OPERATIONAL EXPERIENCES OF CHANDRAPUR- PADGHE HVDC BIPOLE PROJECT

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Abstract—**The Chandrapur-Padghe ± 500 KV 1500MW HVDC Bipolar Transmission Link of 752 km length inter connects the Eastern and Western part of the Maharashtra State. This Bipolar link evacuates power from Chandrapur Super Thermal Power Station to the Western part of the Maharashtra. The system consists of 2 poles of 750 MW each, connected in bipolar configuration. The project is in commercial operation since November 1999 and is running successfully in parallel with Maharashtra State Electricity Transmission Company Limited's (MSETCL) (formerly MSEB) existing 400 kV transmission system. Despite of successful testing and commissioning, performance levels could not be reached owing to various failures those occurred. This paper describes practical experiences of the HVDC bipolar link. Further it also describes that how the occurances has been tackled and the deficiencies came across during this have been taken care of by MSETCL engineers and the contractors (ABB Sweden/ BHEL India) for running the project smoothly.**

***Keywords*—Converter Transformer, HVDC, Light Guides, Snubber Circuit Capacitors**

I. INTRODUCTION

THE power demand in the State of Maharashtra is concentrated in Western part around Mumbai, Pune and Nashik regions, where as the major thermal power generation is concentrated in the Eastern part of the State due to abundance of coal stock in that area. The existing generation of CSTPS is 2340 MW and Central Sector share around 1000 MW is also delivered at Chandrapur bus. The existing transmission network comprising of three 400kV circuits between Chandrapur and Mumbai can safely transmit 1200 MW of power with out considering any contingency outages, it was therefore necessary to provide additional transmission capacity of around 1500 MW between Chandrapur and Mumbai. Expansion of 400 kV transmission network by constructing several 400 kV lines was not feasible due to constraints of right of way. Therefore the other two options viz construction of 800 KV AC link or HVDC bipolar link were under consideration. HVDC bipolar link was found to be a better option, considering long-term requirement and anticipated support to system stability.

The HVDC converter is arranged in 12-pulse bridge as two monopoles each identical in lay out but with different polarity. The simplified single diagram is shown in Fig. 1.

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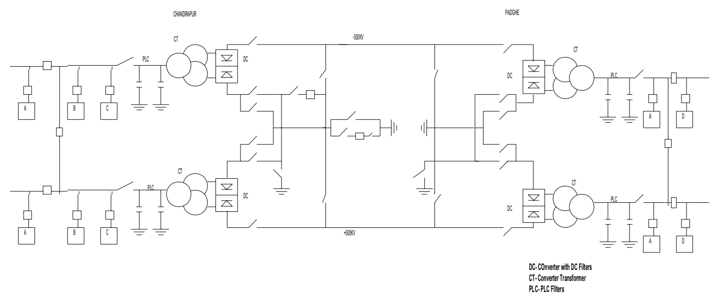

Fig. 1 Simplified single line diagram of HVDC bipolar link

The converter Transformers are single-phase three winding units at both converter stations with three valve winding bushings protruding in to the valve hall.

Each monopole is rated for 750 MW at nominal parameters of 500 KV DC, 1500 A. Each DC converter can be loaded above it's normal rating (1.1pu for 2 hours / 1.33 pu for 5 seconds & low ambient continuous rating 1650 MW continuous below 33 degree Celsius). On both the HVDC converter at both terminal station 800 MVAR of AC filters are installed, these filters are configured as 6 switchable units of 2× 200 MVAR, 2× 120 MVAR and 2× 80 MVAR each at Chandrapur and 4 switchable units of 200 MVAR, each at Padghe. On DC side of each converter 2/6 Band Pass and 12/24 High Pass DC filters are provided. Further on DC side Active DC Filter is provided to counter the harmonics on DC line.

The AC switchable filters ensure that harmonic performance requirements as well as reactive power exchange limits are met over the entire range of power from 75 MW to 1500 MW. Each pole consists of 12-pulse bridge requiring 3 quadruple valves per pole. Each valves has 96 thyristors including 3 redundant thyristors. Each thyristor is rated for 7 KV connected in series to provide necessary voltage rating. Each thyristor is installed with several passive components to achieve voltage sharing and protect it from over voltage, excessive rate of rise of voltage (dv/dt) and rate of rise of in rush current (di/dt). Gate electronics also provides protection to thyristor against forward voltage or dv/dt voltage by forced firing of thyristor under such conditions. Open type Metal oxide surge arrestors accomplish reverse over voltage protection across the valve.

