TRACTION LINE LOSS REDUCTION BY SOLAR POWERED BOOSTER TRANSFORMER

Project Preliminary Report

Submitted to The APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

B.Tech.

in

Electrical and Electronics Engineering

by

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Declaration

We undersigned hereby declare that the Project Preliminary Report **TRACTION LINE LOSS REDUCTION BY SOLAR POWERED BOOSTER TRANSFORMER**, submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Prof.Anu A.G. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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Date : 27/01/2021

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Certificate

This is to certify that the report entitled ***TRACTION LINE LOSS REDUCTION BY SOLAR POWERED BOOSTER TRANSFORMER*** *submitted by* ***Reman Krishnan(TVE17EE094),Anjana K(LTVE17EE129) ,Harija H(LTVE17EE136),Ahalya V.S(TVE17EE010)*** *to the* ***APJ Abdul Kalam Technological University*** *in partial fulfillment of the requirements for the award of the Degree of* ***B.Tech in Electrical and Electronics Engineering*** *is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.*

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Abstact

One of the most commonly used mode of transportation in India is the Railways which spans about 68,155Kms, as it's the cheapest and fastest mode for common man. About 64%, this is about 40,576Kms of railway routes are electrified which demands a large amount of power. 2 phases from the 3 phase system are mainly used by the Indian railway to feed the locomotives. The traction over head equipment (OHE) requires a 25kV supply, so 2 phases are taken to step down to single phase 25kV which is present at the traction substation.This 25kV is fed to the OHE from the feeder to the loco area via pantograph which is placed usually at the roof of the locomotive engine. As the traffic of locomotives increase at a particular substation's area , there is a voltage drop in the OHE. This can cause inefficiency of the motor which can result in large current drawing from the grid.

At present so as to minimize this problems,railways use booster transformer to eliminate stray current and maintain uniform voltage along the line that have distributed loads.The the working of existing booster transformers is by taking useful power from the grid as the load increases which is very inefficient and economic wastage.

Our project introduces a method to reduce this wastage of useful power by incorporating the system with a renewable energy source here Solar energy and to maintain constant voltage in the traction line even in varying loads.The project aims to increase the cost efficiency and power saving in the long run and built an efficient traction system for the railways.

Contents

List of Figures

List of Tables

List of Symbols

V_S	Supply voltage
V_B	Booster transformer voltage
V_f	Feeder voltage
X_L	Reactance
R_L	Load
CB_1	Circuit Breaker 1
CB_2	Circuit Breaker 2

List of Abbreviations

kV	kilo volt
KVA	Kilo volt ampere
OHE	Over Head Equipment
AC	Alternating Current
DC	Direct Current
PV	Photo Voltaic
OCPD	Over Current Protection Device
CT	Current Transformer
PT	Potential Transformer
LDR	Light-Dependent Resistor

Chapter 1

Introduction

This chapter focuses on the basic idea behind this project. It initially introduces the topic of Demand Side Management to this project. It also includes the background, motivation, objectives and expected outcomes of the project.

1.1 Background

Railways is one of the largest mode of transportation in India and it is ranked fourth largest railway network in the world. It was started in 1853 by the British Government from Mumbai to Thane with a steam locomotive.It upgraded rapidly with the advancement of technology. Electrification is one of the most important reasons of the up gradation of Indian railways .In the present scenario approximately 51.2% of passenger traffic and 65.02% of freight traffic is operated by electric traction. The power required for propulsion of locomotive is taken from OHE(Over head Equipment) via the pantograph. AC or DC drives are used for locomotives. The traction motor used are usually DC series motor and 3 phase induction motor. A Traction substation 220/132 KV is step down to 25kV through single phase transformer. The 25 kV AC voltage is drawn, as 1 phase system from a 3 phase system. One connection of transformer is permanently solidly earthed which work as return. The traction substation not only consists

Figure 1.1: Traction System

of transformers but also contains various protective devices like lightning arresters , circuit breakers , transformer protection etc. This 25kV is then supplied to the feeder and then to OHE line.

1.2 Problem Statement

Booster transformers are transformers which are used by the railways in AC catenary feeders to collect the return current from the rails and earth to return conductor as well as to eliminate stray current and the disturbances obliging the return current to flow to the return conductor and to maintain uniform voltage along the line even in distributed load.But line losses are high as the traffic of train in a single area that is number of trains passing in a single area is high. So to compensate this losses the grid supply is used from the electricity board which results in the reduction in useful grid power which is inefficient and uneconomical.Hence the project aims to reduce this ineffeciency by injecting power back with the help of a renewable energy source,here Solar energy.

1.3 Motivation

The existing booster transformers used in traction lines takes the power from the main power supply, which causes an reduction in useful power and is an inefficient method.There is no constant measurement of power losses in the existing system.The existing traction line system has a lot of economical drawbacks.

1.4 Objectives

The main objectives of the project are :

- Measure the power losses in 25 kV traction line
- Design the solar powered booster transformer for meeting the power losses
- Design prototype of the system
- Obtain the simulation result

1.5 Expected Outcome

Line losses were measured and reduced to minimum by employing solar power to the existing system.Using a renewable energy source the power consumption from the main source is reduced.

Chapter 2

Literature Review

2.1 Traction System

The traction system is a component of the train which is usually installed on the roof or underneath the train. The system converts electrical energy collected from the catenary via the pantograph which is a device which makes contact of the train and line, into mechanical energy, thus making the wheels to turn and making the train to accelerate and brake. Traction power network is an electricity grid for the supply of electrified rail networks. Also the three-phase alternating current of the power grid can be converted in substations by rotary transformers or static inverters into the voltage and type of current required by the trains. Railway works under the Indian railway which is a state-owned organization of the Ministry of railway. Indian railway traction system uses 1.5 kV DC around Bombay and 25kV ac is used in rest of the country. The supply for traction system is taken from state utility which is three phase source at 132/220 kV.

2.2 Booster Transformer

A Booster transformer is often used towards the end of a power line to raise the voltage to the desired value. It is used for controlling the voltage of a feeder at a point far away from the main transformer. The secondary of the booster transformer is connected in series with the line, and its primary is supplied from the secondary of the regulating transformer. The output winding of the regulating transformer is so connected to the primary of the booster transformer that the voltage injected in the line V_B is in phase with the supply V_S.

