SMART EMERGENCY – NEW ISSUES OF EMERGENCY SUPPLY SYSTEMS FOR CRITICAL INFRASTRUCTURE

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ABSTRACT

In catastrophic incidents, taking critical infrastructure and equipment back into operation as quickly as possible becomes more and more important. The energy supply of information and communication technology (ICT), services of health, emergency and rescue belong to potential critical infrastructure from an electrical engineering perspective. During outages electrical energy can be provided by standby power devices such as batteries or emergency generators. However, these devices are usually limited in supply duration, and are stationary or difficult to transport in cases of emergency. Thus flexible and dynamic solutions are clearly required. Such cases are considered in the project "Smart Emergency" (funded by the climate and energy fund of the Austrian government), we are currently working on. [1] [4] [5] [8]

NOMENCLATURE

ICT… Information and Communication Technology
UPS… Uninterrupted Power Supply

INTRODUCTION

Major disasters that result in blackouts or power outages in afflicted regions, affect the entire grid in very rare cases. Thus, usually only a part of the medium voltage network and/or individual low-voltage areas are affected. The remaining generation capacity in these grid areas is not enough to cover the entire demand, but could be sufficient to continue operation of the most important infrastructures. [3][6]
The challenge in this case is the operation of the mostly still intact power grid areas, with the objective of supplying the most important consumers respectively devices with power.
In the present work we investigate a new concept of selective power supply in low voltage network areas. According to current status of investigation this is a mostly theoretical approach, that could be realized with relatively little effort in practice.
The concept is similar with the frequency selective load adaption. The difference is that here is just a power-voltage relation instead of a power-frequency relation. This is easily possible in power inverter supplied gird.
Thus the smart meters have some defined switching states depending on the priority and the voltage (reliable power) in the grid.
The switching states are only selective to present physical network conditions, such as voltage. This is a key major benefit due to the independence from the ICT, that gives cyber-attacks no surface.

THE CONCEPT

The concept is based on basic and simple instructions for each intelligent switch or smart meters. These instructions are executed under the condition of under-voltage and absence of other commands (e.g. ICT).
The state information is only derived from voltage and frequency (physical values in the power grid). This technology provides robustness and security for emergencies. All actors are only responding to the grid and no additional information paths are needed.

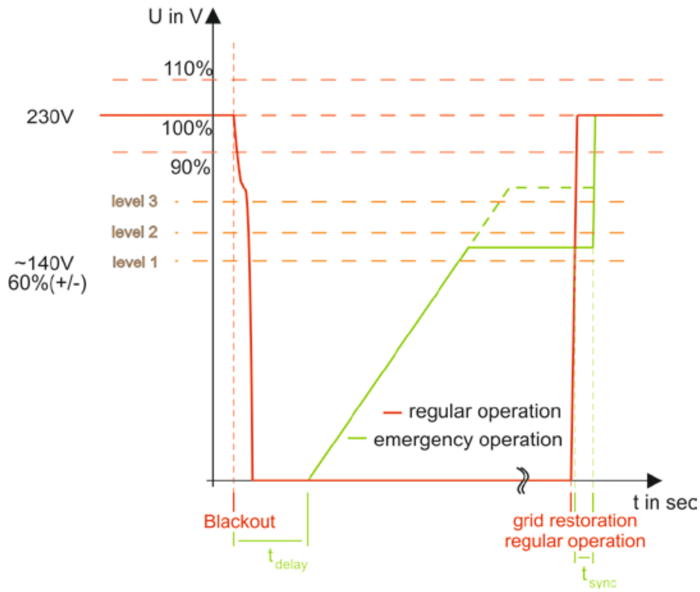

Figure 1: Time course of the voltage in regular and emergency state

In the event of a blackout or partial break down of the power grid, the residual energy is used to switch off all smart meters (loads) in the grid. The residual energy is the energy that is still in the grid during the transient breakdown of a blackout.

If the higher level electricity supply is absent for a certain time t_{delay}, the distributed generation units (PV, wind, emergency power aggregate ...) are switched to an emergency mode.
Another challenge is automatic synchronization, which is solved in three different steps: in the micro grid, between different micro grids and with the main grid.
The distributed power units start to synchronize in the micro grid and start the boot sequence by slowly raising the voltage following a ramp in a range of several volts per second (~2,5-3 V/sec). When the voltage exceeds a certain level, defined smart meters switch on their load. If sufficient power is available, the voltage increases further, following the ramp and more smart meters switch on by priority. If the power balance in the grid is negative, the voltage decreases, and some smart meters, which have no permission for this voltage (power) level, switch off.
The micro grid frequency shifts all the time. Once the normal supply is restored, the circuit breaker next to the restored grid connects the micro grid to the main grid when the frequencies are synchronous - restoration is finished. t_{sync} is the time between voltage recovery and synchronization to the main grid. Figure 1 shows the afore described operation sequence in green (emergency operation). The red lines are the real or regular sequence in case of a blackout (regular operation), that is the normal progress now.

