04

SAFETY AND SECURITY

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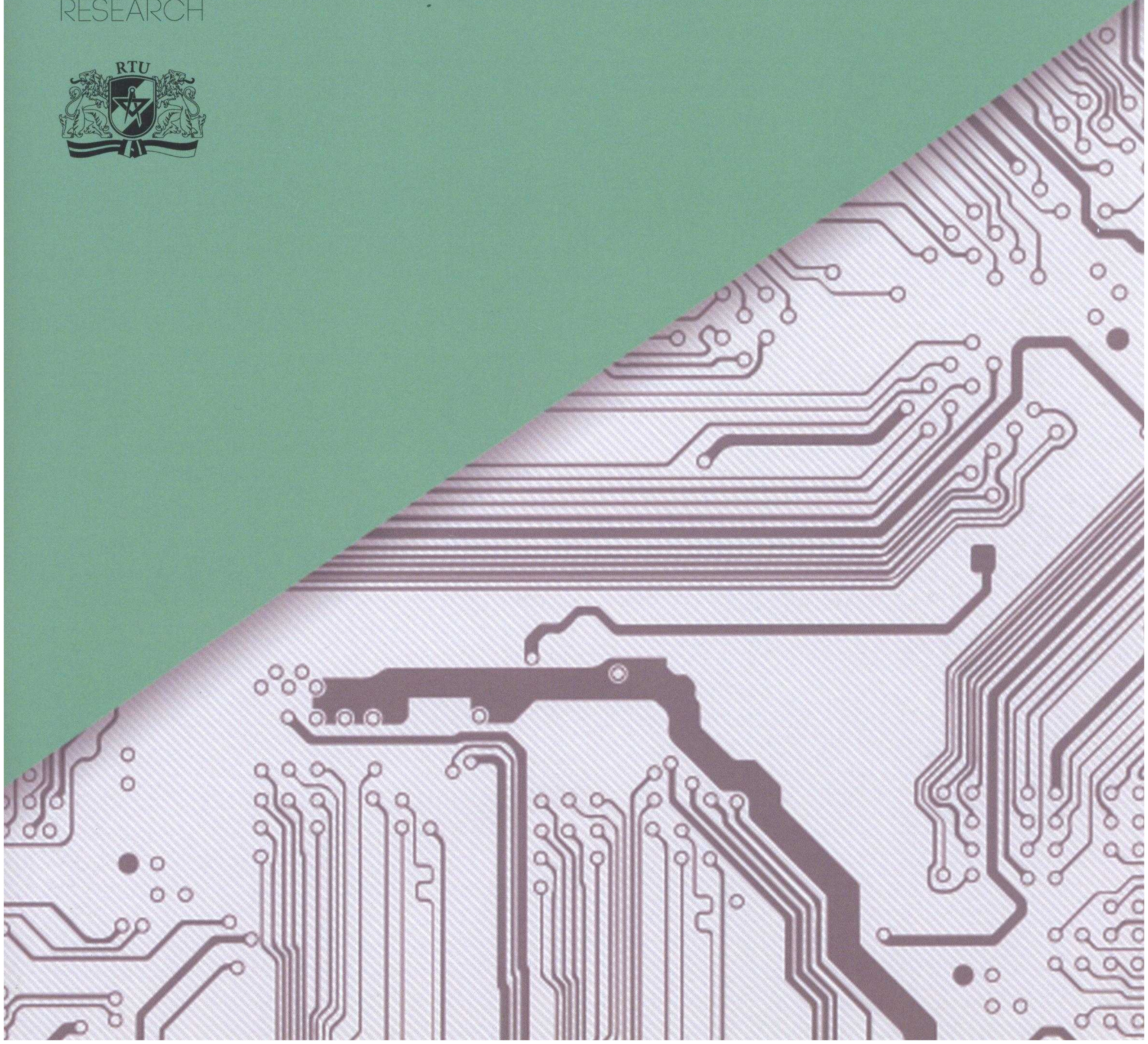
RESEARCH

