ASSESSMENT OF THE RELIABILITY OF POWER BALANCE AND FLEXIBILITY FORECASTS FROM DISTRIBUTION NETWORKS

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ABSTRACT

Recent studies show that more and more information and communication technology (ICT) and smart grid applications (SGA) are used in distribution networks to support network operation. These can also be used to optimize the power balance and to provide flexibility from the distribution network at the interface to the higher-level network. In the future it could be possible to offer ancillary services from distribution networks. Since an availability of 100 % is currently assumed for ancillary services and previous studies show that both ICT and SGA have an influence on the reliability of distribution networks [1, 2] as well as the developments on load and generation side including market influences, this availability cannot be assured by distribution networks. Therefore, a meaningful option is the determination of the reliability of schedule and flexibility potential. The necessary assessment parameters are presented and a first analysis shows the influence on the reliability and its dependence on the actual grid usage.

INTRODUCTION

Current technical challenges in distribution networks and an expansion of ICT are leading to an increasing use of SGA supporting the network operation. This allows distribution network operators to operate networks closer towards technical limits. Furthermore, there is an increasing politically and socially motivated claim for decentral power balancing. So, the next step for SGA could be the usage for optimising schedules, i.e. the power balance at the interface to the higher-level network. Also, the provision of flexibility from the distribution network for the higher-level network of system purposes is discussed. In terms of this paper, flexibility is defined as the potential of adjusting the active power of network users. This flexibility must be available at the interface to higher-level network. Thus, maximum positive and negative flexibility potential specify a flexibility band around forecasted schedule values.

Previous studies [1, 2] show SGA also are significantly dependent on the availability of ICT-infrastructure and both have a nonnegligible influence on the reliability. Hence, additionally to the primary network, both the SGA and the ICT-system have an influence on the reliability of fulfilling the schedule and providing flexibility. Furthermore, distributed power generation units (DG), storage facilities and controllable loads also exhibit specific failure behaviour. Therefore, the schedule and flexibility forecast can only be kept within a certain degree of uncertainty. So, a method for determining reliability of the schedule and flexibility potential for distribution networks is being developed. For this an existing method for calculating the reliability in smart grids [3], which is based on a proven probabilistic analytical approach for reliability calculation, can be used as basis.

The focus of this paper is on the assessment parameters for the reliability of the schedule and the flexibility potential as well as the method of evaluating them.

SCHEDULE AND FLEXIBILITY POTENTIAL

As already mentioned in the introduction, the flexibility potential is currently shifting into the distribution networks. As a result, the provision of flexibility from the distribution network is also increasing. Therefore, the power balance at the interface to the higher-level network, the schedule and the maximum positive and negative flexibility potential, the flexibility band, will be discussed in more detail below. Figure 1 shows an exemplary course of the schedule and the flexibility band.

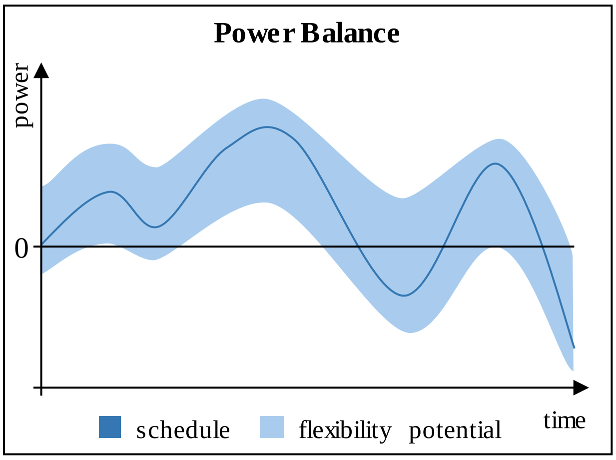

Figure 1: Power Balance at the Interface to the Higher-Level Network

The schedule (drawn in dark blue) describes the power balance at the interface to the higher-level network, which means the time course of the predicted total value of all feed-ins, loads and losses of a distribution network. In doing so, operational measures of the distribution network, e.g. congestion management for the network, are already taken into account. The flexibility band (drawn in light blue) indicates the temporal course of the bandwidth of possible flexibility provision. This means the maximum positive and negative flexibility potential around the schedule value. It must be taken into account that the flexibility potential has to be available at the interface to the higher-level network.

