Chapter: VII
FAULT ANALYSIS OF THE T.P.D.C. SYSTEM AND THE SIX-PHASE SYSTEM

CHAPTER: 7
FAULT ANALYSIS OF THE THREE-PHASE DOUBLE CIRCUIT SYSTEM AND THE SIX-PHASE SYSTEM

7.1 INTRODUCTION:-

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 three-phase to Six-phase conversion is made by superimposing the 2-Three phase supplies displaced by 180^0 from each other to form the Six-phase supply. However, for the Six- phase to Three-phase conversion, the same pair of transformers is placed in a mirror fashion at the receiving end of the transmission line. For the simulation of various faults at different locations, two distributed parameter blocks are incorporated for the transmission line, and the line length of each parameter block is varied to create fault at the desired location.

The graphs of fault currents and phase voltages are obtained for various faults at different locations for an equal amount of load on each system. The simulation is done with **ode15s** simulation tool.

7.2 THREE-PHASE SIMULATION MAIN CIRCUIT:-

The fig. 7.1 shows overall scheme for simulation of the Three-phase Double Circuit (TPDCS), GETCO's 400 KV Line forming the Main Circuit which comprises of many subsystems to circumscribe the whole scheme within a single screen for making it more comprehensive. The subsystem-3 at the sending end encapsulates the transformer pair to step up the generating voltage to 400 KV; while subsystem-1 at the Receiving End is used to step down the transmission voltage to Load voltage. The two "Distributed Parameter Blocks"

have been incorporated for a given line length for creating the desired fault at the desired location, by varying the line length of each of the blocks. The Fault block can create a desired type of fault with different set parameters. The discussion about the subsystems incorporated in the main circuit is, however, made at length in the subsequent sections. The subsystem-4 in the Main Circuit is used for the measurement of various electrical properties of the line, when simulation is run.

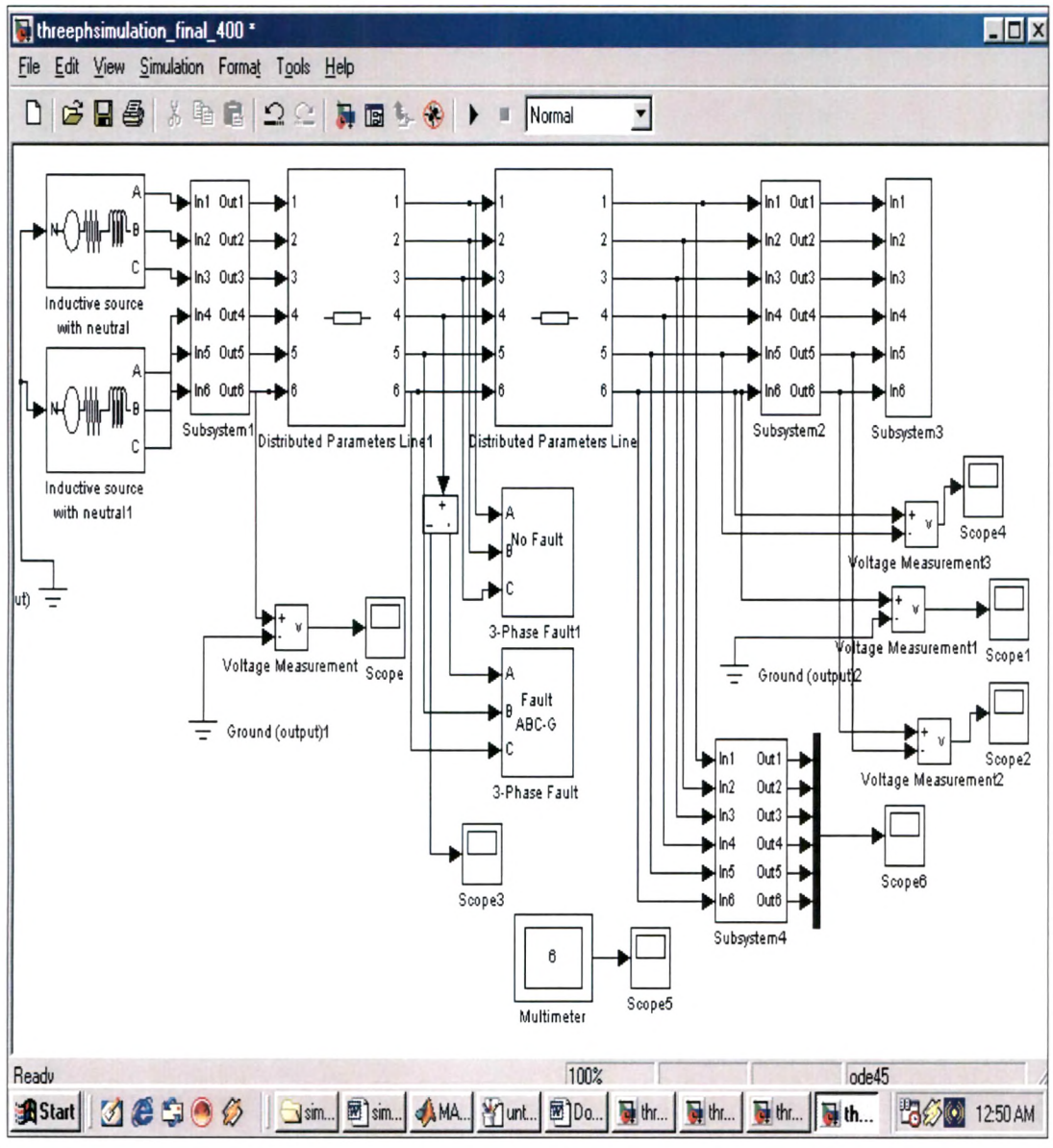


Fig.7.1 Detailed Connection Diagram of the Three-phase Double Circuit Simulation

7.2.1 Block Parameters for the Three-phase Twelve Terminal Transformers:-

The two twelve-terminal transformers pairs are used for the simulation of both the systems (TPDCS as well as Six-phase), in order to retain the inherent characteristic of the transformer sections. The internal connection diagram of each transformer pair is as shown, in fig. 7.2. The block parameters for the transformers are kept to be the same for simulation of both the systems. Figures 7.2 and 7.3 show the connection diagrams of the transformer pairs used at the sending end and the receiving end, respectively.

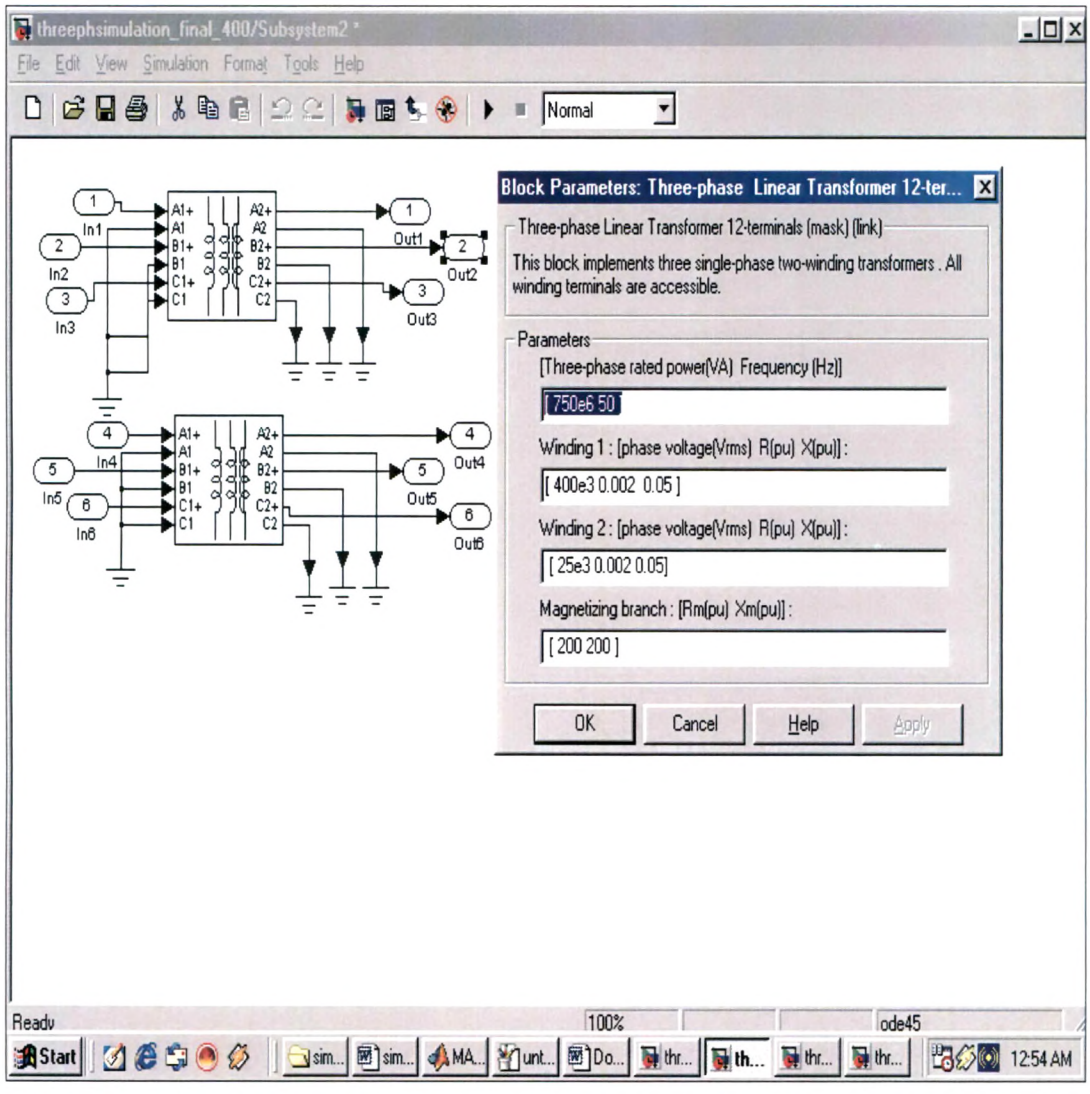


Fig. 7.2 Connection Diagram and Details of Transformers Used at the Sending End

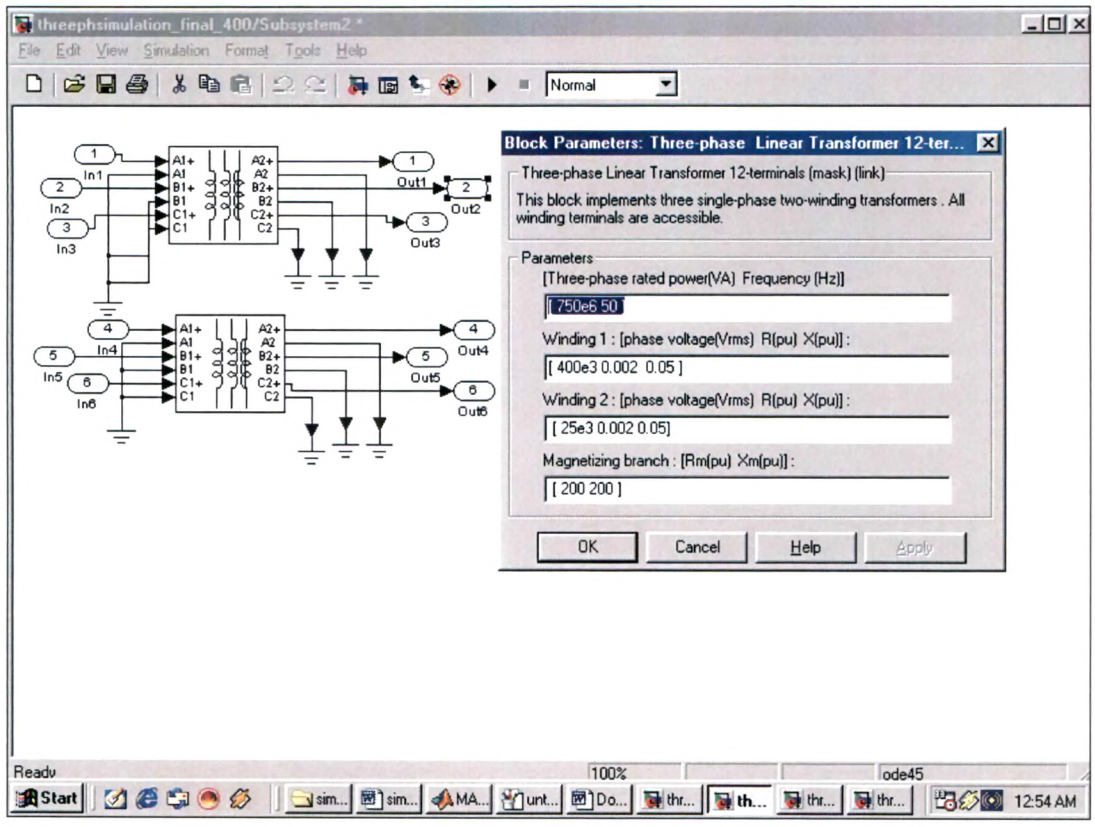


Fig. 7.3 Connection Diagram & Details of Transformers Used at the Receiving End

7.2.2 Distributed Parameter Block for the Transmission Line:-

As discussed earlier, two distributed parameter blocks for the transmission line are used to form a single transmission line of 200 Kms. The length of an individual block (as shown in fig.7.4) can be varied to create a desired fault at a desired location. The measurement window enables the user to measure the selected quantity of the line. We can select a number of phases for the single circuit or double circuit line. Here, six-phases have been chosen in order to meet the conductor requirements of TPDCS as well as of Six-phase system.

The resistance values for both the systems remain unchanged as the same conductor is used for simulation of both the systems. The values for the inductances and capacitances are different from one system to another. In the case of the Six-phase system, the inductances are higher and capacitances are lower, as against those of the TPDCS.

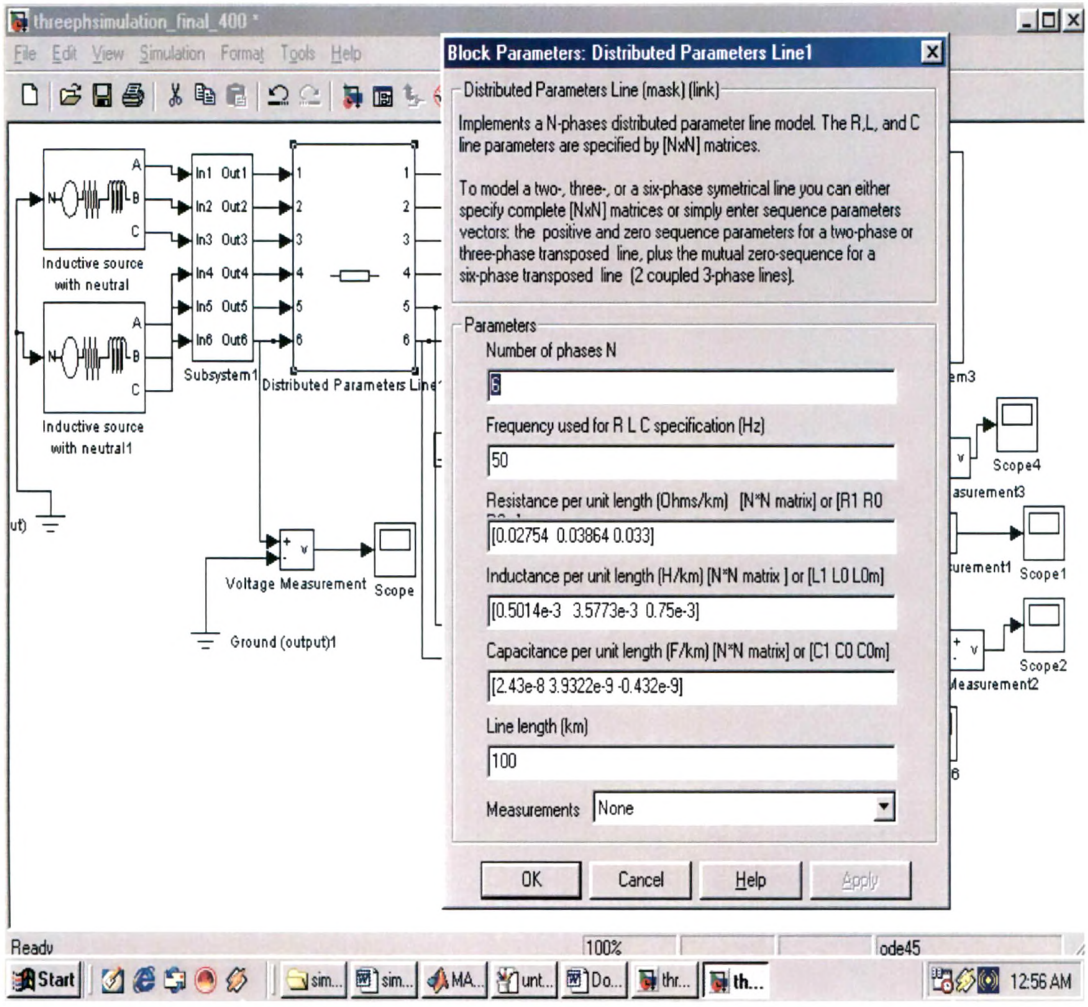


Fig. 7.4 Details of the Distributed Line Block parameters used in the Simulation

7.2.3 Internal Details of the Multi-meter:-

The fig. 7.5 illustrates the in-built facilities available in the Multi-meter block. The Multi-meter block does not require any physical connection for measuring the quantities in the simulation. However, the quantities that are selected to be measured in any of the predefined blocks, can be measured with the multi-meter. On pressing the refresh button of the Multi-meter block, the "Available Measurement Window" displays the final list of quantities intended to be measured. We can select or remove any desired quantity for the purpose of measurement. The finally selected quantities are displayed in the "Selected Measurement Window".

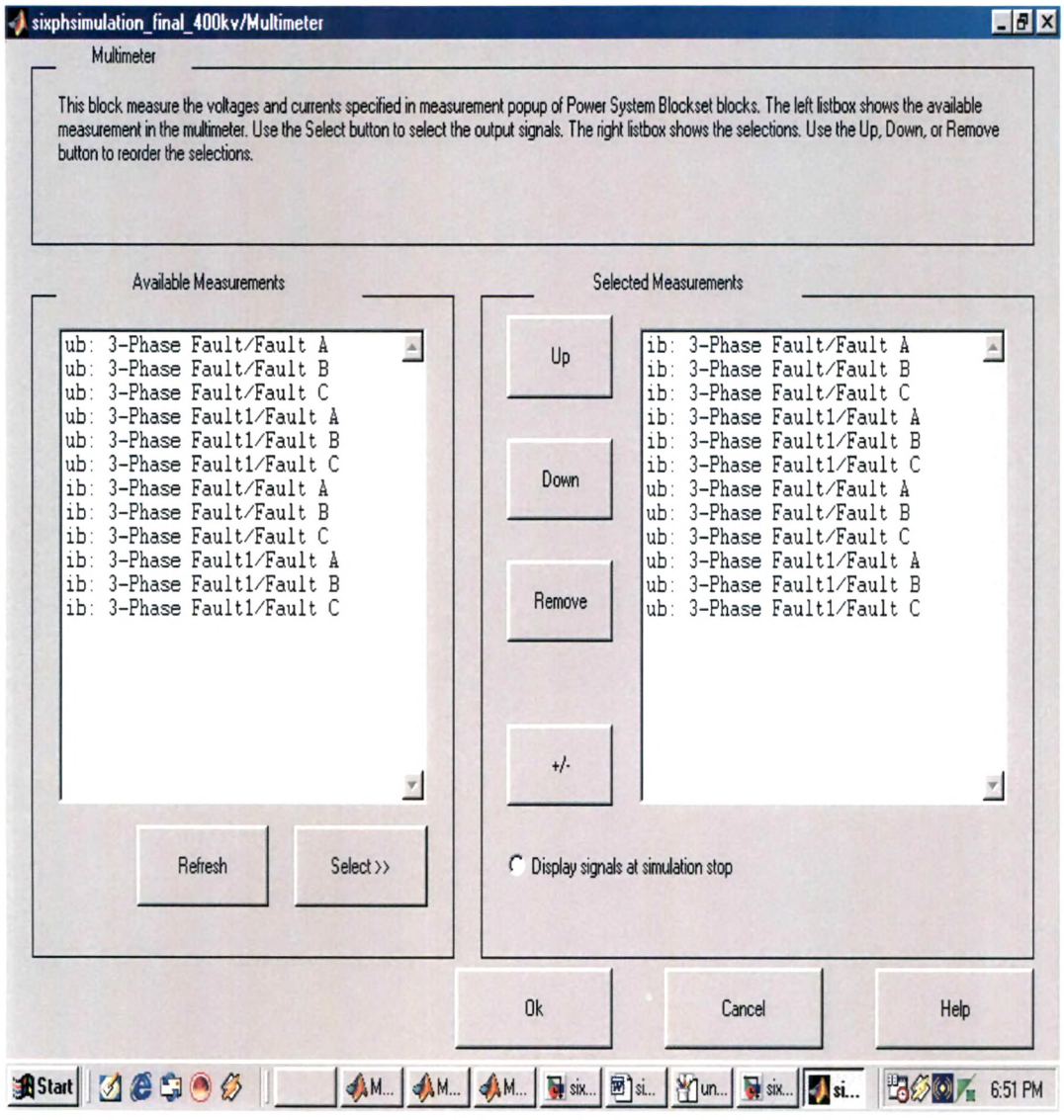


Fig.7.5 Internal Details of Multi-meter used in the Simulation

7.2.4 Mux Block:

This block (as shown in fig.7.6) is useful when more than one quantity is to be displayed simultaneously on a single CRO screen. It multiplexes the scalar or vector signal into bus. Here, for the purpose of simulation, the six inputs are selected to be displayed simultaneously.

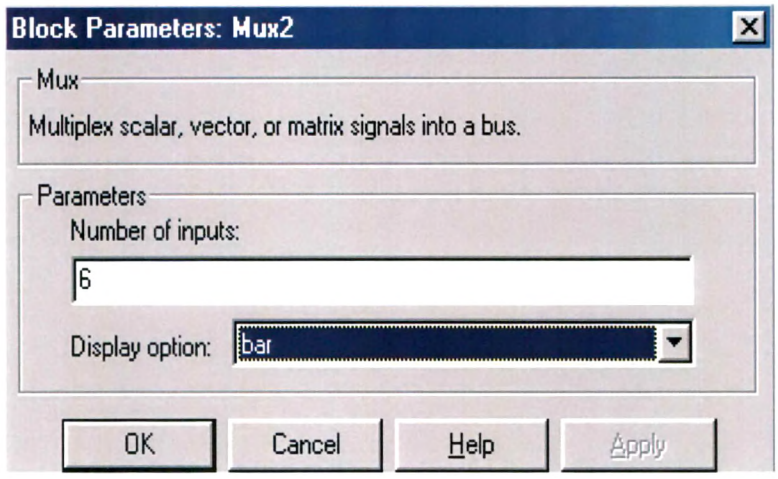


Fig. 7.6 Details of Mux Used in the Simulation

7.2.5 Voltage Measurement Block:-

The voltage measurement block (as shown in fig. 7.7) is actually a subsystem formed to measure voltage-to-ground of all the six lines of a TPDCS system.

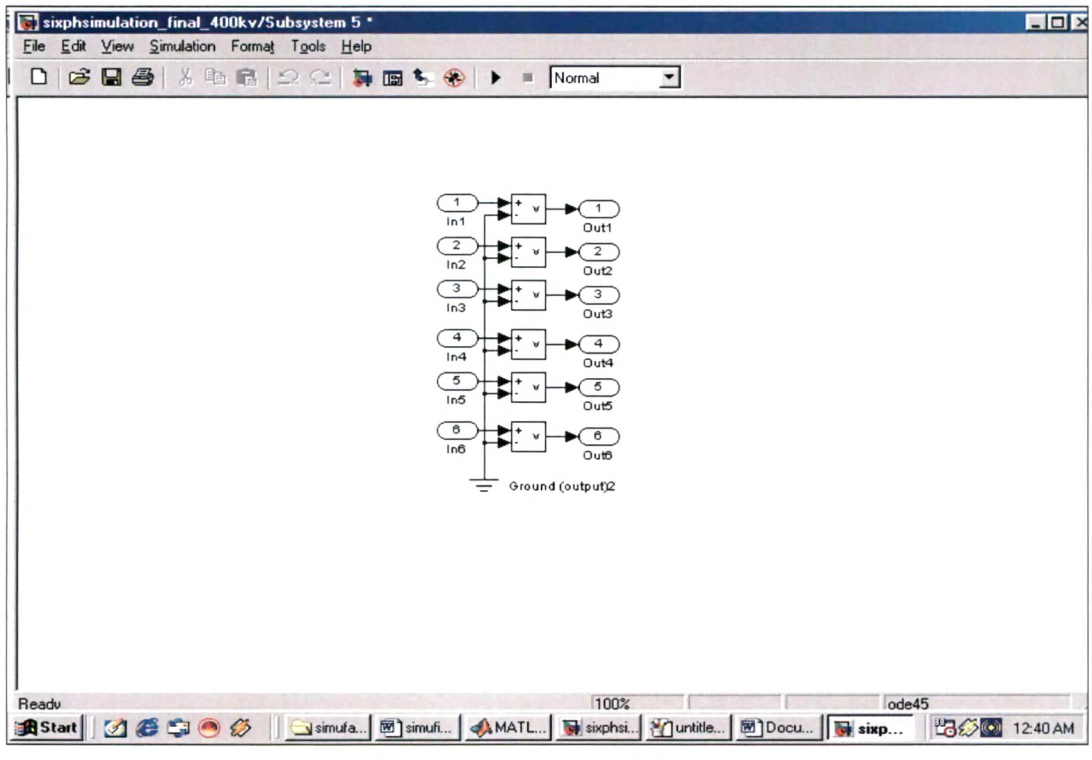


Fig. 7.7 Internal Diagram for the sub-system:5 used for the Voltage Measurement

7.2.6 Block Parameters for the Load subsystem:-

The RLC loads as shown in fig.7.8, for all the phases are same being operated at 25 KV and have the same values of active power; inductive reactive power; and capacitive reactive power for both the systems. The total load on each system is kept to be same for comparing the performance of each system.

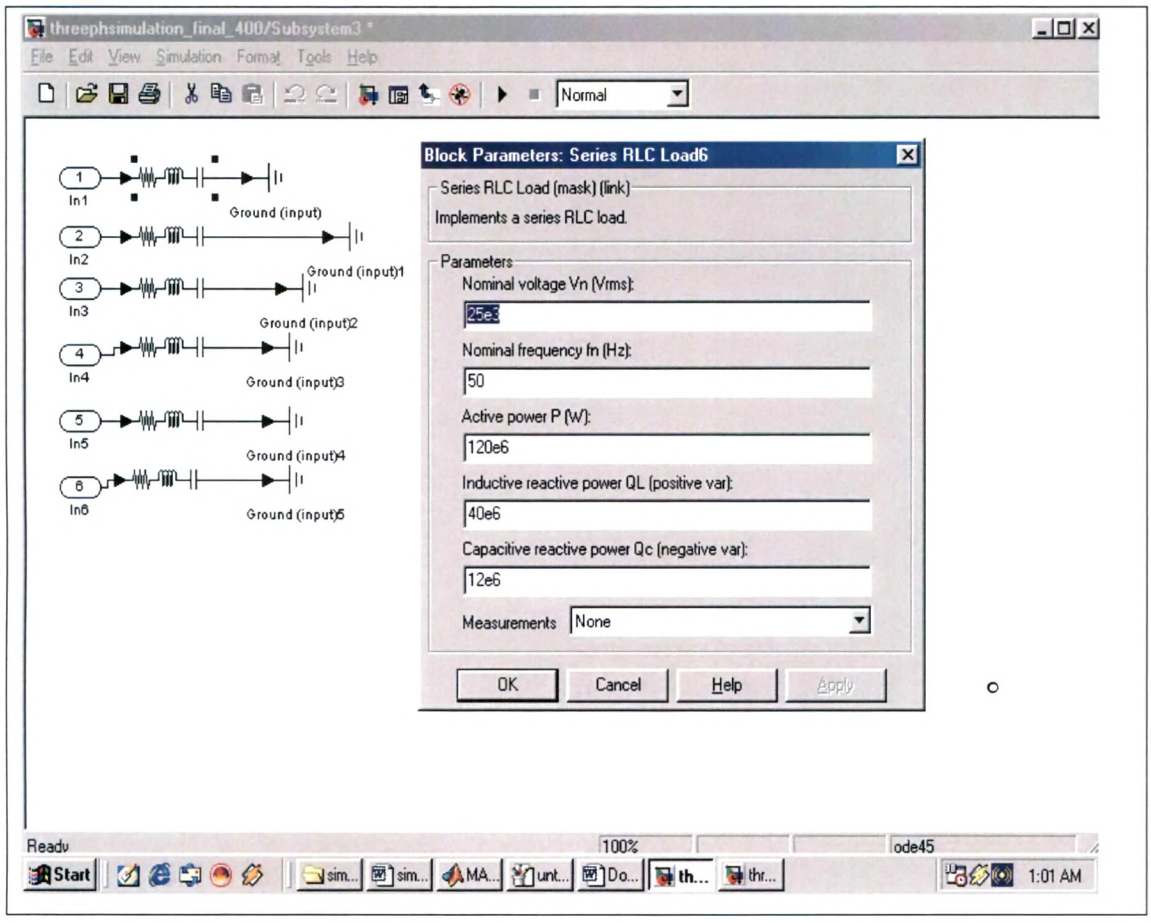


Fig 7.8 Details of the Load Sub-system and details of Load on each phase

The simulations for the different types of faults at the different locations are done and the various electrical quantities of the line are observed on CRO and the graphs for both the systems have been juxtaposed and illustrated.

