Design and Multibody Dynamic Analysis of a Generator VCB with a High Breaking Capability

Jun-Yeon Jo
LMV R&D Unit
LSIS Co., Ltd.
Cheongju-si, Chungcheongbuk-do, Korea
jyjo@lsis.com

Sung-tae Kim, Hong-Ik Yang, Woo-Jin Park,
Kil-Young Ahn, Young-Geun Kim
MV R&D Unit, Electrotechnology R&D Division
LSIS Co., Ltd.
Cheongju-si, Chungcheongbuk-do, Korea
sungtae@lsis.com, hiyang@lsis.com, wjpark@lsis.com,
kyahn@lsis.com, youngk@lsis.com

***Abstract*— Vacuum Circuit Breaker (VCB) consists of the main frame with the operating mechanism and the main circuits including VI (Vacuum Interrupter). Especially, a VCB for the generator protection, which is used in a power plant, requires very large contact spring force because it has to be able to withstand the high short circuit current. In order to release closing energy of VCB, the cam type mechanism using extension spring as energy source is applied. In this study, the prototype generator VCB has been designed and its analytical multibody dynamic model using the Recurdyn has been developed. Based on the simulation result of analytical model, the required design variables of generator VCB are determined. To verify the analytical model, the prototype VCB sample has been manufactured. The dynamic characteristic of prototype VCB sample is also measured and compared with the analytical model.**

***Index Terms*-- Generator, VCB, Multibody dynamics.**

I. INTRODUCTIONNG

A VCB (Vacuum Circuit Breaker) for the protection of generator is always installed between a generator and the step-up voltage transformer. In the past, GCB (Gas Circuit Breaker) is used as the generator circuit breaker because high short circuit current, high rated current, delayed current zeros (DCZ) and high rate of rise of recovery voltages are occurred in the electrical circuits of a generator system. However, nowadays VCBs are able to use as the generator circuit breaker because the interrupting capability of the VCBs has improved significantly.

While VCB is applied instead of GCB, there are several advantages like easy installation, high reliability, maintenance efficiency and environment-friendly. For these reasons, the application range of VCB is expanded to generator applications up to 400 MVA. Fig. 1 shows the VCBs. The purpose of this paper is development of Generator Vacuum Circuit Breaker (GVCB) based on analytical model using Recurdyn which is widely used in the field of multibody dynamics analysis. To evaluate the analytical model, the prototype sample is manufactured and experimental results are compared with simulation results.

II. STRUCTURE OF THE GENERATOR VCB

The generator VCB shown in fig. 2 consists of three main circuit including the VI (Vacuum Interrupter) and main frame with the cam mechanism which is operated by extended closing spring. Inside of the VCB, there are two major springs; one is the close spring and the other is the wipe spring. While the VCB is closing, the repulsive force from contacts is occurred because of its high making current corresponding

Figure 1. Vacuum Circuit Breakers

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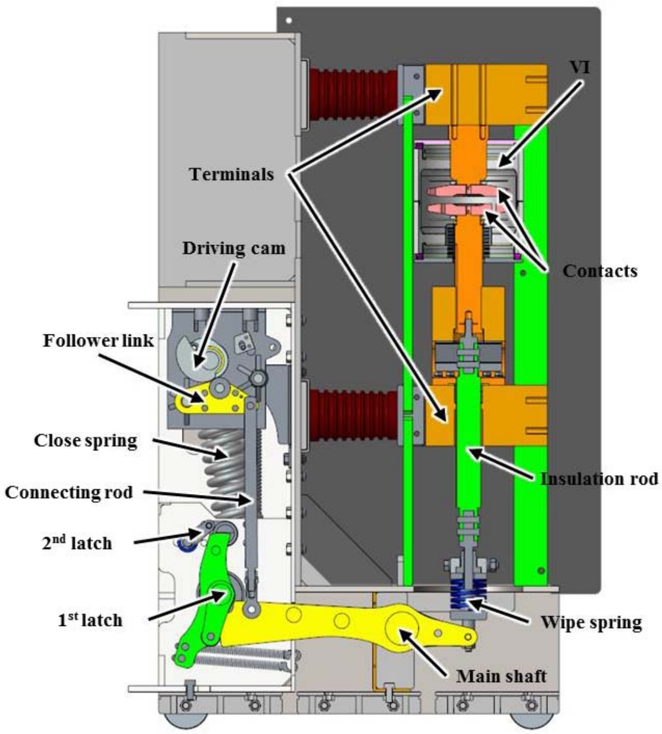


