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Long-range Concept for Improving the Quality of Electric Power in the Public Utility Line, by Applying DC Voltage Energy Distribution

Miklós HORVÁTH, József BORKA

Power Electronics Department, Computer and Automation Research Institute, HAS, Hungary

***Summary*: The concept considers the solution of problems as follows: the rational improvement of the quality of electric power in public utility line and the energy saving of DC electric energy distribution, furthermore, the connection of the environment-friendly, local, alternative energy sources to the electric energy system. The development of a reference system for the elaboration and realisation of the suggestion during a long period would be important, which makes the solution of foreseen and unforeseen problems possible. The paper outlines the layout, the advantages and risk factors of the system proposed.**

Key words:
power quality
power converters
energy distribution

1. INTRODUCTION

In our days AC networks provide energy distribution for industrial and domestic consumers, at the same time, the electronic consumers of increasing number require DC voltage. Network pollution in the local network increases due to using traditional rectifiers instead of "network-friendly" ones. In the interest of reducing the network pollution, more and more standards are initiated. To comply with the standards the producers are obliged to build "network-friendly" input circuits in most electronic equipment. This solution requires extra cost, furthermore, increases the weight and outer dimension of the equipment. In the long-run larger local object having only one common "network friendly" rectifier for providing DC voltage seems to be a more economical solution. DC voltage can be used directly or by applying further energy converters for supplying the consumers. A lot of other possibilities come up, namely, temporary energy storage, the simple interconnection of energy sources, recuperation into the line, the elimination of robust line transformers. Knowing the HVDC and MVDC energy distribution systems, the long-range application of LVDC (400-600 VDC) energy distribution seems to be favourable for supplying office buildings, workshops, small factories, medical and educational institutions, etc. or some of their parts in the lower power range (10-100 kW).

Before the description of the concept relating to the rational improvement of electric network, we summarise the key-issues regarding production, distribution and consumption of electric energy, furthermore, network quality.

1.1. Electric energy available

The growing demand for energy, the environmental pollution and the shrinking energy resources produce a formidable Trilemma with deepening conflict, which is one of the biggest challenges to human beings. In this relation, the role of every environment-friendly, economic and feasible energy generation and saving method is highly appreciated, especially if the most valuable source of energy is concerned.

1.2. Environment-friendly, alternative energy sources in systems

Nowadays electric energy of three-phase AC voltage system of 50/60 Hz supplies consumers through the distribution network. The environment-friendly, alternative energy producers must be taken into account the above when transferring electric energy for the network. The alternative energy producers are to provide energy for local consumers in the network, therefore, the connection of local energy consumers to the line is inevitable. If the local consumers do not make use of all the produced energy, it will be recuperated into the network. The connection to three-phase lines has numerous disadvantages. The energy provided by alternative energy producers must be converted into three-phase AC electric energy if it is originally different [1], [2]. Before connecting the alternative energy producers to the line, the correspondence to the frequency, phase and amplitude must be observed. The latter is called synchronising condition. After the interconnecting the producers, the synchronising conditions are to be maintained, meanwhile, the energy transfer is to be controlled with high accuracy. For solving all the above, a fast and precise control is necessary.

Since some of the environment-friendly, alternative energy producers (wind and wastage energy sources, water turbines, etc.) provide AC energy, while some others DC energy, the problem is complicated. The parameters and the quantity of the produced energy vary in a large-scale. Some kind of intermediate energy storage unit (accumulator set, fuel cells, ultra capacitor set) is used for ensuring the safe and smooth energy transfer. As the next step, the energy is converted into three-phase AC energy system by another unit. Consequently, two energy converters are necessary, one preceding the energy storage unit and one succeeding it [2].

1.3. Problems on the quality of electric energy supply

For consumers using electric energy, the quality of products and services, the safe information change and retention, the adequate operation of therapeutic equipment are highly influenced by the quality of electric energy supply. The high quality of electric energy would be ensured by continually having the network energy in our disposal, furthermore, if the waveform of the voltage in all the three phases were of same amplitude, symmetrical sinusoidal, and the values of the amplitude and frequency were constant. The quality of electric energy at the consumer side is highly influenced by the operation of energy producers, the natural environment of the line system, furthermore, the detrimental interaction of consumers operating on the same line. The line parameters are not ideal in the practice, therefore, strict standards specify the still possible deviations of parameters in the interest of preserving the line quality [3]. Due to the unexpected breakdowns and natural phenomena (lighting flash, windstorm, icing, etc.), furthermore, the line reaction of consumers, the values of parameters determining the line quality are deteriorated in a large-scale.

The deterioration in line quality can be measured in case the adequate measuring instruments, transmitting systems ensuring the data storage for further data processing are at our disposal. Besides, measurement methods of high precision suitable for determining the effective value and power are necessary. Nowadays, up-to-date sensor-, digital technique- and computer devices are available but those are not applied widely. The exact dimensioning of any equipment of high reliability and long lifetime is problematic in case the real effective values are unknown.