Figure 2.1: Booster transformer

By changing taps on the regulating transformer, the magnitude of V_B can be changed and thus feeder voltage V_f can be regulated. The rating of regulating transformer is only the fraction of that the main transformer. It is given by the expression.

Kva $\times$ Rating of booster=Load Kva $\times$ Percentage boost in voltage

The advantage of the above system is that the regulating equipment is independent of the main transformer so that a failure in the former will not throw the latter out of service. Booster transformer is used in railways for eliminating the flow of stray current. The stray current disturbs the communication system and also damage the electronic devices of the trains passing through them.

2.3 Solar Panel

A solar panel which can be called as a Photo-Voltaic array/module (PV array/module) is an assembly of photo-voltaic cells mounted in a framework for easy use and installation. Photo-voltaic cells use sunlight as a source of energy and generate direct current electricity. Arrays of a photovoltaic system supply solar electricity to electrical equipment. Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells.

2.4 Inverter

An inverter is a device which converts the DC electricity from sources like batteries or fuel cells to AC electricity. The AC electricity can be at any required voltage so it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.Source we use here is solar so solar dc currents are inverted for the use here

2.5 Circuit Breaker

A circuit breaker is an electrical switch which is designed to protect an electrical circuit from damage caused by excess current from an overload or short circuits. Its basic function is to interrupt current flow after a fault is detected. Not like a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect low-current circuits or individual household appliance, up to large switchgear designed to protect high voltage circuits feeding an entire city. The generic function of a circuit breaker, or fuse, as an automatic means of removing power from a faulty system is often abbreviated as OCPD (Over Current Protection Device).

vacuum circuit breakers are used in railway traction system mainly. A vacuum circuit breaker is a circuit breaker where the arc quenching takes place in a vacuum medium. The operation of switching on and closing of current carrying contacts and interrelated arc interruption takes place in a vacuum chamber in the breaker called as a vacuum interrupter.

2.6 Current Transformer

A current transformer (CT) is a type of transformer that is used to reduce or multiply an alternating current (AC). It produces a current in its secondary which is proportional to the current in its primary. Current transformers together with voltage or potential transformers, are instrument transformers. It is also used as a protection device as it isolates the device from heavy currents. It can be also used as measurement device when low current rated measuring devices are used as it steps down the currents to required permissible values which can be easily handled.

2.7 Potential Transformer

A Potential transformer (PT) is a type of transformer that is used to reduce or multiply an High Voltages. It produces a voltage in its secondary which is proportional to the voltage in its primary. Current transformers together with voltage or potential transformers, are instrument transformers. It is also used as a protection device as it isolates the device from heavy voltage.It can be also used as measurement device when low voltage rated measuring devices are used as it steps down the voltage to required permissible values which can be easily handled.

2.8 Light-Dependent Resistor

Light-Dependent Resistor(LDR) also Known as photovoltaic conductor a passive component that decreases resistance with respect to receiving luminosity (light) which falls on the component's sensitive surface. The resistance of a photo resistor decreases with increase in incident light intensity that is,it exhibits photoconductivity.

2.9 Power monitor

A Power monitor is a set of devices which is used to measure and evaluate the amount of power,current, and voltage as well as other electrical quantities a system uses while working or connected to the grid. It is also used as for protection as the figures after evaluation can be used to make the protecting devices to work properly.The electricity boards can also monetize the used electricity from customers.The Microcontroller here is an Arduino. Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Arduino boards are available commercially from the official website or through authorized distributors.

2.10 Reverse Power Relay

A reverse power relay is a relay that prevents power from flowing in the reverse direction. This relay prevents high voltages from flowing from high voltage area to low voltage area which is needed in the protection of high voltage systems.

