

*HONOR*  
*Deliverable (D) 5.1*  
*Development of Control System Algorithm*  
*Part – II: Operation and Visualization Concept*

PSI 

**HONOR**  
**Deliverable (D) 5.1**  
**Development of Control System Algorithm**  
**Part – II: Operation and Visualization Concept**

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# List of Abbreviations

CS	Control System
DER	Distributed Energy Resources
FPU	Flexibility Providing Units
FSM	Flexibility Service Mechanism
GCP	Grid Connection Point – The point of common coupling between two networks, e.g. MV distribution network and HV transmission network
GUI	Graphical User Interface
WP	Work Package

# 1 Introduction

This document is the second part and a supplement to the HONOR Deliverable (D) 5.1 – Part I [1] document, where the FSM has been conceptualized and described. The aim of this document is to conceptualize visualization and operating scenarios for FSM. Therefore, this document may be read in addition to the first part of D5.1 document. Furthermore, the result of this documentation will also act as a base for setting the laboratory demonstration in WP8 of the HONOR project.

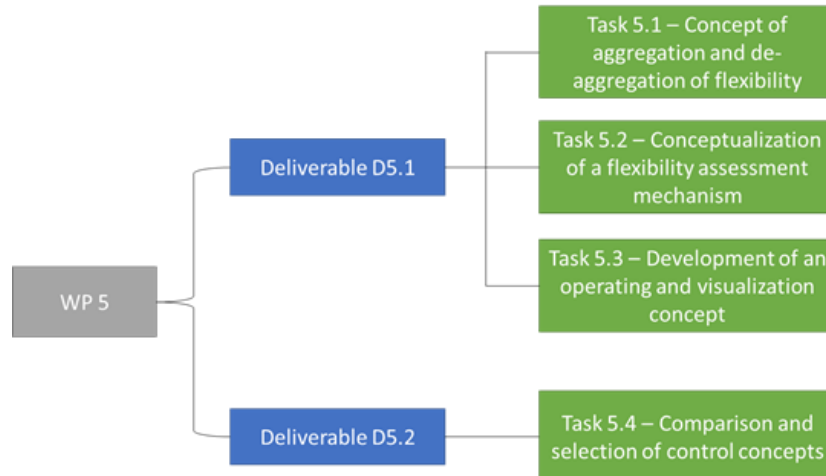
## 1.1 Requirements for visualization and operation for FSM

To integrate FSM module into the control system environment, visualization and decision support will be required for network operation. The purpose of FSM is to support a system operator in managing and utilizing the DERs in the distribution network for flexibility services to the transmission systems. FSM calculates the flexibility potential of the distribution network and provides possible flexibilities in the form of active and reactive power exchanges at the GCP in real-time. These flexibilities can be visualized in the form of two dimensional flexibility maps in the control system. According to the definition of flexibility from FSM, the flexibility is calculated with respect to the current operating point. Therefore, in these flexibility maps, the flexibility will be visualized and monitored with respect to the current operating point and can be updated every few minutes (based on the settings, e.g. every 15 minutes). For this purpose, in this document, concepts have been developed to enable a GUI for calculation of flexibility and monitoring current situation in the grid.

## 1.2 Objective and scope

The objective of this document is to fulfil the Task-5.3 of HONOR Deliverable (D) 5.1 [2] as shown in Figure 1. For visualization, the focus is on the conceptual development of GUI for FSM that can be integrated into a control system (CS). The GUI should be able to support the system operator in displaying the permissible active and reactive power potentials in the form of flexibility maps. Furthermore, various options or functionalities can be provided to the user in terms of utilizing the result and sending in control signals to the flexibility providing units (FPU). FSM has been developed in such a way that the result shows the various flexibility options with the economic dispatch information for FPUs. The scope of this task is only the development of the concept, whereas the development of software and implementation will be performed in WP8 of HONOR project.





*Figure 1: Structure of WP5 of HONOR project*

### **1.3 Structure of the document**

Chapter 1 of this document introduces the motivation, objective as well as the scope of this task in the deliverable. In Chapter 2, the use cases of the GUI in view of FSM’s visualization and operation possibilities have been described. Furthermore, requirements analysis have been performed on these use cases to realize them for implementation. In Chapter 3, various GUI screenshots have been designed to support the previously discussed use cases.

## 2 Development of visualization concepts

This chapter describes the conceptualization of various visualization possibilities in the form of GUI concepts and depending on the operating scenarios with FSM in focus. These GUIs are planned to be implemented into a CS. This chapter describes the main use cases for which the GUI has to be developed in WP8. This is followed by the requirements analysis to realize these use cases in a control system software.

