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# Control Strategies And Adaptive Control Methods For Solar PV Array And Dc-Dc Converter

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**Abstract** A part of an electric strength device can function as a standalone device without any connection to the principle grid. Such self-reliant systems include dedicated strength systems for rural areas, moveable military bases and centers requiring premium electricity quality. For the proper calculation and control operation of independent technology structures, the dynamics of the energy resources and the loads should be nicely accounted for thorough adequate device modeling. In this paper, a photovoltaic (PV) system and a battery bank are presented as power sources, which with the aid of converters, offer electric electricity to three-section balanced stand-alone masses. With the resource of DC-DC converters, source output powers and the DC hyperlink voltage are controlled. A 3 section DC-AC inverter converts the enter DC voltage to AC and controls the frequency and magnitude of the weight voltage. The modeling and constant operation of the device is set forth underneath various running conditions even as accounting for the nonlinearity of the PV supply and cargo type. Besides, the maximum electricity factor tracking set of rules of the solar device is added. The controller design and structures are defined in details and the dynamic behavior of the whole system is studied by computer simulations

***KEYWORDS***: *solar PV aaray, PI and PID Control, DC-DC BUCK converter.*

## 1. INTRODUCTION

Renewable energies are already playing essential roles within the operation of electric electricity device. Most distributed generation (DG) gadgets are the use of renewable energies such as solar (PV) and wind as their sources. Power digital converters control the output electricity and the voltage magnitude of the DG units. Micro grid is a part of the energy machine with its own resources and local masses which can work autonomously (stand-alone) or connected to the primary network. In both situations, it's miles suited to deliver the maximum possible real energy from renewable sources to the grid or self-sufficient loads. In grid connected mode, the frequency and voltage magnitude at the load are adopted from the principle grid. However in self-reliant or even in connection to a susceptible grid with low brief circuit and X/R ratio, the control of those two parameters must be designed.

A PV machine has a nonlinear relationship between the output voltage and the current flowing out of it. In grid connected mode, when the system is running on the maximum power point, we can bear in mind a PV machine as a steady DC voltage source [1], [2]. In the self-reliant mode of operation, due to the want to have a strength balance between assets and masses, the PV system won't always operate at the maximum strength point. Under this situation of capability variation of PV operating point, the control of the system need to naturally consider the nonlinear characteristics of the input source to satisfy load requirements which will be a mixture of linear and non-linear loads. Alternatively, there may be other resources which are simultaneously related which include a battery bank, to preserve the operation of the PV at the maximum power extraction method. Under this condition, the consistent country operation location of the gadget below different masses based at the predefined electricity management approach will be affected. In [4] the dynamic behavior and sensitivity evaluation of a linearized grid connected PV machine is studied. A three phase inverter offers the whole strength of PV to the grid such that there has been no want for electricity restricting consideration. Also [3] controls the nonlinear PV machine linked to the grid in which the steadiness of the machine is investigated primarily based on small-sign linearized system equations. Standalone micro-grid power and voltage manage is studied in [5], wherein the input is believed as a regular DC source and its dynamic is not considered.

In this paper, a stand-on my own micro-grid with a PV gadget as the number one source is considered. In addition, a battery is connected to manipulate the DC hyperlink voltage. A bidirectional DC-DC converter expenses or discharges the battery. The nonlinear feature of PV system is delivered and the steady kingdom operation vicinity of the device and dynamic conduct without linearization for different conditions are studied.

## II. PV GENERATOR OVERVIEW

The creation of the PV (solar) cells involves the use of silicon, and these cells include no liquids, corrosive chemical substances or transferring parts. The operation of such sun cells in all fairness simple, as they convert daylight into direct contemporary (DC) energy without the production of greenhouse emissions or every other harmful gases or emissions. Its operation is virtually silent, consequently making the photovoltaic power one of the cleanest and safest methods of energy generation [8].