The measurement and control of parameters determining the line quality is a common interest of energy producers and consumers. Energy producers are responsible for providing the smooth energy supply, while consumers must not pollute the common energy distribution lines. In the ideal case all the consumers would need current of sinusoidal waveform with the same amplitude and phase in three-phase voltage system, which is considered ideal resistive load. In reality the waveform of loading current of consumers differs significantly from this case, what is more, the loading symmetry does not come true either.

1.4. The characteristic types of network pollution

1.4.1. High-frequency environment pollution

Network pollution is similar to environmental pollution but it is an invisible phenomenon. Electric energy distribution line can pollute human surroundings if the consumers connected to the line have significant power consumption of high harmonic content. In this case the electromagnetic radiation of network wires may disturb the operation of the telecommunication facilities and therapeutic apparatuses. Furthermore, the radiation may have serious effect on human organism directly. The standard relating to EMC (Electro Magnetic Compatibility) refers for cases like this [4]. Following this standard is important because the disturbing effects make the usage and operation of up-to-date equipment impossible, but they may have impact on social coexistence and life quality, as well.

The phenomena related to the EMC display their effect in very high frequency range. Line impedance significantly decreases the high frequency components superimposed to line voltage, because they are far from the location of the source of disturbance. That is why the EMC phenomena do not significantly influence the quality of energy supply. On the other hand, the disturbances in the low frequency range influence the quality. Consumers generate low frequency disturbances in the form of harmonics, see later Figures 1. and 2.a., b. They may cause a significant deterioration in line quality, efficiency and energy transfer capacity, furthermore, the loading of wires, etc.

1.4.2. Waveform distortion

The effect of upper harmonics of lower ordinal number results in a significant waveform distortion of current. For this reason, the effective values of current in the wires and coil of the transformers significantly increase, consequently, the heat effects in the wires, fuses and circuit breakers increase in squares, as well. Due to the above, over-current protective apparatuses will switch off at lower fundamental harmonic current, thus, the energy transfer capacity of the line decreases.

Due to the voltage drops on the impedance of network wires, the waveform of line voltage becomes deformed on the effect of the distorted current waveform, the upper harmonic content increases. This way, the other equipment connected to the common line is supplied by distorted voltage. As a consequence of the above the damaging effects, e.g., overheating, power decrease, additional upper harmonic production, etc. may come about during the operation of the equipment. A typical example for this interaction is phase correcting condenser, which produces current rich in upper harmonics to the effect of the line voltage of high upper harmonic content, thus the condenser, too, also pollutes the line and gets overheated.

1.5. Consumer effects inducing the quality deterioration of energy supply

Generally, a three-phase, four-wire system (phases L1, L2, L3, respectively, zero line N) supplies one- and three-phase energy consumers. If it is possible the loading distribution among the phases should be equal. In this case no current flows in the zero line of a symmetrically loaded three-phase network, since the algebraic sum of sinusoidal phase currents is zero in every moment. But the current equilibrium overbalances at asymmetrical resistive load also in that case if the current waveform is sinusoidal. In the case of phase current full of upper harmonics, the current loading of zero line significantly increases. All the upper harmonic current of well-defined ordinal number flows in the zero line in addition to the fundamental harmonic balancing current. The zero order components of all the phase current harmonics divisible by three are in phase, this is the cause why their sum together with the fundamental balancing current also flows in the zero line [5]. The effective value of current in the neutral line may be higher than the rated one in some cases. If the neutral line were broken to the effect of overloading, the consequences would be extremely detrimental. Namely, in this case the voltage on the consumers operating on the same phase line will be much higher than the nominal. This can results in the deterioration of the equipment connected to the network if an appropriate protective apparatus is not at disposal. Enlarging the cross-section of wires may decrease the overloading of the available neutral line. Instead of enlargement, we may use some parallel wires in the interest of decreasing the skin effect.