### 2.1 Use cases for visualization

Based on the scope of FSM application, there are different use cases of operating and visualization scenarios for which a GUI would fulfill different requirements. These use case descriptions have been grouped together in the form of epics. Epics are larger task units that can be subdivided into several smaller tasks. The three main epics connected to the relevant use cases for the GUI are explained below in Table 1.

Table 1: Description of the operating scenarios

Epic	Description	Use Case
<b>Topology overview</b>	This section provides the interface in CS to visualize the reference network. Additionally, this part of GUI can have the option to visualize other important data such as measurement data and state estimation, if applicable.	<ul style="list-style-type: none"> <li>• Display network topology</li> <li>• Visualize measurements</li> </ul>
<b>Monitoring</b>	<p>Monitoring section of the GUI provides the following options to the system operator:</p> <ul style="list-style-type: none"> <li>• Calculation/Checking of power flow</li> <li>• Calculation and visualization of flexibility</li> </ul> <p>PSI<i>control</i> obtains cyclic update of measurement data from the network every interval. Also, when a control signal is sent to change setpoint or a network topology change is requested, this is updated correspondingly in the data received. To monitor the current power flow situation in the network, the in-built power flow calculation function is called upon by a button which shows the desired output. Additionally, power flow situation can also be visualized after change of setpoint (e.g. after a flexibility control signal is sent).</p> <p>The second option in this section is to calculate the net flexibility at a given GCP. The integrated FSM in the CS will calculate the net flexibility at the GCP according to current power flow situation and provide with the flexible operating points. Once the flexibility is calculated, the visualization</p>	<ul style="list-style-type: none"> <li>• Calculate / Check power flow</li> <li>• Calculate and visualize flexibility</li> <li>• Export results</li> </ul>

	will show the net flexibility at the selected GCP. This will help the system operator to not only monitor the current power flow but also the flexibility associated with that at the GCP.	
<b>Decision Support</b>	In decision support, the options that FSM offers is changing the setpoint at the GCP. Here, once the flexibility has been estimated, the number of flexible setpoints will be made available to the system operator. The system operator can then select one of these flexible setpoints to adjust to a new setpoint. Once this option is executed, the CS can send control signals to the respective FPU's to change their respective setpoints.	<ul style="list-style-type: none"> <li>• Change PQ-setpoint</li> <li>• Export results</li> </ul>

An overview of the above defined use cases in Table 1 has been shown as a screenshot of the proposed GUI in Figure 2. This GUI is supposed to serve as the main interface between the system operator and the CS. As shown in the figure, the 'Topology Overview' allows the system operator to visualize the network topology, whereas the measurement data and/or state estimates can be visualized from 'Other Data' of this section.

In the 'Monitoring' section, power flow result as well as the calculation of flexibility can take place through FSM which will be integrated inside the CS. Furthermore, the results could be exported in the required format from the 'Export Results'.

In 'Decision Support', system operator interface for flexibility dispatch is offered by 'Change Setpoint' option as well as the changed setpoint can be visualized again through 'Visualize PQ-Maps'. Again, the results of the power flow and the changed power flow due to new setpoint could be exported in the required format through 'Export Results'.



Figure 2: A screenshot model of the proposed GUI for FSM's visualization and operation

## 2.2 Requirements analysis for the use cases for GUI

In this section a requirement analysis has been performed to realize the use cases defined in the previous section. This has been subdivided according to the epics defined previously.

### 2.2.1 Epic – Topology Overview

#### 2.2.1.1 Use Case – Display network topology

<b>Use case name</b>	<b>Display network topology</b>
Description	<p><b>Compressed description of the use case:</b></p> <p>Here, the network topology obtained from the grid/network connected to the CS is visualized in the CS GUI. The network diagram can include the most required components, the topological connections of stations including the values and directions of the power flow. Along with the power flow, the current operating point (or setpoint) can be shown graphically on a 2D P-Q axis.</p>
Actor/s and the system	<p><b>Naming of the system:</b></p> <p>CS</p> <p><b>Listing of actors:</b></p> <p>Person / System operator (CS operator)</p>
Trigger	System operator clicks on the ‘Reference Network’ button in the ‘Topology Overview’ section of the GUI.
Preconditions	<ul style="list-style-type: none"> <li>• The CS obtains the network topology information from the network.</li> <li>• Cyclic data related to topology changes is obtained</li> <li>• GUI has been designed to functionalize this use case and is available in the CS</li> </ul>
Normal process	After clicking the ‘Reference Network’ button, the network topology is visualized.
Alternative procedure	
Procedure with errors	<ul style="list-style-type: none"> <li>• Network topology doesn’t show up: <ul style="list-style-type: none"> <li>○ Configure the topology file for the correct version</li> <li>○ Reload</li> </ul> </li> <li>• Power flow values are blank: <ul style="list-style-type: none"> <li>○ Display ‘Power Flow didn’t converge in the GUI’</li> </ul> </li> </ul>
Result	The network topology along with the load flow can be visualized to the system operator via the GUI.

