Flex4Grid

Prosumer Flexibility Services for Smart Grid Management

Project nº: 646428

WP3

D3.1 Initial DMS interface Component

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26 October 2015	0.1	Andrej Krpič (SCOM) Uroš Hrovat (SCOM)	Initial skeleton, Chapter 2, Chapters 4-6
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Internal review history

Date	Reviewer	Summary of comments

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1. Introduction

1.1. Purpose and scope of this deliverable

This deliverable is the output of the task Task 3.3 Interfacing with Distribution Management Systems, which is responsible for the design of a component that interfaces with electro distribution systems.

The system architecture of Flex4Grid (F4G) DMS Interface Component described in this deliverable uses the concepts that provide flexibility, scalability and portability.

1.2. Document structure

The reminder of this deliverable is structured as follows:

- Chapter 2 provides system overview.
- Chapter 3 describes AMI distribution system and data source structure.
- Chapter 4 describes concepts which are used in development.
- Chapter 5 provides an overview of F4G DMS Interface Component.
- Chapter 6 provides instructions for installation, testing and running environment.
- Chapter 7 summarizes and concludes the deliverable.

2. System overview

F4G DMS Interface Component is a gateway between electro distribution systems and Flex4grid Cloud Infrastructure as shown in *Figure 1*. It is the only connection to distribution systems. All the data from distribution systems need to be accessed through this interface.

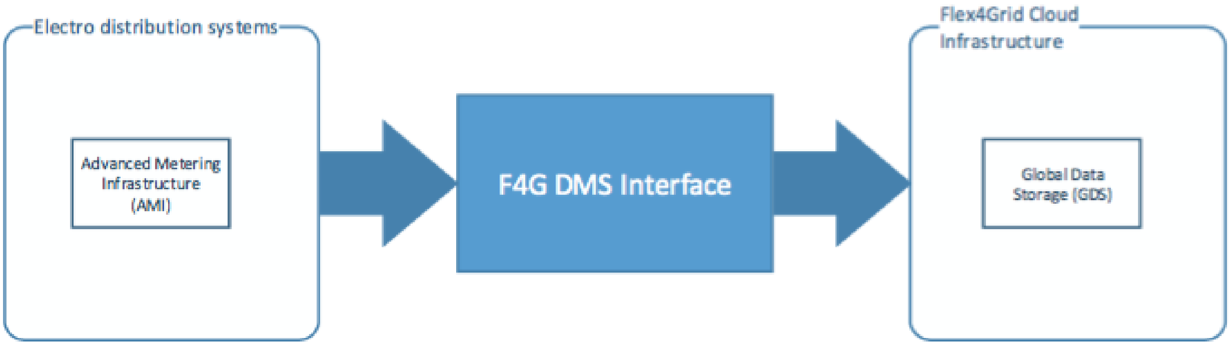


Figure 1: System overview

Distributions (DSO) use various management systems and technologies to monitor health and usage of distribution networks. Some of them are developed for specific customer and do not yet support standards like Common Information Model (CIM) and other communication protocols.
That is why some of F4G DMS interface components are designed as a vertical service where each vertical covers a process, specific for type of data sent from distribution management systems.

The initial functionality of F4G DMS Interface is to collect end user energy consumption data and send it to Global Data Storage (GDS). Advanced Metering Infrastructure (AMI) collects that data at DSO site. The initial F4G DMS Interface Component implements the services that are important for integration with AMI system.

3. Electro Distribution systems

3.1. Advanced Metering Infrastructure (AMI)

Below we will explain why the data for the Global Data Collection & Storage will be taken from Advanced Metering Infrastructure (AMI) and not from DMS, as it was originally conceived.

In Distribution Management system (DMS) of Elektro Celje is modeled only medium-voltage electrical network (electrical substations (110kV/20kV), secondary power lines and distribution substations), but not a low-voltage network. Our system operator of distribution network (SODO) requires modeling the low-voltage network in GIS (Geographic Information System) for all slovenian DSO's up to year 2018 and this is a prerequisite for the modeling thereof. For this reason, our DMS system is not an option in Flex4Grid project, because we will be operated with consumers on low-voltage side of the network, which of course are still not present in the DMS. On the other hand, in the DMS we have described substantial geometrical properties of the distribution network, while data of the consumers themselves will be added from the Outage Management system (OMS) in the future up to year 2018.

Because AMI is used for billing consumtion of electrical energy is essential that we have in our AMI data of consumers. In addition to all the information necessary for billing consumtion of electrical energy we have in AMI also information, in which distribution substations is connected our consumer. In this way, from the project point of view in AMI you can find the following:

1. The problem of detecting peak in a particular part of the network, which could cause trigger activation of customers and their flexibility

2. Detection the area of the distribution substations, on which is the problem of the peak

3. Identifying which consumers are supplied from these distribution substation

4. Determination of what is the flexibility of those consumers - consumption in kW or kWh in the 15-minute load profiles from smart meters

5. Determination of other consumers features, enabling them to better understand its flexibility (the size of a fuse or main power, ...)

Therefore it makes more sense to use data from AMI system.

With the Flex4Grid partners we agreed that we will use data from our AMI system (HES - Head End system), where we keep measurements data. In AMI system we have aggregated measurements from distribution substations and measurements from smart meters installed at the consumers and producers on the 15 minutes and 1 hour base (kW and kWh). When we are talking about a 15-minute interval we mean the 15-minute average power. The smart meters keeps thus power consumption as well as electricity production at customers and producers. Data is collected every night for one day before (Day – 1) on 15-minute interval for each smart meter when the communication between AMI and smart meters is established. We don’t collect “on-line” data like "simple kit", because AMI system is not SCADA and also collecting “on-line” data is controversial for the reason of protecting the personal information which is also mentioned in document D7.1 Data management plan.

3.1.1. Functional and technical description of the AMI System

AMI software is in functions required technical solutions for the entire system of reading and processing of billing data and power management for the needs of Elektro Celje.
AMI System enables:
1. The realization of the remote reading of billing and other metering data for:
    - Household consumption
    - Industrial consumption
    - Control measurements (LOCAL SUBSTATIONS,…)
    - Renewable energy sources (small power plants)
2. Data processing (editing, conversion, aggregation, validation, ...)
3. The providing the information to customers and producers
4. Ensuring the exchange of information for the purpose of billing electricity
5. Provide users access to data with a graphical interface and generate various reports
6. Data archiving
7. Power Management (remote on / off)

8. Exchanging date with other systems in the company (DMS)

AMI is a modular program which includes the following modules:
- MessurementPlaces Module (review, edit and export data)
- Collection Module (setting read data)
- Excel Reports Module (creation, editing, and generating reports)
- Quick Module Validation (validation - verifying the adequacy of the data)
- Management Module (manage smart meters)
- SQLtoDB2 Module (billing)
- EventViewer Module (review of smart meter events)
- Alarming Module (informing the user about critical events)
- Balances Module (creating balance reports)

