POWER ELECTRONIC ON-LOAD TAP CHANGER FOR HVDC CONVERTER TRANSFORMER

PROJECT REPORT

submitted by

ANAS BABU V (Reg. No : **MAC17EE023**)
BASIL BENNY (Reg. No : **MAC17EE042**)
DILSHAD K P (Reg. No : **MAC17EE054**)
RYAN ROMEO (Reg. No :**MAC17EE103**)

to

the APJ Abdul Kalam Technological University
in partial fulfillment of the requirements for the award of the Degree

of

Bachelor of Technology
In
Electrical and Electronics Engineering

Department of Electrical and Electronics Engineering

Mar Athanasius College of Engineering
Kothamangalam, Kerala, India 686 666

JUNE 2021

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
MAR ATHANASIUS COLLEGE OF ENGINEERING
KOTHAMANGALAM

CERTIFICATE

This is to certify that the project report entitled **Power Electronic On-Load Tap Changer for HVDC Converter Transformer** submitted by **Mr. Anas Babu V (Reg.No.MAC17EE023), Mr. Basil Benny (Reg.No.MAC-17EE042), Mr. Dilshad K P (Reg.No.MAC17EE054), Mr. Ryan Romeo (Reg.No.MAC17EE103)** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Electrical and Electronics Engineering is a bonafide record of the project carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Prof. Mohitha Thomas
Project Guide

Prof. Emmanuel Babu P
Project Coordinator

Prof. Beena M Varghese
HOD, EEE Dept.

Internal Examiner(s)

External Examiner(s)

Dept. Seal

07-06-2021

ACKNOWLEDGEMENT

It is a great pleasure to acknowledge all those who have assisted and supported us for the successful completion of our project.

First of all, we thank God Almighty for his blessings as it is only through his grace that we were able to complete our project successfully.

We take this opportunity to extend our sincere thanks to our project guide Prof. Mohitha Thomas, Assistant Professor, Department of Electrical & Electronics Engineering, for her constant support and immense contribution for the success of our project.

We take this opportunity to extend our sincere thanks to our project coordinator and our Faculty Advisor Prof. Emmanuel Babu P, Assistant Professor, Department of Electrical & Electronics Engineering, for his constant support and immense contribution for the success of our project.

We are also grateful to Prof. Beena M Varghese, Head of Electrical & Electronics Engineering Department, for the valuable guidance as well as timely advice which helped us a lot during the preparation of the project.

We are deeply indebted to Dr. Mathew K, Principal, Mar Athanasius College of Engineering, for his encouragement and support.

We whole - heartedly thank all our classmates, for their valuable suggestions and for the spirit of healthy competition that existed between us.

ABSTRACT

Due to a number of advantages over high voltage AC transmission, high voltage DC transmission is becoming increasingly important. In High Voltage DC transmission, the HVDC converter transformer is the primary element. A tap changer is a critical component of any power transformer since it allows for varied turn ratios and hence voltage levels. Mechanical tap changers have traditionally been employed for this. Regular use of mechanical tap changer would lead to a regular maintanance of such tap changers.A tap changer is a critical component of any power transformer since it allows for varied turn ratios and hence voltage levels. Mechanical tap changers have traditionally been employed for this. A power electronic tap changer for arc-free switching and inexpensive maintenance is proposed in this proposal, as well as for normal operations. Using simulation tools and a prototype, the basic operation of the power electronic tap changer, various topologies, and some specification parameters of the power electronic tap changer for High Voltage DC converter transformer are evaluated and checked.

TABLE OF CONTENTS

Sl No. Title Page No.

1 INTRODUCTION **1**
1.1 Objective 2
1.2 Overview 2

2 LITERATURE REVIEW **3**

3 HVDC TRANSMISSION **5**

4 HVDC CONVERTER TRANSFORMER **7**

5 TAP CHANGERS **9**
5.1 NO-LOAD TAP CHANGER 10
5.2 ON-LOAD TAP CHANGER 11
5.3 CONVENTIONAL TAP CHANGERS ADVANTAGES AND DISADVANTAGES 11

6 POWER ELECTRONIC TAP CHANGERS **13**

7 DIFFERENT POWER ELECTRONIC TAP CHANGER TOPOLOGIES **14**
7.1 TOPOLOGY 1 15
7.2 TOPOLOGY 2 17
7.3 SHORT CIRCUITS 19

8 CONCLUSION **23**

References **24**

LIST OF FIGURES

Fig.No.	Title	Page No.
3.1	Components of HVDC transmission.	6
4.1	Circuit diagram of HVDC converter transformer	8
4.2	HVDC converter transformer	8
5.1	No load tap changer internal diagram	10
5.2	No load tap changer	11
5.3	On load tap changer	12
7.1	MATLAB Simulink model of Topology 1	15
7.2	Output waveform of Topology 1	16
7.3	MATLAB Simulink model of Topology 2	17
7.4	Output waveform of Topology 2	18
7.5	Simulation model for simulation of Short circuit AC current	19
7.6	Current waveform with respect to time on DC side when a short circuit fault occurs on high voltage AC side of Converter circuit	20
7.7	Voltage waveform with respect to time when a short circuit fault occurs on high voltage AC side of the Converter circuit	20
7.8	Short circuit Simulink model for simulating short circuit on the DC side of Converter circuit	21
7.9	Voltage waveform when a short circuit occurs on high voltage DC side of Converter circuit	22
7.10	Current waveform with respect to time on the DC side when a short circuit occurs on high voltage DC side of the Converter circuit	22

CHAPTER 1

INTRODUCTION

Electricity is transmitted over long distances with minimal losses and high performance using high voltage DC transmission. Because of its cost and endurance, HVDC transmission is better suited for bulk power transmission. HVDC links can also be used to join two distinct grids with differing frequencies.In a standard 2000 MW HVDC project, the converter transformer contributes about 16% of the overall cost. High voltage power electronic conversion circuits are being used to convert high voltage AC to high voltage DC. A transformer used for HVDC conversion is known as an HVDC converter transformer.Therefore in this type of transformer, tap changers are utilised to achieve various turn ratios and manage the secondary voltage. Tap changers can correct for HVDC conversion-induced reactive voltage dips as well as voltage drops produced by other causes.

Since the DC voltage and electricity flows through the HVDC line are regulated by the tap changer, the number of operations of an on-load tap changer is much greater than that of a traditional power transformer. Both higher-rated transformers have On-Load tap changers that run without disrupting the supply. The No-Load tap changers, on the other hand, can only be used in a de-energized state. Mechanical tap changers are commonly used for this purpose in the past. There are two types of mechanical tap changers on the market: oil-immersed and vacuum-circuit tap changers. Mechanical connections are used for swapping in traditional mechanical tap changers. The biggest drawback of mechanical tap changers is their poor reaction time and the forming of arcs in the contacts when swapping. Tap changers' life is shortened due to arc formation in the contacts. Furthermore, arc forming degrades the consistency of the oil used in oil immersed tap changers. As a result, mechanical tap changers need to be checked and maintained on a regular basis. The issues posed by mechanical tap changers can be solved by converting to solid state units. Solid-state tap changers have the benefits of low maintenance, high performance, and high running speed. This project give a better insight into the implementation of power electronic devices for on-load tap changing and its wide range of merits.

1.1 Objective

The primary objective of the project deals with the principles and working of solid-state tap changers which can be used in High Voltage DC converter transformers. The primary milestone to be dealt with was to find the perfect topology for the power electronic tap changers. The MATLAB Simulink software helped much in the simulation so that a shallow knowledge regarding the hardware and design problems could be drawn. A low voltage prototype is developed based on the above assumptions and simulation so that an in depth realisation of design problems and further results could be analysed. Per phase simulation was done so as to reduce the computational complexity.

