Using ADAMS in the development of high voltage switching gears

Hanspeter Walser
ABB Corporate Research Center
Engineered Structures and Composites
Baden-Dättwil, Switzerland

Abstract

In the ABB Corporate Research Center ADAMS is used in the development of switching gear mechanisms and robots. This paper shows the usage of ADAMS in the development of high current and high voltage switching gears. In order to build up a simulation models very quickly several modules have been developed: a module describes the gas dynamic in the arcing chamber, another describes the electromagnetical force and another module the dynamic behavior of the hydraulic operating mechanism. Which modules are used in the simulation model depend on the type of switchgear. Comparisons between simulation results and corresponding measured curves show a very good correlation.

1. Introduction

ABB is a leading international electromechanical company with core areas:

- power plants
- transmission and distribution
- industry and building systems
- transportation

• 30'000 MUSD annual turnover
• 208'000 employees in 140 countries

1.1 ABB Research Center

Research within ABB is carried out by several Research Centers working together in an integrated and coordinated manner. Each Center serves the entire ABB Group within its assigned area of expertise.

1.2 Engineered Structures and Composites

The Engineered Structures and Composites Group is a part of the Swiss Corporate Research Center (CHCRC). The main tasks of this group are:

- Composite materials
  (thermoplastic fiber placement, modeling of the process, numerical analyses and optimization)
- Structural analyses and optimization
- Simulation and optimization of multi-body-systems (MBS)

In this group we have used the ADAMS product family (ADAMS/View, ADAMS/Solver) for three years. There is another MBS program in use called DYNAMITE. This program has been developed at the ETH Zurich based on the projection method. It has the advantage that Newton's

impact theory is implemented and for optimization the determination of the sensitivity can be done analytically.

In the field of MBS simulations the main customers within the ABB are the following business units:

- ABB High Voltage Technologies Ltd.
- ABB Robotics

In the above mentioned companies there is a big effort to involve MBS programs during the development process to reduce development time and costs.

2. High voltage and high current components

The ADAMS program is mainly used in the development of high voltage and high current components. The high current components are used between the power generator and the high voltage transformer and are located in power plants. High voltage components are used in power distribution and can be situated outside of the power plant.

2.1 High current switchgear

The main application of this type of switchgear is to disconnect the generator from the high voltage transformer. The rated voltage is 24 kV / 27.5 kV, the rated current is up to 13.5 kA (ambient air cooled) and to 20kA (forced air cooled) and the rated breaking currents are 100 and 120 kA.
The following figure (fig. 1) shows a typical connection schema. The components are:

• generator circuit breakers

The generator switching gear (circuit breaker) uses SF6. This medium will be used for internal isolation and to extinguish the arc which occur during an opening process.

• grounding switch

These switches are provided on both sides of the switching gear unit. The switches are designed as protective grounding connections, e.g. they are rated for the full fault current. The switches have no current switching capacity.

• series disconnectors

The concept of this switching gear is to provide a disconnector connected in series with the circuit breaker.

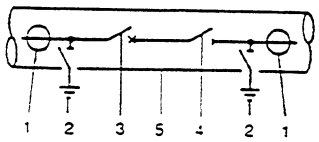

Figure 1 Layout of a SF6 breaker type HEK
1 current transformer, 2 grounding switch,
3 circuit breaker, 4 disconnector, 5 enclosure

2.2 High voltage switchgear installations

In order to ensure reliable operation and a secure supply of electricity all apparatus and auxiliary equipment are connected together in a switchgear installation. High voltage switchgear installations are used in power distribution for towns and cities, regions and industrial centers, and also for power transmission. High voltage switchgears mainly use SF6 gas insulated switchgear (GIS). Its range of application lies between 7.2 and 800kV with breaking currents up to 63kA. The following

figure shows a section through a SF6 switchbay for 420 to 550kV. The switching time is about 40ms.

