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Testing Protocols for Self-Contained Emergency Lighting

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Abstract

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The purpose of this thesis work was to improve the existing testing capabilities of Teknoware OY, with a specific focus on self-contained emergency luminaires. Comprehensive testing is needed to ensure that products perform as intended, necessitating the development of a good testing plan.

Although adherence to differing electronics standards, such as IEC 60598-1 and IEC 61347, is required in the design of the product, the tests outlined in this template do not evaluate compliance with these standards. Instead, the focus is exclusively on determining whether the device under test operates as intended by its designer.

Furthermore, expanding and refining the use of functionality testing provides a solid steppingstone for future development into more complex and specialized areas of testing, including compliance with electromagnetic compatibility (EMC) regulations.

The primary outcome of this thesis is a testing template designed to verify the functionality of various embedded systems produced by Teknoware's emergency luminaire department.

Keywords: testing, emergency luminaire, safety, hardware

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Tämä opinnäytetyö on suunniteltu parantamaan Teknoware Oy:n olemassa olevaa testauskapasiteettia luomalla yksityiskohtainen toiminnallisen testauksen suunnitelma yksikkövalaisimille.

Testaus on tarpeellista varmistamaan, että tuote toimii kuten suunnittelija on sen tarkoittanut toimivan. Tämän toteuttamiseen tarvitaan perusteellinen suunnitelma.

Vaikka erilaisia standardeja, kuten IEC 60598-1 tai IEC61347, tulee noudattaa tuotteen suunnittelussa, tämä testaussuunnitelma ei ota kantaa siihen, onko suunnittelija näitä noudattanut, vaan lopputulos keskittyy varmistamaan, että tuote toimii kuten suunnittelija on halunnut sen toimivan.

Toiminnallisen testauksen laajentaminen ja selkeyttäminen toimii hyvänä lähtökohdana edistämään tuotetestausta erilaisiin ja vaikeampiin aiheisiin tai aihealueisiin, kuten EMC-säädösten noudattamiseen.

Opinnäytetyön lopputulos on testaussuunnitelma, jonka avulla voidaan varmistaa Teknowaren turvavalvosaoston tuottamien erilaisten sulautettujen järjestelmien toiminnallisuus.

Avainsanat: testaus, turvavalvostus, turvallisuus, laitteisto

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List of Abbreviations

AC:	Alternating Current
CBS:	Central Battery System
CE:	conformité européenne standard
DC:	Direct Current
DUT:	Device Under Test
ELD:	Emergency Lighting Department
KBV:	Keysight Bench Vue application
LED:	Light-emitting diode
LiFePo:	Lithium Iron Phosphate (Battery)
PAN ID:	Personal Area Network Identifier
PCB:	Printed circuit board
SCS:	Self-contained System
Ω :	Ohm. Unit of electrical resistance

1 Introduction

This chapter will give an overview of the thesis's foundation, purpose of the work and motivations for writing it. Subchapter 1.1 will give an overview into the company for whom this work is carried out for and the state of testing before this work was started. Subchapter 1.2 clarify the purpose and the need for this work.

1.1 Starting Point

Teknoware as a company is split into subdivisions, these are the Rail department handling LED-lighting for trains, Road department that works on LED-lighting fixtures for public transport such as busses or coaches, and Emergency lighting department (hereafter referred to as ELD), which focuses on emergency lighting solutions for buildings and cruise ships [1]. From this point forward any reference to Teknoware will be specifically to ELD as this is the department for whom this work was carried out for. Teknoware's testing has been improving in many areas over the past few years but like with any new change to a process, there have been some problems. Mainly it seems these have been stemming from a lack of digital documentation of different processes and design methods, leading to multiple situations where roadblocks could only be solved through institutional knowledge that has not been formalised, held by experienced employees rather than documented procedures. This poses a significant challenge when considering that several people that have been crucial in the development of core products are approaching retirement. This leaves Teknoware and its lack of digital documentation susceptible to key person dependency where reliance on specific individuals as a single point of expertise can turn these valuable designers into a single point of failure, in case of an accident or departure from the company. [2]

1.2 Motivation and Goals

Main goal of this thesis is to formalise a style of test reporting that brings certifiable data to the table by asking and answering unambiguous questions that different engineers with varying interpretations can agree on. As one significant problem observed in Teknoware's preproduction testing is a significant difference in similar reports, depending on which one of the engineers performed the tests. Moreover, unifying the style of a report can make the project managers task more manageable, as they can have a higher degree of confidence in the results. There have been several incidents where test reviews have been cancelled early as a result of not having verifiable testing data, leading to time wasted and frustration.

2 Emergency Luminaire

Emergency Luminaire is a type of lighting fixture, independent of the building's main power supply, that is designed to provide illumination for evacuation during a building's main alternating current (AC) power outage due to unforeseen events such as a fire or an earthquake. This type of lighting is codified into building regulations [3] to ensure that safety standards are met. The presence of emergency luminaires is important for enhancing safety in public buildings where an emergency, such as a fire breaking out, can easily create panic among a large gathering of people. In the event of a power outage during any type of unforeseen event, the emergency luminaire will provide a visible exit path to escape from danger ensuring that people know where to go, thus reducing the chances of people getting injured. To achieve this, emergency luminaires are installed in strategic locations, such as stairwells, hallways, and near exits. These luminaires can be divided into two different categories based on their operational modes that are explained in more detail in sections 2.1 and 2.2, while sections 2.3 and 2.4 cover the methods by which these luminaires are powered and controlled [4].