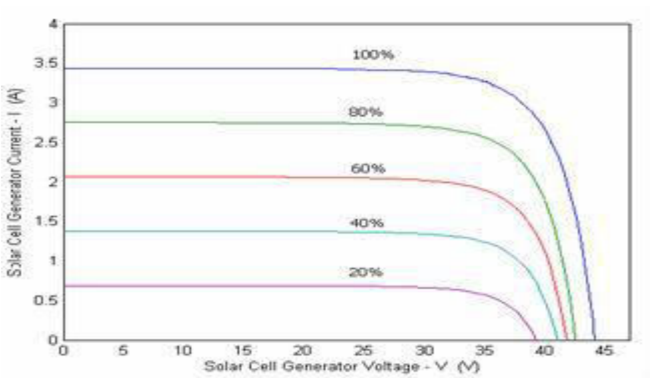
When the silicon inside the sun panel layer is uncovered to mild, electrical charges are generated and this could be conducted away by way of metallic contacts as direct modern-day, (DC). The PV generator is a semiconductor device that converts the sun insolation without delay to electrical strength. Since the electric output from a single cell is reasonably small, more than one cells as connected collectively and encapsulated in the back of glass to shape a module that gives you a sizeable quantity of direct modern-day. A typical silicon PV cell is composed of a thin wafer. inclusive of an extremely thin layer of phosphorous doped (N- type) silicon on top of a thick layer of boron-doped (P-type) silicon. An electric discipline is created close to the pinnacle floor of the cell wherein these two substances are in contact, referred to as the P-N junction. When sunlight moves the floor of a PV cellular, this electric field gives momentum and path to mild stimulated electrons, ensuing in a glide of cutting-edge in which the sun cellular is connected to an electrical load.[8] The modern and strength output of a PV mobile relies upon on the surface area, and is proportional to the depth of sunlight striking the surface of the cellular. The DC output energy under standard check situations determines the performance of PV modules and arrays. Standard take a look at situations (STC) can be defined by a module (cell) operating temperature of 25 ºC and incident sun irradiance of 1000W/m2 and below air mass 1.5 spectral distributions. These situations aren't usually ordinary of ways PV modules and array operate inside the area, and actual overall performance is generally 85 to 90 percent of the standard check condition [9].

## II. METHODOLOGY

A PV generator feeds a load via a regulator (switch) and matches the impedances for maximum strength

Where I is the cutting-edge thru the load, IL is the photovoltaic contemporary throughout the junction, RS is cellular series resistance, RSH is the shunt resistance, ok is Boltzman constant, ko = e/AkT is the coefficient of the exponential, e is the digital charge, A is final touch factor; T is absolute temperature, Io is cellular reverse saturation modern-day.

Fig. 1 I-V characteristics of a PV sun Panel



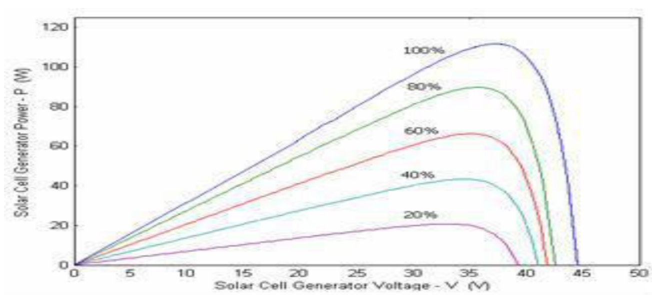

However, fixing for V within the above equation gives establish maximum electricity transfer. PV array is established to get most insolation so that the field current of the DC generator extracts maximum strength out of the PV array. The load is varied thru an inverter related in the gadget to trade DC to AC [10]. The PV generator is a nonlinear tool and may be represented with the aid of the I-V terminal characteristics, derived from the modeling of the sun panels the usage of MatLab. Figure 1, represents the I-V traits of the sun mobile generator for diverse insolation levels (in percentages).

By varying the external load under constant solar radiation (J/m.Sq) and temperature, the modern and voltage will vary, producing the modern-voltage (I-V) curve or I-V feature of the sun module. The maximum voltage at the module terminal is the open circuit voltage Voc. The highest cutting-edge that may be extracted from the module is the short circuit contemporary Isc. The optimal working factor at the I-V

Where Impp is the modern-day at most energy point, Vmpp is the voltage at most energy point , Isc is the brief circuit modern-day, Voc is the open circuit contemporary .

Figure 2, under suggests the strength-voltage courting of the sun panel. The energy curves are obtained from the made from the I-V curves as proven in parent 1. The maximum electricity acquired for an insolation of 100 in be seen from the figure to be very near 110W.

