ENF4GR: Hosting ENF of Mainland Greece

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Abstract—**Electrical Network Frequency (ENF), which refers to the instantaneous frequency of a power distribution network, is adopted for a wide range of applications. Taking into consideration both the lack of reference databases for different power grids all around the world and also the lack of Websites for hosting ENF-related data, we decided to create a website featuring some of the latest web development technologies in order to visually represent ENF-related data obtained from our reference database which is being updated by a Raspberry Pi ENF monitoring system.**

I. INTRODUCTION

Electrical Network Frequency (ENF) refers to the instantaneous frequency of a power distribution network at a given point in time. The frequency of a power distribution network fluctuates around its nominal frequency (50Hz/60Hz). This fluctuation is caused due to the instantaneous imbalance between power generation and consumption [1]. The nominal frequency, in which a power distribution network operates, depends on the geographical region of the distribution network. Wide area distribution networks operate at 60 Hz in the US and at 50Hz almost everywhere else in the world.

ENF is intrinsically embedded into a lot of multimedia recordings. Initially, ENF traces were discovered in audio recordings captured by recorders directly connected to the power grid. Later, further research revealed that ENF traces can be found in audio recordings captured by battery-powered devices mainly due to the acoustic hum produced by electrical devices connected to the mains power grid [2]. ENF's presence has also been discovered in indoor surveillance feed. Indoor light sources operate on both cycles of the alternate current thus they fluctuate at twice the frequency of the power grid. The photons they emit, contain ENF traces which are captured by the imaging sensor of the camera in form of illumination frequency [3].

In [1], the author was able to validate the authenticity of audio recordings, containing conversations between two speakers, which were brought to court by using the embedded ENF signals. This accomplishment led to the proposal of ENF criterion, a forensic technique for evaluating the authenticity of digital audio recordings. Since then, the application spectrum of ENF signals has expanded. They have also been adopted for multimedia synchronization [4] and, more recently, for Frame Duplication Attack prevention at the edge [5]–[7].

While several extraction methods have been proposed including zero crossings [8], conventional short-time Fourier transform [9], spectrum combining [10] and Hilbert-based [11] approaches, a lack of reference databases is observed. As a result, researchers are unable to retrieve ENF data in real time which could be beneficial for their research. Additionally, as previously mentioned, the instantaneous frequency of the power distribution network is related to the instantaneous imbalance between power generation and consumption [1]. Being able to obtain the ENF signal in real-time could provide valuable information for the power grid's maintenance.

There exist currently two websites that are hosting power grid-related information. The first one provides valuable information about the European UCTE interconnected grid, including the ENF [12]. It also presents the data in graph, histogram and Net Time diagrams, which visualizes the impact that frequency deviations have on the way that mains-powered clocks track time. The second website contains a map, in which countries that are powered by the same distribution network are grouped together. Each group is displayed in different colour, each one corresponding to a different range of standard deviation values from the power grids nominal frequency [13]. Both websites use innovative approaches for visualising power grid data.

In order to encourage people to conduct research on ENF-related topics and also provide valuable information about ENF of Mainland Greece we decided to create a website hosting ENF-related information from our reference database. The database is updated with ENF estimations from a system we developed on a Raspberry Pi 3 model B that extracts the ENF directly from the power grid. The reference database data are visualised and their visual representation is updated in real-time. Additional ENF-related information is included. Moreover, the website contains posts related to ENF topics and advancements made in our project.

II. ENABLING TECHNOLOGIES

In order to develop our website (Fig. 1), we incorporated a diverse range of popular web development tools. We used the Flask micro-framework which provides a set of tools and design features for developing web applications in python, Bootstrap for providing the website's responsive UI elements and Chart.JS to generate the real-time plots of the ENF signal. Furthermore, we relied on JQuery, for manipulating the HTML elements and interacting with the Flask application, which also serves as a Back-end. Finally, in order to enable efficient retrieval and organization of the data, a MySQL database was created, containing tables for the ENF stamps, users and posts.

