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DiGriFlex

D1.1 Description of ancillary services provided within and from distribution grids.

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Résumé

Ce rapport est le premier livrable du projet Digriflex, qui vise à développer des méthodes de prévision et de contrôle optimales pour assurer un fonctionnement efficace et sûr des réseaux de distribution. Le WP1 est axé sur i) la définition des services réseaux et des degrés de liberté et ii) l'analyse et la caractérisation des actions possibles au niveau de la planification et de l'exploitation. Ce rapport couvre la première partie. La méthodologie de la tâche 1.1 consiste d'abord à classer les services et à identifier comment la valeur de ces services sera quantifiée pour l'étape d'optimisation prévue dans les lots de travail (WP) ultérieurs. Des services réseaux locaux et à l'exportation ont été proposés pour être étudiés dans la suite du projet. Essentiellement, la valeur des services qui permettent d'éviter le renforcement du réseau sera évaluée en tenant compte des coûts de ce renforcement, tandis que les autres services seront évalués par comparaison avec les produits existants et leur évolution historique. Les activités ont également inclus une série d'entretiens avec les GRD qui ont aidé à orienter la sélection des services, mais aussi à rassembler des données (données de réseau et informations sur les coûts des composants) qui seront utilisées dans les études de cas prévues dans la tâche 1.2 et déjà commencées.

Summary

This is the initial deliverable for the Digriflex project, aiming to "develop effective forecasting and optimal control methods to ensure efficient and secure operation of distribution grids". WP1 is focussed on i) defining services and degrees of freedom and ii) analysing and characterising available operational and scheduling options. This report is covering the first part. The methodology for Task 1.1 is to first classify the services and the to identify how the value of these services will be quantified for the optimisation stage planned in subsequent work packages. Local and export ancillary services have been proposed for consideration. Essentially, the value of those services that allow to avoid network reinforcements will be valuated considering the costs of said reinforcements while other services will be valuated using a comparison with existing products and their historical development. The activities also included a set of interviews with DSOs that helped to steer the services' selection, but also to gather data (network data and cost information for components) that will be used in the case studies planned in Task 1.2 and presently already started.

Acronyms

aFRR	Automatic frequency restoration reserve
DSO	Distribution System Operator
GIS	Geographic information system
LV	Low Voltage
mFRR	Manual frequency restoration reserve
MV	Medium Voltage
RMS	Root mean square
SCCER FURIES	Swiss competence centre on energy research – Shaping the future Swiss electrical infrastructure
V2G	Vehicle to grid
AES	Association des entreprises électriques suisses

Contents

Résumé **3**

Summary **3**

Acronyms **4**

Contents **5**

1 Introduction **6**

1.1 DiGriFlex project description 6

1.2 WP1 description 6

1.3 Deliverable D1.1 definition 6

2 WP planning **7**

2.1 Project plan 7

2.2 Tasks description 7

2.3 Methodology 8

3 Ancillary services definition **10**

3.1 Local services 10

3.1.1 Services, dependencies and value definition 10

3.1.2 Devices, control scheme and constraints 14

3.1.3 Benefits and conventional solution for the cost comparison 14

3.2 Ancillary services exported to higher network levels 14

3.2.1 Services, dependencies and value definition 14

3.2.2 Devices, control scheme and constraints 15

3.2.3 Benefits and conventional solution 17

3.3 DSO Interviews 18

3.3.1 Methodology 18

3.3.2 Summary of interviews 18

4 Bibliography **19**

A DSO interviews **21**

A.1 Questionnaire 21

A.3 Questionnaire objectives 22

B.2 Summary of answers 24

B Literature review **27**

1 Introduction

1.1 DiGriFlex project description

The Digriflex project aims at validating effective forecasting and optimal control algorithms for LV distribution grids. Two high-level objectives are formulated in the project proposal:

1. "develop effective forecasting and optimal control methods to ensure efficient and secure operation of distribution grids, as well as flexibility and ancillary service provision from local low voltage distribution grids to the upstream medium/high voltage grids, under uncertainties"
2. "implement the above forecasting and optimal control methods in a test case low voltage distribution grid"

The general approach in this project is to combine two layers of optimisation: in the prescheduling step, an optimal point of operation for all controllable resources is identified. The real-time optimisation then reduces the deviation between the scheduled and effective outputs of the considered resources.

1.2 WP1 description

WP1 "Definition of the ancillary services to be considered by the distribution system operator" delivers the list of considered ancillary services and their relative value compared to conventional approaches (typically reinforcements of grids or use of centralised ancillary services, e.g.). WP1 consists of two tasks:

- Task 1.1: Definition of services and degrees of freedom
- Task 1.2: Analysis and characterisation of available operational and scheduling options

The next chapter will introduce the detailed contents of each task and its association with the two deliverables planned for this work package. At the end of WP1, the relative value of flexibility in LV distribution grids will have been determined based on several LV networks obtained from Romande Energie.

1.3 Deliverable D1.1 definition

In this deliverable "Description of ancillary services provided within and from distribution grids, taken from literature and DSO experiences", the result of the selection of relevant ancillary services are presented. The method included a literature review, interviews with DSOs and the analysis of previous activities performed by the project team within SCCER FURIES.

