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High Phase Order Transmission System: "A solution for Electrical Power Transmission in Deregulated Environment"

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Abstract:- This paper describes the talismanic role of High Phase Order Transmission System by converting the existing three phase double circuit 400 KV GETCO's (Gujarat Energy Transmission Co.) line in to the Six-phase transmission System. A comparative design study is made in terms of line characteristics, line regulation, transmission efficiency etc., with a brief discussion on the salient features of Six-phase Transmission System with respect to it's counterpart Three Phase Double Circuit System and High Voltage D.C. Transmission (HVDC) System. Both lines are simulated for an assessment of fault currents under different conditions with the same amount of load on both systems. The results obtained are tabulated and graphically plotted for the analysis and readers' perusal.

Keywords:- HPOTS: High Phase Order Transmission System, TPDCS, Three Phase Double Circuit System

I. INTRODUCTION

The HVDC transmission and HPOTS are the emerging two options for addressing the problems with the bulk power transmission over the long distance. Although the HVDC system has many advantages like non-synchronous ties, less numbers of conductors required, less losses etc., it has, however, substantially higher cost for the terminal equipments, its inability to transfer reactive power between the two ends, and difficulty of changing the voltage level. These are the major drawbacks of HVDC system which have shadowed its' aforesaid advantages and as such it has become imperative for the research engineers to tailor a new policy for the electrical power transmission by switching over to the other option that is HPOTS.

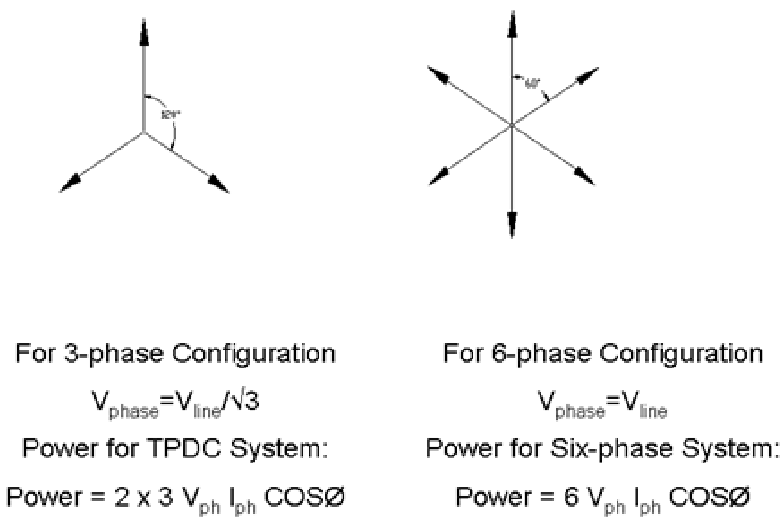

Fig.1, Phase Voltage and Line Voltage Relationship in Three-Phase and Six-phase Systems

The use of higher phase order system, with the same phase to phase voltage, can transfer more power. Conversely, maintaining the same phase to neutral voltage will decrease phase to phase voltage for the HPO lines. It means that lines can be built with less spacing between the phases, reducing the amount of right of way and the tower size to build the HPO line.

Amongst the interesting features of HPO transmission, increased power transfer capability and effective utilization of right of way (ROW) are considered to be the most attractive ones.

II. RATIONALE

The construction of the loadability curves and various related issues will now be addressed with the help of existing GETCO's 400 KV three phase double circuit configuration as shown in Fig: 2. and the loadability curves are constructed for the same configuration when converted in to six phase. A comparative study of the six phase system is made with reference to the three phase double circuit system.