DETERMINATION OF SCHEDULE AND FLEXIBILITY POTENTIAL

First, the flexibility potential of each network user is determined - generation units, loads and storages. Since both the schedule and the flexibility potential at the interface to the higher-level network are relevant and additionally congestions in the distribution network may occur, it is not possible to simply sum up the flexibility potential. Instead, network restrictions and operational measures (e.g. congestion management) of the network operator must be taken into account when determining the schedule and the flexibility potential.
The method used to determine the schedule and the flexibility band is based on the method developed in [4]. An optimal power flow algorithm (OPF) with different parameterisation is applied three times. In the first step the schedule is determined, in the second step the maximum positive flexibility potential and in the third step the maximum negative flexibility potential at the interface to the higher-level network are determined.

RELIABILITY OF THE SCHEDULE AND THE FLEXIBILITY POTENTIAL

In the future the provision of ancillary services from distribution networks is a realistic scenario, therefore the determination of the schedule and the flexibility band should help to determine the flexibility potential at the interface. Currently, the reliability of the provision of ancillary services is assumed to be 100 % and confirmed by a prequalification assessment. Redundancy has to be ensured by the provider of the services, in case of services at distribution level the distribution network operator has to declare availability of sufficient network capacity. However, due to the described complex interactions as well as developments in both load and generation including market influences, this can no longer be assured by the provider nor the network operator any more. For this reason, a meaningful option is, to determine the reliability level, that is linked to the provision of the service, and offer this to the higher-level network of the system operator. The next step is therefore to determine the reliability of the schedule and the flexibility band. Thus, failures in the primary network, the ICT-system and of the network user are taken into account.
In order to evaluate the reliability of the schedule and the flexibility potential, assessment parameters must be developed first. In Figure 2 the assessment parameter for the deviation of the schedule is shown.

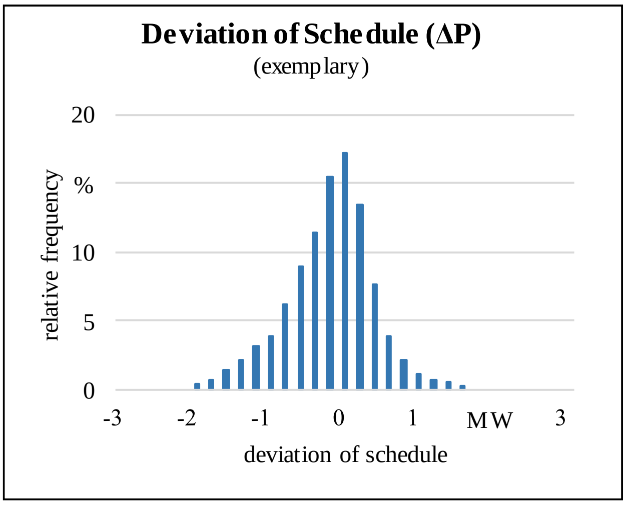

Figure 2: Reliability of the Schedule

First, a calculation of the deviation over the forecasted power balance is carried out for the schedule. This means within the reliability calculation the deviation is determined objectively by an OPF algorithm. That allows the determination of a relative frequency distribution for the deviation. In case of the flexibility potential, the maximum positive and negative potential around the schedule value shall be determined likewise by an OPF within the reliability calculation (Figure 3). Since all values between these potentials can be retrieved, a cumulative frequency distribution is intended describing the flexibility potential.