…

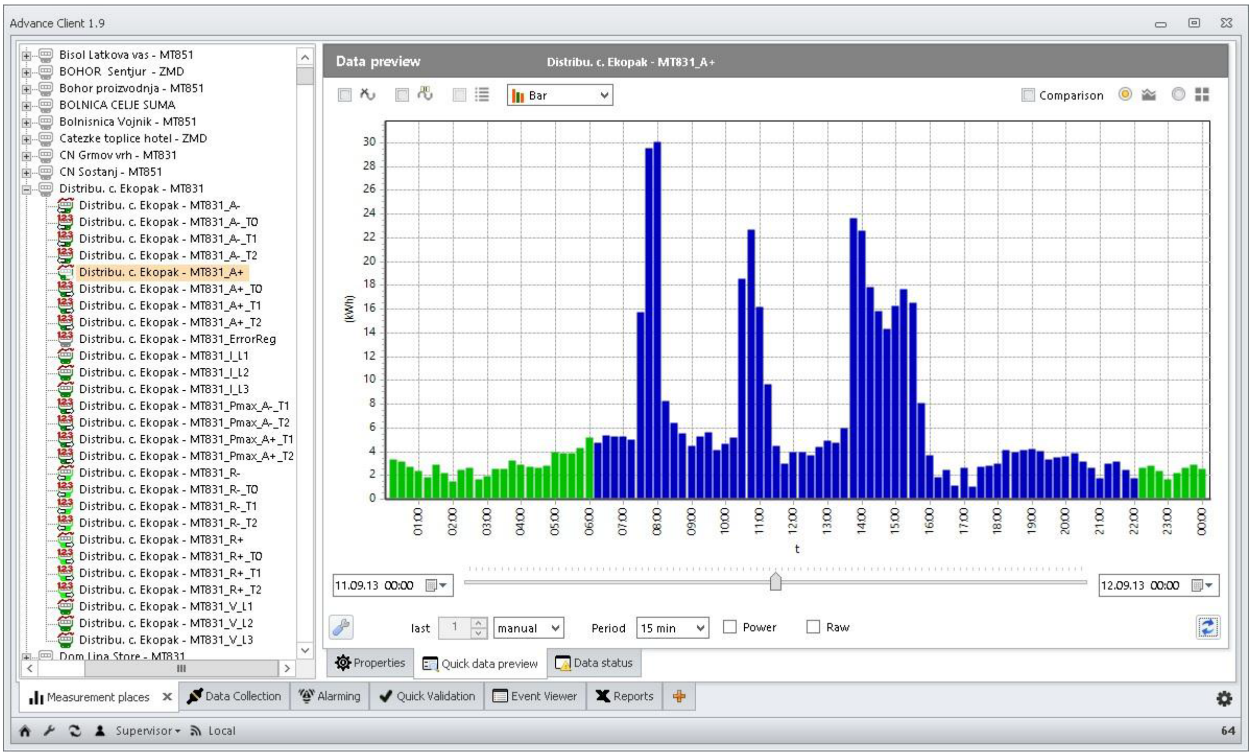


Figure 2: Measurement Places Module

Remote reading of measurement data is implemented through various channels of communication: Ethernet, GSM / GPRS, PSTN, ISDN. The measurement data is stored in a relational database. Data from the smart meteres is first stored in a table of raw values (RAW), and then through a Calculation Service-converted and stored in a table of budgeted cost (CALC).

3.2. Data sources

When we talk about advance metering in Elektro Celje the are in the field of remote reading system installed in the distribution substation 1.837 Data concentrators (which collect data from smart meters of households and small bussines consumers), which represents 48% of all distribution substations, 2.813 smart meters of controling distribution substation which represents 82% of all transformer substation, 81.630 (48% of all electricity consumers), have the energy consumed already calculated according to actual consumption. In the last five years, we have increased the number of locations of remote reading. In Elektro Celje, d.d. is planned that all electricity consumers by 2020 will have installed remote smart meter reading and billing on actual monthly consumption.

Currently is perform the installation of smart meters on the principle of verification period for electricity meters Classes 1, 2, A and B according to IEC or MID, who is 12 years old. This means that every induction electric meter which is 12 year old needs to be replased. This means that the annual replaced is + /- 12.000 electric smart meters and in transformer substation placed at least 100 data concentrators. Smart meters measure the el. energy in all 4 quadrants, so active as reactive power and energy, depending on how you should consult the manufacturer of smart meters. Currently are two in Slovenia namely Iskraemeco, d.d. http://www.iskraemeco.si/emecoweb/eng/index.html and Landis & Gyr http://www.landisgyr.si/.

3.2.1. Standard report

Every day, over the scheduale, AMI automatically send exported data at regular intervals (every day at 12.00h and it can be changeable) of consumers connected on two substations named **TP Buttejev Most** and **TP Lačja Vas** in so called »dump« file (standard report) in .xlsx format via e-mail. Export is possible also in other standard formats for example xml. or it may be disposed on the FTP server. The “dump” file export is needed because in AMI is not integrated CIM. All information about consumers are anonymous.

The reasons why we have decided for these two distribution substations are:

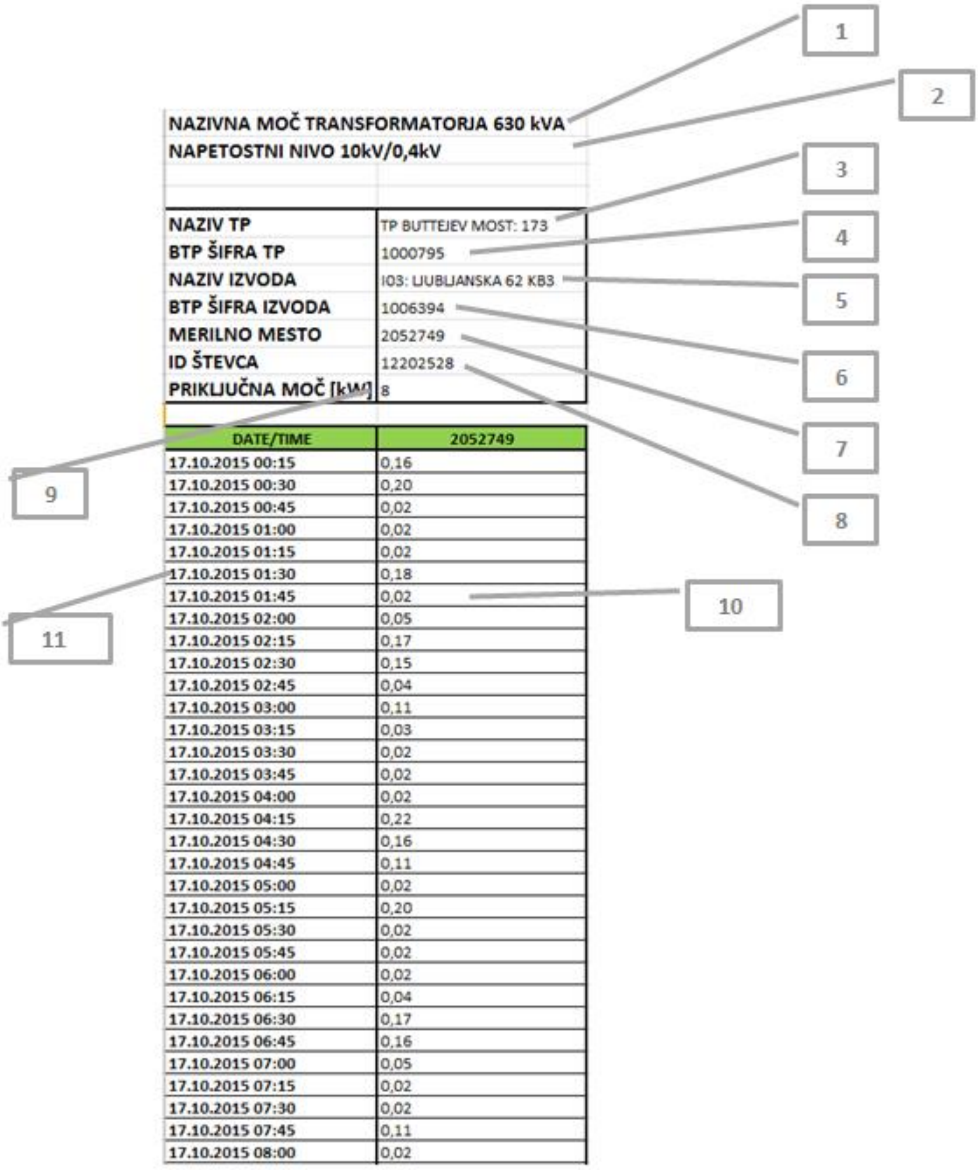
- All consumers have remote reading of electricity smart meters
- All meters are able to read the 15-minute value
- All consumers are households
- The distribution substations have in transformer smart meter, which measures the whole consumption of the distribution substation

This two distribution substations are ideal for the project.

