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DEMOCRAT

Deliverable D3.6 – Report with the technical specification of the Microgrid Management System

Activity: Technical Specification of the Solution and Its Components

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DEMOCRAT ABSTRACT

The DEMOCRAT project aims at demonstrating an integrated and innovative micro-grid concept applied to LV and MV networks, as a suitable solution for efficiently managing their distributed energy resources (DER), working simultaneously as a flexible asset of the distribution networks.

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Executive Summary

This report contains the specification of the microgrid management system that will perform an integrated management of the grid, not only by providing an optimal planning for the operation of the available assets, but also ensuring the operation is kept within the technical constraints constantly over the time. This specification comes in the sequence of the previous work developed in the design of all the sub-modules that will be incorporated in the microgrid management system. For this reason, this report also presents the main work flows and coordination among these modules, in such a way they can contribute for reaching an optimized operation of the network. Within this optimized operation it is targeted among others to increase the share of renewable energy resources in the energy mix, to reduce energy costs and to ensure a proper operation of the network, particularly in islanded mode.

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Glossary

BESS	Battery Energy Storage System
DER	Distributed Energy Resources
DMS	Distribution Management System
DR	Demand Response
DSO	Distribution System Operator
ESCOs	Energy Services Companies
EV	Electric Vehicle
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
SCADA	Supervisory Control and Data Acquisition

1. Introduction

DEMOCRAT – DEMOnstrator of a miCro grid integRAting sTorage – is a demonstration project resulting from an integration process of a set of individual solutions and technologies developed by Efacec Energia within the scope of Smart Grids, jointly with its Storage and Inverters solutions, allowing the development of a turnkey micro-grid solution for wide-scale application for electrical power systems. More than a solution that enables the on-grid and off-grid grid operation, DEMOCRAT extends these functionalities by endowing the micro-grid with advanced management capabilities, in such a way it works as a flexible asset of distribution networks by aggregating and coordinating their Distributed Energy Resources (DER), such as charging stations infrastructures for Electric Vehicles (VE). DEMOCRAT enables, among others, the increasing of the networks capacity to host new DER, to increase the penetration levels of renewable energy in the energy mix and the improvement of the quality of service and energy, while deferring investments in network infrastructures.

This deliverable, D3.6, belongs to the Activity 3 – Technical Specification of the solution and its components -, as depicted in Figure 1.