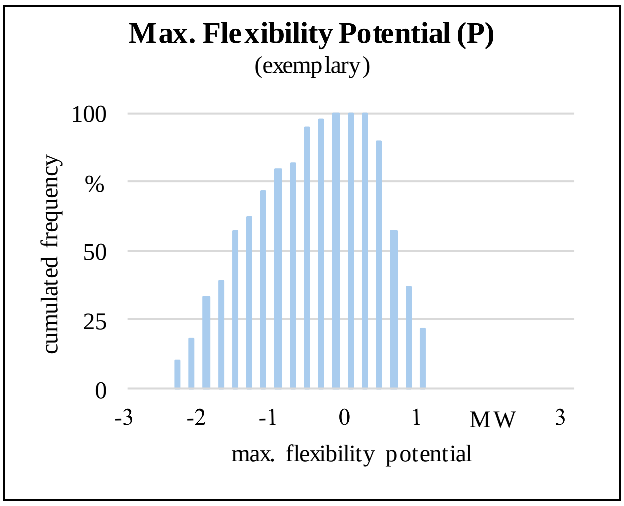

Figure 3: Reliability of the Flexibility Potential

CALCULATION OF RELIABILITY OF THE SCHEDULE AND THE FLEXIBILITY POTENTIAL IN SMART GRIDS

In [3, 5] new algorithms for the reliability assessment in smart grids were developed. These algorithms allow the consideration of ICT and SGA in the reliability analysis. These components are taken into account in the fault simulation as well as in the calculation of resupply. Since both SGA and ICT-connection of the corresponding network users are necessary for the provision of flexibility, these must be considered within the reliability assessment. Therefore, these algorithms can be used as a basis for the assessment of the reliability of the schedule and the flexibility band, but need to be extended. In Figure 4 an overview of the algorithm used is shown.

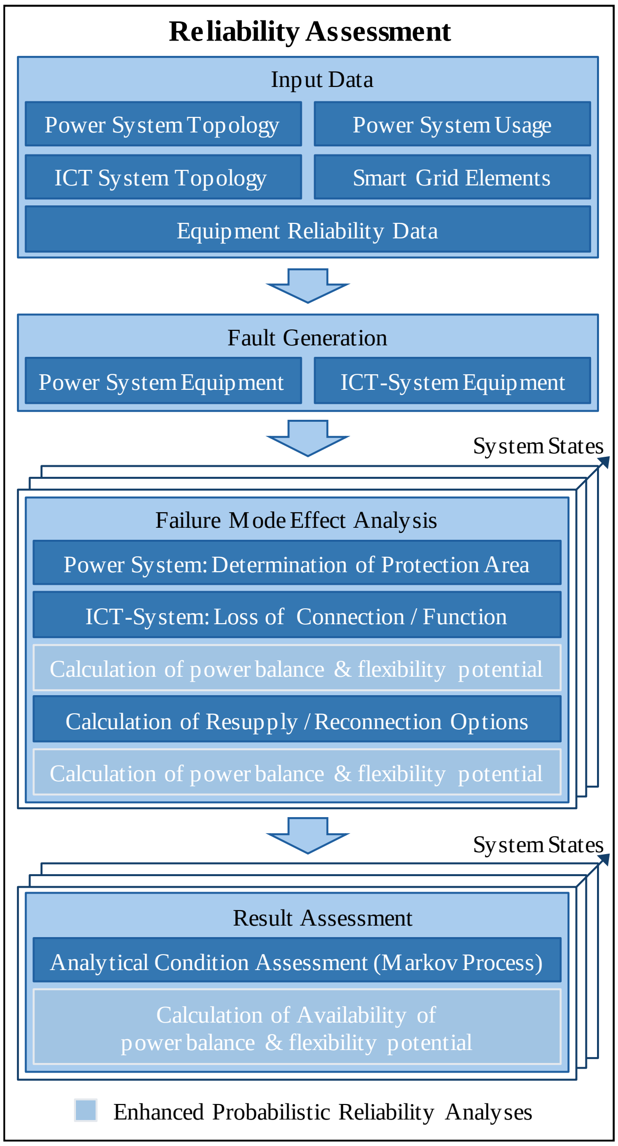

Figure 4: Enhanced Algorithm for Reliability Assessment of Power Balance and Flexibility Potential