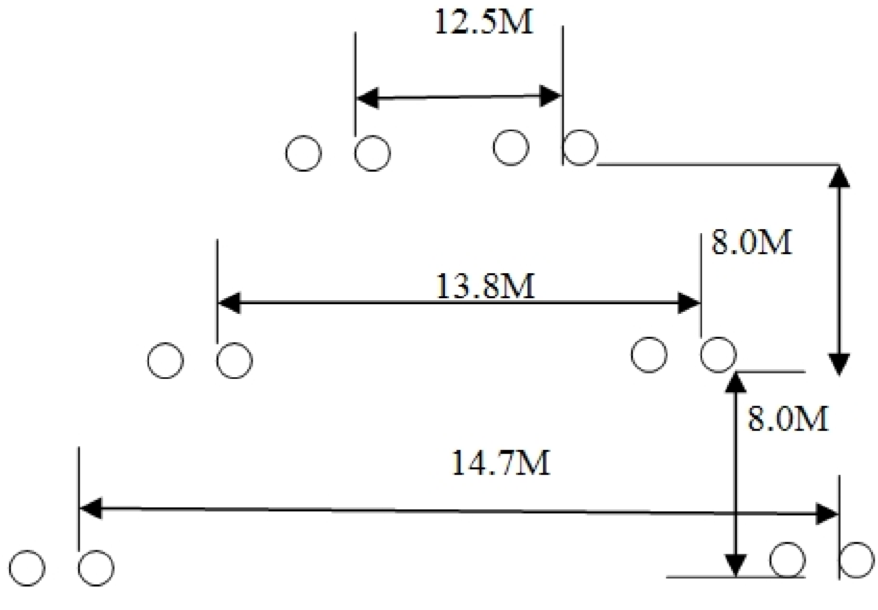

Fig:2, GETCO's Existing 400kv 3-Ph Double Circuit ,10 Inch. Bundle Spacing Twin Mouse Conductor Used, Dia. 31.77 mm, 900A C.C./Conductor Height of Lowest Conductor from Ground: 21.9 M

A. Line constants and assumptions:

Line length **:** 400 to 1000 Kms
Type of conductor **:** Twin mouse
Phase spacing **:** As shown in fig. 2
Height of the lowest
Conductor from ground: 21.9 M

Operating Voltage **:** 400 KV
Bundle spacing **:** 25 Cms

Computed line parameters per Km. for 3-ph Double Circuit:
L= 0.0005014 C= 2.43 E -8

Computed line parameters per Km. for 6-ph conversion of the same configuration:
L= 0.001268 C= 9.01 E -9

- Terminal equipments and machine variants are not considered.
- Shunt compensation specified as susceptance.

COMPARATIVE TABLE										
GETCO'S 3-PH DOUBLE CIRCUIT CONFIGURATION										
SR	TYPE	VOLT	IL	REG	EFFI	L	C	SIL	PF	PS IN MW
1	400 KV GETCO'S CONFIGURATION 3-PHASE DOUBLE CKT	400	1800	7.38	95.88	0.000501	2.34E-08	1112.71	0.9992	1501.78
		400	900	2.98	97.81	0.000501	2.34E-08	1112.71	0.9673	736.06
6-PH CONVERSION OF GETOC'S THREE PHASE CONFIGURATIONS										
2	6-PH GETCO'S CONFIG	400	1800	8.8347	97.596	0.001268	9.01E-09	2558.74	0.9771	4426.39
		400	900	2.9046	98.7628	0.001268	9.01E-09	2558.74	0.9974	2187.06
3	6-PH GETCO'S CONFIG	231	1800	22.005	95.92	0.001268	9.01E-09	853.36	0.8917	2600.15
		231	900	6.9729	97.907	0.001268	9.01E-09	853.36	0.9883	1273.73

Table: I, Comparative design table of TPDCS and HPOTS

The table: I shows the hike in power transfer capability of the existing GEB'S 400 KV line, if converted in to the Six-phase. It can, however, be observed that the regulation is poorer, as compared to the TPDC line. Further, we can see that for the same power to be transferred, the voltage level for six-phase power transmission can be reduced, enabling us to reduce simultaneously, the overall tower size and its cost; and thus overcoming the problems of right of way. The table:I given below is prepared from the GETCO's (Gujarat Energy Transmission Co.) 400 KV TPDC line data and its configuration when converted in to Six-phase. It is assumed that the line is cyclically transposed and the line length is of 200 Kms.