### 2.2.1.2 Use Case – Visualize measurement data

<b>Use case name</b>	<b>Visualize other data</b>
Description	<b>Compressed description of the use case:</b> Measurement data or the state estimates pertaining to cyclic update obtained in the CS can be seen through the usage of GUI.
Actor/s and the system	<b>Naming of the system:</b> CS <b>Listing of actors:</b> Person / System operator (CS operator)
Trigger	System operator clicks on the ‘Other data’ button in the ‘Topology Overview’ section of the GUI.
Preconditions	<ul style="list-style-type: none"> <li>• The CS obtains the measurement data from the network cyclically every 5 minutes.</li> <li>• GUI has been designed to functionalize this use case and the measurement data may be visualized in tabular formats (optional).</li> </ul>
Normal process	After clicking the ‘Other data’ button, the measurement data is visualized.
Alternative procedure	
Procedure with errors	<ul style="list-style-type: none"> <li>• Measurement data is not received cyclically <ul style="list-style-type: none"> <li>○ Automated request will be sent to check for measurement data if not received cyclically.</li> </ul> </li> </ul>
Result	Measurement data can be visualized in the CS by clicking at ‘Other data’ in ‘Topology Overview’ section of the GUI.

## 2.2.2 Epic – Monitoring

### 2.2.2.1 Use Case – Calculate / Check power flow

<b>Use case name</b>	<b>Calculate power flow</b>
Description	<p><b>Compressed description of the use case:</b> This is an optional use case to be developed if the use case 2.2.1.1 doesn't provide the functionality to show power flow.</p> <p>The power flow analysis of the network is performed cyclically in the CS. The power flow in the lines as well as nodal power injections / withdrawal is evaluated and shown to the System operator in the GUI of the CS.</p>
Actor/s and the system	<p><b>Naming of the system:</b> CS</p> <p><b>Listing of actors:</b> Person / System operator (CS operator)</p>
Trigger	System operator clicks on the 'Calculate power flow' button in the 'Monitoring' section of the GUI.
Preconditions	<ul style="list-style-type: none"> <li>• The CS receives the network topology information from the network via process coupling.</li> <li>• Cyclic data related to topology changes is obtained</li> <li>• Cyclic measurement data is obtained</li> <li>• GUI dedicated to this use case has been functionalized</li> </ul>
Normal process	After clicking the 'Calculate power flow' button, the power flow is visualized in the form of table or graphically.
Alternative procedure	
Procedure with errors	<ul style="list-style-type: none"> <li>• Power flow doesn't converge Display 'Power flow didn't converge'</li> </ul>
Result	The network topology can be visualized to the system operator via the GUI.

### 2.2.2.2 Use Case – Calculate and visualize flexibility

<b>Use case name</b>	<b>Calculate and visualize flexibility</b>
Description	<p><b>Compressed description of the use case:</b></p> <p>The FSM integrated in the CS is called upon through the GUI to initiate flexibility calculation. The FSM, based on the current power flow, determines the current setpoint at the GCP. Based on these information, FSM calculates flexible setpoints applicable to the current setpoint. These flexible setpoints are then visualized in the network topology of CS next to the GCP indicated in the network diagram.</p>
Actor/s and the system	<p><b>Naming of the system:</b> CS</p> <p><b>Listing of actors:</b> Person / System operator (CS operator)</p>
Trigger	System operator clicks on the ‘Calculate and visualize flexibility’ button in the ‘Monitoring’ section of the GUI.
Preconditions	<ul style="list-style-type: none"> <li>• Power flow data such as active power, reactive power, voltage angle, voltage magnitude, current value, etc. is obtained.</li> <li>• GUI is designed to visualize PQ- flexibility maps in the network diagram.</li> <li>• FSM is integrated in the CS.</li> </ul>
Normal process	<ol style="list-style-type: none"> <li>1. System operator clicks on the ‘Calculate and visualize flexibility’ button.</li> <li>2. FSM takes time to calculate flexibility. ‘Calculation in progress...’ is displayed in the intended window where flexibility has to be visualized.</li> <li>3. ‘Calculation completed’ is shown once the flexibility estimation process is completed.</li> <li>4. In the network diagram, flexibility is visualized in 2D PQ axes with the current setpoint.</li> </ol>
Alternative procedure	<ol style="list-style-type: none"> <li>1. In the network diagram, system operator clicks on the ‘Calculate flexibility’ button to initiate the flexibility estimation process.</li> <li>2. In the same window, PQ-flexibility map is plotted next to the GCP along with the current setpoint.</li> </ol>
Procedure with errors	<ul style="list-style-type: none"> <li>• FSM doesn’t converge to a solution <ul style="list-style-type: none"> <li>○ The GUI should show ‘Infeasible Solution. Aborting.’</li> </ul> </li> <li>• Timeout error in case of infeasible solutions <ul style="list-style-type: none"> <li>○ The GUI should show ‘Timeout Error. Aborting.’</li> </ul> </li> </ul>
Result	Flexibility is visualized in the network diagram of CS.



