TECHNICAL AND VOCATIONAL TRAINING INSTITUTE (TVTI)

School of Graduate Studies

FACULTY OF ELECTRICAL AND ELECTRONICS TECHNOLOGY AND INFORMATION AND COMMUNICATION TECHNOLOGY
(DEPARTMENT OF ELECTRICAL AND ELECTRONICS TECHNOLOGY)

A Case Study on Hybrid Power Optimization Using Fuzzy pid Controller for Rail Trains (Dire Dewa to Addis Abeba)

MSc Thesis for the Partial Fulfillment of

Master of Science in Electrical Automation and Control Technology Management

By,

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AUGUST 2022
Addis Ababa, Ethiopia

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A Thesis submitted to

TECHNICAL AND VOCATIONAL TRAINING INSTITUTE (TVTI)

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In partial fulfillment for the Degree

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DECLARATION

This study report, titled "A Case Study on Hybrid Power Optimization Using Fuzzy Logic for Rail Trains (Dire Dawa to Addis Ababa"), is the result of my work. It does not contain any previously published or written materials unless an appropriate citation is provided. This report has never been submitted for credit at another college or university.

My original thesis has never been utilized to get a degree anywhere in the world. All used sources are cited.

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Place: Addis Ababa

Date of Submission: **29/08/2022**

This thesis proposal has been submitted for examination with my approval as a TVTI advisor.

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TECHNICAL AND VOCATIONAL TRAINING INSTITUTE (TVTI)
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Thesis on

A Case Study on Hybrid Power Optimization Using Fuzzy pid Controller for Rail Trains (Dire Dewa to Addis Abeba)

BY: ZEKARIAS SISAY

Approved by board of examiners

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ACKNOWLEDGMENT

I want to thank God for everything he's done. Dr. Desta Addis, my advisor, has provided wise counsel, motivation, and inspiration. My family, friends, and workplace have been supportive and encouraging. In conclusion, I appreciate our team's dedication to improving the future.

ABSTRACT

Nowadays, the flexibility with which Rail Train transit is defined speaks to its enormous benefits. However, Rail Trains frequently experience disappointment due to power outages, which reduces the rail train's efficiency. A lack of storage backup power; the ability to use other power sources to operate the Rail Train, and frequent power outages due to technical failures in the power supply because additional power quality impacts the electrical grid.

The idea of using green energy to power railway locomotives could benefit Ethiopia's railway sector by minimizing or preserving grid power. Solar energy is one way to save energy on trains, while regenerative braking is another. We will combine the two for optimal efficiency. This thesis evaluates the technological feasibility of using solar electricity paired with grid supply in Dire Dawa to Addis Ababa train carriages to reduce energy consumption from grid supply. The final report will be used to evaluate the costs and benefits of this alternate control source.

This proposition presents a grid-solar cross breed framework for fueling the auxiliary framework of the Dire Dawa-Addis Ababa train. The LT locomotive's control administration system includes a PV and an auxiliary control box. The LT derives power from the framework, or pantograph, and uses solar panels to reduce control. Sunlight and stack variations are considered. The suggested approach makes use of a maximum power point tracker to maximize the performance of the PV system while consuming the least amount of power possible. It contains hypothetical analyses of solar frameworks and modeling methodologies that employ similar electric circuits. The most advanced control maximum power point tracker (MPPT) is used. The DC-DC converter scheme is validated using MPPT, multiple control techniques, and MATLAB. Power management includes fuzzy logic-based PID controller power level control. A fuzzy logic controller was also created for proper control settings. Before analysis, the whole MATLAB model was simulated.

Key Words: Maximum Power Point; Solar Irradiance, Fuzzy logic control.

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LIST OF ABBREVIATIONS

MPPT	Maximum Power Point Tracking
MPP	Maximum Power Point
ICE	Internal Composition Engine
SOC	State of Charge
EMS	Energy Management System
RT	Rail Train
PV	Photovoltaic
DC	Direct Current
AC	Alternative Current
ESS	Energy Storage System
DOD	Depth of Discharging
PWM	Pulse Width Modulation
GHG	Green House Gas
PHP	Power Hybridization Potential
EMI	Electromagnetic Interference

CHAPTER ONE

INTRODUCTION

1.1 Background

Electric railroads run single cars or reduced trains on free road right-of-way[1These cars, which are fueled by overhead electrical cables, are fast, dependable, comfortable, high-quality, environmentally responsible, and economical [2].Sun oriented vitality could be an essential renewable vitality source that has gotten much consideration. Compared to other energy sources, solar energy is copious and has the highest availability. The sum of vitality provided to the Earth by the sun in an hour is enough to meet the planet's entire energy needs for a year [3]. Sun arranged imperativeness is pollution-free and emission-free because it does not deliver poisons or by-products destructive to the environment.

Railroad drive innovation has made strides colossally since the primary steam motor was installed [4]. Internal combustion engines that run on liquid fossil fuels are more reliable and efficient. Trains with the capacity to transport hundreds of individuals and hundreds of tons of cargo have been planned. Unaware of their environmental impact, governments have begun competing by creating an increasing number of complex and inventive train networks, which has brought about within the creation of diesel locomotives. Diesel trains did not last long because of their characteristics of being noisy, polluting, and extremely dangerous. Its substitution, the diesel-electric prepare, guaranteed superior footing, more secure operation, higher effectiveness and decreased outflows. Electromechanical couplings connect diesel engines to wheel sets on diesel-electric trains. Diesel railway wheels and engines are mechanically connected. Diesel electric trains are powered by diesel engines but rely on electric engines for footing. A generator turns the diesel engine's mechanical energy into electrical energy. Electric footing engines in the wheels convert electrical to mechanical energy. This technique improved train reliability and reduced maintenance costs. The full electrification of railroads was the next imperative step in reducing railway emissions. Cleaner than diesel-electric trains are fully electrified railway systems. In addition, they were significantly more dependable, quieter, faster, and safer. The capacity to link a prepare straight forwardly to the power grid provided it with virtually unlimited power and boosted its acceleration. Be that as it may, within the endless lion's share of cases, the fetched of total electrification remains unreasonably high, Later advancements in vitality capacity framework (ESS) innovation have incited investigate into cross breed electric control trains for railroad vehicles. On trains or processing units, electrical energy storage systems (ESS) can preserve braking energy that would otherwise be wasted as heat [5]. Batteries and super capacitors are ESS.

Two causes usually require them:

1) For rapid acceleration control

2) To better absorb brake-generated energy.

According to study, hybrid electrical ESS reduces the energy required by electrified trains. A hybrid power train makes use of several different types of energy. The requirement for hybridization, sort of crossover framework, and degree of hybridization is all impacted by the inborn qualities of control sources and the sort of stack. In specific, stack flow and control source vitality thickness are foremost components for choices with respect to hybridization. Hybrid systems are typically used to improve specific criteria, such as power train economy, run of travel, increasing speed, regenerative braking, and outflows. The optimization of half breed ESS, like any optimization issue, is constrained by a number of structural and functional restrictions. The actual limitations taken into consideration in this thought process are physical imperatives like mass and volume restrictions.

The work shown, in this recommendation clarifies elective control sources and the significance of sun based control an elective control source. In specific, possibility ponders on control administration frameworks on solar/grid cross breed control supply systems for assistant units of the Dire Dewa to Addis Ababa Rail Train.

This extend does not point to center on any one specific figure of justify but to present a doable run of scenarios. Exceptional thought is paid to the least component sizes required for ceaseless operation. Now Between Dire Dawa and Addis Ababa, it used to be the transportation industry. The railway was built between 1894 and 1917 to connect Ethiopia with French Somaliland. It has be provided Ethiopia's only access to the sea. The railways gradually fell into a condition of disrepair following the Moment World War due to competition from vehicle transport. The Ethiopian National Railway Network conducts rail travel in Ethiopia, which today has three electrified standard railway gauges: the Addis Ababa– Djibouti and the Awash-Weldiya railways. Railroad and the Weldiya–Mekelle Railroad, Other lines are still in their early stages of development. An Ethiopian state-owned company, the Ethiopian Trail Corporation, owns and operates all trains in Ethiopia (ERC). The proposed law empowers the private division to participate in rail transportation, from the advancement of rail framework to its operation and eventually to the operation of secretly claimed trains. The Addis Ababa–Djibouti Railway, which is being renovated, is Africa's to begin with cross-border energized railroad. A 753-kilometer, single-track, standard gauge train line connecting the port of Djibouti and the capital city of Ethiopia, Addis Abeba, with 45 stops in total.

1.2 Problem Statement

Nowadays, the flexibility with which rail train transit (RT) is defined speaks to its enormous benefits. But the TR usually experiences disappointment due to control disturbance and it diminishes the productivity of the TR. Additional harm to the electrical network (sounds, voltage blackouts, and changes) is caused by a require of capacity reinforcement control and the capacity to utilize other control sources to function the RT and visit control blackouts caused by specialized disappointments within the control supply. Thus, a half breed vitality administration framework incorporates sun based vitality, grid energy, and batteries required to charge the reinforcement capacity and intellectuals control the TR's control request and assess the system's hybrid power-optimized railway train.

In this manner, it is proposed to utilize cleverly control fuzzy-PID method can be oversee TR's control request in this way, distant better a much better, a higher, a stronger, an improved a much better alternative due to expanding execution, optimizing vitality and keep up the framework.

1.3 The Research Objective

1.3.1 General Objective

To transfer a solar panel on a train from Dire Dawa to Addis Ababa by rail to use the EMS (Energy Management System). This replaced displaying auxiliary components.

1.3.2 Specific Objective

- To examine the technological feasibility and operational benefits of installing solar panels on train roofs.
- To design the fuzzy-PID controller for PV system connected to grid system.
- To design a grid/solar parallel hybrid power model fuzzy-based controller with PID controller.
- To analysis the overall performance of solar panel system connected to grid system.

1.4 Research questions

The questions is address

1) How to analyze the technical feasibility and operational convenience of solar panels on the roof of trains?
2) How a maximum power point tracking charge controller should be built to get the most out of a PV system?
3) How to make a grid/solar parallel hybrid power model and use that model to simulate?
4) How can you assess the controller's and solar panel system's overall performance?

1.5 Significance of the study

First, this research shows how to utilize energy resources wisely and improve the power outages faced by the transport sector by implementing the recommended directions to improve the energy supply system that benefits this economic sector. The study can also be applied to other industries such as manufacturing and agriculture to measure and improve energy supply. On the other way, this study may provide information for other researchers to do more in this field.

1.6 Scope of the study

- The study's objective was to demonstrate how to maximize hybrid power.
- Only Dire Dawa and Addis Ababa are considered in this ponder.
- Railway transportation cooperation's target audiences include project managers, engineers, site supervisors, and others.
- This investigation focuses on railway transportation.

1.7 Limitation of the study

- This thesis only looks at the causes of the abundance of writing about them. This limits the investigation to discovering a range of variables that may significantly affect how efficiently energy is supplied.
- There may be a number of factors that are not included in the rational model, but they may have the potential to improve the power supply.

1.8 Thesis Organization

The thesis is outlined below.

Chapter 1: an introduction to the thesis. This chapter explains the purpose of the thesis, the problem it addresses, the research questions it seeks to answer, as well as its significance, scope, and limitations.

Chapter 2: It includes a review of the writing and any background information pertinent to the topic at hand.

Chapter 3: clarifies sun powered control applications and the work done to create a total PV framework with a MATLAB modeling reenactment handle.

Chapter 4: Here is the crossover framework for the two control supplies. This building's solar panel powers pantograph/grid auxiliary power boxes.

Chapter 5: This is the final chapter, which includes model findings and development proposals. It's centered on comets.

CHAPTER TWO

LITERATURE REVIEW

2.1 Electric Traction Power

Railroad drive innovation has progressed colossally since the primary steam motor was installed [4]. Inside combustion motors that run on fluid fossil fills are more dependable and effective. Trains with the ability to transport hundreds of individuals and hundreds of tons of cargo have been outlined. Uninformed of their natural affect, governments have started competing by making an expanding number of complex and innovative prepare networks, which has come about within the creation of diesel trains.

There's a broad sort of electric fueled footing frameworks around the division and these have been built in step with the types of railroad, its locale and the time accessible at the time of the set up. Numerous establishments unmistakable nowadays have been to begin with built more than a hundred a long time back, a few whereas electric footing gotten to be scarcely out of its diapers, so to talk, and this has had an exceptional have an impact on what's seen these days. The transmission of power is continually close to the melody through an aerial cord or at disposal of the ground, using encouragement. 1/3 rail laid close the running rails. While DC structures can use either an overhead rope or third rail, AC structures almost always use above wires [6].

Since the introduction of the key steam engines, railroad drive innovation has advanced significantly [4].Using liquid fossil fuels in internal combustion engines boosted performance. Exceptionally successful trains that seem pull loads of individuals and tones of items have been made. Daze to their effect on the environment, governments begun out competing in developing progressively more complicated and imaginative railroad systems. That leads the change of diesel trains.

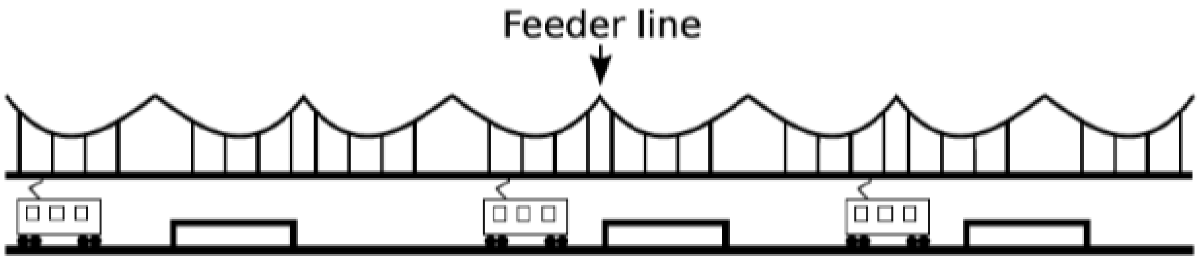


Figure 2. 1. Continuously electrified railroads' operation [11]

Overhead wires that are electrified typically use a single AC control parcel from a nearby application organization. For safety reasons, every segment of an electric route is supplied by a distinct substation and activated by a different group of computer programmers. High-voltage lines deliver system control to the substations. Before use, the voltage is often lowered once there.

2.2 Renewable Energy Systems for Railway Transport Electrification

Developing transportation costs as an arrangement of ever creating people in greatest of the segment worldwide areas has spared intercollegiate railroad machines, advanced transportation gadget.

Finding a green perfect control to diminish teach quality utilization could be a pivotal issue in railroad designing. Future electrical systems will need to solve a number of difficulties to accept variable control sources based on renewable energy.

Renewable energy sources (RERs) have variable, inconsistent, and often non-dispatch competent time. Concerns about nursery fuel discharges and power costs force us to transport near unused power sources.

In current a long time, to fulfill the developing electric call for electric footing and with the presentation of the deregulation advertise, there's a required for adapting with this circumstance with the help of included generation. Over the final decade, there was a high-quality interest in the global to develop excessive-speed railroad systems and enable their green operation. Substations in several regions of the region provide travelers with electric power. If there's enough space between substations, RERs and capacity frameworks can be integrated. RERs and capacity frameworks have reduced the train industry's reliance on the mission-critical electrical network [7].

The growing of value and deficiency of fuel collectively with the squeezing want to lessen discuss contamination are the guideline thought processes that result within the advancement of effective, emission free, financial, environmental friendly and sustainable electrical automobiles inside the world. The arena agreed at the existing time to use sun strength appreciably on many electricity applications due to its abundance

[8], [9]. Ethiopian sun oriented and wind vitality useful resource (SWERA) suggested (2007) that the once a year average daily radiation for the United States of America is three.74kWh/m2/day. In different instances the Ethiopian useful resource group have a see at indicates the radiation is five.5 to 6.five kWh/m2/day inside an average of 345 days [9], [10].

Sharew (2007) forecasts monthly normal averages of global radiation on a flat terrain in Ethiopia. He studied these mechanisms using SMARTS and vapor pressure radiation adaption (vice president-RAD). As end result, the month-to-month suggest of the daily international sun based radiation on a level floor is ready 19.5 MJ m^{-2} and 12 MJ m^{-2} respectively [11].

Tesfaye, et al (1989) estimates the sun radiation of Ethiopia 500 Wh/m2/day through the usage of Angstrom score relation [12]. The application of solar electricity for the railway gadget is constrained due to loss of superior technology, but some nations plan to apply the hybrid device for extraordinary makes use of their railway device. Sun Century is putting 4400 Panasonic Hit solar panels on England's Black friars' railway bridge. This will generate 900,000kWh of power and reduce CO_2 emissions by 500 tons annually [13]. The Indian Railway, the world's largest railway, has decided to use cutting-edge technology to tap alternate power sources to lessen its reliance on fossil fuel and the electricity grid. Solar power will be used for internal lighting and cooling [14]. This study found that sun power helps run system instructions.

2.3 Solar – Grid Hybrid Power System

Photovoltaic boards near train tracks activate most zap devices. These boards can produce enough power to distribute a footing modern to the lattice, or they can be hybridized with solar power to provide efficient, non-stop energy and limit railway grid output. This electricity may not always power the traction machine. Indian Railroads tried to install solar panels on a rail coach's roof. This test examined if a stop-on-demand device reduced the diesel needed to power modern coaches' electrical stacks. Solar-powered rail carriages should be beneficial, according to preliminary study. One solar rail train can generate 18 kWh/day. [15].

2.4 The Science of Hybridization

While choosing the necessary energy resources for hybridization for any utility, there are a lot of considerations to be aware of. The innovation of hybridization is essentially a supply and demand analysis. The choice of crest and cruel values should be justified by the quality request profile.

The regularity of control changes and a factual portrayal of particular power demand profiles may be a helpful tool in hybridization decisions [16].

Online or real-time optimization and offline, universal optimization are the two main subcategories of the best EMSs. Online optimization techniques rely on prior riding cycle knowledge at the same time as on line ideal EMS attempts to optimize parameters at the same time as the gadget is jogging and with no previous understanding of the driving cycle. Energetic programming [17], [16], direct programming [18.], hereditary calculation [19], [20] and recreation hypothesis [21] are illustrations of offline optimization techniques.

Analysts use a two-pronged EMS layout method. They start by offline optimizing certain components based on usage cycle statistics. Next, they use a web optimization technique to improve their outcomes. The analysts in [22] PID controls were employed for online optimization and direct programming for offline. The identical work was rehashed in [23] for the offline optimization phase utilizing an energetic programming calculation. The authors in [24] Researchers integrated an offline optimization method based on dynamic programming with a web-optimized neural network control for a battery/super capacitor hybrid electric car. They said this improved battery life by 66 %.(HEV).

"Ideal feathery manner of reasoning" describes control systems that combine offline optimization with online fluffy logic. This is "feathery logic" Fuzzy logic control requires well-described membership functions. Offline optimization determines hybridization and controller participation. Offline optimization uses specified sets, omitting exploratory calibration for fuzzy reason control. This saves time offline [25, 26].

2.5 Intelligent Fuzzy PID Controller

Commercial applications commonly use PID controllers, which are principal by-product controllers. The PID controller's business procedure execution is subpar. Several attempts have been made to trace the PID choices Kp, Ki, and Kd. These attempts have been mixed [1] - [7], [9].These control strategies and calculations are insufficient for tuning non-linear PID controllers.

When applying a controller to a method, a trained human operator must help retune the controller because of the methodologies and computations needed to tune the PID selects.

Fuzzy controllers are used in commercial systems [10, 27]. The rule buffer encodes a human operator's knowledge and experience. Fuzzy PID controllers have been researched for over a decade [13–28]. Furthermore, self-sustaining or intelligent fluffy PID controller programs are gaining traction, and many academics have researched in the fields of self-tuning fluffy PID controllers. Furthermore, self-sustaining or intelligent fluffy PID controller programs are gaining traction. Self-tuning fuzzy PIDs, for instance, have been used to control frequency and load in the energy conversion and management [29], HVAC [30], and programmable common sense controllers [31] industries, to name a few. This study uses a novel self-organizing fuzzy PID controller that borrows concepts from both the fluffy PID controller and the self-tuning fuzzy PID controller investigations.

A learning controller is the self-organizing fuzzy PID controller. The self-organizing fluffy PID controller generates its own manipulate rule methods during rule creation and modification, and then stores the new rules in the run-the-show buffer. During device operation, the rules are sent and modified continuously in the rule buffer. This is done to retain the underused enjoyment at the set-point and from the managed strategy. Step entries and heading-following instructions are applied to a non-linear revolute-joint robotic arm to build the self-organizing fluffy PID controller. The procedure also incorporates commotion and time. Self-organizing fluffy PID controller for energetic framework bundles uses the revolute-joint robot arm as a check sleeping cushion. The self-organizing fluffy PID controller's computer simulation results are compared to those of the fluffy PID and PID controllers. This comparison evaluates the self-organizing fluffy PID controller for dynamic machine programs and gathers tuning information. The IAE criterion measures the selfsetting fluffy PID controller, the fluffy PID controller, and the PID controller. IAE is useful for PC-based research.

2.5.1 PID controller

A common criticism is the PID controller. By the 1940s, it was the de facto standard for process control equipment. Over 95% of modern preparatory control rings are PID, with most using PI control. PID controllers are utilized in every control application imaginable. Controllers come in many kinds. Frameworks in boxes can hold one or more circles. Annually, 100,000 Frameworks are generated.

Distributed control systems need PID control. Unorthodox reason control systems use controllers.

PID Control is used with reasoning, successive abilities, selectors, and basic job components to build sophisticated computerization frameworks for energy production, item movement, and product creation. These sectors rely on several frameworks. Modern management approaches, such as foresight control, are excessively future-focused.

The multivariable controller provides the focuses for PID control [32].

PID controllers have existed through pneumatics, mechanics, electronic tubes, transistors, and integrated circuits, and microprocessors. The microprocessor's involvement changed the PID controller. Today's PID controllers rely on microprocessors. This allows for continuous adaptation, gain scheduling, and automatic tuning [32].

2.5.2 PID controller Algorithms

PID controllers output an error value when a measured process variable is compared to the set point. The controller uses a controlled variable to increase precision.

Proportional Term: The related phrase generates a yield esteem that is proportional to the error esteem that is currently in effect. The associated reaction can be brought into equilibrium by replicating the error with a constant Kp, which is referred to as the relative pick up consistent. The term that corresponds to this is found in:

$$P_{out} = K_p e(t) \tag{2.1}$$

A high corresponding pick up comes about in a huge alter within the yield for a given alter within the mistake. Too much pick up can make the framework unstable. A little pick up can occur when distinguishing due to a controller's yield reaction to a major input mistake. If the pick-ups are too more.