1. CONTROL MODES & OPERATIONAL FEATURES

In order to enhance operational safety, reliability and stability of the integrated AC / DC transmission system, the proven microprocessor based control system is provided.

Control of the converter is organized in an hierarchical fashion both in terms of their function and location in logical manner as under.

i. Firing angle / extinction angle control

ii. Valve Control
iii. Pole Control
iv. Bipolar Control
v. Master Control

1.1. OPERATING MODES

HVDC system is designed to operate in following three basic modes.

i. Balanced bipolar mode in which the unbalance current between the two poles does not exceed 10 Amp.
ii. Monopolar mode with ground return utilizing the electrode lines and ground electrodes of both terminals.
iii. Monopolar mode with metallic return utilizing the pole line conductors of the blocked pole and isolating the electrode line from ground electrode at Chandrapur. Earth electrode at Padghe is always connected as a reference point.

In addition to the above basic operating modes, the transmission system is designed to operate in the following modes.

1.1.1. UNBALANCED BIPOLAR OPERATION

Under this mode the two poles can be operated with different DC current and /or DC voltages.

1.1.2 INCREASED REACTIVE POWER ABSORPTION OPERATION

The use of higher than normal firing and extinction angles temporarily can be made to assist reactive power management / voltage control.

1.1.3 ISLANDED MODE

At Chandrapur 400 KV bus, six 400 KV lines are terminated. Therefore, chance of getting HVDC link islanded on generators is very remote. Even if such an exigency occurs, the DC link is provided with control facilities.

2. SPECIAL FEATURES

In order to achieve and maintained stability of the AC transmission system network certain special features are designed and incorporated as

2.1 REDUCED DC VOLTAGE OPERATION

The reduced DC voltage operation is required by converter station operators under adverse weather conditions leading to reduced insulation level of the external insulation of DC line is designed to operate continuously at nominal pole to ground voltage of 400 kV in both bipolar as well as mono-polar modes in reduced voltage mode.

2.2 AC SYSTEM STABILIZATION (DAMPING CONTROLLER)

The HVDC system is provided with power modulation feature for stabilization of AC system. The power swing in parallel AC lines occurs in case of system disturbances. Adjusting the power order on the HVDC link reduces this power swing in parallel AC lines. Power modulation of at least 5% of continuous rating is possible so that stability of AC/DC integrated system could be achieved. The power modulation is capable of damping A.C. network oscillation over the range of 0.1 Hz to 3.0 Hz.

2.3 FREQUENCY CONTROL

In the event of isolation of some or all of the generators at Chandrapur from rest of the AC system, the frequency stabilizing control comes into action. The frequency control is provided on pole basis.. A facility to control the frequency of Padghe AC system as long as Chandrapur Generator frequency is within limit is provided.

In the event of any sudden changes in AC frequency due to changes (loss) in generation or transmission capabilities, the frequency dependent power limit shall cause power variation equally on both poles.

2.4. SUB-SYNCHRONOUS DAMPING CONTROLLER

It is likely that under any operating mode, DC system may excite the mechanical, electromechanical or other natural frequencies of generator and turbines individually or combined. Controls are designed in such a way that the possibility of high gain amplitude DC modulation exciting torsional oscillations of generator could be avoided. Exhaustive SSR verification test has also been successfully carried out in real life system at Chandrapur STPS to verify safe operation of the generators with HVDC system and effectiveness of SSDC in damping the SSR frequencies.

2.5. REACTIVE POWER CONTROLLER

Reactive Power Controller (RPC) performs it’s function manually by Station Operator or switching of the filter banks automatically. The RPC is provided at Chandrapur as well as Padghe Station.

2.6 OPEN LINE TEST

This feature is provided for checking the insulation withstands level of external insulation of DC line and DC yard equipment up to full DC voltage level.

2.7. RUN UP FUNCTION

This function is incorporated in HVDC control system at Chandrapur. This function will facilitate the increased transfer of power on HVDC link in the event of tripping of any or all the 400 KV Chandrapur Parli line running in parallel with DC link. Increased power transfer is restricted to the extent of various overload capability limitation of HVDC bipolar link.