## 2.2.3 Epic – Decision support

### 2.2.3.1 Use Case – Change setpoint

Use case name	Change setpoint
Description	<p><b>Compressed description of the use case:</b></p> <p>The CS can visualize the flexible setpoints on the basis of current setpoint. Furthermore, the CS can also be able to change the current setpoint to the flexible setpoint from the available options. It can be done either by clicking on one of the flexible setpoints to change the current setpoint or enter the value of the new setpoint. The change will be made effective after the CS sends the control signals to the respective flexible units to change their output to suit the required change.</p>
Actor/s and the system	<p><b>Naming of the system:</b> CS</p> <p><b>Listing of actors:</b> Person / User (CS operator) Network assets (FPU's)</p>
Trigger	User clicks on the 'Change setpoint' button in the 'Decision support' section of the GUI.
Preconditions	<ul style="list-style-type: none"> <li>• Flexibility is estimated.</li> <li>• Visualization shows the 'potential' flexible setpoints based on the current setpoint.</li> <li>• GUI has been developed to enable the flexible setpoints be available as options to effect setpoint change by 'clicking' on those setpoints.</li> <li>• The GUI is developed for effecting the changing in setpoint by sending the control signals to the network.</li> </ul>
Normal process	<ol style="list-style-type: none"> <li>1. System operator enters the value of the setpoint in a dialog box or in a separate window of the GUI of CS and then clicks on the 'Change Setpoint' button.</li> <li>2. The setpoint is changed after the control signal is sent to respective units and the change is implemented.</li> <li>3. The changes setpoint is then reflected in the network diagram.</li> </ol>
Alternative procedure	<ol style="list-style-type: none"> <li>1. The system operator clicks on the desired setpoint in the PQ-flexibility graph residing in the network diagram.</li> <li>2. Rest of the steps are similar to the normal process.</li> </ol>
Procedure with errors	<ul style="list-style-type: none"> <li>• Setpoint not changed: <ul style="list-style-type: none"> <li>○ Display in GUI 'Couldn't change setpoint. Either the control signal is not relayed or the CS couldn't establish connection.'</li> </ul> </li> </ul>
Result	Setpoint is changed and reflected to the network diagram.

### 2.2.3.2 Use Case – Export results

Use case name	Export results
Description	<p><b>Compressed description of the use case:</b></p> <p>The results obtained after the flexibility estimation or after changing the setpoint can be exported in the required format for further use through this option. The result can be in CIM/CGMES format with detailed information of the power flow calculation for each of the flexible operating points.</p>
Actor/s and the system	<p><b>Naming of the system:</b></p> <p>CS Database</p> <p><b>Listing of actors:</b></p> <p>Person / System operator (CS operator)</p>
Trigger	Clicking on the ‘Export results’ button.
Preconditions	<ul style="list-style-type: none"> <li>• Setpoint change/Flexibility estimation is done is executed.</li> <li>• The results are stored in a database.</li> </ul>
Normal process	<ol style="list-style-type: none"> <li>1. System operator clicks on the ‘Export results’ button.</li> <li>2. The result stored in the database after setpoint is changed is used to convert into a required format for export.</li> <li>3. The result is saved to the desired location.</li> </ol>
Alternative procedure	
Procedure with errors	<ul style="list-style-type: none"> <li>• Result is not generated                             <ul style="list-style-type: none"> <li>○ Display ‘Result not generated because flexibility hasn’t been estimated or set-point hasn’t been changed’</li> </ul> </li> <li>•</li> </ul>
Result	Result of changed setpoint or flexibility is saved in the required format.