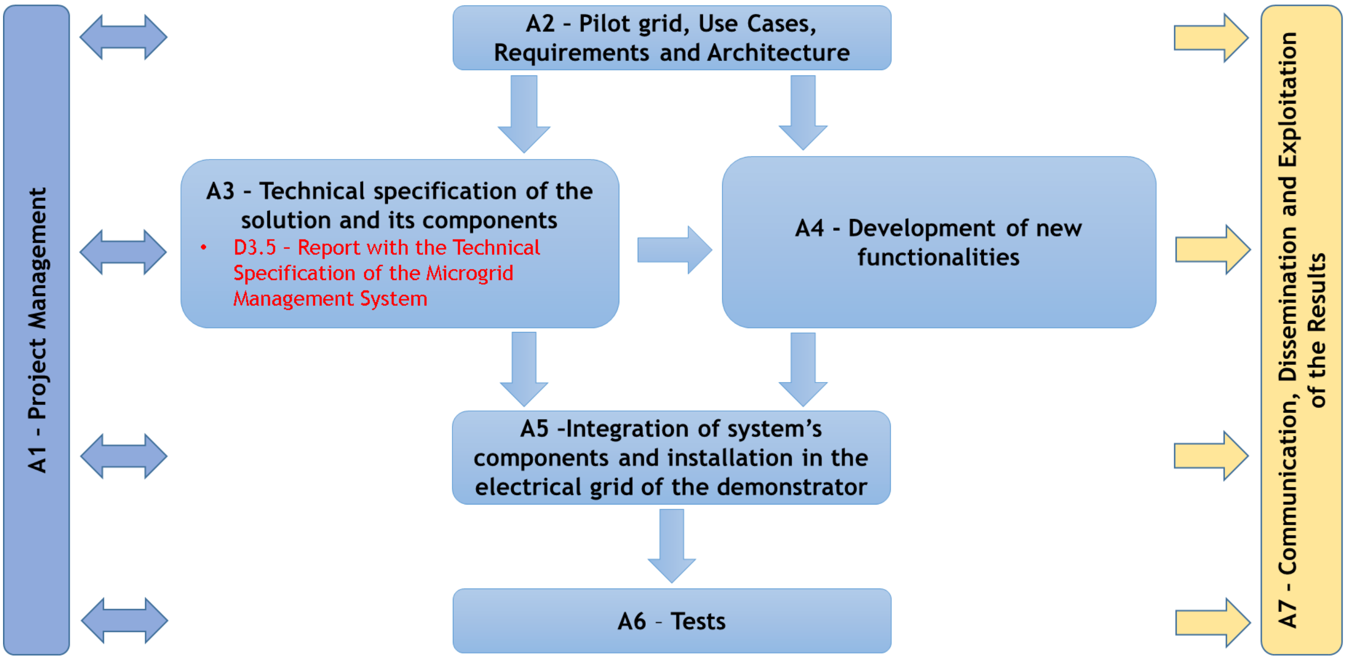

Figure 1 - Position of the deliverable D2.3 within DEMOCRAT activities structure.

The purpose of this document is to detail all the main interaction flows among system and devices present on the solution, and to establish the respective actuation boundaries, when considering the real microgrid operation. In such a way, it is possible to identify on a high-level basis, the main functions of each module and respective inputs and outputs for the microgrid management system.

This document consists of two main chapters:

- Chapter 2, which provides a general overview of the microgrid management system, where are described the main functionalities to be used during the operation. In addition, it also includes a description of the interaction among modules present on the DEMOCRAT microgrid management system solution, focusing on the information flows that will be used to perform the microgrid management.

- Chapter 3 provides a global vision about the operation modes of the microgrid management system and the actuation that is performed according to different scenarios. In this chapter the main interactions among modules and respective logic functions are described.

2. Microgrid Management System

This chapter describes an overall vision of the modules that are present in the micro-grid management system and their main interactions as well.

2.1 General Overview

The Microgrid management system will be responsible for the optimal grid management and control. In order to do so, it will present among others, the following functionalities:

- Load Forecast – will be used to compute the demand forecast for the microgrid up to 48h ahead and with the ability to produce intra-day forecasts in order to continuously provide updated information to the other microgrid modules.

- Generation Forecast – the forecast of renewable generation is crucial for a predictive management of the network as it will allow beforehand to cope with the typical variability associated to this kind of energy sources. Similarly to the load forecast, the generation forecast will be performed for the following hours up to 48h ahead and with the possibility of generating updated forecast data based upon on more recent weather forecast data.

- Smart Charging – given the ever-growing integration of EV charging in electrical grids, namely through fast charging schemes, the system will be capable of programming in quasi real-time the load for charging purposes. This way, it will be enhanced the capability of grids to accommodate suck kind of loads while ensuring a reliable operation of the networks. Furthermore, besides ensuring the safe operation of the grid, this functionality also copes with the EV users' preferences, namely their needs in terms of scheduling the EV charging (e.g. desired departure time).

- Advanced Microgrid management – represents the core of the microgrid management system as will be responsible for the network operation planning where the optimization of the storage control is crucial. As a result, this functionality will be used in such a way to perform a technical/economic operation of grid, namely with the aim of promoting the following controls:

    - Peak shaving
    - Energy costs reduction
    - Increase local self-consumption
    - Increase RES in the energy mix
    - Programmed transition between grid operation modes (grid connected to islanded).

- Demand Response and Energy Market Participation – effective capacity to include demand response features on system management. In case of a public network, the utility can benefit from the possibility of requiring demand flexibility from users by generating DR events. In case of a private network, the microgrid owner can apply for participating in energy flexibility markets.

2.2 Microgrid Management System – Modules

The microgrid management system controls all its directly subordinate system elements, i.e., lower level management units, sensors and actuators. It takes control decisions based upon on the user configuration and depending on external information, such as market information (e.g. energy prices).

