**HARMONIC REDUCTION IN SINGLE PHASE INVERTER USING H-INFINITY TECHNIQUE**

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ABSTRACT-

The motivation for implementation of this project was, as electronic harmonic currents

Generated by non-linear loads increases heat losses and power bills of end users. These Harmonics related losses reduces system efficiency, causes apparatus overheating, and power costs. Therefore main reason for implementation of this project is to design a single phase inverter which can convert DC to AC at high efficiency and low cost.

***Keywords***- h-infinity,harmonics,inverter,controller

## OBJECTIVE

## Use of H-infinity controller in a single phase inverter to increases Robustness of output waveform.

## To reduce total harmonic distortion in output waveform.

* To analyze the output of the inverter with and without the controller

INTRODUCTION

## Inverters are most important power electronic equipment which is being used for various purposes such as variable speed AC drives (VSD), uninterrupted power supplies (UPS), Static frequency changer (SFC), etc. In many applications such as an AC voltage source or a high performance UPS, inverter is necessary to have a perfect sinusoidal waveform in the output, and the variation of load and other disturbances such as link DC voltage changes, nonlinear switching, or filter elements do not affect the output waveform. . Recently, the inverters are also playing an important role in various renewable energy applications as these are used for grid connection of Wind Energy System or Photovoltaic System.

## The DC-AC inverters usually operate on Pulse Width Modulation (PWM) technique. The PWM is a very advance and useful technique in which width of the Gate pulses are controlled by various mechanisms. PWM inverter is used to keep the output voltage of the inverter at the rated voltage (depending on the user’s choice) irrespective of the output load .In a conventional inverter the output voltage changes according to the changes in the load. To nullify this effect of the changing loads, the PWM inverter correct the output voltage by changing the width of the pulses and the output AC depends on the switching frequency and pulse width which is adjusted according to the value of the load connected at the output so as to provide constant rated output.

In this project have work to improve the output of H-bridge Sinusoidal PWM inverter by reducing the harmonics present in the output waveform by using H-Infinity technique. Harmonic currents cause losses in the ac system and can even some time produce resonance in the system. Under resonant conditions, the instrumentation and metering can be affected. We have designed a controller using H-Infinity technique by using Proportional-Integral-Derivative (PID) algorithm then implemented on Peripheral Interface Circuit (PIC) microcontroller 12F683 by using ASSEMBELY Language.A PIC microcontroller is programmed by adding the value of tuned PID algorithm to reduce harmonics in the inverter output. It has been designed to work with high accuracy.

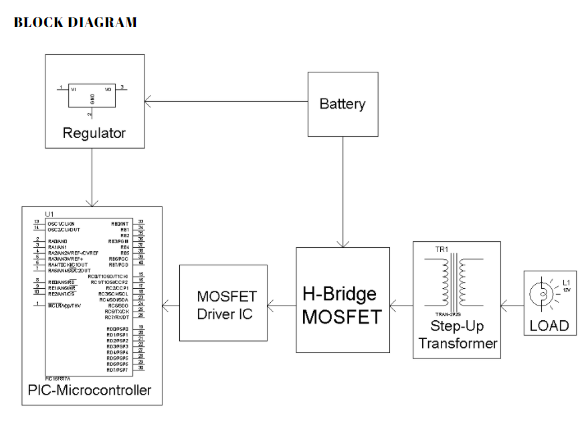


Figure 1: block daigram of proposed system

H-bridge Inverter

We all know that among the different inverter typologies, the H-bridge is the most efficient one, since it does not necessitate the use of center tap transformers, and allows the use of transformers with two wires. The results become even better when four N-channel MOSFET’S are involved. With a two wire transformer connected to an H-bridge means the associated winding is allowed to go through the push pull oscillations in a reverse forward manner. This provides better efficiency as the attainable current gain here becomes higher than the ordinary center tap type topologies.

An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 are closed a positive voltage will be applied across the load. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation.

**Figure 1: inverter circuit**

The switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4. This condition is known as shoot-through.

1. H-infinity Technique

H∞ (i.e. "*H*-infinity") methods are used in control theory to synthesize controllers to achieve stabilization with guaranteed performance. Typical design requirements such as speed of response, control bandwidth, disturbance rejection, and robust stability are

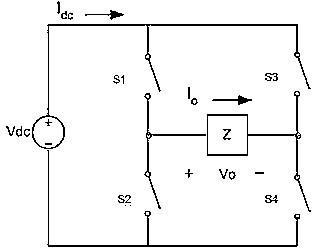
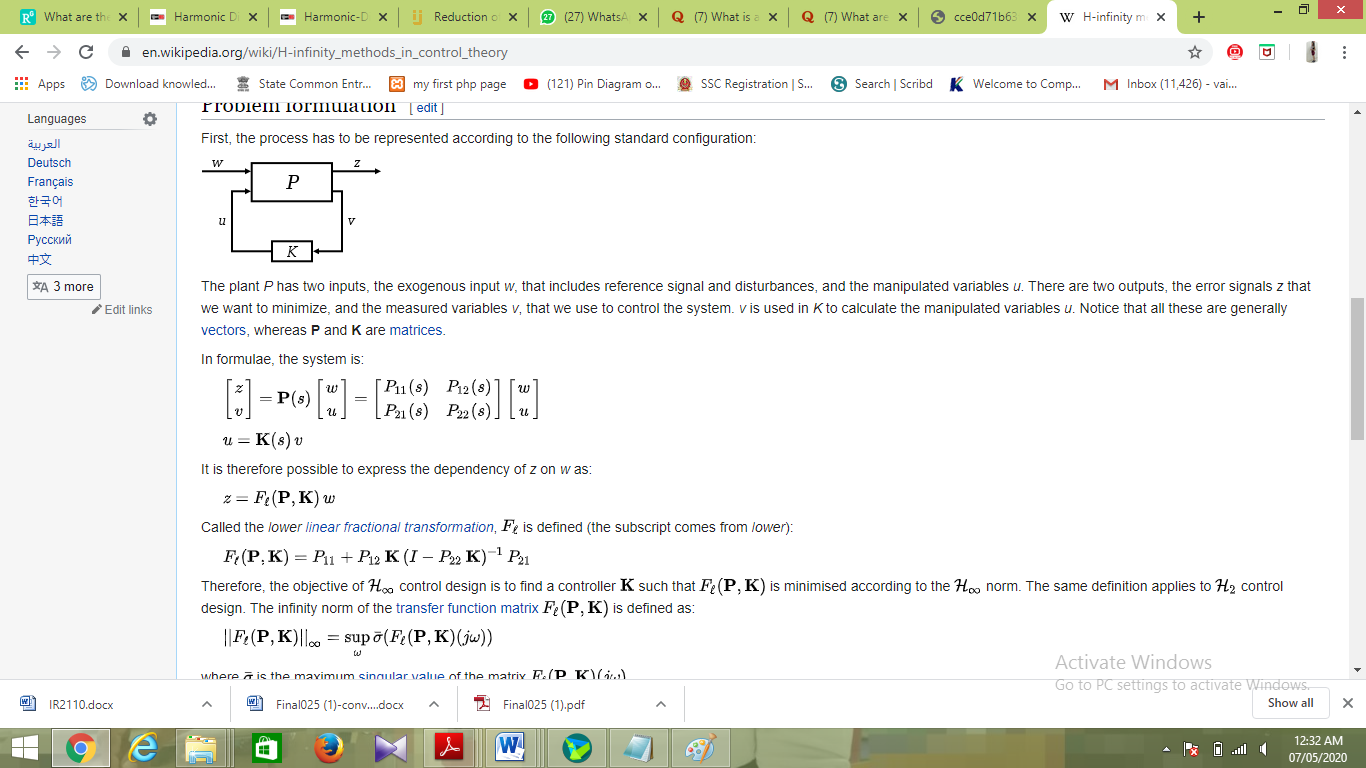
naturally expressed as constraints on the gain (H∞ norm) of well-chosen closed-loop transfer functions To use *H*∞ methods, a control designer expresses the control problem as a mathematical 

Figure 2: inverter bridge

optimization problem and then finds the controller that solves this optimization. The phrase *H*∞ *control* comes from the name of the mathematical space over which the optimization takes place: H∞ is the *Hardy space* of matrix-valued functions that are analytic and bounded in the open right-half of the complex plane defined by Re(*s*) > 0; the *H*∞ norm is the maximum singular value of the function over that space.