Control activity can be too low while response to potentially negative framework influences. Both the tuning theory and the mechanical perfecting suggest that the corresponding term causes most of the change in performance.

Integral Term: The amount and length of the error are related to the term's commitment. In a PID controller, the necessary is the entirety of the momentary over time and supplies the collected counterbalanced. Because a PID controller's necessarily is part of the algorithm. Error total is multiplied by ki

and added to the controller's output.

$$I_{out} = K_i \int_0^t e(\tau)d\tau \tag{2.2}$$

The required period speeds up the technique's approach to the set point and eliminates a proportional controller's steady-state error. The term's necessity brings both benefits. The indispensably term reacts to past errors, which can lead the display value to exceed the initial number.

Derivative Term: First determine the slope of the error as a function of time, then multiply by Kd. Kd is the subsidiary's commitment to overall control. Derivative phrase:

$$D_{out} = K_d \frac{d}{dt} e(t) \tag{2.3}$$

2.6 The Basic Fuzzy Controller

1995: Zadeh coins "fuzzy rationale." It uses arithmetic to analyze human reasoning. Fuzzy logic uses a simple computational equation. Subjective facts become numerical correlations through fallacious thinking. It makes appropriate to explain unpredictable framework behavior that is difficult to model. The traditional set hypothesis and the fluffy hypothesis share the same basic idea, but there are no novel changes between the values. Factors are expressed as capacity between two digits, most commonly between and 1 or any other digit.

An array of weights depicts a variable's position within its range. The standard set hypothesis defines a variable by its uniformity or non-correspondence to certain esteem. [18] For a fuzzy set to be defined, both the values and the weights of each value are needed. Fuzzy logic is used to relate fuzzy sets [33] [19].

Fuzzy set operations include:

Both Set A and Set B:

$$M(x) + B(x) = MA(x).MB(x) \quad (2.4)$$

$$\text{Minimum} \quad (MA(x), MB(x)) \text{ denotes where A and B meet.} \quad (2.5)$$

$$\text{Inverse of A M} = (1 - MA(x)) \quad (2.6)$$

2.7 Membership functions

Membership functions are used in fuzzy logic input/output variables (MF).The shape of the curve dictated the relationship between each input and output [34]. [35] Controller designer chooses membership function.

Consider the following variables while selecting a membership function:

- A wide membership function to identify noise.
- Enough overlap to allow the controller to be identified.
- Gaps in function curves result in a poorly constructed controller.
- Set number and width should be coordinated.

Fuzzy logic controllers have four main parts:

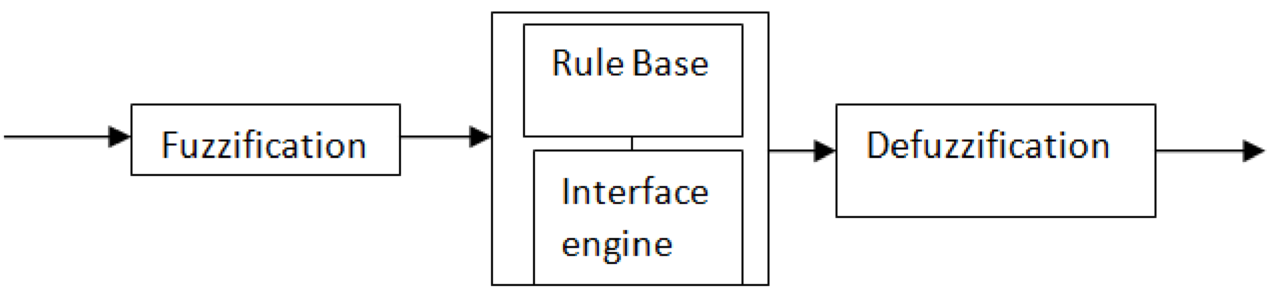


Figure 2. 2 Structure of a fuzzy logic controller [34 35]

Fuzzification: In building a fluffy controller, selecting the state elements that connect to the framework's energetic execution is vital. Fluffy logic uses phonetics instead of numbers.

Fuzzification converts numerical variables, such as actual numbers or freshly formed factors, into phonetic variables, such as fuzzy numbers.

Interface motor is the computer program code that forms run the show, cases, and other data and dominance based on truths and situations. When solving a logic-based problem, we use derivation, association, recognition, and decision making. These procedures are used to solve problems involving objects, information, and expertise based on a given situation.

An induction motor is a data-handling system that uses deduction steps like the human brain.

Rule base: The Mamdani approach works best on weird, broken systems since it relies on human instincts and common knowledge. E.H.Mamdani's fluffy was the show's initial enrollment. Membership functions and fluffy rules are effective with single-input, single-output systems [37]; [38]; [39].

It is combining fuzzy data, control rules, and linguistic expressions to emulate human decision-making. If then is the condition, and if is the conclusion that the computer can execute rules based on input error (e) and error change (de). Rule-based controllers have easy-to-understand control mechanisms.

A run the appearance controller must trigger it, and a non-specialist user can protect it. Normal procedures work on the same controller.

2.8 Assessment of the Existing System Electrified Railway in Ethiopia

The data of railroad and steam motors has been around since the sixteenth century. Wagon streets for coalmines victimization noteworthy boards were starting outlined and inbuilt 1633 [40]. Mathew Murray of city in Britain stunning a railroad train that would run on timber rails in 1804 and this was in all likelihood the essential railroad motor [1].

In spite of the fact that railroad and train advances were habitually created, the essential zapped railroad was presented inside the Eighties [1], [28].

As results of this insurgency, engines and thus the footing control give framework got to be essential components of modern energized railroads.

with the exception of traction motors, traction power provide systems square measure physically large electrical circuits that typically consists of traction station, the curve system, time-varying and moving masses and different electrical system [41].

2.9 Electrified railway profile in Ethiopia

Start with a rewritten paragraph on "The Addis Ababa–Djibouti Railway modernization project is that the 1st cross-border energized railroad in geographical region. The railroad line can be an electrified single-track railroad line 753 klick between Ethiopia and thus the Harbour of Djibouti, with forty five stations in add up to. The new railroad line runs parallel to associate degreed replaces an surrendered one m gauge railway, that was designed quite a hundred years a gone. As an inland country, the road is the foremost transport passageway for Federal Democratic Republic of Ethiopia to its entry of the Port of Djibouti that handles over ninetieth of Ethiopia's international trade. The road runs from Addis Ababa/Sebeta through the 2 massive Ethiopian cities of Adama and Dire Dawa and links industrial parks and dry ports thanks to harmonics, voltage outages, and fluctuations the train failed to run swimmingly. It conjointly caused injury to the train, therefore it's vital to spot different power offer choices that may be utilized for the train. "

As a result, the Dire Dawa railway line from Addis Ababa passes through desert cities; in these cities, it's necessary to use the solar power choice to alter the transport sector to control while not power shortages; so, it's necessary to boost the provision of solar power by meeting the request for energy. Problems with power provide will be solved by exploitation these 2 powers provides, grid and sun based vitality. The system we tend to use may be a fuzzy system; this management system separates power provides from existing power sources adequate power are going to be provided for the train. This can assist you avoid spare losses and harm caused by power fluctuations.

Railway electrification system:-A Railway jolt framework: Electrical circuits require 2 associations (or for 3 area AC, 3 associations). From the beginning, the track was utilized for one perspective of the circuit. In differentiate to demonstrate railroads the track commonly gives as it were 1 angle, the inverse side(s) of the circuit being given one by one.

Electrical traction: - grants the work of regenerative braking, amid which the engines are utilized as brakes and gotten to be generators that rebuild the movement of prepare into electric control that's at that point bolstered back to the lines. This strategy is particularly beneficial in precipitous operations, as down trains will turn out a larger than average parcel of the office required for climbing trains. Most frameworks have a characteristic voltage and, inside the case of AC control, a framework recurrence. A few trains are prepared to handle different voltages and frequencies as frameworks came to cover or were overhauled.

Overhead lines: - Railroads have an inclination to like overhead lines, ordinarily alluded to as "catenaries" once the net usual hold the wire parallel to the foot.

Trolley car pole: - trolley car post can be a long flexible post that locks in the street with a wheel or shoe. Bow collector: Bow collector might be an outline that holds an extended accumulation bar against the wire.

Mechanical device:-Pantograph is a pivoted outline that holds the accumulation shoes against the wire in an awfully mounted unadulterated science.

The mechanical gadget strategy is fitted to high-speed operation. Trains utilize each overhead and rail collection (e.g. British Rail category 92). In Europe, the proposed unadulterated science and shape of pantographs sketched out by standard nut 50367/IEC 60486 [33].

Transformers: A railroad charge system gives control to railroad trains through the transformers. Hence, the electrical device can be a key portion to help cut back issues of the unbalance of voltage and current inside the control system.

H. Battery locomotive is supercharged by aboard batteries; a form of battery electrical vehicle. Such locomotives are used wherever a standard locomotive engine would be unsuitable. Relate degree case is upkeep trains on energized lines once the power of voltage and current inside the control system. Battery locomotive is supercharged by aboard batteries; a form of battery electrical vehicle. Such locomotives are used wherever a standard locomotive engine would be unsuitable. Associate degree example is maintenance trains on electrified lines once the electricity.

2.10 Existing system of electrified railway data analysis

2.10.1 Research Method

The point by point strategy utilized to conduct the in general ponder is examined, such as inspecting and inspecting strategies and disobedient utilized collecting information relating to each of the particular destinations as well as the procedure utilized to analyze information.

2.10.2 Research design

This study examines data quantitatively to answer a specific research question.

2.11 Research Instruments

There were two types of data collection instruments used in this study: questionnaires and interviews.

2.12 Data collection

Nowadays, data s one in all the foremost necessary parts in all fields of an analysis that isn't shocking because the quantity of knowledge generated is consistently growing. The rise of the information that's being generated is very vital inside the field of transportation, since the transportation division is liable for one among its greatest natural handle. Steps since the moment mechanical revolution—electrification of vehicles [4]. The expanded a stream of information enormously impacts the vitality a logical teach field, as communicated by Watson et al. [42], [43].

The upper coarseness of knowledge the higher data framework will be created for optimizing the vitality utilization in extremely advanced systems. The information during this knowledge the domain an analysis field will be gotten through totally different completely different sources and with different ways. The data was accumulated from each essential and auxiliary source. Primary data was the basic data for the consider was gathered from the design report, existing records document at the town Dire Dawa office, and yearly report papers. Railway personnel provided secondary data on this subject. The data was collected through a field visit and data collection at the Dire Dawa town Railway Corporation and sanitation service office. The obtained data were summarized and presented as follows:

2.12.1 Primary Data

Many parameters are directly measured to decide the sum of power loss. The sum of water produced is measured at the subsystem's head, the primary water release reservoirs. Most parameters must also be directly monitored to the foremost critical quantities that customers tap to evaluate nodal pressure and water flow analyses.

2.12.2 Secondary Data

Its information obtained from primary sources and made immediately available to analysts. Analysts can use this information immediately. It's information from the past. One researcher may have obtained project-related information and shared it with another. Census information may be compiled for general use without specialized analysis goals.

Electric Production: - According to information obtained from discussions with experts of the Dire Dawa branch of the Ethiopian Railways. The source of Ethiopia's electricity supply is from the power station. In expansion to the data on electricity production for the complete study area, it is available through the flow meter.

Energy consumption in Ethiopian Railways: - IR accounts for as much as 1.57%3 of country's total electricity consumption, considering the conventional sources of energy. This estimates to 19.02 billion kWh of electricity consumption in 201-20. IR, in its efforts towards sustainable development, has been taking various steps towards enhancing energy efficiency levels. This has led to reducing its specific electricity consumption by about 3.0% in traction on year-to-year basis.

POWER FACTOR: - Most electrical distribution networks employ inductive hundreds. Motors, transformers, aerosolized tube lighting ballasts, and induction furnaces are examples. Inductive hundreds require a spinning force field.

Kilowatts measure operating control power, which is measured on a watt meter (kW). Despite not doing "work," receptive control circulates between generators and the stack. It's measured in kilovolt-amperes-reactive and depletes the capacity supply and dispersion framework (kVAR). Apparent power is a power system's running power plus its reactive power, measured in kilovolt-amperes (kVA).

POWER QUALITY: - A control quality is prime significance decided the potency of any load and one in all the important parameters of the facility quality is Harmonics. Harmonics: Electrical masses will be classified as straight and non-linear loads; a straight stack is one which pulls bended current once subjected to a bended voltage. This wave might or might not have a segment refinement with a connection to the voltage. An unadulterated resistance, inductance or capacitance or any combination of those shapes a straight stack.

2.13 Method of analysis

2.13.1 Assessment of control calculate

Power factor is that the quantitative relation of operating control to clear control and it measures however effectively electric power is being employed. A high power issue signals temperate utilization of electric control, whereas a coffee power issue indicates poor utilization of electric control. In an exceedingly linear or curving system, the results additionally noted because the facility triangle is given below:

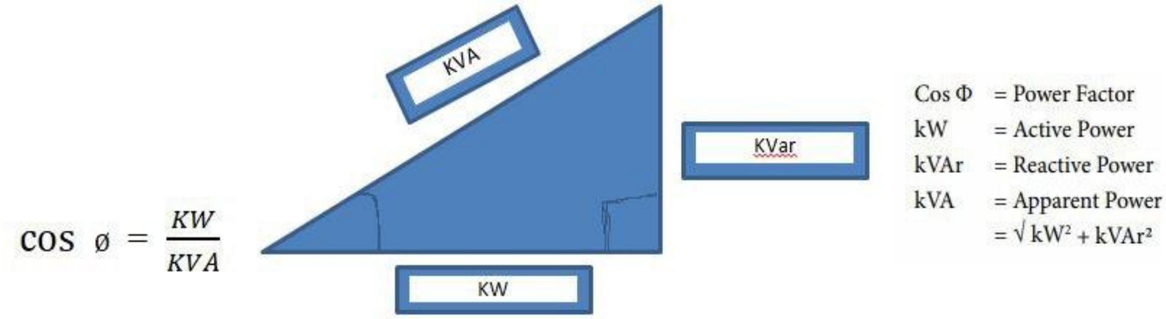


Figure 2. 3 Power Triangle

The supply of responsive control from the framework closes up in decreased establishment proficiency due to expanded current for a given stack; Higher voltage drop within the framework, Increment in misfortunes of transformers, switchgears and cables; Higher kVA request from the supply framework.

It's in this way vital to cut back and oversee the stream of responsive control to realize higher potency of the electrical framework.

The simplest methodology of lessening and overseeing receptive control is by control issue change through control capacitors (Capacitor banks). As control issue tends to solidarity, the electrical framework strength can move forward.

Benefits of Control issue Adjustment

The benefits of control issue adjustment are summarized as beneath: Lessening in request charges; Disposal of control issue penalties; Decrease in current drawn; Reduced electrical device, switchgear and cable losses; Progressed voltage direction; expanded lifetime of switch adapt /cables because of reduced in operation

2.13.2 Assessment of harmonics

2.13.2.1 Sources of harmonics

Following unit a number of the non-linear hundreds that generate harmonics:

- Inactive Control Converters and rectifiers, which are utilized in UPS, Battery charges, etc.
- Bend Heaters ¾ Control Gadgets for engine controls (AC /DC Drives.)
- Computers.
- TV collectors.

- Saturated Transformers.
- Fluorescent Lighting.
- Telecommunication equipment.

2.13.2.2 General flow of harmonic currents in a radial power system

This common inclination of consonant current streams is frequently usual discover sources of sounds. Utilizing a control quality screen, fair live consonant streams in each division beginning at the start of the circuit and take after the sounds to the supply. The powered issue adjustment capacitors will modify this stream design for a least of one in all harmonics. Capacitance can create a disproportionately large quantity of harmonic current in a circuit. Tracing the harmonic current can reveal a capacitance bank instead of the harmonic supply. Power issue capacitors will alter the course of flow of 1 of the harmonic elements of this. Thus, it's typically necessary to briefly disconnect all capacitors to dependably find the sources of harmonics.

In most circumstances, it's easy to distinguish between consonant streams created by actual sources and reverberation, which may contain a capacitance bank. In most circumstances, there is just one dominant harmonic in a resonance current. Harmonic sources only emit one frequency.

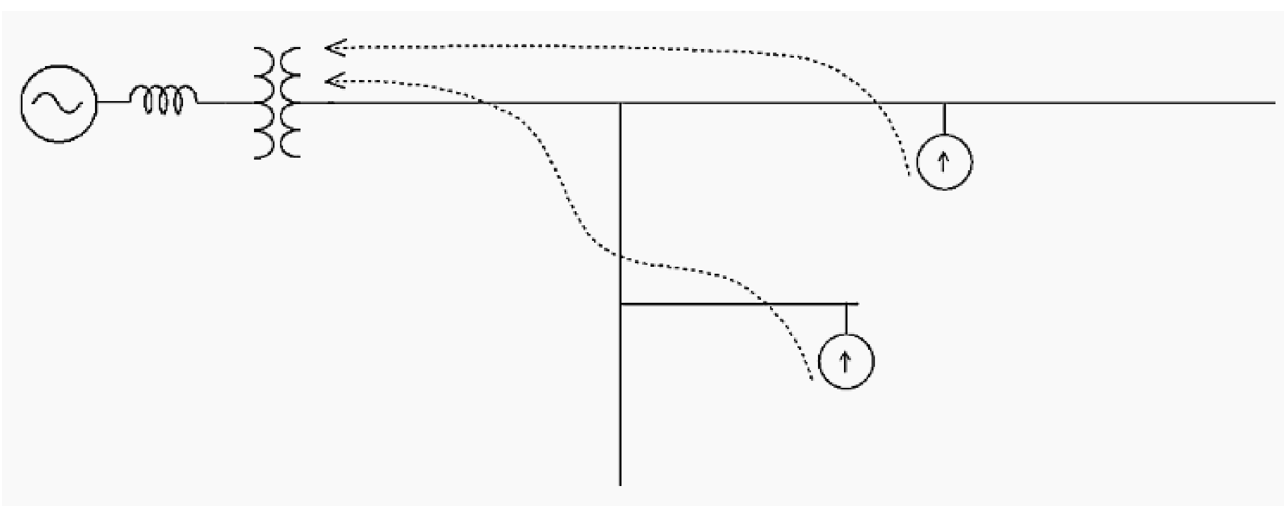


Figure 2. 4 General flow of harmonics current in a ridal power system [51]

Waveforms of those consonant sources have to some degree tact wave shapes wagering on the mutilating wonders; however they contain many harmonics in vital quantities. A single, huge, imperative consonant about persistently implies reverberation. This truth may be misused to see in case consonant reverberation issues unit surely to exist in a really framework with capacitors.

Merely live this within the capacitors. In the event that it contains an extremely extraordinary sum of 1 consonant aside from the fundamental, it's without a doubt that the electrical device is collaborating in a really resonator among the office system. Continually check the electrical device currents 1st in any installations wherever harmonic issues square measure suspected. Another technique to find consonant sources is by relating the time varieties of the voltage twisting with particular client and cargo characteristics. Designs from the consonant mutilation estimations may be compared to explicit varieties of hundreds, like bend heaters, process drives, and mass travels that seem intermittently. Correlating the time from the measurements conjointly the actual operation time will establish the harmonic supply.

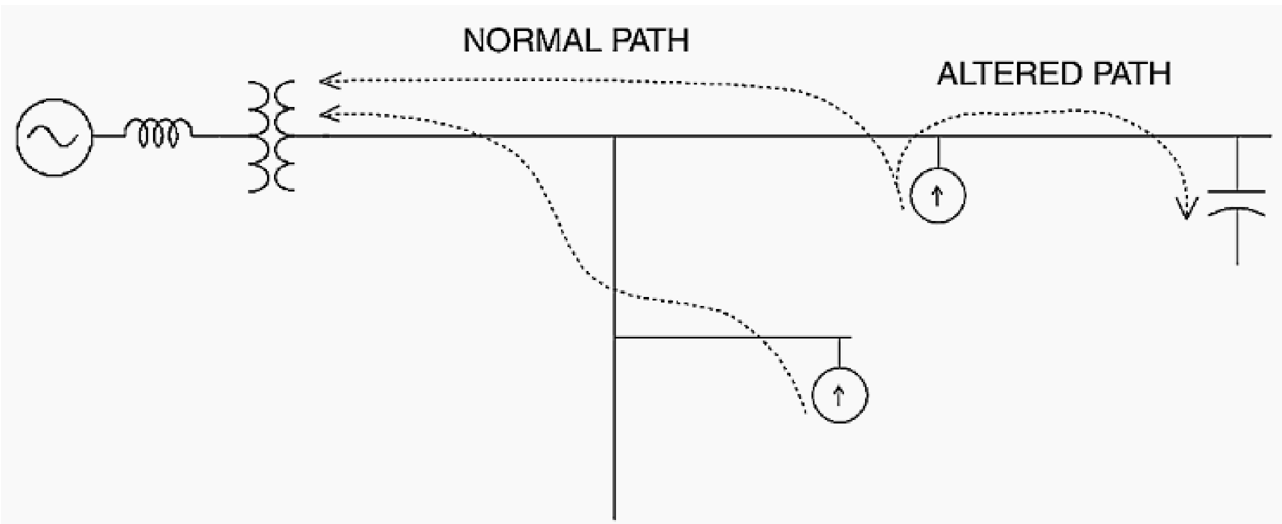


Figure 2. 5 Power factor capacitors can be alter the direction of flow of one of the harmonics component of the current [51]

Effects of Harmonics

Sounds have changed impacts on instrumented and gadgets, an out of order or perhaps add to disappointment looking on the degree of consonant contamination. The consequences of harmonics are often loosely classified as fast effects and long run effects.

Instantaneous effects:-

- Vibrations and clamor in transformers, reactors, and acceptance engine etc. Arrangement / parallel Reverberation leading to harm to instrumentality associated to the arrange defective of delicate electronic Gadgets and interferer in communication and administration circuits (telephone, management and observance circuits).

- Total vitality needed to perform the required operate will increase, imposing the next request on the electrical provide system thereby expanding vitality value.

Long-term effects:-

- Failure of pivoting machines: Consonant turning areas makes beating mechanical torques driving to vibrations and accumulated mechanical fatigue in rotating machines. This comes around in untimely mechanical disappointment.
- Diminishment in capacitance life: capacitance draws unusually tall streams within the nearness of sounds coming about in lessening inside the appraised lifetime of the Capacitor.
- Premature disappointment in machines, transformers, cables etc. harmonics cause additional press misfortunes and copper mishaps (due to skin effect). These extra misfortunes increment the operational temperature of the instrumentality to anomalous levels, subsequently incurring its untimely disappointment.