1.2 Overview

Chapter 1 presents the details of the HVDC transmission and its components.

Chapter 2 shows the literature review.

Chapter 3 describes the types of Tap Changers that is taken into consideration.

Chapter 4 deals with the basic tap changers used conventionally and their different types.

Chapter 5 shows the primary element of the project Power electronic tap changers.

Chapter 6 contains different Topologies and simulation models.

Chapter 7 contains the conclusion derived.

CHAPTER 2

LITERATURE REVIEW

S Kamakshaiah, V Kamaraju [1] has explained about the fundamentals of HVDC Transmission. An in depth knowledge about the construction, principles and operation of HVDC Transmission could be derived and worked upon. Details about the advantages and the necessity of HVDC could be taken up from this reliable source. The source acts as a foundation for our project.

S.V Kulkarni, S.A Khaparde [2] describes about the in depth design details of Transformers. Data regarding converter transformers could be derived from this source and acted as a potential element of our project. Details of other transformer construction also paved way for extra thinking capabilities and finding possibilities regarding to the project.

According to A. Kumar, K. Kumar, N. Kaushik, S. Sharma, and S. Mishra[3] though the nation generates enough power it fils to attain transmission efficiency due to the high impedance loss in HVAC transmission lines. The impedance loss increases as the distance increases. So we direct our project idea to HVDC lines where there is no impedance loss and hence greater power saving and efficiency.

P. Bauer,S.W.H. de Haan [4] demonstrated the implementation of electronic tap changer for 500kvA/10kv Distribution transformers. The source provide all the merits and demerits of electronic tap changer implmentation and its demerits.Heating is a primary issue but compared to the loss incured by the mechanical system it could be considered a better choice. And hence the source act as a blueprint for the implementation of tap changers.

Jawad Faiz, Behzad Siahkolah[5] proposed the usage of solid state tap changers for transformers. Unlike the mechanical tap changers solid-state tap changer provide the advantage of cost and faster response time. These tap changers are easy to manufacture and would increase the application and responsiveness of the system. Hence an implementation of solid-state devices would incur further developmental possibilities in our project.

Osman Demicri, David A Torrey, Robert C Degeneff, Fredrich KSchaeffer, Robert H Fraze[6] presents a fresh perspective to solid-state load tap changing system. Solid-state devices (SCRs) and a variety of transformer taps make up the tap changing system. Our method may give up to 48 steps instead of the 16 steps related to mechanical tap changers due to careful selection of the tap changer topology and a new control method.It can also do so with lesser transformer tap windings and the capability to go from one tap to the next without having to go through any intermediary taps. The notion of a tap changer has been tested in the lab. Definitions are presented to show how the ideas may be implemented to handle 34.5 kV, 30 MVA, and 115 kV, 100 MVA networks.The technique provided can be 20-50 percent less affordable than earlier efforts to develop solid-state tap changers, according to an economic study of these experimental setups.

By analysing various papers we could arrive at the merits of power transmission using HVDC and its effectiveness in maintaining transmission efficiency. We could also come to a conclusion that the inclusion of solid-state devices could add up to the performance of the system as well as provide a cost effective method. It also proved to us that solid-state devices could open up new possibilities. Hence the project aims at designing a power electronic on-load tap changer for High voltage DC converter transformer.

CHAPTER 3

HVDC TRANSMISSION

In an energy environment marked by rising digitalization, decarbonization, and distributed generation, high-voltage direct current (HVDC) transmission systems are becoming increasingly necessary. They provide the most effective means of transmitting vast amounts of power over long distances, as well as assisting in the integration of renewable energy into the grid and the stabilisation of three-phase grids. HVDC systems can be less costly and have lower electrical losses for long-distance transmission. Power can also be transferred between grid systems that operate at different frequencies, such as 50 Hz and 60 Hz, using HVDC. This increases the grid's reliability and efficiency by allowing power to be exchanged between incompatible networks.

In AC transmission, alternating waves of voltage and current pass through the line, changing direction every millisecond, resulting in heat losses. The voltage and current waves in DC do not change direction as they do in AC lines. At the sending end of a combined AC and DC system, the produced AC voltage is converted to DC. The DC voltage is then reversed to AC for distribution purposes at the receiving end.

The components and operation of the HVDC Transmission system are described below.

Converter: The converters perform AC to DC and DC to AC conversions. Transformers and valve bridges are included.

Smoothing Reactors: Each pole is made up of smoothing reactors, which are inductors that are linked in series to the pole. It is used to prevent inverter commutation failures, minimise harmonics, and stop current discontinuity for loads.

Harmonic Filters: These filters are used to reduce harmonics in the voltage and current of the converters. Cables or overhead lines may be used as DC lines.

Circuit breakers: The circuit breakers clear the fault in the transformer.

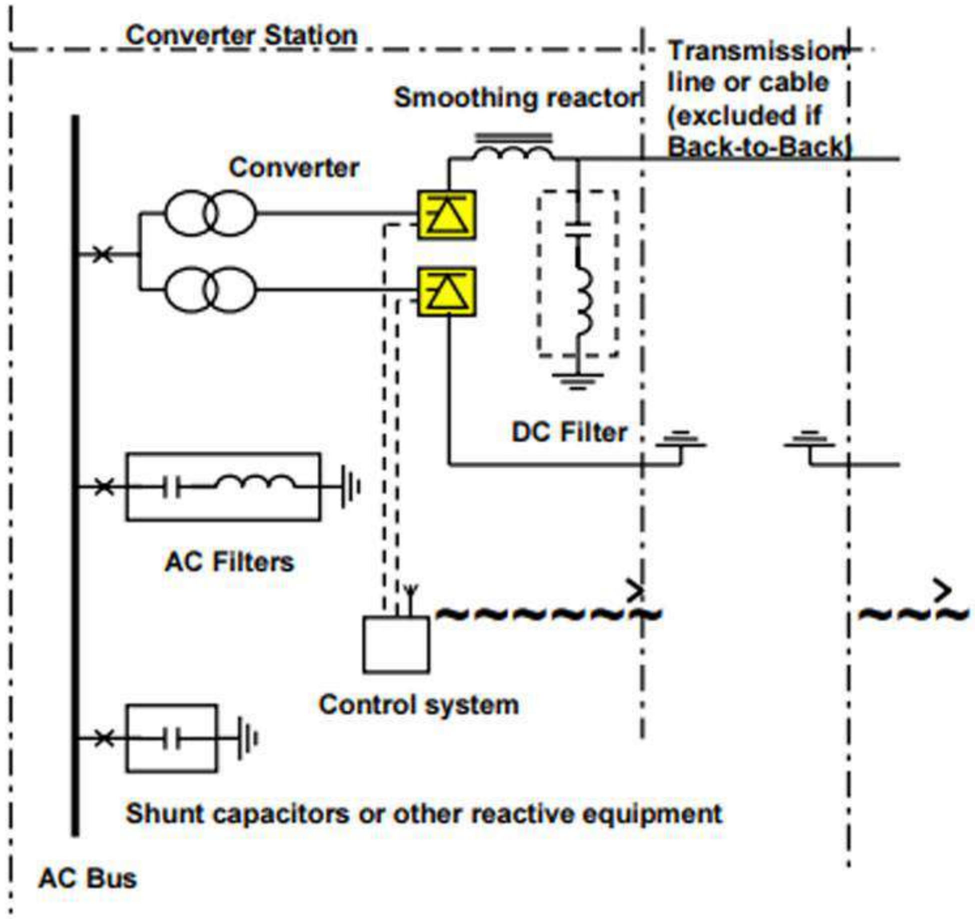

Figure 3.1: Components of HVDC transmission.