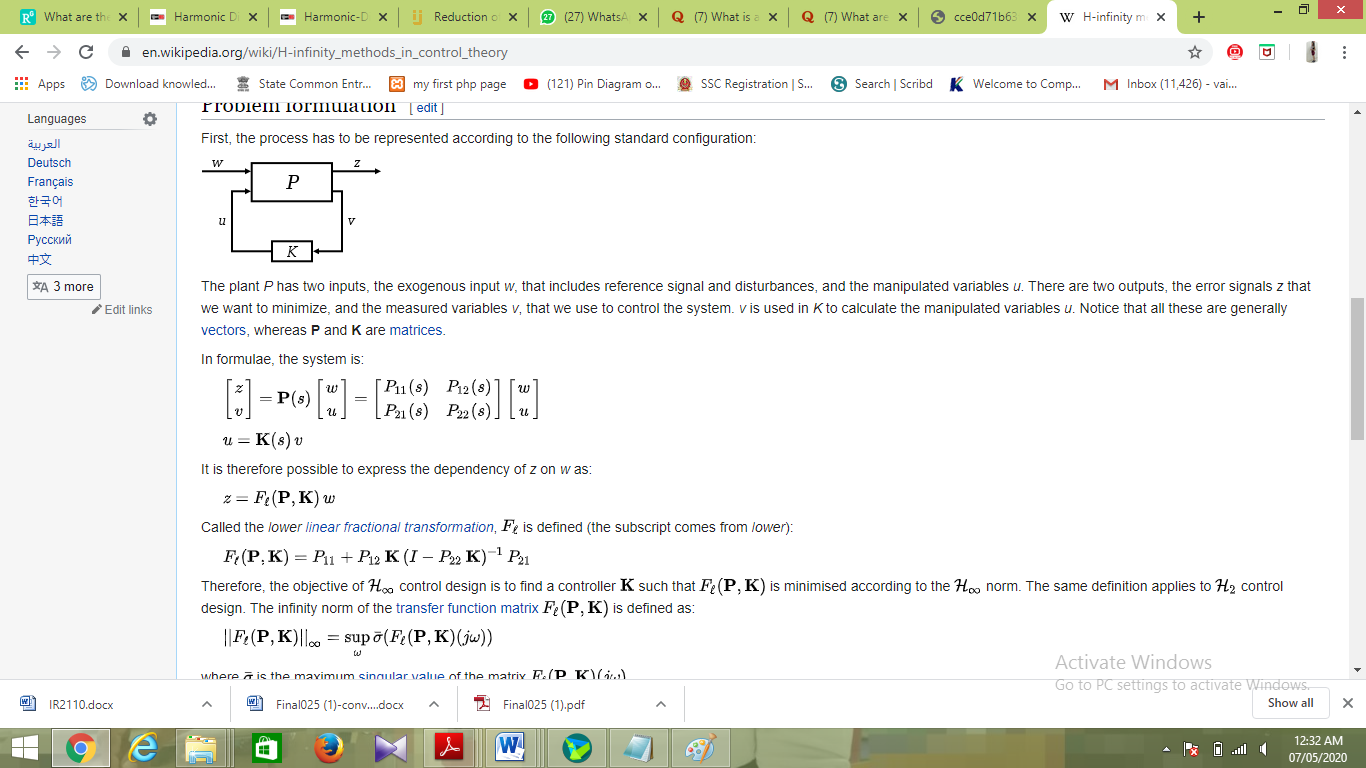
# 1.1 standard *H*∞ synthesis

First, the process has to be represented according to the following standard configuration:

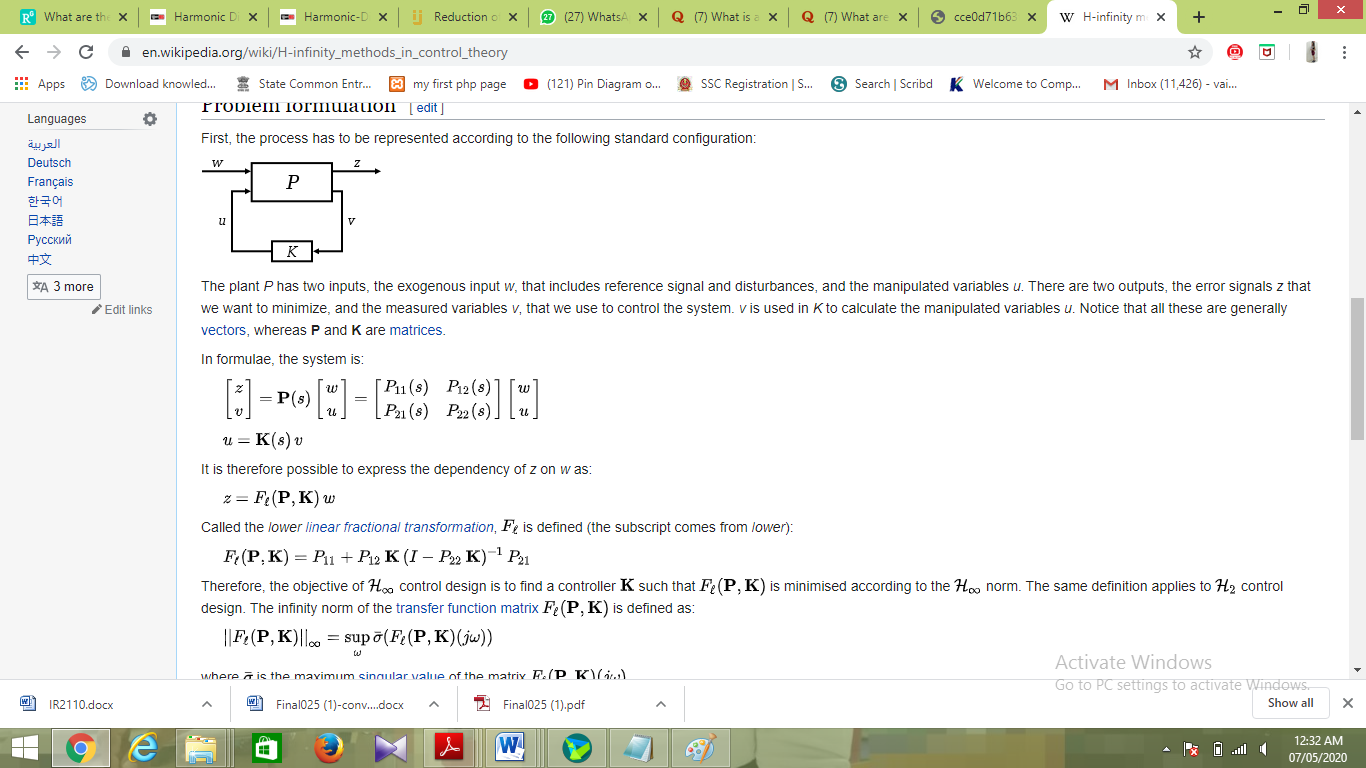
**Figure 2.3.1: Standard Form for standard H∞ Synthesis**