2 WP planning

2.1 Project plan

Based on the breakdown of activities presented in the previous chapter, the time plan of WP1 shown in has been established. Compared to the time planning in the proposal, the paralleling of WP1 and other WPs has been agreed in order to accommodate the resource availability of several partners.

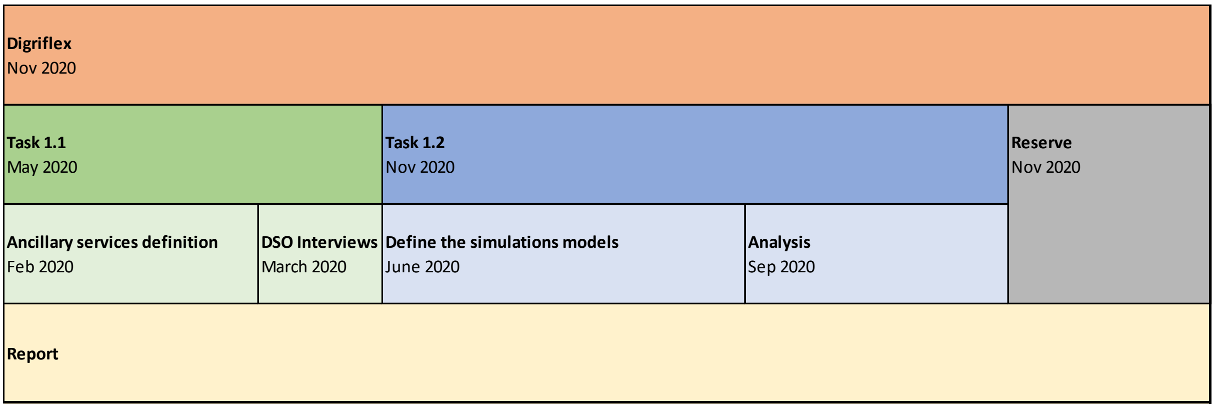

Figure 1: Summary of WP1 time plan

2.2 Tasks description

Figure 2 shows the planned activities for the proposed tasks as well as an approximate effort repartition among the subtasks identified for the main partner of this work package, HEIA-FR. The contribution of all other partners is evenly split across the subtasks as it will mainly consist of interfacing and consulting on some specific questions.

Task 1.1 is reviewing existing facts, knowledge and practices in order to integrate those into the DiGri-Flex project. In a first step the established definitions of ancillary services have be analysed and expanded towards not yet implemented definitions for local use of similar ancillary service products. Proposals for more and novel ancillary services have been gathered from the literature. The comparison basis for the value of local services based on resource flexibility is network reinforcement. The initial data will be the established standardised costs of VSE/AES [1], combined with anonymised case examples provided by some of the interview partners (see below).

In a second step, the opinion and preliminary experience of selected DSOs has been collected in a small series of interviews. The interviews were used as a complement to the literature study regarding potential ancillary services as well as current/future uses of flexibility. The remaining part of the interview was devoted to conventional approaches and the way the costs induced by network reinforcements can be estimated.

In addition, the interviews also provided a means to raise awareness about the planned future activities of the DiGriFlex project.

Task 1.1	150 h	May 2020
Ancillary services definitions	**100 h**	**Feb 20**
Literature study	30 h	
Define ancillary services and actors for local export and costs evaluation	20 h	
Define ancillary services and actors for upstream use and costs evaluation	20 h	
Define alternative solutions and evaluate the costs	20 h	
Preliminary cost comparison of alternative solutions	10 h	
DSO Interviews	**50 h**	**March 20**
Define interview questions based on the ancillary services definition research	20 h	
Contact the DSOs and meetings	30 h	
Task 1.2	**360 h**	**nov.20**
Define the simulations models	**210 h**	**June 20**
Choose a network (real from RE or Relne)	10 h	
Set up the simulation for the flexibility	100 h	
Set up simulations for the alternatives solutions	100 h	
Analysis	**150 h**	**sept.20**
Run simulations and validate results	50 h	
Comparaison between the use of flexibility and alternatives	50 h	
Formulate the flexibility valuation (necessity/cost)	50 h	

Figure 2: Effort breakdown per subtask in work package 1 (HEIA-FR contribution).

2.3 Methodology

Figure 3 shows the methodology adopted in the WP1 tasks described above. The literature review started with a keyword search in established databases. The information gathered in the paper was then organised and compared in tables discussed within the next sections of this report. The candidate services were then selected qualitatively by the experts of each partner represented in WP1 to obtain a shortlist of services considered: one group for export into higher network levels and another group of services for local use within the LV network. These two elements are combined with the first part of the DSO interview results to form the inputs into deliverable D1.1 (this report). The interviews were conducted in person, based on a preestablished questionnaire considering the needs of the project, but with the flexibility to explore other areas if the interviewee felt this was appropriate.

