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DESIGN AND ANALYSIS OF COUPLED INDUCTOR-BASED CIRCUIT BREAKER FOR DC GRID

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Abstract: **The electrical power system has various components such as generators, transformers, transmission lines, etc. We have to protect these components. In the electrical power system, a large number of power conversion steps are required. The lightning arresters, fuses, relays, and circuit breakers are some protective devices of the power system. In the electrical power system, many circuit breakers are introduced and some are still under research. The recently developed circuit breakers play a major role in the electrical power system. But recently developed circuit breakers have some disadvantages compared to this circuit breaker. The recently developed circuit breakers have a complex design structure. The short conducting path and the mutual coupling are the main aspects of this proposed circuit breaker. This circuit breaker is easily switched off in faulty conditions. In this paper, the literature review. Detailed simulation with the help of MATLAB software of the circuit breaker and results are included. This paper also describes the comparison between two circuit breakers based on the various electrical parameters.**

Index Terms - ***Power System, Circuit Breaker, Protection, Fault, Mutual Coupling.***

I. INTRODUCTION

For long transmission lines, DC power has more advantages as compared to AC power. For modern applications such as connecting grids, remote generation, connecting loads as well as renewable energy. While designing DC power systems various factors should be considered such as supply, electrical equipment, protection, fault, etc. For protection purposes, the circuit breaker is considered. Hybrid circuit breakers such as mechanical circuit breakers were proposed which have the ability to operate with AC as well as DC systems. Also, hybrid mechanical circuit breakers are used for both AC and DC power systems. The low losses are the main advantage of these hybrid mechanical circuit breakers [1]. The coupled inductor stores the energy based on the individual design concept used in the proposed electrical system [2] Mechanical circuit breakers have a limited range of applications [3]. Another protection method suggested is the use of converters and associated controls. Alternatively, solid-state dc circuit breakers are considered [4]. These breakers respond quickly to faults but have high power losses. The quick operating response is the main advantage of these circuit breakers. But, it has higher power losses [5].

Fuses have several advantages like very fast operation and impulsive isolation of fault loads. Therefore, in this proposed system we are implementing the concept of substitution in the DC circuit breaker which is closely associated with the Z-source DC breaker, but with the utilization of transformer coupling [6]. In recent years researchers are recommended coupled inductors helpful for fault detection as well as for automatic isolation. The breaker offers its advantages over the Z-source breaker in terms of less number of parts required. It also incorporates a settable level for fault current. There are two fault sensing techniques:

(A) Fault sensing employing a path from the source.

In this technique, a breaker is placed between the source and the load end. In this circuit, the current source is monitored throughout the operation.

(B) Fault sensing employing a path from the breaker.

In this method, the capacitor is usually connected to the ground in the breaker. This method has significant results for detecting oscillatory currents and is used on motor drives for shoot-through currents. That is, a series of low-voltage capacitors with different types of current sensors are connected to the DC bus, allowing the source to sense the fault current for the fault time period. The direction between the extra capacitor and the load easily specifies an error. These two techniques are admirable for the automatic detection of faults. Here, we have considered fault sensing by employing a path from the source [7]. The commutation capacitor is use in the circuit breaker with the design of the coupled inductor [8]. The coupled inductor has two windings. They are mounted on a single core which is shown in fig. 1. These two windings are influences each other due to inductance occurring between two windings. The L_1 and L_2 will be the inductances of the primary and secondary winding. The self-induced voltage and mutual induced voltages are present in the coupled inductor. [9] The proposed circuit breaker is simulated with the help of MATLAB simulation and the shows the results for the 20 second time period.

