DISTRIBUTED ENERGY AND SMART GRID CAN CONTRIBUTE TO SURVIVE DISASTER

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ABSTRACT

The paper presents Czech research project in the field of smart critical infrastructure. Aim of this project is to create bridge between liberalized power business and new challenges rising from global risks. During the disaster it is necessary to ensure basic human needs and protection. The continuity of critical infrastructure must be secured against the consequences of cascading phenomena and the domino effect. Project solves the resilience of power distribution against national transmission grid blackout. Project's goal is to demonstrate possibility of crisis demand side management that enables to provide necessary electricity for residents and critical infrastructure through adaptive distribution grid islanding. This function should be a basic functionality of smart grids. Project N^{o}2A-1TP1/065 „Increasing the resilience of the distribution system against long-term transmission grid blackout in order to enhance public safety" was supported by the Czech Ministry of Industry and Trade in the framework of "Sustainable prosperity" program. Project is called RESPO - REsilient POwer. This paper presents successful story of how society is willing to invest in resilience after a disaster experience.

1. INTRODUCTION

Motto: We shall need a substantially new manner of thinking if mankind is to survive

(Albert Einstein).

Energy flows and exchanges define the life of all living organisms on the Earth. The same mechanism can be seen at such a super-organisms as the human society and civilization. Any human activity cannot stand without energy and its transformation. From the point of view of a basic biophysics and thermodynamics the wealth of a specific society is primarily determined by size and effectiveness of its energy transformations.

Without energy there is not possible to secure neither some basic physiological human needs nor the need of safe being. Access to the energy in its various forms creates a basic condition for the "life" of any society. That's why governments of various countries pay so high attention to the energy security.

The strategic planning of resources goes together with the ensuring of their availability in the time and at the place they are required. The "smartest" kind of energy – electric power – can be very quickly distributed and switched to any place where the power line is installed and transformed easily to any other kind of energy. But has one unpleasant feature: cannot be stored and the consumption and production must be balanced all the time. All the networks and switches are capable to redirect the energy in seconds, but when such super-system fails, it means that millions of people and all the key businesses may be out of energy for a long time – plunge into the black-out.

Blackout is a "Sword of Damocles" of our civilization (figure 1). Due to dependence on electricity, the society could be threatened within a few seconds.

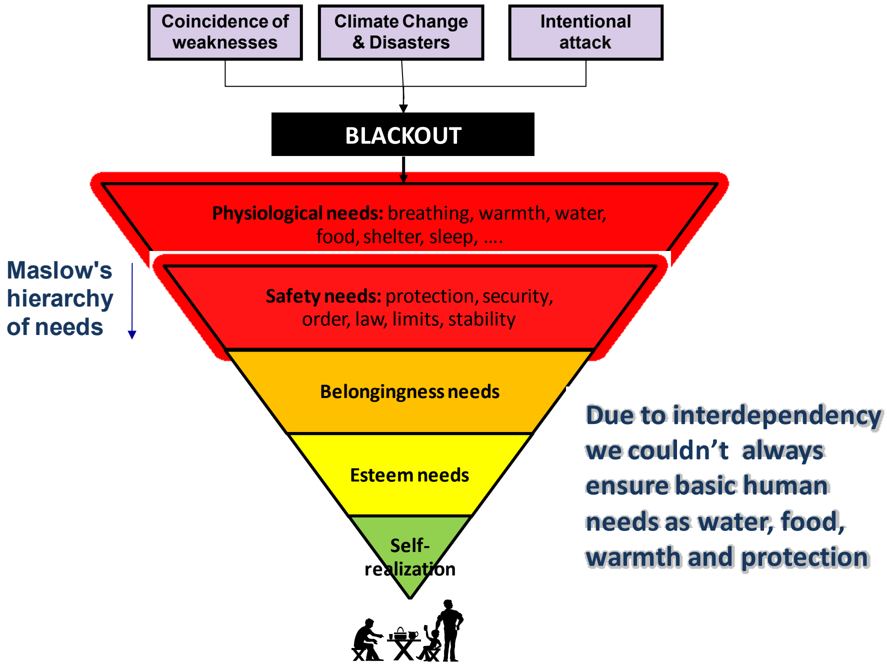

Fig.1 Blackout is sword of Damocles over our life

Basic physiological needs and safety needs would not be possible to satisfy without electricity. If the imbalance of production and consumption in the electricity supply is not immediately removed, the power system breaks down in a few seconds and results into blackout. This situation may then last for days or weeks. The current public distribution networks are passive and they are not able to provide electricity supply from local sources without connection to the transmission grid. Thus blackout will hit all regions.

