INSTALLATION & USER GUIDE

FOR ENERGY METERING SYSTEM~~MINI-GRIDS~~

DEVELOPED BY
THE STRATHMORE ENERGY RESEARCH CENTER
ON BEHALF OF
THE DEUTSCHE GESELLSCHEFT FÜR INTERNATIONALE
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Project for Promotion of Solar Hybrid Mini-grids in Kenya

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1. Background

a. What is the EMS?

The Energy Monitoring System (EMS) is a platform which consists of an open source application and components to interact with the application. The application is developed to monitor the energy generation and distribution of mini-grids. It serves to remotely monitor and report on Key Performance Indicators (KPIs) of mini-grids. Those are generated and distributed energy, ~~system~~ duration and frequency of interruptions, CO_2 emissions saved and system losses. The tool allows for KPIs tracking, and therefore the ability to compare the performance of various mini-grids. Such performance tracking is critical to improve the operations of projects which in essence are usually run remotely. For example, detecting and calculating system losses helps improve the commercial efficiency of mini-grid projects. The EMS also provides a framework for viewing generation and distribution live data, which informs on real time on system failures, thus reducing response inefficiencies in O&M.

The EMS consist of five main components:

- **The energy metering units or sensors CTs**
- **The data collector and transmitter Energy Meter/Logger**
- **The network interface ??**
- **The EMS web application Computer program on hosting computer**
- **The EMS application host Computer/Server**

The sensors send information, for example about the amount of generated electricity, to the data collector. From here the information from the various sensors is sent via the network infrastructure (internet) to the remote EMS application host. Here the data is processed and then displayed by the EMS web application. The web application records the processed data and provides output reports which then can be used to enhance the mini-grid operations.

This System captures the Feeder Electrical Parameters using a Multi-Functional device with isolated Current Transformers. This data is captured specified interval. This captured Data is then stored in a non-volatile memory using a Data logger. This Data logger communicates with each MFD, reads / converts and stores the data in its memory. The logged data from the Data Logger is then transferred to a Computer / Server using Ethernet whenever the computer requests. In case the computer is not working/doesn't request for data, then the data remains in the EM memory. The data in the Computer is then converted to a SQL (Database compatible) format, by the software. This is then available to the entire Client Computer to view the Information Reports.

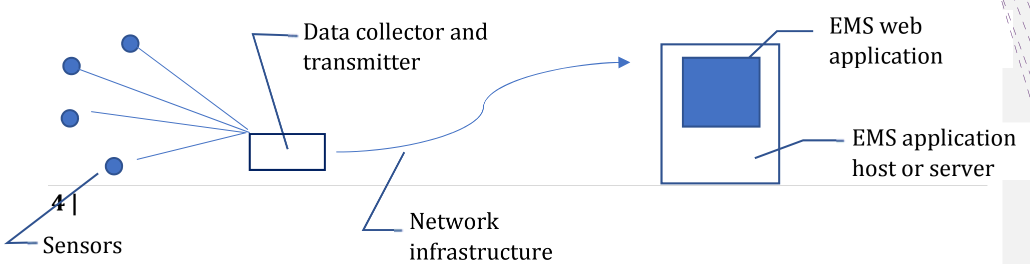

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Figure 1: Components and structure of the Mini-Grid EMS

The EMS web application consists of the grid management system, which is the main platform, as well as a user management system. The latter allows administrators to add new users and assign different user rights. The grid management system is the platform on which performance data of mini-grids is displayed in graphs and tables. The user is the~~can~~ administo~~e~~r of the grids, display data for different time frames, view historical and live data on key performance indicators, and export data in a csv or pdf file.

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b. Who can use the EMS?

The EMS is mainly designed for usage by mini-grid project developers and operators to enable them remotely monitor the power generated and distributed, network losses and interruptions in minigrid systems.~~. For them, remotely monitoring how much power is generated in their systems, how much is distributed, how large losses are and when an interruption occurs is essential for successful operation.~~ This includes long-term improvements of system operation, such as reduction of losses, as well as ad-hoc interference, such as reactions to system interruptions. As appropriate monitoring systems, can be costly or do not track all essential data, the EMS aims at reducing the barriers of costs and low quality of mini-grid monitoring systems and thus to benefit mini-grid project developers and the mini-grid market as a whole.

Commented [O3]: Could be put in a more precise language. I would say; EMS is mainly designed for mini-grid project developers and operators to enable them remotely monitor the power generated and distributed, network losses and interruptions in minigrid systems.

Furthermore, through a function to export data, but also by means of allowing others to view the data on the web platform without allowing them to make any changes, the performance information can be shared with others. Based on discussions with the energy regulatory agency in the course of development of this EMS, the importance ~~to monitor~~of monitoring mini-grid service levels with similar metrics to ensure operational performance comparability was raised. This product was therefore developed with the idea to report on key performance metrics in order to inform on continuous adherence to licensing conditions. The indicators in turn provide guidance to mini-grid project developers on required actions to deliver service levels which achieve regulatory requirements. Adherence to such minimum service levels contribute towards improved value, enhanced overall financial viability as well as increased investment attractiveness of mini-grids.

Currently many isolated mini-grids in Kenya operate widely “under the regulation’s radar”. While operators might track their generation and system interruptions, this data is not generated coherently nor always verifiable. There is no coherence in how and which data is recorded by system operators. This results in a lack of knowledge on the actual electricity access figures, the generated power and the quality of electricity supply in rural areas. For rural electrification planning it is essential to aggregate these data.

Finally, as the government through the Rural Electrification Authority (REA) plans to develop and operate several mini-grids, it is important for REA's future off-grid operations to have a suitable monitoring system in order to coherently document, but also to track and improve performance of those mini-grids and to be able to promptly react to system interruptions.

c. What are the EMS outputs?

The EMS provides a set of useful information to enable sound operations of mini-grids. It generates graphs displaying the history of system performance of one or more mini-grids. The following KPIs on given mini-grids are displayed:

- Distributed electricity (kWh)
- Generated electricity (kWh)
- System interruptions (hours and sources of interruption)
- CO2 emissions saved (kg)
- Total generation system losses (kWh) (Generation and Distribution)
- Total Distribution losses (kWh) (Technical ~~and commercial~~)
- Distribution commercial losses (kWh) (Upon entering manually the invoiced amount of electricity)
- Number of connections.

Commented [SM4]: Does it give the generated power? If so, how does one navigate to it.

Commented [SM5]: Does it provide this information on losses and connestions?

As the historical data on system performance can also be exported, the information can be used to analyze mini-grid performance and improve it, for example by detecting system losses and consequently taking measures to reduce them. The platform can furthermore be used for internal and external reporting. Through the function to export data and graphs, selected information can be shared with relevant stakeholders, such as financiers, but also with the Energy Regulatory Commission to prove compliance with license conditions.

Furthermore, the EMS displays mini-grids live data. It can be seen as the mini-grids SCADA since it also sends SMS and email warnings in case of system interruptions. It thus allows mini-grid operators to promptly react for service reestablishment and to minimize times of system failure.

As the platform is open source, it can be modified by anyone and adapted to specific needs. However, it is recommended to keep at least the initial in-built key performance indicators, since those are aligned with the regulatory reporting requirements.

d. Who developed the EMS?

The Mini-Grid EMS was developed at the Strathmore Energy Research Centre (SERC) by IT Analyst Alex Mari and SPV specialist Kevin Gaitho under the supervision of Karl Mikl. The project was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The project “Promotion of Solar-Hybrid Mini-Grids” (ProSolar) is implemented by GIZ on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The project is part of the German Climate Technology Initiative (DKTI) and promotes the dissemination of technologies in emerging and developing countries with the aim of reducing greenhouse gas emissions. Implementing agencies for the DKTI are both GIZ for technical and KfW for financial assistance. The project’s objective is to improve the electrification of remote areas in Kenya through mini-grids with the participation of the private sector. It furthermore contributes to the improvement of the regulatory framework governing electricity supply in Kenya. Institutional support is provided to public as well as private sector actors to strengthen their capacities in implementation and operation of sustainable and environmentally friendly solar-hybrid village power systems. As a support to the Rural Electrification Authority (REA) of Kenya, as well as mini-grid project developers, GIZ ProSolar has engaged SERC with the assignment of creating a publicly available monitoring system for mini-grids in Kenya. The tool here developed can however be used for any other mini-grid in the world, since the technical settings will be the same. In the event of different regulatory requirements, the project proponent has access to the source code and can adapt the EMS to his specific context.2. Installation guidelines

Disclaimer

It is highly recommended that the required hardware is installed only by a competent professional. The EMS developers do not bear any liability nor carry any responsibility for any risk, damage, impact or unsolicited result to anyone or any object which might occur as a consequence of using this material.

⚠ ~~DANGER~~⚠ CAUTION

- **Only qualified electrical workers** should install the required hardware. Such work should be performed only after reading this entire set of instructions, as well as the instructions for the hardware
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on the equipment, disconnect all sources of electric power. Assume that all circuits are live until they have been completely de-energized, tested, and tagged. Turn off all power supplying the power hub and the equipment in which it is installed before working on it.
- All circuit-breakers powering the power hub must meet the relevant requirements
- Always use a properly rated voltage sensing device to confirm that all power is off.
- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices.
- Before closing all covers and doors, carefully inspect the work area for tools and objects that may have been left inside the equipment.
- The successful operation of the equipment depends upon proper handling, installation, and operation. Neglecting fundamental installation requirements may lead to personal injury as well as damage to electrical equipment or other property.
- NEVER bypass external fusing.
- The power hub should be installed in a suitable electrical and fire enclosure.

Failure to follow this instruction may result in death or serious injury

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2. End User manual

2.1. System Structure

The Energy Monitoring System is designed to monitor key performance indicators for a mini-grid. The EMS web platform consists of:

- A **Grid Management System (GMS)**, which entails the main functions of the EMS. It allows the user to manage the mini-grids effectively. The GMS works on the principle of easy access, use and display of data. It takes raw data on key performance indicators and structures it into information that can be interpreted for different uses. The GMS automatically tracks data, such as generated electricity, but also allows the user to add and modify additional data, for example on customer connections. The system then allows the user to extract data on the performance of a mini-grid. Data is visualized in two sections which incorporate static data which has been collected over time and a live feed section of dynamic data.

- A **User Management System (UMS)**, which allows the administrator to manage the users effectively. The UMS are designed on the principle of privileges, which means different users can be assigned different levels of access to the system by the administrator. Moreover, the UMS allow the users of the system to interact in a forum, for example to discuss how to improve system performance. Views from users, as well as access times can be tracked.

2.2. EMS desktop pages3.2.1 Login

For using the EMS, registration and login are required. For registration, it is required to fill in information about the user. This information and its specifics are depicted below:

a. First Name
b. Last Name
c. E-mail
d. Date of Birth
e. Gender
f. Organization
g. Mini Grid Interest. Why?

Once the request for registration has been made, the administrator has to assign the new user certain usage rights and only after that has happened the user can log in to the system. For login, the email address used for registration and the chosen password need to be used.

After a successful login, the user is directed to the start page which has a list of the grids, the user is authorized to view, their parameters, location and characteristics.

2.2.2 Menu bar

2.2.2.1 Start page

The start page serves as an overview of all the mini-grids that the user is authorized to view and/or edit. It lists the grids that are being monitored, and shows their generated power since commissioning of the grid in a graph. Furthermore, all monitored mini-grids are displayed on a line map, each grid has its own colour Scroll down to the generated energy [kWh] ,distributed energy [kWh] duration of interruption made[h],avoided CO2 [kg] total losses and number of connections of the mini-grid within a year.

Users that are authorized to do so can add a new mini-grid to the system or delete a mini-grid. When adding a new mini-grid, the user is redirected to the settings page, where all information about the new mini-grid, such as the size, location, has to be entered (see section v. below).

When clicking on one of the mini-grid name , the user is directed to the dashboard for that mini-grid.