CHAPTER 4

HVDC CONVERTER TRANSFORMER

HVDC converter transformer is a transformer that is wired for HVDC conversion. To convert high voltage AC to high voltage DC, high voltage power electronic conversion circuits are used.Tap changers are used in this type of transformer to obtain different turns ratios and monitor the secondary voltage. Tap changers can compensate for reactive voltage drops caused by HVDC conversions and voltage drops caused by other factors.Solid state tap changers for HVDC converter transformers can be built in a variety of ways.

In an HVDC system the converter transformer serves several functions.It act as a galvanic barrier between the AC and DC systems to prevent the DC potential to enter the AC system.Reactive impedance in the AC supply to reduce short circuit currents and to control the rate of rise in the valve current during commutation.It's primary function also include providing a fairly large tap range with small steps to give necessary adjustments in the supply voltage.The DC potentials will create extra stresses n the transformer in addition to the normal AC stresses.In a steady state condition the DC stresses are primarily governed by the resistivities of the individual materials in the insulation materials in the insulation arrangement.This is different to the AC stresses which has capacitive distribution given by the different relative permitivities of the insulation materials.Conventional insulation materials used in normal power transformers together with mineral oil have proven to be suitable for converter transformers too. Also the build up of the insulation arrangement is similar.The actual properties of the insulation materials will,however result in quite different stress distributions for AC and steady state DC.

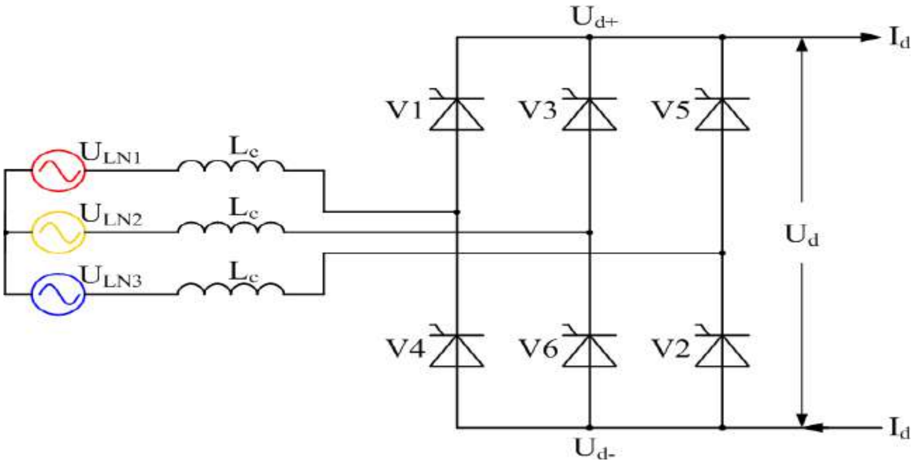

Figure 4.1: Circuit diagram of HVDC converter transformer

Figure 4.2: HVDC converter transformer

CHAPTER 5

TAP CHANGERS

In transformers, a tap changer is a device that allows multiple turn ratios to be picked in discrete stages. This is accomplished by linking to a set of taps located along the primary or secondary winding. There are two varieties of tap changers: no-load tap changers (NLTC)[1], for the turns ratio to be altered it must be de-energized, and on-load tap changers (OLTC), which can vary their turn ratio while in use. Any tap changer can choose between an automated process, which is popular for OLTC, and a manual tap changer, which is more prevalent for NLTC. Automatic tap changers can be installed on either a greater or lower voltage transformer winding, although for high-power generation and transmission implementations, automatic tap changers are typically installed on the greater voltage (lesser current) transformer winding for ease of access and to reduce current load during its process.
Voltage variation in power systems is a normal phenomenon owing to the rapid growth of industries and distribution network. System voltage control is therefore essential for:

- Control of real and reactive power flow in the network.
- Periodical adjustment (1-10%) to check off-set load variations.
- Adjustment of consumers terminal voltage within prescribed limits.

Adjustment is normally carried out by off-circuit tap changing, the common range being 5% in 2.5% steps. Daily and short-time control or adjustment is carried out by means of on-load tap changing gear.Besides the above, tapping are also provided for varying the secondary voltage, maintaining the secondary voltage constant with a varying primary voltage and for providing an auxiliary secondary voltage for a special purpose, such as for providing a low voltage for starting rotating machines.

5.1 NO-LOAD TAP CHANGER

The cheapest method of changing the turn ratio of a transformer is the use of Off Load Tap Changer. As the name indicates, it is required to deenergize the transformer before changing the tap. A simple Off Load Tap Changer is shown in Fig 5.1. It has eight studs marked one to eight. The winding is tapped at eight points. The face plate carrying the suitable studs can be mounted at a convenient place on the transformer such as upper yoke or located near the tapped positions on the windings. The movable contact arm A may be rotated by handwheel mounted externally on the tank.The stop F which fixes the final position of the arm A prevents further anticlockwise rotation so that stud 1 and 8 cannot be bridged by the arm. Adjustment of tap setting is carried out with transformer deenergized.

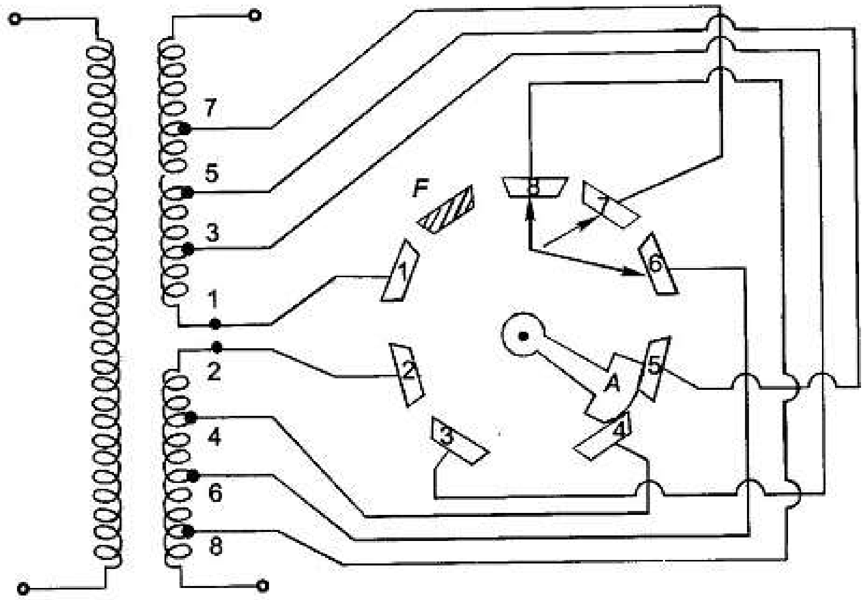

Figure 5.1: No load tap changer internal diagram

To prevent unauthorized operation of an off-circuit tap changer, a mechanical lock is provided. Further, to prevent inadvertent operation, an electromagnetic latching device or microswitch is provided to open the circuit breaker so as to deenergize the transformer as soon as the tap changer handle is moved; well before the contact of the arm with the stud opens.

