VAASAN AMMATTIKORKEAKOULU
VASA YRKESHÖGSKOLA
UNIVERSITY OF APPLIED SCIENCES

Ilkka Laaksonen

A FAULT ANALYSIS TEMPLATE FOR THE FREQUENCY CONVERTER

Tekniikka ja liikenne

2012

FOREWORD

This thesis has been written at Vaasan Ammattikorkeakoulu, University of Applied Sciences Degree Program in Electrical Engineering for Vacon Plc, After Market Services department in Vaasa, Finland.

I would like to thank Dr. Mikko Hankaniemi, Manager, Reliability and Field Quality, from Vacon Plc for help and support during the work. I would also thank my supervisor Olli Tuovinen, Senior Lecturer, MEng, for stretching the limits for me to keep in.

In addition, special thanks belong to Pauliina, and the rest of my family, for patience and support during the studies.

Vilja, my beloved daughter, you kept the smile on my face. Thank you.

Mustasaari 16.5.2012

Ilkka Laaksonen

VAASAN AMMATTIKORKEAKOULU
Sähkötekniikka

TIIVISTELMÄ

Tekijä	Ilkka Laaksonen
Opinnäytetyön nimi	A Fault Analysis Template for the Frequency Converter
Vuosi	2012
Kieli	Englanti
Sivumäärä	40 + 4 liitettä
Ohjaaja	Olli Tuovinen

Opinnäyte tehtiin taajuusmuuttajia suunnittelevan ja valmistavan Vacon Oyj:n toimeksiannosta yrityksen huolto-organisaation tarpeisiin. Vikaantuneiden laitteiden analyysiohjeistuksella pyritään yhdenmukaistamaan analyysistä saatavaa dataa tilastokelpoiseksi, sekä vähentämään logistiikan kustannuksia ja kuormaa Vaasan tehtaan analysoijilta. Ohjeistuksen avulla perustapauksissa analysointi voitaisiin suorittaa huoltopartnerin toimesta.

Tuotevalikoiman laajuuden vuoksi opinnäytteessä keskityttiin yhteen hissivalmistajalle toimitettavan OEM-tuoteperheen laitteeseen. Hissikäytössä laitteeseen asennetut lisälaitteet sekä räätälöidyt optiokortti ja sovellus toivat mielenkiintoisen lisämausteen työhön.

Laitevalmistajan kirjallista materiaalia käytettiin hyväksi tutustuttaessa laitteeseen sekä manuaalin kuvituksen täydentämiseen. Materiaalia oli saatavilla paljon, joten sen karsiminen oleelliseen oli haastavaa. Henkilöhaastatteluilla hankittiin tietoa analysointiprosessista. Varsinkin mittauksien suorittamisesta ns. hiljaista tietoa oli olemassa enemmän kuin dokumentoituja ohjeita. Työn edetessä sen laajuus ja haastavuus paljastui tekijälle. Yksityiskohtaisen analysointiohjeen muotoileminen ilman salaiseksi luokiteltujen piirikaavioiden julkaisemista on lähes mahdoton tehtävä.

Opinnäytteessä esitellään tilaajayritys lyhyesti, huolto-organisaation rakennetta niiltä osin kun se liittyy vikaantuneiden laitteiden logistiikkaan ja analysointiin sekä nykyistä analysointiprosessia kursorisesti. Työn luottamuksellisen luonteen vuoksi se esitellään otsikkotasolla. Kunkin otsikon sisältämää materiaalia kuvaillaan yleisellä tasolla. Hissikäyttöön räätälöidyn taajuusmuuttajan komponentteja sekä sovellusta esitellään työssä myös lyhyesti. Yksi analysoitu tapaus kuvaillaan esimerkiksi.

Opinnäytteen lopputuloksena saatiin luotua perusversio sähköisestä analysointi-, dokumentointi- ja raportointiohjeesta, jonka täydentäminen ja laajentaminen muita laitteita ja tuoteperheitä koskevaksi on mahdollista.

Avainsanat: Vika-analyysi, Ohjeistus, Taajuusmuuttaja

VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES
Sähkötekniikka

ABSTRACT

Author	Ilkka Laaksonen
Title	A Fault Analysis Template for the Frequency Converter
Year	2012
Language	English
Pages	40 + 4 Appendices
Name of Supervisor	Olli Tuovinen

This thesis was ordered by Vacon Plc, a company designing and manufacturing frequency converters, and is aimed for the needs of the company's service organization. The intention was to standardize the data received from analysis so that it can be used for statistics, by the means of the analysis instructions of the damaged devices. In addition, the aim was to reduce the logistics expenses and the work load of the analysts in the factory in Vaasa. In standard cases, the analysis could even be done by a service partner, if they are provided with necessary instructions.

Due to the extensive product range, this thesis only concentrates on one device which belongs to the OEM product family and is supplied to an elevator manufacturer. The extra equipment installed and the tailor-made option board and application gave an interesting additional flavour to the work.

The written material provided by the manufacturer was used when getting to know the device and adding figures into the manual. There was plenty of material available, so it was demanding to cut it down into the essential. Information on the process of the analysis was received by personal interviews. Especially concerning measuring procedures, there was more so called tacit knowledge than there were documented instructions. As the work proceeded, it became obvious how extensive and challenging it was. It is almost impossible to produce a detailed analysis instruction without publishing circuit diagrams that are classified as confidential.

In this study, the ordering company is introduced briefly. The structure of the service organization is demonstrated in those respects as it concerns the logistics and analysis of damaged devices. The current process of the analysis is described only cursorily. Due to the confidential nature of this work, only headings are presented and the material under each heading is described only on a general level. The tailor-made frequency converter components and application used in elevators are also briefly described. One analyzed case is described as an example.

The result of this thesis is a basic version of an electrical analysis, documentation and reporting instruction, which can be complemented and expanded so that it is possible to use it for other devices and product families.

Key Words: Fault Analysis, Manual, Frequency Converter

CONTENTS

LIST OF FIGURES AND TABLES

LIST OF APPENDICES

1 INTRODUCTION

1.1 Vacon Plc

Vacon Plc is a Finnish frequency converter manufacturer, founded in 1993. The company's objective is to design, manufacture and sell the best AC drives in the world. From the staff of 13 the company has expanded to be an employer of over 1400 people. The revenues in 2011 were 380,9 M€ with the operating profit of 24,7 M€. Key figures are presented in Figure 1.

Vacon has R&D and production facilities in Finland, the United States, China, India and Italy.

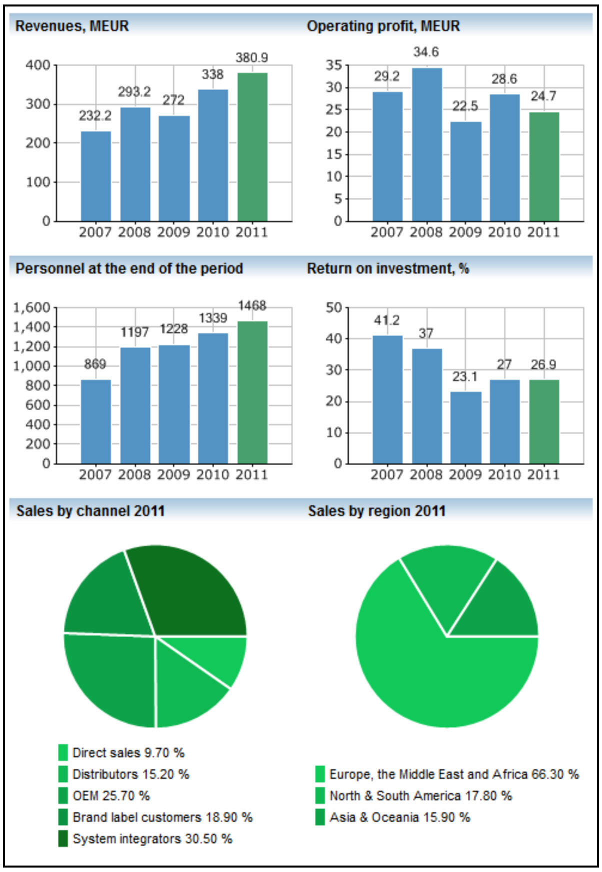


Figure 1. Key Figures. /1/

1.2 Variable Speed AC Drive aka Frequency Converter

Pulse Width Modulated (PWM) Frequency Converter is an electronic device for, mainly, controlling speed and torque of AC Motor or Generator.

Most AC motors in industrial use need speed adjustment for process, based on economical or functional demands. Energy efficiency and adjustability makes frequency converters more and more common in all kinds of industrial applications.

The rotor, thus the axel of the AC motor, rotates accompanied by a magnetic field, generated by the mains. The speed of the motor is controlled by changing the frequency of the electrical supply to the motor. The main components of an AC drive are presented in Figure 2.