2.1 Non-maintained Emergency Luminaire

Non-maintained emergency luminaires are specialised lighting fixtures that remain off while a building's normal power grid is operational, activating only during a power failure. These lights are useful in supporting safe evacuation by illuminating key areas when regular lighting systems fail. Unlike maintained luminaires, which are always on, non-maintained emergency lights are designed specifically to switch on during emergencies and are placed along escape routes leading out of the building [5].

The use of this type of luminaire is prevalent in high-occupancy environments, such as commercial buildings, industrial facilities, and public transportation hubs, where regulatory standards mandate emergency lighting systems for occupant safety. The placement of these luminaires is carefully planned by a civil engineer with the help of a fire safety marshal to maximize visibility, ensure the adherence to differing regulations, and facilitate an orderly evacuation. Non-maintained luminaires are not only installed indoors along evacuation routes but are also often placed outside in designated assembly points, enabling people to gather safely, and facilitating medical assistance if needed. This outdoor installation can be particularly useful during dark winter nights when visibility is low, as it provides clear guidance to individuals who may be disoriented and helps them locate the predetermined safe area.

Non-maintained luminaires that are powered by built-in batteries or capacitors, are called self-contained luminaires. These charge under normal power conditions and then supply the necessary energy to light the fixture during an outage. The durability and performance of these power sources are important for ensuring compliance with safety standards, which typically require emergency luminaires to stay lit for at least one hour when disconnected from the main power supply. However, this requirement can be extended if the exit route is long or unclear, as assessed by a fire marshal. Many models are already designed to exceed regulatory minimums and to provide illumination for extended periods to ensure they are fit to task, even if the safety regulations change,

Modern non-maintained luminaires are built with LED technology, as this is more efficient and have a longer lifespan and are more cost effective when compared

to alternatives such as a fluorescent tube. Proper LED lights allow these fixtures to operate effectively for years with minimal maintenance. Regular testing, as outlined by standards such as SFS-EN 50172 [5] is also necessary. Monthly and annual inspections are needed, to confirm that each luminaire is operational and that its backup power source can meet the required performance levels. This is often done by the luminaire itself, independent of an actual maintenance service provider. The combination of planned placement, and recurring testing makes non-maintained emergency luminaires a big part of safe building design, especially in spaces where safety and regulation compliance are needed.

2.2 Maintained Emergency Luminaire

Maintained luminaires are lighting fixtures designed to remain illuminated during normal operational hours and to continue functions in the event of a power failure. This dual-purpose capability ensures that essential areas within a building are consistently lit, enhancing safety and visibility. Unlike their non-maintained counterparts, maintained luminaires serve as both general lighting and emergency lighting. Figure 1 shows an example of a maintained emergency

luminaire



Figure 1. Maintained emergency luminaire installed atop a door.

These types of luminaires are codified into building regulations in public settings such as hospitals, schools, and retail spaces, where constant illumination is needed for both daily activities and emergency situations. Their continuous operation is aimed to reduce confusion during an evacuation, as occupants that are unfamiliar with the layout can navigate more easily in low-light conditions. The placement consideration of maintained luminaires is determined by civil engineers in consultation with safety professionals, such as a fire marshal, ensuring that they meet specific visibility requirements and compliance standards.

To provide illumination during an emergency, maintained luminaires are equipped with backup systems, such as a central battery system that activates automatically during a main AC power outage. This design ensures that they remain lit even when the main power supply is interrupted, adding to an overall sense of safety for occupants.

Regular maintenance checks and performance evaluations are still necessary, but the reliance on LED technology means longer intervals between servicing. Moreover, the integration of smart technology into maintained luminaires is becoming increasingly common. Features such as self-testing capabilities and remote monitoring allow building administrators to receive updates on the status of the luminaire system. This approach not only enhances safety but also streamlines maintenance efforts, as issues can be addressed before they become serious.

Maintained luminaires play a central role in creating a safe and well-lit environment for occupants, combining the functions of standard and emergency lighting. Their performance and design thus contribute to improve building safety standards.

2.3 Central Battery System

Maintained and non-maintained emergency luminaires often use the same power source, be it central battery system (hereafter referred to as CBS) or as a self-contained unit. CBS is a modular series of batteries usually placed in a maintenance wing of a building. This system then monitors and powers all the emergency luminaires in a given building. These systems can further be divided into addressable and nonaddressable systems depending whether they can give direct commands to a luminaire and gather data on their status or not. Often these types of systems are used when a buildings regulation demands a large number of emergency luminaires to be connected. CBS can be quite clearly equated to a fuse box in the way fuse boxes control electricity; CBS controls the emergency luminaires of a building. As these types of systems are designed to handle at most thousands of emergency luminaires, they can very easily be quite costly. Therefore, many civil engineers do not prefer them for smaller building projects. To connect the CBS to each luminaire, a fireproof cabling is needed. This has caused issues in recent years as the cost of manufacturing has increased dramatically. One CBS can provide addresses and backup power for hundreds or even thousands of luminaires depending on the model. Figure 2 gives a rough example of this with four different named luminaires.