Remedial Measures:-

- In situations with impure Harmonics, correct medicinal measures ought to be taken to moderate the consonant levels. The suggested methodology to hit applicable arrangements is recorded underneath:
- activity of consonant levels and examination of the behavior of electrical organize
- Deciding of kind of therapeutic activity to be taken and style of harmonic filters to realize wanted consonant levels.
- Harmonic channels are to be engineered mistreatment the acceptable parts and devices Installation of harmonic filters to be meted out as per style needs.

2.14 Executive Summary

Climate Catenary-electric powered or Hybrid strength generation, a hit arrangement of the power control administration framework is very critical. Mainly, thinking about the sun – Grid Hybrid power machine, can grow to be pretty powerful with a successful electricity control machine. In this research thesis the fluffy PID controller proposed for the undertaking of hybrid solar-grid power optimization of rail trains (Dire Dewa to Addis Abeba) using MATLAB Simulink.

This data analysis was conducted to study the electricity supply service from Dire Dawa to Addis Ababa railway. It describes the existing system I conducted in Dire Dawa. Ethiopian Railways aims to improve the nation's power supply by auditing existing systems, enhancing transportation administration, and creating renewable energy. The total 5 years of electricity supply in 15,207,595 kw of power was gotten from the Ethiopian Electric Power Corporation, and 11,978,146 kw (79%) was used. Concurring to the office data 3,229,449 kw (21%) of electricity was wasted in five years. When this power loss is calculated at a minimum electricity tariff of 3 Birr / cubic meter, the company loses 16,147,245 birr in 5 years. This appears that the negative effect on the national economy is high.

Numerous components are contributed to control loss, counting human impassion, and administrator error etc. Fundamental require for an electric prepare requires control. Due to the presence of a squander of control it increases the economic burden on the organization.

This fuzzy –PID controller framework will illuminate the issue of control deficiencies and increment the demand for electricity supply from Addis Ababa to Dire Dawa. In general, by choosing when the power supply is higher, the total power disruption and it decreases the effectiveness of the TR. Another negative effect on the electrical lattice (sounds, voltage blackouts, and vacillations) to the utility is avoided. During this work, fluffy - PID controller may be a multi-value logic that permits some intermediate values outlined between typical evaluations, like affirmative or no, high or low, true or false. It's associate professional system that uses a set of participation capacities and rules. The parameters outline a membership perform inside the fluffy - PID controller framework. The degree of membership lies between zero and one. Triangular, Trapezoidal; mathematician is membership functions. The essential fuzzy - inflammatory disease controller model consists of fuzzification, interface, defuzzification, and a mental object. The input to the framework may be a crisp set. Fuzzification is nothing however the transformation of a crisp cluster to a fuzzy set. Fuzzification, the enrollment perform is connected, additionally the degree of membership is chosen. The unclear interference method combines membership functions with management rules to supply a fuzzy output, organized during a tabular type referred to as a look-up table.

The methodology of conveying quantitative leads to numerical rationale is named defuzzification. It's a program that changes over fuzzy sets to genuine numbers [25], [26].

Once analyzing the planned framework, the action of the hypothesis is progressing to be completed by concerning the power offer framework administration proposals.

CHAPTER 3

MODELING AND MATERIALS

This chapter addresses the proposition's resources and methodology. Computers and MATLAB/SIMULINK were used. Modeling a solar-powered framework, planning a fuzzy reasoning structure, planning a fuzzy-PID controller, and analyzing are employed. Following districts, takings are detailed.

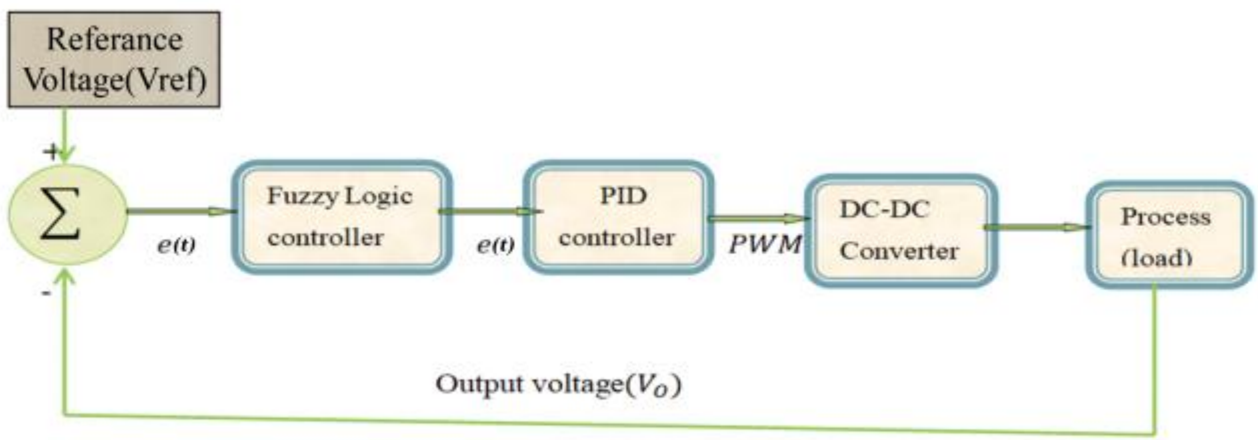


Figure 3. 1 Power management system fuzzy-PID controller schematic

3.1 Energy Demand and Load Estimation for RT

Distinctive sorts of loads are taken from the Traction system, Auxiliary units, air conditioning, charger, television, Camera and microphone. They are displayed in Table 3.1 below.

Table3. 1 Load demand and estimation for RT [47]

Description	Power demand	Energy in 12 hrs.
Traction	350kw	4200kwh
Auxiliary units	35kw	420kwh
Air conditioning	25kw	300kwh

Charger	8kw	96kwh
Door	0.2kw	2.4kwh
Television	0.4kw	4.8kwh
Camera	0.18kw	2.16kwh
Microphone	0.21kw	2.52kwh
Total loads		5,027.88kwh $\approx 5{,}028kwh$

Table 3.1 shows all the visualizations, their energy usage, and the number of processes. The RT's overall power usage is also discussed. Load capacity is 5,028 kilowatt-hours.

Roof beat region = length * width=29.7 *2.65=78.7m2

The length of the zone for the chosen photovoltaic (PV) modeling board is 1.65 meters, and the needed height is 0.988 meters.

The panel's area is = 1.65 * 0.988=1.63.

Minimum number of modeled roof modules:

78.7/1.6 = 49 modules.

To cover the train's roof, 49 modeled modules are required. The largest control produced by these 49 modules is Pmax: Pmax = number of modules * peak control module = 49 * 250W = 12.25kW

The modeled module's real power output is as follows:

Pact=Pmax/Efficiency=12250W * (1/0.85) = 14.7KW. After receiving permission, the real number of modules, expressed by No. of boards = Pact/peak power of module = 58 panels,

Table 3. 2 PV specification [48]

Maximum rated power (PMP)	250W
Voltage at Maximum power (VMP)	26.4V
Current at Maximum power (Imp)	9.46A
Open circuit voltage (VOC)	39.9V
Short circuit current (ISC)	8.6A

Total number of cells in parallel (NP)	1
Total number of cells in series (NS)	60

The panels will be arranged at an inclination angle. Because of the width of the preparation and the length of the boards will be greater than the height of the preparation. The point shaped by the sun based boards is 36.6 degrees and (expecting a board dividing of 10cm) N, B Pmax is for most extreme control and the agreement is for real control.

3.2 Energy saving analysis

When operational, the solar-powered board will reduce grid electricity. The ship's solar panels can provide useful energy for at least 5.6 hours per day, according to table 3.2.

E=14.5KW*55.6hrs=81.2KWHrs.

81.2 KWh x 30 months = 2436 KWh saved every month.

Annual energy savings equals 29.2 megawatt hours.

It will be noteworthy for the Ethiopian railroad to be able to reduce its use of vitality by operating entire trains with auxiliary units in this year (42 trains). Annual Energy=1227.7MWhrs, the solar model panel is able to supply DC 24 V control supply for footing structure control and auxiliary power supply. It is able to power the TR auxiliary power box charger. Give control of the framework, the entryway, the communication hardware, the lighting in the traveler cantina, the illumination in the emergency room, and the appealing rail braking.

3.3 Modeling of PV solar system connected to utility grid system

The main goal of this thesis is to utilize the total potential of a renewable vitality source, namely sun based vitality, to produce power for powering more control single-phase mechanical or residential loads. Generally, sun powered boards are outlined in such a method to have a yield voltage of around 23-38 V at the most extreme control point (MPP) and an appraised control is 350 W at 1000 W/m2 radiation level.

Sun based boards are associated to a DC-DC converter. In this arrangement, can monitor the greatest control using the greatest control point calculation, and the output may be synchronized with the loads. Boost converters are by and large utilized to move forward the sun oriented board voltage produced [33, 38].

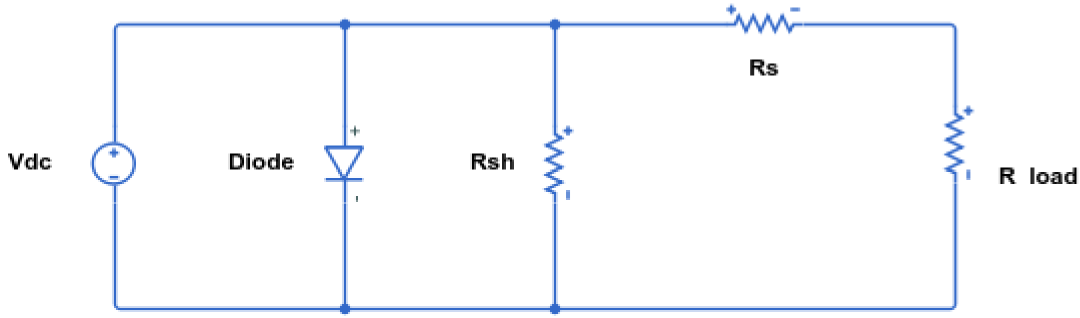


Figure 3. 2 PV string equivalent circuit

Figure 3.2 displays the grid-connected PV equivalent, which comprises a current source, anti-parallel diode, spilt current shunt resistance, and arrangement resistance. Id is diode current, and Ipv is PV current. Connecting PV strings in sequence creates a PV cluster. Figure 3.2 depicts PV strings.

A PV cell's current is:

$$I_{pv} = I_o \left[\exp\left(\frac{q(V-IR_S)}{KT}\right)\right] - 1 \tag{3.1}$$

Where

k is the Boltzmann distribution constant,

T is the temperature,

Rs is the equivalent series resistance of the cluster,

Rsh is the shunt resistance of the

PV cluster caused by leakage current, and

Io is the PV cell's switch immersion current. Solar cells are usually coupled to DC-DC converters. Low PV output voltage must be increased. DC-DC converters boost low voltage.

I = current, V = photovoltaic module voltage, Ipv = photocurrent.

I o stands for turnaround immersion current, n p for parallel cells, and n s for arranged cells,

K = 1.38 x 10-23 J/k; T = PV module temperature.

Additional parameters are needed to produce a viable photovoltaic (PV) module from a few PV cells.

$$I = n_p I_{pv} - n_p I_O \left[\exp\left(\frac{V + R_s I}{V_t \alpha}\right) - 1\right] - \frac{V + R_s I}{R_p} \tag{3.2}$$

Where, $Vt = \frac{N_S K T}{q}$

The scientific model of the sun-oriented cell for a single diode is as follows:

$$I_{ph} = (I_{sc} + K_I * (T - 298) * \frac{G}{1000}$$

(3.3)

$$I_o = I_{rs} \left(\frac{T}{T_n}\right)^3 \exp\left[q * \frac{Eg\left(\frac{1}{T_n} - \frac{1}{T}\right)}{\alpha K}\right]$$

(3.4)

$$I_{rs} = \frac{I_{sc}}{e^{q * \frac{V_{voc}}{\alpha N_S K T}} - 1}$$

(3.5)

$$I_{sh} = \frac{V + I * R_S}{R_{sh}}$$

(3.6)

$$I = I_{ph} - I_o * \left[\frac{e^{q * V + IR_S}}{\alpha . k . N_s . T}\right] - 1 - I_{sh}$$

Where;

Photo current of sun powered cell (I_{ph});

Immersion current (I_o);

Turn around immersion current (I_{rs});

Current through shunt resistor(I_{sh}),

Output current (I);

Current - Voltage Characteristics of a PV

Each cell's operational parameters have one working point. Here, the cell's current (I) and voltage (V) produce the most extreme control.

P = VI calculates P's power. Diagram displays panel power vs. voltage. From the MPP, the curvature falls downward. Maximum power point is the curve's "knee" (MPP). This is when the module is most efficient and produces the most power.

Modeled circuits must be combined into a subsystem to produce a PV module subsystem. Figure 3.3 shows the modeled PV module. PV solar power depends on solar irradiation (G) and temperature (T).

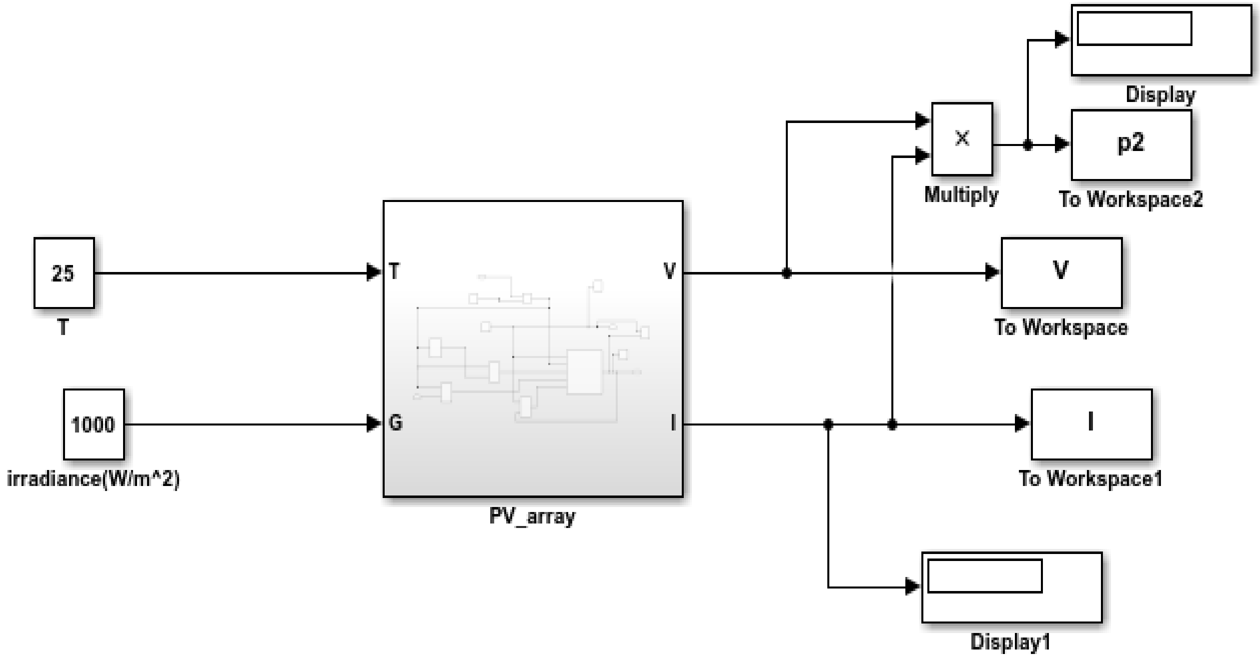


Figure3. 3 PV model as subsystems from mathematical Simulink

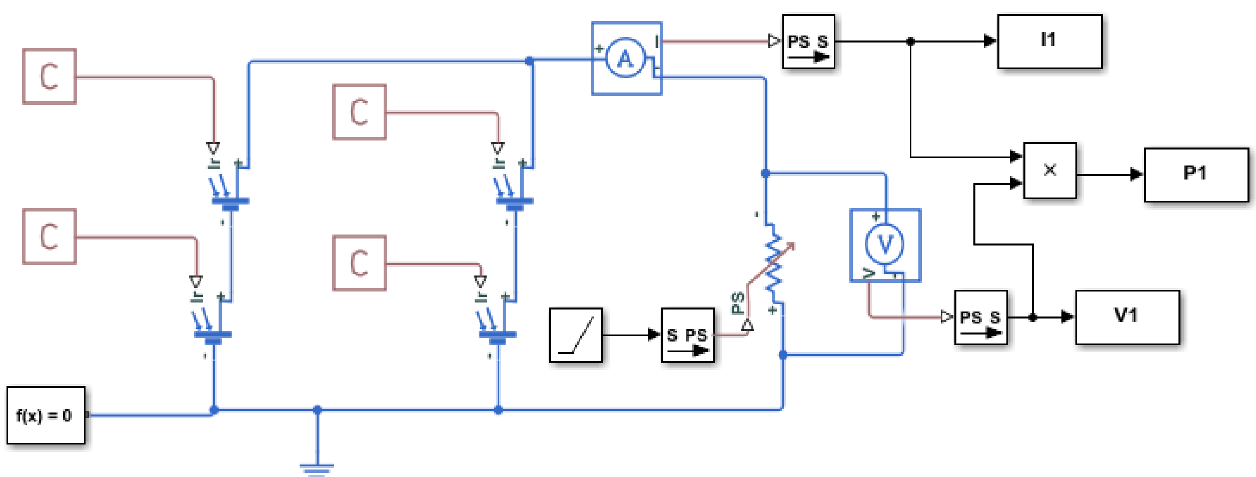


Figure 3. 4 V-I and P-V characteristic of solar PV SIMULIN Model

3.4 CONVERTER DESIGN OF BOOST

High-efficiency DC/DC boost that uses a MOSFET transistor switch to change the inductor's beat width.

Basic Configuration of Boost converter: - Boost converter characteristics include input voltage, yield voltage, yield current, and exchange frequency. Figure 3.9 shows the boost converter circuit. [44].

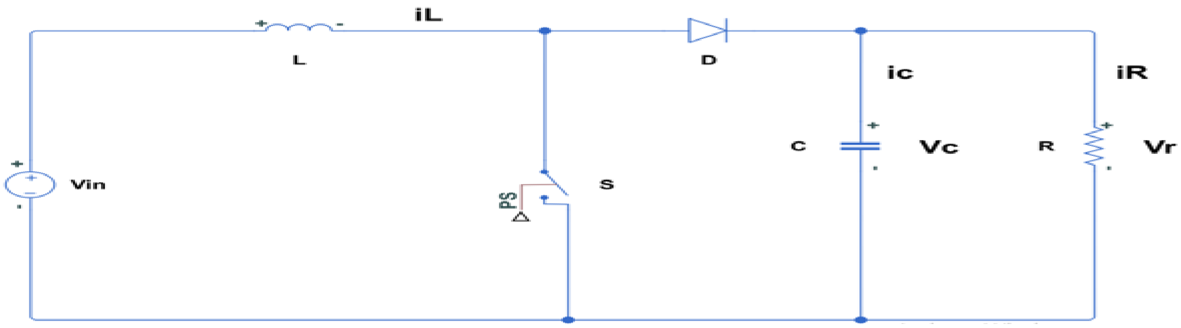


Figure 3. 5 Ideal Boost Converter [45]

Duty Cycle (D): Given the lowest input voltage, determine cycle D. Low input voltage is utilized to maximize current exchange.

$$D = 1 - \frac{V_{in}}{V_o} \qquad (3.7)$$

V_{in} = Input voltage

V_o = craved yield voltage

Load resistance (R):

$$R = \frac{V_o}{I_o}$$

Inductance (L):

$$L = V_{in} * \frac{V_0 - V_{in}}{\Delta I_l * f_s * V_o} \qquad (3.8)$$

ΔI_l = inductor ripple current, 10% of I_o

f_s = switching frequency

V_o = desired output voltage

I_o = desired output current

ESR = proportionate arrangement resistance of the capacitor

D= duty cycle

Capacitance (C):

$$C = I_o * \frac{D}{f_s \Delta V_o};$$

$$\Delta V_o = ESR(\frac{I_o}{1-D} + \frac{\Delta I}{2}) \quad 3.9$$

Diode: Super quick recovery diodes can reduce losses. Minimum forward current rating equals or exceeds maximum yield current. Table 3.3 presents the plan's parameters based on the circumstances.

Table 3. 3 parameters of boost converter [45]

No	Parameters of boost converter	Parameter values
1	Input voltage (V_{in})	60v
2	Input current (I_{in})	5A
3	Output current (I_o)	1A
4	Output voltage (V_o)	300V
5	Duty cycle (D)	0.8
6	Load resistance (R)	300Ω
7	Inductance (L)	240mH
8	Equivalent Series Resistance of capacitor (ESR)	16m Ω
9	Capacitance	$5000\mu F$
10	Equivalent Series Resistance (ESL)	0.5Ω

3.4.1 State Space Model

DC-DC boost converter modeling allows state space selection. MATLAB's state space output shows the system's abdicate and control trade work. This is the system's output. State space averaging describes this approach. Boost converters have two modes [45].