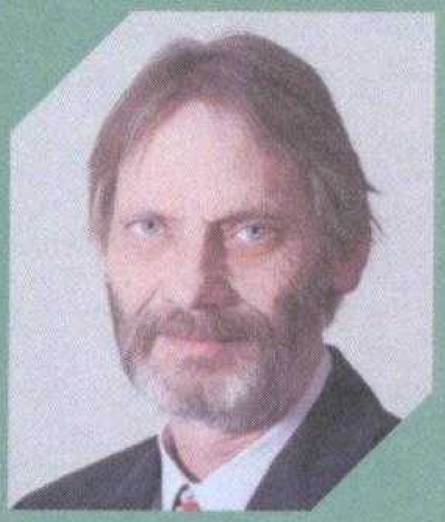
RTU



OUR CIVILIZATION ON ENERGY NEEDLE

Faculty *of Power and Electrical Engineering*

Institute *of Industrial Electronics and Electrical Engineering*



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INTRODUCTION

One man wakes up in the morning. The room is cold and dark. He tries to turn on the light but nothing happens. Nothing works at home at all – household devices, computer, TV – power supply is off.

Next decision is going to the supermarket but cannot get in – the doors do not open, the cash registers and bank machines look dead – no power supply.

He decides to move to other district of the city and sees that the cell phone does not work and the street lights are off and the traffic lights do not work - no power supply.

The car cannot be fueled by a simply reason that the electric pumps are off.

Doomsday would come because our civilization is fully based on electrical energy - we are sitting on the energy needle.

Electrical energy supply stability, safety and "always ON" are crucial for our civilization.

Electricity, as we know it, is a pure design and development of our civilization rooting back to 1750 when Benjamin Franklin developed a concept of electrical charge. During the last 250 years, we learn how to generate, transfer and use electrical energy and enjoy all advantages of electrically powered or driven devices.

And historically, today we have reached the point when some changes must be made in hundred year-old practice of energy generation and transfer, due to alternative energy generators (solar, wind) and growing energy storage possibilities.

CENTRALIZED VS DECENTRALIZED ELECTRICAL ENERGY GENERATION AND SUPPLY

Historically, the topology of the electric grid was based on large coal-, gas- and oil-fired power stations located close to the mines or wells, or close to railways, roads or ports for easy delivery.

Hydroelectric dams in mountain areas also strongly influenced the grid structure.

Nuclear power plants were located within availability of cooling water.

Besides, fossil fuel-fired power stations were initially very polluting and were located as far as economically practicable from population centres if the electricity distribution networks allowed it. Electricity grid reached the overwhelming majority of population in developed countries, with only outlying regional areas remaining "off-grid".

Supply of electricity, especially at peak times, often has a poor power quality and unstable parameters. Time after time it result in blackouts and power cuts.

Electric energy supply is also based on the needs of industry, heating, lighting and communication. Consumers demand ever-higher levels of reliability.

New power stations and transmission lines must be built to overcome the above problems.

Typically, a centralized grid can be described as "one generator – many consumers" system.

Development of renewable energy and other sources, such as solar (photovoltaic), wind, wave or energy harvesting, increasing possibilities of energy recuperation from mowing masses like braking tram or electric car, or slowing down robotic arm, change the existing concept to the concept of a smart grid – "many generators – many consumers".

AC VS DC ENERGY SUPPLY

Today the electrical energy transmission with few exceptions is mainly based on AC (alternating current) transmission, which was historically reasoned by the possibility to change the required voltage by electromagnetic devices - transformers, in order to compensate the voltage drop on transmission lines or change the voltage level from high voltage (lower current) to low voltage, e.g. in households, thus keeping the power on the required level.

Today it is possible to use "electronic transformers" or "solid state transformers" – power electronics devices capable to change the voltage level for both AC and DC (direct current) transmission lines and consumers.

More practically, all household devices (TV, computers) use DC or can be switched over to DC power supply (light sources). From this point of view, DC grid for household is a good option to decrease power losses in AC/DC converters for each individual consumer. Estimated voltage for household is within range 24…28 VDC.

Solar panels, small wind turbines or electrical energy storage devices (batteries or super capacitors) will be easier to integrate in household DC grid, contrary household AC grid.