Activities for task 1.2 started with the establishment of simulation models of suitable LV networks. The basis for these models was provided by SCCER FURIES related activities where a method for the import of data from the GIS database into a state-of-the-art power systems analysis tool (PowerFactory in this case) had been established. The coverage and degree of detail of the data imported was expanded for the needs of this project. The networks are used in order to assess the need for network reinforcement if the penetration of solar PV generation is increased. Using power flow calculations, the cost of upgrading cables and other components in case of capacity or voltage variation violations are used in order to determine the value of the flexibility that would avoid the need for such reinforcement. A certain number (currently still under investigation) of such cases will be analysed in order to determine the cost of reinforcement per unit of energy for different configurations. The average value will then be determined. For the export of services, methods from other SCCER FURIES activities related to average values of services will be used.

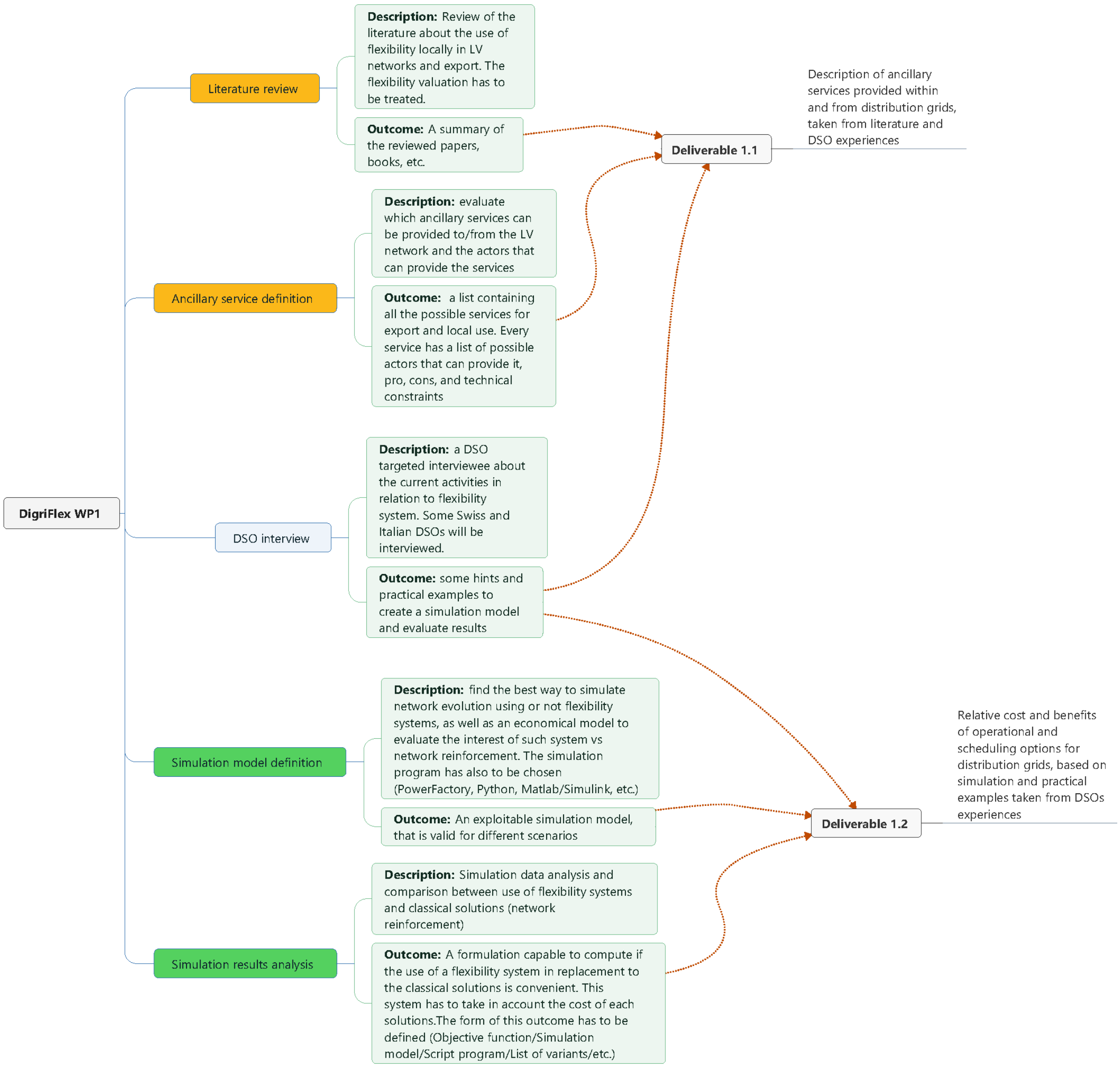

Figure 3: Organisation of activities in WP1 (orange: Task 1.1, green: Task 1.2)

3 Ancillary services definition

Flexibility services identified in the literature [2]–[30], expert opinions and DSOs interviews are listed, clustered and discussed in the next chapters. The detailed findings of the literature study are given in a table form in Appendix B. Two groups of ancillary services have been formed: services for local LV usage and for export to higher voltage level. Then, the actors and technical needs to implement such flexibility systems are listed. The interview reports are given in appendix A and the details for the literature review are given in appendix B.

