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Model Direct Adaptive Control of Buck Converter by using MRAC

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Abstract*—DC-DC converters are commonly implemented in effective packages. One of the regular varieties of DC-DC converters is dollar converter. The flexible controller techniques can decorate framework reaction not just like PID controller with steady parameter isn't hearty enough. The temporary reaction of PID controller exhibitions is multiplied depending on versatile issue. That lets in you to determine excellent placing for the control parameters underneath a few circumstance, a bendy element relying on MIT popular is carried out. Direct MRAC has a simple shape and wonderful execution in a few scenario. The proposed framework is regular and geared up to reach on the reaction of model reference superbly. Be that as it is able to, the react of the framework has straight away overshoot and pursue again the reaction of model reference. The ascent time, settling time, overshoot, and unfaltering country for step response are some destinations that decide if the adjustment additions art work as it should be. The confinement of bendy manage is the choice of the adjustment profits. The adjustment additions of the controller parameters are gotten with the aid of experimental increases.

***Index Terms*—buck converter, PID, MRAC, adaptation gain.**

I. INTRODUCTION

strength converters are the primary aspect in proper software, for instance, DC-DC converters. utilization of DC-DC converters, as an example, in battery stockpiling framework [1], switch mode electricity deliver [2], manipulate thing amendment [3], and control lattice [4, 5]. that allows you to carry together a relevant DC-DC converter, the recurrence of changing must paintings in excessive recurrence to arrive at short effective response. The framework dynamic is wanted to plot a controller which ready to carry out the objective. In contemporary software, Proportional–fundamental–by-product (PID) type is commonly applied with exceptional adjusting strategies and to-date programming machine [6]. PID parameters decide response framework, a few strategies were created to accumulate framework in relentless nation.

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The versatile controller techniques can improve framework reaction not similar to PID controller with fixed parameter is not hearty enough [7, 8]. there are numerous flexible manipulate techniques and a model Reference Adaptive control (MRAC) is taken into consideration one of them [9, 10]. MRAC exhibitions are given as far as a supply of perspective version, implies the reference version can be trailed by using the use of the plant reaction. MIT rule [11] is carried out to compute the accompanying parameter alteration tool.

The paper proposes an non-compulsory controller shape machine for greenback converter. MRAC is applied to change the PID parameters continuously to improve the reaction for some condition in circumstance. The presentation of PID Adaptive and PID conventional can be looked at in awesome situations. In vicinity II will portray the version dynamic of DC dollar converter. In section III, the proposed control is displayed. outcomes and exam; and cease are delivered in segment IV and place V, one after the other.

II. LAYOUT OF DOLLAR CONVERTER

The circuit of dollar converter is appeared in decide 1. it's far created from semiconductor devices, a MOSFET as a managed electricity machine and a diode as an out of manipulate system. This circuit contains basically of an inductor in affiliation with a parallel affiliation of a capacitor and burden.

The usa space version indicate in (1) and (2), wherein and are the kingdom variable and its subordinate in my opinion, and are the statistics and the yield one after the other. , and are the framework grids.

$$\dot{x} = Ax + Bu \tag{1}$$

$$y = Cx \tag{2}$$

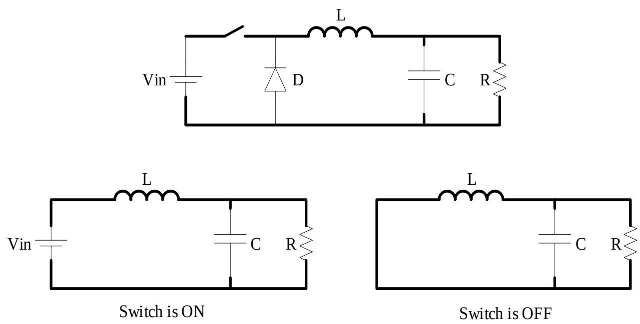

Figure 1: Buck converter Switch ON and Switch OFF

The vector x has the inductor current i_L and the capacitor voltage v_C. During switch is ON, v_C and i_L can be defined in (3) and (4) respectively.