The algorithm for the reliability calculation from Figure 4 must be extended in two points. First, the schedule and the flexibility band for each failure must be determined as part of the failure mode effect analysis. This is done by using the OPF already introduced, which has to be carried through several times during the failure mode effect analysis: the first time after the determination of the protection area and the loss of connection or function of the ICT-system and also in the resupply process. In this process the OPF has to be applied for every state of resupply [3]. Furthermore, the new reliability characteristics for schedule and flexibility band, which have already been described, must be determined during the result assessment.

EXEMPLARY RESULTS

Exemplary Medium Voltage (MV) Network

The enhanced method for calculating the reliability of the schedule and flexibility band is now exemplary used for an MV network (Figure 5). The network data and the time series of the loads and feed-ins used for the exemplary results are based on [3].

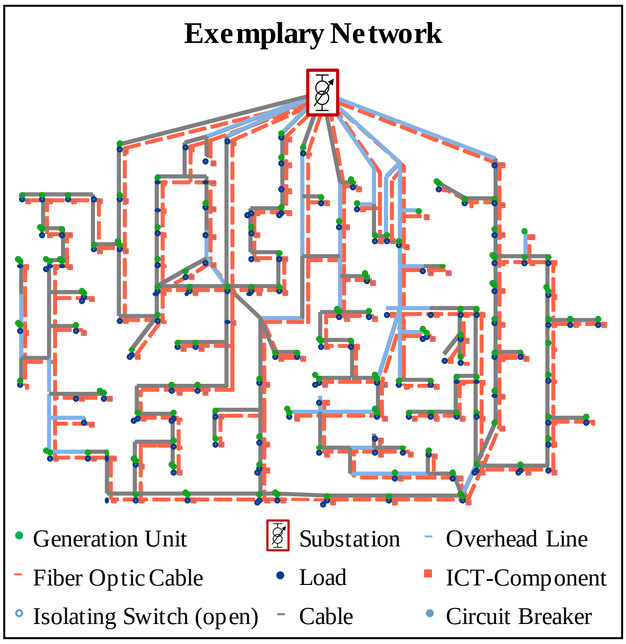

Figure 5: MV Network and ICT- System [2]

The MV network has already connected more generation units than technically possible without generation side management (GSM). As a result, congestion management is already necessary in the base case at some points in time. DG, which are controlled by GSM, are available as flexibilities for the exemplary simulations. The ICT-system consists of fibre optic cables with a ring topology. It is assumed, that the fibre optic cables use the same routes as the primary lines, which is feasible due to the use of empty tubes at cable routes in the past and the consideration of ICT-needs in future network reinforcements. In the case of an ICT error, the maximum feed-in power of the DG is limited to 80 % of the nominal power. The reliability characteristics of the power system [6] and the ICT-system are given in Table 1. The failure rates of the ICT-system are derived from a comprehensive analysis of available data on the reliability of different ICT-technologies [3]. Only the repair times were estimated, as indicated. For the exemplary results failures of the primary system equipment and the ICT-system were simulated.

Table 1: Reliability Data for Power System and ICT-System[3,6]

Equipment	Failure Rate [1/a, 1/(a*km)]	Time to Repair [h]
Overhead Line	0.0197	2.4
Cable-XPLE	0.0013	3.8
Cable-Paper	0.0027	2.8
Switch	0.0001	1.4
Circuit Breaker	0.0020	6.0
Busbar	0.0001	2.0
Transformer	0.0044	2.3
IED	(0.026 / 0.016) *	4 **
Fibre Optic Cable	0.004	6 **

* (Functional Failure / Communication Failure)
** Estimated Value

Calculation of Power Balance and Flexibility Potential

To calculate the schedule and the flexibility potential, an exemplary day of the MV network usage described above was selected. The time series of the aggregated loads and feed-ins (PV, wind, biomass) are shown in Figure *6*.