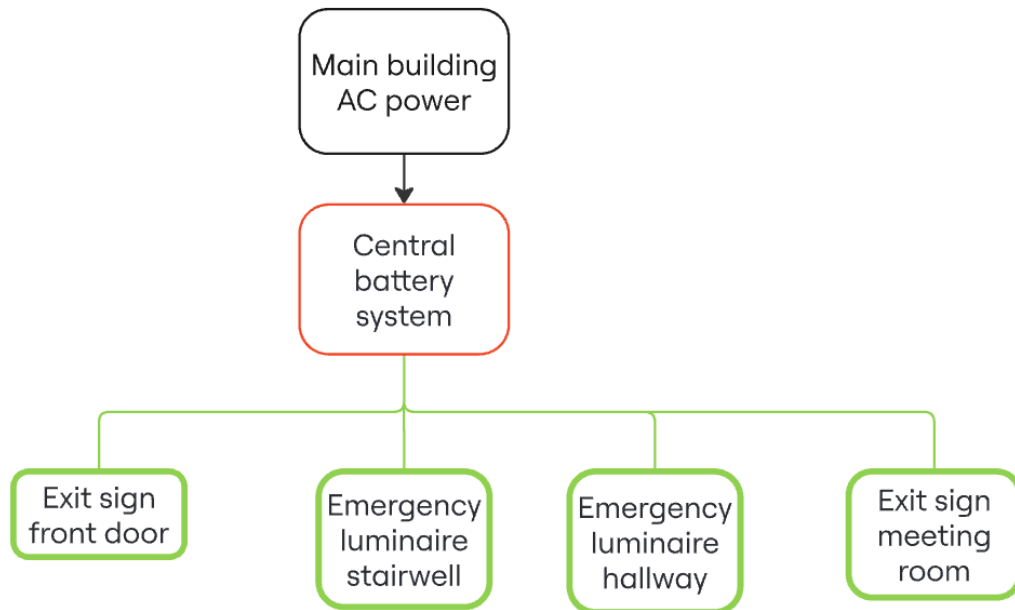


Figure 2. Block diagram of a CBS system with example luminaires.

CBS to luminaire wiring can handle data and power, the cabling also has to be fireproof.

2.4 Self-Contained System

Self-contained System or SCS is a system that does not rely on an outside power bank or controller, meaning it is self-sufficient. The SCS is comprised of a battery, usually LiFePo4 or a supercapacitor to power itself. These systems are controlled using a radio module as opposed to the expensive fireproof cabling that CBS requires [4,71]. Considering these factors, small scale deployment is a lot more straightforward, but this does come with some trade-offs. Mainly this seems to stem from the unreliability of wireless systems in casing that negatively affects the radio waves emanating from the radio module. SCS is often seen as a spurious version of the more expensive and larger CBS. This misconception seems to be originating from users seeing low-cost imports coming from Asian countries with little to no quality control, as the SCS is easy to connect directly to a buildings main AC supply without requiring any outside control of it. Figure 3 is

a block diagram of how power is distributed among a self-contained luminaire.

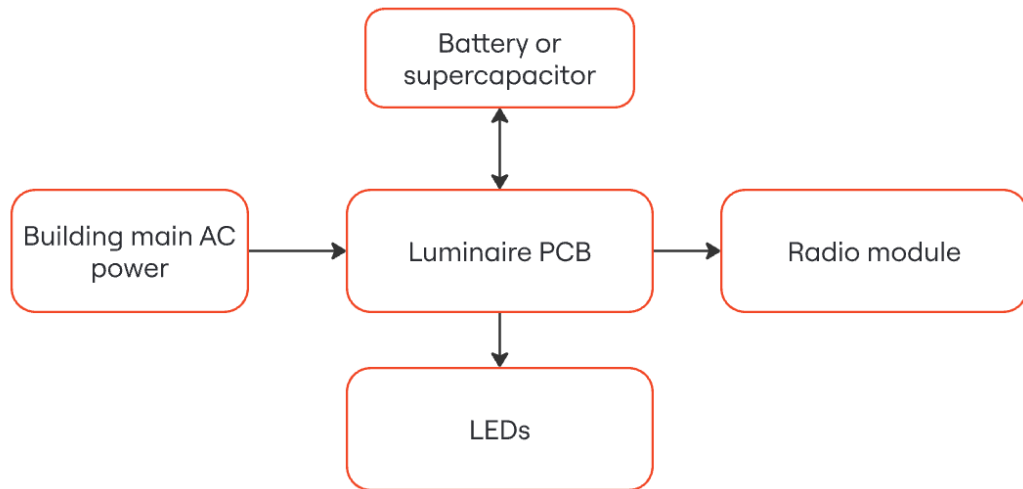


Figure 3. Self-contained luminaire power distribution.