The power output of the PV module, P(S) is the manufactured from the module output voltage and output cutting-edge. However, the statistics on temperature, reference irradiance, maximum energy factor voltage and modern are supplied within the manufactures records sheet [13]. The equal circuit output modern-day I of the module as [2] curve at which the strength this is brought to the burden is maximized is called the maximum

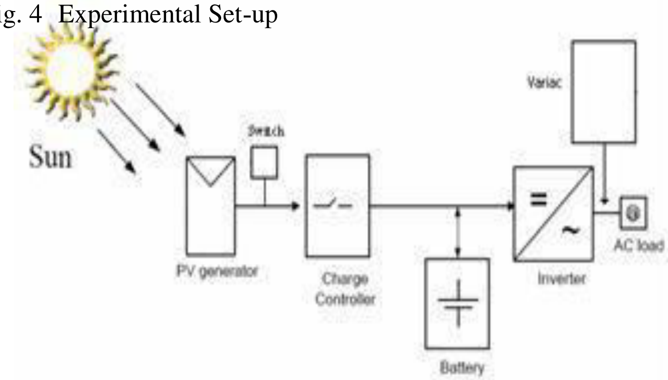



strength factor (MMP)[11]. The module operates at MMP most effective when it's far related to a need to recognize the solar radiation sample at the site. $C_{d1}sV_{m1d} = I_{s1d} - I_{L1d} - I_{1od} + w_{s1}C_{d1}V_{m1q}$ C d1sVm1q = k m1q (s)(Vm1q

Cd1sVm1d = km1d (s)(Vm1d - Vm1q ) = s m1q - Vm1d )
where the PI voltage controllers are:

$k_{m1q}(s) = k_{m1d}(s) = k_{Pm1} + \frac{k_{Im1}}{s}$

Fig. 4 Experimental Set-up



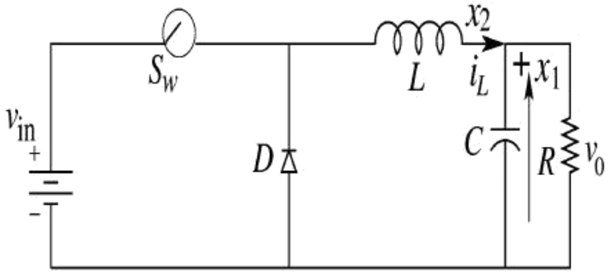
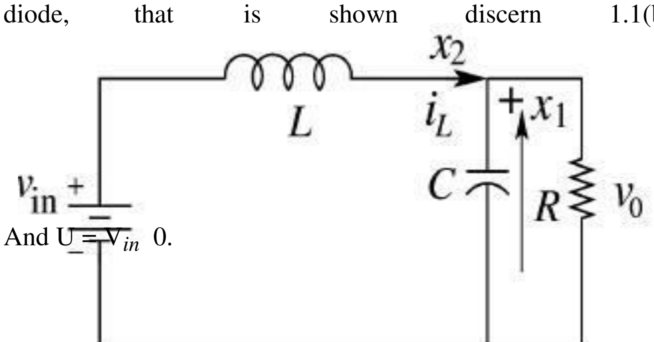



**Figure 1: DC –DC buck Converter**

In the outline of converter operation, it's miles assumed that every one the additives are perfect and also the converter operates in CCM. In CCM operation, the inductor current flows constantly over one switching period. The transfer is both on or off consistent with the switching feature and this outcomes in circuit states. The first sub-circuit kingdom is while the transfer is became on, diode is opposite biased and inductor current flows through the transfer, which can be proven in parent 1.1(a). The second sub-circuit nation is when the transfer is became off and current freewheels via the diode, that is shown discern 1.1(b)




And U = $V_{in}$ 0.

