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36KV-630A SINGLE SHAFT 3-PHASE MAGNETIC ARC INTERRUPTER LBS DESIGN FOR SMART GRID APPLICATIONS

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Abstract- A Load Break Switch (LBS) is the switching device that used to switching of the current in the electric power systems. Among the medium voltage products in the world market, 36 kV LBS is one of the most used products, it is generally produced as double shaft design. Especially in market, double shaft switches are used often. However, in two-shaft 36 kV gas insulated LBS, problems arising from the double-shaft mechanism may be encountered in the transition of the system to the earth position. Therefore, in this study, a magnetic arc contact and single-shaft design is developed for the first time in internal market to obtain a safer product, to increase product functionality as well as to protect user health. In addition, the amount of copper used in the double-shaft contact design is significantly reduced, making a significant contribution to increasing the protection level for the user and also economic benefit as well as the reduction in weight of the LBS.

Keywords: Load Break Switch, Single Shaft, Gas Insulated Load Break Switch.

1. INTRODUCTION

In electrical power systems, large amounts of electrical energy, the generated electrical energy is transmitted to the user using high voltage lines. The large amount of transmitted electrical energy causes major problems in case of probable malfunctions [1, 2]. Therefore, in case of any fault, it is necessary to cut off the current flowing from the transmission line quickly. Fault interruption is not only important for traditional transmission lines and smart grids but also important for load switching and capacitor switching as well [3]. Thus, the environment is prepared for the faulty element to be disconnected from the circuit and the defective element is disconnected from the circuit. Circuit breakers and LBS are used for this interruption process. Switching of the lines also causes the change of the power system state and becomes important aspects for using models for simulations [4].

LBS are circuit elements that are used to open and close the circuit in the on-load condition in medium and high voltage electrical systems. They can interrupt nominal currents. However, they cannot interrupt short circuit currents.

In the last 100 years, electricity has become the world's most flexible and reliable power. Since electricity is so important, the control of this power is just as important in the products developed to use it. Various methods have been tried to improve LBS characteristics in literature. Among these, the methods that are still frequently used today are SF6 LBS, vacuum and magnetic arc interrupter systems [5, 6, 7, 8]. The gas used in SF_6 type LBS forms the insulator and arc extinguishing medium [5, 6].

As a new technology, vacuum systems that completely remove SF_6 gas from the environment are being studied. In these systems, the air in the environment is completely removed and arc formation is prevented. However, since it is a very costly method compared to existing LBS, it is not much preferred yet. As an alternative to air LBS systems, magnetic arc interruption in gas insulated system is a newly developed system.

Among the medium voltage products in the world market, LBS is among the most used products and is generally produced as double shaft. These are the on off shaft and the earthing shaft. These shafts work independently of each other. The simultaneous operation of the shafts causes stress in the system in terms of mechanical, thermal and dielectric as well [3]. It poses a danger to system security. For example, in a two-shaft 36kV air-insulated LBS, problems may be encountered in the transition of the system to earth due to the double-shaft mechanism. Therefore, in the present study, it is planned to develop a safer product by using a magnetic contact and single-shaft design for the first time, and to obtain a system that will protect the user's health as well as product functionality.

A lot of copper material is used in double shaft, double two position switches which increases the cost of the LBS considerably. In this study, it is aimed to reduce the amount of copper used and reduce the production cost with the single shaft LBS to be designed, while at the same time reducing the weight of the LBS. It is also aimed to shorten the assembly time and increase the production amount by reducing the weight of the LBS.

In the continuation of the work, first, the design methodology is explained and the expected outputs from the design are given. Then, the design steps of the mechanism designed for LBS are explained and the production steps are given in detail. Finally, the performed tests according to the standards are applied in order to show that the design is at a usable level.

2. DESIGN METHODOLOGY

Instead of the double shaft LBS, a new design has been made that works on a single shaft and can work in harmony with each other in three positions. In this way, it is desired to eliminate the risks existing in the system and to create a safe working condition.

While designing the mechanism, the design limits are determined to be used in both 36 kV LBS and 12 kV LBS so that it can operate in a wide range. Therefore, first of all, it is necessary for the mechanism to be able to withstand the forces at the highest limits and to be able to open and close the circuit at these forces. The first design is made to meet these two conditions. Later, ground connection is added as the 3rd position and the design is updated. Finally, the design has been designed so that the mechanism can be used with or without a motor, depending on the user's request.

In this study, two different types of mechanisms are designed. These are:

- Motorized 3-Phase LBS Mechanism,
- Non-motorized 3-Phase LBS Mechanism.