3. MODES OF HVDC OPERATION

The predominant mode of HVDC link is transferring energy from east of Maharashtra because of concentrated thermal generation to west of Maharashtra (forward direction) and has been helpful in achieving the voltage profile, enhanced stability of grid The dispatch pattern is more or less constant for major period of the year i.e. October to June/July which is 100 % except for few months in monsoon i.e. July to Sept. every year.

It has been observed that optimum load despatch of 1200 to 1500 MW is smooth and trouble-free and do not impose any undue stress on HVDC equipment. However, due to some of the major failures, which are discussed in subsequent Paras, the Monopolar operation was restored to which has contributed its own share without any significant effect on grid operation. The Monopolar ground return operation of 700 MW continuously for major portion of time, was successful. On certain occasions, unbalanced operation has been resorted to successfully. In normal practice, balanced bipolar operation is preferred, even in monsoon period so as to avoid / reduce electrode corrosion.

Even though the link has been designed for reverse power flow i.e. from Padghe to Chandrapur, there had been no occasion but the feature is successfully tested during the commissioning tests / trials.

Regular maintenance practices and standards as stipulated have helped to achieve trouble-free operation of HVDC link during the peak load despatch period. The constant power transmission (without fluctuation) have not imposed any un due stresses on the equipment and hence no additional maintenance than stipulated is required. Tap changer and AC filter breaker which are major in operation, have been looked into during maintenance to avoid forced outages of the link.

II. OPERATIONAL EXPERIENCES

Commissioning and initial operation of this HVDC bipolar link provided several learning opportunities and unique experience to the utility. Despite successful testing and commissioning, desired performance levels could not be reached owing to various failures that occurred. The major failures are described in the following sections.

1.DEGRADATION OF LIGHT GUIDES

The thyristor valves are installed in controlled atmosphere and the HVDC contractors design required system. The light guides were laid in straight channel and branched out at module locations for connection to the thyristor valves. The light guides were supported at various locations by fourway finger bracket fixed to channel carrying the light guides.

Following incidences took place in Pole-II at Chandrapur:

i. In 2nd Oct' 1999, the reception of indication pulse stopped functioning.
ii. In June 2000, protective firing for large no. of thyristors was recorded by control system.
iii. In Sept' 2000, again protective firing for large no. of thyristors was recorded by the control system.

Every time, the light guides were checked, cleaned and pole was energized. Damage to light guides was visible in all the incidences. But two weeks later, after Sept' 2000, the flashover followed by fire took place. This time four valves (24 Nos. of thyristors) were found to be short-circuited and this resulted in prolonged outage.

During inspection after each occurrence, melting of polymer cover of fiber and signs of partial discharge on fiber and sealing bags in the light guide channel were observed. It was also noticed that, sealing bags put in the channel were partially conducting through the thread used for sewing the seal bags was electrically conducting in nature.

After analysis, the logical chain to explain the phenomenon that occurred was established as below:

i. High humidity in the surrounding air of the valve hall building.
ii. Insufficient dehumidification of incoming air.
iii. Unfavorable wind conditions in the surroundings.
iv. Unnecessarily high intake rate of fresh air.
v. Presence of fine-grained dust in the surrounding air.
vi. Leaky inlet passage resulting into partly bypassing of air filters
vii. Use of lower grade air filter in the air inlet.
viii. Leaky valve hall resulting into less than required overpressure.

Leading to:

i. Increased relative humidity in the Valve Hall.
ii. Risk of dew/condensation causing wet surfaces.
iii. Dust in the valve hall.

Leading to:

i. Deposition of dust on various components and absorption of moisture.
ii. Reduced insulation strength of the air and on surfaces, resulting into:

i. Increased Creepage currents.
ii. Risk of unequal voltage distribution between valve layers.
iii. Risk of partial discharge and flashover.

Leading to:

i. Triggering of chemical reactions
ii. Local drastic rise of temperature

Finally resulting into:

i. Degradation of the polymer cover that shields the optical fibers.

M/s. ABB Utilities and Corporate Research together with independent agency "Swedish Transmission Research Institute" carried out extensive study, research and analysis to find out root cause of degradation finally leading to fire incidence. It was gathered that, such occurrence has also taken place in another HVDC project of M/s. ABB.