### 3 Conceptual GUI for the use cases

To implement the defined use cases in the previous chapter for FSM as GUI, various concepts in the form of screenshots as well as their description is provided in this chapter. These concepts are sketched taking into consideration as a starting point and development plan for FSM’s GUI in WP8 so that they can be demonstrated in the laboratory environment. The scope of conceptualizing these use cases is limited to a generalized design rather than design according to a specific CS. The actual design or development of GUI will depend upon the CS platform and subsequent support systems which will be decided in WP8. Here, these concepts will act as a base for further development.

#### 3.1 GUI concept for network topology (use case – display network topology)

Figure 3 shows a GUI concept for displaying the network topology of the concerned distribution network with respect to the use case described in Section 2.2.1.1. The network diagram shows the different buses along with their unique identifiers which are connected with each other through power lines. It also can include information about the transformers’ position and their connections. Furthermore, any topological changes such as line outage or changes in breaker on/off condition can be visualized with the help of this GUI. The GCP can also be represented in the network topology in the form of the transformer which will serve as the point of common coupling between the two networks (one which provides flexibility and the other receives it e.g. TSO network).

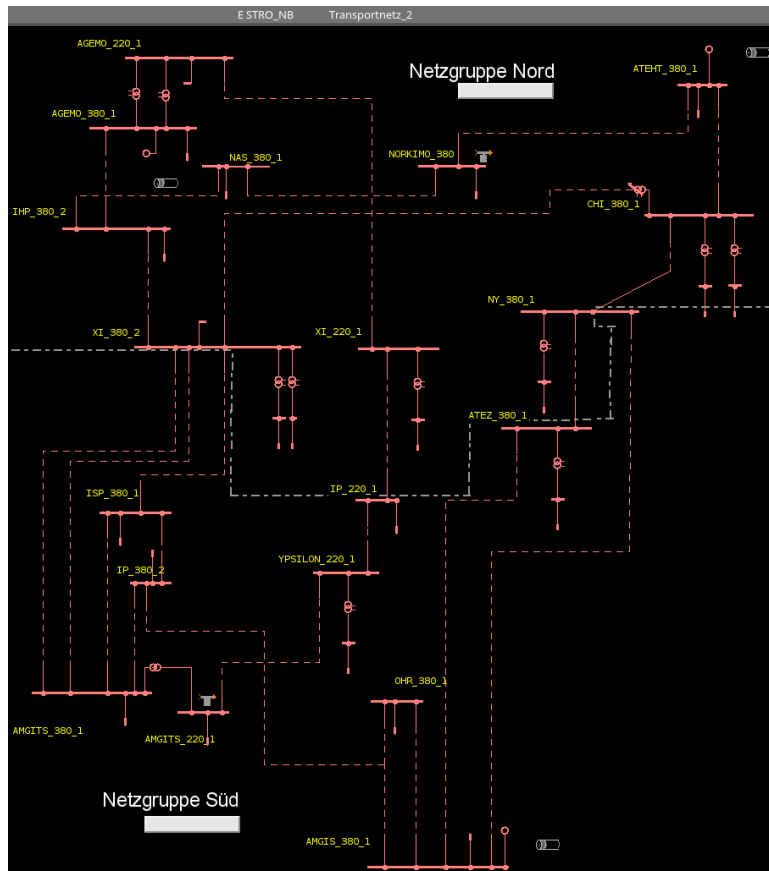


Figure 3: A GUI concept for displaying the network topology of the concerned network

### 3.2 GUI concept to display measurement data / power flow

This GUI concept is supposed to serve the requirements of the use cases mentioned in Section 2.2.1.2 and Section 2.2.2.1. Figure 4 shows an example of a GUI representing the magnified screenshot of a network diagram to indicate the power flow value (indicated in digits beside the branch or line) as well as the direction (marked with 'green' arrow). It shows the most required details of the component without visualizing other information about the topology. In the example, it can be seen that the network diagram is visualized for different regions as well as the voltage level it is connected to, e.g. 'Ampingen 110', 'Stichstadt 110', etc. Other information such as circuit breaker status, (square symbol), as well as switches (dot symbol) can also be visualized. Although the power flow value is shown to be 0 in this figure, in reality it has the actual value depending on the power flow situation.

