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Smart Micro-controller Based Integrated Monitoring and Protection System for Three-Phase Power Transformer

Kristján Guðmundur Birgisson

Thesis of 60 ECTS credits
Master of Science (M.Sc.) in Electrical Engineering

May 2018

Smart Micro-controller Based Integrated Monitoring and Protection System for Three-Phase Power Transformer

by

Kristján Guðmundur Birgisson

Thesis of 60 ECTS creditssubmitted to the School of Science and Engineering
at Reykjavík University in partial fulfillment
of the requirements for the degree of
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May 2018

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Abstract

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Örtölvu Byggt Öryggis og Eftirlitskerfi fyrir Þriggja Fasa Spennubreytir

Kristján Guðmundur Birgisson

maí 2018

Útdráttur

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Kristján Guðmundur Birgisson
Master of Science

Important!!! Read the Instructions!!!

If you have not already done so, LaTeX the `instructions.tex` to learn how to setup your document and use some of the features. You can see a (somewhat recent) rendered PDF of the instructions at `http://afs.rnd.ru.is/project/thesis-template/trunk/ruthesis/latex/instructions.pdf`. There is also more information on working with LaTeX at `http://afs.rnd.ru.is/project/htgaru/trunk/how-to-get-around-projects.pdf`. This includes common problems and fixes.

This page will disappear in anything other than draft mode.

I dedicate this to my spouse/child/pet/power animal.

Acknowledgements

So long, and thanks for all the fish.

Douglas Adams

Acknowledgements are optional; comment this chapter out if they are absent Note that it is important to acknowledge any funding that helped in the workThis work was funded by 2017 RANNIS grant “Survey of man-eating Minke whales” 1415550. Additional equipment was generously donated by the Icelandic Tourism Board.

Preface

This dissertation is original work by the author, Firstname Lastname. Portions of the introductory text are used with permission from Student et al.

The preface is an optional element explaining a little who performed what work. See `https://www.grad.ubc.ca/sites/default/files/materials/thesis_sample_prefaces.pdf` for suggestions.

List of publications as part of the preface is optional unless elements of the work have already been published. It should be a comprehensive list of all publications in which material in the thesis has appeared, preferably with references to sections as appropriate. This is also a good place to state contribution of student and contribution of others to the work represented in the thesis.

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MSc	Masters of Science
PhD	Doctor of Philosophy
kV	kilo Volt
DC	Direct Current
AC	Alternative Current

List of Symbols

Symbol	Description	Value/Units
V	Voltage	Volt
A	current	I
c	Speed of Light	$2.99 \times 10^{8}\,\mathrm{m\,s^{-1}}$

Chapter 1

Introduction

foundation of everyday life a

Electricity is one of the fundamental uses in everyday life. Electricity is widely used com-
the the
modity in advanced countries and is being set up in third world. ~~There is~~ a quote from a
R is
russian politician Boris Yeltsin "We don't appreciate what we have until it's gone"[1]. The
multiple meanings and one certainly holds true for electricity
quote has meaning for multiple varieties and holds true to electricity. When it is operational
Almost all
everybody is happy but when it is non-operational ~~then~~ nobody is happy. There are work-
places ~~that~~ are very dependent on electricity for example hospitals, factories, emergencies
services. The loss of electricity can lead to money loss for the consumer if the power is not
concistant or
working for a long period time.

1.1 Power system

The set up for the basic power station is as follows

1. Electricity Generation
2. Step Up Transformer
3. Transmission Line
4. Step Down Transformer
5. Consumer

[1] https://www.brainyquote.com/quotes/quotes/b/borisyelts371415.html

The basic set up for a power systems can be seen in figure 1.1[2].

