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Universal Design of ICT

Accessible and Usable Web Interface for Power Grid Database

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Preface

This work presented henceforth is the master's thesis dissertation "Accessible and Usable Web Interface for Power Grid Database". This thesis has been written to fulfill the graduation requirements of the Master's program in Applied Computer and Information Technology (ACIT) with Universal Design of ICT major at the Faculty of Technology, Art and Design, Department of Computer Science, OsloMet - Oslo Metropolitan University. I was engaged in writing this thesis dissertation from January 2020 to May 2021. Working on this thesis was a good learning experience.

I would like to thank my supervisors Professors Norun C. Sanderson and Pedro Lind for their guidance and support. Your support kept me motivated throughout this time. I could not have worked on this project without the guidance and willpower you gave me. I really appreciate the weekly meetings we had throughout this time.

I would also like to thank all the participants who responded to the survey, took part in the interviews and user testing activity for this project. I would also like to express my gratitude to the experts who helped me in the heuristic testing procedure. Your input plays a valuable role in completing this thesis.

Further, I would like to acknowledge my classmates at OsloMet, my friends in Oslo, and my friends who are back in my home country Nepal. Finally, I take this opportunity to express my gratitude to my family for their love, motivation, and support.

Sujan Devkota
Oslo, May 14, 2021

Abstract

Different stakeholders of the electric power grid sector need data for their research and decision-making tasks. However, the power grid field lacks an accessible and easy-to-use system that contains openly available data sources that is open to use for everyone.

This thesis creates a prototype of an accessible and usable web interface for the power grid database by following the user-centered design (UCD) methodology. The web interface is targeted to be used by different stakeholders of the power grid sector. The principles of universal design and concepts of accessibility and usability were considered throughout different activities in the thesis.

Different qualitative research methods and research methods from human-computer interaction (HCI) have been used in this study. The research methods employed in this thesis are survey, coding, interviews, paper prototyping, personas, automatic testing, heuristic testing, and discounted testing. Further, ethnographic observation and thinking out aloud methods have also been used.

The prototype development process followed an iterative approach for finding user requirements and deliver a prototype of a web-based interface for the power grid database. The prototype was tested for its accessibility and usability. The prototype presented uses modern web technologies and is found to meet the accessibility and usability requirements of its target users. **The prototype and the instructions to install it have also been uploaded along with this thesis.**

Finally, some topics for future work to further extend this study and to make the software prototype more effective have been presented.

Keywords: Power Grid Data, Universal Design of ICT, User Centered Design, Accessibility, Usability

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Chapter 1
Introduction

Electric power grid is a large and complex system and it will continue to become larger and more complex in the upcoming future as well (Amin & Stringer, 2008). The increased use of renewable sources of energy has added some challenges to keep it manageable. Different stakeholders of power grid systems need data for testing and validating their models and decision making. However, getting data about power grid is not easy at the moment (Medjroubi, Müller, Scharf, Matke, & Kleinhans, 2017; Egerer et al., 2014). This thesis aims to contribute for solving the same problem by making a website that will have power grid data from different sources.

Different stakeholders have developed their own way to collect the data for their use. Academic researchers and engineers have collected the data related to power grid and the sources of electricity in different repositories. Power grid data consists of data about the structure and the components of the power-grid including location and electrical features of the transmission lines and nodes (Medjroubi et al., 2017). Simultaneously, the academic researchers and engineers use different abstract models to represent and carry out their experiments. Data provided to those abstract models and experiments play a major role in making the experiments possible.

The problem of openly available data sources in the field of power grid is pointed out by different parties in involved in power grid research activities. For example see (Medjroubi et al., 2017; Egerer et al., 2014). There are many stakeholders who will benefit from an accessible and easy to use web system with sources of power grid data openly available. Some stakeholders of power grid systems are academic researchers, economists, environmentalists, sociologists, anthropologists, policy makers and more.

This thesis approaches the problem from the perspective of user interface designer and user interface researcher. We will take different stakeholders of power grid field as our targeted users. Therefore, this thesis revolves around activities from collecting the user requirements to delivering an web interface based on the collected user requirements. Additionally, this research also addresses different sources of existing openly available power grid data from different literature and repositories and uses it for building the interface. The thesis is focused on developing an accessible and usable web based system that has all these data sources. Therefore, a comprehensive literature study about how to develop an accessible and usable website for interacting with data system is presented in the next chapter.

This thesis uses the principles of universal design as guiding principles to make the decisions regarding different user interface elements and flow of the user's activities in the application. Moreover, user centered design approach is used to organize the activities throughout the process of research and development of the application. All the steps, viz. requirement elicitation, prototyping, design, and evaluation are carried out in a iterative way.

Further, during the process of development, different guidelines that help to make a web

system accessible and usable is also researched and taken into account. Therefore, the study is also focused on investigating the usability and accessibility aspects of dynamic rich internet applications. Our interface uses interactive elements developed using JavaScript based framework. In this way, the interface enables fluency in user experience as well as uses modern web technologies for making the development process easier and achievable within the given time. All in all, a special focus was given to make the final output as usable as possible.

To sum up, the main objective of this thesis is to identify different data sources related to power grid that are openly available to use and learn how that data can be used by different stakeholders of the power grid system. Further, the concepts of User Centered Design is used to develop a easy-to-use interface on the web to help the end users interact with the data and get the results as per the requirements of their respective fields.

The objectives of this thesis can be summarized as two main research questions:

1. What are the different sources of power grid data and how stakeholders in the field of power grid use the data?

2. How can we address the data related needs of the users of power-grid field via an usable and accessible web based system?

Having presented the aims of this thesis and formulated the research questions to be addressed, we present in Chapter 2, the literature review of the concepts of universal design, accessible and usable websites, user centered design, power grid data, and some related works. Chapter 3 has an overview of the research methodology and methods that has been used in this study. Similarly, chapter 4 discusses how different methods were used to develop the prototype and results of each of the methods used. Finally, in chapter 5, the findings have been analyzed and discussed and some suggestions for further study have been presented.

Chapter 2
Literature Review

2.1 Power Grid Data

The electric power grid is one of the fundamental infrastructures in our modern society. The power grid needs to be there in almost every location where electricity is used. A power grid system is made up of sources of electricity (e.g. solar farm, wind farm, nuclear power plant), the wires, and intermediate distribution facilities that transfer the electricity to the consumers. The power grid system is one of the great innovations of the 20th century and has significantly grown over time making it a very complex system. There are still many places that are not connected to electricity to date. We can, therefore, assume that the number of people who use electricity will continue to grow in the future as well. This means the power grid systems will continue to be bigger, more interconnected, and more complex over time (Amin & Stringer, 2008).

There are different mathematical models developed to represent different energy energy-related problems. These mathematical models are called energy system models. There can be different energy system models based on what they represent (Kondili, 2010). To represent the power grid and its related problems as well, different models have been developed and used by different parties so far. The models used to be proprietary in its early days. But, the number of open-source power grid models has increased in the last decade. Moreover, increased demand for making policies and process of policy-making transparent, scientific reproduce-ability of experiments and data involved in the modeling, and increased popularity of open source software and its benefits have become motivating factors for open power grid models (Morrison, 2018).

Urban Energy systems have been using Geographic Information System (GIS) based models to represent and extend the electricity infrastructure (Alhamwi, Medjroubi, Vogt, & Agert, 2018). GIS-based systems often rely on spatial data objects extracted from the OpenStreetMap database. This makes the GIS-based systems are more realistic and easy to understand for the policymakers as well (Alhamwi, Medjroubi, Vogt, & Agert, 2017).

Medjroubi et al. (2017) have classified the electricity models into two broad categories. First, Grid Simulation Models simulate the technical and physical behavior of electric grids. Second, Electricity System Models which include tools to manage the plan and extend electricity systems. It also deals with the physical behavior of the underlying grid and electricity trading markets.

The grid simulation model can be further classified into a single node model, transshipment model, DC model, and the AC power flow model. Each of them has its own input data. For the models to work, the there has to be the data it demands. Therefore, the more quality data we can have, the more quality results we will get in return from using these models (Medjroubi et al., 2017).

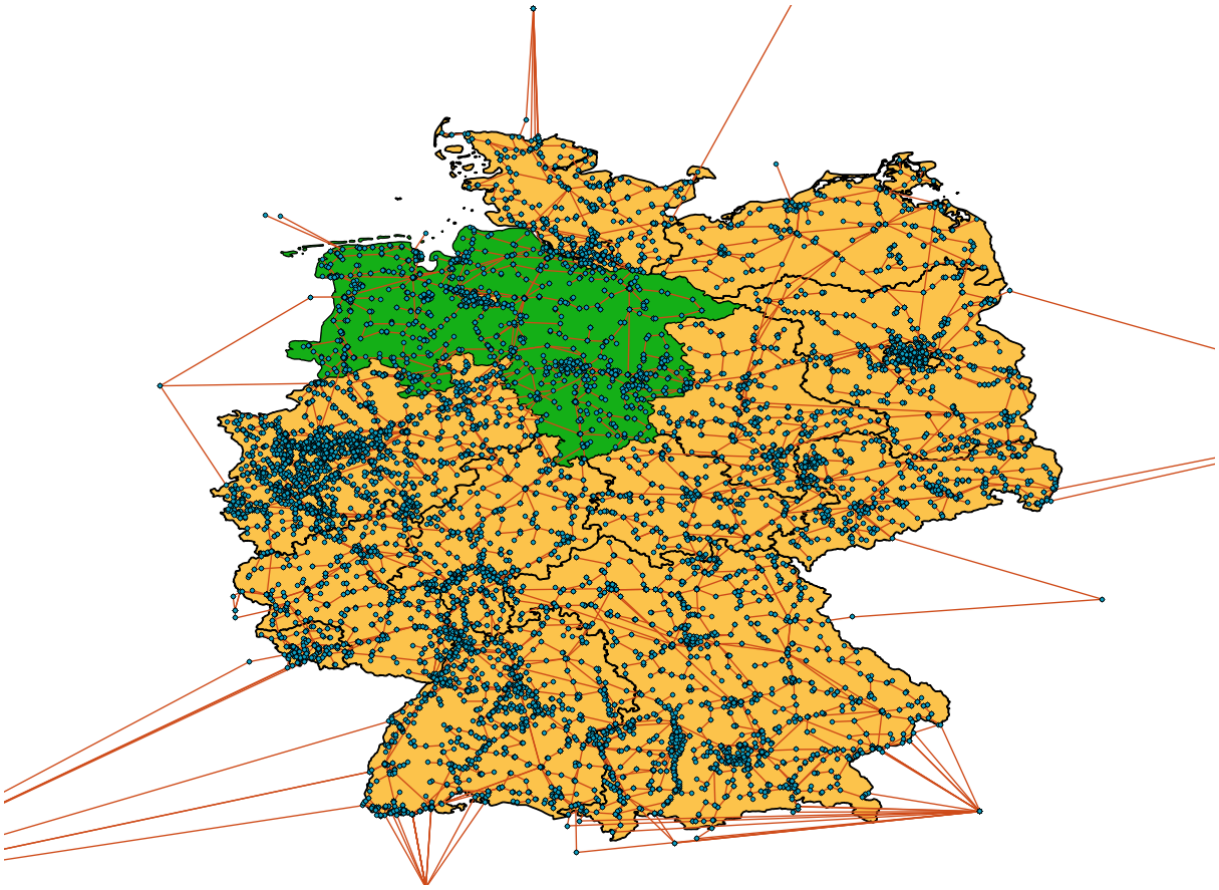


Figure 2.1: Illustration of power grid in Germany. From P. Lind (Unpublished, 2020) with authorization.

The energy sector in Europe is transforming because the share of renewable energy sources is increasing. Also, the use of renewable sources for electricity has increased in Europe. Such sources of electricity are affected by climate change making it more difficult to manage. This increased share of renewable sources of electricity demands a modern electricity grid infrastructure. The European Union (EU) has made a significant investment in research, development, and construction of this modern electricity grid (Medjroubi et al., 2017). For reliable and safe operations of power grid systems, data related to power grid systems plays a significant role (Kim, Thottan, Kolesnikov, & Lee, 2010). Further, the stakeholders who are involved in planning a sustainable energy system need to use the existing data for their decision-making process.

The expansion of the electricity grid attracts many stakeholders that include policymakers, economists, environmentalists, sociologists, anthropologists, and more (Medjroubi et al., 2017). The decisions from each of these stakeholders have more or less role in the expansion process. Therefore, the expansion of the electricity grid is not just a technical problem for the energy sector to solve but also related to our society and economy. Hence, it has become very relevant to have a transparent model that governs the decision making and strategies involved that can be understood by all the stakeholders.

In the following section, we will be discussing different sources of power grid data.

The data released by the European Network of Transmission System Operators for Electricity (ENTSO-E) more or less improved the availability of data related to the power grid in Europe

(Medjroubi et al., 2017). The ENTSO-E data is presented in a map-based visualization on their website https://www.entsoe.eu/data/map/ and you can also download the data in pdf format from the website. However, the data being in PDF format and it not including the geo-references makes it very difficult to use (Medjroubi et al., 2017).

Zhou (2003) in his research about Cross-border congestion management in the electricity market tried to collect the public data about the cross country transmission lines in Europe. Zhou further used ArcGis to digitize the collected ENTSO-E (called UCTE at that time) data and used PowerWorld Simulator to perform his power flow calculations.

Renewable Energy pathways Simulation System (renpass), an open-source model developed by Wiese, Bökenkamp, Wingenbach, and Hohmeyer (2014) in the Centre for Sustainable Energy Systems at University of Flensburg includes data about weather, solar, wind energy, hydropower plants, thermal power plants, demand, prices, storage plants, and emissions. Renpass uses weather-related data from different weather stations in Germany, Norway, and the Baltic countries. Renpass uses MYSQL for database and R programming language. For details see (Wiese et al., 2014).

In one of the researches titled *"Electricity sector data for policy-relevant modeling: Data documentation and applications to the German and European electricity markets"*, Egerer et al. (2014) have done a detailed study about power-related data, different possible sources of data and its availability. The authors also have presented possible data sources for Germany and Europe.

A project called SciGRID, has collected data from Open Street Map (OSM), filtered and abstracted the data to a transmission grid model and exported as .cvsdata file format. SciGRID has got its own graphical user interface. For details see (Medjroubi & Matke, 2016).

Some of the data sources of power grid data is summarized in table 2.1.

Name of Database	**Web Address**	**Types of data**
OpenStreetMap	https://www.openstreetmap.org	Maps
ENTSO-E	https://www.entsoe.eu/data/map/downloads/	PDF Map
SciGRID	http://git.scigrid.de/	CSV
Renpass	https://www.uni-flensburg.de/eum/forschung /abgeschlossene-projekte/renpass/	ZIP file
Open Power System Data	https://open-power-system-data.org/	ZIP, CSV, XLS
European TSOs	https://www.next-kraftwerke.com/knowledge/european-tsos-list	Variable
EUROSTAT	https://ec.europa.eu/eurostat/data/database	TSV
The Wind Power	https://www.thewindpower.net/reports_en.php	XLS, Maps

Table 2.1: Sources of power grid data.

2.2 Universal Design of Information Communication Technology

To implement a usable web interface for power grid data, important background from universal design must be considered. In this section we introduce the main concepts of this research field.

2.2.1 Universal Design

Universal Design is the discipline which deals with the design of solutions and environments that can be used by the users with widest range of abilities without the need of adaptation or specialized design (M.S., 1998). The Center for Universal Design at North Carolina State University in 1997 introduced the seven principles of Universal Design which can be used as the guidelines to design an accessible solution or evaluate an existing solution (M.S., 1998). Universal design principles were proposed as a general guideline for all design related fields. Fuglerud (2009) defines universal design in the context of ICT as, "a design strategy to make ICT products and services accessible and usable to as many people as possible". As websites are also one of the ICT systems, the principles can be used in the context of website design as well.

The seven principles of Universal Design introduced by The Center for Universal Design and some examples relevant to the context of website are described in the following section. For detailed information see (M.S., 1998; Kodai, 2020; Zheng, 2020).

Principle One: Equitable Use

The first principle states that, the design should be useful and marketable to people with diverse abilities. Any design/solution must be fit or must be usable for users with different abilities. It must provide the same means of using for all user types without segregating or stigmatizing them. Moreover, the solution must not compromise the privacy, security, and safety of any users based on their abilities. The design must be attractive as well.

In the context of websites, making sure that the elements have high contrast ratio makes sure that it will equally serve color blind people, people with low vision as well as users who are seeing the content in bright sunlight. Similarly, having alternative text for non-text contents (e.g. images) will help users who use assistive technologies like screen readers. Also, hiding elements behind some mouse click or hover interaction disable users who only use a keyboard to access the web page

Principle Two: Flexibility in Use

The second principle suggests that the design must accommodate a wide range of individual preferences and abilities. There should be a choice in methods of use. The solution should accommodate both right and left-handed use. Additionally, the design must promote accuracy and precision for the users. Further, the solution must be adaptable to the operating speed of the user.

Some techniques like scroll-jacking, i.e., automatically scrolling a web page makes it difficult for users to read the contents at their own speed. Text on some websites does not resize evenly and when the window is resized. Not handling this makes the website content illegible for many

users. If we provide the users with the ability to customize and personalize the layouts, text size, contrast language, and other relevant components, it will be more flexible for many users.

Principle Three: Simple and Intuitive Use

This principle suggests that the use of the design should be easy to understand, regardless of user's experience, knowledge, language skills, or concentration level. That means, the design should not be complex to understand and use. It should be intuitive and consistent with user expectations. Moreover, the design must facilitate the users with a wide range of language skills. Also, the information must be arranged in accordance with its importance. The users must also be provided with effective feedback and prompting while interacting with the system.

There are some known patterns for how the native web elements work and some semantics for things like color, icons, the position of elements. For example, red usually signifies error, the envelope icon represents a message, the next button is usually to the right of the back button, etc. We should avoid breaking such rules as far as possible. Moreover, it is a good practice to reduce visual clutter and prioritize the display of elements based on context and needs. Using progressive disclosure i.e. revealing the essential information in a step by step manner may help to reduce the user's cognitive load and helps to reduce the distractions.

Principle Four: Perceptible Information

According to this principle, the design must communicate necessary information effectively to users, regardless of ambient conditions or the user's sensory abilities. The important information must be presented in different modes like pictures, audio, or tactile feedback. There must be a distinct difference between important information and the environment. The information must be clear enough to read. It must be easy to give instructions. The elements must be differentiated in such a way that they can be described. Further, the solution must be compatible with different variations of techniques or devices used by people with sensory limitations.

Dividing the content into shorter paragraphs and sentences makes it easier to read and digest than a large chunk of text. The use of graphics/images, charts, and graphs makes the information more perceivable. Additionally, for multimedia contents like audio or video, having options for multi-sensory experience by the use of subtitles and transcript makes it perceivable for a larger number of user groups.

Principle Five: Tolerance for Error

The fifth principle suggests that, the design has to minimize hazards and adverse consequences of accidental or unintended actions. The elements in the design must be arranged in such a way that it minimizes any errors or hazards that might occur while the user is interacting with the system. The most used elements must be the most accessible. Similarly, hazardous elements must be removed, isolated, or shielded. The system should provide warnings for any kind of hazard and error. The system must be made fail-safe as far as possible. Any opportunities for unconscious actions that require extra caution must not exist in the system.

Having features like the validation of user input adds value in terms of the robustness of the application. Additionally, accidental errors can be reduced if we hide the permanent actions

inside a menu or have a prompt that asks the user to reconfirm their actions. For example, many apps ask "Are you sure?" before closing the app or deleting something. To add to that, having the option to undo any actions helps users to correct their errors

Principle Six: Low Physical Effort

According to this Principle, the design should be usable with low physical effort so that it can be used efficiently and comfortably and with minimum fatigue. The solution must be usable while maintaining a neutral body position. All repetitive actions and actions that require sustained physical effort must be minimized. Also, no action must require unreasonable force to complete.

Replacing repetitive tasks with keyboard shortcuts helps to decrease the physical effort to a large extent. For example, using Ctrl+C for copying and Ctrl+V for pasting is easier than doing it by multiple mouse clicks. Moreover, if related actions are grouped together, it reduces the physical efforts the users need to make. For example, options for left, right, or center alignment of text are usually placed together.

Principle Seven: Size and space for Approach and Use

Finally, the seventh principle suggests that, appropriate size and space has to be provided for approaching, reaching, manipulating, and using any system regardless of the user's body size, posture, or mobility. All important elements must be in a clear line of sight and comfortable to use for users in any position (i.e., seated or standing). Furthermore, the solution must accommodate various hand sizes and grip size. Also, there must be enough space for the use of assistive devices or additional assistance.

If we consider things like hand size and dexterity of users, it helps users in cases like one hand mobile device use and interacting using touch and finger gestures. Further, assistive technologies like virtual keyboards take some space and cover some parts of the screen. If that is not considered, it might be a problem for some users.

2.2.2 Accessibility and Usability

This thesis will use the concepts of accessibility and usability as its main focus while developing the web based solution for the target users.