Turn OFF the Equivalent Circuit

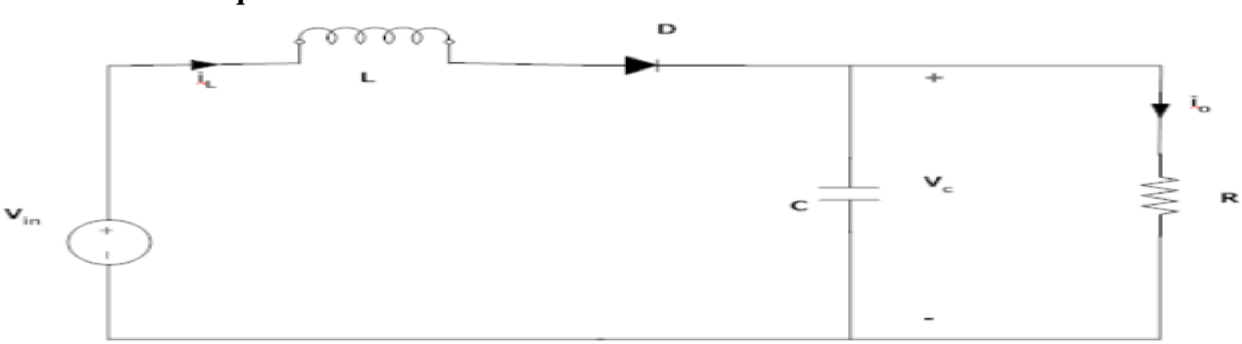


Figure 3. 6 Off mode for the boost converter[45]

The state space conditions amid Off mode as appeared figure 3.5 are communicated as:-

$$\begin{bmatrix} \frac{di_l}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} -R_l & 0 \\ 0 & \frac{1}{C*(R*R_c)} \end{bmatrix} * \begin{bmatrix} i_l \\ V_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} * V_{in}$$

$$V_o = [0 \quad \frac{R}{R+R_c}] * [\begin{matrix} i_l \\ V_c \end{matrix}]$$

Switch ON Equivalent Circuit

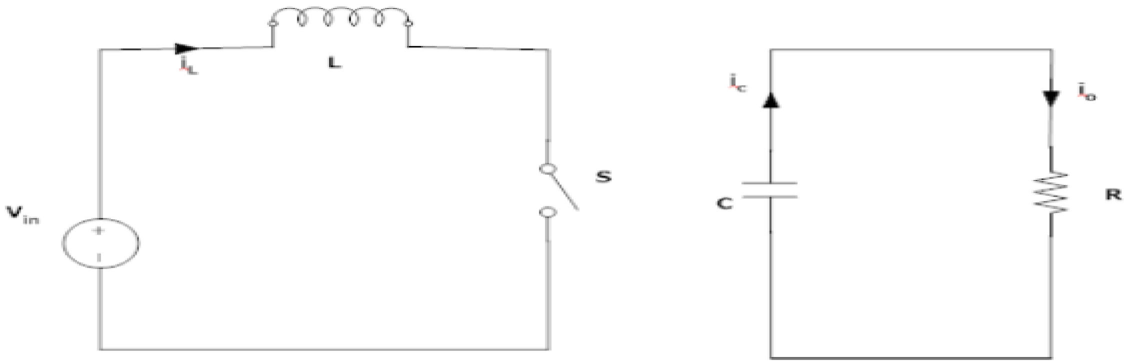


Figure 3. 7 ON mode for the boost converter [45]

The state space conditions amid ON mode as appeared figure 3.5 are communicated as:-

$$\begin{bmatrix} \frac{di_l}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} \frac{(-R_l + (\frac{R}{R_c})}{L} & -\frac{R}{L(R+R_c)} \\ \frac{R}{C(R+R_c)} & -\frac{1}{(R+R_c)} \end{bmatrix} * \begin{bmatrix} i_l \\ V_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} * V_{in}$$

$$V_o = \left[\left(R/R_c\right) \quad \frac{R}{R+R_c}\right] * [\begin{matrix} i_l \\ V_c \end{matrix}]$$

The following form represents a linear system's inputs, outputs, and state variables in state space. As follows:

$X'^{(t)} = A(t)x\dot{(t)} + B(t)u(t),$ (3.10)

$y(t) = C(t)x(t) + D(t)u(t)$ (3.11)

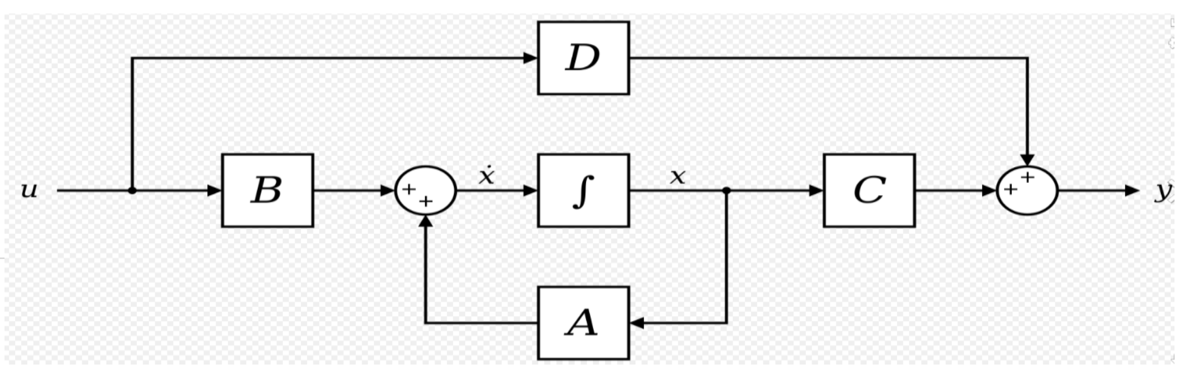


Figure 3. 8 State space model of boost converter

In this stage, the ON and OFF over conditions A, B, C, and D matrices are obtained. Various averaging methods yielded the following matrices:

$A_{avg} = \begin{bmatrix} -2.06972 & -0.8332 \\ 39.996 & -0.666 \end{bmatrix}$

$B_{avg} = \begin{bmatrix} 4.166 \\ 0 \end{bmatrix}$, $C_{avg} = [0.003198 \;\; 0.999]$, $D_{avg} = [0]$

Steps to deduce the exchange work of a persistent time-invariant direct state space:

$$X'(t) = A(t)x(t) + B(t)u(t), sX(s) - X(0) = AX(s) + Bu(s),$$

$$(SI - A)X(s) = X(0) + Bu(s),$$

$$X(s) = (SI - A)^{-1}Bu(s)$$

The yield condition of the exchange work is appeared underneath:

$$Y(s) = CX(s) + Du(s) = C((sI - A)^{-1}Bu(s)) + Du(s),$$

$$Y(s) = G(s)U(s) ,$$

$$G(S) = C(sI - A)^{-1}B + D$$

The yield exchange work gotten by utilizing MATLAB:

$$\frac{V_o}{V_{in}} = \frac{0.0133s+166.5}{s^2+2.753s+34.72} \quad (3.12)$$

The semiconductor device's trading operation causes the boost converter's oscillating behavior.

The structure uses a fuzzy-PID controller to stabilize its temporal response. PWM is the most common trade control mechanism. Easy-to-use FPID controllers are utilized for PWM exchange control.

By little flag modeling procedure, the control exchange work is decided. In organize to stabilize.

$$\frac{V_O}{d} = \frac{-0.7999s^2-996s+49500}{s^2+2.753s+34.72}$$

(3.13)

3.5 TRANSFER FUNCTION DERIVATION OF THE SYSTEM

The following illustration illustrates the transfer function of the PV cluster current to the instantaneous power:

$$\frac{P(s)}{I_{pv}(s)} = \frac{p(s)}{i_{ac}(s)} \frac{i_{ac}(s)}{I_{pv}(s)} = \frac{p(s)}{i_{ac}(s)} \frac{i_{ac}(s)}{I_{dc}(s)} \frac{I_{dc}(s)}{I_{pv}(s)} = \frac{2s^2}{M_1 M_2 (S^2+4\omega^2)} \frac{V_m\left((S^2+\omega^2)S^2+\omega^2\right)}{S^2(S^2+4\omega^2)} \tag{3.14}$$

It is possible to convey the input current of the yield control P to the averaging module of the sun-powered board exchange function using the equation (3.8).

$$\frac{P}{I_{pv}} = \frac{S^2}{(S^2+\omega^2)} \frac{V(S^2+\omega^2)(S^2+2\omega^2)}{KS^2(S^2+4\omega^2)} \frac{1-e^{-sT_s}}{sT_s} \tag{3.15}$$

The disentangled exchange method can be applied to the following types of PV cells:

$$K = \frac{I_{pv}}{\text{solar irradiation}} \tag{3.16}$$

3.5.1 BOOST CONVERTER TRANSFER FUNCTIO

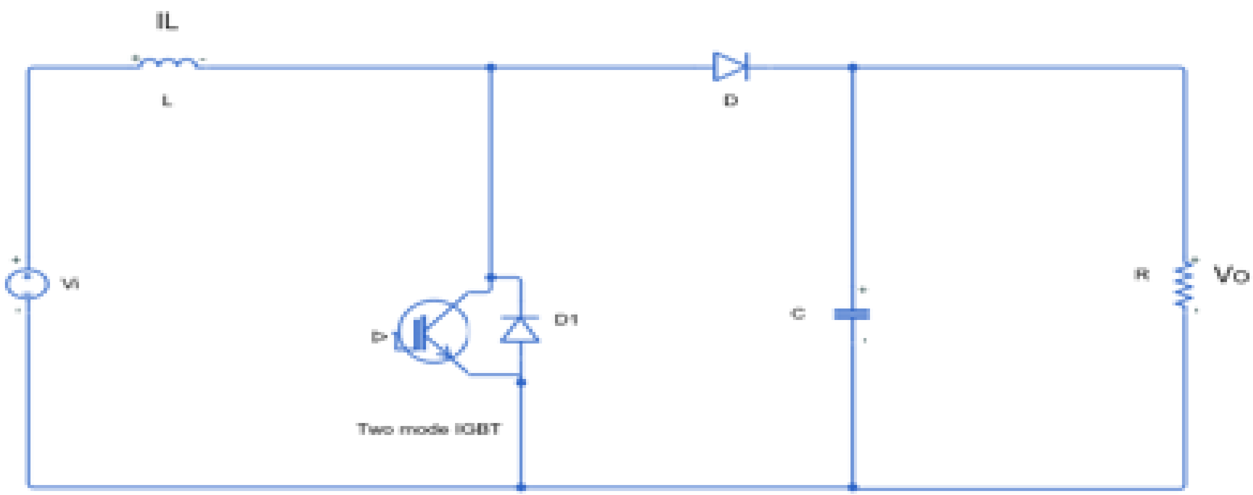


Figure 3. 9 ON mode for the boost converter

When the switch position work is set to s = 1, we obtain, by making use of Kirchhoff's voltage and current laws, the flow that is illustrated by the following set of equations:

$$L\frac{di}{dt} = E \tag{3.17}$$

$$C\frac{dv}{dt} = -\frac{V}{R} \tag{3.18}$$

When the switch position work is set to s = 0, we get the flow depicted by the equations,

$$L\frac{di}{dt} = -V + E \tag{3.19}$$

$C\frac{dv}{dt} = i - \frac{V}{R}$

(3.20)

The flow condition of the Boost converter is communicated as bilinear 1 sort of framework:

$$L\frac{di}{dt} = -(1-s)V + E \quad (3.21)$$

$$C\frac{dv}{dt} = (1-s)\,i - \frac{V}{R} \quad (3.22)$$

In any case, exchange work of a boost converter in genuine time usage can be composed more absolutely as appeared within the underneath condition.

$$G'_1 = \frac{H_1}{1+s\frac{L}{R}+s^2LC} = \frac{\frac{H_1}{LC}}{s^2+\frac{s}{RC}+\frac{1}{LC}} \quad (3.23)$$

By the dc-dc converter of the yield resistance (R) can be composed as communicated in eqn. (3.24).

$$\mathrm{R} = \frac{\mathrm{V}_2^2}{\mathrm{P}} = \frac{\mathrm{P}}{\mathrm{I}_2^2} \quad (3.24)$$

3.6 DC to AC Converter (Inverters) Modeling

The DC-AC converter converts the solar cluster's DC abdicates voltage to AC. It includes a resistor and four control switches. PWM is utilized in inverter modeling to induce a correct trading trigger hail, which controls the abdicate voltage.

The capacitors increase the performance of the DC transport interface by channeling the noise. Inverter is single-phase.

DC to AC conversion transforms the PV DC control into the AC control at the given abdicate voltage and repeats. The investigation's control supply was designed to transition 400V DC to 220-250V AC at 50 Hz. Figure 3.10 shows how an IGBT-based inverter converts DC to AC. IGBT2 and IGBT4 devices can only pass current in one way, however IGBT4 and IGBT3 devices can pass current in reverse.

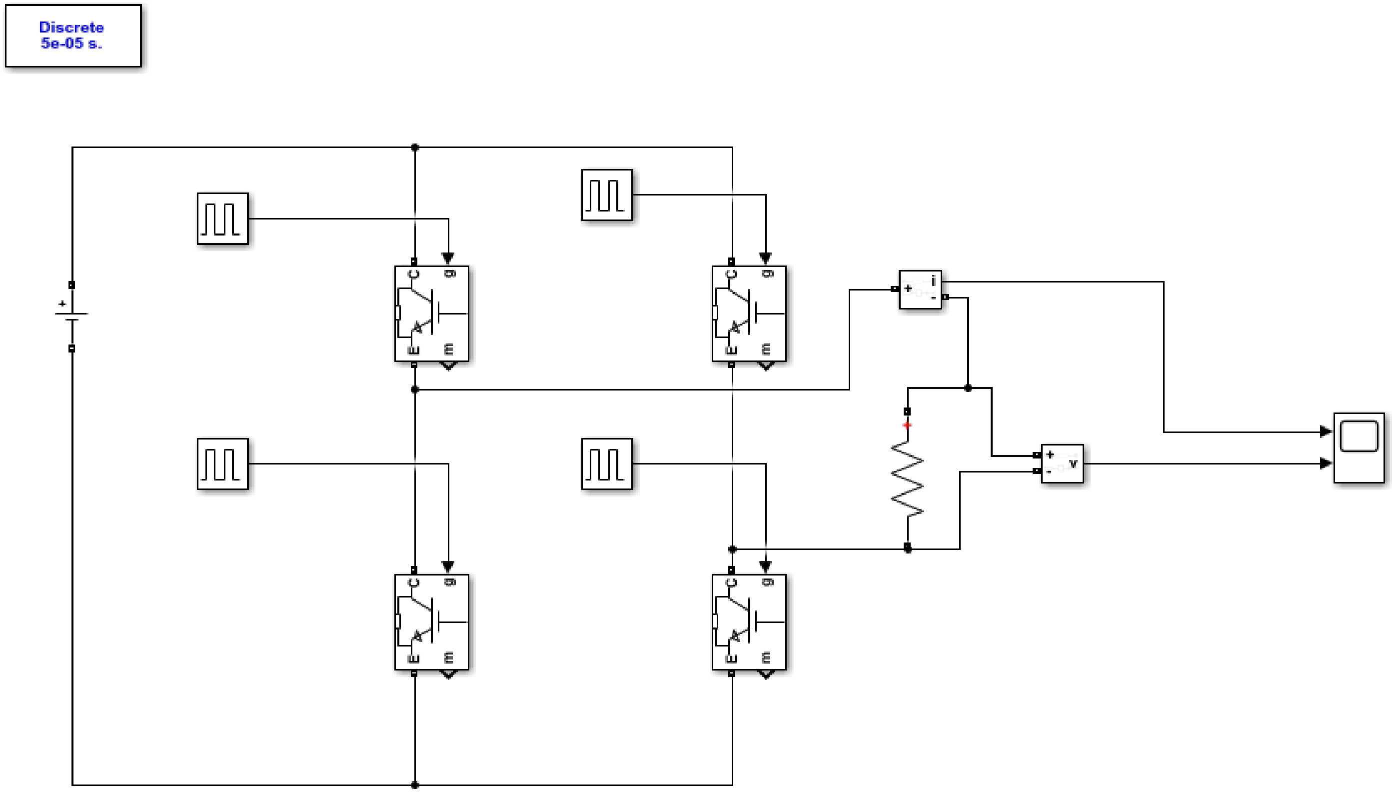


Figure 3. 10 DC-AC converter (inverter) single phase modeling

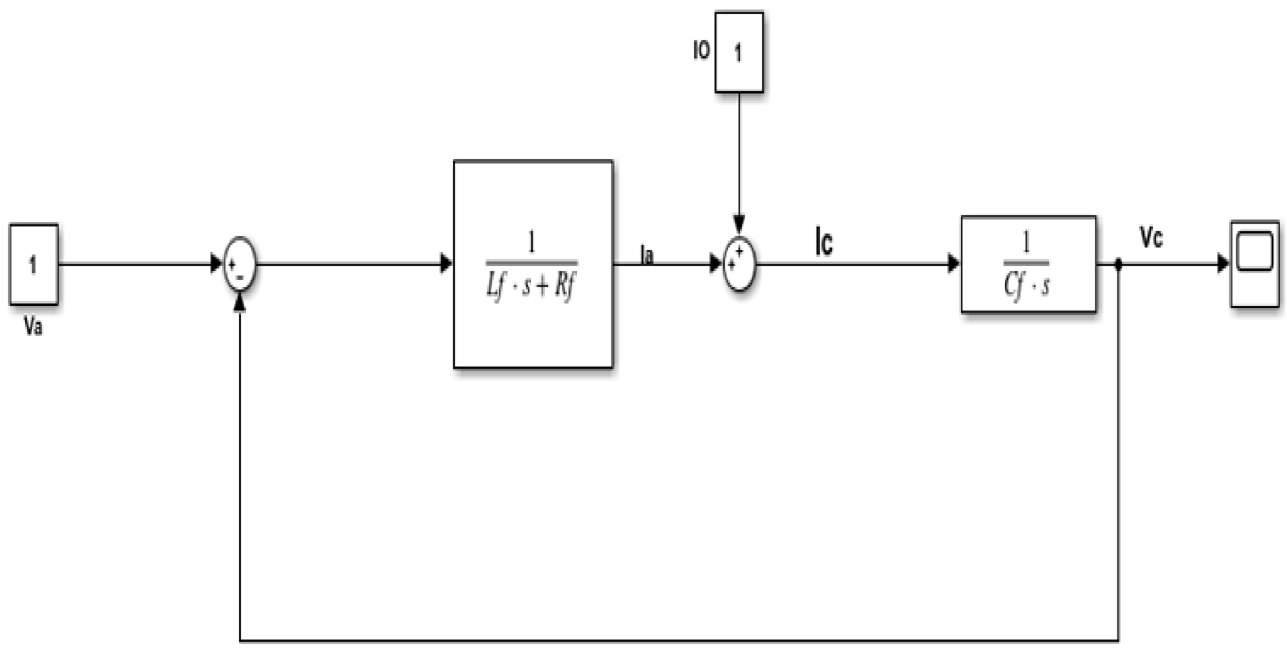


Figure 3. 11 Block diagram of single phase inverter

The single stage inverter the input and yield exchange work of inverter is appeared the framework square chart of the fig 3.10:

$$V_c(s) = \frac{1}{L_f C_f S^2 + jR_f C_f} V_a(s) - \frac{l_f s + R_f}{1 - L_f C_f S^2 + jR_f C_f + 1} I_o(s) \tag{3.25}$$

The recurrence space exchange work can be communicated as:

$$V_c(j\omega) = \frac{1}{L_f C_f \omega^2 + jR_f C_f} V_a(j\omega) - \frac{jl_f \omega + R_f}{1 - L_f C_f \omega^2 + jR_f C_f + 1} I_o(j\omega) \tag{3.26}$$

To decide the exchange work:

$$V_a(s) - sL_f I_a(s) - R_f I_a(s) - V_c(s) = 0 \tag{3.27}$$

$$V_a(s) - V_c(s) = I_a(s)(sL_f + R_f) \tag{3.28}$$

$$\frac{V_a(s)}{V_c(s)} = 1 + \frac{(I_a(s)(sL_f + R_f)}{V_c(s)} \tag{3.29}$$

$$\frac{V_a(s)}{V_c(s)} = 1 + \frac{(I_a(s)(sL_f + R_f)sC_f)}{I_c(s)} \tag{3.30}$$

$$\frac{V_a(s)}{V_c(s)} = \frac{S^2 L_f C_f + SL_f + R_f C_f s Z_L + R_f + Z_L}{Z_L} \tag{3.31}$$

$$\frac{V_c(s)}{V_a(s)} = \frac{Z_L}{S^2 L_f C_f + SL_f + R_f C_f s Z_L + R_f + Z_L} \tag{3.32}$$

When all three exchange capacities of the PV framework, boost converter, and inverter are combined, the system's overall exchange work is as follows:

$$\frac{P}{V_a(s)} = \frac{s^2}{(s^2+\omega^2)} \frac{V(s^2+\omega^2)(s^2+2\omega^2)}{ks^2(s^2+4\omega^2)} \frac{(1-e^{-sT_s})}{sT_s} * \frac{H_1}{1+\frac{sL}{R}+S^2 LC}$$

$$= \frac{\frac{H_1}{LC}}{S^2+\frac{S}{RC}+\frac{1}{LC}} * \frac{Z_L}{s^2+L_f C_f+sL_f+R_f C_f s Z_L+R_f+z_L} \tag{3.33}$$

Below are the DC-DC converter's specifications.

Table 3. 4 DC-DC parameter [44]

Converter parameter	Values
Resonant inductor	10e-10
Resonant capacitor	40e-3
Resistor	100
Switching frequency	120khz

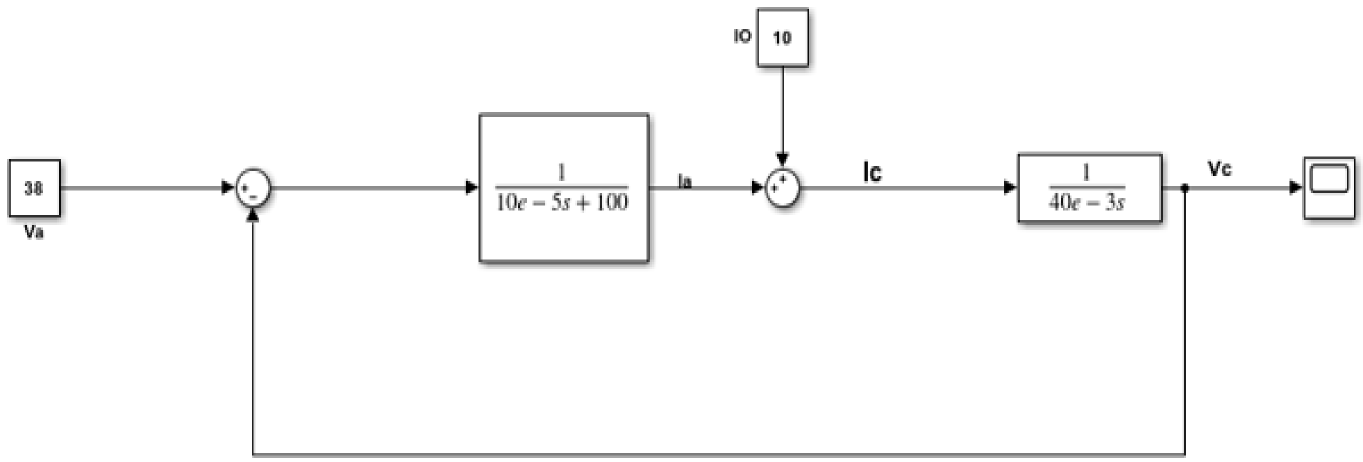


Figure 3. 12 Block diagram of single phase inverter

3.7 The Grid and the PV Array Connection of General Mathematical Modeling

The primary square in interfacing the PV framework to the network after getting the yield from the PV array is the DC-DC boost converter. Within the perfect case, this converter is fair a pick up. To obtain this pick up, it is critical to know the whole pick up required between the DC voltage and the sufficiency of the ultimate AC voltage (m) as appeared in Equation 4.34.

$$m = \frac{V_{DC}}{VAC} \tag{4.34}$$

The esteem of m is in a idealize world less than 0.866, and it has been chosen in this appear to be 0.7.

