C. Critical power check

To protect the power lines of the island system against overload, a power check is implemented, which is active during both normal operation of the grid and during disturbances. As already mentioned in section 2-A.3, the respective power limitations of the two inverters; 18 kVA and 13.8 kVA lead to a maximum power per phase of 6 kVA and 4.6 kVA. In order that the inverters do not deactivate the whole system by exceedance, the control unit does a critical power check. With the help of the energy meters, the control unit knows the actual power per phase. In the event of exceedance of the actual power of one phase, the PCD disconnects the load with the lowest priority of the affected phase. If the power limit is still overstepped or get overstepped later on, the next priority of loads will be shed. This avoids a direct and complete shutdown of the system and makes it more efficient.

D. Load shedding management

The load relays are connected to the central control unit and the main part of the load shedding management. The PCD gets information about the SOC range of values of the accumulators from the inverters. This makes it possible for the PCD to make decisions. During outages of the public grid and depending on the capacity of the accumulators, the EMS which separates the loads with low priority from the island grid, leads to longer supply of the loads with higher priority. The EMS currently distinguishes three levels of priority: 'low', 'medium' and 'high'. The central control unit is connected with control lines to several distribution boxes in both buildings and is responsible for the load shedding. This enables the switching on or off of specific relays and the attached loads. At the moment, loads with high energy consumption and low priority like air conditioner are shed at first, whereas projectors in lecture rooms or PCs have a higher priority and are supported longer. If the SOC-value reaches 40 % or less, the load shedding management separates every load from the system to ensure protection against deep discharge and to extend the life span of the batteries.

E. Generator management

The biofuel generator can be activated by the PCD depending on the SOC-value or due to a direct command of the control unit. For this purpose, a control line is installed between the PCD and the generator starter. The activated generator feeds the loads and charges the battery of the building. Subsequently, the shed loads are connected again. Due to the restriction that the generator can only feed one building, the EMS decides which building is supplied. To make this decision, the buildings get different priorities. As long as the SOC of the building with the higher priority is too low, the generator provides energy to this building from this moment on regardless of whether the generator already feeds the other building or not. This setting can be changed temporarily to offer higher flexibility. An internal timer is also part of the PCD and protects the generator against too fast reconnection and possible hysteresis loops. This is necessary because the generator needs a cool-down time of at least 3 minutes after deactivation. Too fast reactivation can occur in case of frequent starts and shutdowns of the public grid and change to emergency power mode during the cool-down time of the generator. This needs to be avoided because to rapid reactivation would stress the generator too much and can damage it. An internal timer in the PCD avoids this problem and protects the generator from too fast reactivation.

4. Conclusion and outlook

In this paper, a sustainable uninterruptable power supply with renewable energy sources, an energy management system and load management system has been presented based on a field test at the campus of the KNUST. Because of the communication and interaction between the individual components of this system, it resembles a smart grid [4]. The central control unit enables the flexible switching on or off of the loads depending on adjustable priorities and the specific situation. With the use of PV generators, a biofuel generator and accumulators the system can operate in an islanding mode during grid outages. Through the inverter, the uninterruptable power supply is guaranteed. Furthermore, there are several strategies to protect the batteries against deep discharge and the generator and inverter against damages. The critical power check avoids the complete shutdown of the system in the event of an overload and facilitates the supply of the most important loads. Pre-settable load profiles with different load priorities enable the consideration of seasonal effects and make the system more flexible. Finally, the central connection of every energy meter provides the possibility to measure electrical parameters like for example the energy consumption or the utilization factor of the inverters.

Identification of optimization potentials takes several months of system operation and data measurement. Imaginable potentials are situated in the fields of an improved load prioritization, the design of more preinstalled load profiles and a better battery and generator management. Right now the central control unit gets the information whether the SOC of the battery is above 70 %, between 40 % and 70 % or under 40 %. A huge improvement would be, if the central control unit knows the exact SOC. In this case for instance more level of prioritizations can be created and the load shedding could be improved significantly.

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