Chapter 1

Introduction

Chapter one will provide an introduction to the Active Magnetic Bearing (AMB) and Drive Electronic System (ADES) as well as provide the problem statement of this dissertation. Background will be given on two relevant subjects which is digital communication and AMBs. The issues to be addressed during this project as well as the research methodology followed to successfully complete this dissertation will also be discussed. This chapter will conclude with a brief discussion of the dissertation layout

1.1 The digital phenomenon

A recent development in processor technology has placed digital signal processing well ahead of analogue control in most practical applications. General advantages of using digital processing are [1]:

- Flexibility
- Complex controller functions
- Calibrations of sensors
- Testing
- On-line monitoring
- Intelligent reaction
- Diagnosis for maintenance
- Upgrading requires only software changes

Not only is digital signal processing becoming increasingly attractive, but also ***digital communication systems***. The reason for this phenomenon is the ever-growing demand for data processing and communication. Implementing digital communication has various advantages over analogue processing, for example it offers flexibility [2] and essential noise immunity [3]. Therefore the need for communication standards becomes more and more pronounced.

Pioneers of digitally controlled AMB systems incorporate digital processing and digital communication to control and monitor their systems. Mecos, Synchrony, Calnetix, Levitronix and SKF are examples of such companies. These companies implement CAN bus [4], [5], RS 232, RS 485, RS 422 [4], [5] Ethernet [4], [5] MODBUS [6] and other communication protocols.

In order to develop and design a competitive and state of the art AMB system it will be crucial to implement digital signal processing as well as advanced digital communication.

1.2 Background

AMBs have been implemented on over 200 turbo machinery applications world-wide [7]. The distinct advantages of AMBs over conventional bearings are non-contact suspension that implies no friction and thus the elimination of fluid lubricants. When considering the advantages, it becomes understandable why the use of AMBs will improve efficiency, reliability and safety in high temperature gas-cooled reactors [8].

During the past few years the McTronX research group has been conducting thorough research concerning AMBs. Their initial focus was to develop an AMB laboratory in order to obtain the necessary knowledge needed to assist industries already implementing AMBs. After realization of this specific goal a high-speed flywheel system was developed for implementation as an uninterrupted power supply. The McTronX research group's focus is shifting towards assisting with the completion of the next generation nuclear reactors, the Pebble bed modular reactor (PBMR) that is currently in the development phase in South Africa [9].

This will be done by designing and developing an integrated electronic package that will consist of a main controller, power amplifiers, motor driver and various sensors. Development of such an integrated electronic package for an AMB and drive system will finally lead to the implementation of such a system in a high speed helium blower.

High speed helium blowers are used in high temperature gas cooled reactors such as the PBMR. The main purpose is to act as a circulator to ensure that the thermal energy is transferred from the reactor to the turbines aiding in maintaining the exact fluid temperatures [10],[8]. Additional features of helium blowers include, obtaining high speeds and achieving a high mean time before failure (MTBF). This would not be possible when employing conventional bearings, however when implementing AMBs which operate lubrication free these requirements are certainly attainable [11].

It is however necessary to understand the operating principles of an AMB in order to successfully implement it on the specified application.

1.2.1 AMBs

The technical application of AMBs is to provide stable rotor levitation in high speed rotating electrical machines. This frictionless alternative implies that AMBs will have great potential in the nuclear industry. It is important to know that AMBs are mechatronic products that consist of combined electronic and mechanical components. AMBs consist of the following components:

1. Sensors
2. Power amplifiers
3. Controllers
4. Electromagnets
5. Rotor

In Figure 1-1 the basic operating principle of an AMB is illustrated.