When a luminaire switches to backup power it also cuts off the radio module in order to save power in an emergency. Restoring main power switches the luminaire off of emergency mode and radio module resumes working. In a CBS all luminaires report back to the main controller, but a SCS can be controlled remotely using Aalto software, an inhouse developed software system that can monitor every luminaire connected to it via a ZigBee mesh network where it is designated as a coordinator. [6] This topology is a large version of what Figure 4 depicts.

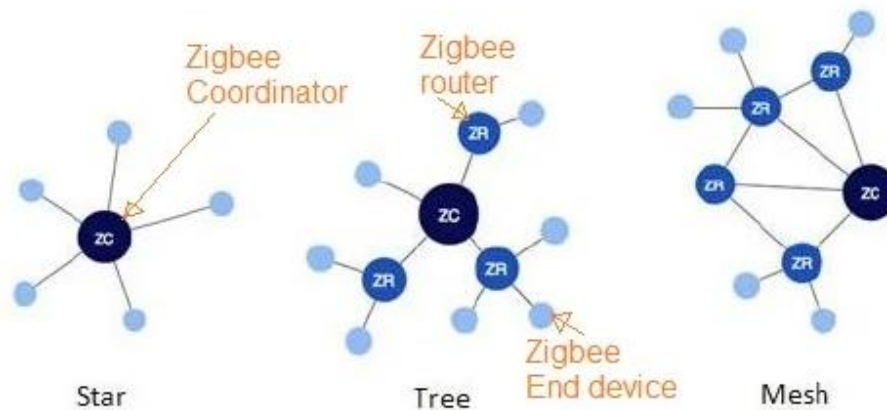


Figure 4. ZigBee topology example. [7]

3 Electrical Safety During Testing

Electrical safety is of the utmost importance when doing any kind of testing, as the live voltage coming from a wall outlet is 230V. This means potentially any lapse of judgement or larger mistake can be dangerous, even fatal. Every person that is actively testing should have electrical work emergency first aid course completed. On top of this training the following safety measures should be always adhered to when interacting with any device under test [8]:

- Keep unnecessary items out of area designated for testing
- Keep unnecessary personnel out of area designated for testing
- Never touch the DUT when there is live voltage
- Turn off all equipment when not in use
- Never make any changes to connections when there is live voltage
- Use of Variable power supply is recommended

- Clearly mark any DUT left with live voltage and without attendance.

This list is by no means an exhaustive one, but it gives general guidance on safe practices. The dangers of electricity on the human body can be roughly estimated with the use of ohm's law, Equation (1). Human body has roughly 1000Ω resistance so calculating the effects of a shock from a 230V wall outlet.

$$U = R * I \quad (1)$$

Where:

U = voltage (V) R = resistance (Ω) I = current (A)

Solving for current.

$$I = \frac{U}{R} \quad (2)$$

$$I = 230V / 1000\Omega$$

$$I = 230mA$$

The danger of 230mA current largely varies on the path it takes through the human body. Different heart current factors are shown in table 1.

Table 1 Heart Current Factors of Different Current Paths [9]

Current path	Heart current factor, F
Left hand to right hand, right foot or both feet	1
Both hands to both feet	1
Right hand to left hand, right foot or both feet	0.8

back to right hand	0.3
back to left hand	0.7
chest to right hand	1.3
chest to left hand	1.5
seat to left hand, right hand, or both hands	0.7
left foot to right foot	0.04

Getting a shock of 230mA from chest to left hand for example would be calculated as

$$I * F \tag{3}$$

$$230\text{mA} * 1.5 = 345\text{mA}$$

The effects of a shock of this calibre depends on how long the current was able to have an effect on the person, this can be determined from table 2.

Table 2 Electricity's Effect on a Human Body at 50Hz Frequency [9]

Current Level	Time	Physical Effect
Amperes	Long	Instant death likely

Amperes	Short	Severe internal burns Waste products in kidneys Severe poisoning
> 500 mA	> Cardiac Cycle	Cardiac arrest during current flow Unconsciousness Burns
> 500 mA	< Cardiac Cycle	Ventricular fibrillation, depending on the cardiac cycle phase of the contact Unconsciousness
50-500 mA	> Cardiac Cycle	Ventricular fibrillation Unconsciousness Skin marks caused by current
50-500 mA	< Cardiac Cycle	No Ventricular fibrillation Strong shock effect
30-50 mA	Seconds to Minutes	Ventricular fibrillation possible at top level Unconsciousness
15-30 mA	Minutes	Tolerance limit Rise of blood pressure Difficult breathing
2-15 mA	Not Relevant	Inability to speak Strong pain in fingers and toes
0.5-2 mA	Not Relevant	Electricity is felt

Consulting the previous tables, we can determine that any electrical testing has the potential to be extremely dangerous. This is why it is always necessary to follow procedure and work carefully.

4 Setting Scope

Testing in general is a wide area that requires specific knowledge and expertise so that it is done successfully. This is why at the beginning of this project there were multiple meetings on setting the scope of this project to keep it manageable. To avoid so called scope creep we had to carefully determine which embedded system would be tested, what functionalities from the selected devices would be tested, how those findings would then be reported, qualifying criteria to pass said tests, and how a project manager could then be certain of the results to approve it for production.