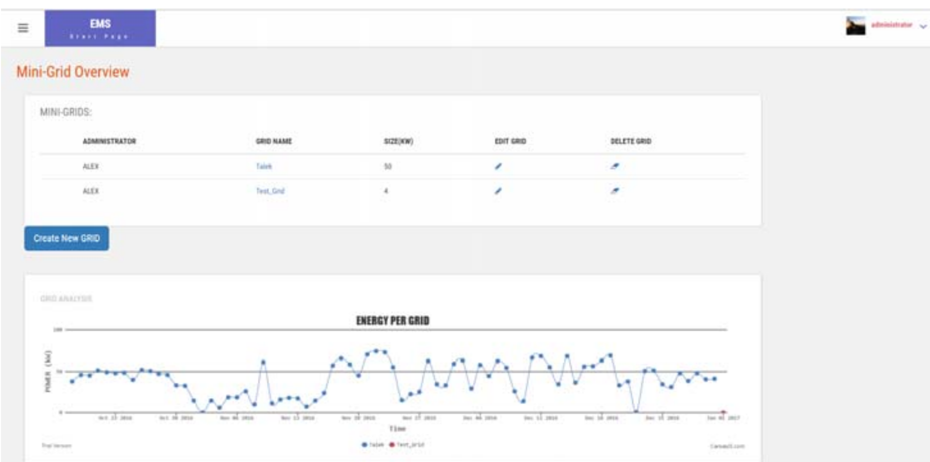

Figure 2: Start page of mini-grid EMS web platform

2.2.2.2 The dashboard

The dashboard gives an overview of the key performance indicators for a selected mini-grid. On the top, the dashboard displays

- The cumulated generated energy for the present day (up to the moment of reviewing the data)
- The amount of ~~energye~~energy that is generated at that specific moment (updated every 10 seconds)
- The losses that have incurred so far on the present day

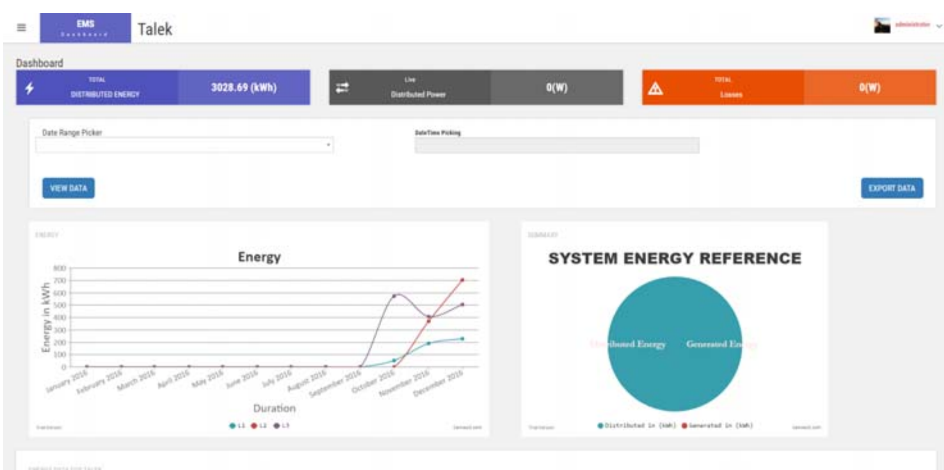

Figure 3: Dashboard of the mini-grid EMS web platform

Below that, the user can choose a certain timeframefor which data can be displayed and exported. For example, the user can choose “annual data” to show data for the year 2016, or “monthly data” to show data for only September 2016.
For displaying the data click on “view datafter specifying the timeframe the respective data is shown in the graphs below according to the selected time frame. The graphs show the historical data that was recorded on the various lines. Furthermore, it shows in a pie chart the distribution losses. Below the charts tables with the data are displayed.

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You can export the data by clicking on “export data”. Data can be exported to a PDF-report or to a CSV-file.

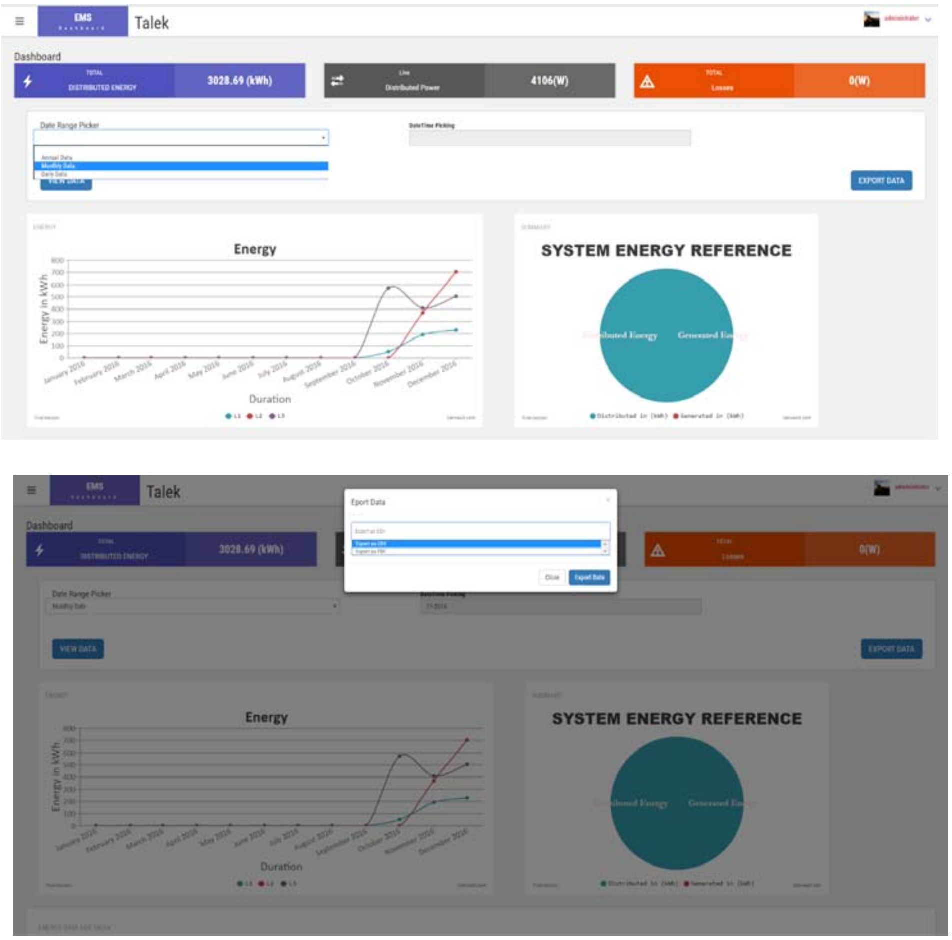

Figure 4: Data Export Functions

iSample Report Generated from mini-grid EMS

Perfomance Report of Talek

Retrieved on 2016/12/31

Data for the duration 11-2016 in Days

System Properties

Commissioning date: 0000-00-00

Total installed capacity: 50 kW

location

longitude

: 35.1947021484375

latitude

: -1.4525716904310186

Performance overview

This is the cumulative Data for the duration 11-2016 in Days

#	Talek
Generated Energy (kWh)	0.00
Distributed Energy (kWh)	968.03
Duration of interruption[h]	39
Avoided CO2 [kg]	321.67
Total Losses	0
Number of Metering Points	3

Energy Data for Talek

Days	Generated Energy [kWh]	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Losses	Number of Metering Points
1	0.00	14.38	1	4.78	0	3

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Figure 5: Page 1 of Export Report from Mini-Grid

Days	Generated Energy [kWh]	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Losses	Number of Metering Points
2	0.00	0.00	2	0.00	0	3
3	0.00	14.50	1	4.82	0	3
4	0.00	5.78	1	1.92	0	3
5	0.00	18.79	1	6.24	0	3
6	0.00	18.87	1	6.27	0	3
7	0.00	26.04	1	8.65	0	3
8	0.00	9.88	1	3.28	0	3
9	0.00	61.12	1	20.31	0	3
10	0.00	11.11	1	3.69	0	3
11	0.00	16.11	1	5.35	0	3
12	0.00	17.90	1	5.95	0	3
13	0.00	17.42	1	5.79	0	3
14	0.00	7.27	1	2.42	0	3
15	0.00	14.50	0	4.82	0	3
16	0.00	24.14	0	8.02	0	3
17	0.00	56.63	0	18.82	0	3
18	0.00	65.49	0	21.76	0	3
19	0.00	58.07	0	19.30	0	3
20	0.00	44.94	0	14.93	0	3
21	0.00	70.33	0	23.37	0	3
22	0.00	74.33	0	24.70	0	3
23	0.00	72.81	0	24.19	0	3
24	0.00	54.91	0	18.25	0	3
25	0.00	14.92	0	4.96	0	3
26	0.00	22.30	0	7.41	0	3
27	0.00	25.16	0	8.36	0	3
28	0.00	62.51	0	20.77	0	3
29	0.00	34.72	0	11.54	0	3
30	0.00	33.10	0	11.00	0	3

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Figure 6:Page 2 of Export Report from Mini-Grid EMS

FEED NAME: L1

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	3.50	0	1.1623
3	1.46	0	0.4866
4	0.67	0	0.2215
5	1.77	0	0.5882
6	2.05	0	0.6807
7	8.91	0	2.9614
8	6.18	0	2.0522
9	37.21	0	12.3651
10	5.39	0	1.7919
11	4.19	0	1.3920
12	8.24	1	2.7379
13	7.10	0	2.3584
14	1.04	0	0.3451
15	1.16	0	0.3844
16	2.03	0	0.6746
17	3.23	0	1.0734
18	5.21	0	1.7329
19	8.70	0	2.8896
20	6.89	0	2.2890
21	10.00	0	3.3215
22	10.35	0	3.4397
23	10.97	0	3.6458
24	8.21	0	2.7298
25	4.45	2	1.4776
26	4.63	3	1.5375
27	4.23	0	1.4056
28	10.06	0	3.3417
29	5.83	0	1.9366
30	5.56	0	1.8485

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Figure 7: Page 3 of Export Report from Mini-Grid EMS

FEED NAME: L2

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	0.00	0	0.0000
2	0.00	0	0.0000
3	0.00	0	0.0000
4	0.00	0	0.0000
5	0.00	0	0.0000
6	0.00	0	0.0000
7	0.00	0	0.0000
8	0.00	0	0.0000
9	0.00	0	0.0000
10	0.00	0	0.0000
11	0.00	0	0.0000
12	0.00	0	0.0000
13	0.00	0	0.0000
14	0.00	0	0.0000
15	1.29	0	0.4301
16	5.42	0	1.8019
17	32.98	0	10.9591
18	39.25	0	13.0440
19	31.19	0	10.3637
20	24.07	0	7.9969
21	38.40	0	12.7601
22	39.13	0	13.0035
23	39.26	0	13.0469
24	29.78	0	9.8954
25	4.81	5	1.5968
26	10.07	4	3.3469
27	12.73	0	4.2295
28	31.42	0	10.4400
29	15.61	0	5.1879
30	16.01	0	5.3195

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Figure 8: Page 4 of Export Report from Mini-Grid EMS

FEED NAME: L3

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	10.88	12	3.6170
2	0.00	2	0.0000
3	13.03	0	4.3306
4	5.12	0	1.7004
5	17.02	0	5.6545
6	16.82	0	5.5909
7	17.13	0	5.6921
8	3.71	0	1.2313
9	23.91	0	7.9438
10	5.71	0	1.8984
11	11.92	0	3.9598
12	9.66	2	3.2112
13	10.32	0	3.4293
14	6.23	0	2.0704
15	12.05	0	4.0046
16	16.69	0	5.5449
17	20.42	0	6.7844
18	21.02	0	6.9863
19	18.19	0	6.0440
20	13.98	0	4.6469
21	21.94	0	7.2897
22	24.84	0	8.2559
23	22.58	0	7.5033
24	16.92	0	5.6230
25	5.67	5	1.8838
26	7.60	3	2.5250
27	8.20	0	2.7250
28	21.03	0	6.9889
29	13.28	0	4.4129
30	11.53	0	3.8321

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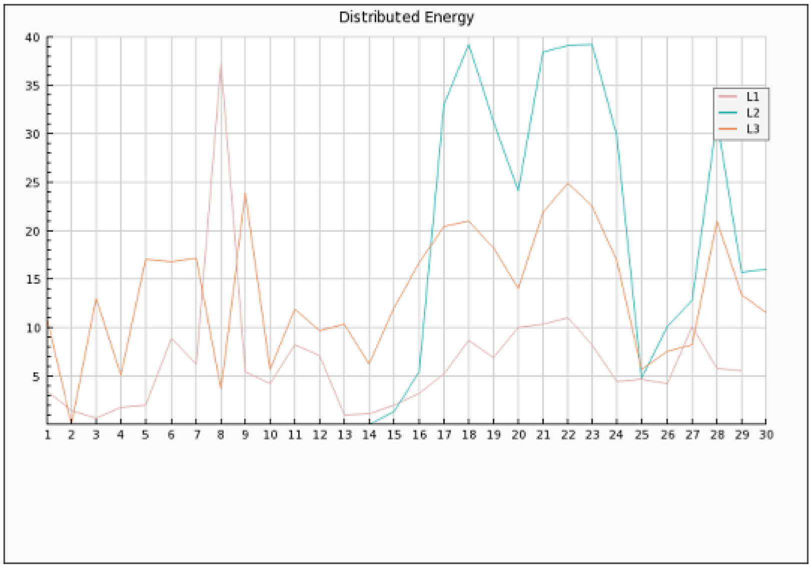
Figure 9: Page 5 of Export Report from Mini-Grid EMS



Time	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Number Grid Connections	Total Consumption	Distributed Losses

Figure 10: Page 6 of Export Report from Mini-Grid EMS

2.2.2.3 Live data

The live data section is visible in the menu bar after you open the dashboard of the mini-grid. The live data section displays the data as it comes in from the feeders. The data on this page is updated every few seconds. On the top of the page the user can observe the amount of energy that is currently being generated, the amount of energy that is distributed and the CO_2-Emissions that have been saved on the current day up to this moment.