The World Wide Web Consortium Web Accessibility Initiative (W3C WAI), an organization which is involved in developing specifications, guidelines, techniques, and resources about accessibility, defines web accessibility as - people with disability being able to use the web. It explicitly points out people with disabilities like hearing, cognitive, visual, neurological, physical, and speech impairments. Moreover, W3C WAI has also pointed out the relevance of accessibility for people without physical impairments that are disabled by their context. For example, with aging, people's ability decreases. Similarly, in a noisy environment, you cannot listen to audio, people with a slow internet connection have limited bandwidth (Lawton, 2016). For a web content to be accessible, there are several components responsible which includes web technologies, web browsers and user agents, authoring tools, content in the website itself, and the humans

involved namely; the developers involved in developing the website, the content creators, the end users any other user (Lawton, 2016; Chisholm & Henry, 2005).

According to The International Organization for Standardization (ISO) in its report *9241-20:2008 - Ergonomics of human-system interaction*, any system can be accessible only if it considers abilities and limitations of its users and helps the users to complete their goals by interacting with the system. Therefore, considering a wider range of the user's goal, abilities, and limitations, and context of use makes any ICT system more accessible (ISO/TC 159/SC 4, n.d.).

Larry Hull, in his article *Accessibility: it's not just for disabilities any more*, suggests that accessibility is a relative concept which depends on understanding the needs of your audience (Hull, 2004). He also says that accessibility is beyond people with disabilities as any website can be inaccessible because of other issues like limited internet bandwidth, using alternative devices to access the website and more.

Some researchers at the University of York did a study to find out what researchers and practitioners think about web accessibility. They collected 50 definitions of web accessibility from different books, papers, standards guidelines, and online sources and analyzed those definitions to propose a new unified definition of web accessibility. They define web accessibility as all people being able to use the website for different contexts of use. The website should be accessible to the disabled and older people who might be using assistive technologies. They also suggest that to make an accessible website, the website needs to be designed and developed in such a way that it supports usability in all contexts of use (Petrie, Savva, & Power, 2015).

W3C WAI is also the main body for the development of Web Content Accessibility Guidelines (WCAG). WCAG is a widely accepted set of guidelines that explains how to make components of the web more accessible. The current version WCAG 2.1 was published on 5th June 2018. WCAG is directed towards different stakeholders of a website viz. web content developers (i.e., page authors, site designers), developers of web authoring tools (for example, What you see is what you get (WYSIWYG) editors), developers of web evaluation tools, students, teachers, policymakers and anybody who is looking for a standard for web accessibility. WCAG 2.0 is also an international standard: ISO/IEC 40500:2012 (Lawton, 2005).

WCAG is based on four main accessibility principles: perceivable, operable, understandable, and robust. There are a total of 13 guidelines that guide web content creators to make their content accessible. For, each guideline, success criteria are provided. Each success criteria has three conformance levels A, AA, and AAA, A being the lowest, and AAA being highest. Further, for each guideline, the WCAG document also explains how to achieve the success criteria for all conformance levels (Connor, Cooper, Kirkpatrick, & Campbell, 2018).

Usability of software is defined as how effectively and efficiently users can achieve their goals using the software and how satisfied the users are while using the software in their context of use (Matera, Rizzo, & Carughi, 2006). Usability of software is also the measure of its quality. The success or failure of any web application heavily depends on its usability (Matera et al., 2006). Nielsen (1994b), in his book *Usability Engineering* claims that usability applies to any kind of interaction between the humans and system. He also claims that usability is a part of the larger issue of the system's practical acceptability. Nielsen has defined usability as a multi-dimensional

component which has the following attributes:

- Learnability: Any system should have an easy learning curve i.e. it must not take long to learn the system to get the work done.
- Efficiency: Users must be able to perform their tasks at high productivity after they learn the system.
- Memorability: The system must be easy to remember so that the users do not have to relearn every time they access the system.
- Errors: The system must be robust, less prone to error, and free of any catastrophic failures.
- Satisfaction: The users must find the system pleasant to use.

Nielsen (1994a) collected usability heuristics from many published sources and evaluated them to introduce a list of usability heuristics that cover the widest range of usability problems. Ten different usability heuristics derived by Nielsen and a brief description of them are mentioned below:

1. **Visibility of system status:** The current sate of any ongoing action or the system should be communicated to the user in a timely manner via. an appropriate feedback mechanism.
2. **Match between system and the real world:** The system should have information in a natural and logical order. It should use concepts, phrases, and words that are familiar to the users.
3. **User control and freedom:** The system should support undoing and redoing any action. The users must be free to cancel any action as per their wish. And such features must be clearly marked.
4. **Consistency and standards:** The system must follow a consistent pattern through the system so that it is predictable and learnable for the users.
5. **Error Prevention:** Any kind of error or error-prone conditions must be prevented as far as possible.
6. **Recognition rather than recall:** All the actions and options must be visible to the users. The user's memory load must be minimized as far as possible. Any information the user will need while performing any task must be made visible or easily retrievable.
7. **Flexibility and efficiency of use:** The system should serve a range of users who can be novice or an expert in using the system. It should be flexible enough for new users to learn and efficient for expert users.
8. **Aesthetic and minimalist design:** Only the essential information must be displayed. The content and features that are disabled must be prioritized according to their relevance.

9. **Help Users recognize, diagnose, and recover from errors:** Error message must be conveyed in a simple to understand way which will help the users recognize the error and recover from it.

10. **Help and documentation:** It is always a good idea to have easily accessible help and documentation that will guide the user to perform their tasks.

In their study, Di Blas, Paolini, Speroni, et al. (2004), have used two different terms "usable accessibility" and "technical accessibility". The study claims that only being "technically accessible" i.e., just complying with the guidelines does not ensure that a website is effectively accessible. Further, they suggest that the efforts must be focused to provide the users with an effective experience by making the website effectively accessible instead of just technically accessible (Di Blas et al., 2004).

Petrie and Kheir (2007) has tried to study the relationship between accessibility and usability. The problem was approached from the perspective of users with and without disabilities. The problems experienced by users with disabilities and users without disabilities while accessing a website were taken into account. It was found that there were two sets of problems and around 15% of the problems occurred to both the groups. Sometimes, the same problem can be experienced by both user groups whereas, in some cases, the problem might present itself only for users without disabilities and the solution work perfectly for users with disabilities or vice versa (Petrie & Kheir, 2007).

Maguire (2001), claims that if a system is designed with a focus on usability, the users will get the system as they want and that makes the system easy to use and hence such system becomes more productive. Additionally, Maguire also claims that human errors on the system are to a great extent caused by a poorly designed user interface. Therefore, if we make our user interface consistent, less ambiguous, and devoid of any design faults, it will help to reduce the errors. Moreover, good design also helps reduce the time needed to learn to use the system. Lastly, a well designed and easy to use system is more liked and trusted by the users (Maguire, 2001).

Many people, especially the designers and developers think that accessible websites are plain and simple and visually unappealing. Petrie, Hamilton, and King (2004), suggest this may not be true. Petrie et al. claim that plain and simple websites might be accessible but do not agree with the statement that accessible websites cannot be interesting and sophisticated. An experiment that involved an evaluation of 100 websites using both manual and automated checking was performed. The results of the experiment indicated that adhering to WAI guidelines is important but does not make sure that the website is practically accessible. It was found that using the WAI guidelines, only 55 percent of the total problems discovered. Also, contrary to general belief, good visual design was found to contribute to accessibility and usability. The major problems of accessibility were found to be because of the cluttered and complex structure of the page, poor contrast, and text size is too small (Petrie et al., 2004).

Di Blas et al. (2004) claims that WCAG just ensures "technical readability" of the contents of the website. Therefore, Di Blas et al. consider WCAG as a way to ensure only the "technical accessibility" not the practical and "usable accessibility" of any website.

Another similar study was conducted by Rømen and Svanæs (2012) to test how effective WCAG can be for checking the website accessibility. In an experiment performed among a total of 13 users, it was found that WCAG 1.0 only found 27 percent of the total accessibility issues, and WCAG 2.0 performed slightly better with 32 percent. Therefore, Rømen and Svanæs also concludes that, only the guidelines provided by WAI will not be sufficient to ensure the accessibility of any website.

2.3 Web based user interface for data search

In this thesis, we will focus on designing and developing a web-based user interface for searching and interacting with the data related to the power grid field. The objective is to make the interface highly accessible and usable for its users.

Users visit any information system either to retrieve information and communicate it elsewhere or they just browse the information to learn something related to the field. According to Marchionini and Shneiderman (1988), information searching in a hypertext system (i.e., system where the related section of the content is cross-linked) have different constraints namely; Task domain, Search System, Setting, User, and Outcomes. Although this was research from before the internet era the concepts are relevant for any kind of system that deals with searching and presenting the data. The connection between these constraints has been presented as a model that has users at its center. The model presented by Marchionini and Shneiderman has been discussed in brief in the section below.

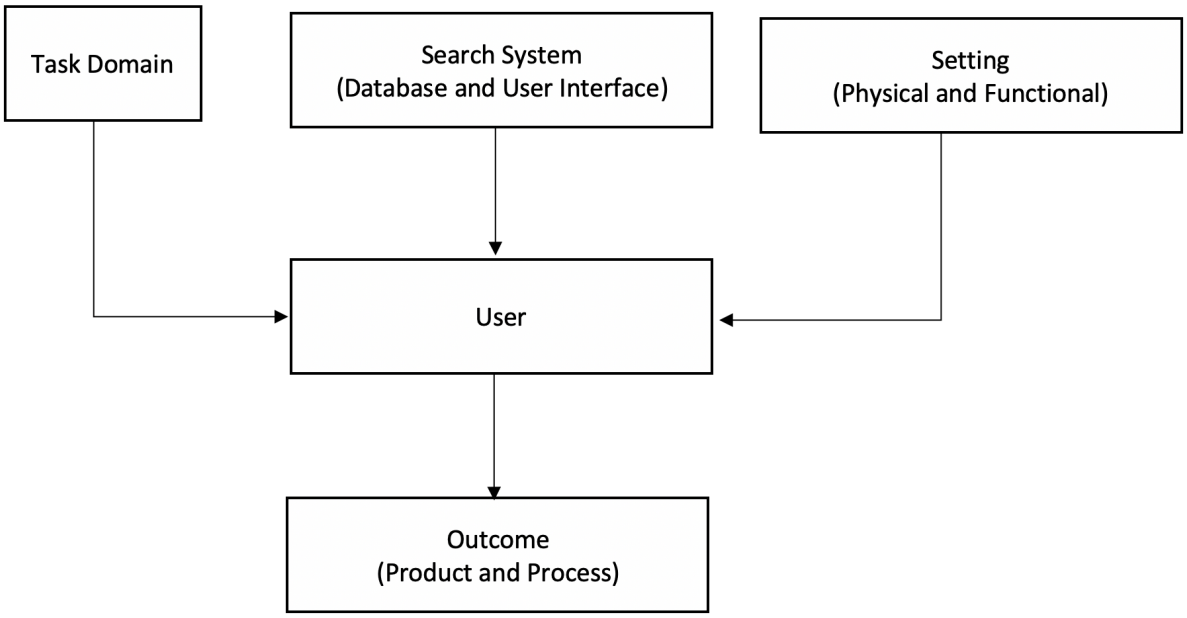


Figure 2.2: Different constraints of a search system. The complexity of the task domain, physical and functional setting and the search system that has database and user interface and user's knowledge about these constraints determines the outcome of a system which usually is combination of both product and process (Marchionini & Shneiderman, 1988)

Every software system serves one or more disciplines which is also known as the task domain. The task domain consists of many entities and relationships between those entities.

The complexity or specificity of the task domain, to a large extent, determines the type of interaction that occurs in a software related to that task domain.

A search system consists of database and human computer interface. How the content has been organized and presented by the designer determines how the users interact with the system. Human computer interface connects the hardware and software components of a system to its users. A search system defines how the data is presented and how it is to be accessed by the users.

The environment or the setting in which the task is performed also impacts the process of information search. For example, the physical setting where the task is performed determines the constraints like time available, physical accessibility, cost associated and more. Further, functional constraints like user's motivation and objective behind performing the task also affects what the users select in the system and how the users use the system. For example, weather the task is being done for entertainment, research and studies, or as a part of job.

Different users have different abilities, different level experience, different level of knowledge about the task domain, and different use case to use any system. It is therefore a designer's responsibility to design the interface in such a way that it serves all the features to all the users.

The outcome of any information search process is the information itself or the search results in different formats like documents, text etc and the process involved in finding the result. The steps followed by the users and decisions made by them in different steps of the search reflects the mental model of the system in user's mind and also helps to guess user's cognitive activity and effectiveness of a system. Further, the process also remains as experience or knowledge in user's mind and used in future actions.

The user interface helps the users perform their tasks in a faster and efficient fashion than traditional command languages. User interface components like menus help even novice users to easily access the information. Although traditional command languages are very powerful, the user interface makes the process faster and more accurate. The user interface must help users to perform their work in a rapid, incremental, and reversible way to give the users a sense of confidence and control on the system. Also, the user interface reduces the cognitive load and thus helps users to perform their tasks with less working memory.

Users must always be at the center of any user interface design process. However, the designers of the user interface do not have any knowledge of how much the user knows about the task domain, the user's past experience, and possible sources of information and more. *Therefore, if the designers have an understanding of the basic cognitive process that guides information seeking helps to a large extent.* Cognitive Science helps to give insights on how to structure the knowledge to make the information-seeking more accessible and effective. Learning different use cases and the current workflow of the potential users helps understand how the users might learn and use the system and hence makes the user interface more noticeable and prominent.

All the users have an internal representation of the external world in their minds, which is called a mental model. In the case of user interface as well, the users, in their mind, have a representation about each user interface (UI) component and possible actions that can be performed on the component-based on their past experiences, learning, and intuition. Users

develop a mental model by reading documentation, training, experience, and comparing them with another system they used before.

According to Shneiderman (1996), exploring the information becomes difficult and complex with the increase in amount of data. He suggests that a visual presentation can be far easier to use than a textual description. A visual way of displaying the data can be leveraged to do scientific visualization of different phenomena which was never possible with textual mediums. Similarly, abstract information visualization can help reveal patterns, clusters, gaps, outliers, and more. He strongly suggests that his "Visual Information-Seeking Mantra: overview first, zoom and filter, then details on demand", can be used for designing a graphical user interface for large, complex, and heterogeneous data from different domains.

A concept called Dynamic Queries explained by Shneiderman (1994) makes the use of different graphical UI widgets such as sliders to interact with the data and the search results are presented as a visualization. The objective behind doing so is to provide an easy to use option to the users over the traditional Query Languages (e.g. SQL) which are difficult to remember and complex to write for novice users. Dynamic queries techniques were found to improve the user's speed and satisfaction to a large extent. Shneiderman have developed principles for Visual information Seeking that includes dynamic queries, starfield displays (i.e. data presented in axes with options for selection and zooming) and tight coupling between the two. Tight coupling means logically updating different information with the change in the input to immediately reflect the change. For example, if the output of one step is being used as input on next or if it limits or expands the input options in the next step. Therefore, dynamic queries provide "flying through the data experience" to the users (Ahlberg, Williamson, & Shneiderman, 1992).

During the very early days of the development of the Graphical User Interface, some interesting studies were done and interesting artifacts were developed for searching the data from complex databases. This study also aims to develop a web-based system for searching power-grid data from different databases. Some related studies that dealt with development of search systems are discussed briefly in the following sections.

A study called GUIDE (Graphical User Interface for Database Exploration) explores the use of graphical user interface for interacting with complex databases like census data and energy data. The authors saw different problems in accessing such data. Having too many things to remember and lack of any option to browse through the metadata and schema were seen as problems. The data itself being heterogeneous in nature made it complex to use different mathematical concepts from calculus, algebra, or set theory. Also, users usually followed an exploratory approach and went through multiple intermediate steps to find the desired result. GUIDE included examples, illustrations, help messages, etc to remove the memory burden from the users. Similarly, it also included a logical and hierarchical grouping of entities implemented as menus that helped users to properly navigate through the data. Colors and pictorial methods were used to indicate the scope and meaning of queries. Objects were ranked according to their relevancy and different user groups had different ways to classify the data. The use of partial queries helped users to build up solutions in a step-by-step fashion. See details in (Wong, Kuo, et al., 1982).

Shneiderman (1987) made a system called Hyperties with an objective to use computers to

make a new information-sharing medium that will be effective than paper. The system consisted of a browser, an authoring tool for creating and editing new articles, and a collection of different databases each of which had many articles. Many experimentally proved techniques were deployed in the system to make sure that human factors were considered in the design. The efforts were focused make it effective even for novice users who did not have any computer-related knowledge. Interesting insights were found during the evaluation of the system. Arrow keys were found to be a more effective medium to navigate. Different menu types were found to be effective for different use cases. For selecting the content, the touch method was found to be very fast but had quite many errors as well. For searching the content, using paper was faster for simple searches, and Hyperties was faster for complex searches. However, people still liked to use Hyperties even though it took more time. Users also preferred having less content to see on the screen at a time. (Shneiderman, 1987) also believes that different colors, spacing, and size of the window also matters in the user's experience.

With the development of modern web technologies, the use of a graphical user interface for searching and interacting with data has also evolved to make use of those modern web technologies. Some of such examples are explained below.

Koo, Battista, and Brownjohn (2011) at the University of Sheffield, UK made Sheffield structural health monitoring (SHM) data management system (SSDMS), a data management system for structural health monitoring data. It was targeted for SHM researchers, structure operators, and structural designers. The objective behind developing the system was to make the SHM related data easily and instantly accessible which will make data mining and knowledge discovery easier. The system consisted of a MYSQL database for storing data from different sources, MATLAB interface for processing the data, and web interface that visualized the data. The web interface had an online panel that displayed time-histories of many pre-selected data and allowed the users to select the time frame. It also had an interrogator mode which allowed the users to browse through different options available and generate their own time-history and scatter plots. The system used JavaScript and Google Chart API for visualization and AJAX (Asynchronous JavaScript and XML) for retrieving the data from the server. Further, it also used web forms that help users to select different options to get their desired output.

McKenna, Staheli, Fulcher, and Meyer (2016) developed a system called BubbleNet, which is an interactive dashboard for cybersecurity data with an objective of making discovery and presentation of data effective. The field of cybersecurity have a variety of data types and data sets. BubbleNet presented data as different visualization methods like bar-charts, scatter plots, and heatmap matrix. It used map-like visualization to display spatial (location related) data. Different data-driven rules were implemented for abstraction. For example, circles over a map location were used to present the data for that location. The size of the circle represented the quantity of data and the color of the circle represented deviation from the average value. Aesthetics was also considered for making decisions about different components and their shape and size used in the system. Different modes provided options for different use cases. Filter options were provided to help the users divide the data into different time frames which helped to reduce the cognitive load. BubbleNet used a JavaScript library called D3.js to create the visualization. Python scripts on the back-end were used to prepossess the data and provide it to

the browser as JSON objects.

The Dublin Dashboard project used different open source tools to collect, analyze, and visualize the data about the city of Dublin from multiple sources. It was developed as a web application that has 12 different modules. It had modules for real-time city data from multiple sources like the current transportation situation, noise levels, water levels, and more. Further, it also had some administrative data for example demographics, employment status, housing prices. The project focused on visualizing all this data in an accessible way and also have a low cognitive load in the users. It used "overview first and details on-demand" approach. It had fully interactive graphs and also feature that enabled exporting and downloading the graphs as images. It also used UI elements like gauge (i.e. car speedometer like interface), maps, charts, tables. Further, the clustering of data was done to reduce visual clutter. Color ramps were used to represent the different statuses of some data. The application handled a variety of data types which included JSON, API, CSV, XML, EXCEL, PDF, and more. It used CAKE PHP framework on the server-side. Model View Controller (MVC) pattern was used which kept the data, processing logic, and presentation layers of the application separately making it easier to manage. MYSQL was used as the database. Moreover, JavaScript libraries were used for making the GUI part. Open source tools Highcharts and Leaflet were used for charts and interactive maps respectively. Cascading Style Sheet (CSS) was used to make the dashboard adjust on different screen sizes and devices. Data from different providers was inserted in a MYSQL database or a file server that was accessed by the controller layer in the web server and supplied them to the web browser as per the user's demand. Human-Computer Interaction guidelines and heuristics were used while designing and developing the system but any usability test was not done. See details in (McArdle & Kitchin, 2016).

Web Applications nowadays are not as simple as it used to be in the past. It does not just include the static components on the page but also includes the interactive elements that make changes in the web page in response to the user's action. Different elements like a carousel, slider, menu bars, accordions, etc. are commonly used nowadays. Two examples mentioned above, (Koo et al., 2011; McKenna et al., 2016) also show that using JavaScript and different JavaScript libraries is a common practice these days. The development of technologies like Asynchronous JavaScript and XML (AJAX) has made these highly interactive web pages possible. Such applications are called Rich Internet Applications (RIAs).

Fogli, Provenza, and Bernareggi (2014) have pointed out some major accessibility challenges brought by the RIAs. Features like auto-completion, displaying feedback for success or failure of the user's actions, form validation is commonly used features. Moreover, services like chat use AJAX like technologies to dynamically update areas of a web page. Also, some elements are hidden by default and displayed or activated after mouse hover or click. This causes inconsistency between the visual output and output generated by assistive technologies such as screen readers. Moreover, it also adds a challenge to the user who uses a keyboard to navigate the web page. Web pages also have different landmarks like search boxes, navigation menus, etc. This, therefore, takes forever for the assistive technologies to parse all this information and move to the main content. This becomes very frustrating to the users who use keyboard only or some assistive technologies. Further, custom controls and widgets like tool-tips, fly-out menus,

modal windows, drop-downs are also widely used. Also, non-native elements are used to extend the functionality of native HTML and to add some aesthetics.