7.3 SIX-PHASE SIMULATION MAIN CIRCUIT:-

The fig. 7.9 shows overall scheme for the simulation of the Six-phase Transmission System whose conversion is made from Three-phase Double Circuit (TPDCS), GETCO's 400 KV Line, forming the Main Circuit which comprises of many subsystems to circumscribe the whole scheme within a single screen for making it more comprehensive. The subsystem-2 at the sending end encapsulates the transformer pair to step up the generating voltage to 400 KV; while subsystem-1 at the Receiving End is used to step down the transmission voltage to Load voltage. The two "Distributed Parameter Blocks" have been incorporated for a given line length for creating the desired fault at the desired location, by varying the line length of each of the blocks. The Fault block can create a desired type of fault with different set parameters. The discussion about the subsystems incorporated in the main circuit is, however, made at length in the subsequent sections. The subsystem-4 in the Main Circuit is used for the measurement of various electrical properties of the line, when simulation is run.

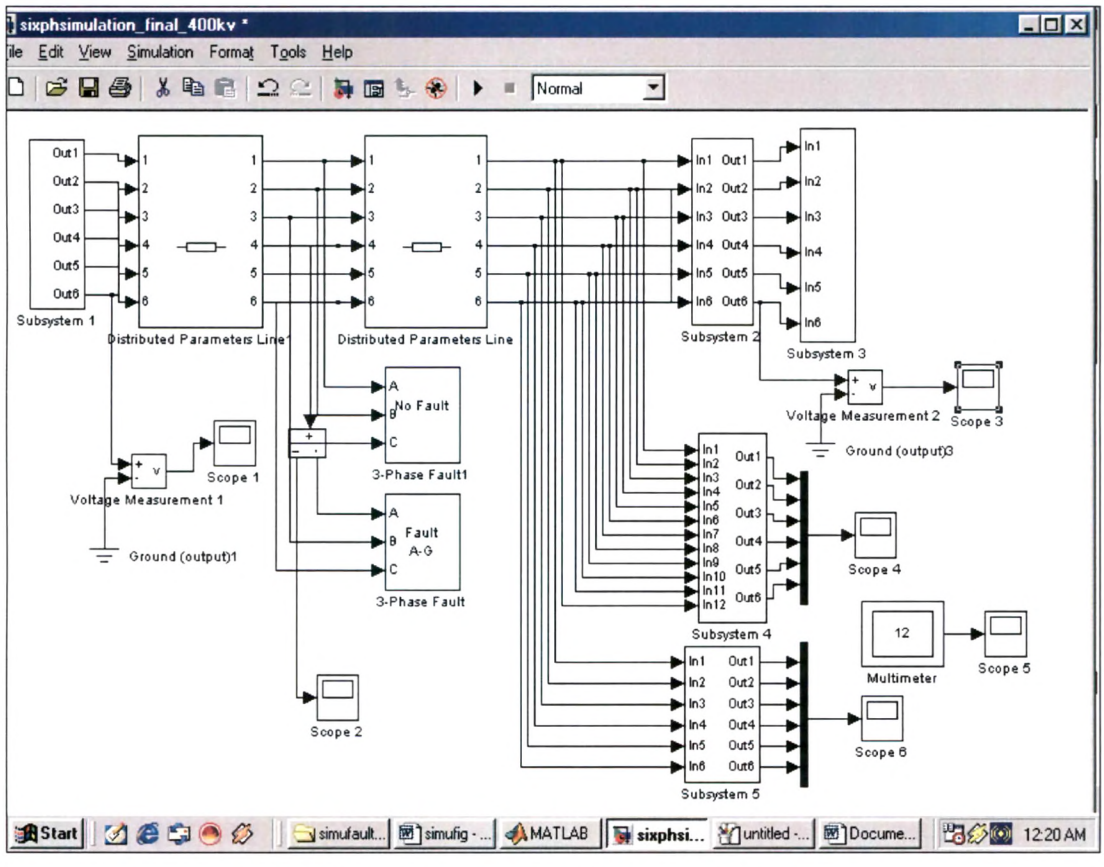


Fig. 7.9 Six-phase System Simulation overall view

7.3.1 Block Diagram of the Generators:-

The fig.7.10 shows the block diagram of the generators used for the input to the six-phase system. The generator parameters like voltage, frequency, Source resistance, Source inductance can be set to the desired values.

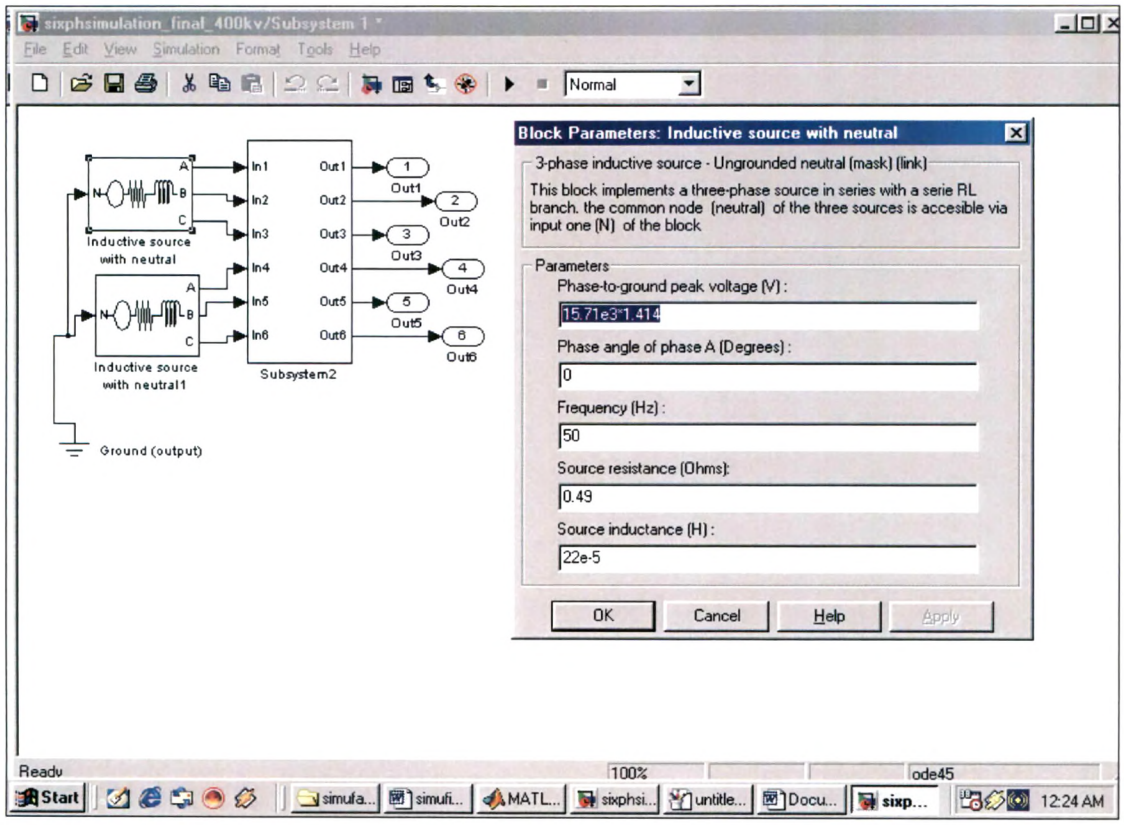


Fig. 7.10 Subsystem:1 Details of Generator Parameters

7.3.2 Connection Details of transformers used in Six-phase Transmission System:-

The fig.7.11 illustrates the connection details for converting the Three-phase supply in to the Six-phase. The Six-phase conversion is made by using two 12-terminals three phase transformers. The three-phase to Six-phase conversion is made by superimposing the 2-Three phase supplies displaced by 180^0 from each other to form the Six-phase supply. This is achieved by connecting the mid-point of each phase to ground. The Fig.7.12 illustrates the Six- phase to Three-phase conversion with the same pair of transformers placed in a mirror fashion at the receiving end of the transmission line.

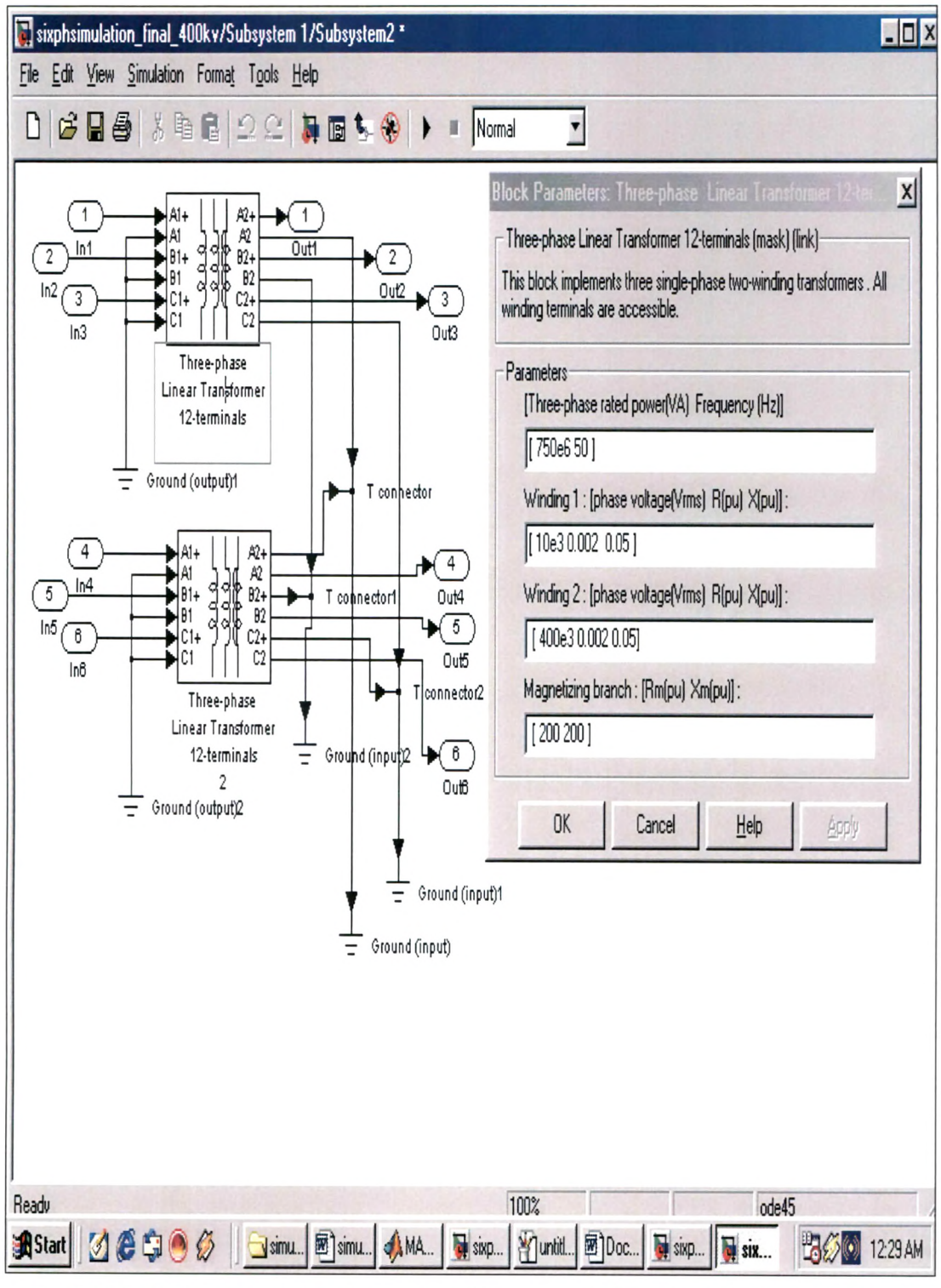


Fig.7.11 Sub-Subsystem:1/2 Connection Diagram and Details of the 3-phase Twelve Terminal Transformers Used for the conversion of Three-phase to 6-phase at S.E.

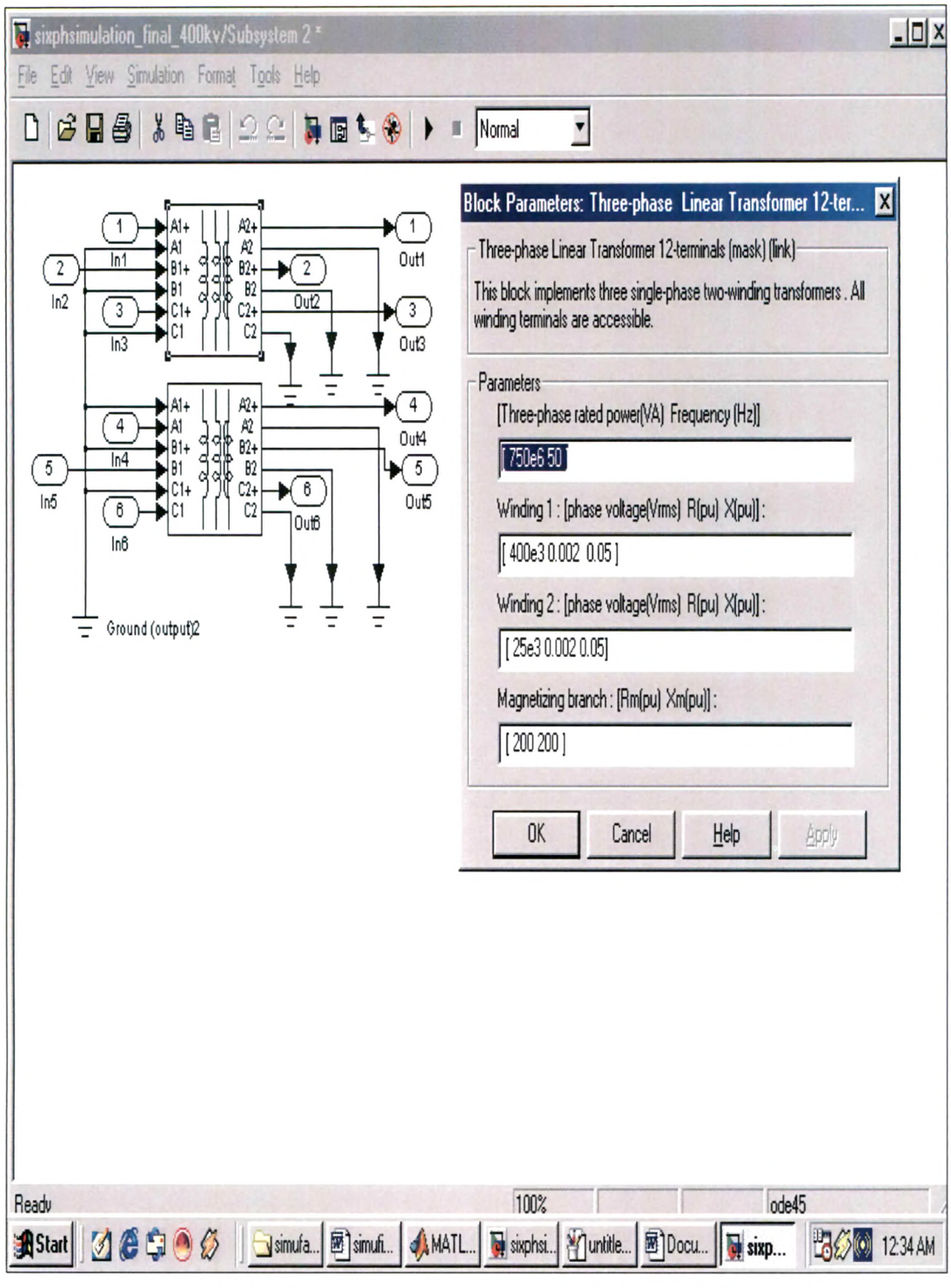
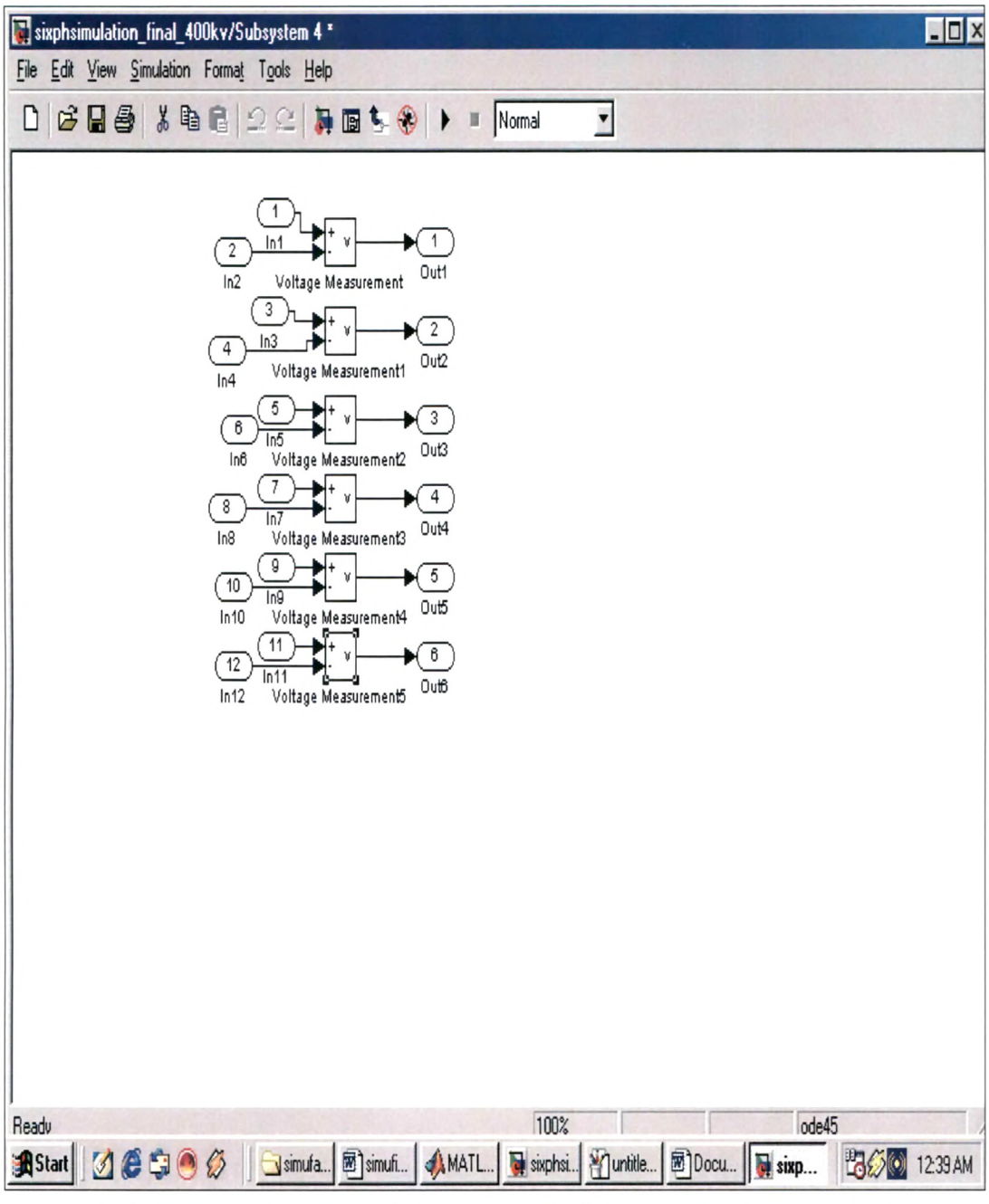


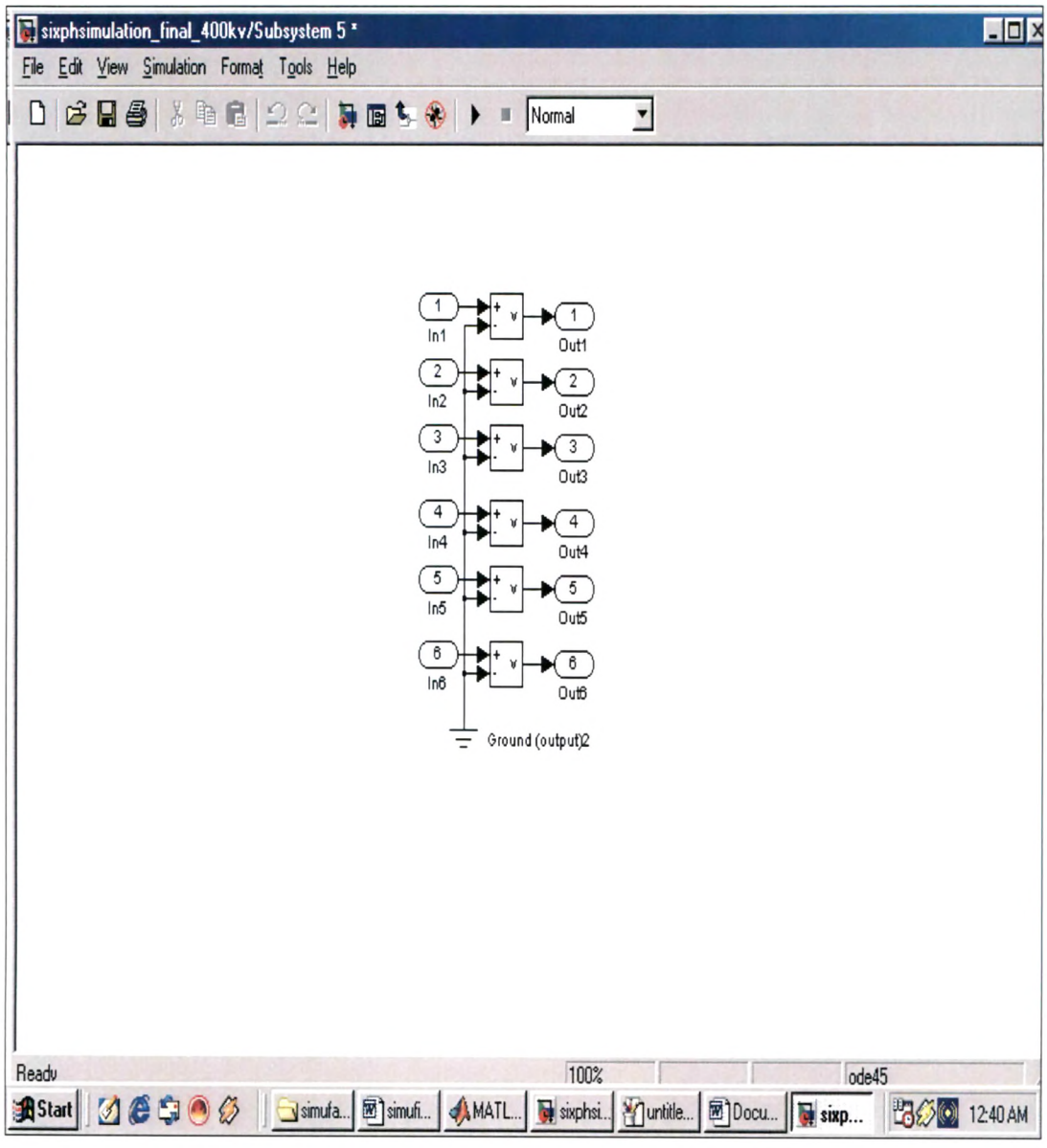
Fig.7.12 Subsystem:2 Connection Diagram and Details of the Three-phase Twelve Terminal Transformers Used for the conversion of Six-phase to Three-phase at R.E.