B. Salient points

From the table:I we can derive the following important points regarding the High Phase Order Transmission:

- If symmetrical configuration, inherently balanced is used , less effect of transposition is observed
- For Six-phase system, Vphase = Vline, as it forms equilateral triangle (Angle = 60).
- For TPDCS, Power = 2x3 Vph Iph cosθ   Where, Vphase = Vline / √3
- For 6-ph, Power = 6 Vph Iph cosθ   Where, Vphase = Vline.
- This fact gives 1.7 to 1.74 times more power than the existing three phase double circuit line depending upon the line configuration.
- For the same amount of power transfer, if we keep Vphase same, it will reduce Vline for the Six-phase system, enabling us simultaneously to reduce the overall dimension of the tower, its foundation cost, right-of-way problem and line congestion problem in deregulated environment .
- For the same amount of power transfer, Six-phase conversion gives better voltage regulation as it has higher SIL.
- If 6-phase conversion is made for more power transfer, it results in poorer regulation, but this problem can be well addressed with the available FACTs devices.

III. EXPERIMENT & RESULTS

The MATLAB simulation has been done for the GETCO's 400KV TPDCS line and its conversion into Six-phase. The Six-phase conversion is made by using two 12-terminals three phase transformers. The phase conversion is made on the principle that 2-Three phase supplies being displaced by 180^0 to form Six phase. For the simulation of various faults at different locations, two distributed parameters blocks are kept, and line length of them are varied to create fault at the desired location. On the receiving end, the same pair of transformers in mirror fashion is used for Six- phase to Three-phase conversion.

The graphs of fault currents and phase voltages are obtained for various faults at different locations for the same amount of load on both the systems. The simulation is done with **ode15s** simulation tool. Owing to the paucity of space, only the selected graphs (Fig.6 to 17) have been furnished below for the readers' perusal.

