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Reconfigurable Solar Converter

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Abstract- **The main objective of the research is to develop a RSC with different topologies, but with the same system parameter conditions, such that it is suitable for solar/battery powered hybrid home. Solar home is considered to be having both AC and DC loads. These loads are separated to reduce the harmonic problems. Finally, the selected topology would be validated through hardware realization.**

1. INTRODUCTION

SOLAR photovoltaic (PV) electricity generation is not available and sometimes less available depending on the time of the day and the weather conditions. Solar PV electricity output is also highly sensitive to shading. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output falls dramatically.

Therefore, solar PV electricity output significantly varies. From an energy source standpoint, a stable energy source and an energy source that can be dispatched at the request are desired. As a result, energy storage such as batteries and fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV systems has been dramatically increased, since, with energy storage, a solar PV system becomes a stable energy source and it can be dispatched at the request, which results in improving the performance and the value of solar PV systems. There are different options for integrating energy storage into a utility-scale solar PV system. Specifically, energy storage can be integrated into the either ac or dc side of the solar PV power conversion systems which may consist of multiple conversion stages. Every integration solution has its advantages and disadvantages. Different integration solutions can be compared with regard to the number of power stages, efficiency, storage system flexibility, control complexity, etc.

A solar cell is the most fundamental component of a photovoltaic (PV) system. The PV array is constructed by many series or parallel connected solar cells to obtain required current, voltage and high power [8]. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce currents by the photovoltaic effect. The output power characteristic curves for the PV array at an insulation. It can be seen that a maximum power point exists on each output power characteristic urve.

1.1BRIEF INTRODUCTION ON MULTI LEVEL INVERTERS

MLI's have been attracting increasing attention for power conversion in high-power applications due to their lower harmonics, higher efficiency, and lower voltage stress compared to two-level inverters. Though the numbers of topologies were introduced for MLI's, three among them are considered to be important. Viz.,

1. Diode clamped (neutral point clamped) inverter
2. Capacitor clamped (Flying-capacitor) inverter
3. Cascaded H bridge inverters

2. RSC FOR SOLAR POWERED HYBRID AC/DC HOME

As a summary of above discussions, the converter system has been designed with different operating modes. Due to the emerging development of MLI, the AC loads are supplied with diode-clamped 3 level inverter configurations for further analysis. The topology for this converter system is shown in the Figure 3.5. In this, five control switches are used for mode selection. These switches S_1, S_2, S_3, S_4 and S_5 are the control switches.

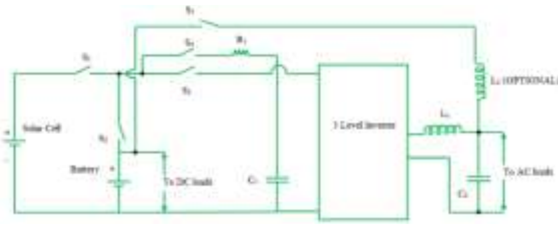

Figure 2.1 RSC topology with 5 control switches and 3 level inverter

2.1 SYSTEM SPECIFICATIONS

System Specifications chosen for both the topology is common. This is because to analyze both the topologies with same specifications. The Specification details are listed in Table 3.1. The circuit components L_1 and C_2 are acts as filter components at the inverter output. Since the ripples are removed by the L_1 itself, the inductor L_2 is optional. Series combination of R_1 and C_1 is introduced at input side of the system to arrest the inrush current occurred due to mode switching.

Table 2.1 List of system specifications

Circuit components	Specifications
L_1	5mH
L_2	2.3mH
R_1	1kΩ
C_1	2200µF
C_2	2200µF
DC Load	2 KW
AC Load	1 KW
Grid Connected Transformer	15V/230V

3. RSC WITH THREE CONTROL SWITCHES AND 2 LEVEL INVERTER

The research work can be further improved by reducing the number of control switches when compared to the previous topology which is discussed in the chapter 3. This idea is extracted from the observation of Figure 13. In this, the pulse for the control switch is always high. This means that the control switch S_3 is always ON. So, simply this switch can be ignored with a closed path.

Another option is the switch S_4, which is used to connect the R_1 and C_1 to arrest the inrush current during mode switching. When compared to the battery, the chance of inadequate changes and rushing current is more when the loads are switched to the solar panel source. This is because of irregular solar radiations. Though the battery voltage will get down while supplying the load, it is a gradual response and so the R_1, C_1 series combination is permanently connected in parallel to the solar panel and the switch S_4 can be removed.

