Cluster Voltage Balancing for Cascaded H Bridge Statcom

Mrs. K. Preetha,
Assistant Professor,
Department of EEE,
Dhanalakshmi Srinivasan Engineering College
(Autonomous), Perambalur,

C. Nivetha, A. Durgadevi, C. Jaya,
Final Year Students,
Department of EEE,
Dhanalakshmi Srinivasan Engineering College
(Autonomous), Perambalur,

Abstract:- An improved fault-tolerant control strategy is proposed for CHB based static synchronous compensator (STATCOM) under SM faults. First of all, compared with the conventional fault-tolerant method of directly by passing the faulty SMs, the proposed fault-tolerant method takes advantage of the healthy switches of the faulty SMs, where they are still able to generate either positive or negative voltage level. As a result, more output voltage levels can be generated, and it raises the attainable balanced line-to-line voltage, especially when different fault types exist at the same time. Then, based on the specific condition of OC fault or SC fault, when the output voltage reference of the faulty phase reaches its limit, the references of the other two healthy phases are redistributed to generate the desired line-to-line voltage. With the reconfiguration of

modulation waves, the attainable balanced line-to-line voltage can be further improved. In addition, the proposed fault-tolerant method possesses the ability of cluster voltage balancing, which is an important issue for the STATCOM application.

INTRODUCTION

Multilevel converters such as flying capacitors converters, diode-clamped converters and cascaded converters are gaining more and more popularity due to their lower voltage stress, lower switching frequency, and higher output voltage and so on. With the rapid development of power technology and the widely applied power electronic devices, power quality is becoming an important and series issue. As one of the most effective compensation devices, Static synchronous compensator (STATCOM) draws much attention in recent years. It can effectively compensate for the reactive current, improve the power factor, and reduce the power loss on power transmission, thereby enhancing the stability of the power network. For high-voltage STATCOM applications, cascaded H-bridge (CHB) converter is one of the most superior topologies due to its modularity, scalability, and so on.

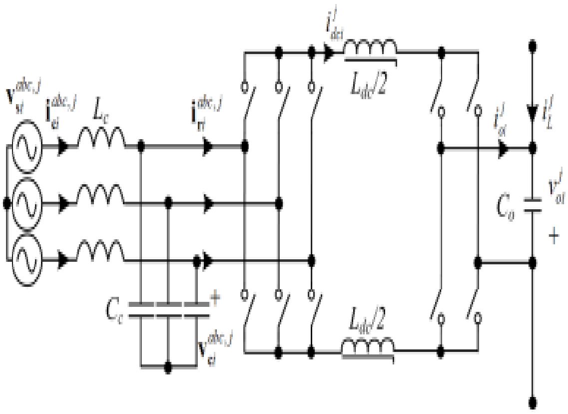
In recent years, due to arising power quality issues in the power network and remarkable developments in power electronic Multilevel Converters (MCs), Flexible AC Transmission Systems (FACTS) based on multilevel converters have achieved noticeable attention. Among FACTS devices, Static Synchronous Compensator (STATCOM) is a well-known parallel connected device which improves power factor, power transmission capability, voltage controllability and stability of the power networks. Among multilevel topologies, cascaded H-bridge (CHB) topology is accepted as one of the most efficient and beneficial topologies for Multilevel-STATCOM. In addition to general advantages of CHB topology- such as modularity, straightforward controllability and less number of power electronic elements- there is no need for isolated power sources to feed the dc-side of H-bridge cells in the application of reactive power compensation; however, the voltage of capacitive dc links should be controlled in addition to reactive power control.