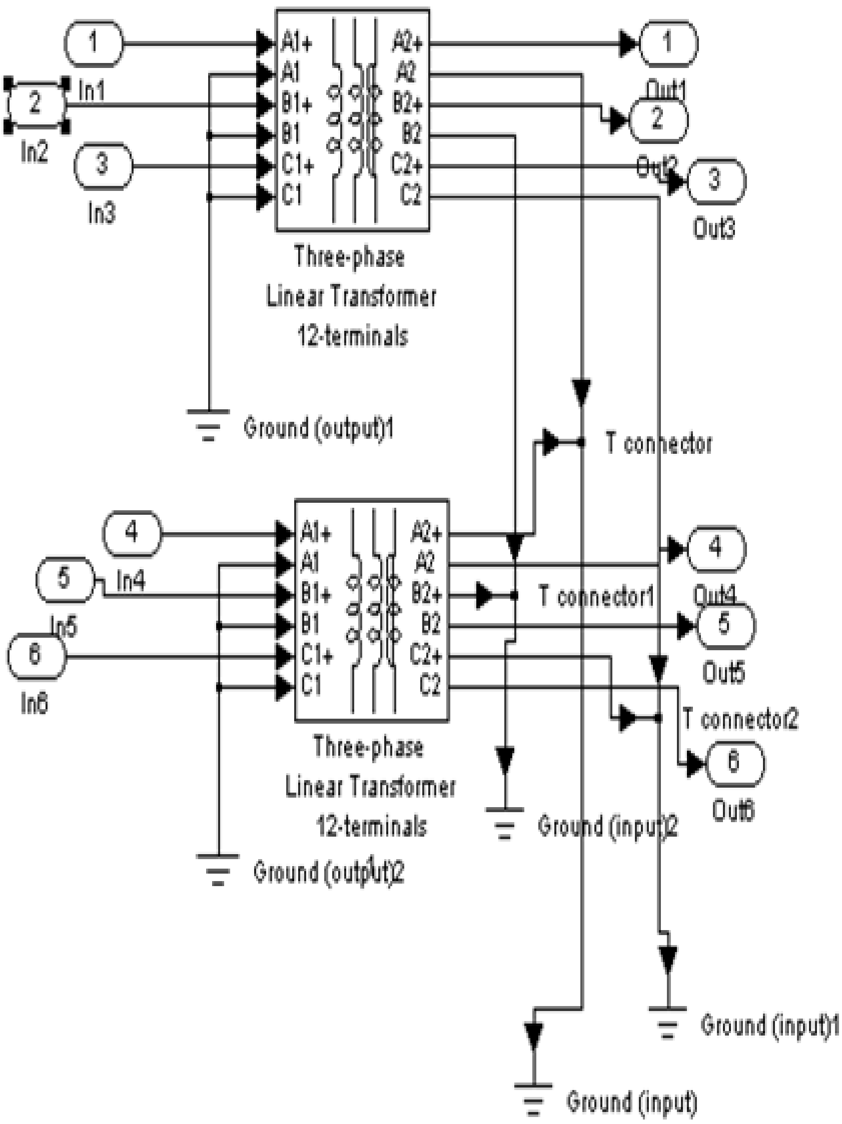

Fig. 3: Three-phase to Six-phase Conversion using two Three-phase twelve winding Transformers

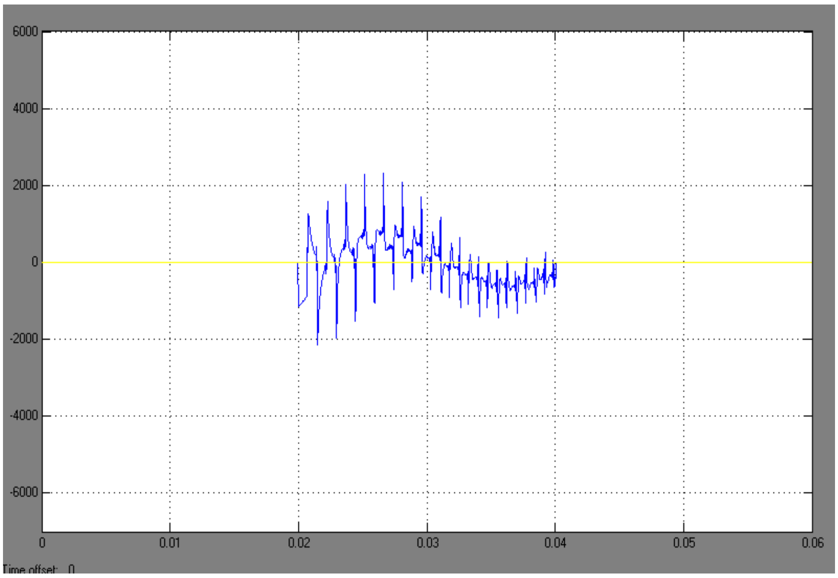

Fig.4 Fault Current for fault Phase-to-Ground in TPDCS at Mid-point.

