OUC Transformer Flood Sensor

Gold Team

Engineering Design Specification (Milestone 2)

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Abstract

When flood waters reach the bus bars inside a transformer, this creates a risk of the failure of an in ground transformer as well as potential electrocution that can inflict injury or death to the members of the public. This design project is about creating a device that can detect when there is flooding in a pad mounted transformer and open the primary circuit to prevent failure of the unit, increase repair or power restoration response time, and increase electrical safety to the general public.

Current OUC pad mounted transformers do not have a system in place to automatically open the primary circuit. To improve over the current transformers, adding a flood detection system that is capable of sending a signal to alert the utility company of flooding would lead to a decrease of transformer failures and electrical grid downtimes as well as increase safety for the public. With this in mind, reliability is the most critical aspect in the design project, since any failure would not mitigate current transformer failure rates and down time, but would also still result in electrical safety hazards.

The primary user of this system would be utility companies installing them into pad mounted transformers. However, the open-ended nature of detecting water and sending a signal to turn off a transformer could translate into flood detection in homes or businesses to prevent damage during floods. Tertiary users could even use the basic function to check for water leakage after leaving the device anywhere.

Overall, this design is intended to help protect the general public from electrocution during flooding. Since, electricity has become a daily necessity for normal life, making the grid

that brings that electricity safe and reliable all the more important. Progress for this design is currently under research before the design phase.

House of Quality

1. **Customer Wants & Needs**

This is the provided list of wants and needs as voiced by the Orlando Utility Company. The weight scale out of 100% is to determine the relative importance of each requirement, helping to distinguish between want and need, as well as rank the wants and needs against one another.

Item #	Weight Scale	Customer Requirements
1.1	20%	Recognizes Transformer is Flooded
1.2	15%	Reliability
1.3	15%	Price can not exceed $250 for float and wireless communication system and receiver and external switch not exceed $100.
1.4	10%	Survives Submerged, elements or external weather
1.5	10%	Fit within Pad Mounted Transformer
1.6	10%	Manual reset (on automatic external switch)
1.7	10%	3 Each To-Scale models
1.8	5%	Requires all engineering documentation, including CAD, EAGLE, schematic Assembly guide etc (.stp file)
1.9	5%	Manufacturing availability, CNC machine, lathe, and/or out
1.10	5%	Security (Against Personnel & Wildlife)
1.11	5%	Installability

1.12	**100%**	**Total Weight**

1.1 Recognizes Transformer is Flooded

The main objective of the customer for the design being created, as such it is weighted most highly.

1.2 Reliability

The motto of our customer, Orlando Utility Company is literally “The Reliable One”. As such we have weighed Reliability as one of our most heaviest customer requirements. The design is also built for safety in communities so reliability ensures that safety.

1.3 Price Cap

Since the project is a proof of concept keeping the design cheap is highly valued by the customer.

1.4 Survives Submerged, elements or external weather

The longer the design can survive submerged the longer it has a chance to activate. It will also increase the life cycle of the system allowing for less replacements for the customer as systems are installed.

1.5 Fit within Pad Mounted Transformer

The design’s objective is to detect flooding in a pad mounted transformer, the customer requires the device to fit inside of the ground mounted transformer.

1.6 Manual Reset

The manual reset allows the customer to, after inspection, restore power much easier. The manual reset also guarantees that if the area is still flooded the customer knows the transformer is not energized.

1.7 Three (3) Each To-Scale Models

While the customer is only requiring one (1) metal box, there will be three systems working from that metal box. This works in conjunction with 1.2 Reliability, but there needs to be proof of concept with 3 working systems.

1.8 Requires Engineering Documentation

This project functions as a proof of concept for the customer and as such replication is important for continued iteration on the design. However, if the design fails the documentation will have less value so it's weighed less.

1.9 Manufacturing Availability

Manufacturing within the customer's capabilities helps reduce product cost and maintenance time, as well as, makes modifications easier.

1.10 Security

Stopping parties not associated with the customer of the design with tampering will assist reliability.