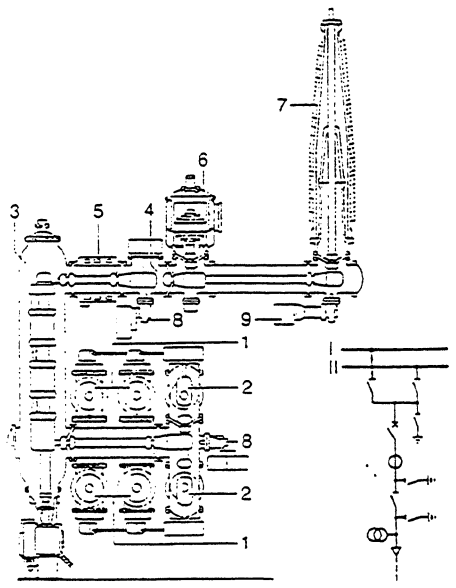

Figure 2 Section through SF6 switchbay for 420 to 550 kV,1 busbar, 2 busbar disconnector, 3 power switching gear, 4 feeder disconnector , 5 current transformer, 6 voltage transformer, 7 outdoor bushing, 8 maintenance grounding switch, 9 high speed grounding switch

3. Modeling process

ADAMS has especially been used in the development of high voltage switching gears (power switching gears), grounding switches and disconnectors. In systems like switching gears not only the perfect functionality of the arcing chamber is of importance. Reliability and costs of switching systems depend on the construction of the driver and transmission parts as well. The questions which can be answered using such a simulation tool do not only refer to the correct functionality of a mechanical system, but in addition address the stresses and the corresponding energy to move the contacts. Since the different switchgears can have different components, for the simulation it was decided to build each component as a single module. This means to model a switchgear several modules are connected together. A module is for example the arcing chamber, the hydraulic operating mechanism, the transmission part, the influence of the electromagentic force and so on.

In the following section some of these modules are described in more detail.

3.1 Simulation Modules

In order to very quickly build up a simulation model , some modules have been developed. Which module will be used depends on the type of switchgear. Figure 3 shows the different modules. In the case of a high current switchgear the module for the arcing chamber and the module for the hydraulic operating mechanism are used. The transmission part will be built up in the ADAMS/View environment individually. In order to build a high voltage switchgear the same modules are mainly used. In the case of a grounding switch especially for a high speed grounding switch, only the module for the determination of the electromagnetic force is used. The remaining components are built up in ADAMS/View individually.

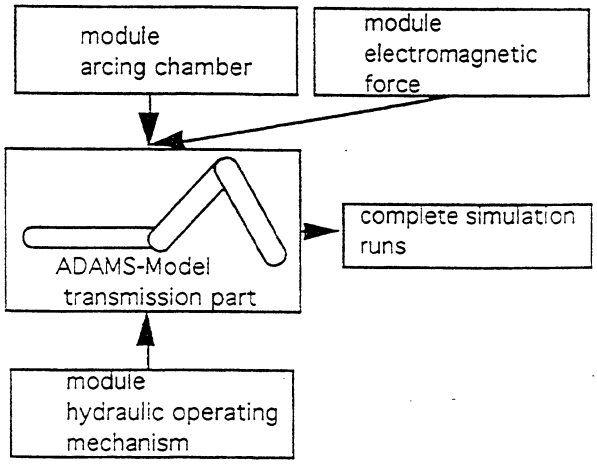

Figure 3 Modules for simulation of high voltage switchgears, high current switchgears and high speed grounding switches.

3.2 Modeling of high voltage and high current switching gears

The models of high voltage and high current switchgears have no significant differences. As an example, a typical high voltage switching gear is pictured in figure 4 and consists of 3 modules:

- a hydraulic spring mechanism
- a transmission part
- the arcing chamber, one for each phase

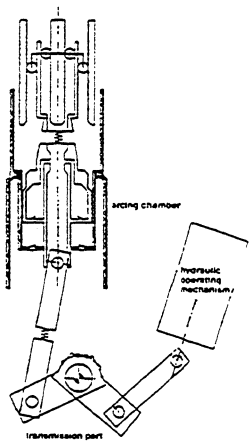

Figure 4 Typical high voltage circuit breaker

In the above mentioned type of switchgear only the transmission part is a typical multi-body system that can be modeled by ADAMS/View directly using ADAMS standard elements. In a power switching gear (high current switchgear) the main influence to the transmission part comes from the hydraulic operating mechanism and the arcing chamber.

The hydraulic spring mechanism is a combination of hydraulic and spring systems. The energy is stored by a set of springs which are tensioned hydraulically. The power is transmitted hydraulically. The contacts are closed and opened by means of a differential piston. A section through a hydraulic spring mechanism for self-blast breakers is shown in figure 5.