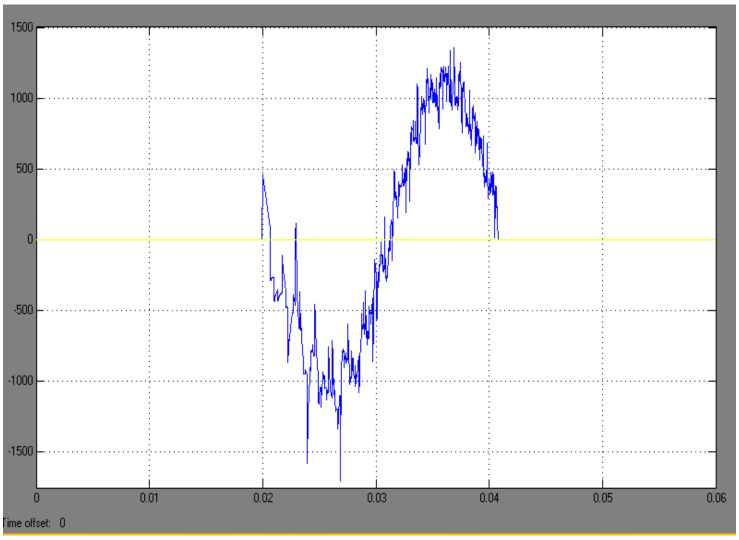

Fig.5 Fault Current for fault Phase to Ground in Six-Phase at Mid-point

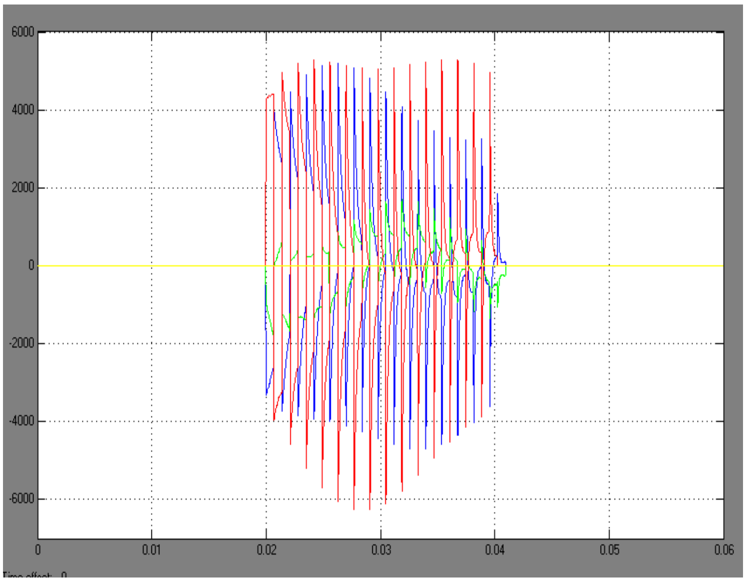

Fig.6 Fault Currents for fault Triple-Phase to Ground in TPDCS at Mid-point.

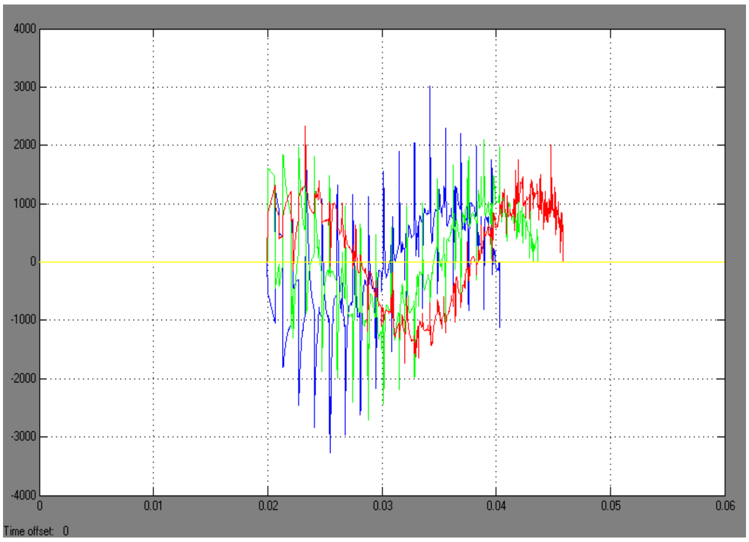

Fig.7 Fault Current for fault Triple Phase to Ground in Six-Phase at Mid-point.