7.3.3 Internal Diagram of the Sub-Systems 2 & 3:

Fig. 7.13 & 7.14 illustrates the internal diagram of the subsystem used in the simulation



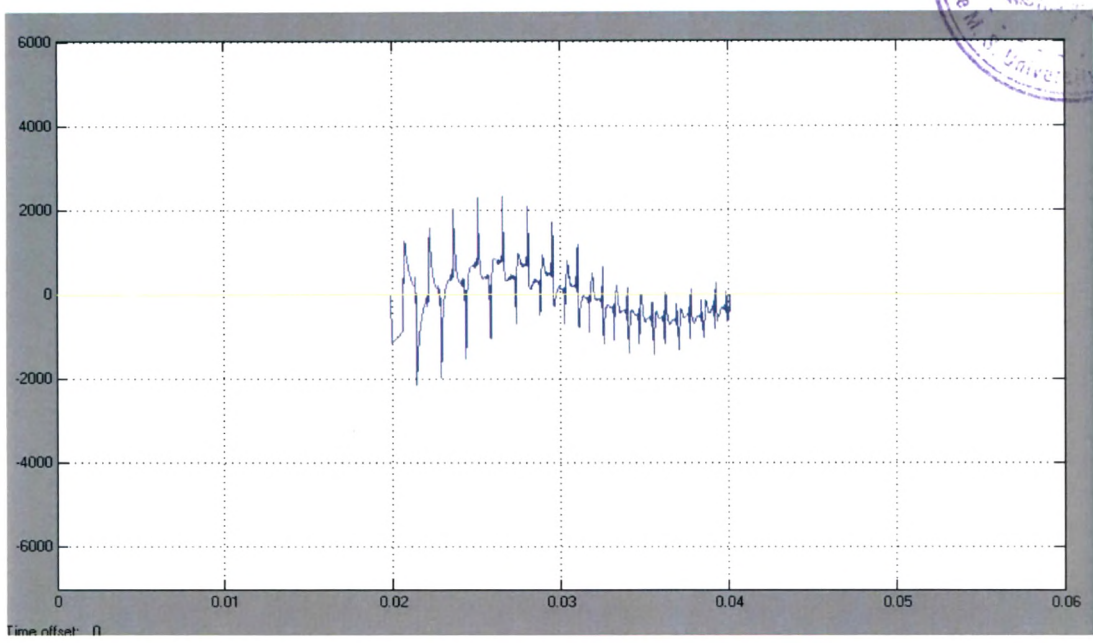
7.13 Internal Diagram of Subsystem: 4 for Line Voltage Measurement



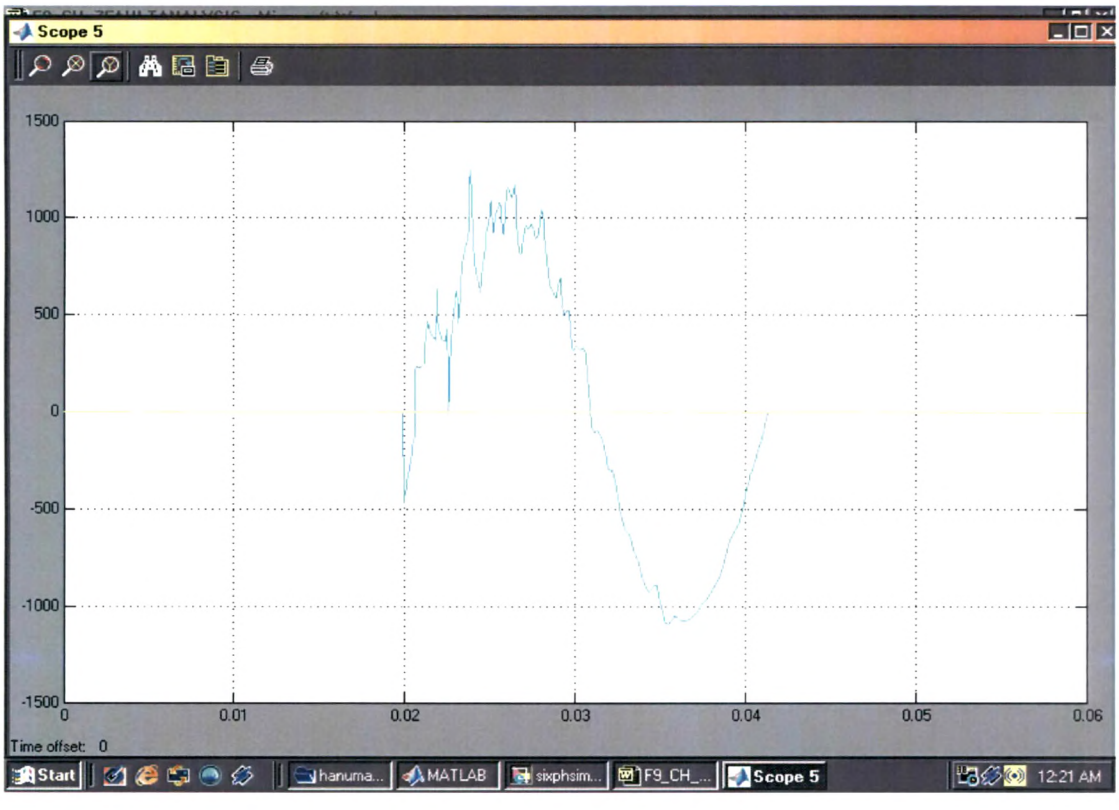
7.14 Internal Diagram of Subsystem: 5 for Phase Voltage Measurement

7.4 SIMULATION RESULTS:-

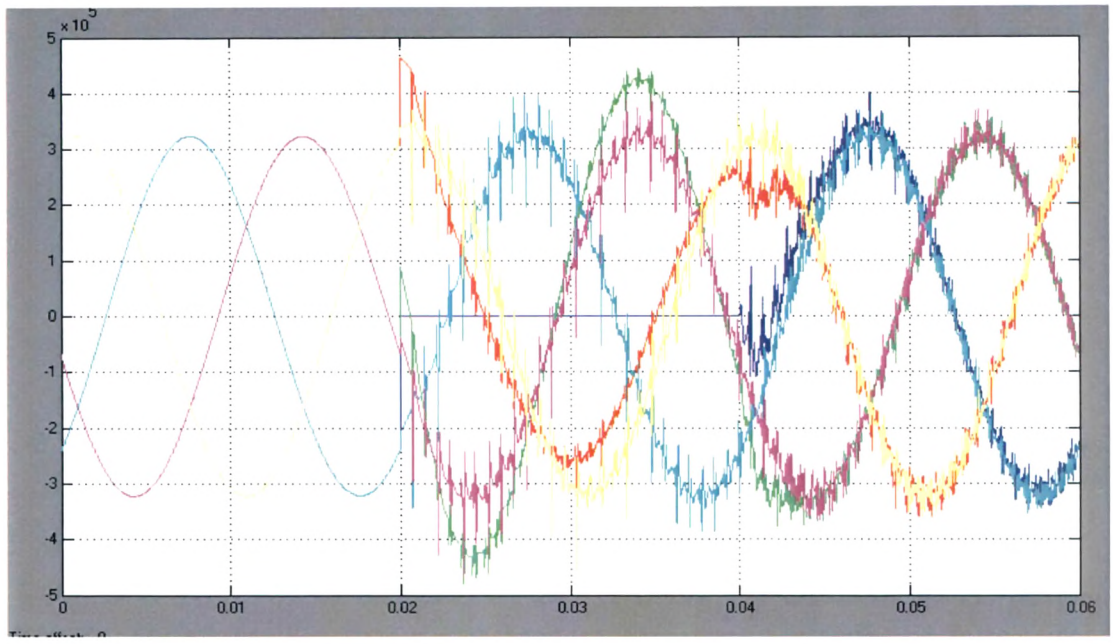
The results of the simulation of both the systems (TPDCS and Six-phase) have been obtained in the form of graphs showing currents and voltages for the different types of faults at various locations. The simulation graphs of both the systems are juxtaposed and illustrated below, for a comparative study of the systems.



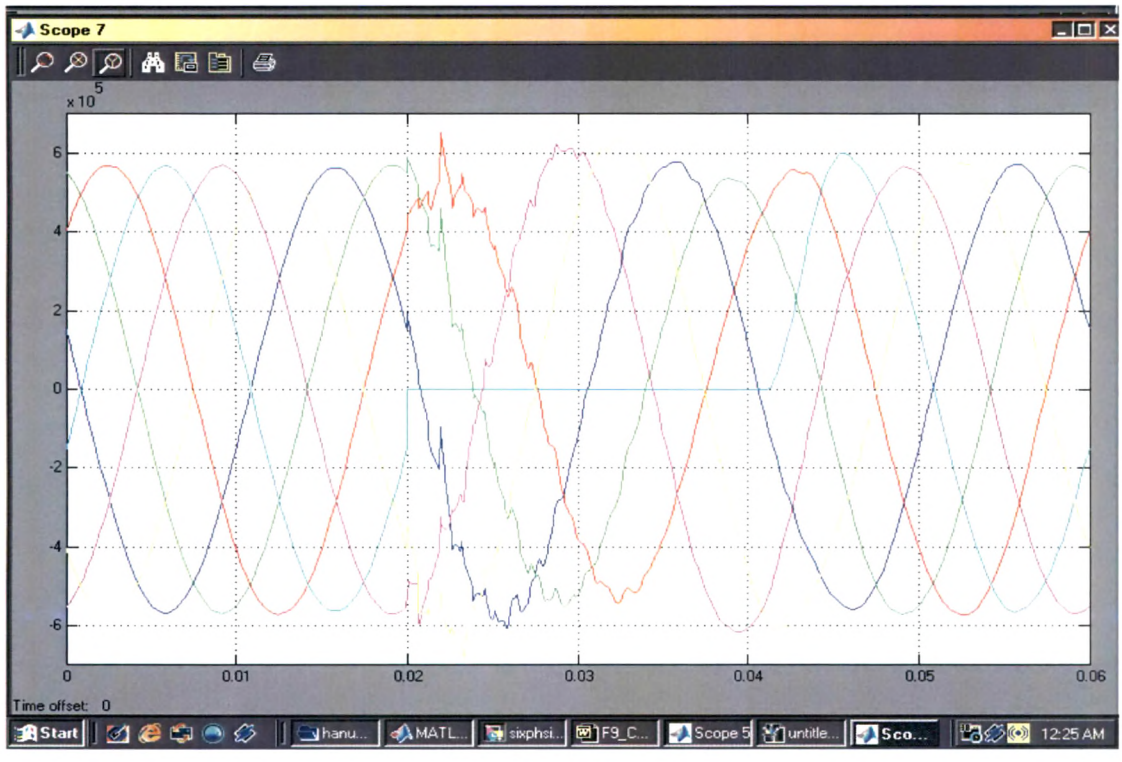
Fault Current for fault Phase to Ground in TPDCS at Mid-point



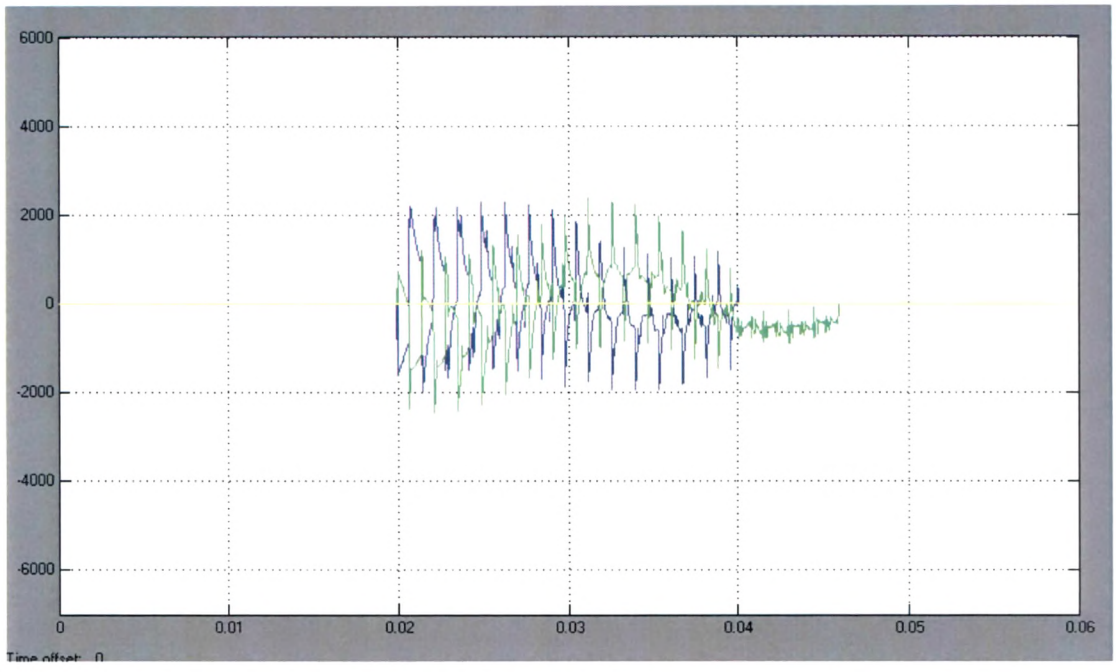
Fault Current for fault Phase to Ground in Six-Phase at Mid-point



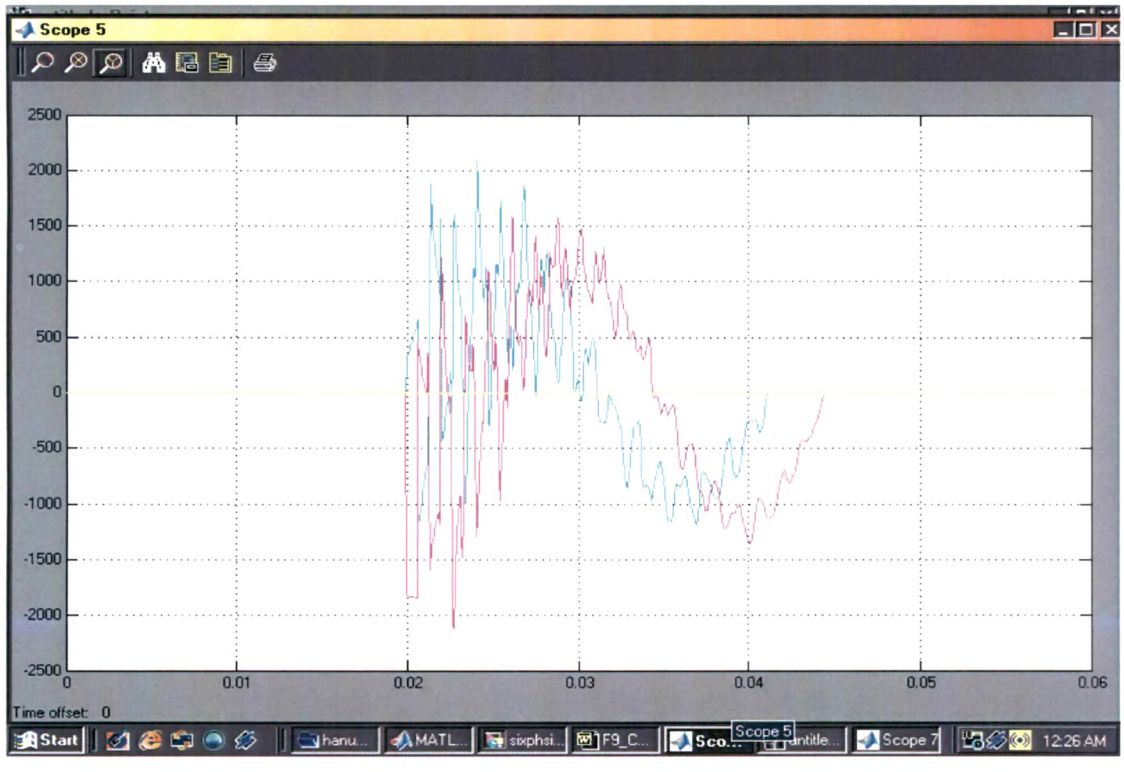
Fault Voltages for fault Phase to Ground in TPDCS at Mid-point



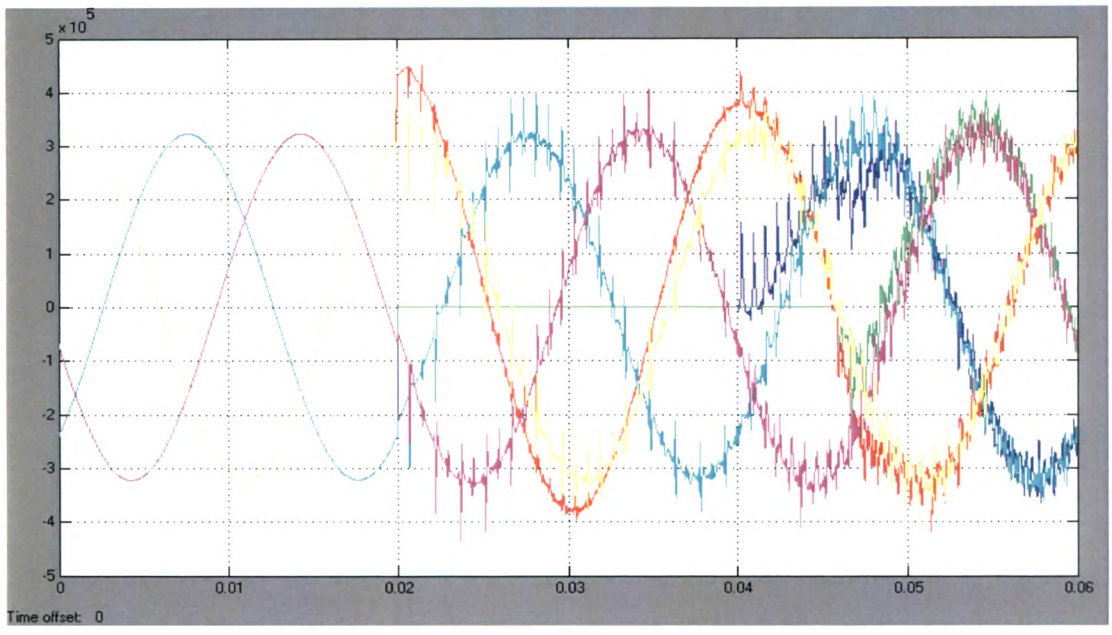
Fault Voltages for fault Phase to Ground in Six-Phase at Mid-point



Fault currents for fault Double Phase to Ground in TPDCS at Mid-point

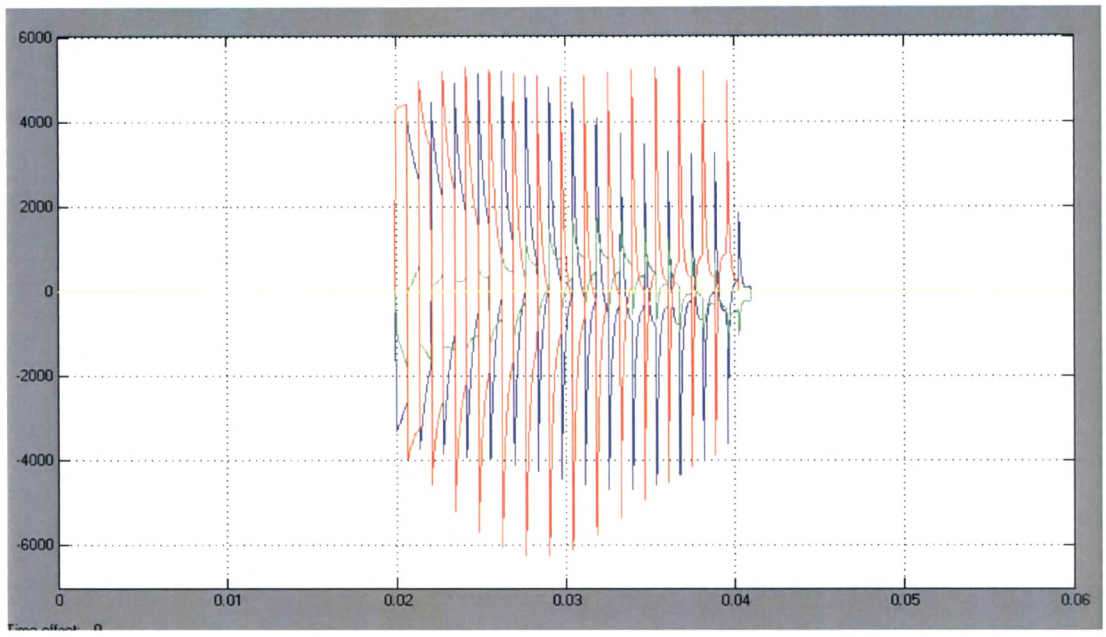


Fault Current for fault Double Phase to Ground in Six-Phase at Mid-point

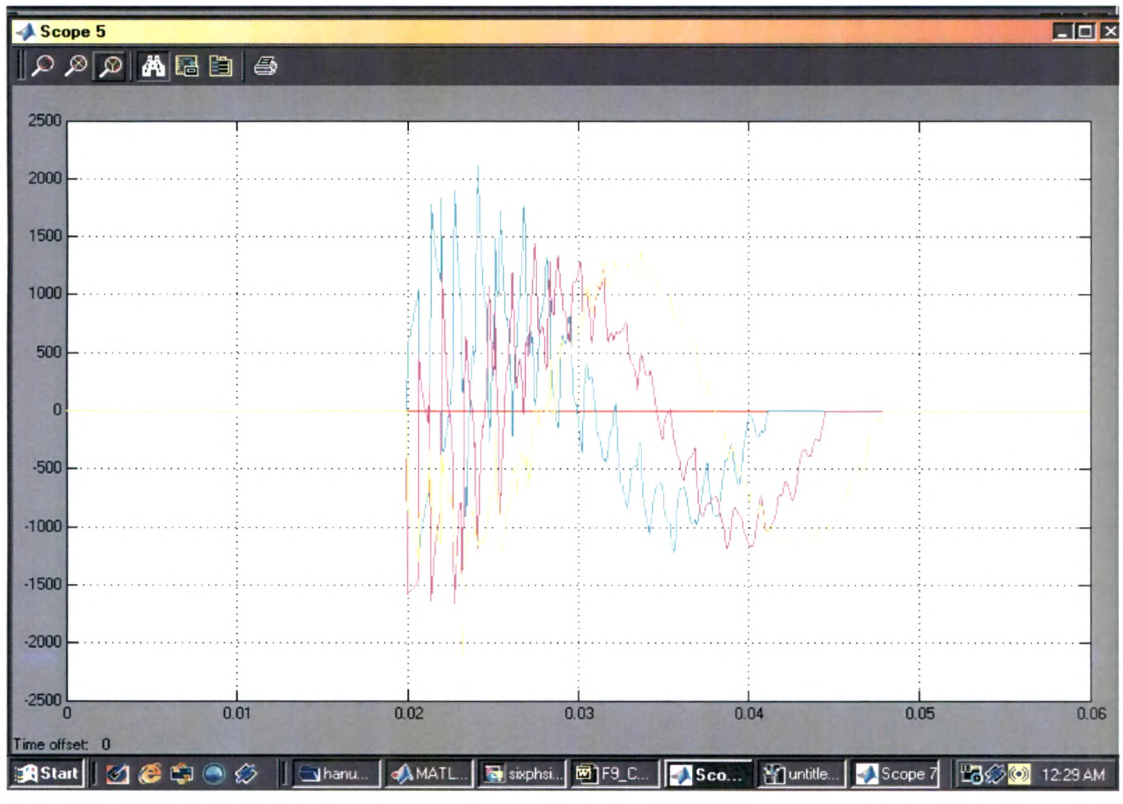


Fault Voltages for fault Double Phase to Ground in TPDCS at Mid-point

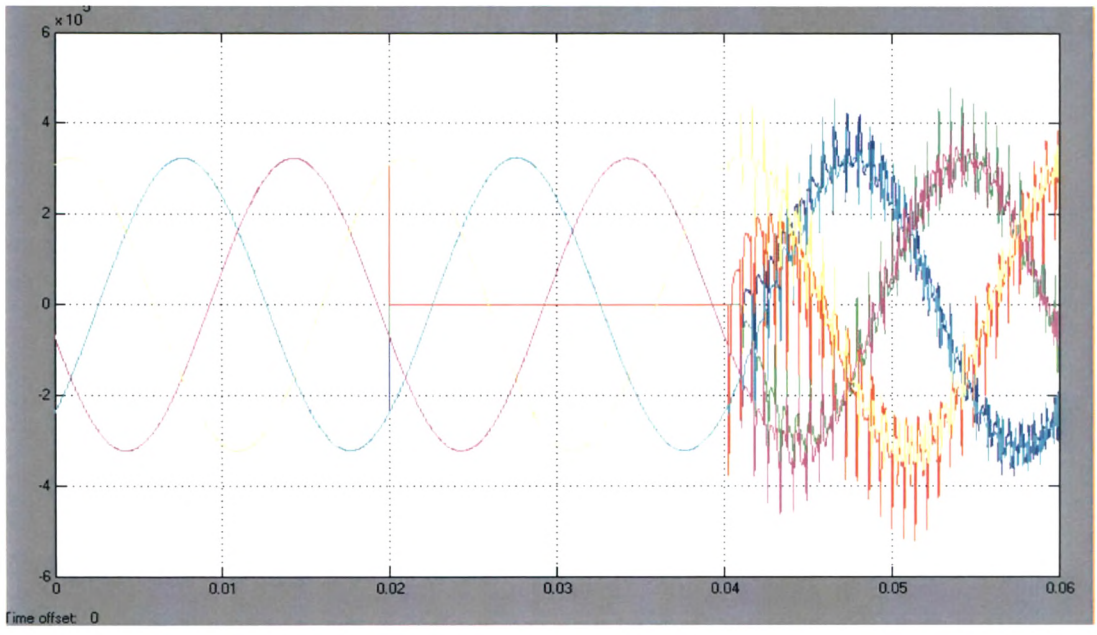
Fault Voltages for fault Double Phase to Ground in Six-Phase at Mid-point



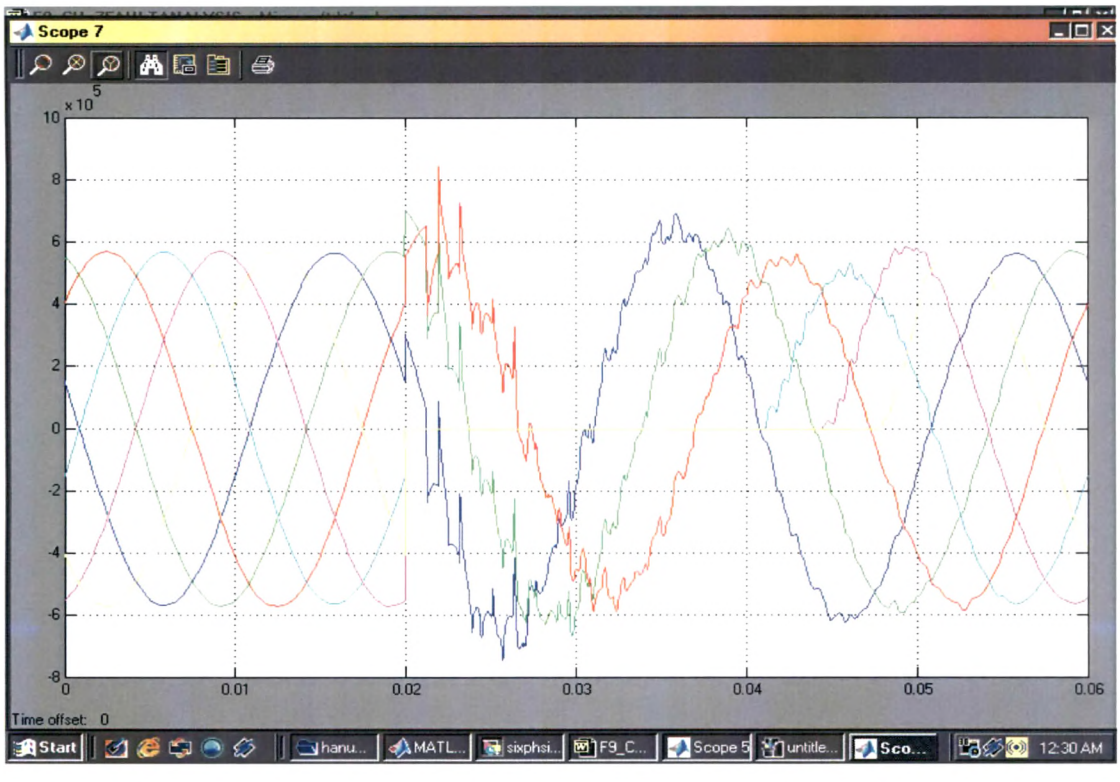
Fault Currents for fault Triple Phase to Ground in TPDCS at Mid-point



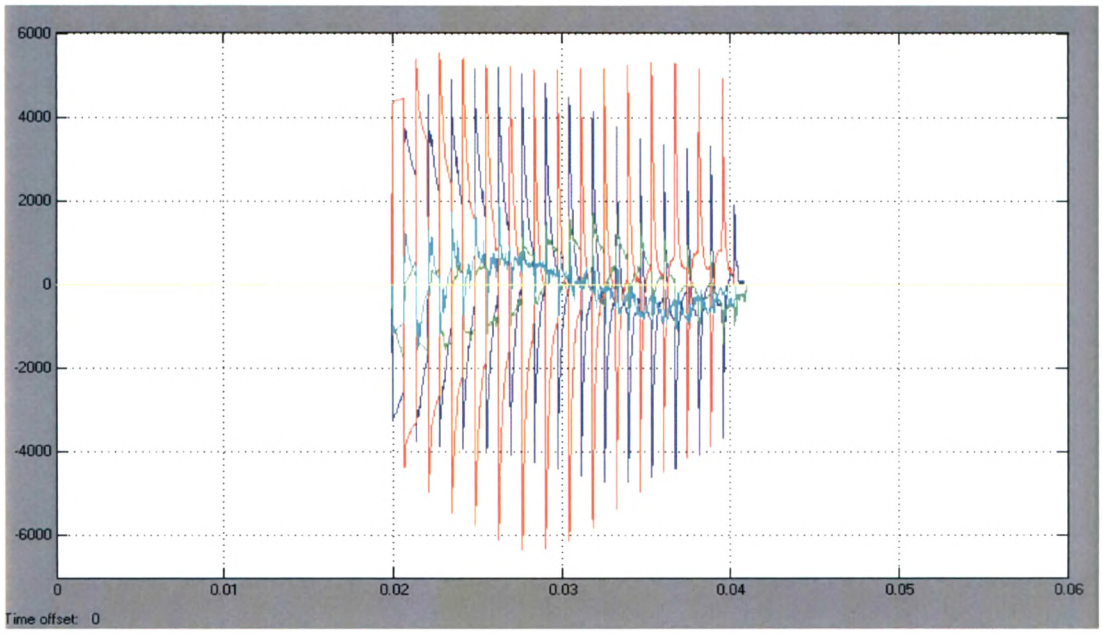
Fault Current for fault Triple Phase to Ground in Six-Phase at Mid-point