4.1 Types of Testing

Starting off it was determined what are the tests a product must go through before it can be sent in for production. These key areas were Type testing and Functional testing. At first it was deemed that all of these should be included in the testing template to ensure that CE certification and customer's inspection satisfaction are met. However, this was quickly reduced to only functionality testing as requirements for type testing was seen as too broad for this thesis work. In short, type testing is ensuring that a device performs according to CE certification, this is done by measuring the EMC of the DUT, breakthrough current of the DUT, and more. Type testing requires extensive knowledge and equipment to perform correctly, thus it will not be handled further in this work. Functionality testing is a part of pre-production testing designed to ensure that the engineer responsible for any changes to a device has not made any mistakes, calculation error, or erroneous inputs during their process. This type of testing ensures that the DUT functions as it is supposed to, so it is thus called functionality or functional testing. These tests include, at least in this case, electrical power input of the DUT, LED response, backup power switching voltage, and ensuring that the Xbee radio

module can get enough range in the casing it is being housed in. However, it was determined that the radio module range testing should have its own template, as it is to be done even on occasions that do not warrant the full functionality testing template, such as using the same electronics on a new or different housing.

4.2 Devices to Test

Selecting the devices these types of tests would be performed on was determined solely on current needs of the ELD. Currently there are multiple self-contained maintained and non-maintained emergency luminaires waiting testing to be able to be assembled and sent to customers, so in the name of urgency CBS was completely left out. Also, multiple design changes, such as changing the backup power source to a LiFePo4 battery and swapping through hole radio module for a surface mounted one, to name a few, meant that all the previously in production and well working self-contained products needed to be re-tested for functionality.

4.3 Test Cases

Designing test cases for the template was straightforward process, as there already was a pre-existing document that outlined all the necessary functions to be tested on the devices. This included hardware related tests such as measuring the electrical input power using a power analyser, testing the voltage at which the DUT would swap from main power to back up power, and vice versa. If and when these hardware test results are as the designer wanted them to be, software side of the functionality testing could begin. So called software side of the functionality testing is a lot larger, as the functionality of LEDs, control commands, and failure modes is tested using software commands via XCTU and a radio module. One of the biggest hurdles here is the unclear language of the original testing document, as it was done by a former employee documenting some of his thoughts on the testing he had done without a structured approach. Unclear language needed to be specified by having discussions with the electrical engineer responsible for the design, asking what he thought the previous testing engineer had meant with some of the test cases. After some clarification,

objective pass and fail cases for different self-contained luminaires could be established. If pre-existing documents could not have been found, one of the main ways to establish functional testing is to list all the promised functions of the device and then test if all of them can still work as promised to the customer.

5 Options for test platform

In the wake of a larger testing and production management overhaul ELD started looking into different ways of testing their devices and reporting the findings. This culminated in two different options, keeping the existing style of making an excel sheet that would be then printed to pdf for approval, or going into Atlassian product family with Jira, keeping track of tasks and Confluence for document approval. Rolling out an extensive testing overhaul is a task that would easily be out of the scope of this project. Nevertheless, the usage of Atlassian products were discussed, and the possible benefits over the chosen model will be briefly mentioned in 5.3. Largely due to the size of this improvement, it was decided that an excel based template would be the one to be proceeded with. Brief overview of the problems in the old model will be discussed in 5.1 and 5.2 will introduce changes done to make it work better.

5.1 Pre-existing Template

The original template that served as a way to confirm the functionality of Teknoware's devices was flawed, as many of the tasks to be completed had multiple possible interpretations and unclear pass and fail cases. Because of these problems the results could heavily depend on the skills of a given engineer, as they would have knowledge outside of the testing template itself that would compensate for some of the parts it was lacking in. To give an example, non-maintained luminaire's main LED is not supposed to answer to a direct "turn LED on/off" command in the same way a maintained luminaire would, this was however stated as "Indication LED does not respond to turn LED on/off.". Without proper definitions and term usage, this would have left someone without deeper product knowledge wondering, as both the maintained and non-maintained

luminaire could have indication LEDs. Issues such as this led the team to make multiple measurements and corrections, to tests as someone more knowledgeable on the matter would point out that someone else had made a clear mistake, but as the test case left something out or used the wrong terms to describe what is to be done, the mistake part was never really clear and led to confusion with newer engineers wondering why this was something we would have to correct. Figure 5 is a screenshot of the official pre-existing template PDF used to determine the validity and functionality of ELD's self-contained luminaires. One of the striking mistakes this makes is that the tests that have been performed are only marked with an X, as been having completed. This does not however tell us if the test case is a pass or a failure. So, a project manager that approves the tests, but might not know exactly what had been tested could not easily tell if the product is working as intended or not. This also runs into some aforementioned errors in the clarity of the test cases, as part 3, faults in lighting, mentions that "Luminaire can detect a faulty source of light (LED short circuited + LED detached)" yet it only has one space to make both of these different types of measurements.