The exported table contains information about:

- Topology of consumers and substation
- Readouts from electricity smart meters on 15 min bases
    - Readouts from electricity smart meters on 15 min bases - consumers
    - Readouts from electricity smart meters on 15 min bases - measurment readout from transformer meter in distribution substation.

Figure 3 represents data from smart meters installed at consumers.



NAZIVNA MOČ TRANSFORMATORJA 630 kVA	
NAPETOSTNI NIVO 10kV/0,4kV	
NAZIV TP	TP BUTTEJEV MOST: 173
BTP ŠIFRA TP	1000795
NAZIV IZVODA	I03: LJUBLJANSKA 62 KB3
BTP ŠIFRA IZVODA	1006394
MERILNO MESTO	2052749
ID ŠTEVCA	12202528
PRIKLJUČNA MOČ [kW]	8

DATE/TIME	2052749
17.10.2015 00:15	0,16
17.10.2015 00:30	0,20
17.10.2015 00:45	0,02
17.10.2015 01:00	0,02
17.10.2015 01:15	0,02
17.10.2015 01:30	0,18
17.10.2015 01:45	0,02
17.10.2015 02:00	0,05
17.10.2015 02:15	0,17
17.10.2015 02:30	0,15
17.10.2015 02:45	0,04
17.10.2015 03:00	0,11
17.10.2015 03:15	0,03
17.10.2015 03:30	0,02
17.10.2015 03:45	0,02
17.10.2015 04:00	0,02
17.10.2015 04:15	0,22
17.10.2015 04:30	0,16
17.10.2015 04:45	0,11
17.10.2015 05:00	0,02
17.10.2015 05:15	0,20
17.10.2015 05:30	0,02
17.10.2015 05:45	0,02
17.10.2015 06:00	0,02
17.10.2015 06:15	0,04
17.10.2015 06:30	0,17
17.10.2015 06:45	0,16
17.10.2015 07:00	0,05
17.10.2015 07:15	0,02
17.10.2015 07:30	0,02
17.10.2015 07:45	0,11
17.10.2015 08:00	0,02

Figure 3: Consumers data

Table consist of (figure 3):

1. Rated power of transformer installed in local distribution substation in kVA
2. Voltage level of the system (you can get 20 or 10 kV)
3. Name of local distribution substation – unique ID
4. Id number of local transformer substation – unique ID
5. Name of the branch on which consumer is connected – unique ID
6. Id number of the branch – unique ID
7. Number of metering point – unique ID
8. Serial number of meter which is installed at the consumer – unique ID
9. Installed capacity in kW
10. Value of the measurment - 15 min average power in kW
11. The period of measurement readout – 15 min

Each column in the table represent load profile of the consumer, that is connected on local distribution substation.

The last column in the table represents measurment readouts from transformer meter in local distribution substation (Figure 4).

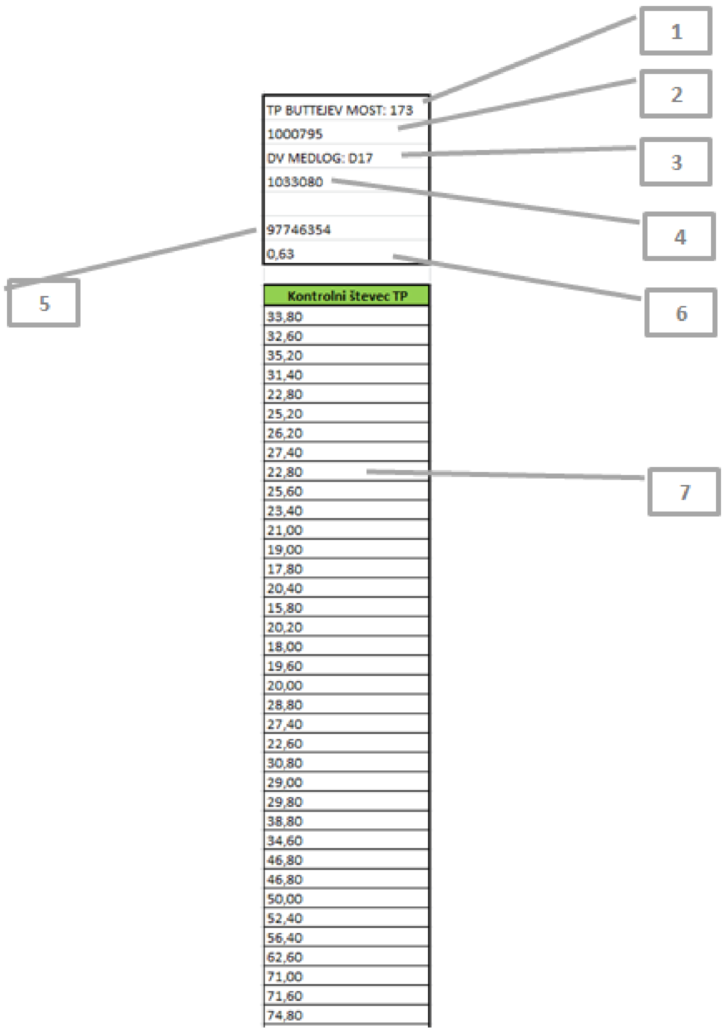


Figure 4: Data from transformer meter

Table consist of (figure 4):

1. Name of local distribution substation – unique ID
2. Id number of local transformer substation – unique ID
3. Name of the landline where the local substation is connected
4. Unique id of the secondary power line
5. Serial number of meter which is installed at the substation – unique ID
6. Rated power of transformer installed in local substation Value of the measurment in MVA
7. Value of the measurment - 15 min average power in kW

In the future, there will be more substations included in the project.

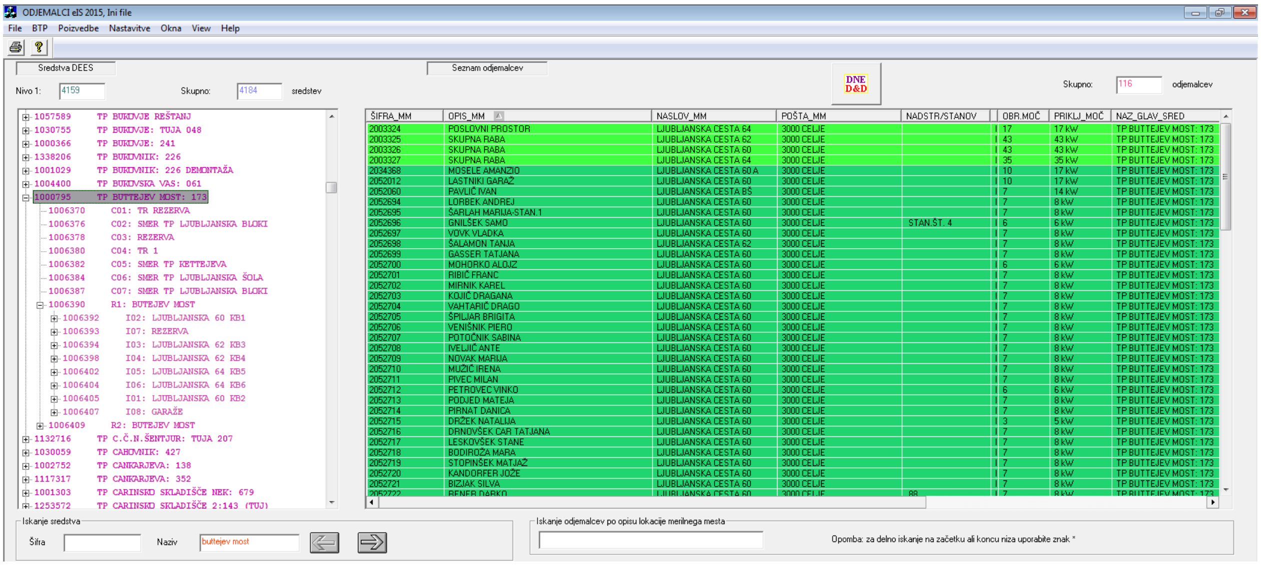


Figure 5: Topology of consumers and substation TP Buttejev most

3.2.2 Detecting the peak

Each substation has rated power, which depends on the size of the built-in transformer. In the event that the maximum load of the transformer substation is approaching an upper limit would normally replace the transformer with a larger.