Requirements to end user devices
A basic requirement is the functionality during undervoltage condition. Measure and test of selected typical end user devices under this condition have been carried out. Figure 2 shows the main types. Normal function is indicated in the upper sector of the bars (green). The middle sector (blue) corresponds to reduced function. Here the devices are still working correctly but with reduced or abnormal functionality. In the lower section (red) there is no or insufficient function of the device.

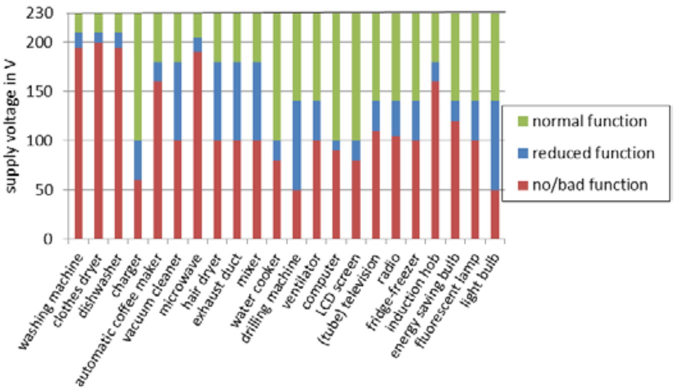

Figure 2: Required voltage for the function of end user devices [7]

Figure 3 shows the main types of devices classified by different classes of use cases. Apparently large appliances are not very tolerant with respect to undervoltages. In contrast to these are IC- and entertainment technologies. These are still working with decreased function down to 60 V and normal or correctly down to 100 V. Between the two main classes there are the lighting, heating and cooling appliances. Most of them are still operating but with reduced functionality respectively performance.

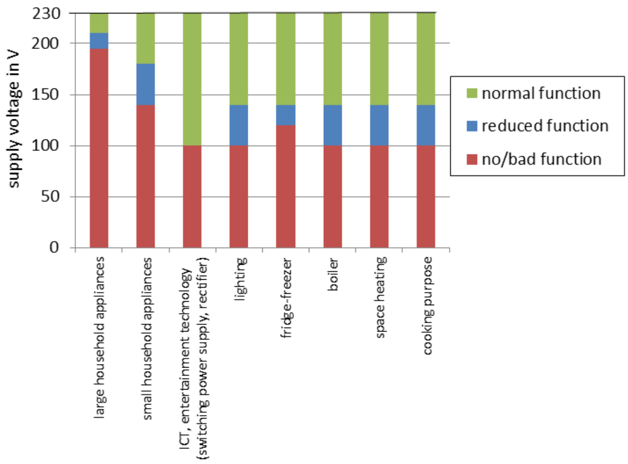

Figure 3: Required voltage for the function of clustered end user devices [7]

The most important devices in critical infrastructure are still working down to 100 V. If you need the function of some other devices that need more voltage, there is the possibility to use a UPS. The UPS still charges the battery and gives a output voltage of 230 V. The disadvantage is that it costs money and that an additional device is needed.
Thus, the challenge of keeping end user devices operational can be handled in a limited effort.

Requirements to Smart Meters or Smart Switches
Also a quite important part of the concept are the "Smart Switches. These are implemented in the grid in form of Smart Meters combined with circuit breakers at the end users side, and as circuit breakers at the beginning and at the end of every electrical line.
They need to be able to measure the angle, the voltage, the current and the frequency of every phase.
For example, if there is a short circuit, the current raises and the circuit breakers have to switch off the line with the short circuit. The remaining grid should stay whole in parts as big as possible and build micro grids. [9]
For the grid recovery some features are needed too.
To be able to connect two grids if they are synchronous (recovery feature) the switches need the information about frequency and angle in both grids. The voltage is needed to determine if every single circuit breaker switch has to switch on or off, if the voltage is above or below the respective emergency level.

Most of these requirements are basic features and already implemented in modern circuit breakers and Smart Meters. But some of them, like the synchronisation feature, will need to be implemented. This should be possible with maintainable effort.

OUTLOOK

The supply concept developed in the project "Smart Emergency" should make it possible to operate a certain emergency supply for a longer period of time, which in turn allows maintaining the operation of certain critical infrastructure.
It should ensure a smart but elementary operation, while using as few additional technical structures as possible, such as ICT. This gives the advantage of few potential important structures or devices that need to be robust or secure.
For the next steps it is planned to investigate the amount of still healthy (connected) grid parts in incidents that occurred in the past.
We also want to record some facilities that are critical infrastructure, to learn more about the characteristics of them.

CONCLUSION

The proposed concept could be an important step towards safe and robust power supply or at least give a possible opportunity in emergency incidents.
It is a robust possibility to use the still intact parts of a highly tattered gird without use of conventional and on fossil fuel dependent aggregates.
Up to a good implementation in the current grid structure there need to be investigated which capabilities have respectively must have the intelligent switch and smart meters. The challenge of the operation of the end user devices during undervoltage condition is manageable.

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