WAI-Accessible Rich Internet Applications (ARIA) specification was introduced by W3C to address the challenges brought by RIAs. Improving the accessibility of the content that is dynamically loaded by a script (e.g. JavaScript and AJAX) and making the RIAs compatible with different assistive technologies are the objectives of WAI-ARIA. (Craig & Cooper, 2014)

2.4 User Centered Design (UCD)

User-Centered Design (UCD) is an approach that actively involves the users throughout the design process to understand the users and their requirements and to evaluate and improve the design in iterative manner (Mao, Vredenburg, Smith, & Carey, 2005). User-centered design is internationally known as the best practice. ISO 13407, Human-centred design processes for interactive systems, is an international standard established in 1999. It is a standard that provides guidance for a user-centered design process to build an interactive system (ISO, 1999). A wide group of researchers and practitioners of the field internationally agree with this standard (Mao et al., 2005). It is a multidisciplinary approach as it merges the concepts from different disciplines. ISO 9241-11:2018(en), Ergonomics of Human-System Interaction, defines Human-Centered Design as "an approach to design any system with the objective of making the system more usable by taking the knowledge from disciplines like ergonomics and usability into consideration" (Jokela, Iivari, Matero, & Karukka, 2003).

The ISO 13407 standard describes user-centered design from four different aspects: (ISO, 1999)

- **Rationale for UCD** This aspect describes the benefits of a usable system. For example, improved user satisfaction, increased productivity, and less training and support cost.
- **Principles of UCD** There are four general principles of User-Centered Design. It includes:
  - The active involvement of users and a clear understanding of user and task requirements
  - An appropriate allocation of functions between users and technology
  - Iteration of design solutions
  - Multi-disciplinary design
- **Planning UCD** This aspect includes guidance about how to use user-centered design activities in the overall system development process. Special emphasis has been given on incorporating iteration and user feedback, and teamwork and communication.

  Some methods used in planning a UCD are Usability Planning and scoping, usability cost-benefit analysis. Meetings with main stakeholders, project managers, usability specialists, and representatives of end users can be done. This will help the stakeholders to empathize with the benefits of using the human-centered approach to connect the usability of the system with project objectives and helps in developing a usable final product.

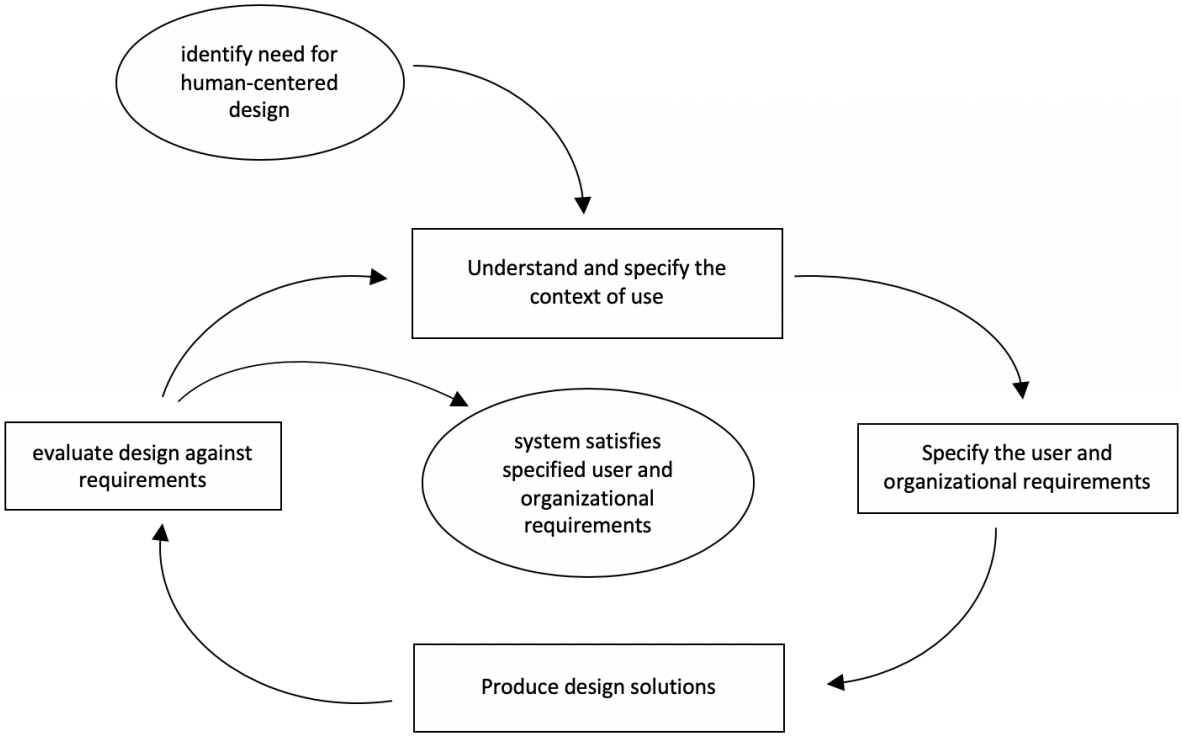


Figure 2.3: Activities in UCD as defined in ISO 13407 standard (ISO, 1999)

- **Activities of UCD** The main part of the ISO 13407 standard has explicitly mentioned four main activities in the user-centered design process.
  - Understand and Specify the Context of Use
  - Specify the User and Organizational Requirements
  - Produce Design Solutions
  - Evaluate Designs against Requirements

2.4.1 Activities and Methods in UCD

In each step of user-centered design, different activities and methods can be performed. Maguire (2001) has described the main processes and activities that can be done in each step of the user-centered design cycle. They are briefly described in the following section. For further details see (Maguire, 2001).

Understand and Specify Context of Use

The first activity is about understanding the end-users of the product. Different relevant characteristics of the potential end-users are their knowledge, skills, experience, education, training, physical attributes, habits, preferences, and capabilities. Also, the product might require user roles (for example, Administrator, Editor) who again have different characteristics. Additionally, the tasks users will perform should be understood. This should not be limited to understanding the functionality and features but this should also consider the overall goal of the system. This

is an important step for finding the usability matrices of the system, i.e., frequency of the task and performance of the system. Additionally, the environment in which the users will use the system should also be taken into consideration. This can include different hardware and software dependencies, different standards, ambient conditions, legislation, and social and cultural context.

Different methods can be used for this activity. Some of them are Identifying stakeholders, Context of use analysis, Survey of existing users, Field study/ User observation, Diary keeping, Task Analysis, and more. Meeting with the project manager, representatives of user groups, and the design team can help to list all users and stakeholders and also provides background and context. Further, a short survey can be done with current users to collect their current approach to doing the task and functional requirements and preferences. An unobtrusive user observation or field study can also be done to identify the work pattern. A Diary can be created and the users can be asked to fill it up in certain times or during certain activities. This will help to record the behavior of users and help to visualize how the future system can help the users. Different user's main roles and what they are required to do in terms of actions or cognitive processes to complete their task can be identified using a task analysis method.

Specify the User and Organizational Requirement

This activity deals with the requirements elicitation and analysis for the system. There can be requirements from the user's side that include usability requirements i.e. effectiveness, efficiency, and satisfaction in general. Further, there can also be other usability related requirements which include understandability, learnability, operability, flexibility, and attractiveness. Additionally, the identification of organizational requirements is another important activity. Organizational requirements depend on the current structure, roles and responsibilities, values and ethics, level of control and autonomy, health and safety legislation and more attributes of the end user's organization.

This step also has a number of methods that can be deployed to find out the user and organizational requirements. Stakeholder Analysis can help to get an overview of different user roles. Meetings and interviews can be organized with the stakeholders to get detailed ideas about their role. User cost-benefit analysis is another method that helps to compare the cost and benefits for each user group. This method will also provide an opportunity to rethink the system design to provide a more acceptable solution for all user groups. User requirements interviews can also be performed to get input from each user. It can be face to face or a telephone interview. Users can give their initial thoughts and the rest of the interview can be a planned one. Focus groups is a method in which a group of similar users is brought together and possible requirements are discussed. Users who belong to a similar group can also have contrasting views. Focus group interviews can help identify those views. Scenario mapping is another method that can be used. A scenario is a short story about how a user will perform a task using the system we will be making. In a scenario mapping exercise, how a user who belong to a specific role will perform an action in the future system is analyzed by the design and development team. Any ideas, questions, and comments on the scenario are discussed among the team which with help the designers explore the usability issues in the early stage.

Personas is another useful method in which a detailed profile of each of the main user groups is made. This method is useful when real users cannot be part of the design team. The design solutions are evaluated with different personas. Analysis of existing systems or competitors can help to find out the existing problems and gaps in the current system. Task/Function mapping is a process that will help to specify the system function that will be required for different tasks the users will be performing. During this method, the most critical tasks are identified so that they can be given more priority during usability study. It also helps to add or remove functions in the system depending on their values. The allocation of function is a method in which the tasks are divided into tasks performed by the system and task performed by the user. Different options are explored to find an optimal way to divide the efforts among the users such that all the users will have a good experience while doing the task. The ISO (2000b) provides a framework for specifying measurable user, usability, and organizational requirements.

Produce Design Solutions

In this step, different design prototypes are made. The insights collected so far are used to make a prototype and it is iteratively evaluated and feedback is collected. This helps in identifying the major design flaws before the actual development of the system starts. There are many methods for developing the prototype but it is suggested that at least a low fidelity prototype, i.e. paper mock-up or scripted demonstration, and high fidelity prototype, i.e working simulation or operational system, is made. This will help to evaluate the usability requirements as well as functional requirements.

Brainstorming is one of the widely used methods used in this phase. A set of design and task experts sit together and think about different ideas. Parallel design is another concept where multiple designers work in parallel to create multiple designs. It helps to evaluate different ideas before selecting one idea to move forward with. Moreover, there are many design guidelines and research that guide the software user interface design process. Few important guidelines are the ISO 9241 standard for Ergonomics of human-system interaction, inclusive design, etc. Style guides can help in making a consistent design in a shorter time span. It is therefore suggested to have a style guide based on good web design principles. Storyboarding is another method in which the relationship between the user's input and the system's outputs are illustrated as basic sketches. A persona and a scenario are selected and different steps the user performs in the selected scenario are drawn sequentially and then distributed among other participants for feedback. Storyboarding helps to empathize with the users by visualizing their workflow. An affinity diagram is another method that helps to understand the structure and relationships between potential screens or functions in a domain that is not understood much. In this method, potential screens or functions for the new system are listed and grouped together. Card Sorting is another method in which different concepts are written down on a set of cards and are sorted into a hierarchical structure. Users will arrange the cards into groups that can reveal common patterns and can be analyzed and taken into account in the design process. In another interesting method called paper prototyping, paper-based designs of the user interface are created and simulated in front of the users. The user's comments and difficulties are recorded or noted. This is a quick way to do user testing in the early phase. Similarly, in the software

prototyping method, computer simulations are made and tested with users. It is more realistic in terms of the look and feel of the future system than the paper prototyping method. Wizard-of-Oz is another similar technique in which users are provided with a computer system and asked to interact with it and a hidden developer actually operates the system to respond to the actions performed by the users. This can be suitable to explore the difficulty to implement systems like expert systems and natural language interaction. Organizational prototyping is another method in which the user's working environment (e.g. office) is simulated and communication and information flow between different users of different roles are simulated. This will help to test different operational procedures that will be integrated with the future system.

Evaluate Designs against Requirements

The evaluation activity needs to be performed simultaneously with the design and development activity. It is suggested that the evaluation activity must also be carried out from the earliest stage of the system development life cycle. The evaluation will help to know about the status of the project i.e. how many objectives have been met and it will also provide information about making improvements in the design before it becomes too expensive to make changes.

A number of methods can be used to perform the evaluation of the work in different phases. Participatory evaluation is a method where the user freely explores the system to perform different tasks in the given scenario and the user observation and comments are recorded. This will help to find out some ambiguous patterns in the design. Similarly, in an Evaluation Workshop, the developers and users meet together and go through an intense session of testing activities. The users try to complete some tasks in the system and the designers watch the sessions and discuss it later. Evaluation walkthrough or discussion is an activity where a facilitator goes step-by-step through the design and the reaction of the users is noted. A list of problems is reviewed and changes in the system are proposed at the end of the session.

Assisted Evaluation is another method for evaluation where the user is invited and given a series of tasks and a specialist will record the problem and comments from the user. This can be helpful to find out how well users can use the system with minimal help from the evaluator inf required. The users give verbal feedback which is recorded by the evaluator and analyzed later. Heuristic or expert evaluation is a technique where the experts test the system and identify potential problems. As there can be a potential bias in each evaluator, it is suggested to have multiple experts employed. This is a quick and easy way to find feedback and recommendations. Controlled user testing is an activity where a session with 8-25 users is performed. The users will be asked to perform a series of tasks in the system and the information about the user's performance, real-time comments, and post-test reactions are recorded. This test is conducted in almost real use cases. This will need extensive planning before the activity is done. This will help to get new insights that can affect the system design. Satisfaction questionnaires is a quick and inexpensive way to measure user satisfaction. A questionnaire is given to the users to capture their subjective impressions based on their experiences with the system or the prototype. Cognitive Workload Assessment helps to assess the mental effort a user needs to make while using the prototype of the system. A questionnaire or some physiological measure is deployed to collect the outcome. Critical incidents are a method that can help to find out the system

features that can cause errors. Problems faced by the users are recorded using automatic system monitor and via a user interview where the user's recall and report the errors they faced. Post-experience interviews are an inexpensive way to get subjective feedback about the system after they use it. Users are asked for their initial feedback followed by interview questions.

User-centered design is followed by technology-related companies all over the world irrespective of their size. It is a widely used approach to make a useful and usable product. It is therefore suggested as a method for creating user-friendly web design (Mao et al., 2005).

According to Lazar (2001), User-centered design helps to make a website that is "Useful and easy to use" for the users. In his book, *User Centered Web Development*, Lazar has presented different concepts and processes for using user-centered design in web development. He suggests that the process should start by defining the mission of the website and the potential target users of the website. Secondly, he suggests that gathering the requirements for your web site from your target users will also help to learn about the users. For example, what kind of content they are looking for, what kind of devices will they use to view the website, what demography do they belong to, how experienced are they, and more. After that, we can create a conceptual design of the website that includes navigation and page layout, color scheme, content, and more. It is suggested to involve the user and get the feedback so that you will know the website design is not too complex or too technologically advanced and it has content that is interesting to the users. After all the steps above, the design can now be implemented in code e.g. HTML, JavaScript, etc. After the code implementation is complete, the website will go through a round of usability testing and it can be made "live" i.e. accessible for all the users. The website needs to be periodically updated so that it continues to meet the user needs.

McKenna et al. (2016) used user-centered design approach to take users, their needs, and workflows into consideration while designing their BubbleNet system. Contextual semi-structured interviews were performed and different user personals were identified. Further, the requirements of each of those personas were identified. Different output options were collected and given scores based on the user's needs and priorities and first prototype was made. The first prototype went through evaluation using Nielsen's usability heuristics and Gestalt principles which helped to identify low-level problems and fix them. Further, twenty different options were presented to the users and their feedback was collected. The feedback helped in making the decision between different options. This way the authors iteratively developed the second prototype. A usability study to evaluate the second prototype was done. Finally, the final output was developed which incorporated the feedback from the usability study (McKenna et al., 2016).

Hunter College Libraries did their website redesign project following a user-centered design approach with an aim to make the new design using the latest technology and also make the navigation and language used in the website simpler. The main usability goals of the new website were identified quite early in the redesign phase. Usability testing was conducted throughout the process. The results reflected that iterative testing can be an effective way to build a website that meets all the user requirements and preferences. For details see (Becker & Yannotta, 2013).

Chapter 3
Methodology and Methods

The following chapter discusses the research approach, framework and methods used, and the ethical considerations made in this thesis. This study is a interdisciplinary study because it aims to solve a problem of power-grid sector by approaching the problem from the perspective of human computer interaction (HCI) design.

For this study, there are two major topics the research design had to consider, viz., learn the requirements from users and implement those requirements to develop a prototype. This thesis uses qualitative approach to do the user research and discover the user's requirements. Therefore, qualitative data analysis methods have been used to analyze the inputs from the users so that they could be used as inputs for the prototype development process. User centered design (UCD) has been used as a framework to bind all these methods together to design the overall flow of this research.

3.1 Research Methodology

Qualitative approach was employed in this thesis. For any design activity to be successful, the designers must have a clear idea about the end users and their objectives to use the system being designed. Additionally, the functionality of the application must also be equally considered. Studying these things requires qualitative study methods. Data about user's activities are different than the data from other sciences. Therefore, it is difficult to quantify this kind of data into numbers. This makes HCI research different than the research in other natural sciences. It has to use many theories and concepts borrowed from social science disciplines like Anthropology, Sociology, Psychology, Communications etc (Salvador, Bell, & Anderson, 1999). Only qualitative research will provide the real detail of complex human behaviour, their aptitude and attitudes and the technical contexts of the product to be designed. Moreover, qualitative methods can also help to study how existing similar solutions are used and empowers the design team to make informed decisions in different phases of the design process. Qualitative methods are usually quick and less expensive way to discover the valuable insights that makes the design better (Cooper, Reimann, Cronin, & Noessel, 2014). In the past, the research in HCI was more task-centric and it was possible to quantify and measure the results. However, this method is not suitable for all kinds of HCI research because there are also situations where the tasks cannot be measured in quantity (ShneIderman, 2011).

Moreover, the focus of HCI design research is about what kind of interface will people like and want to use and in what environment will the users be using the interface (Lazar, Feng, & Hochheiser, 2017b). In recent years, topics like mobile devices, touchscreens, gestures and natural computing, accessibility and more are at the center of HCI research (Lazar et al.,

2017b). These facts are equally relevant for this thesis as well. In qualitative research, the goal is understanding the context and user's needs rather than measuring some specific value. In addition to that, there are some other things, such as user's motivation, collaboration, empathy, trust and social impacts, which the researcher has to consider. These phenomena are difficult to measure using the classic quantitative approach of scientific research. For these kinds of topics, multi-method approaches are suggested to be suitable (Shneiderman, 2011). Multi-method approach involves methods like case studies, observations, interviews, data logging, and other longitudinal techniques. This study has also used multiple qualitative methods to carry out the user research.

User centered design (UCD) was used as a framework to bind all the methods used in this thesis together and perform them in an iterative fashion to gradually develop the prototype with the help of input from the users. A major advantage of using UCD is that, it is a well defined yet flexible methodology. UCD is defined as a international standard by the *"ISO 13407: Human-centred design processes for interactive systems"* (ISO, 1999). Moreover, UCD has a set of well-defined process for analyzing the needs, designing the interface by taking the needs into consideration, and evaluation of the design in the end (Henry, 2007). However, to follow the process, the design team is free to select the methods and activities that are best fit for their project's context.

In addition to that, the User-Centered Design focuses on user's usability goals, characteristics, environment, tasks, and workflow while designing a user interface. The claim that UCD ensures improved user satisfaction, increased productivity, and less training and support cost (ISO/TC 159/SC 4, n.d.) is another rationale for selecting it as the methodology in this thesis.

Moreover, the principles of UCD are other rationale for its selection as a methodology to guide this thesis. The UCD approach abides by the principle to actively involve the end users and clear understanding of users and their task requirements and development of the design in iteration. This helps to be in touch with the end users multiple times during the design process. UCD also suggests the use of multi-disciplinary design team which is perfect for the interdisciplinary study such as this.

There are different methodologies defined in the academic literature and practised by the designers which are similar to UCD. They are defined and used differently based on their degrees of user contact, user involvement, user sensitivity and critical thinking involved in the process. Inclusive design, user sensitive inclusive design, emphatic design, user involvement and participatory design and so on are some examples of such methodologies (Begnum, 2016). All of these approaches adhere to the Human-centred design processes for interactive systems (ISO/TC 159/SC 4, n.d.). They are different only because of how they use different methods in the process. In this study, we have used a general UCD process in which methods used are determined by different the constraints of this study such as availability of stakeholders or participants for our user research, time and budget constraints and more.

3.2 Methods

In the following sections, different qualitative data collection and analysis methods used for user research, the methods used for applying user centered design, as explained in section 2.4.1,

and to develop the final prototype and the rationale to select those methods are presented and explained.

3.2.1 Survey or Questionnaires

Survey is the most commonly used research method for all kinds of research. Survey is simply making a list of well defined questions and getting the responses from individuals for those questions. Reviewing literature related to the product or its domain is usually very helpful for the design team while developing questions to ask during the interview and survey. Literature might include product marketing plans, brand strategy, market research, user surveys, technology specifications and white papers, business and technical journal articles, competitive studies. It might also include different websites and web pages about similar competitor products and news articles and reports and more (Cooper et al., 2014).