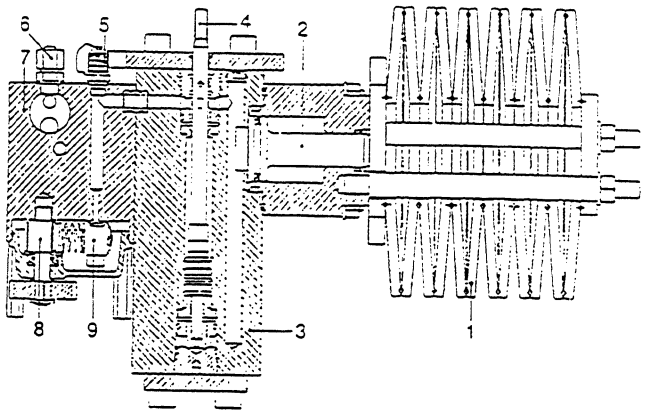

Figure 5. Section through a hydraulic spring operating mechanism for SF6 self-blast breakers.
1 springs, 2 spring piston, 3 actuating cylinder, 4 piston rod, 5 measuring connection, 6 oil filter connection, 7 pump block, 8 pump drive shaft, 9 pump unit

The dynamic behavior of the hydraulic operating mechanism is described as a USER -Fortran subroutine, which gives the acting force to the transmission part. The dynamic description is given as a set of 2 first order differential equations.

The next component is the arcing chamber. The arrangement and operating principle are shown in figure 6. The extinguish unit consists of a fixed contact and a moving contact. The moving contact is connected with the blast cylinder. During an opening movement the volume of the blast cylinder is reduced steadily and the pressure inside the cylinder will be increased until the fixed contact and the moving contact are separated. The contact disconnection causes an arc. This results in a pressure rise. If the gas pressure reaches a specific magnitude the gas will be released and blow out the arc, depleting its energy and extinguishing the arc. With small current the required pressure to blow out the arc is created

during the opening movement by compressing the gas in the compression volume. In the case of a short current the high amp arc heats and raises the pressure of the gas in a separate heating volume. This pressure imposes no extra demands on the operating mechanism. This extra pressure rise is called the self-blasted principle.

As in reality, the model of the arcing chamber consists of several gas volumes. The pressure of the gas has a breaking effect (pressure force). The description of the gas dynamic in the arcing chamber consists of a set of 7 first order differential equations and is also implemented in a USER-Fortran subroutine.

3.3 High speed grounding switch

In a high speed grounding switch the driver is only a simple spring, charged by a motor. The main influence to the transmission part in this kind of switching gear is the electromagnetical force. In ADAMS models this force is also described in USER-Fortran subroutines.

4. ADAMS Models

Figure 7 shows a typical ADAMS model of a high voltage switching gear. In most cases the mechanical mechanism is not so complex. It consists of about 12 elements.

In order to handle the ADAMS model easily most of the mechanical system is built up fully parametrically. Modification and parametric studies can be done very quickly. The variables of each component, e.g. hydraulic operating mechanism, transmission part and arcing chamber are summarized into unique groups. Finally each group has its own ADAMS-Panel.

5. Parameter identification

Some modules like the arcing chamber and the hydraulic operating mechanism are described with a mathematical model and consist of a large set of variables. The variables of the modules (arcing chamber and hydraulic operating mechanism) are found by parameter identification using measured curves. A comparison between the simulation and measurement results in the case of the arcing chamber is shown in figure 8.

6. Analysis of the simulation results

In order to get good reliability and functionality of the switchgears the following criteria need to be fulfilled.

- sufficient speed during opening the contacts
- sufficient gas pressure in the arcing chamber to extinguish the electric arc
- minimizing the necessary energy of the hydraulic operating mechanism.

7. References

[1]DYNAMITE Ein Simulations- und Optimierungstool für Mehrkörpersysteme und Mechanismen, ETH Zürich, Institut für Mechanik