In the previous case, DC load is connected across the battery in such a way that during the Mode 1 operation, it is isolated from the topology. So, if the system operates for a long time in the Mode 1, the battery voltage may rapidly get down. To avoid this, DC load can be connected such that solar panel takes care about it during the Mode 1 operation.

Another change is,a simple 2 level inverter is used instead of 3 level inverter for the comparative analysis of output voltage harmonic distortion.

The above mentioned ideas are considered to propose another topology with three control switches. This configuration is analysed in this chapter. Circuit diagram for this topology is shown in Figure 3.1.

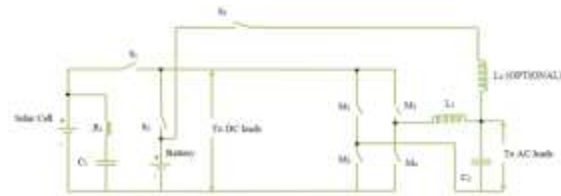

Figure 3.1 RSC with 3 control switches and 2 level inverter

4. DC VOLTAGE REGULATOR

4.1 INTRODUCTION

DC voltage regulator is used to convert the unregulated DC input into regulated DC output. The reference voltage is the required voltage at the load terminals. The block diagram for DC voltage regulator is shown in Figure 5.1.

4.2 NECESSITY OF DC VOLTAGE REGULATOR IN RSC

The DC loads must be supplied with constant input voltage, which leads to a regulator circuit at the DC load terminals. Let us consider a case, that the maximum voltage from the solar panel(250W) is 30V at $1000W/m^2$. To supply 1KW load, 4 panels must be connected in series. So, the net voltage will be 150V.So, the input voltage is not constant, which depends on solar radiations. Thus there is a need to provide a DC regulator.

This can be accomplished by providing DC buck converter with closed loop configuration. The duty cycle for the MOSFET switch is controlled by Proportional Integral Derivative (PID) controller so as to obtain the constant output voltage.

4.3CHOICE OF DC REGULATORS SUITABLE FOR RSC

Most of the DC loads recently manufactured for home appliances are operating with 24V. As stated above, the maximum voltage from the solar panel (250W) is 30V at 1000W/m ^{2}. The net voltage available across the terminals of array is depending upon the number of panels connected in the array. So, the net voltage will be higher than the required voltage. Also due to the weather conditions, the solar voltage is lower than the required voltage level. So, to obtain the constant required 24V DC voltage at load terminals, DC buck – boost converter is preferable. This is explained in the section 5.4.

4.4 CLOSED LOOP CONTROL OF DC-DC BUCK-BOOST CONVERTER

The buck-boost converter is used for regulating the DC voltage from solar panel/battery. As the solar radiation will vary instantaneously, the voltage generated by the solar cell also varied. So, instead of open loop control, closed loop control is preferable. A closed loop configuration is shown in the Figure 5.2.

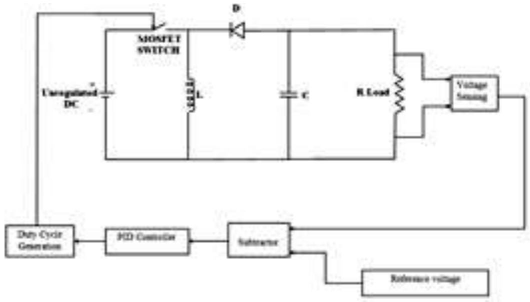

Figure 4.2 Closed loop control of DC-DC buck-boost Converter

The output voltage from the converter is sensed through the voltage sensor and it is compared with the required reference voltage. The difference is given to the PID controller to adjust the duty cycle.

5. RESULTS AND DISCUSSIONS

In this chapter the RSC topology consists of 5 control switches with MLI and 3 control switches with two level inverter has been discussed.

5.1 SIMULATION RESULTS

For simulation studies, MATLAB/SIMULINK software is used in order to model and test the system under investigation.

5.1.1 Simulation results of RSC with 5 control switches and MLI

The simulation parameters are choose such that same as in the system parameters for the actual output. This is given in Table 6.1. The simulation time is 0.1 seconds.