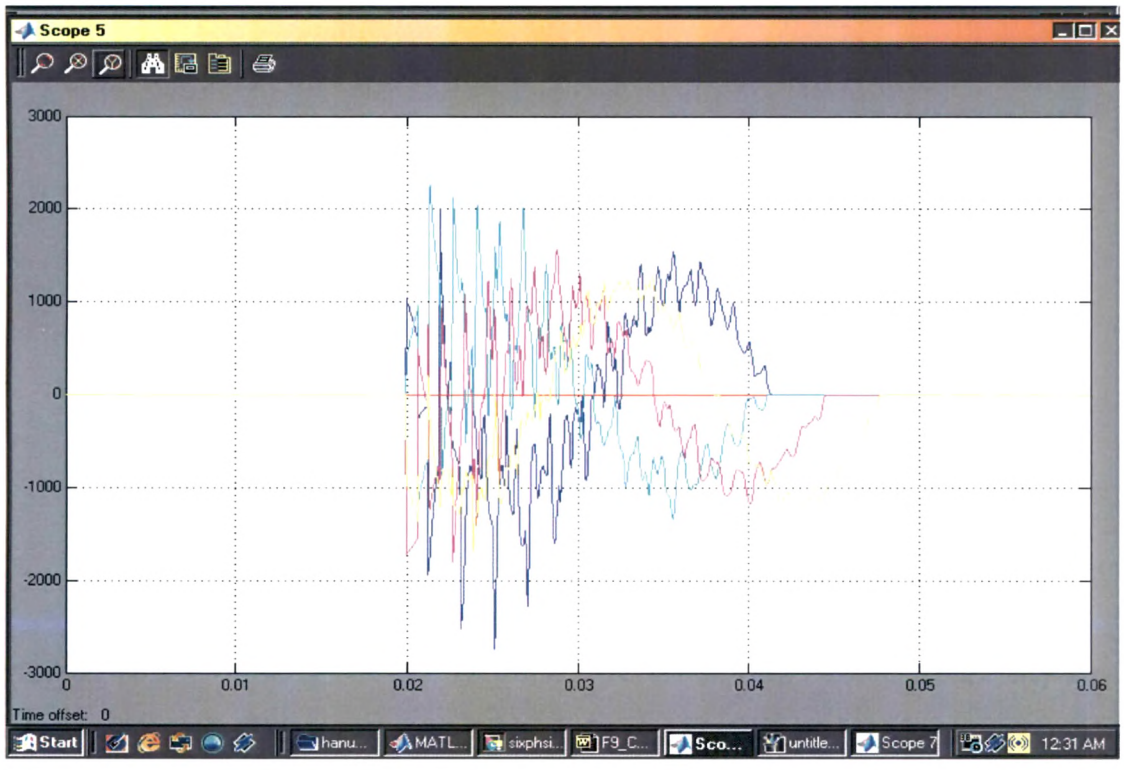
Fault Voltages for fault Triple Phase to Ground in TPDCS at Mid-point



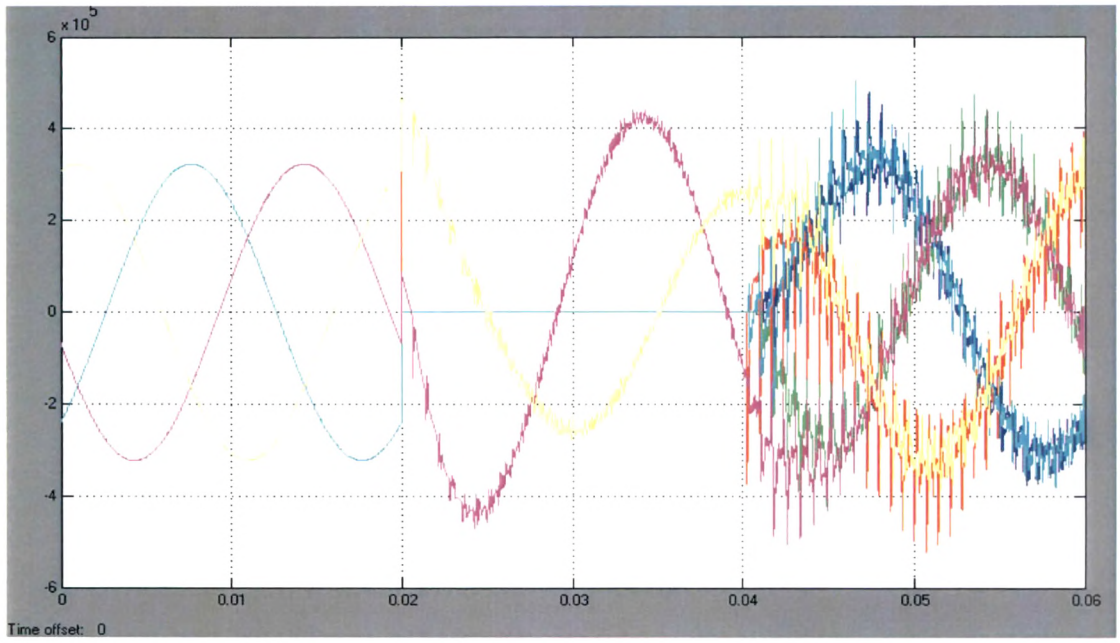
Fault Voltages for fault Triple Phase to Ground in Six-Phase at Mid-point



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

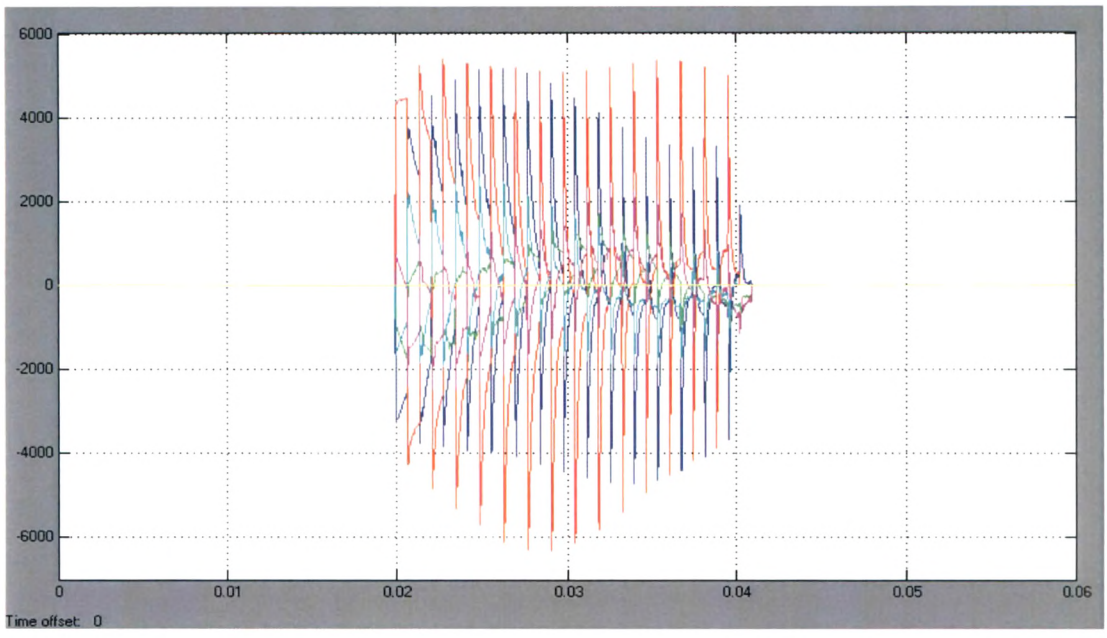


Fault Current for fault Four Phase to Ground in Six-Phase at Mid-point

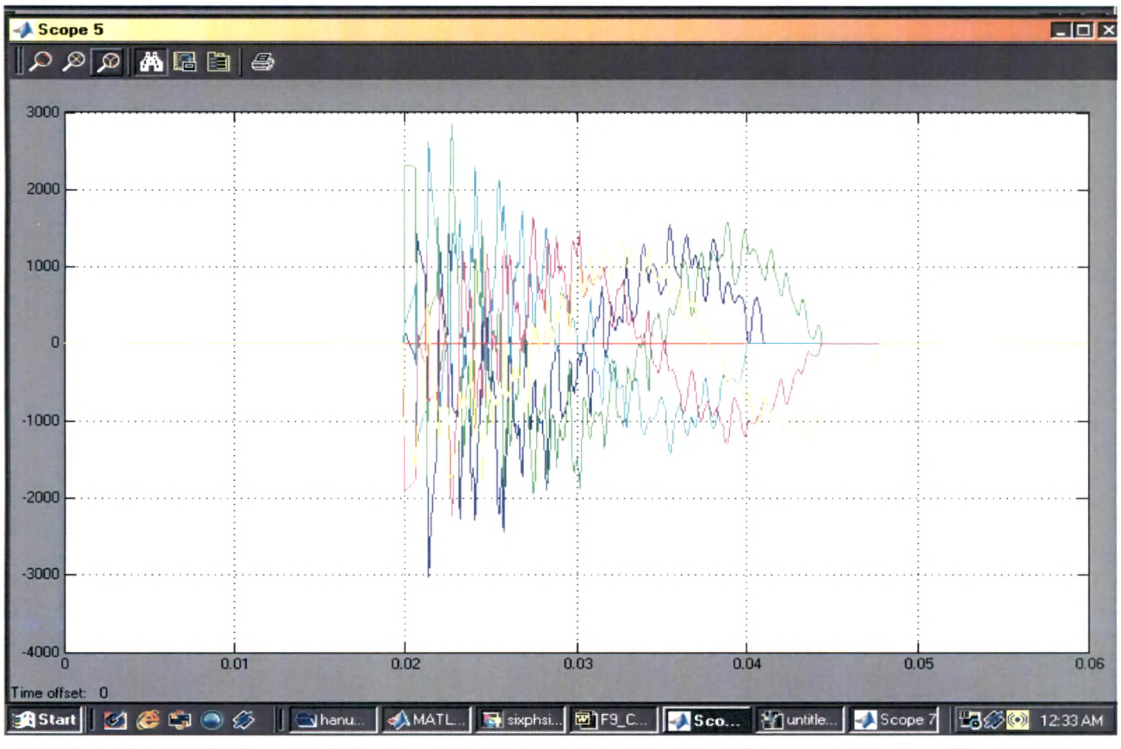


Fault Voltages for fault Four Phase to Ground in TPDCS at Mid-point

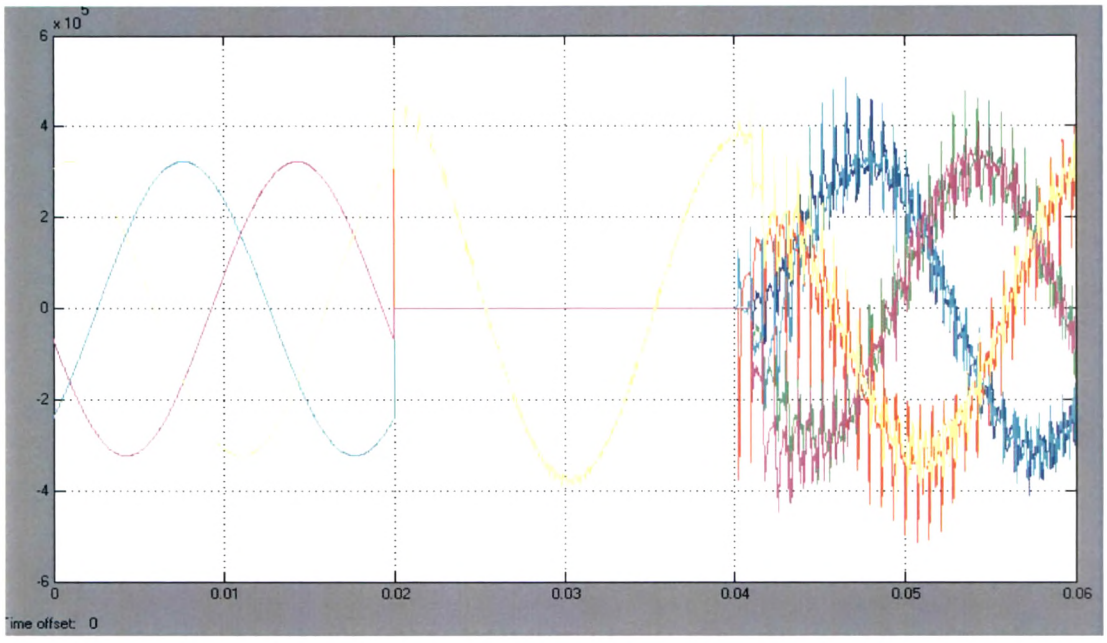
Fault Voltages for fault Four Phase to Ground in Six-Phase at Mid-point



Fault Currents for fault Five Phase to Ground in TPDCS at Mid-point

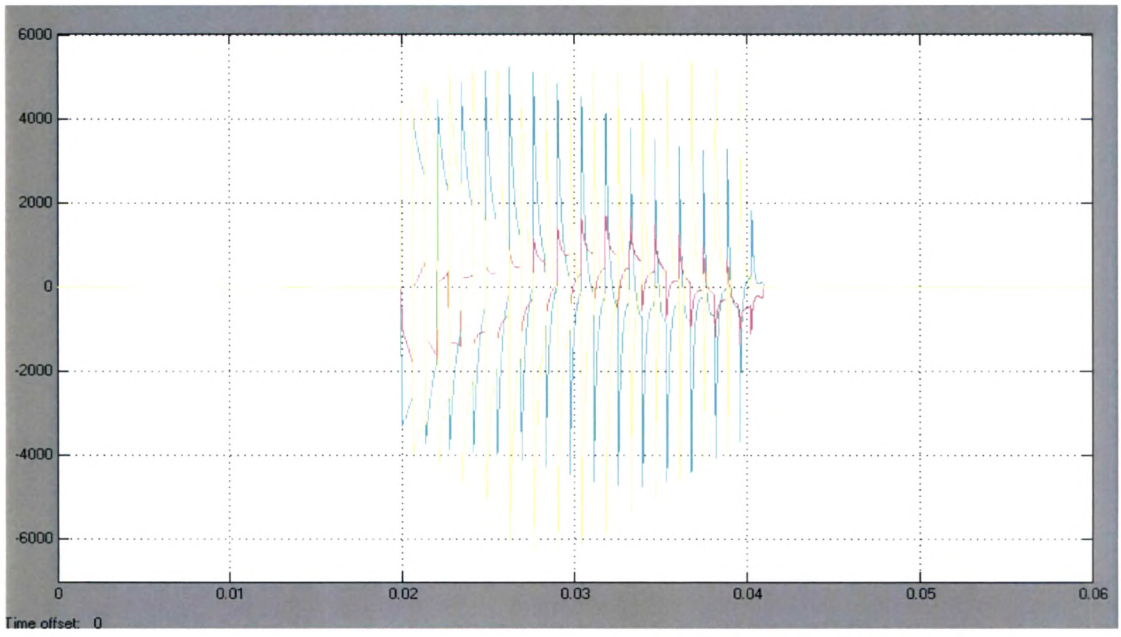


Fault Current for fault five Phase to Ground in Six-Phase at Mid-point

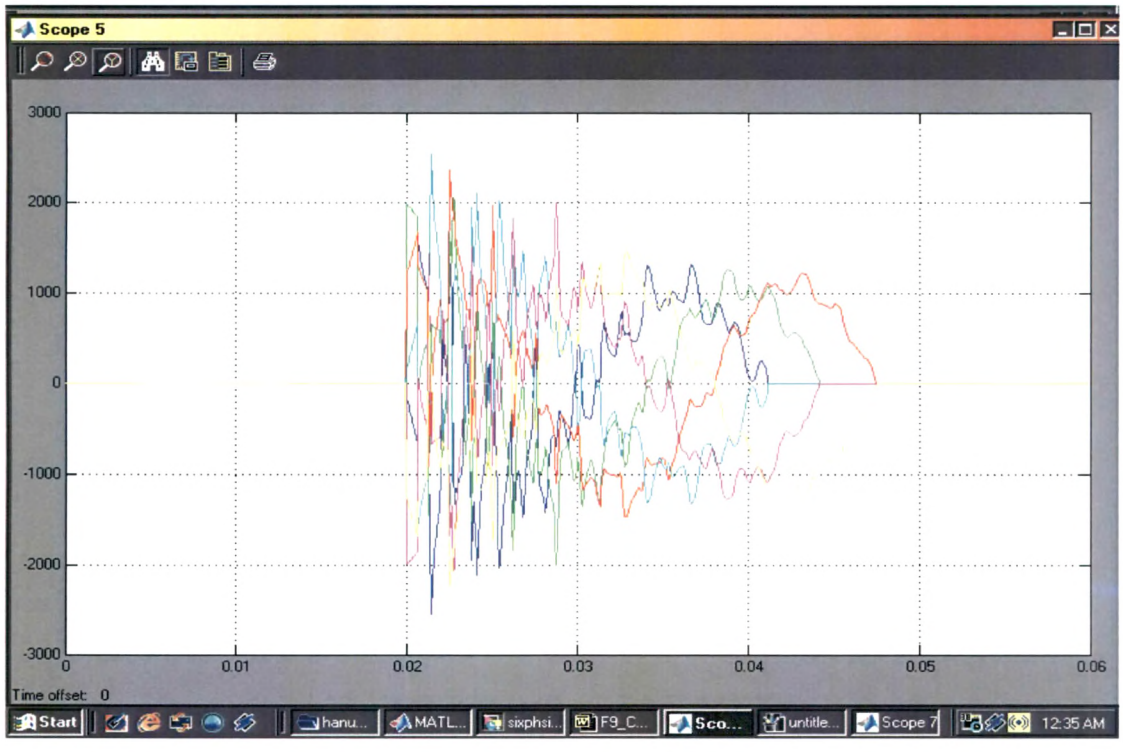


Fault Voltages for fault Five Phase to Ground in TPDCS at Mid-point

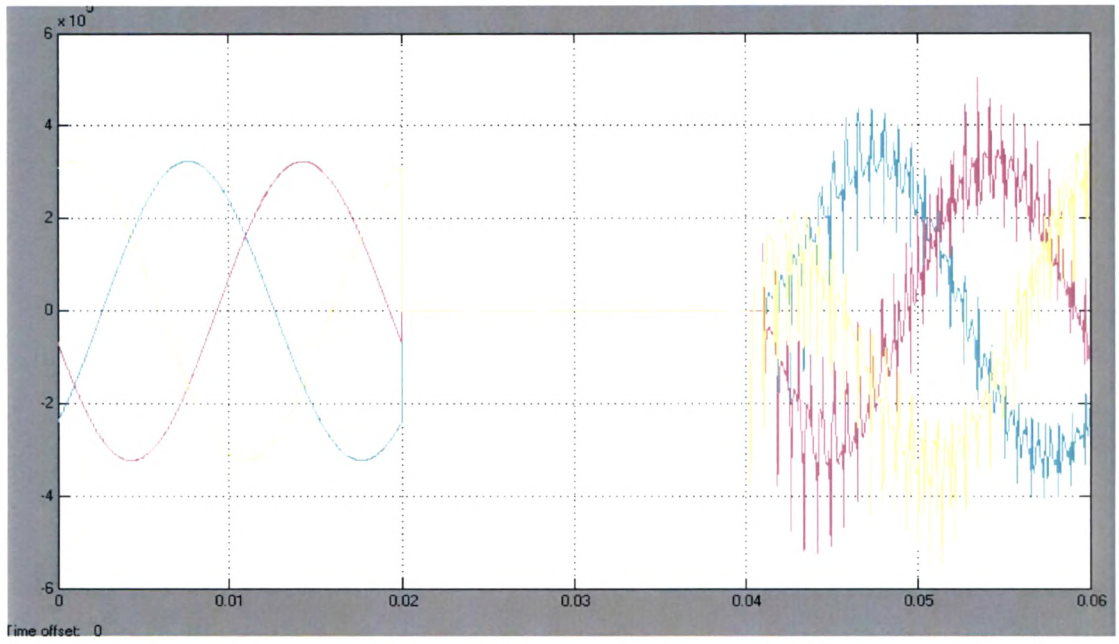
Fault Voltages for fault Five Phase to Ground in Six-Phase at Mid-point



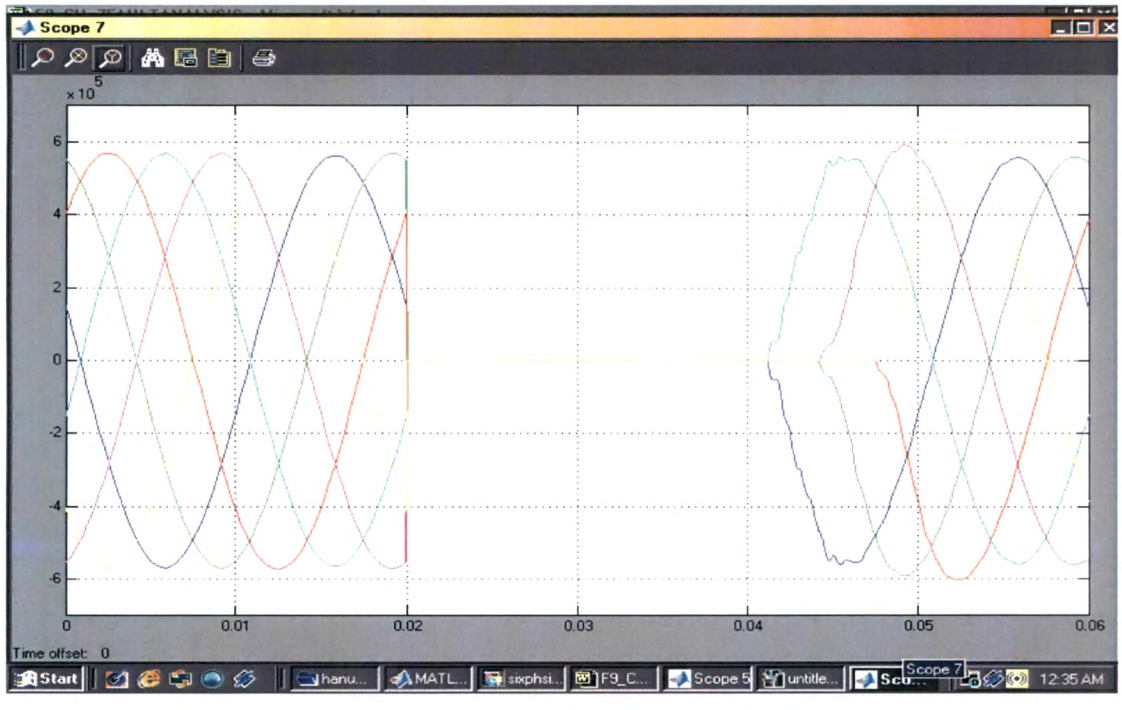
Fault Currents for fault Six Phase to Ground in TPDCS at Mid-point



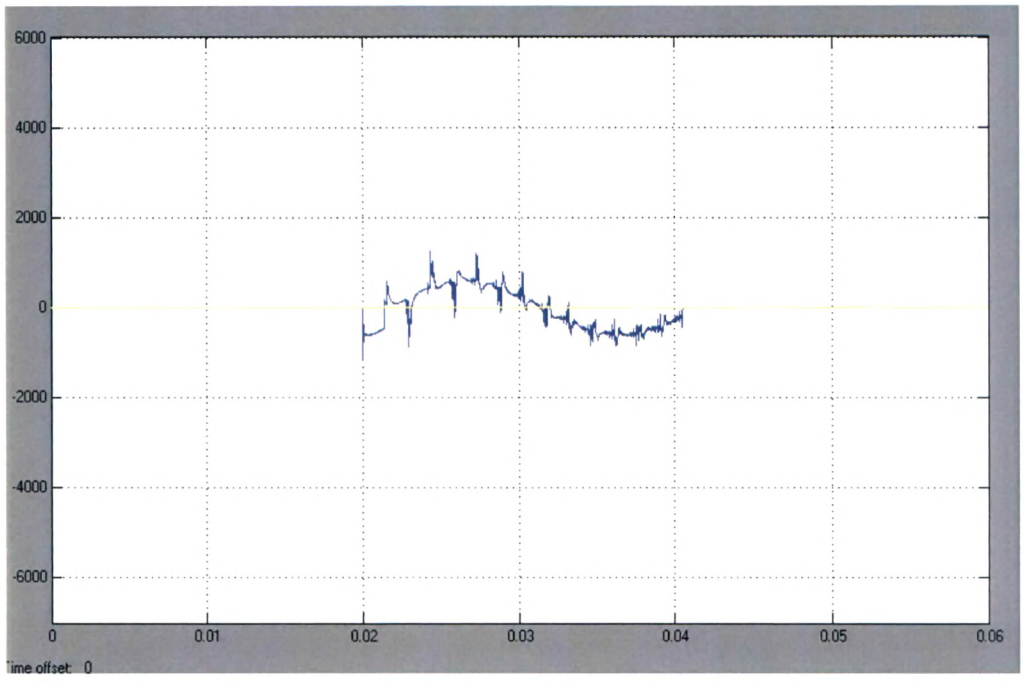
Fault Current for fault Six Phase to Ground in Six-Phase at Mid-point



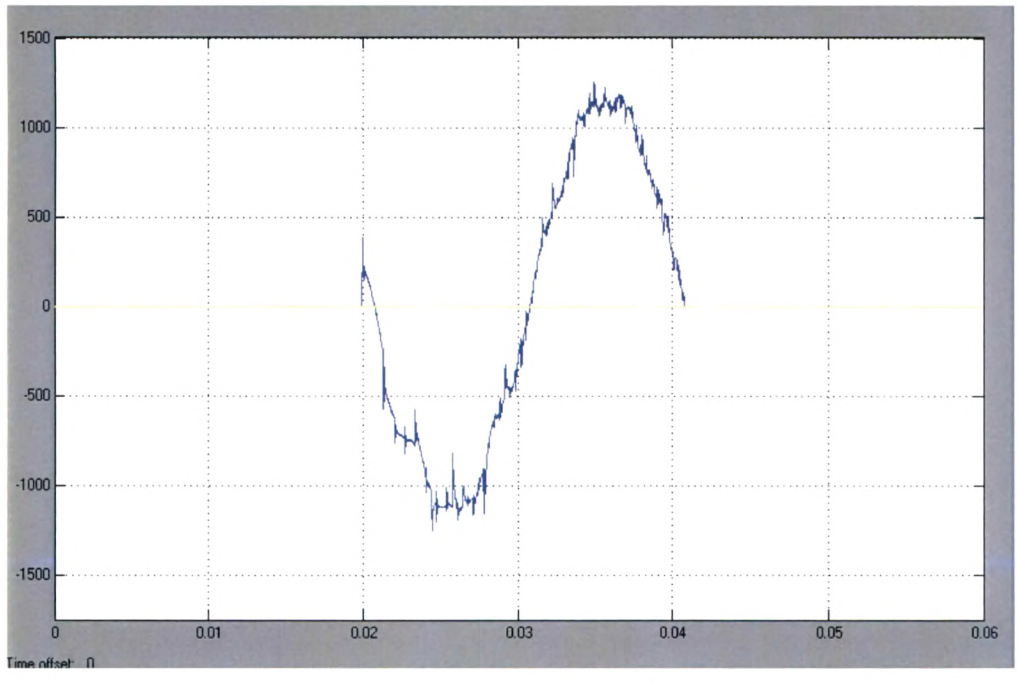
Fault Voltages for fault Six Phase to Ground in TPDCS at Mid-point



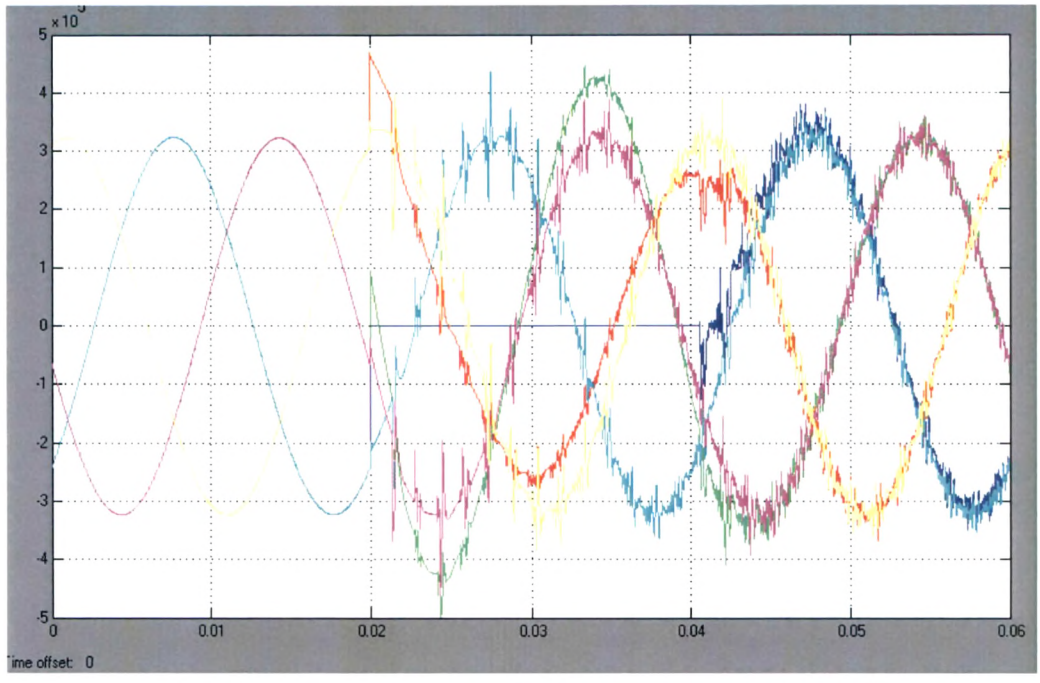
Fault Voltages for fault Six Phase to Ground in Six-Phase at Mid-point