The PV framework works at a steady DC voltage Vdc=5kV, whereas the yield current and control of the PV clusters alter agreeing to the irradiance of the sun and the temperature. Since this DC regard is unfaltering, by choosing m for this specific system, the ampleness of the AC voltage will additionally remain steady, taking off the AC current and control to vary a long side the changes.

This m can presently be utilized within the calculations to discover the esteem of the voltage required after the boost converter (V2) as appeared in equation 4.35. The PV framework is connected at the moo voltage side of the network and the RMS esteem of the framework line voltage of the customary framework that's considered here is 15kV. This means that the grid phase voltage is Vm = V (AC, rms=15/√3) Kv. This is often the esteem that will be utilized since in this photovoltaic framework as it were a single stage is considered.

$$V_2 = \frac{V_m}{m} = \frac{\frac{15}{\sqrt{3}}}{0.7} = 12.37KV \tag{3.35}$$

The boost converter gain can be expressed as

$$M_1 = \frac{V_2}{V_1} = \frac{12.37KV}{5KV} = 2.474 \qquad (3.36)$$

Since $M_1 = \frac{V_2}{V_1} = \frac{I_1}{I_2}$, in this manner, expecting a perfect DC-DC boost converter (with the exchanging recurrence much higher than the framework flow), and the gain for the boost converter is $\frac{1}{M_1} = \frac{1}{2.474} = 0.404$ representing the first transfer gain as follows:

$$G_1 = \frac{1}{0.404} \qquad (3.37)$$

The another organize is the DC-AC inverter which changes over this DC current to an AC current that will be sensible for the affiliation with the conventional AC based control system. The trade work can be gotten by separating the Laplace alter of each term. The AC current (i_{AC}) is expressed in the form of$I_m \cos(\omega t)$, and it has Laplace transform function of $\frac{S}{S^2+\omega^2}$, where$\omega = 2\pi f = 2 * 3.14 * 50 = \frac{314.159rad}{s}$. Within the same case, I2 (the current after boost converter) is the DC esteem steady so it has the Laplace change work is $\frac{1}{S}$. Hence, the exchange works of the moment square (current inverter) is given as takes after:

$$G_2 = \frac{i_{Ac}(s)}{I_2} = \frac{\frac{S}{S^2+\omega^2}}{\frac{1}{S}} = \frac{S^2}{S^2+\omega^2} = \frac{S^2}{S^2+98700} \qquad (3.38)$$

The third organize is to change over this current to immediate control since the yield of the routine control framework is control, hence, the input from the PV framework to the framework ought to moreover be in terms of control. The exchange work of this piece can be gotten comparative to the strategy of getting $G2$. To begin with, the immediate control p (t) is given by:

$$p(t) = \frac{V_m}{I_m} i_{AC}^2 = \frac{V_m}{I_m} (I_m \cos(\omega t))^2 = \frac{V_m I_m}{2} + \frac{V_m I_m (\cos(2\omega t))}{2} \qquad (3.39)$$

The pickup Vm/Im is impedance which is genuine without a nonexistent portion since the stack is simply resistive. From the condition (4.39) Laplace change work can be composed as takes after:

$$P(s) = \frac{V_m I_m}{2s} + \frac{V_m I_m}{2} \frac{s}{s^2+(2\omega)^2} \qquad (3.40)$$

Where iAC is the same expression gotten already. In this manner, the exchange work for the change from AC current to momentary control is:

$$G_3(s) = \frac{P(s)}{i_{AC}(s)} = \left(\frac{V_m I_m}{2s} + \frac{V_m I_m}{2}\frac{S}{S^2 + (2\omega)^2}\right)/(I_m \cos(\omega t)$$

$$= \frac{V_m(S^2 + \omega^2)(S^2 + (2\omega)^2)}{S^2(S^2 + (4\omega)^2)}$$

$$= \frac{\frac{15Kv}{\sqrt{3}}(S^2 + (314.159)^2)(S^2 + (2 * 314.159)^2)}{S^2(S^2 + (4 * 314.159)^2)}$$

$$= \frac{8660.25(S^2 + 98{,}695.87)(s^2 + 197{,}391.75)}{S^2(S^2 + 159{,}134.03)}$$

$$= \frac{8660.25(s^4 + 296{,}087.62s^2 + 1948.1750497 * 10^7)}{s^2(s^2 + 159134.03)} = \frac{8660s^4 + 2.562 * 10^9 s^2 + 1.687 * 10^{14}}{s^2(s^2 + 1.591 * 10^5)}$$

(3.41)

The required abdicate control of the PV system that will be an input to the standard control system is the typical control not the prompt in organize to form them reliable with each other, Thus, the ultimate organize here is to alter over the quick control to ordinary control. The condition for the ordinary control inside the time space is given by:

$$P_{avg} = \frac{1}{T}\int_0^T V_{AC} * i_{AC} dt = \frac{1}{T}\int_0^T V_m \cos(\omega t) \,.\, I_m \cos(\omega t)\, dt$$

$$= \frac{1}{T}\int_0^T \frac{V_m I_m}{2} + \frac{V_m I_m(\cos(2\omega t))}{2} dt = \frac{V_m I_m}{2} \qquad (3.42)$$

The stack is simply resistive, and the normal control would be a steady. The Laplace change work of the normal control ($Pavg$) is given by:

$$P_{avg}(s) = \frac{V_m I_m}{2S} \qquad (3.43)$$

To get the exchange work of the transformation from momentary control to normal control after disentanglement is given following as;

$$G_4(s) = \frac{P_{avg}(s)}{p(s)} = \frac{V_m I_m}{2S} / \left(\frac{V_m I_m}{2s} + \frac{V_m I_m}{2}\frac{s}{s^2 + (2\omega)^2}\right)$$

$$= (S^2 + (4\omega)^2)/2(S^2 + (2\omega)^2$$

$$= \frac{s^2+(4*314.159)^2}{2(s^2+(2*314.159)^2}$$

$$= \frac{(s^2+\left(3.948*10^5\right)}{2s^2+(3.948*10^5)}$$

(3.44)

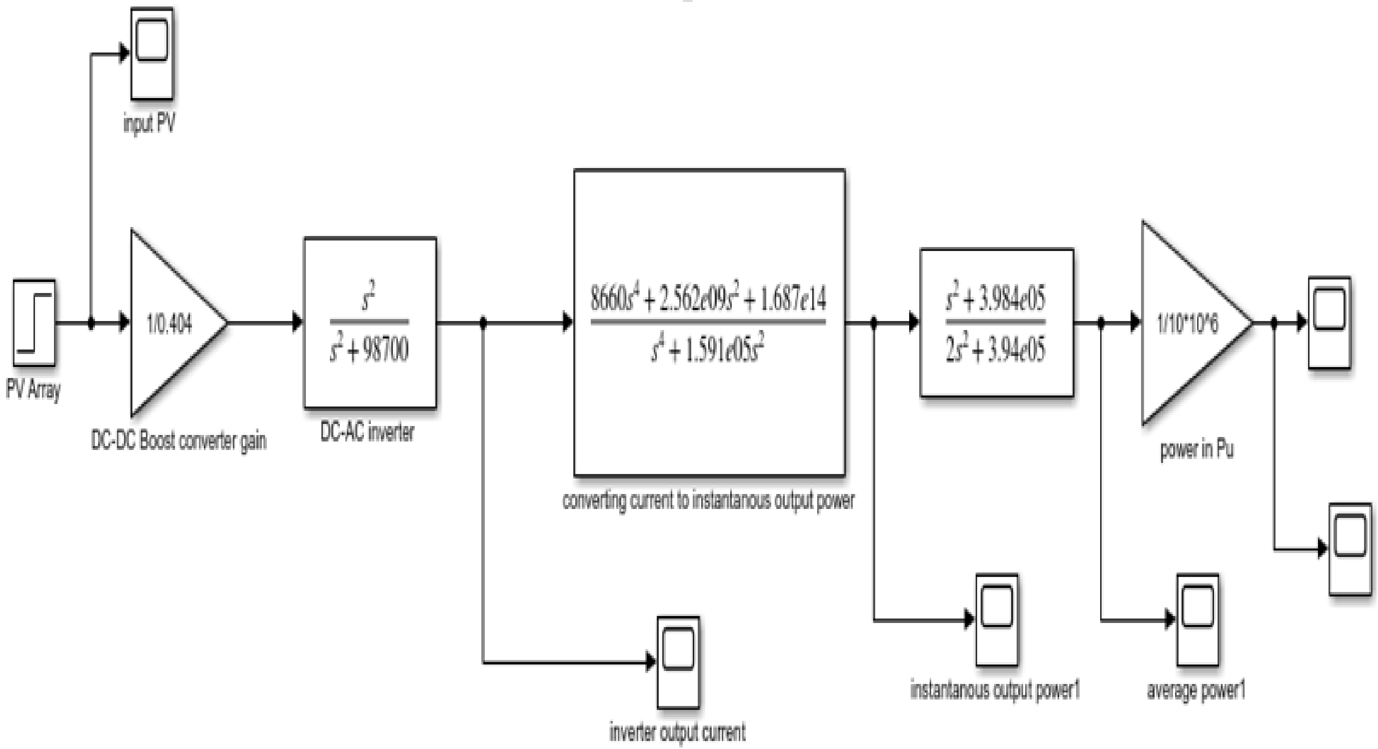


Figure 3. 13 PV system design of open loop system

CHAPTER 4

CONTROLLER DESIGN

4.1 Design of fuzzy logic controller for hybrid power management

The concept of fluffy rationale is based on a concept comparable to that of the two fold rationale (0, 1). In any case, within the two fold rationale, any esteem can either be in a set (subsequently, having an esteem of 1) or not in a set (having a value of 0). Things within the parallel rationale are either dark or white. But in fluffy rationale, each esteem can be considered as a part of a set by a certain rate (either a small or a tall rate). Figure 4.2 appears the common steps of planning a fluffy rationale controller (FLC) for a framework. After characterizing the input(s) of the FLC, the registration capabilities and the matching ranges to each should be decided by the organization called Fuzzification. The number of these participation capacities and what each one speaks to are decided. The input to the Fluffy controller are light concentrated blunder “(t)” and change-error "Δe (t)”. The input of the fluffy rationale controller is communicated within the taking after way.

$$e(t) = P_{pv}(t) - Pl(t); \tag{4.1}$$

$$\Delta e(t) = e(t) - e(t-1) \tag{4.2}$$

Steps in fuzzy system design:-Inputs and yields should be labeled. Adjust fuzzy participants for each input and output; create the show's basis so it can run. Changing the guidelines specifies how to do the assignment.

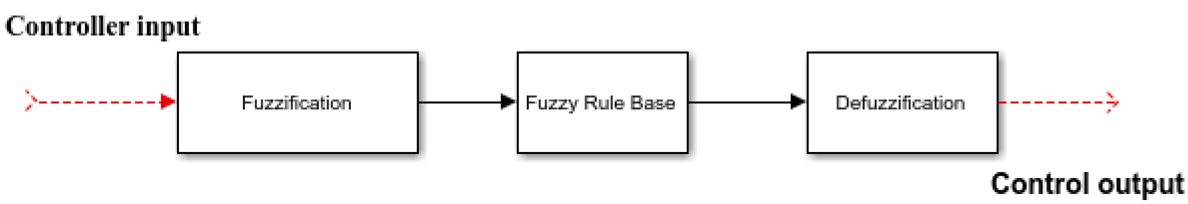


Figure 4. 1 General fuzzy logic controller design stages [36]

The Madmani sort of fuzzy is proposed in this consider, at the side the Min-Max **Fuzzification** strategy and the centroid **Defuzzification** strategy [36]. It contains a single input called alter in control P, which is the distinction in control between PV and load control (PL). NB = Big Negative, NM = Medium Negative, NS = Small Negative, ZO = Zero, PS = Small Positive, PM = Medium Positive, and PB = Big Positive. In Fig.4.2, the input parameters are e (t) and de (t)/dt, the system have 49 rules. The output parameters are Ki, Kp and Kd adopt the fuzzy logic controller. The Kp, Ki; and Kd detect e (t) and de (t)/dt continuously and reason concurring to the fluffy rationale rules and controls in arrange to fulfill the want of the two input to the parameters of the controller at any time [46]. These criteria create the most possible combination of sources under varied loads. The output membership function has three grades, thus are ΔK_p , ΔK_i *and* ΔK_d. This is one of the best techniques to adjust the system's output voltage. In this suggested work, a fuzzy-PID controller regulates the Nano scale network structure and battery charging and release. Figure 4.10 shows the fuzzy-PID controller, which combines the fuzzy and PID controllers. Using a fuzzy-PID controller combines all of these benefits.

$e(t)$ = {NB, NM, NS, ZO, PS, PM, PB}

The truth esteem of input etymological factors e (t) and de/dt are communicated as:

$$\frac{de}{dt} = \{-150\ 150\}$$

Bumble E and CE in Voltage selection are standard FIS inputs. The FIS surrender is a feathery control action. The following diagram shows our comfy controller's FIS technique.

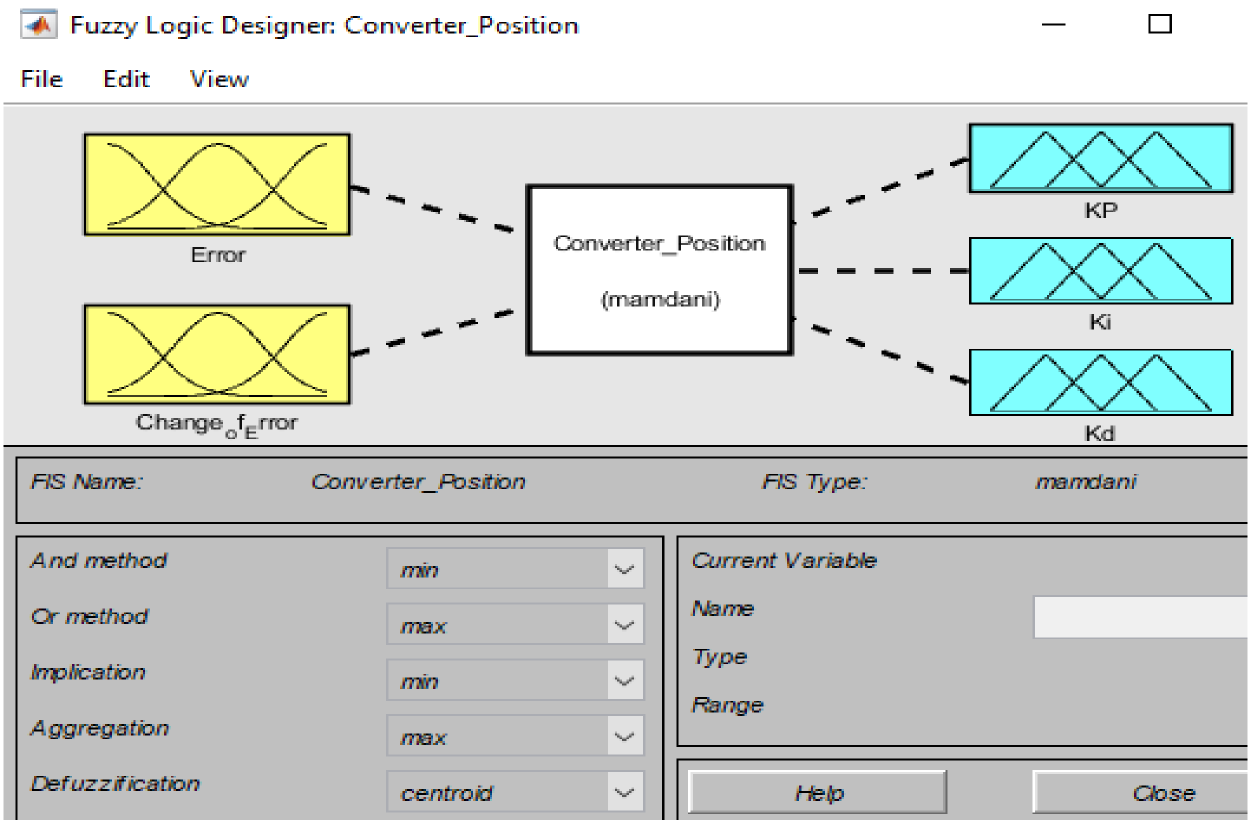


Figure 4. 2 Fuzzy-PID controller interfacing

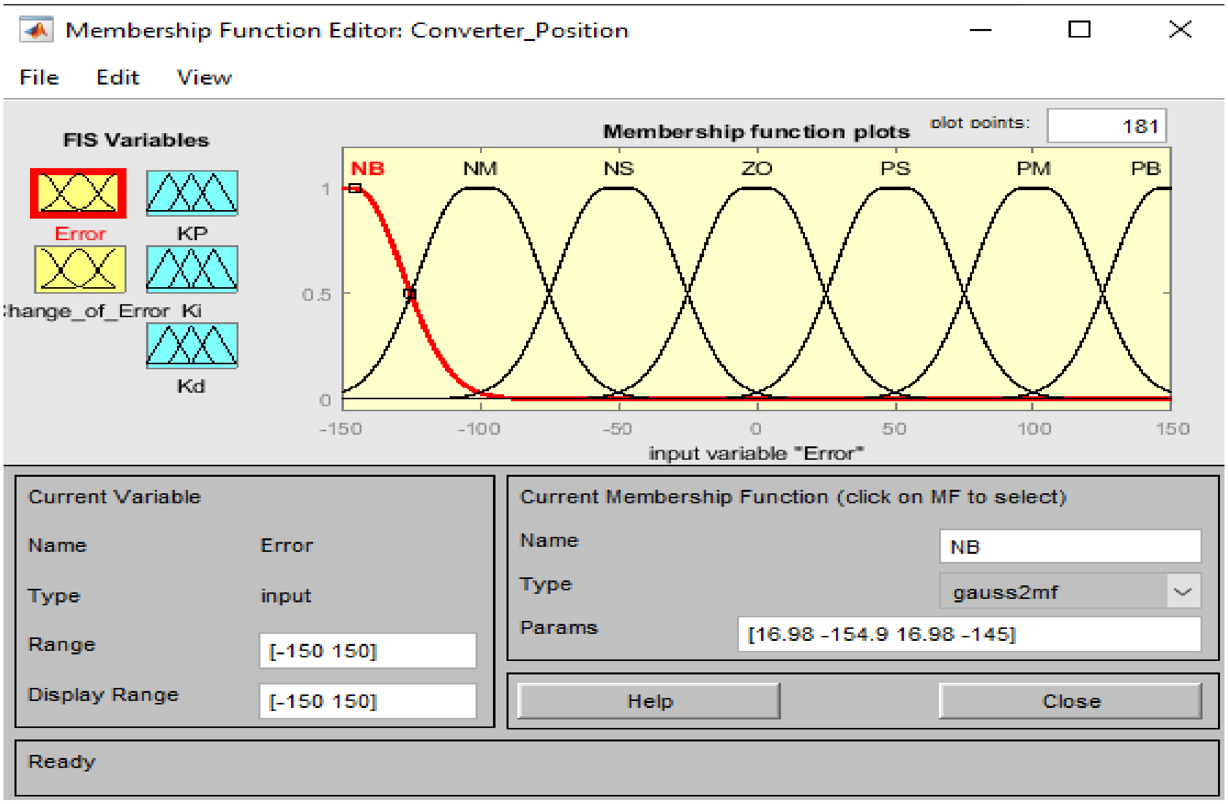


Figure 4. 3 Memberships of the input variable error

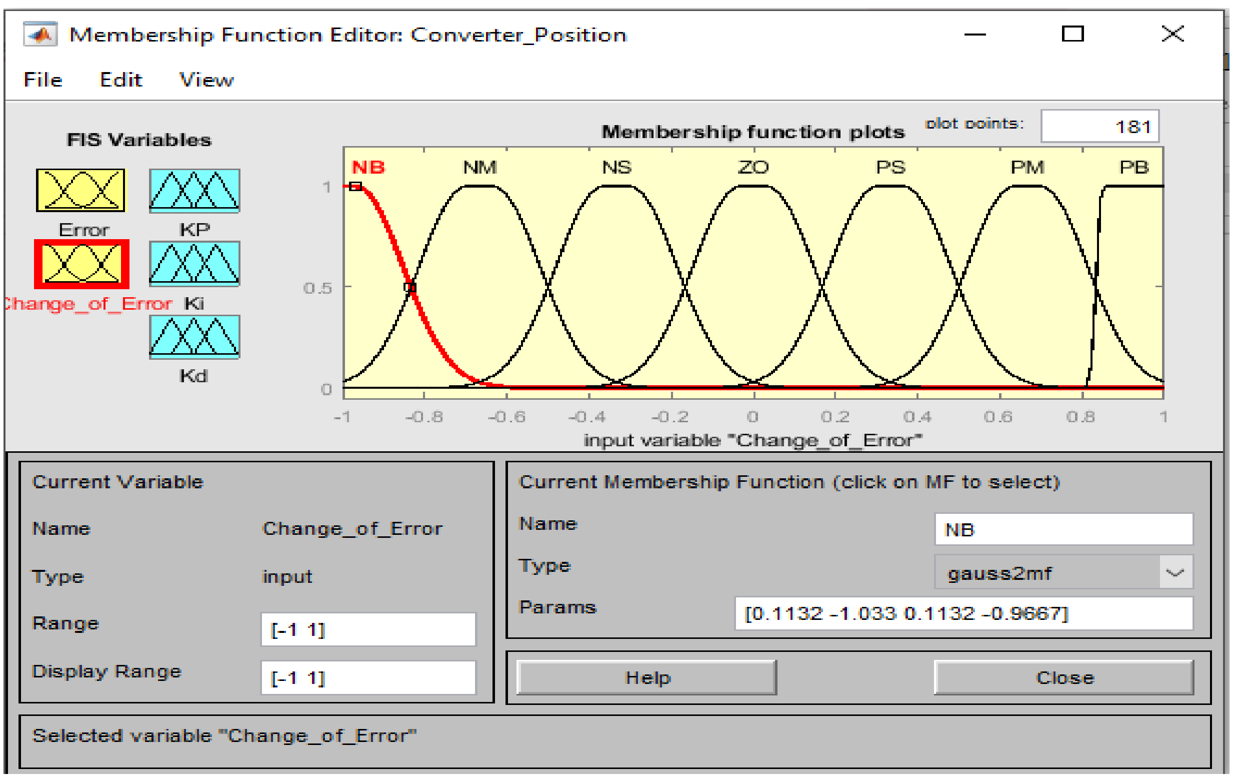


Figure 4. 4 Membership functions of the input variable change of error

Table 4. 1The fuzzy rules for $\boldsymbol{K_p, K_i}$ ***and*** $\boldsymbol{K_d}$ ***respectively***