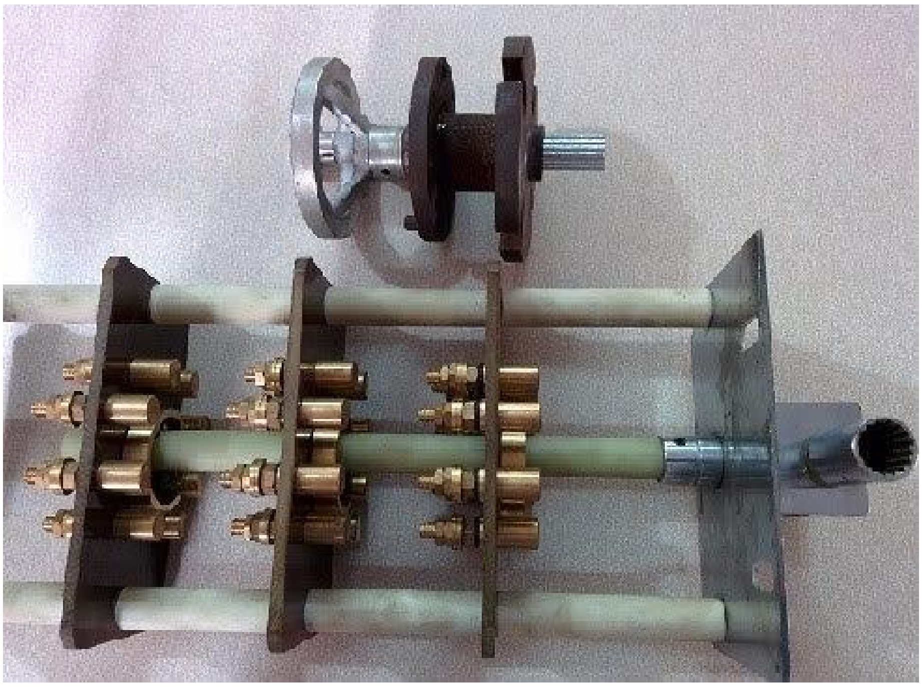

Figure 5.2: No load tap changer

5.2 ON-LOAD TAP CHANGER

On Load Tap Changing Transformer are used to change the turn ratio of transformer to regulate system voltage while the transformer is delivering load. With the introduction of On Load Tap Changing Transformer, the operating efficiency of electrical system gets considerably improved. Nowadays almost all the large power transformers are fitted with on load tap changer. During the operation of an on load tap changer the main circuit should not be opened to prevent sparking and no part of the tapped winding should get short-circuited. All forms of on load tap changer circuits are provided with an impedance, which is introduced to limit short-circuit current during the tap changing operation. The impedance can either be a resistor or centre-tapped reactor. The On Load Tap Changing Transformer can in general be classified as resistor or reactor type. In modem designs the current limiting is almost invariably carried out by a pair of resistors. On Load Tap Changing Transformer gear with resistor transition, in which one winding tap is changed over for each operating position.

5.3 CONVENTIONAL TAP CHANGERS ADVANTAGES AND DISADVANTAGES

Mechanical tap-changers' tap-changing procedure is often sluggish, incoherent, and step-by-step. The incoherent operation of voltage regulation results in non-continuity

Figure 5.3: On load tap changer

in the tap change implementation. Due to limitation of number of permissible tap changes, a reduction of frequency of taps changing is one of required feature of controller. Tap changes from one point to past and the next ones are only feasible with a mechanical tap changer (step by step process). Electronic tap changers have no limitations, since they may leap from the highest to the lowest point in a moment. There is no need to use sophisticated voltage fluctuation detecting techniques in a slow-operating tap-changer.As a result, averaging approaches across multiple cycles can be employed. to compensate for voltage variations. The typical OLTC transformer's mechanical regulating tap changer generates an electric arc during the tap changing operation, and the tap changer's velocity is moderate, leads to a longer regulating reaction rate.Brushes, contactors, and mechanical drive elements all require routine restoration. Brushes can be damaged by frequent overloads.

CHAPTER 6

POWER ELECTRONIC TAP CHANGERS

Solid state tap changers for HVDC converter transformers can be built in a variety of ways. In the case of converter transformers, the use of a power electronic tap changer is more important since tap changers must be operated frequently.If traditional mechanical tap changers are utilised for this operation, they will need to be serviced on a regular basis. To reduce flipping on heavy current, the power electronic tap changer is linked to elevated voltage side of the power transformer, similar to a classic tap changer. It's better to adjust high voltage than it would be to adjust high current.

Two antiparallel-connected thyristors are linked to the corresponding tap in the power electronic tap changer. By sending a triggering pulse to a group of thyristors, a specific tap is selected based on the requirements. The thyristors receive the triggering pulses at the zero crossing point. When triggering pulses are provided, the forward biased thyristor will turn on. The tap changers have a tap selector switch for manual selection of necessary taps. If two tap selector switches are turned on at the same time, the winding will short circuit, and a large amount of short circuit current will flow through the short-circuited winding. So operation of only one tap switch at a time is ensured. The PIV also known as the peak inverse voltage along with the current rating of thyristors are the most important factors in their selection.

CHAPTER 7

DIFFERENT POWER ELECTRONIC TAP CHANGER TOPOLOGIES

Different configurations can be used to design solid state tap changers for HVDC converter transformer.Economical factors, harmonic administration into the system, short circuit rating of power electronic components are all factors to consider when designing solid state tap changers for HVDC converter transformers.

The prototype is aimed at attaining least cost with maximum efficiency. One of the major cost consuming device is obviously the HVDC Converter Transformer. Apart from that the power electronic controllers as well as the rectification.

Taking into account all of these issues, the best of the topology could be selected for our work.Primarily two topologies are taken into consideration. By using appropriate topologies for the tap changer, power quality issues caused by power electronic tap changers can be reduced. The cost of a tap changer is also heavily influenced by the topology.

7.1 TOPOLOGY 1

Each tap location is linked to two anti parallel thyristors in topology one. The configuration of this tap changer is similar to that of an AC voltage controller. These anti parallel thyristors could be compared to that of a bidirectional switch that allow a current circuitry in both direction. To get a waveform that is highly similar to sine wave and to reduce transients during switching operation , the thyristors are activated at zero crossing points. The waveform of this configuration is continuous and the output is AC.