1.11 Installability

OSHA says the highest weight limit a single individual can lift is 50 pounds. As such keeping the design weight below this value is important so the customer doesn't always need to send multiple lineman. Though performance is more highly valued, it was weighed lower.

1.11 Total Weight

The total breakdown ends up organized into 4 different tiered sections of 20%, 15%, 10% and 5%. The top 2 tiers are direct requirements from OUC from the scope of work dictating what the system needs to do. The 10% tier, while some are scope of work items, are parameters the system will need to account for and work around. The bottom tier is the final items that will be included but not a focus of the system.

2. Benchmark & Engineering Design Requirements

The *FLS DSC WS4985* flooding sensor is an electronic sensor that detects every kind of liquid spillage and the prevention of any harm caused from liquid leakage. The DSC WS4985 flooding sensor has the capability to warn devices, draining systems, and cellular phones. In addition, this sensor is equipped with a red/green LED light for warning.

The Advance Warning Equipment (AWARE) Flood System is one of the leading brand flood sensors. The AWARE flood sensor is a simple, cheap, and durable sensor that detects and automatically notify users when floods are approaching. This brand is widely used in North Carolina by their government officials to safekeep the community and their citizens.

Item #	Features	Short Description	Intellisense AWARE flood sensor	FLS DSC WS4985 flood sensor
2.1	Water Detection	Able to detect any liquid form	Tap water, condensed water, chilled water, rainwater, purified water	Rainwater, purified water, or any kind of liquid
2.2	Wireless Communication	How does it communicate	900 MHz - DigiMesh Protocol	(Wired Sensor) - 433.92 mhz range transmitter
2.3	Reporting	How do we know, often, type?	·Auto reporting mode (Switches to Slow Mode on low Battery) · Fast Mode (10-min) · Slow Mode (1-hr)	·Beeping system ·Red/green LED lamp for local warning
2.4	Operating Temperature	At what temperature does it operate?	-30°C to 85°C (-22°F to 185°F)	-10°C to 55°C (14°F to 131°F)
2.5	Power Source	Are they plugged-into the power or battery-powered?	Battery-powered and solar powered	Battery-powered
2.6	Battery Life	How long do they last?	Indefinite	4 years
2.7	Battery Type	What type of battery?	Nickel Cadmium 4.8V battery pack	3V Lithium, CR2

2.8	Wireless	Are they wired or wireless?	Wireless	Wired/Wireless
2.9	Range	How far can the signal reach?	Distance: 0 to 105 km (0 to 65 mi.)	Distance: 0 to 100 m (0 to 0.062 mi.)
2.10	Waterproofing	Can they stay underwater?	Yes	Yes
2.11	Compatible with other device	Is the brand compatible with other devices such as, phone, laptop, desktop, etc.?	Compatible with phone (LTE-M communication)	N/A

2.1 Water Detection

Both brands meet the requirements when it comes to detecting water.

2.2 Wireless Communication

The AWARE flood sensor communicates through a small chip which they call DigiMesh Protocol. It communicates in 900 MHz. On the other hand, the WS4985 flood sensor communicates with a transmitter if the wired sensor touches or detects any liquid.

2.3 Reporting

The AWARE flood sensor can be set in auto mode. In auto mode, the data will be reported every 10 minutes when the battery voltage is 5V or greater, and every 1 hour

when the battery voltage is 5V or fewer. On the other hand, the WS4985 flood sensor has LED lamp that is color green, but it will turn red when it detects liquid. It will also sound a beeping and will serve as an alarm to notify if it detects liquid.

2.4 Operating Temperature

The AWARE flood sensor operates in the temperature from -30°C to 85°C (-22°F to 185°F) while the WS4985 flood sensor operates from -10°C to 55°C (14°F to 131°F).

2.5 Power source

The AWARE flood sensor can be powered by solar and battery if the sunlight is not present. . On the other hand, the WS4985 flood sensor can only be powered by a battery.