1.1. RECOMMENDATIONS AND IMPLIMENTATION

Based on the relationship of various parameters and subsequent conclusion in the laboratory studies as explained above, following recommendations given by M/s. ABB for improvement.

i. The maximum permissible limit of % RH settings of 60% has been changed to 50% during operation.
ii. Curved light guide channels have been installed in place of straight light guide channels to increase the Creepage distance.
iii. Existing fine air filters are replaced by EU9 filters (absolute filter).

iv. The air inlet is made further tight to ensure that incoming air pass through the filter only.

v. Fresh air intake is minimized and setting of over pressure in the Valve hall is also reduced.

After implementation of the above recommendation in year 2001, the light guide channels are regularly checked during annual outage and so far no damages to the light guides are found.

2. FAILURE OF CONVERTER TRANSFORMER

The converter transformers are single phase three winding units of 298.6 MVA capacity each and having line winding of $400/\sqrt{3}$ kV and Delta and Star connected valve windings of 211 and $211/\sqrt{3}$ kV voltage ratings respectively. Transformers are designed by M/s. ABB Sweden. Out of total 14 Transformers, M/s. BHEL, India, supplies 8 numbers and 6 numbers are supplied by M/s. ABB Sweden.

After bipolar operation for a few months, failures of converter transformers at Chandrapur and Padghe, which are unique in nature, started from June 2001. From June 2001 to Junes 2005, eight Transformers have failed. Out of eight failed transformers three numbers are of BHEL, India make and five transformers are of ABB Sweden make. Out of these, failed transformers, one transformer each of BHEL and ABB make, which has failed, was repaired earlier. In all the cases, transformers connected to star winding have failed. The failed transformers were sent to factory for investigation and repairs.

The failure was analyzed considering the following:

i. Frequent and high amplitude transients.

ii. Failure occurred in normal operation, however no direct external cause for the breakdown was identified.

iii. Turn to turn breakdown in star winding.

iv. No breakdown paths to earth in the Transformer

As a part of investigation of failure of the converter transformer, activities were divided into three parts namely:

i. Permanent changes in the protection system

ii. Site measurement i.e. survey of operating parameters

iii. Operational limitation.

2.1. PERMANENT CHANGES IN THE PROTECTION SYSTEM

It was agreed to implement the following changes as a precautionary measure to avoid aggravation of failure of converter transformer.

i. In commutation failure protection, commutation failure counter reset time has been changed from 10 seconds to 30 minutes. Acceptable 12 pulse commutation failures have been changed from 15 to 5. Hence within 30 minutes if 5^{th} commutation failure occurs the system will trip and avoid the further stresses.

ii. In DC line protection, restart attempt counter reset time has been changed from 30 seconds to 1 hour. Restart attempt for normal voltage has been changed from 2 to 1 and for reduced voltage it has been removed. On occurring of Line fault the system will go into Reduced voltage mode. If again line fault occurs within 1 hour the system will trip, reducing the further stresses on the system.

2.2 SITE MEASUREMENT

A survey of operating parameters to be carried out to check any deviation from those specified.

2.3 OPERATIONAL LIMITATIONS

As far as possible, following operating modes to be avoided

i) Use of "Increased Reactive Power Consumption" function.

ii) Manually set "Reduced voltage operation".

iii) "Reduced Voltage Operation" set by protective action. If DC line is not withstanding operation at 500 kV DC and automatically enters Reduced Voltage mode, the power can be reduced in controlled manner and pole be blocked. After clearing DC line problem, the pole can be restarted.

To avoid reflection of disturbance from associated AC and DC network, following precautions were to be taken:

i) Avoiding manual re-closing of tripped AC line without ensuring that fault is cleared.

ii) To carryout maintenance of insulators of DC line whenever repeated failures occur.

To reach to the root cause of failure of converter transformer, all the above said changes have been implemented and strictly adhered to. The intention was not to put the restrictions on operation but to enhance the availability of the link for operation under the close supervision to avoid any further damage to the equipment, which may otherwise would have caused disruption in power transmission. It was in the interest of both, the HVDC contractors and our organization. A survey of operating parameters was conducted by M/s. ABB and it was observed that, failure of the transformer seem to occur randomly and the transformer behave as if they have constant but high failure rate.

2.4. INVESTIGATION

The design was scrutinized with design tools. The strength of the insulation against repetitive transients was also verified and concluded that no design deficiency is causing the breakdowns.

