1200 kV UHV Transmission Line Simulation Study

Satyadharma Bharti
Dept of Electrical Engineering.
Rungta College of Engineering & Technology
Bhilai, India

Satya Prakash Dubey
Dept of Electrical Engineering.
Rungta College of Engineering & Technology
Bhilai, India

***Abstract* – Ultra High Voltage (UHV) transmission, at 1200 kV, is comparatively a new field which has ample scope for technological advancement and research. At Bina, Madhya Pradesh (India), Powergrid Corporation of India has established a National Test Station. This UHV test station operates at world's highest transmission voltage of 1200 kV. Several technical tests are being carried out to make the UHV system commercially viable. In order to carry out various studies related to Thyristor Controlled Series Capacitor (TCSC), Controlled Shunt Reactors (CSR) and other FACTs devices a basic simulation model of Transmission line is designed using PSCAD software, in which required FACTs devices may be incorporated to carry out the performance analysis and other advanced studies. Present paper covers the basic simulation model of the line operating at 1200 kV. It is based on the standard specifications and parameters of Indian UHV transmission system. The simulation model will be also useful in the size optimization of ultra high voltage overhead transmission line structure.**

Keywords – **Controlled Shunt Reactors, Thyristor Controlled Series Capacitor Component, Transmission system, Ultra High Voltage.**

I. Introduction

The Indian Ultra High Voltage transmission of India, operating at 1200 kV has proved its technical feasibility as the 1.6 km long transmission line is charged and UHV transformers at Bay-1 and Bay-2 are energized at National Test Station Bina. The station is planned, designed and worked out indigenously by Powergrid Corporation of India Limited (PGCIL) in association with 35 Indian manufacturers to study the performance of 1200 kV UHV system [1]-[2]. This development was a result of continuous R &D and innovation in the field of 1200 kV system of the past few years which has proved the capability of Indian power sector. With this, Indian manufacturers have got a global exposure by developing an efficient bulk UHVAC power transmission system in India. Commercialization of 1200 kV technology, in terms of cost optimization, will help in ensuring a reliable and dependable power supply which will enhance the growth of the country [3]. Simulation study The 1200kV system is a step towards overcoming the challenges in the power sector such as Right of Way, environmental considerations, optimization of cost, faster project implementation, coordinate development of transmission corridor together with other infrastructure, and reduction of losses.

Earlier, a system of 1200 kV a.c. transmission lines was developed in the USSR also. A. A. Akopyan et al described the technical characteristics of this system; consist of a bundle arrangement for the overhead line. Issues related with overvoltage protection, Insulation of transmission line and substation are also described with the appropriate test voltages for the accessories, equipments and the structural elements. Problems of scientific and engineering nature are discussed [4]. Technical requirements for substation equipment exceeding 800 kV were presented by working group A3.22 in 2008 [5]. According to this, few phenomena peculiar to UHV have been address by different working groups and committees of IEC and CIGRE for the design of equipments, accessories and system components. Prominent Ferranti effect and Temporary Overvoltage (TOV) due to large capacitance of overhead lines for surge arrestor and shunt reactor; Possibly reduced corona onset voltage with increased corona losses and audible noise-for line and Air Insulated System; Prolonged secondary arc extinction time due to higher induced voltage- for 4-Legged Reactor high speed grounding switches (HSGS), Gas Circuit Breaker (GCB); Higher slow front overvoltage at grounding fault occurrence due to low damping of travelling waves, High amplitude factor in TRVs due to low losses of power transformers and transmission lines, High Transient Recovery Voltage (TRV) peak value for out-of-phase due to low damping of travelling waves - for Circuit Breaker, Surge Arrester are few specific issues of UHV AC systems exceeding 800 kV. Few more issues related to circuit breakers which are addressed by IEC and CIGRE working groups are reduced line surge impedances due to multi-bundle conductors with large diameter; Large time constant of DC component in fault current due to low losses of transformers and lines; Reduced first-pole-to-clear factor due to small zero-sequence impedance in the UHV systems and Severe Very Fast Transient Overvoltage (VFTO) due to geometry and topology of UHV substation such as Mixed Technologies Substation (MTS).