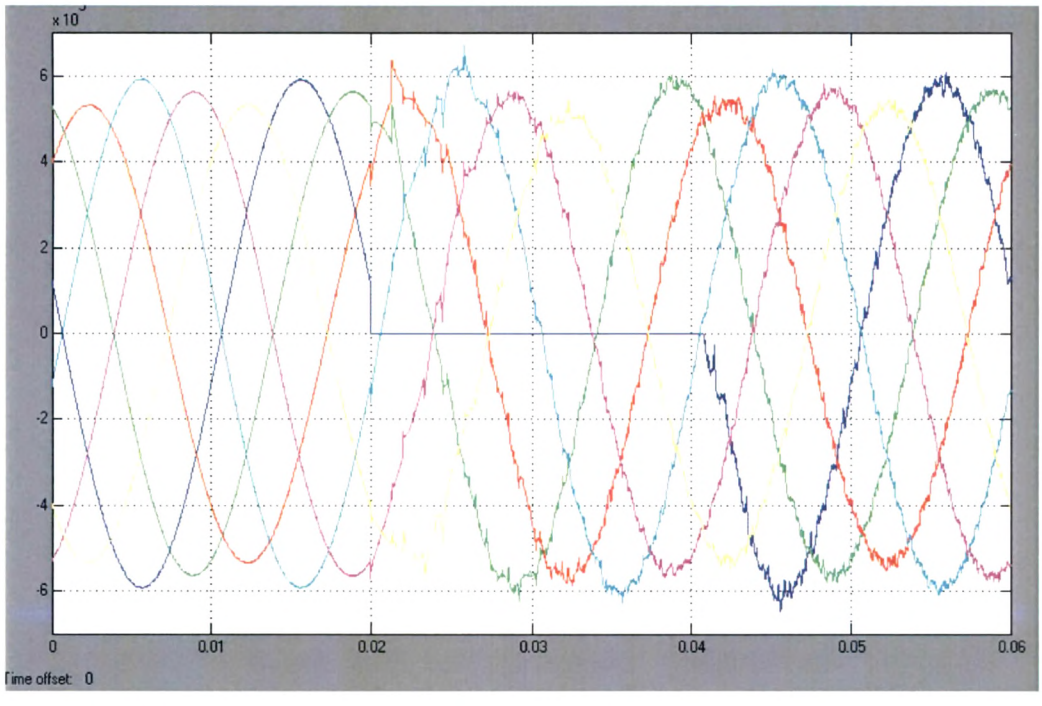
Fault Currents for phase to Ground Fault on TPDCS at Receiving End



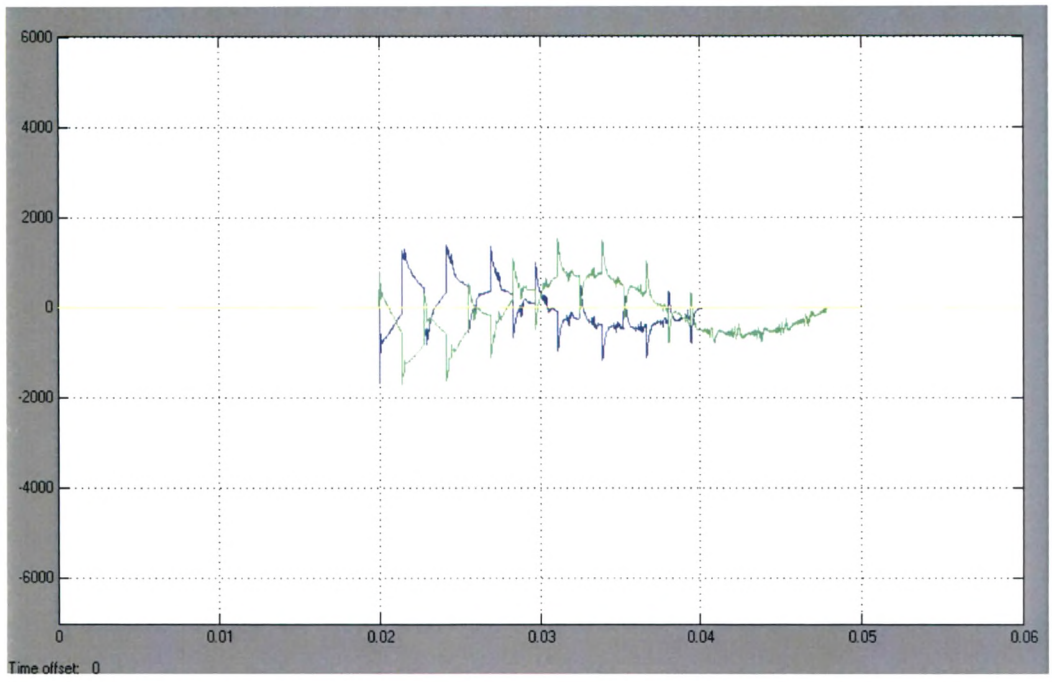
Fault Current for fault Phase to Ground in Six-Phase at Receiving End



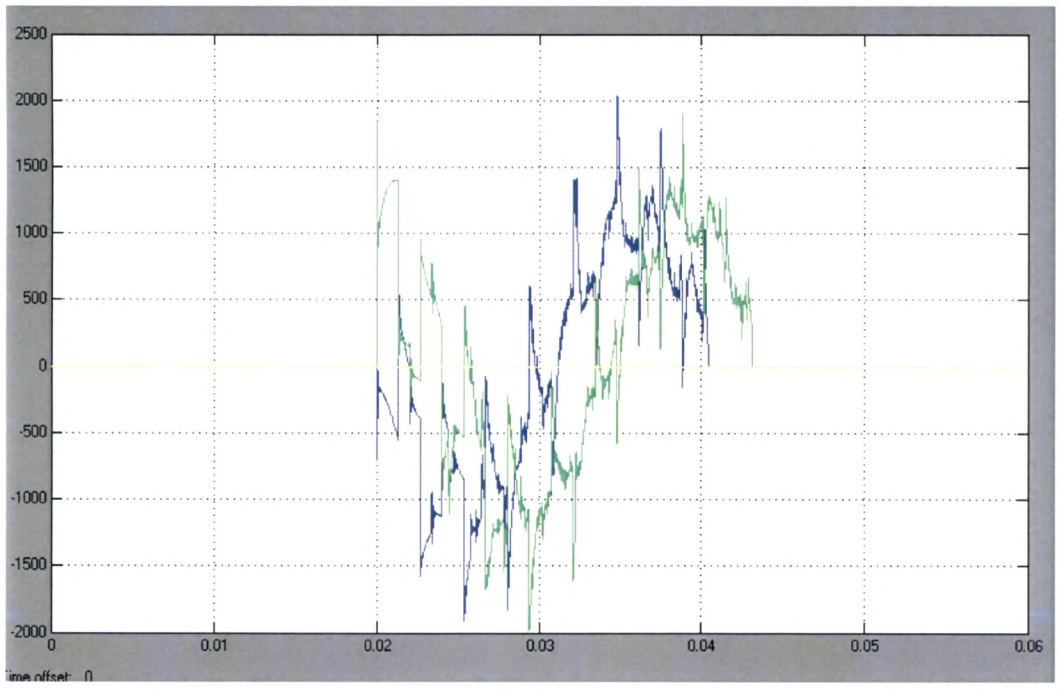
Fault Voltages for phase to Ground Fault on TPDCS at Receiving End



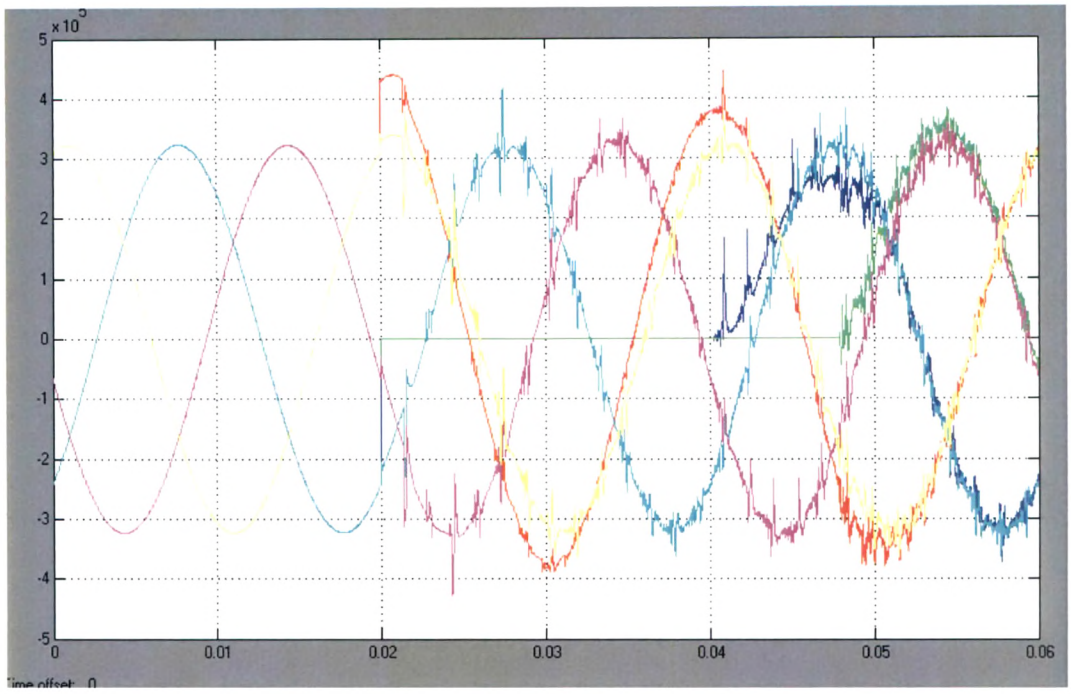
Fault Voltages for fault Phase to Ground in Six-Phase at Receiving End



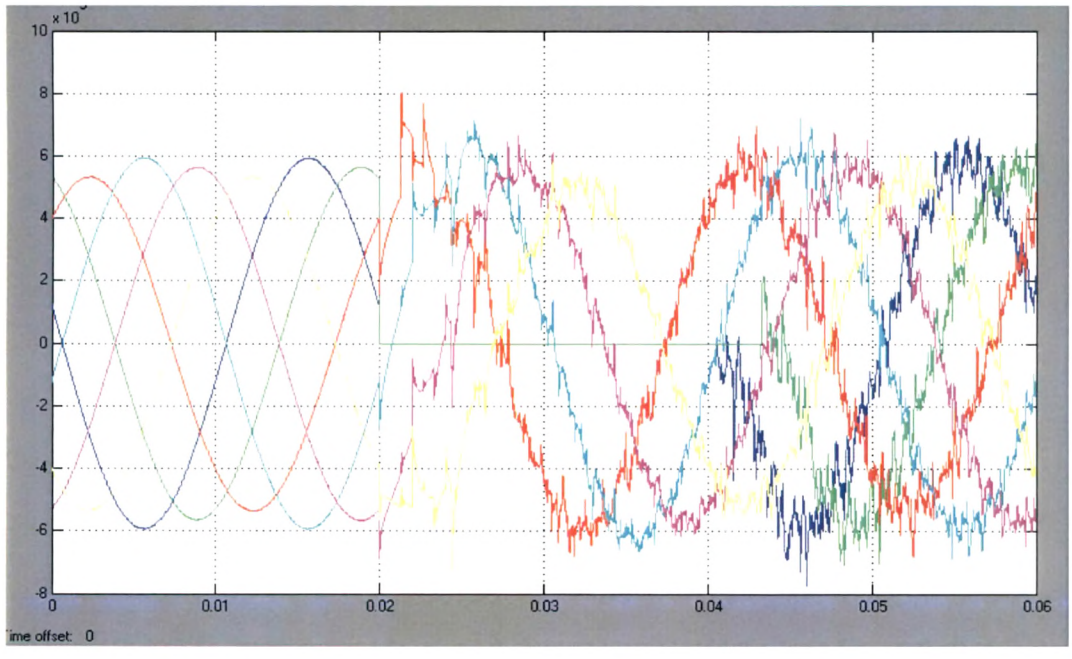
Fault Currents for Double phase to Ground Fault on TPDCS at Receiving End



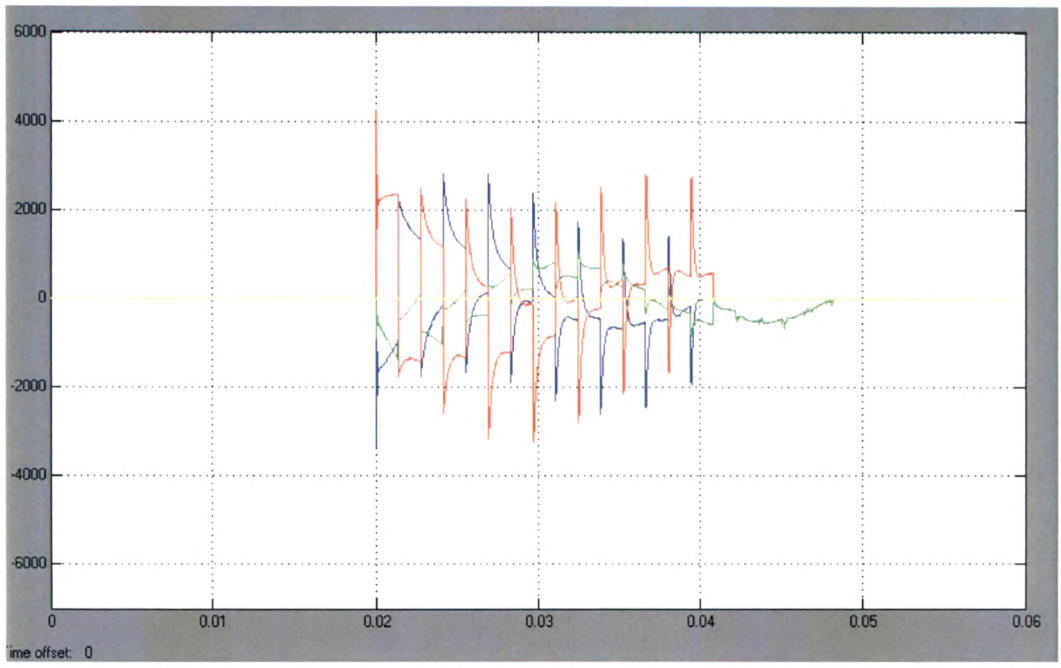
Fault Currents for fault Double Phase to Ground in Six-Phase at Receiving End



Fault Voltages for Double phase to Ground Fault on TPDCS at Receiving End



Fault Voltages for fault Double Phase to Ground in Six-Phase at Receiving End



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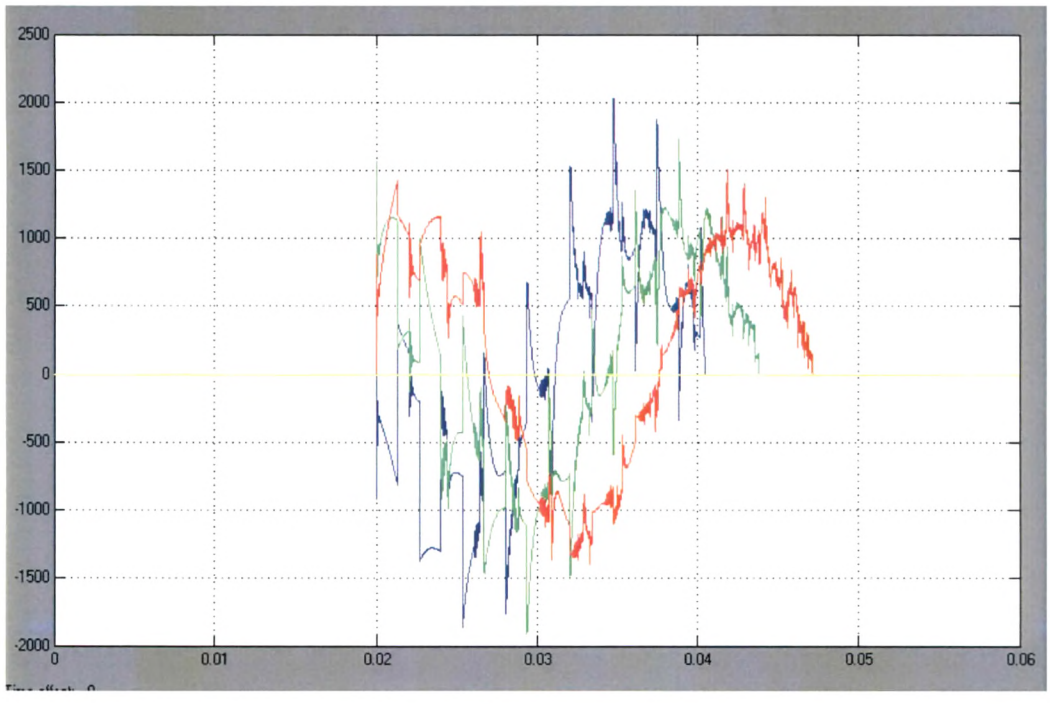

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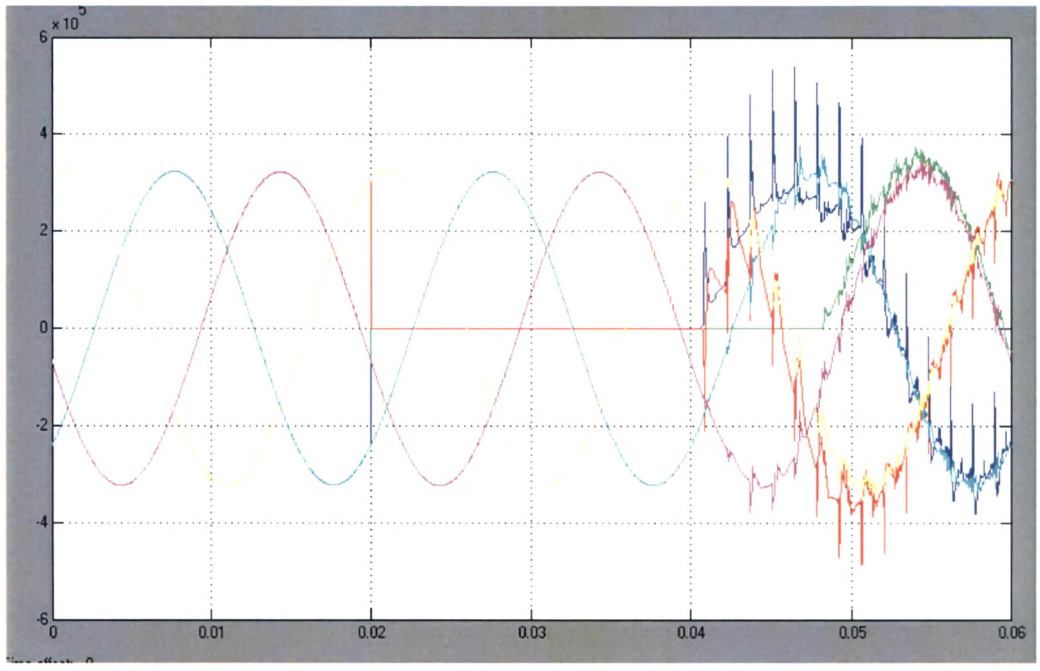

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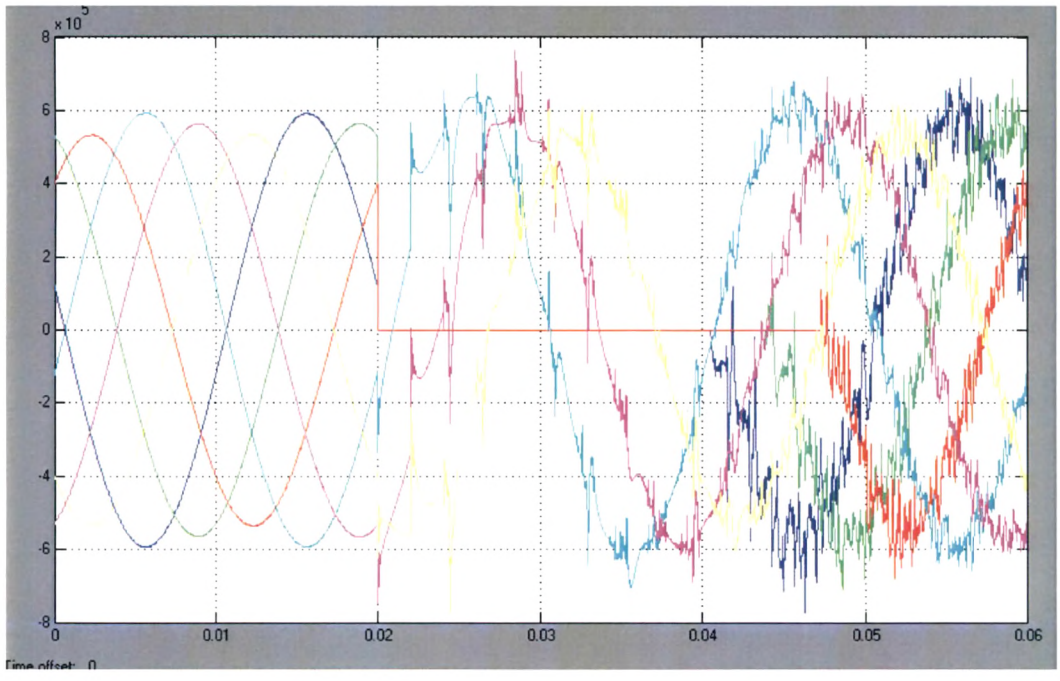

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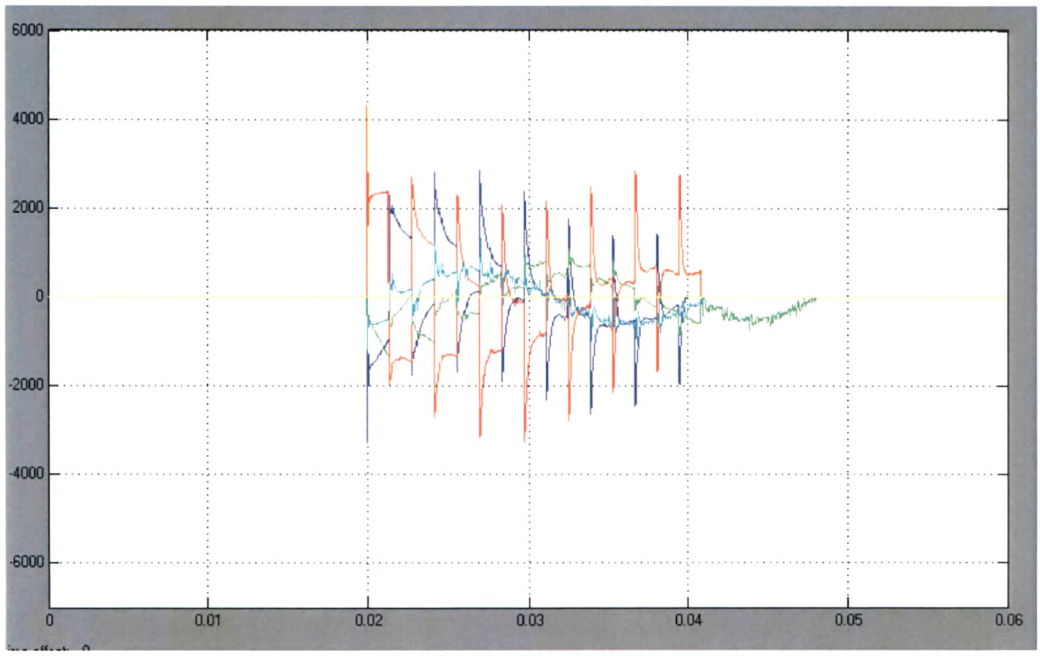

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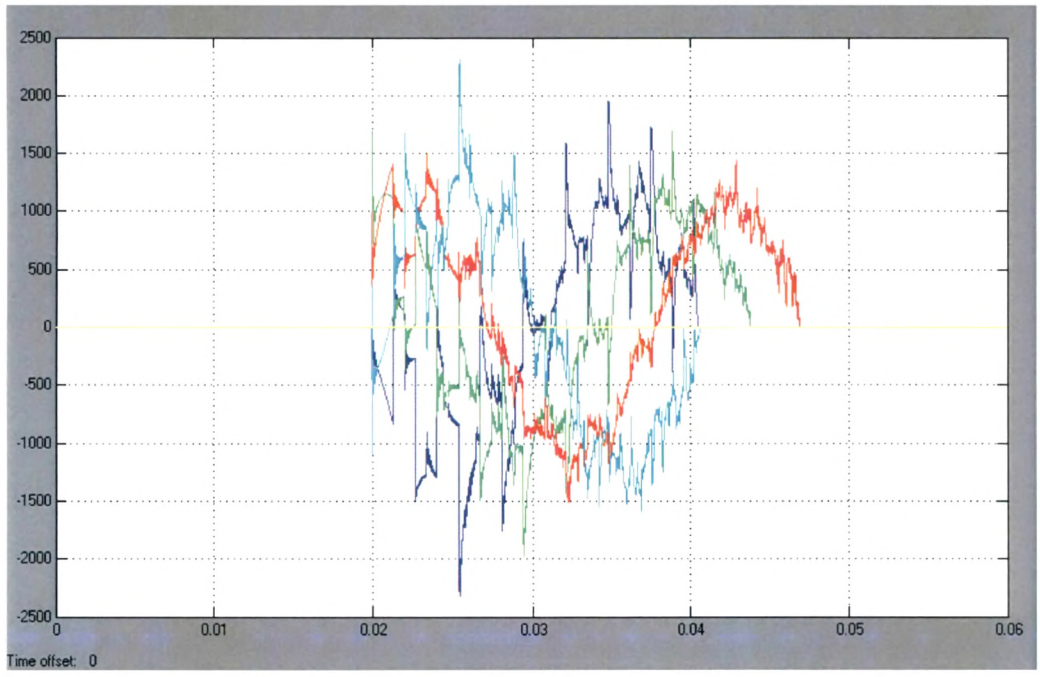

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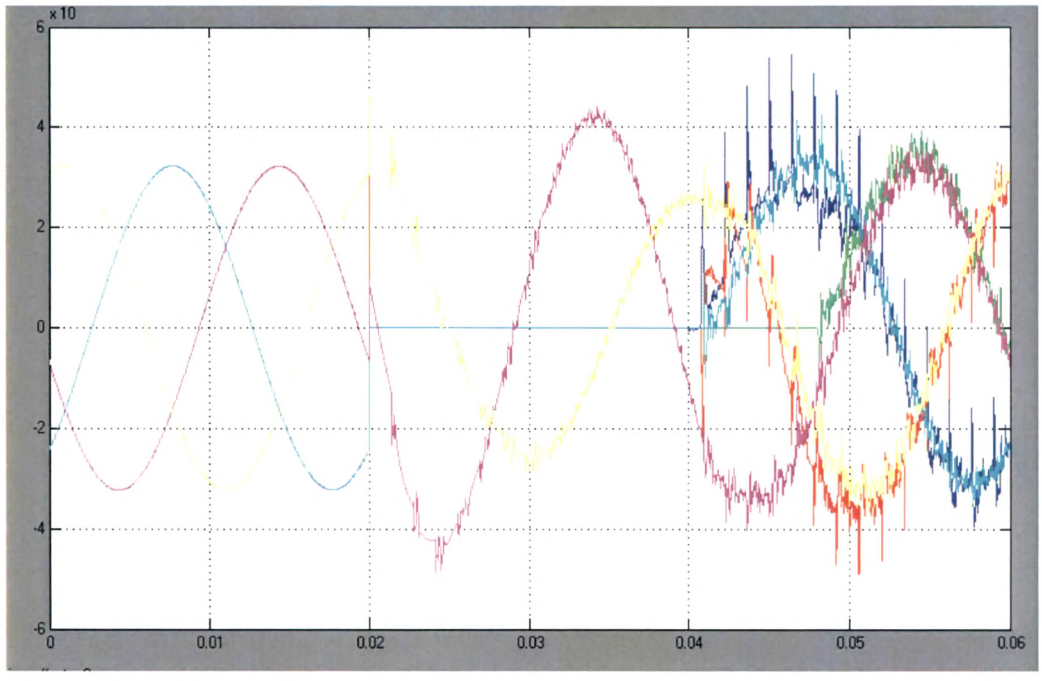