CHB converters are made of several identical H-bridge cells in phase legs. Hence, a high number of power switches such as insulated gate bipolar transistors (IGBTs) increase the probability of fault occurrence in the converter. In the first step of fault detection, the power switch failure should be detected and localized. This issue has been studied in the literature and different techniques have been introduced for detection of both open-circuit and short-circuit failure in a semiconductor power switch. Beside this, due to series connection of H-bridge cells in a CHB converter, a power switch failure may cause the whole system interruption and the damage of rest parts of the converter. Hence, as the next step, the fault tolerant operation of a CHB converter is brought up as a significant challenge in order to manage the post-fault condition and guarantee continuous and uninterrupted operation of the system after failure event with the maximum possible capacity of the converter which should be investigated in the various applications of the CHB converter. Different fault tolerant methods for the CHB converter, generally, can be classified into two approaches: hardware approaches and software approaches

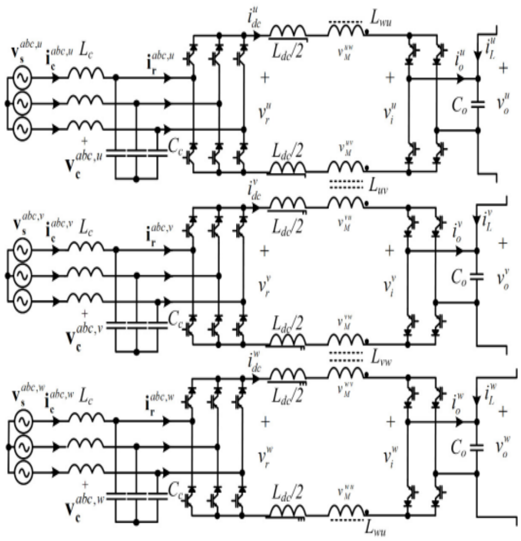
In high-voltage high-power applications there are many sub modules (SMs), each containing four IGBTs and one capacitor. The open-circuit (OC) fault and short-circuit (SC) fault of IGBTs may even lead to the interruption of the CHB STATCOM, due to the cascaded connection of each H-bridge. As a result, the fault-tolerant control method for CHB STATCOM has to be studied. Many studies have been carried out on fault-tolerant control of CHB based converter, which mainly can be divided into three categories, additional power unit (APU) method, special modulation technique (SMT), and zero-sequence voltage (ZSV) injection method.

For APU methods, an additional unit with an isolated DC voltage source is used to provide post-fault operation ability. However, the additional isolated DC source is usually not economic. It takes advantage of an auxiliary H-bridge SM together with 3 additional switches to realize the post-fault operation. The H-bridge SM can be connected to an arbitrary phase by three additional switches. However, it requires seven extra switches and one capacitor as a redundant unit. It further reduces the switches and use one capacitor together with six more switches in the auxiliary SM. The auxiliary SM is in a three-phase bridge connection to the CHB converter, and the post-fault operation can be realized by manipulation of the six additional switches. However, these APU methods can only deal with one SM fault in one single phase.

CIRCUIT DIAGRAM



MODES OF OPERATION



FAULT-TOLERANT CONTROL METHOD

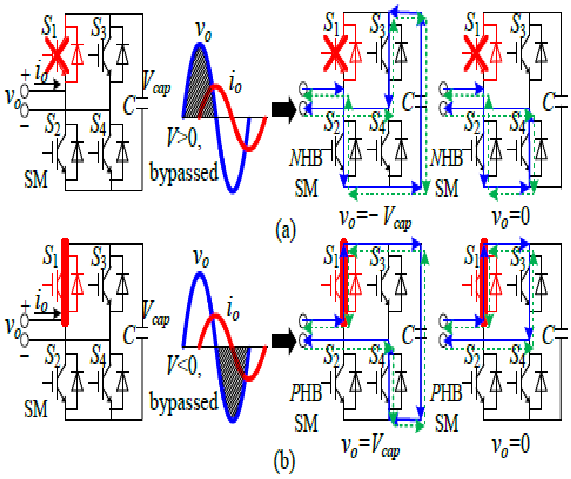


Fig. Configuration of the Faulty SM

SHORT CIRCUIT FAULT (SCF)