Furthermore, the page offers a graph displaying the live data from the various feeders. It shows the generated and distributed energy for the last hour and is updated every few seconds.

Commented [V8]: How do I get here?

Commented [O9]: Include step by step instructions on how to view life data

Figure 11~~21~~: Live data section of the mini-grid EMS web platform

2.2.2.4 Settings

When clicking on the button “Create new grid” on the start page, the user is redirected to the settings section. It is also possible to access this page when clicking on “Settings” in the menu on the top left corner of the web platform.

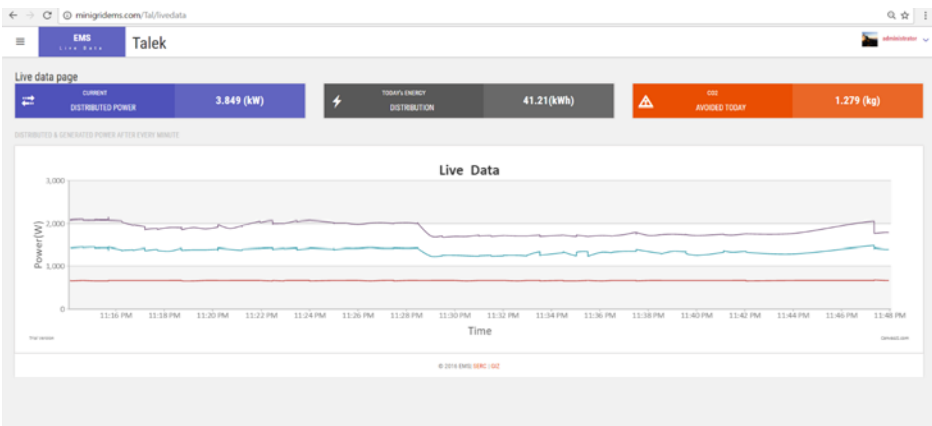


Figure 11: Live data section of the mini-grid EMS web platform

The user is asked to enter the name and size of the new grid. On the settings page, grid parameters have to be entered. This includes the date of commissioning, the manufacturer and the model type, as well as the coordinates. The grid is then displayed on the map.

Furthermore, the settings page allows for manually inserting data that cannot be automatically retrieved through the system, such as specific users and data on sold power.

The data inserted includes the mini grid parameters such as the name, size of grid, commissioning date & the plant type. These go into uniquely identifying the mini grid configured. Also, the location is set so as to pin an identifier in the map inclusive.

Commented [O10]: An step-by-step guide on how to input this data could be helpful

The mini grid also has data inputs that dictates the number of users (connections) and their consumption. This is used to calculate the system losses which are then represented on the dashboard of the mini-grid ems platform. Each user has a unique reference number and is allocated a certain value for power

Commented [O11]: Is it possible to calculate system losses with one-time consumption data? How often should this be updated. A realistic value could be real time measurement of end user consumption, distribution and generation. A separation of technical and non-technical losses could be appropriate

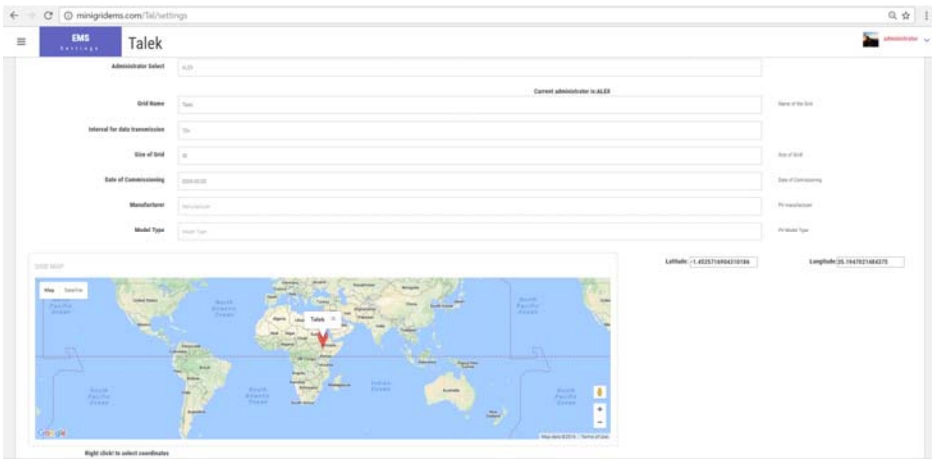


Figure 12: Settings of the mini-grid EMS web platform

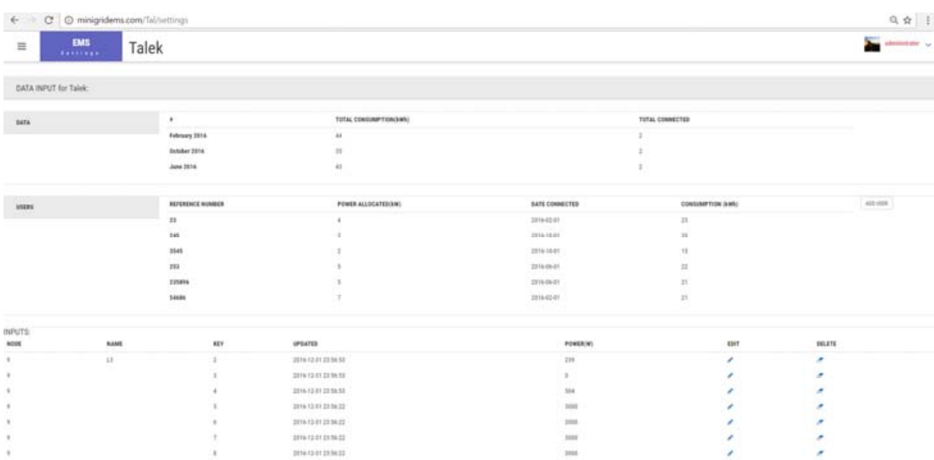


Figure 13: User Settings of the mini-grid EMS web platform

2.3. Additional functionalities

i. Assigning user rights

In the user management system, which can be accessed when clicking on the arrow in the top right corner of the web platform, users can be assigned different rights. That way, some users will be restricted to only view and export data, while others will be able to enter additional data in the settings section and others will be enabled to add new grids and assign rights to other users. Furthermore, it can be defined which users receive warning sms or emails when system interruptions occur.

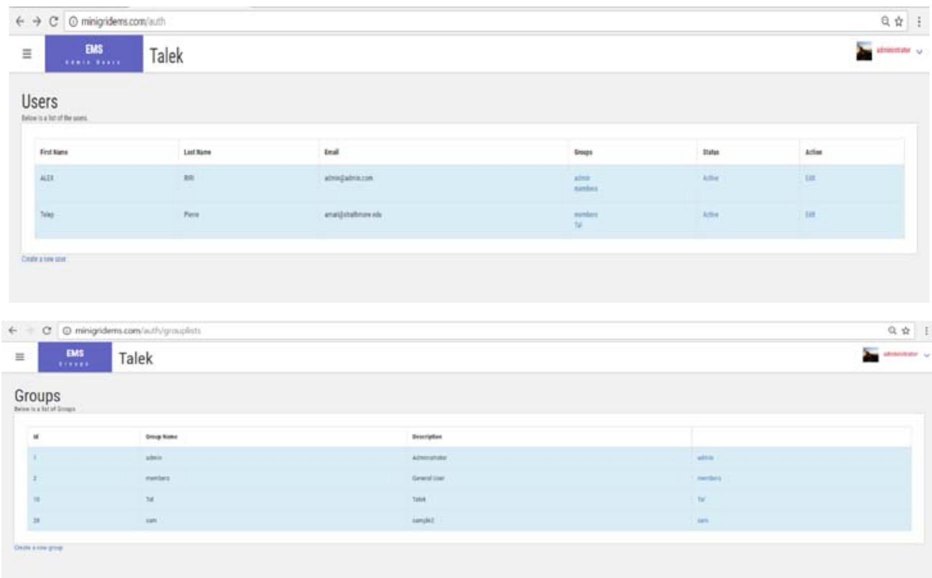


Figure 14: Editing users

ii Receiving sms notifications (/warnings)

The mini-grid EMS can send users that have been registered for this function in the user management system warnings via sms and/or email whenever an interruption occurs on one of the feeders. This way the operator can promptly react and within a short timeframe detect where the error comes from and consequently fix it. In the section where users can be edited, test sms and emails can be sent to see whether the communication system is working. For mini- grid EMS we used the Nexmo API service.

The working methodology is below:

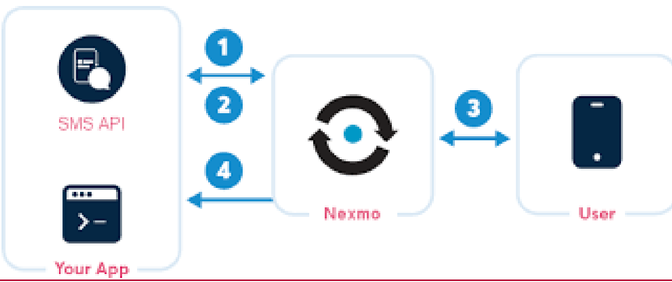


Figure 15: How the SMS Platform Works

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ii. Message Board & Forum Communication

In the Message Board, users can post a topic of discussion and it is immediately displayed in the forum. The active users on the grid as well as the administrators are allowed to reply. This function can help coordination among those involved with a specific grid and can, for example, be used to communicate about actions to be taken when a system interruption occurs.

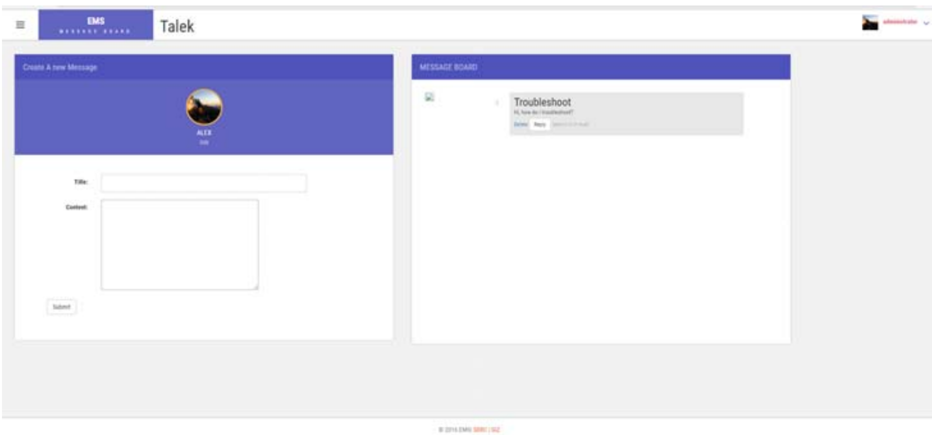

Figure 16: Message board in the mini-grid EMS web platform

Customizing the EMS

The EMS system obtains remote data via RESTful service in the form of Json. It stores the information in 3 databases: input, feeds and daily feeds. Each feed will create a new feeds database that will store the data. After every hour, the daily feeds will be updated. This is a feature that will reduce multiple data from being loaded at once and also ensure data is stored for a long period.

To customize the EMS an understanding of RESTful service, as well as PHP and codeigniter is required.

REST stands for **Re**presentational **S**tate **T**ransfer. (It is sometimes spelled "ReST".) It relies on a stateless, client-server, cacheable communications protocol -- and in virtually all cases, the HTTP protocol is used.

REST is *an architecture style* for designing networked applications.

To customize your mini-grid EMS, follow the steps below.

1. Changing input identifier: Go to application/controllers/Rest.php
   - To change how your data is being obtained, this is set under the function data.
   - In $data = $this->input->raw_input_stream('data'); data represent the url segement that holds the data for example, For a url http://example.com/rest/data/apikey?data=
   - The data is set after "data=" , this can be change to either http://example.com/rest/data/apikey?q= or http://example.com/rest/data/apikey?example=

2. Then change the name of input
   - from *$data = $this->input->raw_input_stream('data'); to* *$data = $this->input->raw_input_stream('example');*

3. Changing the rest API settings
   - Go to application/config/rest/php
   - Under every identifier there is a description, to which you can make changes.
   - Make a change as per the description.

3 Installation procedure

3~~2~~.1. Hardware requirements

In order to install the EMS, various hardware parts are required that need to be installed correctly for the system to be able to extract the relevant data. The following table gives an overview of the required parts, as well as their minimum specifications:

a. **Sensors**

These are current transformers (CT's) that are feeder sensors that measure the amount of current flow in a device allowing it to convert the current flow into power and eventually into energy.