A. Flask Framework

Flask is an open-source web framework used for building web applications in Python. One of the main advantages of
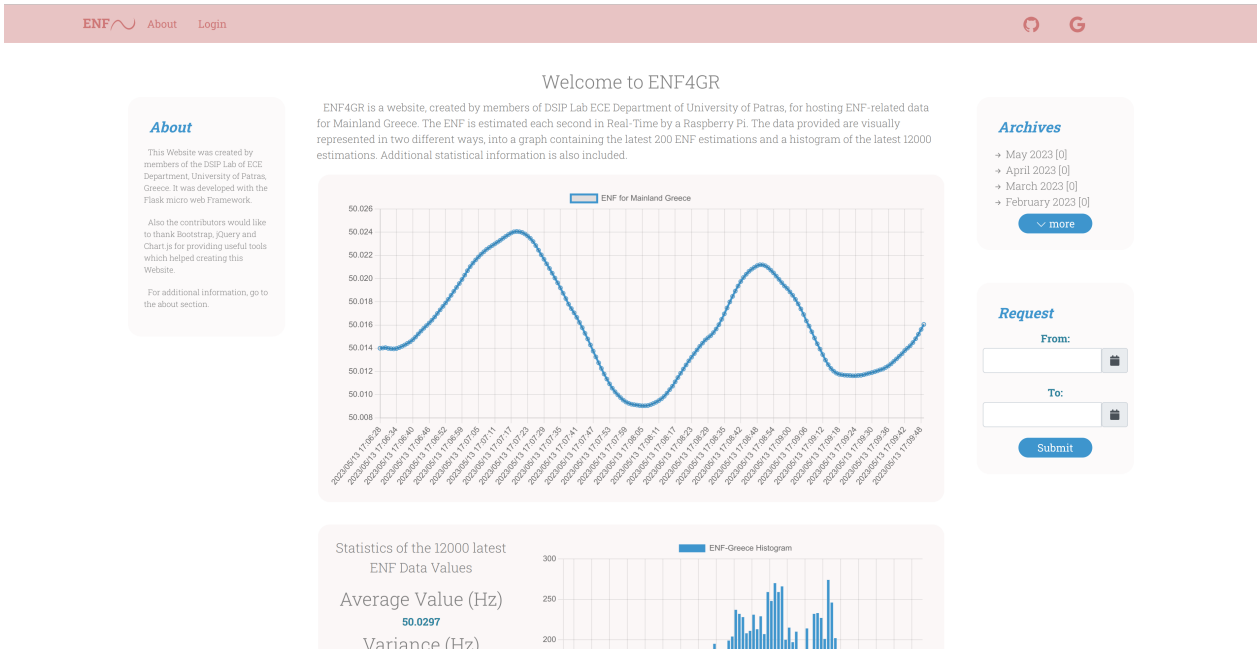
Fig. 1. The ENF4GR website.

the Flask Framework is the flexibility it offers compared to an other popular Python Framework, Django. It is also beginner friendly and the go-to solution for setting up projects quickly and efficiently.

Flask is built on top of the Jinja template engine and the Werkzeug WSGI toolkit [14]. Werkzeug WSGI is a web server gateway interface toolkit that describes how a Web Server is communicating with a Web Application and Jinja2 is a templating engine for rendering HTML files. It features special placeholders that allow to write code similar to python. The template is the processed and data is passed in order to render the final document. For example, with just a single line of code we could select to render parts of the HTML document based on the user's login status.

B. Front-End Technologies

The Bootstrap framework, Chart.js, and jQuery were used in the front-end. HTML files were rendered using the Jinja2 template. CSS was used to style the HTML page and JavaScript was used in order to enable user interaction with the page as well as for updating the charts.

1) Bootstrap: Bootstrap is an open-source front-end development framework that is used by developers from all over the world for developing responsive and compatible across most devices websites [15]. It provides templates along with a collection of fully customizable HTML, CSS, and JavaScript components that can be combined in order to create modern and visually pleasant user interfaces. The framework features a wide range of UI components, such as navigation bars, forms, buttons, modals, carousels. The framework is fully customizable and can be extended with additional plugins and third-party libraries.