A short circuit fault (SCF) arises when two different nodes in the original, fault-free circuit, are joined through some kind of low resistance "object" (called a short); a common case is a drop of solder which wrongly connects two or more neighbour nodes, what happens when electronic boards are heated to solder/attach the components. A short circuit can be defined as an abnormal connection of very low impedance between two points of different potential, whether made intentionally or accidentally. These are the most common and severe kind of faults, resulting in the flow of abnormal high currents through the equipment or transmission lines. If these faults are allowed to persist even for a short period, it leads to the extensive damage to the equipment. Short circuit faults are also called as shunt faults. These faults are caused due to the insulation failure between phase conductors or between earth and phase conductors or both. The various possible short circuit fault conditions include three phase to earth, three phase clear of earth, phase to phase, single phase to earth, two phase to earth and phase to phase plus single phase to earth as shown in figure. The three phase fault clear of earth and three phase fault to earth are balanced or symmetrical short circuit faults while other remaining faults are unsymmetrical faults.

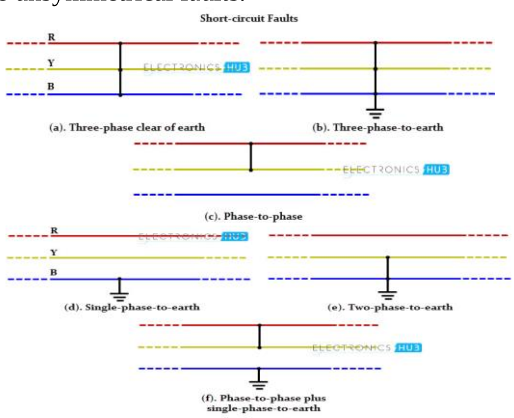


Fig. Short Circuit Fault

SIMULATION DIAGRAM

i)GENERATION UNIT

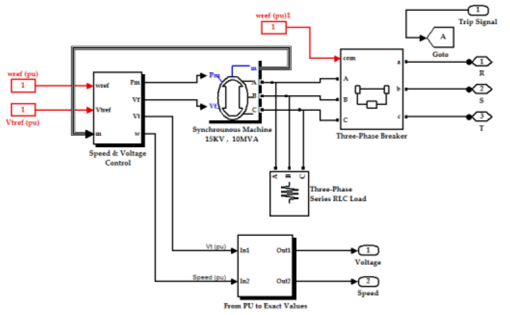


Fig. Simulation Diagram of Generation unit

ii) SPEED AND VOLTAGE CONTROL

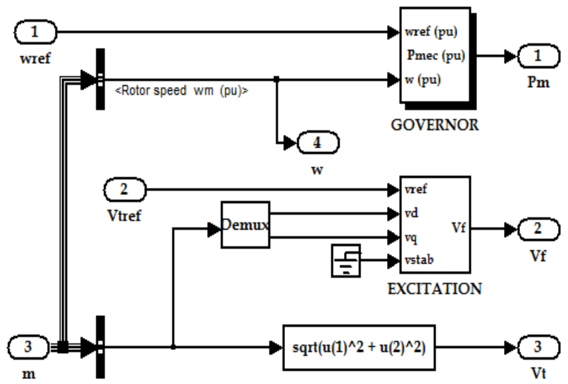