The working group A3.22 [5] concludes that there are a number of challenging technical topics which are particularly in the UHV range and in many cases, simple extrapolation of assumptions from lower voltages is not appropriate. Several distinctive phenomena have been identified including a prominent Ferranti effect, large DC time constant of fault current, severe TRVs and slow front

Over-voltages, prolonged secondary arc extension and reduced first-pole-to-clear factor etc require detailed study. Optimal insulation coordination to reduce the construction costs of UHV systems by applying compact transmission towers can be realised using high-performance Metal Oxide Surge Arresters (MOSAs). The design of insulation coordination by means of accurate computer aided simulations is common practise for such projects.

A simulation study is useful to study basic parameters of UHV Technology in terms of requisites and constraints of system along with the system performance studied including stability and reliability criteria, normal and extreme contingencies, overvoltage compensation and other enhancements etc. Areas of over-voltage studies namely temporary and switching overvoltage leading to proper insulation coordination can also be studied through computer simulation for different combination of line parameters, conductor sizes, clearances etc.

Here, it is to worth mention that except India; nowhere in the world does a 1,200-kV line exist. Many countries do not have the requirement of such high capacity lines. Operating voltage at China, which needs bulk power to be transmitted over long distances, is 1100 kV.

II. PSCAD SIMULATION MODEL

As a planning initiative, considering need of higher capacity transmission corridor between Aurangabad and Wardha, the Aurangabad - Wardha 400 kV, quad, double circuit line has been planned and designed in such a way that this line would be converted into a 1,200 kV single circuit line.

The present paper proposes a PSCAD based model of the Wardha-Aurangabad 1200 kV transmission line of India. Block diagram of the proposed line is shown in Fig 1. This line will generate 2700 MVAr reactive power at no load condition. The equivalent sources at sending and receiving end representing Wardha and Aurangabad are shown by three phase source A and B, 50 hertz, 1150 kV infinite source with short circuit capacity of 27800 MVA [6].

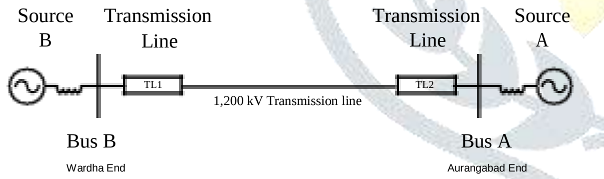


Fig. 1. Block diagram of proposed transmission line with Thevenin equivalent source at both ends.

For the transmission line shown in Fig. 1, further addition of FACTs devices can be made and simulation studies can be performed. Fig. 2. indicates a single line diagram of TCSC Installation in the basic model of Transmission line.

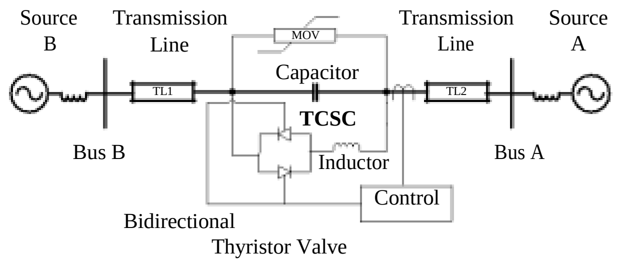


Fig. 2. Single line diagram of TCSC Installation

Standard R, X, B Data for 1,200 kV Line are given in table I [7], whereas table II gives the line constraints solved using PSCAD.