Chapter 3

Methodology

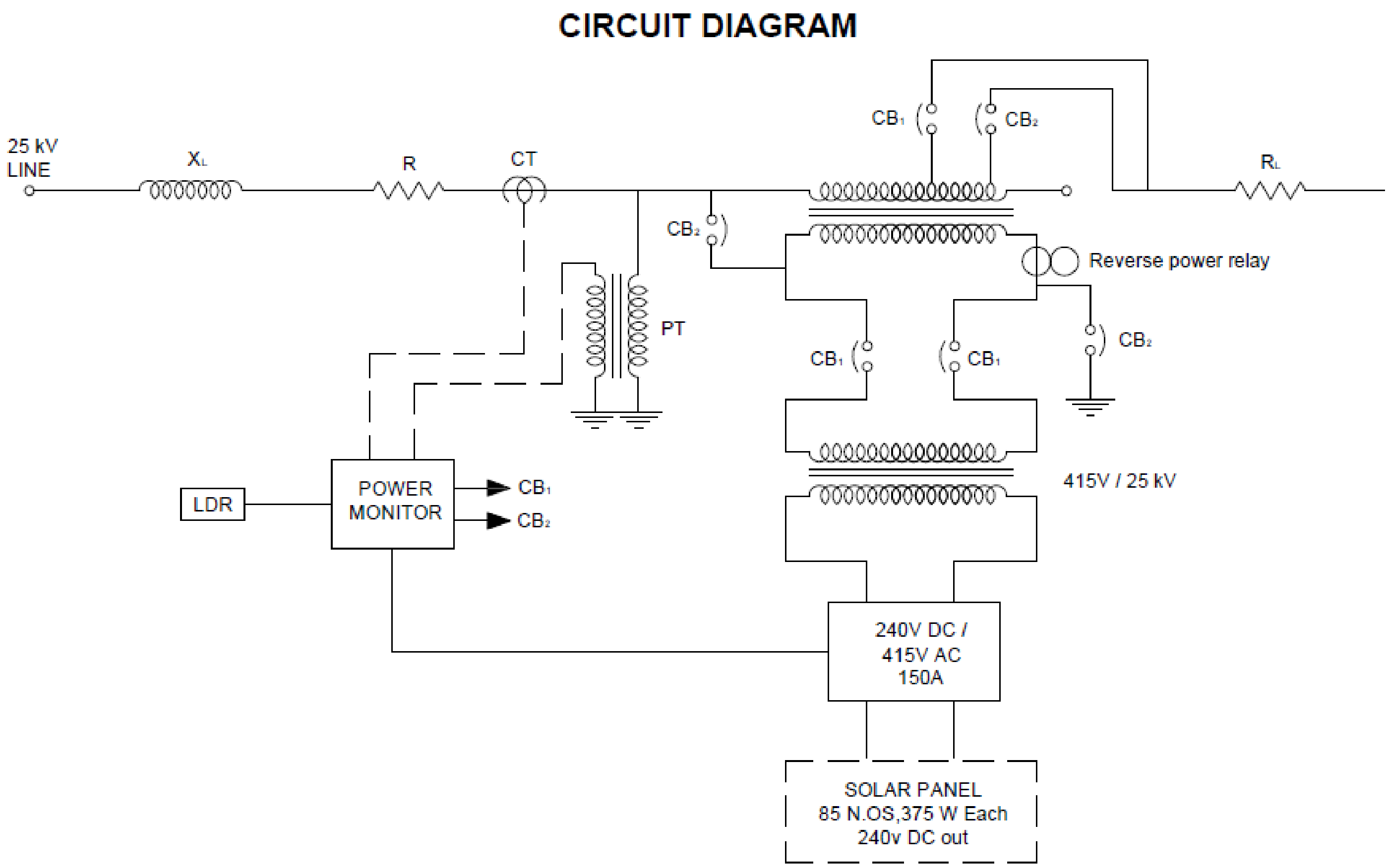


Figure 3.1: Circuit Diagram of the system

Parameters R andX_L represents the traction line parameters. CT is the current transformer and PT is the potential transformer which is used to convert the current and voltage respectively to particular ratios and for protection. CB_1 and CB_2 represents the circuit breakers. The power monitor used is an Arduino circuit. R_L represents the load(train). LDR is used to sensor the intensity of light of the sun. In traction systems, there is a voltage drop between the receiving and supplying end due to transmission line parameters and losses due to the load. To overcome these losses, we use a booster transformer even in presence of the existing booster transformer though some losses occur. The losses are continuously monitored and the lost power is injected back to the line through the Solar powered booster transformer. Solar panels are used for solar power and the DC voltage from the panels is converted to AC using inverters and is fed back to the booster transformer. In the circuit given, the transformer coil acts as booster transformer , auto transformer or tap changer respectively based on 2 conditions.

3.1 Stage 1

During night or rainy days when the solar power harvested is not available ,the LDR will sense the intensity of light which is less than the preset value, a signal is send from power monitor to OFF all the CB_1 circuit breakers and ON all CB_2 circuit breaker. Then the secondary of auto transformer cum booster transformer will act as 25kV line and power is injected back to the line by tap changing at the primary of autotransformer cum booster transformer

3.2 Stage 2

During the day time when sunlight is available that is when solar power is harvested,The intensity of the light is greater than the preset value a signal is send from the power monitor to OFF all the CB_2 circuit breakers an ON all theCB_1 circuit breakers.Now the Lost power is injected back to the line which was harvested from the solar panels through the inverter and step up transformer to the booster transformer.

Based on the data from PT ,the inverter output voltage is always kept greater than the line voltage or else power will flow in the reverse direction . So as to avoid this, the line voltage is continuously monitored and the inverter output is kept greater than the line voltage. If there is any reverse power flow from booster it will trip all CB_1circuit breakers ; reverse power relay are used.

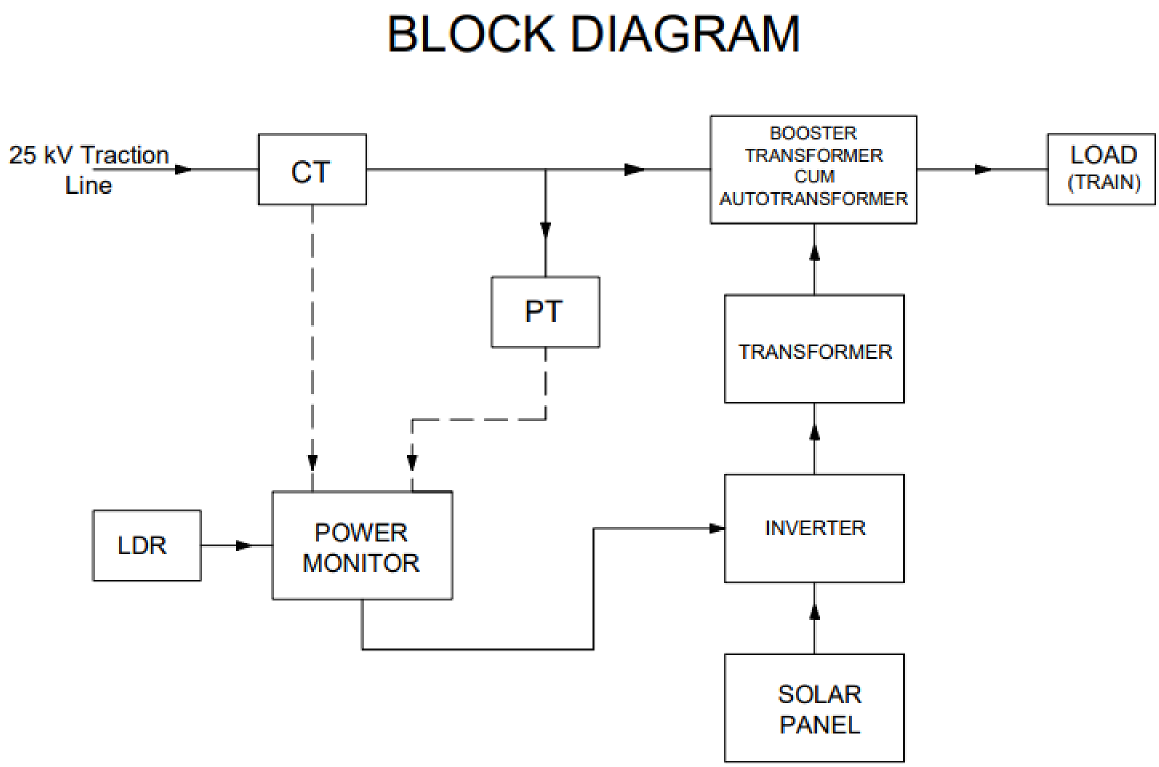


Figure 3.2: Block Diagram of the system

Chapter 4

System design and specifications

Design specifications of different components of 25 kV traction line is discussed in this section

4.1 Design of Autotransformer

The design of the Autotransformer is as shown

We know from transformer equation that $N_1/N_2 = V_1/V_2$

Assume $N_1 = 500$ turns

$V_1 = 25000$ -Losses

$= 25000 - 2000$ (Assuming 8% loss)

=23000

$V_2 = 25000$

$N_2 = (V_2/V_1)^* \ N_1$

$= (25000/23000)^*500$

$= 543.4$

$= 543$ Turns

4.2 Design of Solar Panel

Assuming 8% voltage fluctuation

Line voltage = 25kV

8% voltage of 25kV = 2000 V

Available Panel specifications is 375 W/24 V

Number of Panel = 2000/24 = 83.3

Taking approximately 85 numbers Total power injected = 85*300 = 25.500KW

Size of a panel = 1970*990*35 mm Area of one panel = 1.97*0.9 = 1.95 m^2

Total area required for 85 panel = 85*1.95

$$= 165.77 \text{ m}^2$$

In practical application the solar panels can be kept in open fields and open areas of the railways like railway stations rooftop, the substation areas and so on.