3. Valoviat		OK
1. Tunnistaa vikaantuneen valonlähteen (LED oikealla + LED irti):		
A. Vihreä LED vilkkuu hitaasti, punainen palaa		x
B. Aalto-vikatiedoissa "H" -vika aktiivisena		x
2. Vika ei saa poistua sähkökatkolla		x
5. Vika kuittaantuu onnistuneella testillä:		
A. Vihreä LED palaa, punainen pois päältä		x
B. Aalto-kyselyissä ei aktiivisia vikoja		x
4. Testiestot		OK
Asetetaan Aalto Control järjestelmään testiestoja siten, että vain yhden tunnin aikana on mahdollista tehdä testit		
1. Valaisin kyselee sekä valo- että akkustieston tilaa		x
2. Valaisin noudattaa testiestoja (+5minuuttia)		x
5. Yleinen reagointi		OK
1. Turvalaisin ei reagoi sytytys/sammutuskäskyihin		x
2. Valaisin reagoi ja vastaa vilkkukäskyyn		x
3. Merkkivalo reagoi sytytys/sammutuskäskyihin		N/A

Figure 5. Page 2 of the pre-existing testing template showing test cases 3 – 5.

5.2 New Excel Template

At the time of this project the company was undergoing an overhaul in terms of testing and test reporting. It was deemed in the interest of time and continuity that a purely Atlassian product using test template is not yet to be made. This is the main reason for a new and improved Excel based test template that could be easily printed to PDF and then returned to Jira for approval. Most notable improvements made can be seen in Figure 6. This Figure is of the new testing template going over same test cases as Figure 5. All of the persons that were asked to judge the readability of the new test plan reported a marked improvement on the clarity of not only the technical language but also the results gotten.

TTS0004 Testisuunnitelma yksikkövalaisimille
 Luonut: VLÄ 01/09/2024
 Versio: 4

Testattavan laitteen tiedot

Nimike: Thesis Luminaire
 Elektronikan nimi ja rakenneversio: Electronics part 69
 PCB nimi: PCB num. 420
 Elektronikan ja radion softaversio: software version 14.23

P = Testi läpi
 F = Testi epäonnistunut
 X = Suoritettu
 N/A = Ei suoriteta/Ei koske kyseistä valaisinta

Hardware-testit				
Tehtävä	Selitys	Saatu arvo	Läpi	Huomiot
1. Ottotehot				
Ilmoita laitteen määritelty W / VA	Todenna laitteen tyyppitarrasta tai kysy laitteen suunnittelijalta	W : <u>9 W</u> VA: <u>11 VA</u>	X	
Mittaa 230 VAC syöttöjännitteellä latauksen aikana	Power analyserin ilmoittamana Wattien ja Volt-ampereen määrä akkulatauksen aikana	W : <u>8.78 W</u> VA: <u>10.7 VA</u>	P	
Mittaa 230 VAC syöttöjännitteellä ylläpitolatauksessa	Power analyserin ilmoittamana Wattien ja Volt-ampereen määrä ylläpitolatauksen aikana	W : <u>5.2 W</u> VA: <u>6.8 VA</u>	P	
2. Syötönvaihtorajat				
Kytkeytyminen varavoimalle syöttöjännitettä laskiessa	Lasketaan syötön jännitettä kunnes laite siirtyy varavoimalle Stantardin rajat ovat 138V - 195V	Voltit : <u>175 V</u>	P	
Kytkeytyminen verkkovirrälle syöttöjännitettä nostaessa	Nostetaan syötön jännitettä kunnes laite siirtyy verkkovirrälle Stantardin rajat ovat 138V - 195V	Voltit : <u>145 V</u>	P	
Software-testit				
3. Valaisimen tiedot XCTU:sta				

Figure 6. New functionality testing template filled out with example data to showcase its functions.

Not only does the new version clear any confusing language, but it also made marked improvements by clearly stating a pass or fail, as indicated with a P or F, and a colour associated with that state. This new style can give confidence that no matter who does the measuring and who checks the results they are clear and accurate. Also added on to the plan is a second column giving instructions on how to complete the task, this is often the specific command to be given for the luminaire. In addition to that, the third column gives expected results where appropriate.

5.3 Atlassian Products Jira and Confluence

The use of premade templates is practical when working with a varied product catalogue, but as it expands so do the requirements for the variety in templates. This is where Jira and Confluence would come handy. Managing more than a couple testing templates without a rigid framework tends to lead to mistakes even

when being careful, as the possibility of making them increases with every new task. Jira is a task management software that specialises in the controlling and management of different types of tasks. This testing template could have been done quite easily on the platform if it had been setup prior to the beginning of the work. A comprehensive transition to this management style should be considered as a long-term goal, as the tracking and managing of work is a lot easier. Confluence on the other hand is a web-based corporate wiki, handling all the necessary data and knowledge of a company. This can then be linked to specific tasks in Jira to give insight into what the task is referring to, if necessary. Using these tools in conjunction with an excel based testing template should provide the most comprehensive testing capabilities. This is mainly due to the ease of project management with Jira, usage of wiki to make sure engineers are talking about the same thing, and the simplicity of a excel sheet.