Table I: Standard R, X, B Data for 1,200 kV Line

Rated Nominal Voltage (L-L rms kV)	1150
Resistance(p.u./km)	$4.338x10^{-7}$
Reactance (p.u./km)	$1.772x10^{-5}$
Susceptance (p.u./km)	$6.447x10^{-2}$
Surge impedance loading (MW)	6030

Table II: The line constraints solved using PSCAD

Sequence Resistance [p.u.] for 225 km Segment	
Positive Sequence Self:	0.831127020E-04
Zero Sequence Self:	0.363970508E-02
Sequence Reactance [p.u.] 225 km Segment	
Positive Sequence Self:	0.448522513E-02
Zero Sequence Self:	0.145315265E-01
Sequence Susceptance [p.u.] 225 km Segment	
Positive Sequence Self:	13.0774298
Zero Sequence Self:	9.07326117
Height of all conductors , measured at tower	37 m
Horizontal spacing between phases	26 m
Number of ground wires	2
Conductors are regularly transposed	Yes
Steady State Frequency	50 Hz
Number of Conductors	3
Number of Sub-conductor in bundle	8
Bundle Spacing (m)	0.4572
Total length of transmission line	450 km

PSCAD software has the provision to simulate the transmission line tower by changing tower dimensions, conductor diameter, number of conductors in bundle etc. Fig. 3. gives tower configuration of proposed model.

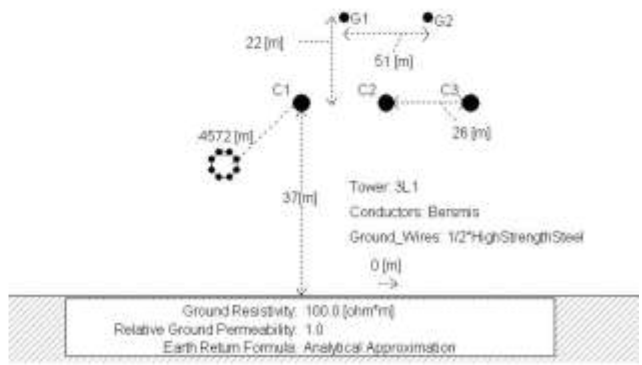


Fig. 3. Tower Configuration of proposed model

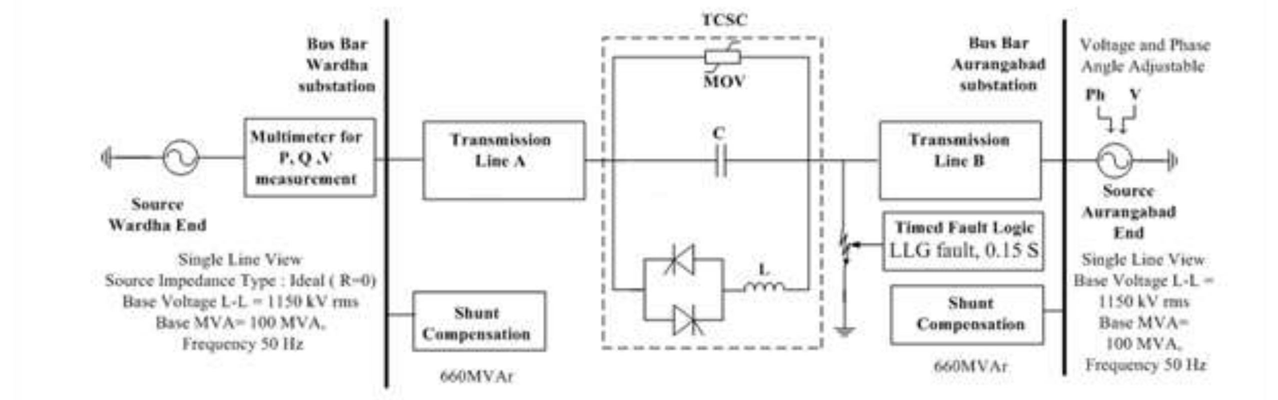


Fig.4. Schematic Diagram for Simulation Study of TCSC Performance.

