Design and Implementation of a Compact 36 KV 1250 A. Front Mechanism Vacuum Circuit Breaker

Sabri UZEL ¹, Özhan ALADAĞ ², Sercan KESKİNŞAŞ ³, M. Cengiz TAPLAMACIOĞLU ⁴

¹ Ulusoy Electric, R&D Department, Sincan/Ankara-TURKEY
ORCID ID: 0000-0003-0449-4821

² Ulusoy Electric, R&D Department, Sincan/Ankara-TURKEY
ORCID ID: 0000-0003-2961-2142

³ Ulusoy Electric, R&D Department, Sincan/Ankara-TURKEY
ORCID ID: 0000-0002-0764-4509

⁴ Gazi University, Engineering Faculty, Electrical&Electronics Engineering Department, Ankara-TURKEY
ORCID ID: 0000-0001-5283-8866

Abstract

The vacuum circuit breakers constitute the most important part of distribution network owing to their advantages such as big electrical strength, long life, easy maintenance, safe operation, low price and high short circuit current etc. This type of circuit breakers is produced in Turkey with domestic facilities as a result of various research and development studies. In this paper, the step by step development and modification studies for 36 KV 1250A front mechanism vacuum circuit breaker is presented in order to be ready for the 5000 cycles test. In this way, it is intended to be an example and guiding study to the researchers worked in this field. At the end of the study, the circuit breaker successfully passes the 5000 cycles test.

Keywords: Vacuum circuit breaker, Development and modification, 1000 cycles test, 5000 cycles test

¹ Some part of this study was presented in International Congress on Energy Research in Alanya, Turkey, 31 October – 2 November 2018.

Corresponding author e-mail: taplam@gazi.edu.tr
1. Introduction

The electric power network is one of the extraordinary structures that realized by human being. A big amount of electric power generated in various power plants is transported with as high efficiency as possible to the consumers. On the other hand, maintaining safety and reliability of this huge system is very difficult challenge for the energy control and management system who needs powerful, resistant and reliable tools in order to interfere to the necessary area of the network under high electric energy. There is no doubt, one of these tools used in electric power network is circuit breakers. The circuit breaker instantaneously breaks the electric current which flows in a high voltage transmission line in case of applying any control action or if there is any fault. To perform this duty, the circuit breakers must be both a good conductor and a good isolator, also they must change from the closed to open position in a very short period of time and not cause overvoltage during this rapid change [1].

Nowadays, the circuit breakers constitute the most important part of both transmission and distribution networks owing to their current breaking ability under load condition [2]. Although, the general six types of circuit breakers have been designed and used historically, SF6 and vacuum circuit breakers is commonly used at the present time. In particular, while the SF6 circuit breaker have to be used at the high voltage transmission lines due to their high-power switching capacity, the vacuum circuit breaker which is relative new technology is preferred to the SF6 circuit breaker in a distribution network due to its switching efficiency [3]. Actually, the vacuum circuit breaker has important superiorities according to the SF6 one such as big electrical strength, long life, easy maintenance, safe operation, low price and high short circuit current etc.

In this paper, the step by step development studies of 36 KV 1250A front mechanism vacuum circuit breaker which will be worked in a distribution network is discussed in order to be ready for the 5000 cycles test. In this way, it is intended to be an example and guiding study to the researchers worked in this field. The rest of the paper is organized as follows: the working principle of vacuum circuit breaker is presented in Section II, development and modification process is presented in Section III, the results are discussed in Section IV and conclusion is given at the last section.

2. Working Principle of Vacuum Circuit Breakers

This type of circuit breakers uses the arc extinction ability and high insulating strength of the 10^{-7} - 10^{-5} Torr vacuum. Generally, they include two contacts in a vacuum tube with a pressure of approximately 10^{-3} N/m². One of these is moveable contact. The arc formed during interruption is very diffuse and burns in evaporated contact material. It consists of a large number of independent arcs burning in parallel. Each arc carries about 100A and moves freely about the contact surfaces. The motion of the individual arcs over the contact ensures that surface heating and thus evaporation of the contact material is minimised. With the minimal evaporation and the low arc particle density the arc extinguishes itself with no external aid at a current zero [4].