$$v_c = v_{in} - L\frac{di_L}{dt} \qquad (3)$$

$$i_L = C\frac{dv_C}{dt} + \frac{v_C}{R} \qquad (4)$$

Now $i_L = x_1$ and $v_C = x_2$, we can write the derivative ($\dot{x}_1$ and $\dot{x}_2$) equations (5) and (6) from rearranging the terms (3) and (4). State space model matrices during switch is ON became equations (7).

$$\dot{x}_1 = -\frac{1}{L}x_2 + \frac{1}{L}V_{in} \qquad (5)$$

$$\dot{x}_2 = \frac{1}{C}x_1 - \frac{1}{RC}x_2 \qquad (6)$$

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}V_{in} \qquad (7)$$

During switch is OFF, equation (8) can formulate the state space matrices for buck converter in (9).

$$\dot{x}_1 = -\frac{1}{L}x_2 \qquad (8)$$

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ 0\end{bmatrix}V_{in} \qquad (9)$$

Combining both set of matrices by using the equation (7) and equation (9) according to switching duty cycle d, we obtain the average A and B matrices which is shown (10) and (11) respectively.

$$\bar{A} = A(on)d + A(off)(1-d)$$

$$\bar{A} = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}d + \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}(1-d) = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix} \qquad (10)$$

$$\bar{B} = B(on)d + B(off)(1-d)$$

$$\bar{B} = \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}d + \begin{bmatrix}0\\ 0\end{bmatrix}(1-d) = \begin{bmatrix}\frac{d}{L}\\ 0\end{bmatrix} \qquad (11)$$

The state space averaged model for buck converter is shown in (12).

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}\frac{d}{L}\\ 0\end{bmatrix}V_{in} \qquad (12)$$

III. ADAPTIVE CONTROLLER DESIGN

PID controller has a straightforward structure which is anything but difficult to execute in genuine condition in light of the fact that the calculation gives fulfill execution. PID parameters are utilized in single info single yield (SISO) framework which can't make up for varieties in condition. In this segment, structuring an immediate model reference versatile control (DMRAC) to create parameter adjustment laws for a PID control utilizing MIT rule. The square outline in Figure 2 demonstrates the structure of a DMRAC.

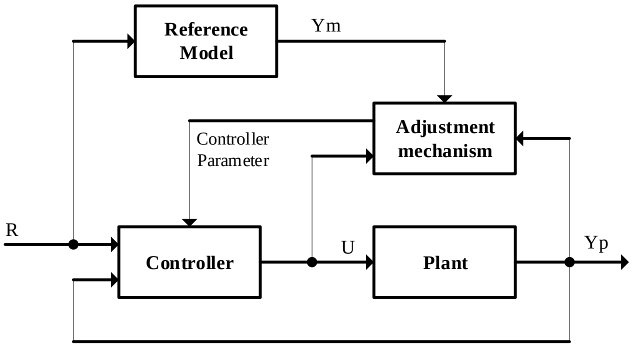

Figure 2: Block diagram of a direct model-reference adaptive control system

The system is described by 2nd order model as:

$$\frac{Y_p(s)}{U(s)} = \frac{b}{s^2 + a_1 s + a_2} \qquad (13)$$

The reference model given by:

$$\frac{Y_m(s)}{U(s)} = \frac{bm_1 s^2 + bm_2 s + bm_3}{s^3 + am_1 s^2 + am_2 s + am_3} \qquad (14)$$

The term of controller PID as (15)

$$\frac{U(s)}{R(s) - Y_p(s)} = K_p + \frac{K_i}{s} + K_d s \qquad (15)$$

Transfer function of close loop system is

$$\frac{Y_p(s)}{R(s)} = \frac{b(K_d s^2 + K_p s + K_i)}{s(s^2 + a_1 s + a_2) + b(K_d s^2 + K_p s + K_i)} \qquad (16)$$

And

$$Y_p(s) = \frac{b(K_d s^2 + K_p s + K_i)}{s(s^2 + a_1 s + a_2) + b(K_d s^2 + K_p s + K_i)}R(s) \qquad (17)$$

The adaptation error:

$$\varepsilon = Y_p - Y_m \qquad (18)$$

The cost function chosen is of the form:

$$J(\theta) = \frac{1}{2}\varepsilon^2(\theta) \qquad (19)$$

Where ε represents the error between the plant and model output. The θ is adjustable parameter and it is set in such a way such that J is minimized to zero.