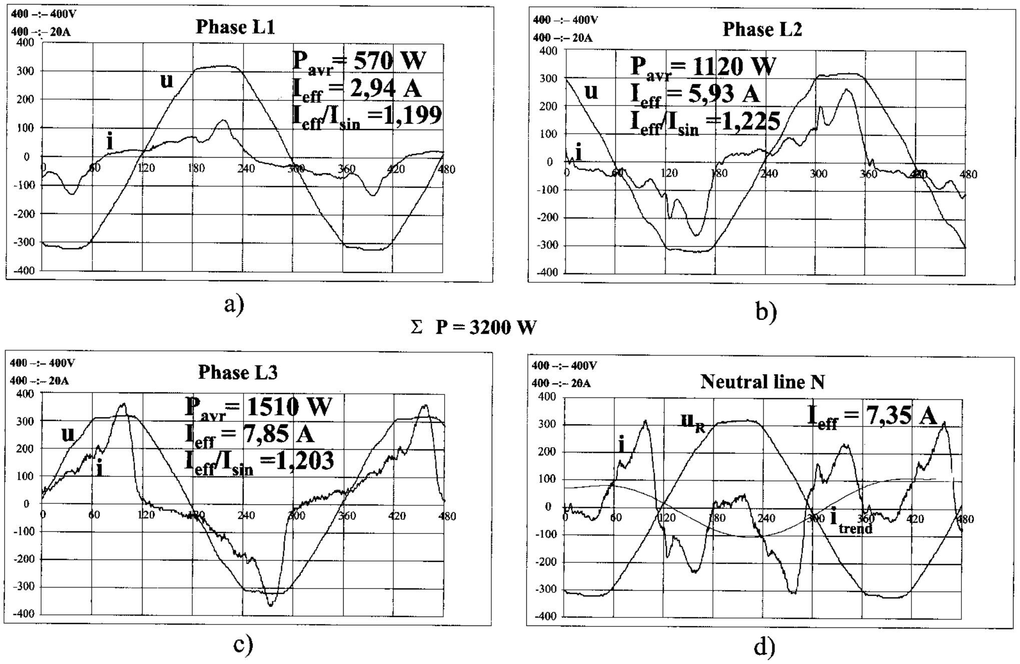
The problem relating to the phase and neutral lines is discussed in details because it is the decisive factor of network quality. As we stated earlier, the effective value of current in the phase and neutral lines significantly depends on the harmonic content of power consumption of consumers on the network. If the system designer does not exactly know the concerning data, he is not able to determine the accurate cross-section of phase and neutral lines. Especially the neutral line is critical. In every network system it is important to control the characteristics of the current drain of the equipment so that the new consumers should not further deteriorate the network quality.

For the illustration of the above, the oscillogram pictures of current and voltage waveforms of a four-wire, three-phase AC line system supplying a computer laboratory can be seen in Figure 1., L1, L2, and L3 are the phase lines and N the neutral line. Figures 1.a., 1.b., and 1.c. show the line current and the phase voltage, respectively. Generally, one-phase consumers draw distorted current from the network. This current differs from the sinusoidal waveform and is rich in upper harmonics. Furthermore, the load distribution among the phases is asymmetrical. I_{eff} denotes the effective value of line currents, while I_{sin} denotes the appropriate fundamental current. The quotient I_{eff}/I_{sin} shows the rate of the real and ideal effective current, which is the reciprocal value of the distortion factor μ according to the definition in [5]. Also the reaction of the distorted current to the network can be seen on the voltage waveform. Figure 1.d. shows the current in the zero line N and the phase voltage L1. The presence of current of third harmonics is worth of attention. The trend-line of current i_{trend} shows the presence of the fundamental harmonic balancing current. The effective value of current in the neutral line is almost the same as in the phase line of largest load.

2. CONSUMERS PRODUCING NETWORK POLLUTION

It is known that only resistive load has no detrimental effect to the quality of a line system if we disregard the transient phenomena of step-change load variation at switch on and off [6]. The current waveform of resistive load is proportional to the waveform of line voltage in every moment, therefore, the power consumption from the line system is active. In the case of inductive and capacitive loads the proportionality among the momentary values of voltage and current does not hold, thus detrimental effects come about on the network. Reactive power consumption will result, which increases the current in the line. This is only useful

Fig. 1. Network loads in computer rooms, 3x400/230V, and 50Hz



if all the reactive current (inductive and capacitive) can compensate each other, and the resulting current loading the network will be pure resistive. The capacitive and inductive load is linear if the value of capacitance and inductance does not depend on the magnitude of voltage, current, respectively. The core inductive elements cannot be considered linear in all cases, since their saturation inclination can cause some kind of distortion. This phenomenon can be especially well observed on the current waveform of the under-dimensioned transformer in no-load condition. The distorted current of this kind of non-linearity can be neglected by comparing it with the nominal current, resulting in an insignificant network reaction.

Especially, electronic equipment imply non-linear load, their network reaction and pollution are significant, causing serious problems nowadays. In the circle of the industrial consumers the above process started with the application of mercury rectifiers. Later this detrimental process has deepened by deploying thyristor technique. Nowadays, all consumers requiring control (electric drives, power supplies, energy converters, etc.) imply non-linear load in the era of up-to-date power electronic equipment with MOSFET and IGBT [7]. The general use of electronic equipment has been accelerated in the field of public consumers, thus the network pollution will be higher and higher.

The non-linear quality of electronic equipment is significantly influenced by the characters of their operation modes. In the case of equipment of higher power range, designers prefer continuous conduction operation mode. This latter means that the equipment loads the network with square waveform current of steep leading edge, and phase displacement may be arbitrary, as well. This kind of current has significant upper harmonic content, and its reactive power consumption (e.g. controlled converters with thyristors) is significant. Another group of electronic equipment works in discontinuous operation mode, characterised by the fact that no loading current flows in a section of the line period. Current is drawn in one section of supply voltage period when the input voltage exceeds that of the smoothing capacitor (see later, Figure 2.). It is easy to see that the same active power consumption in a discontinuous operation mode within a shorter line period can be attained by a current peak much higher than that of the ideal sinusoidal case. Consequently, in discontinuous operation mode the consumer loads the network with an impulse-like current of high upper harmonic content [7]. This kind of equipment (computer devices, entertainment electronics, household appliances, etc.) is used in the lower power range. In the majority of practical cases a lot of equipment operate from the same phase line, and by this they evoke substantial network pollution. In consequence of the above, the waveform of line voltage is significantly distorted due to the voltage drop on the line impedance. The high current peaks cause some clipping distortion in line voltage, its up and down edge become wavy and line voltage is full of upper harmonics. Figure 2. (See later) shows the oscillogram pictures of voltage and current of a compact fluorescent lamp and a computer polluting the network. The effective value of current in the compact fluorescent lamp is 1.85-times, and in the computer is 1.53-times larger than that of the ideal sinusoidal current.