Survey can be used to get large number of responses in short time. And the results of survey can help the design team get a birds eye view of the problem being solved. Survey is one of the easiest research methods. It can simply be done by asking the candidates to fill up the paper or by sending the questionnaire via email. But, selecting good candidates who can give input to the research is critical for the survey to be successful and give valuable outputs (Lazar, Feng, & Hochheiser, 2017c). In case of HCI research, stakeholders, subject matter experts (SMEs), users and customers can be the candidates for survey (Cooper et al., 2014).

However, the survey method has some drawbacks as well. It cannot be used to get the detailed data. Also, the survey is usually self-administered because of which the researchers cannot ask the follow up questions if they need some context or explanation to understand the answers submitted by the candidates (Lazar et al., 2017c).

3.2.2 Interviews

User interviews helps to identify what the end users want in the final product. It also helps to identify the motivation of the users to use the system and what are the things that are currently lacking and what kind of feature can serve as success factors for the product being built (Mulder & Yaar, 2006).

There can be different kinds of interviews for different objectives. Stakeholder interviews, Subject Matter Expert interviews, User and Customer Interviews, User Observation and Ethnographic Field Studies, Product/Prototype and competitive audits are some types of interviews that can be done for HCI research.

Stakeholder interviews helps to understand the business and technical context of the product. A stakeholder is anyone who is in some way related to the product being designed. It is a good idea to do stakeholder interviews in early stage of the research. Stakeholder interviews can be used to gather information about product vision, budget and timeline of the product, understand technical constraints and opportunities. Moreover, stakeholders can also inform the design team about the critical business drivers for the product. Some stakeholders can have important insights about the users of the product.

Subject matter experts (SME) are the individuals who are experts on the domain in which the product will operate. SMEs are therefore knowledgeable and can give an idea about making the

product better. In case of complex technical products, the guidance from SMEs is a must-have input in the design process. They can give information about industry best practises and complex phenomenons. It is therefore a good idea to be in touch with the SMEs throughout the design process and get their input on the verification of different design components and features. However, SMEs are not designers. Therefore, we have to be aware about the biases they might have in their perspective.

Customers are the people who make the purchase. Depending on the type of product and the context the customers and users can be same or different. For example, parents are the customers for children related product, IT manager is often the person who makes purchase decisions for corporate products. For any product to be viable, it is necessary to satisfy the customer's goals as well. Interviewing customers can help understand their frustrations with existing products, domain related issues and vocabulary and issues related to installation, maintenance and management of the product.

Users are the individuals who will be actually using the product. Therefore, the design process must have the users at the centre. Interview with users can inform the design team with many important insights. Users can explain the context they will be using the product on and workflow they are used to. Moreover, users can inform the task and activities they want to perform using the product and their current way of doing things using some other solution. Additionally, user interviews helps to learn user's frustrations with current products and their goals and motivations for using the product (Cooper et al., 2014).

According to Salvador et al. (1999), "Ethnography is a methodology used to represent the perspective of everyday life." Ethnography helps in conceptualization of new products and services by looking at the patterns of everyday life.

Ethnography is about not asking but understanding by observing what the users are doing, saying and thinking. Ethnographic observation can inform design by refocusing attention on the details of everyday life that are meaningful for design (Salvador et al., 1999). Combination of user interview and ethnographic observation is an effective technique for user research. Combining the observation and interview brings the context to the questions asked during the interview and helps the users explain the details with examples (Cooper et al., 2014).

Based on the inputs from different literature, interviews, surveys and all other activities performed for the design process, a hypothesis has to be made about what kind of individuals should be selected as the interview candidates. Such hypothesis is called persona hypothesis. All potential users can be classified into groups based on how their needs vary, their environment and behaviour. It can be different roles in a company, demography, level of expertise, different domains and more. At least one candidate from each group can be interviewed. (Cooper et al., 2014).

To collect capture what users are saying, the interviewer makes use of audio nor video recorders in a non obstructive way. Taking notes on a notebook during the interview is also a common technique (Cooper et al., 2014).

3.2.3 Coding for analyzing qualitative data

Coding is a common method used by researchers to find meaning from their qualitative data (Blair, 2015). Coding is the method that can be used to make a summarized description of qualitative input types like text, multimedia, drawings, music and videos and more. In another word, coding can be defined as the process of objectively and systematically inferring the characteristics of qualitative research data (Lazar et al., 2017b). Qualitative data is more prone to bias of the researcher. Therefore, it demands a standard procedure such as coding to eliminate such biases (Lazar et al., 2017b).

Emergent coding is the process without any theory or model to guide the analysis. Interesting concepts are noted and continuously refined until a coherent model that captures important details is found. The categories might come from previously published work in related areas for from own previous investigations on the topic at hand. Sometimes, participants provide terms that explains main ideas and the terms can be borrowed directly. This is called in-vivo coding (Lazar et al., 2017b).

A priori coding is the coding technique which is done using established theory or hypothesis to guide the selection of coding categories. During the research design stage at the beginning of the project, a theoretical framework can help to formulate the research questions for the activities like survey, interview, focus group etc. Also while analyzing text information after the activities, following a theoretical frameworks can help to identify main categories and concepts and explain the findings of the research (Lazar et al., 2017b).

For small text based outputs from activities like interviews, observations, focus groups, it is recommended to read the text before starting the coding process. Based on the level of experience of the coders, they might not find anything interesting or they might find the text full of interesting ideas. Emergent or a priori coding can be used to generate coding categories from the data based on the context of research (Lazar et al., 2017b).

3.2.4 Paper Prototyping

A paper prototype is a low fidelity prototype that can be rapidly made. It is a communication tool that can help the designers validate multiple design concepts and make and evaluate multiple page layouts at a very early stage of software development. It is preferred because it can help to collect the requirements and also validate the proof of concept at a very low cost (Rudd, Stern, & Isensee, 1996). Heaton (1992) suggests rapid prototyping to be most practical and less time consuming way for the design team to explore design options and deliver usability.

Traditionally, the paper prototypes were made using real pen and paper. It was therefore difficult to convey navigation and flow of the software using the paper prototype (Rudd et al., 1996). There are software based prototyping tools available which helps to rapidly make a paper prototype and also add some interactive elements to it.

3.2.5 Personas

Persona is a method or a tool that helps the design team to identify the user's goal i.e. features the users will be looking for in a product and user's behaviours i.e. how the users want the

features to work (Mulder & Yaar, 2006). Persona is a powerful tool that helps the design team to present the huge amount of qualitative user research data (for example, text, audio, video, interview notes etc) as an abstract user model similar to how scientists from other natural science use a abstract model to represent a phenomenon in a simple manner (Cooper et al., 2014). Mulder and Yaar (2006) suggests that - "personas put a face on user research in a way that turns data into the kind of knowledge that leads to better user experiences and better websites."

Persona can be a very handy tool for user research. It helps the design team to focus on the needs on one specific user at a time. Cooper et al. (2014) suggests that trying to deliver a solution that focuses on all types of users and their needs and expectations will increase the cognitive load and make the product difficult to navigate. It is therefore recommended to focus on one user type that is most critical to success and make sure the user's needs are met without compromising the needs of less user types which are less critical (Mulder & Yaar, 2006; Cooper et al., 2014). Moreover, the designers and developers usually tend to build products based on their assumptions about the end users which might not be true all the time. Persona helps the design and development team to empathize the real user's needs and deliver accordingly. Additionally, when there are more than one user types and multiple teams have done the user research tasks, they perceive things differently and therefore bring different ideas on the table. These diverse requirements and expectations from different users might confuse the design team. In such case, Personas will help the team to agree upon one feature based on the needs of one specific user type and act and deliver on that. Persona can help in mapping the results from qualitative user research to the information architecture, design decisions in interaction and visual design and development of content and to make user testing criteria. Persona also increases the efficiency of the design process as it serves as a summary of all the user research activities making it easier to make design decisions without having to go back to the results of different user research activities every time the team needs some information (Cooper et al., 2014). Miaskiewicz and Kozar (2011) suggests that including persons as a part of UCD process will help to overcome the disconnect between the designers and the end users. They fond that persons can be beneficial to focus on audience, prioritization of product requirements and audience, challenge the false assumptions and prevent self referential design.

3.2.6 Automated data collection

Using automated tools for collecting data is a widely used method in HCI research. Automated data collection is a powerful method because computers collect the data automatically. Using this method, a large amount of data can be quickly collected with a very minimal human effort. Data from web servers, proxies, different software, web browser, web browser extensions, email clients and some special tools and applications can be used for research. It is necessary to identify the study goal and type of data that can help with the study (Lazar, Feng, & Hochheiser, 2017a).

There are some tools that can help with automatic evaluation and analysis of different aspects of the user interface. Such tools can be used to evaluate different components of user interface such as layout, content, language, colors, accessibility, usability and more. These tools come really handy when inspecting weather a user interface complies by some guidelines or not (Lazar

et al., 2017a).

3.2.7 Heuristic Testing

Heuristic evaluation or heuristic testing is one of the usability assessment methods where a number of evaluators evaluate the given user interface on the basis of given heuristics and list down the problems they find. It was introduced by Nielsen and Molich in 1990. In this method, a group of usability experts test the user interface based on a set of heuristics and make a note of the problems found. Heuristic testing is an informal method which is often classified as a discount method for usability inspection (Nielsen, 2009).

Some other usability inspection methods that can be used for evaluating user interface design include formal methods such as empirical usability testing, thinking aloud analysis, GOMS (Goals, Operators, Methods and Selections rules) and more. There are also some other informal methods such as cognitive walkthroughs, pluralistic walkthroughs, software guidelines, questionnaires and checklists, feature inspection and so on (Wang & Caldwell, 2002). Many studies have found heuristic testing to be very effective way of conducting usability assessment when the traditional methods are not feasible because of limited available funds, time and human factor expertise required for the procedure (Wang & Caldwell, 2002) (Nielsen & Molich, 1990) (Desurvire, Kondziela, & Atwood, 1992). Nielsen and Molich (1990) in their experiments also found that aggregating the evaluation from just three to five people most of the usability issues were found. Nielsen and Molich (1990) therefore recommend using heuristic testing because it is a cost effective and intuitive method for evaluating the user interface.

However, there are a few things to be considered before using the heuristic testing. In the heuristic testing procedure, practitioners use their intuitiveness and past experience to check the given user interface. Therefore, for the results to be effective, it necessary that the evaluators are experts in the field of usability (Desurvire et al., 1992; Nielsen & Molich, 1990). Nielsen and Molich (1990) also suggest that the results are most effective when the participants are experts of both usability and the subject matter the interface is about. Another important thing to remember is that, only aggregated results from all the participants are effective. Results from just a single evaluator might not help in finding all the usability problems (Nielsen & Molich, 1990).

In the heuristic testing procedure, the evaluators disguise the end user's persona and perform the tests. Therefore, it is found that heuristic evaluation performed by the experts of usability have chances of missing the domain/task specific errors. Another problem that might occur with heuristic evaluation is that, things that are not real problems can also be listed as problems (Hassan, Tukiainen, & Qureshi, 2019).

3.2.8 Discounted User Testing

A regular full-fledged usability testing is often expensive. It is therefore difficult for low budget projects to conduct an elaborate usability testing. To make the usability testing possible for such projects, Nielsen(2009) proposed a simple and cheap user testing method which can be done with a small number of participants. Such method is called discounted user testing (Nielsen, 2009).

There are a number of studies that advocate the use of discounted usability inspection methods for projects with low budget (Hassan et al., 2019) (Nielsen, 2009). In his article that summarizes his 20 years of practise using discount testing, Nielsen (2009) claims that discounted usability tests gives better results than full-fledged usability testing methods and it can also be done by spending very less time than the traditional usability inspection methods. Nielsen (2009) also suggests that discounted testing is not an alternative for full-fledged or "deluxe" usability testing. He suggests using full full-fledged usability testing whenever the resources are available to do so. When the resources are scarce, discounted testing is only option that can be used for usability inspection (Nielsen, 1997).

(Hassan et al., 2019) also recommend using a discounted usability testing method with real end users in addition to the heuristic evaluation method. In their study, Hassan et al. (2019) found that the participants who were the actual end users helped to find a lot of task and domain related problems. As different studies point that heuristic evaluation can miss these kind of problems, this method can supplement the heuristic evaluation method give better results.

3.3 Recruitment of participants and ethical considerations

HCI research demands real users and subject matter experts as participants. One cannot recruit just anyone from your university or workplace. It is therefore a complex task to find the users to take part in the research. Moreover, it is also beneficial to have a group of participants that is inclusive if different age, education and technical expertise (Lazar et al., 2017b).

For this thesis, the stakeholders of power grid field were selected as participants for methods that required inputs from the end users. Similarly, for the heuristic testing activity, usability experts were asked to help.

All the participants in this thesis were informed about the project, the activities they are supposed to help with and their rights. A consent was taken from the participants before proceeding forward with any activity performed in this thesis. Moreover, in this study we have tried to maintain the anonymity of the participants considering their privacy. The personal details of the participants such as their name, email, address, IP address, gender and anything that might revel their identity have not been collected as far as possible. Special attention was given to make sure that the user's input used in this thesis and any documents that will be published will not revel the private information.

Therefore, all the activities done in this study are in accordance to the General Data Protection Regulation (GDPR). The methods used, procedure followed and the data collected for this thesis have been assessed and validated by the Norwegian Centre for Research Data (NSD). The summary of the assessment done by NSD can be seen in appendix A.

The details of the methods which required input from the participants were documented and sent to NSD for assessment. Also, a copy of the letter that informed the participants about the project, the activities they are supposed to participate, and their rights was attached and sent to NSD. A copy of that can be seen in appendix B. After the assessment, NSD verified that *"the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13"*.

In addition to that, NSD also validated that, the Nettskjema [1] software, which is the data processor used in this study, also *"meets the requirements under the General Data Protection Regulation arts. 28 and 29"*.

To summarize, it has been validated that this project meets the GDPR requirements related to processing of personal data. NSD's assessment has verified that *"the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data"*.

[1] https://nettskjema.no/

Chapter 4

Developing the prototype of the website interface

This chapter explains different activities performed in this thesis by using different research methods described in chapter 3 as directed by the user centered design methodology described in 2.4. In this thesis, the activities were performed in an iterative way. The iterations continued up until the available time. The following figure 4.1 shows an overview of all the activities performed to develop the final prototype, i.e. Accessible and Usable Web Interface for Power Grid Databases.

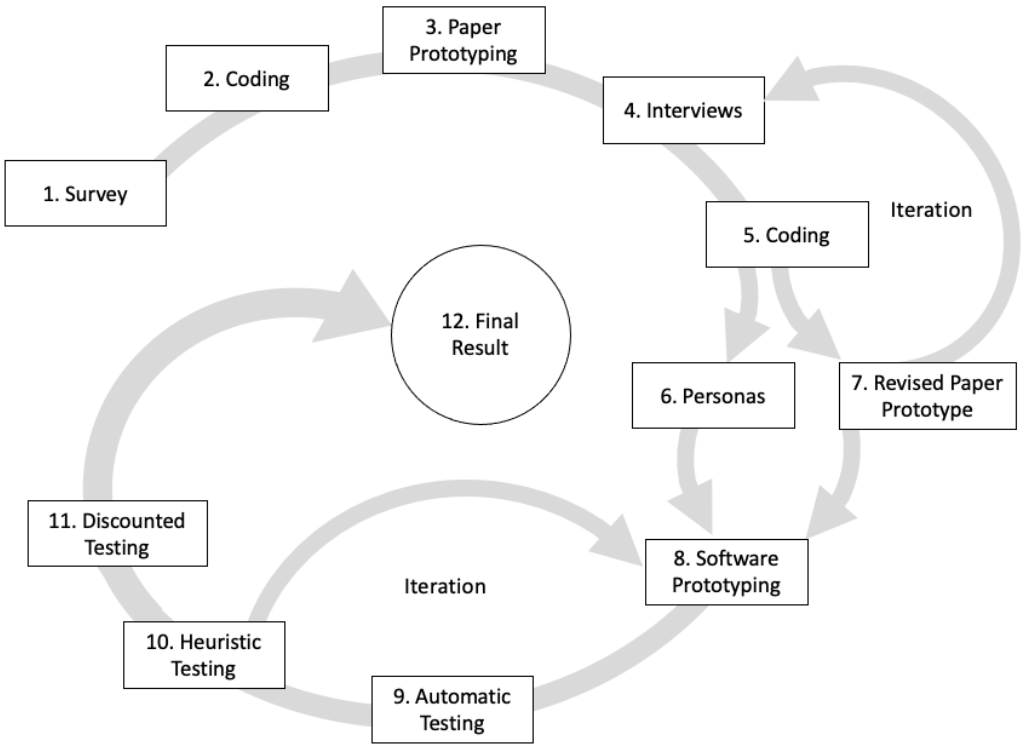


Figure 4.1: Overview of the activities as unfolded in the research carried out for this thesis.

A list of all the tasks done in this thesis is as follows:

Task 1. Survey

Task 2. Coding for analysis of survey results

Task 3. Paper Prototyping

Task 4. Interviews

Task 5. Coding for analysis of online interviews

Task 6. Personas

Task 7. Revised paper prototype

Task 8. Software Prototyping

Task 9. Automatic Testing

Task 10. Heuristic or Expert Evaluation

Task 11. Discounted Testing

Different activities that were performed in this thesis are explained in the following sections of this chapter.

4.1 The survey for assessing user requirements for power grid data

An online form titled *"User Requirements Survey for Developing Web Based Database for Power Grid Data*" was created in Nettskjema [1] to collect the requirements from different stakeholders. The form was sent to a number of subject matter experts via email. The questionnaire can be viewed in Appendix C. The objective of the survey was to collect the requirements from different stakeholders. The literature review of the power-grid domain (See 2.1) helped to formulate the questions for this survey. The questionnaire consisted of four subjective questions. The aim was to collect the input from real subject matter experts who belong to power grid field who are involved in different power gird related activities. The online form was sent to different universities, research organizations and different companies. The participants submitted their form anonymously. There were 15 submissions in total. After eliminating the test submissions, 11 submissions were considered valid and taken into consideration for the analysis. Corresponding results of the survey are given in Appendix D.

4.2 Coding for analyzing the survey

The questions in the questionnaire in were framed a way that the respective answers were already categorized in different conceptual blocks. The coding method explained in 3.2.3 was used. Key items from each of the answers given by the candidates were noted. The results were compared and refined in a iterative fashion to formulate the inputs for upcoming steps in the research.

The form submissions were read and rewritten as inputs for the different tasks in the User-Centered Design process as mentioned in section 2.4. Most of the participants are scientific

[1] https://nettskjema.no/- An online application for creating, distributing, and seeing the survey results

researchers. The participants have mentioned that they have some kind of experience in using power grid data for their scientific work. They pointed out the problems in finding necessary data, data from different sources being heterogeneous in nature. The responses suggested that having a centrally accessible system that combines different data sources and allows us to select and save the data in their desired format would be beneficial.

4.3 First paper prototyping

By using the submissions of the survey, a prototype was created using a software called Balsamiq [2]. A preview of the home page and the results page of the first paper prototype can be seen in the figure 4.2 and figure 4.3.

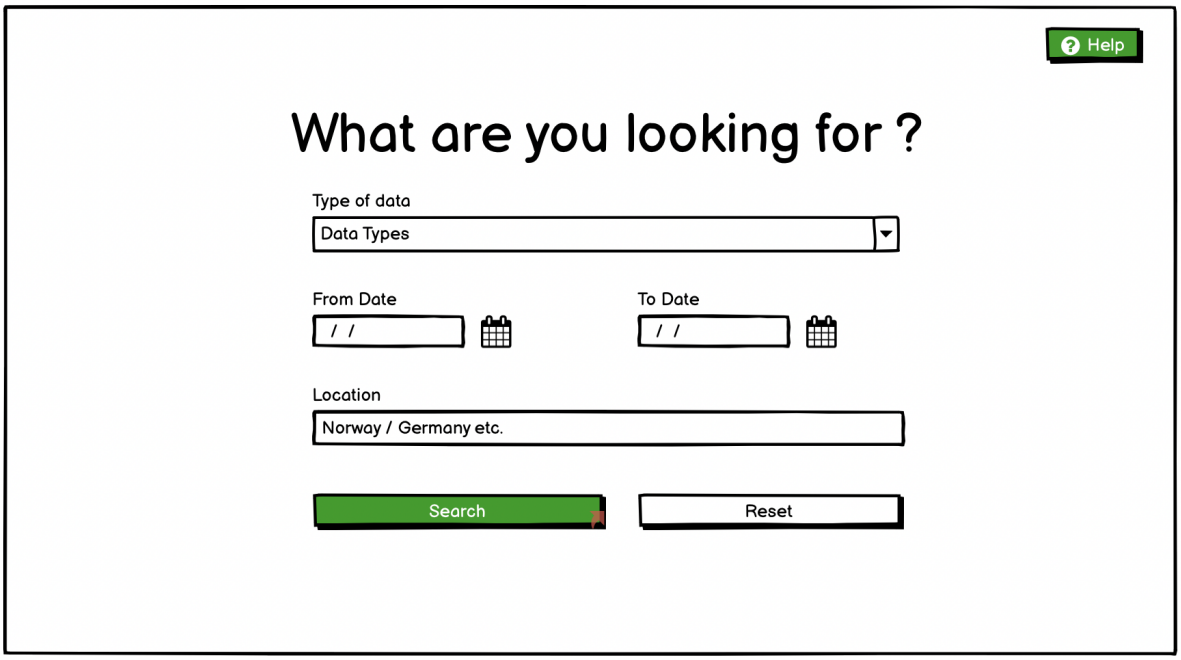


Figure 4.2: Main page of the paper prototype

The analysed survey results from section 4.2 were used to inform the features that should be there in the design. For example, different data types, countries and date of the data. Similarly, user interface design was informed by the usability heuristics as suggested by Nielsen (1994a). The prototype was made minimal and aesthetically clean. Both the pages in the prototype follow a pattern of same color, fonts and icons making it consistent and easy to recognise. A help button is placed at the top of both pages which makes it easy to find in case the users need some help on how to use the system. The back button helps the users navigate back to the main page.