[2] Swichgear Manual, ABB Poket Book

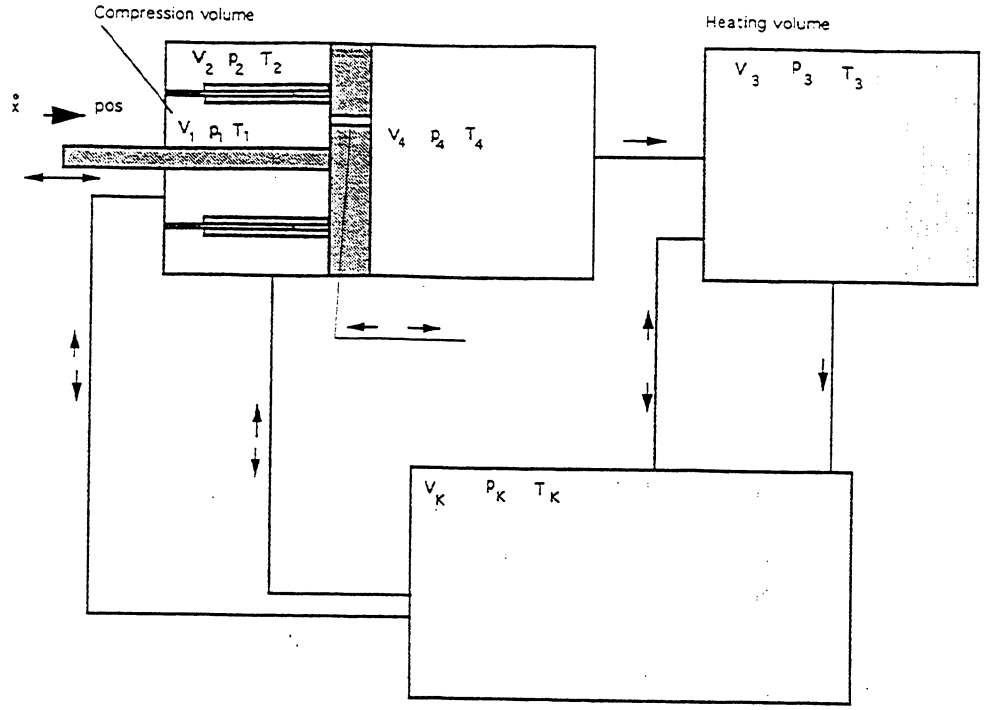

Figure 6 Model of the arcing chamber

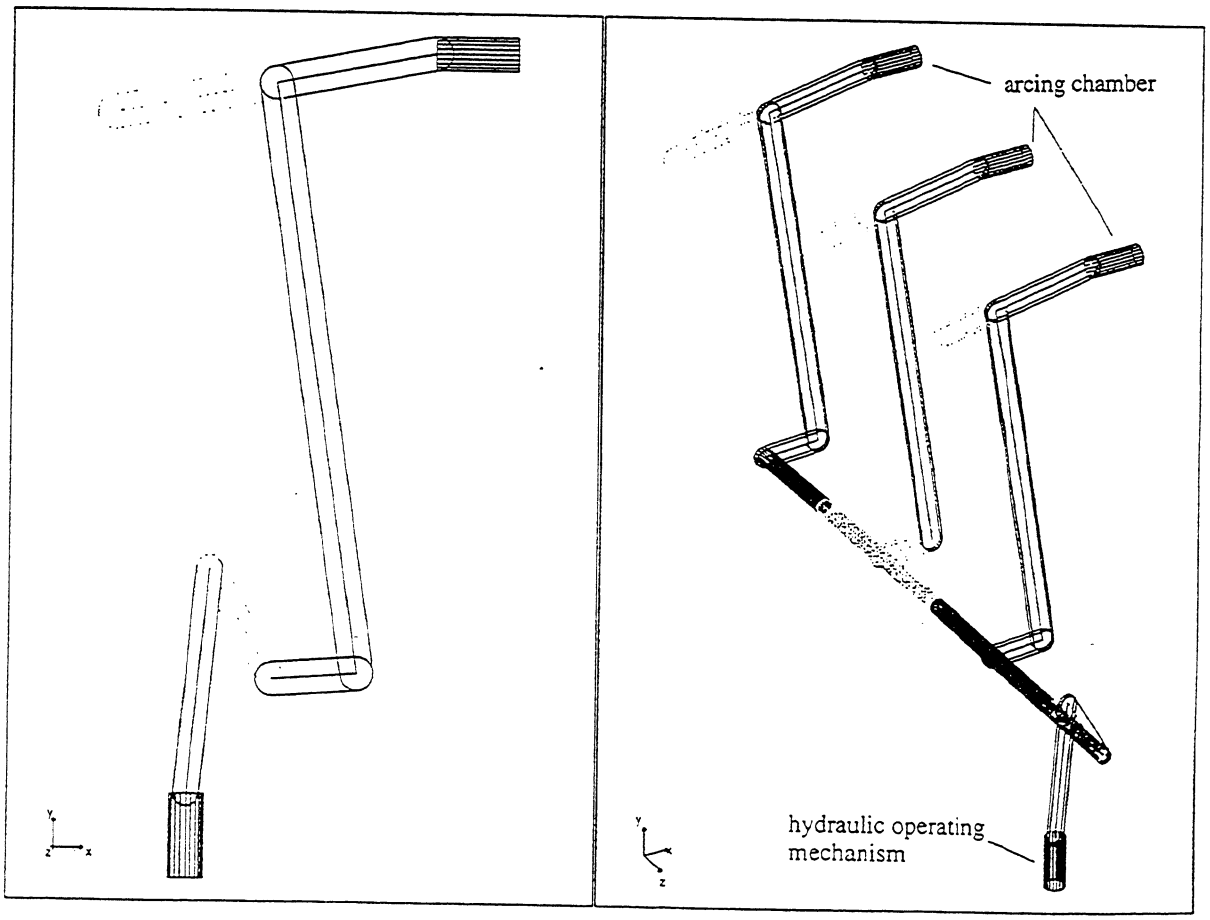