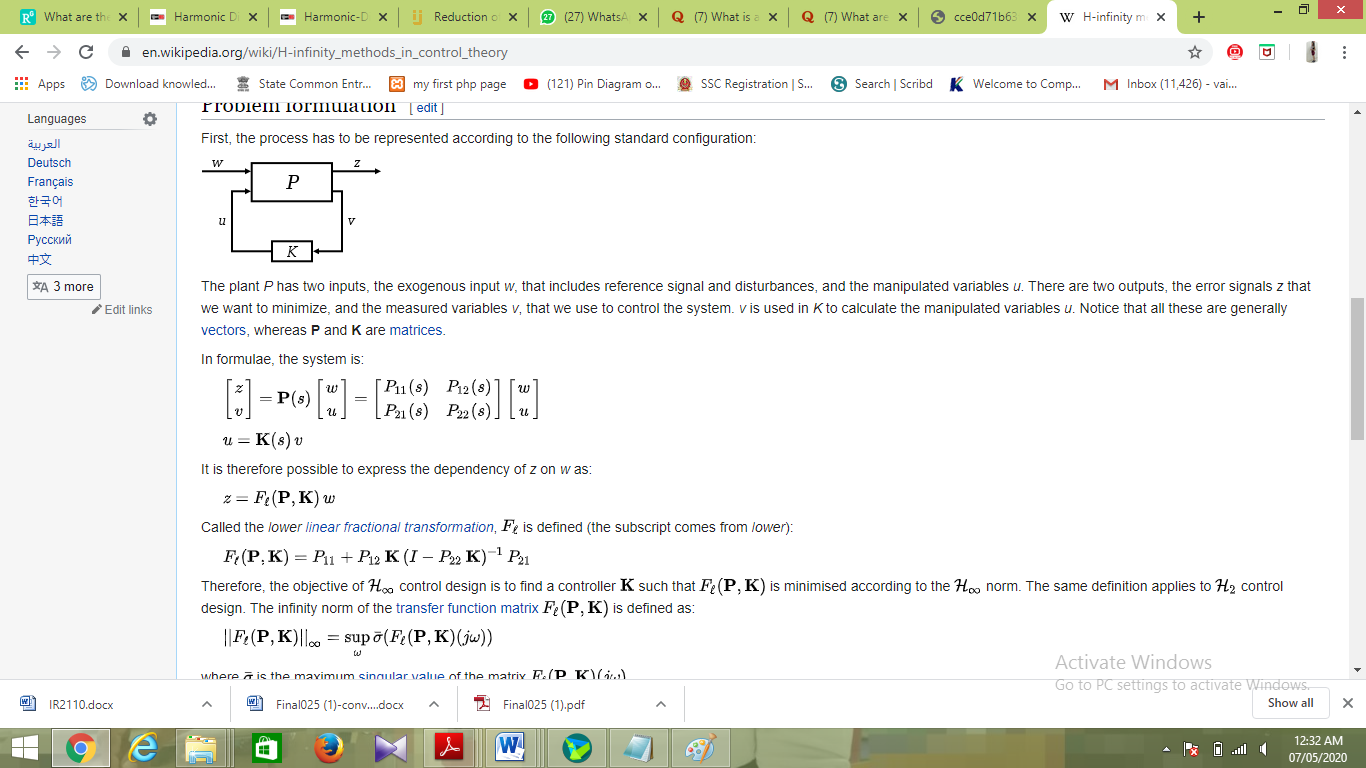
The plant *P* has two inputs, the exogenous input *w*, that includes reference signal and disturbances, and the manipulated variables *u*. There are two outputs, the error signals *z* that we want to minimize, and the measured variables *v*, that we use to control the system. *v* is used in *K* to calculate the manipulated variables *u*. Notice that all these are generally [vectors](https://en.wikipedia.org/wiki/Vector_(geometry)), whereas **P** and **K** are matrices.

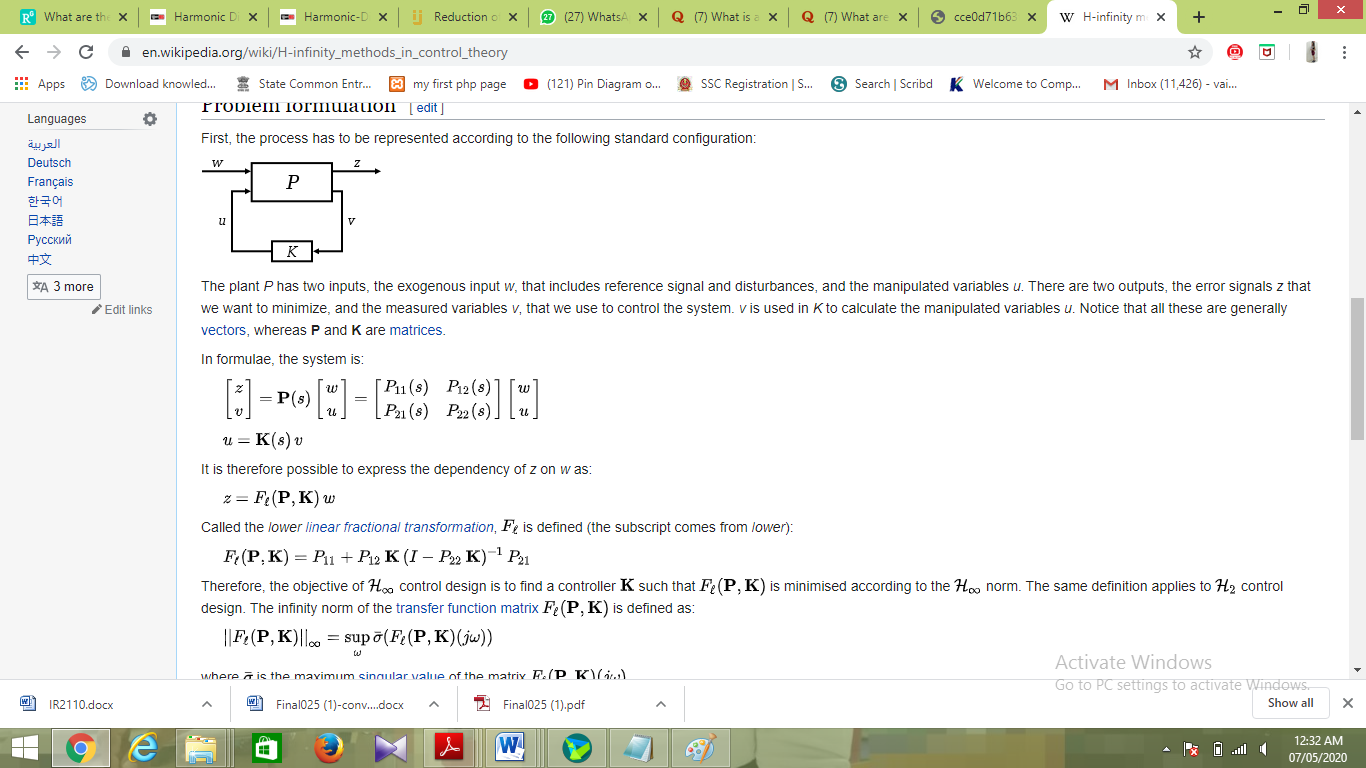
In formulae, the system is:

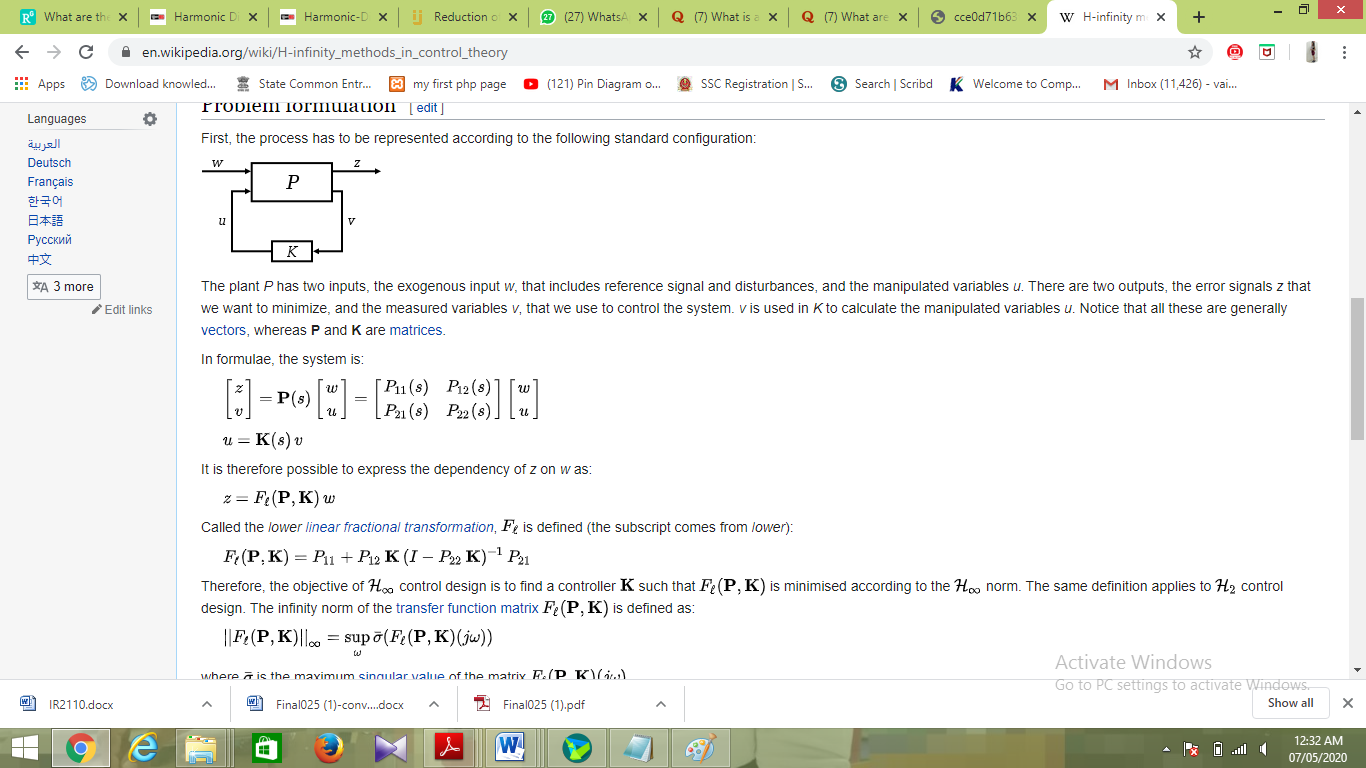


It is therefore possible to express the dependency of *z* on *w* as:



Called the *lower linear fractional transformation*   is defined



Therefore, the objective of H∞ control design is to find a controller **K**  such that    is minimized according to the H∞ norm.

H∞ controllers are monolithic whereas most embedded control architectures are decentralized collections of simple control elements. Since the controller given by H-infinity synthesis is very complex and its order is higher than the system its meant to control, it is impractical to use directly. It indicates, however, that there’s at least this controller that can achieve your specifications. The “structured H-infinity synthesis”, in which the H-infinity method is applied, but the controller’s structure is specified (for example, the controller could be a simple PID with tunable gains). Here, the implementation is straight-forward.

# structured H-infinity synthesis

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The process has to be represented according to the following standard configuration:

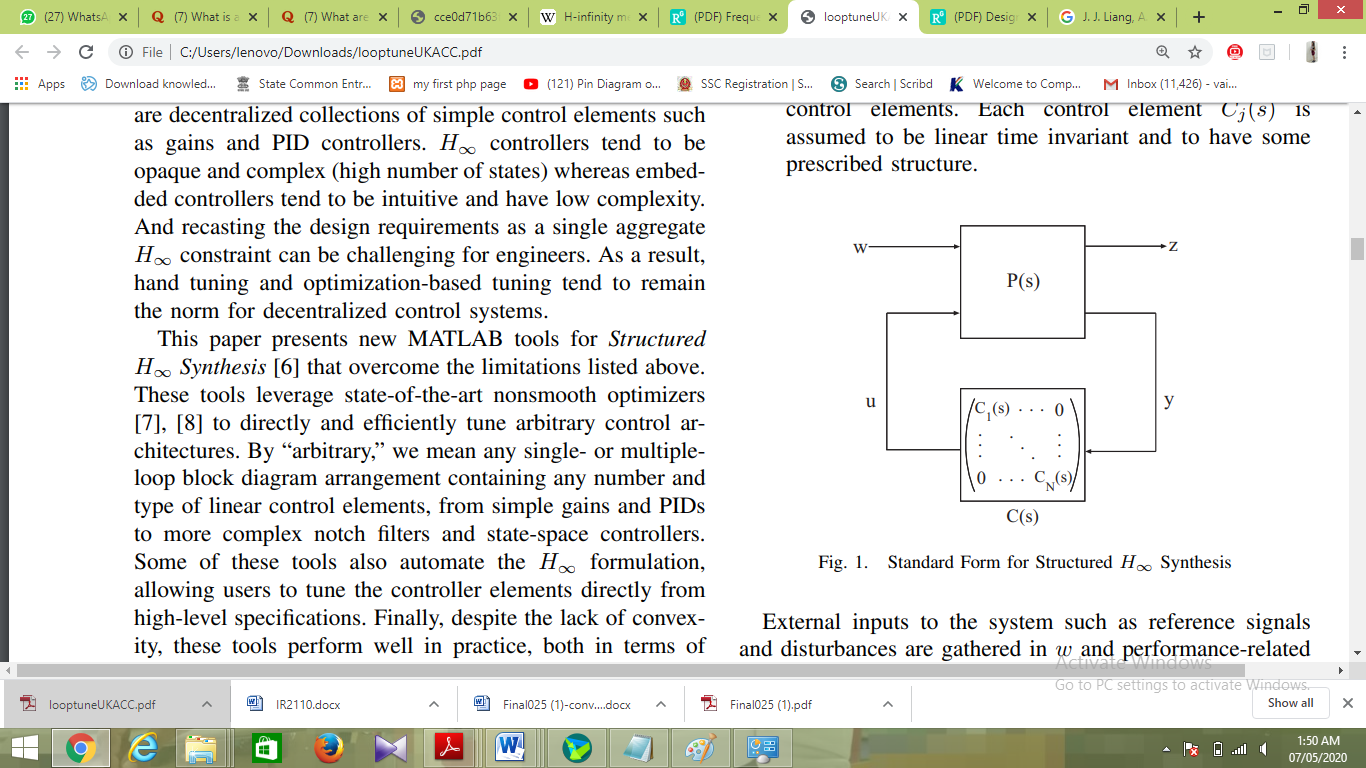
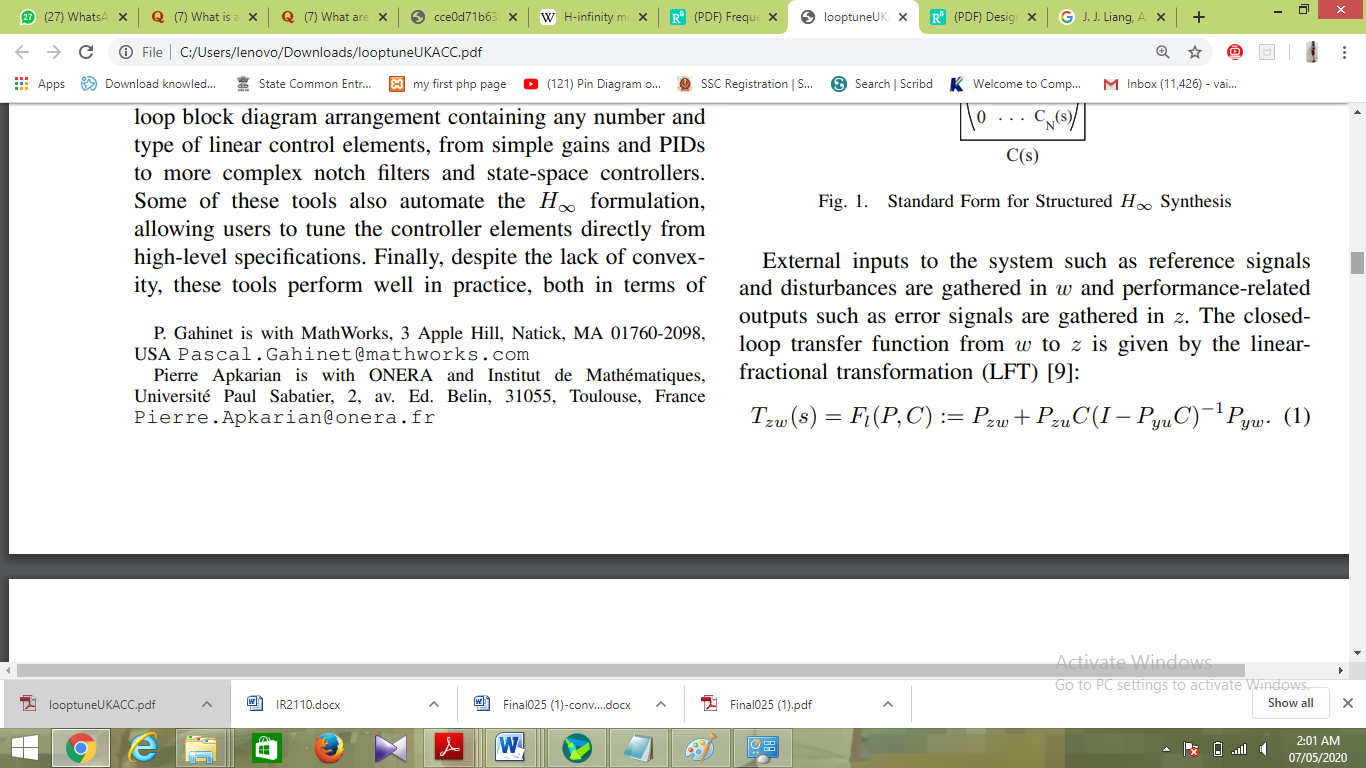