2.6 Battery Life

The AWARE flood sensor operates indefinitely with adequate solar. Lasts 7 days without any solar recharging. On the other hand, the WS4985 flood sensor is powered by a battery that can last up to 4 years.

2.7 Battery Type

The AWARE flood sensor is equipped with Nickel Cadmium 4.8V battery pack. On the other hand, the WS4985 flood sensor is equipped by 3V Lithium, CR2.

2.8 Wireless

The AWARE flood sensor is wireless and communicates through wireless communication. On the other hand, the WS4985 flood sensor can be both wired and wireless.

2.9 Range

The AWARE flood sensor can reach the distance from 0 to 105 km (0 to 65 mi.). However, the WS4985 flood sensor can reach the distance from 0 to 100 m (0 to 328 ft or 0.062 mi.).

2.10 Waterproofing

The AWARE flood sensor and WS4985 flood sensor are both waterproof.

2.11 Compatible with other Devices

The AWARE flood sensor is available in mobile devices and is capable of connecting through two-way cellular LTE-M and also compatible with leading network brands, such as, AT&T, Google Fi, T-Mobile, and Verizon.

3. Engineering Design Requirements Relationship

Using a relationship matrix we can determine how different characteristics impact on another, and how much of a correlation they have. This next section is dedicated to explaining why.

In terms of Reliability, the largest correlation is aspects that must be successful to complete the core function of the design such as Flood Detection. However, since all critical parameters are core to the design function as intended and reliability being our highest weighted customer value, a high correlation has been assigned to all quality characteristics.

Recognizing the Transformer is flooded corresponds to qualities that involve water, this once again, involves most of the characteristics since the main function of the device is to detect flooding and the critical parameters are generated from that. With the exception being the manual reset, which should require no power.

Surviving Submerged is most relevant to qualities that keep water out, with an ideal waterproof box and properly sealed wires the design will keep water out for longer. Though the more time the design can survive submerged, the more time response of the external switch and wireless transmission have to complete their tasks.

Fitting within a Pad Mounted transformer is most affected by size and this most heavily correlated to the box the system is built inside of and how large an apparatus needed to detect flooding. Multiple Identical systems must all fit in the transformer or they would not be identical.

The Manual Reset is contingent most on the external switch being flipped, which in some respects correlates it to the entire device. However, just having a manual reset would not require power, detection or electronics functioning. It would just need to work reliability in all systems and have the external switch reset.

Documentation, asides from reliability, correlates to the most quality characteristics. Since the customer requires all the information gathered for the design and how the project was created, having a clear explanation of each Quality characteristics is vital so they can be replicated again after the project. Meaning all aspects of the project will generate documentation and all documentation has a strong correspondence to all aspects of the project.

CNC Machine and Lathe are for easy manufacturing of the project within OUC, as such the box and making multiple systems should be done with these machines as much as possible along with making the manual reset.

Security is most important in avoiding outside tempering with the design which would reduce its reliability. While this has a moderate relation to the box and wires being designed to be discreet. It most correlates to the system of wireless transmission and the external switch reset which could be hacked to prevent the core function of the design.

Finally, Instability is more important to the box design, since its weight and how it attaches to the transformer greatly influence how easy for a single technician handling would be. Wireless Transmission is also critical since with more simplification of the end of the user installation would be easier.

Quality Characteristics (a.k.a. "Functional Requirements" or "How s")	Flood Detecttion	Waterproof Metal Box	Pow er Connection	External Sw itch Automatically opens	Identical Working Systems	External Sw itch is manually reset	Response Time of External Sw itch	Wireless Transmission
Legend Θ Strong Relationship O Moderate Relationship ▲ Weak Relationship **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")								
Reliability	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ
Recognizes Transfromer is Flooded	Θ	O	Θ	Θ	Θ	▲	Θ	Θ
Survives Submerged	▲	▲	Θ	▲	Θ	O	Θ	O
Fit w ithin Pad Mounted Transformer	Θ	Θ	▲	O	Θ	▲	▲	▲
Manual Reset	▲	▲	▲	▲	Θ	Θ	▲	▲
Documentation	Θ	Θ	O	O	O	Θ	Θ	Θ
CNC machine, lathe	▲	Θ	▲	▲	Θ	O	▲	▲
Security	▲	O	O	▲	▲	Θ	▲	Θ
Installability	▲	Θ	▲	O	▲	O	▲	Θ