Fig. Simulation Diagram of Speed and Voltage Control

iii)15 KV TO 132 KV SYSTEM

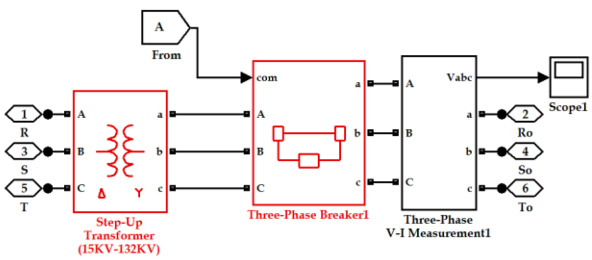


Fig. 5kv to 132 KV Systems

iv) THREE PHASE MEASUREMENT VOLTAGE AND CURRENT OUTPUT

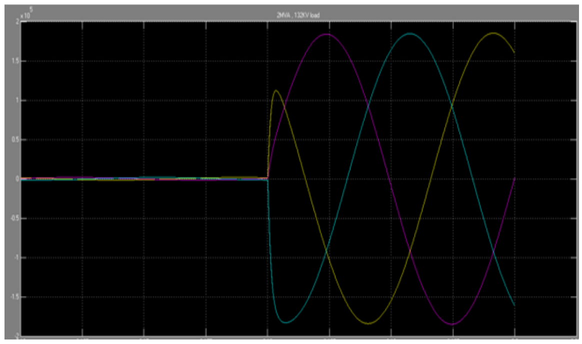


Fig. Three Phase Measurement Voltage and Current Output

v) EMERGENCY SYSTEM

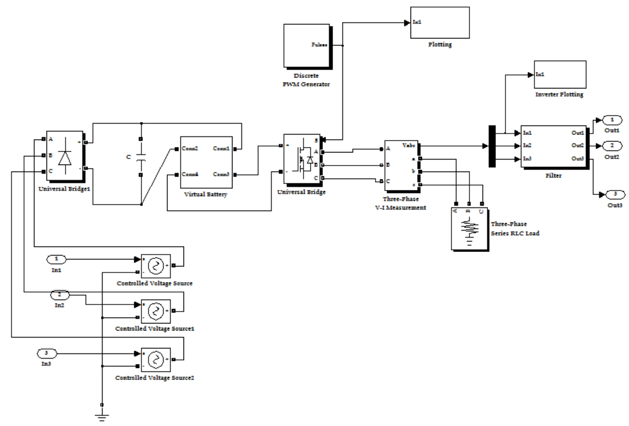


Fig. Emergency System

vi) BYPASS SYSTEM

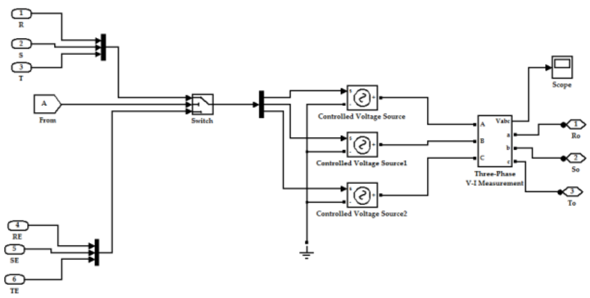
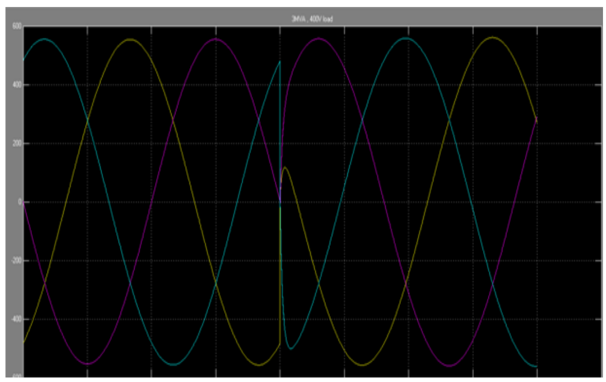


Fig. Bypass System



CONCLUSION

An improved fault-tolerant method with higher attainable balanced line-to-line voltages is proposed to deal with multiple SM faults in the same phase. Compared with the conventional fault-tolerant method, the main advantages mainly include: Instead of bypassing the faulty SM directly, the proposed method takes advantage of the healthy switches of the faulty SM, which can provide higher attainable line-to-line voltages, especially when different fault types (*P*HB and *N*HB) exist at the same time. Instead of injecting the FZSV, the proposed method modifies the voltage references in such a way that the higher attainable line-to-line voltages can be generated. Moreover, the proposed method is able to keep the active power equally distributed among the three phases, which is a key factor in the STATCOM application. It is noted that this paper mainly focuses on the basic principle of the proposed method, and the SM faults condition in a single phase has been analyzed and validated. However, the multi-phase fault condition will be discussed in detail in the future work.

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