Figure 7 ADAMS model of a three phases high current switchgear

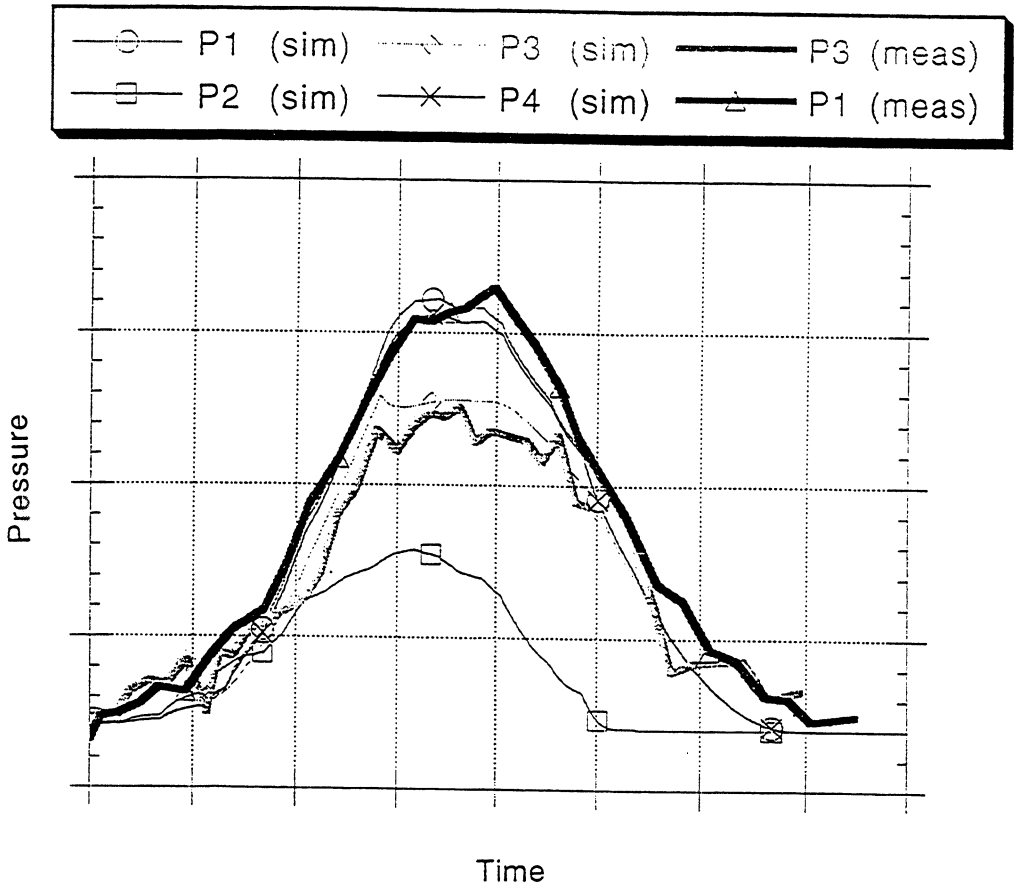

Figure 8 Comparison between measured curves and simulation of the gas pressures in the arcing chamber