2.5. COPPER SULPHIDE DEPOSITS

Inspection of the winding when disassembled turn by turn showed that, at some locations there was a shiny deposits on spacers and conductor insulation. These deposits were identified as Copper Sulphide (Cu_2S).

2.6. INFLUENCE ON DIELETRIC STRENGHT

The electric conductivity of Cu_2S is significantly higher than the conductivity of paper and oil. This means that the presence of Cu_2S may change the electric field distribution.

The series of tests were performed on both Cu_2S contaminated material and unaffected materials. The result of these tests shows that:

i. Partial Discharge (PD) initiation voltage and the breakdown voltage of the Cu_2S coated material are significantly reduced as compared to the uncoated material

ii. Uncoated and unaffected insulation has the same strength as brand new insulation.

2.7. IMPACT OF TRANSIENTS

Cu_2S lowers the PD-initiation level. Depositions of Copper Sulphide on the winding alone are not sufficient to create a short circuit or partial discharge between two turns. For either of these two happens the insulation has to be further degraded by frequent repetitive transients.

During line faults, a very high stress on the turn-to-turn insulations occurs

2.8. FORMATION OF COPPER SULPHIDE (Cu_2S)

The transformer oil is basically highly refined mineral oil & consists of mainly mixture of hydrocarbons and other compounds, containing Oxygen, Nitrogen & Sulphur. Most of the compounds containing Sulphur can react with copper under extreme conditions and form Copper Sulphide deposits.

2.9. CONCLUSION

After investigation ABB arrived at final conclusion as:

i. Aggressive oil produces Copper Sulphide
ii. Copper Sulphide weakens the insulation
iii. Transients arising due to α-90^0 operation or transients from continuous higher MVAR operation are sufficient to initiate partial discharges. Repetitive Transients further degrade the insulation.
iv. A partial discharge in sufficiently degraded insulation, will not extinguish.
v. When the insulation is sufficiently degraded, PD will continue at normal service voltage levels.
vi. A partial discharge leads to a turn-to-turn fault and Transformer breakdown.

Finally the transformer oil has been identified as a culprit of failure. Further M/s ABB have suggested to use the Nytro 10X oil instead of Naptha base oil and to add a passivator called irgamet-39 in the transformer oil as 1Kg / 10Kl of oil.

After this final conclusion and adopting the recommendations bipolar operation started on 24^{th} May 2004. But on 14^{th} June 2005 the ABB make repaired transformer in which all recommendations were adopted has failed with inter turn short. Now M/s. ABB / BHEL have to further investigate the cause of failure.

Presently, all ABB make transformers and one BHEL make are filled with Nitro 10X oil as suggested by ABB with metal passivator. However, BHEL make transformers are still filled with old Napthabase oil with passivator added.

3. FAILURE OF DC NEUTRAL CABLE

The neutral of the rectifier bridge is brought out in the DC switchyard through underground three nos. aluminum 25 kV DC XLPE insulated cables connected in parallel. In the year 2003 the DC Pole tripped on Neutral Bus DC Differential Protection. From the Transient Fault Recorder graphs it was analyzed that the dc neutral current amplitude is decreasing prior to fault. This indicated that there must have some leakage path for this current. There were only two possibilities for this, either due to failure of the surge arrester connected on the neutral side or the cable itself. After measurement of the insulation resistance, it was found that the one of the cables is showing very poor results as compared to others. The cable was tested for high voltage and it was found that there was a hole in the insulation through which the current was getting leaked.

The aluminum cable is having a Impulse Level of 375 KV while the equipments connected on the neutral bus are having Impulse Level of more than 375 KV. During earth faults on DC side maximum stresses will be on neutral. Since the Impulse level of Cable was less as compared to the equipments connected to neutral bus, the cable sustained the maximum stresses during faults.

These cables have been replaced by XLPE copper cables having Impulse voltage 550 KV replaced the old cables for both the Poles. After replacement of cables no leakage current has been noticed.

4. SNAPPING OF EARTH WIRE ON DC LINE

Throughout the entire span of the DC line the OPGW is run over one and on the other Pole AAAC (All Aluminum Alloy Conductor) earth wire is used.