If, however, we use the system Flex4Grid, instead a new transformer, we may use the flexibility consumers. When the peak would reach of say 90% of the rated power of the transformer, the alarm would be raised and triggered.

Topology and flexibility of consumers would be known, so the system on one hand would be able easily determined what is the exceeding of the peak and on the other hand how much flexibility must be activated to stabilize the system.

Information would come from the AMI system, ie. from transformer meter placed in local distribution substation (shown Figure 4). This meter covers overall consumption through a transformer on 15 minutes level in the form of xml, txt or Excel file with a lag of one day (Day-1). From historical data you can predict a peak for one day ahead.

Because of the D-1 data, they would come into play only those transformer substations to which would be the most connected households, because consumption of such a segment of users is predictable and do not fluctuate dramatically as shown on Figure 6 and 7. From both diagrams of energy consumption is clearly visible that data is comparable. It can be seen that the maximum power is always achieved through Sunday at lunchtime for this case.

Flexibility of the consumers would not be used continuously, but only in the critical period when we would expect that power peak would be the highest.

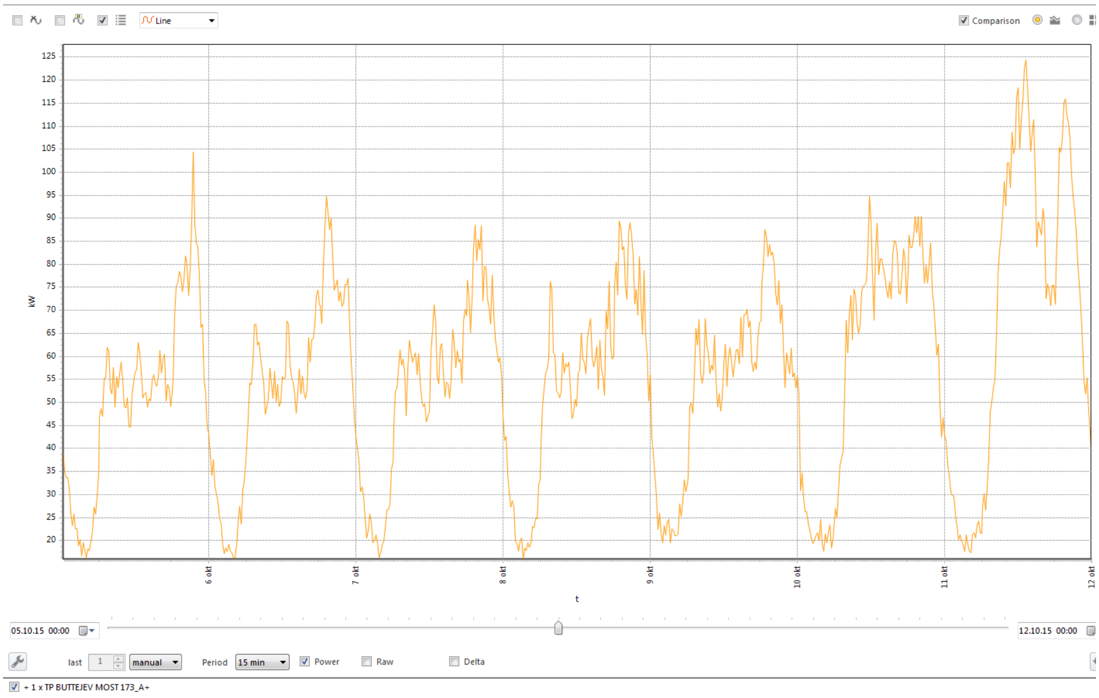


Figure 6: Load profile of TP Buttejev most between 5.10.2015 – 12.10.2015

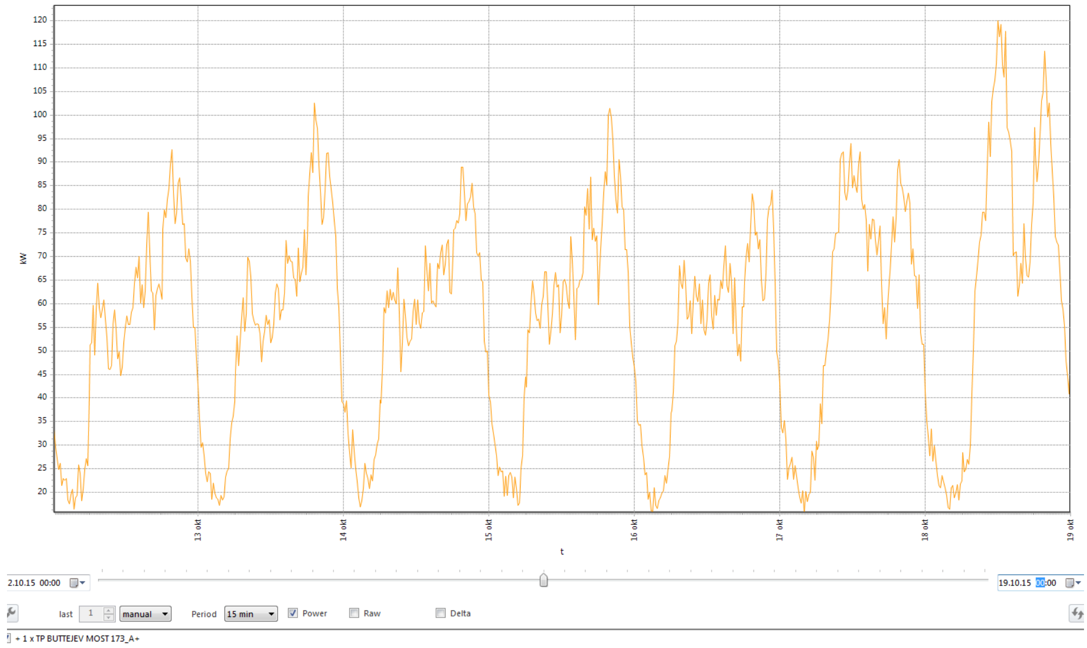


Figure 7: Load profile of TP Buttejev most between 12.10.2015 – 19.10.2015

4. Concepts

4.1. Containers

Container-based virtualization, also called operating system virtualization, is an approach to virtualization in which the virtualization layer runs as an application within the operating system. In this approach, the operating system's kernel runs on the hardware node with several isolated guest virtual machines installed on top of it. The isolated guests are called containers. [1]

Container technology like Docker[2] provides an ideal environment for deployment of small services. Docker is one of the most rapidly growing open source projects on Github[3]. It is an open platform for automating the deployment of applications inside portable containers that are independent of hardware and host operating system.
Docker Engine[4] with a lightweight runtime and tools that builds and runs containers, is the core of the Docker platform (see *Figure*).