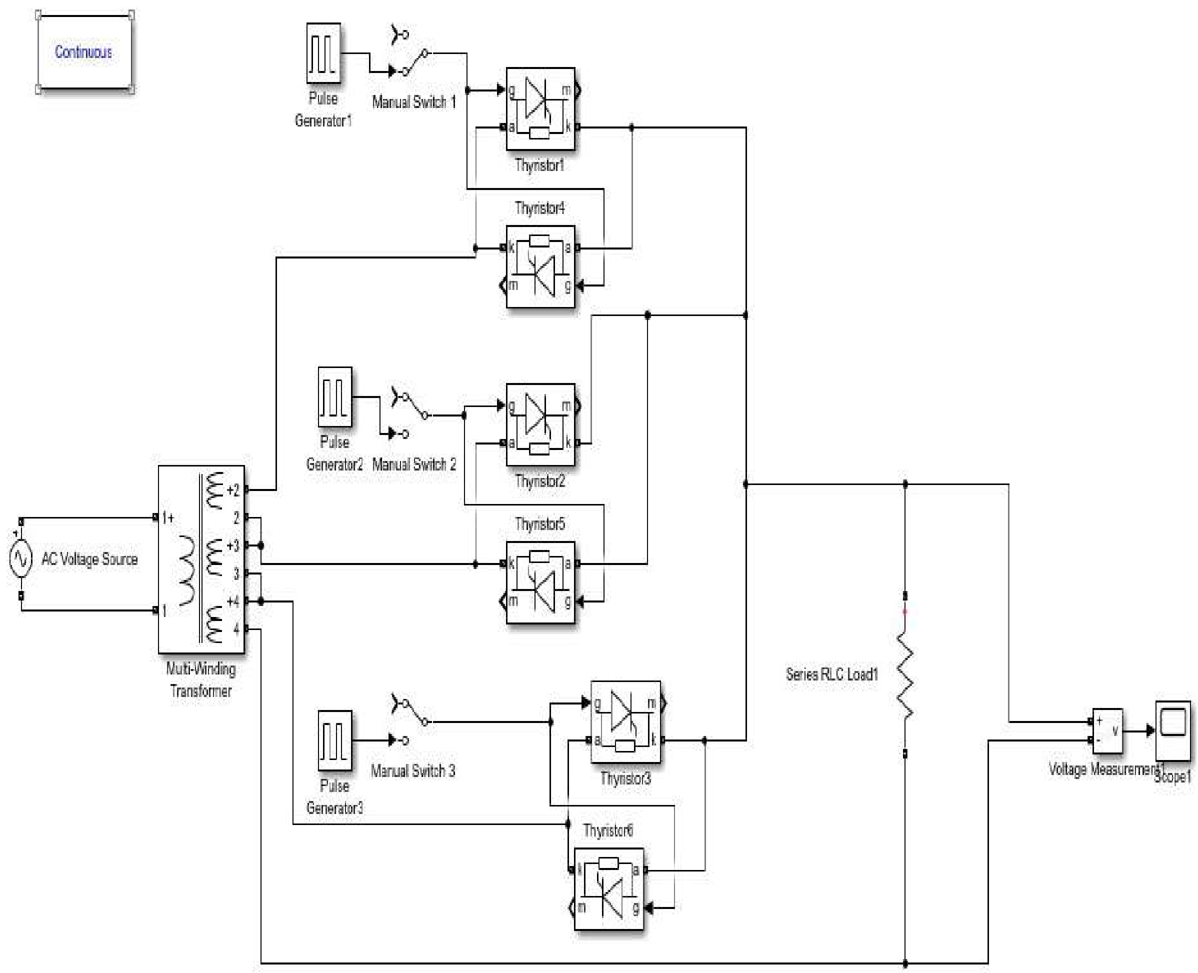

Figure 7.1: MATLAB Simulink model of Topology 1

The given topology have three manual switches. These switches would be able to turn on and turn off a tapping. However, incorrect operation of these switches would result in incorrect output voltages. The manual switch 1 is operated first and then the manual switch 2 and finally the manual switch 3 and under no circumstance more than one switch is operated at a moment and such an output voltage waveform is shown in

Fig.7.1.

Several outputs are generated by altering the tap locations by sending the initiating pulse to matching thyristors in this arrangement, which is modeled. The tap changer is more expensive because there are many more thyristors in this arrangement. This topology has the advantage of reducing harmonics. To transform a high voltage AC source to a HVDC supply, a dedicated HVDC converter is required.

Fig. 7.2 explains the output wavefrom that could be captured from the scope of Topology 1 depicted in Fig. 7.1. The waveform is much to explain about the oscillating characteristic of the wave. This existence of positive and negative half cycle could be converted to a DC voltage by the usage of converters.

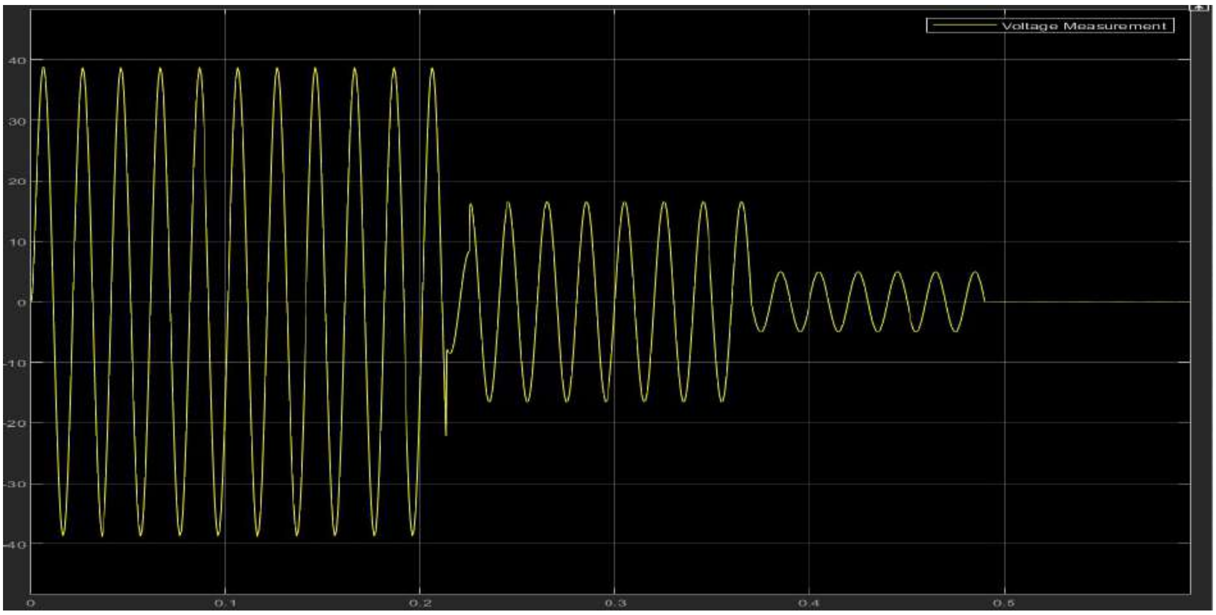

Figure 7.2: Output waveform of Topology 1

7.2 TOPOLOGY 2

This topology consists of a single thyristor linked to each tap points. The model is similar to a half-wave diode rectifier. This setup only requires current to flow in a single direction. This ensures that only the positive or the negative half of an AC supply cycle is passed into the thyristors at a cycle. When the zero crossing point is reached the thyristors are enabled. There is no need for a dedicatecd AC to DC converter as the output of the setup is a pulsating DC.