The microgrid management system can be applied either on public or private networks. Thus, depending on the target application, the components of DEMOCRAT microgrid solution may have different roles as the processes and functionalities carried out may operate on behalf of different stakeholders and process data from different stakeholders. Notwithstanding, since at every level the concept of data collection and processing is similar, the management algorithms applied on the microgrid management system share the same conceptual base, which endows this approach with an increased scalability.

Figure 2 illustrates the main architecture of the microgrid management system, where can be observed the main modules responsible for ensuring the high-level operation of the microgrid. In addition, the interactions between modules are also detailed.

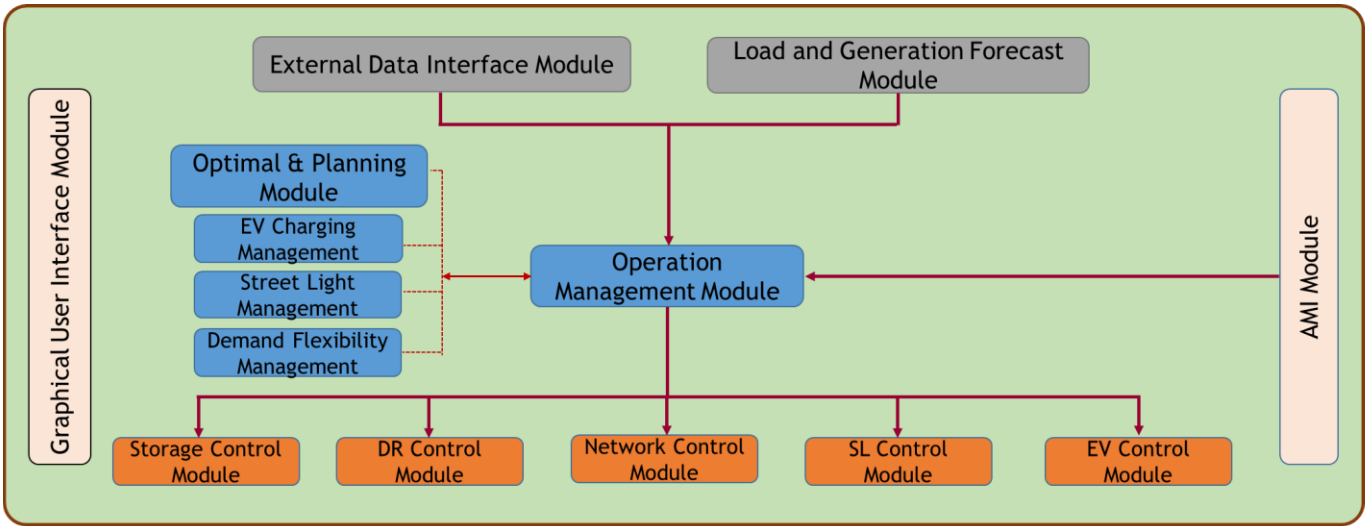

Figure 2 – Detailed representation of the microgrid management system modules.

Description of the modules:

- Graphical User Interface: this module presents the main function of enabling the operator of the microgrid to online monitor the operation state of the microgrid including the different assets and planned operation. In addition, it also enables the operator to manually operate the microgrid, namely by sending control commands to the field. On the other hand, in case of a private microgrid solution, this module will mainly be used by the consumer to visualize data and other customer-oriented information, such as energy usage and billing.

- External Data Interface: module that has particular importance for private owned microgrids and which will be used to receive external data regarding market information, being used to interconnect with other entities such as energy retailers and energy services companies.

- Load and Generation Forecast Module: includes different algorithms for computing the forecasts for the local energy generation, from renewable energy resources, and the load consumption. For this purpose, this module receives information from a third-party service that is external to the management system with information concerning to weather forecasts. In addition, this module receives historical data from the AMI module.

- AMI module: represents the main component responsible for all the tasks that involve the treatment of the data received from the field. Works as the gateway between the field and the system comprising all the algorithms used to manage the raw data and extract relevant features for supporting the other microgrid management modules. It handles the large amounts of data resulting from the IEDs, smart meters and other measurement sensors, with communication capabilities, installed at microgrid. It performs among others the verification of the consistency of data by identifying outliers (erroneous measurements), performing data imputation (replacing missing values) and selecting the most observable period, so that the operation of the other modules is not jeopardized.