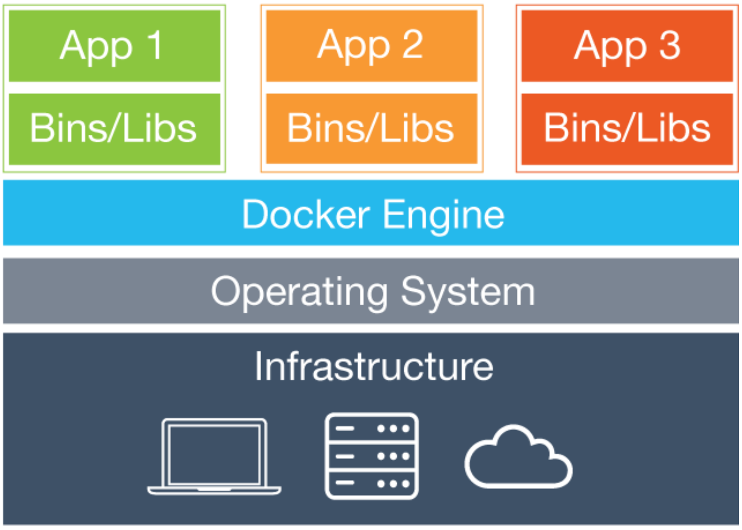


Figure 8: Docker Containers

Docker containers share the operating system with other containers and use resource isolation features of the Linux kernel such as cgroups and kernel namespaces. This allows independent containers to run within a single Linux instance.

Docker Compose[5] is a great tool that easy orchestrates multi-container application. It allows us to define multi service application in a single file. Applications can be started using a single command.

4.2. Service Interaction

Interaction between services is based on REST web services. REST stands for Representation State transfer, which is an architectural style for networked hypermedia applications. RESTful web services use HTTP/HTTPS as its underlying protocol. It is an application protocol that runs on top of the TCP/IP suite of protocols.

Principles of REST:

- Resources (understood directory structure URIs),
- Representations (JSON or XML to represent data),
- Messages (use HTTP methods)
- Stateless

4.3. Reverse Proxy

In computer networks, a reverse proxy is a type of server that retrieves resources on behalf of a client from one or more servers. These resources are then returned to the client as though they originated from the proxy server itself [7]. While this architecture has many possible uses, in the context of DMS Interface Component it can be used as a) a router that directs service interaction to specific service and b) in future as a load balancer.

5. Microservices

Microservices architecture is an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms, often an HTTP REST API.

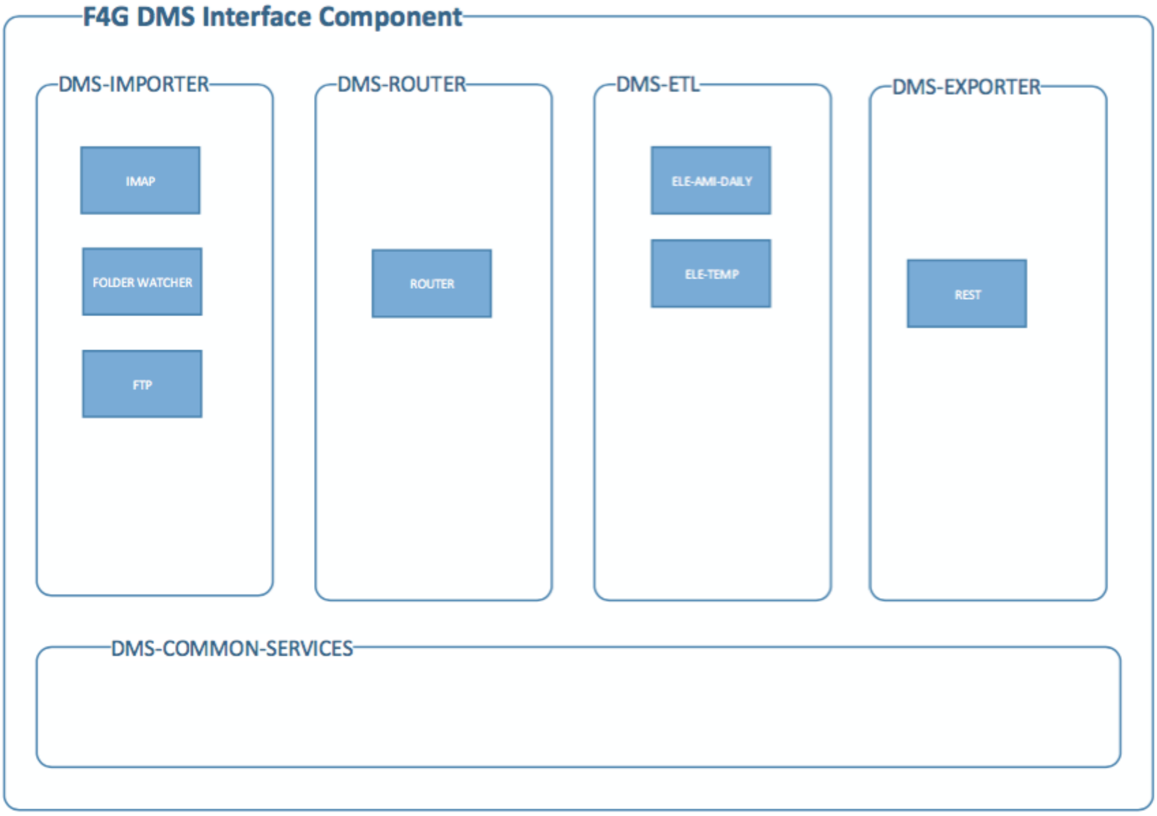


Figure 9: Microservices architecture of DMS Interface Component

F4G DMS Interface Component consists of several microservices. We grouped services according to the role they perform. *Figure* shows groups and services which we were able to define for this deliverable. Brief explanation for each group of services is presented in this chapter. Services implemented in initial F4G DMS Interface Component are explained in more details.

5.1. DMS-IMPORTER

It is a group of services which main role is collecting data from external sources.

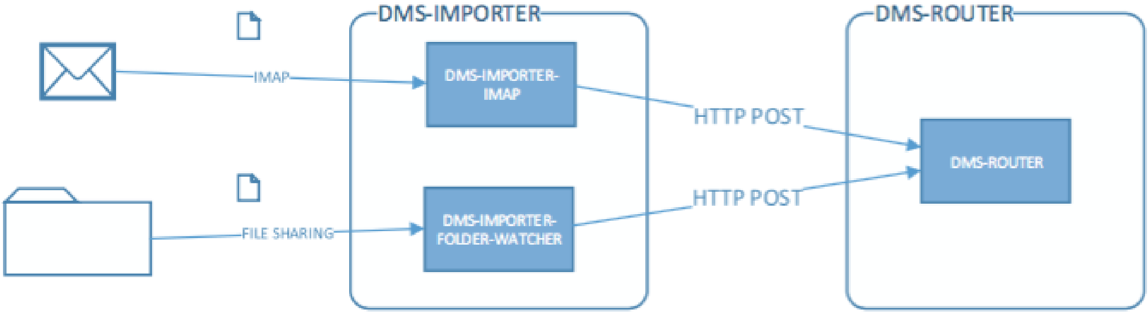


Figure 10: DMS-IMPORTER services

DMS-IMPORTER services use external sources as input. Communication on input side depends on the type of source. There are a lot of different sources and different communication protocols, which is why we use different DMS-IMPORTER services for different communication channels and data sources.

Output from DMS-IMPORTER services is the same for all services and is compatible with specific DMS-ETL service input interface. Content of the file is encoded using Base64 encoding and pushed to the DMS-ROUTER service or directly to a specific DMS-ETL service. Destination is set by setting DMS_ROUTER_URI as described in *Table 2*. This interaction is executed through REST based interface by using HTTP POST method specified in *Table 1*. Body of a RESTful webservice is presented below.

```
{
    "filename": "example.xls",
    "content": "<base64 encoded content of file >",
}
```

Table 1. RESTful interface between DMS-IMPORTER, DMS-ROUTER and DMS-ETL services.

