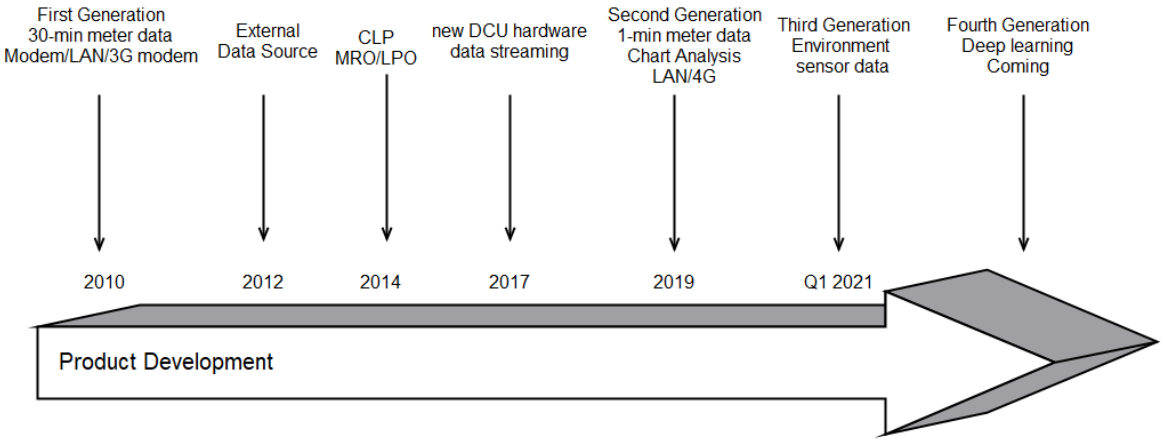
Energy Management System

Introduction

Energy Management System is to collect metering and environmental data from different sources through different means and to provide different levels of analysis using Web interface. The first generation was deployed in 2010 after working on several projects on meter reading for utility such as China Light & Power. Its preliminary version was installed in 2005 on 5 buildings in Tin Shui Wai of Hong Kong while it was used as case study for CLP AMR (Auto-Meter Reading) project on non-commercial sector's meter reading and billing.



The first generation was deployed for large property management company in Hong Kong on commercial buildings with shopping mall and second phase of CLP AMR project. While it served for 2 different kinds of industry, utility mainly for billing and commercial sector for data analysis, the system was designed in modular structure supporting different plug-in libraries. As shown in the above timeline, external data source incorporated metering data from external data sources in commercial sector and the system acted as central database filtering in important data for further data analysis. MRO (billing) and LPO (meter online service) of CLP were specific modules for utility. Category of device was introduced in commercial sector to depict what part of power consumption it belongs to, e.g. lighting, air-flow, lift etc. Each category of devices can be formulated as metering group for performance analysis. In addition, meters under same site can be formulated as billing group for bill calculation in commercial sector. Meanwhile, incomer was used to group meters under same trunk to find out load distribution. A very simple chart was provided in the first generation on either power consumption or demand.

DCU (Data Concentrator Unit) is one of components in this system and it is responsible for collecting metering and environmental data in a site to upload to the system. A separate document is available for this product because it can operate independently with the system as in its deployment in the government offices since 2010.

The second generation provides real time data collection over LAN or 4G mobile network. Unlike previous generation, it collects data immediately after DCU gets metering data instead of scheduling read. Thus, dial-up modem support is dropped though the components in two generations can be working together without issue. Furthermore, more data analysis based on either pie or line charts is introduced. These include load distribution, multiple fields of single meter and single field of multiple meters.

On-line data in the transaction database is kept up to 3 years while earlier data is moved to historical database. The Web GUI allows data export across these two databases transparently. In addition, intra-day (depending on how frequent DCU collects data), minimum interval data across system (common data interval across the system e.g. 15-minute), daily and monthly data are provided. For charting analysis, only minimum interval data and daily are supported.

Without using DCU, the system can retrieve data directly over LAN (or 4G modem through special module) from Elster meter. Same kinds of metering data are processed. This model would be deployed for CEM (Companhia de Electricidade de Macau) soon.

The third generation is being developed to incorporate environmental data such as temperature, humidity, in-door air quality, TVOC (ppb) and eCO_2 (ppm) which is collected from another type of DCU using Raspberry Pi IoT (Internet of Thing). Thus, power consumption and these kinds of environment information can be studied. Since it is non-invasive installation, the measurement provides casual study.

After these kinds of data are collected, deep learning no matter supervised or unsupervised can be further carried out. Of course, edge computing is to be used in future to better manage the whole eco-system but it is out of scope of this system.

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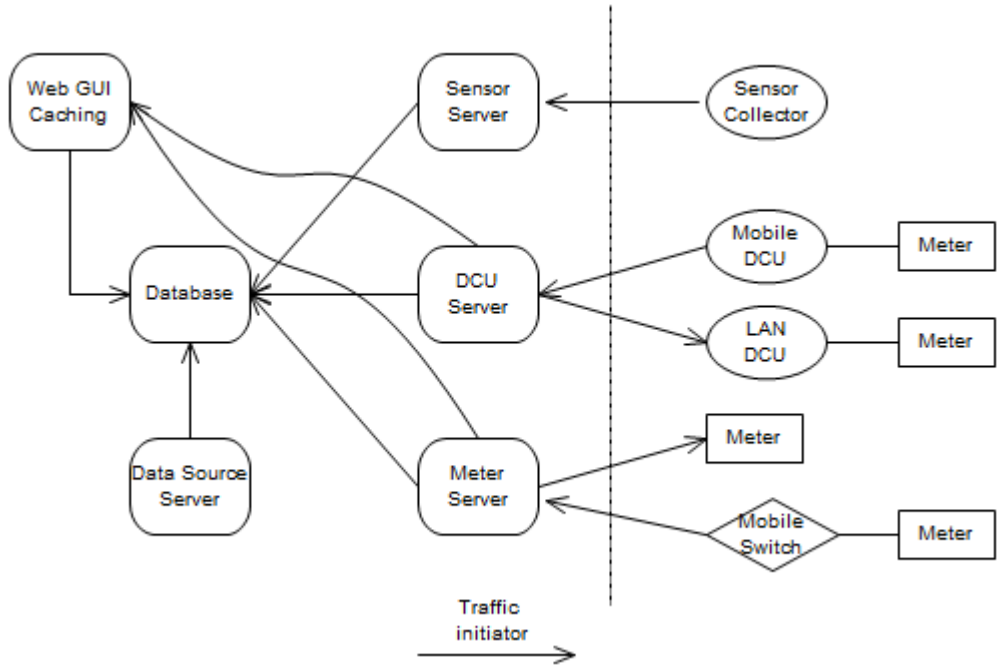
Features of the system

Data Collection



As shown in the above diagram, there are 3 ways to collect metering data, through DCU Server and Meter Server, Data Source Server for external system. Apart from updating data to database, it works together with caching server living within Web GUI. It provides updated status and information so that the user can get it instantly. It is achieved through standard Web Socket interface that data can be populated on the browser.

While multiple number of units of DCU Server or Meter Server are running in parallel for load sharing, the management job is processed in caching server. This scalability with minimum effort of system upgrade can lower the initial investment. Each DCU Server or Meter Server is operating in either one of modes, waiting for connection or making connection upon request from caching server. A small piece of communication module (mobile switch) is required in dynamic IP address meter in order that the system identifies the connection is valid one. In the first generation, some units of DCU was deployed in 2.5G mobile network where an intelligent mobile modem communicated with the server to authenticate with each other before actual data communication was made. These various kinds of connection method facilitate the deployment in different environments.

Since Elster meter provides historical data (load profile and instrumentation) stored inside the meter, the system collects and categories data before storage. Besides storing snapshot data from DCU instantly, the system requests the whole day data during its day end processing to recover those lost due to communication interruption. Data time is very important, and it serves one key parts in the data so the time synchronization between DCU server and DCU in site is performed once a week. Besides, modbus meter type is also supported through DCU while the system makes use of the data collected to provide historical data.

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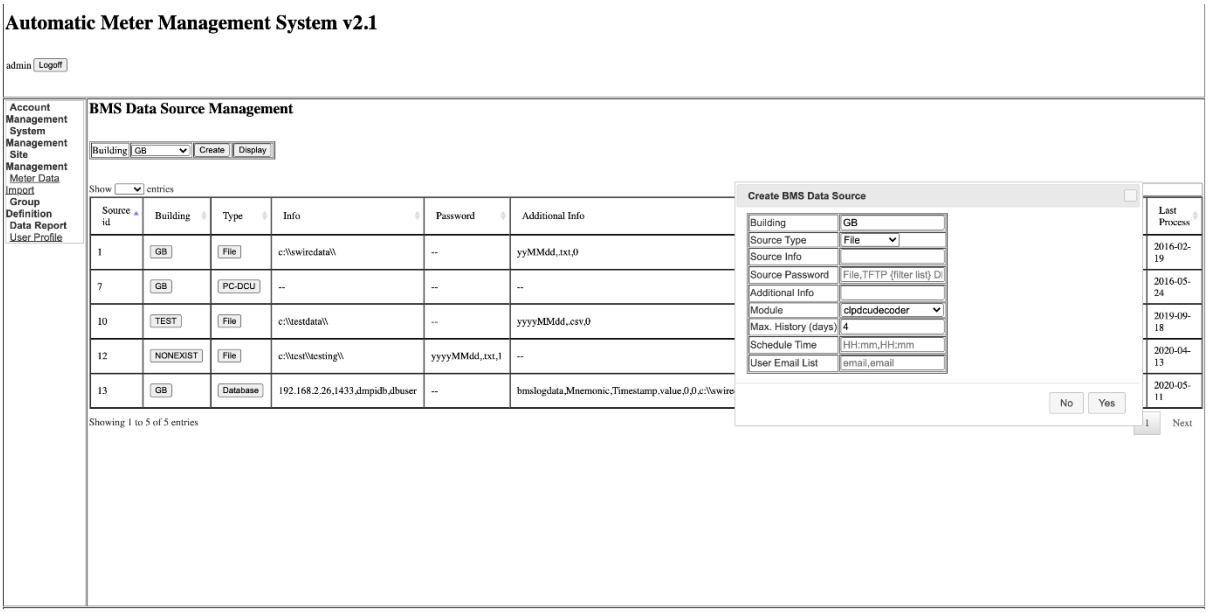
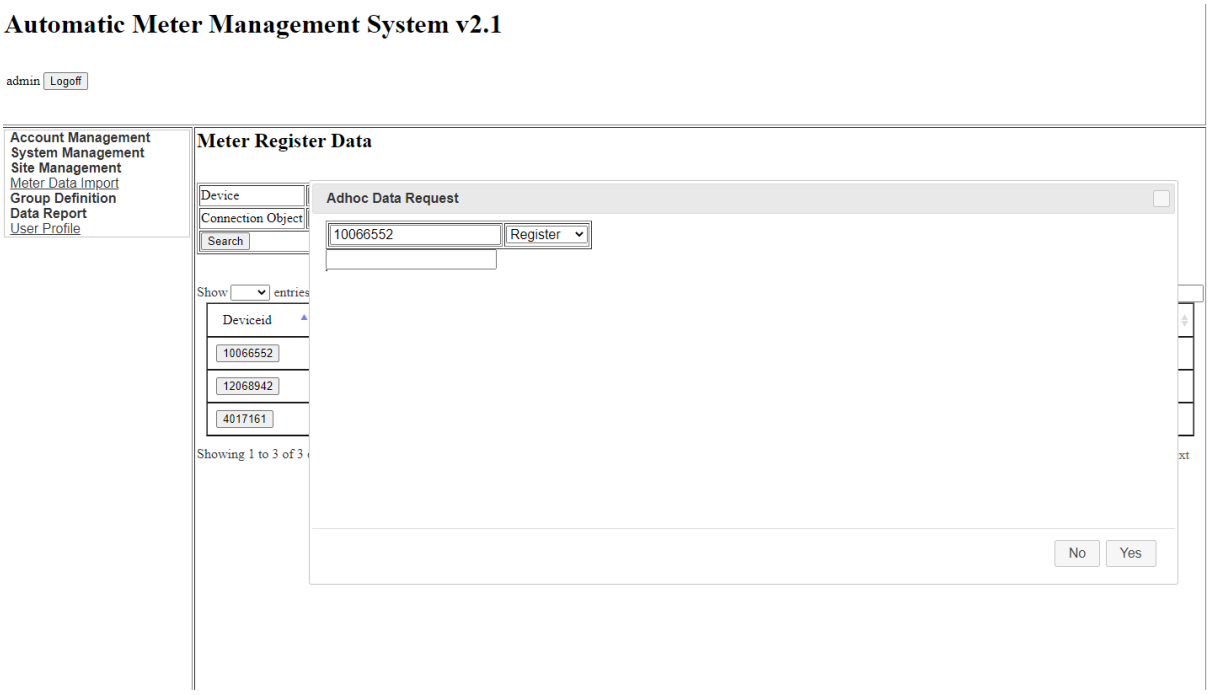
For external data source, it generally supports file and database type. File should be in tab delimited format. A mapping file is used for database access to map the end point and field to the system used device name. The corresponding decoder should be set up.