The first occurrence of snapping of $80mm^2$ AAAC earth wire took place on 15^{th} November 1998 (Before commissioning of the line). Thereafter repeated snapping has been noticed at number of occasions. After inspection it was noticed majority of snapping were at the tip of fixing point of Vibration Damper supplied by M/s EMI Transmission Ltd. M/s EMI and M/s MML supplied 50% each of the total quantity. The chemical analysis, mechanical tests revealed that there is no problem with the $80mm^2$ AAA Conductor. Matter was referred to Central Power Research Institute (CPRI), Bangalore, India for investigation.

After tests on ground wire and vibration damper, CPRI opined that the design of M/s EMI make vibration dampers was defective. Therefore M/s EMI replaced all the vibration dampers supplied by them by the end February 2001.

After replacement of EMI make vibration dampers in February 2001 the breakdown due to snapping of earth wire were reduced. From February 2001 to May 2003, 20 numbers of occurrences were observed at the places where the MML make vibration dampers were used. This happened especially from January to May every year. As per the testing report of CPRI Bangalore, AAAC earth wire is very sensitive to notches, which accelerates the fatigue failure, more in case of high wind velocity.

The following conclusion is drawn from the snapping of AAAC earth wire:

The basic metal of AAAC is soft in nature and does not have sufficient ultimate tensile strength to withstand the tension at higher line spans. The cutting of strands on AAAC wires starts at hardware as well as on fixing points of dampers. This gradually aggravates during swinging of wire under high wind condition and results in snapping of wire after a period of 2-3 years.

It was therefore decided to replace the total AAAC ground wire by 7/3.66 G.I. wire. Till August 2008, 100% of AAAC ground wire has been replaced by 7/3.66 G.I. wire. G.I. wire has a better strength and arrests the problem of frequent snapping of ground wire has been totally arrested.

5. FLASHOVER DUE TO ENVIRONMENT ON DC LINE

Out of total 752 Km DC line, a small stretch of length of about 4 Km (Location no. 1792 to 1802) passes over hilly area of Naneghat. During the month of May 2003, the line used to go into the Reduced Voltage mode frequently. The line patrolling did not show any apparent faults on DC line as well as insulators. The site was visited during early morning and it was observed that complete towers are engulfed in low-lying clouds at top of the hill. Heavy audible noise was heard momentarily. However no flashovers were seen, but during night time, heavy flashovers were seen followed by loud chattering noise.

The polluted insulators on all the towers (mainly dust pollution) were washed by de-ionized water and silicon grease was applied on the insulators. Afterwards there were no flashovers and due to this line did not go to reduced voltage mode again.

There is one more location at about 5 Kms. away from a Sugar factory near Rahuri where similar phenomenon took place. The problem was arrested as above.

6. PROBLEMS WITH ELECTRODE STATION

Earth electrode was in used for quite long period during outage on Poles because of transformer failure. The earth electrode at Chincholi (Chandrapur) was found to have undergone electrolytic corrosion and one of sections was replaced. However at Anjur (Padghe) the cable insulations was deteriorated due to excessive heating. The cables are now laid in trenches and are reinforced.

The electrode station had otherwise no problems.

7. FAILURE OF SNUBBER CIRCUIT CAPACITORS

The purpose of the Snubber Circuits (Voltage divider circuits) is to give even voltage distribution among the thyristors at all frequencies. As per Fig. 2 three different dividers are connected across the thyristor.

i. R1C1-branch is damping the commutation overvoltage and reduces the voltage unevenness due to spread in thyristor recovery charge.

ii. R3C3-branch is the main source for charging the TCU (Thyristor Control Unit).

iii. R4-branch is a direct voltage divider.

From the January 2008 to June 2008 the Chandrapur-Padghe link (Pole 1/Pole 2) has failed 10 times due to failure of Snubber Circuit capacitors. After every occurrence the corresponding location were inspected. And in most cases the capacitor C1X found either burst or with their capacitance very much deviated from the permissible once. Due to bursting of the capacitors the light guides, which are placed over these capacitors, also got burnt and damaged the light guides.

The occurrences were discussed with the M/s. ABB Sweden. The Expert from M/s. ABB visited Chandrapur as well as Padghe Terminal station and inspected few of the thyristor modules. As a part of investigations all the capacitors in Pole 1 was measured. From the statistical data of measured values 84 nos. out of 5760 nos. of C1X capacitors and 31 nos. out of 1152 nos. of C3 capacitors were found values beyond the permissible limits. Also on approximately 60% of total capacitors small leakage at the capacitor terminals in the form of black spot were observed.