The innovative aspects of the study are given as follows:

- Magnetic arc interrupter will be used for the first time in local market.
- There will be a 15% reduction in the amount of copper used in the contacts.
- While the amount of copper used in the contacts in double-shaft LBS is approximately 1 kg, 700 gr of copper will be enough in the designed single-shaft system. This will provide over 10% gain in system weight.
- 5% reduction in assembly time will be achieved.
- System security will be increased.
- 3 positions will be provided with a single shaft.
- There will be an approximately 20% advantage in cost.
- System life will be increased by using smaller springs.

The success criteria of the designed system are given in Table 1.

Table 1. Success criteria

Success Criteria	Target Value
Arc Interruption	Magnetic
Gain in system weight	%10
Reduction in the amount of copper use	%15
Increase system life	%15-%20
Shortening of assembly time	%5

The 3-position LBS design is completed in 4 steps. First, the necessary literature studies for the design are made. Afterwards, the preliminary design of the disconnector boiler is made. The kinematic analysis of the boiler movements is performed using Solidworks software. After the boiler design, the mechanism needed for the separator is designed and analyzed, following studies are carried out for the prototype. Finally, the requirements for the part where the LBS will be placed are determined and a preliminary design is made.

2.1. Mechanism Design Steps

In the first step, a design should be capable for high speeds and forces, which is the most important design criterion, and has the ability to open and close is made properly. The initial design is given in the Figure 1.

In the second step, the design is carried out to be two-phase (open-close) and can be installed with a motor. Second design draw is given in the Figure 2.

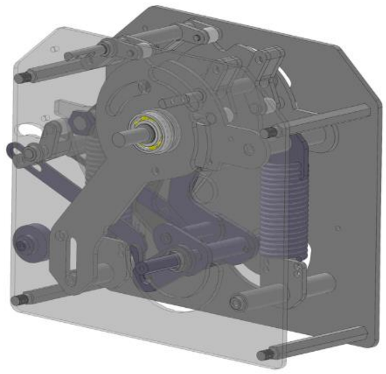

Figure 1. First design (There are only two positions, open and closed.)

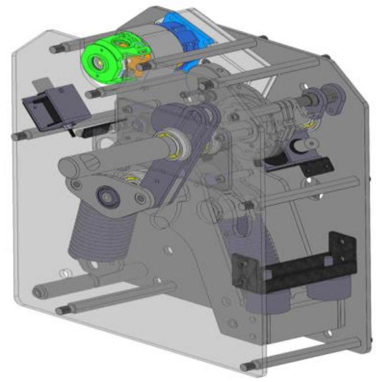

Figure 2. Second design

In the third step, the earth is added to the design. There are now open, close and earth positions in the design. Springs have been changed to compression springs. In addition, since the single shaft design is made, geometric modifications are applied so that the shaft could stop at the middle point. Third design is given in the Figure 3. Finally, the design is optimized and the dimensions are reduced and cost reduction studies are carried out.

2.2. Prototype Fabrication

From the beginning of the mechanism design, prototypes are produced at every stage and necessary tests are carried out. As a result of these tests, sections that did not work or that worked incorrectly are determined and progress is achieved by making revisions. Parts are constantly optimized at every stage to make manufacturing easily.

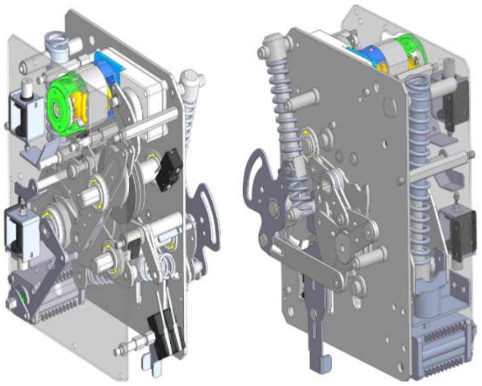

Figure 3. Third design

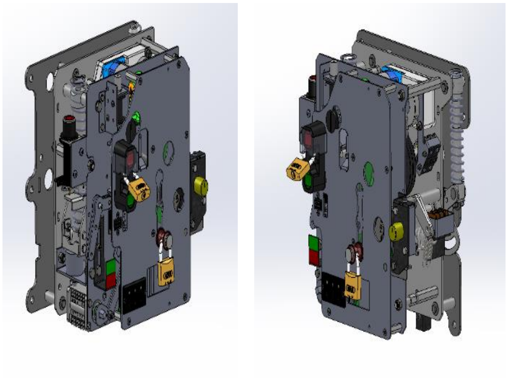

Figure 4. Final design

From the first designed mechanism to the last mechanism, many improvements have been applied in the design. It is subjected to different tests in different laboratories and the test results are obtained. The first mechanism that is trial tested is given in Figure 5.