4.3 Design of transformer

$E_1 = 4.44fN_1\Phi_{\mathrm{m}}$

$E_2 = 4.44fN_2\Phi_m$

$E_1/N_1 = E_2/N_2$

The value of induced emf in $1^0E_1 = 415$ V

The value of induced emf in $2°E_2 = 25$kV

F = 50 Hz

$\Phi_{\mathrm{S}x} = 0.05$(from material chart)

$E_1/N_1 = 4.44f\Phi_{\mathrm{m}}$

= 4.44*0.05*50

= 11.1

$N_1 = 415/11.1$

$= 37.38$

Approximately we choose 1^0 number of turns as 38.

Similarly

$$E_2/N_2 = 11.1$$

$$N_2 = E_2/11.1$$

$$= 25000/11.1$$

$$= 2252.25$$

Approximately we choose 2^0 number of turns as 2252.

So 1° or input = 415 V/75 A/38 turns

2^0 or output= $25Kx, 1.245$ A, 2252 turns

Natural air cooled transformer is used

4.4 Design of CT and PT

Ratio of Potential transformer used is 25kV/110 v and Current Transformer used is 1000:5

Chapter 5

Prototype

5.1 Introduction

The rating and values of the components in the industrial application of the project is very high so it was decided to step down the project that is to create a prototype in the ratio 1:100.The voltage of traction line is step down to 250V from 25kV so as to reduce the cost of making and simplify its applicability as a project.

5.2 Methodology

The above circuit diagram represents the idea of the prototype of the design.The working remains same as the main circuit but for simplicity certain components are replaced .The main design changes are

- The circuit breakers are replaced with contactors which are selected on the basis of current rating that is about 1.5 times greater the system current.
- CT and PT are replaced with an aurdino circuit with current and voltage sensors.

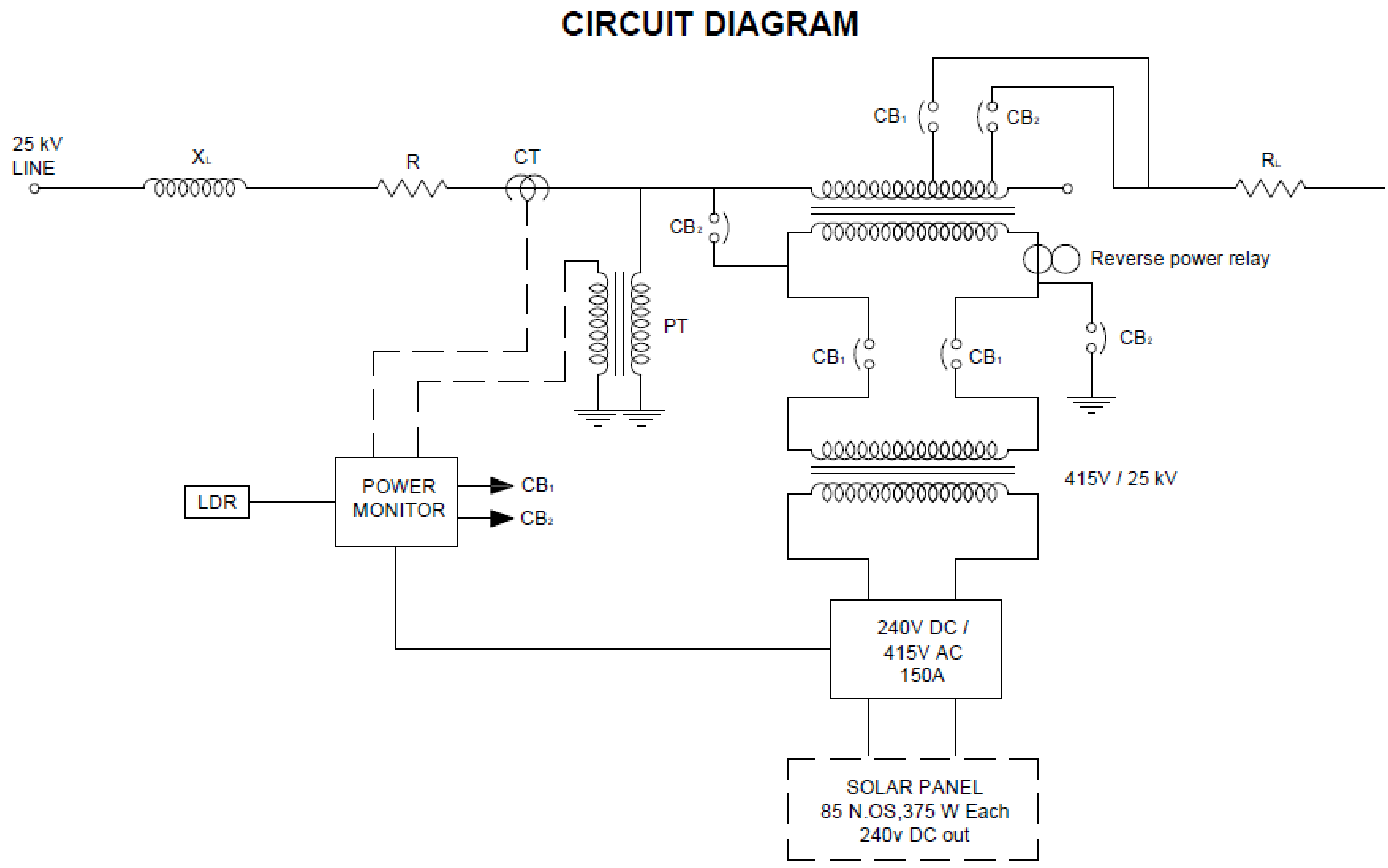


Figure 5.1: Circuit Diagram

- The Step up transformer and reverse power relay is removed to simplify the circuit instead reverse power relay is integrated into the aurdino circuit where contactor 1 gets OFF during any reverse power flow.