The proposed model is used to carry out performance study of TCSC, an appropriate control strategy can be applied to the model shown in Fig. 4.;

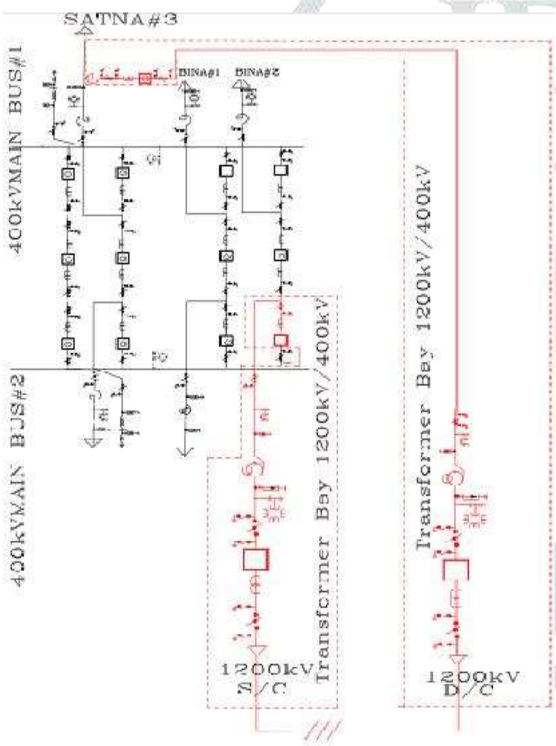


Fig. 5. Single Line Diagram for 1200 kV National Test Station Bina (The portion marked with red colour indicates 1200 kV Test Station [7].

A single line diagram for 1200 kV National Test Station Bina is shown in figure [7]. The portion marked with red colour indicates 1200 kV line. Based on the tower structure and bundle conductor used in this line simulation model of Wardha Aurangabad line is prepared using PSCAD software. One Source, connected to Aurangabad end Bus, is taken as $1150\angle 0^0$.whereas the other source is connected at Wardha side Bus and is taken as a variable source, set with initial setting of $1150\angle 25.39^0$. To study the performance of the line, following switching sequence is planned.

(1) At time t= 0.2 sec., the source at Wardha bus is switched on through Breaker.

(2) At time t= 0.4 sec., the source at Aurangabad bus is switched on through breaker, feeds power upto t=20 Sec.

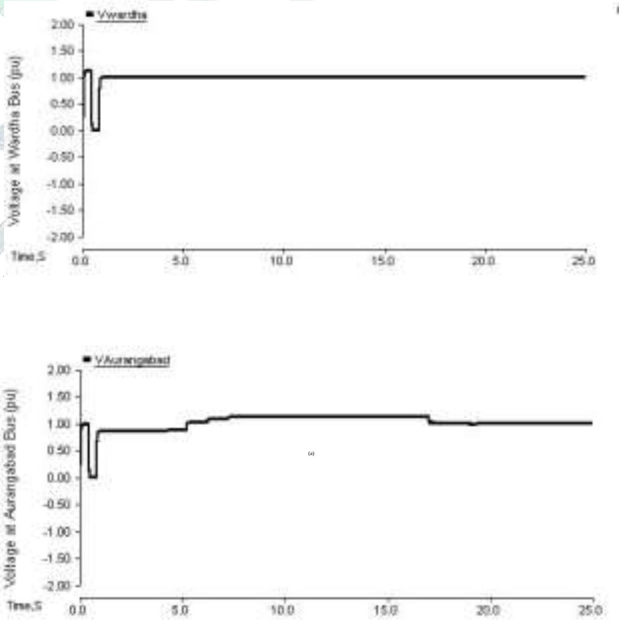
(3) At time t= 0.8 sec., the transmission line is connected between the two buses.

(4) Different constant loads which are connected at Aurangabad Bus are switched off through breakers at 4.2 Sec, 5.2 Sec, 6.2 Sec and 7.2 Sec.

(5) All the loads of step (4) are connected at 17.50 Sec.

Any desired fault (L-G/ LL-G, LLL-G) can be connected in the line to judge the system performance at that time.

Voltage of Wardha and Aurangabad bus are depicted in the Fig 6 (a) and (b) and voltage of mid-point of the transmission line is shown in Fig. 7.