3. Development and Modification Process

The 36 kV 1250A front mechanism vacuum circuit breaker which has been produced in ULUSOY factory is presented in Figure 1. This circuit breaker completes the 5000 cycles test in 850 cycles at the first trial upon request of TEIAŞ company. After examining the reasons of the failure, the development and modification study in the light of these results has been started in order to the fact that the vacuum circuit breaker can pass this test. The studies are separated into two parts in order to pass the 1000 cycles test and the 5000 cycles test [5].
At the first part of the development and modification study, the work is carried out to make the coil release plate suitable, the surface deformations of solid film coated parts are examined, the deformation of Y-02-MIL-1059 (36 KV Pole Power transmission shaft) and the deformation of the cams are examined. After that, the modifications below are performed on the circuit breaker (Figure 2);

• Y-03-SAC-1516 (24-36 kV Mechanism opening tripping arm), Y-03-PRC-1000 (36 kV Mechanizm 3-arm tripping part), Y-02-MIL-1055 (36 kV Mechanizm tripping shaft) parts are coated with solid film (dry lubrication) to increase wear resistance.

• Y-02-MIL-1059 (36 KV Pole Power transmission shaft) is manufactured from 4140 quality steel by changing the material of piece.

• Y-02-MIL-1055 (36 kV Mechanizm tripping shaft) and Y-03-SAC-1516 (24-36 kV Mechanism opening tripping arm) parts were prepared to be tested at 5 different sequential angles starting at one degree.

At the end of the study, the 1000 cycles test is completed with 1011 cycles. After that, 2300 cycles are reached at these tests. However, the following problems are encountered:

• The tongue on the Y-03-GRP-1024 (36 kV Mechanizm charging corner plate) core has lost its function in the 2300th cycle and remains in its slot. The system has not received a closing position.
• Because the position of the Shock Absorber is incorrect, a part is broken every 50-100 cycles. After the component changed 3 times, it continued to deteriorate. The test is run without Shock Absorber after 300 cycles.

• The shaft of the shaft connected to cams in the C phase decreased in the 50th cycle. The test is continued by inserting a new tab.

• Deformation on the outer surface of cams in C phase is caused by balancing washers.

The second part of the study covers the following developments and modifications processes. The spring of the tongue on the belly is broken in the 3300th cycle in the first attempt. When the production process is examined, it is observed that during the welding of the sheet piece on the tongue to the main body, the spring pushing the tongue is deformed. For the purpose of the measure, the welding process is replaced with rivet. But, the riveted parts start to compress the tongue after a little work. This is the same problem encountered for the second time. In order to make the rivet process healthier, it is decided to increase the thickness of the core body and to bury the sheet that holds the tongue and the parts are produced from the 8620-grade material. In order to prevent deformation in the tongue, it is decided to process the material as Hardox 500. Figure 3 shows the deformed spring and the partially deformed tongue. Also, Figure 4 presents the deformation in the slot of the tongue.

At last, it is decided to design the slot with self-channel and invoice. Due to the increase in the length of the sheet on the tongue, the work piece (Y-03-MIL-1007) is reworked and the wall thickness is brought to the appropriate level. The new design is represented in Figure 5.
Additionally, the problem of failure of tripping coil is coped with by the following solution process. The disconnection of the electrical tripping and manual opening systems are applied to the mechanism. Previously, the coil is pulled by the opening trip plate and the system is replaced by the coil by pulling the coil up and the tripping plate. The packages produced before is changed, a new work is started on the coil and the force measurements are taken from these coils. All coils in production are assembled after load cell measurement. The most suitable front plate design is selected and the necessary revisions are made. All mechanisms are thought to be universal in the process. Depending on the requirements, the mechanisms can be changed to RMU, HMH, Metal Clad etc. The old and new design of the tripping coils of modified vacuum circuit breaker is depicted in Figure 6.