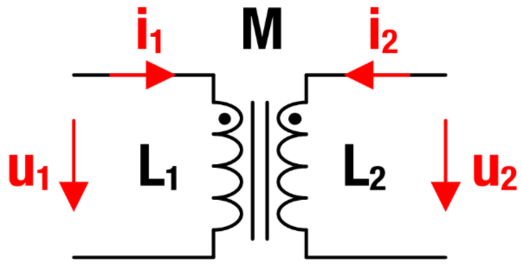

Fig. 1 Circuit Diagram of Coupled Inductance

II. LITERATURE REVIEW

The hybrid opening switch (HOS) is introduced for charging for a long charging period. The applications such as protection of DC circuits, battery-based inductive storage systems, and uninterruptible power supply (UPS) where a long charging period is required. This HOS design gives the field analysis of the indirect magnetic components. This system required high maintenance. After each operation, some changes are required. These are some major disadvantages of the system [1]. The author Heinz Zenkner describes the coupled inductor and EMC advantages that are used in switching power supplies. The two coupled inductors are represented as two separate devices. These two devices share a common partly due to the magnetic flux. In a common part, the two devices induce a voltage on one another. This is called mutual coupling. The coupled inductor provides another advantage such as voltage transformation, lesser ripple current, and galvanic isolation [2]. The capacitive discharge in power converters, coordination of circuit breakers has difficulty during fault conditions, and the necessity of adding a circuit breaker are some issues in power converter fed dc systems. For mitigation of these issues, the mechanical circuit breaker is introduced. But, the mechanical circuit breaker slows down the operation speed of the electrical system. The operational losses are much more than the other type of circuit breaker. The installation and recurring costs are very high [3]. During fault conditions, it is required to limit the short circuit current. The authors discussed the controlled circuit breaker which is proposed to control the short circuit current during the fault condition. The overcurrent tripping due to excessive flow of current is one of the common methods in the converter. The main target is the current is controlled at a maximum level where the inductive components should not be saturated. Therefore, the fault should be sustained [4]. The author J.D. Park and Jared Candelaria describe the advantages of DC protection of AC devices and DC protection of DC devices. The DC protection of DC devices has more advantages than other methods[5]. In the year 2009, the authors D. Salomonsson, L. Soder, and A. Sannino introduced the Protection of Low Voltage Microgrids. In this paper, the low voltage dc microgrid protection system is proposed. The low voltage microgrid is convenient for sensitive loads such as computer loads, buildings, etc. This proposed protection system consists of protection devices, relays, measurement equipment, and grounding. This proposed system is for the DC as well as the AC system. This may lead to high maintenance and highly economical [6]. The author K. Corzine proposed the circuit breaker for DC applications. This circuit breaker is based on the idea of coupling inductors [7]. For bulk power transmission thyristor-based HVDC systems are used. In the recent, the voltage source converter-based HVDC system is widely used. For the protection of this system, some ideas are described in this paper. The line-to-ground (LG), line-to-line (LL), overcurrent, and overvoltage are the possible faults that occurred in this system [8]. The author A. Shukla gives the survey on the hybrid circuit breaker based on the different topologies. The hybrid circuit breaker can operate in high-power applications and at higher temperatures [9]. The author A. Ray and S. Banavath proposed a new hybrid circuit breaker. This circuit breaker has zero switching for fast fault interruption. This circuit breaker is based on a technique of mutual coupling. From analyzing all the literature surveys, we proposed a circuit breaker for the DC grid applications based on the coupled inductor.

III. NECESSITY OF THE WORK

There are many circuit breakers are available in the recent trends. The main types of circuit breakers are AC circuit breakers and DC Circuit breakers. The DC devices of DC protection are more convenient. The AC devices of DC protection have many disadvantages. For AC circuit breakers, high maintenance is required. For the automatic isolation of the devices requires high technology. If a complete AC failure occurred in the system the battery banks supply the DC circuit breaker to close or trip the power of the breaker. This is the main advantage of the DC circuit breaker. In the AC system, the power conversion steps are more. This will operate in a faster manner. This may lead to the production of harmonics in the system. The mechanical circuit breakers slowdowns the speed of operation. It is difficult to control and monitor the AC system. The cost of the hybrid circuit breaker is higher compared with another circuit breaker. This circuit breaker is used for low voltage, medium voltage, and higher voltage levels. For this work, we are using MATLAB software which helps in finding and analyzing all the parameters of the system. So, we have proposed a circuit breaker with the help of different fault techniques for the different voltage levels.

IV. SYSTEM DESIGN

The two fault sensing techniques are fault sensing path from the source and fault sensing path from the circuit breaker. These two strategies are excellent but, in addition, a short path can be used for switching the circuit breaker during fault. Figure 1 shows the proposed DC circuit breaker. During the operation of the steady-state, current flows into the SCR, and the coupled inductors from the source to the load. The fault on the side of the load will give rise to the impulse current i_c in the capacitor and secondary winding of the coupled inductors. Including the turns ratio, this current becomes visible to be the primary and shoots the SCR current to zero; at which time, the SCR switches off. It should be noted that the turns ratio is set such that the breaker does not show a significant change in load incorrectly.

