency situations or localizing them (in case of occurrence). For this reason, breakthrough scientific and technical energy systems using these principles are called intersectoral systems with active adaptive networks.

The growth of non-linear consumers has aggravated the issue of electricity quality, for example, indicators such as distortion of the sinusoidal voltage of the network and the deterioration of the power factor of consumers. Consumers that worsen the quality of electricity include electrical engineering complexes of many industrial facilities, which are characterized by the use of a system of several DC valve electric drives that receive energy from a power source, the power of which is comparable with the power of electric drives [4]. This circumstance leads to the fact that DC valve actuators and an energy source form a system of comparable power, which is characterized by the following features:

• low power factor;
• a significant deviation of the mains voltage from the nominal;
• distortion of the sinusoidal form of voltage.

The above features negatively affect both the performance characteristics of the electric drives themselves and the operation of other electrical equipment. Losses of electric energy in electrical equipment are increasing, the service life of power receivers is reduced due to additional aging of insulation, the error of electrical measuring instruments is increasing, the operation of automation systems, etc., is deteriorating.

Also, the problem of ensuring the quality of power supply becomes more urgent, the more widespread is high-tech equipment that is extremely sensitive to voltage fluctuations, interruptions in power supply, and the presence of harmonic components. Examples are modern domestic drilling rigs for exploration and production drilling for oil and gas, extruders in oil refineries, engines with frequency drives in oil and gas production and transportation enterprises, equipment for chemical and metallurgical industries, equipment for computer centers, etc. Voltage fluctuations and interruptions in energy supply lead to a malfunction of technological processes, a decrease in the quality of products and, as a result, to a large economic damage. The presence of harmonics leads to increased heating of the elements of engines and generators, rapid wear of insulation and, as a result, to premature failure of electrical equipment, both of consumers and enterprises of transmission and distribution of electricity [5].

For example, periodic measurements in electric networks supplying the Trans-Siberian Railway reveal significant violations of regulatory requirements for electric power quality in two groups of indicators: 1) by voltage unbalance and by reverse sequence; 2) the distortion of the sinusoidality of the voltage curve. Voltage distortions at substations located along the Trans-Siberian Railway are generated by electric locomotives consuming a single-phase non-sinusoidal current from the network. The daily average values of these values regularly reach 5-7%, which is 2-3 times higher than the maximum permissible values in accordance with GOST 54149-2010 "Standards for the quality of electric power in general-purpose power supply systems".

Of particular relevance is the problem of bringing the quality of voltage to regulatory requirements recently acquired due to the connection to the transit of 220 kV industrial consumers with a powerful motor load. As an example, we can cite periodic technological violations associated with the shutdown of the engines of the oil pumping stations of Vostoknefteprovod LLC, powered by the PS 220 Skovorodino buses, due to the protection connected with increased asymmetry in the supply voltage [6]. An analysis of power supply disturbances at Tobolsk-Neftekhim LLC enterprises revealed about 10 annual cases of interruptions and voltage dips lasting from 0.13 to 0.3 s, after which there were stops of pumps, compressors and frequency drives. An energy survey of Sibneft-NNG OJSC showed that about 1,000 outages occur annually, as a result of which about 50,000 tons of oil are not produced. Statistics of emergency violations confirms that about 40% of all violations of oil producing enterprises are caused by the fault of the supplying Norilsk electric networks. Shutdowns occur during the startup of electric motors and other high-voltage equipment due to voltage dips with a depth of 10-12% and a duration of 0.2 to 3.5 s.

III. TECHNICAL CONSEQUENCES OF REDUCING THE QUALITY OF POWER SUPPLY

Damage segmentation by type of electric power quality indicators, according to European studies [7, 8], is shown in Fig. 1 and Fig. 2. Deviations (overvoltages / undervoltages), subsidence and short-term voltage interruptions account for 37% of the damage, another 16% of the damage is caused by voltage unbalance and harmonics, while the majority of the damage relates to industrial consumers.