**figure 1.1(a). turn on switch**

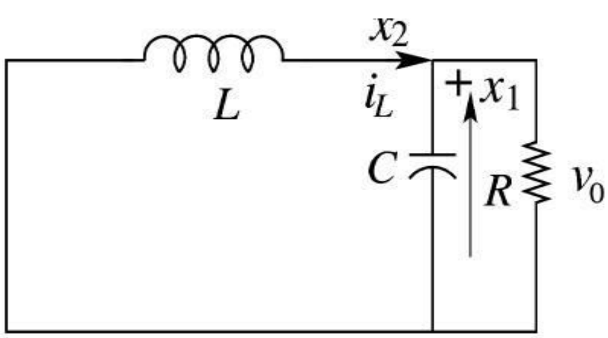



**figure 1.1(b). turn off switch**

When the switch $S_1$ is on and D is reverse biased, the dynamics of inductor current $i_L$ and the capacitor voltage $V_c$ are

$$\frac{di_L}{dt} = \frac{1}{L} V_m - V_o \quad \text{and} \quad \frac{dv_o}{dt} = \frac{dv_c}{dt} = \frac{1}{C} i_c \;........(1)$$

When the switch $S_1$ is off and D is forward biased, the dynamics of the are

$$\frac{di_L}{dt} = -\frac{1}{L} V_m - V_o \quad \text{and} \quad \frac{dv_o}{dt} = \frac{dv_c}{dt} = \frac{1}{C} i_c \;........(2)$$

When the switch $S_1$ is off and D is also not conducting,

$$\frac{di_L}{dt} = 0 \quad \text{and} \quad \frac{dv_o}{dt} = \frac{dv_c}{dt} = \frac{1}{C} i_c \;..............(3)$$

The state space representation for converter circuit configuration can be expressed as

$$\frac{dx}{dt} = \begin{cases} A_1 x + B_1 U; & \text{When S is Closed} \\ A_2 x + B_2 U; & \text{When S is Opened} \end{cases} \;..........(4)$$

Where $X = [x_1, x_2]^T = [V_c\ i_L]$ is the state vector and A's and B's are the system matrices.

The state matrices and the input vectors for the ON and OFF periods are

$$A_1 = A_2 = \begin{bmatrix} -\frac{1}{RC} & \frac{1}{C} \\ -\frac{1}{L} & 0 \end{bmatrix}, \quad B_1 = \begin{bmatrix} 0 \\ \frac{1}{L} \end{bmatrix}, \quad B_2 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

## III. CONTROL METHODS

A control technique suitable for DC-DC converters must deal with their intrinsic nonlinearity and wide input voltage and load variations, making sure balance in any working condition even as supplying fast temporary response. Various control techniques are there: Fuzzy common sense controller, Artificial Neural Network (ANN), PID controller, PI controller, sliding mode controller. From these control strategies PI, PID are linear control techniques and SMC, SMC PID are the non- linear control methods. Comparison among linear and nonlinear control strategies are given below. In this paper the performance and homes of the sliding mode controller, PID controller and PI controller has been focused.

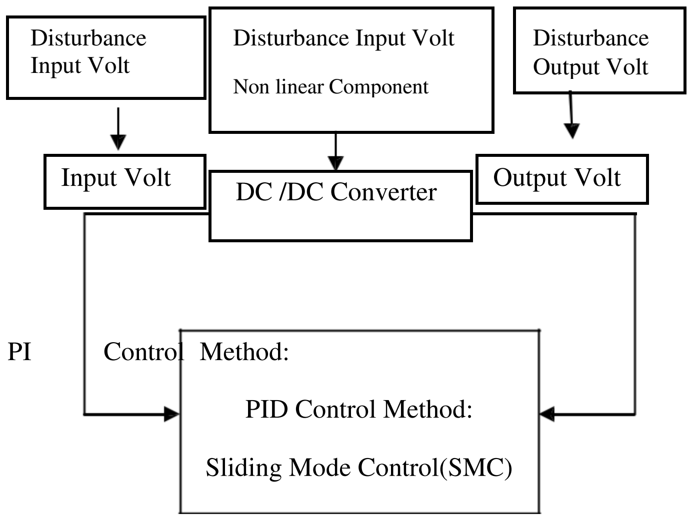



**Figure 3. Type of Controller**

### 3.1 PI-CONTROLLER

The integral time period in a PI controller causes the constant-state blunders to reduce to zero, which isn't the case for proportional- handiest manage in general. The lack of by-product motion can also make the machine greater constant within the consistent state within the case of noisy data. This is because by-product movement is greater touchy to higher-frequency terms inside the inputs. Without by-product motion, a PI-controlled machine is much less attentive to real (non-noise) and comparatively fast alterations in nation and so the system can be slower to attain set-point and slower to reply to perturbations than a well-tuned PID device might also be.