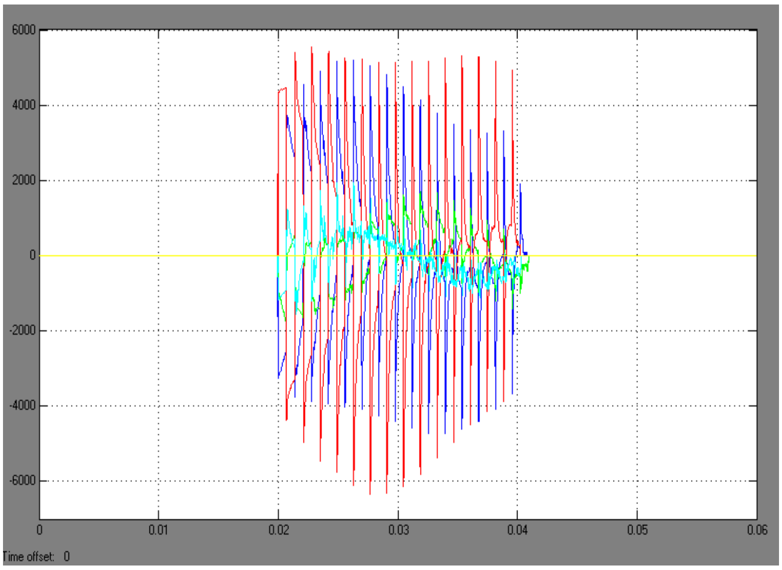

Fig.8 Fault Currents for fault Four-Phase to Ground in TPDCS at Mid-point.