Figure 2. Structure of the prototype generator VCB

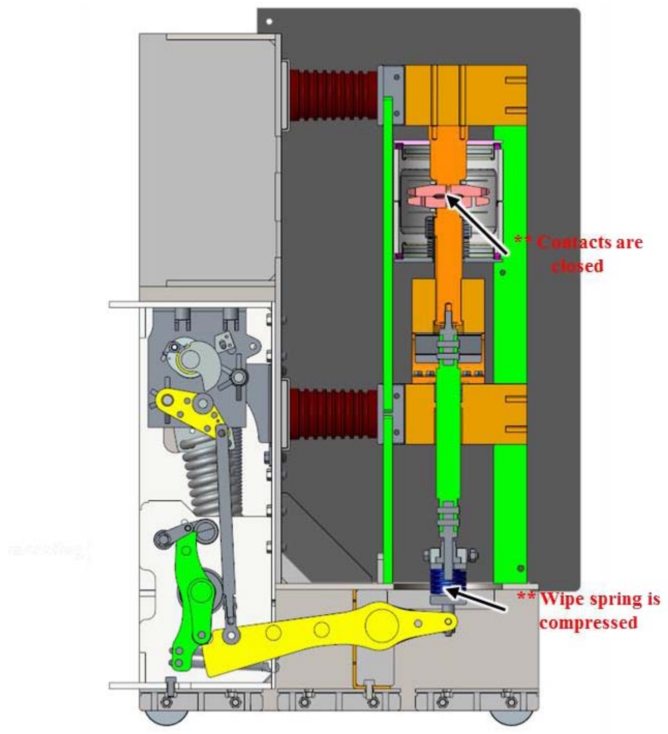


Figure 3. Closed state of the generator VCB

2.74 times of rated short-circuit current. In order to overcome the making current, the large close spring energy is required.

Also, at the moment of closing of VCB, contacts are melted and welded because of pre-arc energy. The wipe spring is used as energy source in order to separate welded contacts forcibly. The generator VCB with the breaking capability 72kA should be had welding force about 700 kgf, so the wipe spring is bigger than 700 kgf.

As a result, wipe spring force with 800 kgf is determined. In fig. 2, driving cam is rotated counter clockwise when charged close spring energy is released. Then the follower link is rotated through the surface of driving cam. By the connecting rod between follower link and main shaft, rotation motion of main shaft is occurred and the moveable contact is translated upward through the insulation rod. After the moveable contact reaches the fixed contact, the wipe spring is compressed and storage the energy. Fig. 3 shows the closed state of VCB. From fig. 3, it is necessary to determine adequate close spring force that successfully overcomes wipe spring force.

III. MULTIBODY DYNAMIC ANALYSIS AND DETERMINATION OF DESIGN SPECIFICATION

For the initial design of generator VCB, the analytical model is developed by Recurdyn. Recurdyn is widely used in field of multibody dynamics analysis.

Fig. 4 shows the Recurdyn analytical model. Based on the simulation result of analytical model, close spring force is required about 980 kgf including 115% margin to overcome