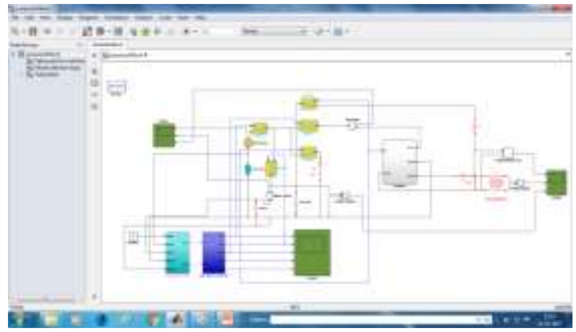

Figure 5.1 MATLAB / SIMULINK model of RSC with 5control switches and MLI

Mode selection Logic

The relational operators are used for comparison of voltage values. The voltage values are sensed through the voltmeter measurement outputs.

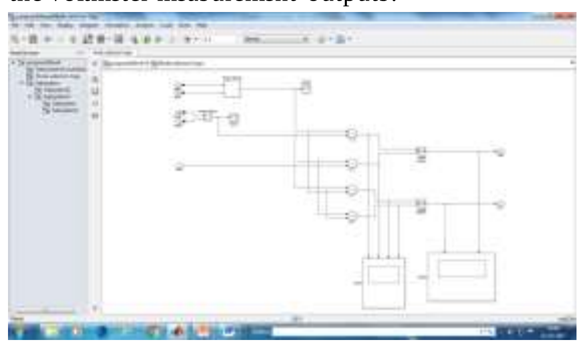

Figure 5.2 MATLAB / SIMULINK model for mode selection logic

Pulse generation for control switches

The basic gates are used from simulink library to simulate this circuit. As high value pulse is directly taken for third switch, a constant is add to that particular pulse to make easy implementation

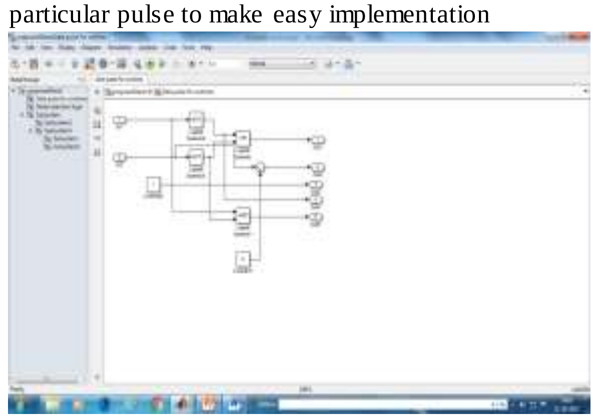

Figure 5.3 MATLAB / SIMULINK model of pulse generation for control switches

PWM generation for 3 level inverter

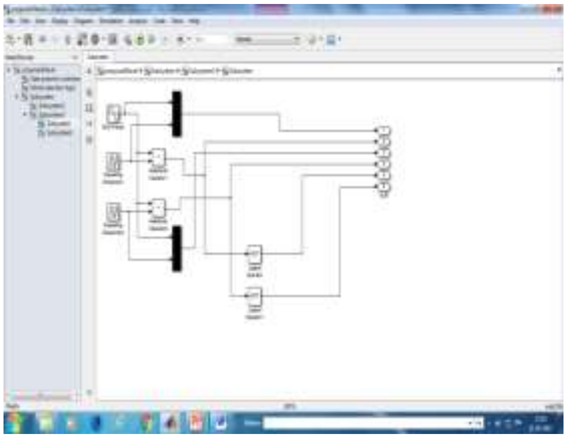

Figure 5.4 MATLAB / SIMULINK model for pulse generation of inverter

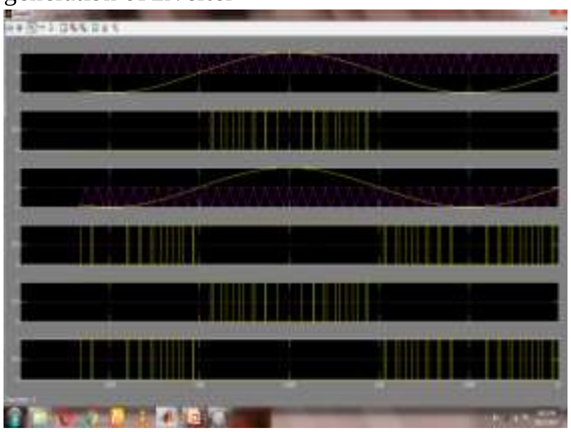

Figure 5.5 PWM pulses for 3 level inverter (for first leg switches)

PWM pulses are generated as explained in the previous chapters. The repeating sequence is used for triangular carrier with required frequency.