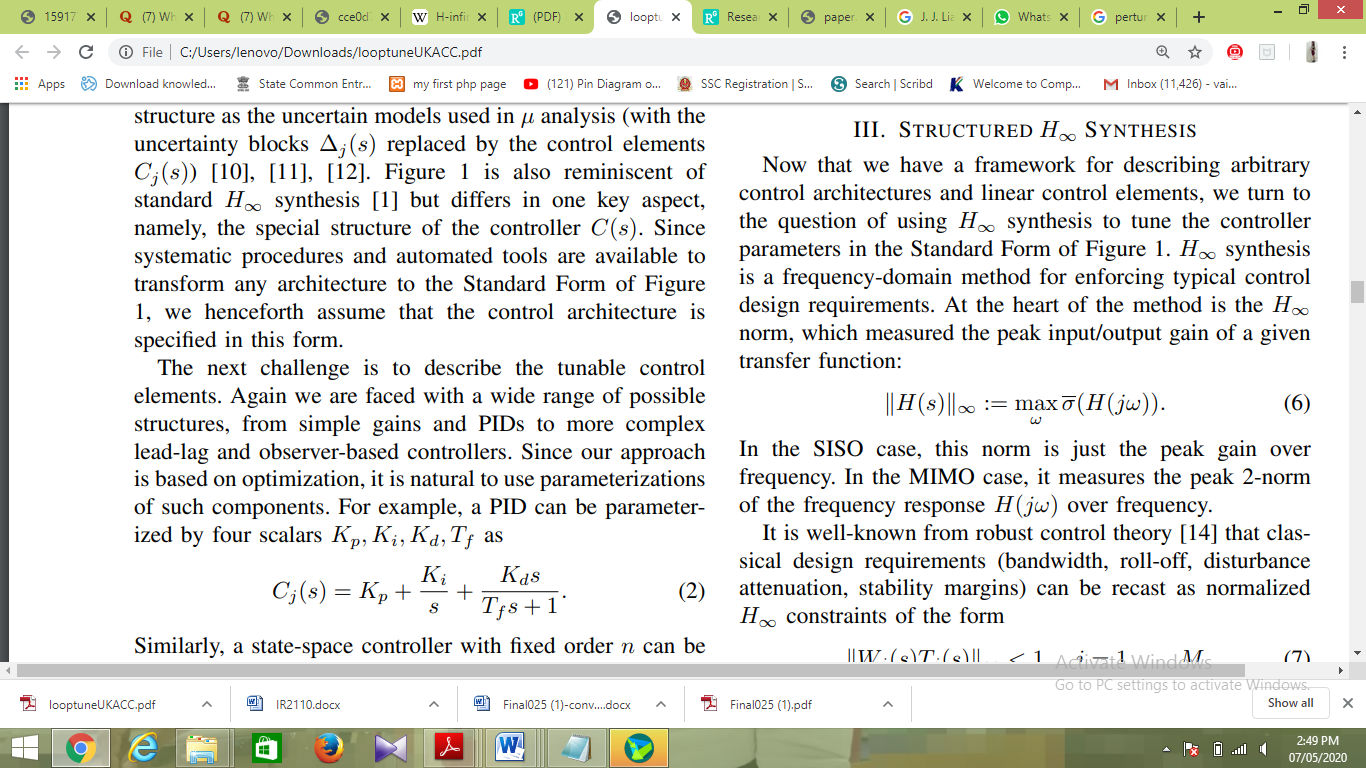
Figure 4: Standard Form for Structured H∞ Synthesis

An linear time invariant model P(s) that combines all fixed (non tunable) blocks in the control system . A structured controller C(s) = Diagonal matrix (C1(s), . . . , CN (s)) that combines all tunable control elements. Each control element Cj (s) is assumed to be linear time invariant and to have some prescribed structure. External inputs to the system such as reference signals and disturbances are gathered in w and performance-related outputs such as error signals are gathered in z. The closed loop transfer function from w to z is given by the linear fractional transformation (LFT):