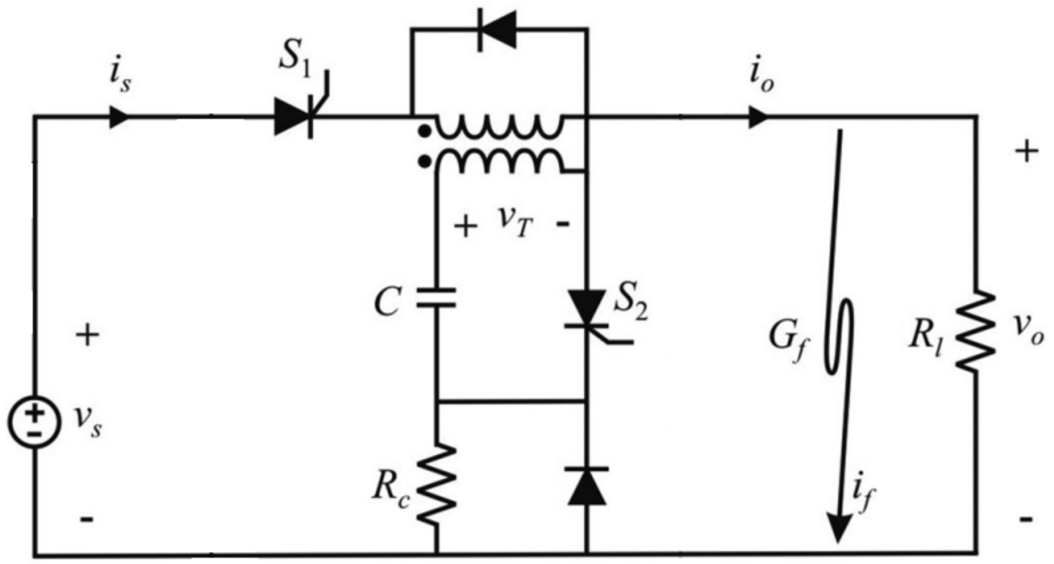

Figure 1. Proposed Circuit Breaker

V. DETAILED SIMULATION

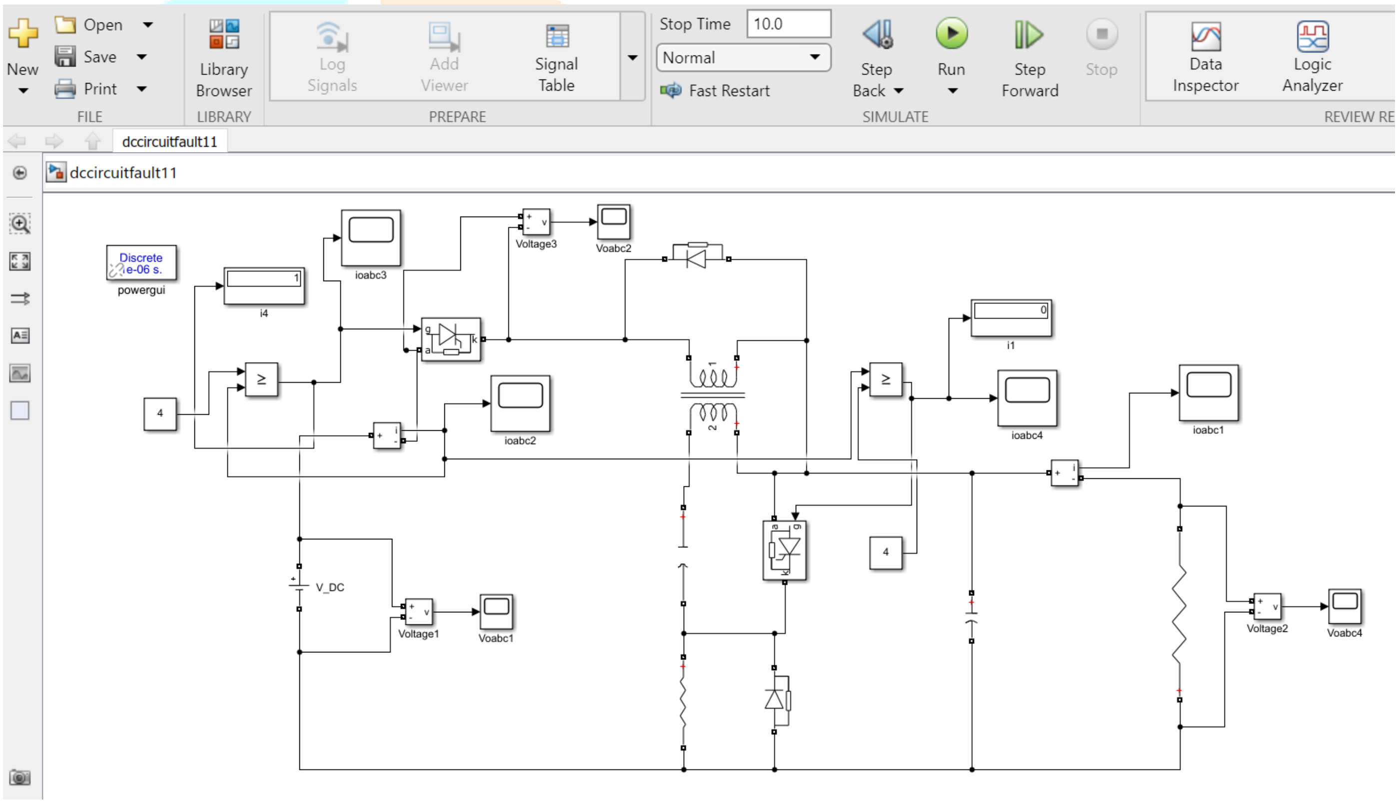

Figure 2. Simulation Diagram of Proposed Circuit Breaker

Based on the parameters, the detailed simulation is carried out. The followings are the parameters used for this simulation. The source voltage is 400 V DC and load is purely resistive. The Figure 2 shows the simulation of the proposed circuit breaker. The simulation time for this circuit is 10 sec.

The Figure 3 shows the input voltage, current and output voltage, current during normal condition.