4. Critical Performance Parameters

Item #	Components & Functions	Target or Limit Value
4.1	Flood Detection	Detects water within 12 inches from bottom of Pad Mounted Transformer
4.2	Power Connection	Connects to 120 VAC, 208 VAC, or 240 VAC, or 277 VAC

4.3	External Switch Automatically opens	No physical interference upon submersion, then inspection
4.4	External Switch is manually reset	3 inspections
4.5	Response Time of External Switch	Less than 1 Second
4.6	Wireless Transmission	Transmit flood detection signal wireless to an external switch within (200 feet)

4.1: Flood Detection:

The Tragedy of Lake Okeechobee in 1928, was the largest flood in the history of Florida, since water from the lake was pushed out by 150 mph winds. Due to this flood waters rose on average 4 to 6 feet an hour. Since the height of the flood transformer provided by OUC is 12 inches. Meaning the device must have detected water and opened the external switch by the time the height of the water is the same as the bus bars. This would mean the design must detect water by 5 minutes, not from submersion, but from water entering the pad mounted transformer. However, faster response time would only be beneficial for the reliability of the design and increase safety.

4.2: Power Connection:

The design will need to draw power from the transformer in which it is installed. As stated by customer requirements the only connections available are 120 VAC, 208 VAC, or 240 VAC, or 277 VAC.

4.3: External Switch Automatically opens:

For the switch to be automatic it must function without interference from outside parties. When the device is submerged, it begins its test and should no longer be interfered with. The external switch will be shown as functioning with an indicator, which can vary from a light to raising a flag, inspection of that predetermined indicator will show if the switch was opened successfully. Though no interference should take place upon this visual inspection.

4.4: External Switch is manually Reset:

To manually reset the external switch, physical inspection is necessary. To make sure the switch does not automatically reset, the device should be left after submersion for a few minutes or resubmerged. Afterwards, the physical inspection will take place where the reset will be completed and the test for external switch automatically opening is redone. This method ensures the system cant reset itself, must be manually reset, and the reset works correctly.

4.5: Response Time of External Switch:

Tied into 4.1, the water must be detected and switched flipped by the time flood waters reach the bus bars. As such together they must have a response time of less than #. Building on this further, depending on the way flood water is detected, allocation of time to each task specifically, response time and detection, could be allocated.

4.6: Wireless Transmission:

The average distance between a Pad Mounted Transformer and its associated primary circuit is a couple hundred feet. This sets the range between 100 to 900 feet. However this is not ideal because the average would only encompass most situations and as the design is intended as failsafe planning for the worst case scenario is important. Wireless Transmission also degrades with distance, depending on the wireless system chosen for the design in the future, which would limit the maximum distance. To compromise for the initial requirement a distance of (200) feet will be set however a stretch goal would be 1000 feet.

5. Engineering Requirements

Below are the Engineering Requirements broken down by Component. There are 4 main components to this system to include the Metal Box, PCB Main Unit, PCB Receiving Unit and the Life Cycle Operations.

Engineering Characteristic		Requirements	Verification
C1. Metal Box			
1.1	Length	Size of Box for demonstration TBD by OUC	Inspection
1.2	Width		Inspection
1.3	Height		Inspection
1.4	Volume	Minimum 1 Gallon	Analysis
1.5	Weight	Under 25lbs (OSHA +)	Inspection
1.6	Cost	Less than $100	Inspection