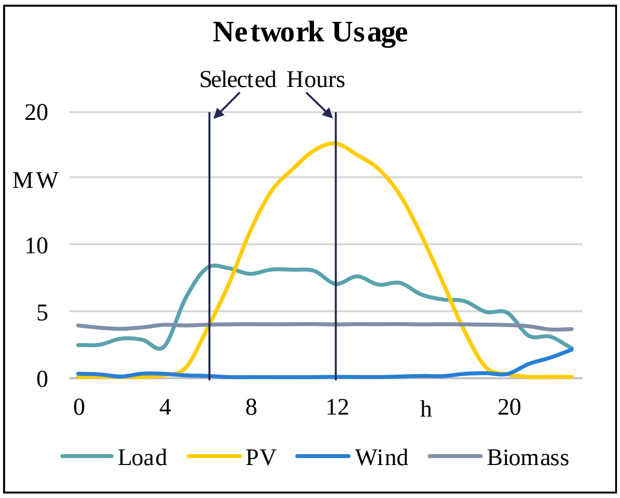

Figure 6: Usage of the MV Network for One Day

Basically, the day is characterized above all by high PV feed-in, with the classic PV curve. Furthermore, there is almost no feed-in by wind and the biomass power plants feed in nearly constantly. For this day, the schedule (dark blue) was determined first and in the next step the negative flexibility potential (light blue), shown in Figure 7, was determined.

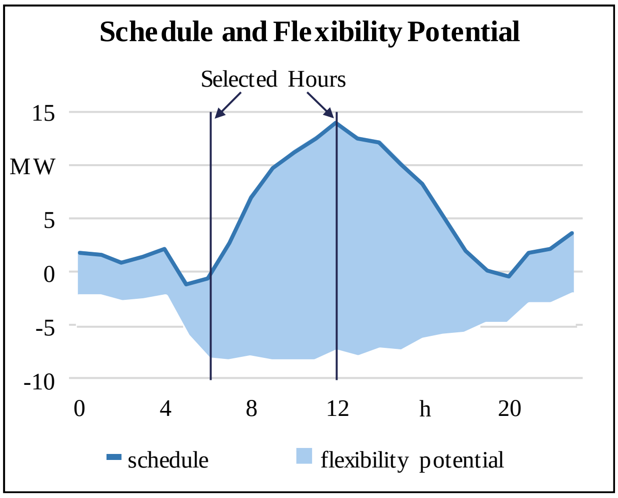

Figure 7: Resulting Schedule and Flexibility Potential for the Network Usage of the Selected Day

The described time series of the loads and feed-ins lead to the fact that the schedule is dominated by the PV feed-ins. The same applies to the negative flexibility potential, which has its maximum around 12 pm. Outside the feed-in through PV units, the flexibility potential mainly results from the control of the biomass power plants, which have a lower potential than the PV units.

Calculation of Reliability of Schedule and Flexibility Potential

Two hours (6 am / 12 pm) of the presented day were selected for the calculation of the reliability of the schedule and the flexibility band (violet). First the results for 6 am are presented. This hour is characterized by a low PV feed-in and a high load. The schedule value is 0.625 MW and the negative flexibility potential is 7.734 MW. Figure 8 shows the deviation of the schedule value as a relative frequency distribution.