Rectifier unit

The AC drive is supplied by the electrical network via a rectifier. The rectifier unit can be uni- or bidirectional. When unidirectional, the AC drive can accelerate and run the motor by taking energy from the network. If bidirectional, the AC drive can also take the mechanical rotation energy from the motor and process and feed it back to the electrical network. /2/

DC circuit

The DC circuit will store the electrical energy from the rectifier for the inverter to use. In most cases, the energy is stored in high-power capacitors. /2/

Inverter unit

The inverter unit takes the electrical energy from the DC circuit and supplies it to the motor. The inverter uses modulation techniques to create the needed 3-phase AC voltage output for the motor. The frequency and voltage can be adjusted to match the need of the process. /2/

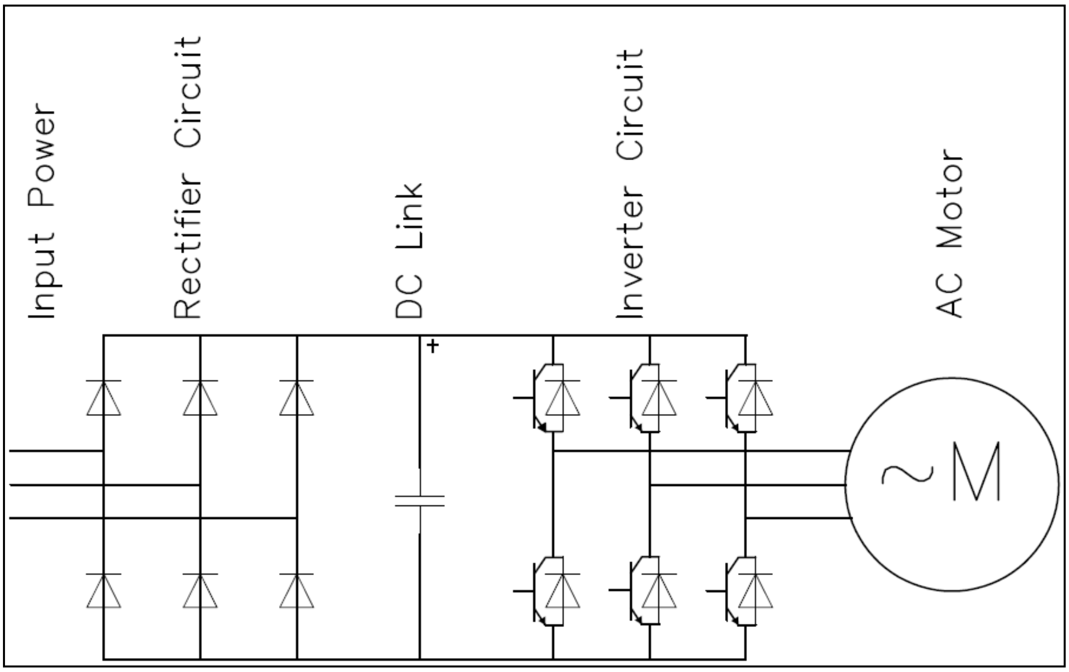


Figure 2. The main components of an AC drive.

1.3 The Need for the Fault Analysis Manual

The purpose of the thesis is to produce a template for analyzing and reporting failures of the frequency converters and their root causes for Vacon service organization.

In principle the device itself is simple. However, the electronics to protect, to measure and to control the device makes it more complicated and more prone to component failures. Semiconductors in device are controlled in very high speed with switching frequencies up to 16 kHz. Because of many measurements and self protecting functions even a little malfunction in controlling software or hardware can produce a failure that trips the device.

In case of a failure, the customers who use the drives are forced to call to the nearest service partner to solve the problem. If under warranty, the device is usually replaced with the new one. The service partners send the failed devices to Vaasa factory for further analysis.

The final decisions in the warranty issues are often dependent on the results of the analysis. The analyst solves a payer of the warranty costs.

At Vaasa factory, the service organization acts also as a technical support and fault analysis team. Partners and offices around the world strain the service department with a root cause analysis requests. If most failures, under warranty period, and their root causes could be analyzed without sending devices to Vaasa factory the analyzing process would be more efficient. More effective the analysis processes are, the higher is customer satisfactory in warranty issues. Also the quality improvement and R&D organizations receive the information about the quality issues more quickly. For compensating the billing between different business units, the information obtained from fault analysis is also necessary.

2 DRIVE AND THE CURRENT FAULT ANALYSIS

Frequency converters of each type (types, or families are presented in Figure 3) and size are made at the different production lines in the factory. Devices are tailored for different mains voltages, different maximum power and, if needed, with the customized software. Each device is tested with the programmed test cycle before packing and shipping to the customer to ensure the quality of the device.

Figure 3. Different Drive families of the Vacon. /3/

2.1 Quality Control in the Production Line and the Warranty Policy

The quality of all materials is inspected continuously during the assembly phase with the visual inspections. Assemble workers control the quality of each other's work. The assembling instructions are available in every working cell in electronic form. If needed the simple electrical measurements are made to ensure e.g. correct value of the shunt resistors. Every component of the device is traced to factory SAP system with bar codes or serial numbers for future needs.

The functional tests are made with specific automated testing equipment. The high-voltage test, the warming and the other critical measurements and values are inspected during the test run.

The manufacturing defects are covered by the warranty. The Manufacturer's time of warranty is 18 months from the delivery or 12 months from the commissioning whichever expires first.

2.2 Service Organization

The service organization of Vacon is based on service partner contracts. The company has service partners all over the world. The service partners are selected individual companies who are trained to perform installations, maintenance and repairs to the Vacon devices. Often the service partner is a local company that has years of experience in maintenance and repairs of electrical devices in industrial environment. The structure of the service organization as far as it relates to the analyzing process is presented in Figure 4. The service department at the Vacon Vaasa factory acts as a final analyst as well as technical support team.

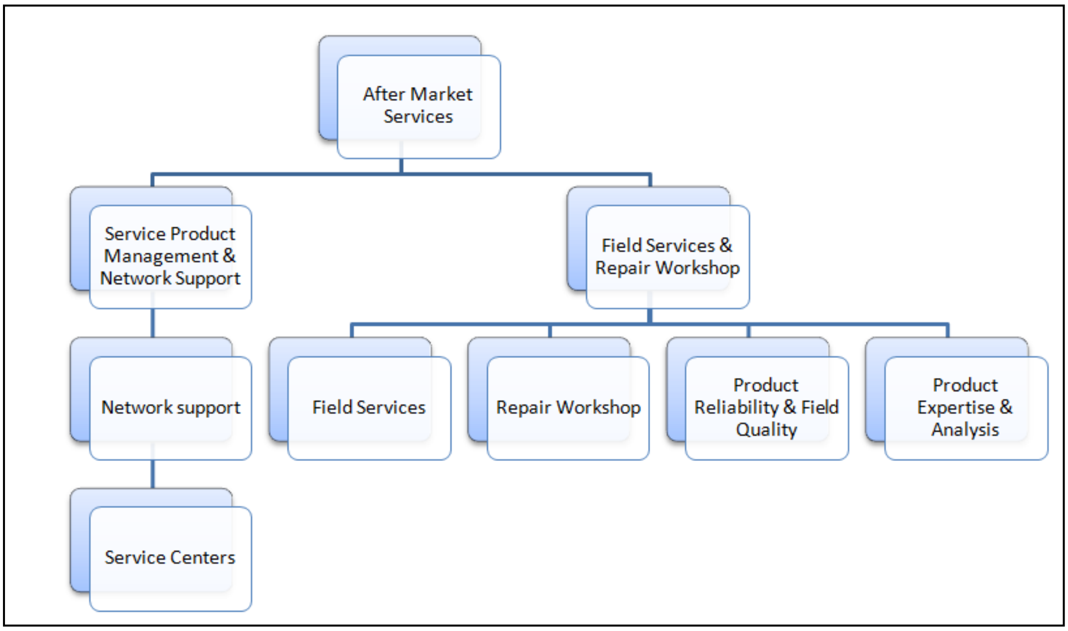


Figure 4. The Service Organization.

2.3 Procedure in Case of a Failure

When device fails under the warranty period, the service partner receives a request to solve the problem. The physical actions after the analysis vary to the case. The flow of the entire process, as it is related to device under the warranty period is presented in Figure 5.