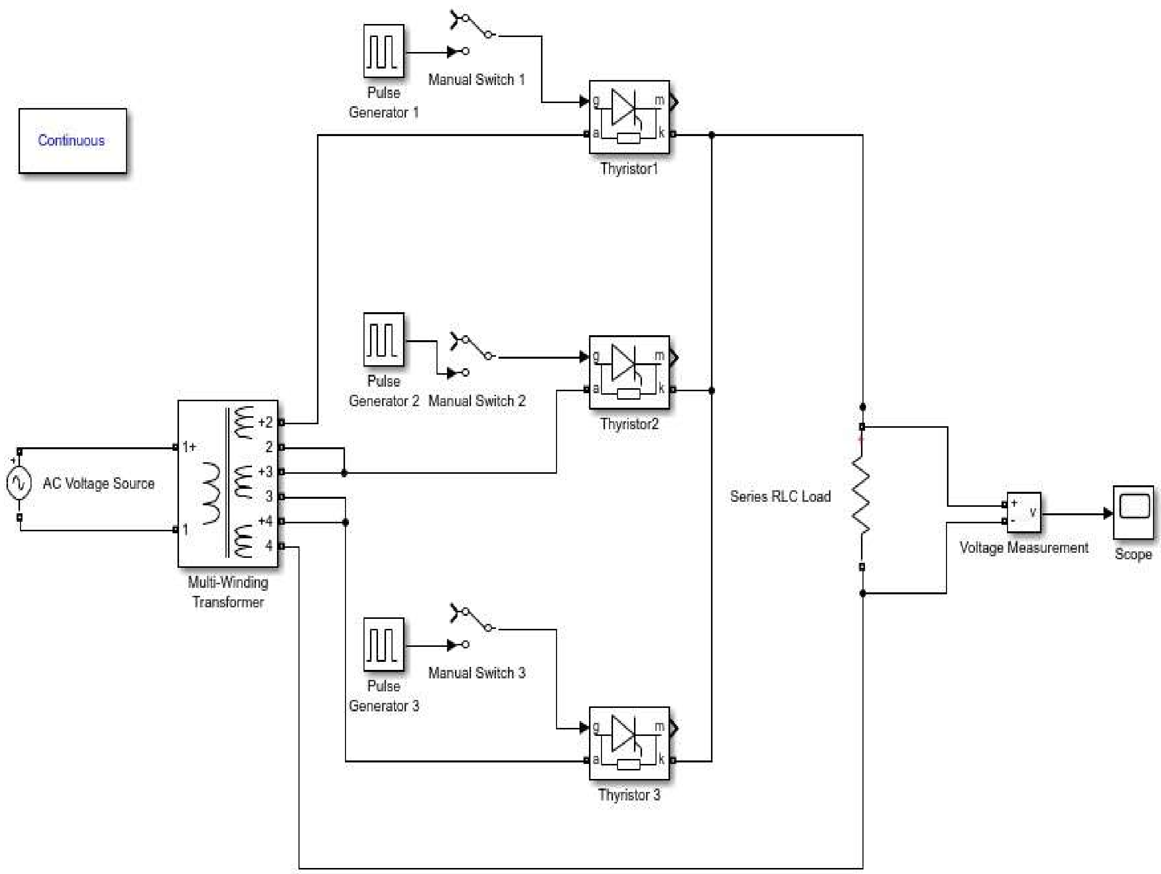

Figure 7.3: MATLAB Simulink model of Topology 2

Since a limited number of thyristors are used in this setup as shown in Fig.7.3, the expense of the tap changer is therefore minimized.The harmonic distortion and discontinuity in the supply voltage waveform are disadvantages of this setup. This topology will be used if the economic dimensions of the tap changer are taken into account. However, when power efficiency problems are taken into account, it is not a viable option.A voltage measurement block is used to test the voltage through the load, and the output is sent to the oscilloscope block.

This model though economically feasible the output waveform as per the Fig 7.4 does not promise more of a sinusoidal waveform. It would be tedious to generate a dc from such a waveform. The waveform in the Fig 7.4 is obtained from 3 different tapping positions and hence we could see the three different voltage peaks.The voltage peaks evidently have only the positive half cycle and have a zero voltage in the situation of a negative half cycle.

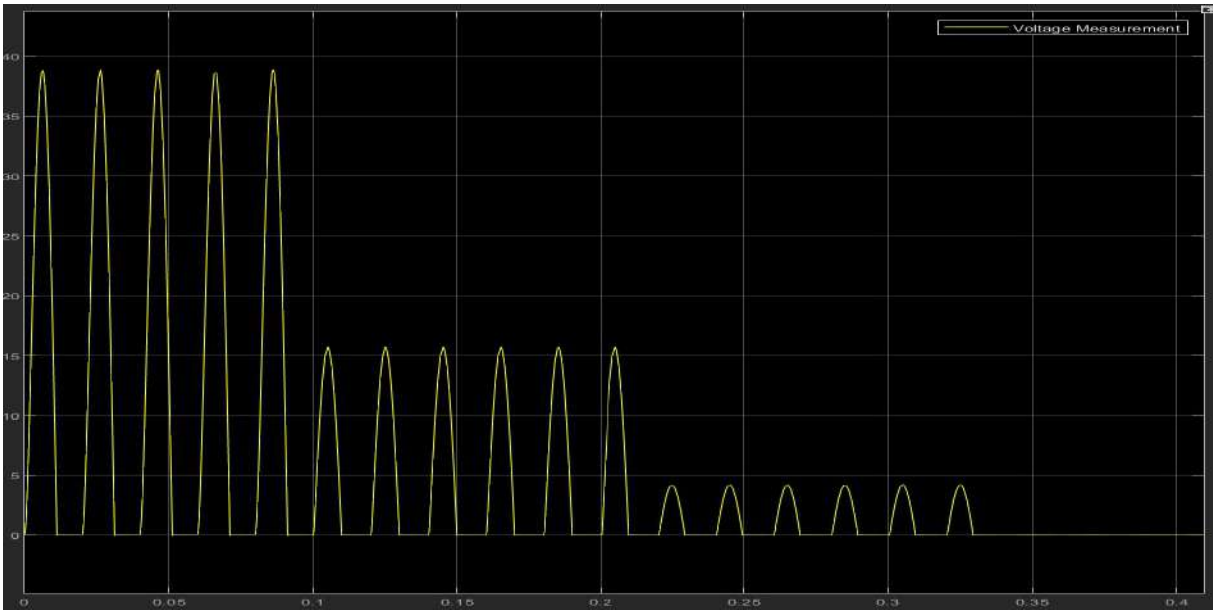

Figure 7.4: Output waveform of Topology 2

7.3 SHORT CIRCUITS

At any time during its operation, power system components can be exposed to short circuits or other disruptions. Since a variety of control electronic components are involved in the operation, fault detection and isolation are critical in the case of HVDC transformers. Since the machine contains a large number of control electronic components, the fault current in the tap changer and HVDC converter will destroy the power electronic components. A failure can occur on either the AC or DC side of the system.

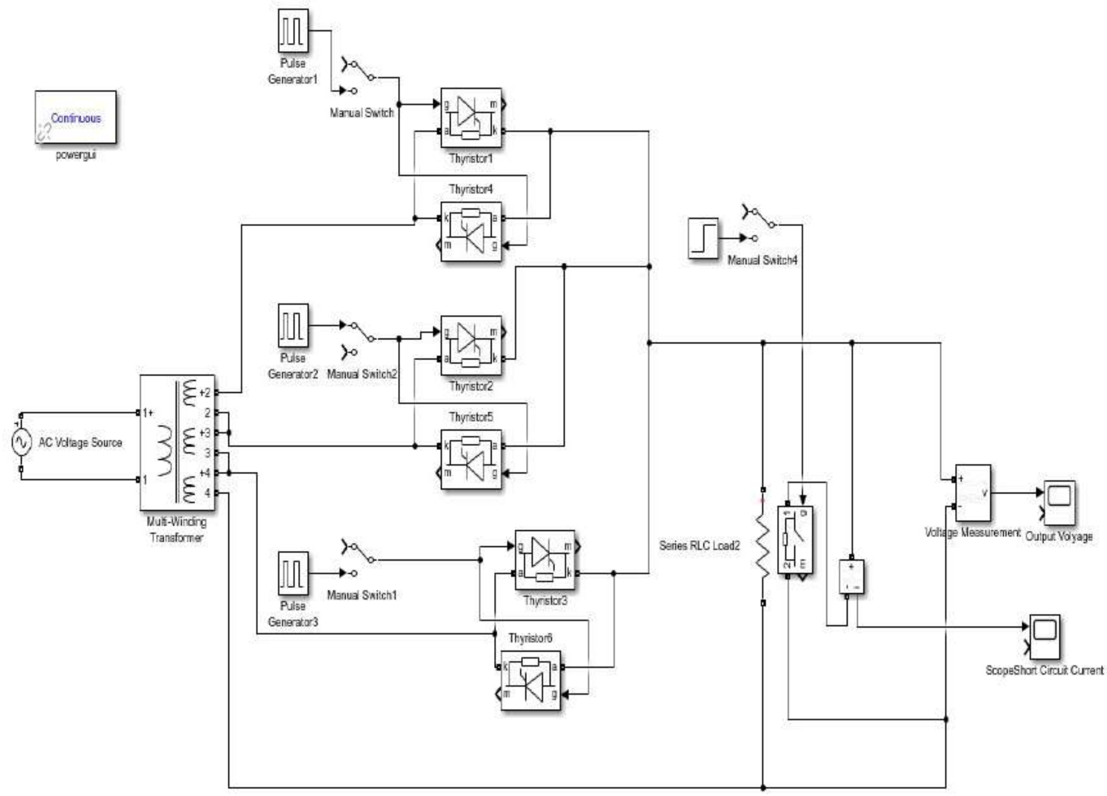

Figure 7.5: Simulation model for simulation of Short circuit AC current

Moreover, there is no circuit breakers on the DC side of the converter transformer.The fault is cleared by blocking the converter circuit and dissipating the accumulated energy, ensuring that no faults in the DC side of the solid-state tap changer are affected. Asymmetrical faults are the most common faults on AC sides, with symmetrical faults being very rare.