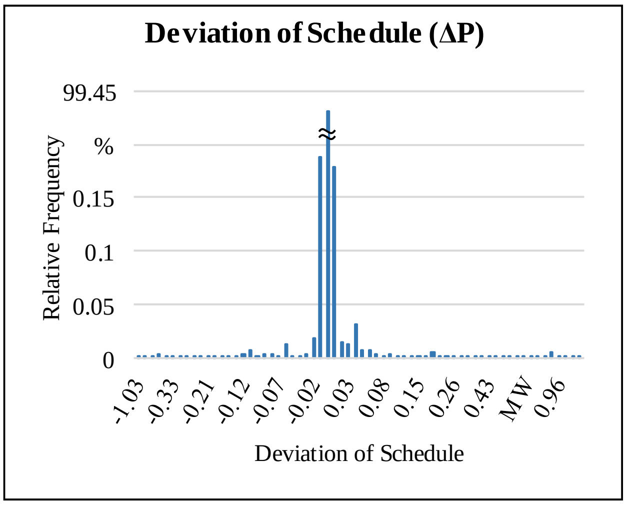

Figure 8: Reliability of the Schedule for 6 am

The reliability of the schedule for the selected hour is 99.43 %. The largest positive deviation is 1.03 MW and the largest negative deviation is 1.09 MW, but with a very low probability. The highest probability for a deviation is in the range of -0.02 MW and 0.04 MW.

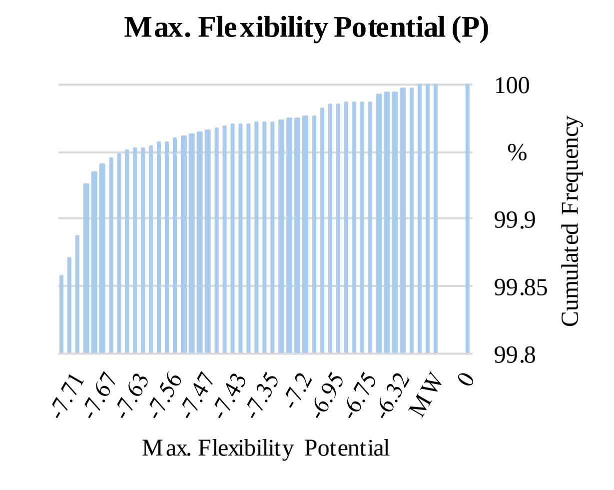

Figure 9: Reliability of the Flexibility Potential

The reliability of the max. negative flexibility potential (Figure 9) is 99.85 %. The lowest negative flexibility potential is 5.94 MW, as the probability of a non-availability below that level is so low that it can be neglected. So at least 5.94 MW are available and therefore a maximum deviation of 23.2 % is possible but only with a very low probability.

At 12 pm the schedule value is -13.747 MW and has a reliability of 99.03 %. The maximum negative deviation of the schedule is -1.884 MW und the maximum positive deviation is 13.788 MW and is therefore significantly higher than at 6 am, which results from the high feed-ins from DG. The max. negative flexibility potential is 21.342 MW with a reliability of 99.03 %. The min. negative flexibility potential is 0 MW, which is a maximum deviation of 100 %. These values show that with a large flexibility potential and a high utilisation of the grid, the deviation can be very large and must therefore be taken into account when dimensioning ancillary services for the higher-level network or at system level.

CONCLUSION

In principle, the results show that the reliability of the schedule and flexibility band for individual hours is very high and that the provision of flexibility for the higher-level network is possible. Nevertheless, the deviation of schedule and a reduction of the flexibility potential due to outages is remarkable and exceeds usual dimensioning standards for active power reserves of 4 h/a like in Germany. However, it is to be expected that the consideration of the reliability of DG will have a further negative influence on the reliability of the schedule and flexibility band. Furthermore, the results show a dependence of the reliability and the deviation of the flexibility potential on the amount of the forecasted flexibility potential, on the utilisation of the network as well as network characteristics and connection points of customers, that provide flexibility. Therefore, it is necessary to consider the reliability of the flexibility potential when dimensioning ancillary services for the higher-level network. In addition, the use of flexibility for distribution network purposes hamper the use of standard availability requirements. In Summary this asks for enhanced determination and control of security margins for ancillary services for active power balancing.

ACKNOWLEDGMENTS

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