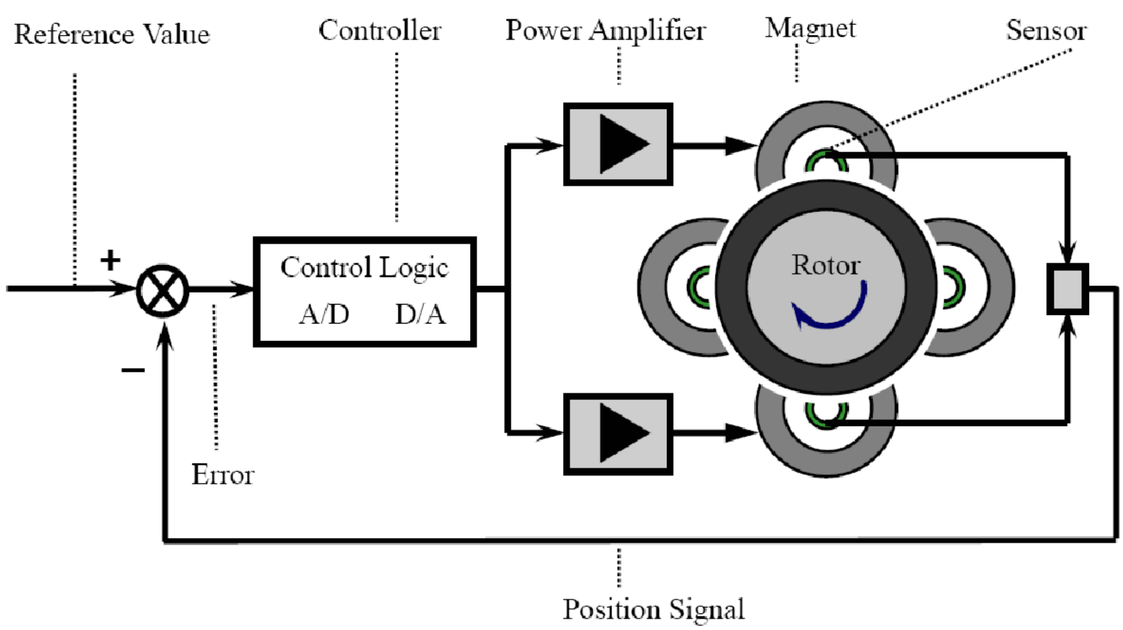

Figure 1-1: The basic operating principle of AMBs [8]

The basic principle of AMBs requires the measurement of rotor displacement along one axis by means of a position sensor. The position sensor continuously generates a voltage signal that is fed to the digital controller as analogue or digital values. The rotor displacement signal obtained is compared with a given reference value as shown in Figure 1-1. The main controller then applies a control algorithm. After computation, the main controller generates a new control signal that is directly applied to the power amplifiers. This particular control signal is converted to a current signal by the power amplifiers. The output current from the power amplifiers is then applied to the electromagnets which generates a force to levitate the rotor.

1.2.2 ADES

The ADES involves the development of an integrated electronic package for an AMB and drive electronic system (from here on referred to as ADES) that will be implemented in a high speed helium blower.

1.2.2.1 Previous system outline

Although the McTronX research group has not yet developed an AMB system for a specified application, an AMB system has already been developed. In Figure 1-2 the dSpace system configuration is shown. This system makes use of MATLAB®, Simulink® and a dSpace® controller card (dSpace® is a real-time development tool mostly used for rapid prototyping) to control the AMBs as shown in Figure 1-2.

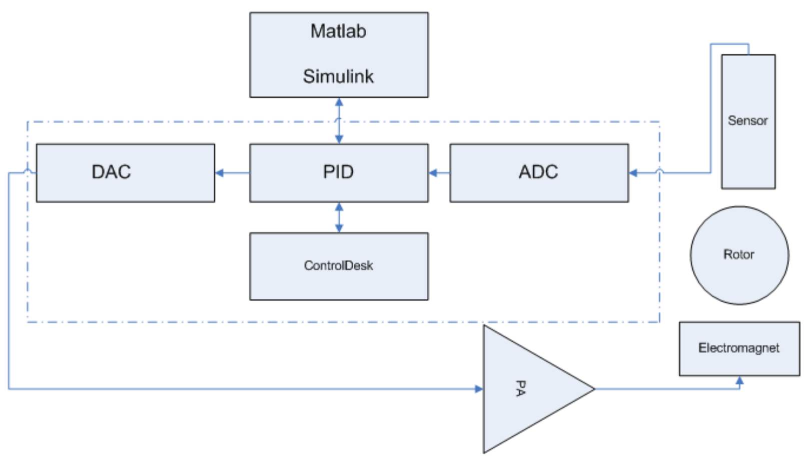

Figure 1-2: dSPACE® system configuration

The dSPACE® card slots into the peripheral component interface (PCI) bus of a Personal Computer (PC). This card consists of various analogue to digital converters (ADCs) and digital to analogue converter (DACs) and digital or analogue input and output ports. The dSPACE® system interfaces with MATLAB® where a complex Simulink® model is used to control the AMB system. ControlDesk® is an added feature of dSPACE® used to monitor the system [12].