In Massachusetts Institute of Technology (MIT) rule, the time rate of change of θ is proportional to negative gradient of J. That is

$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma\varepsilon\frac{\partial \varepsilon}{\partial \theta} \qquad (20)$$

$$\frac{dK_p}{dt} = -\gamma_p\frac{\partial J}{\partial K_p} = -\gamma\frac{\partial J}{\partial \varepsilon}\frac{\partial \varepsilon}{\partial Y_p}\frac{\partial Y_p}{\partial K_p} \qquad (21)$$

Where; $\frac{\partial J}{\partial \varepsilon} = \varepsilon$, $\frac{\partial \varepsilon}{\partial Y_p} = 1$

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Apply MIT gradient rules for determining the PID controller parameters K_p, K_i, and K_d in (22).

$$\frac{dK_p}{dt}=-\gamma_p\frac{\partial J}{\partial K_p}=-\gamma_p\left(\frac{\partial J}{\partial\varepsilon}\right)\left(\frac{\partial\varepsilon}{\partial Y_p}\right)\left(\frac{\partial Y_p}{\partial K_p}\right)$$
$$\frac{dK_i}{dt}=-\gamma_i\frac{\partial J}{\partial K_i}=-\gamma_i\left(\frac{\partial J}{\partial\varepsilon}\right)\left(\frac{\partial\varepsilon}{\partial Y_p}\right)\left(\frac{\partial Y_p}{\partial K_i}\right) \quad (23)$$
$$\frac{dK_d}{dt}=-\gamma_d\frac{\partial J}{\partial K_d}=-\gamma_d\left(\frac{\partial J}{\partial\varepsilon}\right)\left(\frac{\partial\varepsilon}{\partial Y_p}\right)\left(\frac{\partial Y_p}{\partial K_d}\right)$$

Where, $\partial J/\partial\varepsilon=\varepsilon$, $\partial\varepsilon/\partial y=1$

$$\frac{\partial Y_p}{\partial K_p}=\frac{bs}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right) \quad (24)$$

$$\frac{\partial Y_p}{\partial K_i}=\frac{b}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right) \quad (25)$$

$$\frac{\partial Y_p}{\partial K_d}=\frac{bs^2}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right) \quad (26)$$

From equation (24), (25), and (26), it obtained $\frac{\partial Y_p}{\partial K_p}$, $\frac{\partial Y_p}{\partial K_i}$, $\frac{\partial Y_p}{\partial K_d}$ as equation (27), (28), and (29).

$$\frac{dK_p}{dt}=-\gamma_p\frac{\partial J}{\partial K_p} \quad (29)$$
$$=-\gamma_p\varepsilon\frac{bs}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right)$$
$$\frac{dK_i}{dt}=-\gamma_i\frac{\partial J}{\partial K_i}$$
$$=-\gamma_i\varepsilon\frac{b}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right)$$
$$\frac{dK_d}{dt}=-\gamma_d\frac{\partial J}{\partial K_d}$$
$$=-\gamma_d\varepsilon\frac{bs^2}{\left(s^3+(a_1+bK_d)s^2+(a_2+bK_p)s+bK_i\right)}\left(R(s)-Y_p(s)\right)$$

b, a_1, and a_2 have an unknown number, then we define $am_1=a_1+bK_d$; $am_2=a_2+bK_p$; $am_3=bK_i$ (30)

IV. RESULTS AND ANALYSIS

in this phase, some parameters will be applied inside the proposed controller check by contrasting and everyday controllers. the ones conditions that checked are differing input voltage, fluctuating burden, and step unit. The sort of DC converter applied is buck converter. desk I demonstrates the dollar converter parameter. within the reenactment effects there are three charts of model reference, ordinary controller, and proposed controller.