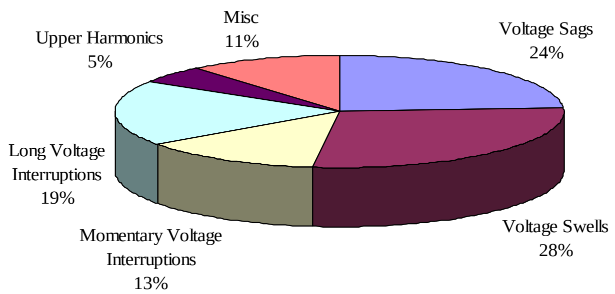

Fig. 1. Damage segmentation in terms of power quality indicators

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2755-2760

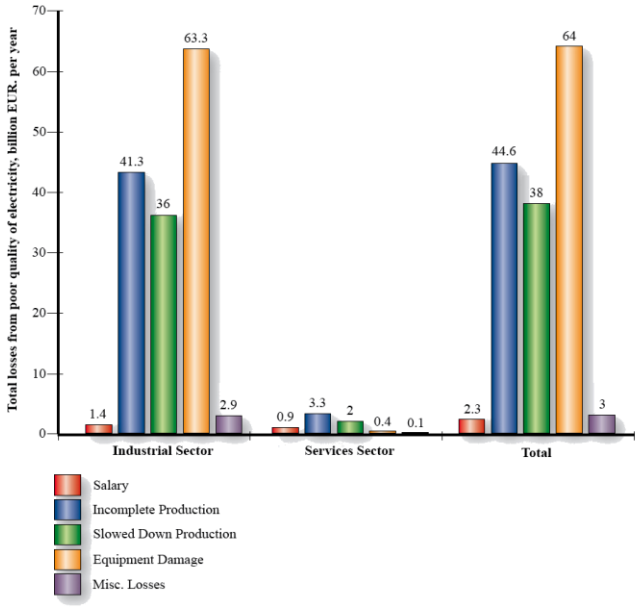

Fig. 2. Damage segmentation in terms of category consequences

The total losses from the poor quality of electricity for 25 EU countries amount to 150 billion euros per year - losses associated with damage to equipment and the suspension of the production process make up approximately 90% of this amount.

A list of the main types of decline in the quality of power supply and their main consequences are shown in Table 1.

Table 1. The main types of decline in the quality of power supply and their impact on equipment

No.	name	physical manifestation
1	Reactive power	Increased heating of conductors, loss of electricity, degradation of network bandwidth.
2	Interruptions	An interruption of voltage, including short-term interruptions (for example, with successful automatic reclosure) can cause an emergency shutdown of consumer equipment.
3	Harmonic distortions	Increased uneven heating of conductors, loss of electricity, accelerated aging of electrical insulation, the danger of resonance of currents in the network.
4	Voltage asymmetry	Overheating of the windings of electric motors, shutdowns of overheating (if protected), accelerated aging of electrical insulation, deterioration of performance and reduction of the service life of electric motors.

IV. MODERN METHODS AND TECHNICAL MEANS TO IMPROVE THE QUALITY OF ELECTRICITY

The energy quality problem is complex, it affects the producing, supplying and consuming parties, both in terms of factors that reduce the quality and in terms of solutions designed to counteract them.

It is obvious that the cost of technical devices to improve the quality of power supply mainly depends on the place of their connection in the enterprise circuits, and primarily on the level of the worker from the voltage in them. Thus, the price of the device for voltages from 35 kV is obviously higher than for voltages of 0.4-10 kV, and this is the limiting factor in the strategy for reducing damage from low quality of electricity. On the other hand, the limitation is the feasibility of using a large number of low-voltage solutions and the total cost of them. This situation leads to the lack of a single optimal solution to the problem - in each case, the choice is individual and, often, based on a compromise.

The list of some devices for improving the quality of power supply is given in Table 2.