3.1 Local services

A local service is an action of resources within a LV network fed by a single MV/LV transformer that helps to achieve an objective which is only expressed in terms of quantities (voltages, loadings, total consumption, etc.) of that network. Typically, if an imbalance is solved locally or loadings are adjusted locally, costs can be avoided and therefore a relative value can be assigned to the service. The following paragraphs will discuss these effects. There can however be limitations in using flexibility for several purposes: fulfilling different objectives might lead to contradictory actions. While this is not directly relevant to the optimisation approach followed later in this project (where the optimisation is performed centrally), such conflicts might arise when several actors of a grid are activating flexibility with incomplete coordination. Such "service dependencies" are thus also indicated in the following sections.

3.1.1 Services, dependencies and value definition

In order to facilitate the analysis, the services have been assigned to service groups that will be sharing several characteristics. Table 1 contains the services and dependencies definitions. A definition for the value of flexibility used for the provision is also proposed. For the purpose of this project, the value definitions in italic will be used later for simulations and comparisons.

Service Group	Service by flexible resource	Service dependencies	Value definition (comparison to alternative)
Balancing	Short-term reserve for local balancing + Short-term reserve for local balancing - (incl. Demand response)	Frequency control Voltage control Reduction of unplanned exchanges	*Historical value of mFRR*[1]
Voltage control	Reactive power control Active power control Voltage quality	Congestion management	*Cost of tap changer* *Cost of voltage regulator*
Congestion management	Node voltage management Line loading management Transformer loading management Peak demand management	Voltage control	*Cost of reinforcement reduced or cancelled* *Avoided increase in cost of network interconnection to upper grid level*
Continuity of service	Black start capability Islanding capability	Voltage control Frequency control	Possibly the cost of the interruption of activity for commercial customers could give an indication for this service.

Table 1 Local services, dependencies and value definition for the flexibility used

As shown, not all services are presently taken in account for a value definition, as not all services have a current direct representation for a local value in today's regulatory setup. For example, local balancing has not a conventional comparison for local use. In this project, an approach taking into account future developments of local market designs will be take.
Several of these services correspond to standard products known in the transmission system (see e.g. [31]) that would indeed need some adjustments in order to be used in distribution networks but nevertheless would be produced and used with some similarities:

- Active power balancing: for this service, a remote signal is sent to the resource in order to adjust upwards or downwards the active power fed to or drawn from the network. It is useful to distinguish between positive and negative control reserves, similar to the current situation of corresponding aFRR and mFRR products. In distribution, the intended use of the mechanism would likely mostly be the reduction of unplanned exchanges (this could be interpreted in analogy to the recently launched "integrated market" approach [32]).
- Reactive power control: reactive power could classically be used in order to control the voltage, although with limited effectiveness in distribution systems. Compensation of non-conform power factors could also be done, but this appears to be a limited necessity at LV level.
- Node voltage control: in the context of distribution network, this is to be understood as a means to increase the hosting capacity in terms of renewable generation, hence this item has been

[1] Previously referred to as tertiary reserve (TRL)

assigned to the service group congestion management (this however does not restrict the use of the service in any optimisation algorithm).

Other services are effectively specific to distribution grids, and therefore not currently used and documented in reference documents:

- Active power control for voltage control: due to the high R/X ratio of distribution grids, reducing active power flows has beneficial issues on voltage variations.
- Voltage quality: maintaining required voltage quality characteristics might arise as a service in the future. Other than for maintaining the RMS value of the voltage within defined ranges, this is not further considered in this report.
- Loading management for single branches (line or transformer): in order not to exceed the ratings of a branch element in the network, flexibility could be activated. This would suppress the need to reinforce the network accordingly.
- Peak demand management (peak shaving): the maximum power exchanged with other network levels is limited to a set value. Reasons are not linked to the system considered.
- Islanding and black start capability: these capabilities are often discussed but rarely implemented, also for safety reasons. Therefore, they are not considered in this work.

Service Group	**Device providing service**	**Control scheme providing service**	**Technical constraints**
Balancing	DER Storage Flexible loads	*Scheduler sending a signal to participating flexible participants*	Measurements availability Device control system Load/production shedding capability
Voltage control	DER Storage Flexible loads Voltage regulator (LV/LV)	*Limit power injection (inverter setting)* *Power factor adjustment (inverter setting)*	Measurements availability Centralized control system Devices control systems Communication infrastructure Flexibility concentrator
Congestion management	DER Storage Flexible loads	Controller identifying which flexibility providers impact on the loading and sending control signal to required flexible participant(s).	Measurements availability Centralized control system Devices control systems Communication infrastructure Flexibility concentrator
Continuity of service	Storage	Frequency controller, islanding detection and protection schemes	Measurements availability Devices control systems Communication infrastructure