$e(t)\downarrow$ \ $\frac{de(t)}{dt}\rightarrow$	K_p						
	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	NM	PS	ZO	NS	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

$e(t)\downarrow$ \ $\frac{de(t)}{dt}\rightarrow$	K_i						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NM	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	NM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

$e(t)\downarrow$ \ $\frac{de(t)}{dt}\rightarrow$	K_d						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ME	PS	PS
ZO	NM	NM	NS	ZO	PB	PM	PM
PS	NM	NS	ZO	PS	PB	PM	PB
PM	ZO	ZO	PS	PS	PS	PB	PB
PB	ZO	ZO	NB	PM	PS	PB	PB

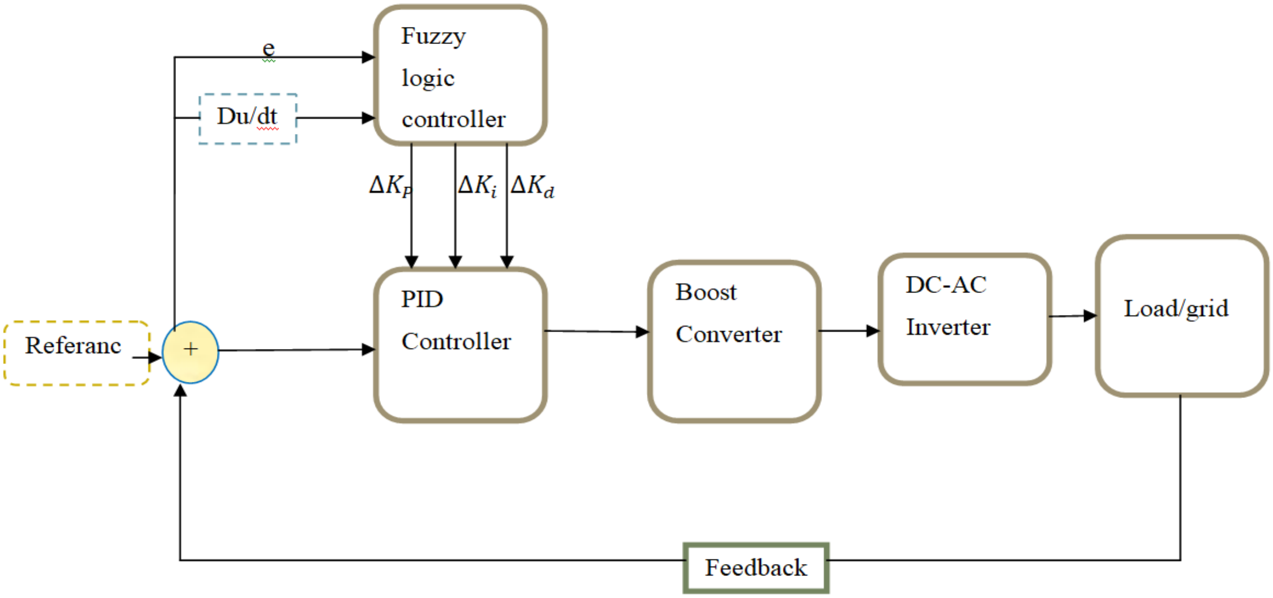


Figure 4. 5 Self-tuning Fuzzy-PID controller model block diagram

The PID controller's settings undergo a process of soft self-tuning, which locates the soft link between "e" and "de". Because the Kp, Ki, and Kd parameters of the PID controller are no longer distinct from one another, the soft approach is no longer utilized.

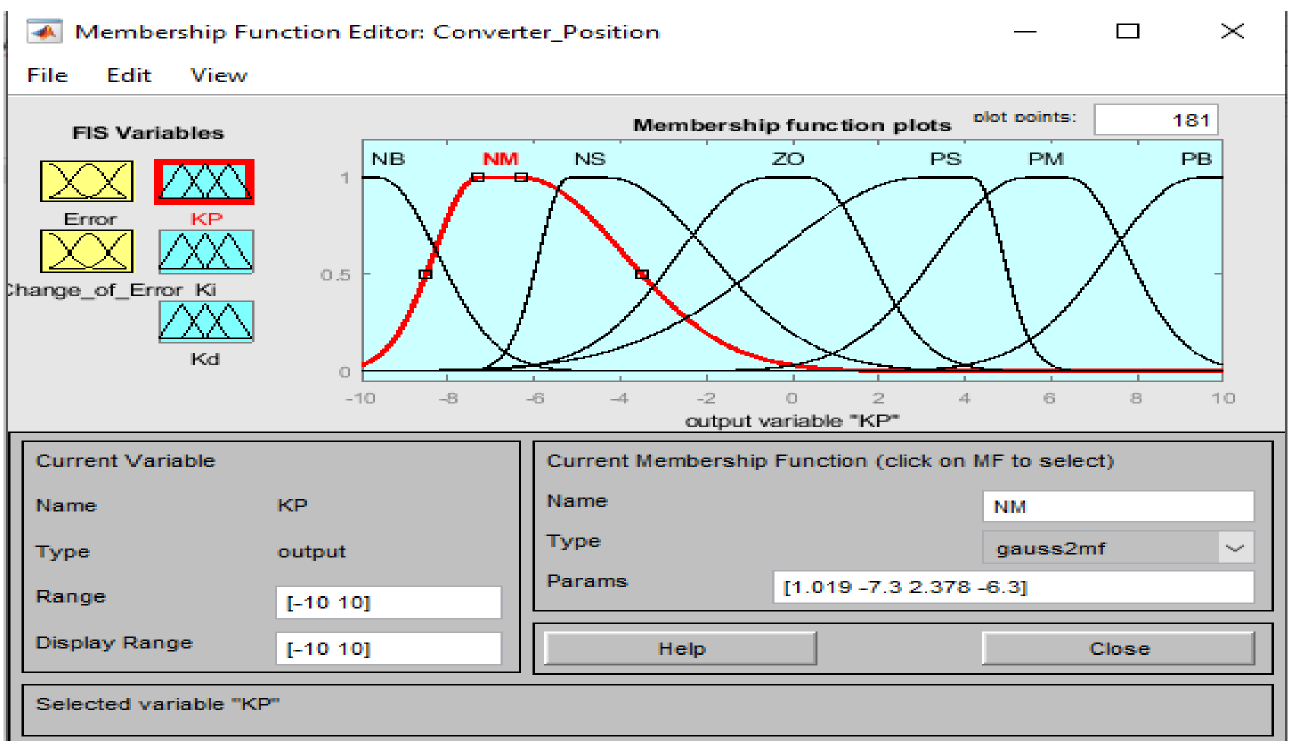


Figure 4. 6 Kp output variable membership functions.

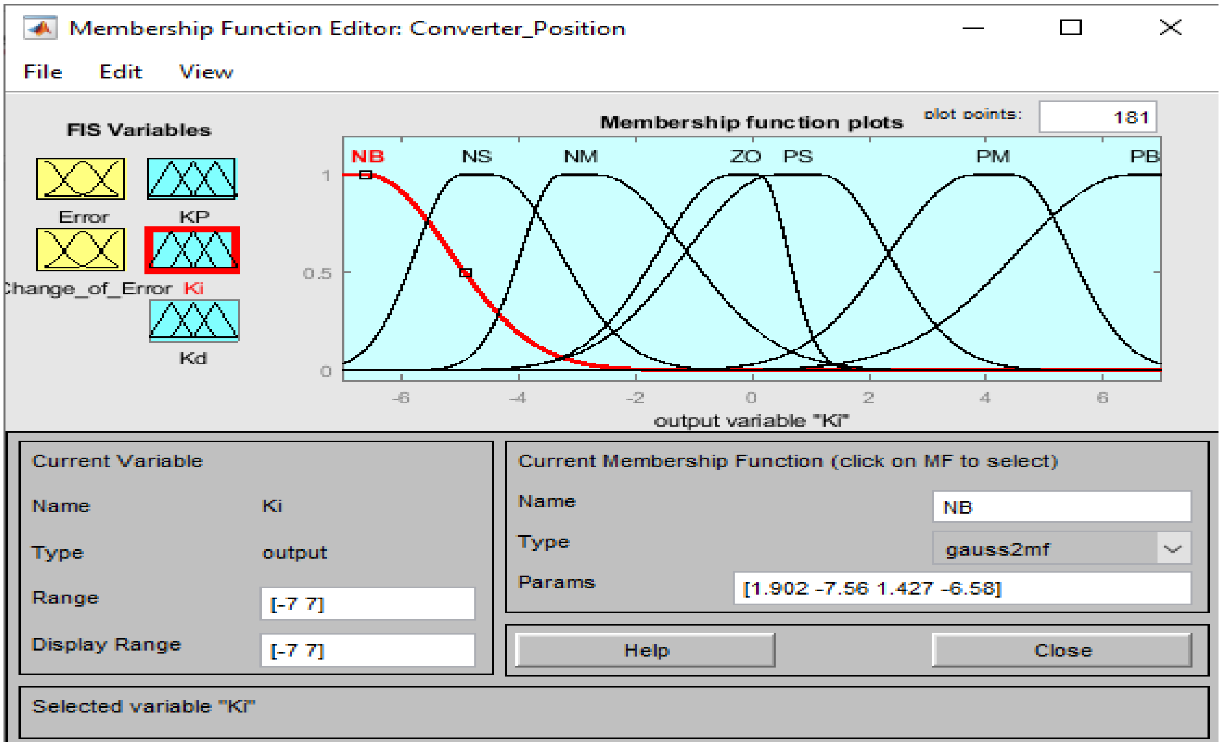


Figure 4. 7 $\boldsymbol{K_i}$ output variable membership functions.

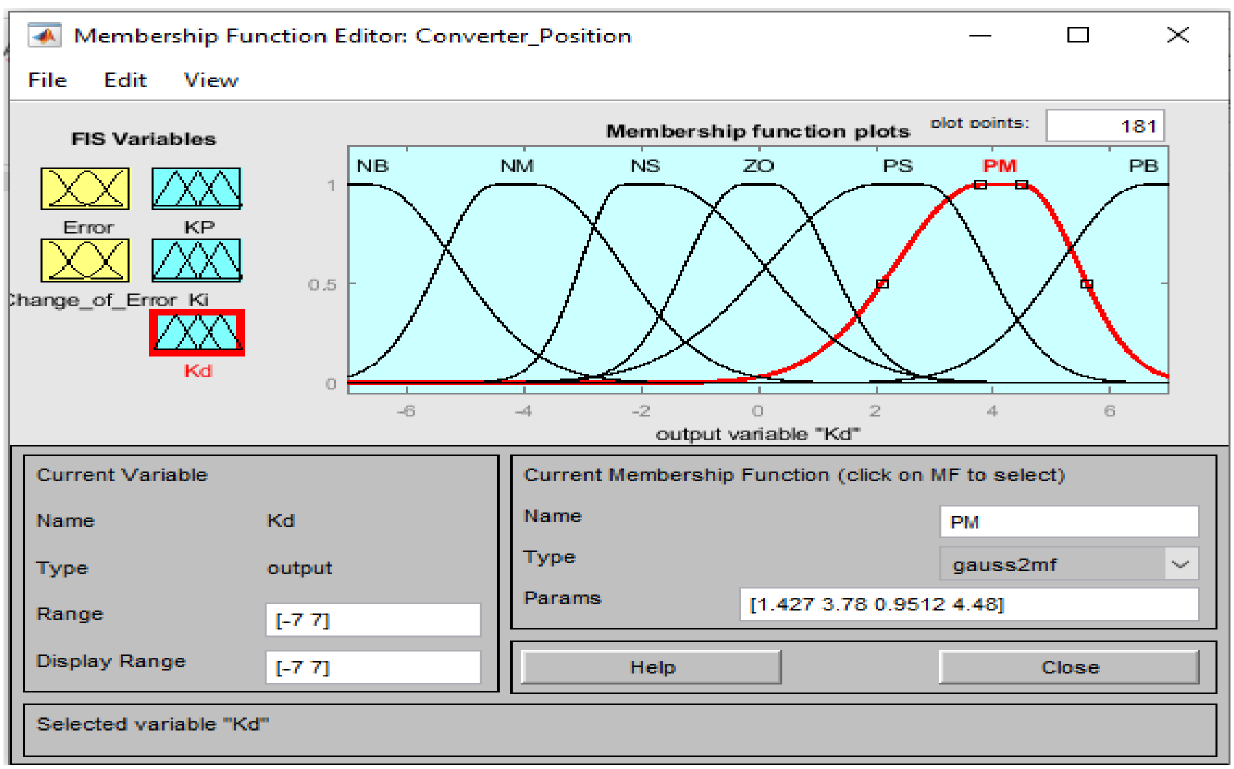


Figure 4.8 Kd output variable membership functions.

4.2 Tuning the PID parameters using Ziegler-Nichols method

The working run of the boost converter is primarily characterized by the input voltage and the yield current. The parameters of the PID controller are tuned at diverse working focuses. The tuning prepare points minimize rise time, settling time, swell and swell and unfaltering state mistake of the yield voltage.

4.2.1 Mechanism for Loop Tuning

A. Manual tuning

Reset Ki and Kd to zero to calibrate. After increasing KP until the circle's abdication fails, it must be halved to trigger the "quarter adequacy collapse" Until then, work on strengthening your Ki. Extra Ki causes instability.

Raise Kd if needed so the circle can return to its reference position following a stack-disturbing effect. This step is needed if Kd was reduced.

Excess Kd causes order reaction and overshoot. Some systems can't detect overshoot, requiring an overdamped closed-circle framework. Fast PID circle tuning overruns to reach the set point faster. This framework may require Kp settings, which may require settings, etc. Manual circle tuning adjusts PID parameters. Kp = 0.036283, Ki=0.24085, and Kd=-1.01 Figure4.8 shows the MATLAB/SIMULINK model and the PID controller transfer function equation (4.2).

$$G(s) = 0.036283 + \frac{1}{0.24085s} - 1.01s \qquad (4.3)$$

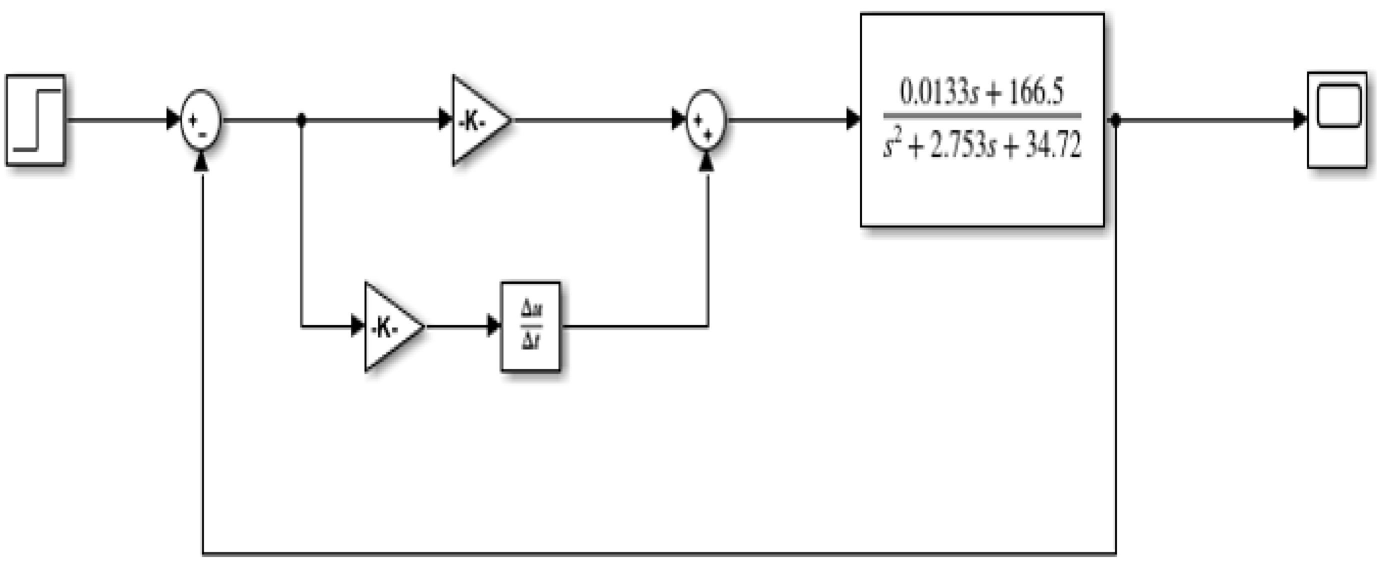


Figure 4. 8 SIMULINK PID controller modeling of boost converter

PID settings affect framework flows. Closed-loop step response has four main components.

1 .The amount of time it takes for a plant to climb above the required level for the critical period of time is referred to as the rise time.

2. Overshoot; when normalized against the unchanging state, the greatest level is greater than the reliable state.

3. The amount of time necessary for the system to reach a steady condition is referred to as the "Settling Time."

4. Consistent- state Blunder: the difference between the necessary yield and the steady-state yield

Table 4. 2 The impact of individual P, I, and D tuning on closed-loop system response

Closed loop response	Rise time	Overshoot	Settling time	Steady state error	stability
Increasing K_p	decrease	Increase	Small increase	Decrease	Degrade
Increasing K_i	Small decrease	Increase	Increase	Large decrease	Degrade
Increasing k_d	Small decrease	Decrease	Decrease	Minor change	Improve

B. Convectional PID tunings methods

Most PID controllers are tuned online due to diverse machines and handles. Tuning criteria can be used to avoid speculative PID computations. There are several ways to tune convectional PIDs, including selecting system models using framework-recognized validation procedures or choosing drive or input surrender.

C. **Z-N Closed Loop Tuning Method**

Ziegler and Nichols invented closed Circle tuning at the same time as open Circle. It's built with approach components and called the rehash reaction strategy. Their solution was based on the location of the procedure exchange task G(s) Nyquist's bend, which focalizes the negative real center. Based on this information, they constructed two factors, Ku and Tu, which allow for an exceptional selection using the Routh-Hurwitz criterion approach and an exceptional period. Here's how to choose these parameters: Disengage the essential control by setting Ti to 0 and deactivate

Td. Increase pickup Kp till the method wavers. Manual tuning can define the period of the motions, Tu = x, and the extreme pick up, Ku=y. Ziegler and Nichols constructed an extra set of fundamental equations that relate Ku and Tu to K, Ti and Td for P, Pi, and table4.3's PID controller.

After verifying the maximum pick up and period, the Ziegler–Nichols tuning rules (Table4.3) are used to get the PID tuning constants. This planning technique increases kp until it reaches Kcr, the point at which the yield shows supported motions. First, set Ti = 0 and Td = 0; then, play to find Kcr and Pcr. Table 4.3 shows the Ziegler-Nichols equation used to determine PID values.