3. TRADITIONAL SOLUTIONS FOR REDUCING NETWORK POLLUTION AND JOINT PHENOMENA

The usual means for reactive power compensation and network pollution reduction are condensers and passive filters. The phase correcting condensers generate zero phase displacement between line voltage and fundamental harmonic current. But the presence of the condensers between the connecting points of phase correcting condensers and the feed points of consumers increases the amplitude of current upper harmonics [6], consequently those result in high voltage drop in this line section. By this not only the network polluting effect increases but the current upper harmonics flow across the phase correcting condenser, which may result in the overheating of the condenser and also in its breakdown. For eliminating the damaging effects, a choke is connected in series with the phase correcting condenser, which cannot result in perceivable phase displacement on the fundamental harmonic frequency but significantly mitigate the current upper harmonics. But the circuit built in the above manner can result in a resonant condition on the effect of line transient. This fact further increases line disturbances. Similar situations may come about on the effect of passive, upper harmonic filters since they consist of LC resonant circuits tuned to the harmonic frequencies of given ordinal number. The harmonic filters, too, increase the amplitude of current upper harmonics, furthermore, the radiating network- and environmental pollution.

4. ELECTRONIC DEVICES FOR IMPROVING THE NETWORK QUALITY IN AC LINE SYSTEM

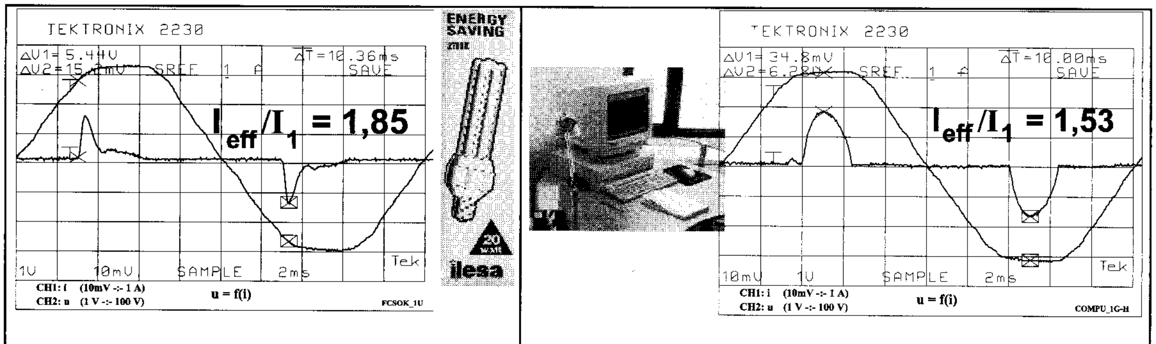
Uninterruptible power supplies (UPS), active filters and single „network-friendly" rectifiers are ranked into active, electronic, protective devices decreasing network pollution and consumer reaction.

UPS stores energy for supplying AC consumers in an accumulator set, then the DC energy in the accumulator set is converted to AC energy similar to that of the AC line system, by using an inverter. The current drain rich in harmonics on the inverter output has no immediate effect on the line system because the accumulator set separates the two systems. Naturally, the interaction of consumers on the same network remains unchanged. The energy producers are freed from the network reaction of consumers if the battery charger draws upper harmonic-free current from the line. This is true if the battery charger is of „network-friendly" character (see later). UPS-s can also ensure the energy supply of consumers if the line system drops-out temporarily. The voltage transients on the line system cannot effect to the consumers due to the separating role of the accumulator set. The power range of UPS-s is restricted. Generally, they are used for the safe energy supply of consumers of vital importance, their role in eliminating network pollution is secondary.

The role of active filters is decisively to reduce network pollution. The active filters consist of power electronic converters. Their task is solved by the continuous analysis of the current drain of consumer groups operating on the given line system. If the waveform of current differs from the voltage waveform, the active filters provide a current waveform to the terminals of consumers that the line current should be in phase and proportional to the line voltage [8]. This way the consumers will be of resistive character. This effect can be brought about by a power electronic energy converter of very fast reaction time. Their power range is, practically, not restricted. Their application is effectual, first of all, for eliminating the network pollution of high power consumers.

At present, the majority of electronic appliances connecting directly to the AC public utility line does not utilise the AC energy directly but require filtered DC current or voltage. The DC energy is stored in a condenser of high capacitance value. The electric quantities required for the appliances are produced from the filtered, intermediate DC voltage. Consumers like these are all the computer devices, entertainment electronics, medical and other instruments, up-to-date fluorescent and controllable lamps, etc. The network pollution of highest degree comes about in course of rectification if a traditional diode rectifier supplies the buffer condenser operating as an energy storage unit. Current drain from the line is of impulse-like as it was earlier stated, see Figures 2.a. and b.