The Fig.7.5 explains more about the simulation model for the simulation of short circuit at the AC side. The model is made in such a way that the current could me measured at run time.A provision for shorting or opening at run time is also provided by means of a manual switch which is connected to an ideal switch as given in the figure.

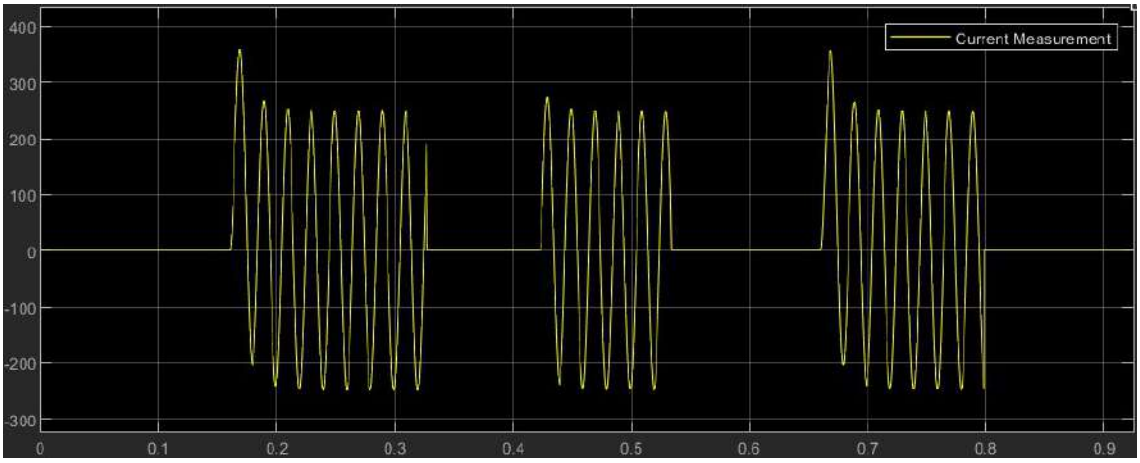

Figure 7.6: Current waveform with respect to time on DC side when a short circuit fault occurs on high voltage AC side of Converter circuit

The current waveform at the DC side during short circuit condition at the AC side of the converter circuit is shown as in Figure 7.7. The short circuit is applied on the instant at which the graph show noticeable change in the peak value and the short circuit is removed at the time where the graph retains its peak value.

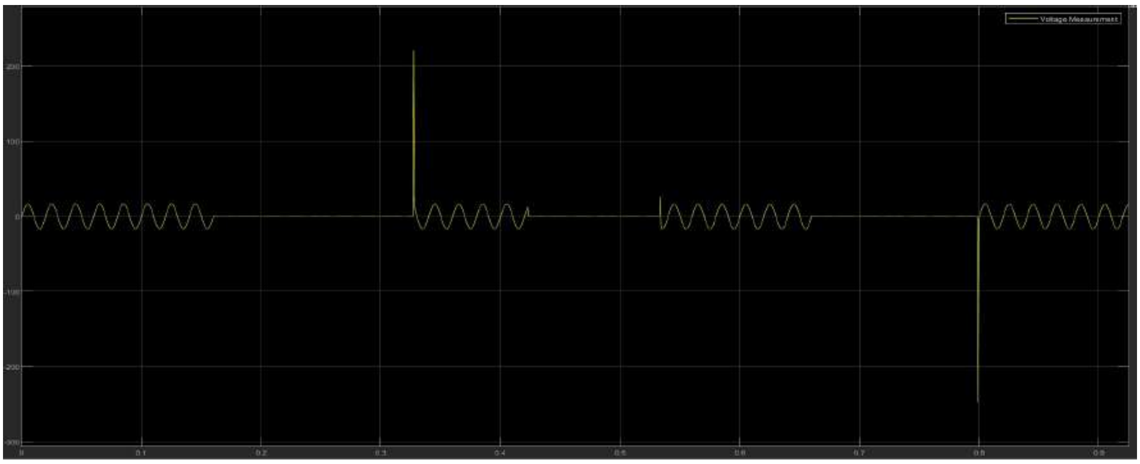

Figure 7.7: Voltage waveform with respect to time when a short circuit fault occurs on high voltage AC side of the Converter circuit

The system is shorted thrice so as to obtain a clear view of the upcoming short circuit current waveform.Though the voltage waveform as in Fig.7.7 and Current waveform as in Fig.7.6 exhibits an anomalies during the initial shorting, these anomalies die out within a very short interval and a steady state is achieved and short circuit current could be observed.

The simulation model for simulating the DC side short circuit current is given in Fig.7.8. The given model is shorted once using the ideal switch connected across the load. The short circuit current is obtained from the scope used for current measurement connected along with the current measurement unit connected in parallel across the load.