Devices from the above list at a relatively low price do not provide a comprehensive solution to the problems and the required quality of electricity in case of deep voltage drops and especially during power outages. Uninterruptible power systems, as a rule, solve almost the whole complex of problems associated with low quality of electricity and interruptions in power supply, but they are expensive and their use is justified for the most demanding consumers, for whom uninterrupted and high-quality power supply is an essential condition for their functioning (for example, data centers, telecommunications companies, etc.)

The target market for technical means of improving the quality of electricity is segmented by the category of electricity consumers, which are the third, second, first and special categories.

Consumers of the third and second categories as a rule need to protect their power-consuming installations from poor-quality power supplies, but in most cases do not have a budget for their installation. The use of devices such as UPC could protect their equipment from failure in case of emergency. Network organizations could provide comprehensive protection for their networks, but in most cases they have no direct interest in this, since Russia does not have any significant sanctions for the supply of low-quality electricity. Therefore, consumers are forced to protect their equipment individually, selectively setting protection for the most sensitive equipment. As a rule, they use low-voltage protective devices. Such consumers can be equipped with UPC only in certain cases.

Consumers of the first category with significant connected power need redundancy, since voltage unbalance, short-term dips and interruptions in power supply lead to the shutdown of technological processes. Oil-producing and oil-pumping enterprises represent one of the most promising target segments of consumers, since they are often connected to “weak” or local networks in remote regions (Siberia), in which quality problems are especially sensitive. Also, these enterprises suffer the most significant losses due to poor-quality power supply, but have stable solvency. In Siberian regions, power is supplied to oil production and transportation facilities from electric networks supplying traction substations of the BAM and the Trans-Siberian Railway, which are sources of voltage asymmetry and non-sinusoidality.

Table 2. Technical means of improving the quality of electricity [9]

No.	Devices	Types of glitches												
		Reactive power	Power sagging	Interruptions			Ejections	Lopes	Over-voltage	Low-voltage	Harmonic distortions	Lope distortions	Fluctuations	Voltage asymmetry
				Short	Semi	Long								
1	Voltage regulator							+						
2	Battery power storage system		+	+	+	+	+	+	+	+			+	
3	Reactive Power Static Compensator (STATCOM)	+						+	+	+			+	
4	Capacitor bank parallel connection	+		+						+			+	
5	Dynamic source of uninterruptible power supply		+	+	+	+	+	+	+	+			+	
6	Dynamic device of voltage recovery		+				+	+					+	
7	Power factor corrector								+	+	+			
8	Superconducting magnetic energy system		+	+			+	+	+	+			+	
9	Switch of output transformer windings		+				+		+	+				
10	Solid state / mechanical transmission key		+	+			+							
11	Solid state breaker			+										
12	Static thyristor reactive power compensator STC	+	+				+		+	+			+	
13	Capacitor bank thyristor controlled							+		+				
14	Uninterruptable power source		+	+	+	+	+		+	+				
15	Active Power Filter / Resonance Filter							+			+	+		
16	**Universal Electric Power Converter (UPC)**	+	+	+							+		+	+

For this category of consumers, it seems possible to reduce the frequency of short-term power outages (to increase the reliability of power supply) by several times. In fact, interruptions can occur only with unsuccessful switching of feeders.

An additional advantage for consumers of this category is the UPC functionality for reactive power compensation and elimination of higher harmonics.

Thus, consumers of the first category can be considered the most promising segment for the sale of UPC. The market size of UPC consumers is determined by the economic effect of its use.

Consumers of a special category are not interested in using UPC, since they are usually equipped with uninterruptible power systems, which have wider functionality compared to UPC. Table 3 shows the gradation of the degree of criticality of the quality of electricity by categories of consumers.

Table 3. The interest of different categories of consumers in the application of the UPC

Consumers of 2 and 3 category	Consumers of 1 category	Consumers of special category
Economy class housing, small enterprises and organizations that do not have a continuous technological cycle, agricultural farms.	Large industrial consumers with a continuous technological cycle, utilities, social facilities	Data centers, communication and computer equipment, surgical departments of hospitals, luxury housing, etc.
Not interested in UPC	Interested in UPC	Not interested in UPC

Thus, consumers for whom the UPC installation appears to be cost-effective can be determined on the basis of indicators of the quality of power supply in the region of location, the specific amount of damage from interruptions in power supply, connected load.