DC micro-grids coupled with AC transmission lines between them can significantly increase the energy use efficiency, energy supply reliability as well as energy supply independence and power quality.

The same relates to industrial electric grids in factories and production units, especially in case when many energy recuperation devices (production robots, local transport, etc.) are in use. Here the energy storage devices can significantly reduce overall energy consumption: first experiments demonstrate up to 25% energy savings.

DEVELOPED MICRO-GRIDS

Currently, 600V industrial DC grid (Fig.1), connecting energy sources, recuperating consumers and energy storage

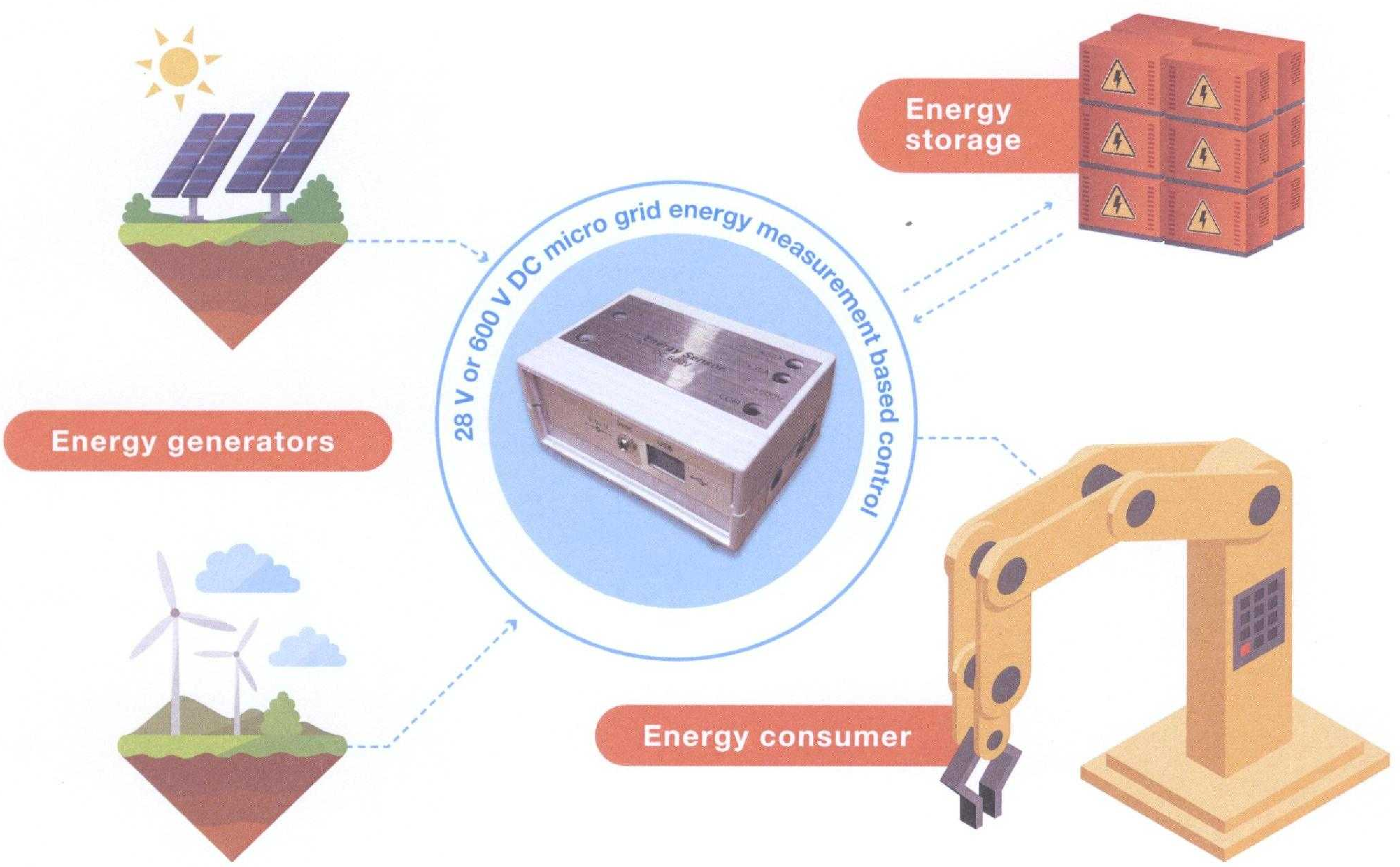

Fig.1. *Energy measurement modules installation on AC side and DC micro-grid*

devices, is under development [1] at RTU in cooperation with industry partners.