1.7	Manufacturing	Cutting, Welding, Sealant	Inspection
1.8	Box Material	Metal (Steal)	Inspection
1.9	Waterproofing	NEMA 6 (IP67)	Demonstration
C2. PCB Main Unit			
2.1	Voltage	Operate off of or step down from 120 VAC, 208 VAC, or 240 VAC, or 277 VAC	Inspection
2.2	Power needed for device	14.29u - 2.5W	Inspection
2.3	Enclosure Material	Durable Plastic able to withstand handling, installation, and heat	Analysis
2.4	Enclosure Protection	NEMA 5 (IP52) Minimum	Demonstration
2.5	Enclosure Resistance	Withstand 90% humidity and Temperature Range up to to 120°F	Analysis
2.6	Programming Language	Meet existing architecture for ease of integration	Analysis
2.7	Wire Protection	Shield Material Type	Inspection
2.8	Microcontroller	Processing Speed to meet critical performance parameters for communication and response time	Test
2.9	Communication Type	Wired, Wifi, Bluetooth, Cellular Network	Demonstration
2.10	Communication Distance	TBD by OUC, 30ft maximum current assumption	Test
2.11	Communication Protocol	Visual, Audio, Digital Notification, Automated	Demonstration
2.12	Water Detection Sensor	Detect Water, send signal to PCB	Test
C3. PCB Receiver Unit			

3.1	Voltage	Operate off of or step down from 120 VAC, 208 VAC, or 240 VAC, or 277 VAC	Inspection
3.2	Power needed for device	14.29u - 2.5W	Inspection
3.3	Enclosure Material	Durable Plastic able to withstand handling, installation, and heat	Analysis
3.4	Enclosure Protection	NEMA 5 (IP52) Minimum	Demonstration
3.5	Enclosure Resistance	Withstand 90% humidity and Temperature Range up to to 120°F	Analysis
3.6	Programming Language	Meet existing architecture for ease of integration	Analysis
3.7	Wire Protection	Shield Material Type	Inspection
3.8	Microcontroller	Processing Speed to meet critical performance parameters for communication and response time	Test
3.9	Communication Type	Wired, Wifi, Bluetooth, Cellular Network	Demonstration
3.10	Communication Distance	TBD by OUC, 30ft maximum current assumption	Test
3.11	Communication Protocol	Visual, Audio, Digital Notification, Automated	Demonstration
C4. Lifecycle/Operations			
4.1	Persons needed to install	2 Person Team	Demonstration
4.2	Persons needed to reset	1-2 Person Team	Demonstration
4.3	Number of Boxes/Systems	3 EA	Inspection
4.4	Reliability	Maintenance Schedule and life cycle of components (10 years)	Analysis

4.5	Backup/Power Outage	Short running and standby operations	Demonstration
4.6	Security	Protection from wildlife and personnel	Inspection

C1.1 Metal Box: Length

The dimensions of the metal box will be determined by OUC. This will be delivered via photos, measurements, and plans of a typical ground mounted oil cooled transformer

C1.2 Metal Box: Width

See Section C1.1.

C1.3 Metal Box: Height

See Section C1.1.

C1.4 Metal Box: Volume

Per OUC, the BUS bars are 18" above the ground surface of the transformer. While the overall volume of the metal box will be dictated by simulating the buildout of a ground transformer, the amount of water required to reach a height of 18" will be the measured requirement and designed to contain at least 1 gallon.

C1.5 Metal Box: Weight

The box will be Under 25lbs and under OSHA regulations for a 1 man lift.

C1.6 Metal Box: Cost

Per OUC, the Box will cost under $100 in construction materials.

C1.7 Metal Box: Manufacturing

The metal box shall be able to be constructed from typical machine shop tools (cutters, grinders, welders, and sealant materials).

C1.8 Metal Box: Material

Steel as specified by OUC

C1.9 Metal Box: Waterproofing

The metal box shall meet NEMA 6 standard: General Purpose Submersible. Intended for use indoors or outdoors with protection from occasional submersion. The metal box will hold water for testing the equipment's water detection functions and protection.