5.3 Design Of Traction line parameters

The traction line is represented for a 3km section here.This is because usually after 3kms a booster transformer is used, so we have sectionalized a part for the prototype. The parameters are

Resistance R=0.41 $\times$3 =0.42Ω

Reactance X_L=0.385 $\times$3 =1.153Ω

We can see the resistance is a very small value so we use materials like Gold or Silver for the sake of representation. Coils can replace reactanceX_L .

5.4 Design of Contactors

Contactors are selected on the basis of current rating.Contactor of 1.5 times greater than the actual value is chosen.We select 26A Contactor between inverter and booster transformer and a 16 A contactor for main line.

5.5 Design of Booster Transformer

Design of Autotransformer

We know that $N_1/N_2 = V_1/V_2$

Assume $N_1 = 500$ turns

$V_1 = 250$ -Losses

$= 250 - 20$ (Assuming 8% loss)

=230

$V_2 = 250$

$N_2 = (V_2/V_1)^* \ N_1$

$= (250/230)^*500$

$= 543.4$

$= 543$ Turns

5.6 Design Solar Panel

Assuming 8% voltage fluctuation Line voltage = 250 V

8% voltage of 250 V = 20 V

Available Panel specifications is 300 W/24 V

Number of Panel=1

5.7 Design Of Inverter

Inverter design is divided to following subsections

5.7.1 Switch selection for Inverter

We are using full bridge inverter for the operation of circuit. Input voltage = 24 V

Output current = 10 A

Output voltage = 250 V

Drain to source voltage is always twice the input voltage and drain current should be 1.5 times output current.

V_{ds} = 2*24

= 48 V

So we select 50 V

Drain current I_d = 9.38*1.5 (I_{sc} from data sheet of solar panel)

$$= 14.07$$

We are selceting I_d approximately as 15 A.Considering input and output parameters we select IRFZ20P$_BFN$ is a 50V single N channel power MOSFET with extremely low on- resistance per silicon area and fast switching performance using advanced planar technology. The drain to source voltage (V_{DSS}) is 50 V, continuous drain current (I_D) is 15 A and ON resistance R_{DS}(ON) is 0.10ohm.

5.7.2 Switching control for Inverter

Taking peak voltage of sine wave $V_{\text{CONTROL}} = 0.8$ V

$$\mathrm{M_a} = 0.8$$

Amplitude modulation index=Peak of control voltage/ Peak of triangular wave voltage ($\mathrm{V_t}$) $\mathrm{V_{tr}} = 1$ Modulating Frequency $\mathrm{F_M} = 50$ Hz Switching frequency $\mathrm{F_s} = 20\ \mathrm{F_M}$

$$= 1\text{kHz}$$

Frequency modulation $\mathrm{M_F} = \mathrm{F_S}/\mathrm{F_M}$

$$= 20$$

The maximum output comes in fundamental frequency 50 Hz Output peak $V_0 = M_a{}^*V_D$

$$= 0.8^*24$$

$$= 19.2 \text{ V}$$

RMS output voltage of inverter $= 19.2/2^{1/2}$

$$= 13.57 \text{ V}$$

Unipolar switching scheme is used. A PIC16F877 Micro Controller are selected to implement unipolar switching. It have 256 byte of EEPROM data memory.

5.7.3 Gate driven circuit

$$V_{GS} = +/-20V$$

Total gate charge = 17nc Rise time = 90 ns Gate charge current= Total gate charge / Fall time

$$= 17\text{nc}/90 \text{ ns}$$

$$= 0.1888 \text{ A}$$

This is required to turn on the MOSFET.For selected MOSFET of inverter total gate charge (Q_G) is 17nc and rise time is (t_r) is 90 ns and gate to source voltage $\left(\underline{V_{GS})}\right.$ is $= +/-20V$

Selecting single channel isolated gate drive according to MOSFET specification UCC27222.

5.7.4 LC filter

Since the fundamental frequency is 50 Hz and the higher harmonic components need to be removed, a low pass LC filter is required. For unipolar sine PWM, the first harmonics occur at 2fs $\pm$ 1 i.e. at 1999 Hz and 2001 Hz. Therefore a LC filter is designed with a frequency fc, where 50 $\leq$ fc $\leq$ 1999. Taking fc = 250 Hz and let L = 10mH $fc = 1/2\pi vLC$ C = 40μF The value of L and C areto be further tuned in simulation to reduce the THD and to obtain 230 V, 50 Hz sine wave.

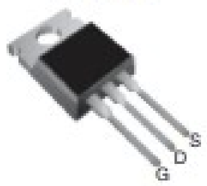
5.7.5 Transformer

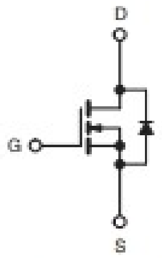
Since the RMS voltage output of inverter is about 13 V and the utility RMS voltage is 250V, we need a 13 V/250V transformer to get 250V, 50Hz, single phase AC supply.

Power MOSFET

PRODUCT SUMMARY		
V_{DS} (V)	50	
$R_{DS(on)}$ (Ω)	V_{GS} = 10 V	0.10
Q_g (Max.) (nC)	17	
Q_{gs} (nC)	9.0	
Q_{gd} (nC)	3.0	
Configuration	Single	

TO-220AB





N-Channel MOSFET

FEATURES

- Extremely Low $R_{DS(on)}$
- Compact Plastic Package
- Fast Switching
- Low Drive Current
- Ease of Paralleling
- Excellent Temperature Stability
- Parts Per Million Quality
- Compliant to RoHS Directive 2002/95/EC

Available
RoHS*
COMPLIANT

DESCRIPTION

The technology has expanded its product base to serve the low voltage, very low $R_{DS(on)}$ MOSFET transistor requirements. Vishay's highly efficient geometry and unique processing have been combined to create the lowest on resistance per device performance. In addition to this feature all have documented reliability and parts per million quality!

The transistor also offer all of the well established advantages of MOSFETs such as voltage control, very fast switching, ease of paralleling, and temperature stability of the electrical parameters.

They are well suited for applications such as switching power supplies, motor controls, inverters, choppers, audio amplifiers, high energy pulse circuits, and in systems that are operated from low voltage batteries, such as automotive, portable equipment, etc.