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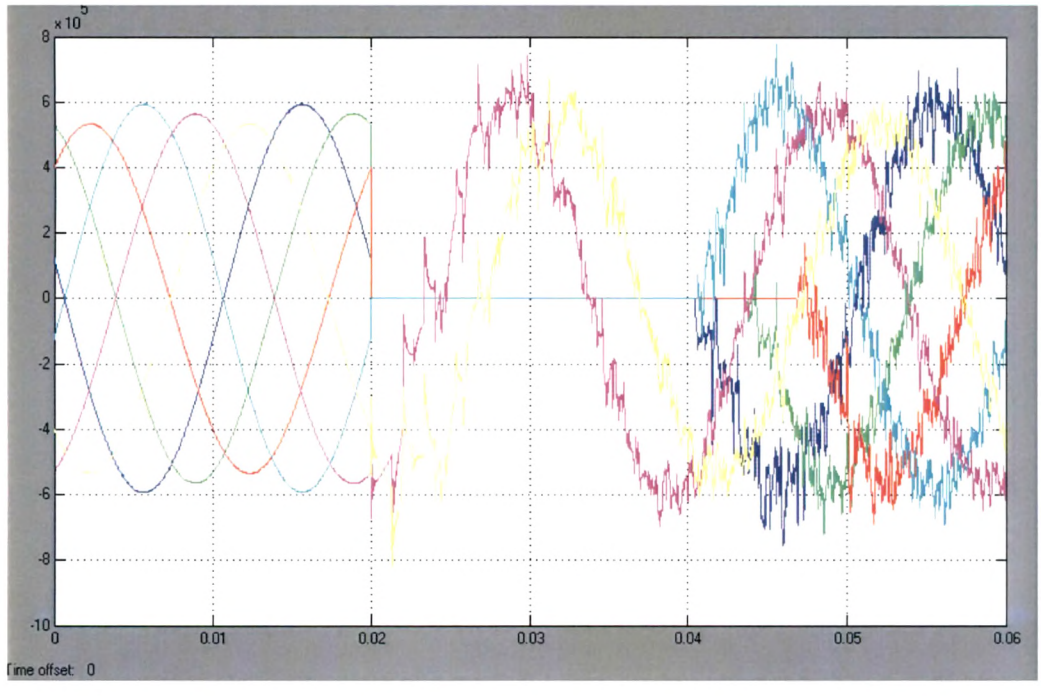

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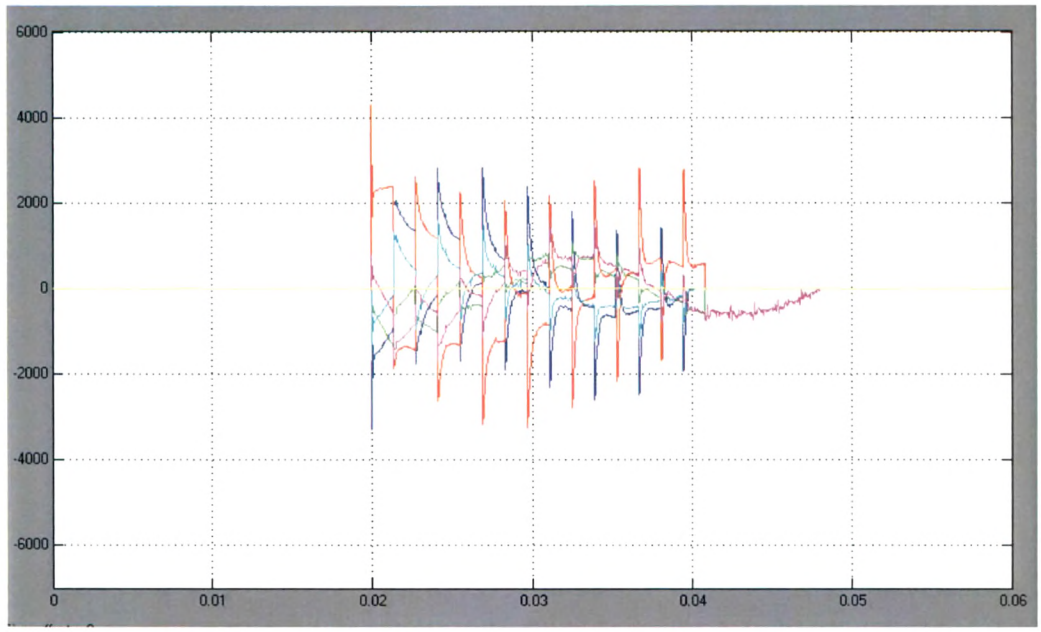

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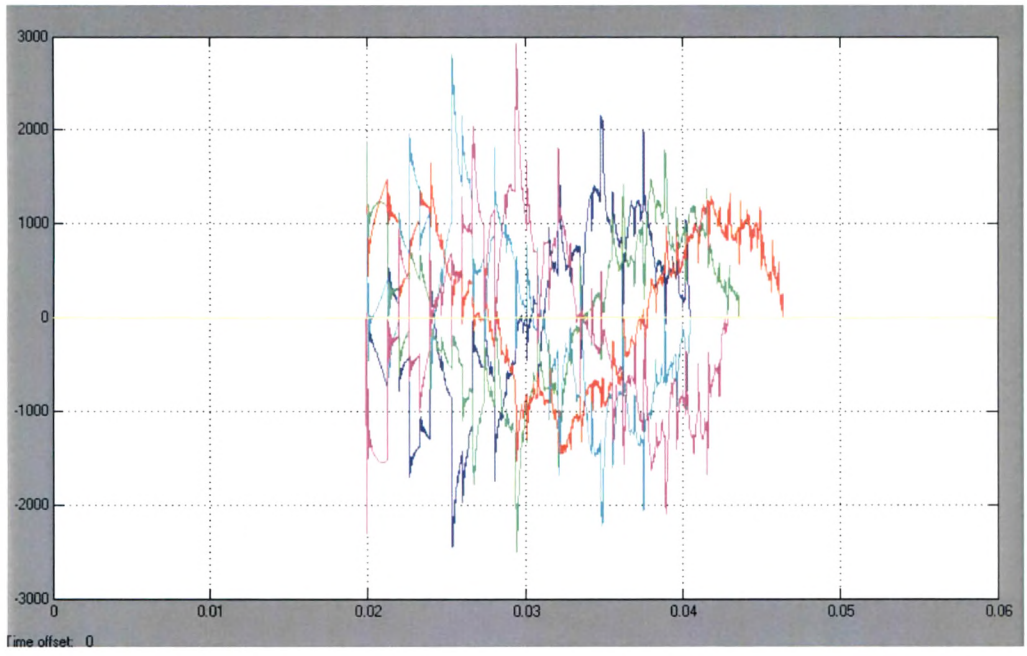

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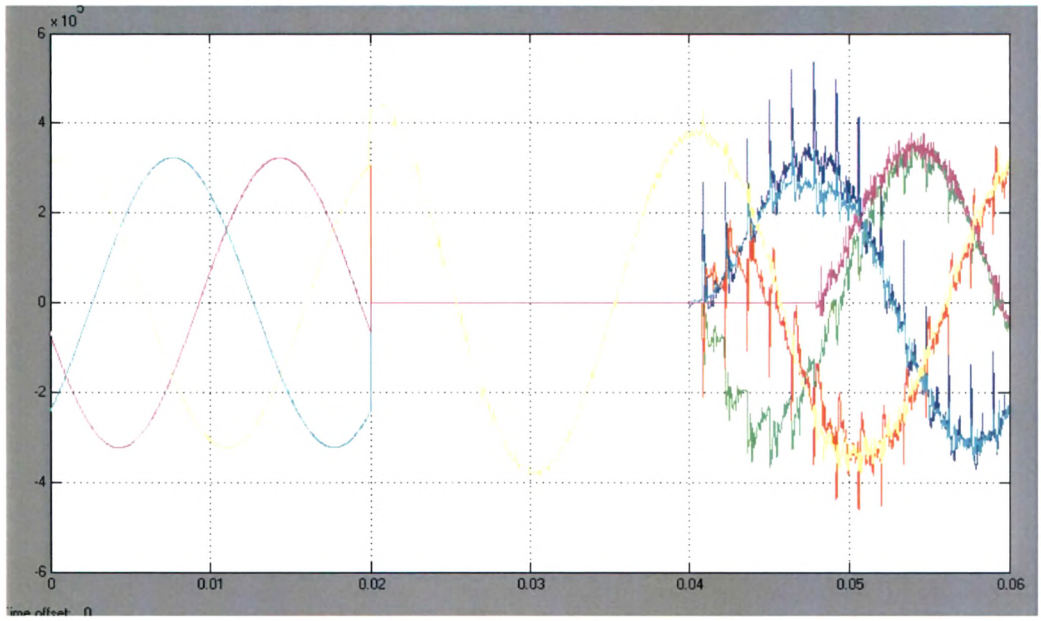

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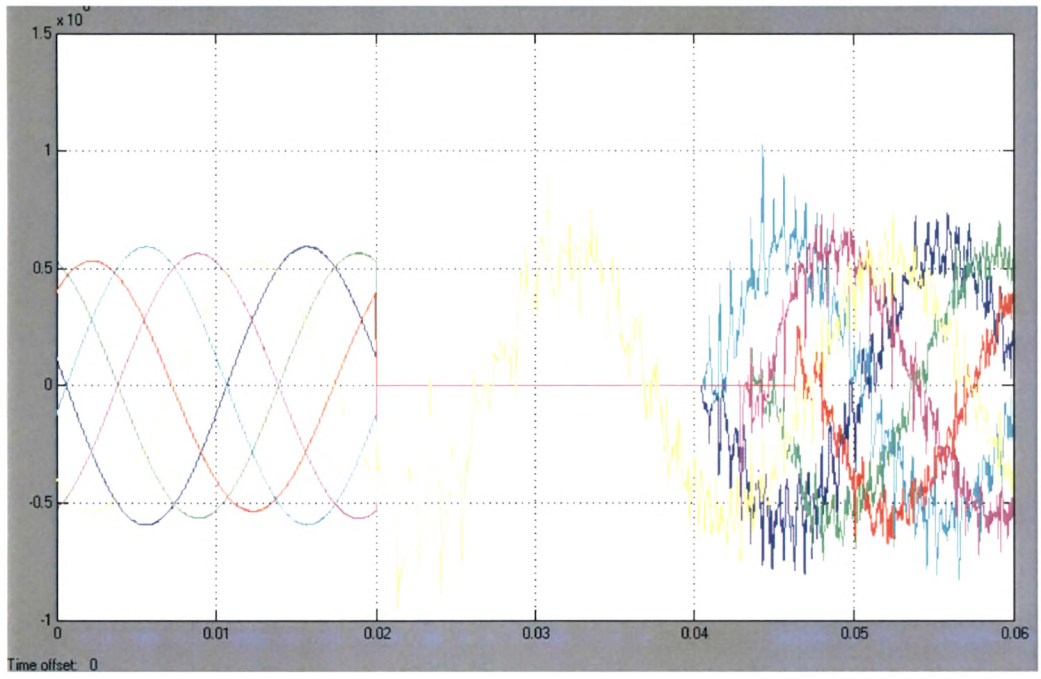

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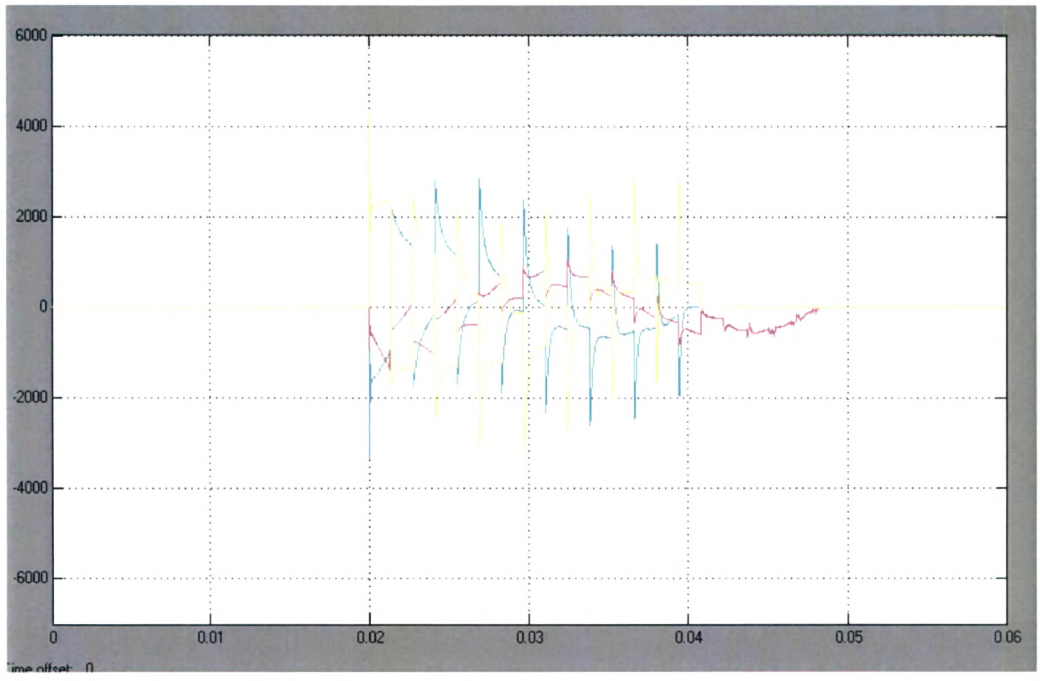

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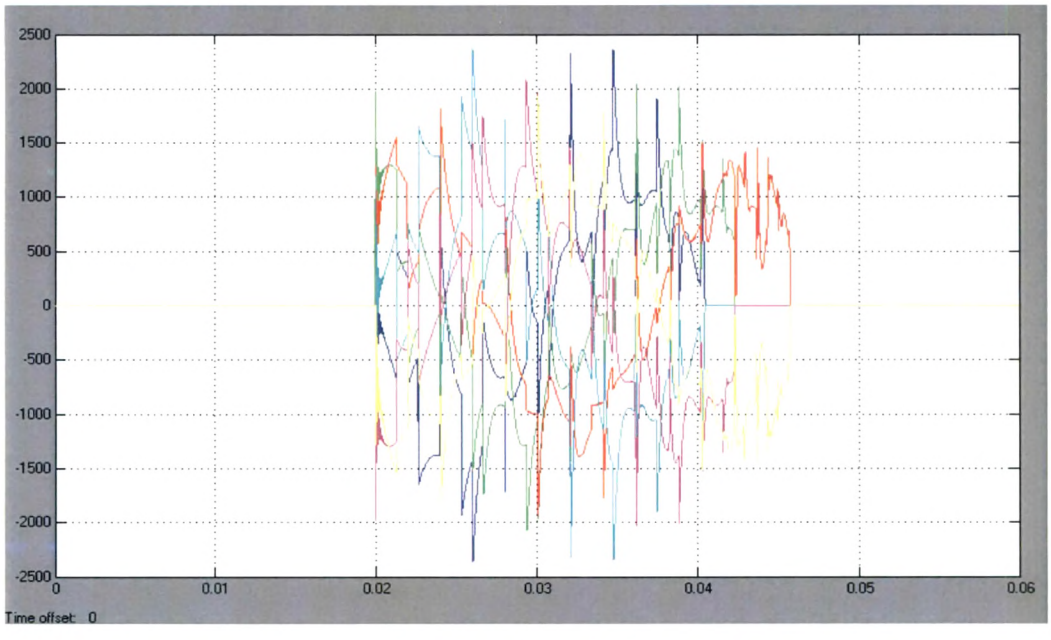

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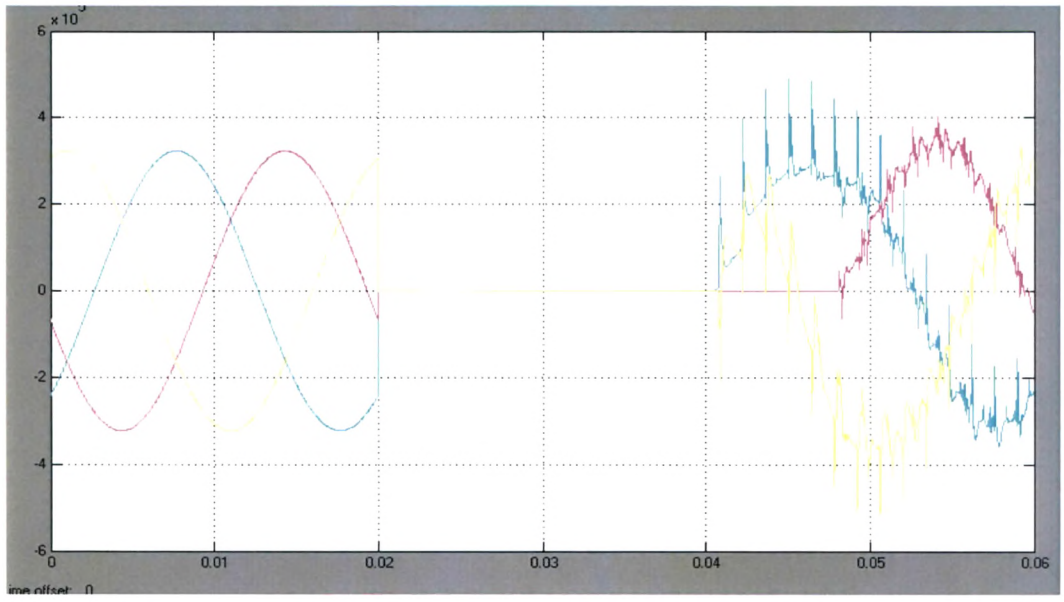

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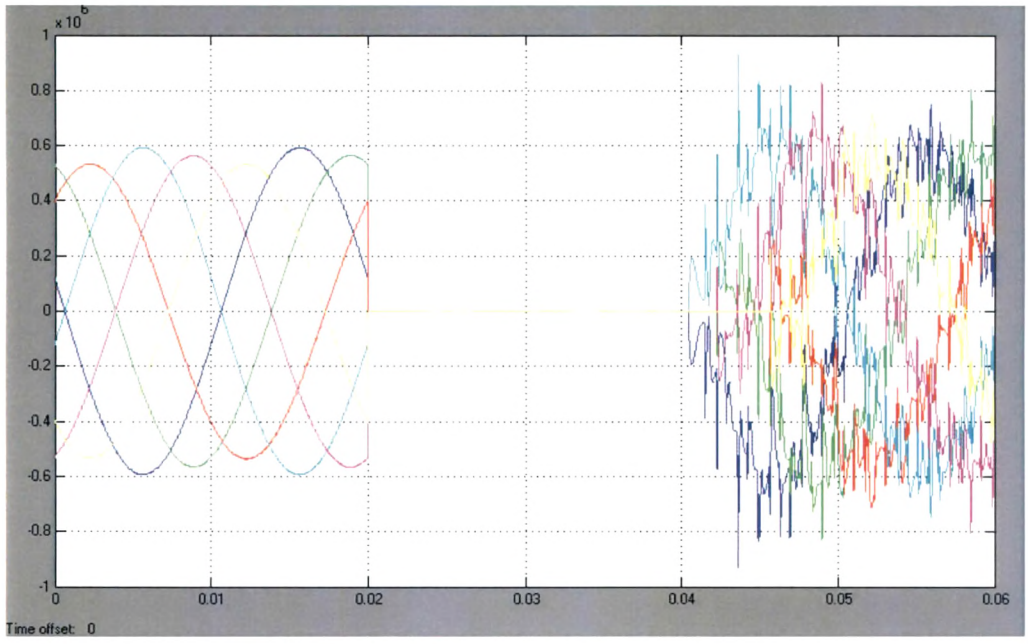

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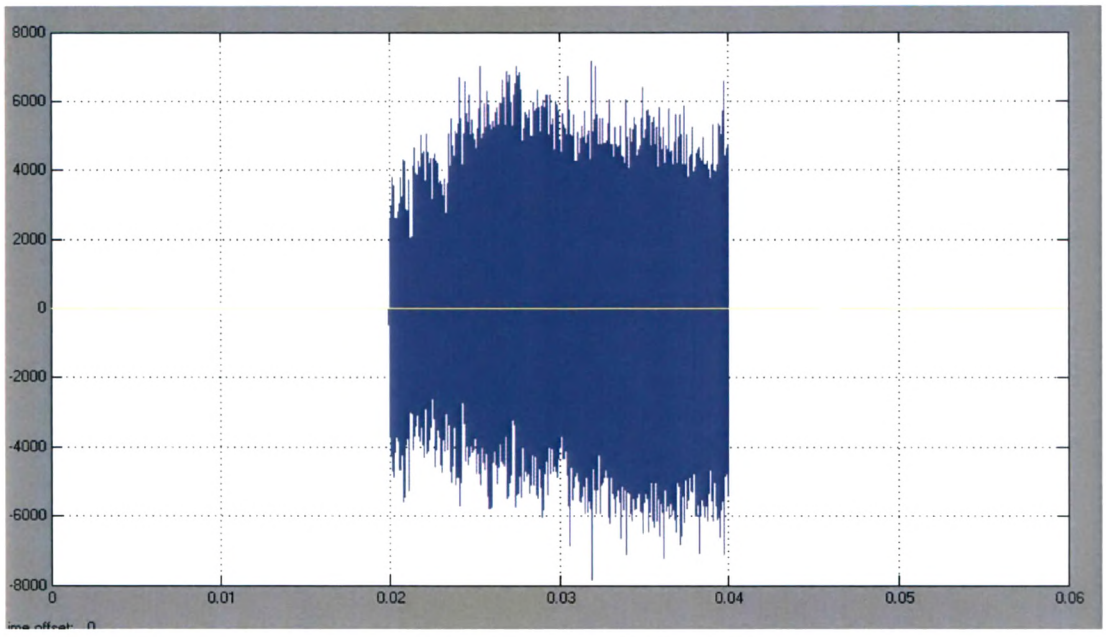
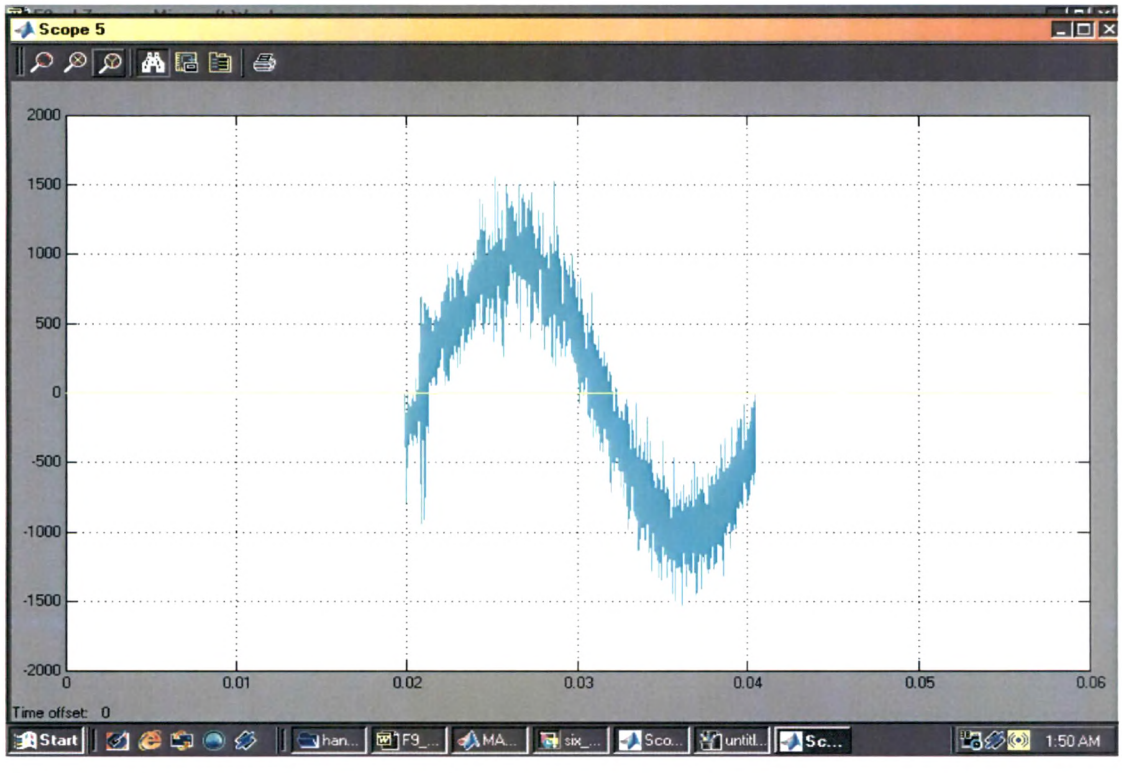


Fault Currents for phase to Ground Fault on Three-phase at Sending End



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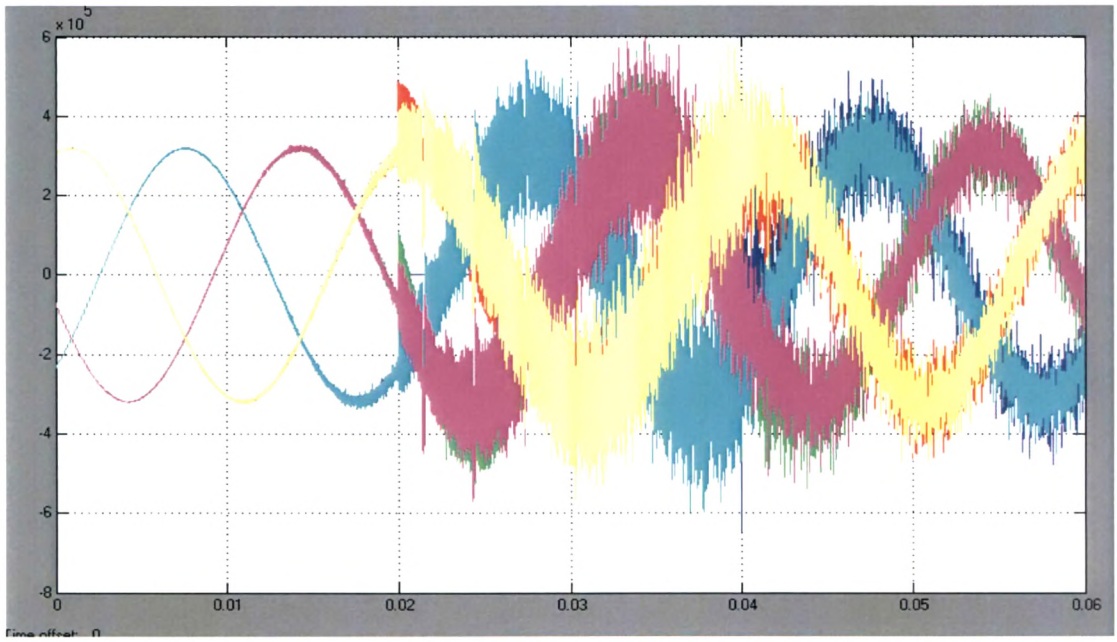
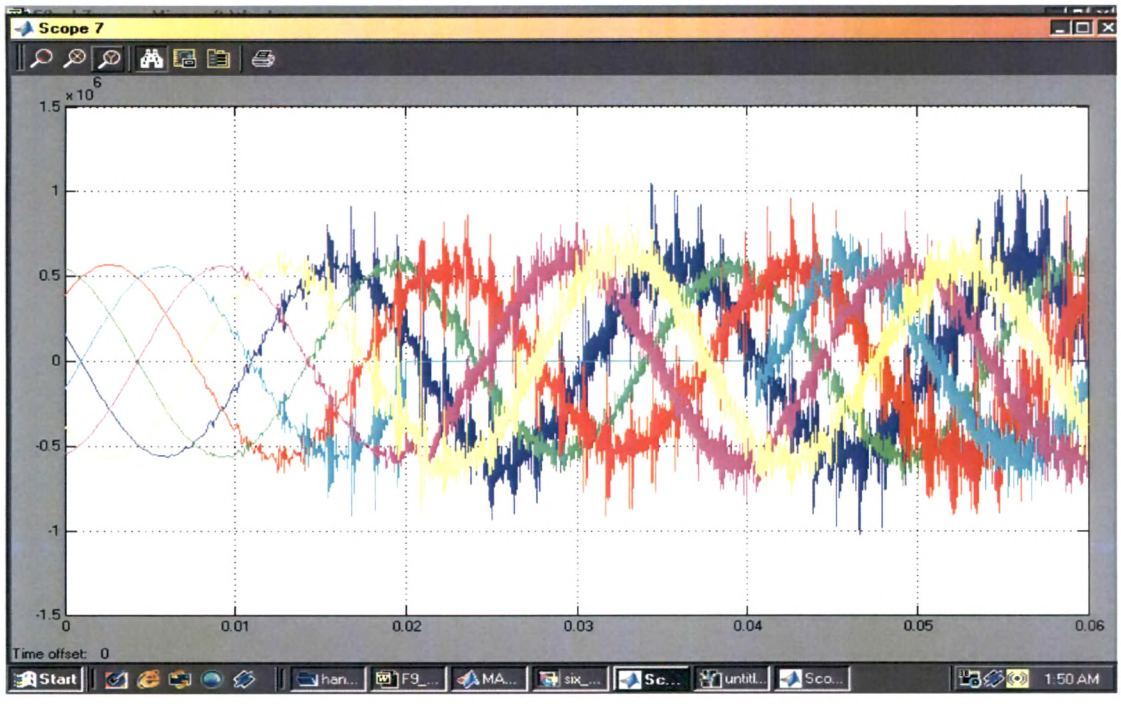