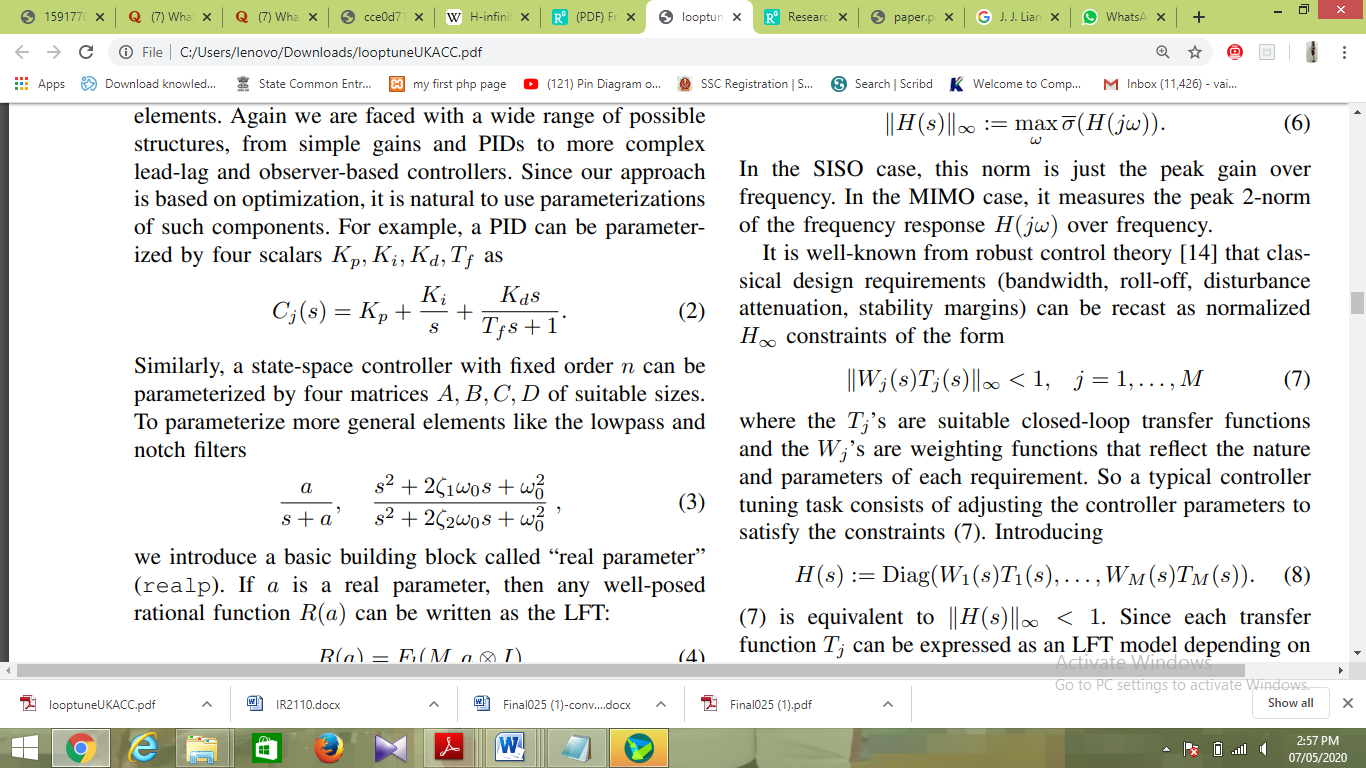
 (1)

It is well known from Robust Control theory that any block diagram can be rearranged into this Standard Form by isolating the tunable blocks and collapsing the rest of the diagram into P(s). Figure 2.3.2 is also reminiscent of standard H∞ synthesis shown in Figure 2.3.1 but differs in one key aspect, namely, the special structure of the controller C(s).

H∞ synthesis is a frequency-domain method for enforcing typical control design requirements. using H∞ synthesis to tune the controller parameters in the Standard Form of Figure 2.3.1, At the heart of the method is the H∞ norm, which measured the peak input/output gain of a given transfer function is:

 (2)

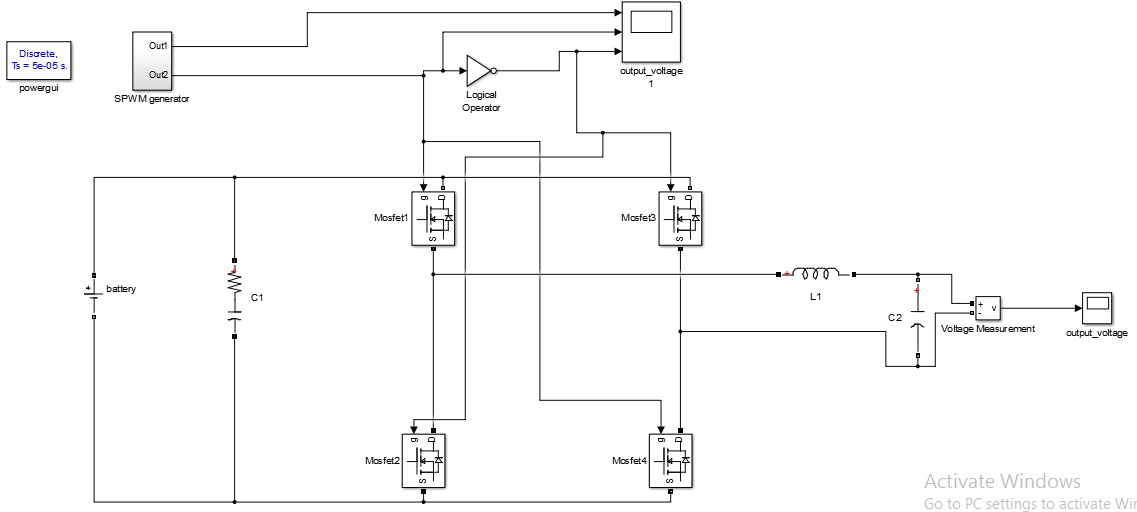
In the SISO case, this norm is just the peak gain over frequency. In the MIMO case, it measures the peak 2-norm of the frequency response( that is, the peak gain at each frequency point.) H(jω) over frequency. It is well-known from robust control theory that classical design requirements (bandwidth, roll-off, disturbance attenuation, stability margins) can be recast as normalized H∞ constraints of the form

 (3)

where the Tj ’s are suitable closed-loop transfer functions and the Wj ’s are weighting functions that reflect the nature and parameters of each requirement. So a typical controller tuning task consists of adjusting the controller parameters to satisfy the constraints (3).

# SIMULATIION

In this chapter we are going to view the simulation results of H bridge inverter and analyze its output waveform for harmonic content using FFT analysis in MATLAB.

FIGURE 5::SIMULATION OF PROPOSED SYSTEM

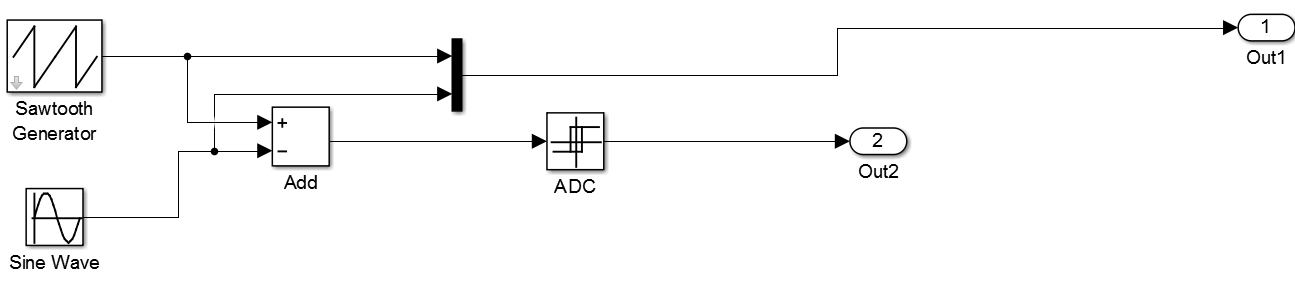


FIGURE 6:SIMULATION MODEL OF SPWM

MOSFET1 ,MOSFET 2,MOSFET3,MOSFET4 form the H-bridge inverter circuit. The SPWM generator generates the signal to trigger the MOSFET.