4. Results and Discussion

At the end of the developments and modifications in the study, the vacuum circuit breaker is certified as M1 Class by operating 2000 cycles. Then, 5000 cycles are completed successfully. In this way, TEIAS's requirement is met. It is observed and evaluated that the correct material selection is very important to mechanical design of the circuit breaker because of mechanical stresses and deformations during breaking interval. On the other hand, the vacuum circuit breaker has been also considered suitable for 10000 cycles test. This test failed in 9880 cycles. Detailed investigation is initiated and problems are identified. If necessary, the M2 class 10000 cycle test is expected to be successful. Currently, the 5000 cycles working certificate is sufficient for production. With the establishment of the production line, all processes will be controlled. Thus, zero defect production is targeted.
5. Conclusion

Because of the vacuum circuit breakers constitute the most important part of distribution network owing to their advantages such as big electrical strength, long life, easy maintenance, safe operation, low price and high short circuit current etc., to produce this type of circuit breakers in Turkey is very important. For this reason, some of the development and modification studies are presented in this paper to produce 36 kV 1250A front mechanism vacuum circuit breaker. At the end of the study, the circuit breaker passes the 1000 and 5000 cycles test for M1 Class certified. Also, it is observed that it is ready for 10000 cycles test for M2 Class certified. In this way, it is intended to be an example and guiding study to the researchers worked in this field.

6. Acknowledgements

The authors would like to express their gratitude to Assoc.Prof.Dr. Haluk Gözde for his support and encouragement to prepare this paper.

7. References

[1] Kapetanovic, M., SMEETS, R. P. P., SLUIS, VAN DER, L., & KNOL, P., “High voltage circuit breakers” ETF, Sarajevo, 2011

[2] D. Dufournet, “AC High-Voltage Circuit Breakers”, IEEE Switchgear Committee Portland, October 201, Maine, USA.

[3] S. Ochi, K. Kagawa, G.A. Calhoon, K. Beamer, “Vacuum Circuit Breaker Technology Vacuum Interrupters – How They Work”, Feature, NETA WORLD Summer, 2010.

[4] Lecture Notes, “ELEC9712: Circuit breaker”, https://subjects.ee.unsw.edu.au/elec9712/ELEC9712%20-%20Lec8%20-%20Circuit%20breakers%20Notes.pdf

[5] Project Technical Report Form, “Development and modifications of 36 KV 1250A front mechanism vacuum circuit breaker for 5000 cycles test”, Ulusoy Electric Company, 2016.
ömrü, kolay bakım, güvenli çalışma, düşük fiyat ve yüksek kısa devre akımı gibi nedenlerle SF6 devre kesicilere göre önemli üstünlüklerde sahiptir.

Bu makalede, bir dağıtım ağında çalışacak olan 36 kV 1250A önden mekanizmalı vakumlu devre kesici adm adım geliştirme çalışmaları verilerek, 5000 çevrim testine hazır hale getirilme üzerine tartışma ve analizler yapılmıştır. Böylece, bu alanda çalışan araştırmacılara örnek ve yol gösterici bir çalışma olması amaçlanmıştır.

**Metot**

Vakum devre kesiciler, vakumun 10⁻⁷-10⁻⁵ torr ardı söndürme yeteneğini ve yüksek yalıtım gücünü kullanır. Genellikle, bir vakum tüpü yaklaşık 10⁻³ N/m²'lik bir basınç altında iki kontakt içerir. Her bir vakum taşıyıcı 100A taşır ve kontakların temas yüzeyleri etrafında serbestçe hareket ederler. Birleşen arkaların temas yüzeyindeki hareketi, yüzeyin isınmasını ve böylece temas malzemelerinin buharlaşmasını en aza indirgemeye çalışılır. Minimum buharlaşma ve düşük arkaların yoğunluğunu da 2300 aralıkta ilerleyen ve mevcut ortamda harici yardımcı olmadan kendini söndürür [4]. Ulusoy fabrikasında üretilen 36kV 1250A ön mekanizmalı vakumlu devre kesici, TEİAŞ’ın belirlediği 5000 çevrim testini ilk denemedede 850 çevrimde tamamlamıştır. Arzанны nedenlerini inceledikten sonra vakum devre kesicinin bu testi geçebilmesi için sonuclarının işgında geliştirme ve modifikasyon çalışması başlatılmıştır. Çalışmalar 1000 döngü testi ve 5000 döngü testini geçmesi durumları şeklinde iki bölüme ayrılmıştır [5].