### 3.2 PROPORTIONAL, INTEGRAL & DERIVATIVE CONTROLLER (PID)

For control over steady state and transient errors all the three Control strategies discussed so far should be combined to get proportional-integral derivative (PID) control. Hence the control signal is a linear combination of the error, the integral of the error, and the time rate of change of the error. All three gain constants are adjustable. The PID controller contains all the control components (proportional, derivative, and integral).

In order to get acceptable performance the constants $K_P$, $K_D$ and $K_I$ can be adjusted. This adjustment process is called tuning the controller. Increasing $K_P$ and $K_I$ tend to reduce errors but may not be capable of producing adequate stability. The PID controller provides both an acceptable degree of error reduction and an acceptable stability and damping.

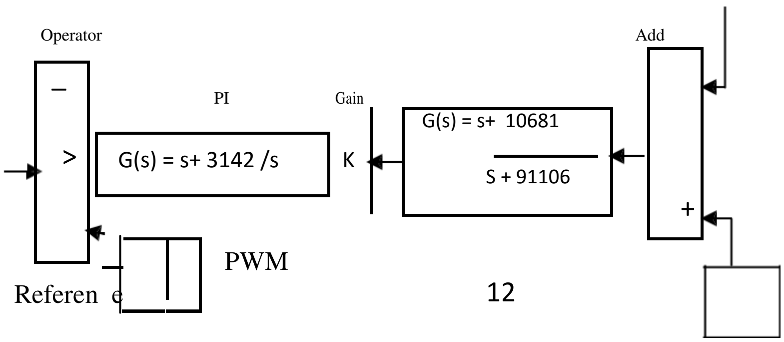



**Figure 3.2 Buck converter with PID control**

## IV SLIDING MODE CONTROL

Sliding mode controller provides a systematic approach to the problem maint Aining balance and consistence performance within the face of modeling imprecision [5]-[6]. For example, the profits in every feedback route transfer between values according to a rule that depends on the price of the nation at each instant. The purpose of the switching manipulate law is to force the nonlinear plant's state trajectory onto a pre-specified (person chosen) surface in the country area and to hold the plant's nation trajectory for the subsequent time. This floor is referred to as the switching floor [6]. When the plant trajectory is above the floor a feedback path has one benefit and a different advantage if the trajectory drops beneath the surface. This floor defines the rule for proper switching. This floor is also called a sliding surface (sliding manifold). Ideally, as soon as intercepted, the switched manipulate maintains the flowers nation trajectory on the surface for all subsequent time and the plant life state trajectory slides alongside this surface. By right design of the sliding surface, VSC attains conventional goals of control including stabilization, tracking, regulation etc.