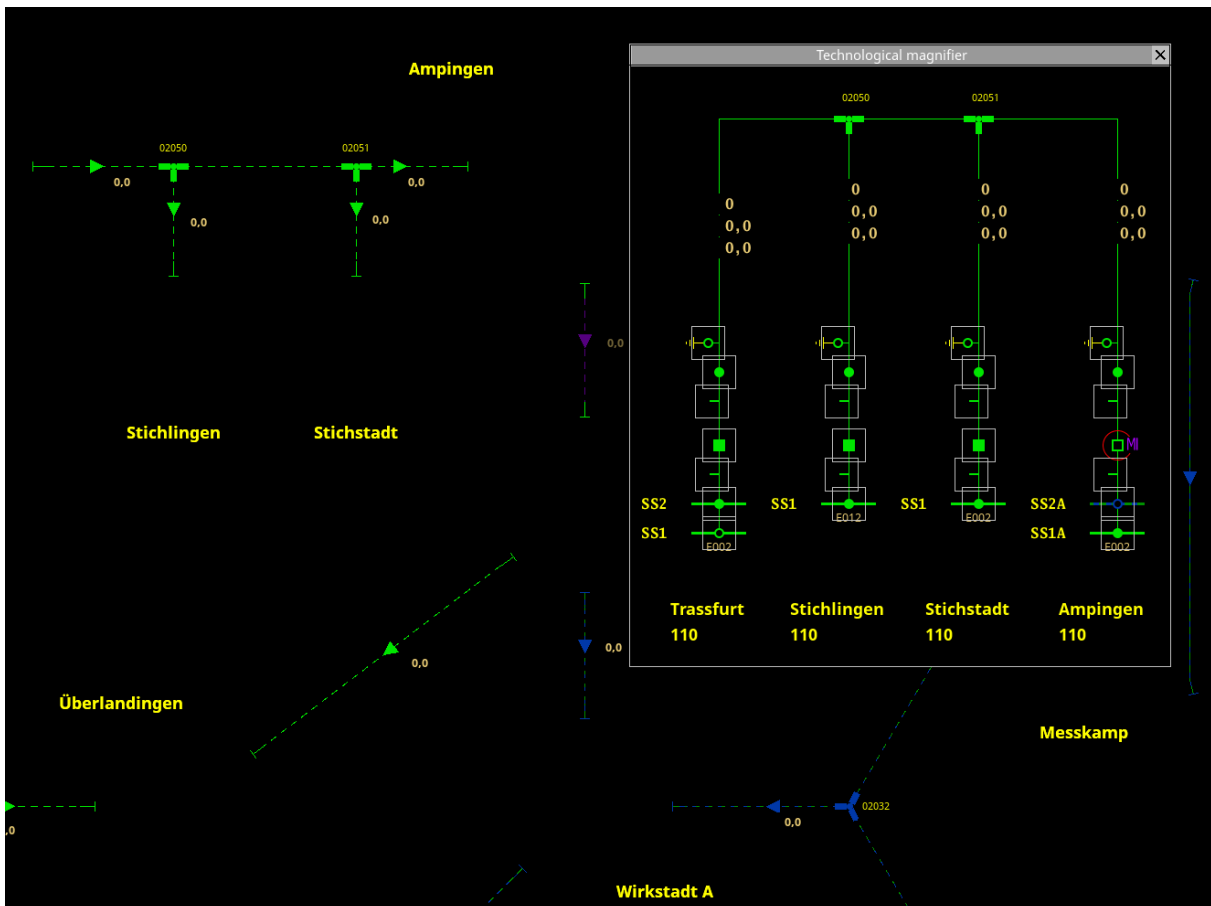


Figure 4: An example GUI concept which can be developed to display power flow diagram of the network

### 3.3 GUI concept to calculate and visualize flexibility

There can be various possibilities with how the flexibility calculation is triggered. As mentioned in the description of the use case in Section 2.2.2.2, one way is to use the GUI as shown in Figure 2 to launch a FSM window as shown in Figure 5 where the flexibility calculation process as well as the visualization is performed. Another way could be to launch this window directly from the network diagram as shown in Figure 3.

In Figure 5, the FSM window has the button to calculate flexibility, whereas the current setpoint and the GCP are also shown in a dialog box. Furthermore, as soon as the system operator clicks on the ‘Calculate Flexibility’ button, the FSM integrated in the CS fetches the required data and initiates the calculation process. While this process is running, it can be shown to the system operator with a message ‘Calculation in progress ...’ message as shown in the figure. Similarly, once the calculation process is finished, it can be shown as ‘Calculation completed successfully’ message as shown in Figure 6.