The prototype consisted of two screens, the main page and the results page. The main page or the home page of the prototype had a form to initiate the data search. The form on the home page had fields for entering the dates, country and type of data. The results page listed the

[2] https://balsamiq.com/

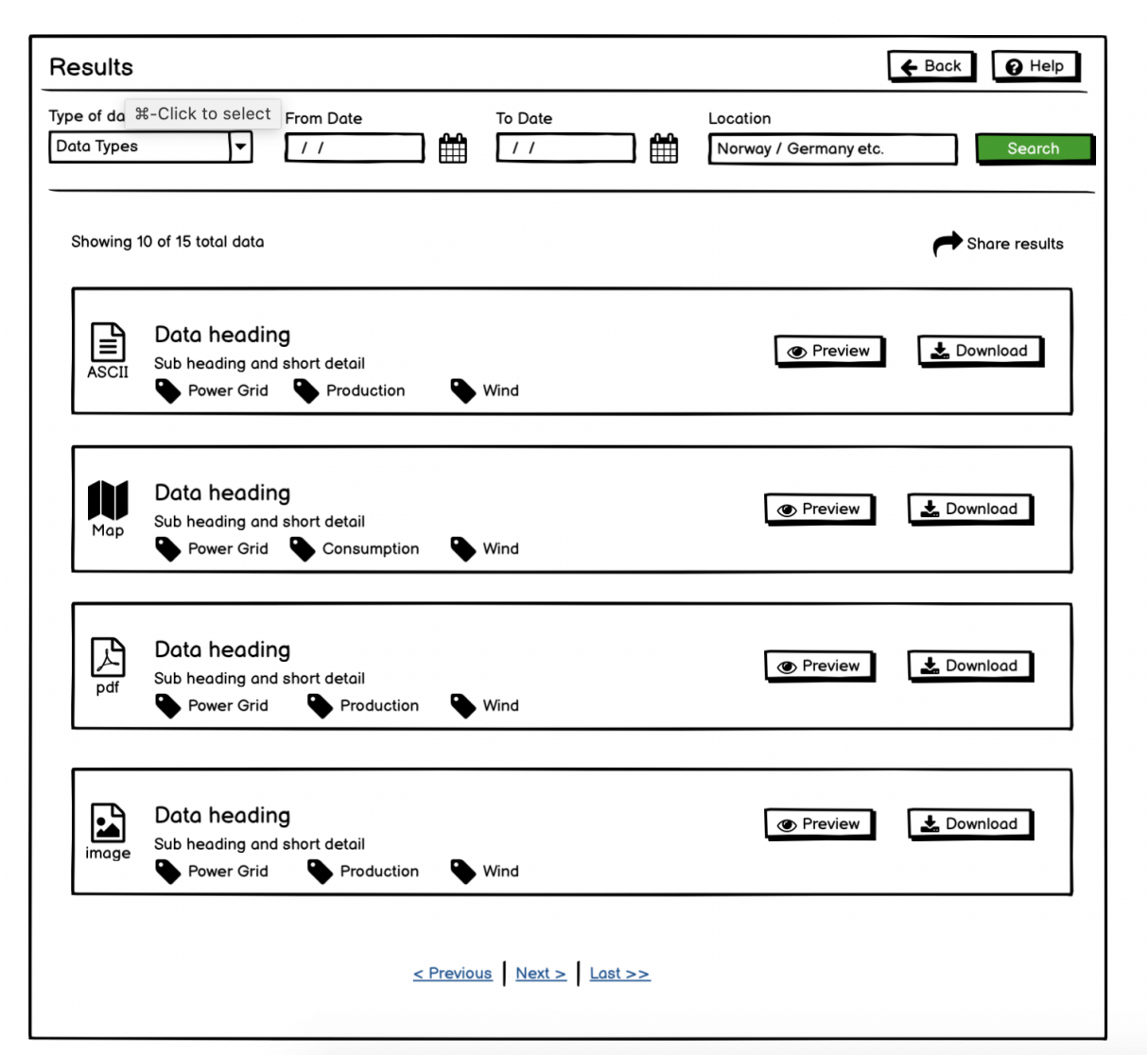


Figure 4.3: Results page of the paper prototype

search results. Each result had a title sub title or short description, tags and a option to preview the data and download the data. The page also had the form from the home page at the top. At the bottom of the results page, there was a section with pagination which helped to navigate the results if they are more than one page. The results page also had a back button at the top to go back to the home page.

Using Balsamiq, you can also interact with the paper prototype to mimic the final product. Those interactive elements were also added to the prototype. For example, you could fill the form on home page and click the button to go to the results page. Similarly, the form on the results page also could be filled up and the back button took the user back to the home page.

4.4 Interviews

The objective of the online interview was to understand the requirements and expectations of each of the stakeholders' groups and potential users in a detailed manner. Another objective of

the online interview was to get feedback on the paper prototype. Additionally, the interviews also had some questions for making personas. The guide for the interview can be seen in appendix E.

The interview was done with two participants. It was done using Skype [3] for the first participant and using Zoom[4] for second participant. The interviews were approximately one hour long. The participants were academic researchers who were then working on some research activities that involved power grid data.

The interview started with general introduction and setting the context and a formal consent was taken from the participants using a consent form. The consent form can be seen in appendix F. The interview consisted of both open ended and closed questions.

In the first part, some basic details about the participant and his/her work was collected. Questions included age, occupation, devices used by the participant. Moreover, some other questions addressed which operating system the participants used, top five websites and software they use frequently, for how long they use internet in their daily routine and what their internet speed is. These information were collected to make persona document that represents the participant.

In the second part, ethnographic observation of how the participants search for and use the power grid data. The participants shared their screen and gave a demo of where they look for power grid related data, how they download and use the data. Some more sources of power grid data were discovered during the interview. The participants also shared the problems they face while following their existing workflow.

Also, another objective of the interview was to get feedback on the paper prototype (see section 4.3). In the third part of the interview, the interviewer shared the screen and explained the workflow using the interactive paper prototype. The participants were asked to give feedback on the first paper prototype.

Finally, in the last part of the interview, the participants were asked to give general feedback, recommendations or features they wish to have on the application being developed.

The participants gave practical feedback. They are listed below -

- The date field does not make sense for all data types.

- It is impossible to make one size fits all solution for all kinds of power grid related data that are available online. Because the data is very heterogeneous in nature. A single preview option cannot work for all kinds of data. For example: some data are multiple files comma separated files available in github. Previewing just one single csv/ tsv file does not make any sense. And logically combining two or more files to do some experiment is what the researchers usually do. But, finding the github page can be very helpful.

- Sometimes the data you are looking for is a numeric value in the middle of a pdf file published by a TSO. That specific value is needed to make some simulation and perform experiments. Similarly, images produced by some other researchers can be helpful. They

[3] https://www.skype.com/en/
[4] https://zoom.us/

cannot be directly used in the experiment but the contents of the image give valuable insights.

- Many people prefer looking at a map based interface. But again, the data is heterogeneous in nature and all kinds of data cannot be displayed as a map.

4.5 Second paper prototype

After the interviews and based on the results of user research activities, the first paper prototype was modified to make an updated paper prototype. The results of the interview (see: 4.4) was used to inform the decisions made while revising and making second paper prototype.

Some updates were made in the first paper prototype based on the ethnographic observation done during the interview and the feedback we got from the participants. Some components on the form to initiate the search process on the main page were removed as suggested by the interview candidates. Fields for dates and location were removed because those fields were suggested not to be relevant for all kinds of data. A text field for entering the search keyword was added. Similarly, the preview and download buttons were removed from the results page because it was pointed out by one of the participants that making a preview feature that displays all kinds of data will be impossible and as most of the data sources are multiple files download button becomes irrelevant.

The results of the revised prototype can be seen below in figure 4.4 and 4.5:

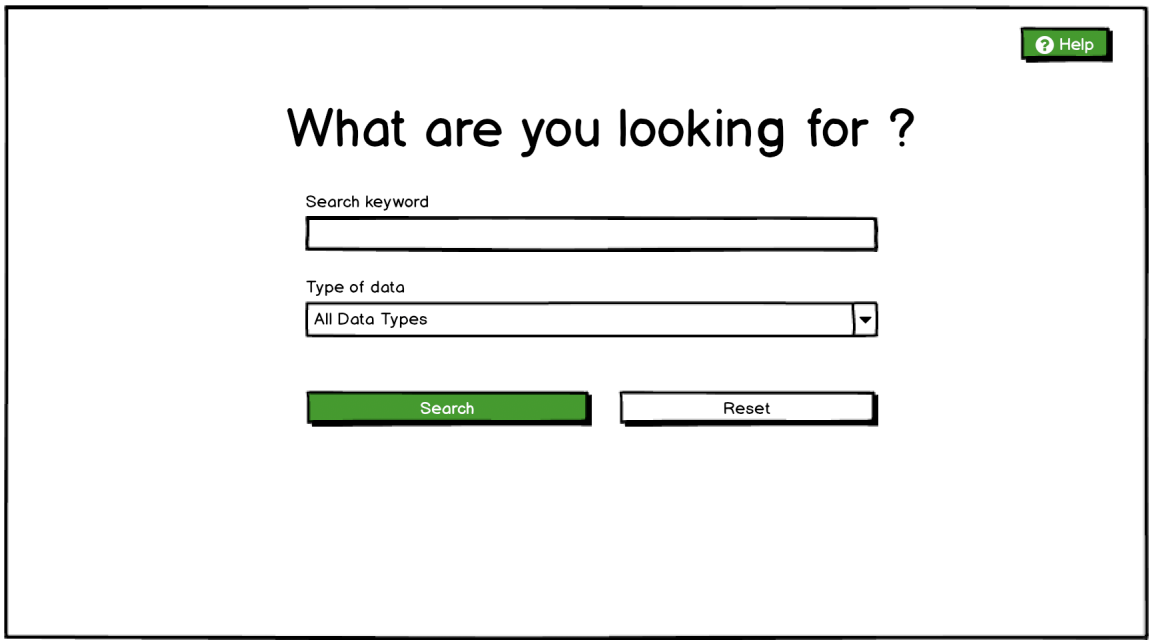


Figure 4.4: Main page of the revised paper prototype.

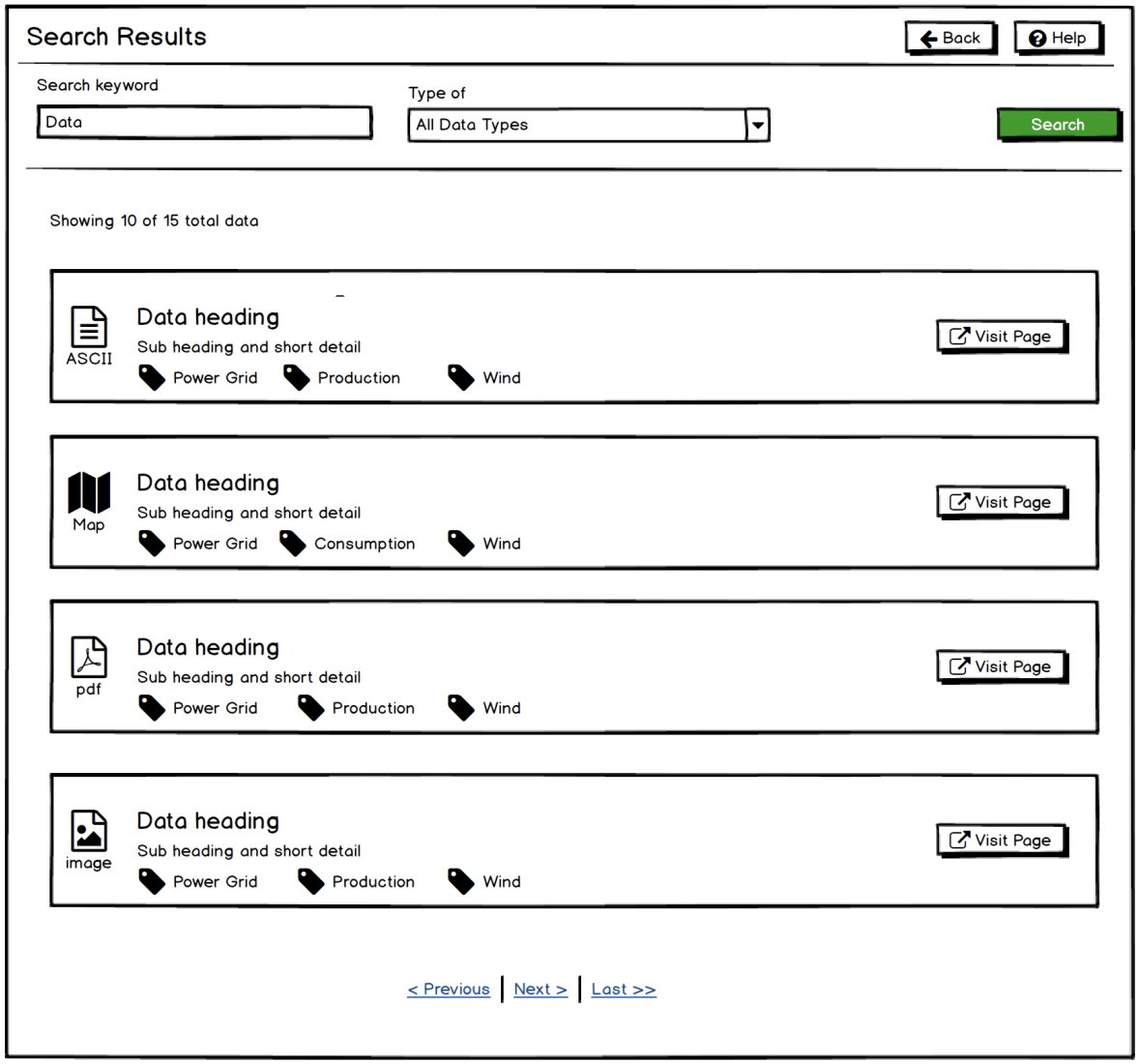


Figure 4.5: Results page of the revised paper prototype.

4.6 Personas

The results of the interviews and all other user research activities performed so far in the process was used to create persona. Maximum number of respondents on the survey (see section 4.1) were academic researchers. Also, both the participants interviewed for online interview (see section 4.4) were academic researchers. Academic researcher was therefore selected as one of the persona types.

The output persona can be seen in the figure 4.6. It has basic information like job title, demographics and location of John Doe, our fictional academic researcher. Further, the document also has a short bio of him. The document explains the goals, frustrations and motivation of a academic researcher to use the prototype this thesis is developing. The persona document also makes a note of John's experience level and his work environment.

Ideally, there would be a persona for each type of stakeholder. However, we have only got input from one type of the stakeholder, therefore only one persona has been made.

John Doe

Job Title	Demographics	Located
Researcher	Male, 38 years	Hamburg, Germany

Bio

John works as an academic researcher at a university. His research topics include power grid and related phenomenon. He does different experiments and simulations. He also supervises many master's thesis projects for students to carry out research in a similar subject matter. He also likes to build online tools that might be helpful to other researchers like him.

Goals

He gets power grid data from different online sources and writes code to use that data to perform his experiments.

Frustrations

The power grid-related data is too diverse in nature and it is very difficult to find the required data in a single place. He, therefore, has to spend a lot of time looking for appropriate data to perform his experiments.

Motivations

It would be great if he could find the data used by other researchers or the output of other research or commercial activities going around the world. This would make his work life so much easier.

Experience

- Expert at using computer
- Uses Ubuntu Operating System
- Uses internet 10-12 hours a day
- Never uses the mobile phone for work
- Frequently Used Software and website:
- Email
- Google.com
- Journal articles
- Github
- Internet radio
- MATLAB
- IDE for Python Programming

Photo Generated from: https://generated.photos/

Figure 4.6: Persona for academic researcher

4.7 Software prototype

The web application was divided into three major parts, i.e, the front-end, back-end and data from different sources. The overview of the application can be seen in figure 4.7.

The front-end part, was the main focus of this thesis. This is the part which was supposed to be visible to the end users and the end users were supposed to interact with this part of the

application to obtain the results as per their needs. The back-end, was a server-side application that computed the results as per the actions performed by the users in the front end. The back end also had a database that stored the data that the users interacted with. In addition to that, the database also had some additional data required for proper functioning of the application.

Some sources of openly available power grid data were identified from different literature and some sources were mentioned by the respondent of the survey performed earlier. Such data from different sources were different in nature. They belonged to different geographic locations and represented different components of the power grid system. Also, the data sources were of different nature and different file formats (e.g. ASCII, CSV, Images). The data sources were parsed and made uniform before they were stored in the back-end database.

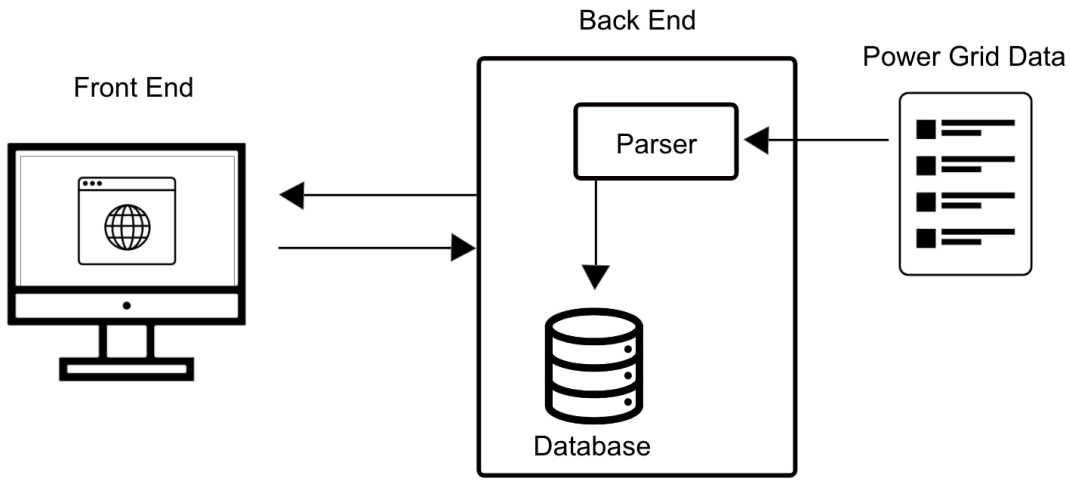


Figure 4.7: Sketch of the web application developed in this thesis.

A back-end system was developed using a tool called Strapi[5]. Strapi is a open-source content management system made in JavaScript (nodejs). It helped to rapidly develop the database and the API to support the functionality of the front end. Strapi also created the user interface to enter the data for the administrator of the application. The data entered in the back-end was served as API for the front end to interact with. Different sources of power grid data used by and pointed by different literature at different times which have been listed in table 2.1 in section 2.1 were also inserted in the back-end database of the software prototype. A preview of the back-end web application created using Strapi can be seen in appendix G.

The front end of the web application, which is the part that will be evaluated for usability and accessibility was developed using Reactjs [6]. It used a concept called styled components to make the user interface elements look and function in a consistent manner throughout the application. The home page and the results page from the revised paper prototype (see figure 4.4 and figure 4.5) was converted to a functional front end.

[5]https://strapi.io/
[6]https://reactjs.org/

4.8 Automated testing

While developing the software prototype, it was also tested for accessibility using automated testing tools. The WAVE Evaluation Tool[7] and Lighthouse Tool [8], which are additional extensions in the Google Chrome browser, were used. The prototype was tested for all the success criteria of WCAG 2.1. The automated testing performed using WAVE and the report generated by the Lighthouse tool can be seen in appendix H.

Only problem found was the background and foreground colors for the button to initiate search on the home page and the results page did not have a sufficient contrast ratio. It was immediately fixed. As automated testing did not take much time to perform and it could be immediately performed in the browser that is being used to view the prototype, the prototype was tested using this method every time after any change was made in it.

4.9 Heuristic testing

The objective of heuristic testing method in this study was to find the usability issues in the software prototype. For testing the prototype, Jacob Nielsen's 10 usability heuristics was selected. It was selected because Nielsen's heuristics are general purpose heuristics that can be used for testing almost all kinds of user interfaces. Unless, the interface being developed do not have any domain specific heuristics propounded, Nielsen's heuristics is usually the best choice.

In this study, the students who were doing master's degree in Universal Design of ICT at Oslomet - Oslo Metropolitan University were selected as experts. Some participants who were in the software development industry with experience in user interface design and development were also reached out and asked to help.