ORDERING INFORMATION	
Package	TO-220AB
Lead (Pb)-free	IRFZ20PbF
	SiHFZ20-E3
SnPb	IRFZ20
	SiHFZ20

ABSOLUTE MAXIMUM RATINGS					
PARAMETER			SYMBOL	LIMIT	UNIT
Drain-Source Voltage[a]			V_{DS}	50	V
Gate-Source Voltage[a]			V_{GS}	± 20	
Continuous Drain Current	V_{GS} at 10 V	T_C = 25 °C	I_D	15	A
		T_C = 100 °C		10	
Pulsed Drain Current[b]			I_{DM}	60	
Single Pulse Avalanche Energy[c]			E_{AS}	5	mJ
Linear Derating Factor (see fig. 16)				0.32	W/°C
Maximum Power Dissipation (see fig. 16)	T_C = 25 °C		P_D	40	W
Operating Junction and Storage Temperature Range			T_J, T_{stg}	- 55 to + 150	°C
Soldering Recommendations (Peak Temperature)	for 10 s			300 (0.063" (1.6 mm) from case	

Notes

a. T_J = 25 °C to 150 °C

b. Repeditive rating: Pulse width limited by max. junction temperature. See transient temperature impedance curve (see fig. 11).

c. Starting T_J = 25 °C, L = 0.07 mH, R_g = 25 Ω, I_{AS} = 12 A

Figure 5.2: Absolute maximum rating)

THERMAL RESISTANCE RATINGS				
PARAMETER	**SYMBOL**	**TYP.**	**MAX.**	**UNIT**
Typical Socket Mount, Junction-to-Ambient	R_{thJA}	-	80	°C/W
Case-to-Sink, Mounting Surface Flat, Smooth, and Greased	R_{thCS}	1.0	-	
Junction-to-Case	R_{thJC}	-	3.12	

ELECTRICAL CHARACTERISTICS (T_J = 25 °C, unless otherwise noted)							
PARAMETER	**SYMBOL**	**TEST CONDITIONS**		**MIN.**	**TYP.**	**MAX.**	**UNIT**
Static							
Drain-Source Breakdown Voltage	V_{DS}	V_{GS} = 0 V, I_D = 250 μA		50	-	-	V
Gate-Source Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 250 μA		2.0	-	4.0	V
Gate-Source Leakage	I_{GSS}	V_{GS} = ± 20 V		-	-	± 500	nA
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} > Max. Rating, V_{GS} = 0 V		-	-	250	μA
		V_{DS} = Max. Rating x 0.8, V_{GS} = 0 V, T_C = 125 °C		-	-	1000	
On-State Drain Current	$I_{D(on)}$	V_{GS} = 10 V	V_{DS} > $I_{D(on)}$ x $R_{DS(on)}$ max.	-	-	15	A
Drain-Source On-State Resistance[b]	$R_{DS(on)}$	V_{GS} = 10 V	I_D = 10 A	-	0.080	0.10	Ω
Forward Transconductance[b]	g_{fs}	V_{DS} > $I_{D(on)}$ x $R_{DS(on)}$ max., I_D = 9.0 A		5.0	6.0	-	S
Dynamic							
Input Capacitance	C_{iss}	V_{GS} = 0 V, V_{DS} = 25 V, f = 1.0 MHz, see fig. 11		-	560	860	pF
Output Capacitance	C_{oss}			-	250	350	
Reverse Transfer Capacitance	C_{rss}			-	60	100	
Total Gate Charge	Q_g	V_{GS} = 10 V	I_D = 20 A, V_{DS} = 0.8 max. rating, see fig. 18 for test circuit (Gate charge is essentially independent of operating temperature)	-	12	17	nC
Gate-Source Charge	Q_{gs}			-	9.0	-	
Gate-Drain Charge	Q_{gd}			-	3.0	-	
Turn-On Delay Time	$t_{d(on)}$	V_{DD} = 25 V, I_D = 9.0 A, Z_0 = 50 Ω, see fig. 5[b]		-	15	30	ns
Rise Time	t_r			-	45	90	
Turn-Off Delay Time	$t_{d(off)}$			-	20	40	
Fall Time	t_f			-	15	30	
Internal Drain Inductance	L_D	Modified MOSFET symbol showing the internal device inductances		-	3.5	-	nH
Internal Source Inductance	L_S			-	4.5	-	
Drain-Source Body Diode Characteristics							
Continuous Source-Drain Diode Current	I_S	MOSFET symbol showing the integral reverse p - n junction rectifier		-	-	15	A
Pulsed Diode Forward Current[a]	I_{SM}			-	-	60	
Body Diode Voltage[b]	V_{SD}	T_C = 25 °C, I_S = 15 A, V_{GS} = 0 V		-	-	1.5	V
Body Diode Reverse Recovery Time	t_{rr}	T_J = 150 °C, I_F = 15 A, dI_F/dt = 100 A/μs		-	100	-	ns
Body Diode Reverse Recovery Charge	Q_{rr}			-	0.4	-	μC
Forward Turn-On Time	t_{on}	Intrinsic turn-on time is negligible (turn-on is dominated by L_S and L_D)					

Notes

a. Repeditive rating: Pulse width limited by max. junction temperature. See transient temperature impedance curve (see fig. 5).

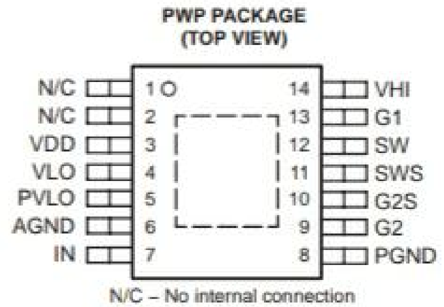
b. Pulse test: Pulse width ≤ 300 μs; duty cycle ≤ 2 %.