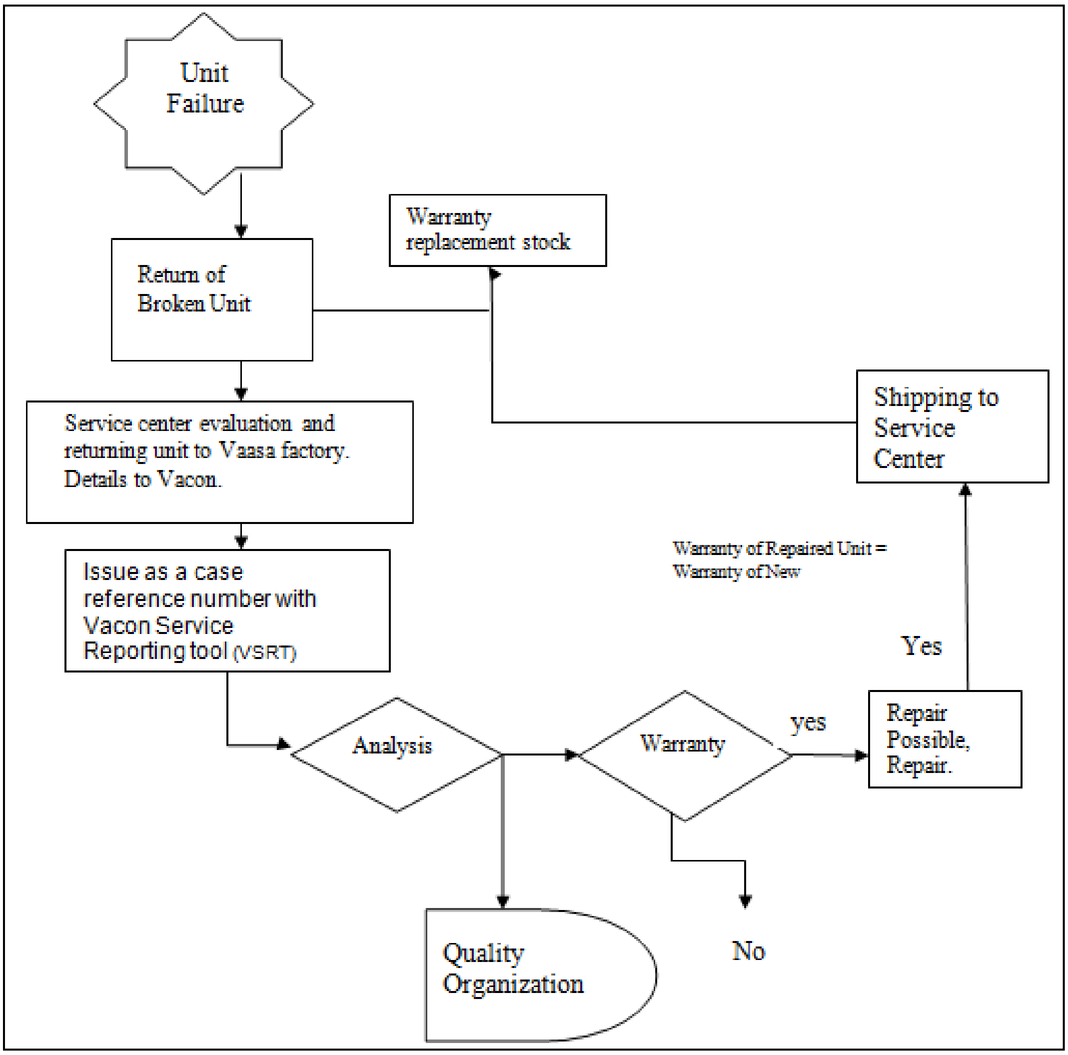


Figure 5. The shortest possible route of the device, in case of warranty.

Vacon service organization uses tailored software called the "Vacon Service Reporting Tool". Every failed device gets the VSRT number to identify and follow the device during the service and analysis process.

Shipping the device between workshops around the world wastes time and money in the current procedure. Also the stand by time in Vaasa factory workshop can delay the conclusions and the stream of money.

The analysis process depends on the case. The device will be stored for the analysis when it arrives to Vaasa factory workshop. The standby -period depends on the length of the queue. The analysis engineer starts the analysis with the visual inspection and with getting familiar with the information available from the device. In most cases the passive measurements of the power unit and voltage measurements from the control board will be performed. The flow of the analysis depends on the failure descriptions and on the experience of the engineers. In each case the process can proceed with different ways. Engineers in the Vaasa factory have access to the circuit diagram –files and therefore their routes to the root causes can vary to the intuition and to the experience. The tacit knowledge is the most important factor in the current analysis process.

The conclusions of the analysis are reported to several targets. There are many parties who need information from the results of the analysis. The customer in addition to many of the Vacon departments receives the data. To limit the data to allowed and needed, there is few different software and several files to save and describe the data from the analysis. The quality team, R&D and after market services team, besides the analysis team itself, is the customers in reporting of the analyst. The current practice of reporting is laborious to the analyst. It is also hard to get comparable and usable data because of the non-standard reporting practice.

2.4 Tools for Analyzing the Device

The ways to analyze failed drive at the field are limited. The device is usually a vital part of a specific process. It is obvious that service personnel cannot test or disconnect the drive without disturbing the customer’s process. Under these circumstances the drives are always analyzed in the regional service centers.

Vacon offers the required official service training for service personnel. The basic service training is offered for all service and maintenance personnel and the advanced service training is offered to service partners only. The service training is held in Vacon training centers. The 21 training centers network are located worldwide. The locations of the Training centers are presented in Figure 6.

Vacon has made recommendations for equipment in the service facilities. The service partners and regional service centers have their own recommended equipment. Tools for the service engineer and for the service partner are mainly tools for disconnecting, inspecting and repairing the device at the site or at the workshop. In addition to engineer's tools, the workshop tools include measuring equipment and special equipment (Figure 7), produced by Vacon, for analyzing the devices.

Each Vacon product family has its own type specific service manual. The service manuals contain a lot of information about the specific device. The mechanical construction, power unit, testing, removing and replacing parts and the needed technical specifications are described in the document. The service manuals are available for service personnel via the Internet. A trained person can perform maintenance, troubleshooting and repairs with the help of the service manuals. The tables of contents of the Vacon NX family service manual are presented in Figures 8 and 9. Different frame size specialties are described in the appendices of the service manual. An example of the table of contents of a service manual appendix is presented in Figure 10.

The manuals are good source of information for troubleshooting and for repairing the device, but the root cause analysis is more or less depending on the competence of the analyst. The analyst can notice the burned or melted components easily but in which functional circuit they are located is harder to find out without circuit diagrams. If the component failure is not visible, finding it can be very hard. The deep going root cause analysis is not possible without the specific circuit diagrams. Because of the concern of the information leaks, the circuit diagrams are not published in the service manuals.

Due to new updates of the devices, several supplementary documents are published. These documents are mainly short notifications, directives or informative attachments to manuals. The documents deal with improvements, changes in components, identified quality issues, guide to inspect and measure the drive or other important information about the device. The manufacturer continually develops the devices, so the number of the supplementary documents increases.

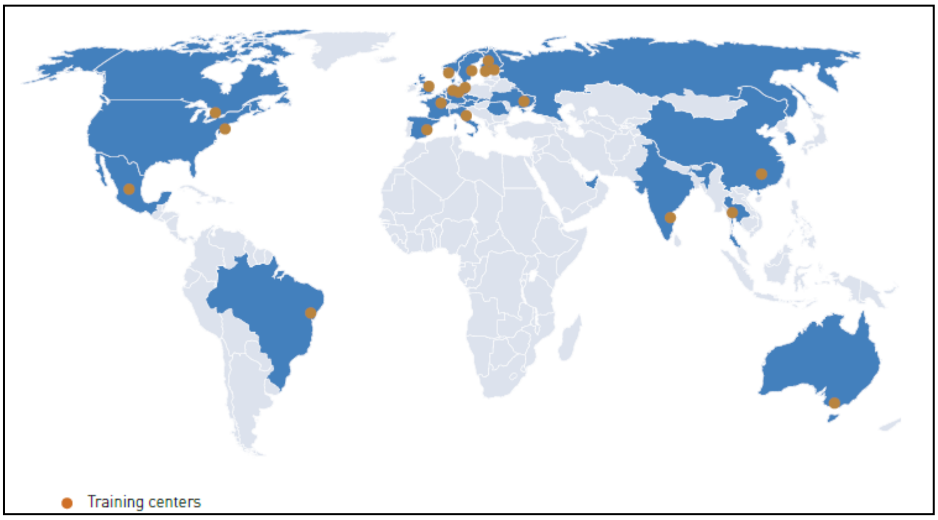


Figure 6. Vacon training centers. /4/

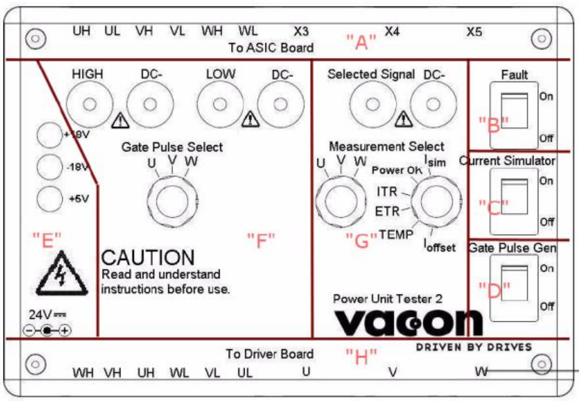


Figure 7. Special testing equipment, Illustration of the Power Unit Tester. /5/

Table of contents 1

1. SERVICE MANUAL VERSION HISTORY..6

2. AFTER MARKET SERVICE INFORMATION..8
2.1. Foreword 8
2.2. An overview of the manual information 9
2.3. Appendix manual information 9
2.4. Important instructions for various service situation 10
2.4.1. Personal requirements 10
2.4.2. Personal safety notice 10
2.4.3. Material requirements 11
2.4.4. Tool safety notice 11
2.5. Service policy 11
2.6. Warranty terms 12
2.7. ReplacementT units and spare parts 12
2.8. Maintenance 13
2.8.1. Recommended maintenance 13
2.8.2. Recharging the capacitors in stored units 14
2.8.3. Recharging individual capacitors that have been stored ... 14
2.8.4. DC link capacitor tests and replacement 15
2.8.4.1.Test 15
2.8.4.2.Replacement 15

3. TROUBLESHOOTING OF THE AC FAN 16
3.1. Troubleshooting of the main fan 16
3.2. Troubleshooting steps 17
3.2.1. Fan control and LED status 17
3.2.2. Checking the fuses 17
3.2.3. Checking the output of the fan driver board 17
3.2.4. Checking the output of the fan insolation transformer 18
3.2.5. Checking the fan and the starting capacitor 18

4. SERVICE TOOLS 21
4.1. Information 21
4.2. NC Load 1.0.17 21
4.3. NC Drive 21
4.3.1. NC Drive 2.0.7 21
4.3.2. NC Drive 2.0.8 22
4.3.3. NC Drive 2.0.11 22
4.4. NC Service 22
4.4.1. Software version 1.09 22
4.4.2. Software version 1.10 22
4.4.3. Software version 1.11 22
4.4.4. Software version 1.12 22
4.4.5. Software version 1.13 23
4.5. Device Properties Service 23
4.5.1. Version 2.0.2 23
4.5.2. Version 2.0.3 23
4.5.3. Version 2.0.4 23
4.6. 3-PUT2 23

Figure 8. Vacon NX Service Manual, Overview, Table of Contents, Page 1. /6/

2 Table of contents

Figure 9. Vacon NX Service Manual, Overview, Table of Contents, Page 2. /6/

Figure 10. Vacon NX service manual, Appendix FR4, Table of Contents. /7/

3 FUTURE MODEL FOR ANALYZING THE FAILURE

In the future the main responsibility of the analysis is meant to be at the regional service centers. Only exceptional cases will be analyzed at the Vaasa factory. The fault analysis manual is meant to be exact enough to any trained engineer to use. The reporting procedure should be standardized as well.