Local power distributors can manage this unacceptable risk if they would be able to stay in operation islanding with utilization of local generation, even if system services from the transmission grid are lost (i.e. during the system failure).

2. METHODS AND DISCUSSION

Past projects, sponsored by Czech Ministry of Interior, have been devoted to an analysis of population protection from possible failure of critical infrastructure systems [1]. These preliminary works were focused on relevant disasters, impact analysis and risk analysis. The risk scoring has shown that the most vulnerable energy infrastructure is the power system. Due the N-1 practice (power system is resilient to only one failure of key element), the multiple malfunctions (or multiple attacks) can cause the serious system failure - blackout. The most vulnerable part of the power system is transmission grid, from impact point of view. While it is possible to increase surveillance and resilience of power plants and the transmission substations with vulnerable HV transformers, it is almost impossible to increase surveillance on power lines that lead over country with free access to its pylons. Collapse of transmission system means loss of system services that provide balance of frequency and voltage level, and thus distribution grids cannot remain in operation.

If we consider that 30% of power production is connected into distribution networks (e.g. municipal district heating plants and independent power producers), it seems to be attractive option ensure emergency power supply with utilization of distributed power generation. The lost system services coming from transmission could be replaced by special function of smart grids that will provide crisis demand side management. It will allow not only supplying of the critical infrastructure but also supply indispensable amount of power for inhabitants and business, although limited.

The consequent project "Resilience of the distribution system against national grid blackout to improve human safety" was partly sponsored by Ministry of Trade and Industry in the framework of "Sustainable prosperity" programme. Goal of five-year project with a budget of 2 million EUR was to improve security of citizens, protect environment and decrease the damages caused by long-term power failures. Results will help to diminish the unacceptable risk associated with possible crisis in the electric power supply [2].

The project team has been consisted from five experienced organizations (CITYPLAN, ViP, EGU CB, T-Soft, AF consult). During the first phase the project team had executed search and analysis of possibilities to achieve the appointed goal. In the second phase the project team developed the overall conception. In third phase the technical requirements for new equipment were defined. The technical development of new equipment was subject of the fourth phase and technical documentation was created in the fifth phase. Based on acquired data the economic analysis has been performed during the sixth phase. In 2011 project team has implemented the pilot project on a local micro-grid. This pilot project has demonstrated functionality of all necessary equipment and concept as a whole.

Research project have been discussed many times with officials from the Czech parliament and Czech government. The vision of island operation as an "island of life" for fulfilling basic human needs has been understood by General directorate of the Fire rescue service of Czech Republic. This organization is responsible solve all no-military crisis situation, like fires, floods, blackouts, car accidents, extreme weather, etc.

3. RESULTS

When searching for a suitable location for the pilot project it was decided to implement a pilot project in the wastewater treatment plant City of Ceske Budejovice (about 100 thousands inhabitants). The reason for this choice was the fact that the project was interesting for management and also won the support of the mayor. Water supply and wastewater treatment are sensitive and vulnerable to power failure. Based on the severe flooding experience in the year 2002 City of Ceske Budejovice was willing to reduce vulnerability. It can be achieved using smart design and by specific synergies. In particular, the water supply has to be independent from the external power grid.

So far, the city was supplied by only one water pipeline from the distant dam. During the flood in 2002 year, there was danger, that this pipe will be destroyed. During this flood, the wastewater treatment plant was destroyed. Based on this experience it was decided to realize new water well in the adjacent area of the wastewater disposal plant as an emergency source of potable water for the city.

During recovery, the wastewater treatment plant was equipped with biogas cogeneration units. They can operate independently on the external grid in the mode of island operation. So during the blackout the wastewater treatment plant remains in operation. Nevertheless in the mode of island operation it is necessary to reduce the load of wastewater treatment plant. This local power and heat cogeneration can supply not only the wastewater treatment plant. During the power outage and after reduction of unnecessary consumption it can supply electricity to power pumps for emergency sources of potable water. The necessary equipment was installed and the actual test was presented at the workshop in September 2011. The City of Ceske Budejovice has now ensured operation of wastewater treatment plant as well as emergency source of fresh water independently of the electrical network. This project shows how an experience from disaster creates willingness to implementation of potential smart solutions to achieve resilience for the future. Figure 2 shows the rack with the necessary technical equipment and automation.