In Figure 7, flexibility map is visualized with respect to the current setpoint. It shows the flexible setpoints marked in blue while the current setpoint is visualized in green. Furthermore, the flexible setpoints can also be shown as values in the dialog box. Here, it can be seen that the results obtained (which could be stored in a database) could be exported in the relevant format through the ‘Export Results’ button. This functionality is applicable to the use case to export results as described in Section 2.2.3.2.

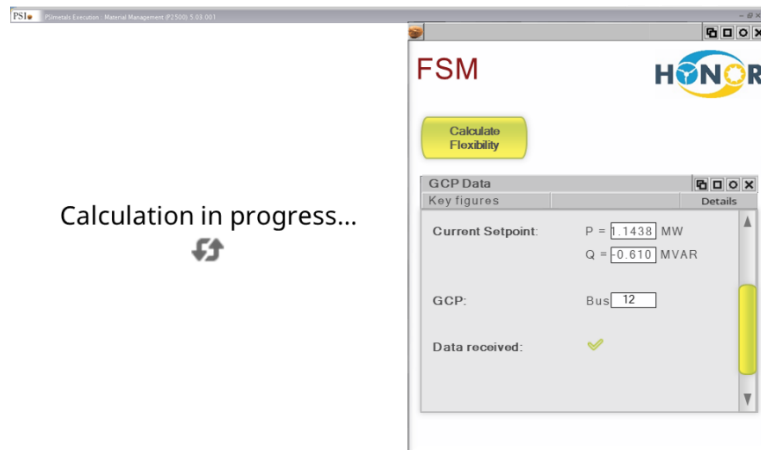


Figure 5: Example GUI depicting the FSM window for calculating flexibility

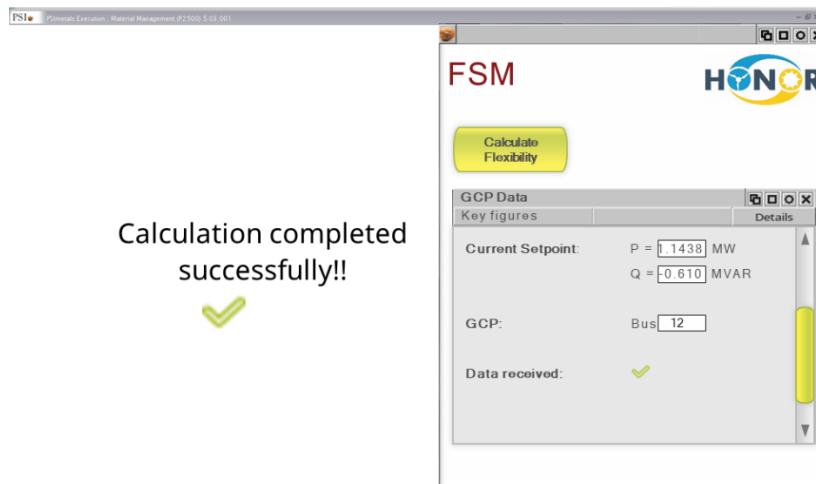


Figure 6: 'Calculation completed successfully' message being displayed after FSM completes calculation

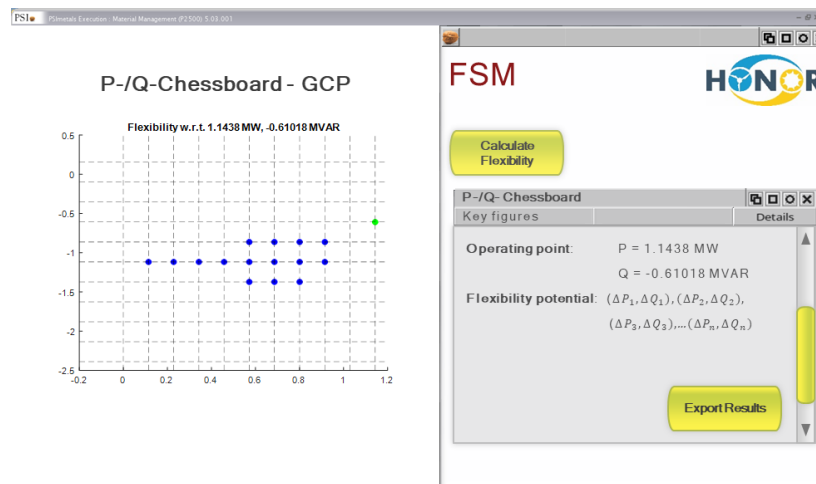


Figure 7: Visualization of flexibility map with respect to a setpoint (operating point)

### 3.4 GUI concept to dispatch flexibility

Once the flexibility has been determined, the system operator can change the setpoint depending upon the flexible setpoints he obtains. Figure 8 shows a GUI to change the setpoint of the power flow in a network from the obtained flexibility result in the previous step. In Figure 9, the change in setpoint is effective and shows a successful message with the changed setpoint also reflecting in the dialog box too.