For direct meter data request through Meter Server, the corresponding metering protocol is running on top of mobile network. The checksum being used in the protocol and retry mechanism in the server can ensure the data accuracy. Some meter protocol includes sequence number to further guard against error. Meter request schedule can be specified by either set of fixed schedule or period such as 15-minute.

The system also supports adhoc mode in Meter Server and that means the user can make request through Web GUI to request data immediately. This was used in the first generation by CLP to check the billing information (power consumption) for immediate needs.



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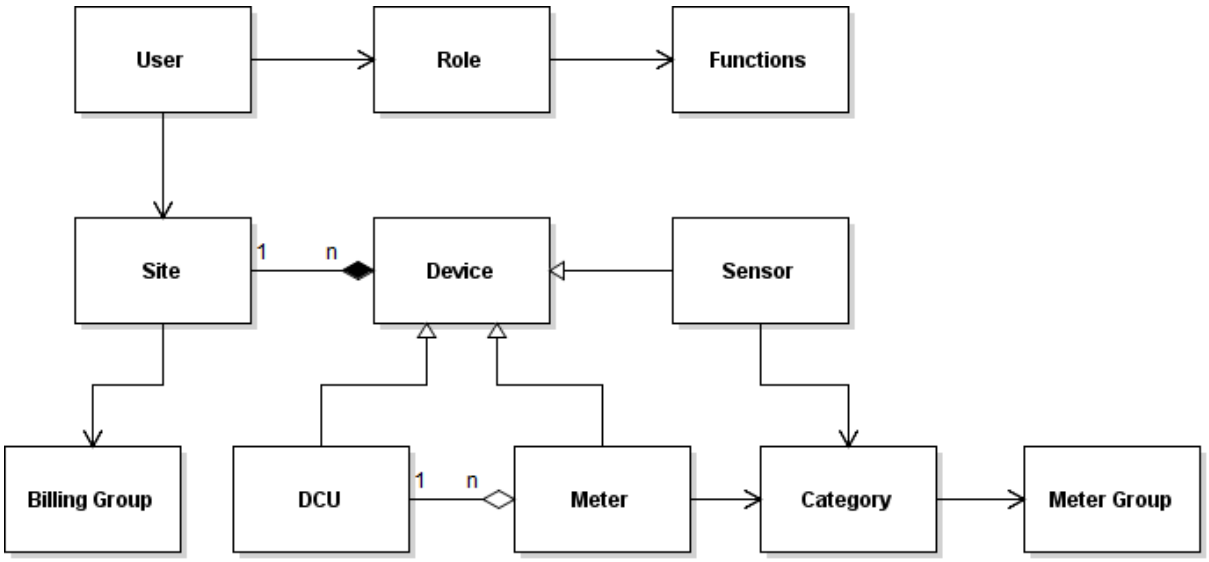
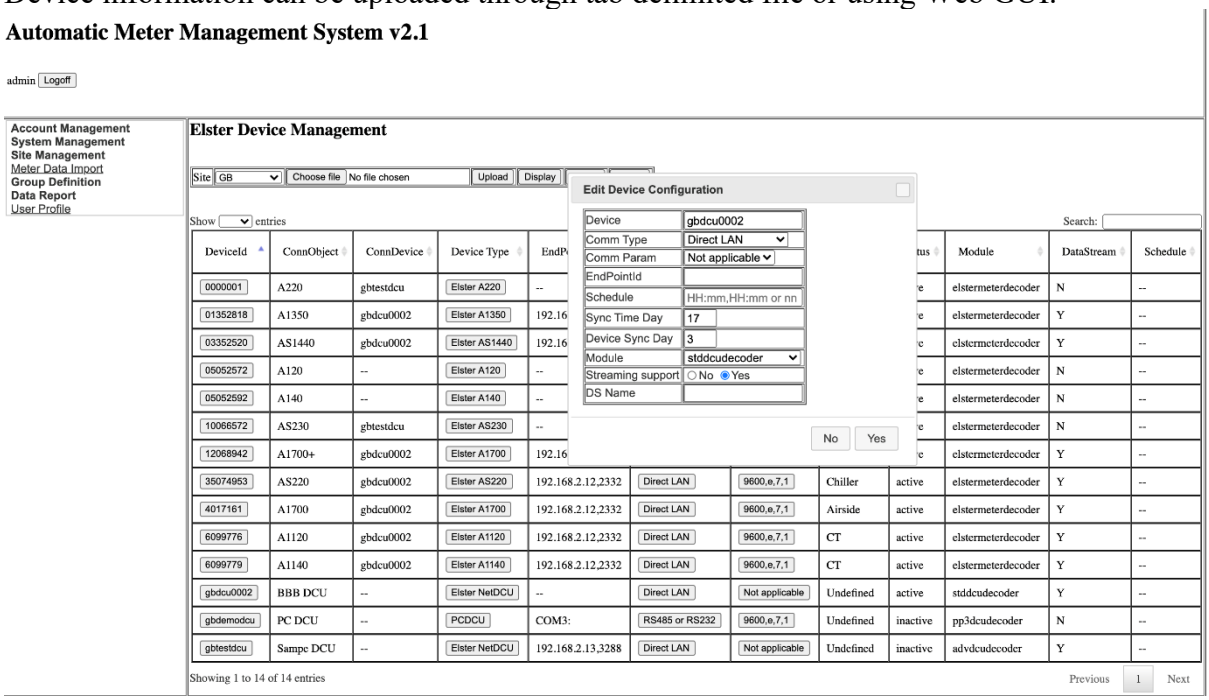
Central Management

User in the system is assigned the role which maps to a set of functions. Only allowed functions can be found in the Web GUI. Every request is to be verified again to prevent user from accessing the function. Data permission in terms of site is configured for the user. Thus, the user can only access data from the sites. In addition, the system reserves field for special permission. It was used by CLP in the first generation to control additional data permission such as writing back data to database for adhoc request or remotely turning on or off meter.



Device information can be uploaded through tab delimited file or using Web GUI.



Similarly, device information from external data source can also be configured through file upload. In general, the module would create the basic information automatically from the filtering file or the data file through file-based mechanism.

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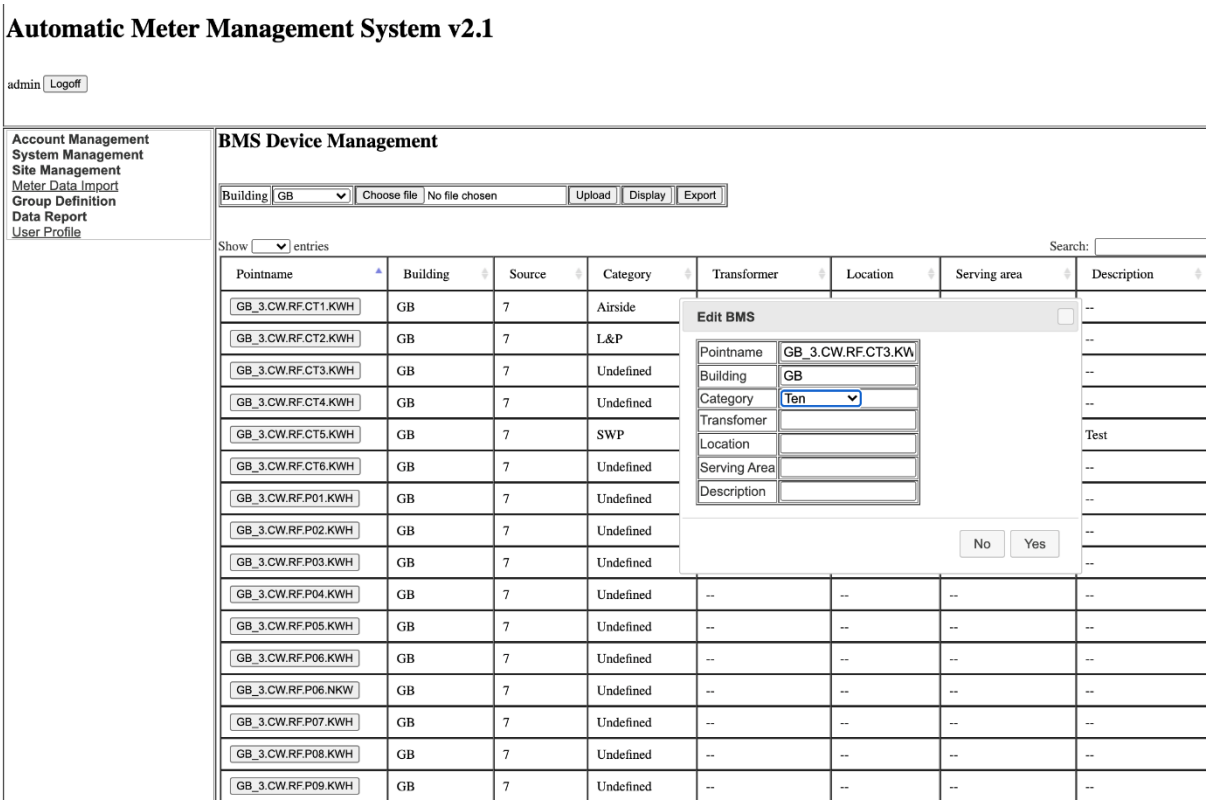
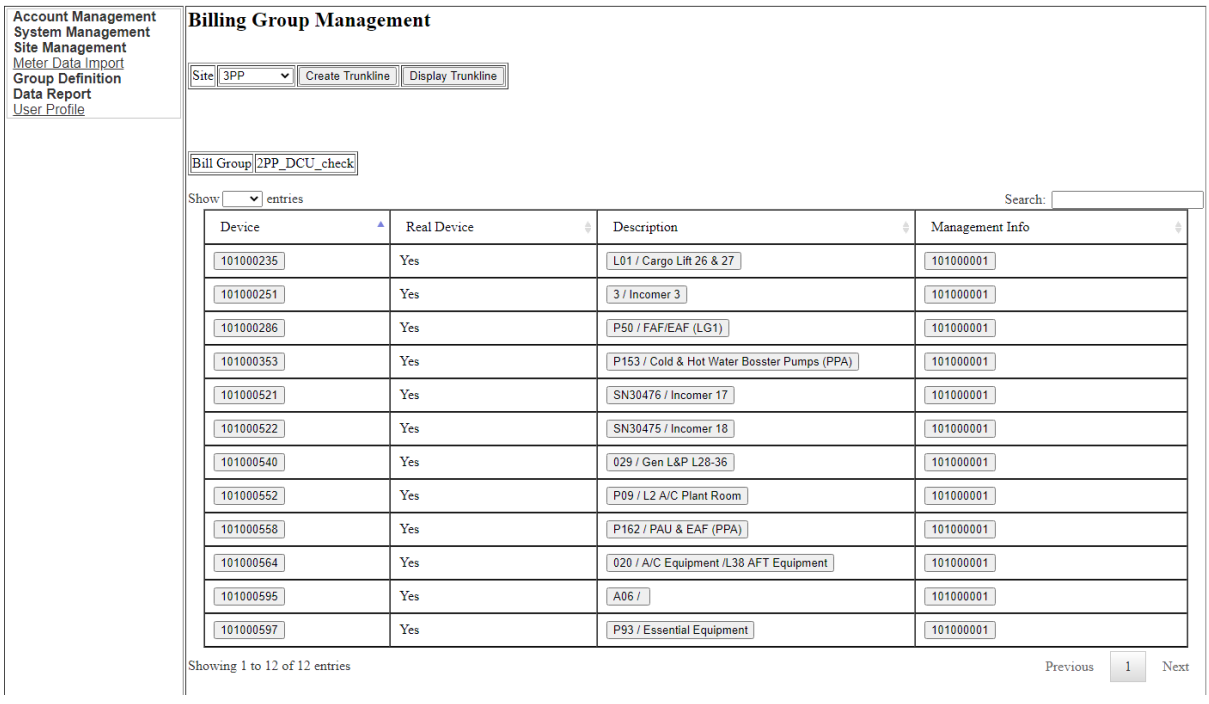


There are 3 kinds of meter grouping, incomer, billing group and meter group. The first two limit the meter under same site whereas meter group is based on category of the meter but bounded by user's site permission. The user can choose the option to share meter group with others. Incomer describes the relationship of meters in physical world. Billing group is mainly for bill calculation while meter group is generally for data analysis.