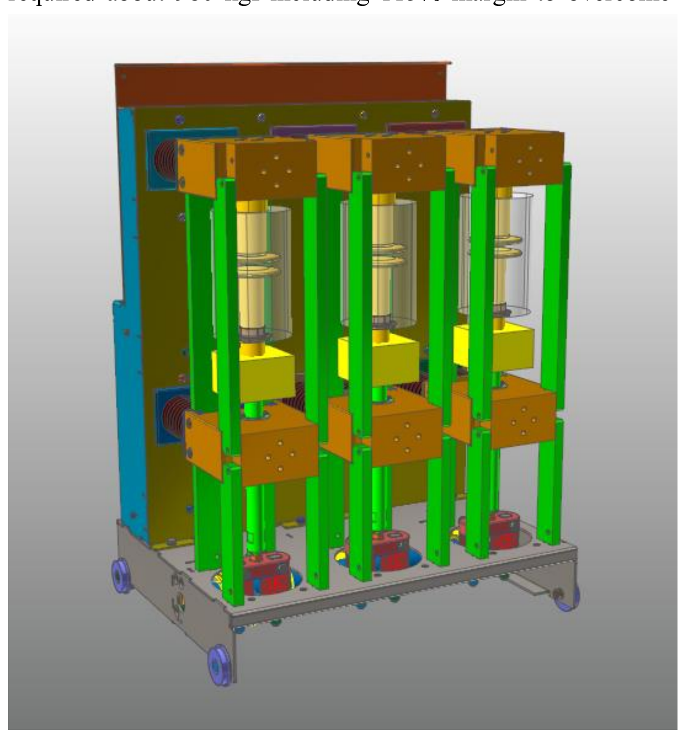
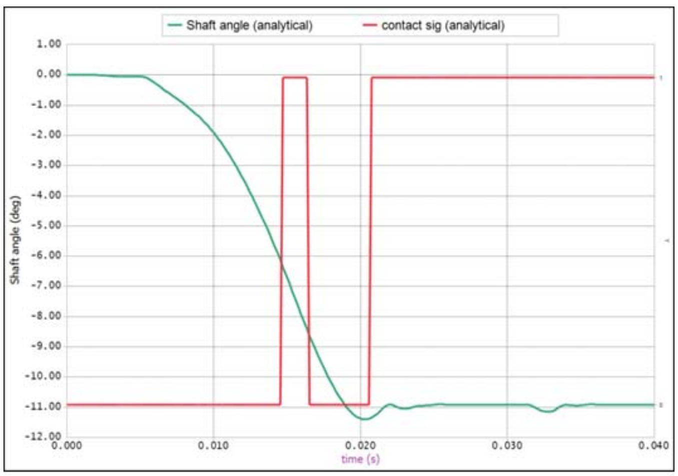


Figure 4. Recurdyn analytical model

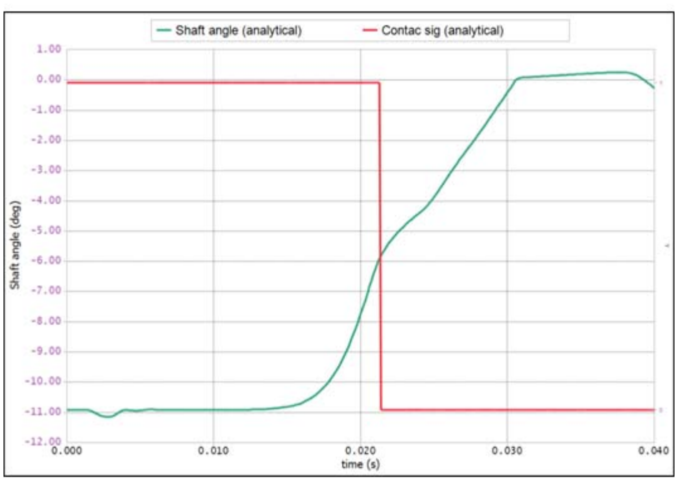
three wipe springs force about 800 kgf. From the simulation result, dynamic characteristics of the VCB separate design specifications. And the close spring force is enough to overcome three wipe springs force. The simulation result is shown in fig. 5 and designed requirements are summarized in table 1. But there are many contact elements in analytical model and non-linear effective in real products like friction force and several losses. So, in order to verify the analytical model, it is essential to compare with experimental results.

IV. Comparison between Dynamic Characteristics of Prototype VCB and Analytical model

Fig. 6 represents the prototype VCB sample manufactured by the simulation result. Generally, to measure the dynamics characteristics of VCB, the main shaft angle is measured using a rotary sensor. The comparison results between simulation results and experimental data is represented in fig. 7 and table 2.