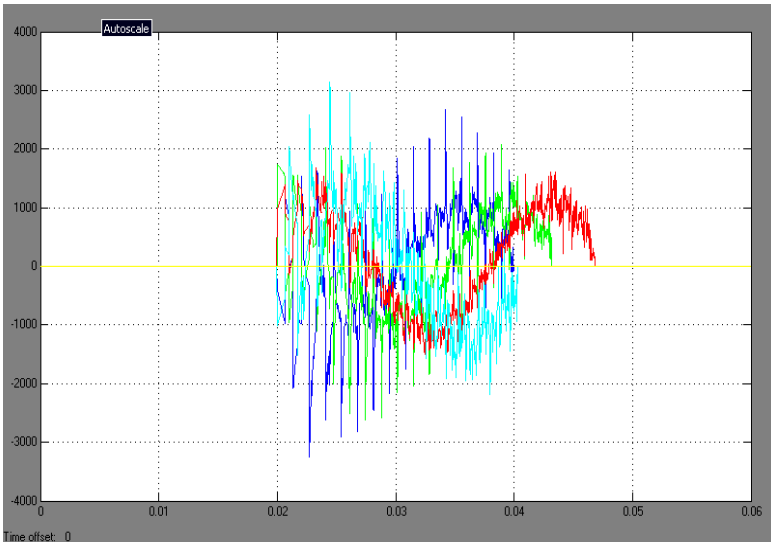

Fig.9 Fault Current for fault Four Phase to Ground in Six-Phase at Mid-point

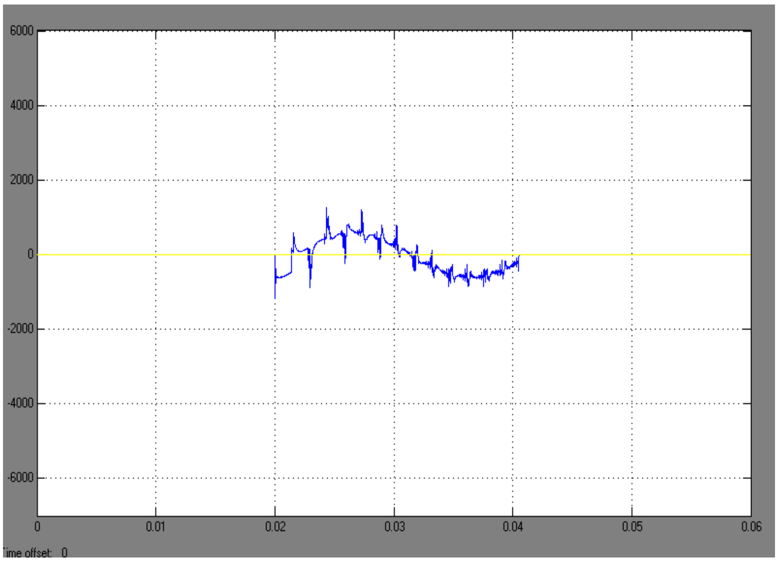

Fig.10 Fault Currents for phase to Ground Fault on TPDCS at Receiving End

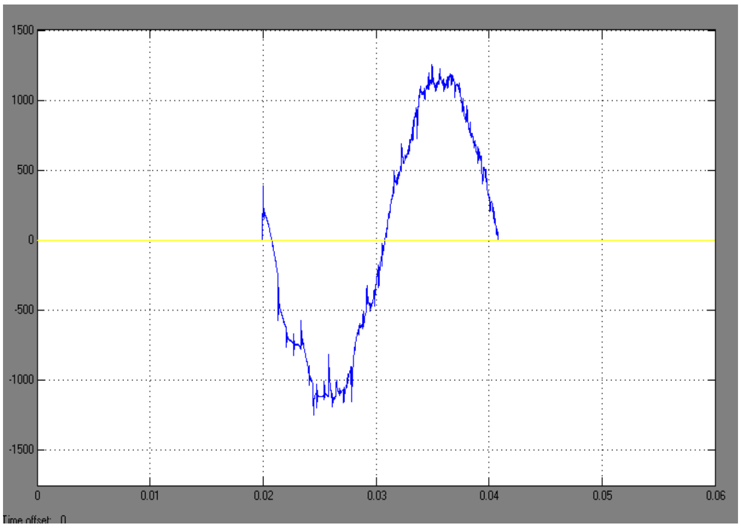

Fig.11 Fault Current for fault Phase to Ground in Six-Phase at Receiving End

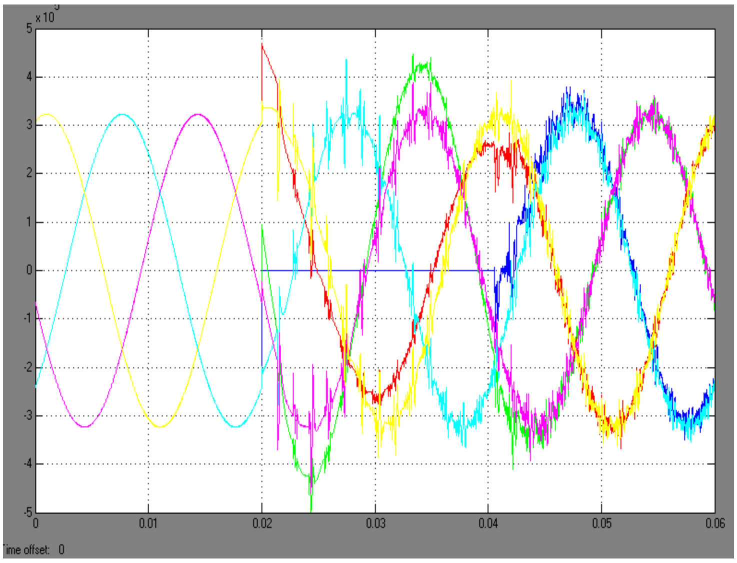

Fig.12 Fault Voltages for phase to Ground Fault on TPDCS at Receiving End.