Additionally, the power flow result of the new setpoint can be exported in the required format through the 'Export Power Flow Result' button as shown in Figure 9. This functionality also fulfills the requirement of use case mentioned in Section 2.2.3.2. To calculate flexibility again with respect to the new setpoint, the GUI described in Section 3.3 is utilized.

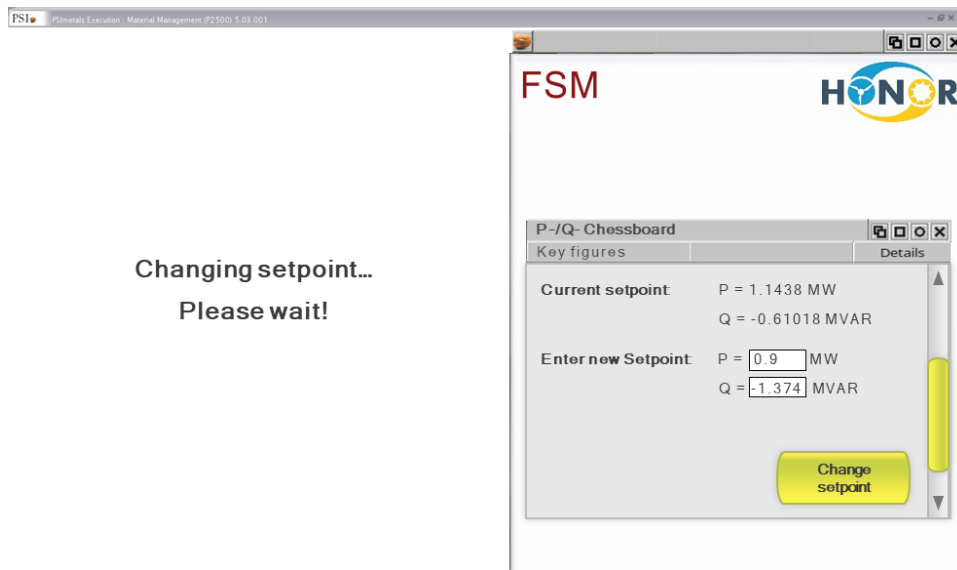


Figure 8: GUI depicting the possibility to change setpoint after the flexibility has been determined

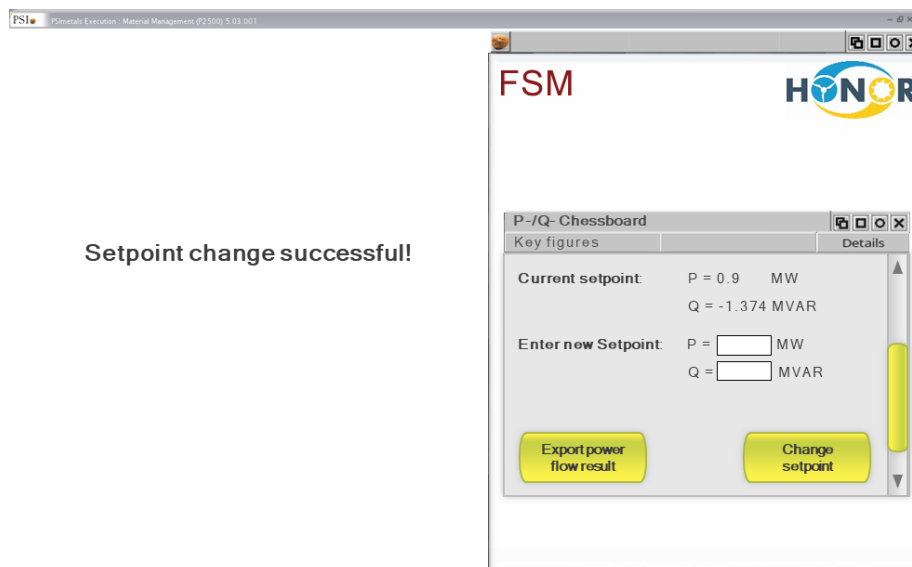


Figure 9: Setpoint change successful

## **4 References**

- [1] HONOR, *Deliverable D5.1: Part I - Flexibility Service Mechanism*, 2022.
- [2] HONOR, *Joint project description*, 2018.