Geliştirme ve modifikasyon çalışmalarının ilk bölümdünde, bobin serbest bırakma plakasının uygun hale getirilmesi, katı film kaplı parçaların yüzey deformasyonları ve Y-02-MIL-1059’un deformasyonu (36KV Kutup Güc Transmişyon Milli) çalışmaları ve kamların deformasyonu incelenmiştir. Çalışmanın sonuna 1000 döngü testi 1011 döngü ile tamamlanmıştır. Daha sonra, bu testlerde 2300 çevrime ulaşılmıştır. Ancak, buna rağmen aşağıdaki sorunlarla karşılaşılmıştır:

- Y-03-GRP-1024 (36kV şarj eden köşe plakası) çekirdeğindeki dil, 2300'üncü döngüde işlevini yitirmiş ve yuvaması kalır.
- Amortisörün konumu yanlış olduğu için her 50-100 devirde bir parça kırılmıştır. Bileşenler 3 kez değiştirildikten sonra hala ariza devam etmiştir. Test, 300 çevrinden sonra amortisörüz olarak gerçekeştirilmiştir.

Çalışmanın ikinci kısmında belirttiğim geliştirme ve modifikasyon süreçlerini kapsamaktadır. Göbek üzerindeki dil yuvasının ilk denemede 3300’üncü üretim prosesi inceleldiğinde, sac parçasının dil üzerinde anlaşılmıştır. Kaynaklanmasının sırasında dünün itildiği yaygın deformasyonu gözlemlenmiştir. Tedbir alınması ile kaynak işleme perçinle değiştirilmiştir. Ancak perçinlenmeyi parçalar, küçük bir çalışma sayısının ardından dili sıkıştırılamamıştır. Bu ikinci kez karşılaşılan aynı sorununca, sac parçası perçin içinde 8620 ölçekli malzemeden üretilmesi karar verilmiştir.

Sonuçlar ve Tartışma

Çalışmadaki geliştirmeler ve modifikasyonların sonunda, vakum devre kesicisi 2000 açma-kapama ile M1 Sınıfı olarak onaylanmıştır. Bu sayede TEİAŞ’ın şartı yerine getirilmiştir. Test, 300 çevrinden sonra amortisörüz olarak gerçekeştirilmiştir. Savunma komisiyasının dahil ettiği test 1011 döngüde tamamlanmıştır. Daha sonra, bu testlerde 2300 çevrime ulaşılmıştır. Ancak, buna rağmen aşağıdaki sorunlarla karşılaşılmıştır:

- Y-03-GRP-1024 (36kV şarj eden köşe plakası) çekirdeğindeki dil, 2300'üncü döngüde işlevini yitirmiş ve yuvaması kalır.
- Amortisörün konumu yanlış olduğu için her 50-100 devirde bir parça kırılmıştır. Bileşenler 3 kez değiştirildikten sonra hala ariza devam etmiştir. Test, 300 çevrinden sonra amortisörüz olarak gerçekeştirilmiştir.

Çalışmanın ikinci kısmında belirttiğim geliştirme ve modifikasyon süreçlerini kapsamaktadır. Göbek üzerindeki dil yuvasının ilk denemede 3300’üncü üretim prosesi inceleldiğinde, sac parçasının dil üzerinde anlaşılmıştır. Kaynaklanmasının sırasında dünün itildiği yaygın deformasyonu gözlemlenmiştir. Tedbir alınması ile kaynak işleme perçinle değiştirilmiştir. Ancak perçinlenmeyi parçalar, küçük bir çalışma sayısının ardından dili sıkıştırılamamıştır. Bu ikinci kez karşılaşılan aynı sorununca, sac parçası perçin içinde 8620 ölçekli malzemeden üretilmesi karar verilmiştir. Dildeki deformasyonu önlemek için malzememin Hardox 500 olarak kullanılmasına karar verilmiştir.

Bu makale, ilgili alanda çalışan araştırmacılara örnek ve yol gösterici bir çalışma olması amacıyla hazırlanmıştır.