Table 1. System Parameters

No	Parameter	Symbol	Value
1	Input Voltage	V_{in}	$48V$
2	Inductance	L	$0.001H$
3	Resistance	R	4Ω
4	Capacitance	C	$470\times10^{-6}F$

A. Condition 1: Varying Input Voltages

This condition have three variation input voltages, the input voltage will be adjusted in 0s with $V_{in}=48V$ then 0.1s with $V_{in}=68V$ until 0.15s with $V_{in}=168V$.

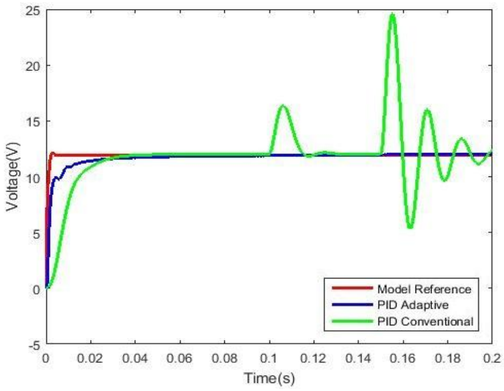


Figure 3: Responses of system with input V_{in} has been adjusted

when the input voltage modifications to 68V, the output voltage of Adaptive PID can reach regular country with out overshoot. in line with parent three, the transient response of Adaptive PID is quicker and in the direction of reference model, the tension strain of the adaptive PID is greater stable even though the is changed at and . those effects have variations with the traditional PID takes location oscillation and re-observe the reference model.

B. circumstance 2: various Load

on this condition have similar to voltage variation circumstance. the weight may be set resistance commenced in , commenced out in , and began in . by the usage of the enter voltage 48V at , 68V at , and 168V at . The output response is tested in determine 4.

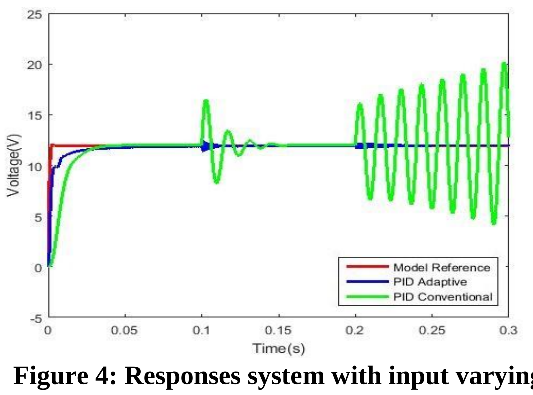


Figure 4: Responses system with input varying resistance's value

It very well can be visible that the short response of the flexible PID is quicker and nearer sufficient to the reference version. at the factor whilst the obstruction is modified at and , the flexible PID response pursues the reaction of the reference version. on the aspect even as , the information voltage of not unusual PID is changed to and competition too, a piece wavering takes area subsequently pursues the reference model. at the aspect at the same time as , the progressions of information voltage and obstruction take place, it has swaying and can't pursue the reference model.

C. circumstance three: Step Reference Output

in this condition, it has numerous in reference model reaction (step signal). it'll possibly be changed into 2 stage sign, at , the reference version reaction is then on the reference model response modified to . this alteration is relied upon to make revel in of the response of framework, regardless of whether or not it stays at yield reference or not.

