Z - SOURCE DC CIRCUIT BREAKER WITH VOLTAGE TRANSIENT CAPABILITY AND ON LOAD TURN OFF

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Abstract – The paper gives light to a solid state circuit breaker with transient voltage capability and load turn off is proposed to build. The breaker utilizes a z-source *LC* circuit in order to automatically commutate a main-path GTO during a fault. Compared to existing dc circuit breakers, the z-source breaker features fast turn-off, simple control, and the source does not experience the fault current. As the performance of regular solid state breakers utilizing the Z source is worst with the MVDC-HVDC power grid applications, some problems including the on-load turn off and transient voltage incapability also comes in to existence. In this project the GTO with parallel varistor topology using a Z-source commutation has been simulated and verified. The system uses a GTO based breaker with MOV module having circuit compatibility with HVDC power grid. A modified Z source which is prior to the existing module is also proposed.

I. INTRODUCTION

The industrial growth of nation required increased consumption of energy, particularly electrical energy. This has lead to increase in the generation and transmission facilities to meet the increased demand. In developing countries like India, the demand doubles every seven years which requires considerable development in electric power sector. The imperatives of supplying energy at reasonable costs coupled with the depleting reserves of non renewable energy sources had lead to the establishment or remote generating stations predominantly fossil fuels fired thermal stations at pit head. Environmental considerations also dictate sometimes, siting of power stations at remote locations. The need to economise on costly investments in generation reserves, sharing of benefits in utilizing variability in generation mixes and load pattern have given rise to interconnection of neighbouring systems and development of large power grids.

II. D.C CIRCUIT BREAKER OVERVIEW

2.1 INTRODUCTION

A high-voltage, direct current (HVDC) electric power transmission system uses direct current for the bulk transmission of electrical power, in contrast with the more common alternating current (AC) systems. For long-distance transmission, HVDC systems may be less expensive and suffer lower electrical losses. For underwater power cables, HVDC avoids the heavy currents required to charge and discharge the cable capacitance each cycle. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be warranted, due to other benefits of direct current links.

High voltage cannot readily be used for lighting or motors, so transmission voltages are reduced for end-use equipment. Transformers are used to change the voltage levels in alternating current (AC) transmission circuits. AC became dominant after the War of Currents competition between the direct current (DC) system of Thomas Edison and the AC system of Westinghouse because transformers made voltage changes practical, and AC generators were more efficient than those using DC. Practical conversion of power between AC and DC became possible with the development of power electronics devices such as mercury arc valves and, starting in the 1970s, semiconductor devices as thyristors, integrated gate-commutated thyristors (IGCTs), MOS-controlled thyristors (MCTs) and insulated-gate bipolar transistors (IGBT).

III. PROJECT DESCRIPTION

A. EXISTING SYSTEM

In recent years, the U.S. Navy has focused on development of the next-generation of integrated power systems (NGIPS) for electric ship propulsion and ship service power. Shipyards have been contracted to work interactively to evaluate the Navy's open-system architecture for the NGIPS and provide recommendations to maximize opportunities for common component development. Of particular interest is the far-term medium-voltage dc (MVDC) power system architecture. One of the largest obstacles to this technology is the circuit breaker. Unlike ac systems, there is no zero crossing of the current to extinguish the arc that occurs upon breaker opening. There after a novel "z-source" dc breaker is introduced, which creates a thyristor zero current crossing to provide a method of interrupting load carrying currents. The circuit utilizes SCRs that are inexpensive, reliable, and capable of handling large currents and voltages.

B. Z-source dc circuit breaker and operation

When the fault occurs in this system, there is no direct short of the capacitor voltages, because of the inductors in the z-source circuit. The breaker components act together to quickly mitigate faults in a dc system. When a fault occurs at the output of a z-source breaker, current sources into the fault from the downstream system capacitance *Cl* as well as from the z-source capacitances as shown by the fault conduction path in Fig. 3.3. The operation of the z-source circuit can be understood by considering the current path shown in Fig. 3.3. A portion of the fault current will come from the z-source breaker capacitances. The conduction path is then through the z-source capacitors and back to the source as shown in Fig. 3.1.