1.2.3 Proposed system structure

The proposed system structure for the ADES was obtained by taking various requirements listed for a high speed helium blower into account. The most important requirements were:

- Compatibility with an industrial system setup
- Reliability
- Cost effectiveness
- Robustness

The ADES will be divided into internal components and external components. The internal components will be used to control the AMBs. These components are the main controller, power amplifiers, motor drive, inductive sensor driver (ISensorboard) and the power conditioning unit. The external components are the maintenance port, SCADA and remote-access port. These components will be used for data logging and system monitoring. Figure 1-3 is an illustration of the proposed system configuration. Between each of these components digital communication will be utilized assisting in attaining the specified requirements.

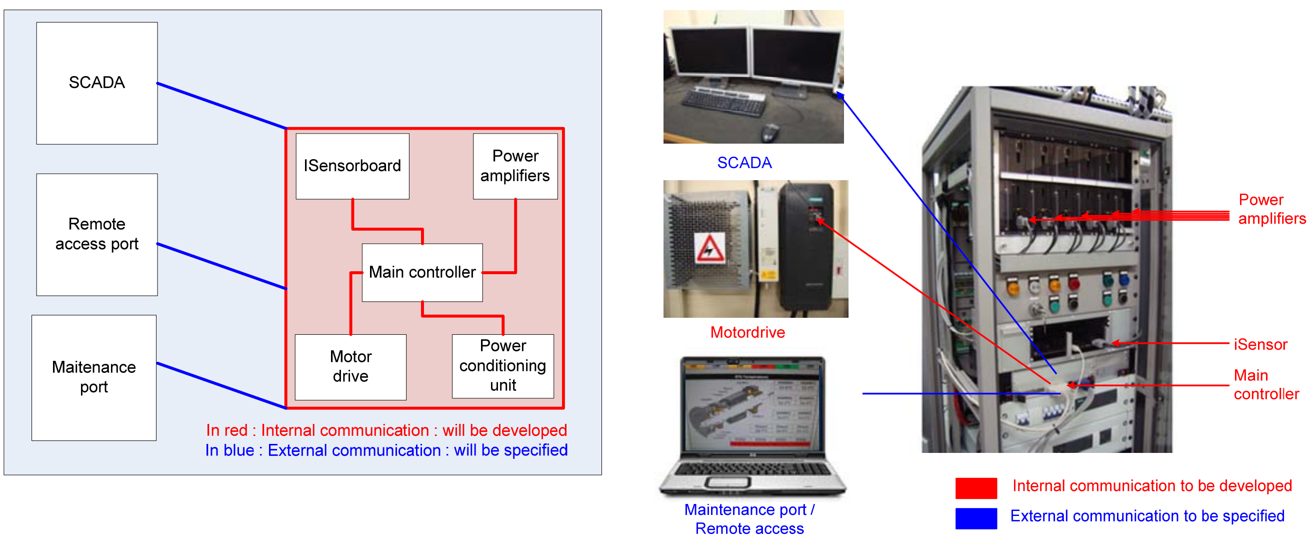

Figure 1-3: Proposed system configuration and definition of the scope of this project

1.3 Problem statement

The ADES requires the development of a complex embedded system. This particular embedded system consist of a powerful main controller and co-processors in order to attain the computational speed required to efficiently control the AMB system. However if the communication architectures between the different internal interfaces are not meticulously designed, the ADES most definitely will not achieve the computational speed needed.

The performance of the ADES directly relates to the communication busses that connect the different units [13], thus it was considered important to thoroughly develop the communication architecture.

The aim of this project is to ***develop*** a communication system to be implemented between the ***internal components*** that will satisfy the specific requirements of an ***AMB application***. Furthermore the best suited solution will be ***specified*** for the ***external components*** to interface with the ***main controller.***

1.4 Issues to be addressed and methodology

The ADES main controller which will also consist of the communication controller is to be developed by making use of commercial of the shelf units (COTS). This decision was made due to the following reasons:

1. The McTronX research group does not have sufficient knowledge about hardware architecture development. By purchasing this very advanced module, the technical risk will be decreased immensely.
2. The development cost of such a module will be extremely high and for the first version of the ADES one of the main requirements is cost effectiveness.
3. This particular project is subjected to a very short development time. By purchasing this module the project will need to focus solely on the development of the very specialized software.