Resources	GET	PUT	POST	DELETE
/ELE_AMI_DAILY			Push file to DMS-ETL service directly or through DMS-RUTER service	

Table 2. Common DMS-IMPORTER configuration settings.

Setting	Description
DMS_ROUTER_URI	URI to DMS-ROUTER or to DMS-ETL service

5.1.1. DMS-IMPORTER-IMAP

This service is a mail client that connects to remote mail server using IMAP protocol. It is part of Initial F4G DMS Interface Component where it is used for AMI data source access at Elektro Celje (ELE). Sequence diagram in *Figure* explains the process.

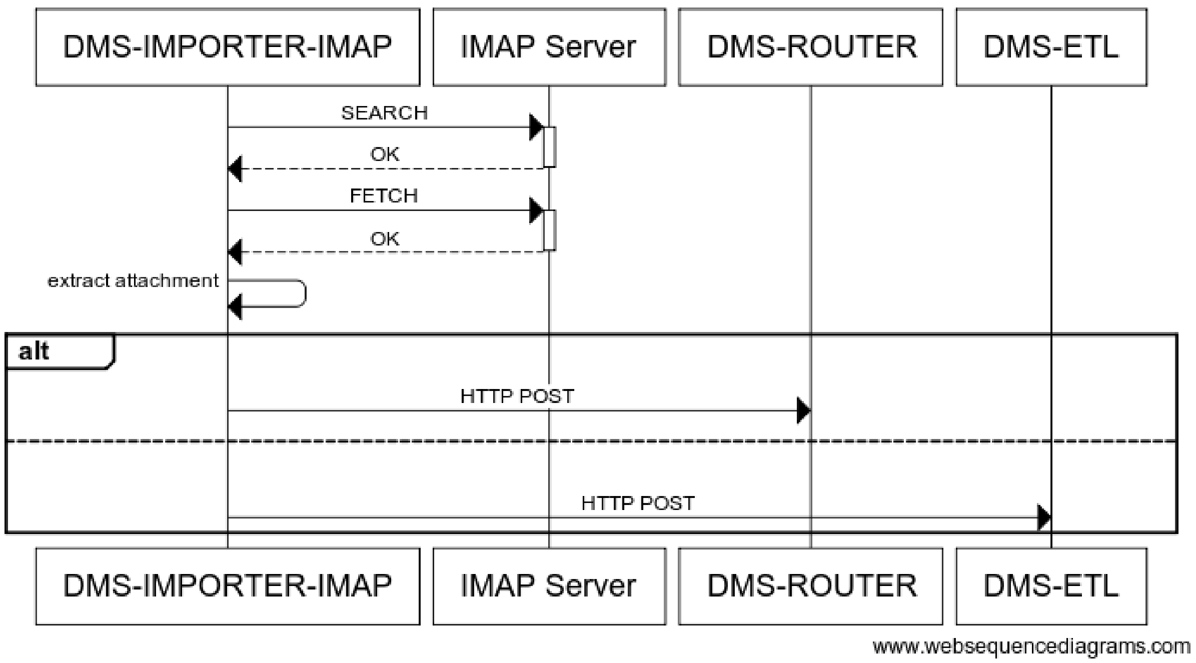


Figure 11: DMS-IMPORTER-IMAP sequence diagram

Service connects to remote mail server with credentials specified using configuration variables listed in *Table 3*. Emails, searched based on setting DMS_IMPORTER_IMAP_SUBJECTFILTER are fetched to DMS-

IMPORTER-IMAP. Service then extracts attached file and sends it to DMS-ROUTER or DMS-ETL service directly.

Initial F4G DMS Interface extracts attached excel files and sends them directly to DMS-ETL-ELE-AMI-DAILY service.

Table 3. DMS-IMPORTER-IMAP configuration settings.

Setting	Description
DMS_IMPORTER_IMAP_SERVER	IP address of remote mail server
DMS_IMPORTER_IMAP_USERNAME	Email username at remote mail server
DMS_IMPORTER_IMAP_PASSWORD	Email password at remote mail server
DMS_IMPORTER_IMAP_SUBJECTFILTER	Subject for filtering
DMS_IMPORTER_IMAP_POLLPERIOD	Watch interval in seconds

5.1.2. DMS-IMPORTER-FOLDER-WATCHER

This service implements an importer that interacts with a file system. Service scans given directory for new files based on settings specified in *Table 4*. Files from watched directory are sent to DMS-ROUTER or specific DMS-ETL service. Sequence diagram in *Figure* explains the process.

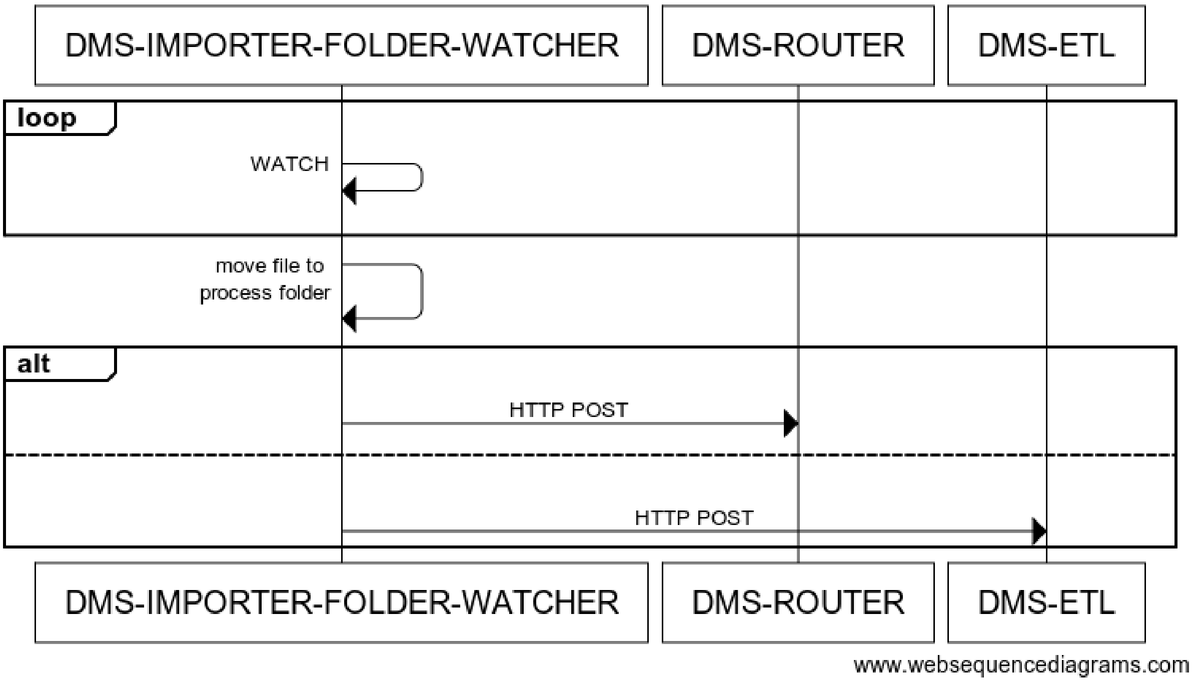


Figure 12: DMS-IMPORTER-FOLDER-WATCHER sequence diagram

Table 4. DMS-IMPORTER-FOLDER-WATCHER configuration settings.

Setting	Description
DMS_IMPORTER_FW_FOLDER	Location of the source directory
DMS_IMPORTER_FW_POLLPERIOD	Watch interval in seconds
DMS_IMPORTER_FW_GLOB	Pattern for matching files (e.g. *.xls)
DMS_IMPORTER_FW_FOLDERPROCESSED	Location of the directory where processed files are moved to.