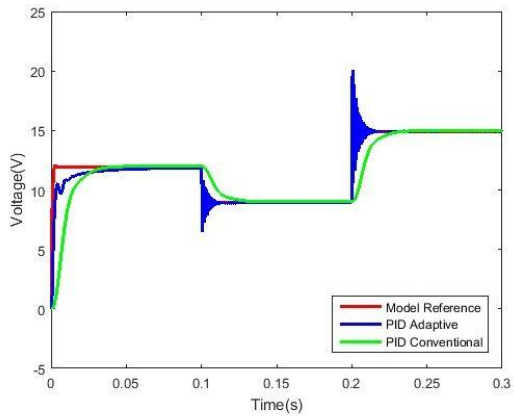
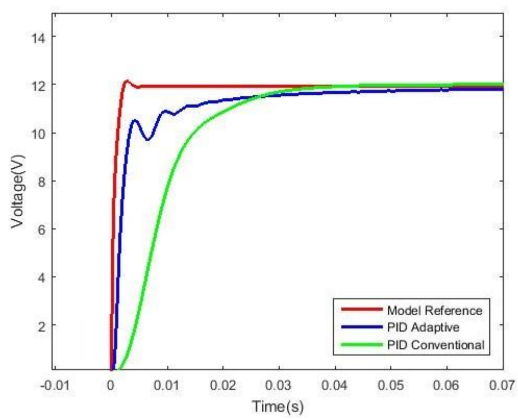
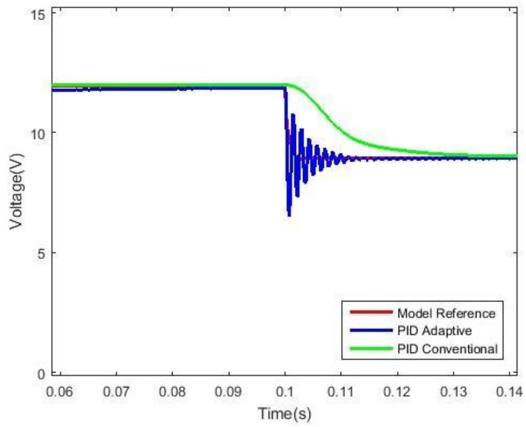


Figure 5: Response with 3 steps different reference model

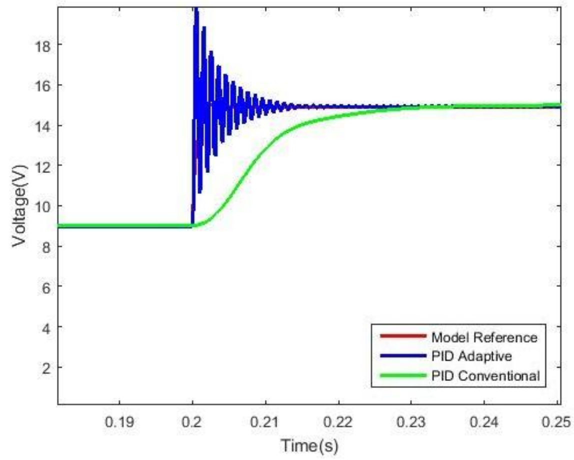
As shown in Figure 5, the transient response of the adaptive PID is faster and closer to the response than with the reference model compared to the conventional PID. When response of reference model is changed from $12V$ to $24V$ at t = 0.1, Adaptive PID response occurs oscillation and follows the response of reference model at $t = 0.1s$. Conventional PID response is changed to $24V$ when $t = 0.1s$, it has no oscillation and is able to follow reference model as shown in Figure 6.



(a)



(b)



(c)

Figure 6: Response in reference model at (a) 12V, (b) 9V, and (c) 15V

D. Comparison PID Adaptive and PID Conventional

The proposed PID Adaptive compared to PID conventional have some parameters. The parameters t, ts, and $error$ are obtained in the several condition. Calculating errors with two different methods with Integral of the absolute value of the error (IAE) and integral of the square value of the error (ISE) has a performance results as shown in Table 2.

Table 2
Performance Results

Performance	Model Reference	PID Adaptive	PID Conventional
t(second)	$4.9x10^{-4}$	$1.923x10^{-3}$	9.6×10^{-3}
ts(second)	$6x10^{-3}$	0.109	0.043
Error (IAE)	-	0.04712	0.1198
Error (ISE)	-	0.10508	0.9198
ESS (%)	-	0.083%	0.58675%
Recovery time(second)	-	0.02	0.026

It is shown from Table 2 that the result of t and ts on PID adaptive is smaller and error using IAE and ISE get smaller result than conventional PID to approach reference model.

V. CONCLUSION

in this papers, the flexible manage methods are applied for controlling framework with differing conditions, as an instance, load unsettling influences and facts voltage. MRAC might be very a splendid deal stated for its smooth form and wonderful execution. The proposed framework could be very regular and may pursue the reaction of version reference impeccably. It has overshoot at the same time as the reference model response changed and pursue the response of reference version proper away. The alteration tool has duty to expand the quick execution of the reaction as a ways as overshoot, upward thrust time, settling time and regular nation for model reference step reaction.

VI. AFFIRMATION

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