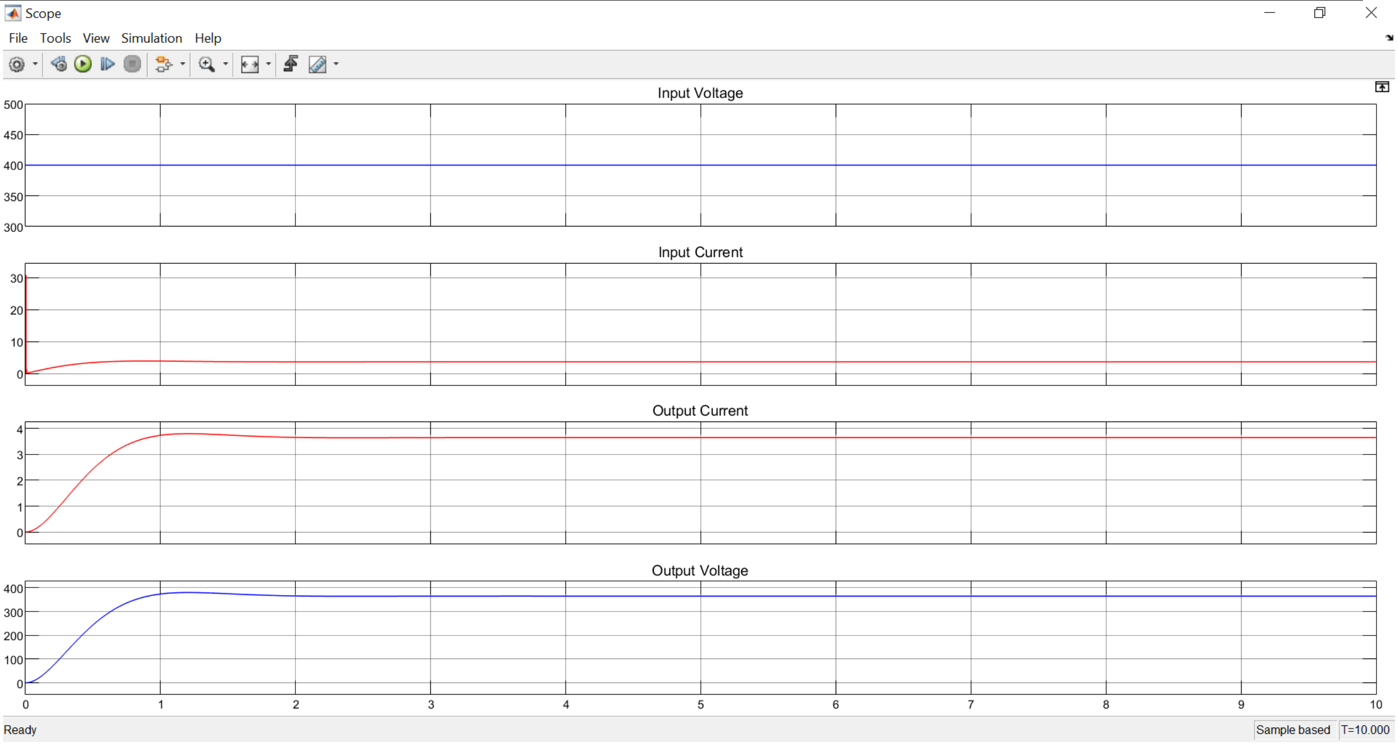

Figure 3. Input and Output Parameters

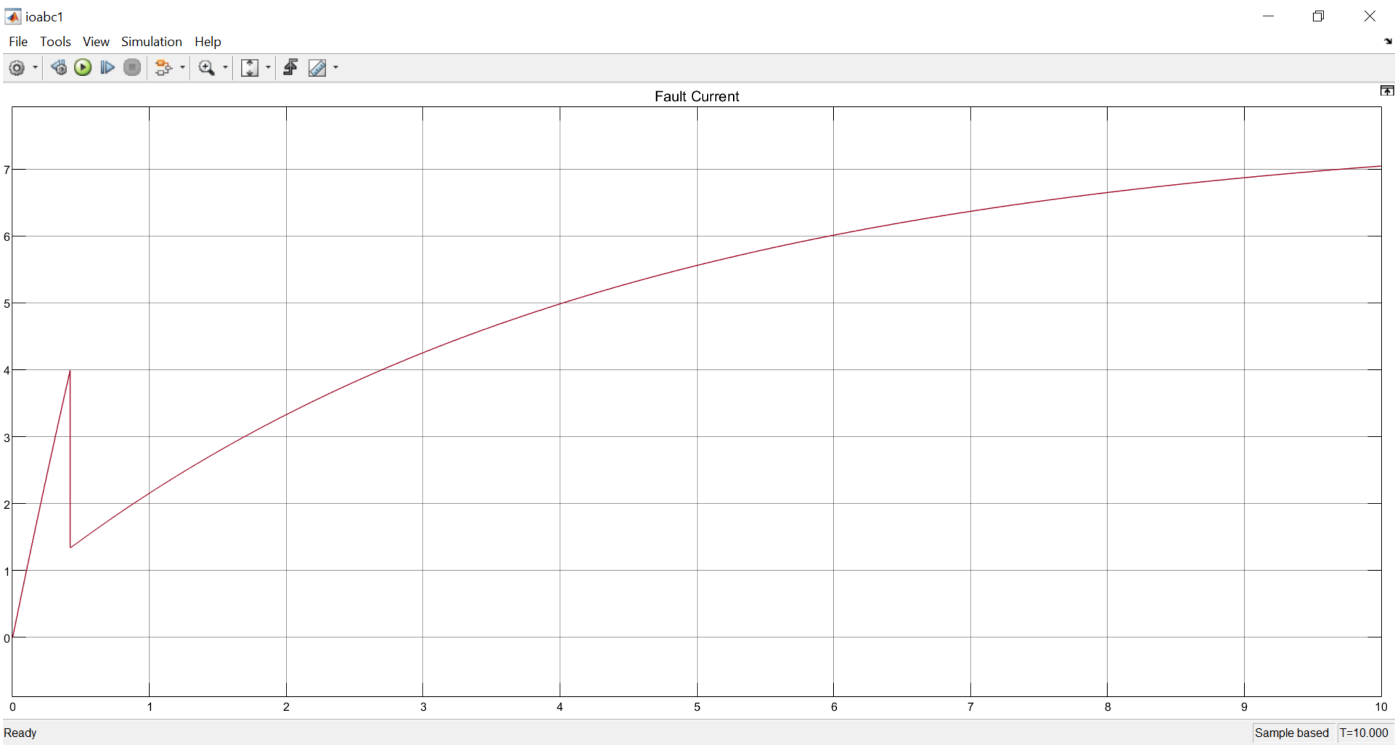

Figure 4. Fault Current

The Figure 3 shows the current waveform during fault occurs in the system.

VI. CONCLUSION

As dc sources and dc microgrids become more prevalent, a solution is sought for dc switches and circuit breakers. Traditional methods relied on oversized ac breakers, hybrid breakers, and solid-state breakers. The dc switch proposed in this paper is a variation on the solid-state breaker, but has the added feature that it can automatically switch OFF in response to faults. Furthermore, there the turn's ratio in the circuit's transformer allows the designer to determine the amount of transient current that will be identified as a fault; as opposed to a step change in load. Analysis, design, and laboratory measurements demonstrate the proposed breaker's response to a step change in load and to a fault. The breaker compares favorably to recent designs in that it has a common ground between source and load, is invariant to step changes in load, and does not produce ringing resonance in the source current.

VII. REFERENCES

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