	Sensor (1,2,3) L1, L2, L3	**Specifications**
1.	Class of Accuracy	0.5
2.	Rated Burden	5.00 VA
3.	Power Frequency Withstand Voltage	3KV
4.	Highest System Voltage	433 V
5.	Nominal System Voltage	415 V
6.	Frequency	50 Hz
7.	Supply System	3 Ph. Solidly grounded Neutral System

Table 1: Hardware requirements for the Mini-Grid EMS

In order to set up the hardware correctly, please follow the following steps:

a. Turn off the mains of the incoming lines for the mini-grid.
b. Test the line to line and line to neutral voltage to ensure no residue current.
c. Install your sensors (current transformers as illustrated below)

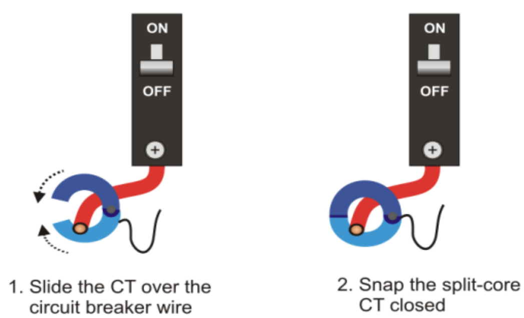

Figure 17: Illustrative Figure on How to Insert a Current Transformer

Once the current transformers are in place, connect them to the EMS hub (the device for interpreting the data and sending it to the ems platform.

b. EMS Hub

The EMS Hub is the hardware device that is connected to the PV generation system for metering and energy monitoring that is responsible for the following functions:

- Connection point of the current transformers interface
- Interpretation of currents to data using an ADC.
- Structuring data to transmittable packets
- Sending the packets via a communication network such as LAN/ Ethernet or via GSM to the mini grid ems platform.
- A memory for storage of data in case of a network failure

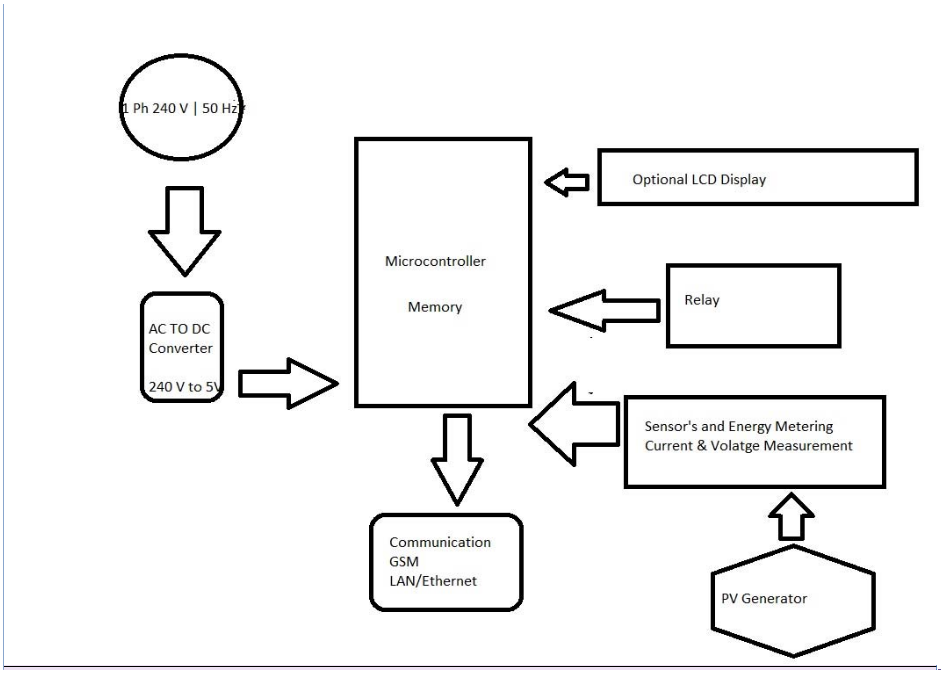

Figure 18: Block Diagram for EMS Hub

*** The LCD display is optional*

*** The same would apply for a 3- Ph system. 1- Ph is for powering the EMS Hub, the energy metering unit is where the current transformers would be and where the EMS Hub would collect and gather the readings for data.*

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The EMS Hub, must have the following parameters for it to be able to communicate with the mini grid ems platform.

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1. Ability to communicate via a network module either an integrated GSM or LAN cable.
2. Transmit data via HTTP protocol
3. Transmit data in json (JavaScript Object Notation) format.
4. Able to get reading from Current Transformer sensors
- (A Current Transformer sensor that can read a pulse, convert it into useable data)
- (A Current Transformer sensor that is able to detect voltage reading with instantaneous change readings)
5. Preferred Data format (example [0,1,200,0,239,0, 300….])
   This is also elaborated below

The hardware should send data via http/https protocol. The data format for the ~~hard~~hardware should be
{[0, Nodeid, value1, value2, value3, value4.]} for Json format.

- Nodeid – device identification
- Value1, value - Power values in terms of WATTS.

ii. Go to the settings file of your hardware and change the url to face your url: for example, http://example.com/rest/data

Set the API KEY (Application Programming Interface Key)

Note this system uses API KEY to communicate, if you disable the API KEY, some functions may not work

Electrical Characteristics		
Type of measurement		Current (18 channels) Voltage (3 channels)
Accuracy	Current	1% from 10% to 110%
	Voltage	1% from 230 to 240VAC – L1
	Frequency	±0.01 Hz from 45 to 65 Hz
Sample rate		8 kHz
Input voltage	L1 L2, L3	100 to 240VAC 0 to 277VAC
Input Frequency Nominal		50Hz or 60Hz
Input Power	L1	10 W max
	L2, L3	100 mW max

Environmental Characteristics		
Operating Temperature	EMS Power	0 °C to +70 °C
	Power Line Network	0 °C to +50 °C
Storage Temperature	EMS Power Hub	-40 °C to +85 °C
	Power Line Network	-40 °C to +70 °C
Humidity Rating		5 To 95% RH at 50 °C (non-condensing)

Communications	
Ethernet / GSM	IEEE 802.3

Firmware Characteristics	
Firmware update	Update via network

Table 2: Specifications of Sensors of EMS Hub

3~~2~~.1.1. EMS Hub Sample (Open Energy Monitor)

How to build an Arduino energy monitor that measuring mains voltage and current

The voltage measurement is done via AC-AC voltage adapter and current measurement is done via a CT sensor.

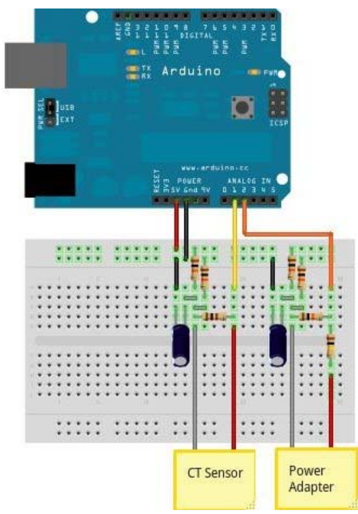

Figure 19: EMS Hub (Open Energy Monitor)

This guide details how to build a simple electricity energy monitor on that can be used to measure how much electrical energy you use in your home. ~~It measures voltage with an AC to AC power adapter and current with a clip-on CT sensor, making the setup quite safe as no high voltage work is needed.~~

The energy monitor can calculate real power, apparent power, power factor, rms voltage, rms current. All the calculations are done in the digital domain on an Arduino.

See annex for components

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~~2.1.1.1. Step One – Gather Components~~

~~**You will need:**~~

~~1x Arduino~~

~~**Voltage sensing electronics:**~~

~~1x 9V AC-AC Power Adapter~~

~~1x 100kOhm resistor for step down voltage divider.~~

~~1x 10kOhm resistor for step down voltage divider.~~

~~2x 470kOhm (for voltage divider, any matching value resistor pair down to 10K)~~

~~1x 10uF capacitor~~

~~**Current sensing electronics**~~

~~1x CT sensor SCT-013-000~~

~~1x Burden resistor 18 Ohms if supply voltage is 3.3V or 33 Ohms if supply voltage is 5V.~~

~~2x 470kOhm (for voltage divider, any matching value resistor pair down to 10K)~~

~~1x 10uF capacitor~~

~~**Other**~~

~~1x A breadboard and some single core wire.~~

~~Oomlout do a good arduino + breadboard bundle~~

2.1.1.2. Step Two – Assemble the electronics

The electronics consist of the sensors (which produce signals proportional to the mains voltage and current) and the sensor electronics that convert these signals into a form the Arduino is happy with.

CT sensors - An introduction

Current transformers (CTs) is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. They are sensors that measure alternating current.

Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. They are particularly useful for measuring whole building electricity consumption (or generation, for that matter).

Often referred to as a current clamp, a CT is in fact, **not** a clamp.

These are Clamps. On the left are two busbar clamps, on the right, a carpenter's G-clamp:

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Figure 20: Types of Current Measuring Devices

Note the tensioning screws.

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Split Core Ct	Magnelab Split-Core Ct	Solid-Core Ct
		

Table 3: Table Indicative of Different Types of Current Sensors~~Transformers~~

Basics

~~Current transformers (CTs) are sensors that measure alternating current. They are particularly useful for measuring whole building electricity consumption (or generation, for that matter).~~

The split core type, such as the CT in the picture above, is particularly suitable for DIY use, as it can be clipped onto either the live **or** neutral wire coming into the building, without the need to do any high voltage electrical work. Like any other transformer, a current transformer has a primary winding, a magnetic core, and a secondary winding.

In the case of whole building monitoring, the primary winding is the live **or** neutral wire (not both!) which is equivalent to one turn~~(not both!)~~ coming into the building, that is passed through the opening in the CT. The secondary winding is made of many turns of fine wire housed within the transformer case. By increasing the number of secondary windings, N2, the secondary current can be made much smaller than the current in the primary circuit being measured because as N2 increases, I2 goes down by a proportional amount. In other words, the number of turns and the current in the primary and secondary windings are related by an inverse proportion.

The alternating current flowing in the primary produces a magnetic field in the core, which induces a current in the secondary winding circuit.

The current in the secondary winding is proportional to the current flowing in the primary winding:

$$I_{secondary} = CT_{turnsRatio} \times I_{primary}$$

$$CT_{turnsRatio} = \text{No of Turns}_{primary} / \text{No of Turns}_{secondary}$$

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Normally, this ratio is written in terms of currents in Amps e.g. 100:5 (for a 5A meter, scaled 0 - 100A). The ratio for the CT above would normally be written as 100:0.05.

Burden resistor

A "current output" CT needs to be used with a burden resistor. The burden resistor completes or closes the CT secondary circuit. The burden value is chosen to provide a voltage proportional to the secondary current. The burden value needs to be low enough to prevent CT core saturation.

Isolation

The secondary circuit is galvanically isolated from the primary circuit. (i.e. it has no metallic contact)

Safety

In general, a CT must **never** be open-circuited once it's attached to a current-carrying conductor.
A CT is potentially dangerous if open-circuited.

If open-circuited with current flowing in the primary, the transformer secondary will attempt to continue driving current into what is effectively an infinite impedance. This will produce a high and potentially dangerous voltage across the secondary winding. Some CT's have built-in protection. Some have protective Zener diodes as is the case with the SCT-013-000 recommended for use in this project. If the CT is of the 'voltage output' type, it has a built-in burden resistor. Thus, it cannot be open-circuited.

Installing a CT

The primary winding of the CT is the wire carrying the current you want to measure. If you clip your CT around a two or three core cable that has wires carrying the same current but in opposite directions, the magnetic fields created by the wires will cancel each other, and your CT will have no output.

A split-core CT, especially one that has a ferrite core (such as the ones made by YHDC) should **never** be "clamped" to the cable using any sort of packing material, because the brittle nature of the ferrite core means that it might easily be broken, thus destroying the CT. You should only clamp the CT to the cable or busbar if the housing is specifically designed to do so. Similarly, a ring-core CT should **never** be forced onto a cable that is too large to pass freely through the centre. The position and orientation of the cable within the CT aperture does **not** affect the output.

CT sensors - Interfacing with an Arduino

To connect a CT sensor to an Arduino, the output signal from the CT sensor needs to be conditioned so it meets the input requirements of the Arduino analog inputs, i.e. a **positive voltage between 0V and the ADC reference voltage.**

Note: This page give the example of an Arduino board working at 5 V ~~and of the EmonTx working at 3.3 V~~. Make sure you use the right supply voltage and bias voltage in your calculations that correspond to your setup.

This can be achieved with the following circuit which consists of two main parts:

1. The CT sensor and burden resistor
2. The biasing voltage divider (*R1 & R2*)

<u>Calculating a suitable burden resistor size</u>

If the CT sensor is a "current output" type such as the **YHDC SCT-013-000**, the current signal needs to be converted to a voltage signal with a burden resistor. If it is a voltage output CT you can skip this step and leave out the burden resistor, as the burden resistor is built into the CT.

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1) Choose the current range you want to measure

The YHDC SCT-013-000 CT has a current range of 0 to 100 A. For this example, let's choose 100 A as our maximum current.

2) Convert maximum RMS current to peak-current by multiplying by √2.