Overall DC micro-grid power is up to 50 kW at 600 V (Fig.1.).

The main task is the micro-grid control for standalone micro-grids, micro-grids connected to AC grid and several directly connected micro-grids, creating smart DC grids connected to traditional or smart AC grid.

Bidirectional DC energy flow measurement modules must be capable to measure the parameter values of bidirectional energy flow due to recuperation or energy storage.

Special bidirectional AC and DC energy flow measurement devices are designed in order to control the grid energy flow and thus use the generated or supplied energy in most efficient way. The developed energy flow measurement modules utilize a different approach to energy flow measurement instead of well-known "typical" [2]. These modules (developed by RTU) are inexpensive and less power self-consumption devices, compared to known ones.

3-phase bidirectional AC energy flow module practically represents three (symmetric AC energy consumption in both half-periods) or six (asymmetric AC energy consumption in both half-periods) DC energy flow measurement modules. AC modules utilize only one MCU for all readings, calculations data storage and communication (Fig.2).

Energy flow measurement modules include 32-bit Cortex M4 microcontroller. Popular and low-priced 8-bit microcontrollers also can be applied in cases when reduced precision is acceptable, mainly for energy flow monitoring and overall estimation.

Data communication in industrial systems typically use EtherNet, Modbus or Profinet protocols. Additional modules or protocol converters must be added in order to realize these protocols.

Energy values can be measured over short time periods - starting from 10 ms. At the same time, energy measurements within short periods generate a considerable data flow and large data log files.

AC modules include a resettable fuse and a varistor protection, DC module includes protection against possible reverse DC polarity connection to voltage-frequency converter.

Several developments (based on different MCUs) of devices were tested: converters, software and communication.

CONCLUSIONS AND FUTURE WORK

Practically all household devices use DC or can be switched over to operation DC power supply. Solar panels, small wind turbines or electrical energy storage devices also are DC operating devices. It is logical that DC grid will simplify connections between generators, consumers and storage devices and reduce AC/DC conversion losses.

Independent DC micro-grids increase the reliability and safety as well as provide the energy "when it is needed", thus helping to get along without the centralized "energy needle".