It is possible to insert an electronic circuit between the rectifier and energy storage unit that gives pure resistive character to the consumer regarding the line terminals. Consequently, the current of consumer with a good approximation will be proportional to the line voltage in every moment. The rectifier of the above character is named „network-friendly" rectifier or pre-converter [6], [7].



a. Network polluting fluorescent lamp

b. Computer

Fig. 2. The oscillogram pictures of voltage and current of electronic equipment

„Network-friendly" rectifiers are one of the most up-to-date products of power electronics. It is the most effective device for the elimination of network pollution because its operation provides the criterion characteristic to the resistive load. Consequently, the current drain from the line is proportional to the line voltage in every moment. Nowadays, the majority of electronic appliances is equipped with „network-friendly" rectifiers in the EU. This is required by the standards valid for improving network quality. „Network-friendly" rectifiers are frequently named pre-converters or PFC-s (Power Factor Corrector), as well.

In the practice one- and bi-directional „network-friendly" rectifiers, respectively, converters are used. These pre-converters as separate units can be built in all electronic appliances in small and medium power range. Figure 3.a. illustrates the oscillogram pictures of line voltage and current of welding equipment with a traditional rectifier, while Figure 3.b. shows the pictures of welding equipment with a „network-friendly" one. The difference is trivial!

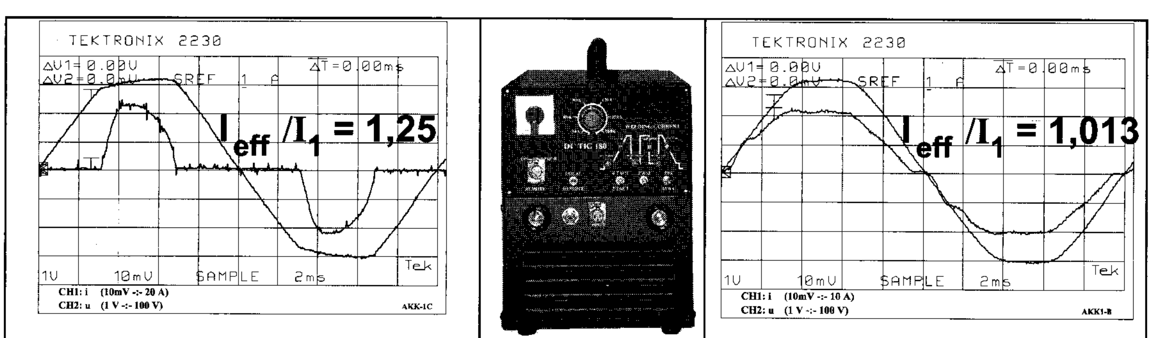
5. DISADVANTAGES FROM AC ENERGY DISTRIBUTION AND THE UP-TO-DATE ELECTRONIC CONSUMERS

The extension of electronic consumers connecting to the public utility line is a decisive trend all over the world. The majority of electronic consumers convert the electric quantity in course of operation from intermediate DC voltage. Consumers operating directly on AC voltage system gradually become obsolete. Simple asynchronous motor drives will be exchanged by up-to-date electronic solutions. The operation and structure of simple electric motors will be adapted to the means of electronics. The number of electric motors connecting directly to the public utility line decreases in everyday applications. That is why, the symmetrical, sinusoidal waveform of three-phase line voltage is not so decisive for the operation of synchronous and asynchronous motor [9]. The distorted current waveform of consumers deviating from sinus is detrimental due to high effective value. This means that the active energy transfer capacity of the network decreases, the loss increases in the line impedance, furthermore, it is problematic to exactly measure the consumed active energy.

The growing number of electronic consumers of non-linear character and their respectively extending power result in numerous, disturbing technical consequences in the AC line. Their effects are not simple to cease. Network pollution, together with numerous detrimental qualities, plays a leading role.

It is trivial that in the interest of eliminating network pollution the most effective measure is to realise the electronic equipment with pure resistive character. „Network-friendly" rectifiers

Fig. 3. The oscillogram pictures of line voltage and current of welding equipment



a. Traditional rectifier

b. "Network-friendly" rectifier

and converters built in all consumers would provide a most up-to-date device for the above. Namely, each single „network-friendly" rectifier or converter eliminates the network reaction of the consumer in question, just like network pollution on common distribution lines. A similar effect may be attained by active filters but they are so expensive that their insertion in a line section is costly. In this case the interaction of single consumers may prevail due to the impedance of common line sections among the active filters.

Single „network-friendly" rectifiers or converters in a power range from some hundred W up to 10-20 kW are frequently applied for supplying further electronic energy converters. But their setting-in may evoke a price surplus from 15% up to 80% depending on the power range and mode of energy transfer (one-or bi-directional). The efficiency of many „network-friendly" rectifiers of low power is significantly lower than that of a single one of high power. The paper tries to give answers to these questions.