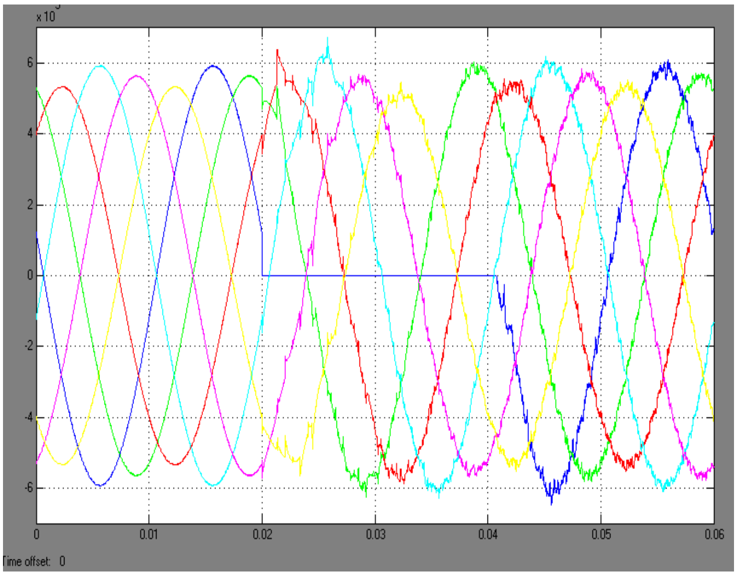

Fig.13 Fault Voltages for fault Phase to Ground in Six-Phase at Receiving End

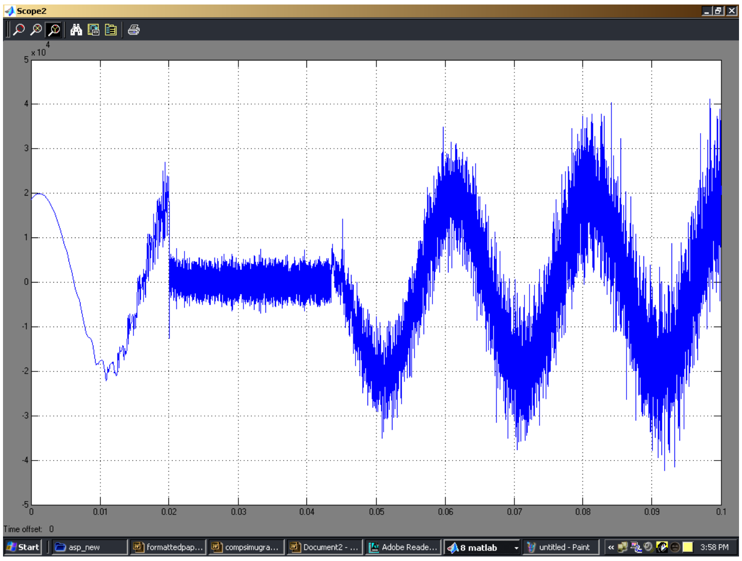

Fig.14 Load Side Phase Voltage on Single Line to Ground Fault at mid-point on TPDCS

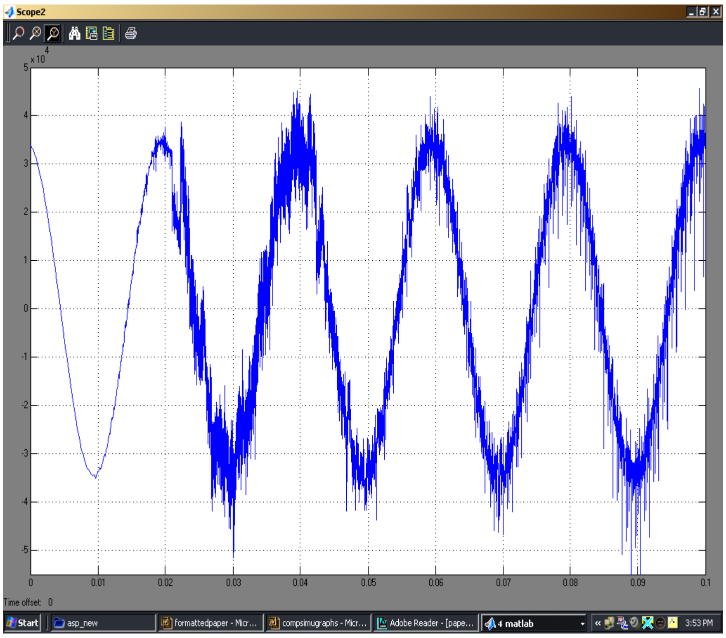

Fig.15 Load Side Phase Voltage on Single Line to Ground Fault at mid-point on Six-phase

IV. CONCLUSIONS

- From the graphs, it is observed that, the magnitude of fault current is less for the Six-phase system than that for the three phase double circuit system, with the same fault resistance, fault type and fault location.
- It is also observed that Three-phase to ground fault is the most severe fault in the case of Three-phase double circuit system, while Four-phase to ground fault is the most severe fault in the case of Six-phase system.
- The curves plotted for the load voltages for line to ground fault on Mid-point of transmission line, show significantly less distortion in the case of the Six-phase system as compared to the Three-phase double circuit system.

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