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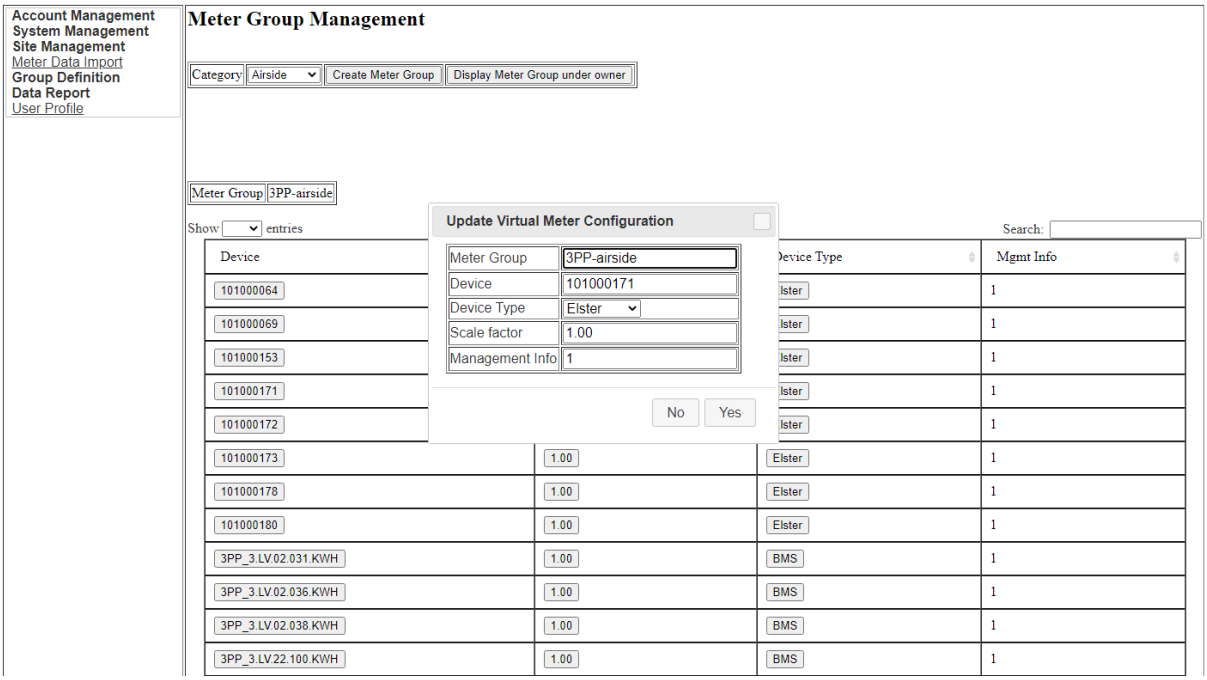
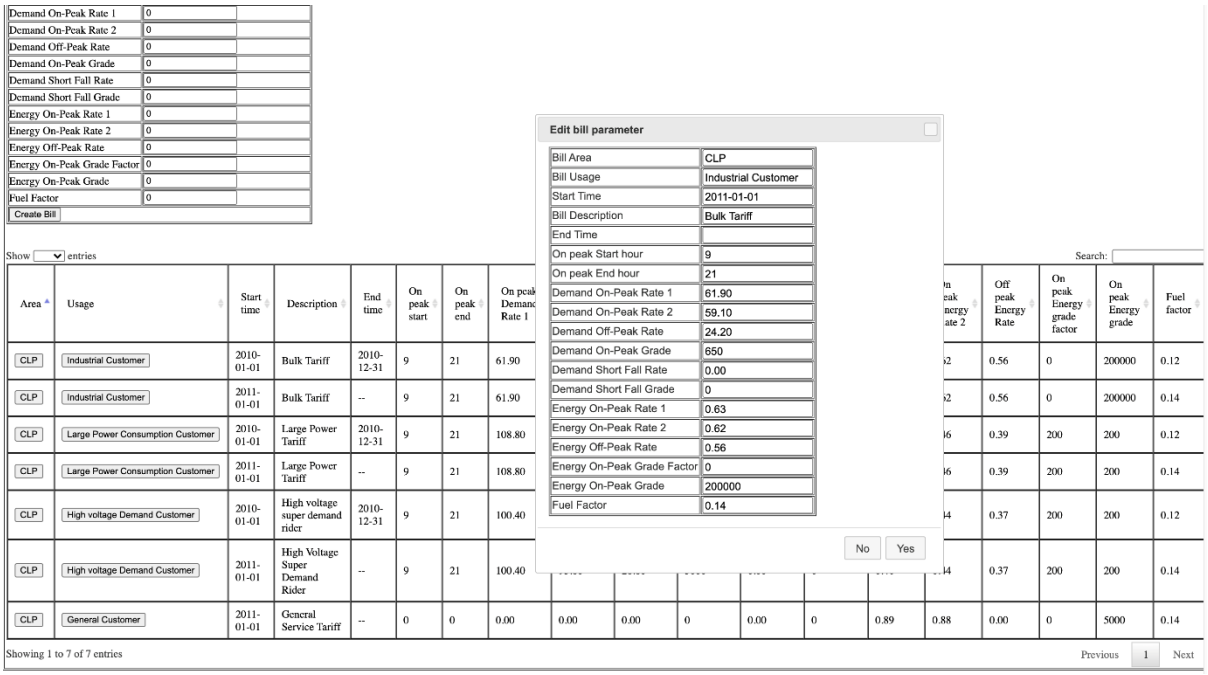


A scaling factor is introduced in each meter within category group and it is used to calculate the result for single virtual meter. Billing group requires both bill parameters and billing rules. Coming with the system is a general rule in 4 categories being used in Hong Kong. The bill parameters are specified in period basis and it is managed by the user.



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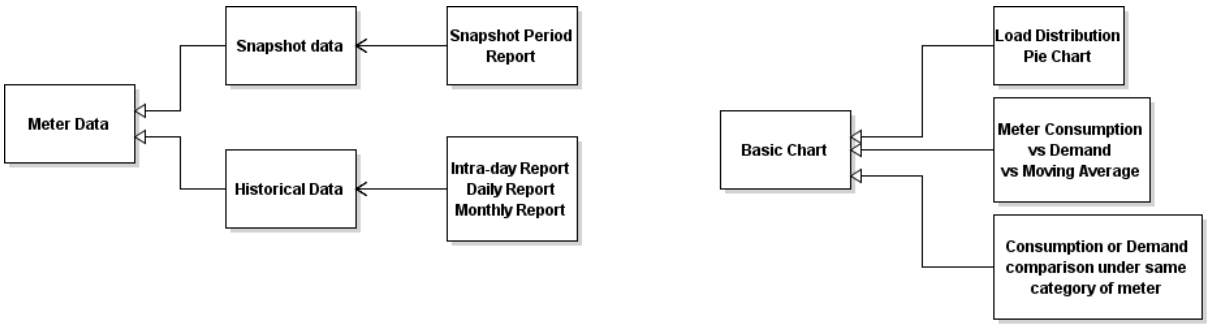
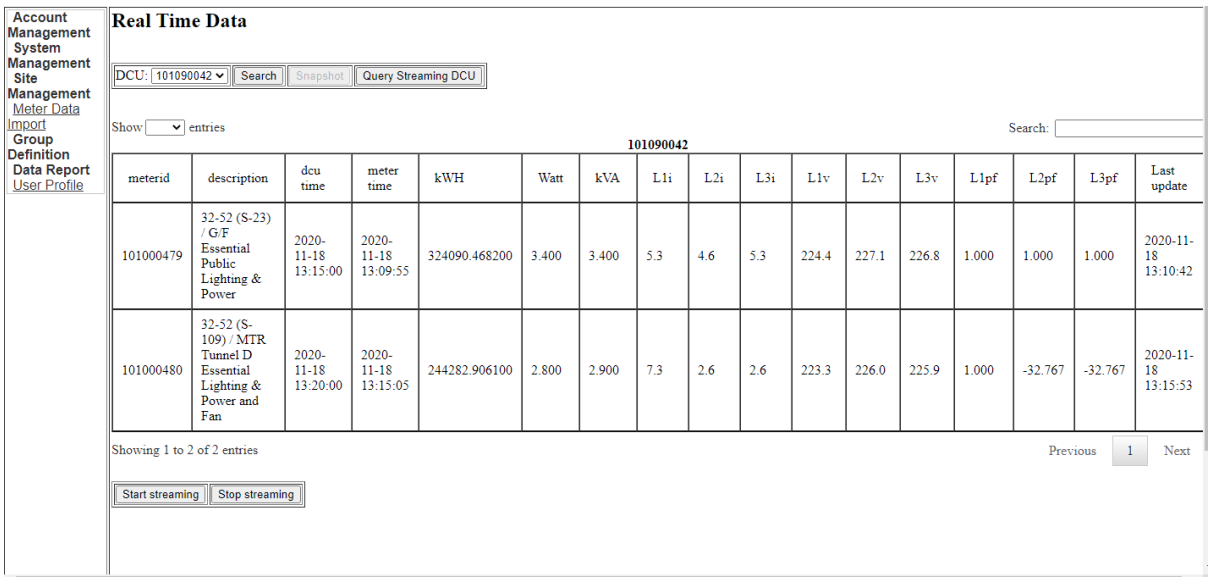
Report

There are 3 kinds of meter data for Elster meter in the system, snapshot data and historical data (load profile and instrumentation). Snapshot data comes from the polling mechanism in either DCU or system whereas historical data is stored in the meter itself. The minimum period attained by DCU and system is 1-minute and 15-minute respectively. This is based on two factors, data time associated with the historical data in Elster meter and the time required to get historical data in DCU (details in DCU product specification). Snapshot data (real time data in Web GUI) is populated together with instrumentation data to give system-wise periodic data.



Snapshot data is presented with reference to DCU which connects to meter. Besides displaying and exporting data in 4 kinds, intra-day (per DCU polling period), periodic (system wide period), daily and monthly), the system provides facility through Web Socket to give real time update data. Thus, when the data is retrieved from DCU, the information in the Web page is automatically updated immediately.



In addition, snapshot data can also be plotted using one of the configured fields. “Zoom in” is provided to look at details.