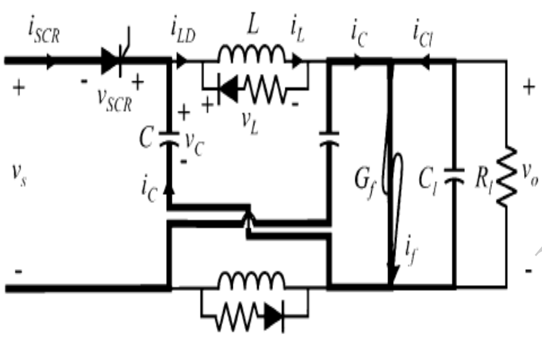

Fig 3.1 Conduction path of transient fault current

At the point when two currents becomes opposite at a common point, *i*SCR will go to zero causing the SCR to commutate off. A simple circuit can then detect that the SCR has switched OFF, removing the gate voltage from the SCR. After the SCR switches OFF, the z-source components are configured as two-series *LC* branches connected to the load and fault. These circuits start a resonance where they are supplying the fault, but since the source has been disconnected and the fault impedance is low, the output voltage collapses to zero. By Kirchhoff's voltage law (KVL), with the output voltage at zero, *vL* must be equal to *vC*. Also, by KVL, it can be shown that when these voltages reach half of the source voltage *vs*, the SCR will become forward biased. Therefore, the time when *v*SCR is positive is the amount of time available for the control circuit to remove the gate pulse and the SCR to undergo its reverse recovery transient. The resonance continues until the inductor voltage attempts to go negative. At this point, the diode will turn ON. The current in the capacitor will switch OFF and the current will continue in the inductor/diode/resistor loop until it decays to zero. It can also be shown by KVL that since the inductor voltage does not go negative; the SCR voltage will not go above the source voltage.

V. THE MODIFIED GTO MODEL

A. System description

The problem of turn off transient and the lack of load voltage capability arises some issues, when the breaker finds its application in MVDC-HVDC networks. While handling high voltages up to 600kV the life of the device will surely be questioned. The proposed network is now introducing a new GTO based topology with a parallel connected MOV as the voltage suppressor. The MOV module not only supports to eliminate the voltage transients during turn off but also improves the capability of load turn off. The existing system using the simple Z source topology fails in this operation, there is nothing implemented to suppress the over voltage. The module also becomes helpful with the long distance transmission system if proper insulation co-ordination has been done.

A disadvantage of the z-source breakers described in is that they cannot be used for re-energizing the load after the fault is cleared. There will be a large current spike through the thyristor, when the dc source reconnects with the breaker. A fault is simulated by the breaker across the load at 0.3 and 0.1sec for the GTO-MOV topology and Modified Z source respectively. Performance evaluation has been done on the basis of degree of accuracy and parameter assessment.

B.Matlab-Simulink modeling-GTO-MOV topology

The Matlab Simulink model of the proposed system is shown in figure 5.1, which employs a GTO-MOV topology with Z source commutating circuit. The fault is simulated by a fault breaker connected across the load.

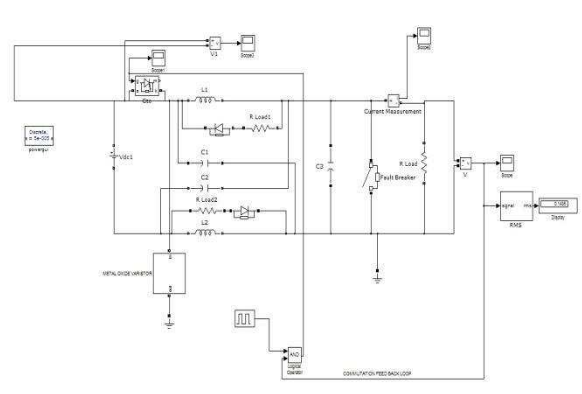

Fig 5.1Proposed GTO topology with MOV

The table below shows the circuit parameters used in the preparation of modified Z source topology.

Table 5.1 - Circuit parameters-GTO-MOV model

C. Model- Modified Z source topology

The Matlab Simulink model of the modified Z source system is shown in figure 5.2, which employs a GTO topology with modified Z source commutating circuit. The fault is simulated by a timer switch connected across the load. The table 4.3 shows the circuit parameters used with the Simulink Model.