5.2. DMS-ROUTER

It is a reverse proxy service placed between DMS-IMPORTER and DMS-ETL services (*Figure*). Interaction is executed through REST based interface using HTTP POST method.

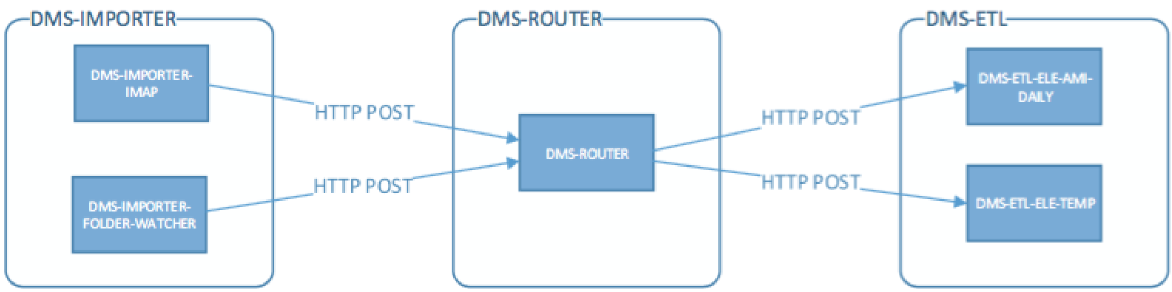


Figure 13: DMS-ROUTER service

Sequence diagram in *Figure* explains the process.

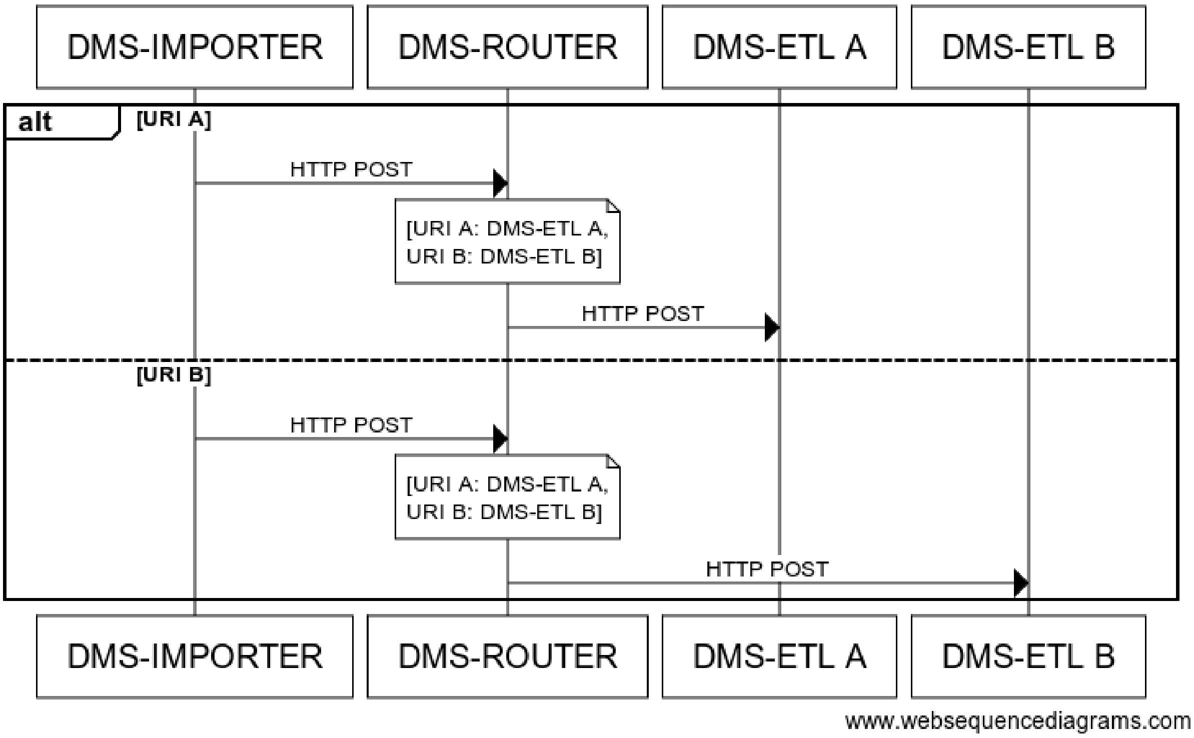


Figure 14: DMS-ROUTER sequence diagram

The main role of this service is forwarding messages to the right DMS-ETL service based on the setting DMS_ROUTER_TABLE specified in *Table 5*. It can also provide load balancing and scalability for DMS-ETL services.

Table 5. DMS-ROUTER configuration settings.

Setting	Description
DMS_ROUTER_TABLE	List of URI matching patterns and corresponding DMS-ETL service URIs

5.3. DMS-ETL

Main functionalities of DMS-ETL group of services are:

- Extraction (extract from different data formats, e.g. excel file, csv),
- Data sanitizing (clean-up of data),
- Transformation (convert to proper format or structure)

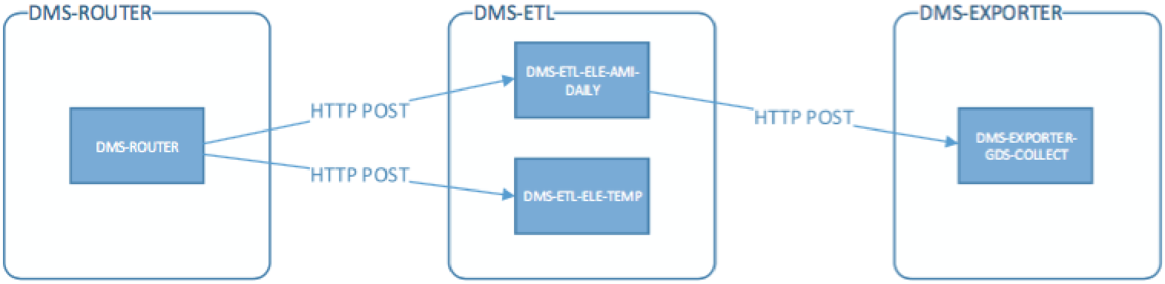


Figure 15: DMS-ETL services

DMS-ETL services interacts with DMS-ROUTER service as an input (*Figure*). Output interacts with DMS-EXPORT service or Global Data Storage directly. Interaction is executed through REST based interface. Common DMS-ETL configuration settings are presented in *Table 6*.

Table 6. Common DMS-ETL configuration settings.

Setting	Description
DMS_EXPORTER_URI	URI to DMS-EXPORTER service or Global Data Storage

5.3.1. DMS-ETL-ELE-AMI-DAILY

This service is the main component of Initial F4G DMS Interface Component. Process depends from external data source specification and Global Data Storage RESTful interface specification.

Sequence diagram in *Figure* explains the process.