Figure 5.3: Drain-Source body characteristics

Figure 5.4: Pin diagram of pic microcontroller

TERMINAL NAME	NO.	I/O	DESCRIPTION
AGND	6	–	Analog ground for all internal logic circuitry. AGND and PGND should be tied to the PCB ground plane with vias.
G1	13	O	High-side gate driver output that swings between SW and VHI.
G2	9	O	Low-side gate driver output that swings between PGND and PVLO.
G2S	10	I	Used by the predictive deadtime controller for sensing the SR MOSFET gate voltage to set the appropriate deadtime.
IN	7	I	Digital input command pin. A logic high forces on the main switch and forces off the synchronous rectifier.
PGND	8	–	Ground return for the G2 driver. Connect PGND to PCB ground plane with several vias.
PVLO	5	I	PVLO supplies the G2 driver. Connect PVLO to VLO and bypass on the PCB.
SW	12	–	G1 driver return connection.
SWS	11	I	Used by the predictive controller to sense SR body-diode conduction. Connect to SR MOSFET drain close to the MOSFET package.
VDD	3	I	Input to the internal VLO regulator. Nominal VDD range is from 8.5 V to 20 V. Bypass with at least 0.1 μF of capacitance.
VHI	14	I	Floating G1 driver supply pin. VHI is fed by an external Schottky diode during the SR MOSFET on-time. Bypass VHI to SW with an external capacitor.
VLO	4	O	Output of the VLO regulator and supply input for the logic and control circuitry. Connect VLO to PVLO and bypass on the PCB.

Figure 5.5: Pin Function



AVAILABLE OPTIONS

T_A	PWM INPUT (IN)	PACKAGED DEVICES PowerPAD™ HTSSOP–14 (PWP)
–40°C to 105°C	INVERTING	UCC27221PWP
	NON-INVERTING	UCC27222PWP

†The PWP package is available taped and reeled. Add R suffix to device type (e.g. UCC27221PWPR) to order quantities of 2,000 devices per reel and 90 units per tube.

absolute maximum ratings over operating free-air temperature (unless otherwise noted)†‡

Supply voltage range, VDD	–0.3 to 20 V
Input voltage, VHI	30 V
SW, SWS	20 V
Supply current, I_{DD}, including gate drive current	100 mA
Sink current (peak) pulsed, G1/G2	4.0 A
Source current (peak) pulsed, G1/G2	–4.0 A
Analog input, IN	–3.0 V to V_{DD} + 0.3 V, not to exceed 15 V
Power Dissipation at T_A = 25°C (PWP package)	3 W
Operating junction temperature range, T_J	–55°C to 115°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature soldering 1.6 mm (1/16 inch) from case for 10 seconds	300°C

Figure 5.6: Pin Configuration of UCC27222

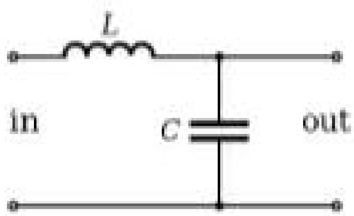


Figure 5.7: LC Filter

Chapter 6

Results and Discussions

The results obtained after simulating the model we proposed is shown in this chapter.

6.1 Simulation Model of main system

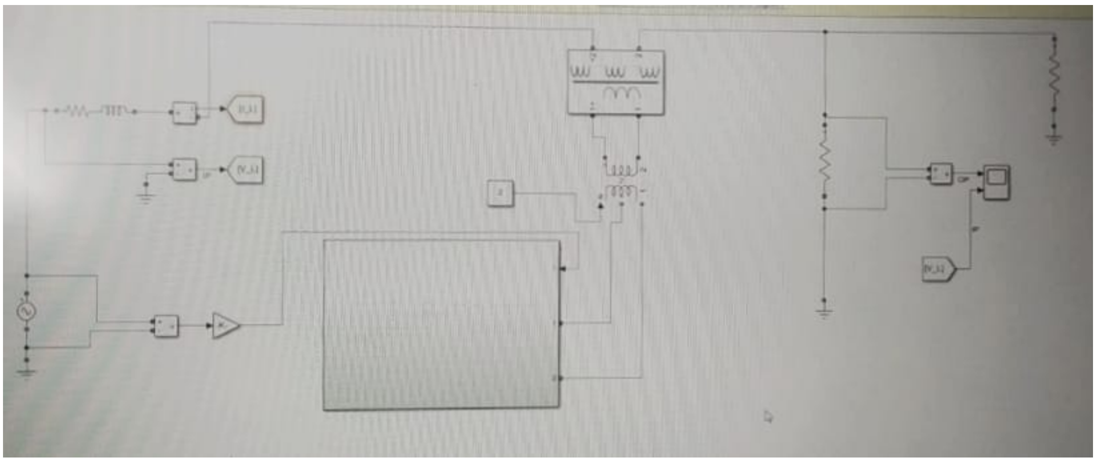


Figure 6.1: Main system Simulation

Since there is no reference for the circuit developed for this system ,only with the future development of the full prototype the full simulation results can be developed.During the development of the hardware,using trial and error method and the completion of prototype the full simulation result will be developed and submitted.