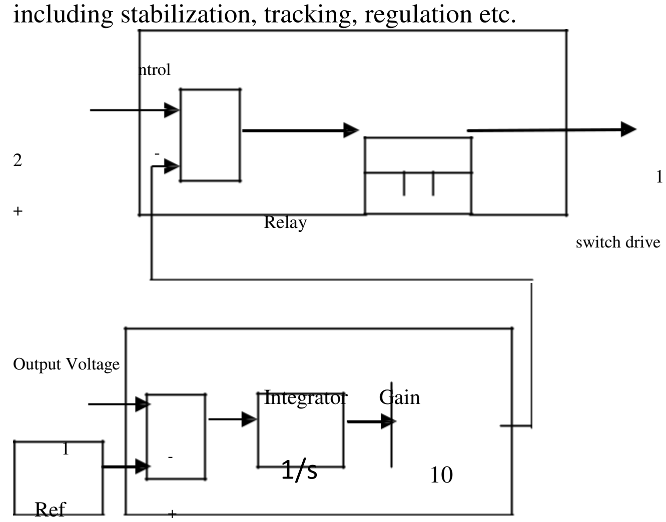



***Figure No. 4. The simulation controller block diagram SMC.***

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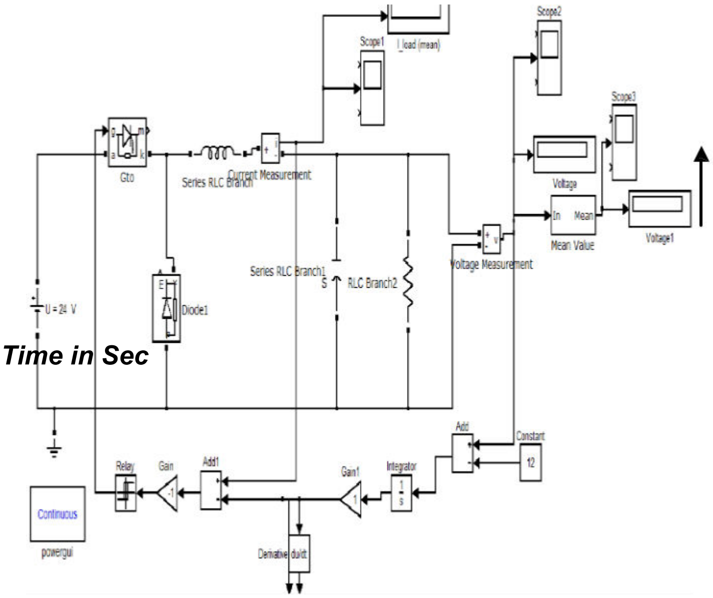
#### 4.1 BUCK CONVERTER WITH SMC SIMULATION DIAGRAM




***Time in Sec***

***Figure No. 4.1 Simulation diagram for buck converter with SMC***

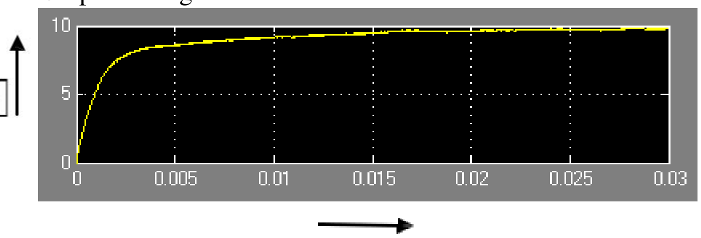
TABLE - 1

**LIST OF PARAMETERS** ***Time in Se Figure.***

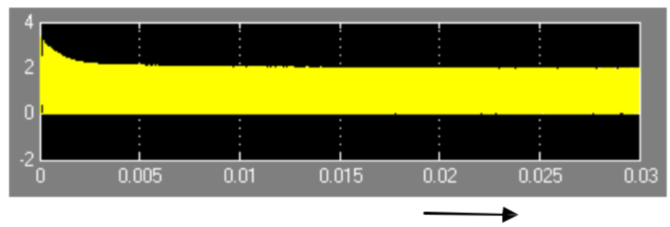
| DESCRIPTION | PARAMETER | NOMINAL VALUE |
|---|---|---|
| Input Voltage | $V_{in}$ | 24 v |
| Output voltage | $V_O$ | 12 v |
| Capacitor | C | 220 µF |
| Inductor | L | 69 µH |
| Load Resistance | RL | **13Ω** |
| Nominal Switching Frequency | r | 100kHz |
| Switch Off | SW 1 | u = 0 |
| Switch On | SW 1 | u = 1 |

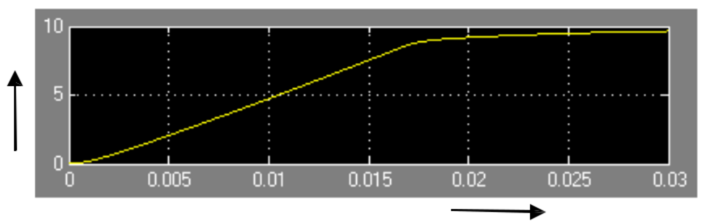
**Result**: For input voltage of Vin=24v,Vo=9.48.5v,Io=9.82 with linear curve.

Output Voltage




Inductor Current




***4.2 simulation result for sliding mode controller***

## V. CONCLUSION

As SMC is not operating at a constant switching frequency and Converters have a distinctly nonlinear and time varying nature therefore it is selected to control such sort of DC- DC converter. Therefore it is also decided on as control method for performance analysis. The waveforms of simulated output. Voltage and modern were obtained, studied and compared with the waveforms from other controllers for performance evaluation. By studied references papers in information the waveforms have been found to be in precise proximity of theoretical waveforms. Some concluding points which might be analyzed in following points. From performance comparison of SMC with PI and PID .

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