The future model of the analyzing process is meant to be more effective than the present one. The time and costs of the logistics should decrease significantly. Because of the division of the mass of devices to analyze between the service centers, should the process time been shorter. The standardized analyzing and reporting process gives the accurate data to make decisions without shipping the device around the world.

3.1 Template

The template for analyzing the device was the purpose of the thesis. It was known that the work was comprehensive with limited experience and knowledge about Vacon AC drives. The Vacon service organization has a need for the template and they had already started the mind work for it. The preliminary titles of the manual were collected and the flow of the template was thought.

The template is meant to be a digital document. In digital format the updating of the document and the distribution to the organization is effective. For a reasonable scope to the thesis, only one specific device from NXP family was treated. The template should be easily modified to other drives and the drive families.

The information to the template was collected by interviewing Vacon personnel and from the Vacon internal material.

3.2 Specifications of the Template

From the preliminary titles the template was modified into following structure.

Introduction

The section explains the focus of the material and informs the user that the document is based on the existing documents.

Safety

The safety requirements of the electrical workshops based on the standards IEC 61010-1 "*Safety requirements for electrical equipment for measurement, control and laboratory use"* and EN 50110-1 "*Operation of electrical installations"* are mentioned in this section. Some phrases to warn the reader and to protect the company will be added later.

Needed Tools

The electrical tools, hand tools, electrical measurement equipment and other miscellaneous items needed are presented in this section. Specific descriptions were ignored but Vacon recommendations for equipment were highlighted.

Type Code Identification

This chapter gives information from where the type codes can be found and how they should be decoded. The type code key tables for the Vacon NX power unit and for the OEM elevator drives were located to this chapter.

Variants and Differences

The version history of Vacon NXP FR4 drives in a table.

Pre-Analysis Procedures

The chapter contains instructions for preparatory actions e.g. making the needed file to attach pictures of the device to analyze.

Customer Failure Description

The chapter guides to collect and record all available information of the case from the customer. The process conditions, external conditions, malfunction descriptions, fault code from the device are mentioned as examples.

Documentation

The information and guidance to document the analysis process and the findings are located in this chapter.

Serial Numbers and Batch ID

The information how to photograph and record the serials is located in this chapter.

Photographing the Device

The chapter contains more accurate instructions for photographing and pointing out the components or other significant findings from the device. A request to inspect the conductivity of possible foreign materials is located here, too.

Recording the Findings

The chapter presents the electronic form that should be used for recording, reporting and submitting the conclusions of the analysis.

Known Failures and Their Identification

The section is divided into two parts, top 10 failures and less common failures.

Top 10 Failures

Top 10 failures, their possible fault codes from the device, the possible customer descriptions of malfunction and the identification code to the failure for Vacon database are tabulated in this chapter.

Other Analyzed Faults

Some of less commonly known and analyzed faults are tabulated in this chapter. The information about the unit of the drive, the fault in it, possible sub faults and failure codes for the treated sub faults can be seen from the table. Short written descriptions of failed components are included.

Fault Codes to Cause

The part of the document contains quick guide “From Fault Code to Part to Check” and map for the functions on the circuit boards.

Quick Guide

The chapter contains a tabulated quick guide. The user can follow the fault code of the device to the function or/and components that may have failed. Mentioned faults are based on analyzed NXP FR4 failures. Fault codes which do not guide to a fault unambiguous in this specific frame size are left empty.

Functional Map of the Device

The fault code, the customer’s description of the failure or an observed malfunction can reveal a circuit where the failures are possibly located. The chapter contains pictures of the circuit boards with drawn map of the functions on boards. The map of the top side of the power board is presented in Figure 10 as an example.

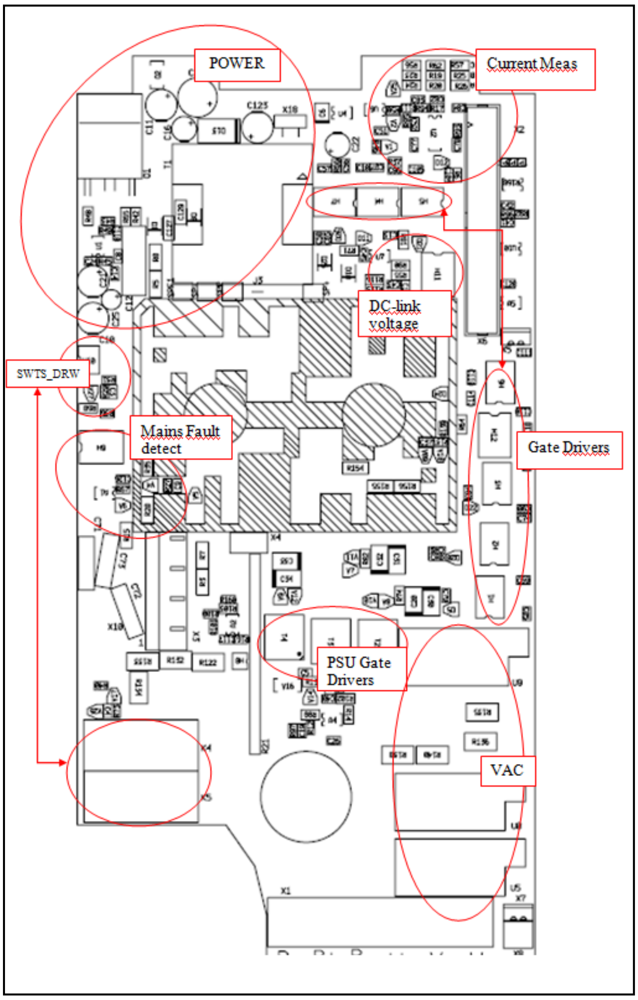


Figure 11. The Map of the Top Side of the Power Board.

Analysis

Passive Measurements

The reader will be informed to disconnect the device from the mains and to ensure that the life threatening potential is not present.

The chapter is divided to chapters on the basis of the main units of the device.

Power Unit

The preparatory disassembling needed to measure the power unit components is guided step by step in this section. The main terminals of the device and the diode measuring techniques are advised with the pictures presented in Figure 12.

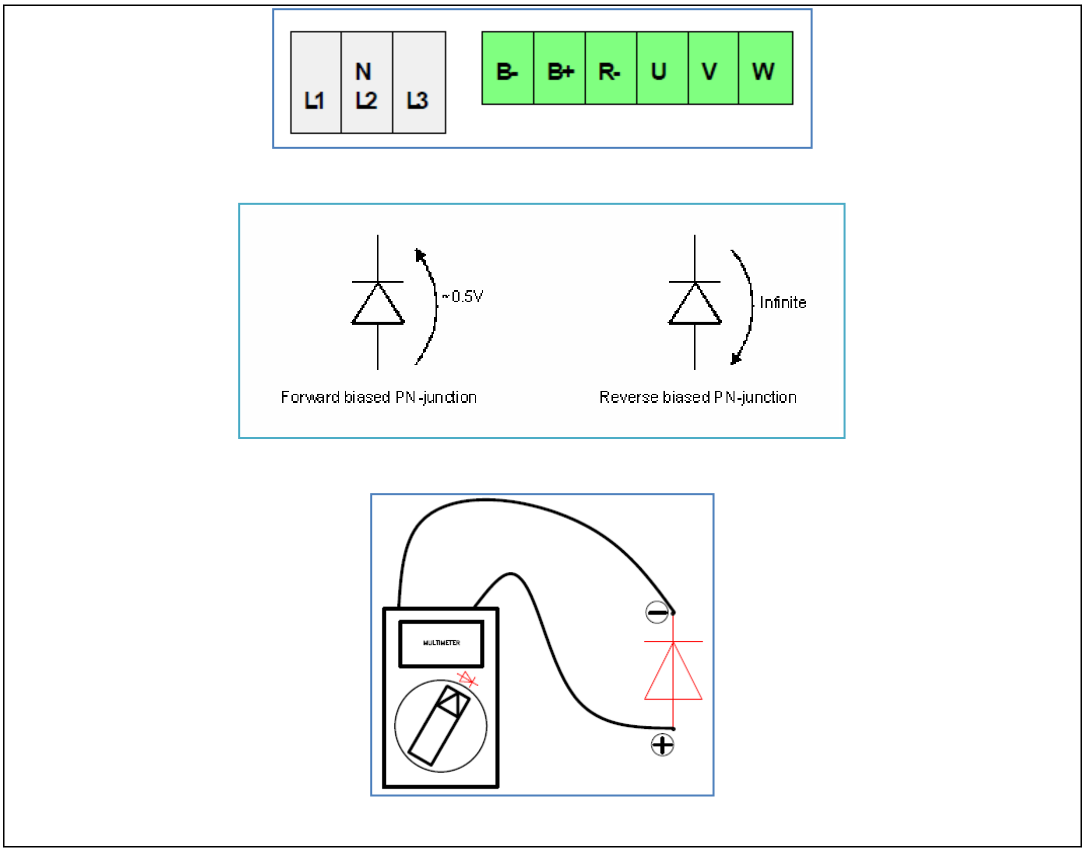


Figure 12. The Main Terminals and the Diode Measuring Techniques.