The mechanism designed and turned into a product successfully meets the requirements stated at the beginning. As a result of this work, two types of 3-phase LBS mechanisms were obtained. The mechanism has reached a level where it can be used as a product. The final state of the non-motorized mechanism is given in the Figure 6. The final state of the motorized mechanism is given in the Figure 7. The latest design mechanisms have successfully passed various electrical and mechanical tests under different conditions and in the laboratories.

In Figure 8, the mechanism that went to the 1000 test and completed, and in Figure 9, the mechanism with the mechanical strength tests are given.

Figure 5. The first mechanism

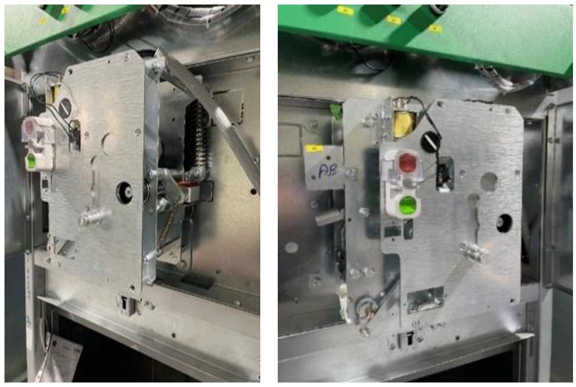

Figure 6. Latest design of non-motorized single-shaft three-position disconnector mechanism

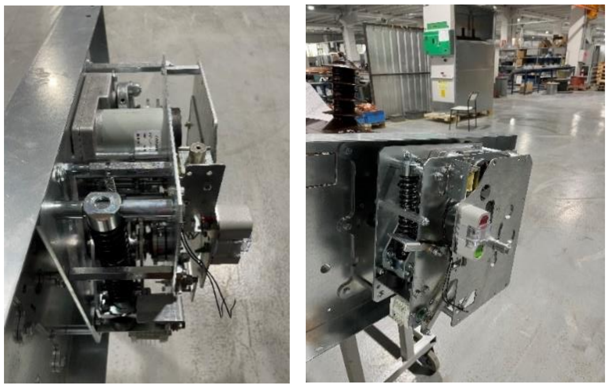

Figure 7. Latest design of motorized single-shaft three-position disconnector mechanism

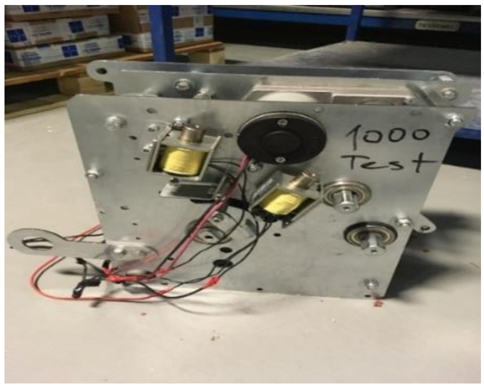

Figure 8. Mechanism with 1000 tests completed

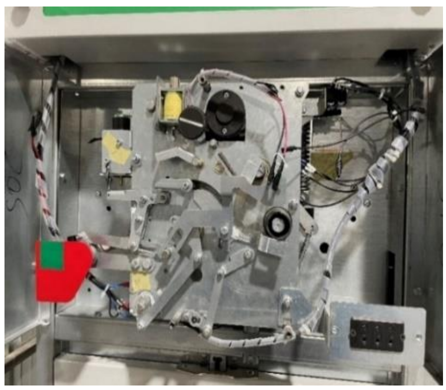

Figure 9. Motorized mechanism tested for mechanical endurance

3. FUNCTIONALITY TEST FOR SINGLE SHAFT LBS

The designed 36 kv single shaft LBS has been tested according to IEC 62271-1, IEC 62271-200 and IEC 60060-1 standards. These tests:

- Making & Breaking tests on SF6 Load Break Switch (LBS)
- Short Time and Peak withstand current test on main circuit
- Short Time and Peak withstand current test on earth bar
- Short Time and Peak withstand current test on the earthing switch
- Short Circuit Making Test on the earth switch
- Power Frequency Voltage Withstand Test
- Lighting Impulse Voltage Withstand Test
- Temperature Rise Test and Measurement of Main Circuit Resistance
- Verification of the IP coding
- Verification of the IK coding
- Dielectric test on auxiliary (LV) circuits
- Mechanical operation tests (interlocks, doors, removable parts, switching devices)
- Mechanical Endurance test on the LBS
- Mechanical Endurance test on the Earth Switch
- Gas Tightness tests
- Pressure withstand test for gas-filled compartments

These tests are carried out in laboratories at the company and independent laboratories in the Turkey. According to the results obtained, design changes are made if necessary, and in some cases, material changes are applied [9, 10]. As a result of these tests, the optimum separator design is made and obtained ready for production.