- Operation Management Module: can be considered as the backbone of the microgrid management system as it will responsible for coordinating the execution of the other modules. It is responsible for the autonomous trigger execution of all the tasks involved in the microgrid operation. this module will be responsible for distributing the control actions by the different control modules, dividing therefore the information for each one according to the particularities of each system or device in the field. Will also be responsible for computing the control actions to be sent on near to real time considering the observed operation conditions of the microgrid. Is therefore used for the reactive operation of the microgrid as its actuation scope is focused on the calculation of corrective measures to the planned operation provided by the Optimal & Planning Module.

- Optimal & Planning Module: represents the component in which most of the algorithms for computing the microgrid operation under different scenarios are comprised. It is responsible for calculating control actions for the different controllable systems available in the microgrid, attending to the forecasted conditions in terms of demand and generation. Its actuation scope is therefore focused on planning the operation of the microgrid in a short to medium term (up to 24h) with the aim of, using the forecasted operation conditions, to optimize the microgrid operation. This module has a direct coordination with the following modules:

  - Demand Flexibility Management: sub module that will be responsible for managing the demand response features of the microgrid management system. Within this purpose and on public operated microgrid this module will be responsible for generating DR events for requesting flexibility to consumers that have subscribed the participation in DR programs. On the contrary side, in private applications, this module will be responsible for participating in DR events and to coordinate the operation of the flexible assets jointly with the Optimal &Planning Module with the aim of minimizing energy costs and needs.

  - EV Charging Management: component that will be responsible for computing the operation of the EV charging depending on the planned operation of the microgrid. In addition, this module will be called whenever is observed the need of providing flexibility to the microgrid.

  - Street Light Management Module: component that will be in charge of controlling the street light infrastructures namely by scheduling the operation over the time. On top of that, this system may also be executed during network contingencies in the network, by proving identifying controls action to provide flexibility.

- Control Modules (Storage, DR, Network, Street Light, and EV): these modules are used to translate and convert the internal information provided by Execution Management Module in the proper data structure, according to the protocols used by each particular system and device.

3. Microgrid Management System – Hierarchical coordination of the modules and respective workflows

This chapter comprises a definition of the main operation scenarios for the microgrid and identifies the main workflows to be followed with the aim of ensuring the fulfilment of the network operation technical constraints, following both technical and economic criteria.

3.1 Microgrid operation – planning operation mode

This operation mode aggregates all the processes carried out with the aim of planning the operation of the microgrid for the next hours, on a time horizon of up to 24h ahead. This planning is performed with the aim of providing output controls for all the controllable assets available in the grid, taking into account the expected operation conditions such as level of demand and generation. This operation mode is used on both grid-connected and islanded modes.

This planning of the microgrid operation is performed on a daily-basis, with a cyclical intraday mode with the aim of adjusting the previous planning with updated information from the field. The timeline of microgrid operation planning is exemplified in Figure 3. The first planning is performed for the day ahead -Day Y-, with the aim of providing a macro guideline for the microgrid operation. Since the real micro-grid operation may present some discrepancies when comparing with the initial planning, namely due to the existence of non-controllable and forecastable variables, such as the user needs regarding EV charging purposes, the planning of the micro-grid will be recalculated on an hourly basis to take cope with these uncertainties (intra-day planning). It is worth to mention that the intra-day planning will be performed for the remaining hours of the day – Day Y.