(b)

Fig. 6. Voltage profile:
(a) at Wardha Bus and
(b) at Aurangabad Bus

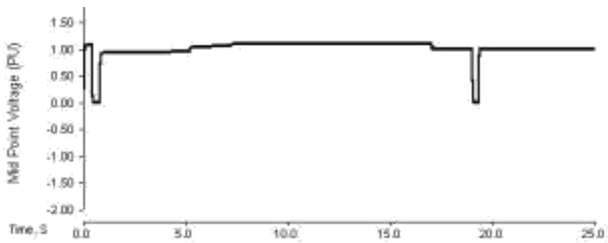


Fig. 7. Voltage profile at the midpoint of Wardha-Aurangabad Line

III. CONCLUSION

The proposed PSCAD model can be used to carry out performance study of 1200 kV transmission line. For example Voltage overshoot of 1.12 pu observed at the bus when the load is thrown off. Active and reactive Power at Mid-point of the transmission line can also be investigated for any type of fault in the line.The addition of TCSC and other FACTs devises can also be added in the model for study and R&D purpose[8].

REFERENCES

[1] S. Bharti, S. P. Dubey. "No-load performance study of 1200 kV Indian UHVAC transmission system." *IET High Voltage, Oct 2016, 1;1(3), 130-7.*

[2] S. Bharti, S. P. Dubey. "Application of Smart Computing Techniques in Cost Optimization of 1200 KV Autotransformer." *Journal of Information and Optimization Sciences, 2017, pp249-262 doi: 10.1080/02522667.2017.1374727.*

[3] Dr. S. K. Agrawal, D.P. Tamoli, B. N. De. Bhowmick, B. N. V. R. C. Suresh Kumar, S. B. R. Rao and Akhil Sundaran. " 1200kv National Test Station: Taking Indian Power System To Next Orbit." *1200kV UHVAC Indigenous Development, New Delhi, CIGRE session 2013.*

[4] A. A. Akopyan, G. I. Alexandrov, N. P. Emelyanov, Yu. I. Lyskov,S. S. Rokotian & V. P. Fotin. "Characteristics of UHV 1200 kV Transmission Lines." *CIGRE, International Conference on Large High Tension Electric Systems Paris, 1972 Session.*

[5] Technical Requirements for Substation Equipment Exceeding 800 kV (Field experience and technical specifications of Substation equipment up to 1200 kV). *Working Group A3.22 CIGRE 2008.* ISBN : 978-2 85873-049-0.

[6] S. V. N. J. Sundar, R. Koul, M. Kumar, Y. A. Raju. "Application of Controlled Shunt Reactor for Reactive Power Management of 1200 kV UHVAC Transmission Line." *GRIDTECH 2013 - 4th International Exhibition & Conference. New Delhi, 2013,* pp16-22.

[7] Nayak, R. N., Bhatnagar, M.C., Bhowmick, B.N. De, and Tyagi R.K. "1,200 kV transmission system and status of development of substation equipment / transmission line material in India." *Water and Energy International 66.4 pp 70-77, 2009.*

[8] K. R. Padiyar, "FACTS controllers in power transmission and distribution" (New Age International (P) Limited Publishers, 2007)

Author Profile

Satyadharma Bharti received degree of B.E. Electrical Engineering in 1990, and Master of Technology in 2007. He is Pursuing Ph.D. from Chhattisgarh Swami Vivekanand Technical University, Bhilai, India. Currently he is Associate Professor in the department of electrical engineering, Rungta College of Engineering & Technology Bhilai. His research interests include high voltage engineering, electrical machines and power system.

Satya Prakash Dubey has received his Bachelor of Electrical Engineering from Govt. Engineering College (now National Institute of Technology) Raipur, India, in 1995. He completed his Master in Engineering (Power Apparatus & Electrical Drives) from Indian Institute of Technology, Roorkee, India in 2000. He obtained Ph.D. Degree from Birla Institute of Technology and Science, Pilani, India in 2006.
Currently he is Professor in the department of Electrical Engineering Rungta College of Engineering and Technology, Bhilai. India. His current Research include Power Converters, UHV, active filtering, power conditioning, AC and DC drives, neural network and fuzzy logic based controller design for electrical drives, genetic algorithm technique for LC filter design.