Table 2 Devices, control scheme and technical constraints of ancillary services

Service Group	Benefits for interconnected system	Relative value evaluation	Local benefits	Relative value evaluation
Balancing	Reduce power demand	*Historical mFRR value*	Reduce transformer load Peak shaving	*Cost of network reinforcement (line or transformer) if any is required*
Voltage control	Support voltage plan	*Only relevant for NL1: tariffs according to Swissgrid voltage management* [33][2].	Voltage level maintained	*Cost of tap/changing transformer*
Congestion management	Reduce power demand	Cost of network reinforcement (line or transformer) or *historical mFRR value*[3]	No lines overload Transformers can be discharged Reduce outages Peak shaving Voltage is maintained in limits	*Cost of network reinforcement (line or transformer)*
Continuity of service	Support system black start capability	(no relative value since the approach is new)	Consumer supplied in fault cases SAIDI/SAIFI improved	(no relative value since the approach is new)

Table 3: Benefits and relative value determination for local services

[2] In this project this will not be considered: a voltage plan would be needed for the transmission grid. Alternatively, the nominal voltage could be used. This would however require to have a network model for the upstream network, including the load flows, which is not realistic for this study. A simplified average tariff method will be applied.

[3] The approach depends on market design choices. The method for evaluating the cost of reinforcements is essentially the same as for local services. The equipment costs are different in higher voltage levels. However, the approach using mFRR prices is closer to recent evolutions suggesting that redispatch will be done using standard products in the future [32]

3.1.2 Devices, control scheme and constraints

Table 2 shows the devices potentially able to provide the service, control schemes and constraints related to the service groups. For certain devices, some control schemes are already in use (either commercially or as pilot schemes) by the utilities interviewed (indicated in italic). Other control schemes would require new controllers and possibly measurement points (or at least communication with existing measurement points) to be added. Resources providing the services finally also need to fulfil constraints, e.g. the capability to provide a communication interface for receiving commands and returning measurements.

3.1.3 Benefits and conventional solution for the cost comparison

Table 3 shows the benefits of each service and the method proposed for the evaluation of the flexibility value compared the value of an eventual conventional solution, if it exists. As shown, the benefits are separated for the local and the interconnected system. The benefits to the interconnected system correspond to the export of services. This aspect will be discussed in the next sections.

The methods for determining the relative value marked in italic are those that are relevant for the DiGriFlex project and will be needed for the two-stage optimisation. The methods will be developed in the next steps of WP1 and described in deliverable D1.2 "Relative costs and benefits of operational and scheduling options for distribution grids".

3.2 Ancillary services exported to higher network levels

Exported services are uses of flexibility that are done with the purpose of selling ancillary services to higher network levels. In this project the focus is on selling to the network level 1, since this is currently the only established market. However, the framework proposed and developed in the project would also allow for exports into intermediate network levels.

3.2.1 Services, dependencies and value definition

Table 4 shows the services that could be exported towards higher grid levels in addition to the benefits of local services to the interconnected network mentioned in Table 3. Obviously, exporting active and reactive power will have an impact on the local system: voltages will be affected and component loadings will be modified. In an optimisation approach, this is covered by adequate constraints. In principle there is no adverse effect on the balancing of the local system, provided that balance group mechanisms are taking the export of ancillary services into account.

The services mentioned in this section correspond to the standard products currently in place in the central European system [31], respectively elsewhere for synthetic inertia [34]. Within this project, their value will be estimated using current tariffs or historical market prices as indicated in Table 4.

Two ancillary services related to innovative use of storage devices can be considered within the framework of frequency control and congestion management, respectively. With reference to frequency control, the charging of vehicle fleets connected to the local networks can be managed to provide frequency regulation to the upstream grid; this is performed through the services known as V1G (smart charging) and V2G [26], [27]. Regarding congestion management, storage devices connected to the local network can be used to provide load levelling which allows flattening the power demand at the upstream grid thanks to appropriate charging/discharging strategies [28]-[30].

Service Group	Service	Service dependencies	Flexibility value definition
Frequency control	Frequency containment reserve Automatic frequency restoration reserve Manual frequency restoration reserve (In the future: synthetic inertia) V1G (smart charging) and/or V2G	Congestion management in the local network	aFRR and mFRR prices (historical)
Voltage control	Reactive power control Active power control	Voltage control in the local network	Only relevant for NL1: tariffs according to Swissgrid voltage management [33][4].
Congestion management	Load Leveling	Congestion management in the local network	Cost of reinforcement of the upstream network reduced or cancelled (this will not be considered coherently with footnote 4)

Table 4 Services, dependencies and value definition for the flexibility used

3.2.2 Devices, control scheme and constraints

Table 5 shows the devices that could be delivering the exported services as well as the control scheme that would be required to achieve the delivery. The devices will also need to fulfil the technical constraints listed.

[4] In this project this will not be considered: a voltage plan would be needed for the transmission grid. Alternatively, the nominal voltage could be used. This would however require to have a network model for the upstream network, including the load flows, which is not realistic for this study.