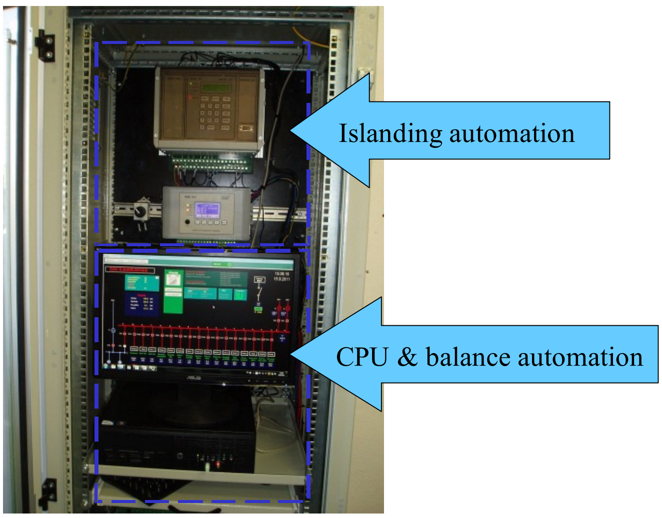

Fig. 2 Arrangement of pilot project automation

Figure 3 shows display of normal operation. Cogeneration units generate electricity into the public grid and switching station is supplied from the grid by means of 2 transformers. Balancing automation is providing constantly calculation difference between local generation output and consumption.

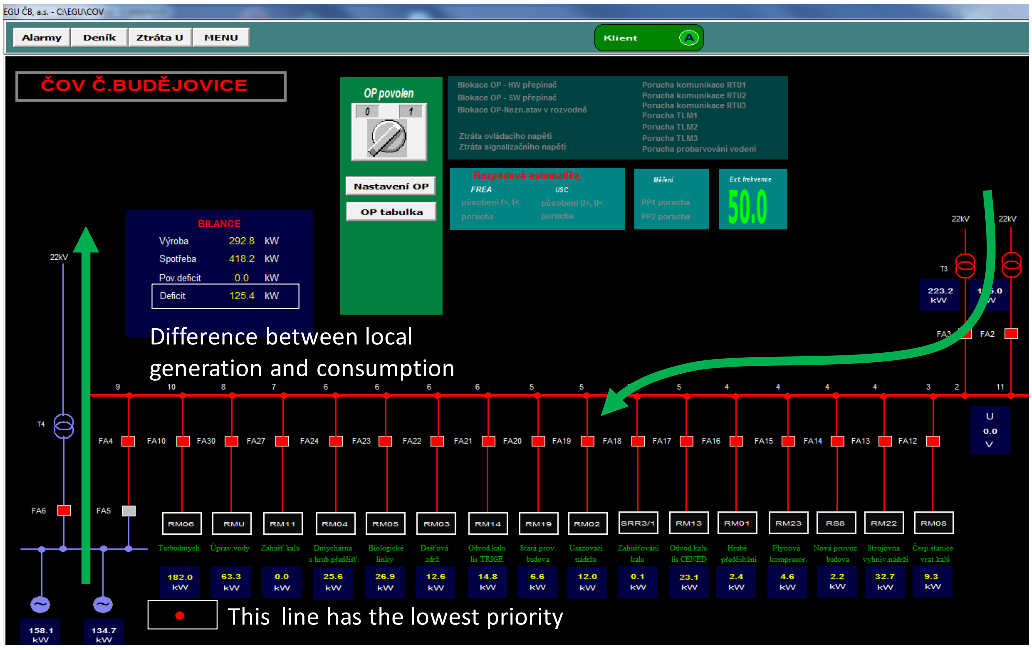

Fig. 3 Control panel display – normal operation

During the grid blackout the automation immediately creates island. The local switching station is disconnected from the external grid and connected to the local cogeneration (figure 4). The island is created within 200 milliseconds (figure 5). The load management automation ensures balancing by switching off the less important consumption.