5.1.2 FFT analysis for RSC with 5 control switches

Since the FFT analysis is mainly to analyze the harmonic distortion at the inverter output voltage, it is obtained only for that parameter for mode.

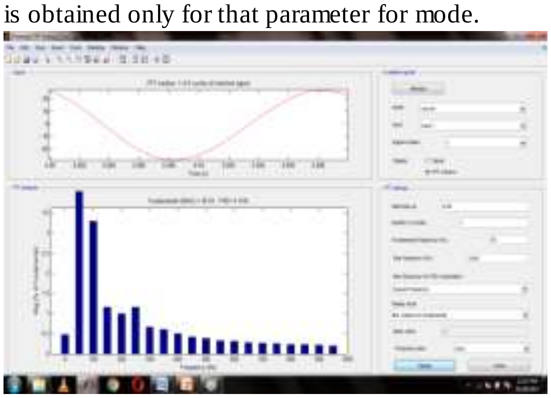

Figure 5.6 FFT analysis for inverter output voltage at mode 1

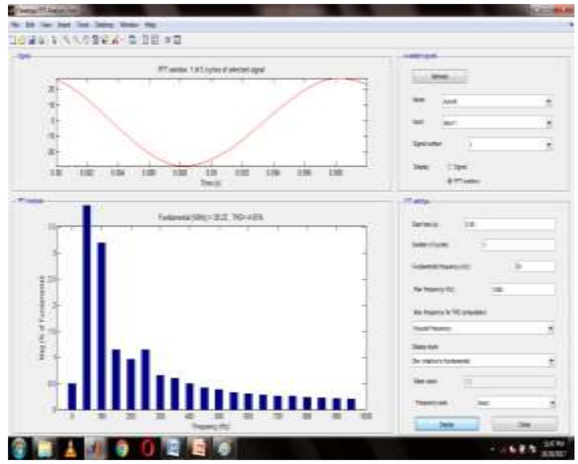

Figure 5.7 FFT analyses for inverter output voltage at mode 2

In the mode 1,2 and 4 the inversion process is done. But in the mode 3 the inversion process is not carried out due to the battery charging process of converter. So, %THD is comparatively more in this case.