Algorithm of PWM Signal

The SPWM generator works on the following algorithm. In this flow chart "Initialize the program variables, Vref, lookup-table and PWM module" and initializes the ports in software by which the ports work as output ports. Then “Initialize Sine Look up Table” stores the sampling value of sine wave. Those sampling value will go in PWM duty cycle register of PWM module. Then the signal becomes Sinusoidal PWM signal.

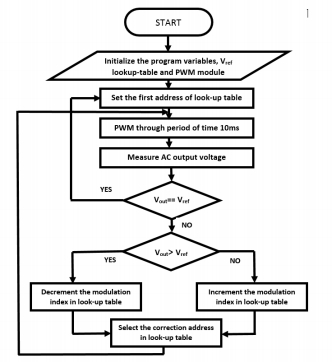


FIGURE 6.3 : The flow chart for programming the signal phase inverter SPWM

Initialize the program variables, Vref lookup-table and PWM module

1. Setting the address of the look up table.
2. Calculating the PWM modulation index.
3. Measuring the amplitude of the output voltage.
4. If there is equality between the output voltage and ref- erence voltage, then returns to step 2.
5. If the output voltage is more than the reference voltage, then the address of the look up table is incremented and returns to step 3.
6. If the output voltage is less than the reference voltage, then the address in the look up table is decremented and returns to step 3.

**Output Waveforms of simulation**

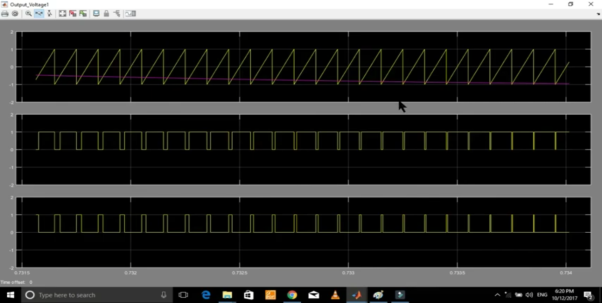


FIGURE 7: OUTPUT OF SPWM GENERATOR

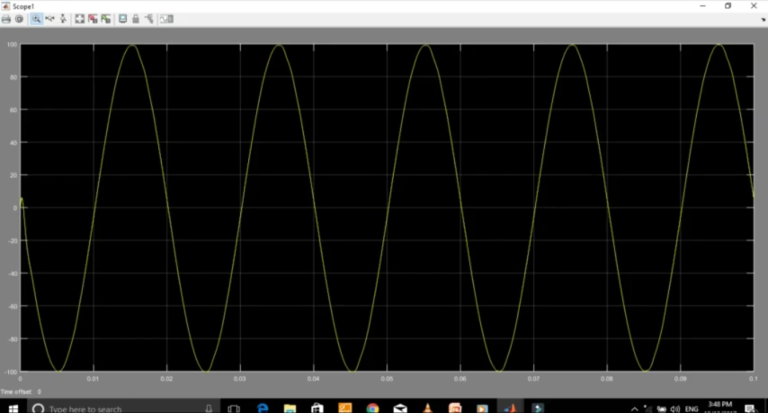


FIGURE 8:: OUTPUT OF THE H-BRIDGE INVERTER CIRCUIT

As seen from Figure 6.5 the output obtained is the sinusoidal wave with minimized harmonic content. The FFT analysis of the simulation is shown in figure below the total harmonic distortion is 2.10%.

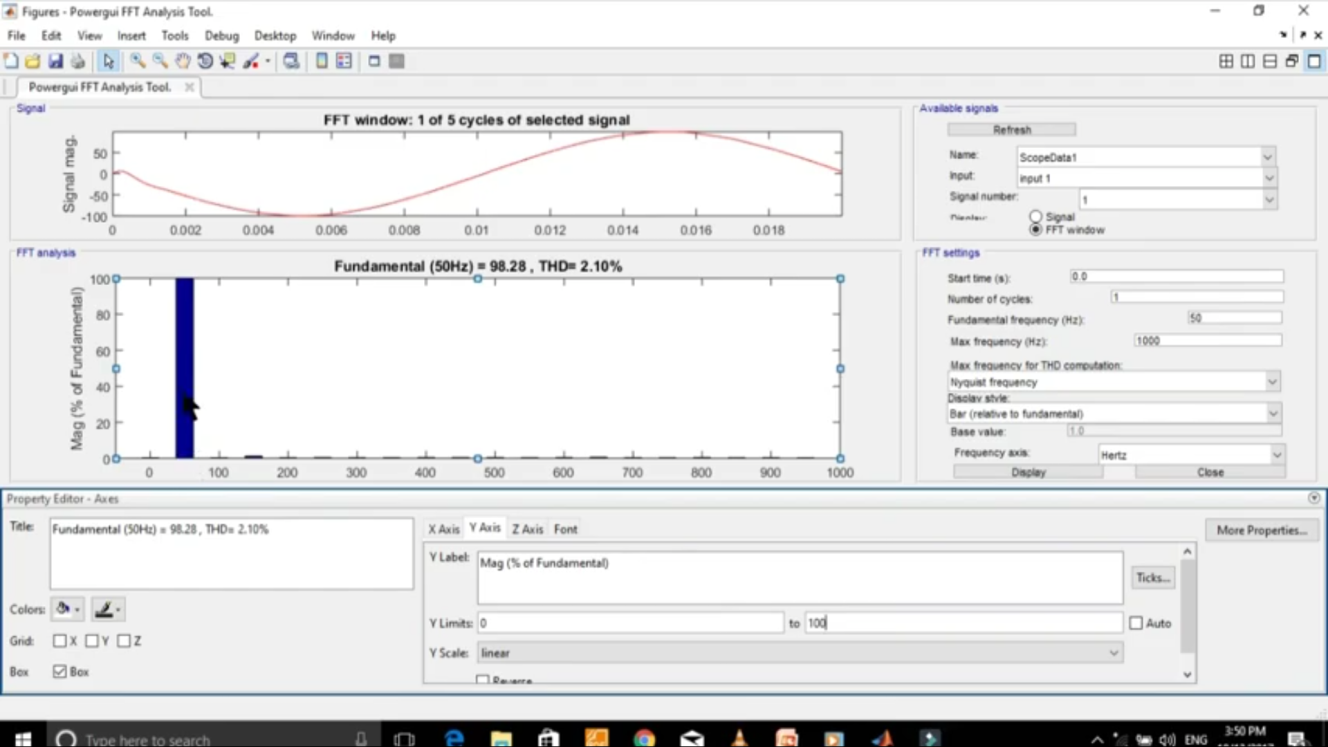
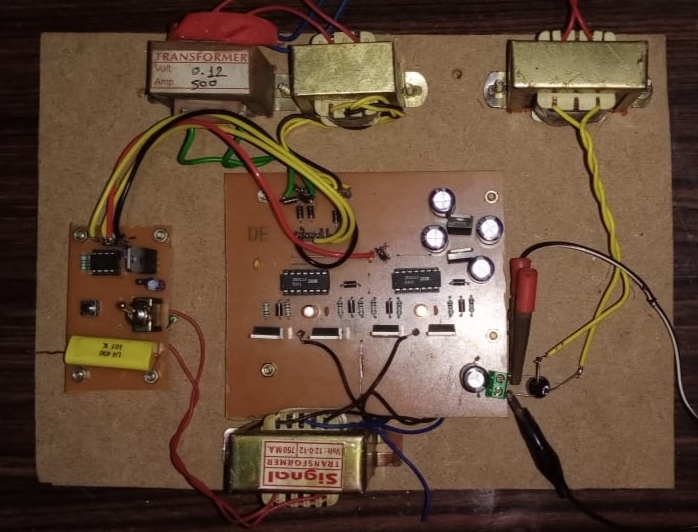