4. TEST RESULTS

Type tests for the designed LBS have carried out in KEMA High Power Laboratory, Netherlands. These tests are performed according to the International Standards-IEC and both test and ambient conditions are recorded. During first test a failure is occurred and after minor design revisions the tests are repeated and the final test results are given in Table 2.

As seen from the table, the new designed LBS successfully passed all the type tests carried out in the KEMA High Power Laboratory Laboratory.

After the design work and prototyping are compleed, process improvement studies have carried out at the determined points and the tests have repeated. The tests performed according to the standards and the results are given in Table 3.

Table 2. Test Plan for the LBS Session I

SESSION I		
ITEM-1 (standard: IEC62271-200, IEC62271- 102, IEC62271- 103)		Result
STC Tests on the main and earth bar	I = 16 kArms; t = 1 sec; I_{peak} = 40 kA peak	Successful
Mainly active load test TDload2 for class E3	$U = U_r$ =36 kV; $I = I_{load}$ = 630 A; n = 100 operations	Successful
Mainly active load test TDload1	$U = U_r$ = 36 kV; $I = 0.05 \times I_{load}$ = 31.5 A; n = 20 operations	Successful
Closed loop distribution circuit current Tdloop	$U = 0.20 \times U_r$ = 7.2 kV; $I = I_{loop}$ = 630 A; n = 20 operations	Successful
Cable charging current TDcc2 for class C2	$U = U_r$ = 36 kV; I = Icc = 20 A; n = 10 operations	Successful
Cable charging current TDcc1 for class C2	$U = U_r$ = 36 kV; $I = 0.4 \times I_{cc}$ =8 A; n = 10 operations	Successful
Line charging current TDIc for class C2	$U = U_r$ =36kV; $I = I_c$ = 2 A; n = 10 operations	Successful
Earth fault current TDef1	$U = U_r$ = 36 kV; $I = I_{ef1}$ = 60 A; n = 10 operations	Successful
Earth fault current TDef2	$U = U_r$ = 36 kV; $I = I_{ef1}$ = 35 A; n = 10 operations	Successful
ITEM-2 (standard: IEC62271-200, IEC62271-103)		
Pre-condition test TDload2	$U = U_r$ = 36 kV; $I = I_{load}$ = 630 A; n = 10 operations	Successful
Short circuit making current test TDma on the main	$U = U_r$ = 36 kV; I = 16 kA rms / 40 kA peak, n = 5 operations	Successful
ITEM-3 (standard: IEC62271-200, IEC62271-102		Successful
STC on the earth switch	I = 16 kArms; t = 1 sec; I_{peak} = 40 kA peak	Successful
Short circuit making current test on the earth switch(class E2)	$U = U_r$ = 36 kV; I = 16 kA rms / 40 kA peak; n = 5 operations	Successful

Table 3. Test Plan for the LBS Session II

SESSION II		
ITEM-1: Test for LBS & FUSE (Switch & Fuse)		Result
TDIsc: making and breaking tests at the related short-circuit	U = 36 kV; $T_D I_{sc}$ = 16 kA	Successful
TDIwmax: Making and breaking tests at the maximum breaking	U=36 kV; $T_D W_{max}$ = 4.2 kA	Successful
TDItransfer: Breaking tests at the related transfer current	U=36 kV; $T_D I_{trasnsfer}$ = 630 A	Successful
TDIto: Breaking test at the related take-over current	U=36 kV; $T_D I_{to}$ = 630 A	Successful
Test for FUSE EARTH SWITCH		
Three Phase STC test on the Earth Switch	I_{sc} = 1 kA rms / 2.5 kA peak; n = 1 shot	Successful
Short Circuit Making Current Test	U = 36 kV; I_{sc} = 1 kA rms / 2.5 kA peak; n=5 shot	Successful

5. CONCLUSIONS

In the present study, unlike the other devices in the market, 36kV-630A single shaft, 3-phase, magnetic LBS is designed and made ready for series production. First the epoxy resin housing design is completed, then the LBS mechanism is designed. The kinematic properties of the designed mechanism are different from the LBS in market. Contrary to the double shaft structure in existing LBSs, switching is made with a single shaft. Thanks to this structure, the risks in terms of security in the operation of the system are minimized. The new design has an easier working principle with its simpler design. It is smaller in size as well. The amount of copper used has been reduced compared to the LBSs in the market, in addition reducing the weight on the mechanism springs as planned beginning of the work. This resulted in a reduction in all the system weight. Reducing the amount of copper used is also reduced the cost as aimed.

As a result of this new design, a highly reliable and safe, environmentally friendly, minimum maintenance required an air-insulated switchgear is provided. A design that can be offered to the market at a price that can compete with the market has been made. It has a simplified design and material savings with the advantage of single shaft and magnetic arc interruption concept comparation with the double shaft other type of LBSs with and without SF6 puffer system will be a future work of this study.

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