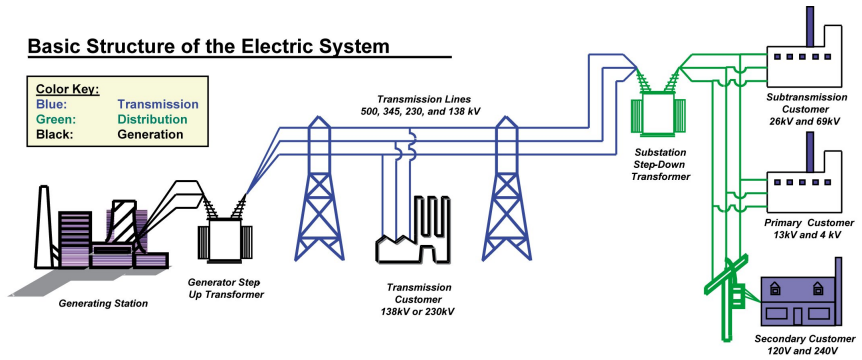

Figure 1.1: Structure of a Power System

The

First step is the power generation that can be varied from oil, hydro, gas, nuclear, coal, what? The wind, solar and other renewable as a single unit or a combination of multiple units. World WHICH energy council[3] shows the usages of these electricity generations from the past 15 years are changing as can be seen in figure 1.2[4].

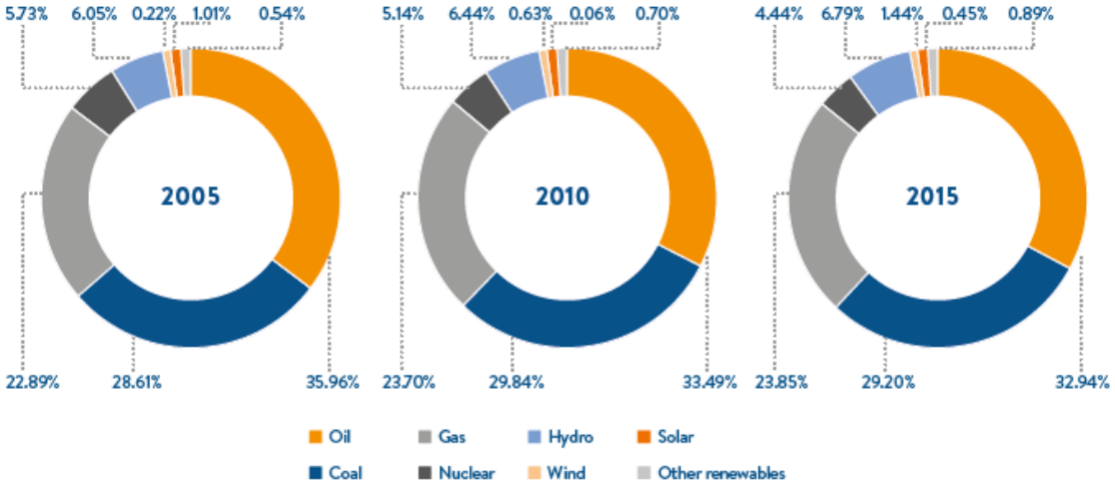

Figure 1.2: Electricity generation from 2005 to 2015

are s

Step 2,3 and 4 there is two kind of transformer that are the step up and step down and the transmission line between them. Since in many instances the power generation is not in to what close proximity where the consumer is then the electricity needs to be sent to the consumer.

[2] http://www2.econ.iastate.edu/classes/econ458/tesfatsion/Home458Team.htm

[3] https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

[4] https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

The voltage needs to be scaled up to be able to go through the transmission line, where the loss of voltage is inconsequential. When the distance to the consumer is reached than the voltage needs to be scaled down to be in working conditions. The consumer can also be directly connected with the transmission line, for example factories with heavy electrical consumption. The regular consumer needs the voltage to be between 230 to 250 V in Europe and 110 V in America [5]. The electricity can have gone through multiples of transformers until it has reached its final destination.

1.2 Transformer

The transformer is one of the main units in a power structure, since they able the power companies to send the voltage from the power generators over long distances and be usable for the consumer. The transformer is the most valuable unit and the the price and size of the transformer varies by manufacturer and some can cost millions of dollars [1]. The workability of the transformer is crucial and there-fore the maintenance and protection is of high importance. The failure of the transformer can be divided into two groups

1. Internal

2. External

It will be in more detail in next chapter about what failures are in each group.