Primary peak-current = RMS current × √2 = 100 A × 1.414 = 141.4A

3) Divide the peak-current by the number of turns in the CT to give the peak-current in the secondary coil.

The YHDC SCT-013-000 CT has 2000 turns, so the secondary peak current will be:

Secondary peak-current = Primary peak-current / no. of turns = 141.4 A / 2000 = 0.0707A

4) To maximise measurement resolution, the voltage across the burden resistor at peak-current should be equal to one-half of the Arduino analog reference voltage. (AREF / 2)

If you're using an Arduino running at 5V: AREF / 2 will be 2.5 Volts. So the ideal burden resistance will be:

Ideal burden resistance = (AREF/2) / Secondary peak-current = 2.5 V / 0.0707 A = 35.4 Ω

35 Ω is not a common resistor value. The nearest values either side of 35 Ω are 39 and 33 Ω. Always choose the smaller value, or the maximum load current will create a voltage higher than AREF. We recommend a 33 Ω ±1% burden. In some cases, using 2 resistors in series will be closer to the ideal burden value. The further from ideal the value is, the lower the accuracy will be.

Here are the same calculations as above in a more compact form:

Burden Resistor (ohms) = (AREF * CT TURNS) / (2√2 * max primary current)

emonTx V2

If you're using a battery powered emonTx V2, AREF will start at 3.3 V and slowly decrease as the battery voltage drops to 2.7 V. The ideal burden resistance for the minimum voltage would therefore be:

```
Ideal burden resistance = (AREF/2) / Secondary peak-current = 1.35V / 0.0707A = 19.1 Ω
```

19 Ω is not a common value. We have a choice of 18 or 22 Ω. We recommend using an 18 Ω ±1% burden.

emonTx V3

The emonTx V3 uses a 3.3V regulator, so it's V_{CC} and therefore AREF, will always be 3.3V regardless of battery voltage. The standard emonTx V3 uses 22 Ω burden resistors for CT 1, 2 and 3, and a 120 Ω resistor for CT4, the high sensitivity channel.

2) Adding a DC Bias

If you were to connect one of the CT wires to ground and measure the voltage of the second wire, relative to ground, the voltage would vary from positive to negative with respect to ground. However, the Arduino analog inputs require a **positive** voltage. By connecting the CT lead we connected to ground, to a source at half the supply voltage instead, the CT output voltage will now swing above and below 2.5 V thus remaining positive.

Resistors R1 & R2 in the circuit diagram above are a voltage divider that provides the 2.5 V source (1.65 V for the emonTx). Capacitor C1 has a low **reactance** - a few hundred ohms - and provides a path for the alternating current to bypass the resistor. A value of 10 µF is suitable.

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Choosing a suitable value for resistors R1 & R2:

Higher resistance lowers quiescent energy consumption.

We use 10 kΩ resistors for mains powered monitors. The emonTx uses 470 kΩ resistors to keep the power consumption to a minimum, as it is intended to run on batteries for several months.

Measuring AC Voltage with an AC to AC power adapter

An AC voltage measurement is needed to calculate real power, apparent power and power factor. This measurement can be made safely (requiring no high voltage work) by using an AC to AC power adaptor. The transformer in the adapter provides isolation from the high voltage mains.

Figure 21: An AC DC Adapter for Powering the EMS Hub

As in the case of current measurement with a CT sensor, the main objective for the signal conditioning electronics detailed below, is to condition the output of the AC power adapter so it meets the requirements of the Arduino analog inputs: **a positive voltage between 0V and the ADC reference voltage** (Usually 5V or 3.3V ~~- emontx~~).

AC to AC power adapters are available in many voltage ratings. The first thing important to know is the voltage rating of your adapter. The output signal from the AC voltage adapter is a near-sinusoidal waveform. If you have a 9V (RMS) power adapter the positive voltage peak be 12.7V, the negative peak -12.7V. However, due to the poor voltage regulation with this type of adapter, when the adapter is un-loaded (as in this case), the output is often 10-12V (RMS) giving a peak voltage of 14-17V. The voltage output of the transformer is proportional to the AC input voltage,(240V-single phase, 415V-three phase) ~~see below for notes on UK mains voltage~~.

The signal conditioning electronics needs to convert the output of the adapter to a waveform that has a positive peak that's less than 5V ~~(3.3V for the emonTx)~~ and a negative peak that is more than 0V.

So, we need to:

scale down the waveform and

add an offset so there is no negative component.

The waveform can be scaled down using a voltage divider connected across the adapter's terminals, and the offset (bias) can be added using a voltage source created by another voltage divider connected across the Arduino's power supply (in the same way we added a bias for the current sensing circuit).

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Commented [SM23]: Is this part necessary? The adapter to power the Arduino board is readily available and is not being fabricated. Can we instead give the example of an Arduino board working at 5 V and of the EmonTx working at 3.3 V as stated in the header for this literature?

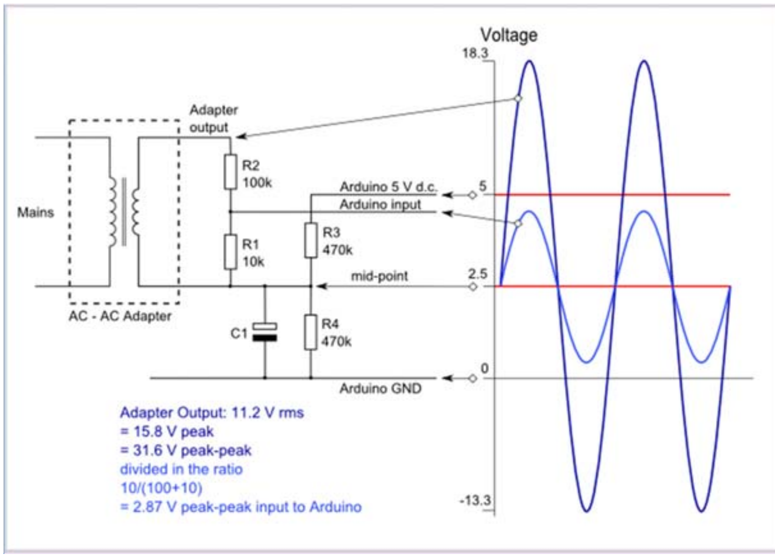

Figure 22: Voltage Waveforms Diagrams

Resistors **R1** and **R2** form a voltage divider that scales down the power adapter AC voltage. Resistors **R3** and **R4** provide the voltage bias. Capacitor **C1** provides a low impedance path to ground for the AC signal. The value is not critical, between 1 µF and 10 µF will be satisfactory.

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https://learn.openenergymonitor.org/electricity-monitoring/ct-sensors/interface-with-arduino

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R1 and R2 need to be chosen to give a peak-voltage-output of ~1V. For an AC-AC adapter with an 9V RMS output, a resistor combination of 10k for R1 and 100k for R2 would be suitable:

peak_voltage_output = R1 / (R1 + R2) x peak_voltage_input =
10k / (10k + 100k) x 12.7V = 1.15V

The voltage bias provided by R3 and R4 should be half of the Arduino supply voltage. As such, R3 and R4 need to be of equal resistance. Higher resistance lowers energy consumption. For a battery, powered emonTx, where low power consumption is important, we use 470k resistors for R3 and R4.

If the Arduino is running at 5V the resultant waveform has a positive peak of 2.5V + 1.15V = 3.65V and negative peak of 1.35V satisfying the Arduino analog input voltage requirements. This also leaves some "headroom" to minimize the risk of over or under voltage.

The 10k and 100k R1 and R2 combination works fine for an emonTx powered at 3.3V, with a positive peak of 2.8V and a negative peak of 0.5V.

Improving the quality of the bias source

This relatively simple voltage bias source does have some limitations.

Notes on Mains Voltage Limits

The standard domestic mains supply for Europe is 230 V ± 10%, giving a lower limit of 207 V and an upper limit of 253 V. It is permissible under BS 7671 to have a voltage drop within the installation of 5%, which would give a lower limit of 195.5 V.
The UK standard prior to harmonization was 240 V ± 6%, giving an upper limit of 254.4 V.

Although the UK nominal standard is now 230 V, the supply system has not generally been adjusted, and the voltage centers around 240 V.

2.1.1.3. Step Three – Upload the Arduino Sketch

The Arduino sketch is the piece of software that runs on the Arduino. The Arduino converts the raw data from its analog input into some nice useful values and then outputs them to serial.

a) Download EmonLib from github and place in your arduino libraries folder.

b) Upload the voltage and current example:

```
#include "EmonLib.h"             // Include Emon Library
EnergyMonitor emon1;             // Create an instance

void setup()
{
  Serial.begin(9600);
```

```
  emon1.voltage(2, 234.26, 1.7); // Voltage: input pin, calibration, 
phase_shift
  emon1.current(1, 111.1);    // Current: input pin, calibration.
}

void loop()
{
  emon1.calcVI(20,2000);        // Calculate all. No.of wavelengths, time-
out
  emon1.serialprint();           // Print out all variables
}
```

c) Open the arduino serial window

You should now see a stream of values. These are from left to right: real power, apparent power, rms voltage, rms current and power factor.

3~~2~~.2. Software installation

Users can either install the software automatically or manually. The installation package, which can be downloaded at http://137.74.40.197/install/ entails all required software, which can either be used for running an automated installation process or to manually install the system. For installing the software, the following server specifications are required:

i. **Server requirements**

1. PHP version 5.1.6 or newer.
2. A Database is required for most web application programming. Current supported databases are MySQL (4.1+), MySQLi, MS SQL, Postgres, Oracle, SQLite, and ODBC.
3. Apache 2.4 or higher with mod_rewrite enabled
4. Curl Enabled
5. Set minimal *memory_limit 128M* in php
6. Transmit data in json (JavaScript Object Notation) format. This is described below below, it is a collection of name/value pairs. In various languages, this is realized as an *object*, record, struct, dictionary, hash table, keyed list, or associative array.

   These are universal data structures. Virtually all modern programming languages support them in one form or another. It makes sense that a data format that is interchangeable with programming languages also be based on these structures.

   A *value* can be a *string* in double quotes, or a *number*, or **true** or **false** or **null**, or an *object* or an *array*. These structures can be nested.

ii. **What is included in the installation package?**

The installation packaged is encompassed with the following:

a. The system code
b. The installation script
   i.e. The lines of system code, the database and any relevant file to the system performance

iii. **Automatic installation**

Assuming your domain name is http://example.com then let your browser face http://example.com/install/ . Follow the on-screen instruction to install the system.

The on-screen instructions are illustrated below in sequence:

a. Selection of Preference
   Here the user selects the language and the installation mode:

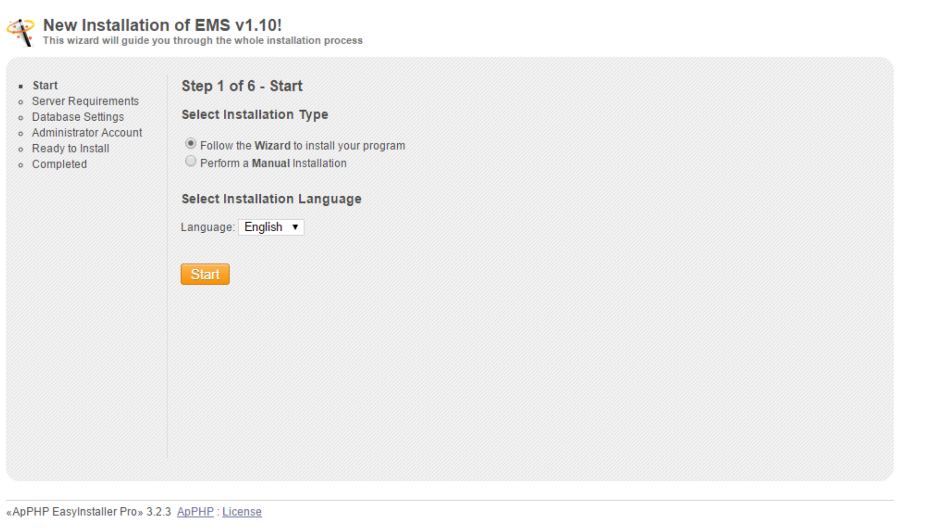

Figure 23: Step 1 of Automatic Installation

b. Server Requirements & System Checks

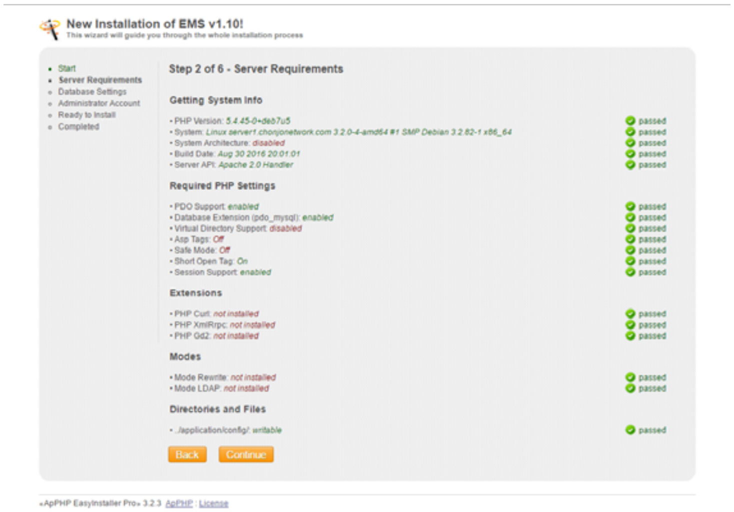

Figure 24: Performance checks on the suitability of your system ~~9~~

c. Database Settings

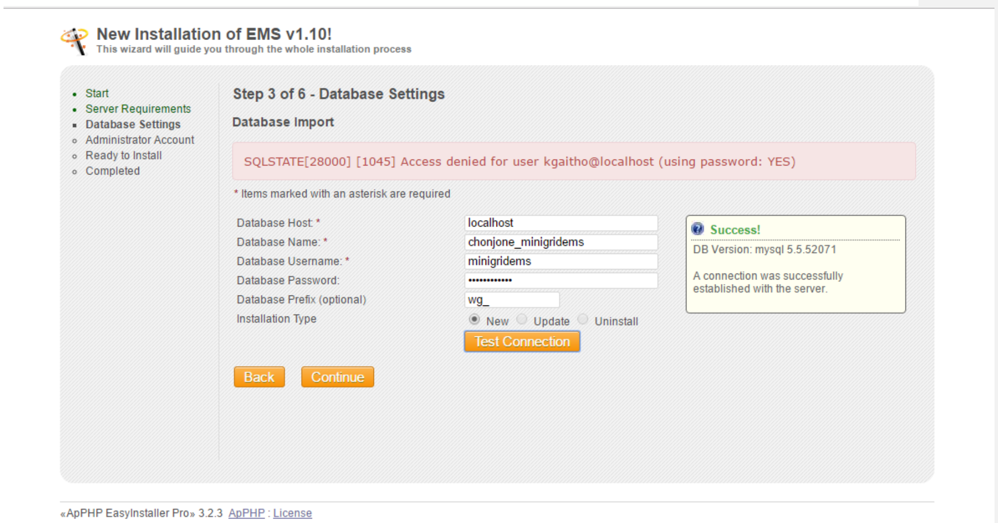

Figure 25: Database Settings

Here the user defines the database parameters for the specific EMS Hub and the log in credentials.

Kindly enter the details as indicated below for the package to be on the same database as follows: (this is just an example)

database name: chonjone_minigridems

database username: minigridems

database password: JT-x*wZb}?Vk

***use different database prefix for testing.*

The installation can only be done once

d. Administration & Ready to Install

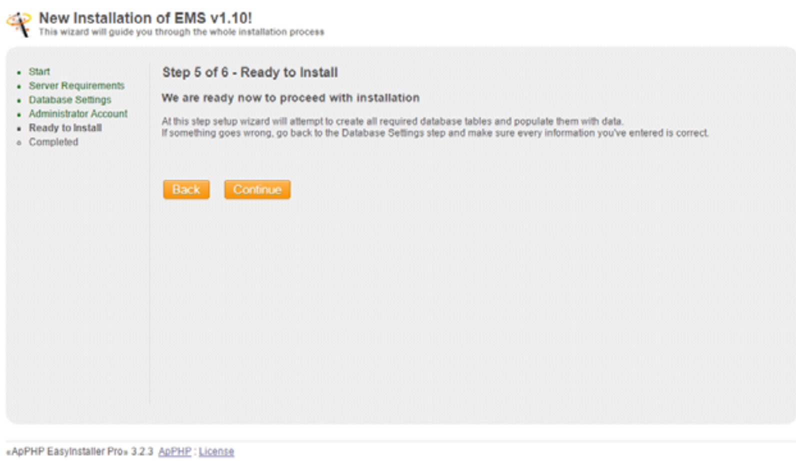

Figure 26: After database validation, ready for installation

iv. Manual installation

Go to the following URL: http://137.74.40.197/install/ and select manual installation. Follow the instruction to the fullest for the installation of the system.

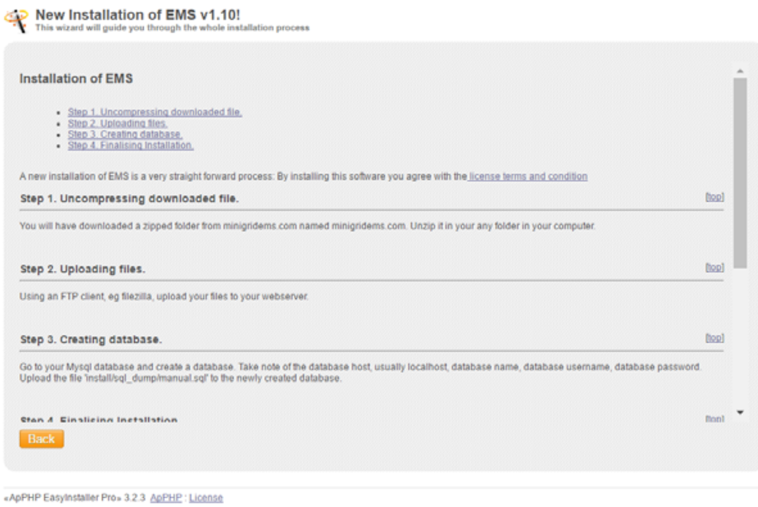

Figure 27

~~3. User manual~~

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~~3.1. System Structure~~

~~The Energy Monitoring System is designed to monitor key performance indicators for a mini-grid. The EMS web platform consists of:~~

- ~~A **Grid Management System (GMS)**, which entails the main functions of the EMS. It allows the user to manage the mini-grids effectively. The GMS works on the principle of easy access, use and display of data. It takes raw data on key performance indicators and structures it into information that can be interpreted for different uses. The GMS automatically tracks data, such as generated electricity, but also allows the user to add and modify additional data, for example on customer connections. The system then allows the user to extract data on the performance of a mini-grid. Data is visualized in two sections which incorporate static data which has been collected over time and a live feed section of dynamic data.~~

- ~~A **User Management System (UMS)**, which allows the administrator to manage the users effectively. The UMS are designed on the principle of privileges, which means different users can be assigned different levels of access to the system by the administrator. Moreover, the UMS allow the users of the system to interact in a forum, for example to discuss how to improve system performance. Views from users, as well as access times can be tracked.~~

~~3.2. EMS pages~~

~~i. Login~~

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~~For using the EMS, registration and login are required. For registration, it is required to fill in information about the user. This information and its specifics are depicted below:~~

~~a. First Name~~
~~b. Last Name~~
~~b. E-mail~~
~~b. Date of Birth~~
~~b. Gender~~
~~b. Organization~~
~~b. Mini Grid Interest. Why?~~

~~Once the request for registration has been made, the administrator has to assign the new user certain usage rights and only after that has happened the user can log in to the system. For login, the email address used for registration and the chosen password need to be used.~~

~~After a successful login, the user is directed to the start page which has a list of the grids, the user is authorized to view, their parameters, location and characteristics.~~

~~ii. Start page~~

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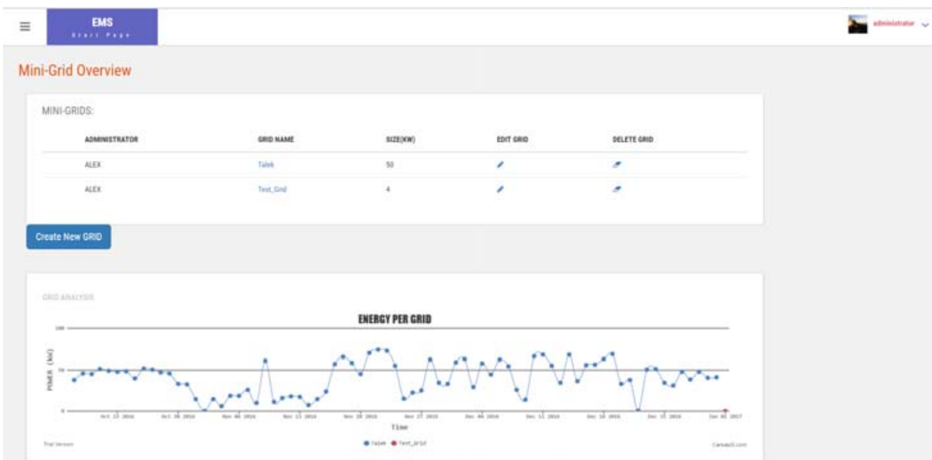
~~The start page serves as an overview of all the grids that the user is authorized to view and/or edit. It lists the grids that are being monitored, and shows their generated power since commissioning in a graph. Furthermore, all monitored mini-grids are displayed on a map. Below the map a quick overview of the lifetime performance of the various grids is given in a table.~~

~~Users that are authorized to do so can add a new mini-grid to the system or delete a mini-grid. When adding a new mini-grid, the user is redirected to the settings page, where all information about the new mini-grid, such as the size, location, has to be entered (see section v. below). When clicking on one of the mini-grids displayed, the user is directed to the dashboard for that mini-grid.~~

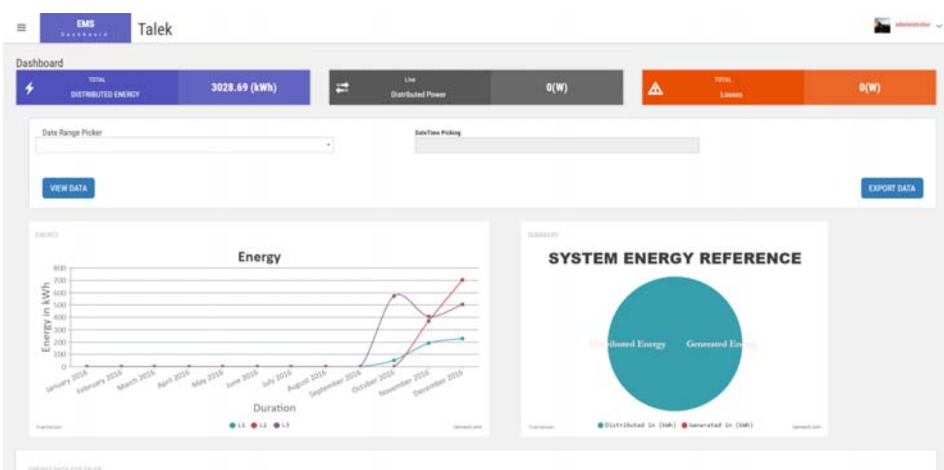


~~Figure 12: Start page of the mini-grid EMS web platform~~

~~iii. The dashboard~~

~~The dashboard gives an overview of the key performance indicators for a selected mini-grid. On the top, the dashboard displays~~

- ~~The cumulated generated energy for the present day (up to the moment of reviewing the data)~~
- ~~The amount of energy that is generated at that specific moment (updated every 10 seconds)~~
- ~~The losses that have incurred so far on the present day~~



~~Figure 13: Dashboard of the mini-grid EMS web platform~~

~~Below that, the user can choose a certain timeframe and time period for which data can be displayed and exported. For example, the user can choose "annual data" to show data for the year 2016, or "monthly data" to show data for only September 2016. When clicking on "view data" the respective data is shown in the graphs below according to the selected time frame. The graphs show the historical data that was recorded on the various feeders. Furthermore, it shows in a pie chart the distribution losses. Below the charts tables with the data are displayed.~~

~~When selecting a certain time period the user also has the option to export the data as it is displayed, when clicking on "export data". Data can be exported to a PDF-report or to a CSV-file.~~

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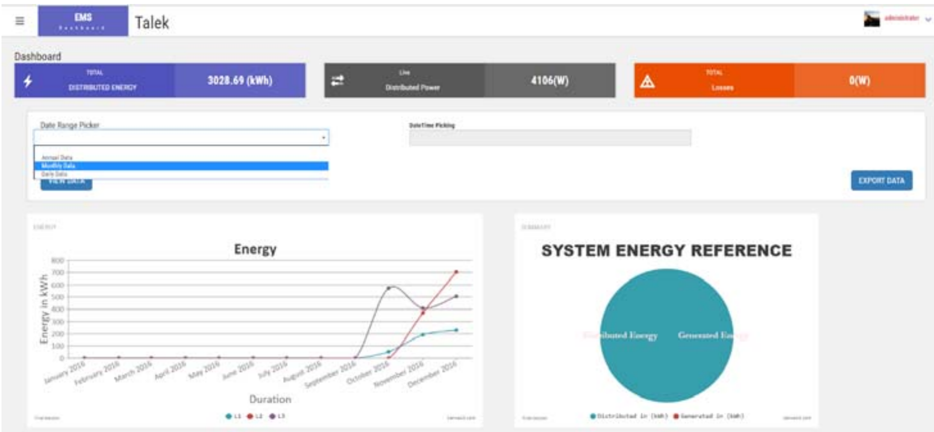