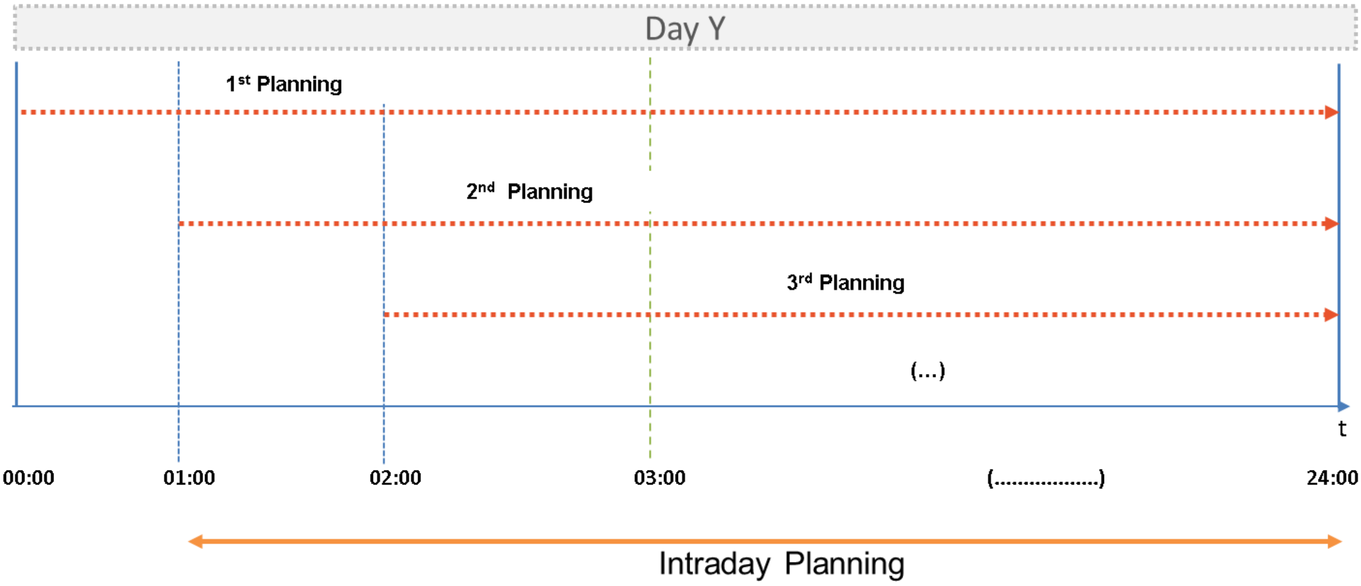

Figure 3 - Exemplification of the timeline for microgrid operation planning.

From the abovementioned, the EV charging demand represents the variable with higher level of uncertainty for the microgrid operation planning. For this reason, the microgrid management system has an embedded functionality – smart charging – that will be used to cope with the EV charging but always considering the existing planning for the micro-grid operation. As a result, the processing will be performed as following:

Every time a planning of the micro-grid operation is performed the system will provide a report with the network availability – network operation plan - to accommodate EV charging load. This way, every time a new EV charging arises, the EV charging management will be responsible for computing the charging profile attending to the network operation plan. It is worth to point out that the EV charging profile are computed considering both restrictions of the network but also the user's preferences such as time of departure and user's priority (e.g. in case of lack of power availability from the network for all the charging processes, consumers with higher priority will have more power for charging that others with lower priority). This way, it is possible to maintain the operation within the technical constraints. Afterwards, on the next planning of the microgrid operation – intra-day planning -, the charging profile calculated by the EV Charging Management module will be incorporated in the load forecast module, in order to reflect the new load introduced by the EV charging. This process is depicted in Figure 4.