6 Test Setup

Working with the testing template begins with a proper testing setup. To begin testing, it is first necessary to document the information of the DUT, such as, product name of the device, version name, and version of the PCB (Printed Circuit Board), software version of the radio module, and software version of the microcontroller. After this has been completed the DUT is connected to a power analyser with a variable power supply providing the voltage, and a virtual battery that is meant as a LiFePo substitute for more accurate measurements,

as shown in Figure 7.

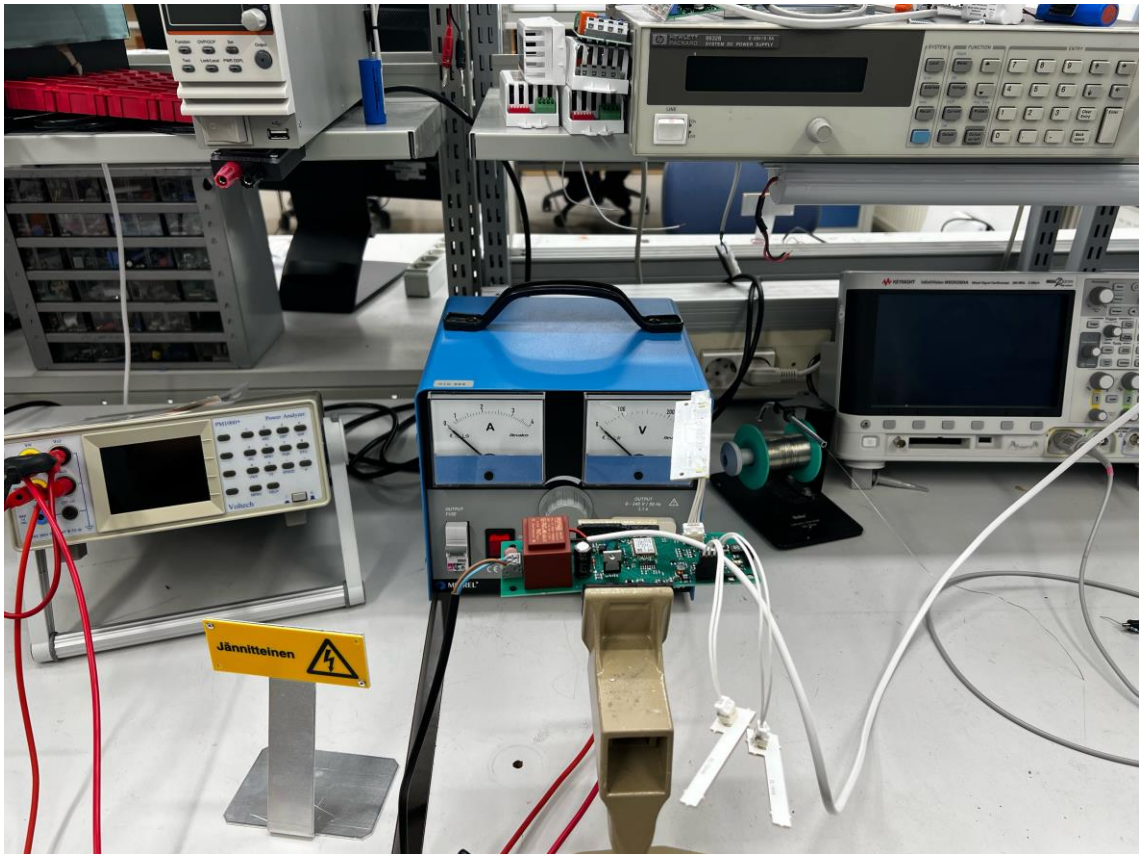


Figure 7. A staged DUT without casing connected to a power analyser, virtual battery, and a variable power supply. with a “live voltage” sign next to it.

With the preliminary setup done, hardware testing can begin, at this point it is necessary to pay close attention to electrical safety, as the DUT does not have casing and live voltage can be directly touched. Hardware testing is short, due to most of the functionality being checked by commands covered in software side of the testing. These hardware tests include measuring the wattage of the luminaire during a charge cycle and during an upkeep cycle, also measuring the backup power switching voltage levels. These tests are measured as passes or failures depending on if they meet the standards as laid out in the new template.

6.1 Software Tests with XCTU

To begin software testing it is first necessary to designate a PAN ID (Personal Area Network Identifier) for the radio module so that it can then be communicated

with using XTCU. After this has been successfully done and a connection with the DUT is established, the DUT can then be placed into its proper casing and connected to a wall outlet in a safe manner as seen in figure 8.



Figure 8. A staged DUT with its casing and a “live voltage” sign next to it.

Software testing can be quite lengthy depending on the version of the DUT, as this testing includes checking every failure mode of the luminaire that is possible, including but not limited to, LED short circuit, LED disconnected, backup power disconnected, backup power quality not sufficient [10]. These failures are first produced on the DUT, then the DUT should notice that a problem has occurred, notifying the user with a special LED blinking sequence and an error code when asked for its status via radio module. Testing engineer working with the new template can check for expected outcomes on the template itself, leaving no room for confusion if and when a test case is passed or failed. Some test cases maybe marked as failed, but the document can still be considered a pass if a proper explanation for the failure can be found, one such case has been that the DUT

could not properly indicate that the LED-strip has short-circuited (see figure 8, short-circuit of the LED with a button). This failure of the testcase was noted by the tester, but after a review explaining why this fail case did not compromise the overall product, the document was accepted by the electrical designer and project manager.