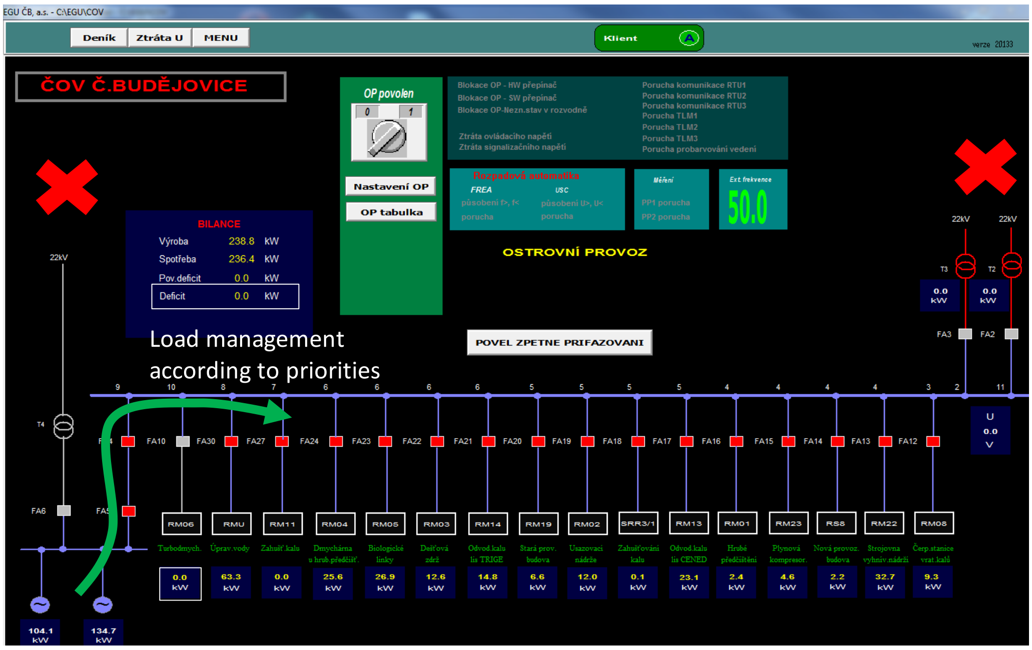

Fig. 3 Control panel display – island operation

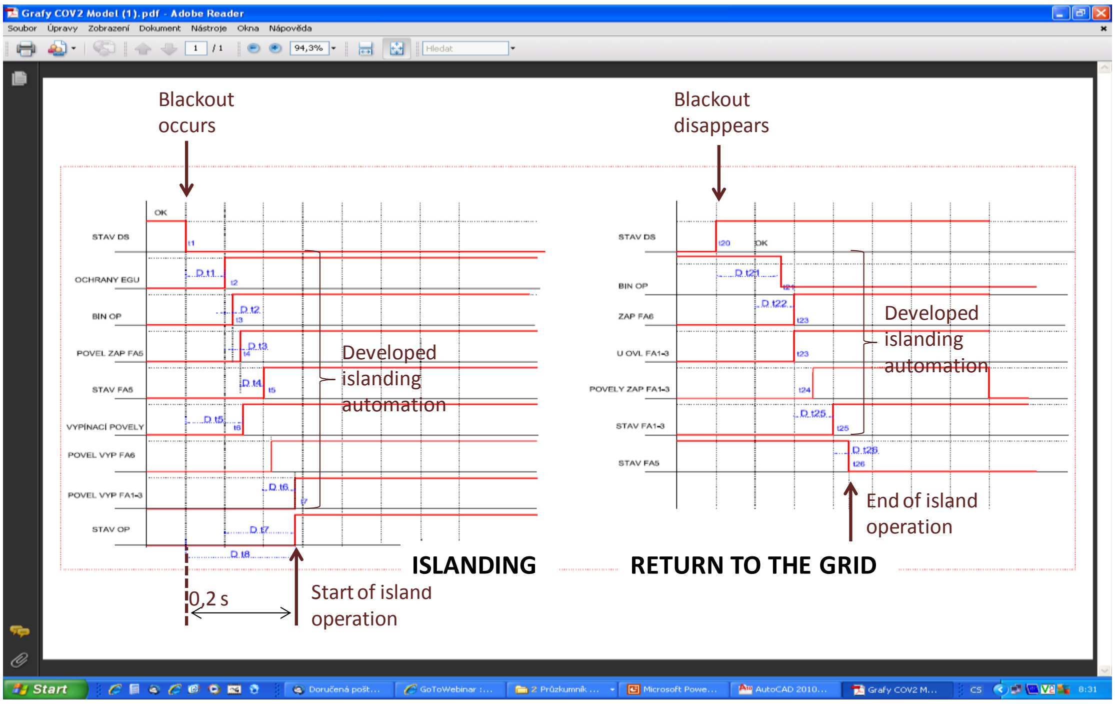

Fig. 4 Snapshot of island operation

If the pilot project is realized in the public grid it is possible to use smart meters to direct control of demand side management. The idea is presented on the figure 5.