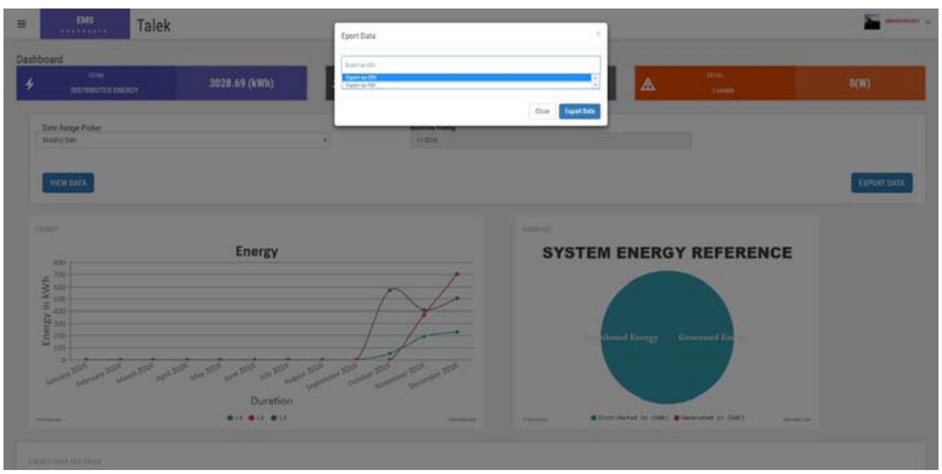

~~*Figure 14: Data Export Functions*~~

Field Code Changed

~~iv. Sample Report Generated from mini-grid EMS~~

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Perfomance Report of Talek

Retrieved on 2016/12/31

Data for the duration 11-2016 in Days

System Properties

Commissioning date: 0000-00-00

Total installed capacity: 50 kW

location

longitude

: 35.1947021484375

latitude

: -1.4525716904310186

Performance overview

This is the cumulative Data for the duration 11-2016 in Days

#	Talek
Generated Energy (kWh)	0.00
Distributed Energy (kWh)	968.03
Duration of interruption[h]	39
Avoided CO2 [kg]	321.67
Total Losses	0
Number of Metering Points	3

Energy Data for Talek

Days	Generated Energy [kWh]	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Losses	Number of Metering Points
1	0.00	14.38	1	4.78	0	3

minigridems.com *1* *Sat, 31 Dec 16 23:32:29 +0300*

~~Figure 15: Page 1 of Export Report from Mini-Grid EMS~~

Field Code Changed

Days	Generated Energy [kWh]	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Losses	Number of Metering Points
2	0.00	0.00	2	0.00	0	3
3	0.00	14.50	1	4.82	0	3
4	0.00	5.78	1	1.92	0	3
5	0.00	18.79	1	6.24	0	3
6	0.00	18.87	1	6.27	0	3
7	0.00	26.04	1	8.65	0	3
8	0.00	9.88	1	3.28	0	3
9	0.00	61.12	1	20.31	0	3
10	0.00	11.11	1	3.69	0	3
11	0.00	16.11	1	5.35	0	3
12	0.00	17.90	1	5.95	0	3
13	0.00	17.42	1	5.79	0	3
14	0.00	7.27	1	2.42	0	3
15	0.00	14.50	0	4.82	0	3
16	0.00	24.14	0	8.02	0	3
17	0.00	56.63	0	18.82	0	3
18	0.00	65.49	0	21.76	0	3
19	0.00	58.07	0	19.30	0	3
20	0.00	44.94	0	14.93	0	3
21	0.00	70.33	0	23.37	0	3
22	0.00	74.33	0	24.70	0	3
23	0.00	72.81	0	24.19	0	3
24	0.00	54.91	0	18.25	0	3
25	0.00	14.92	0	4.96	0	3
26	0.00	22.30	0	7.41	0	3
27	0.00	25.16	0	8.36	0	3
28	0.00	62.51	0	20.77	0	3
29	0.00	34.72	0	11.54	0	3
30	0.00	33.10	0	11.00	0	3

minigridems.com *2* *Sat, 31 Dec 16 23:32:29 +0300*

~~*Figure 16: Page 2 of Export Report from Mini-Grid EMS*~~

Field Code Changed

FEED NAME: L1

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	3.50	0	1.1623
3	1.46	0	0.4866
4	0.67	0	0.2215
5	1.77	0	0.5882
6	2.05	0	0.6807
7	8.91	0	2.9614
8	6.18	0	2.0522
9	37.21	0	12.3651
10	5.39	0	1.7919
11	4.19	0	1.3920
12	8.24	1	2.7379
13	7.10	0	2.3584
14	1.04	0	0.3451
15	1.16	0	0.3844
16	2.03	0	0.6746
17	3.23	0	1.0734
18	5.21	0	1.7329
19	8.70	0	2.8896
20	6.89	0	2.2890
21	10.00	0	3.3215
22	10.35	0	3.4397
23	10.97	0	3.6458
24	8.21	0	2.7298
25	4.45	2	1.4776
26	4.63	3	1.5375
27	4.23	0	1.4056
28	10.06	0	3.3417
29	5.83	0	1.9366
30	5.56	0	1.8485

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~~*Figure 17: Page 3 of Export Report from Mini-Grid EMS*~~

Field Code Changed

FEED NAME: L2

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	0.00	0	0.0000
2	0.00	0	0.0000
3	0.00	0	0.0000
4	0.00	0	0.0000
5	0.00	0	0.0000
6	0.00	0	0.0000
7	0.00	0	0.0000
8	0.00	0	0.0000
9	0.00	0	0.0000
10	0.00	0	0.0000
11	0.00	0	0.0000
12	0.00	0	0.0000
13	0.00	0	0.0000
14	0.00	0	0.0000
15	1.29	0	0.4301
16	5.42	0	1.8019
17	32.98	0	10.9591
18	39.25	0	13.0440
19	31.19	0	10.3637
20	24.07	0	7.9969
21	38.40	0	12.7601
22	39.13	0	13.0035
23	39.26	0	13.0469
24	29.78	0	9.8954
25	4.81	5	1.5968
26	10.07	4	3.3469
27	12.73	0	4.2295
28	31.42	0	10.4400
29	15.61	0	5.1879
30	16.01	0	5.3195

minigridems.com 4 *Sat, 31 Dec 16 23:32:29 +0300*

~~*Figure 18: Page 4 of Export Report from Mini-Grid EMS*~~

Field Code Changed

FEED NAME: L3

Days	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]
1	10.88	12	3.6170
2	0.00	2	0.0000
3	13.03	0	4.3306
4	5.12	0	1.7004
5	17.02	0	5.6545
6	16.82	0	5.5909
7	17.13	0	5.6921
8	3.71	0	1.2313
9	23.91	0	7.9438
10	5.71	0	1.8984
11	11.92	0	3.9598
12	9.66	2	3.2112
13	10.32	0	3.4293
14	6.23	0	2.0704
15	12.05	0	4.0046
16	16.69	0	5.5449
17	20.42	0	6.7844
18	21.02	0	6.9863
19	18.19	0	6.0440
20	13.98	0	4.6469
21	21.94	0	7.2897
22	24.84	0	8.2559
23	22.58	0	7.5033
24	16.92	0	5.6230
25	5.67	5	1.8838
26	7.60	3	2.5250
27	8.20	0	2.7250
28	21.03	0	6.9889
29	13.28	0	4.4129
30	11.53	0	3.8321

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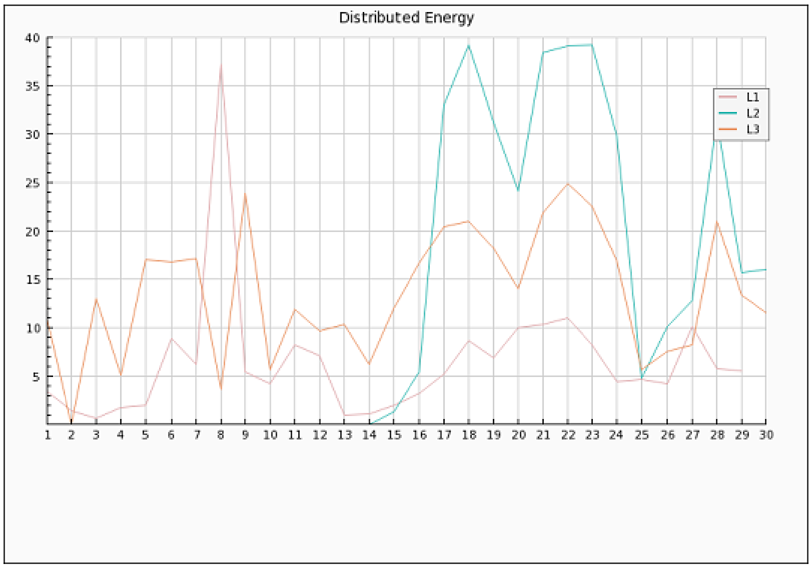
~~*Figure 19: Page 5 of Export Report from Mini-Grid EMS*~~

Field Code Changed



Time	Distributed Energy [kWh]	Duration of interruption[h]	Avoided CO2 [kg]	Number Grid Connections	Total Consumption	Distributed Losses

~~*Figure 20: Page 6 of Export Report from Mini-Grid EMS*~~

Field Code Changed

~~v. Live data~~

~~The live data section displays the data as it comes in from the feeders. The data on this page is updated every few seconds. On the top of the page the user can observe the amount of energy that is currently being generated, the amount of energy that is distributed and the CO_2 Emissions that have been saved on the current day up to this moment.~~

~~Furthermore, the page offers a graph displaying the live data from the various feeders. It shows the generated and distributed energy for the last hour and is updated every few seconds.~~

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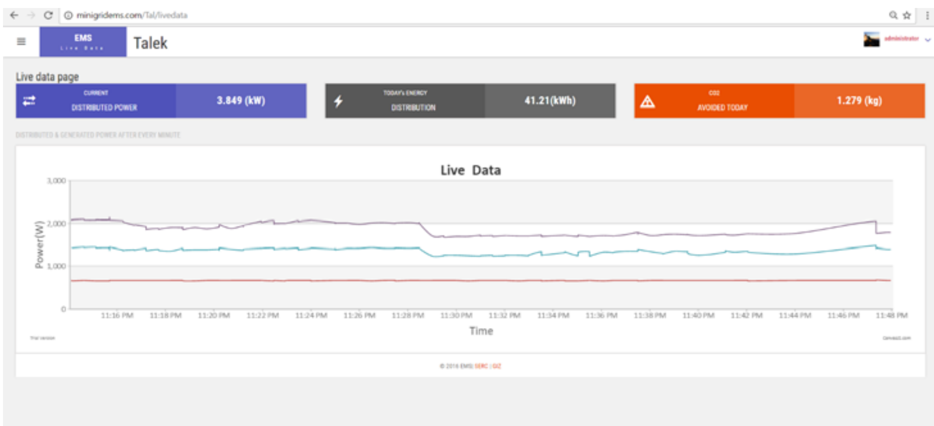

Figure 31~~21~~: Live data section of the mini-grid EMS web platform

~~vi. Settings~~

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~~When clicking on the button "Create new grid" on the start page, the user is redirected to the settings section. It is also possible to access this page when clicking on "Settings" in the menu on the top left corner of the web platform.~~

~~The user is asked to enter the name and size of the new grid. On the settings page, grid parameters have to be entered. This includes the date of commissioning, the manufacturer and the model type, as well as the coordinates. The grid is then displayed on the map.~~

~~Furthermore, the settings page allows for manually inserting data that cannot be automatically retrieved through the system, such as specific users and data on sold power.~~

~~The data inserted includes the mini grid parameters such as the name, size of grid, commissioning date & the plant type. These go into uniquely identifying the mini grid configured. Also, the location is set so as to pin an identifier in the map inclusive.~~

~~The mini grid also has data inputs that dictates the number of users (connections) and their consumption. This is used to calculate the system losses which are then represented on the dashboard of the mini-grid ems platform. Each user has a unique reference number and is allocated a certain value for power~~