6. RATIONAL DEVICE FOR IMPROVING NETWORK QUALITY

Based on our earlier experience, DC voltage energy distribution seems to be the most rational solution for eliminating the previously enumerated problems in connection with the public utility line in the long-range. This way a common, central, „network-friendly" rectifier or bi-directional converter would transform the AC voltage energy of line to DC voltage energy for a local consumer group chosen appropriately (Figure 4.).

The „network-friendly" rectifier (see Figure 4.) supplies DC distribution bus where the energy storage units (accumulator set, fuel cells, condenser set, etc.) and further energy converters (DC/AC inverter, AC/DC-rectifier, DC/DC-converter, DC/±DC-converter with polarity changer) are connected to. All the alternative energy sources belonging to the local consumers can also be connected to the common DC bus by applying appropriate energy converters.

Nowadays, DC voltage energy distribution systems on the present technical level can be realised in some fields and have numerous advantages. The most characteristic features are as follows:

- The system is appropriate for connecting other, local, energy sources (wind power plant, a power plant utilising waste energy, a solar power plant, etc) to energy distribution system with slight difficulties. The connection of local energy resources to the line in the case of AC voltage system is more

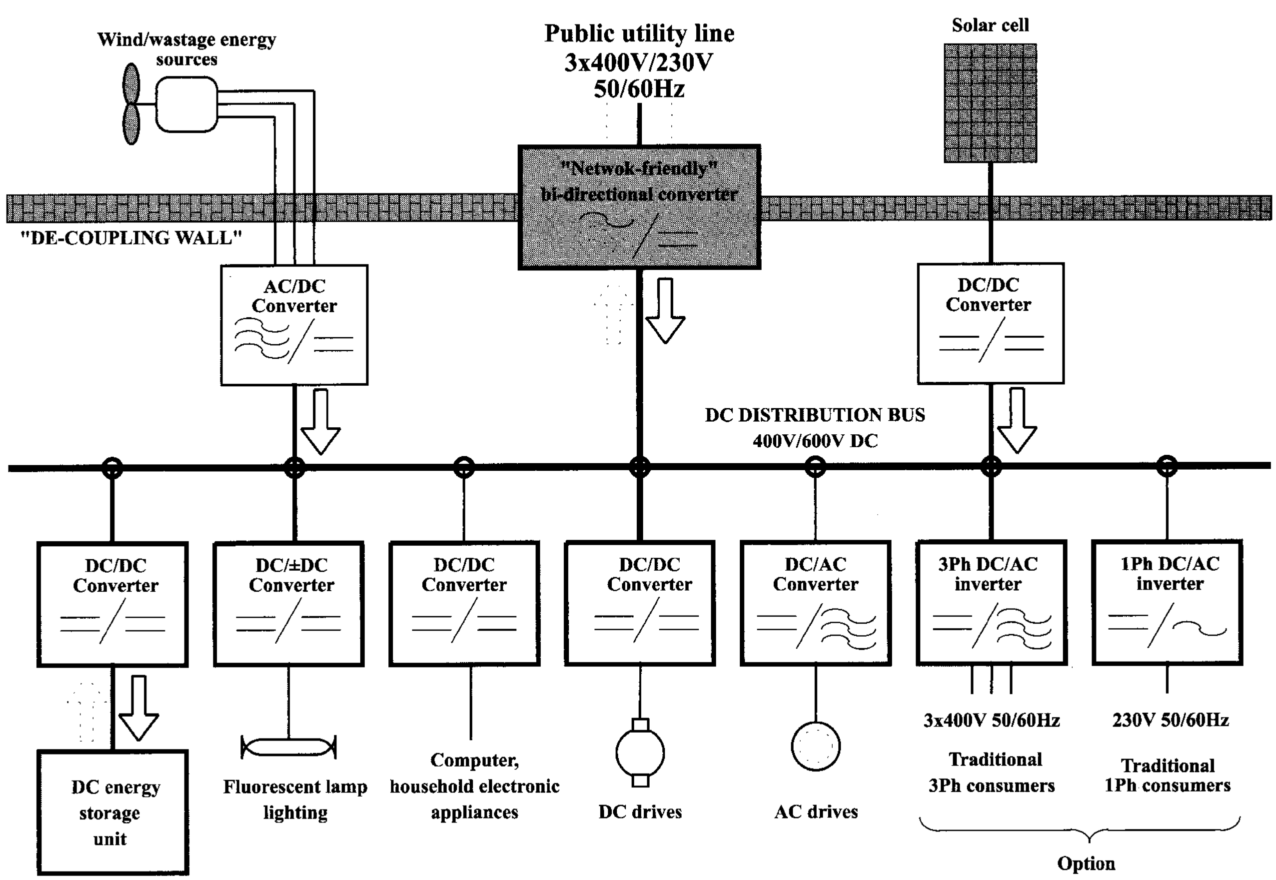


Fig. 4. The block-scheme of DC voltage energy distribution

complicated than that of the DC voltage system. The energy storage unit of DC distribution system can be used well for compensating the uneven energy production of alternative energy sources.