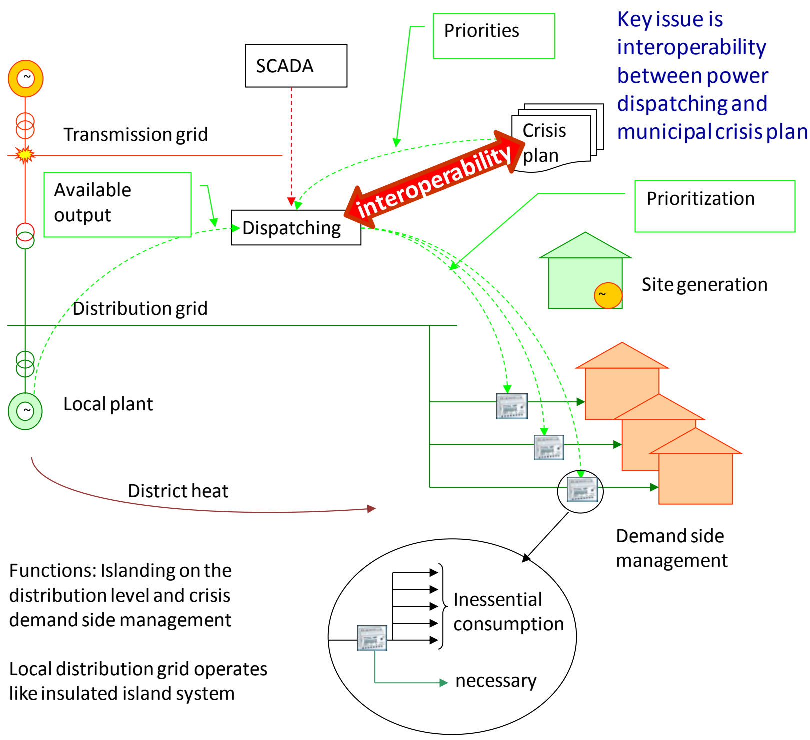

Fig. 5 Concept of power distribution resilience

The smart meter will be able to provide decrease consumption instead switch off. Existing practice of rolling blackout is replaced by rolling gray-out which leads to enhanced population protection. The pilot project has demonstrated this functionality. Dispensable consumption was represented by an electric kettle; necessary consumption was represented by a light (figure 6).

Fig. 6 Demonstration of selective load management

During the blackout local distribution grid operates as an island. Through forced demand side management the homes can have in operation lights, refrigerators, TV and some others small necessary appliances, but dispensable appliances like kettles, washing machines, irons cannot be used. Load is controlled by means of remote load limitation using smart meter. So when the smart meters will be installed, the distributor can remotely switch the households to the emergency, without the material loss, keeping people with the basic living conditions.

4. CONCLUSION

The results of various analyses shown that (not only in the Czech Republic) the black-out might become a reality and that it might be caused by several reasons. Although current high-voltage network is reliable, it may break due to for example excessive demand of wind-power transfer from one part of Europe to another or due to a hostile attack.

The concept of dynamic islanding comes out of the assessment of the threats and risks. It decreases the vulnerability of citizens by decreasing the impact of the long-term break of the transmission network. The distribution network is safer from the global point of view, because its failure has only local impact. The solution in RESPO project is based on the fact that the island type of operation existed already 100 years ago, when there was no long-distance transmission system (of course the quality of the power supply was poor).

The utilization of local sources together with the upgrade of equipment and distribution networks may help to progressively decrease the impact of possible national blackout. Pilot project has demonstrated feasibility of the power supply resilience.

Recommendation based on this research was included into the proposal of updated Czech energy policy. All bigger cities should have resilient distribution system with ability to switch into island operation during national transmission system outage. Research project solves also crisis demand side management according to prioritization of critical infrastructure. Research results were demonstrated by the successful pilot smart grid implementation.

5. REFERENCES

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