2) Chart JS: Chart.js [16] is an open-source JavaScript library which is used for creating interactive and responsive charts and graphs on web applications. It allows developers to easily create a wide range of chart types, including line, bar, radar, pie, doughnut, and more. Each chart type comes with a variety of customization options, including support for multiple datasets, colors, fonts, and more. It also includes a range of interactive features, such as tooltips, hover effects, and animations, that help users understand and interact with the data. It features a rich documentation and it used by developers worldwide, regardless of their skills [17].

3) jQuery: jQuery is a lightweight and feature-rich JavaScript library that simplifies the process of using JavaScript for the creation of dynamic user interfaces on web applications [18]. It provides a powerful set of functions and methods that make it easy to perform common tasks like selecting and modifying HTML elements, animating page elements, making AJAX requests, and working with browser events. jQuery is cross-platform and compatible with a wide range of browsers. It is has a small learning curve, making it a popular choice for developers who want to simplify and speed up the process of creating interactive and dynamic web pages.

C. Back-End Technologies

1) MySQL Database: A MySQL database [19] was build and three tables were created. A table for the users, a table for the posts and a table for storing the ENF stamps generated by our ENF monitoring application. The use of the MySQL database enables the real-time visualisation of the data while making their manipulation easier.

2) Database Handler: Given the fact that our website's operation relies on efficient manipulation and retrieval of the ENF data, a Database Handler was designed in order to simplify common interactions and queries on the database tables performed by the web application. For example, let's assume that we wanted to know the number of posts made in a given
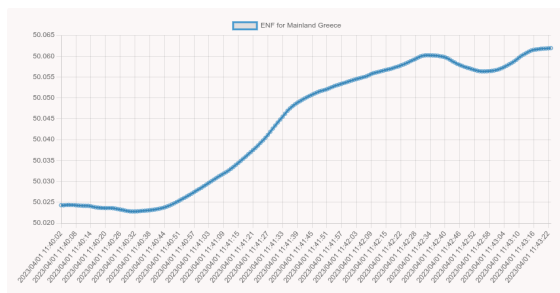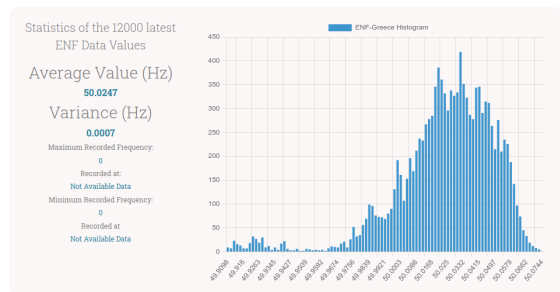
Fig. 2. Real-time ENF signal plot

Fig. 3. Real-time ENF histogram with additional information

Posts and Announcements

First Post of this page

2022-12-16 16:16:54

Fig. 4. Post section of the Website.

Fig. 5. Right column of the Website

month. We would have to fetch all posts, extract the month from the obtained date-time information, then add to a list each post that was uploaded during the given month and finally return the list. With the Database Handler this is executed into a single line of code. Additionally, by implementing a function we can simply pass the month as an argument. This function is performed for each month in the archive section of the page.

III. The Website

A. Real-Time Visualization of ENF

In the middle section of the webpage, there is a graph and a histogram, alongside with additional ENF-related information (Fig. 2,3). The graph plots the latest 200 ENF estimations from our reference database against time. The corresponding timestamp of each estimation is displayed on the x-axis, while the estimation itself is displayed on the y-axis. The graph is updated dynamically every 10 seconds via an API request, performed with the help of the jQuery library.