The points to measure the rectifier, IGBT-bridge and the brake chopper and the desired results of the measurements are tabulated as presented in Table 1.

Table 1. The Main Circuit Measurements for the Rectifier.

Measurement Point	Value	Measurement Point	Value
Rectifier forward: L1/L2/L3 to B+	0,45 V	Rectifier reverse: B+ to L1/L2/L3	Infinite
Rectifier forward: B- to L1/L2/L3	0,45 V	Rectifier reverse: L1/L2/L3 to B-	Infinite

Control Unit

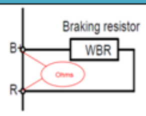
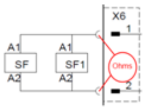
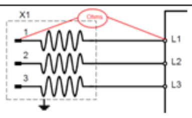
Option Boards

The chapter advises the reader to the specific document about the diagnostics of the option board. The most common damaged components are presented in the photograph and measuring the rectifier on the board is guided with the figures.

Enclosures

The passive measurements of the enclosures of the elevator drive are presented in this chapter within the informative table. The tabulated introductions are presented in Table 2.

Table 2. The Enclosures.

Enclosure	Measuring points	approx Measured value	Value between = OK
BRK Resistor	 Between B+ R-	67 Ω	65-70 Ω
Contactor windings	Between Contactor leads 	109 Ω	
Choke	 X1L1 - L1 X1L2 - L2 X1L3 – L3	0.6 Ω / each	

Electrical Tests

After the accepted passive tests of the power unit, the electrical testing can be carried out. The chapter is divided into two sections.

Power Unit Tester (PUT)

The chapter guides the reader to the service manual where the introductions to use the Power Unit Tester (PUT) can be found.

General Functionality

The tabulated step by step introduction to testing the devices functionality is located into this chapter. The table guides the analyst through the test. Every step contains the value or action to pass the step. If the step cannot be accepted, the further actions are advised.

Power Board Analysis

The chapter contains more specific introductions to detect and to measure failed components on the power board.

Main Power FET

Measuring the main power supply circuit is guided in this chapter with the illustrations. Mainly the main power FET and its feeder capacitor are components to inspect. The introduction to measure the FET is presented in Figure 13.

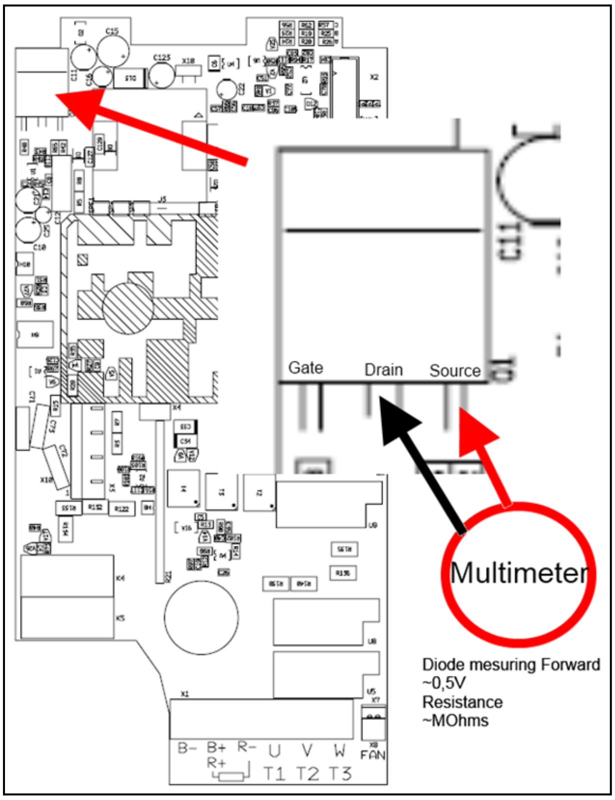


Figure 13. Measuring the FET.

Diodes in the Power Board

The chapter contains an illustrated instruction to measure and detect the failed diodes from the power board.

Charging Resistor

Illustrated instruction for inspecting the condition of the charging resistor(s) are located in this chapter.

Control Board Analysis

The chapter contains instructions for inspecting the control board. There are several test points to measure the voltages from the board. In the chapter there is an enlarged photograph to find the test points and to locate the LEDs which indicate the functioning of the software. The proper testing point voltages are tabulated. For more accurate testing of the control board and the option boards the chapter guides the reader to the instructions of the special test equipment.

Documents Needed

The chapter contains a tabulated list of the source files and the supporting documents of the template.

3.3 Reporting the Failures

The reporting of the failure is an important part of the analyzing process. Without specific data from the case the information cannot be used for statistics to improve the quality of the product or the process. The format of the received data must be standardized. In the template there are several instructions how to document the analyzing process of the device. There is guidance how to photograph the exceptional findings and record the measured values. Due to human factor, there can be variation in the quality and accuracy of the received data. To eliminate the inaccuracy, one possible way of reporting the analysis was designed in this thesis.

The electronic report form was designed with the Microsoft InfoPath –software. The data fields were chosen to collect and send forward the minimum information needed. The form was designed for a model and it is not yet compatible with the company database. To develop the form further is out of the focus of the thesis. With the carefully designed and programmed form the received data can be selected and standardized. The form is presented in the Appendix 1 as an example.

4 ELEVATOR DRIVE

The focus during the thesis work was on the elevator drive. Vacon has an OEM contract with a certain elevator manufacturer. This customer is a very important business partner to Vacon and therefore the pilot manual was produced for the particular drive. The fault analysis manual focuses on the one specific device model. The extension of the template to the different frame sizes and power classes can be done easily.

4.1 Drive and Application in General

The drive modules consist of a Vacon NXP frequency converter, an external brake chopper resistor module, THD reactor and two contactors, mounted on a chassis. The differences in appearances to the standard Vacon NXP and the elevator drive are presented in the Figure 14 and the main circuit diagram of the NXP device in the Appendix 2.

The special components are linked to the safety functions of the elevator and regulations or to the filtering the harmonics to the feeding network. The THD reactor, or choke coil, acts as a filter between the device and feeding network. Contactors are connected in series to ensure the stopping of the motor, in case of one contactor fails. An external brake resistor consumes the energy generated by the engine functioning as a generator. The illustration of the Vacon delivery is presented in the Appendix 3.

The frequency converter in the elevator drive combination is a standard Vacon NXP device with a tailored application and an option board for the I/O. The elevator application in the device is tailored for the customer. The elevator controlling software is running in the upper level programmable logic controller (PLC). The elevator controller collects the calls from the button panels and the software algorithm in the PLC transfers the commands to the drive via CAN -bus. Mainly the drive takes care of the smooth and safe operation of the elevator. The elevator is driven by closed loop speed control with an internal position correction.

For the safe and comfortable functioning of the elevator, the drive has to be parameterized. Besides the motor parameters the elevator mechanics, the safety functions and the speed control needs their parameters. The list of needed parameters is presented in the Appendix 4.

Figure 14. The Standard Vacon NXP Device and the OEM Elevator Drive.

For the safety functions there are a few hardwired analog and digital inputs in the option board.

- DIN1 and DIN2 for the status of the motor contactors
- DIN3 for the requests of the evacuation drive
- DIN4 for the “car on the floor” – contact
- DIN5 and DIN6 for the surveillance of the position of the electro mechanical brake
- AI1 for thermostat of braking resistor
- AI2 for the motor thermistor

Outputs are used for monitoring the state of the device.

- RO1 for FC Ready –signal
- RO2 for Brake Close –signal
- RO3 for Motor Fan Off –signal

4.2 Typical Faults of the Elevator Drive

70% of all failures are in the Top 10. Failures of the analyzed Top 10 are mostly known and repaired (7 out of 10) quality issues caused by supplied components on the circuit boards or the board layout based problems. The 5th most common failure was “No Reported Fault Found” with the 6% share.

Failures with low count and share are considered as individual and random. In most analyzed cases the root cause of the component failure was the overvoltage from the external circuits. Top 10 faults by the unit of a drive are presented in Figure 15. Top 10 failures by the fault code, without the “No Fault” are presented in Figure 16. The distribution of the failures outside the Top 10 by the part of the device is presented in Figure 17.

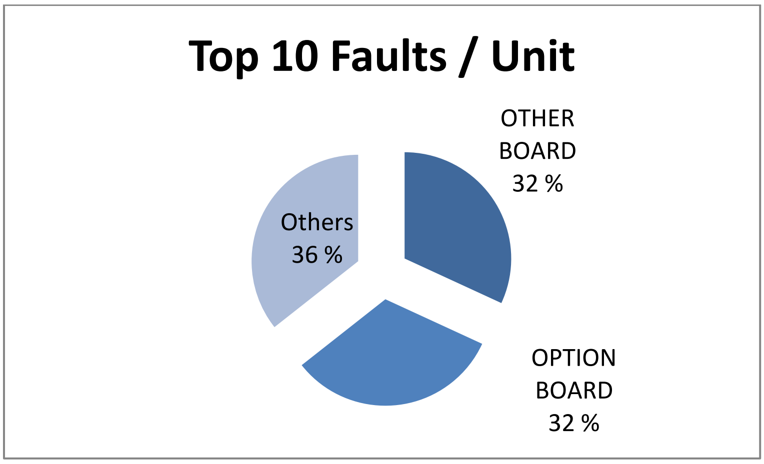
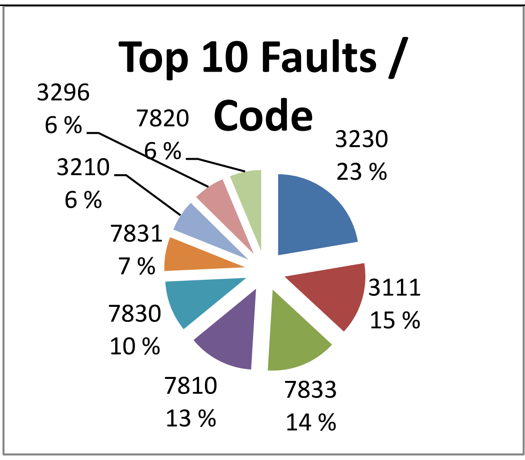


Figure 15. Top 10 Faults by the Unit.