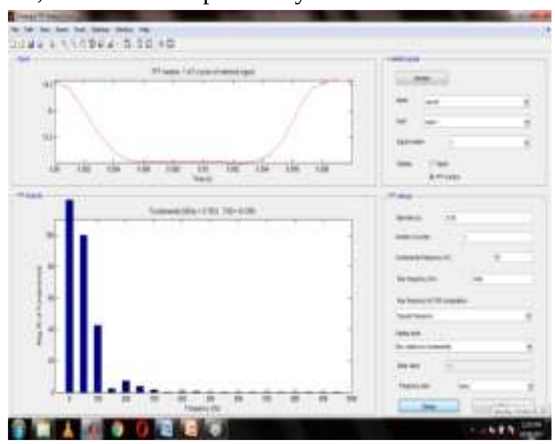

Figure 5.8 FFT analyses for inverter output voltage at mode 3

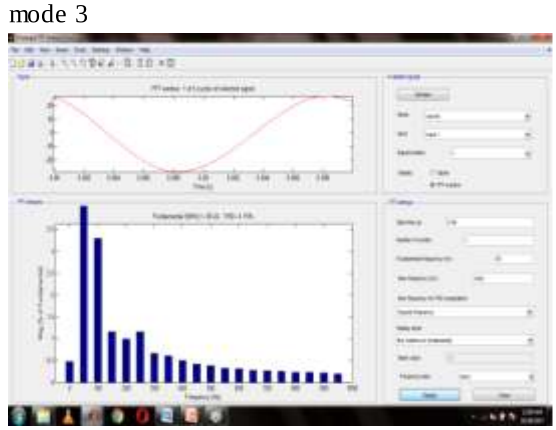

Figure 5.9 FFT analysis for inverter output voltage at mode 4

5.1.3 Simulation results of RSC with 3 control switches

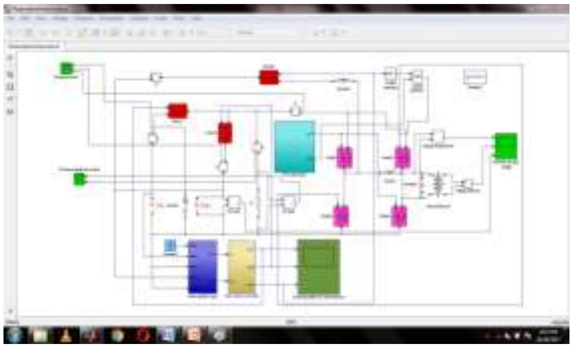

Figure 5.10 MATLAB / SIMULINK model of RSC with 3 control switches

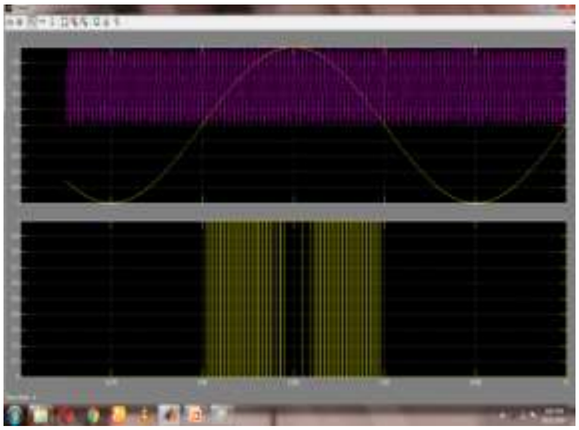

Figure 5.11 Pulses for positive cycle switches

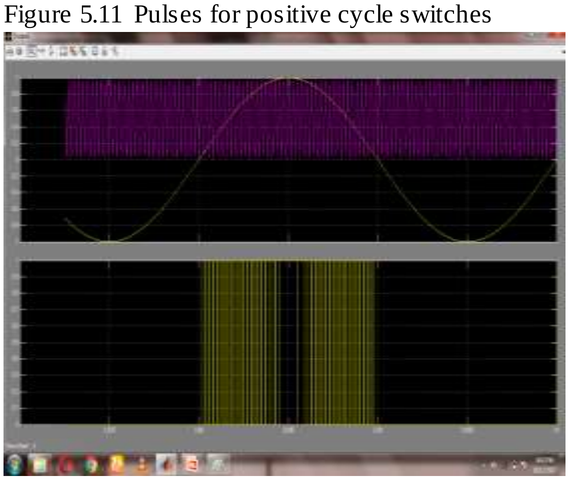

Figure 5.12 Pulses for negative cycle switches

The modes of operations for both the converters are almost same. The simulation of both the topology is mainly done to obtain the %THD of AC output voltage to compare them. This will help to find the better topology among those two. As in the previous case, the simulation results for all the modes are given and finally the %THD is compared in the Table 7.2