In the histogram (Fig. 3), the latest 12000 ENF estimations are displayed, which were obtained from our reference database. We divide the entire frequency range of those estimations into 100 equally spaced bins. The width of the bins is determined from the range of data and the total number of bins. Each ENF estimation is placed into it's corresponding bin in order to construct the histogram. On the left side of the histogram, additional ENF-related information, such as the average ENF value, the variance of the latest 12000 estimations and the maximum and minimum recorded frequencies for the day, are displayed. The histogram values are updated every 30
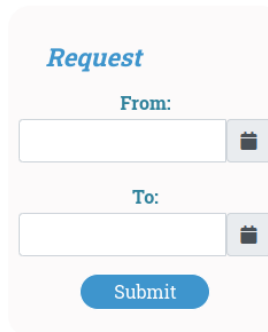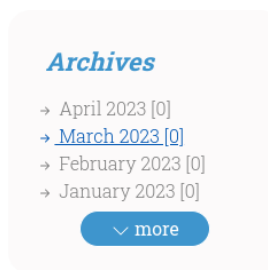
seconds via an API request, performed with the help of the jQuery library.

B. Posts

We also dedicated a section of the middle page for sharing posts about ENF-related topics and updates of our project (Fig. 4). The post section is placed at the bottom of the page.

In the post section, the latest 5 post titles are displayed. At the bottom left corner of each post, a blue timestamp is displayed, providing information about the upload date and time of the post. By clicking the post's title, the user is redirected to the post's page where the post content is available.

At the right side of the page an Archive for the posts sorted by month is included. By selecting a specific month, the user is redirected to a page where all posts that were uploaded during that month are available. Then, the user can select a specific post and be redirected to the post's page. At the bottom of the archive, a button named "more" is displayed. By selecting the "more" button, all months from the month of the oldest post to the current month are displayed. Right next to each month, the month's post number is displayed.

C. Data Request

On the right side of the page below the archives, a section of the page is dedicated to a dynamic user interface for requesting ENF estimations (values) from the web server (Fig. 5). Before requesting the ENF estimations from our reference database, the user has to specify the desired time interval between the first and the last ENF estimation. Then, by pressing the submit button, the ENF values are fetched via an AJAX request and they are automatically downloaded in a .csv file.

Fig. 6. Navigation bar of the Website

D. Google Drive and GitHub

On the right side of the navigation bar, two buttons can be found. One with Google Drive's logo and one with GitHub's logo (Fig. 6). By selecting the Google Drive button, the user is redirected to a Google Drive folder containing all one day's archived one-hour files of ENF estimations. The Google Drive folder is updated every day with the previous days ENF recordings. Furthermore, by clicking to the GitHub button the user is redirected to the GitHub repository of this project [20].

E. Admin Mode

The website can be accessed with administrative rights by logging in. In order to login, the user will have to select the login button from the navigation bar. Now, by entering his/her credentials the user can login with administrative rights. This feature was added in order to delete, edit posts and write new posts easily. As a consequence, a new User class was created which inherits from the UserMixin class provided by the Flask framework. This step was mandatory because Flask uses object-oriented logic with users. Now with administrative access, a new navigation bar button, called 'New Post' is visible to the user. By selecting to write a new post the user is redirected in a new page, where the post title and content can be written inside two separate text containers. After the post is ready the user can upload it by clicking the submit button. Additionally, in each post, a yellow edit button appears right next to the blue timestamp of the post. By selecting to edit a post the user can modify the post's title and contents and also permanently delete it.

IV. CONCLUSION - FUTURE WORK

By incorporating some of the latest web development tools, we were able to design a website that visualizes ENF data of Mainland Greece in two different ways, i.e. through a real-time plot of the ENF Signal and a Histogram constructed by the latest 12000 ENF estimations. Also, we have added features such as ENF data retrieval directly from the website and a post section for sharing ENF-related topics and advancements in our projects. The Website can also be accessed with administrate rights enabling efficient manipulation of the post through the Website. We also designed templates that are available online to encourage the creation of websites hosting ENF data for power grids from all over the world.

In the future, we consider adding more ENF-related visualizations, and based on the gathered ENF-related data, we will attempt to provide insights about the behavior of the ENF in long-term periods. Our last goal is to make the GUI more user-friendly and visually appealing.

ACKNOWLEDGMENT

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