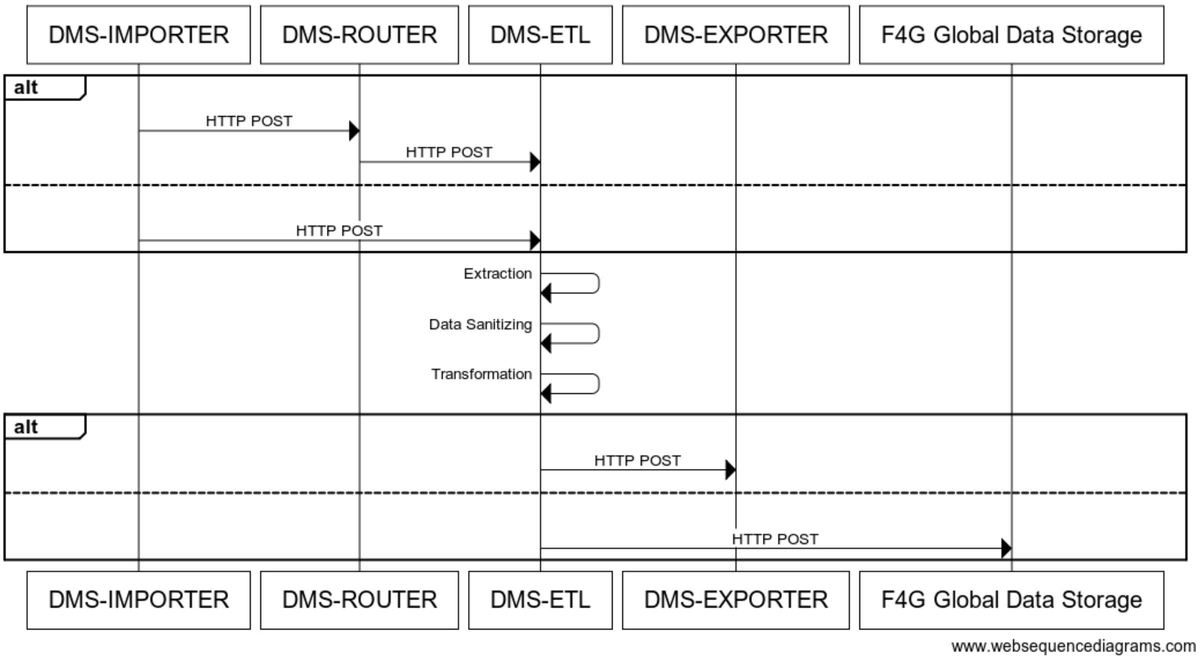


Figure 16: DMS-ETL sequence diagram

DMS-ETL extracts single measurements from the input excel document. It then calculates missing parameters (e.g. energy) and transforms it to a structure compatible with F4G Global Data Storage collect interface specification. F4G GDS expects structure presented below.

```
{"measurements"= [{
    "id",
    "parent_id",
    "timestamp",
    "sample_rate",
    "tag",
    "e_power": {  min: max: avg: unit: },  // optional
    "e_energy": { min: max: avg: unit: },  // optional
    "temperature": { min: max: avg: unit: }  // optional
}]}
```

5.4. DMS-EXPORTER

This is a group of services whose main role is pushing validate data to Flex4Grid Global Data Storage. They interact with DMS-ETL services and Flex4Grid Global Data Storage (*Figure*).

Figure 17: DMS-EXPORTER services

DMS-EXPORTER service is not provided in initial F4G DMS Interface Component. It is crucial when load balancing and scalability of DMS-ETL services is needed Common DMS-EXPORTER configuration settings are presented in *Table 7*. Sequence diagram in *Figure* explains the process.

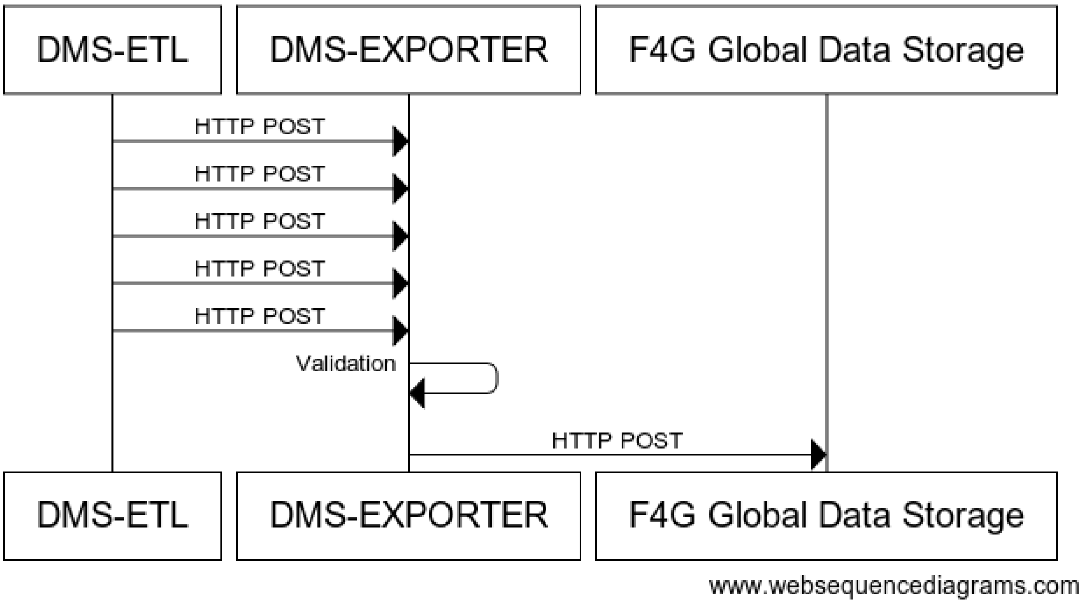


Figure 18: DMS-EXPORTER sequence diagram

Table 7. Common DMS-EXPORTER configuration settings.

Setting	Description
DMS_GDS_URI	URI to Global Data Storage

5.5. DMS-COMMON-SERVICE

This service provides support to all other services described in this chapter. Its main functionality is sharing data between services. It is currently not part of initial implementation. It is a crucial service if a variety of data sources will need to be implemented, which is not the case in the initial implementation.

6. User Manual

6.1. Preparing environment

6.1.1. Prerequisites

F4G DMS Interface Component depend on other software components to be installed in order to run properly:

- Operating System (OS) that supports Docker installation
- Docker 1.7.1 or greater (Docker Engine)
- Docker Compose
- Git

6.1.2. Installation

F4G DMS Interface component is part of a Flex4Grid project on Github. For installation access to git repository is needed.

Software, run environment and configurations stored in directory Flex4Grid/SCOM/DMS.
DMS directory structure:

- dms
  source code of a DMS Component

- test
  resources needed for tests - test containers and test code
- run_tests.sh
  shell script used to run tests
- Dockerfile
  build file for microservices used in F4G DMS Interface Component
- pip-requirements.txt
  Python dependencies needed by DMS Component

6.2. Testing

Implemented microservices are tested using black-box testing method, commonly used in software testing, where functionality of an application is tested without peering into its inner workings [6]. Mock services such as email server and other microservices, whose interfaces are defined in this document are used, so a) a microservice that is a subject of a test has known input and output and b) tests do not rely on external services (e.g. email server and F4G Global Data Storage)

Initial test groups used to test microservices:

- DMS-IMPORTER-IMAP
  Mock email server and mock DMS-ETL microservice are used to test data flow. Tests send emails with attachment(s) and resulting POST request to mock ETL service is expected.

- DMS-IMPORTER-FOLDER-WATCHER
  After placing a file into watched folder, tests expect DMS-IMPORTER-FOLDER-WATCHER to make POST request to the mock DMS-ETL microservice.

Running tests:
After completing prerequisites and installation (chapters 6.1.1 and 6.1.2), tests can be run using:

```
$ cd flex4grid/SCOM/DMS/

$ ./run_tests.sh
```

This script builds and starts containers needed for tests and then runs single tests inside them. Results can be obtained visually by inspecting the output, or programmatically using process's exit code status, where error code 0 represents success:

```
$ [ “$?” -eq “0” ] && echo “Success”
```

7. Conclusions

The current deliverable presents the initial architecture view for the F4G DMS Interface Component. Implementation of the F4G DMS Interface Component implement services which need it to integrate AMI distribution system with Flex4Grid system.

A variety of distribution management system implemented at DSO increase integration complexity. The concepts explained above help manage this issue.

Anonymization and security have been ignored in the initial implementation plan and will be specified and implemented in later phases.

8. References

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