Fault Voltages for phase to Ground Fault on Three-phase at Sending End



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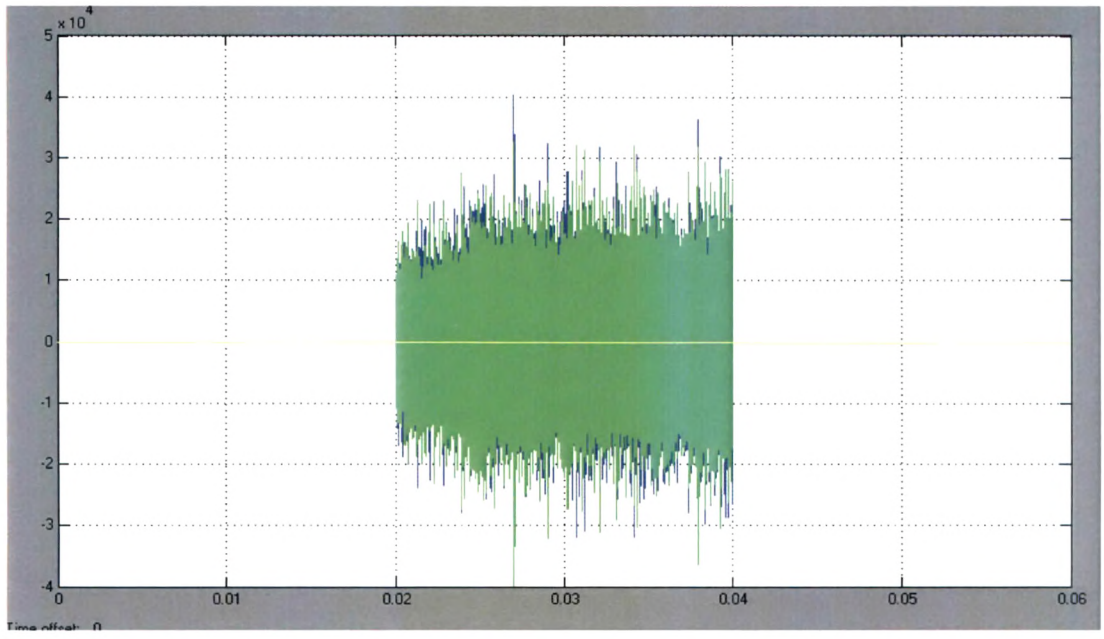

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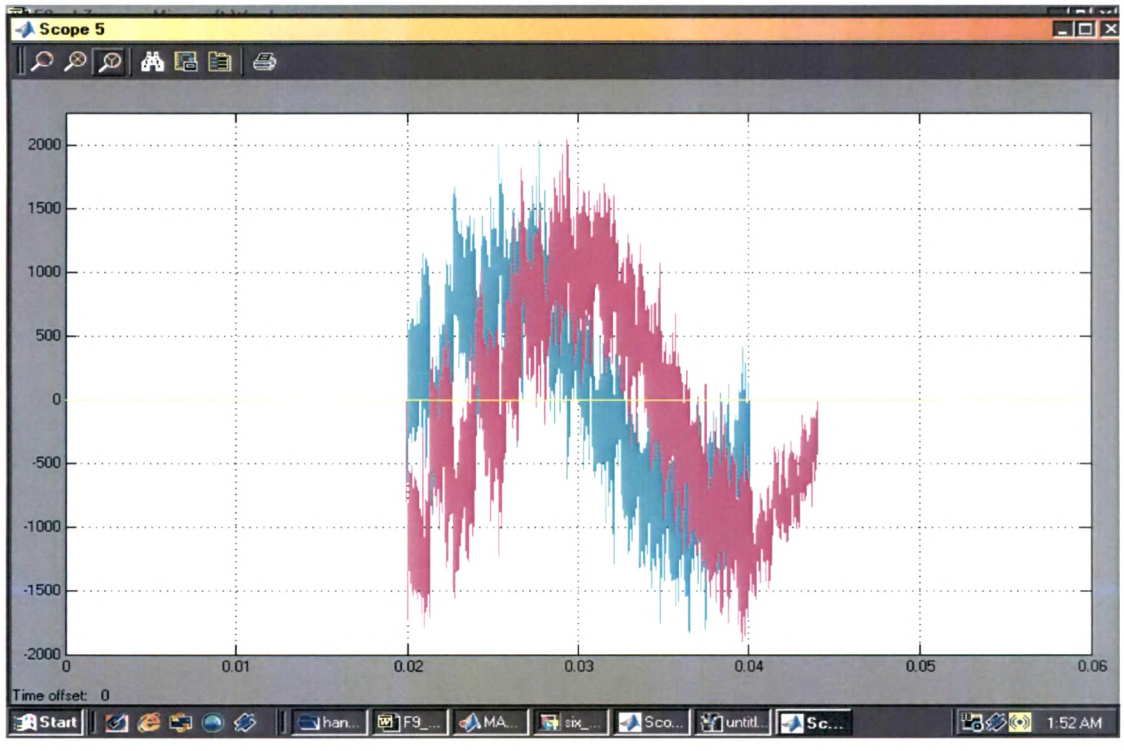

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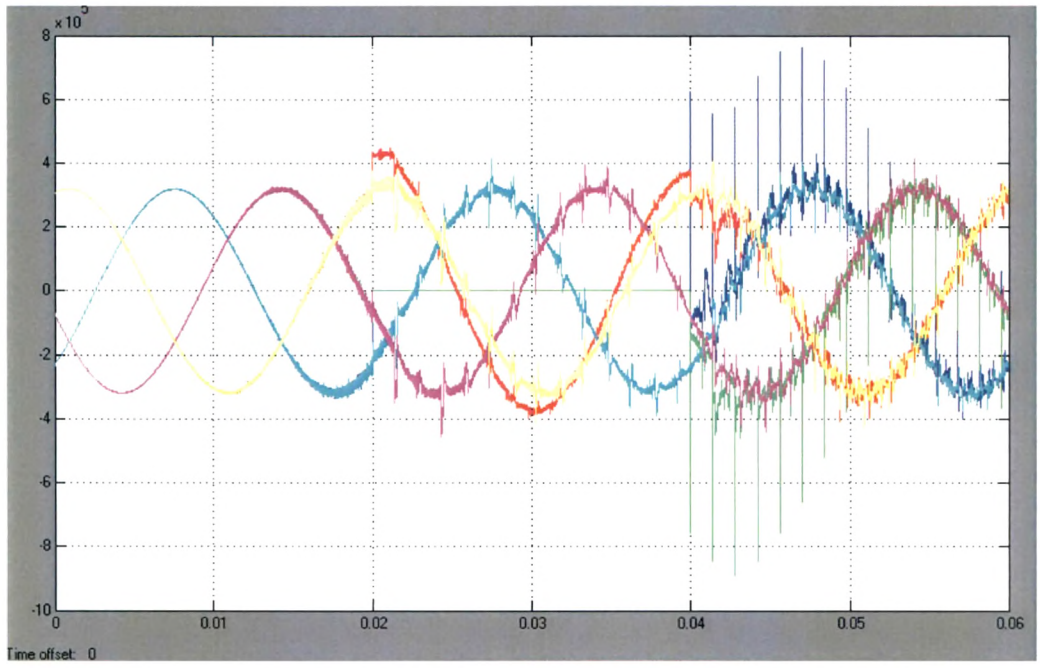

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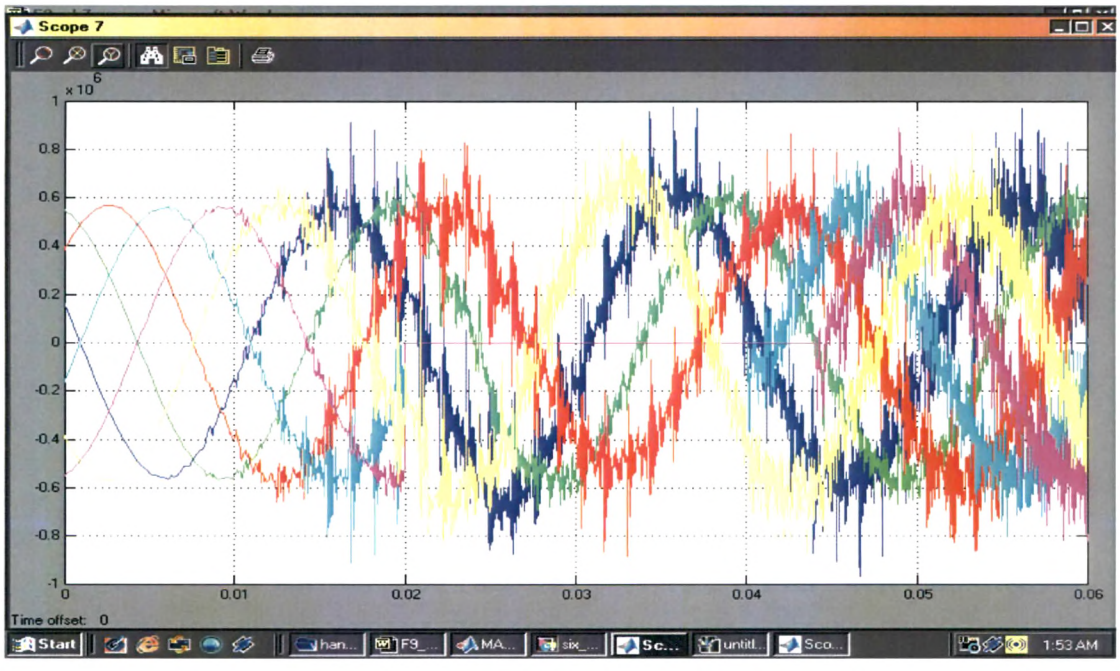

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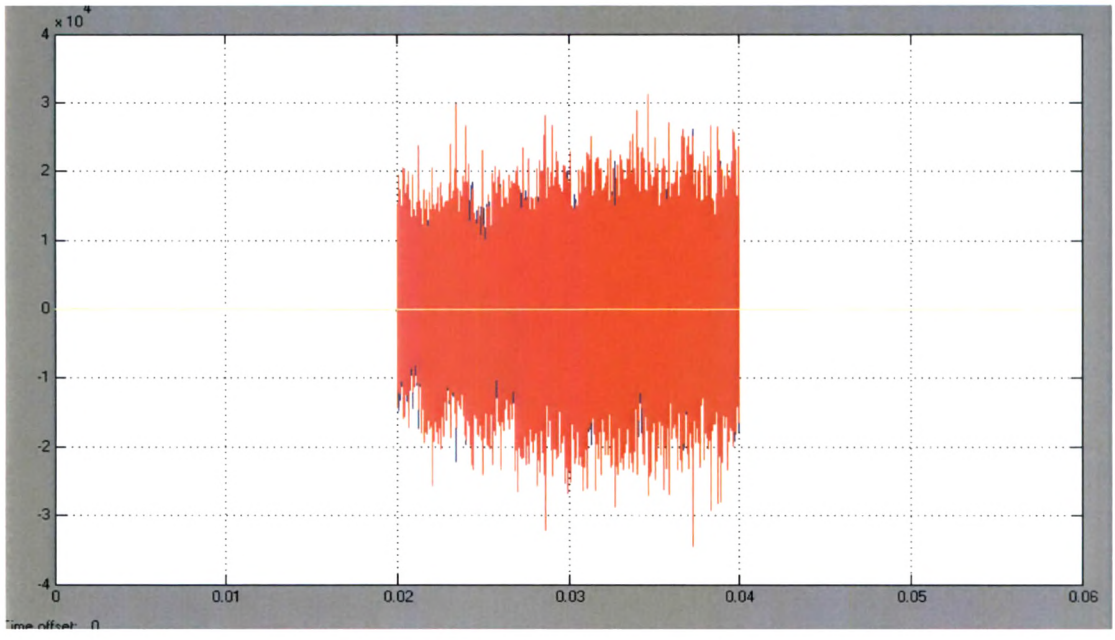

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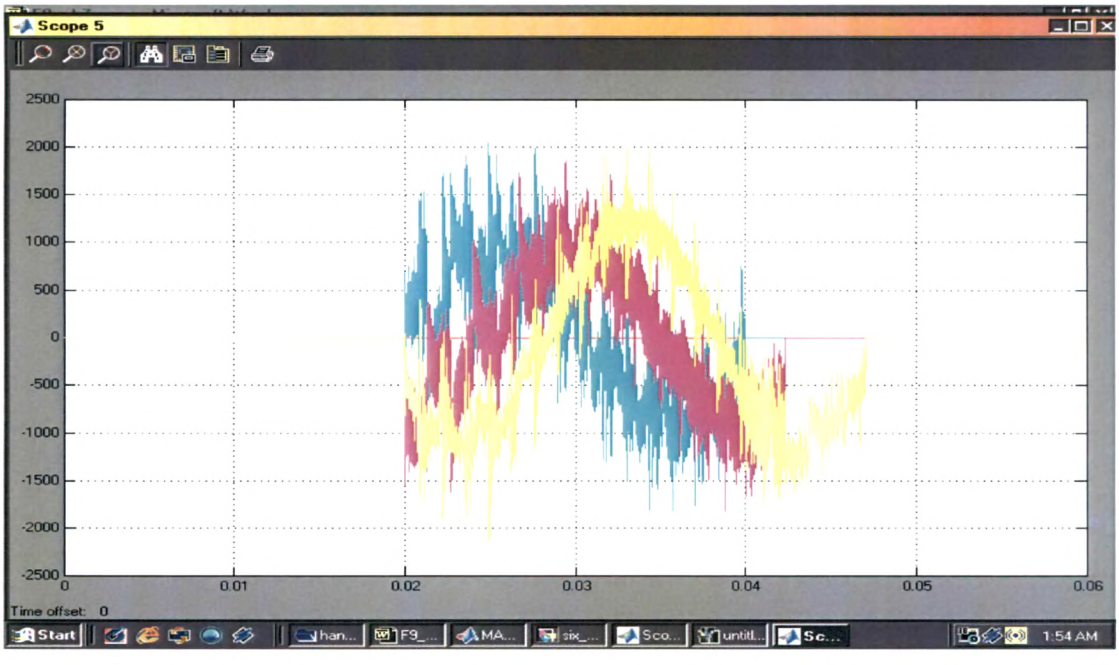

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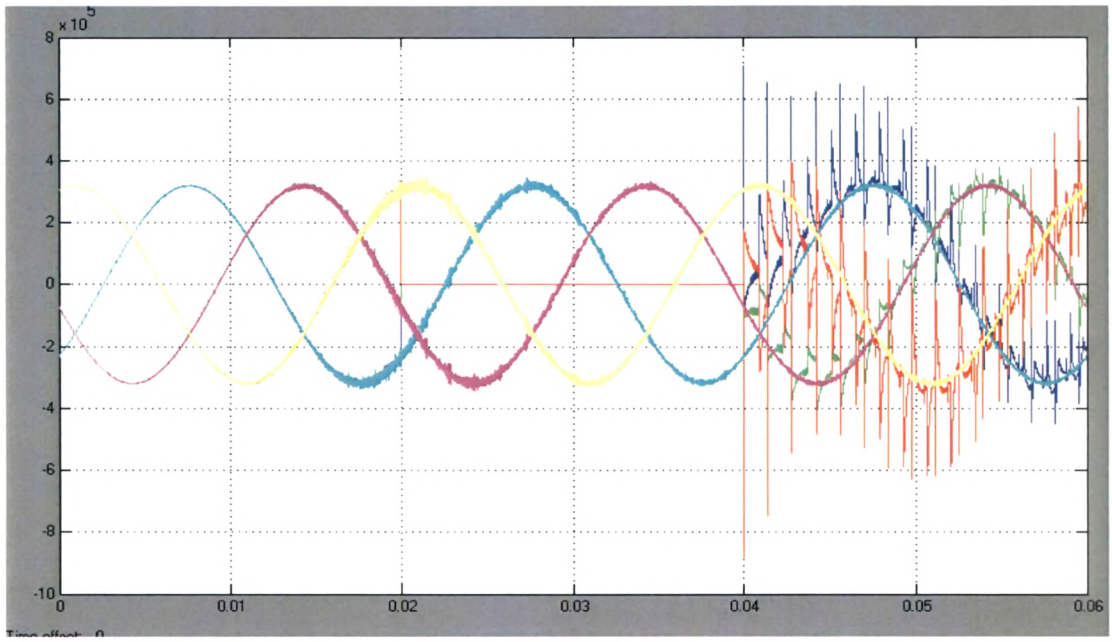

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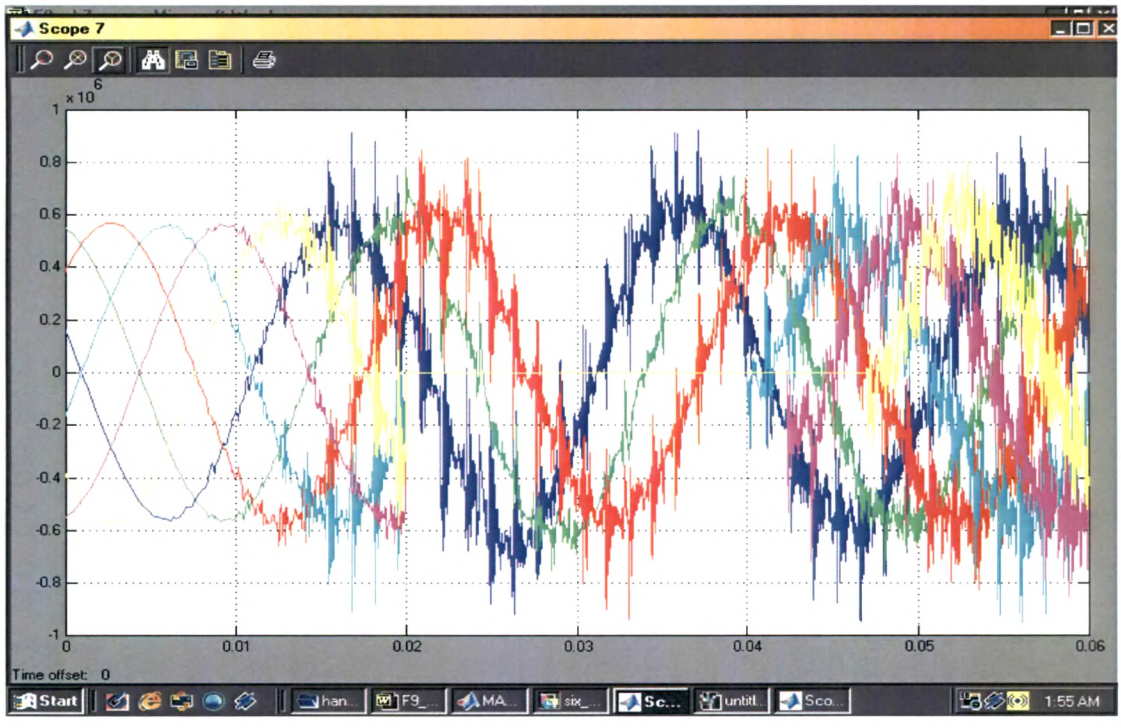

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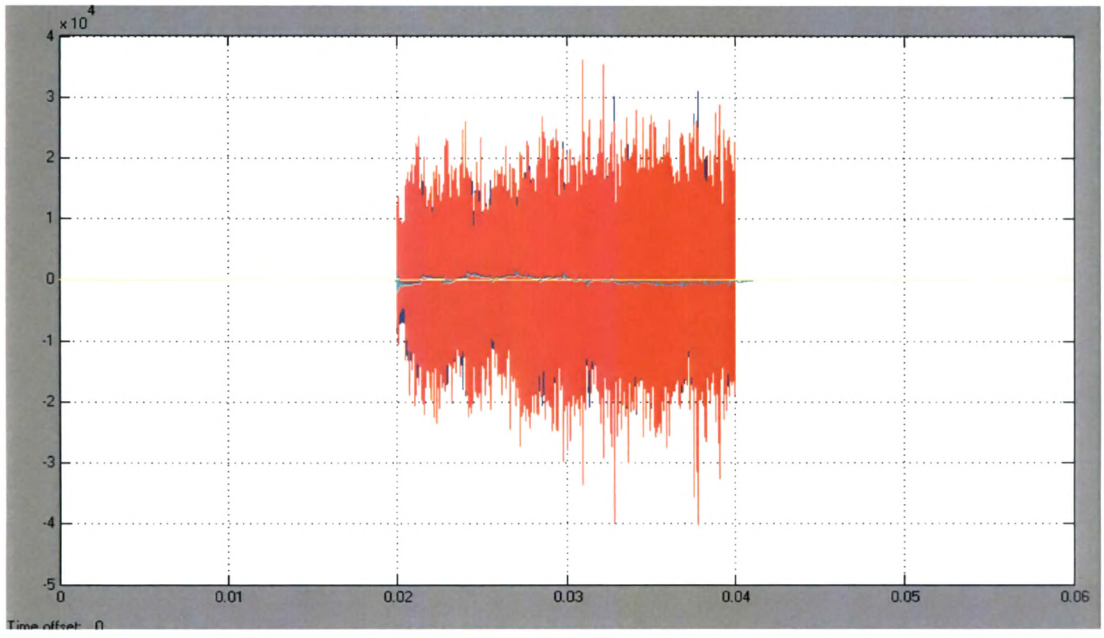
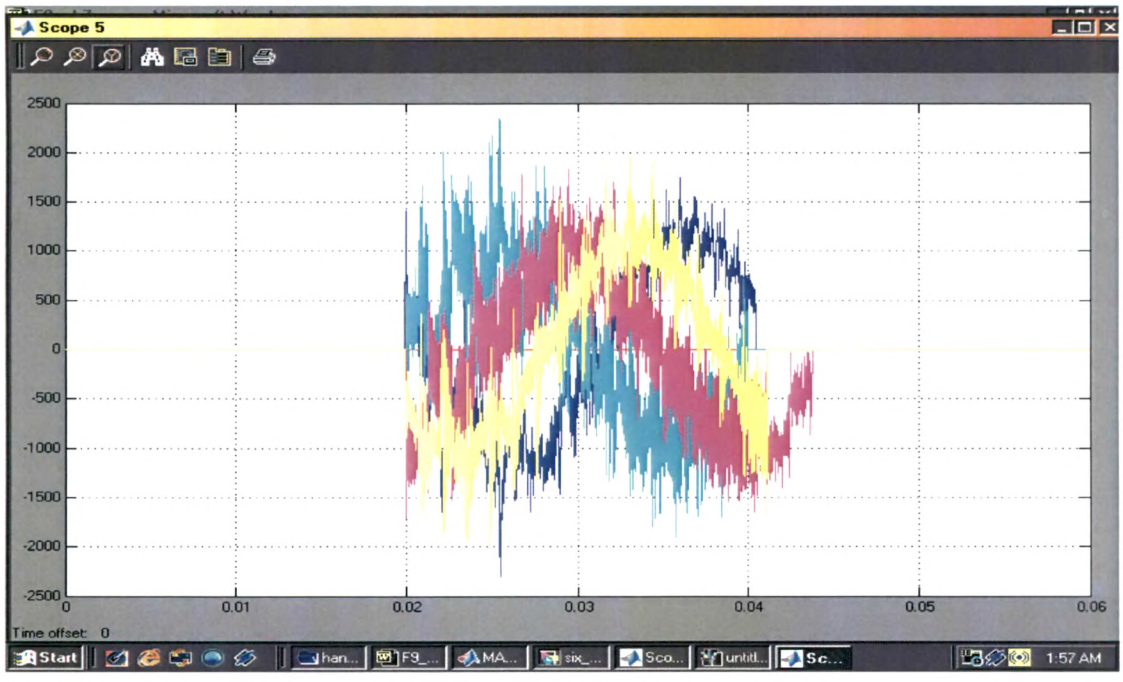
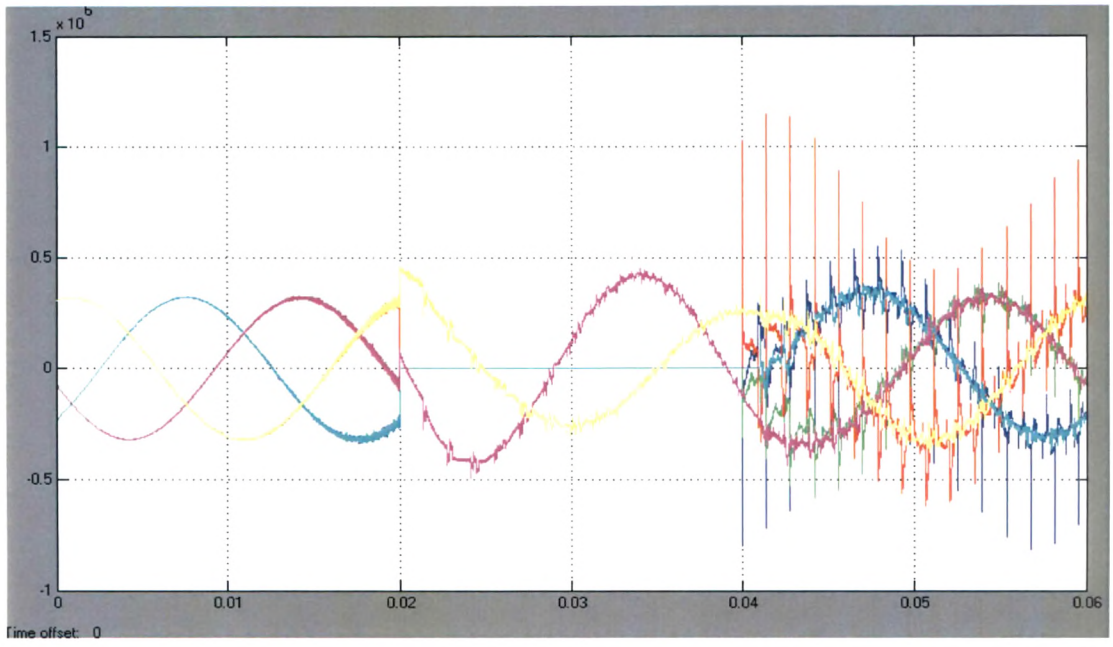