(a) Close characteristics of analytical model



(b) Open characteristics of analytical model

Figure 5. Simulation results of analytical model

TABLE I. Simulation results of analytical model and design requirements

	Simulation results	Design requirements
Main shaft rotating angle	10.9 deg	-
Wipe spring force	950 kgf	> 800 kgf
Closing time	9.5 ms	< 40 ms
Opening time	9.7 ms	< 30 ms

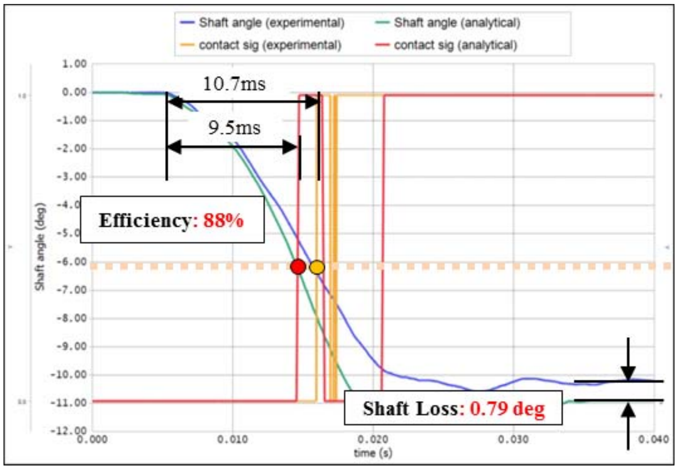
Figure 6. Manufactured prototype VCB sample

From the comparison results, we found out that the dynamics characteristics loss rate is about 12%, but in spite of losses, the design specification in table 1 is satisfied. Also, the loss rate of main shaft angle is about 9% and wipe spring deformation loss is about 3 mm. Because of loss of wipe spring deformation, wipe spring assembly length is adjusted consequently and finally wipe spring force is determined about 850 kgf with bigger value of design requirement.

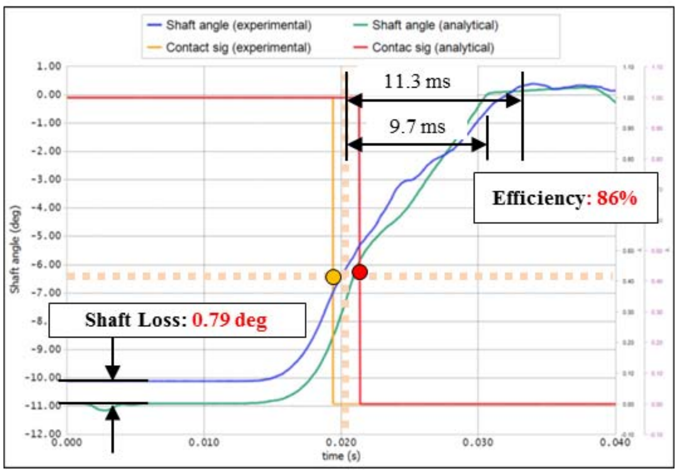
The loss of the opening time of prototype VCB sample is existed about 14% because the wipe spring force is reduced from 950 kgf to average 860 kgf. But also, it is enough to separate the melted contacts from high short-time withstand current and have sufficient breaking capability with high short circuit current.

V. Conclusions

In this paper, in order to develop the generator VCB, the design based on multibody dynamics analysis using Recurdyn is applied. Prototype generator VCB sample is designed and manufactured to verify simulation results. The simulation result of multibody dynamics analysis is compared with experimental measuring data of prototype VCB sample. Even though the manufactured prototype VCB sample has a few



(a) Close characteristics compare with measuring data



(b) Open characteristics compare with measuring data

Figure 7. Simulation results and measured data of prototype VCB sample

losses of main shaft angle, dynamic characteristic and wipe spring deformation, the successful close operation is carried out and all of design requirements are satisfied. From this study, firstly, analytical model of generator VCB is validated and then the prototype generator VCB sample is also developed.

TABLE II. COMPARISON RESULTS BETWEEN ANALYTICAL MODEL AND EXPERIMENTAL MEASURING DATA OF PROTOTYPE VCB SAMPLE

	Simulation results	**Experimental Measuring data**	**Loss rate**
Main shaft rotating angle	10.9 deg	10.19 deg	0.07
Wipe spring force	950 kgf	860 kgf	-
Closing time	9.5 ms	10.7 ms	0.12
Opening time	9.7 ms	11.3 ms	0.14

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