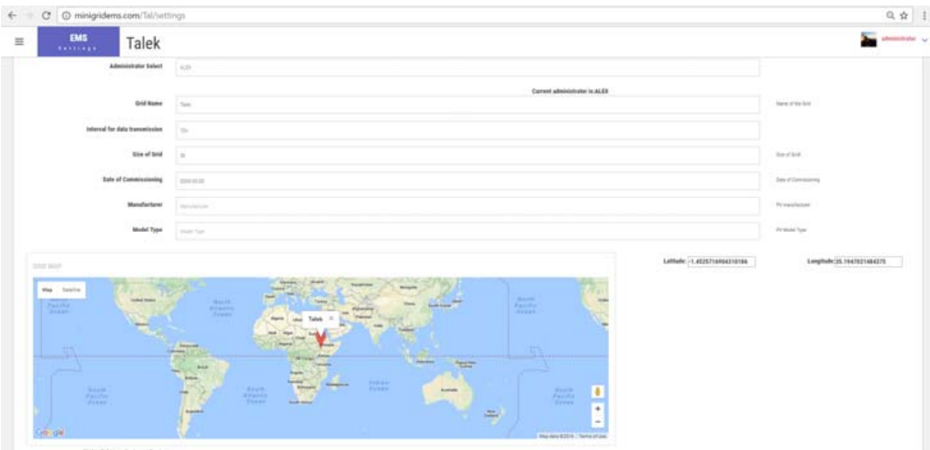
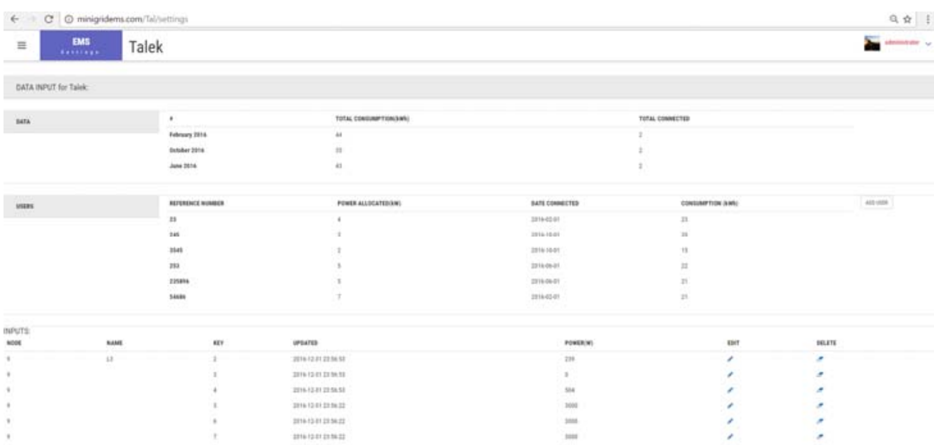


Figure 38~~22~~: Settings of the mini-grid EMS web platform



~~*Figure 23: User Settings of the mini-grid EMS web platform*~~

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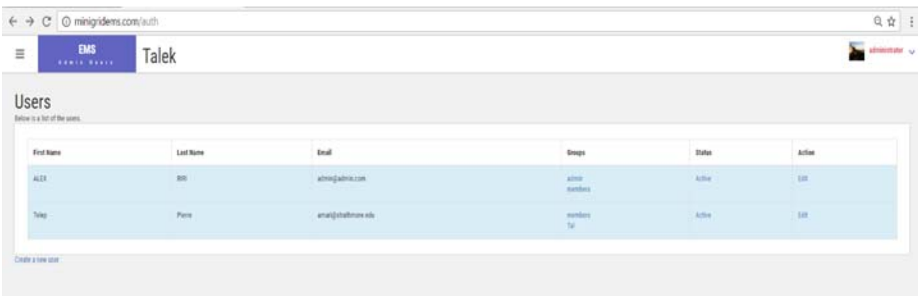
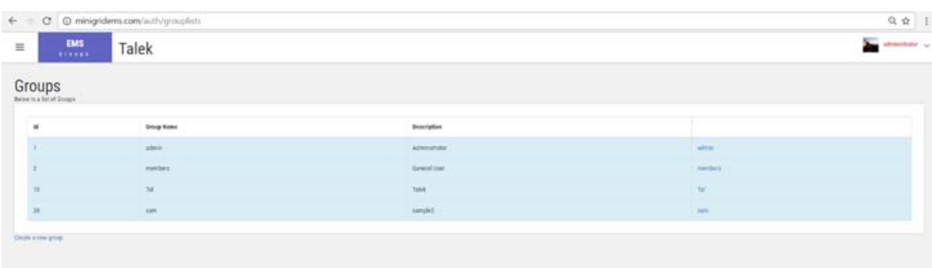
~~3.3. Additional functionalities~~

~~. Assigning user rights~~

~~In the user management system, which can be accessed when clicking on the arrow in the top right corner of the web platform, users can be assigned different rights. That way, some users will be restricted to only view and export data, while others will be able to enter additional data in the settings section and others will be enabled to add new grids and assign rights to other users. Furthermore, it can be defined which users receive warning sms or emails when system interruptions occur.~~





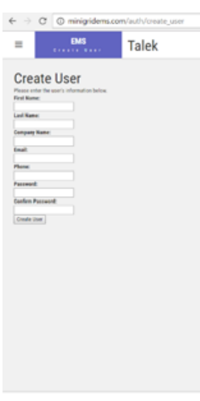


Figure 7: Editing users

Figure 7: Editing users

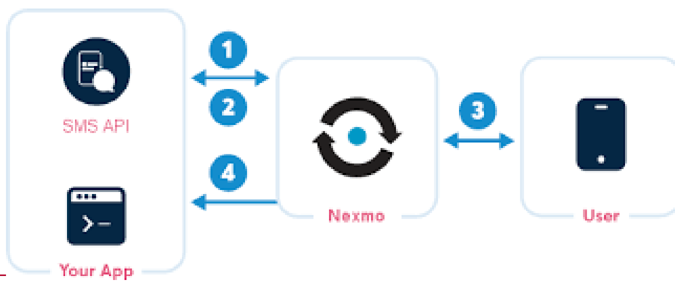
~~Receiving sms notifications (/warnings)~~

~~The mini-grid EMS can send users that have been registered for this function in the user management system warnings via sms and/or email whenever an interruption occurs on one of the feeders. This way the operator can promptly react and within a short timeframe detect where the error comes from and consequently fix it. In the section where users can be edited, test sms and emails can be sent to see whether the communication system is working. For mini- grid EMS we used the Nexmo API service.~~

Figure 7: Editing users

Figure 7: Editing users

~~The working methodology is below:~~



~~Figure 24: How the SMS Platform Works~~

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~~. Message Board & Forum Communication~~

~~In the Message Board, users can post a topic of discussion and it is immediately displayed in the forum. The active users on the grid as well as the administrators are allowed to reply. This function can help coordination among those involved with a specific grid and can, for example, be used to communicate about actions to be taken when a system interruption occurs.~~

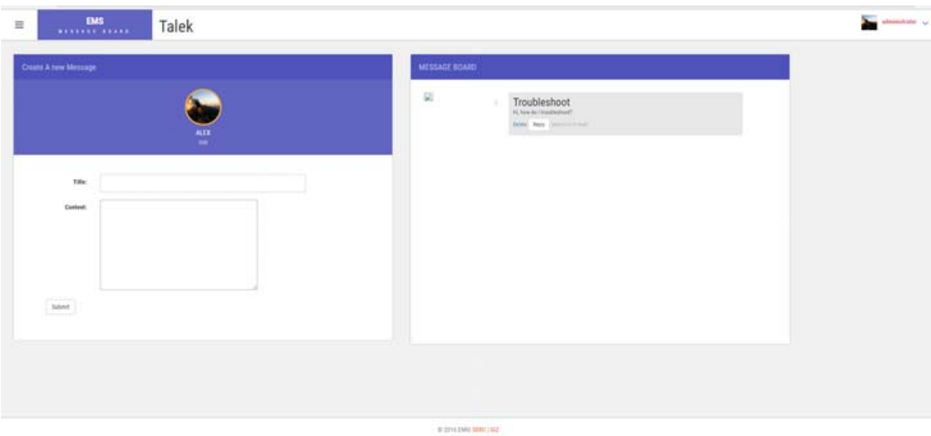

Figure 8: Message board in the mini-grid EMS web platform

Figure 8: Message board in the mini-grid EMS web platform

Figure 42~~11~~: Live data section of the mini-grid EMS web platformFigure 8: Message board in the mini-grid EMS web platform

Figure 8: Message board in the mini-grid EMS web platform

~~Customizing the EMS~~

~~The EMS system obtains remote data via RESTful service in the form of Json. It stores the information in 3 databases: input, feeds and daily feeds. Each feed will create a new feeds database that will store the data. After every hour, the daily feeds will be updated. This is a feature that will reduce multiple data from being loaded at once and also ensure data is stored for a long period.~~

~~To customize the EMS an understanding of RESTful service, as well as PHP and codeigniter is required.~~

~~REST stands for **Re**presentational **S**tate **T**ransfer. (It is sometimes spelled "ReST".) It relies on a stateless, client-server, cacheable communications protocol -- and in virtually all cases, the HTTP protocol is used.~~

~~REST is *an architecture style* for designing networked applications.~~

~~To customize your mini-grid EMS, follow the steps below.~~

0. ~~Changing input identifier: Go to application/controllers/Rest.php~~
    - ~~To change how your data is being obtained, this is set under the function data.~~
    - ~~In $data = $this->input->raw_input_stream('data'); data represent the url segement that holds the data for example, For a url http://example.com/rest/data/apikey?data=~~
    - ~~The data is set after "data=" , this can be change to either http://example.com/rest/data/apikey?q= or http://example.com/rest/data/apikey?example=~~

0. ~~Then change the name of input~~
    - ~~from *$data = $this->input->raw_input_stream('data'); to* *$data = $this->input->raw_input_stream('example');*~~

0. ~~Changing the rest API settings~~
    - ~~Go to application/config/rest/php~~
    - ~~Under every identifier there is a description, to which you can make changes.~~
    - ~~Make a change as per the description.~~

4~~5~~. Support

4~~5~~.1. Error Codes

In case of any errors the EMS hub shows an error code. In the Annex a list of the potential problems and their possible causes can be found. Furthermore, the Annex describes possible solutions for the various problems.

4~~5~~.2. Troubleshooting

In case a problem cannot be solved by referring to the suggested actions as described in the Annex, the developers of the EMS can be contacted by using the contact form on the web platform.

Annex

1. Codes by Mini-Grid Power Parameters

Code	Description	Possible causes	Remedy
S101	Grid voltage beyond permitted limits	1. Mains voltage error 2. Incorrect values in the service menu 3. Internal fault	1. Check grid voltage, check circuit breakers are ON 2. Change values in the service menu
S104	Mains frequency beyond permitted limits.	1. Mains frequency error 2. Incorrect values in the service menu 3. Internal fault	1. Check mains frequency, check circuit breakers are ON 2. Change values in the service menu
S107	Synchronisation with the mini grid feeder supply not possible	1. Mains not connected 2. Incorrect values in the service menu 3. Internal fault	1. Connect mains power, check circuit breakers are ON 2. Check values in the service menu

2. Errors by Monitoring Device

Code	Description	Possible causes	Remedy
S201	Grid voltage is higher than the specified limit	1. Grid voltage error on the mini grid feeder 2. Internal fault	1. Check grid voltage
S202	Grid voltage is lower than the specified limit		
S203	Grid frequency is higher than the specified limit	1. Grid frequency error on the mini grid feeder 2. Internal fault	1. Check grid frequency
S204	Grid frequency is lower than the specified limit		
S205	Change of mini grid feeder impedance	1. Serious disturbances on the	1. Reinforce mains cables

		mini grid feeder 2. Internal fault	
S207	Mains relay does not open in spite of switch off signal	Internal fault	
S208	Mains relay does not close in spite of switch on signal		

3. Errors by Faulty Hardware or Incompatible Software

Code	Description	Possible causes	Remedy
S402	Write access to the internal EMS Hub IG memory failed		
S403	The area in the internal memory for the country setting is incomplete		
S404	Connection between the control unit and the EMS Hub is faulty	1. Mini grid feeder not connected 2. Internal fault	1. Check the mini grid feeder
S405	An old or incorrect version of the sensors has been recognised	Internal fault	
S408	Unsymmetry on the mini grid feeder detected	1. Mini grid feeder disturbances 2. Internal fault	1. Error is remedied automatically
S412	Value for fixed voltage is set higher than the open		

	circuit voltage of the PV generator		
S414	Memory array for EMS Hub IG type in EE-PROM faulty	1. One-off – memory error 2. Internal fault	1. Error is remedied automatically
S436	Error transmission faulty		
S 442	Master for one phase could not be assigned	1. Temporary communication error 2. Internal fault	1. Error is remedied automatically

Annex

References:

1. https://wiki.openenergymonitor.org/index.php?title=EmonTx_V3#Burden_Resistor_Calculations
2. https://openenergymonitor.org/emon/buildingblocks/how-to-build-an-arduino-energy-monitor
3.] E.F. Camacho, M. Berenguel, F.R. Rubio, and D. Martinez. Control of Solar Energy Systems. Berlin: Springer Verlag, 2010

Annex

Components for the EMS Hub

You will need:

1x Arduino

Voltage sensing electronics:

1x 9V AC-AC Power Adapter

1x 100kOhm resistor for step down voltage divider.

1x 10kOhm resistor for step down voltage divider.

2x 470kOhm (for voltage divider, any matching value resistor pair down to 10K)

1x 10uF capacitor

Current sensing electronics

1x CT sensor SCT-013-000

1x Burden resistor 18 Ohms if supply voltage is 3.3V or 33 Ohms if supply voltage is 5V.

2x 470kOhm (for voltage divider, any matching value resistor pair down to 10K)

1x 10uF capacitor

Other

1x A breadboard and some single core wire.

~~3.~~ Oomlout do a good arduino + breadboard bundle

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