Service Group	Device providing service	Control scheme providing service	Technical constraints
Frequency control	DER Storage including on board vehicle battery Flexible loads	Power / frequency control Power control (on receipt of a command signal) Synthetic inertia (inverter setting)	Measurements availability Centralized control system for all local resources Devices control systems Communication infrastructure (if required)
Voltage control	DER Storage	Power factor adjustment VAR export (on receipt of a command signal)	Measurements availability Centralized control system for all local resources Devices control systems Communication infrastructure (if required)
Congestion management	Storage	Power control (on receipt of a command signal)	Measurements availability Centralized control system Devices control systems Communication infrastructure

Table 5 Devices, control scheme and technical constraints of ancillary services

Broadly, two schemes exist: a self-organised control based on a local criterion without a need for communication with higher network layers and on the other hand, a local controller obeying a command signal sent by the upper network level's control system (or another market actor). This is of course an important aspect for the implementation of such a scheme, however this aspect is outside of the DiGri-Flex project scope.

3.2.3 Benefits and conventional solution

Table 6 shows the benefits of each service and the method proposed for the evaluation of the flexibility value. It is important to note that at this stage, it is assumed that any flexibility provided to higher network layers will be used, implying a prioritisation of non-conventional providers over conventional (similarly to the encouragement of renewable energy providers in energy supply). This is correct at an early stage of deployment of such schemes, but might not be true in the future, when supply will exceed demand.

Again, the provision of services to higher network levels might conflict with local voltage or loading constraints (or not). An optimisation approach will consider this.

Service Group	Benefits for interconnected system	Relative value evaluation	Local benefits or conflicts	Relative value evaluation
Frequency control	New reserve providers	*aFRR and mFRR historical value*	Component loadings will be influenced	-
Voltage control	Support voltage plan	*Only relevant for NL1: tariffs according to Swissgrid voltage management* [33][5].	Voltages will be influenced	-
Congestion management	Reduce variation of power demand	Cost of network reinforcement (line or transformer).	Reduce outages	-

Table 6: Benefits and relative value determination for export services

[5] In this project this will not be considered: a voltage plan would be needed for the transmission grid. Alternatively, the nominal voltage could be used. This would however require to have a network model for the upstream network, including the load flows, which is not realistic for this study. A simplified average tariff method will be applied.

3.3 DSO Interviews

3.3.1 Methodology

In order to retrieve information about the current status of the flexibility implementation in Switzerland, some selected DSOs have been interviewed. Table 7 shows the list of the interviewees. These DSOs are the larger ones within the activity area of the partners represented within the project. The interview structure is given in appendix A. Two different types of questionnaires for different levels of involvement of the interviewee in technical respectively strategic matters have been established and sometimes combined. The objective was to increase the interviewees' ability and willingness to provide relevant information.

Name	Company	Interview type
Arnoud Bifrare	Romande Energie SA	1
Daniel Vela	Romande Energie SA	2
Loïc Dunand	Groupe-e	1,2
Philippe Rothermann	BKW	1,2
Stefano Lava	SES (Sopraceneri regional utiliy)	1,2
Anonymous	Anonymous	1,2

Table 7: List of interviewees for DSO interviews

3.3.2 Summary of interviews

Appendix A.1 and A.2 describes the questions and the objective pursued with the DSO interviews. Appendix A.3 contains a tabular summary of the interviewees' answers. These answers have been grouped by items, rather than by question in order to facilitate the use of the answers within the project.

The interviews showed that most utilities are aware of the potential for flexibility use in the operation of future systems. The limitations mentioned by the DSOs are in the legal area: can the DSO take unlimited control? can the DSO access directly or via service providers? Network reinforcement as a conventional means of solving issues of increased PV production are well known, with an increasing number of tap-changers and voltage regulators installed as a consequence of the regulatory requirement to consider active network solutions. The few examples for assets currently managed by the DSO are those that are not PV (e.g. micro-hydro and cogeneration plants). Interesting to note, but outside of the project's scope, a high number of issues linked with reliability and quality of service has been mentioned.

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A DSO interviews

A.1 Questionnaire

The survey is divided in two types and they are designed for two different target persons: the type 1 is thought for a project leader or sector manages, type 2 is for an operating engineer.

The questions of the two types are different, but can be mixed, according to the person interviewed and the actual course taken by the interview.

Type 1

1. What are your activities and maturity level in term of flexibility for:
    a. Distributed control (congestion management, local voltage control, …)
    b. DSO-TSO interaction
2. Are you doing some research for new flexibility systems or analysis? (like ROCOF measurements, energy vault, battery plants, etc.)
3. At what grid level do you have flexibility systems? What kind of flexibility services are you using/providing?
4. What are the usual reinforcement solutions you are considering? (some examples taken from your projects)
5. Are you using/testing a flexibility market? If yes:
    a. How the market is structured? (local market per station/substation, a global market for the whole network, a mixed architecture, etc.)
    b. How the flexibility value is calculated? (Selling price)
6. For the current rules and regulations, what kind of control do you have on the final customer? (reactive power control from a PV plant, using of storage systems and EV, etc.)

Type 2

1. What kind of generation systems are installed in your networks? (end customer and bigger plants installation)
2. What kind of storage systems are installed in your networks? (end customer and bigger plants installation)
3. What are the pros and cons using the following systems, according to your experience:
    a. With customer battery systems and PV plant (or prosumer)?
    b. With big battery plant?
    c. With big solar plant?
    d. With electric vehicles?
    e. With other DER systems?
4. How these systems affect the grid reliability?