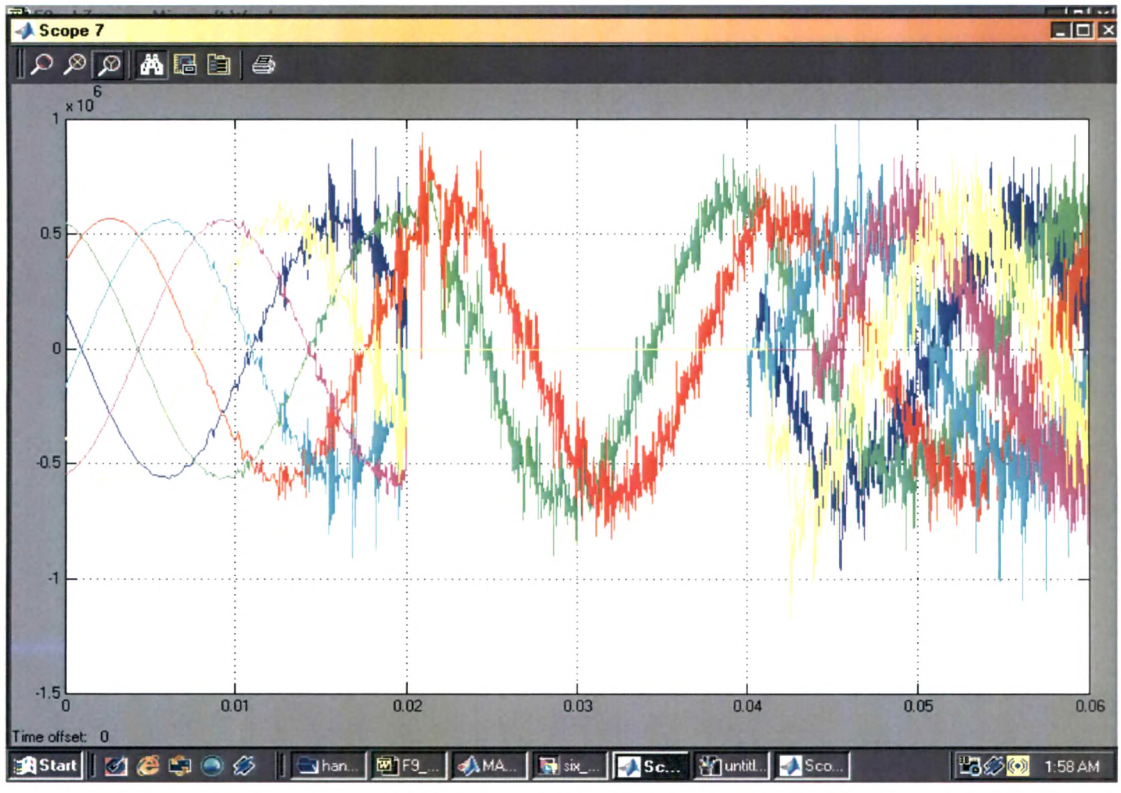
Fault Currents for Four phases to Ground Fault on Three-phase at Sending End



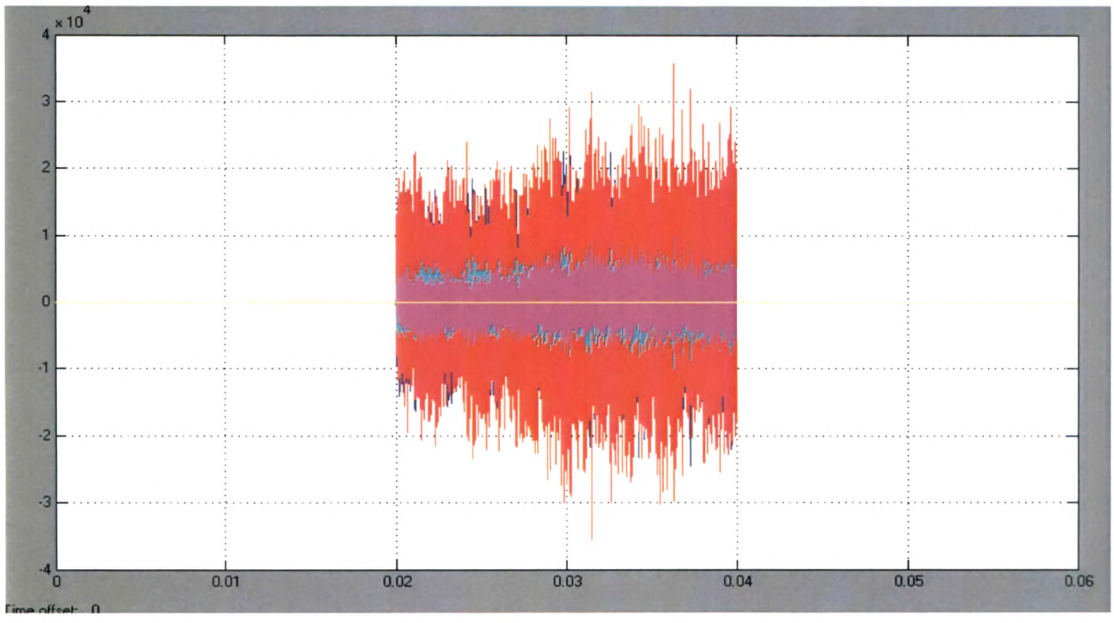
Fault Currents for fault Four Phase to Ground in Six-Phase at Sending End



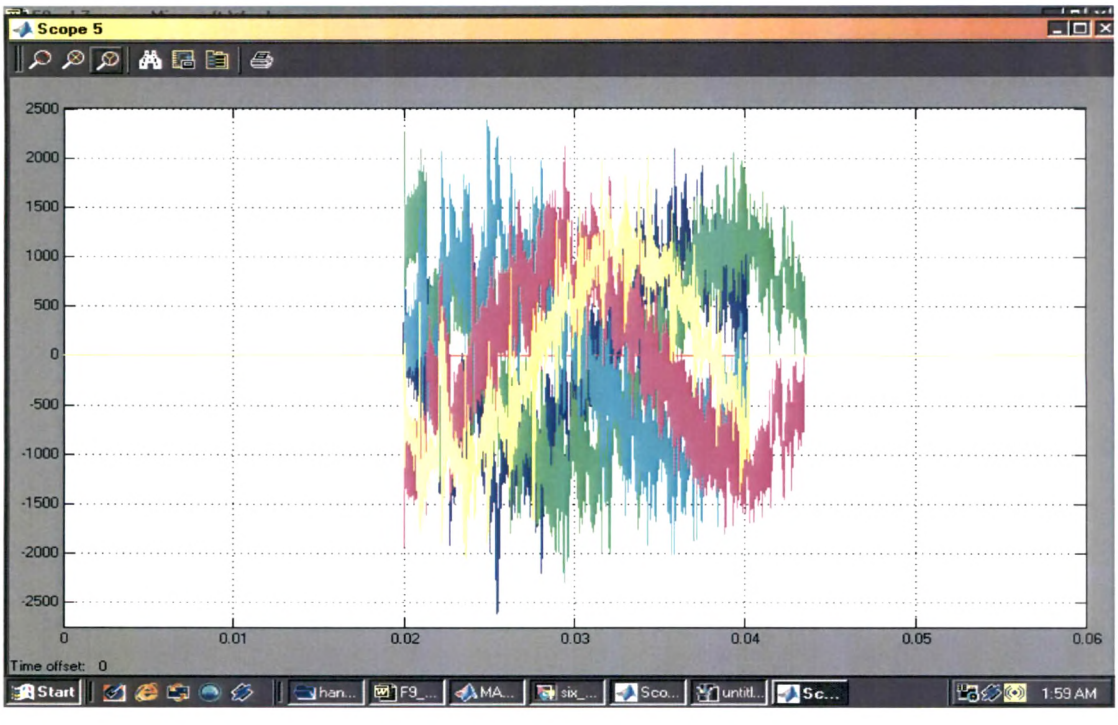
Fault Voltages for Four phases to Ground Fault on Three-phase at Sending End



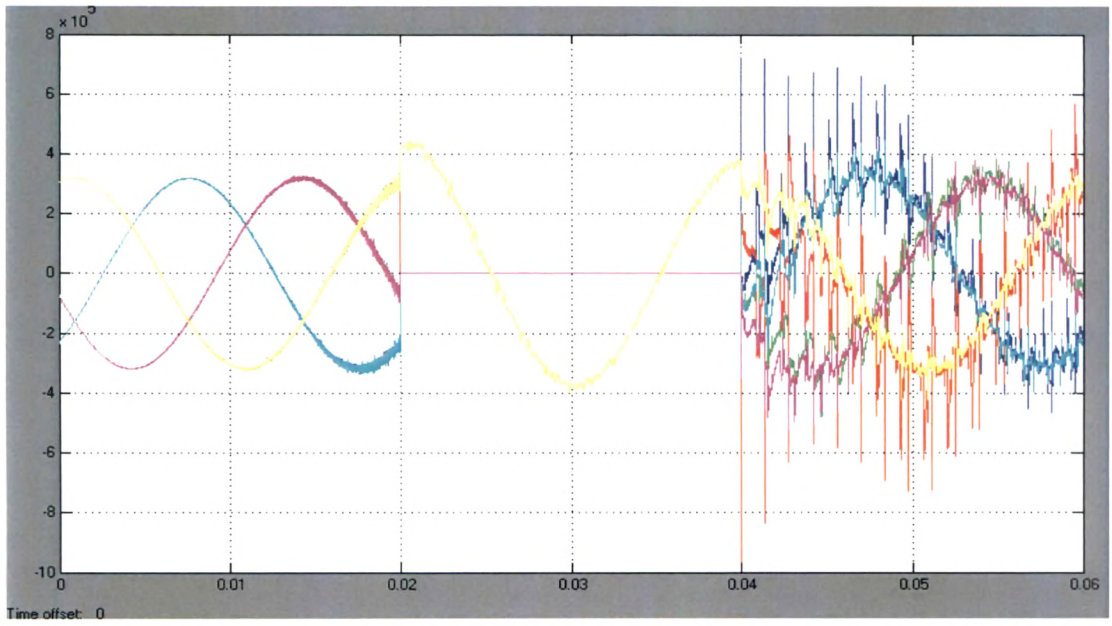
Fault Voltages for fault Four Phase to Ground in Six-Phase at Sending End



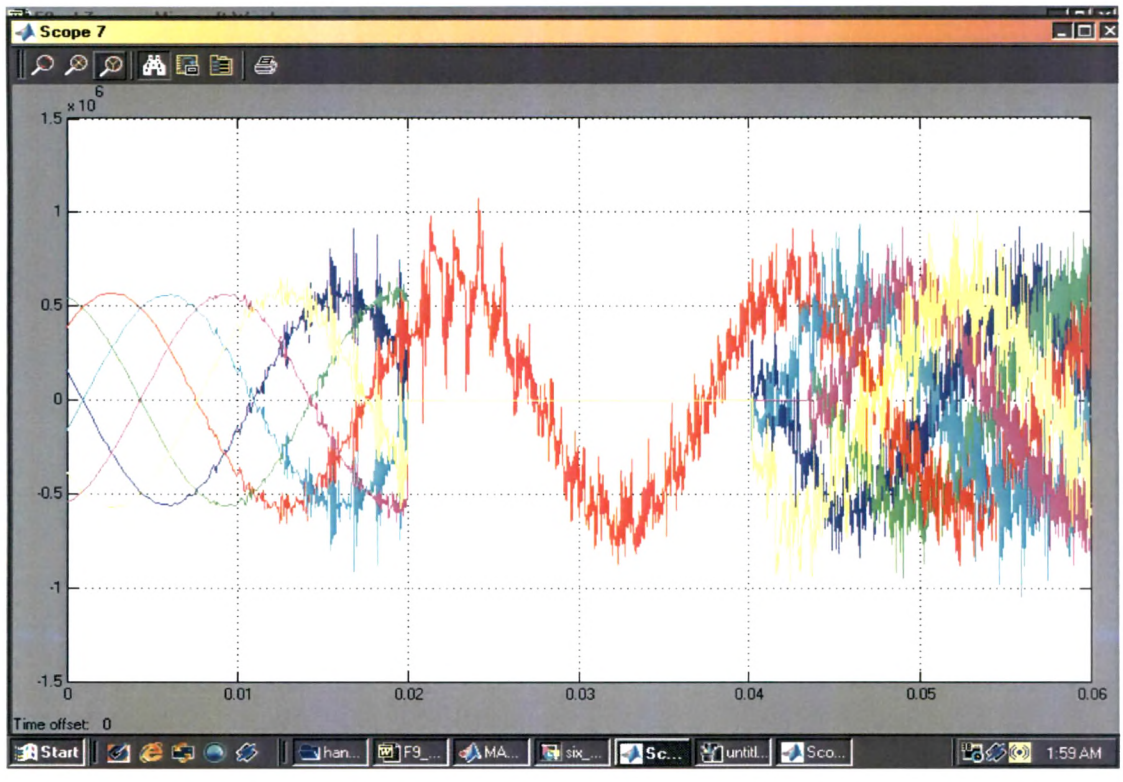
Fault Currents for Five phases to Ground Fault on Three-phase at Sending End



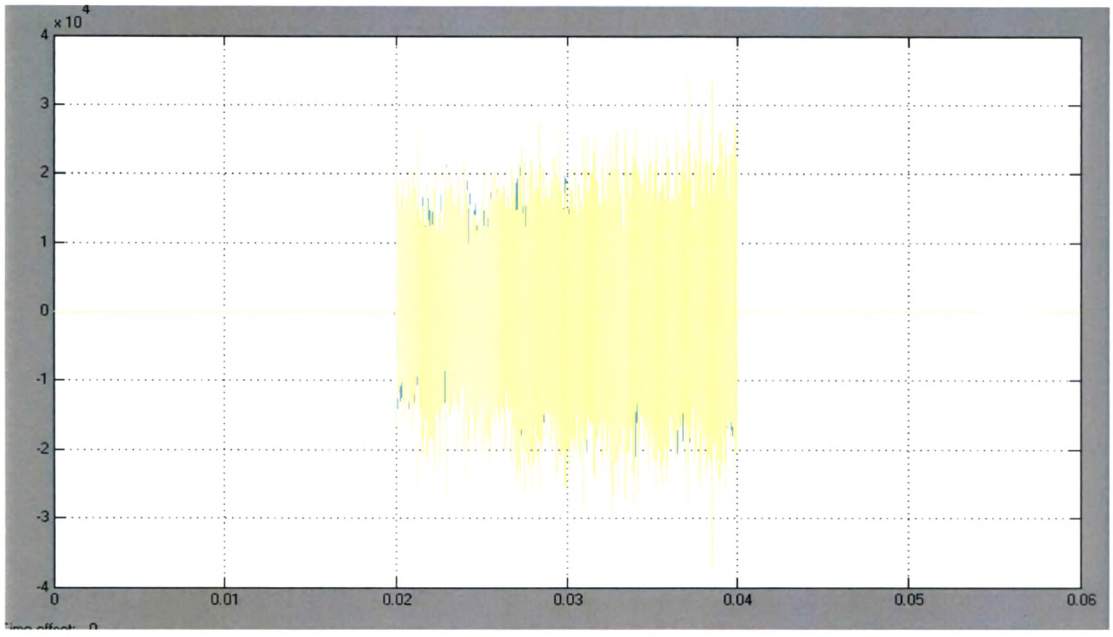
Fault Currents for fault Five Phase to Ground in Six-Phase at Sending End



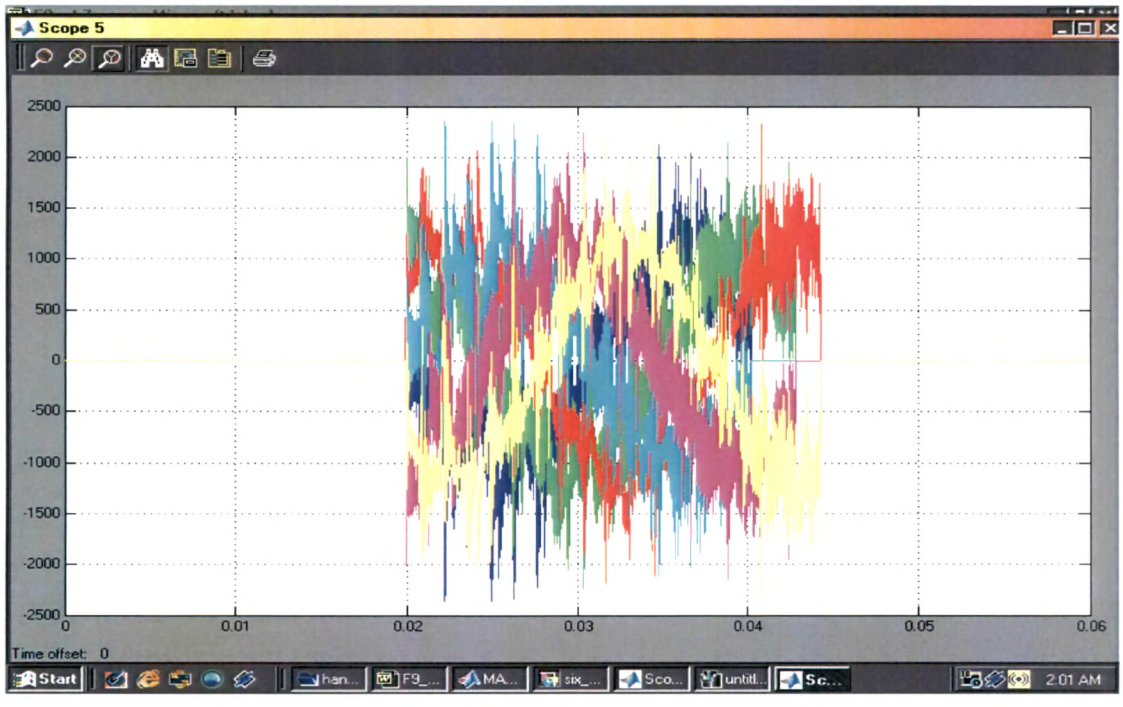
Fault Voltages for Five phases to Ground Fault on Three-phase at Sending End



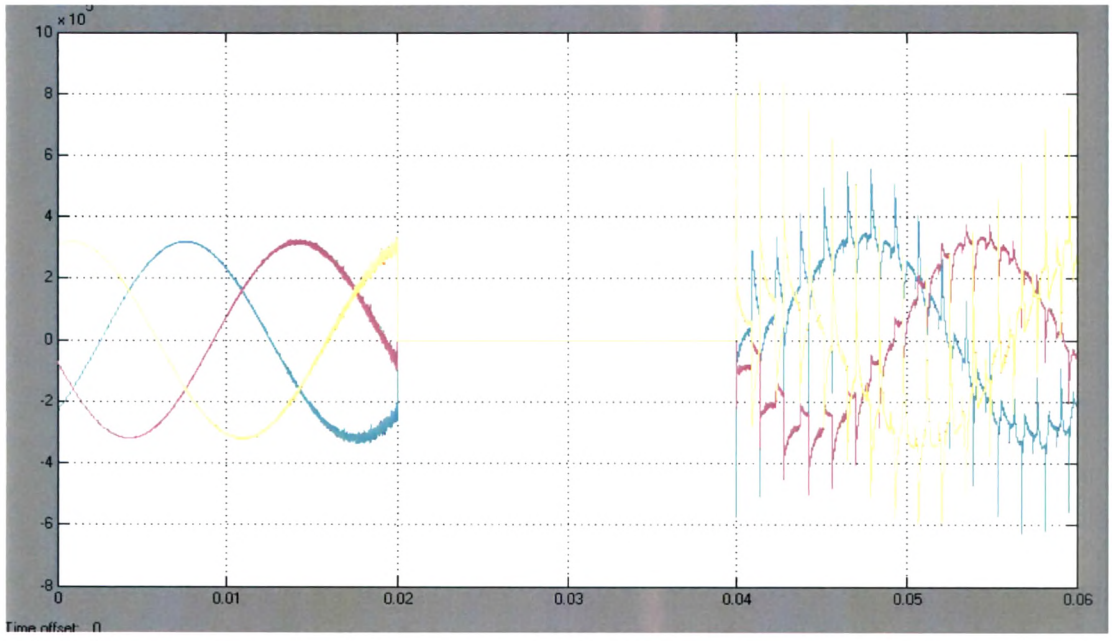
Fault Voltages for fault Five Phase to Ground in Six-Phase at Sending End



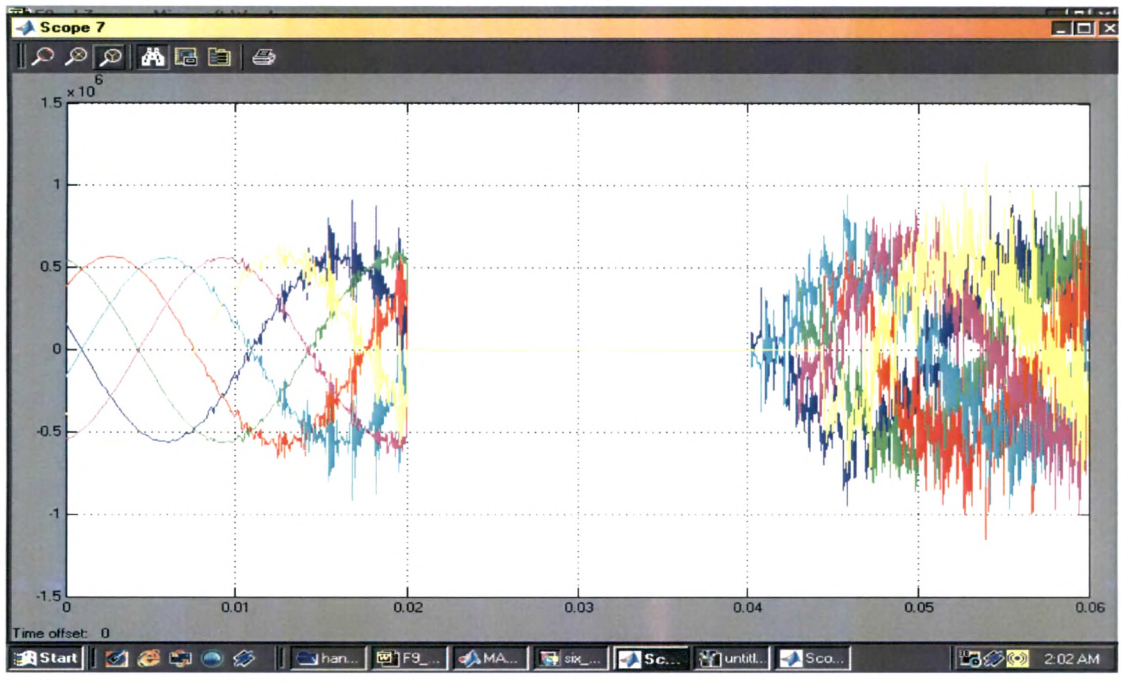
Fault Currents for Six phases to Ground Fault on Three-phase at Sending End



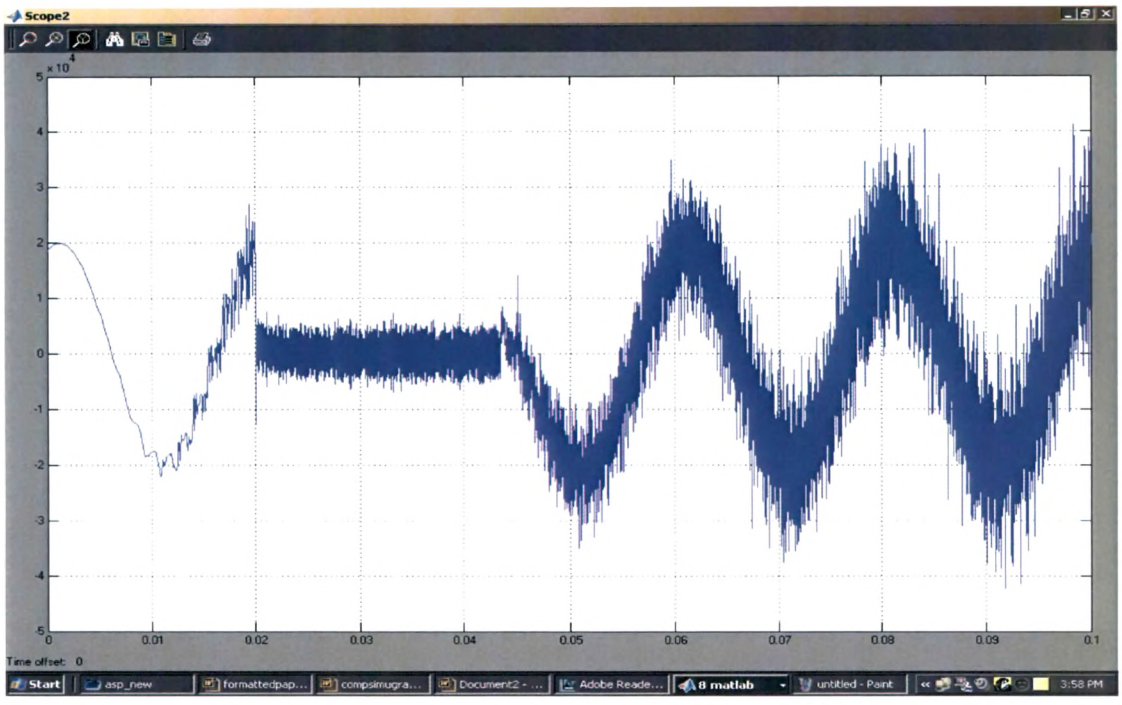
Fault Currents for fault Six Phase to Ground in Six-Phase at Sending End



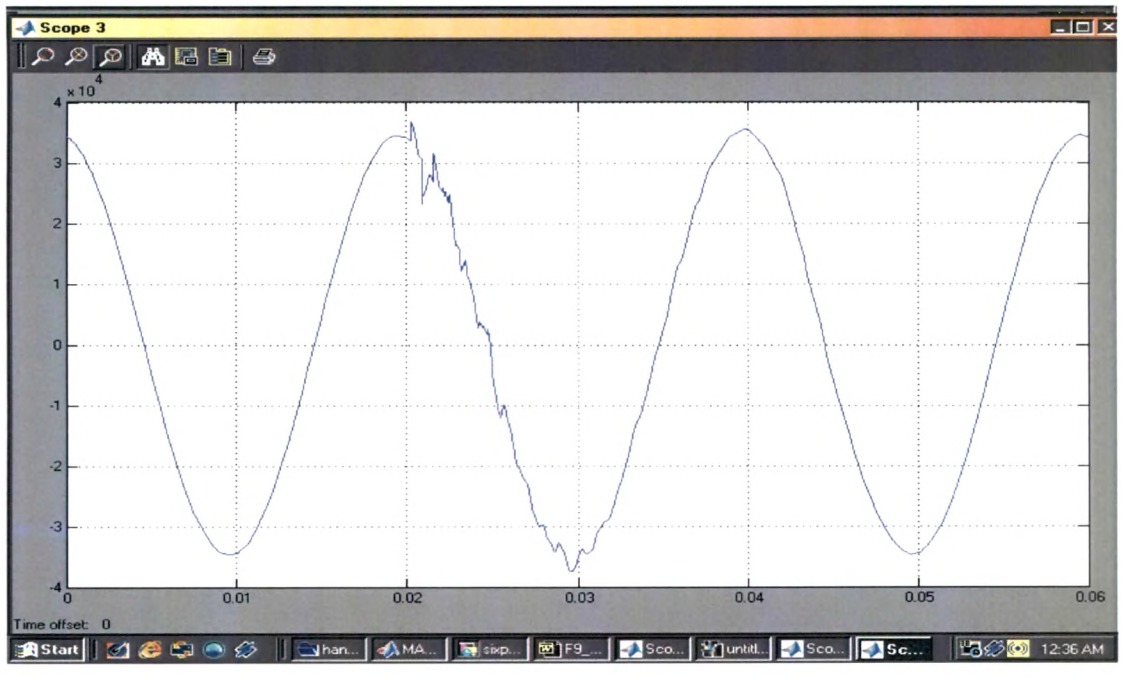
Fault Voltages for Six phases to Ground Fault on Three-phase at Sending End



Fault Voltages for fault Six Phase to Ground in Six-Phase at Sending End



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



Load Side Phase Voltage on Single Line to Ground Fault at mid-point on 6-phase

7.5 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 having 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 Line regulation is good in Six-Phase System compared to that of TPDCS.
- 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 that of Three-phase double circuit system.