[5] http://engineering.electrical-equipment.org/electrical-distribution/importance-of-voltage-criteria-for-consumer-distribution-system.html

1.2.1 Working of transformer

The working s of a power transformer is that two windings are on a single core to get magnetic coupling see fig 1.3[6]

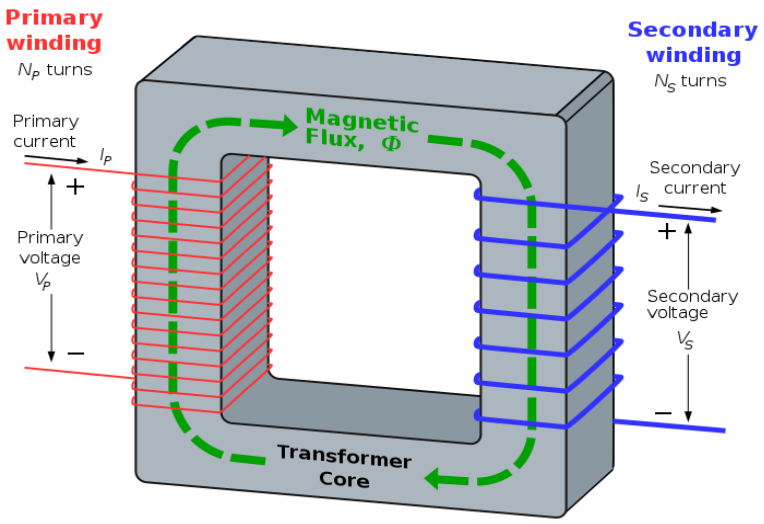

Figure 1.3: Ideal transformer with two winding on a single core

The windings are split into the primary (N_p) where the primary voltage (V_p) and current (I_p) goes through that produces a/the magnetic field. Secondary windings (N_s) gets or catches the magnetic field and creates electric current (I_s) and voltages (V_s) . The idealized model for the transformer is the following[2]:

$$\begin{aligned} \frac{V_p}{V_s} &= \frac{N_p}{N_s} \\ \frac{I_p}{I_s} &= \frac{N_s}{N_p} \end{aligned} \tag{1.1}$$

where the V_p and V_s are proportional to the number of windings in N_p and N_s. For a step up transformer then the windings would be $N_p < N_s$ and for a step down it would be the other way around as the figure above shows how step down transformer windings would be.

1.3 Objective of this thesis

ive

The object of this thesis is to research, build and make a monitoring and protection system for a three phase power transformer by using sensors and micro-controller (M-C). The M-C

[6] https://en.wikipedia.org/wiki/Transformer

will read data from the sensors that will be placed on tested transformer. The research will provide with that transformer failures happens to a transformer and what to look out for. There are optimal operating values for transformers but they depends on what kind and for what use it is for. If the values are not in the given optimal values the M-C will send an alarm and if needed cut off the power to the transformer before to much damage happens. The data collected in the M-C is sent to a program that will display the information for a human operator. The program will also allow the human operator to some control of the operation of the M-C.

Chapter 2

Literature-review

The history of the transformer may be found in the early 1800's where the discovery of the property of induction and the invention of the induction coil. It was between 1880 to 1882 where Sebastian Ziani de Ferranti with William Thomas that designed one of the earliest AC power systems. Lucien Gaulard and John Dixon Gibbs built the first step down transformer in 1882 with an open iron core that was first shown in exhibition in Italy 1884 but was not efficient to make and work. In 1884, Ottó Bláthy, Károly Zipernowsky and Miksa Derí came with the first closed built transformer with toroidal shape. It was not until William Stanley who went to the exhibition in Italy and saw the open iron core step down transformer. His boss George Westinghouse bought the patent to the Gaulard and Gibbs transformer design. George W. and William S. created a transformer that was more practical in production than the Gaulard and Gibbs. They changes the shape from toroidal shape that was hard to wind the wire around to a square shape that was much easier to work with. Mikhail Dolivo-Dobrovolsky a Russian born engineer who was working at AEG in Germany developed the first three-phase transformer[1]

[1] http://www.edisontechcenter.org/Transformers.html

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[1] A. S. Patricia Hoffman and D. A. S. William Bryan, “Infrastructure security and energy restoration office of electricity delivery and energy reliability u.s. department of energy”, 2012.

[2] D. W. Hart, *Power electronics*. Mcgraw-Hill Education, 2011, pp. 265–267.

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