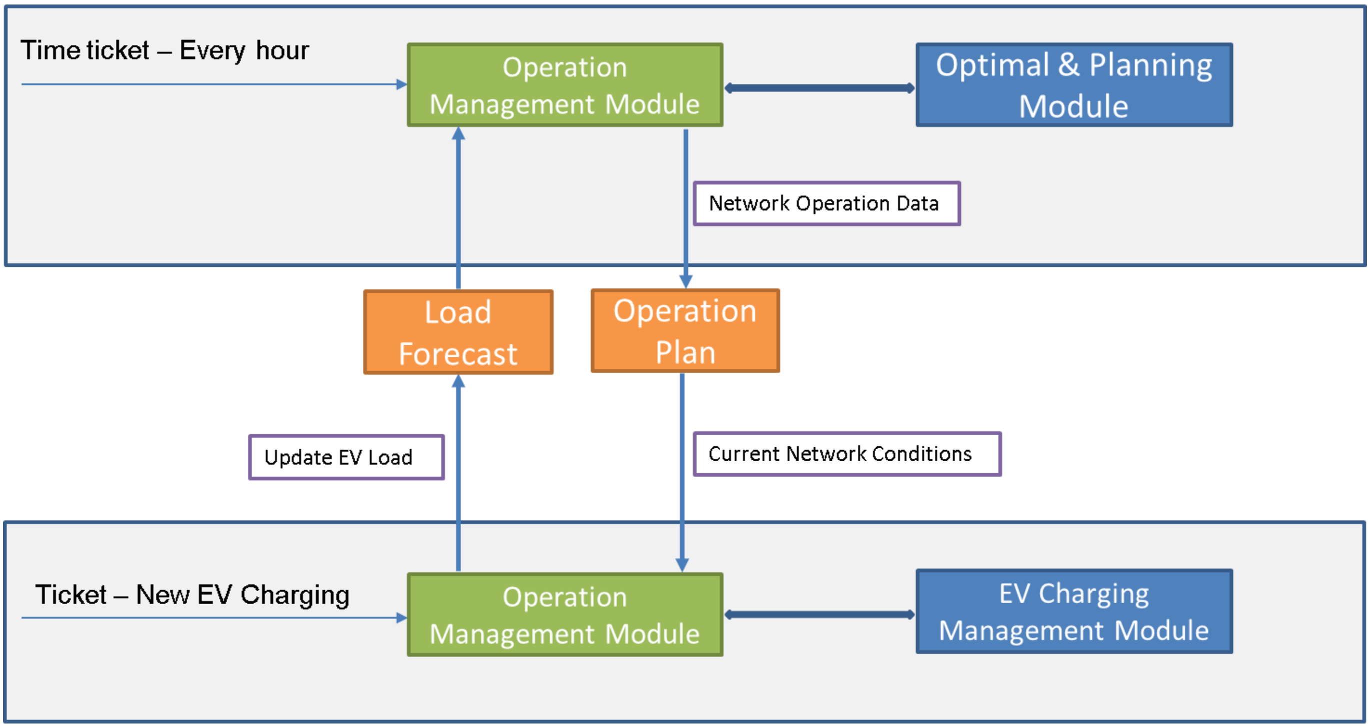

Figure 4 - Process used to cope with the uncertainty associated to EV charging needs.

3.1.1 Tackle non-feasible planning solutions

During the microgrid planning there may occur the occurrence of non-feasible solutions considering the expected forecast conditions for the network and thus, it may be required to find ways of providing flexibility to the network. In order to address these technical restrictions (e.g. voltage violations, congestions) the micro-grid management system can use the following strategies:

- Demand Response flexibility: the microgrid management system has the possibility of requiring flexibility services from consumers. In such a way, based on the reported flexibility forecasts provided by those consumers that have subscribed the DR program, the micro-grid management may request such flexibility to ensure microgrid operation within technical restrictions. This control is performed at the level of the Demand Flexibility Management Module. In addition, this module can also be responsible for load shedding controls in case none of the other control actions are enough to fulfil the technical operation restrictions (the load shedding controls can be particularly important on islanded mode). The demand response flexibility from consumers is only applicable for public microgrids.

- EV charging flexibility: since the EV charging load can present a significant part of consumption in the micro-grid, the microgrid management system may request the EV charging management module the recalculation of the charging profiles to tackle the foreseen operation problems.

- Street Lighting flexibility: in addition to the previous controls, the microgrid management system may request the Street Light Management Module to provide flexibility to microgrid, particularly in islanded mode.

In order to coordinate the flexibility actions to address contingency situations, the microgrid management system follows a merit order list that determines the sequence of assets to be used as a mean of providing flexibility. This processing is illustrated in Figure 5.