Table 4. 3 PID tuning guidelines for Ziegler-Nichols [50]

Types of controller	K_p	K_i	K_d
P	$0.5K_u$		
PI	$0.45K_u$	$\frac{T_u}{1.2}$	
PID	$0.6K_u$	$\frac{T_u}{2}$	$0.125T_u$

To decide the values of Kp, Ki, can be substituting the esteem of Ku, Tu utilizing the over table 4.3. The Exchange work of PID controller tuned utilizing recurrence method.

$$G(s) = K_p(1 + \frac{1}{T_i s} + T_d s) \tag{4.4}$$

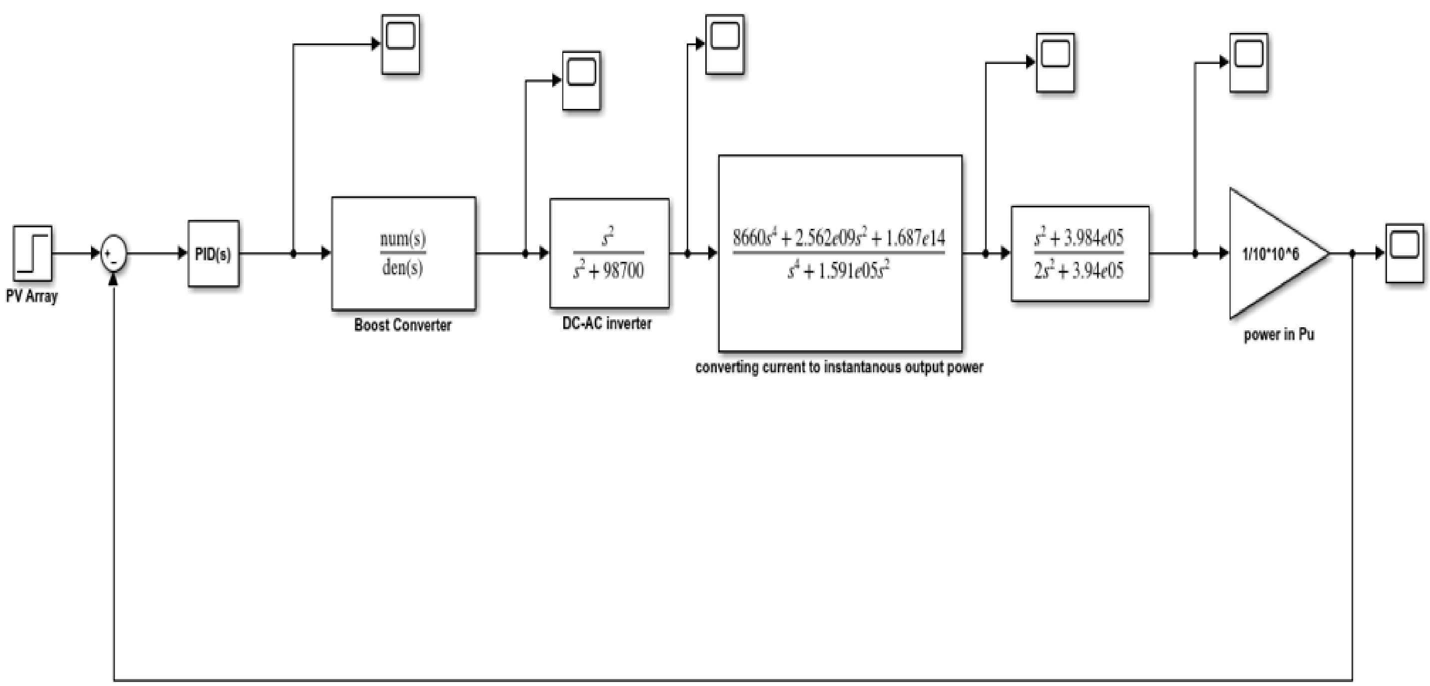


Figure 4. 9. PID Controller tuning method with the system

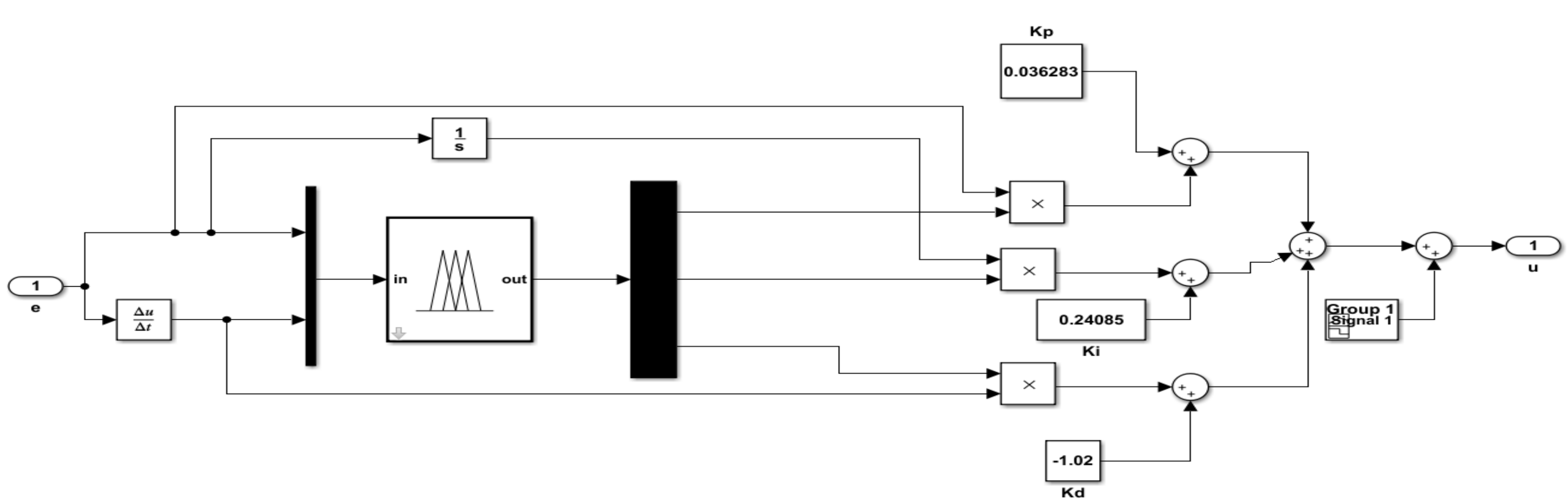


Figure 4. 10 Fuzzy-PID controller SIMULINK model

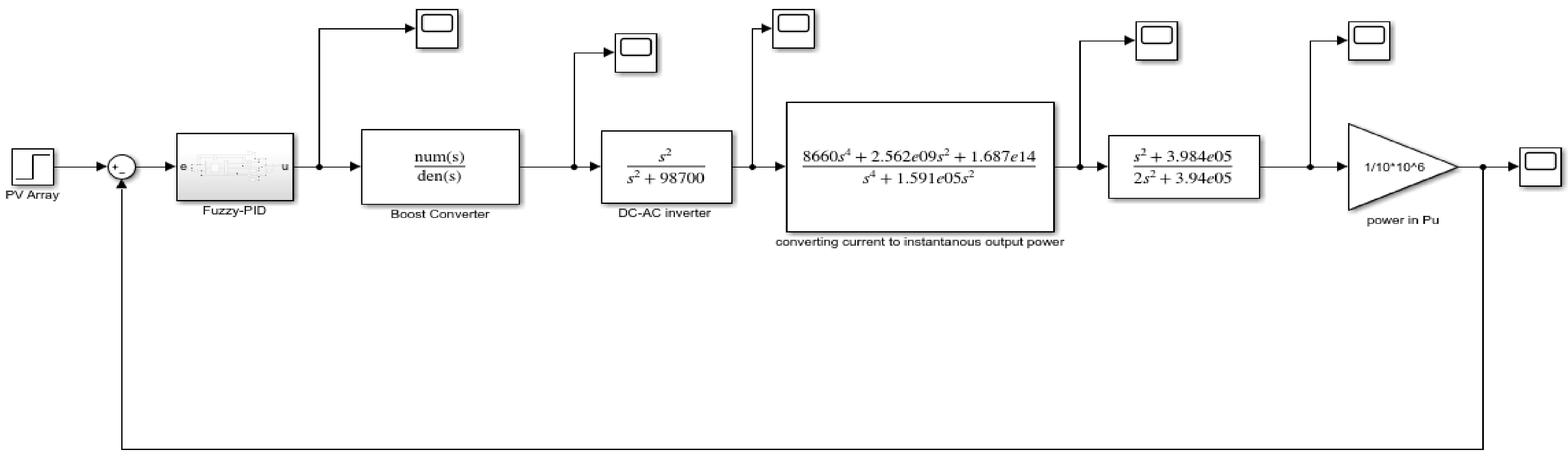


Figure 4. 11 Fuzzy-PID controller for hybrid system

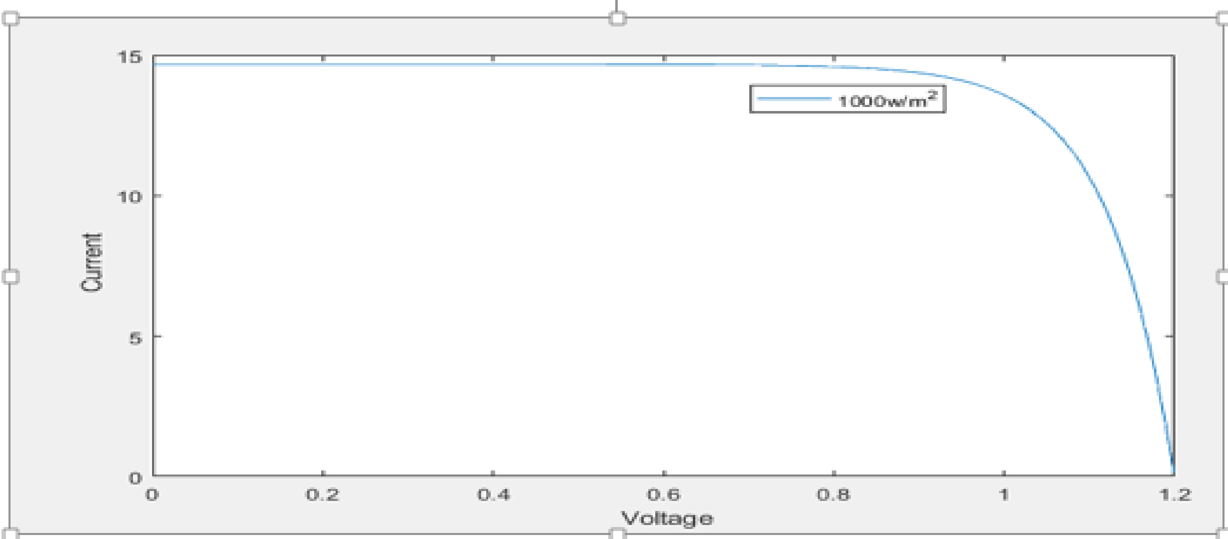
CHAPTER FIVE

RESULTS AND DISCUSION

This chapter describes the analysis performed on MATLAB/SIMULINK models of proposed DC-DC PV converters to assess if the following controllers are useful for future photovoltaics' (PV) systems.

5.1 V-I and P-V Characteristics of solar PV system using MATLAB SIMULINK

V-I Characteristics of Sun powered PV framework result is appeared with in the taking after plot chart and mat lab workspace is appeared in appendix A.



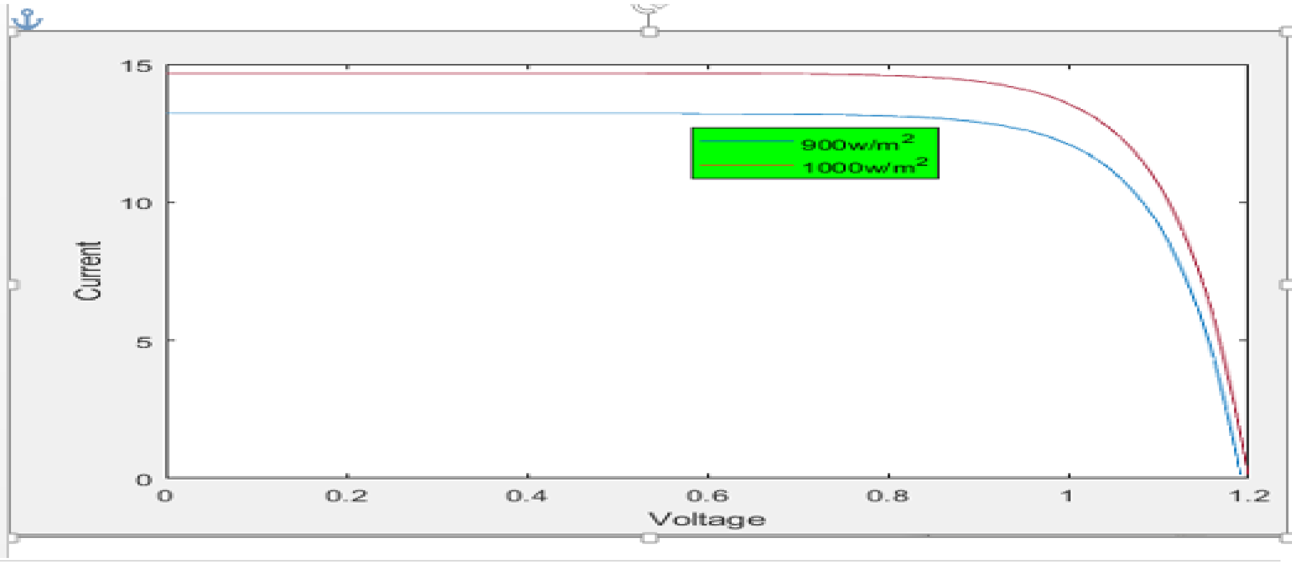


Figure 5. 1 V-I characteristic of solar PV system at different radiation

From the over figure 5.1 V-I characteristics of sun based PV framework, the most extreme current is 14.58A, voltage 1.1994V @1000w/m^2 and 13.21A @ 900w/m^2. The plot is shown that the radiation of sun light is expanding the current and the voltage is expanding and inversion is true.

5.2 P-V Characteristics of solar PV system using MATLAB SIMULINK

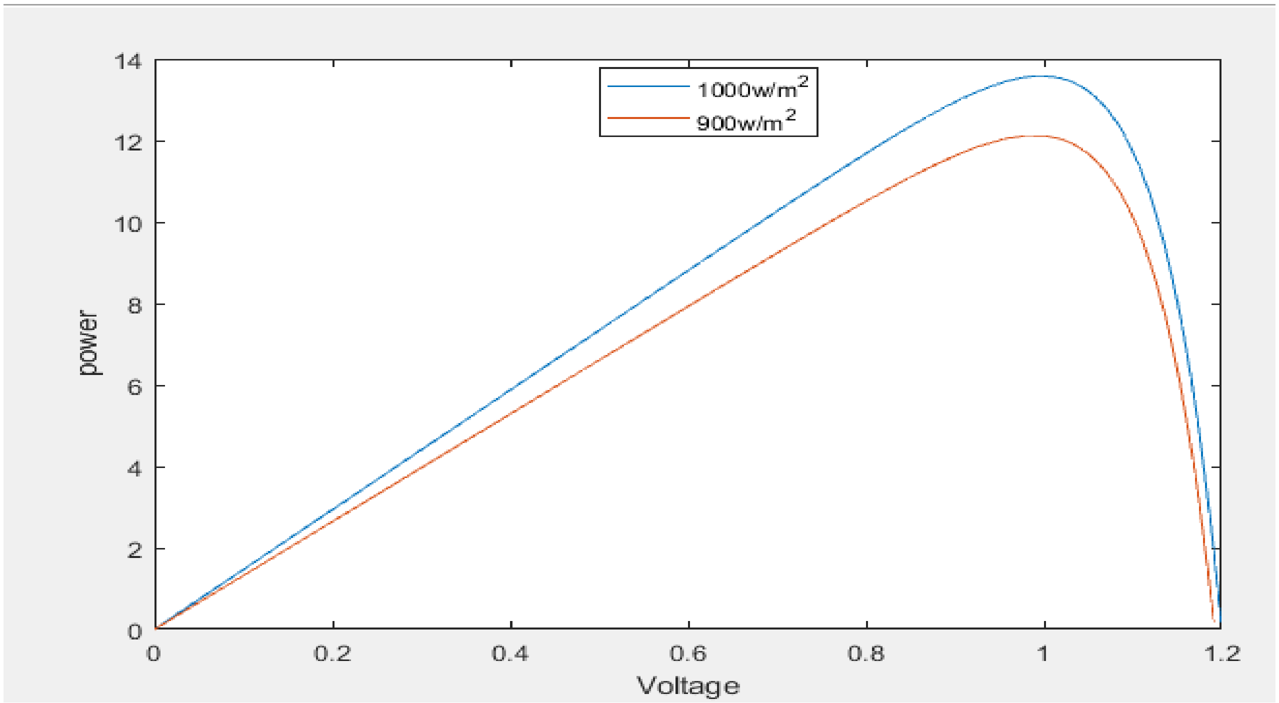


Figure 5. 2 characteristics of solar PV in MATLAB SIMULINK

Within the over figure 5.2 control of the P-V characteristics bend is 13.58w @ 1000w/m^2 and @ 900w/m^2 is 12.119w. This appears that control is expanded when the concentrated of the sun light is expanded.

5.3 Step Response of PID controller tuning method for boost converter

The PID controller parameters are gotten from the PID tuning component until the framework is steady. Those parameters are; $K_P = 1.8427e - 12, K_i = 6.0985e - 12, k_d = 1.202e - 13$, the step respones of the PID controller of the framework is appeared within the take after figure 5.3.

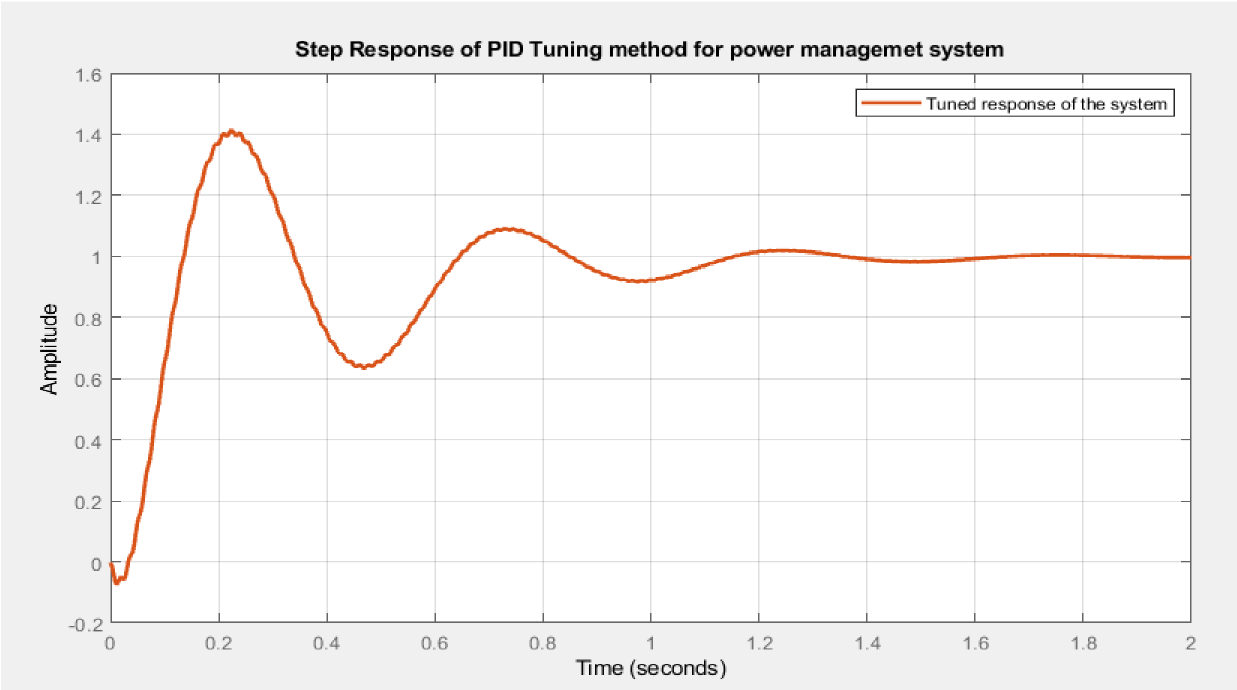


Figure 5. 3 Step response of the PID Controller tuning mechanism

Step response of manual Ziegler Nichols method is show in the following figure5.4

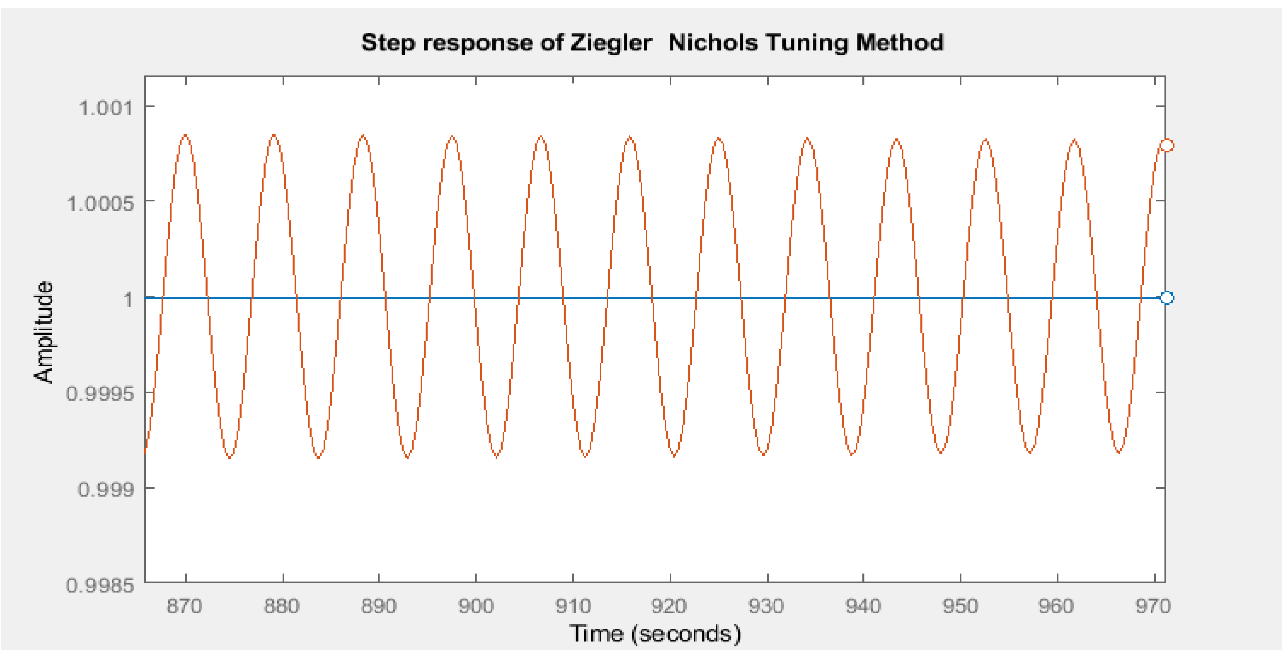


Figure 5. 4 Step response of Ziegler Nichols manual method

In the above figure5.4 the parameters of the PID controller is obtained from this method that is:

Unity G = 9.87e04 s^2………………………………………………………………. (5.1)

Continuous-time transfer function

$$C = K_P + K_i * \frac{1}{s} + K_d * s \ldots\ldots (5.2)$$

With Kp = 0.0025, Ki = 0.062, Kd = 0.14. The framework is Continuous-time PID controller in parallel form, in the table underneath that appears the controller execution and robustness.

Table 5. 1 PID controller performance and robustness

Rise Time	0.0772sec
Settling Time	1.12sec
overshoot	41.3%
Peak	1.41
Gain margin	12.5dB @ 38rad/s
Phase margin	24deg @ 12.9rad/s
Closed loop stability	stable

The Fuzzy-PID controller comes about gotten from MATLAB SIMULINK OF the boost converter is appeared within the taking after figure5.5 and the rise time is 2.899ms, settling time is 5.077e-3sec and overshoot is 0.505%.