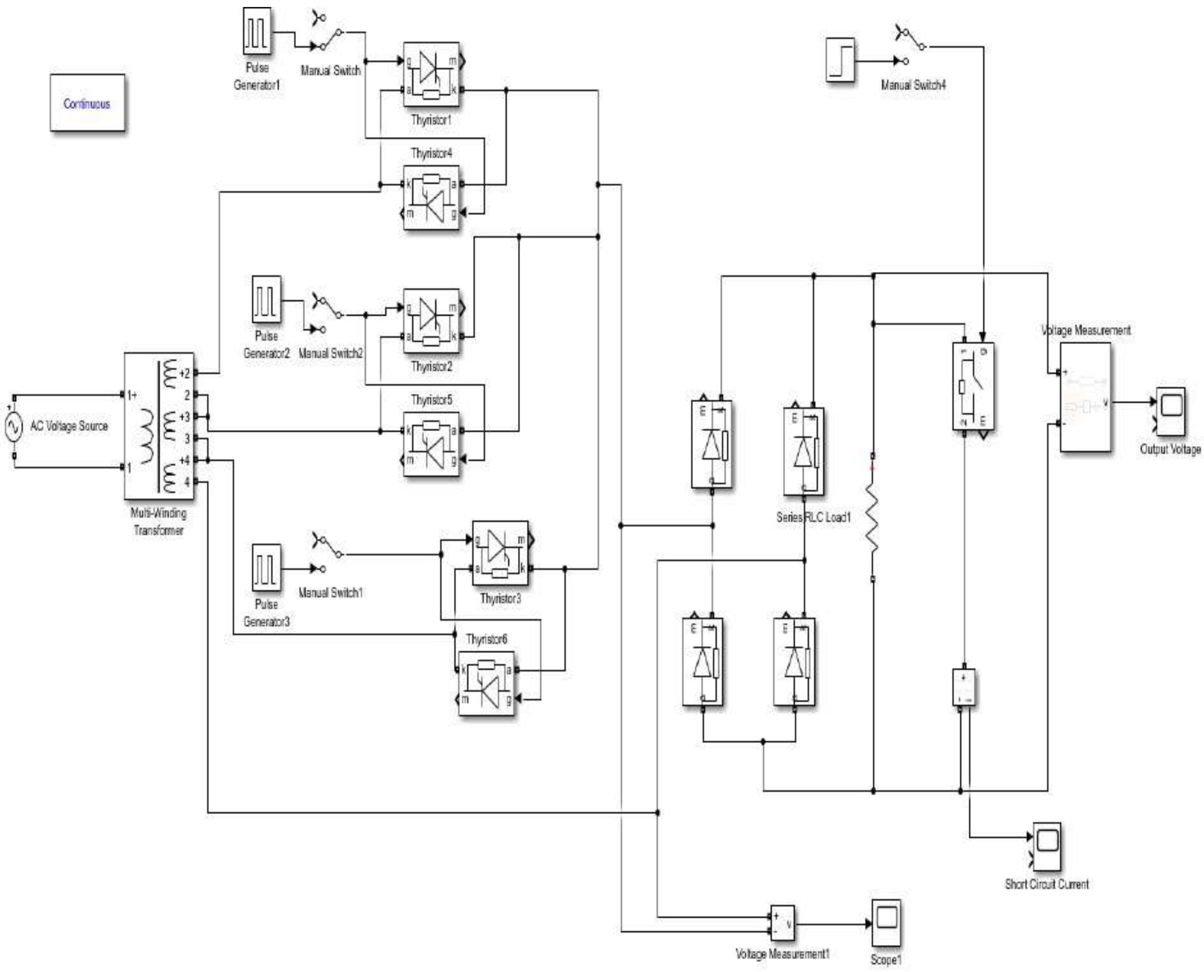

Figure 7.8: Short circuit Simulink model for simulating short circuit on the DC side of Converter circuit

The current waveform at the DC side during short circuit condition at the DC side of converter circuit is shown in the Figure 7.10 . It is clear from wave form modeling that a short circuit on the high voltage AC side has a greater impact on the power electronic tap changer than a defect on the high voltage DC side. The defects in the high voltage AC side of the HVDC converter transformer are not as severe as in other AC systems since the workload is an HVDC converter and it does not deliver any more

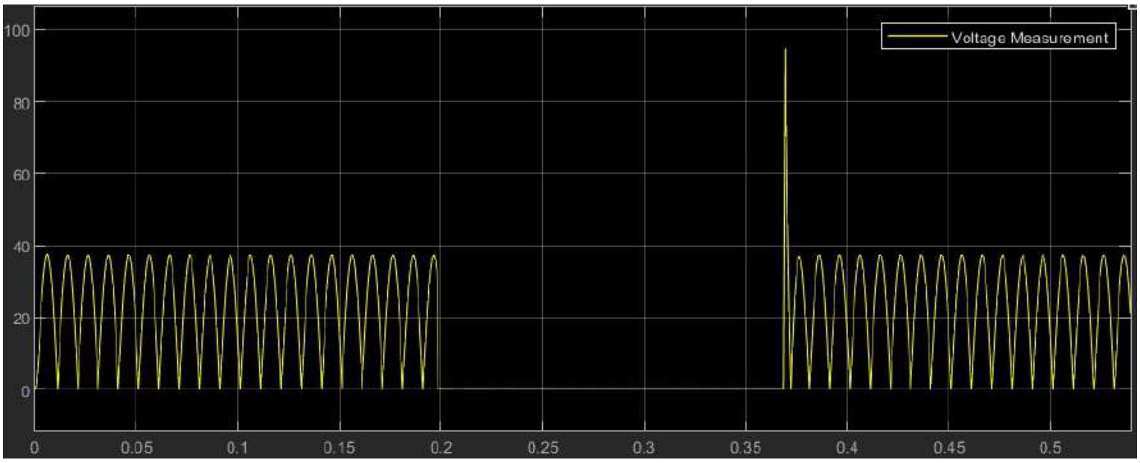

Figure 7.9: Voltage waveform when a short circuit occurs on high voltage DC side of Converter circuit

current to the fault.

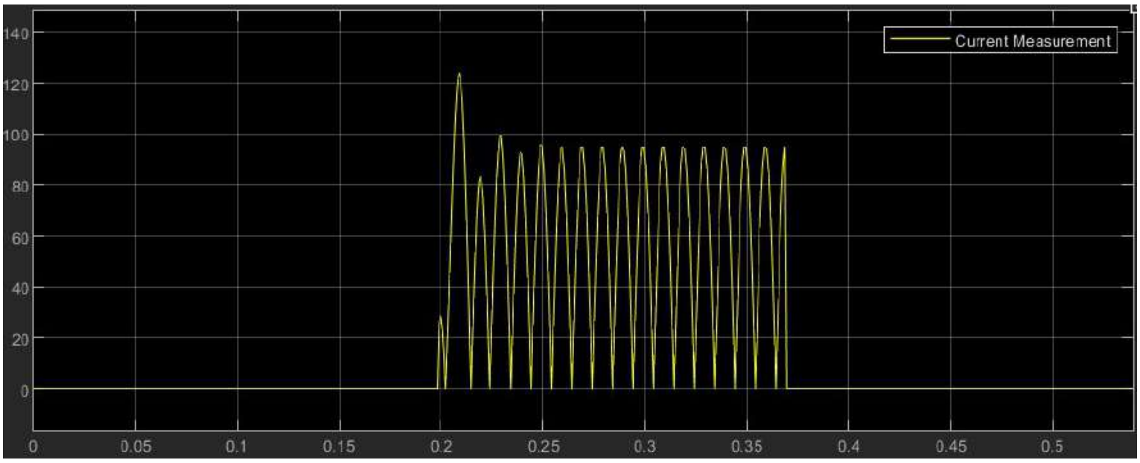

Figure 7.10: Current waveform with respect to time on the DC side when a short circuit occurs on high voltage DC side of the Converter circuit

The voltage waveform do have an anomaly during the instant of switching but as seen previously they do die out and a steady state voltage would be regained immediately after the process of shorting which is seen evidently from Fig.7.9.

CHAPTER 8

CONCLUSION

A new solid-state tap changer for greater voltage DC converter transformers is given in this study. The solid-state tap changers have many advantages over mechanical tap changers. Fast performance, little maintenance, no shifting arc, and no movable contacts are all advantages of this system. The short circuit rating and PIV across the power electronic switches are two essential design criteria for solid-state tap changers. Power quality issues are the main drawback of solid state tap changers. Harmonic administration is the primary power quality issue which affects the transformer. The flowing harmonic current via the winding might generate Further heating in the system. Significant increase in the K rating is found with the intervention of power electronic tap changers. The switching speed of the Tap changer could be controlled due to the power electronic intervention and the proposed system could act as the best substitute for the mechanical tap changing process.

REFERENCES

[1] S Kamakshaiah V Kamaraju ,***"HVDC Transmission" McGrawHill Education (India)private limited***, New Delhi

[2] S.V Kulkarni, S.A Khaparde,***"TransformerEngineering Design, Technology and Diagnostics"***, second edition, CRC Press

[3] A. Kumar, K. Kumar, N. Kaushik, S. Sharma, and S. Mishra, ***Renewable energy in India: Current status and future potentials***vol. 14, no. 8, pp. 2434.2442, Oct. 2010

[4] P. Bauer,S.W.H. de Haan, ***"Electronic Tap Changer For 500kvA/10kv Distribution transformers: Design, Experimentalresults and impact in distribution network"***, IEEE 1998

[5] Jawad Faiz, Behzad Siahkolah, ***"solid-state tap-changer of transformers: Design, control and transformers"***,Elsevier, 2010, Electrical power and Energy systems.

[6] Osman Demicri, David A Torrey, Robert C Degeneff, Fredrich K Schaeffer, Robert H Frazer, ***"A new approach to solid –state on load tap changing trasformers"***, IEEE transactions on power delivery,VOL 13, NO. 3, July 1998