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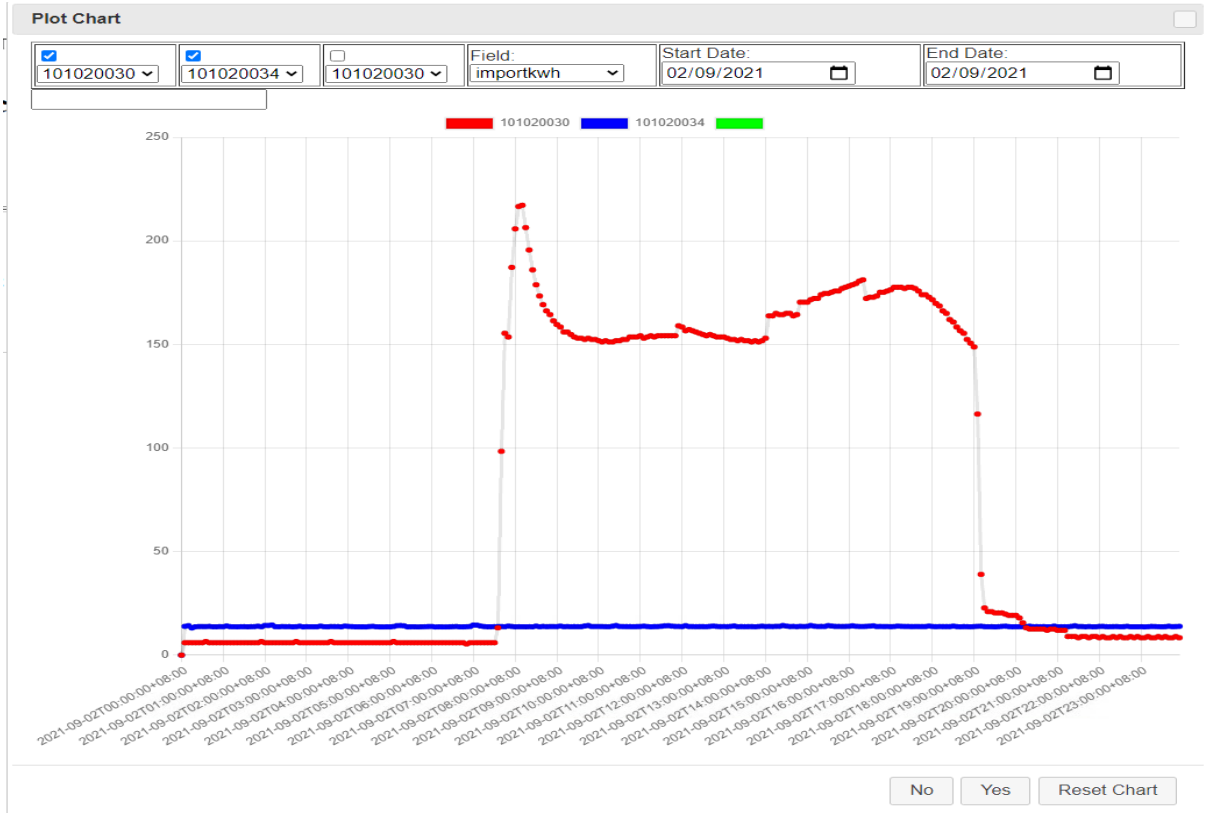

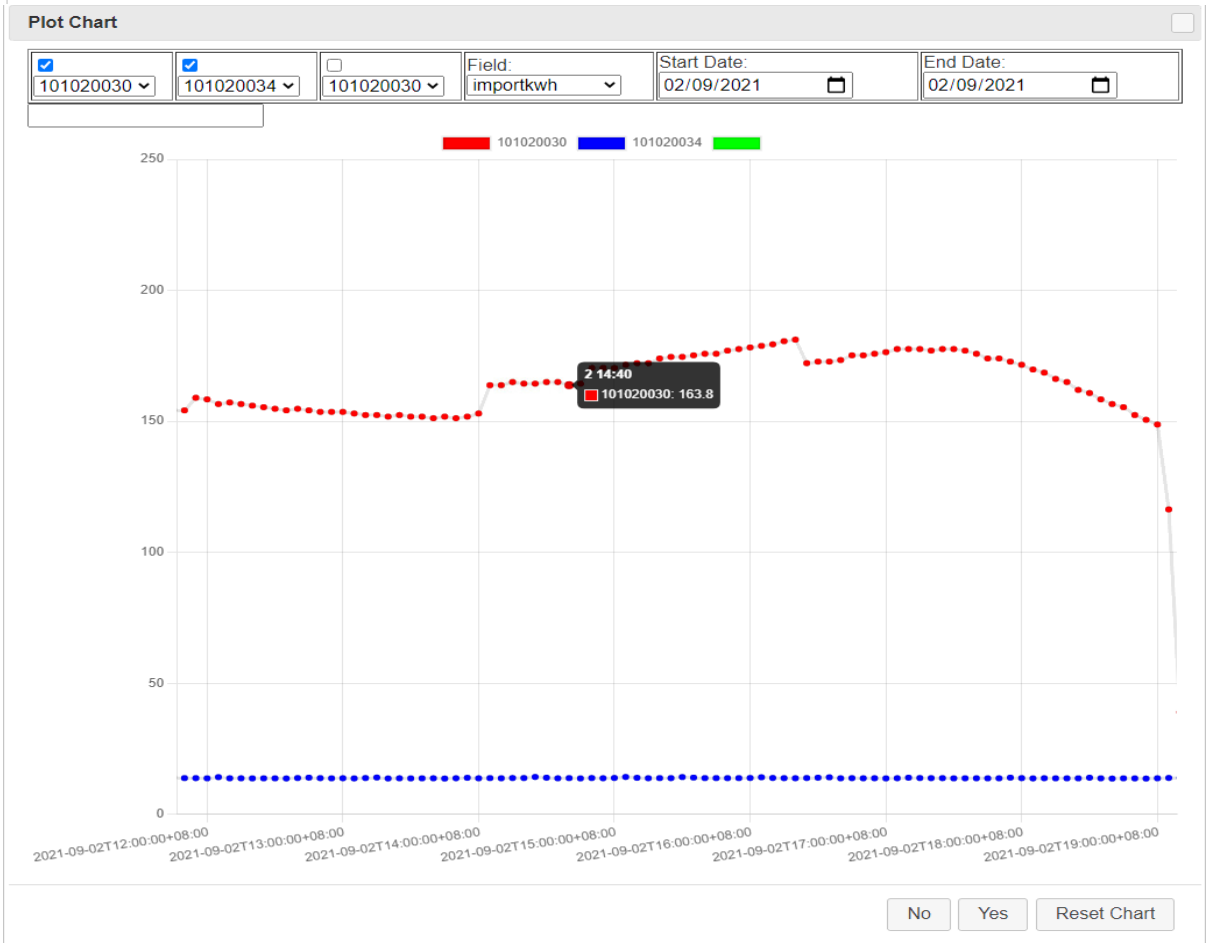

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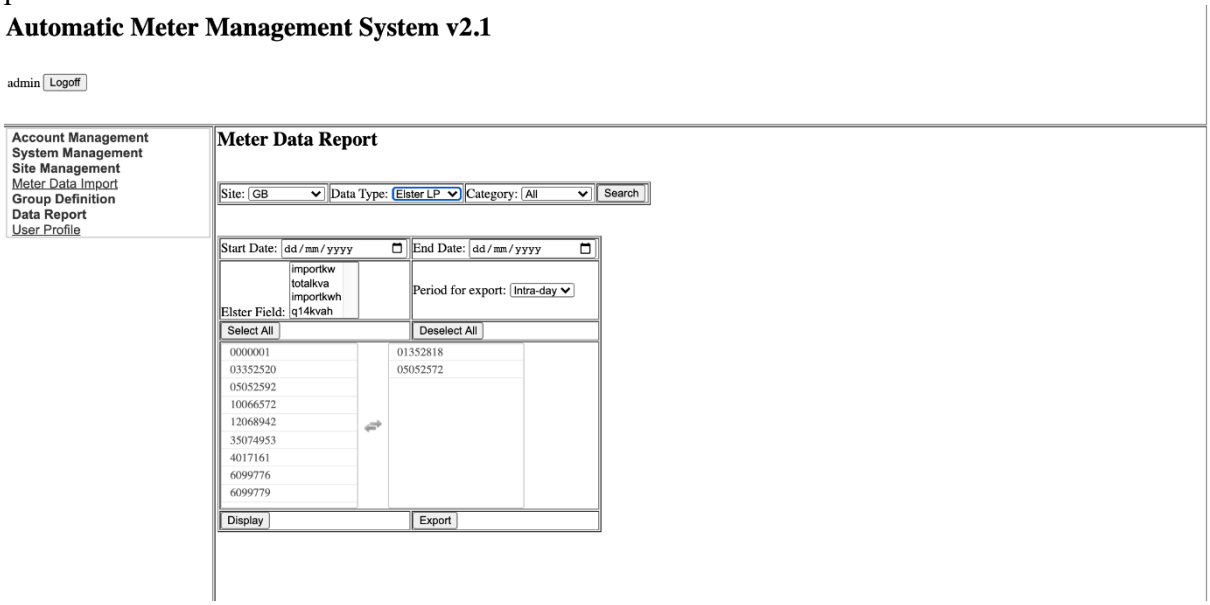
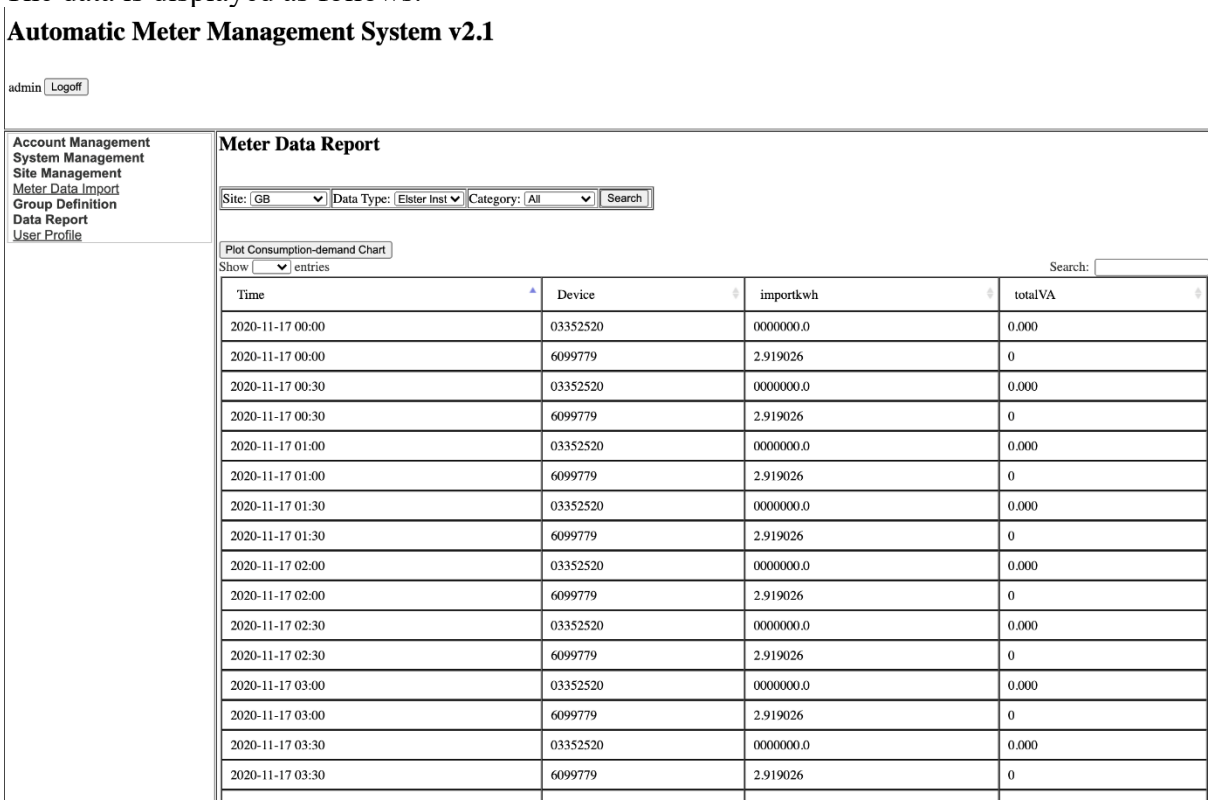
Meter data is displayed or exported with reference to the site. The data type includes Elster load profile, instrumentation and external data presented as BMS. 4 kinds of periodic data can be specified, system wise specific period (term as intra-day), hourly, daily and monthly. “Intra-day” applies to all reports except real time data report whose data comes from polling period of DCU.