- If the central, "network-friendly" converter is appropriate for bi-directional energy flow, the unused energy can be recuperated into the AC line.
- The „network-friendly" rectifier or converter creates a „de-coupling wall" from the viewpoints of network reactions. The electric input quantities in phase with one another (see the line voltage and load current in Figure 3.b.) make the application of the phase compensating equipment and active filters unnecessary, furthermore, difficulties in measuring technical parameters are eliminated.
- The effective value of impulse-like current in the discontinuous conduction mode of equipment with a traditional rectifier (see Figures 2. and 3.a.) is larger by 30-35% than that of the equipment with a „network-friendly" rectifier with the same effective power. It follows from the above that energy producers can transport an energy surplus of 30-35% in the same line if the consumers in question are supplied by a central, common, „network-friendly" converter.
- In the case of a one-phase system the overload of zero wire caused by the upper harmonic is eliminated. In the case of a three-phase system the symmetrical load of the three-phase line is realised automatically and zero line is not necessary.
- The switch on and off of the controlled equipment do not result in significant over-voltage and over-current transients as a soft-start process takes place. This feature also greatly improves the quality of public utility lines.
- In the case of voltage dip or line breakdown the energy supply of the consumers of vital importance remains continuous if an accumulator set or other energy storage unit of appropriate power is connected to the DC bus. Thus the safety and quality of energy supply for the consumers improve.
- By applying a „network-friendly" rectifier, a remarkable energy saving is generated (e.g., at fluorescent lamp lighting the energy saving is 30% compared to the solution with traditional ballast) [11].
- In the case of DC voltage energy distribution it is not necessary to build in „network-friendly" rectifiers into the electronic consumers. By this, their outer dimension, weight and cost decrease considerably.
- The majority of electronic consumers with traditional or „network-friendly" rectifiers can be supplied from the DC bus. This property facilitates the smooth change from AC voltage energy supply to DC.
- The outer dimension and weight of inductive components (transformers, chokes, etc.) considerably decrease by applying DC/DC or DC/AC energy converters of high operating frequency. The robust transformers can be omitted [12].

The enumerated features facilitate to solve the numerous problems of AC voltage systems. All of the enumerated features can be considered as one-one „building block" in the interest of quality improvement of AC voltage energy supply. There is no doubt that DC energy distribution requires radical changes within the „de-coupling wall", which needs a long time. The total conversion would be a program of 10-15 years if the enumerated advantages of the system were proved. But for solving this task, we need a bulk of experience that we can have by establishing a well-considered and developed reference plant.

The outlined LVDC (LVDC = Low Voltage Direct Current) distribution system for public utility line can be considered of the latest type. At international conferences more and more lectures discuss the methods for preventing the network reaction, but up-to-now, the idea for local DC energy distribution has not been raised yet. The proposals for the elimination of network pollution cover individual solutions. In HVDC (High Voltage Direct Current) [13], [14] and MVDC (Medium Voltage Direct Current) [15] systems DC voltage energy transfer is applied from other viewpoints. The DC energy is converted into AC in both cases and AC energy supplies the consumers on the public utility line. The detrimental, network-polluting effect of consumers is not ceased. Lately, some patent descriptions [16], [17], [18] have discussed LVDC energy distribution systems within buildings, but these systems convert DC voltage into AC line voltage of 50-60 Hz, as well. This means that the line rectifiers of electronic consumers are not to be omitted.

7. THE SUGGESTED REFERENCE PLANT

The reference plant equipped with the necessary energy converters and other components may be an object for local DC voltage energy distribution. This solution, as a complete system, according to Figure 4., seems to be favourable for supplying office buildings, workshops, small factories, medical and educational institutions, etc. or some of their sections where the majority of consumers pollutes the public utility line significantly. The reference plant could serve for the demonstration of the attainable future and the advantageous features of DC voltage energy distribution systems. Furthermore, it gives a chance for testing any aspect of the system. They are as follows: the determination of optimal voltage level, parameters of energetics, energy saving, network reaction, operational safety, measuring technique, etc.

It is needless to emphasise that the outlined reference plant can be realised only in the co-operation of specialists working in different fields, e.g., power electronics, lighting systems, electric machines and drives, data acquisition and procession, network quality control and measurements, etc.

8. THE UTILISATION

In the above the novelty and advantages of the system are properly emphasised, furthermore, the numerous possibilities for the long-range utilisation are enumerated, as well. We consider that the general use of electronic consumers may result in the broad application of LVDC systems. This may evoke a significant change in electric energy distribution and consumption. Some publications show the trend in this direction [17], [18]. The operation of the reference plant shown in our paper may justify the advantages of LVDC distribution systems. All this may result in economical and environment-friendly energetic systems.

The participation of specialists in the development of equipment is required in the subsequent phase of work because the consumers have used the different electric devices exclusively for AC voltage application up-to-now. The suggested project demands the development of new products (e.g. DC electronic switches, distant control switches, circuit breakers, fuses, isolating switches, etc.), that may lead to a new innovation wave. The well-equipped reference plant in the operation can become the scene of a most versatile testing and developing work. This may be a suitable base for testing the new standards.