To conduct the heuristic testing activity, a web form titled "Heuristic Testing" was created in Nettskjema which had the information about the activity and form fields where the participants can write and submit the problems they found. The from can be seen in appendix I. The first page of the form had a basic introduction to the project and a question to ask for the consent to participate in the activity. The participants who gave their consent were taken to the second page. The second page had a link that opened an web page with details of Nielsen's ten heuristics. A graphics with summary of all those heuristics was also placed in the same page. Those details were placed there so that it would be a quick refresher to recall the heuristics for the participants. Below that, some example tasks were mentioned in the form so that it will be easy for the participants to get started with the evaluation process and to understand the flow of the software prototype. But the participants were not limited to those tasks. They could look at the prototype in the way they wanted. A pilot test of the procedure and the form was performed before it was sent to the experts for data collection. The form and the procedure was tested with one of the experts and updated to make to easy to understand for rest of the participants. There were five experts in total who evaluated the application using the given heuristics and

[7] https://wave.webaim.org/

[8] https://developers.google.com/web/tools/lighthouse

listed the problems. The summary of all the problems submitted by the participants can be seen in appendix J.

As the literature suggests, when using heuristic evaluation, only the aggregated results from all the participants are effective (Nielsen & Molich, 1990). The data collected from the experts was aggregated and duplicates and irrelevant problems were removed to make a list of problems to be fixed on the prototype. The list is as follows:

1. Pressing enter does not initiate the search:
    - Brought up by almost all evaluators
    - Heuristic 7 - Flexibility and efficiency of use
    - Heuristic 4 - Consistency and standards
    - Potential Fix- initiate search when enter key is pressed
2. What happens when the tags are clicked is confusing
    - Heuristic 10 - Help and documentation
    - Potential Fix - have a tool-tip that says what will happen when the tags are clicked
3. What happened when the tags are clicked is also confusing
    - Heuristic 1 - Visibility of system status
    - Potential Fix - Display a message or show an alert that says what happened when the tags are clicked
4. Open links in new tab
    - Heuristic 4 - Consistency and standards
    - Potential Fix - make links open in new tab
5. Nothing happens when data types picture is clicked
    - Heuristic 4 - Consistency and standards
    - Potential Fix - Make the images clickable and open the link
6. First time users get confused about the application and what to do
    - Heuristic 10 - Help and Documentation
    - Potential Fix- Some help and guideline for 1st-time users
7. Icons used in tags are confusing. Some evaluators did not understand the location icon and some did not understand the tags icon
    - Heuristic 2 - User control and freedom
    - Potential Fix - Have a text to explain what the icons or small buttons represent
8. Give feedback when the search is being processed

- Heuristic 1 - Visibility of system status
- Potential fix - Add a progress bar or a loader that indicates something is happening

9. Text “No results found” is not accessible for screen reader
    - Potential Fix - Fix accessibility issues
10. What to do when no results are found?
    - Heuristic 10 - Help and documentation
    - Add links to go back to the home page or give instructions to initiate a new search
11. Display Search suggestions
    - Heuristic 4 - Consistency and standards - all other search systems have this
    - Heuristic 7 - Flexibility and efficiency of use - it will be faster to search frequently searched keywords
    - Heuristic 9 - Help users recognize, diagnose, and recover from errors - will be easier for users with dyslexia
12. Search often returns no results
    - Potential Fix - Display the number of results that are there for each file types
    - Heuristic 7 - Flexibility and efficiency of use - it will be easier and faster to look for results
13. The text descriptions are really long and the text is small and difficult to read
    - Potential Fix- Increase the text size, display a short description by default with the option to display more if the users want to see more text.
    - Potential Fix -add an option to increase or decrease the font size
14. Clearing inputs in the search form is difficult / resetting the form
    - Heuristic 4 - Consistency and standards
    - Potential Fix - add an option to clear/reset the text in the search field

For each of the problems listed above, some work was done on the software prototype to fix the problems. The fixes done for each problem are listed below:

1. Pressing Enter key initiates the search
2. Added tooltip that shows what happens when the links are clicked
3. Added a box with text that says "Searching.." when the search in progress
4. Clicking on data type images opens the page linked
5. Added help and documentation in home page

6. Removed the icons and added labels in front of the list of location and icons
7. Removed icons and added labels before the list of tags and locations
8. Added a box with text that says "Searching.." when the search in progress
9. Made the text "No results found" accessible
10. Added instruction and link to go back to the home page when no results are found
11. Added help and documentation (Search Suggestions)
12. Added count of total results for the data type in parenthesis in the dropdown for selecting data type.
13. Displayed just 2 lines of description text and added a link to show more or less
14. Added a button to reset the search field

4.10 Discounted User Testing

The objective of the discounted user testing method was to find domain/ task specific problems in the software prototype within limited time and budget. Moreover, its results were also supposed to supplement the results of heuristic evaluation method.

For this method, actual end users were asked to participate. Academic researchers who are involved in research activities related to power grid were reached out for participation. For this method as well, a web form was created in Nettskjema. The form can be seen in appendix K.

The participants were provided with the link to access the web form. The web form had two pages. The first page included the introduction of the project and asked for the consent of the participants. The participants who agreed to participate were taken to second page. The second page of the web form had three sections.

In the first section, the basic information of the participants was collected. It included their occupation/ job title, device they are using for the activity, operating system they use and the web browser they are using.

Secondly, they were provided with an URL that opened the software prototype accompanied by some tasks to be performed. They were requested to open the software prototype in their browser and try the given tasks. They were also told that they were not limited to those tasks only. The participants were therefore free to perform other tasks as well. They were also asked to list down the problems they found while doing the tasks or while using the software prototype. The facilitator also took notes of the problems by viewing their screens and problems verbally reported by the participants. The notes have been summarized in appendix L.

The third section of the form was related to the research questions. The participants were asked whether they would use websites like the given software prototype. They were also asked whether an website like this will be beneficial for the stakeholders of power-grid field. Finally, they were asked to give feedback or recommendations for the prototype. The submissions made by the participants can be seen in appendix M.

There were three participants who participated the discounted user testing procedure. The procedure with the first participant was done by meeting the participant physically. The procedure with the second participant was performed over an online screen shared meeting using Zoom. The third participant used the instructions on the online form and submitted the responses without any help from the facilitator. It was therefore not possible for the facilitator to take notes for the third participant.

Most of the problems identified by the participants were domain/ task specific. It was more related to the data in the back-end rather than the user interface. Some of the suggested changes were implemented and some of the suggested changes are taken into consideration as future work.

4.11 Final Software Prototype

An screenshot of the final output can be seen in the figure 4.8. It has been hosted on a server and can be accessed by visiting **the web page** (`http://128.39.121.205/`) .

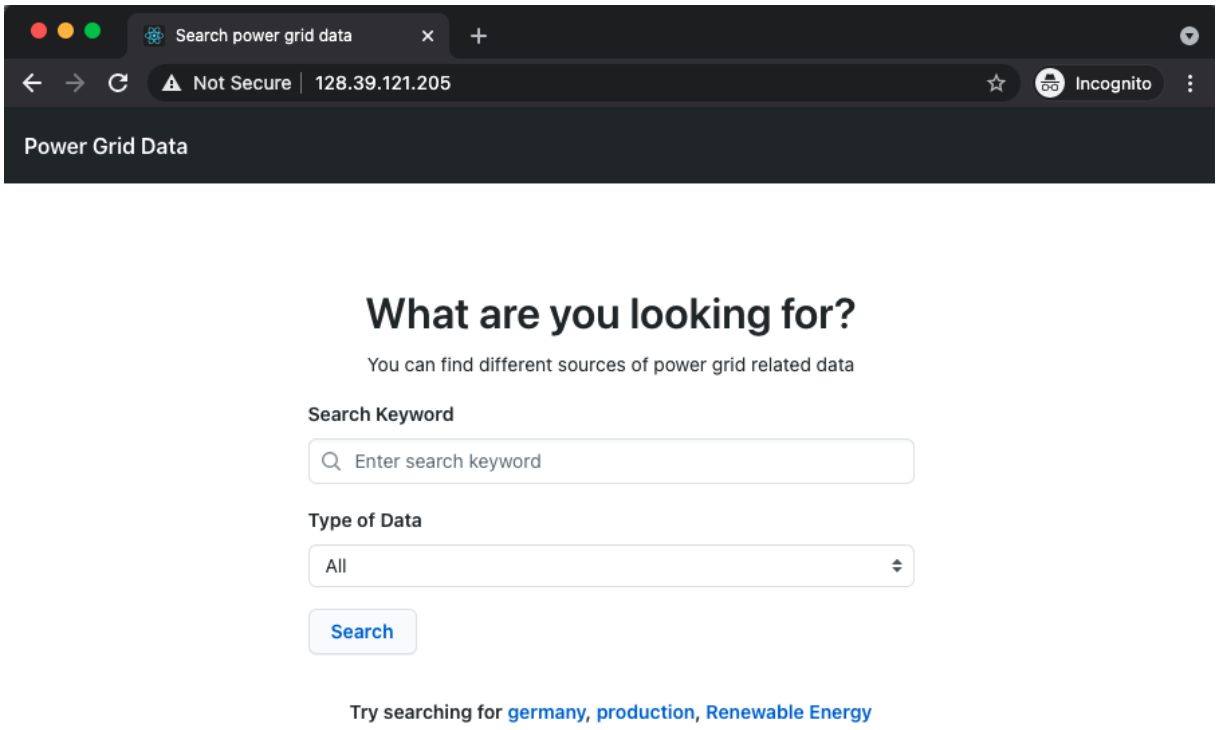


Figure 4.8: Final software prototype

Chapter 5

Discussion and conclusions

This chapter includes the discussion of results from different methods performed as related to the literature for accessible and usable web interface design, user centered design methodology and methods, power-grid data and its sources. This chapter also includes the discussion on how the findings of this study resembles or differs from other similar studies. Further, a discussion of the limitations of this study and topics for future research is also presented. In the end, this chapter concludes by answering the research questions.

5.1 Insights from the prototype development

This study approaches the problem power-grid sector is having i.e., not having a single place to search for power grid data, from the perspective user interface designer. This study performed different methods step-by-step as directed by the user centered design methodology to reach the final output which is a software prototype for web interface for power grid database. Results of each of the methods used have contributed to this prototype.

In the beginning of this study, we performed three methods for our qualitative research to better understand the problem so that a solution can be developed to solve the problem. Firstly, a literature review was done to understand the power grid domain. The results helped to understand the needs of the stakeholders of the power grid field. It also helped to create a list of different sources of power-grid data. Second, a survey was done to access the user requirements for power-grid data. Third, the results of the survey was analyzed using coding method.

The results of these three methods were used as input for creating a paper prototype. Interviews were conducted where the researcher observed how the participants look for and use the power-grid data from different sources. The participants also gave feedback on the paper prototype. Using the feedback from the participants, a second version of the paper prototype was made. Also, using the results of the interview, a persona was made to represent the end user which documented the profile of the participants, their bio, goals, frustrations and motivations.

Using the results of the methods and activities performed so far, a software prototype which is an web application where the users can search for power-grid data from different sources was developed. The automatic testing and heuristic testing was done to identify the accessibility and usability problems in the software prototype and the problems were fixed. Finally, a simple discounted user testing was done with the representatives of actual end users to evaluate the software prototype.

The results of different activities performed in this study indicate that including the end users from the very beginning of the design process is helpful. Moreover, it indicates that, by following

the user centered design (UCD) approach, user interface/ user experience practitioner with almost no prior domain knowledge can develop a usable solution even for complex domains like power-grid. These results are therefore in line with some of those previous studies which used UCD to develop a user interface (Becker & Yannotta, 2013; McKenna et al., 2016). Therefore, this study corroborates the idea of Mao et al., who suggested user centered design being one of the best approaches to follow to develop any system .

UCD is a conceptual framework with some defined principles to direct the design process. ISO/TC 159/SC 4 also defines four main activities to be done in the UCD design process, they are :

1. Understand and specify the context of use
2. Specify the user and organizational requirements
3. Produce design solutions
4. Evaluate designs against requirements

These activities just generalize and give a title to other sub-activities to be performed. It can be said that, these four main activities associate each of the methods performed to a bigger objective. Therefore, the methods and tasks performed while following UCD might be different for different projects and use cases. The researcher has tried to justify the reason behind selecting and using each of the methods used in this study. But, the same project can be done by following a totally different trajectory given that the factors like time, the size of team and budget and other resources remain same or different.

Literature review of the power grid field which was done in the very beginning of this thesis had two objectives i.e. understand the power-grid domain and make a list of sources of power grid data and to make a list of questions to be asked to the participants in the survey. The literature review proved effective to understand the domain and formulate the questions for the online survey. However, it was not very effective for finding data sources. Literature study of power-grid field done only during a limited time helped to find only a limited number of data sources. Finding a potential solution for this can be a issue for further extending the research to make the software prototype more effective. This is discussed more in the future work section of this chapter.

A number of research methods used in this thesis were found to be effective and hence supports the claims made in the literature about those methods. The survey & interview methods found to be very effective in discovering the domain specific contexts of use. Specially, interviews that were semi-structured was found to be very effective in learning the requirements and getting feedback from the participants. Similarly, the paper prototyping method helped to rapidly create and evaluate and modify the prototype. Using a software based prototyping tool made it even more easier and effective.

The results of some methods performed in this study validates some claims made in the literature in the past. For example, literature about the heuristic evaluation suggest that the heuristic evaluation performed by the participants who are experts of usability usually find more

user interface related problems but miss the task/domain specific problems (Hassan et al., 2019). The findings of this study also supports those claims.

Similarly, the results of the discounted user testing done with actual end users are in line with those of previous studies which also found that the user testing done with the actual end users helped to find more domain / task specific problems (Hassan et al., 2019). Moreover, these findings suggest that the discounted testing methods are very powerful and effective tools that can be used for small scale and low budget projects. Therefore, these methods can make the iterative approach, i.e. getting feedback from the users and updating the requirements and prototype frequently, possible with even for such projects. This is also in line with one of the principles of UCD discussed in (ISO/TC 159/SC 4, n.d.). These results provide further support for the hypothesis by Nielsen that discounted testing is not a choice but only option available to use for projects with limited resources because regular usability testing methods are very costly to conduct.

5.2 Challenges and Limitations

In this study, the major hurdle was finding enough participants for different activities conducted during the study. This study had 11 participants for in the survey, all of them were researchers. There were only two participants in the interview. There were five participants for heuristic evaluation who were not the actual end users but were usability experts. Similarly, there were three participants in the discounted testing activity.

For the usability testing activities, i.e. heuristic evaluation and discounted user testing, (Nielsen, 1997) Nielsen suggests 3-5 participants to be perfect number considering the cost-benefit-ratio of those methods. However, for other activities used for user research, it would have been better if there were more participants.

Not having enough participants of course has some implications in the end results as well. The initial literature review suggested that that are many stakeholder groups who are related to power-grid. But, in this study only the researchers participated. We therefore had only one stakeholder group whose requirements were taken into account in the design process. We therefore created persona for only one stakeholder group i.e. researchers. As discussed earlier, focus on audience and their needs is one of the benefits of using personas in the design process. In this thesis, the same benefit became one of limiting factors. The artifact presented as end result considers the inputs from only stakeholder group i.e. researchers, it therefore only fulfills the requirements discovered from that user group. However, there is also another perspective of looking at this. Some literature claim that - "the products that satisfy 100% of the needs of a few personas will have a great chance of success than products that serve 10% of the needs of the all encompassing ‘everyone’" (Miaskiewicz & Kozar, 2011). Evaluating the prototype for usability with other stakeholder groups can be an important issue for future research.

Some activities done in this study were used by slightly modifying them from their formal definitions. For example, to perform the ethnographic observation during the interview (See 4.4), users were asked to share their screen over an online meeting using Zoom or Skype. Similarly, during the discounted user testing, thinking aloud method was used (See 4.10) but it was slightly modified to remove the potential bias that might adulterate the results.

Moreover, for this study, some activities were performed via online mediums like Skype [1] and Zoom [2]. There are still many unanswered questions about the strengths and weaknesses of that approach because there are no relevant literature available so far that explains the implications of using online tools instead of face-to-face meeting.

This thesis uses a number of qualitative methods. As the qualitative methods are subjective in nature, the results and depends on how the participants perceive the questions and how the facilitator perceives the answers. Therefore, qualitative methods in general are criticized for being subjected to the researcher's and the participant's biases. It is therefore important that the observations are not adulterated by researcher's bias but the subjectivity of researcher is important part observation and interpretation (Adams, Lunt, & Cairns, 2008).

It is impossible to eliminate all these biases. However, some decisions made while designing some of the activities carried out in this study were done considering the biases that can be there and to reduce such biases. For example, in the survey and interview methods, open ended questions were asked. Such questions help to eliminate the acquiescence biases, i.e. simply answering yes/no to agree or disagree with the researcher, in the participants. Also, different questions were worded differently so that the participants would perceive and clearly understand similar but slightly different questions and answer specifically what was asked by the questions. Moreover, the researcher was aware about maintaining neutrality while asking and explaining the questions and verbally communicating with the participants so that the participant's response was not influenced. In addition to that, the researcher was also aware about the question-order bias and leading question wording bias while conducting the meetings with the participants. For analyzing the qualitative data, coding method was used which has a defined standard procedure that helps to eliminate the confirmation and other biases of the researcher. Also, making users the part of the design process and involving their input time and again in more than one phase of the design process helps to correct the wrong decisions that might have been made during some process.

5.3 Implications for future work

There are some recommendations and updates that needs to be made in the artifact presented as result of this study to make it more effective. Some of these updates were pointed out by the participants during the user testing activity whereas some of them are obvious next steps that were identified but have not been implemented yet in this artifact because of time constraint and complexity of the problems some of which are beyond the scope of this study.

Any search system is effective only if it has enough data in its back-end. This study has identified a number of sources of power grid data. However, there are more sources that needs to be identified and added in the back-end of the system. Moreover, some data sources become obsolete if they are not regularly updated. This is an important issue for further research. A solution that crawls the internet to find new data sources and automatically add the them to the back-end database of this solution and also update the existing data sources in the backed database with new records would help to answer our first research question more effectively.

[1] https://www.skype.com/en/
[2] https://zoom.us/

Moreover, the researcher of this study only found researchers of power grid field as the participants for user research. A new study can be done to test the artifact's usability and to the get the inputs from other stakeholder groups such as economists, environmentalists, sociologists, anthropologists, policy makers and more.

There also some additional topics that needs future work to be answered. For example - how do you rank the results available in the back-end database based on search keywords used and make the most relevant result appear at the top? Similarly, for a given source of power grid data, what meta information is to be saved in the back-end database of this system so that it will be found when the users search using relevant keywords? It can be the readme file, column headings, location information and more.

There are also some additional user interface components and functionalities that can be added in this artifact. For example - additional filter options, search by country/continent/location and more can be added. Similarly, one of our participants as pointed out that an option to exclude certain search terms or conditions in the user interface would be helpful. Also, a feature to save the search results for future use has also been pointed out by the participants. Each additional feature can be a new iteration which can involve user research, implementation and testing activities.

5.4 Conclusion

To recapitulate, there are two research questions this thesis tries to answer. They are -

- What are the different sources of power grid data and how stakeholders in the field of power grid will use the data?
- How can we address the data related needs of the users of power-grid field via an usable and accessible web based system?

The answer to the first research question is - Yes, this study has identified different sources of power grid data from different literature and has also studied how different stakeholders in the field of power grid will use the data by doing user research. The ways in which this question can be answered more effectively has been listed in the section 5.3 above.

Similarly, for answering the second research question, an artifact, which is a software prototype for "Accessible and usable web interface for power grid database", has been presented as the final output (see 4.11). This thesis identified the user requirements and developed the artifact to fulfill those requirements by following user centered design approach. Based on the feedback provided by the actual target users, it can be concluded that the software prototype developed in this thesis can address the data related needs of the users of power-grid field.

Appendix A

NSD assessment

The summary of assessment done by NSD is presented below.

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD's assessment

Project title

Accessible and Usable Web Interface for Power Grid Database

Reference number

982108

Registered

23.02.2021 av Sujan Devkota [redacted]@oslomet.no

Data controller (institution responsible for the project)

OsloMet – storbyuniversitetet / Fakultet for teknologi, kunst og design / Institutt for informasjonsteknologi

Project leader (academic employee/supervisor or PhD candidate)

Pedro Lind[redacted]@oslomet.no, tlf: [redacted]

Type of project

Student project, Master's thesis

Contact information, student

Sujan Devkota, [redacted]@oslomet.no, tlf: [redacted]

Project period

04.01.2020 - 31.07.2021

Status

21.04.2021 - Assessed

Assessment (1)

21.04.2021 - Assessed

Our assessment is that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 21.04.2021, as well as in correspondence with NSD. Everything is in place for the processing to begin.

SHARE THE PROJECT WITH THE PROJECT LEADER
For students it is mandatory to share the Notification form with the project leader (your supervisor). You can do this by clicking on "Share project" in the upper left corner of the Notification form.

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify NSD. This is done by updating the information registered in the Notification Form. On our website we explain which changes must be notified. Wait until

you receive an answer from us before you carry out the changes.