The data is displayed as follows.



Time	Device	importkwh	totalVA
2020-11-17 00:00	03352520	0000000.0	0.000
2020-11-17 00:00	6099779	2.919026	0
2020-11-17 00:30	03352520	0000000.0	0.000
2020-11-17 00:30	6099779	2.919026	0
2020-11-17 01:00	03352520	0000000.0	0.000
2020-11-17 01:00	6099779	2.919026	0
2020-11-17 01:30	03352520	0000000.0	0.000
2020-11-17 01:30	6099779	2.919026	0
2020-11-17 02:00	03352520	0000000.0	0.000
2020-11-17 02:00	6099779	2.919026	0
2020-11-17 02:30	03352520	0000000.0	0.000
2020-11-17 02:30	6099779	2.919026	0
2020-11-17 03:00	03352520	0000000.0	0.000
2020-11-17 03:00	6099779	2.919026	0
2020-11-17 03:30	03352520	0000000.0	0.000
2020-11-17 03:30	6099779	2.919026	0

Consumption, moving average of consumption and demand can be plotted per device so that the user can find out the trend of the power usage before detail analysis is to be carried out.

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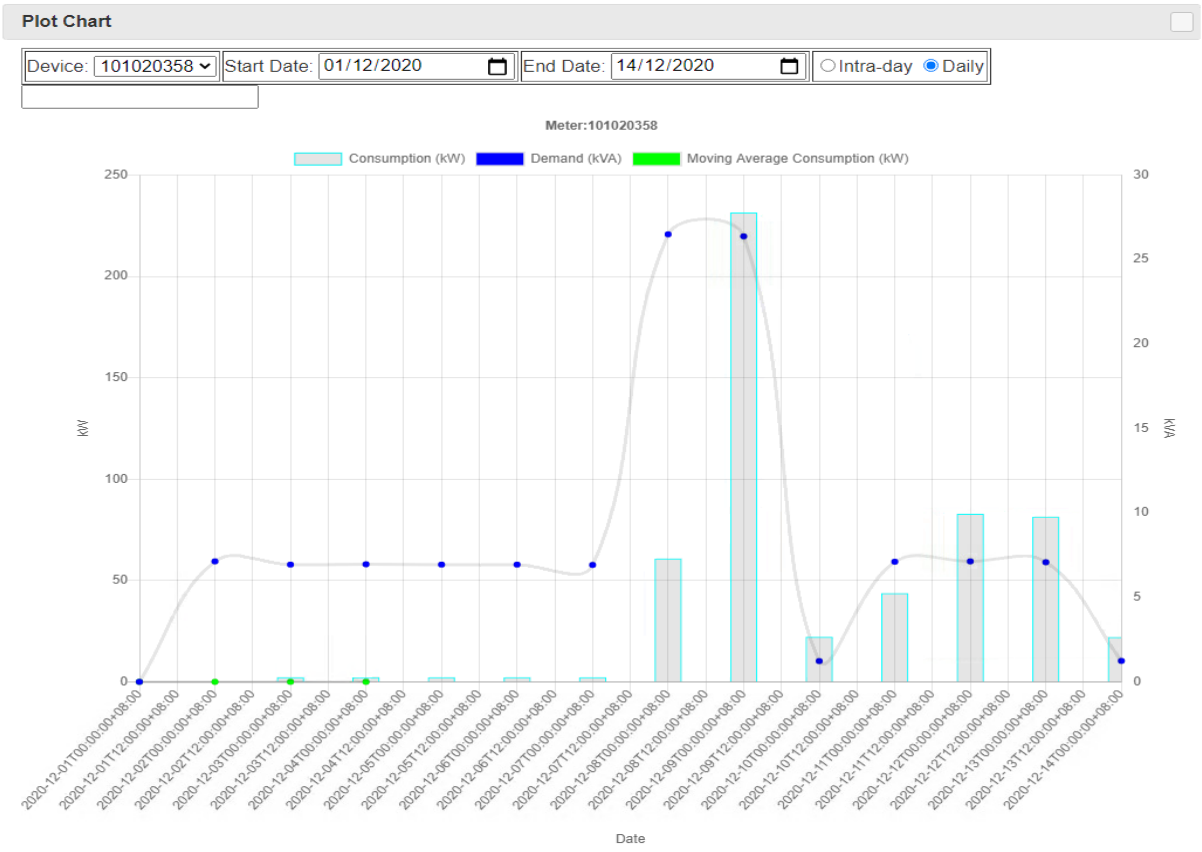

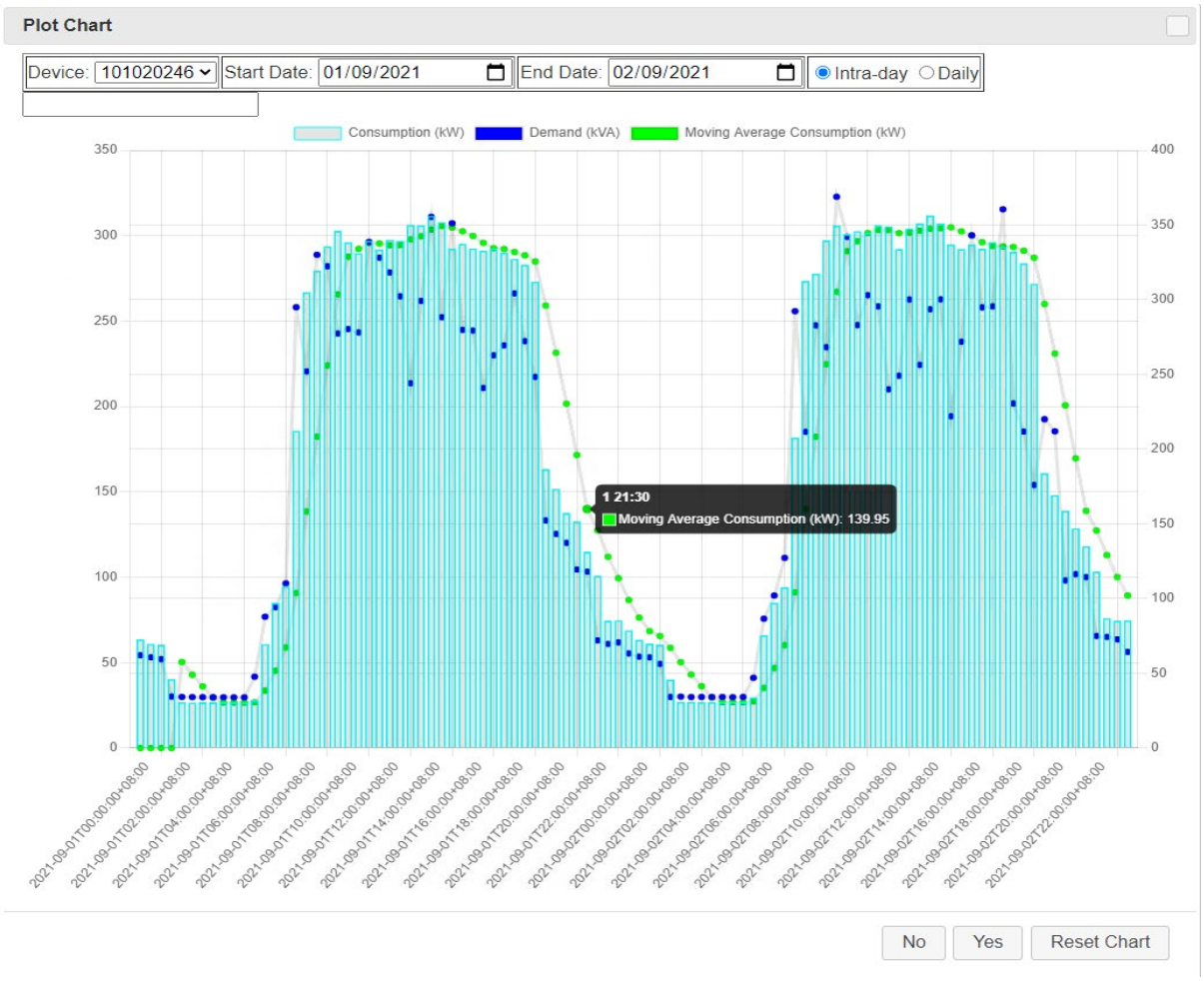

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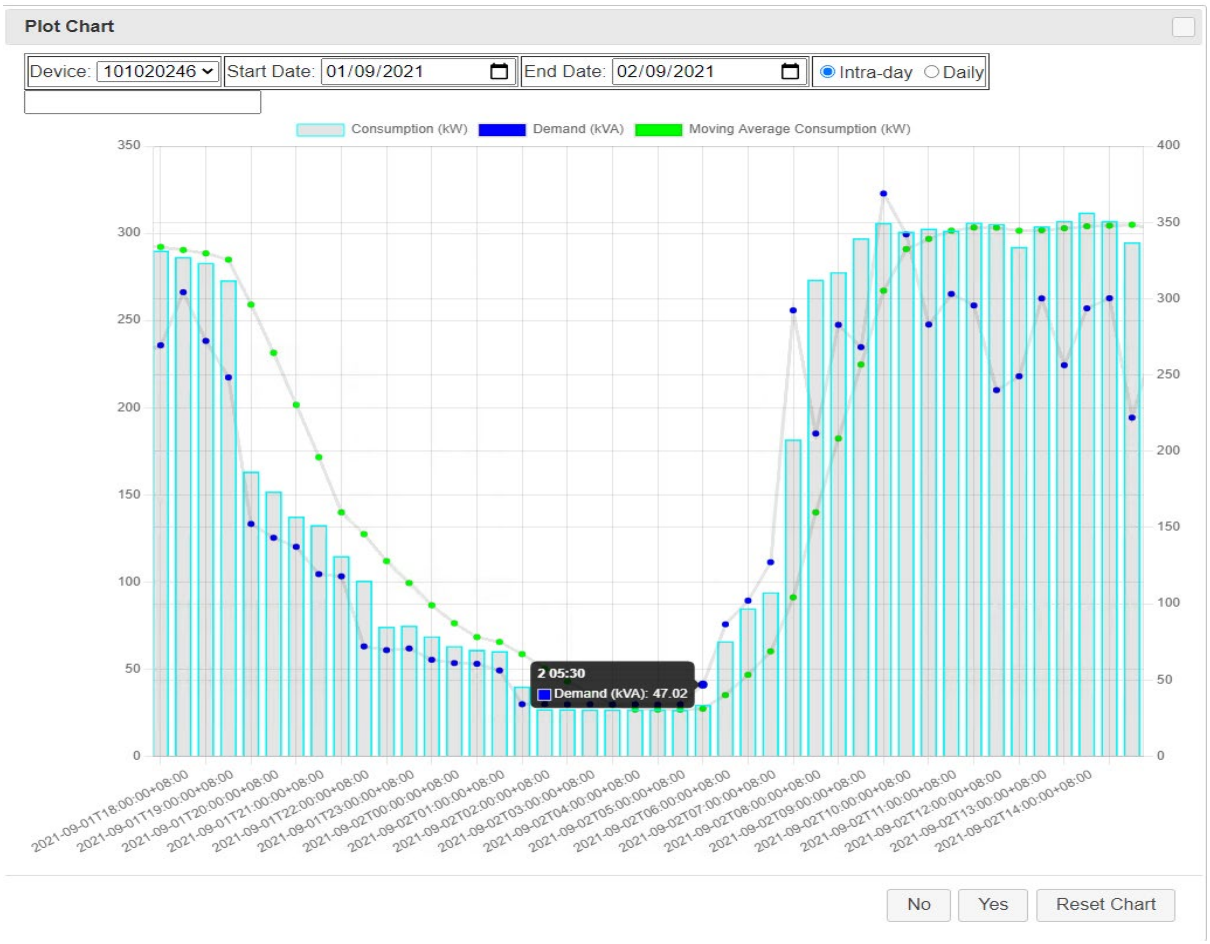
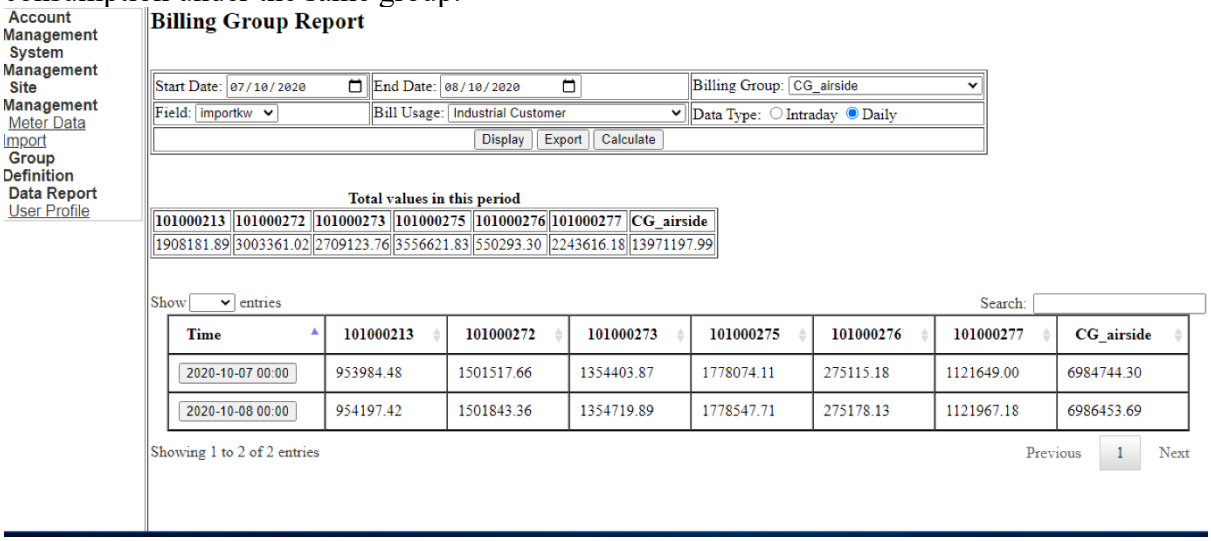