V. MARKETING RESEARCH RESULTS

Based on the calculations given in the Feasibility Study [1], consumer groups were identified in each region for which the UPC installation is cost-effective. The capacity of such consumers by segment reflects, to a first approximation, the capacity of the Russian UPC market. Based on the calculations, the total volume of the domestic market is estimated at 1,680 units. with a total capacity of 5,040 MVA. Possible sales volume - 956.6 million USD.

It can be assumed that in the first place UPC will be acquired by enterprises that have the greatest savings potential from the use of this device. To select priority groups of potential UPC consumers, it was shown that the marketing campaign should primarily be aimed at oil refineries in the Perm Territory, as well as at chemical enterprises in the Vologda, Kirov, Nizhny Novgorod, Tula and Volgograd Regions. It can also be concluded that the chemical industry enterprises are most interested in UPC, which should be taken into account in terms of sales.

The UPC sales plan drawn up on the basis of the analysis of the calculation results is presented in Table 4.

Table 4. UPC sales plan

Consumer segments	Quantity of saled UPC	Total power of UPC	Sales volume
	pieces	MVA	Th. USD
Chemical industry	1 074	3 222	612 032
Oil refining	573	1 719	326 261
Pharmaceutics plants	33	99	18 333
Итого:	1 680	5 040	956 626

The consumers of electricity shown in Table 4 mainly relate to the first category of reliability of power supply.

When forming a marketing policy, it is advisable to use a well-known set of marketing efforts in relation to innovative systems such as UPC. These include:

- set of information events - publishing articles in specialized magazines, speaking at conferences, development presentations at thematic exhibitions;
- formation of a specialized energy audit unit to conduct feasibility studies in relation to the specifics of specific industries.

Another equally important aspect of promoting the development of UPC is the use of its additional technical advantages associated with the ability to protect networks and other consumers from disturbances arising from the operation of specific electrical equipment of certain enterprises, mainly in conditions of “weak” and decentralized networks, as noted above. Currently, when operating electrical equipment of such enterprises, nearby consumers suffer, and the "culprits" of these disturbances themselves do not bear real responsibility for this. The tasks of the project company will include lobbying for laws and technical regulations requiring the installation of systems for protecting networks from reactive power, higher harmonics, voltage unbalance, and the deterioration of other indicators of the quality of electric energy by energy-intensive enterprises.

To assess the prospects for foreign sales of UPC, it should be borne in mind that, compared with the Russian energy system, the networks of European countries, the USA and other countries are more reliable, the quality of power supply in them is at a much higher level. The number of power outages in them is about an order of magnitude lower compared to the UNEG of Russia. Therefore, despite the high solvent demand from the enterprises of these countries, the prospects for the implementation of the UPC in this segment are quite limited. Potential customers may be enterprises interested in mitigating the negative impact of their own equipment on the network, in reactive power compensation, etc.

The markets of developing countries may be more interesting in terms of promoting development, since the quality of electricity supply in them can be comparable with the Russian one. However, it can be assumed that solvent demand in them may be limited. Those interested in acquiring a UPC may be primarily the factories of transnational corporations located in these countries. Figure 3 shows, as an example, the distribution of ASEAN countries by the integrated indicator of the quality of electricity supply [10]. From the given values it follows that some of the countries have extremely low quality of electricity and may be potentially interesting for the development development.