TYPE OF DATA AND DURATION
The project will be processing general categories of personal data until 31.12.2021

LEGAL BASIS
The project will gain consent from data subjects to process their personal data. We find that consent will meet the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed and unambiguous statement or action, which will be documented and can be withdrawn. The legal basis for processing personal data is therefore consent given by the data subject, cf. the General Data Protection Regulation art. 6.1 a).

PRINCIPLES RELATING TO PROCESSING PERSONAL DATA
NSD finds that the planned processing of personal data will be in accordance with the principles under the General Data Protection Regulation regarding:

lawfulness, fairness and transparency (art. 5.1 a), in that data subjects will receive sufficient information about the processing and will give their consent
purpose limitation (art. 5.1 b), in that personal data will be collected for specified, explicit and legitimate purposes, and will not be processed for new, incompatible purposes
data minimisation (art. 5.1 c), in that only personal data which are adequate, relevant and necessary for the purpose of the project will be processed
storage limitation (art. 5.1 e), in that personal data will not be stored for longer than is necessary to fulfil the project's purpose

THE RIGHTS OF DATA SUBJECTS
Data subjects will have the following rights in this project: transparency (art. 12), information (art. 13), access (art. 15), rectification (art. 16), erasure (art. 17), restriction of processing (art. 18), notification (art. 19), data portability (art. 20). These rights apply so long as the data subject can be identified in the collected data.

NSD finds that the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13.

We remind you that if a data subject contacts you about their rights, the data controller has a duty to reply within a month.

FOLLOW YOUR INSTITUTION'S GUIDELINES
NSD presupposes that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

Nettskjema is a data processor for the project. NSD presupposes that the processing of personal data by a data processor meets the requirements under the General Data Protection Regulation arts. 28 and 29.

To ensure that these requirements are met you must follow your institution's internal guidelines and/or consult with your institution (i.e. the institution responsible for the project).

FOLLOW-UP OF THE PROJECT
NSD will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!

Data Protection Services for Research: +47 55 58 21 17 (press 1)

Appendix B

Information letter sent to participants

A copy of information letter sent to the participants can be seen below.

Are you interested in taking part in the research project for developing an accessible and usable web interface for power grid database?

This is an inquiry about participation in a research project where the main purpose is to develop an Accessible and Usable Web Interface for Power Grid Database. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
The purpose of this project is to develop an online platform aimed at the different audiences interested in accessing and processing data sets from power-grid databases by following the guidelines of universal design. The main objective is to make the system easy to use, accessible, and usable for all stakeholders of power gird related fields. In particular, by following the guidelines of universal design approaches, this platform will be manageable also by users with special needs. This is a master's thesis project.

The objectives of this thesis can be summarized as two main research questions:

1. What are the different sources of power grid data and how stakeholders in the field of power grid will use the data?
2. How can we address the data related needs of the users of power-grid field via a usable and accessible web-based system?

Who is responsible for the research project?
OsloMet - Oslo Metropolitan University is the institution responsible for the project.

Project leaders / Supervisors:

1. Pedro Lind
   Professor
   OsloMet - Oslo Metropolitan University

2. Norun Christine Sanderson
   Associate Professor
   OsloMet - Oslo Metropolitan University

Student:
Sujan Devkota
Master's in Applied Computer and Information Technology (Universal Design in ICT)

Why are you being asked to participate?
You are being asked to participate in this study as one of the stakeholders on the power grid field. Your input is required to get some ideas from experts and stakeholders in the field of power-grid and implement them in the prototype to be built in this study. Your input will be helpful to learn which kind of input and output you would expect in such a platform. Your input will be helpful to understand and develop functionalities in the system accordingly.

What does participation involve for you?
If you chose to take part in the project, this will involve that you participate in online interview. It will take approximately 45 minutes. The procedure includes questions about power grid data sources and your experience with it. You'll also be asked some questions and given some tasks to be performed. You will be asked to share your screen and you'll be observed while you perform the given tasks. Your answers will be recorded electronically, notes will be taken.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- Only the student and the supervisors will have access to the collected data.
- The collected data will not include your name or contact details. And other inputs provided by you will be accessible only to the researcher and authorized personnel.
- Nettskjema (nettskjema.no), an online software for collecting data, will be used to collect the data.
- Zoom (zoom.us) will be used to conduct the online interview. The student will be logged in via the university account to conduct the interview.
- The participants will not be recognizable in any publications.

What will happen to your personal data at the end of the research project?
The project is scheduled to end by August 2021. All the collected data will be deleted after December 2021.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with OsloMet - Oslo Metropolitan University, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

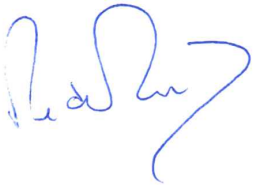
Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- OsloMet - Oslo Metropolitan University via Pedro Lind (pedrolin@oslomet.no).
- Our Data Protection Officer: Cecilia Roberts (ceciliar@oslomet.no)
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Project Leaders
(Researchers/supervisors)

Student



Appendix C

Questionnaire for survey of existing users

We did a questionnaire in Nettskjema (https://nettskjema.no/) called *"User Requirements Survey for Developing Web Based Database for Power Grid Data".* In this appendix the questionnaire as published in Nettskjema (https://nettskjema.no/a/146331) is presented.

User Requirements Survey for Developing Web Based Database for Power Grid Data

My name is Sujan Devkota. I am a student at Oslo Metropolitan University (Norway) and I am doing my Master's Degree in Applied Computer and Information Technology, specialization in Universal Design of ICT.

I am making an online platform aimed at the different audiences interested in accessing and processing data sets from power-grid databases. I will be following the guidelines of universal design. The main objective is to make the system easy to use, accessible, and usable for all stakeholders of power gird related fields. In particular, by following the guidelines of universal design approaches, this platform will be manageable also by users with special needs.

To implement my first prototype, I would like to collect some ideas from experts and stakeholders in the field and learn which kind of input and output you would expect in such a platform. Your input will be helpful to understand and develop functionalities in the system accordingly.

Answers, even if brief, on the following questions would be most welcome. Thank you in advance for all your help.

Do you agree to help with your inputs? Yes / No

If the users select yes for the following questions were displayed:

1. Do you have experience in using/constructing power-grid databases and/or interfaces which give access to power-grid data? In which quality do you use/construct them (e.g. researcher, policy-maker, other)?

_____

2. For which purpose do you use/construct such databases/interfaces?

_____

3. Are there any common drawbacks or lack of functionalities in such databases/interfaces?

_____

4. Are there any improvements in such databases/interfaces you think should be developed for better attend your purposes?

_____

Appendix D

Results of survey of existing users

We sent the questionnaire mentioned in Appendix C to the users via email and got some responses. The responses received so far has been presented below.

1. **Do you have experience in using/constructing power-grid databases and/or interfaces which give access to power-grid data? In which quality do you use/construct them (e.g. researcher, policy-maker, other)?**
   - In different roles in my career I used or considered the use of power grid databases.
   - Yes, I have experience as a researcher. I have been using openly available data and we are preparing a publication of an open data base on our own.
   - test
   - Yes, as researcher
   - I have used https://open-power-system-data.org/ multiple times. I am a researcher.
   - No
   - I am building a power-grid frequency database here: https://github.com/LRydin/Power-Grid-Frequency for research projects.
   - no, but would like to use them as a researcher
   - I use power grid data from different publicly available platforms, such as the ENTSO-E transparency platform. I need the data for my PhD thesis. researcher, teacher
   - - usage in research context, no experience in construction
2. **For which purpose do you use/construct such databases/interfaces?**
   - First as a researcher (1), then as an analyst (2) and as product manager (3). In the first one, I was interested in examining the fluctuation of the supply / demand as well as the fluctuation of prices in the spot market. In the second and third cases, I was interested in optimizing machinery usage, i.e. the balance of energy production and lifetime consumption of wind turbines for the given right demand / supply (and price of energy).
   - For scientific investigations and sharing data with others (mainly scientists)
   - test
   - Use for access data to calibrate models
   - Mostly energy system modeling and energy system analysis

- To model power grid dynamics
- Research only
- research on complex networks
- I use the data to analyze the statistical properties of power grids stability and operation.
- research, projects with data engineering students
- - obtaining benchmark/test cases - analysis of empirical properties of real-world power grids

3. **Are there any common drawbacks or lack of functionalities in such databases/interfaces?**
   - - Free open access time-series were limited. - Initial cost for validating the value proposition. - Real-time connection for decision making in the field was unclear from the documentation found.
   - Main problems evolve around finding the necessary data. Few scientists and articles release their data and if they do they are spread out throughout different journals and communities. Furthermore, recording and data format standards vary
   - test
   - Lack of combined data sets (from different databases) and establish a common time stamp.
   - Consistency. Data about industrial processes often missing.
   - In my knowledge, it is impossible to find different data sets at same time in one place.
   - Yes. For the aforementioned database, we have access to some publicly available data which we don't know the exact location of the measurement device, nor its specifications. The data, for example, from Continental Europe and the Nordic Grid is sampled at different time scales (10 sec, 1 sec, and 0.1 sec are a few examples)
   - no idea
   - 1) Some data has no open license. This is problematic, as it is unclear whether we are allow to re-published a processed version of the data. However, this is often desirable to avoid double processing work in the scientific community. 2) Some databases do not have an interface for automatic (machine-driven) download. One has to create complicated scripts to download large amounts of data. This could be avoided. 3) For some countries variable X is provided, for some it is not. That is also a problem, as it prevents consistent modelling of all locations. missing data.
   - - lack of easily accesible common data format - missing dynamics line/node parameters

4. **Are there any improvements in such databases/interfaces you think should be developed for better attend your purposes?**

- A simpler pay-as-you go for initial product development - Cloud access via API. - Data as a Service format.
- Set up a centrally accessible and visible node to link other data bases to. Conduct a study on how to link different data sources
- test
- Enable to save in single tables variables from different data sets and choose the desired format (e.g. csv, tsv, etc)
- More sectors, not just power, are important for modeling.
- A complete data base to include different data sets
- Must definitely. I have started to gather this, in my specific case, to make the data uniform across power grids, and ready for research usage. The data mainly needs a uniform format, with clear time sampling.
- node and link attributes (type, weights, coordinates, voltage levels)
- see above
- more open source data on shorter time scales
- - a good free import/export tool for CIM16(CGMES) in e.g. python

Appendix E

Guide for the interview

We did interviews with the potential users, subject matter experts, stakeholders or anyone who can use power grid related data. In this appendix the, the plan for the interview session is presented.

1. Introduction, get consent and set the context (Time: 10 minutes)
2. Basic Details (Time: 10 minutes)
    - Name
    - Age
    - Occupation / Job Title
    - Devices used
    - Devices used for work
    - Operating System
    - Internet speed
    - Top five websites you visit
    - Most frequently used software
3. Ethnographic Observation (Time: 15 minutes)
    a) Can you (on your computer or by sharing your screen) show me an example of you looking for power grid related data and also explain me how you use it?
    b) Follow up questions
4. Feedback on my first prototype (Time: 15 minutes)
    a) Open the interactive paper prototype on my own laptop and do some interaction and ask for feedback.
5. Additional feedback / recommendations (Time: 10 minutes)

Appendix F

Consent form for the interview

A consent form was made to get the formal consent from the participants of the interview. In this appendix, the consent form is presented.

Consent Form - Interview for Developing Web Based Database for Power Grid Data

My name is Sujan Devkota. I am a student at Oslo Metropolitan University (Norway) and I am doing my Master's Degree in Applied Computer and Information Technology, specialization in Universal Design of ICT.

I am making an online platform aimed at the different audiences interested in accessing and processing data sets from power-grid databases. I will be following the guidelines of universal design. The main objective is to make the system easy to use, accessible, and usable for all stakeholders of power gird related fields. In particular, by following the guidelines of universal design approaches, this platform will be manageable also by users with special needs.

To implement my prototype, I would like to collect some ideas from experts and stakeholders in the field and learn which kind of input and output you would expect in such a platform. Your input will be helpful to understand and develop functionalities in the system accordingly.

I request you to be part of an online or on-site interview with me and help with my research. Thank you in advance for all your help

Do you consent to be part of this interview?

[ ] Yes

Participant Id (To be filled by the interviewer.)

_____

Appendix G

Results of software prototyping - backend

We developed a backed for the web application during the software prototyping. It was made using Strapi and serves JSON API to the front end of the application. The results can be seen below:

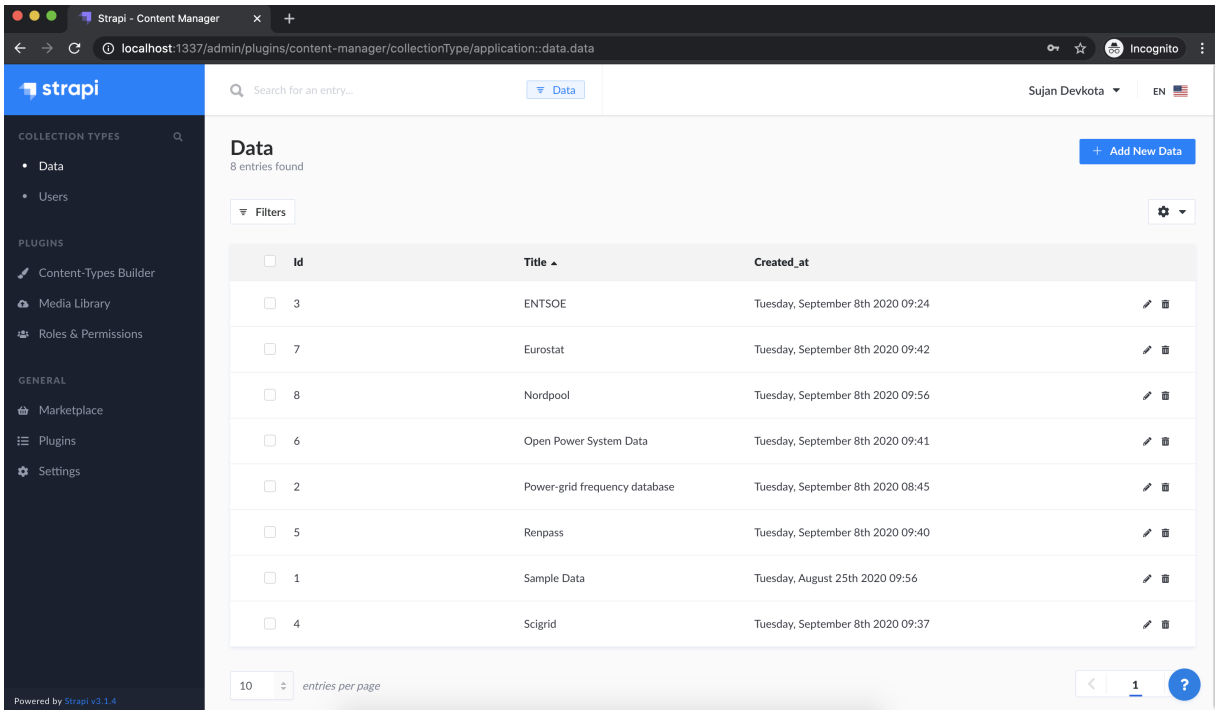


Figure G.1: The backend made using Strapi

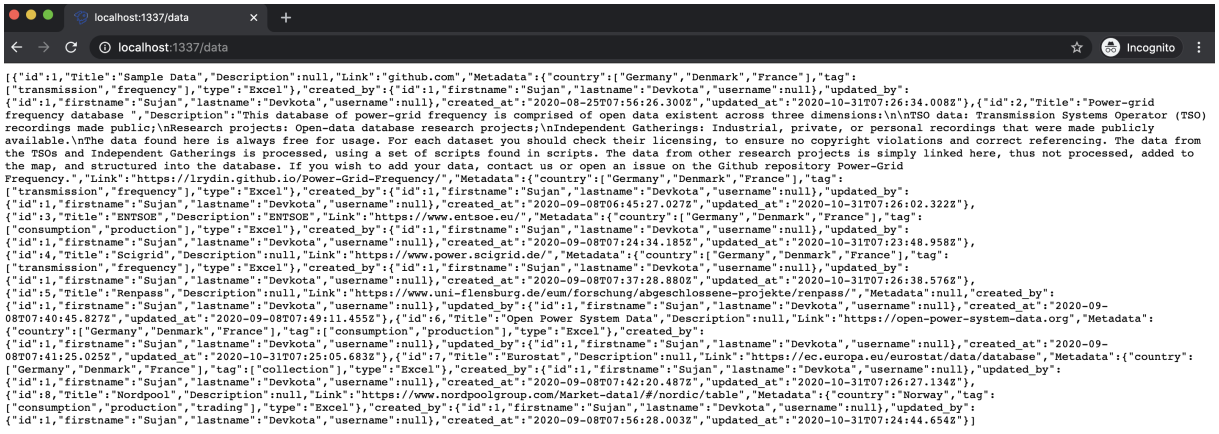
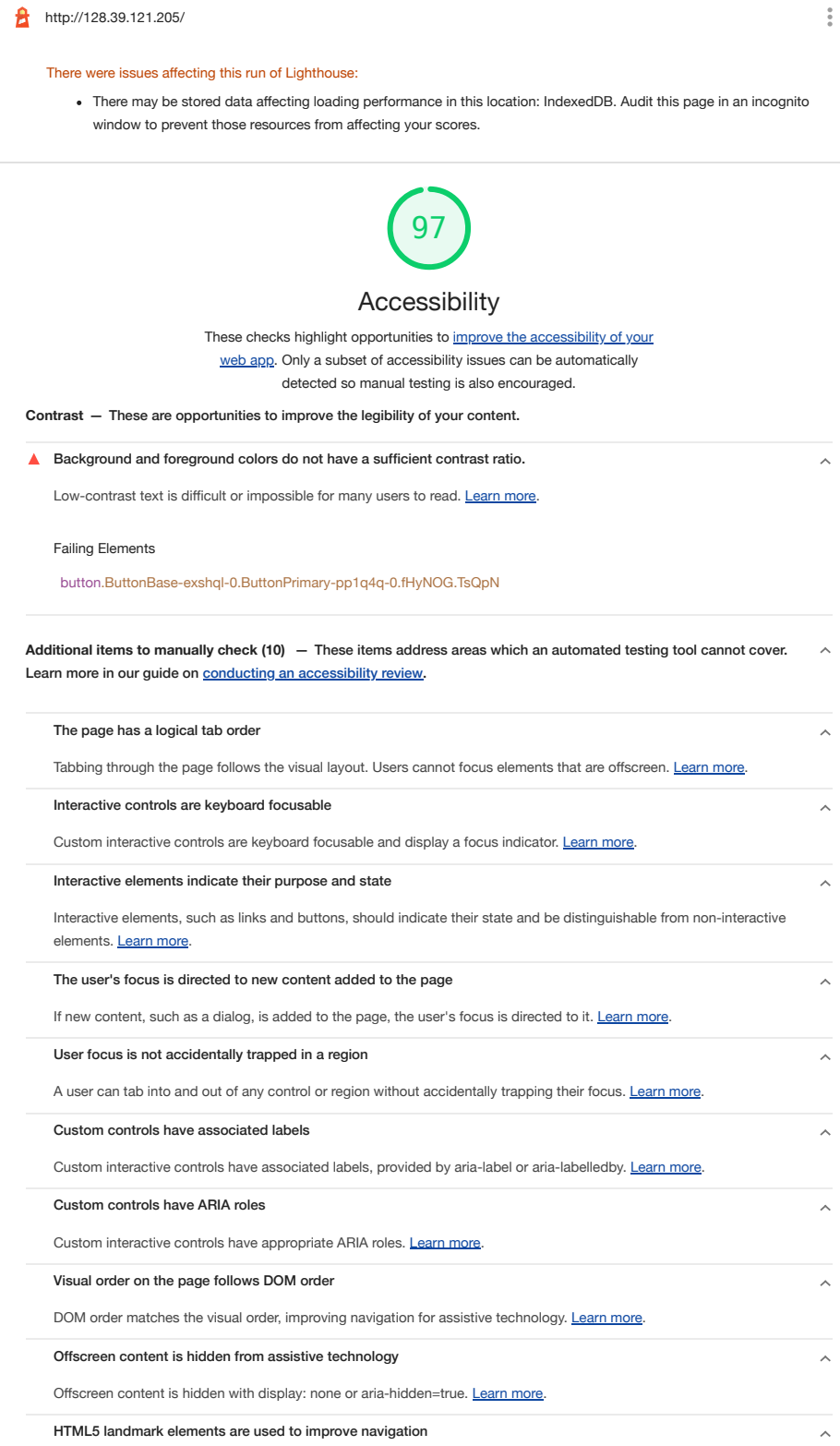


Figure G.2: The backend returning data in JSON format

Appendix H

Automated testing

Report of automated testing generated by Lighthouse tool in google chrome is presented here.



Landmark elements (<main>, <nav>, etc.) are used to improve the keyboard navigation of the page for assistive technology. Learn more.

Passed audits (14)

`[aria-*]` **attributes match their roles**

Each ARIA `role` supports a specific subset of `aria-*` attributes. Mismatching these invalidates the `aria-*` attributes. Learn more.

`[aria-hidden="true"]` **is not present on the document** `<body>`

Assistive technologies, like screen readers, work inconsistently when `aria-hidden="true"` is set on the document `<body>`. Learn more.