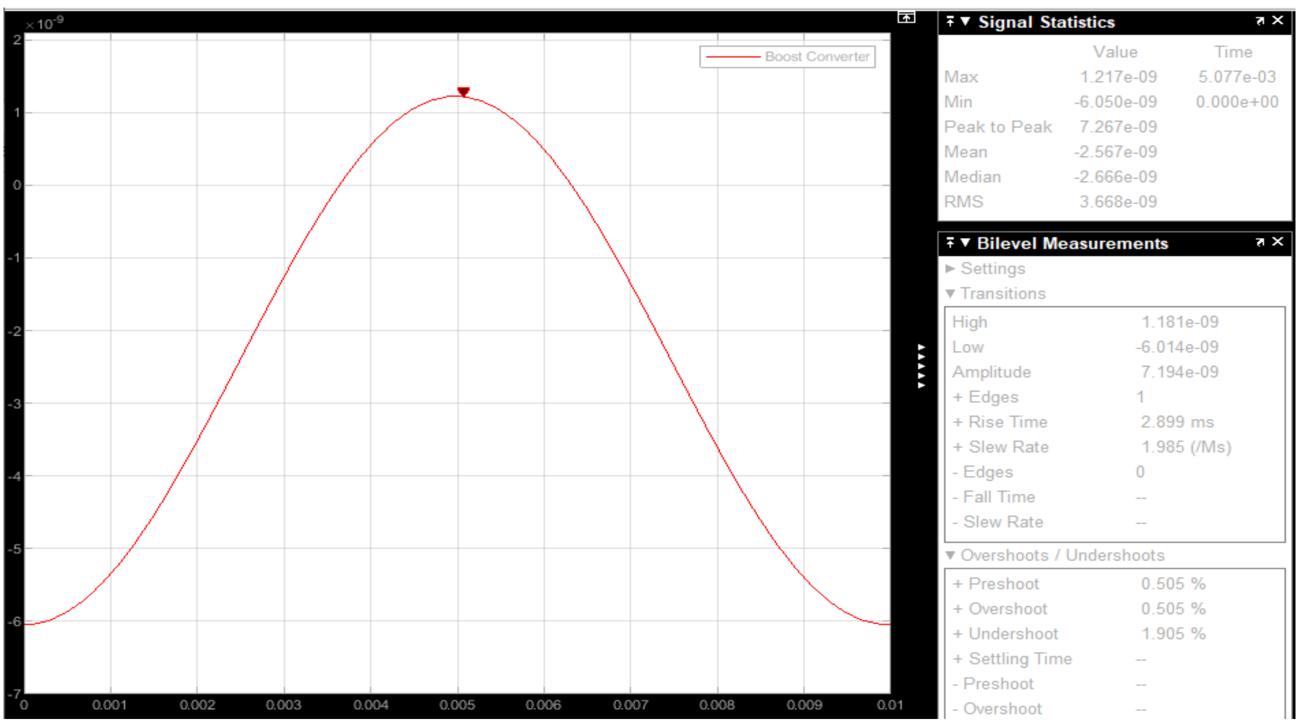


Figure 5. 5 Fuzzy-PID controller SIMULINK model of the system

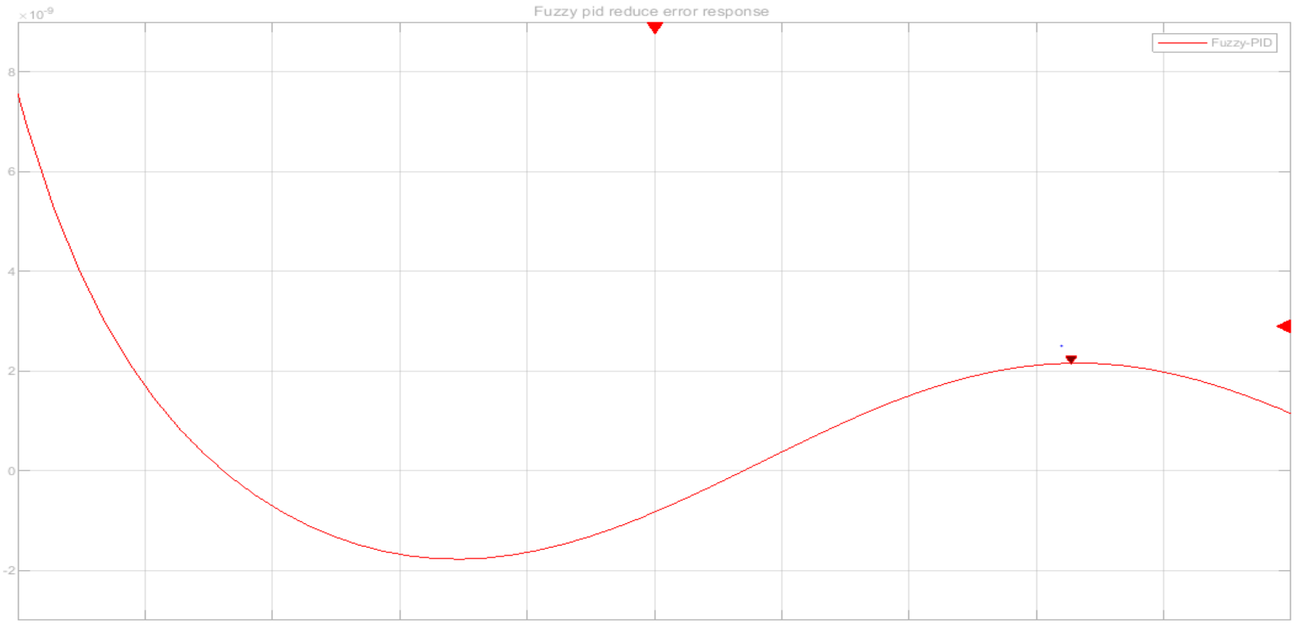


Figure 5. 6 Error and change of error is decrease using fuzzy-PID controller

Table 5. 2 Comparison of PID controller and Fuzzy-PID Controller performance

Characteristics of the controller		PID Controller	Fuzzy-PID Controller
1.	Rise Time	0.0772sec	2.899ms=0.002899sec
2.	Settling Time	1.12sec	5.077e-3sec=0.005077sec
3.	overshoot	41.3%	0.505%

CHAPTER SIX

CONCLUSION AND FUTURE

6.1 CONCLUSION

This thesis; “hybrid power optimization using fuzzy PID controller for rail trains” is mostly studied to design and analysis the performance of PID controller and Fuzzy-PID controller for the hybrid systems which is used boost converter; the inverter and the grid system(as load) and the input of the system is the solar cells. This solar cell is affected by the solar radiation and other environmental conditions. The generating of the maximum output energy is affected by the radiation and temperature.

The fuzzy-PID controller is controlled the error of reference voltage of the boost converter and the output voltage differences which is the error and change of error is decreased. The hybrid power performance optimization of the proposed PID and fuzzy-PID controller is checked through simulation conceders using MATLAB/SIMULINK. It is analyzed that from Ziegler-Nichols closed loop PID controller tuning method simulation results that the overshoot is 41.3%, rising time is 0.0772 seconds, and the settling time is 1.12 seconds with the proposed fuzzy-PID controller while overshoot is 0.505%, rising time is 2.899m seconds and the sampling time is taken as 0.01seconds In this thesis, “hybrid power optimization using fuzzy PID controller for rail trains’’ system is designed to increase the performance optimization of hybrid system

6.2 Recommendation

The work done can be further researched on hardware implementation. Solar panel using different control method to be able to control the maximum power it can be used at full capacity throughout the day. In order to achieve more efficient energy use, further research can be done on how to reduce AC power and how it can be implemented. Likewise, less energy will be replaced with renewable energy or hybrid energy.

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[15] DARIO ZANINELLI, PhD, is a Full Professor in the Electric Power Systems sector at Department of Energy of Politecnico di Milano. He has authored or coauthored more than 250 journal and conference papers on power systems and electric systems for transportation. Since 2011,

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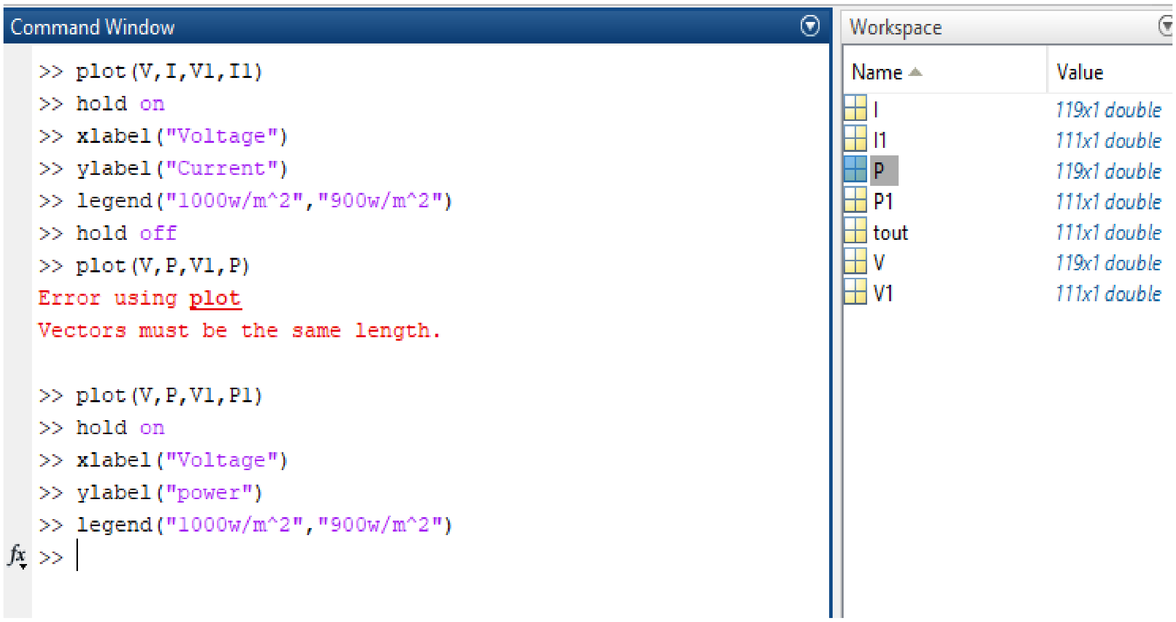
Appendix

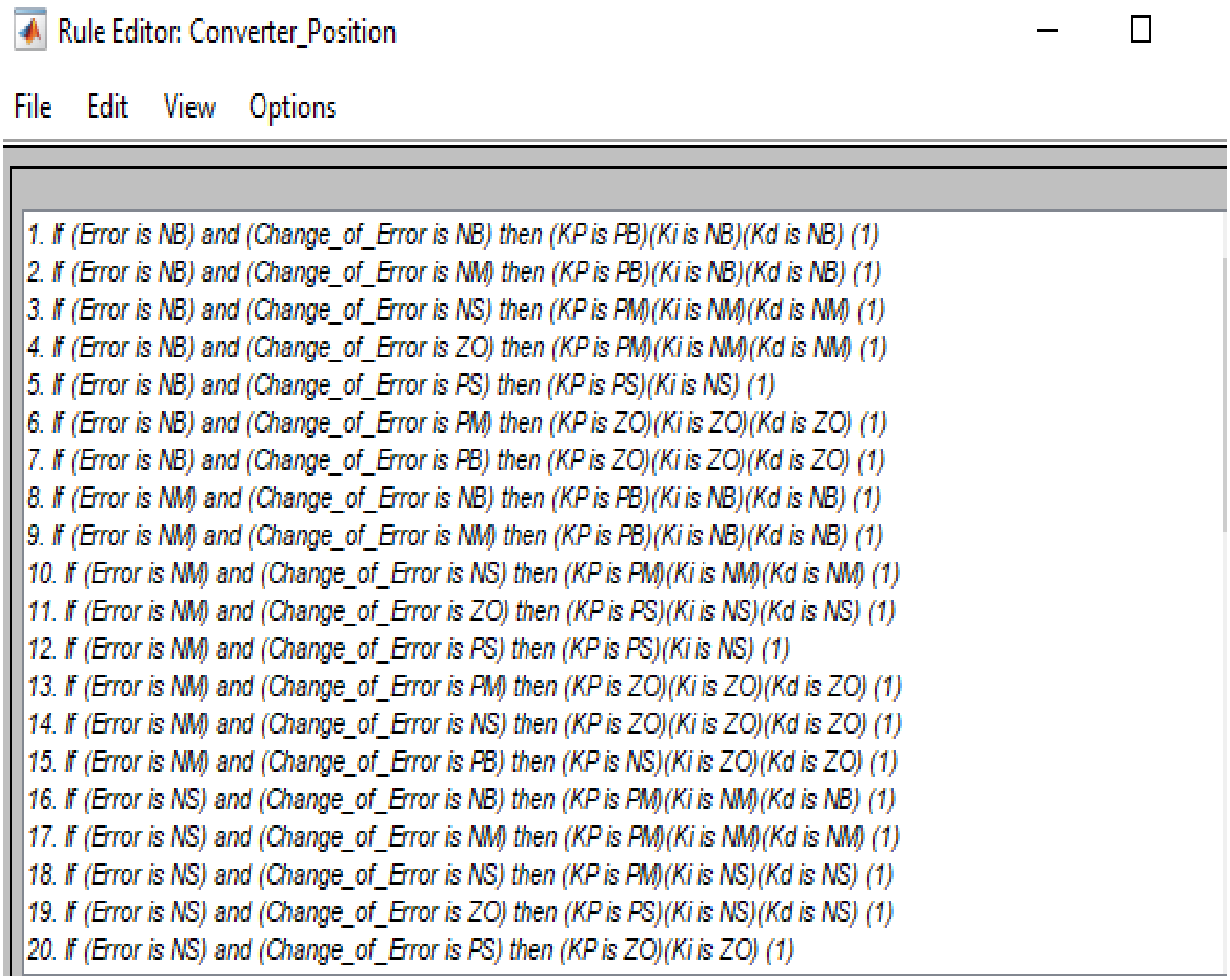
A. PV characteristics



B. Zgler Nicholas

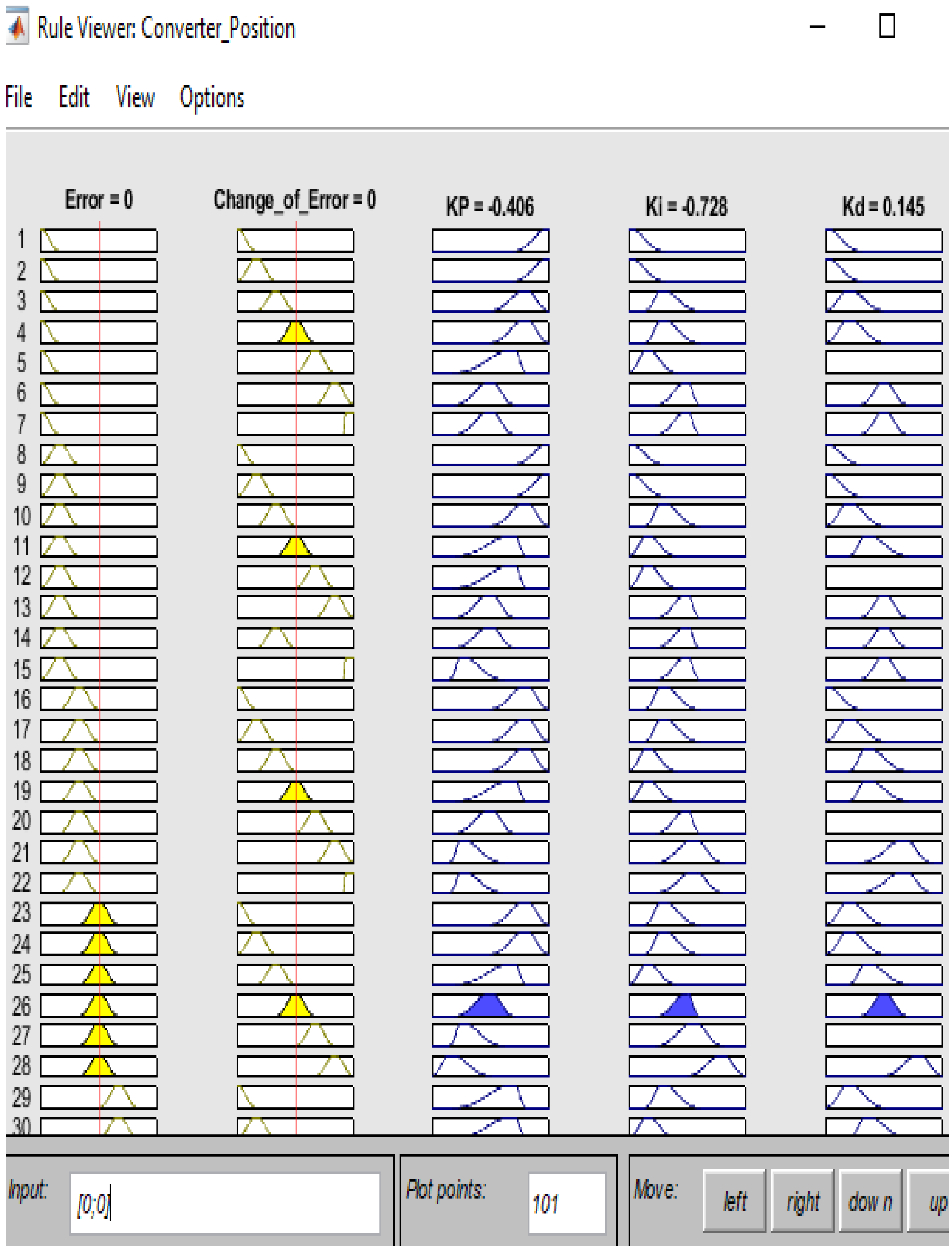
```
% Ziegler _ Nichols Tuning Method
close all; clear all;
s = tf('s');
G = s^2/s^2+9.87*10^4;
sys = step(G);
unity_G=feedback(G,1)
step(unity_G)
hold on
Kp = 2.05548531059143e-12;
Ki = 0.00562;
Kd =0.012;
C = pid(Kp,Ki,Kd)
sys_G=feedback(C*G,1);
step(sys_G);
```

C. Fuzzy Rule


Rule Editor: Converter_Position
File
Edit
View
Options
1. If (Error is NB) and (Change_of_Error is NB) then (KP is PB)(Ki is NB)(Kd is NB) (1)
2. If (Error is NB) and (Change_of_Error is NM) then (KP is PB)(Ki is NB)(Kd is NB) (1)
3. If (Error is NB) and (Change_of_Error is NS) then (KP is PM)(Ki is NM)(Kd is NM) (1)
4. If (Error is NB) and (Change_of_Error is ZO) then (KP is PM)(Ki is NM)(Kd is NM) (1)
5. If (Error is NB) and (Change_of_Error is PS) then (KP is PS)(Ki is NS) (1)
6. If (Error is NB) and (Change_of_Error is PM) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
7. If (Error is NB) and (Change_of_Error is PB) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
8. If (Error is NM) and (Change_of_Error is NB) then (KP is PB)(Ki is NB)(Kd is NB) (1)
9. If (Error is NM) and (Change_of_Error is NM) then (KP is PB)(Ki is NB)(Kd is NB) (1)
10. If (Error is NM) and (Change_of_Error is NS) then (KP is PM)(Ki is NM)(Kd is NM) (1)
11. If (Error is NM) and (Change_of_Error is ZO) then (KP is PS)(Ki is NS)(Kd is NS) (1)
12. If (Error is NM) and (Change_of_Error is PS) then (KP is PS)(Ki is NS) (1)
13. If (Error is NM) and (Change_of_Error is PM) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
14. If (Error is NM) and (Change_of_Error is NS) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
15. If (Error is NM) and (Change_of_Error is PB) then (KP is NS)(Ki is ZO)(Kd is ZO) (1)
16. If (Error is NS) and (Change_of_Error is NB) then (KP is PM)(Ki is NM)(Kd is NB) (1)
17. If (Error is NS) and (Change_of_Error is NM) then (KP is PM)(Ki is NM)(Kd is NM) (1)
18. If (Error is NS) and (Change_of_Error is NS) then (KP is PM)(Ki is NS)(Kd is NS) (1)
19. If (Error is NS) and (Change_of_Error is ZO) then (KP is PS)(Ki is NS)(Kd is NS) (1)
20. If (Error is NS) and (Change_of_Error is PS) then (KP is ZO)(Ki is ZO) (1)

21. If (Error is NS) and (Change_of_Error is PM) then (KP is NS)(Ki is PS)(Kd is PS) (1)
22. If (Error is NS) and (Change_of_Error is PB) then (KP is NS)(Ki is PS)(Kd is PS) (1)
23. If (Error is ZO) and (Change_of_Error is NB) then (KP is PM)(Ki is NM)(Kd is NM) (1)
24. If (Error is ZO) and (Change_of_Error is NM) then (KP is PM)(Ki is NM)(Kd is NM) (1)
25. If (Error is ZO) and (Change_of_Error is NS) then (KP is PS)(Ki is NS)(Kd is NS) (1)
26. If (Error is ZO) and (Change_of_Error is ZO) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
27. If (Error is ZO) and (Change_of_Error is PS) then (KP is NS)(Ki is PS) (1)
28. If (Error is ZO) and (Change_of_Error is PM) then (KP is NM)(Ki is PM)(Kd is PM) (1)
29. If (Error is PS) and (Change_of_Error is NB) then (KP is PS)(Ki is NM)(Kd is NM) (1)
30. If (Error is PS) and (Change_of_Error is NM) then (KP is PS)(Ki is NS)(Kd is NS) (1)
31. If (Error is PS) and (Change_of_Error is NS) then (KP is ZO)(Ki is PS)(Kd is ZO) (1)
32. If (Error is PS) and (Change_of_Error is ZO) then (KP is NS)(Ki is PS)(Kd is PS) (1)
33. If (Error is PS) and (Change_of_Error is ZO) then (KP is NS)(Ki is PS)(Kd is PB) (1)
34. If (Error is PS) and (Change_of_Error is PM) then (KP is NM)(Ki is PM)(Kd is PM) (1)
35. If (Error is PS) and (Change_of_Error is NM) then (KP is NM)(Ki is PB)(Kd is PB) (1)
36. If (Error is PM) and (Change_of_Error is NB) then (KP is NM)(Ki is ZO)(Kd is ZO) (1)
37. If (Error is PM) and (Change_of_Error is NM) then (KP is PS)(Ki is ZO)(Kd is ZO) (1)
38. If (Error is PM) and (Change_of_Error is NS) then (KP is ZO)(Ki is PS)(Kd is PS) (1)
39. If (Error is PM) and (Change_of_Error is ZO) then (KP is NS)(Ki is PS)(Kd is PS) (1)
40. If (Error is PM) and (Change_of_Error is PS) then (KP is NM)(Ki is PM)(Kd is PS) (1)

41. If (Error is PB) and (Change_of_Error is NB) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
42. If (Error is PB) and (Change_of_Error is NM) then (KP is ZO)(Ki is ZO)(Kd is ZO) (1)
43. If (Error is PB) and (Change_of_Error is NS) then (KP is NM)(Ki is PS)(Kd is NB) (1)
44. If (Error is PB) and (Change_of_Error is ZO) then (KP is NM)(Ki is PM)(Kd is PM) (1)
45. If (Error is PB) and (Change_of_Error is ZO) then (KP is NM)(Ki is PM)(Kd is PM) (1)
46. If (Error is PB) and (Change_of_Error is PS) then (KP is NM)(Ki is PM)(Kd is PS) (1)
47. If (Error is PB) and (Change_of_Error is PM) then (KP is NM)(Ki is PB)(Kd is PB) (1)
48. If (Error is PB) and (Change_of_Error is PM) then (KP is NB)(Ki is PB)(Kd is PB) (1)
49. If (Error is PB) and (Change_of_Error is PB) then (KP is NB)(Ki is PB)(Kd is PB) (1)


Rule Viewer: Converter_Position
File
Edit
View
Options
Error = 0
Change_of_Error = 0
KP = -0.406
Ki = -0.728
Kd = 0.145
1
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26
27
28
29
30
Input:
[0;0]
Plot points:
101
Move:
left
right
dow n
up