Billing Group meter report is to depict the contribution of individual meter to overall consumption under the same group.



Load distribution pie chart can be plotted at particular instant or entire period of data from individual meter. This is available in both bill group and meter group reports.

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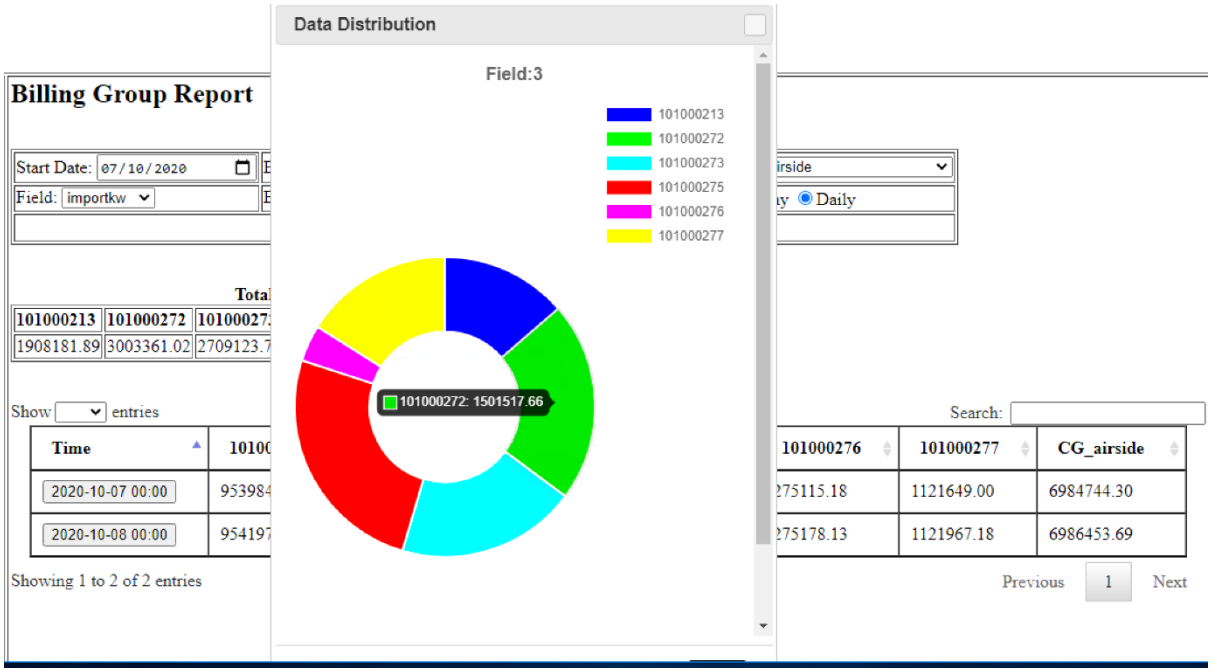
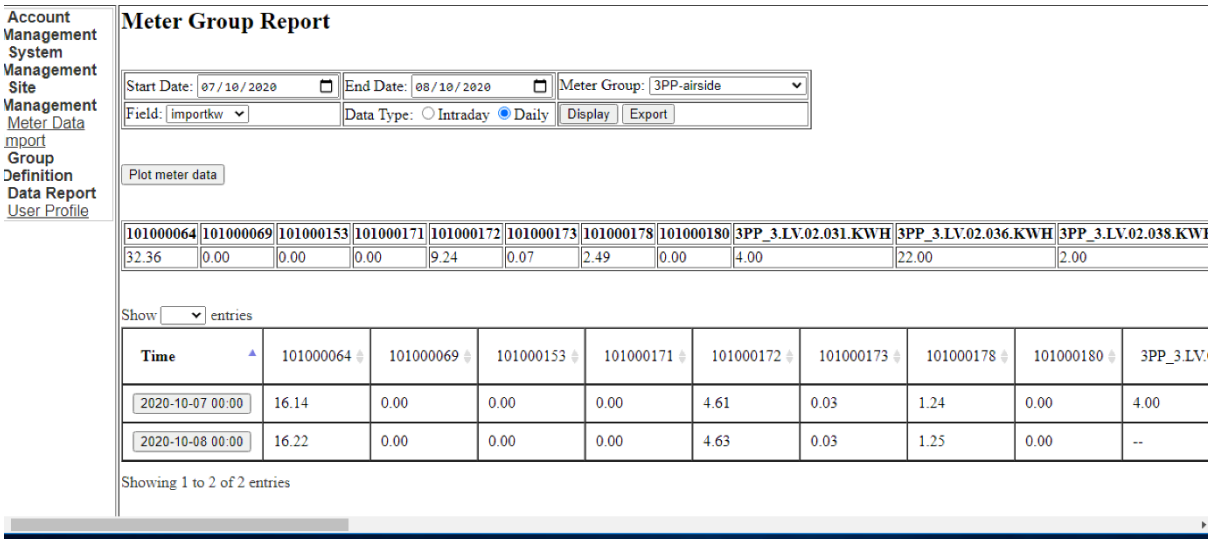


The meter group report is focus on the meter under same category.



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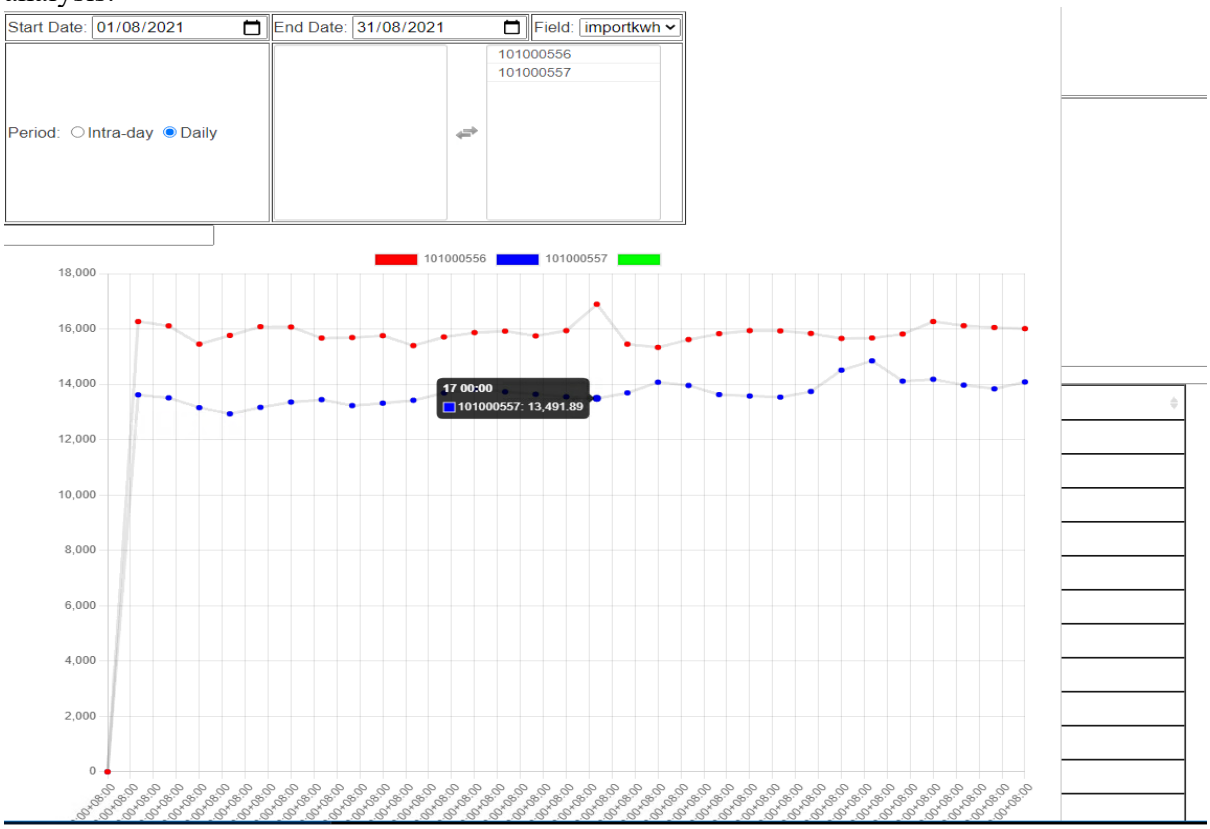
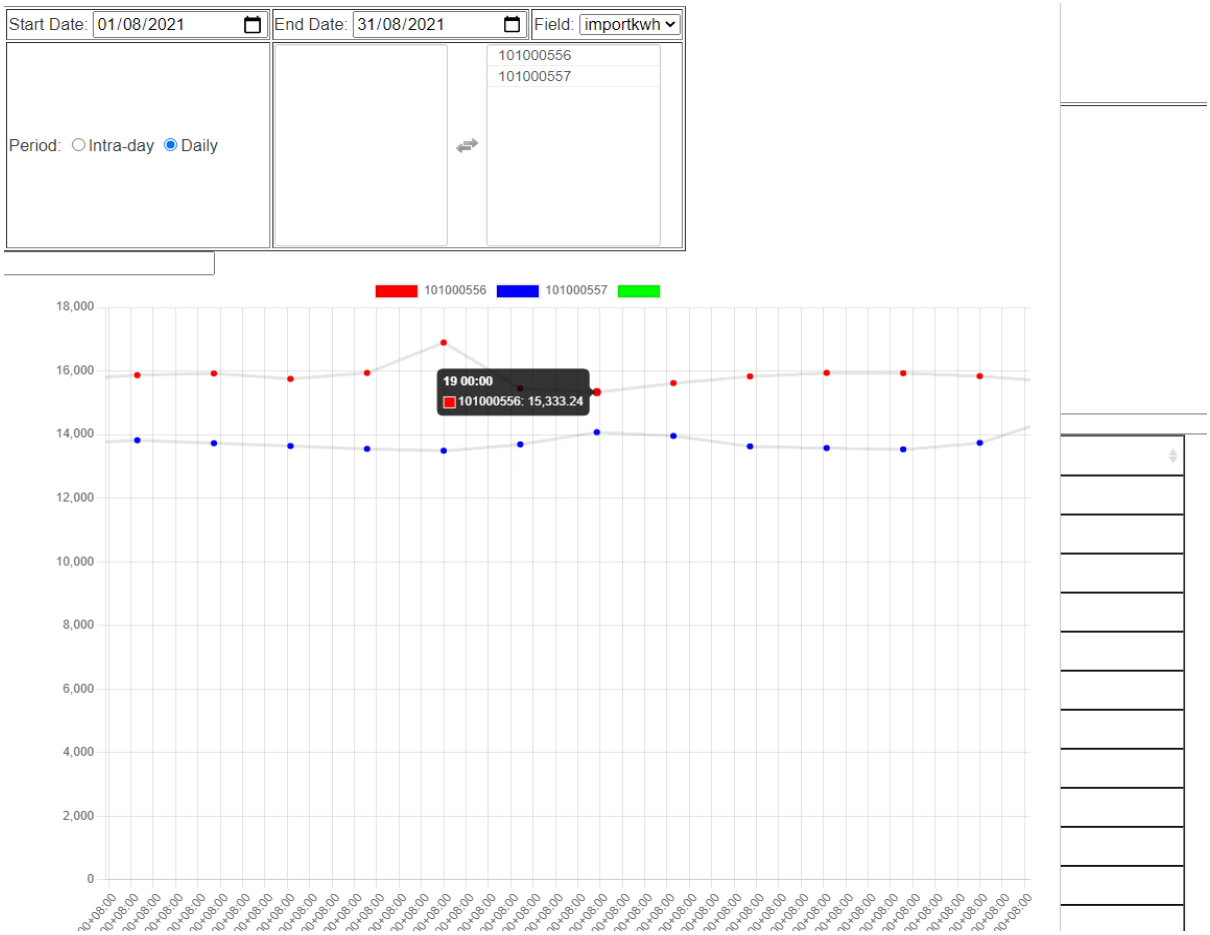
Up to 3 units of meter under same meter group can be plotted in same chart for visual analysis.