Code	Cause
3230	Measurement
3111	Watchdog
7833	Brake Gate Driver
7810	Varistor
7830	Brake Main Circuit
7831	Brake Main Circuit Rectifier
3210	Main PSU
3296	Gate Driver PSU
7820	PSU

Figure 16. Top 10 Failures by Fault Code.

Coils in the contactor and in the mechanical brake circuits can generate high overvoltage. If the voltage suppressor components are not rated properly or there are some deviations in the component quality, the surge can break to the circuit board.

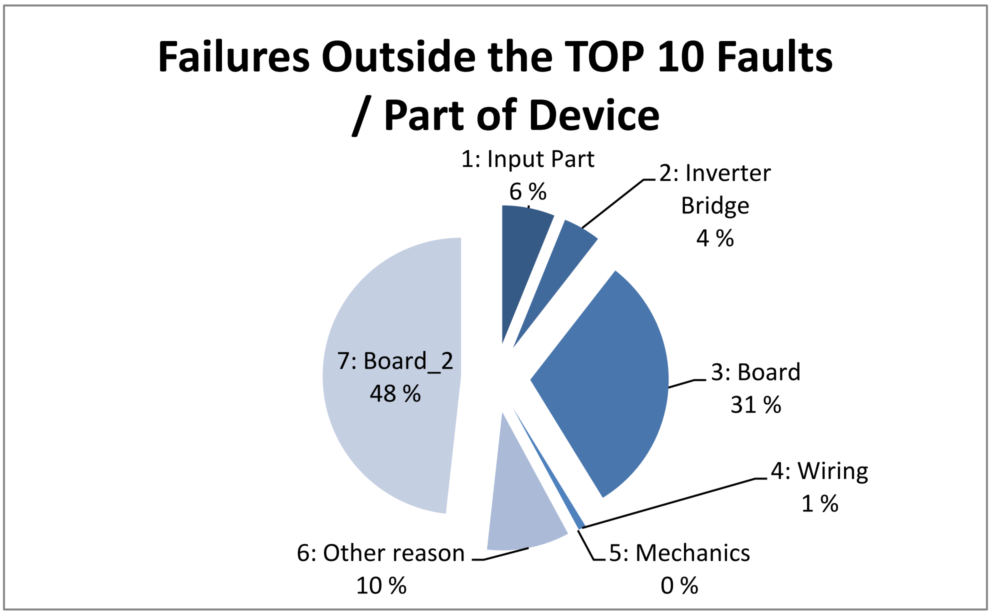


Figure 17. Distribution of the Failures by Part of the Unit.

Until the end of the year 2011, the most common conclusion of the analysis, according to the statistics, was a shorted diode or the capacitor.

5 FAULT ANALYSIS

5.1 Case Example 1: F7, Saturation

The customer's description of the failure was "F7 Saturation". Saturation is a critical fault that can appear if the IGBT –transistor or the saturation detection circuit fails. A shorted brake resistor can also cause the saturation trip. The saturation trip is not a resettable from the panel of the device.

Components related to saturation fault are located in the power board and the measurements started there. The saturation detection circuit is located both, top and bottom, sides of the circuit board. The main functionality of the detection circuit is in the gate drive optocoupler. The optocoupler has integrated desaturation detection and fault status feedback circuits. When the gate signal is high and potential difference between the DC+ and the IGBT output exceed the internal reference of 7V, the fault signal is activated. Fault protected IGBT gate drive in principle is presented in Figure 18. The circuit diagram of the HCPL-316J optocoupler is presented in Figure 19.

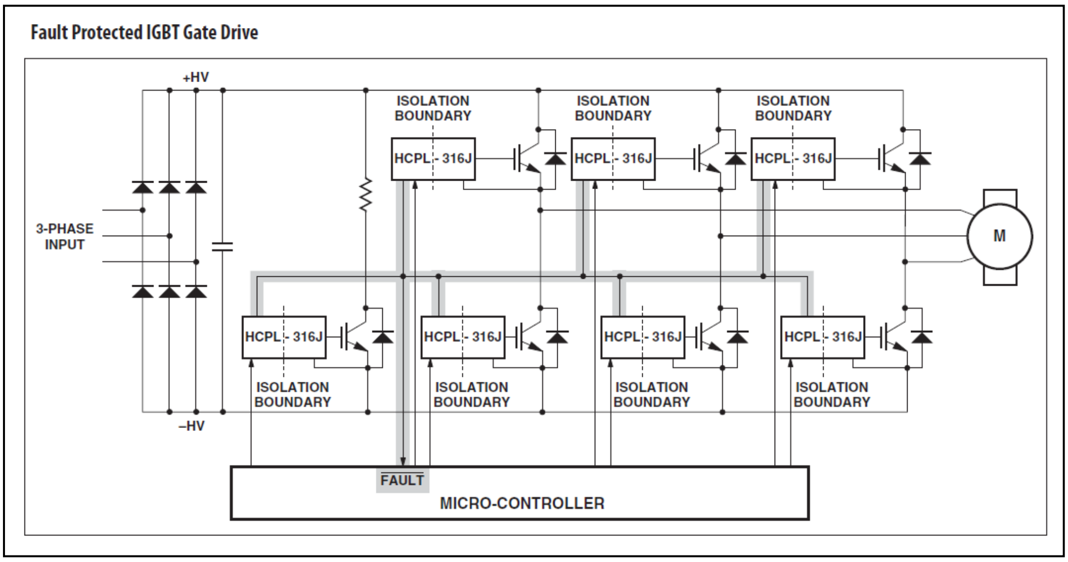


Figure 18. Fault Protected IGBT Gate Drive. /8/

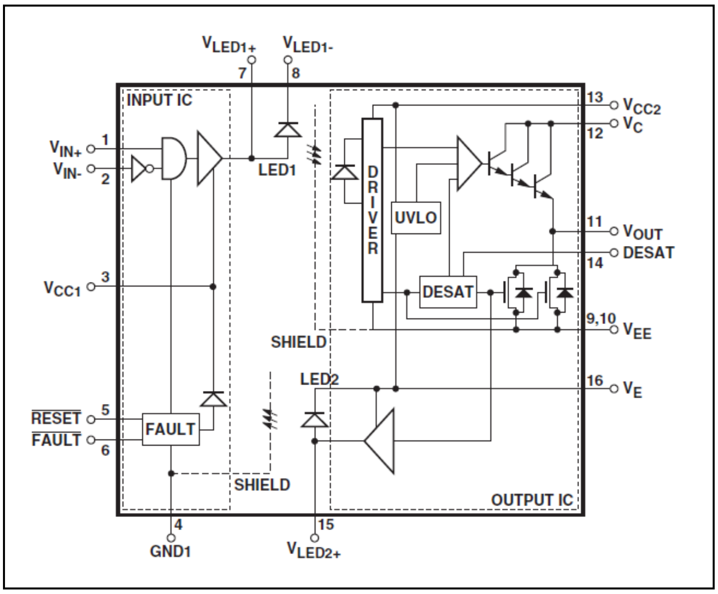


Figure 19. HCPL-316J Gate Drive Optocoupler. /8/

Step 1:

From the top side of the board the rectifier diodes of the supply transformer, through the transformer windings, and gate supply voltages over capacitors were measured. The threshold voltage of diodes was around 0,5V and the supply voltages 10…17V.

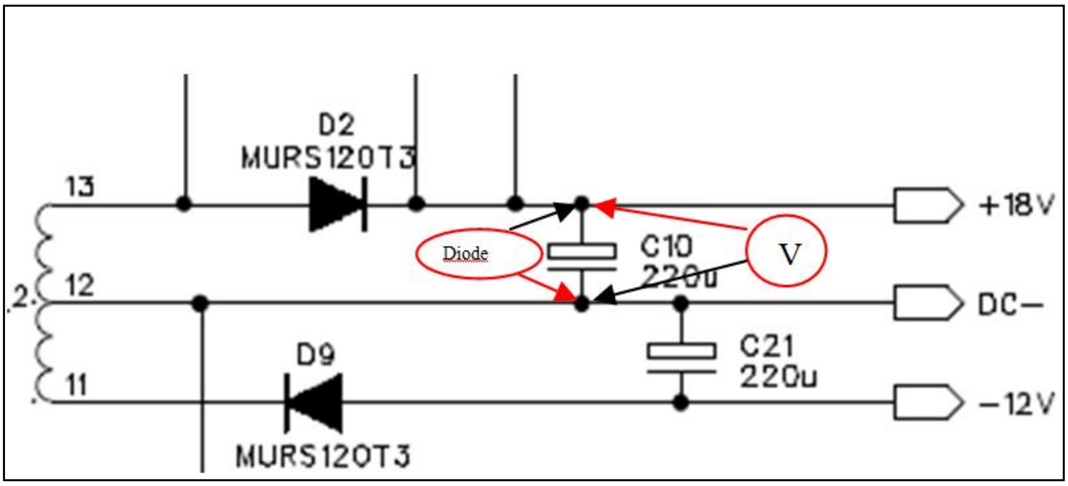


Figure 20. Step 1 Measurements.