`[aria-*]` **attributes have valid values**

Assistive technologies, like screen readers, can't interpret ARIA attributes with invalid values. Learn more.

`[aria-*]` **attributes are valid and not misspelled**

Assistive technologies, like screen readers, can't interpret ARIA attributes with invalid names. Learn more.

Buttons have an accessible name

When a button doesn't have an accessible name, screen readers announce it as "button", making it unusable for users who rely on screen readers. Learn more.

The page contains a heading, skip link, or landmark region

Adding ways to bypass repetitive content lets keyboard users navigate the page more efficiently. Learn more.

Document has a `<title>` **element**

The title gives screen reader users an overview of the page, and search engine users rely on it heavily to determine if a page is relevant to their search. Learn more.

ARIA IDs are unique

The value of an ARIA ID must be unique to prevent other instances from being overlooked by assistive technologies. Learn more.

Heading elements appear in a sequentially-descending order

Properly ordered headings that do not skip levels convey the semantic structure of the page, making it easier to navigate and understand when using assistive technologies. Learn more.

`<html>` **element has a** `[lang]` **attribute**

If a page doesn't specify a lang attribute, a screen reader assumes that the page is in the default language that the user chose when setting up the screen reader. If the page isn't actually in the default language, then the screen reader might not announce the page's text correctly. Learn more.

`<html>` **element has a valid value for its** `[lang]` **attribute**

Specifying a valid BCP 47 language helps screen readers announce text properly. Learn more.

Form elements have associated labels

Labels ensure that form controls are announced properly by assistive technologies, like screen readers. Learn more.

Links have a discernible name

Link text (and alternate text for images, when used as links) that is discernible, unique, and focusable improves the navigation experience for screen reader users. Learn more.

`[user-scalable="no"]` **is not used in the** `<meta name="viewport">` **element and the** `[maximum-scale]` **attribute is not less than 5.**

Disabling zooming is problematic for users with low vision who rely on screen magnification to properly see the contents of a web page. Learn more.

Not applicable (26)

`[accesskey]` values are unique

Access keys let users quickly focus a part of the page. For proper navigation, each access key must be unique. Learn more.

`[aria-hidden="true"]` elements do not contain focusable descendents

Focusable descendents within an `[aria-hidden="true"]` element prevent those interactive elements from being available to users of assistive technologies like screen readers. Learn more.

ARIA input fields have accessible names

When an input field doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

`[role]`s have all required `[aria-*]` attributes

Some ARIA roles have required attributes that describe the state of the element to screen readers. Learn more.

Elements with an ARIA `[role]` that require children to contain a specific `[role]` have all required children.

Some ARIA parent roles must contain specific child roles to perform their intended accessibility functions. Learn more.

`[role]`s are contained by their required parent element

Some ARIA child roles must be contained by specific parent roles to properly perform their intended accessibility functions. Learn more.

`[role]` values are valid

ARIA roles must have valid values in order to perform their intended accessibility functions. Learn more.

ARIA toggle fields have accessible names

When a toggle field doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

`<dl>`'s contain only properly-ordered `<dt>` and `<dd>` groups, `<script>`, `<template>` or `<div>` elements.

When definition lists are not properly marked up, screen readers may produce confusing or inaccurate output. Learn more.

Definition list items are wrapped in `<dl>` elements

Definition list items (`<dt>` and `<dd>`) must be wrapped in a parent `<dl>` element to ensure that screen readers can properly announce them. Learn more.

`[id]` attributes on active, focusable elements are unique

All focusable elements must have a unique `id` to ensure that they're visible to assistive technologies. Learn more.

No form fields have multiple labels

Form fields with multiple labels can be confusingly announced by assistive technologies like screen readers which use either the first, the last, or all of the labels. Learn more.

`<frame>` or `<iframe>` elements have a title

Screen reader users rely on frame titles to describe the contents of frames. Learn more.

Image elements have `[alt]` attributes

Informative elements should aim for short, descriptive alternate text. Decorative elements can be ignored with an empty alt attribute. Learn more.

`<input type="image">` elements have `[alt]` text

When an image is being used as an `<input>` button, providing alternative text can help screen reader users understand the purpose of the button. Learn more.

Presentational `<table>` elements avoid using `<th>`, `<caption>` or the `[summary]` attribute.

A table being used for layout purposes should not include data elements, such as the th or caption elements or the summary attribute, because this can create a confusing experience for screen reader users. Learn more.

Lists contain only `<li>` elements and script supporting elements (`<script>` and `<template>`).

Screen readers have a specific way of announcing lists. Ensuring proper list structure aids screen reader output. Learn more.

List items (`<li>`) are contained within `<ul>` or `<ol>` parent elements

Screen readers require list items (`<li>`) to be contained within a parent `<ul>` or `<ol>` to be announced properly. Learn more.

The document does not use `<meta http-equiv="refresh">`

Users do not expect a page to refresh automatically, and doing so will move focus back to the top of the page. This may create a frustrating or confusing experience. Learn more.

`<object>` elements have `[alt]` text

Screen readers cannot translate non-text content. Adding alt text to `<object>` elements helps screen readers convey meaning to users. Learn more.

No element has a `[tabindex]` value greater than 0

A value greater than 0 implies an explicit navigation ordering. Although technically valid, this often creates frustrating experiences for users who rely on assistive technologies. Learn more.

Cells in a `<table>` element that use the `[headers]` attribute refer to table cells within the same table.

Screen readers have features to make navigating tables easier. Ensuring `<td>` cells using the `[headers]` attribute only refer to other cells in the same table may improve the experience for screen reader users. Learn more.

`<th>` elements and elements with `[role="columnheader"/"rowheader"]` have data cells they describe.

Screen readers have features to make navigating tables easier. Ensuring table headers always refer to some set of cells may improve the experience for screen reader users. Learn more.

`[lang]` attributes have a valid value

Specifying a valid BCP 47 language on elements helps ensure that text is pronounced correctly by a screen reader. Learn more.

`<video>` elements contain a `<track>` element with `[kind="captions"]`

When a video provides a caption it is easier for deaf and hearing impaired users to access its information. Learn more.

`<video>` elements contain a `<track>` element with `[kind="description"]`

Audio descriptions provide relevant information for videos that dialogue cannot, such as facial expressions and scenes. Learn more.

Runtime Settings

URL	http://128.39.121.205/
Fetch Time	Mar 6, 2021, 1:54 PM GMT+1
Device	Emulated Desktop
Network throttling	40 ms TCP RTT, 10,240 Kbps throughput (Simulated)
CPU throttling	1x slowdown (Simulated)
Channel	devtools
User agent (host)	Mozilla/5.0 (Macintosh; Intel Mac OS X 11_2_1) AppleWebKit/537.36 (KHTML,

	like Gecko) Chrome/88.0.4324.192 Safari/537.36
User agent (network)	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_14_6) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/84.0.4143.7 Safari/537.36 Chrome-Lighthouse
CPU/Memory Power	982
Axe version	3.5.5

Report of automated testing generated by Wave tool in google chrome is presented here.

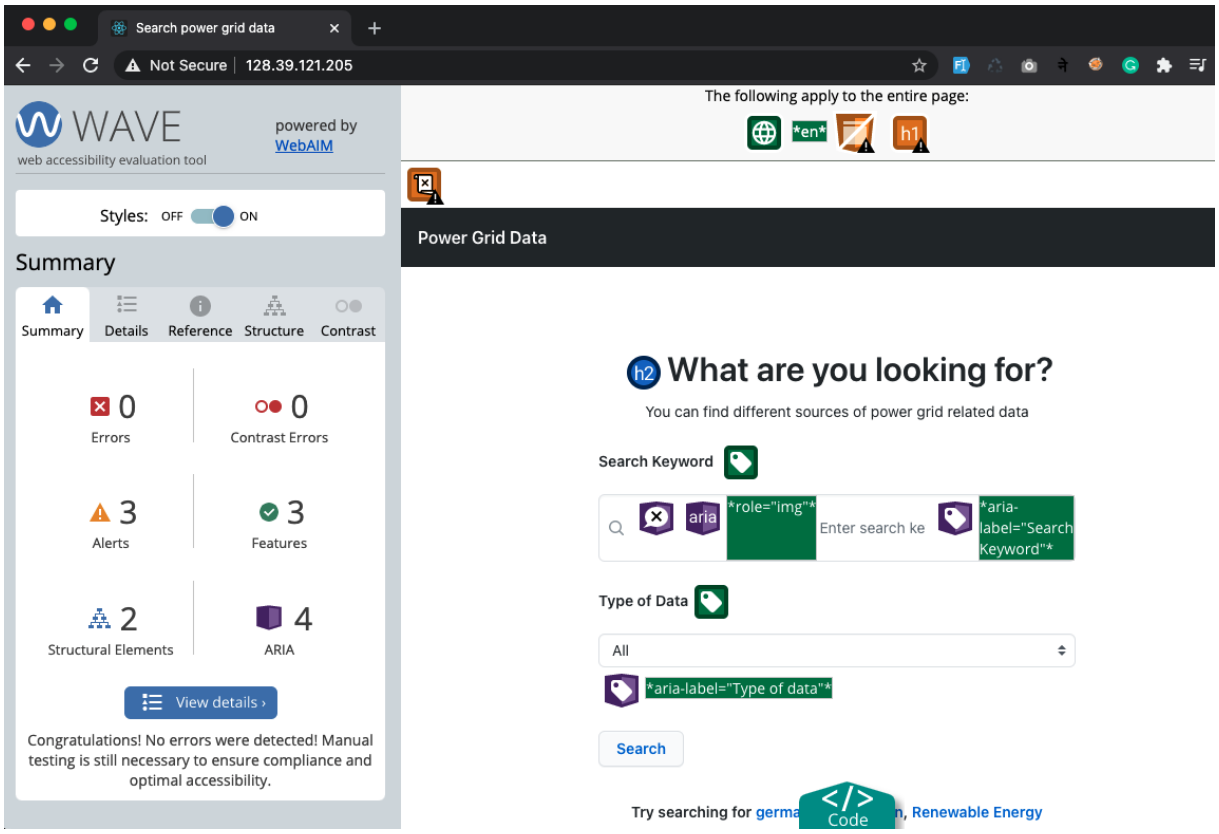


Figure H.1: Screenshot of automated testing using WAVE

Appendix I

Form for the Heuristic testing procedure

Form used for heuristic testing activity made in Nettskjema is presented here.

Heuristic Testing

Page 1

My name is Sujan Devkota. I am a student at Oslo Metropolitan University (Norway) and I am doing my Master's Degree in Applied Computer and Information Technology, specialization in Universal Design of ICT.

I am making an online platform aimed at the different audiences interested in **accessing and processing data sets from power-grid databases**. I will be following the guidelines of universal design. The main objective is to make the system easy to use, accessible, and usable for all stakeholders of power gird related fields. In particular, by following the guidelines of universal design approaches, this platform will be manageable also by users with special needs.

For the evaluation of the prototype I have developed, I would like your feedback as an expert in the field of universal design, accessibility, and usability.
Your input will be helpful to find out the problems in the prototype and fix them.

I request you to be part of the **Heuristic Testing** procedure with me and help with my research.

The procedure will be half an hour long.

Thank you in advance for all your help.

Do you consent to be part of this heuristic testing procedure? *

- ○ Yes
- ○ No

Page break

Page 2

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

The objective of this research is to address the data-related needs of the users of the power-grid field via a usable and accessible web-based system.

Application URL: http://128.39.121.205/

The application is to be tested using Jakob Nielsen's 10 Usability Heuristics for User Interface Design.
You can read the details about it here - 10 Usability Heuristics for User Interface Design.

All 10 heuristics have also been summarized in the image below.

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Evaluate the software prototype

(URL: http://128.39.121.205/) and list the problems below.

Example Tasks you can try doing:

- Find data from Germany
- Find data from Germany that is a Map
- Find data related to Trading
- Find all data of type Web

Problem 1

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

Problem 2

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

Problem 3

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

Problem 4

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

All Other Problems

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

write about the problems you found and suggestions on how to fix them (Optional - also write based on which heuristic)

Appendix J

Results of the heuristic testing form

The submissions made in the Nettskjema form for heuristic testing is presented here.

Evaluate the software prototype (URL: http://128.39.121.205/) and list the problems below. Example Tasks you can try doing:

- **Find data from Germany**
- **Find data from Germany that is a Map**
- **Find data related to Trading**
- **Find all data of type Web**

Problem 1 write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

- tooltip (#10? pro-active help) - info about what grey/green buttons do (eg. if narrow search or sort or new search)
- Based on 10, When we click the data, the link is directed to the website. User may get lost while searching for the information and could end up spending more time for the information. Help and documentation should be needed.
- Based on heuristic 2. Problem: The search interface has some information with icons along with results in each row. The small boxes with icons do not clearly indicate what they represent, one is a very common icon of location. The other one is not so meaningful. It might be problematic for those who don't know what those icons represent and what is being presented via the icons and keywords. Potential Fix: Add an extra information like location or keywords which collectively represents it.
- You can give feedback or suggestion when the system couldn't find any result based on the search text. i.e You can suggest how the user can fix the search key. I think this issue is related to Heauristc 1.
- When I am trying to click the "enter" button to search after I have written in a search query nothing happens. By activating the enter button you'd follow conventions that I am used to using every time that I use search fields such as google, yahoo, other search fields that uses enter button instead of me having to mouse click the button. So number 4

Problem 2 write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

- to be able to click enter to start search instead of click button (#7, #4?)
- Based on 2, In the landing page we see only keywords and types of data. But there is no description of what we are going to search. The only information provided is grid data. This can be solved by adding more information about the purpose of this application. So, before getting started the user will have general idea about what are the information that he is going to get from the next page.
- Problem: The results do not have a defined heading for each row. It can be assumed that the pictures with keywords like web/csv represent the type of data the link leads to. But a collective heading would make more sense. Same goes for the title in each results. Users can have problem in understanding what it is referring to. Potential Fix: Add collective header for each column in every row of results.
- I used JAWS 2018. 1811.30 ILM as a screen reader. The screen reader couldn't access the message 'No Results Found' after I click the 'Search' button with 'abc' search text (search key). This may be related to Heuristic 4.
- Since I am not really sure what's existing in the database a search suggest list that f. example google uses would indicate what type of data or keywords that I as a user can use. It would lessen my cognitive load, and also help me remember my previous searches. So that I don't have to double search for a term that I have already looked at. This for me falls under the usability heuristics 4 – since I am used to this from other search applications, 7 – cause it makes my work go faster, 9 – since the suggestions might help me if I struggle with dyslexia.

Problem 3 write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

- feedback about what happened when clicked grey button (#1)
- based on 4, I tried to search the data by pressing enter button, it did not worked. I needed to click the search button or use tab to select the search option. To make it accessible we should be able to access the files through only clicking enter button.
- Based on heuristic 7: Problem: Unable to get results after typing in search field and hit enter. (commonly used in many interfaces with search field) Potential Fix: Make it keyboard flexible to cover wide range of users.
- I also prefer to have an indication of how many files there exists of each type of data in the drop-down feature. That way I don't have to wonder about what exists and not, cause it is indicated in the list of data types what exists. For me this is tied to 1 and number 6. Cause right now I have no idea if there even exists a data file that is of type excel, so I have to manually search one round to figure out if it exists.

Problem 4 write about the problem you found and suggestions on how to fix it (Optional - also write based on which heuristic)

- maybe open link in new tab/window??? (but not sure which heuristic would be relevant)
- Based on heuristic 3: Problem: users have to delete the whole search field to clear the previous search. Potential fix: A clear/reset button to reset the search would be more flexible for users.
- The search button with the white text fails in contrast checking, so that is something that needs to be solved. By changing the text to black that issue would be solved. I am however not sure which heuristics this falls under, but I assume 4 is a good alternative as those who have a visual impairment might find this hard to see and might wonder what the button does.

All Other Problems write about the problems you found and suggestions on how to fix them (Optional - also write based on which heuristic)

- I am tempted to click the data type picture to go to result web page , but nothing happens (perhaps #4??)
- The problems that I found was based on evaluation criteria, 10, 2 and 4. For 1: This can be solved by adding more information about the purpose of this application. So, before getting started the user will have general idea about what are the information that he is going to get from the next page. For 2: It can be solved by adding more information about the purpose of this application. So, before getting started the user will have general idea about what are the information that he is going to get from the next page. For 3: To make it accessible we should be able to access the files through only clicking enter button.
- Some of the text descriptions are really long, so to lessen the cognitive burden I would either try to summarize the longer ones. This would help with no 7, and I would either use a bigger font size for the small text, or include a button where the user can adjust the text size. It is really small and I struggle to read the text without having to use the browsers zoom feature. Which again for me goes under no 7. It would also make me feel like no 3, that I am in control.

Appendix K

Form for Discounted User testing

A form made using Nettskjema for discounted user testing procedure can be seen below.

User Testing

Page 1

My name is Sujan Devkota. I am a student at Oslo Metropolitan University (Norway) and I am doing my Master's Degree in Applied Computer and Information Technology, specializing in Universal Design of ICT.

I am making an online platform aimed at the different audiences interested in **accessing and processing data sets from power-grid databases**. I will be following the guidelines of universal design. The main objective is to make the system easy to use, accessible, and usable for all stakeholders of power gird-related fields. In particular, by following the guidelines of universal design approaches, this platform will be manageable also by users with special needs.

For the evaluation of the prototype I have developed, I would like your feedback as a stakeholder of the power grid field.
Your input will be helpful to find out the problems in the prototype and fix them.

I request you to be part of the **User Testing** procedure with me and help with my research. The procedure will be half an hour long.

Thank you in advance for all your help.

Do you consent to be part of this heuristic testing procedure? *

- ○ Yes
- ○ No

Page break

Page 2

Occupation/ Job title *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Device Used (Laptop, Phone etc) *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Operating System *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Browser used *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Open the software prototype: http://128.39.121.205/ and use the software prototype.
You can do the tasks listed below but you do not have to be limited to these tasks only.

1. Search for production data
2. Search for data from Germany
3. Search for data related to trading
4. Search for map data
5. Search for keyword renpass and data type csv
6. Search for consumption data

Did you find any problems while doing the tasks? *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Would you use an website like this to search for power grid data? *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Do you think an website like this will be beneficial for the stakeholders of power-grid field? *

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Do you have any feedbacks or recommendations for this prototype?

This element is only shown when the option "Yes" is selected in the question "Do you consent to be part of this heuristic testing procedure?"

Appendix L

Notes form the discounted user testing

Notes taken by the facilitator during the discounted user testing procedure is presented below.

Participant 1

1. On the results page, highlight the search keywords
2. If the data type is multiple files, display list of files as well
3. Add location wise search option
4. Add categories such as wind power, solar
5. The search functionality did not find the keyword available in the readme file of the github repository.

Participant 2

1. Add a feature to tag/save the results for later use
2. Display a map for location based data
3. Include Reports you can get from different sources. But reports often contain aggregated data as well that might cause duplicates.
4. Filter out feature would be helpful. For example: option to exclude certain search keywords or results while searching.
5. User Interface can be more flashy
6. Include data from https://www.re3data.org/ as well
7. Include license information of the data.

Participant 3

Participant 3 submitted the response without any help from the facilitator.

Appendix M

Results of the discounted testing form

Results of discounted user testing Nettskjema form has been presented here.

Q1. Occupation/ Job title *

- Professor
- Researcher
- Research Fellow

Q2. Device Used (Laptop, Phone etc) *

- Laptop
- Laptop
- Laptop

Q3. Operating System

- Linux (Ubuntu)
- Linux (Ubuntu 20.04)
- Windows

Q4. Browser used *

- Firefox
- Chromium
- Chrome

Q5. Open the software prototype: http://128.39.121.205/ and use the software prototype. You can do the tasks listed below but you do not have to be limited to these tasks only.

1. Search for production data
2. Search for data from Germany
3. Search for data related to trading
4. Search for map data

5. Search for keyword renpass and data type csv
6. Search for consumption data

5.1. Did you find any problems while doing the tasks? *

- 1. (and 6.) Ok, but with other typical words may not function, e.g. "wind power consumption" 2. It works for "Germany", but not for other countries also in some of the data, e.g. Belgium. See "Conventional power plants" of "Open Power Grid Data" (README file) 3. Ok for "trading" 4. Okfor "map" (="map data"?). It does not detect the existence e.g. of .xlsx-files in OPen Power Grid Data datasets 5. No results are retrieved
- Search by tags, i.e., similar to "Types of data" with a dropdown menu; For the moment, the ability of the users to add tags to an entry, if they find a tag suiting (monitored later by admin.); Additive filtering, i.e., select more than one filter at a time, e.g. to search for all data, expect something specific (reports, maps),
- Some problems: Searching for "consumption " yields no results. Consider auto-deleting spaces I would have expected that searching by regions, e.g. "CE" or "Nordic" also works

5.2. Would you use an website like this to search for power grid data? *

- Yes
- Must certainly
- Yes

5.3. Do you think an website like this will be beneficial for the stakeholders of power-grid field? *

- Yes, perhaps. Complementary to another platform with software having the models for power grid data modelling.
- For research purposes, yes.
- Yes

5.4. Do you have any feedbacks or recommendations for this prototype?

- See above.
- Try to connet this to other databases (re3data.org); For some particular items, add/include the license (for .csv files).

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