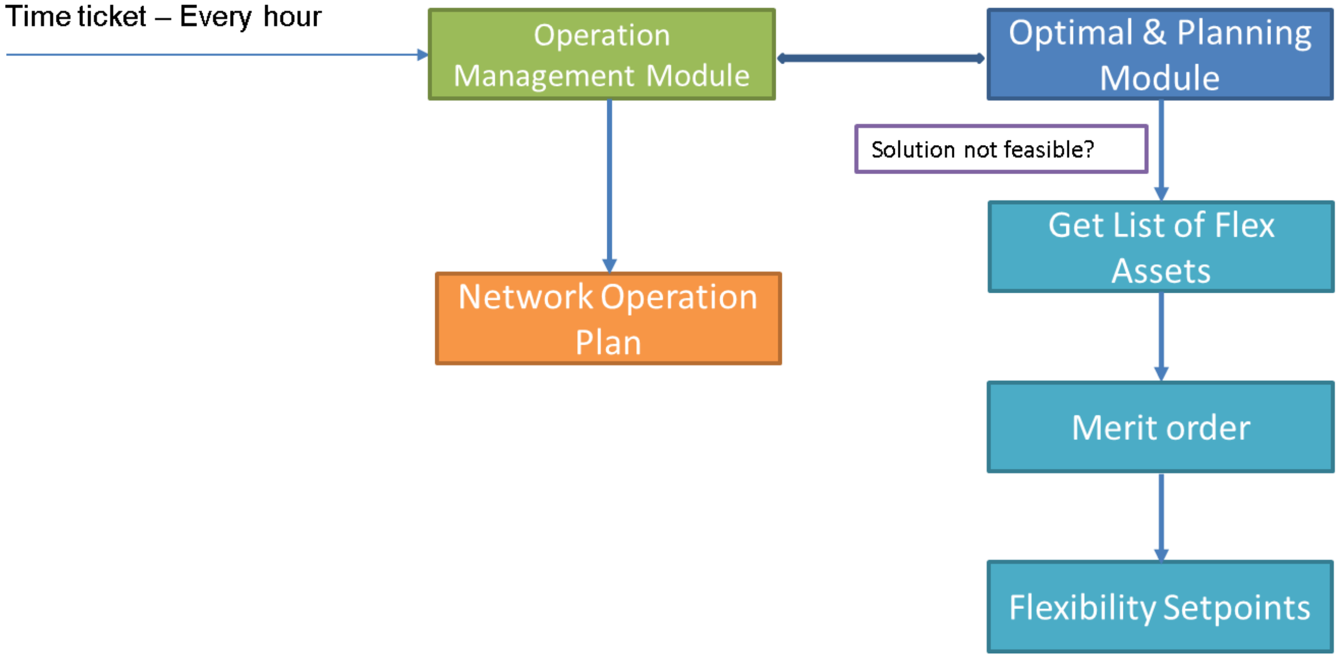

Figure 5 - Microgrid processing to address foreseen contingencies in network operation.

The merit of order is typically as following, depending on the availability of the assets to provide flexibility and the respective technical-economic cost associated. Nevertheless, the cost of using flexibility from these assets is identified by the operator of the system, which can therefore change the merit order list.

1. EV Charging Management
2. Demand Response - flexibility from consumers
3. Street Light Control
4. Direct Load Control

The microgrid management tries to minimize the number of flexibility controls and thus, only requests flexibility from assets on a higher level of the merit order list if strictly necessary.

3.2 Microgrid operation - real-time operation mode

This operation mode, represented in Figure 6, is characterized by ensuring the near to real-time operation of the microgrid considering on one hand the operation planned and on the other hand the real information gathered from the different devices available on the field. Based on this information, it will assess if the current operation conditions have changed when comparing with the planned operation that was previously used to establish the operation point of each controllable asset. If there is significant discrepancy on the operation conditions (e.g. differences between expected and real demand), the microgrid management system will monitor these differences so that in the following intraday planning there will be an update of the planned operation for the microgrid accordingly, i.e., to cope with the discrepancies observed (e.g. compute new forecasts for the demand and generation).

Besides the evaluation of the current execution of planned operation conditions, the microgrid management system will also look for unexpected contingencies. In order to do so, the microgrid management system will compute the current operation state of the grid, relying on the devices available on the field, such as the smart sensors that can provide grid measurements regarding a multitude of different electrical measures and generate events when some problem is observed. In such case, corrective actions will be calculated to address the operation problem observed and the planned operation will be recalculated. It is to point out the role of the energy storage system in this situation to provide fast actuation controls to ensure the safety of operation. After the contingency has been addressed on the next intraday planning the planned operation will be recalculated to take into account the impact on the controllable assets resulting from the corrective measures applied to re-establish normal grid operation.