5.1.4 FFT Analysis for RSC with 3 control switches

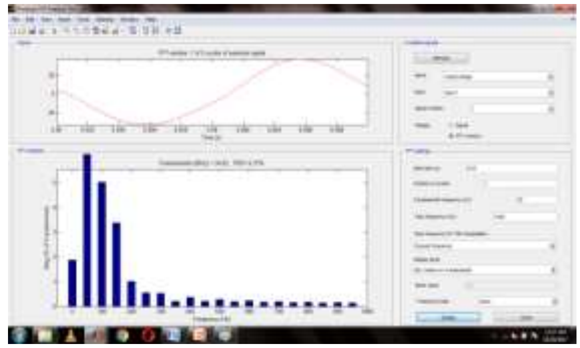

Figure 5.13 FFT analysis for inverter output voltage at mode 1

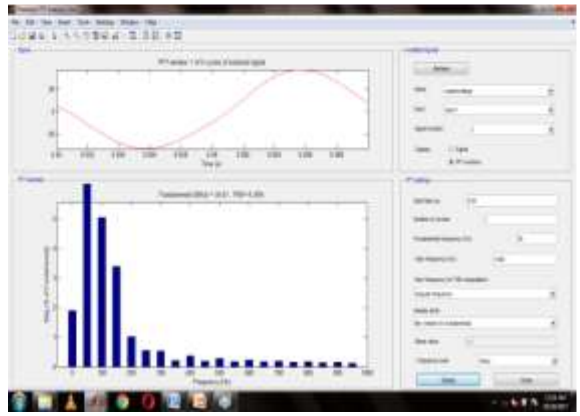

Figure 5.14 FFT analysis for inverter output voltage at mode 2

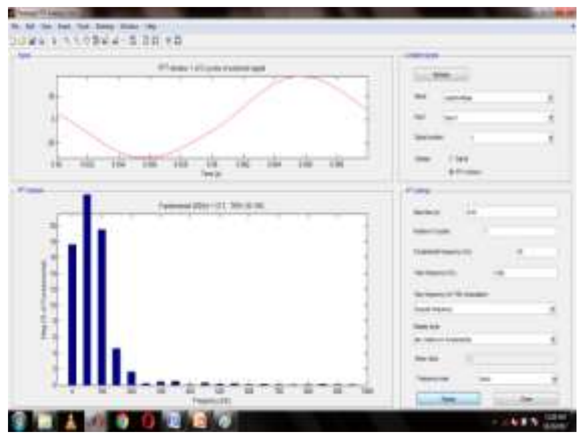

Figure 5.15 FFT analysis for inverter output voltage at mode 3

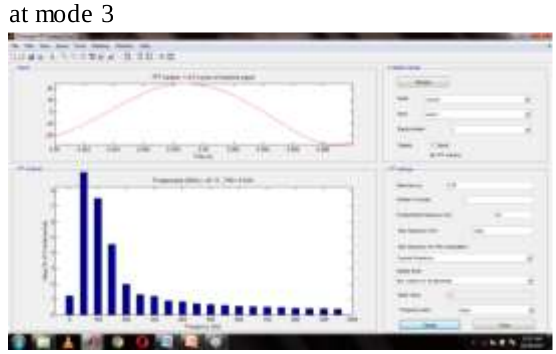

Figure 5.16 FFT analysis for inverter output voltage at mode 4

5.1.5DC voltage regulator

The DC-DC buck-boost converter is simulated by using librarycomponents of PID controller and PWM generator. The values for P,I and D are given below.

P - 0, I – 1, D – 0.

The simulation time is set to 1 second.

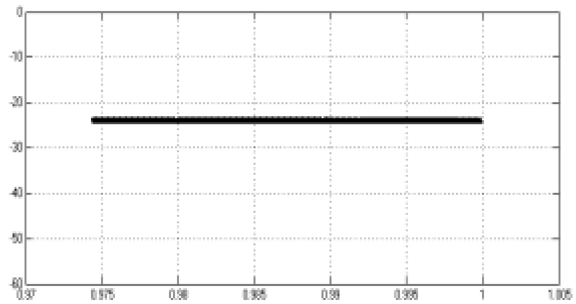

Figure 6.35 Simulation output for DC voltage regulator

The output of the DC voltage regulator was observed to be constant throughout the simulation period of 1second for different input voltages and is shown in Figure 6.35.

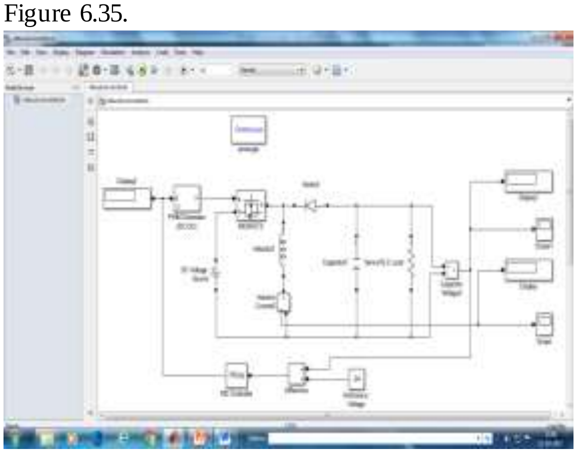

Figure 5.17 MATLAB /SIMULINK model for DC voltage regulator

6. CONCLUSION

The simulation for two different topologies of Reconfigurable Solar Converter has been done and their simulation results were obtained. From the results it is clear that the circuit parameters are not affected while reducing the number of control switches, when compared to the existing topology. The %THD of both the topology is compared and tabulated. From this tabulation it is concluded that the %THD can be reduced around 2% for all the modes except battery charging mode. This can be avoided by combining the RSC with 3 switches and MLI topology.

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