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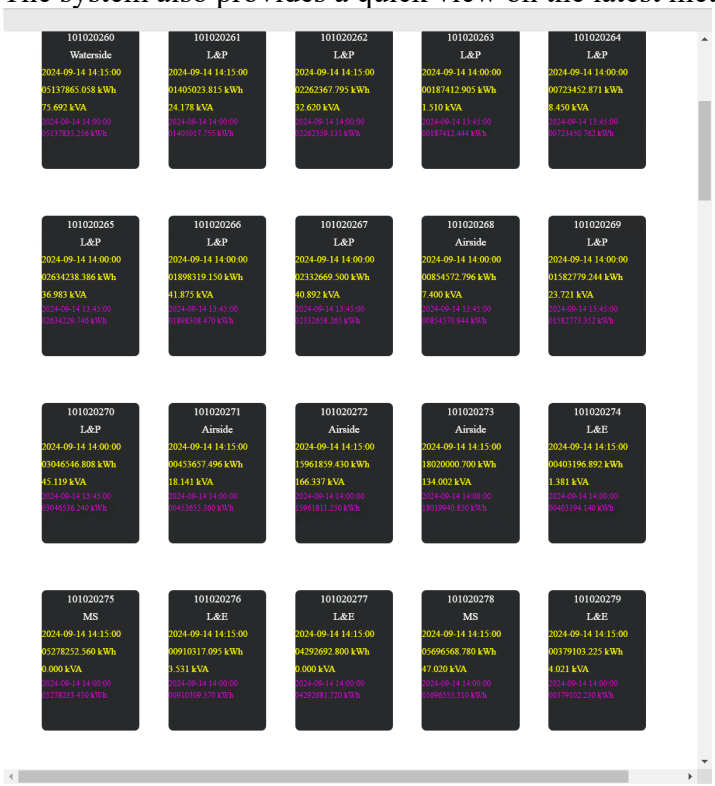
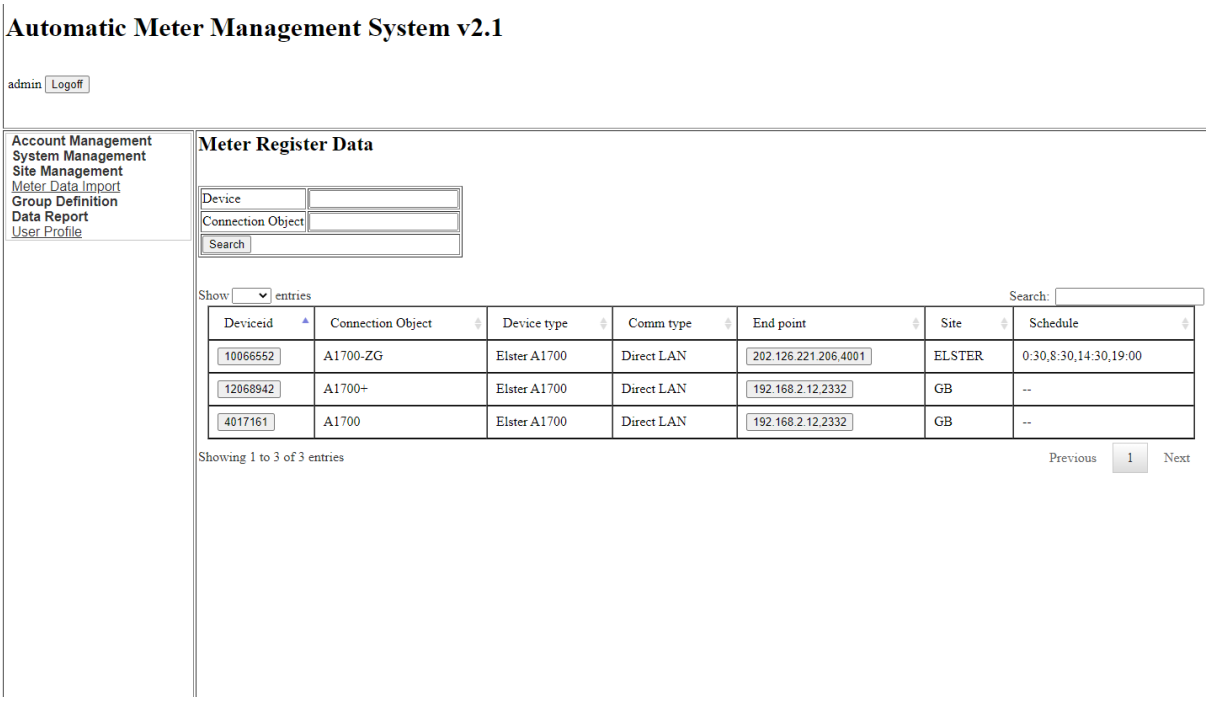
The system also provides a quick view on the latest metering data collected as follows.



For those meters managed by the system directly, a separate functional tab is introduced, and it occupies same menu item as real time data report.



Basically, meter information is queried through device identity or connection object (full description of the device). Data permission is applied to the search.

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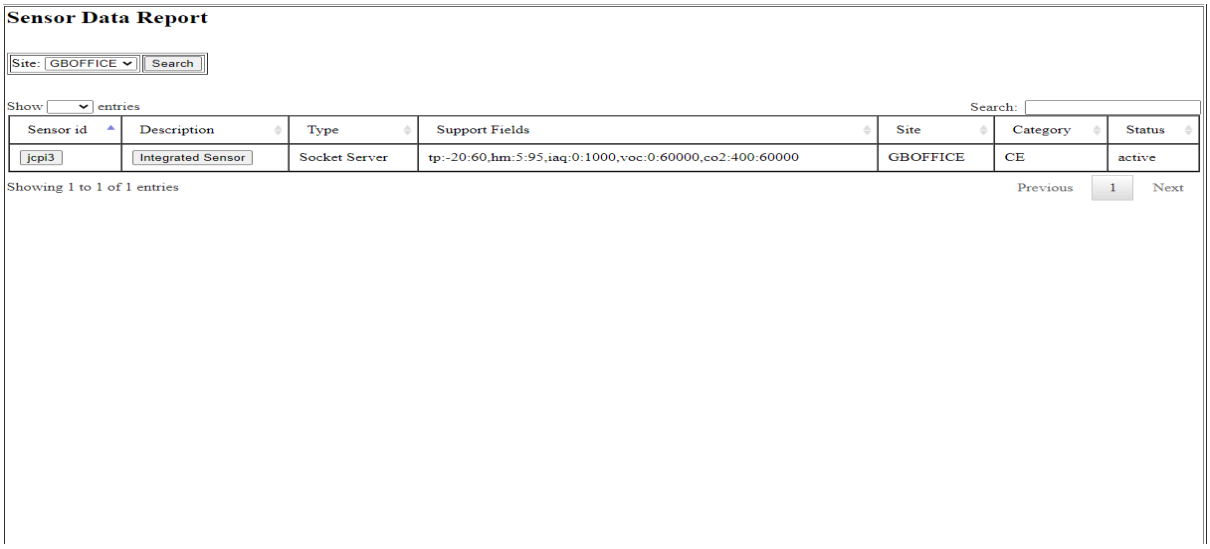
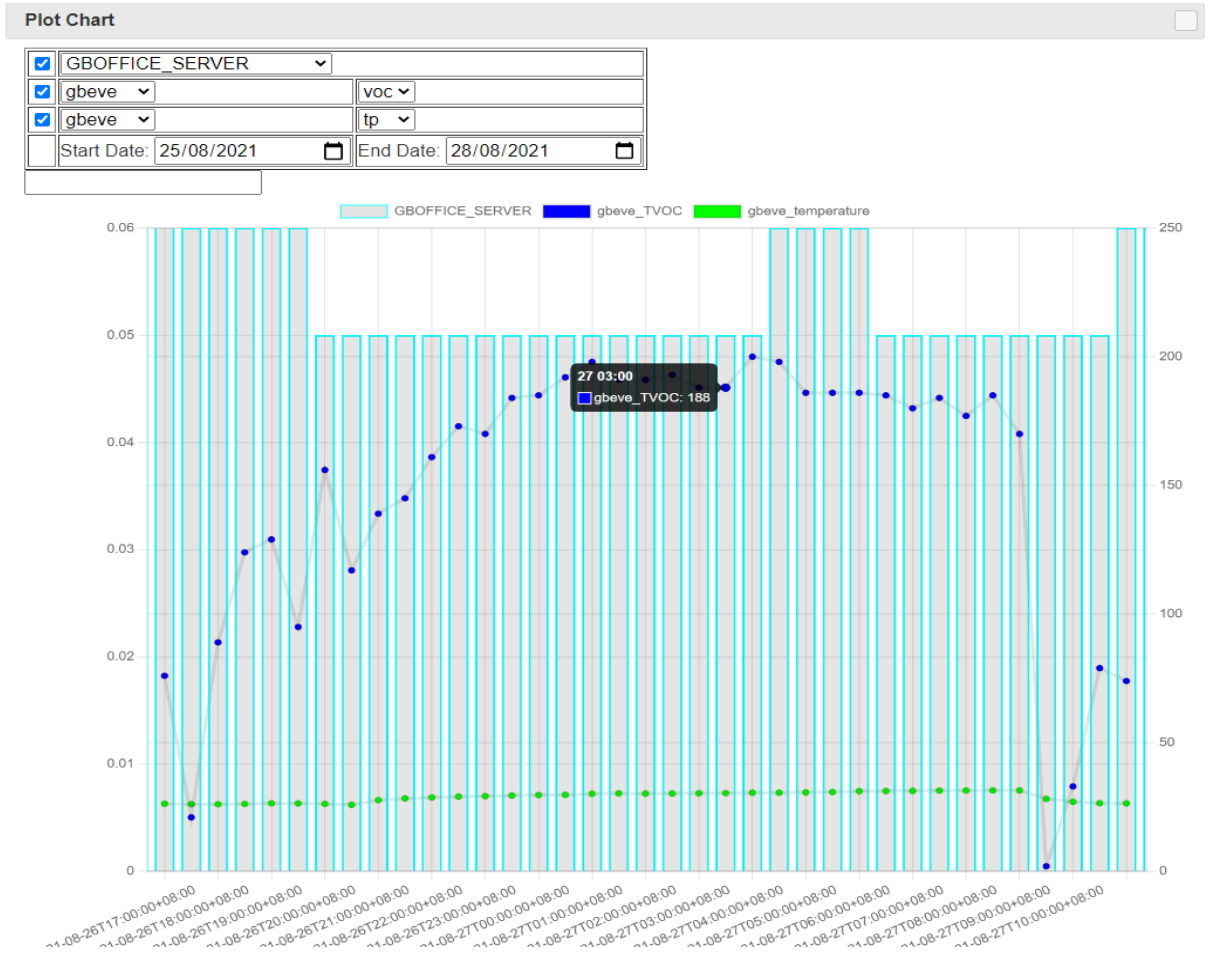
In addition of meter data analysis, the system also introduces sensor data referring to environmental data such as UV index or eVOC. This is accomplished through sensor report.