FIGURE 9 : FFT ANALYSIS OF THE H-BRIDGE INVERTER CIRCUIT

**RESULT**

**Hardware model**

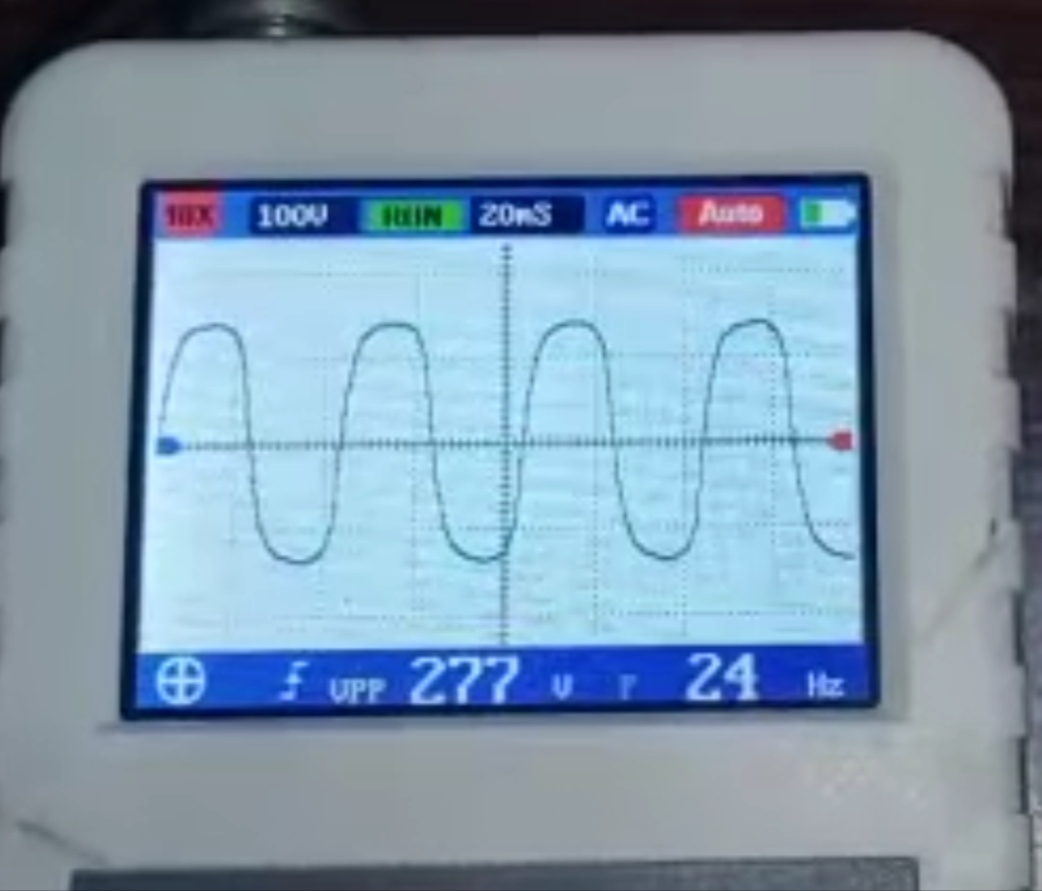
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**Figure 10: hardware model**

**Output without controller**

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**Output with controller**

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By using the H-Infinity technique the harmonics in the inverter circuit are reduced to the greater extent also this method has more efficiency in comparison with the other methods. In this project we have seen the output of inverter with and without the controller and the distortion in the waveform can be compared in both the cases and it can be seen that the circuit with controller has less harmonic distortion and hence the robustness of the output waveform can be increased.The generation of output voltage wave form of ideal inverters should be sinusoidal. The measured total harmonic distortion (THD) are very small THD=2.7% for output waveform. The output voltage waveforms show that the experimental results are very similar to simulation results. As expected, the higher the switching frequency, the smoother the output voltage waveform.

**CONCLUSION**

The major problem of harmonic content in different type of inverter limits its use. Same limitation is also proposed by cost factor. With the increasing demand of inverter in various field of electrical engineering this problem has to be solved, for that reason we had analyzed the inverter on different basis to get optimal solution of this problem.

This project describes the design and implementation of a digitally controlled single phase SPWM inverter by using H-infinity technique to develop the controller and control circuit for a single phase inverter which has been implemented using PIC12F683 microcontroller based control applications. The H∞control method is one of the most

advanced techniques available today for designing robust controllers. These inverter topologies can be used for WECS applications and particular inverters for the AC-Module. The unipolar SPWM pulses are generated for fundamental frequency of 50 Hz and its switching frequency of 20 kHz are simulated in Simulink simulator. The output voltage of inverter is changing by modulation index of the unipolar SPWM pulses according to the load condition which is given as the gate pulses to inverter switches.

REFERENCE

1. Abdel-Salam Shaaban , Jean Thomas, and Ramadan Mostafa “Design and Implementation of a Single Phase SPWM Inverter Based Microcontroller for Wind Energy Conversion Systems” INTERNATIONAL JOURNAL OF SYSTEMS APPLICATIONS, ENGINEERING & DEVELOPMENT
2. M.A.Ghalib, Y.S.Abdalla, R.M.Mostafa "Design and Implementation of A Pure Sine Wave Single Phase Inverter for Photo Voltaic Applica- tions", [Online]. Available: [http://www.asee.org.](http://www.asee.org/)

1. Tomas Hornik and Qing-Chang Zhong*, Senior Member, IEEE* “A Current-Control Strategy for Voltage-Source Inverters in Microgrids Based on *H* *∞* and Repetitive Control” IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 26, NO. 3, MARCH 2011
2. Salman Tahir and Abdul Khaliq “Operation of Microgrid with cascaded Current- Voltage Control of Voltage-sourced Converter based on H-infinity Repetitive Control Strategy” Proc. of the 4rth International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET) 10-12 September 2018, Islamabad, Pakistan
3. G.Weiss, Q.-C. Zhong, T. Green, and J. Liang, “H∞ repetitive control of DC–AC converters in micro-grids,” IEEE Trans. Power Electron., vol. 19, no. 1, pp. 219–230, Jan. 2004
4. Ajith K1 Dhivakaran M2 Loganathan M3 Sri Krishna Kumar4 “ Harmonics Reduction in Three-Phase Inverter using H-Infinity Technique” IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 04, 2016.
5. Majid Zamani, Nasser Sadati, and Masoud Karimi Ghartem “Design of an H∞ PID Controller Using Particle Swarm Optimization” International Journal of Control, Automation, and Systems (2009) 7(2):273-280
6. Ardavan Maghsadhagh\* "Implementation of PID Controller by Microcontroller of PIC and Controlling the Height of Liquid in Sources" Adv Robot Autom, an open access journal Volume 5 • Issue 3 • 1000156 ISSN: 2168-969
7. Eli Gershon Uri Shaked Isaac Yaesh's book "H∞ Control and Estimation of State multiplicative Linear Systems"
8. A.A. Stoorvogel "The H∞ control problem: a state space approach"