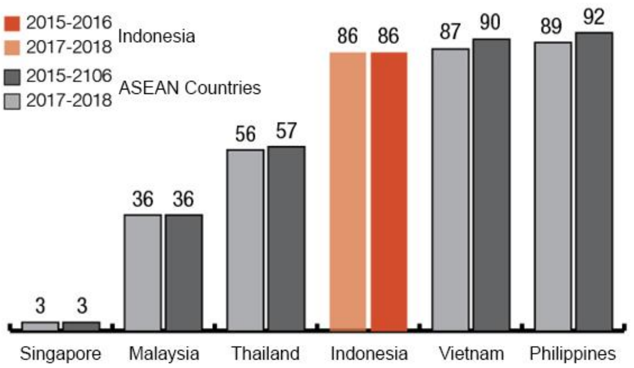

Fig. 3. Distribution of ASEAN countries by integrated indicator of the quality of electricity supply (numbers indicate the number of places occupied by countries according to the indicator in the world)

VI. CONCLUSIONS

1. UPC is a device that allows the consumer to improve the quality of electricity consumed, as well as mitigate the negative impact that he himself can have on the network.

2. The device in terms of functionality occupies an intermediate position between equipment for improving the quality of electricity and uninterruptible power systems.

3. Consumers of the 1st category of reliability of power supply, for whom the device can improve the quality of power supply, and also exclude short-term power outages associated with switching the load between the supply feeders, are most interested in applying the UPC.

4. Consumers interested in using UPC are determined by assessing the damage that they incur as a result of poor-quality power supply and power outages. Corresponding calculations were performed as part of this study; segmentation of potential device consumers was performed by regions and types of enterprises.

5. It is noted that the most interested consumers will be the chemical, oil refining and pharmaceutical industries, the most promising regions for the introduction of UPC are Volgograd, Tula, Nizhny Novgorod, Yaroslavl, Kirov regions (chemical production) and Perm Territory (oil refining)

6. Estimated potential volume of the domestic market - 1680 pcs. devices with a total capacity of 5040 MVA. In monetary terms, the market volume is estimated at 956 625.7 thousand USD.

7. It is shown that the markets of developed countries may be less promising for development compared to the domestic market due to the higher quality of power supply in centralized power grids. Promising may be access to the markets of developing countries.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Education and Science of Russia (agreement No. 14.604.21.0178, unique identifier of project is RFMEFI60417X0178).

REFERENCES

[1] Buzoverov E A, Varaksin A Yu, Denshchikov K K. Ensuring the Quality of Power Supply to Industrial Enterprises Using Universal Power Converters. IJERT. 2019; in press.

[2] Denshchikov K K, Varaksin A Yu. Hybrid Technologies for Creating Energy Accumulation Systems. International Scientific Journal for Alternative Energy and Ecology. 2019;(07–09):106–115.

[3] Denshchikov K K. Stacked Supercapacitors of New Generation. International Scientific Journal for Alternative Energy and Ecology. 2019;(07–09):97–105.

[4] Apraksin M A, Mineev A V. Improving the Quality of Electricity in the Power Supply System of Drilling Rig Drives. Mountain Information and Analytical Bulletin. 2012.

[5] Zhezhelenko I V, Saenko Yu L, Gorpinich A V. Reliability Assessment of Electrical Equipment with Reduced Power Quality. News in the Electric Power Industry. 2006;(6):13–17.

[6] Matinyan A M. Evaluation of the Potential for Increasing the Efficiency of Using STK for Voltage Balancing on the Example of NPS-21 Skovorodino. Electric Stations. 2019;(2):2–32.

[7] PAN European LPQI power quality survey // Proceedings of 19th International Conference on Electricity Distribution (CIRED 2007). – Vienna, 2007.

[8] Economic Framework for Power Quality: TB 467 2011 / CIGRE Publication, 2011. – 151 p.

[9] Pérez N L., Donsión M P. Technical Methods for the Prevention and Correction of Voltage Sags and Short Interruptions inside the Industrial Plants and in the Distribution Networks // International Conference on Renewable Energy and Power Quality (ICREPQ'03), 2003.

[10] Indonesia's Infrastructure: Successes and Hurdles. So, what's next? URL: http://www.constructionplusasia.com/id/indonesias-infrastructure-successes-hurdles-whats-next