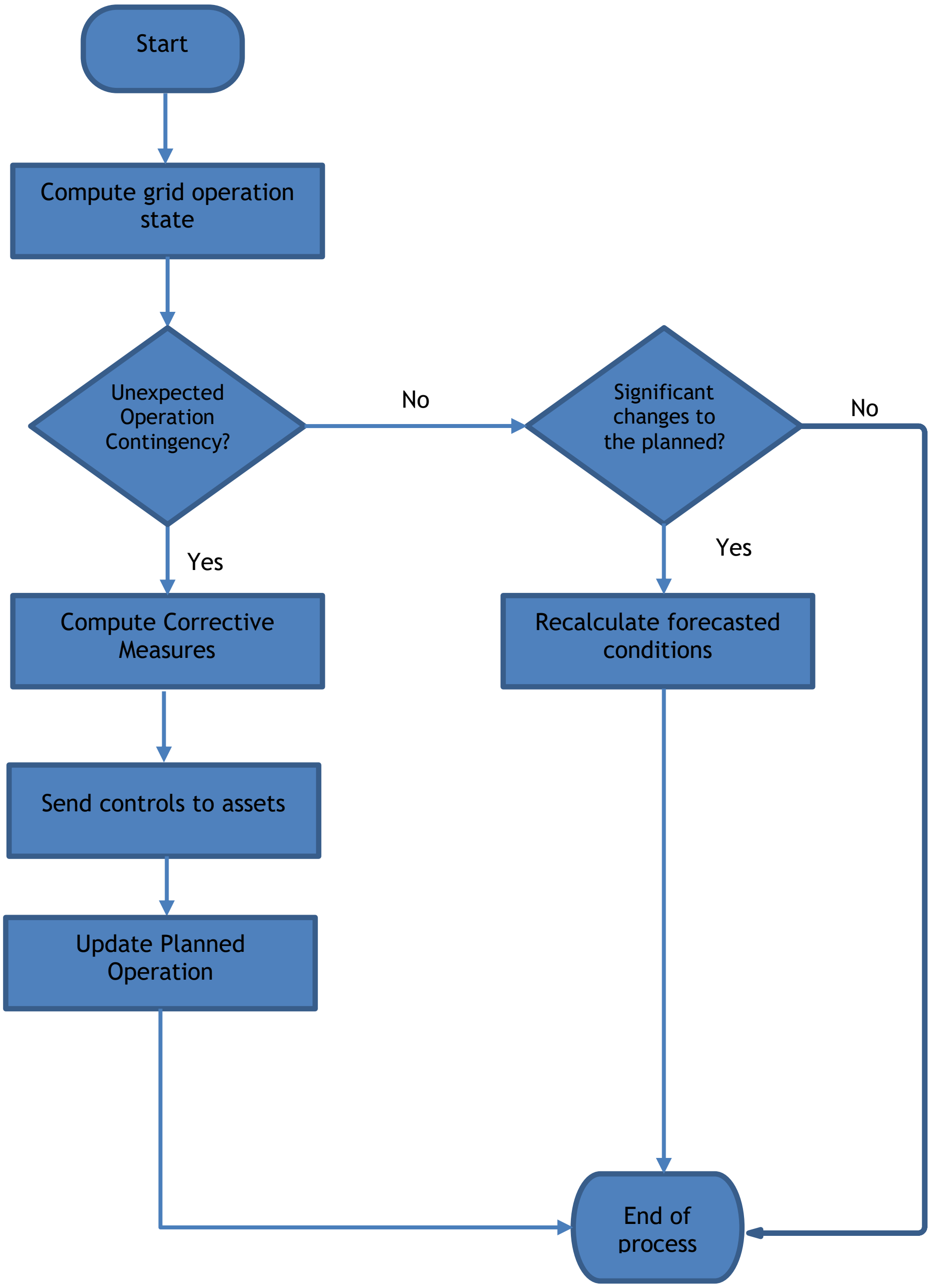

Figure 6 - High level diagram of processing during real-time operation.