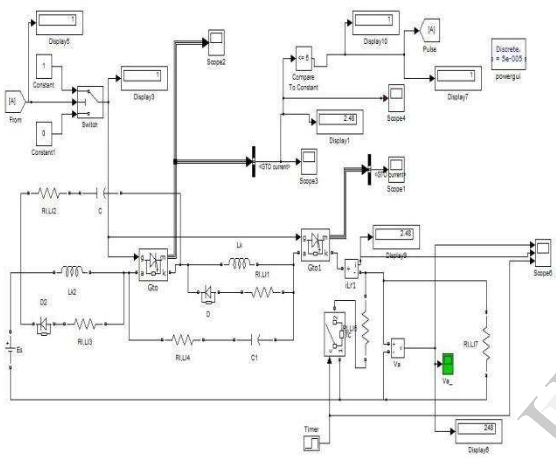

Fig 5.2 Modified Z-source model

D. SIMULATION-TRIAL OUTPUTS

Fig 5.3 shows the simulation results of the proposed GTO-MOV topology with a simulated fault at 0.3 sec. The variation of output voltage, current and the turn off transient are observed with the model and are as follows. The voltage waveform shows a transient voltage at the turn on and the device current also shoots up with the voltage. The turn off transient which may become severe with the high voltage switching is successfully eliminated with the MOV module.

The simulation results of the GTO-MOV system are as follows

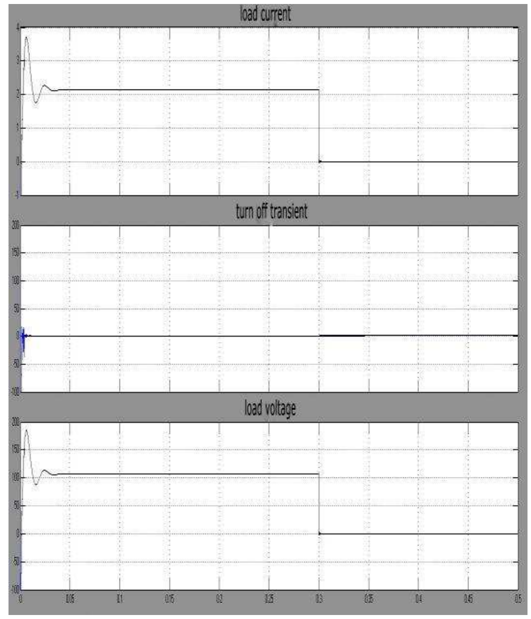

Fig 5.3 Simulation Result-GTO-MOV topology

E. Output – Modified Z – Source topology

Fig 5.4 shows the simulation results of the modified Z source-GTO topology with a simulated fault at 0.1 sec. the variation of output voltage, current and the switch timing are observed as follows. The voltage and current transient at the turn on is now reduced with the modified circuit.

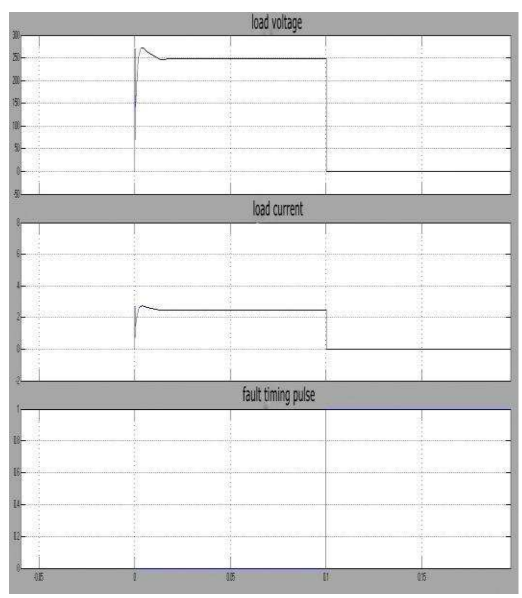

Fig 5.4 Simulation Result-Modified Z-source topology

D. Inference

- Turn off transient gets eliminated with the parallel connected MOV.
- The CB is now suitable for grid applications and supply schemes of high voltage fluctuations.
- A feeble voltage spike has been observed with the turn on time.
- Its effect is not severe as GTO turn on time is much small.
- The modified Z source makes the circuit lighter.
- Soft starting or soft wake up can be obtained with the new topology.
- Possible turn on problems can thus eliminate when using with MVDC transmission.

VI. CONCLUSION

A new type of circuit breaker has been introduced here with applications varying from protection of bulk power transmission lines to motor control circuits. The breaker uses Z-Source technology to enable automatic turn off and advanced control system for turn on purposes. The system uses a GTO-MOV topology to find its place in MVDC transmission network. Soft switching capability was also incorporated in to the circuit with a modified Z source also. With the expected future growth in the DC transmission this new age technology holds lot of ground as it helps us overcome one of the biggest drawbacks of DC transmission technology, the design of an automatic circuit breaker. The breaker will finds its fully automated service in the future with automated power transmission systems. The fundamental concepts were validated on a laboratory system where the z-source breaker isolated a direct short across the dc bus.

VII. REFERENCES

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