6.2 Simulation Model Of Inverter

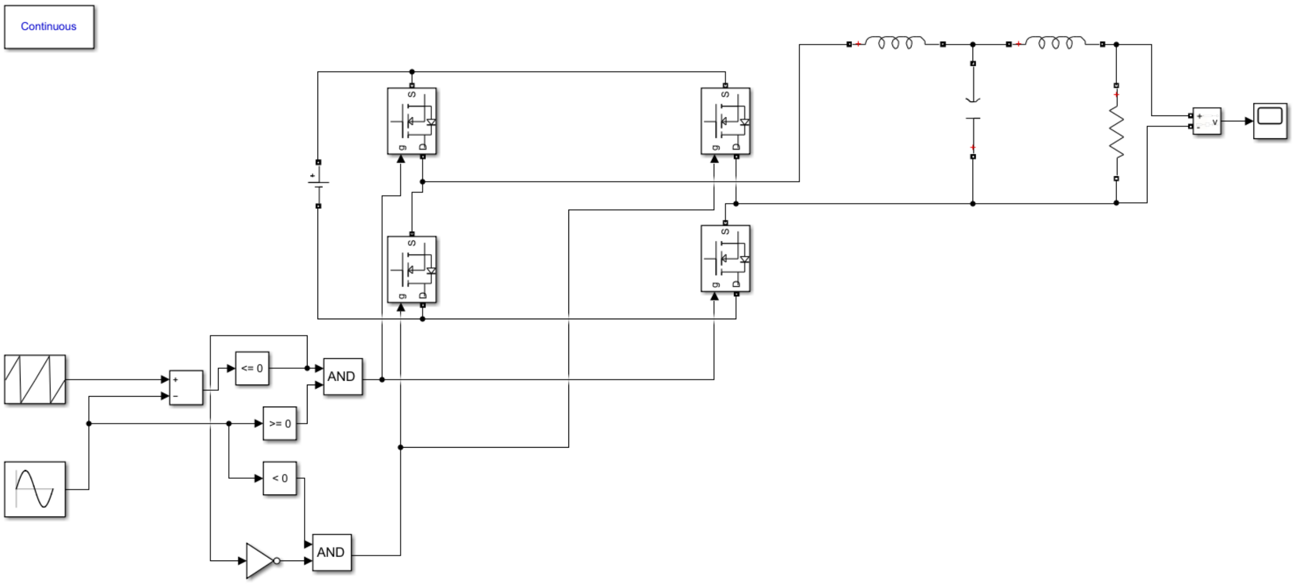


Figure 6.2: Inverter Simulation model

6.2.1 Simulation Results Of Inverter

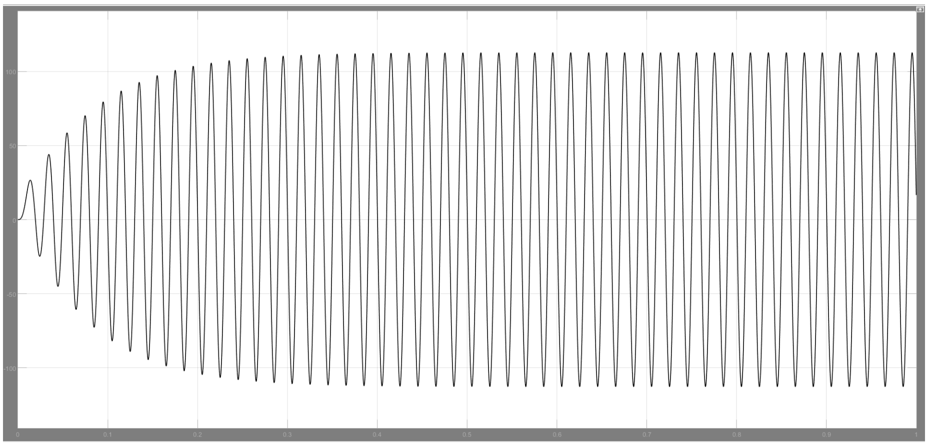


Figure 6.3: Inverter Simulation result with filter

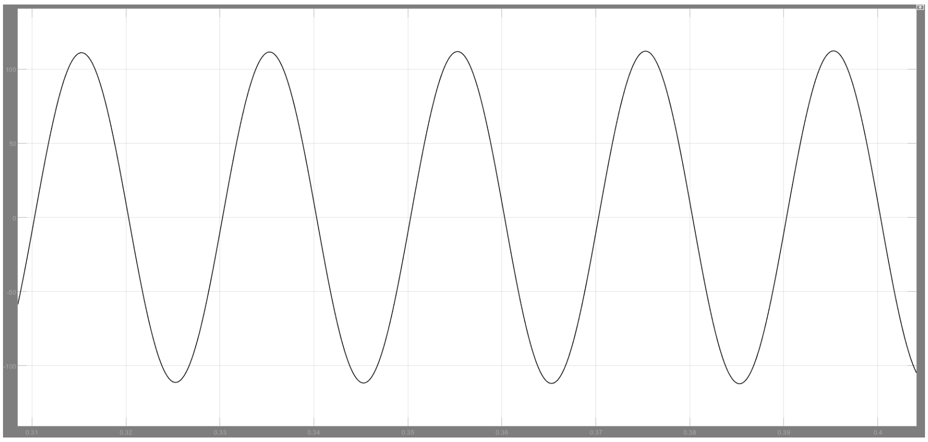


Figure 6.4: Inverter Simulation result with filter

Chapter 7

Cost Estimation Of The Proposed 25kV traction system and the prototype

7.1 Cost of The 25kV system

Table 7.1: Cost of 25kV system

Component	No of Units	Cost per unit in (Rs)	Total cost in(Rs)
Current Transformer	1	60,000	60,000
Potential Transformer	1	45,000	45,000
Booster Transformer	1	3 Lakhs	3Lakhs
Arduino Circuit	1	1600	1600
Light Dependent Resistor	1	48	48
Solar Panel	85	10,500	8.952Lakhs
Inverter	1	80,000	80,000
Circuit breaker	2	3.25Lakhs	6.5Lakhs
Reverse Power Relay	1	6500	6500
-	TOTAL COST	-	20.3458Lakhs

The Total cost was roughly estimated to be Rs20.3458 Lakhs .The total cost can vary as many of the systems are already established in the traction system by the Indian railways.

7.1.1 Cost Of The Prototype(250V)

Table 7.2: Cost of 250V system

Component	No of Units	Cost per unit in (Rs)	Total cost in(Rs)
Resistance	1	1800	1800
Reactance	1	1000	1000
Booster Transformer	1	2500	2500
Arduino Circuit	1	1600	1600
Light Dependent Resistor	1	48	48
Solar Panel	1	7500	7500
Inverter	1	3000	3000
Contactor Relay	6	527	3162
-	TOTAL COST	-	20610

The total cost for building the Prototype is estimated to be around Rs 20,610.

Chapter 8

Conclusions and Future scope

8.1 Conclusions

The existing booster transformers used in traction lines takes the power from the main power supply, which causes an reduction in useful power and is an inefficient method.To tackle this issue a solar panel is employed for providing line losses through an inverter and booster transformer.Constant monitoring of line losses are done . A prototype of 25 kV traction line is designed and studied for different operating conditions.A simulink model of the same is obtained.

8.2 Future Scope

In recent years, continuous depletion of conventional energy resources and the fluctuating fuel cost have motivated research and utilization of renewable sources for different applications. Solar energy being the foremost among all other renewable energy resources has evolved as a reliable substitute for the conventional power generation. With zero environmental threat, solar energy has gained universal attention for its huge potential and inexhaustible nature. Moreover, eco friendly renewable power generation is considered to be an important asset for the mankind.So solar powered booster transformers for providing line losses is a need of the hour and also a step towards energy efficient future.As we know private trains will be common in India within few years.This study can give motivation for using solar energy for different applications in private sector also. Overall its a great step towards an energy efficient future

8.3 Future Plan

The future improvement of the project are to convert the manual operation of circuit breakers into automatic operation, to introduce MPPT technique to system for improving efficiency and to create hardware model of the system.

Bibliography

[1]Electric Vehicle into the Grid: Charging Methodologies Aimed at Providing Ancillary Services Considering Battery Degradation, Gaizka Saldaña , Jose Ignacio San

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