6.2 Keysight BenchVue Data logging

Keysight datalogger is a useful tool for data harvesting and then visualizing the information gathered. An emergency luminaire must be able to recharge its backup power from completely empty back to full within a 24h timeframe as dictated by safety standards [11]. This and other information such as an automatic backup power test after a failed one, deep discharge protection voltage level, and the proper charge-discharge cycles are verified with the use of Keysight BenchVue data logger. Three wires are soldered to the DUT to monitor battery voltage, LED amperage, and charge amperage, as the data logger follows these three parameters. After a sufficient time has passed the data can be used to confirm the charge functionality of the DUT, this usually takes multiple full charge cycles and forcefully failed tests, so a work week is almost a requirement [12]. Figure 9 is an example of data logged from an emergency luminaire.

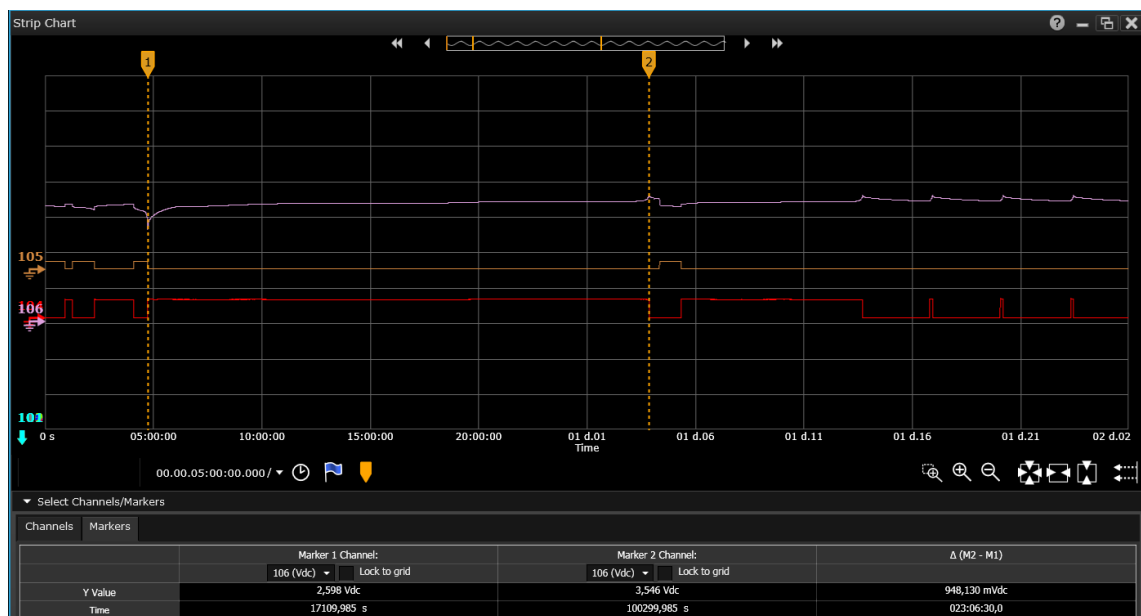


Figure 9. Example view of BenchVue application after data logging.

In figure 9, upmost line is battery voltage, middle line is LED amperage, and bottom line is battery charge amperage. Using this data, it can be determined that the battery has entered deep discharge protection at marker one, then fully recharged in 21h time passing the test case for it, and then retested its battery capacity automatically. With verification such as this, it is possible to be certain that the luminaire works, and no mistake has been made designing the PCB portion responsible for recharge of the luminaire battery system. This part of the document is an adaptation of an old word document found in internal ELD server. This document was at some point used to determine the same functionalities, but in the old testing template that engineers had worked with, it was only stated as “charge functions as intended, add document.” Only one of the engineers familiar with the previous template understood the meaning of this sentence or test case [N. Salo, Electrical engineer, July 2024, personal communication]. Furthermore, datalogging lacked formal structure and was left completely to the discretion of the tester. New testing template broke down the charge function from a vague external word document into new testing cases previously mentioned in this chapter.

7 Conclusion

The main goal of the thesis work was to reimagine the pre-production testing procedures of self-contained luminaires and the reporting of the findings of the tests made. This goal has been achieved but not as extensively as I had hope at the start of the work. New testing template brought clarity, conciseness, and unity to the results of preproduction testing of these types of luminaires, the reporting of said findings still leaves much to be desired. As the initial intention was to also improve this area with an assignable Jira template, it is a shame that it had to be narrowed out near the halfway point of the project. However, this template has already been adapted to cover the Xbee radio module range testing by copying a unified reporting style. To improve this project further would likely be a tremendous task, as Implementing changes to the reporting structure would require such significant modifications that it would likely be considered a new system rather than an update to the existing one. Qualitative data about the efficacy of this new testing regime is hard to gather, even so the production alone has had a marked improvement on ELD's documentation as previously missed issues with documentation have been reeled up. Significance of this thesis is likely only to the ELD, and Teknoware in the form of proof of concept and documentation improvement.

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