5. How DER (including storage systems) changed the network planning and operation routines? For instance: implementation of new analysis, new considerations or limits, etc.
6. What are the additional costs or economization for the network operator when a new production/storage/EV system is installed? (For instance, financial contributions, connection adaptation, etc.)
7. What kind of model did you use to simulate this new production systems? (In other words: what kind of simulations do you use for which problem?)
8. Are there capacity problems in MV/LV networks?

A.2 Questionnaire objectives

Table 8 and Table 9 contain the list of objectives for the DSO interviews.

#	Objective
1	Try to understand how flexibility is mature into DSOs and find a direction to integrate this in simulation models
2	Find which “new” systems are interesting the DSOs and evaluate for which one an evaluation can be effective
3	Capture more detail about are currently used by DSO
4	Try to understand how grid reinforcement is evaluated and how can be used in an evaluation for other alternatives, like flexibility systems
5a	In the case that the flexibility is bought from the costumers, a market has to be set. In order to give a value to the flex energy, the market price must be known
5b	In order to simulate the flexibility value, it can be interesting to compute the flexibility market price (if exist). This can be used to generate some application scenarios.
6	This information can be used to create a comparison between the theoretical simulation and the real applicable methods.

Table 8 Objectives for interview of type 1

#	**Objective**
1	Try to understand if some special generations systems are present in the network and if the behaviour is interesting for a simulation (in addition to classical production systems)
2	Try to understand if some special storage systems are present in the network and if the behaviour is interesting for a simulation (in addition to classical storage systems)
3	Generate a list of pro and cons and try to understand which ones have an economic impact that has to be taken in account into the flexibility evaluation (valid for a, b, c, d and e)
4	The improvement/degradation of the system reliability can have big economic impact that has to be taken in account
5	Try to evaluate how DER are taken in account in DSO planning, and how this affect the normal planification work. Understand how flexibility is take in account into planification
6	Try to better define the cost of a new DER installation (from DSO point of view), as good as the marginal costs
7	Pure practical simulations questions to evaluate what kind of simulations are used by DSO to evaluate the behaviour of DER in the system.

Table 9 Objectives for interview of type 2

A.3 Summary of answers

Type 1 questionnaire summary

<table>
<tr><th>Question number</th><th>Item</th><th>Description</th><th>How</th><th>Limitation</th><th># of mentions</th></tr>
<tr><td rowspan="7">1, 3, 6</td><td rowspan="7">Current Practices</td><td>Voltage regulation</td><td>Static function Q=f(U) on inverters</td><td></td><td>1</td></tr>
<tr><td>Voltage regulation</td><td>Fixed cosphi regulation on inverters</td><td></td><td>2</td></tr>
<tr><td>Congestion management</td><td>Limit power injection on inverter</td><td>Client has to be refund</td><td>2</td></tr>
<tr><td>Congestion management</td><td>Using centralized remote control (peak shaving)</td><td>The regulation of this command is static</td><td>5</td></tr>
<tr><td>Solar Cloud (grid used as a big storage)</td><td>From client POV, the grid is a big battery (Solar Cloud)</td><td>No regulation on PV is made</td><td>1</td></tr>
<tr><td>Contribution to regulation market</td><td>Production reserve, flexible load, no DER, PowerPool</td><td>Energy availability not assured for DSO-TSO coordination when using DER</td><td>2</td></tr>
<tr><td>Contribution to voltage plan</td><td>Reactive power by PV plant</td><td>Losses on inverters</td><td>1</td></tr>
<tr><td rowspan="3">2, 3</td><td rowspan="3">Options for future</td><td>Node load management</td><td>Power distribution on every node</td><td>SmartMeter measurements (legal limitation), seasonal storage, prevision system, no market exists, a flexibility concentrator is needed (e.g. Tiko)</td><td>1</td></tr>
<tr><td>Load control</td><td>Using a smart-meter gateway to optimize peak shaving
Using GridEye to control loads</td><td>Legal limitation on client-side control</td><td>1</td></tr>
<tr><td>Storage</td><td>Battery at neighbourhood level
Boiler for seasonal storage</td><td>These systems are still in study</td><td>2</td></tr>
</table>

4	Reinforcement	Cable and transformer replacement	-	-	5
		Voltage regulation	Installation of MV/LV transformers with tap changer (9 tap)		1
		Voltage regulators	LV/LV voltage regulator, on MV/MV pilot project	-	2
		Batteries	At neighbourhood level	No business plan exist, batteries are still expensive	2
5	Flexibility market	Powerpool	Sell flexibility from big customers (only TSO-DSO coordination)	-	1

Type 2 questionnaire summary

Question number	Item	Description	Status	# of mentions
1	Generation systems	Photovoltaic	Present but not used by DSO	5
		Mini and micro hydroelectric plant	Present and managed by DSO	1
		Biomass	Present but not used by DSO	1
		Cogeneration	Present and managed by DSO	1
2	Storage systems	Battery	Usage in study phase	2
		Hydroelectric	Present and managed by DSO	1
		Thermic	Usage in study phase	1
		V2G	Usage in study phase	1
5, 6, 7	Planning	Problems for cable refund due to distributed micro-turbine	Problem in study phase	1
		New scenarios for LV and MV networks	LV: 100% production and 0% consumption MV: 100% production and minimal measured consumption	1
		PV panel installation forecast	Estimation of potential using roof surfaces provided by maps.geo.admin.ch	1