1.4.1 Literature study

The literature study will require thorough research of all the aspects relating to the project. In every project a literature study is of the essence and needs to be conducted concerning all the various aspects relating to communication. Aspects that will be reviewed comprehensively are:

- Digital vs. analogue communication
- OSI model
- Data transmission methods
- Asynchronous vs. synchronous communication
- Serial vs. parallel communication
- Comparing bus solutions
- Field busses
- Network busses
- Limitations of busses
- Overview of communication layers
- Overview of metrics for determining communication architecture performance.

This will be done by obtaining as many books and papers as possible concerning the listed subjects. All the abstracts will be reviewed and only relevant papers and books will be selected to be studied intensively, where after a comprehensive literature study will be written.

1.4.2 Conceptual design

The conceptual design will start off by determining all the system specifications of the ADES. This will be done by writing a detailed systems requirement specification document. This document was generated by the McTronX research group. Without a thoroughly documented systems requirement specification it will not be possible to design the system architecture, let alone develop the communication architecture. The next step of the conceptual design will be to design the entire ADES system architecture**.** This will be done by investigating various system architectural options and selecting the optimum solution which adheres to the system requirement specification.

After the system architecture is selected the project will shift towards the communication architecture development. The communication architecture development will start off by acquiring the relevant specification from the systems requirement specification document. These specifications will be used to formulate detailed specifications for the communication system.

The communication system specifications will include the precise data that needs to be communicated between the various sub-systems at the required bit rate. After the detailed specifications have been formulated, trade-off studies for the internal and external components will commence. Finally, the best communication solution will be specified for the internal and external components.

1.4.3 Detailed design

The detailed design will involve the procurement of the hardware that adheres to the architectures specified during the conceptual design phase. After the hardware is procured vigorous training will start. Training will involve learning to program a cutting edge programming language referred to as Very-High-Speed Integrated Circuit (VHSIC) Hardware Development Language (VHDL).

After training the development of an in-house protocol between the internal functional units will commence. The power amplifiers and the ISensorboard hardware and software will be developed in-house, therefore it will be necessary to design the driver circuits for each of these boards. After the physical layer has been designed by selecting the appropriate drivers and transmission medium the communication controllers will be designed, simulated and coded by making use of Modelsim®.

The various communication controllers will be programmed on each of the functional units where after system integration will commence. System integration will involve integrating all the internal components with the main controller.

1.4.4 Verification and validation

Verification will be done in parallel with the detailed design. Extensive verification will be conducted on each of the lower level assembly software units by making use of Modelsim® simulations. Verification of the hardware will be done by constructing laboratory experiments and analysing the results by using digital oscilloscopes. When each of the software and hardware units reach the stipulated specifications, verification will be considered adequate. After the system is fully operational, validation will be conducted by evaluating the system performance against the system requirements.

1.5 Dissertation layout

This dissertation will consist of six chapters:

Chapter 2 will contain a comprehensive literature study which includes all the aspects relevant to this project. Some of these relevant aspects are listed in Section 1.4.1. After all these aspects are studied and documented a critical literature review will be given.

After the literature study is completed Chapter 3 consisting of the conceptual design will commence. This chapter will start off by briefly discussing the system specifications of the ADES, where after various functional architectural options for the system will be constructed. Out of these architectures the optimum solution will be selected. From here on the focus will shift toward the primary goal of this project, which is selecting the optimum communication solution for the internal and external interfaces. This will be done by formulating a design process. Finally the best communication architecture will be specified for the external and internal communication interfaces.

Chapter 4 will consist of the detailed design and will commence with the hardware selection according to the system and communication architecture selection. Hereafter the focus will shift towards the development of an in-house protocol to be implemented between the internal units. The external interfaces will not be discussed in the detailed design, because only the communication architecture specifications of these interfaces were required.

Verification and validation will be documented in Chapter 5.This chapter will be divided into three sections. The first section will focus on discussing the clear difference between verification and validation from a systems engineering view point. The second section will focus on developing a test and evaluation plan for the verification process, where after the test and evaluation plan will be carried out. Finally a test and evaluation plan for the validation process will be created and carried out.

The dissertation will conclude with Chapter 6 which will include the recommendations and the conclusions. This chapter will give a conclusion on how implementing digital communication between the internal units improved the system performance. Overall conclusions will also be made about various design selections. Finally recommendations will be made to improve the protocol as well as future work that can be done on this project.

1.6 Conclusion

This chapter provided the necessary background on AMBs and the ADES. After the ADES was explained briefly the problem statement of this dissertation was given. The main issues that needed to be addressed as well as the research methodology were discussed. Finally a short summary of the dissertation layout was given. Now that it is clear what will be research the literature study can commence.