Step 2:

To ensure there is no leaking current through the gate of the IGBT, the capacitance between the gate and the emitter of the IGBT, was measured. The measured value in this model should be and was around 20nF. The power board was disassembled to perform these measurements.

Step 3:

The power module was tested to ensure the proper functioning by driving the device with accurate test board.

Step 4:

The power board was fastened to accurate “MiniSkiip” module to test the board. DC link voltage, 540V, was simulated with an auxiliary voltage source. The gate signal from the control unit was simulated with an external source and the functioning of the optocouplers was ensured with measuring the potential between pins 14 and 16 (Figure 21). The difference was at the correct rate with 15mV.

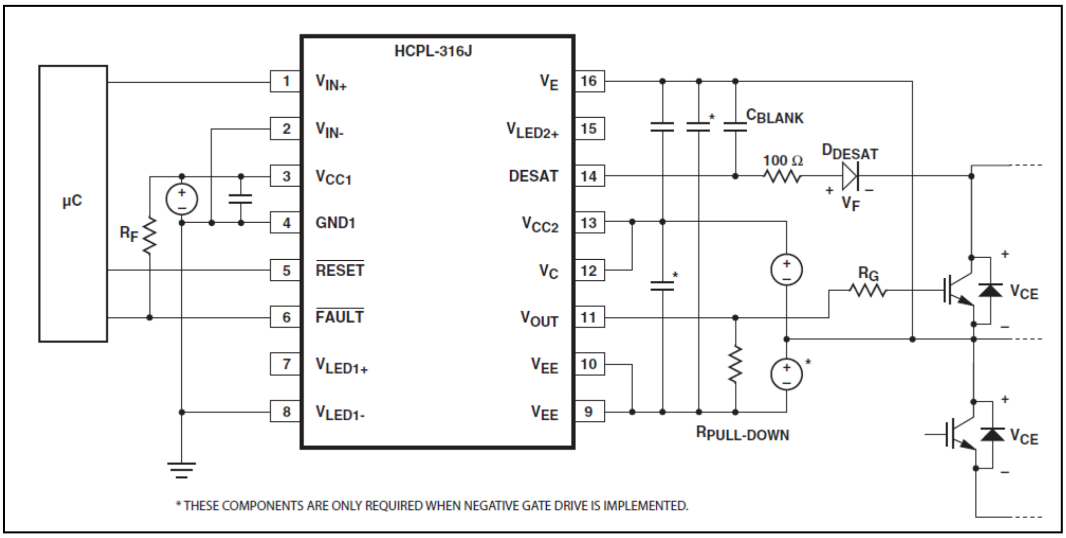


Figure 21. Gate Driver Circuit Example. /8/

Step 5:

The control unit was connected to the power board and the drive was driven with 50Hz. The saturation trip occurred.

Step 6:

The power board was disassembled and bottom side components were inspected. A shorted diode and burned resistor was found. The failed components are pointed out from the figure 22.

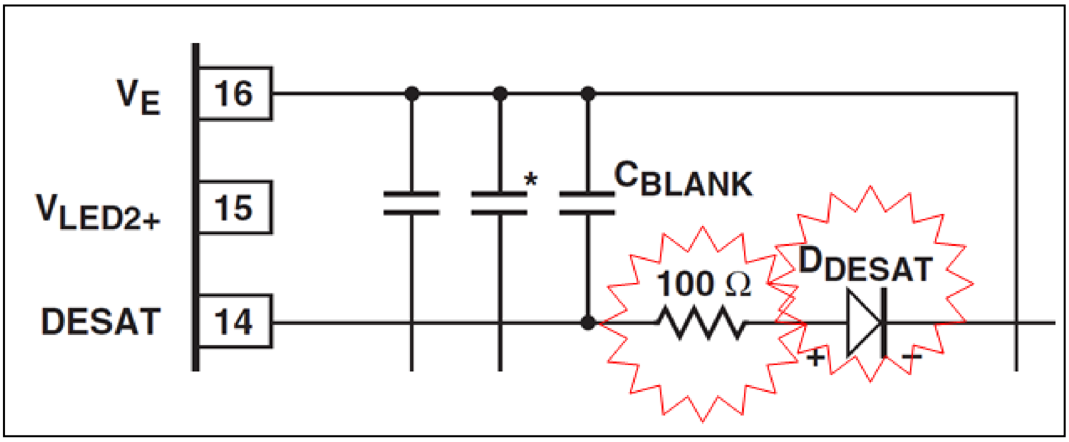


Figure 22. Components that caused the F7 Saturation Trip. /8/

Step 7:

The root cause of the component failure was recorded as a possible component problem or reverse breakdown.

6 CONCLUSION

In this thesis we established the company confidential template or manual for analyzing and reporting the root cause of the frequency converters failure.

The work was known to be a big challenge. Collecting the available data and documents, getting familiar with the drive and analyzing processes needs was a bigger challenge than we realized. Because of the electronics, there are hundreds of possible ways how the device can fail. There are going to be enormous job to document all possible failures and procedure to analyze them. By the help of Vacon personnel, studies in Vaasa University of Applied Sciences and couple of summers' experience in assembling AC drives at Vacon, the work could be performed to the present point.

For a thesis worker the assignment was interesting. Besides getting to know nice and helpful people, a load of knowledge in the measuring techniques, Vacon drives in general, elevator drives in particular and company processes was adopted.

The template was set to a good start and the flow of the chapters was designed as presented in the thesis. There are contents in every chapter of the document. For the company the thesis is, in our opinion, at a good starting point for further development. In the future the template can be updated for other device models and drive families.

REFERENCES

/1/ Vacon in Brief. 2012. Vacon Company web pages. *http://www.vacon.com/Default.aspx?id=461829*

/2/ What is an AC Drive? 2012. Vacon Company webpages. *http://www.vacon.com/Default.aspx?id=464743*

/3/ Products. 2012. Vacon Company web pages. *http://www.vacon.com/Default.aspx?id=481764*

/4/ Vacon Training, Develop your in-house expertice. Vacon Company web pages. Brochure. *http://www.vacon.com/Default.aspx?id=450403&FileView=485015*

/5/ User's Manual, 3-PUT2 Service Tool. Vacon 2008.

/6/ Vacon NX Service Manual, Overwiew. Vacon 2011.

/7/ Vacon NX Service Manual, Appendix FR4. Vacon 2009.

/8/ Data Sheet-HCPL-316J, 2,5 Amp Gate Drive Optocoupler with Integrated Desaturation Detection and Fault Status Feedback. Avago Technologies 2011.

VACON DRIVEN BY DRIVES

Analysis Path for Vacon Drive

CUSTOMER

Customer:

VSRT

Date received:

SERVICE

Service Organization:

Author:

Analysis started:

Case closed:

DRIVE

Frame size:

Choose Frame Size

Type Code:

Op.Days:

Serial Number:

Power unit type:

Powerboard model:

Failure description:

MEASUREMENTS

Powerboard model:

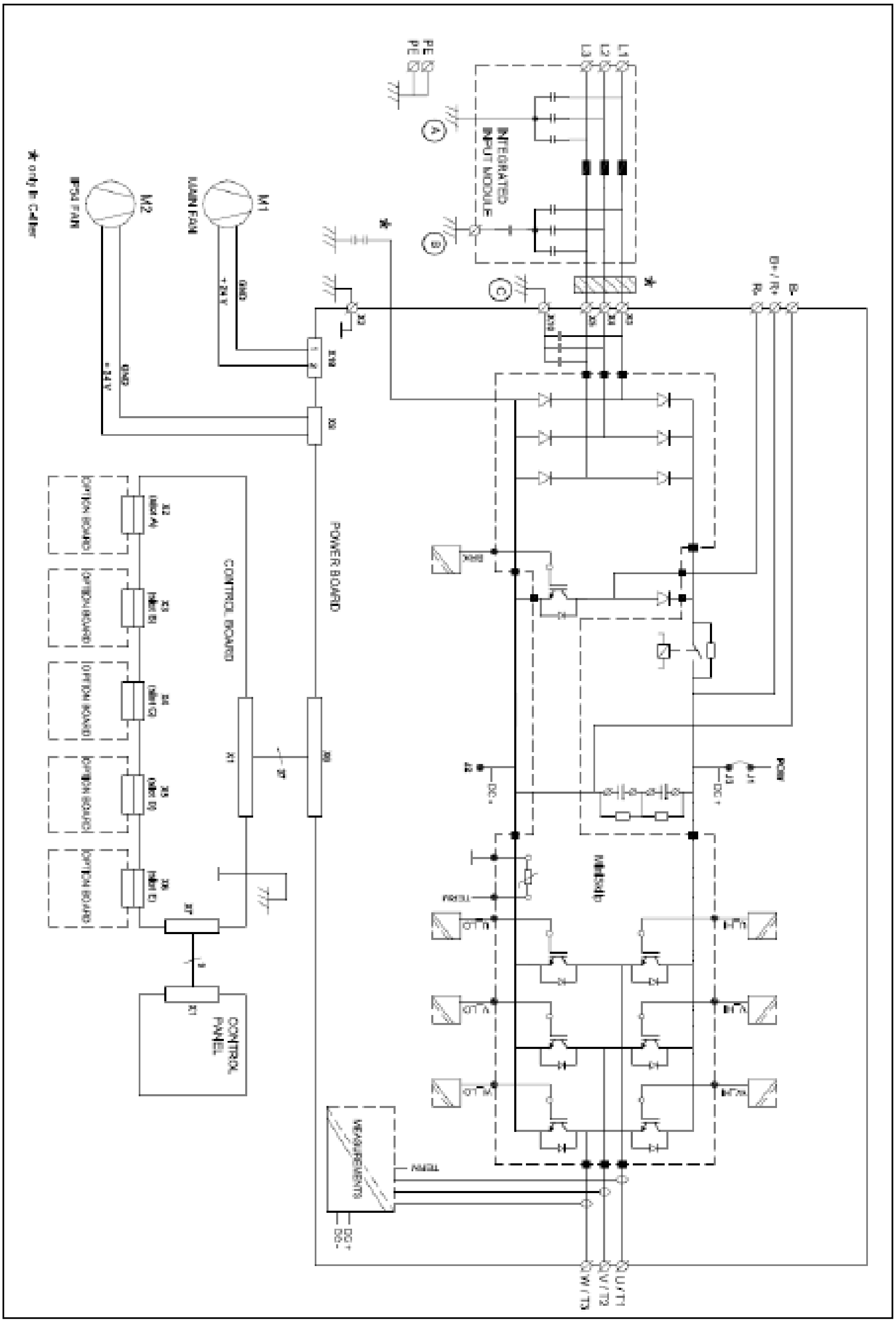
Checkings:	OK	NOK	**Details:Measured values, notes, rootcause.**
Charge circuit	☐	☐	
Capasitors	☐	☐	
Rect.Diodes	☐	☐	
IGBT	☐	☐	
Gate drive	☐	☐	
Brake IGBT	☐	☐	
Brake drive	☐	☐	
PCB	☐	☐	
Main PSU	☐	☐	
Gate PSU	☐	☐	
DC-link meas.	☐	☐	