The investigation was carried by M/s. ABB Ltd. Investigation report says that the capacitors have developed minor leaks around the top sealing, allowing the insulating oil to absorb moisture from the air. The increased moisture level of the oil and the subsequent loss of the insulating capacity have caused accelerated ageing of the capacitors. The voltage withstand capability of the capacitors has been reduced leading to degeneration and in some cases destruction.

M/s. ABB's recommendation is to replace all the electrolytic capacitors in the Snubber Circuit with the gas-filled capacitors.

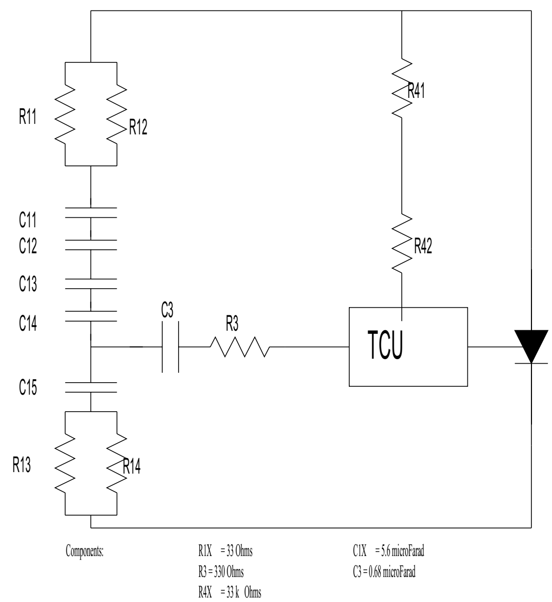

Fig. 2. Thyristor Level with Voltage Divider and Thyristor Control Unit

III. OPERATIONAL PERFORMONCE

Despite of the various failures/problems incorporated above, the HVDC system had helped to survive the associated grid at two crucial occasions:

i. During the year 2003 in the month of December 2003 the complete WREB system was disturbed due to heavy power swing in Western Network of the Maharashtra State. The Islanding mode of HVDC system got enabled and helped to survive the grid for 18 minutes.

ii. On 28th of February 2005 due to fire occurrence at KTPS grid control room, the generation and out going lines were totally affected. During this occurrence all parallel AC lines from Chandrapur towards Western Part of Maharashtra were tripped on power swing and the HVDC poles got islanded along with generators and survived the Eastern and Western grid of MSETCL.

iii. During transient fault in parallel AC lines the damping controller always get activated and stabilize the network

iv. During year Feb 2007 there was a system disturbance, all the parallel AC lines were tripped and the VKM – KTRT grid was separated and Islanding mode of HVDC got enabled and survive the MSETCL system from complete collapse.

IV CONCLUSION

The reason for failures in Light Guides, DC Neutral Cable, DC line Earth Wire, Earth Electrodes and Converter Transformers were identified, analyzed and were appropriately addressed to achieve stable operation of the Chandrapur-Padghe HVDC Bipolar link. Only the Converter transformer problem, which are thought to have been solved are still to be identified for proper technical reason and are thus a major task before us. The investigation of these problems in the HVDC Link provided learning opportunity to the MSETCL engineers. The experience gained in overcoming problems has instilled confidence in smooth operation of the project in the long run.

The availability of HVDC link is now reaching a higher figure which is an outcome of whole-hearted and dedicated efforts put in by the MSTCL Engineers, who have proved their excellence in operation and maintenance of HVDC link as a user and the HVDC Contractors who are keenly involved in assisting the MSETCL for overcoming the typical faults/problems encountered during the operation of the HVDC Link.

The operating restriction imposed as a part of investigation of transformer failure such as changes in commutation failure protection, restart attempts on line faults, etc. though still unchanged have not affected the performance in any way. Certain occasions necessitated the use of manually set Reduced Voltage Operation, though in force.

Run up Function being incorporated in the control system is based on the operating experience to further enhance the grid stability.

With the trifurcation of MSEB and formation of **Maharashtra State Electricity Transmission Company Ltd**., HVDC link has proved to be a backbone of the MSETCL Transmission system. Operation of HVDC link embedded with existing HVDC system has fulfilled the commitment of enhanced grid stability, reliability and also reduction in transmission losses etc.

V. ACKNOWLEDGEMENT

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