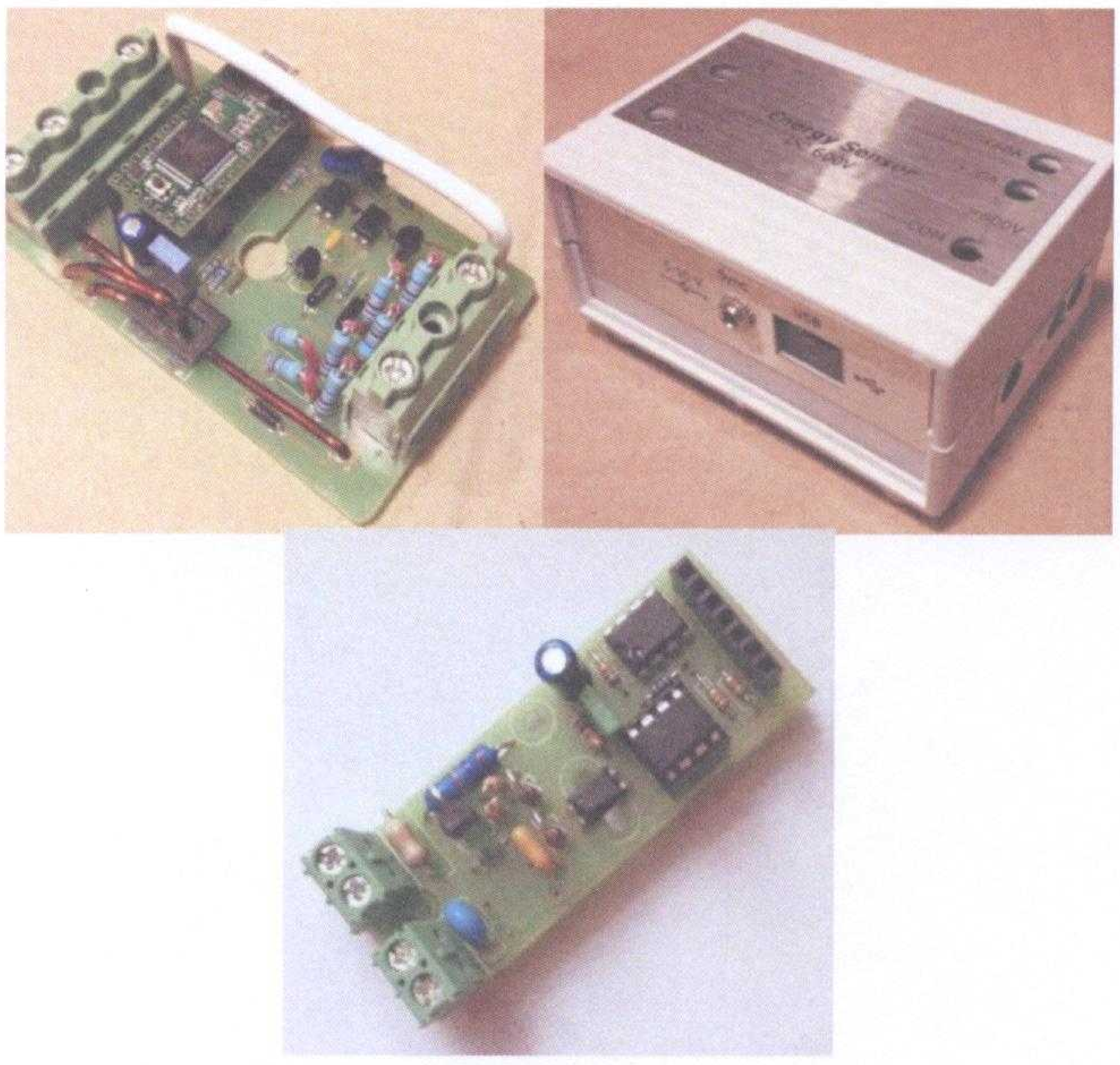

Fig.2. *AC (bottom) and DC (top right and left) energy sensor modules*

AC grids are easier for redesigning to smart AC grids by implementation of smart DC micro-grids. The concepts of T.A. Edison and N.Tesla will probably start cooperating instead of fighting.

Energy flow sensors can also act as possible detectors of electrical equipment faults due to wearout and ageing - permanently increasing energy consumption is a source of concern about possible problems in future.

REFERENCES

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2. Apse-Apsitis, P.; Avotins, A.; Ribickis, L., A different approach to electrical energy consumption monitoring, Power Electronics and Applications (EPE'14-ECCE Europe), 2014, DOI: 10.1109/EPE.2014.6910970, IEEE CONFERENCE PUBLICATIONS

KOPSAVILKUMS

Publikācijā autori pieskaras elektroapgādes drošības un uzticamības jautājumiem. Publikācijā aplūkotas iespējas maiņstrāvas tīklu kombinēt ar līdzstrāvas mikrotīklu un tā izmantošanas iespējas.

Līdzstrāvas mikrotīklā samērā viegli iespējams iekļaut enerģijas uzkrājējus, vieglāk pieslēgt alternatīvos enerģijas avotus, piemēram, saules un vēja ģeneratorus.

Tā kā mājsaimniecībā praktiski visas elektroiekārtas izmanto līdzstrāvu un katrai iekārtai ir individuāls maiņstrāvas pārveidotājs, kas palielina kopējos elektroenerģijas zudumus, tad līdzstrāvas mikrotīkliem ir perspektīva. Īpaši plaši nākotnē varētu tikt izmantoti viedie elektrotīkli, kuros paredzama plaša maiņstrāvas un līdzstrāvas tīklu kopdarbība.