Attached photos etc.

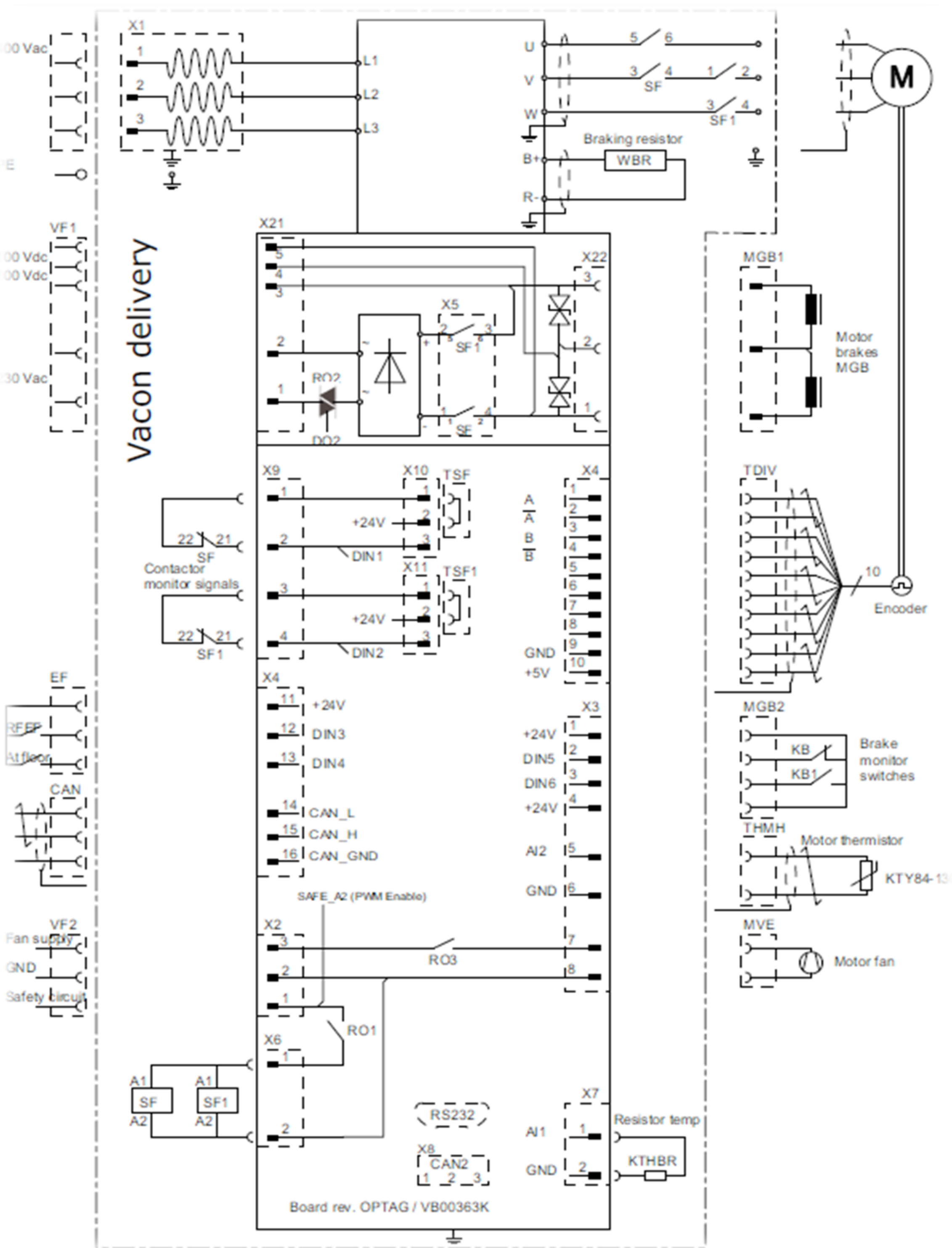
Make an document (.doc, .pdf) and copy all photos etc. to it. Attach the document here. Liitetiedosto

REPAIR ACTIONS

Case closed:


INTEGRATED INPUT MODULE
M1
MAIN FAN
M2
POWER BOARD
CONTROL BOARD
OPTION BOARD
OPTION BOARD
OPTION BOARD
OPTION BOARD
OPTION BOARD
CONTROL PANEL
MEASUREMENTS

APPENDIX 3. The illustration of the Vacon delivery. 1/1



CATEGORY	DESCRIPTION	UNIT	DFLT VALUE
MOTOR PARAMETERS			
	Motor Nom Voltg	V	340
	Motor Nom Freq	Hz	50.0
	Motor Nom Speed	rpm	1440
	Motor Nom Current	A	12.0
	Phase sequence	-	1
	Motor Nom Power	kW	7.5
	FC Comm NumberHi	-	0
	FC Comm NumberLo	-	0
SPEED CONTROL PARAMETERS			
	Leveling Speed	m/s	0.20
	Nominal Speed	m/s	1.0
	Inspection Speed	m/s	0.25
	Rated_Low Speed	m/s	0.80
	Acceleration 1	m/s^2	0.50
	Deceleration 1	m/s^2	0.50
	Acc Inc Jerk 1	s	1.0
	Acc Dec Jerk 1	s	1.0
	Dec Inc Jerk 1	s	1.0
	Dec Dec Jerk1	s	1.0
BRAKE CONTROL PARAMETERS			
	FreqLimitClose	Hz	0.01
	0 Hz TimeAtStop	s	1.25
	SmoothStartTime	s	0.90
	SmoothStartFreq	Hz	0.0
	BrakeStopDelay	s	0.0
	DC Boost Time	s	0.15
	PreTorque Time	s	0.40
	FinalTorqueTime	s	0.15
	FinalTorqueLimit	%	0
	DelayAfterKBx	s	0.10
MOTOR CONTROL PARAMETERS			
	Field WeakngPnt	Hz	f_N
	Voltage at FWP	%	100.0
	Switching Freq	kHz	8.0
	Overvolt Contr	-	0/Off
	Undervolt Contr	-	0/Off
	Rpm Identification	-	0/No Action
	Delta Speed Max	Hz	0.05
	RpmIDTorqueLimit	%	30.0

CATEGORY	DESCRIPTION	UNIT	DFLT VALUE
PROTECTION PARAMETERS			
	ShaftSpeed Time	s	0.40
	ShaftSpeedLimit	m/s	0.30
	ShaftServiceTime	S	0.20
	ShaftServiceLimi	m/s	0.08
	ShaftTimeEva	S	0.40
	ShaftSpeedLimEva	m/s	0.30
	Autom. Restart	-	1
	ShaftTimeRelevel	s	0.20
	ShaftSpeedLimRel	m/s	0.08
EVACUATION PARAMETERS			
	Evacuation Speed	m/s	0.10
	AccelerationEva	m/s^2	0.15
	SpeedCtrl_Kp_Eva	-	20
	SpeedCtrl_Ti_Eva	ms	30.0
	StopDistanceEva	mm	100
CLOSED LOOP PARAMETERS			
	MagnCurrent	A	6.8
	SpeedCtrlLimit 1	Hz	2.0
	SpeedCtrlLimit 2	Hz	9.0
	Speed Ctrl Kp 1	-	20
	Speed Ctrl Kp 2	-	30
	Speed Ctrl Ti 1	ms	15.0
	Speed Ctrl Ti 2	ms	45.0
	CurrentControlKp	%	110.0
	Encoder1FiltTime	ms	3.0
	Slip Adjust	%	82
	Motor thermistor	-	1/On
	System Inertia	kgm^2	-0.01
	SlipAdjustMin	%	70
	SlipAdjustMax	%	100
	ModIndexLimit	%	135