3, 4, 8	Grid reliability and quality of service	Over-voltages in LV from PV and Hydroelectric	Present in networks	2
		Over-voltages in MV from Hydroelectric	Present in networks	1
		Protection	Settings have to be adapted due to power flow inversions	1
		Power quality reduced from PV	Present in networks	2
		Grid uncertainty bigger caused by stochastic production	Present in networks	1
		Congestion caused by big PV installation (ex. Farm)	Present in networks	1

B Literature review summary

The following table is a list of the literature sources used for the initial analysis, definitions, DSO interview definitions and follow-up.

Reference	Objective	Comments
[2]	TSO-DSO coordination model	Presentation of scenarios, products, services and coordination schemes used in the Coordinate demonstrator
[3]	Manage local congestion	Presentation of a GMS (Grid Management System) build by Enexis as a part of the Interflex project. The GMS use external grid measurement and weather data to forecast local loads and prevent congestion
[4]	Voltage control	Simulation of active distribution networks, where distributed generation is used to support voltage stability
[5]	Providing ancillary services	A proposal on how use photovoltaic and wind to provide ancillary services for frequency and voltage control
[6]	Flexible generation management	A model proposal for the coordination of flexible units in distribution grids based on the traffic light approach
[7]	Providing ancillary services	Presentation of a demonstrator for ancillary services provision from RES. The results of the test are presented in this paper
[8]	RES contribution on ancillary services	Presentation of the different ancillary services currently considered in the Spanish electrical system and the participation of RES, focusing particularly on its provision with wind energy.
[9]	Load flexibility control	Presentation of a framework used to control the aggregation of detached houses with direct electric space heating (DESH).
[10]	Flywheel energy storage systems	Developing a magnetic bearing flywheel to stabilize the electrical output fluctuation of a solar power plant.
[11]	Synthetic inertia	Explanation of inertia principle in a network and the outcoming inertia problem, due to the new energy generation system. The current approaches are explained and some recommendations are described.

[12]	Providing ancillary services	Description of a new ancillary service (called Generation Smoothing) implemented by the Norwegian. The idea is to mitigate the deterministic frequency deviations, using a day-ahead state estimator.
[13]	Providing ancillary services	Using smart buildings control systems in order to provide flexible loads to the grid. There is a need to create a market that suit these new technologies and services.
[14]	Local flexibility management	New framework model that consider the peak coincidence network charge and fixed charge and allocation this peak to the customer according to their contribution during network peak hours.
[15]	Flexibility evaluation	Presentation of a decision-making process to unlock flexibility in the network. This model relates the cost of an over-loading and the financial risk of a black-out to the price a distribution system operator is willing to pay for flexibility.
[16]	Storage system	Main aspect description related to the integration of storage system in transmission and distribution grid, for different application.
[17]	Flexibility evaluation	Analysis of the actual ancillary service market in order to find the constraints to integrate battery flexibility.
[18]	Ancillary services definition	Description of actual necessary ancillary services with current challenges and market definition
[19]	Providing ancillary services	Using energy storage system and DER to defer distribution capacity investments. A planning approach is presented.
[20]	Flexibility evaluation	A framework to evaluate the locational marginal value of DER in a short-term window. The objective is to evaluate the interest of DER as replacement of grid reinforcement.
[21]	Flexibility evaluation	Resolving a planning problem, to optimize the capacity investment and DER operation as decision variables. Finally, an optimal solution can be found in a real situation.
[22]	Flexibility evaluation	Resolving a planning problem, to optimize the capacity investment and DER operation as decision variables. Finally, an optimal solution can be found in a real situation.

[23]	Providing ancillary services	Using storage systems for strategically differing distributed generator and load curves is evaluated, aiming to improve the overall network performance while increasing the level of DG penetration.
[24]	Peak shaving	V2G control algorithm for peak shaving and valley filling, taking into account vehicle requirements and load demand.
[25]	Providing ancillary services	A new method for determining the optimal offering strategy of battery storage systems simultaneously participating to day-ahead energy, reserve and regulation markets.
[26]	Frequency regulation	Using plug-in vehicle fleet to provide active and reactive power to the upstream grid in response to a demand dispatch signal.
[27]	Frequency regulation	Demonstration of a concrete example of demand dispatch as it can be applied to plug-in electric vehicles: smart charging
[28]	Load levelling – voltage regulation	An optimal scheduling method for µGs aimed at regulating voltage and levelling the active power at the interconnection bus, minimizing also security margin to avoid congestion.
[29]	Load levelling	Storage-system control strategy to level the active power requested to an upstream network at the substation.
[30]	Load levelling – voltage regulation	Combining energy capacity and power rating of a battery energy storage system for control purposes aimed at load levelling and voltage control.