Each IoT is equipped with different kinds of sensor subject to what kinds of measurement to be taken. Just like meter type DCU, it stores data in flash and also publishes to the sensor server of the system. Each sensor is bounded by range of value as shown in the above diagram.



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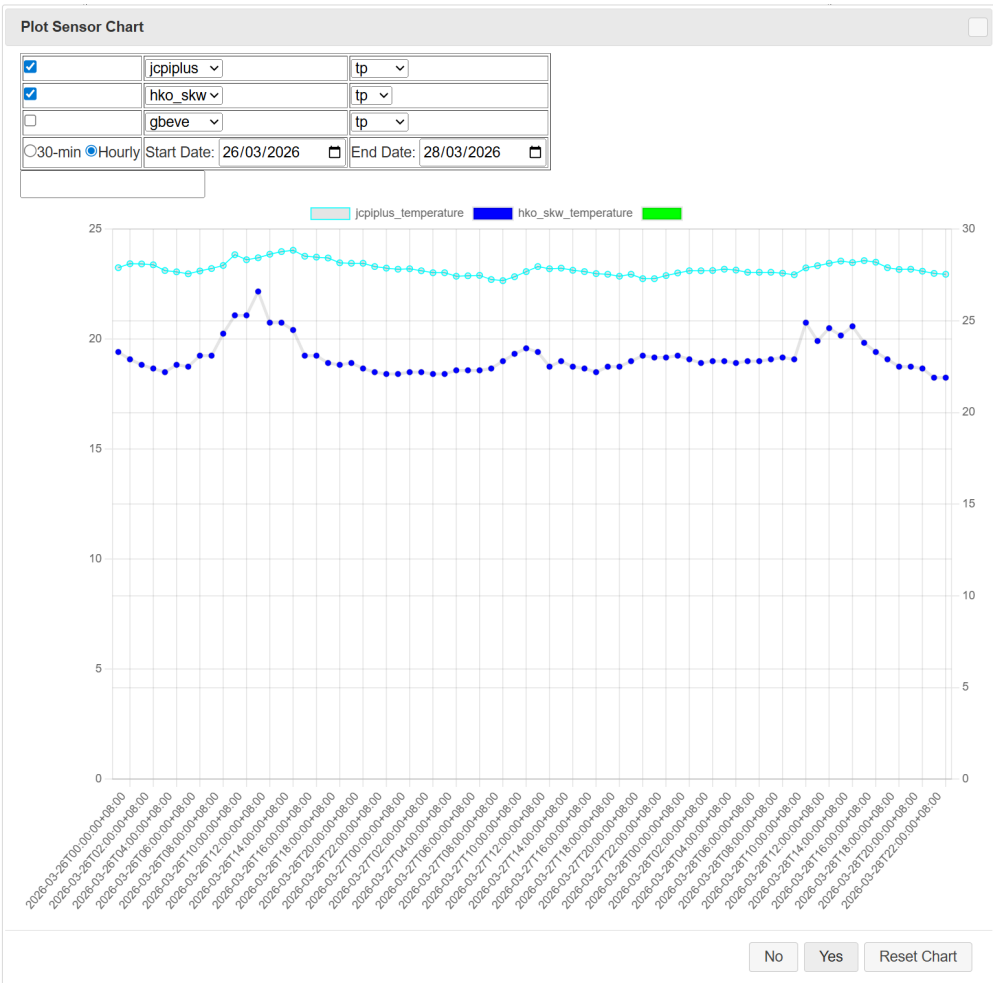
In addition, different sensors can also be used for different studies such as the following chart comparing the external temperature and room temperature from the official and installed sensor respectively.



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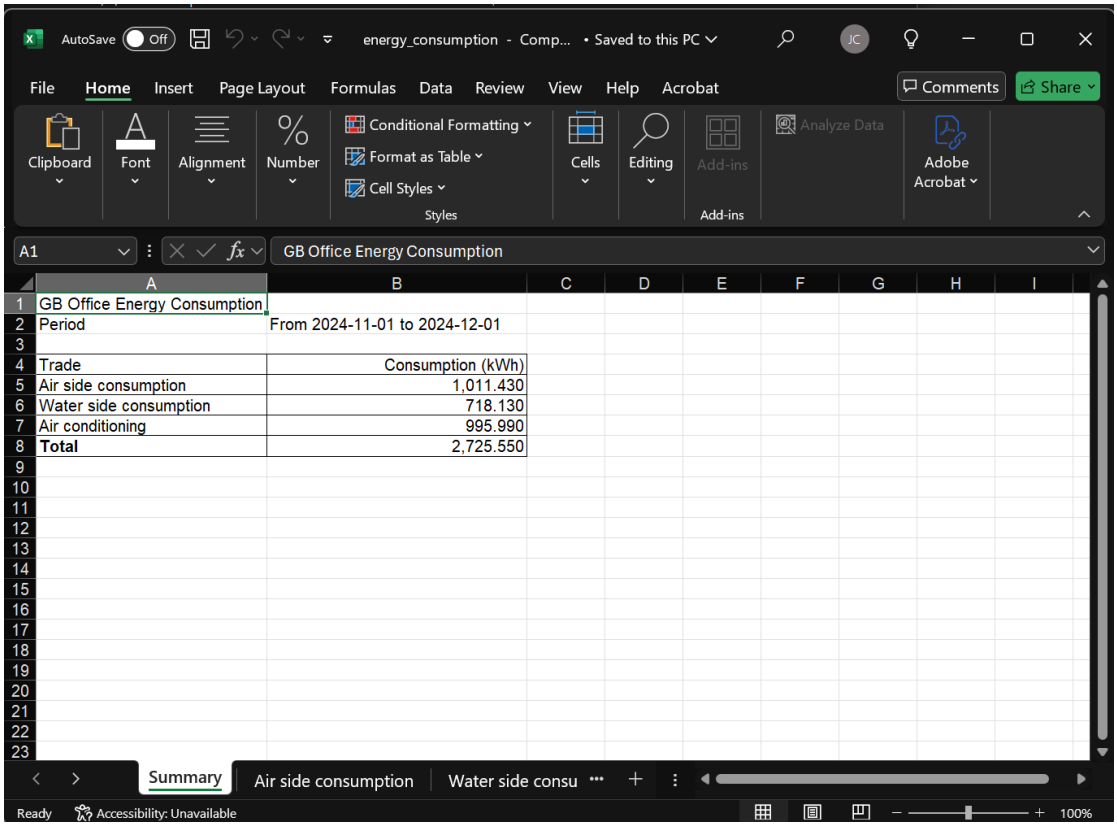
A few summary data reports are available in the system, daily and monthly report on the quantity of data collected and specific report such as consumption and harmonic.



	A	B	C	D	E	F	G	H	I
1	GB Office Energy Consumption								
2	Period	From 2024-11-01 to 2024-12-01							
3									
4	Trade	Consumption (kWh)							
5	Air side consumption	1,011.430							
6	Water side consumption	718.130							
7	Air conditioning	995.990							
8	**Total**	2,725.550							

	A	B	C	D	E	F	G	H	I	
		Incomers		main_1			main_3			main
				1	of	2022				
				03352520			35074953			6099
				L1	L2	L3	L1	L2	L3	L1
		Max total harmonic distortion		9.2	8.5	5.8	8.1	8.2	5.1	8.4
		No of record with total harmonic distortion > 4%		4	4	1	3	4	1	
		No of record with total harmonic distortion > 5%		2	3	1	3	1	1	
		No of record with total harmonic distortion > 8%		1	1	0	1	1	0	
		Max. total harmonic distortion on 2022/01/01								
		recorded at 0								
		Max. total harmonic distortion on 2022/01/02		4.1	3.7					
		recorded at 0		2022-01-02 03:00:00	2022-01-02 13:00:00					
		Max. total harmonic distortion on 2022/01/03						8.2		
		recorded at 0						2022-01-03	11:00:00	
		Max. total harmonic distortion on 2022/01/04					8.1	4.1		
		recorded at 0					2022-01-04 21:0	2022-01-04	21:00:00	
		Max. total harmonic distortion on 2022/01/05								2.8
		recorded at 0								2022
		Max. total harmonic distortion on 2022/01/06			8.5					
		recorded at 0			2022-01-06 05:00:00					
		Max. total harmonic distortion on 2022/01/08						4.2		
		recorded at 0						2022-01-08	19:00:00	
		Max. total harmonic distortion on 2022/01/09							5.1	
		recorded at 0							2022-01-09	04:0
		Max. total harmonic distortion on 2022/01/10		5.2	3.6		5.1			4.8
		recorded at 0		2022-01-10 08:00:00	2022-01-10 16:00:00		2022-01-10 13:0	0:00		2022
		Max. total harmonic distortion on 2022/01/14						3.5		
		recorded at 0						2022-01-14	06:00:00	
		Max. total harmonic distortion on 2022/01/15		9.2					3.1	4.8
		recorded at 0		2022-01-15 12:00:00					2022-01-1	2022
		Max. total harmonic distortion on 2022/01/16			5.1					
		recorded at 0			2022-01-16 11:00:00					
		Max. total harmonic distortion on 2022/01/20			4.2		5.9			3.1
		recorded at 0			2022-01-20 10:00:00		2022-01-20 03:0	0:00		2022
		Max. total harmonic distortion on 2022/01/21				5.8		4.2		
		recorded at 0				2022-01-21 18:00:00		2022-01-21	21:00:00	
		Max. total harmonic distortion on 2022/01/27			3.1			3.6		
		recorded at 0			2022-01-27 16:00:00			2022-01-27	13:00:00	
		Max. total harmonic distortion on 2022/01/28			6.9					

Energy Management System

Technical Information

System Requirements

- Up to 30 units of meter and less than 5 users
    - Intel i5 with 16 GB RAM, 256 GB storage holding all modules in one machine
    - MS SQL Express on Windows 10 Professional edition (note that up to 10 GB storage is allowed in MS SQL Express edition)
- Enterprise Usage
    - Intel XEON with at least 16 GB RAM, 1 TB storage with MSSQL Server on Windows or Linux and Tomcat Server for Web GUI
    - Intel i5 with 8 GB RAM, 128 GB storage for DCU Server and Meter Server on Windows 10 Professional or Linux (if the system requires to communicate with Elster UK Meter type directly, Windows machine is required)

Development environment

- Pure Java except the module to encapsulate the Elster meter encryption library using .NET framework C# which provides Web Service
- Spring framework, Mybatis and a set of open source libraries
- Apache Tiles, JQuery, Chart.js