9. PRECEDENTS OF THE THEME

We started to deal with the above-discussed theme both theoretically and experimentally. The idea of the DC voltage energy distribution system for consumers on the public utility line is in course of granting the patent. The suggestion for establishing a reference plant comes from the above. The first paper in the theme was published in the Proceedings of International Electrical Drives and Power Electronic Conference (High-Tatras, Slovakia) in 2003 [6]. It was followed by a lecture at the EPE-PEMC'2004 Conference (Riga, Latvia) [7]. The next paper will discuss some details about the theme at the IEEE International Symposium on Industrial Electronics, ISIE'2005, in Dubrovnik, Croatia. Besides, numerous lectures were held in conferences in Hungary, and some papers in periodical reviews were published. The effect of the proposed project may be significant. We are looking forward to reactions.

10. THE RISKS OF THE SUGGESTED LVDC PROJECT

A great number of power electronic converters for the realisation of LVDC system is known in the practice, some of them can be bought on the market, and only few equipment is to be developed.

One of the most important points of the project is to develop control circuits for the „network-friendly" converter and alternative energy sources, furthermore, converters connecting to accumulator sets or other energy storage units. The charge and discharge of energy storage units have to be carried out in well-determined strokes. That is why the controlled current operation in the charging state and voltage stabilisation in the discharging state of energy supplying equipment („network-friendly" rectifiers or converters, energy converters of alternative energy sources) have to be realised. Besides, the recuperation of unused energy within the „de-coupling wall" of the alternative energy producers to the line has to be made possible if the „network-friendly" converter is suitable for bidirectional energy flow. The above tasks can be carried out without any difficulty.

The other problem regarding the reference plant is the analysis of the common operation of components and that of their interaction. The fact, that all components within the „de-coupling wall" are connected to the DC bus, creates very good filtering conditions for eliminating the low- and high frequency line reactions. The parallel DC wires have a filtering effect, as well. Their distributed capacitance considerably filters out the high frequency noises, their radiant magnetic field is low as the parallel wires deteriorate the interaction of magnetic fields. The filter condensers on the terminals of energy converters can eliminate the effect of low frequency disturbances and transient phenomena. Consequently, the interaction of equipment connected to the DC distribution line will not cause any problems. The accomplishment of exact measurements is a routine task for specialists.

The voltage level of DC distribution system requires a thorough consideration, but it is probable that the voltage level will be in the range of some hundred V. Probably, the DC voltage level in the case of one-phase and three-phase supplies will be different. The DC level in the range of 4-600 V seems to be the best solution. But on the DC voltage level of 4-600 V the connection of consumers to the line is problematic, requiring an appropriate development of the circuit breakers, isolating switches, fuses, etc. The available devices are not suitable for DC voltage of some hundred V. Nearly suitable devices are at our disposal for urban electric trams only. Presumably, they are not appropriate for application in the DC voltage distribution system.

A special property of electronic energy converters simplifies the situation, namely, they can be switched on and off by their control circuits, e.g., distant control switches (the stand-by work of air-conditioning equipment, TV sets, entertainment electronics, etc.). It is probable that developing semiconductor switches for the suggested system is required. The mechanical switches may not be applied because of striking of arc. The semiconductor switches can break a circuit without any problem and serve for the current limiting function. Keeping safety issues in mind, naturally, the fuses cannot be omitted, furthermore, it is necessary to apply suitable, mechanical switches for isolating purposes, as well. These devices have to be developed by specialists of the field concerned. In course of laboratory tests, the traditional measuring devices can be used with necessary precautions. Also the directives for the protective systems, factors of safety, shockproof problems have to be observed in the laboratory.

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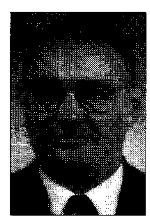

Miklós HORVÁTH
graduated at the Technical University of Budapest, Hungary, in 1960. His main research fields are as follows: Current Source Asynchronous Drives, Power Electronics, especially DC/DC Converters, High Power Factor Equipment. The number of his publications is 75; the number of patents is 24. He is a researcher at the Power Electronics Department, Computer and Automation Research Institute, Hungarian Academy of Sciences and a college lecturer. Mailing address: H-1111 Budapest, Kende u. 13-17, Hungary. Phone/Fax: 36-1-2796233/4667503, e-mail: mhorvath@sztaki.hu

Dr. József BORKA
received the B.Sc., M.Sc., and Ph.D. degrees in 1958, 1964 and 1981, respectively, at the Technical University of Budapest, Hungary. His main research fields are as follows: Line Commutated DC and AC Drives, Special Electrical Drives, SRM drives, High Power Factor Equipment. The number of his publications is 80; the number of patents is 16. He is the head of Power Electronics Department, Computer and Automation Research Institute, Hungarian Academy of Sciences. Mailing address: H-1111 Budapest, Kende u. 13-17, Hungary. Phone/Fax: 36-1-2796233/4667503, e-mail: jborka@sztaki.hu