C2.1 PCB Main Unit: Voltage

The electronics shall operate off of or step down from any of the voltages provided by OUC (120 VAC, 208 VAC, or 240 VAC or 277 VAC). The electronics can operate off AC or DC, but must receive and convert the power provided by OUC.

C2.2 PCB Main Unit: Power Needed for Device

The operational power of the unit will operate in a range from 14.29u-2.5W in order to minimize the footprint and meet EE Senior Design parameters.

C2.3 PCB Main Unit: Enclosure Material

The enclosure material type must be a durable plastic that will operate handling and installation as well as protect the electronics from potential damage. The material must also not interfere with the operations of the system and provide as needed utility to mounting and supporting structure.

C2.4 PCB Main Unit: Enclosure Protection

The enclosure shall be NEMA 5 rating at a minimum: General Purpose Dust-Tight. Intended for use indoors or outdoors with protection from dust provided by gaskets.

C2.5 PCB Main Unit: Enclosure Resistance

The enclosure shall withstand internal conditions within the oil cooled pad mounted transformer from humidity and temperatures up to 120°F.

C2.6 PCB Main Unit: Programing Language

The programming and communication language must work with existing OUC infrastructure for ease of integration and troubleshooting.

C2.7 PCB Main Unit: Wire Protection

The wire shielding shall protect itself from not only external elements such as humidity, temperature and abrasion, but also potentially shield itself from electromagnetic interference.

C2.8 PCB Main Unit: Microcontroller

The microcontrollers used in the system shall perform at a speed and frequency needed to meet performance parameters set section 4.5 as well as be compatible with attached sensors and consume under the power consumption requirement set in C2.2.

C2.9 PCB Main Unit: Communication Type

Communication between the two units shall work within any wired or wireless transmission type. Any wireless frequency will not interfere with current OUC operations nor have interruptions from outside frequencies being used by adjacent services.

C2.10 PCB Main Unit: Communication Distance

Communication Distance will be determined by OUC, current distance requirement to be maximum of 30ft from the pad mounted transformer.

C2.11 PCB Main Unit: Communication Protocol

Any external communication will have a visual signal such as a light when water has been detected. Additional protocols can be added for errors from the system and/or to include additional information such as water height.

C2.12 PCB Main Unit: Water Detection Sensor

The water detection sensor shall detect water when submerged and send signal to the Main PCB unit.

C3.1 PCB Receiver Unit: Voltage

See Section C2.1.

C3.2 PCB Receiver Unit: Power Needed for Device

See Section C2.2.

C3.3 PCB Receiver Unit: Enclosure Material

See Section C2.3.

C3.4 PCB Receiver Unit: Enclosure Protection

See Section C2.4.

C3.5 PCB Receiver Unit: Enclosure Resistance

See Section C2.5.

C3.6 PCB Receiver Unit: Programing Language

See Section C2.6.

C3.7 PCB Receiver Unit: Wire Protection

See Section C2.7.

C3.8 PCB Receiver Unit: Microcontroller

See Section C2.8.

C3.9 PCB Receiver Unit: Communication Type

See Section C2.9.

C3.10 PCB Receiver Unit: Communication Distance

See Section C2.10.

C3.11 PCB Receiver Unit: Communication Protocol

See Section C2.11.

C4.1 Lifecycle/Operations: Persons needed to install

The system shall be installable by a 2 person team as per OUC requirements.

C4.2 Lifecycle/Operations: Persons needed to reset

The system shall be able to be reset by a 1 or 2 person team as per OUC requirements.

C4.3 Lifecycle/Operations: Number of Systems

The system shall include 3 identical systems that operate out of the same metal box.

C4.4 Lifecycle/Operations: Reliability

The system shall be able to operate with or without power and have a serviceability life cycle for all components of at least 10 years for replacement of any components.

C4.5 Lifecycle/Operations: Backup/Power Outage

The system must be able to withstand any power surges, outages and must continue to operate for a short period of time in the absence of power.

C4.6 Lifecycle/Operations: Security

The system must not only be secure from wildlife and thievery but will also contain digital security protocols to prevent tampering.

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