Design and Implementation of Closed Loop Boost Converter with IMC Controller

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Abstract — *This paper presents the design, simulation and implementation of a DC-DC Boost converter manipulating an IMC controller, enhances the system performance. The goal is to maintain the output voltage constant of the DC-DC boost converter irrespective of variations in the voltage at input side. The reason behind using an IMC controller is due to its output response which gives the better results of time domain specifications than PID controller also the efficiency of converter. The efficiency of the converter is improved as tuning problem associated with the PID controller is overcome by the implementation of IMC controller for a boost converter. A IMC (Internal Model Control) controller instead of a conventional PID (Proportional, Integral and Derivative) controller has been applied to Boost converter and tested in MATLAB-Simulink environment achieving improved voltage regulation. The preferred closed loop implementation gives better results both in Simulink and hardware environment. This systems used in communication systems, battery operated systems such as hybrid electric vehicles and renewable energy systems.*

Key Words: **DC-DC converter; voltage regulation; Boost converter; dynamics response; open loop boost ;boost with PID; boost with IMC, stability**

1. INTRODUCTION

In the world of power conversion a SMPS plays an efficient way for power conversion. They came into picture for several applications due to their advantageous characteristics such as size, efficiency, cost, weight and the whole performance of system.

Generally the SMPS are categorised in DC-DC, Flyback, Forward and self oscillating flyback converters. So here the preferred system uses a DC-DC converters normally in that we have three categories Buck, Boost, Buck-Boost converters. In dc-dc converters the power at input is received from AC and then it is converted into DC simply a rectification is done or it uses source which is a dc source such as battery which is then converted into dc output which is a dc-dc conversion process. Mostly the converter work is depend on the states of the switches (ON and OFF) this states are related to the duty cycle and hence the output is controlled by controlling the duty cycle or duty ratio respective to output. So to control the output and switching performance we use the techniques called as modulation techniques. Also by using these techniques the quality of the output can be enhanced because it helps to reduce losses in switching and improves the efficiency of the converter further it helps in achieving the better implementation for real life applications. The different modulation techniques used are sinusoidal pulse width modulation, delta modulation, modified pulse width modulation, space vector modulation etc.. The goal behind this technique is to achieve a desired amplitude of output quantity, reduce losses in switching, good controllability of system, harmonic effect on source, a better implementation. Among the different techniques used for modulation here a basic technique which is a Pulse Width Modulation is used. This paper presents a closed loop converter with IMC controller. The intent of the system used with a controller i.e. in closed loop form is to achieve a better voltage regulation and to improve the dynamic performance of a system by improving the characteristics such as settling time ,maximum peak overshoot. The purpose of using an IMC controller is due to some adverse circumstances of PID controller such as its tuning very difficult, overshoots in the output response. So a refined performance of SMPS with IMC gives a better results with the better conversion efficiency and boosted performance of the dynamic response.

1. The assets offered by IMC structure in comparison with typical feedback framework. In design point of view the feedforword controller which is much accessible than designing a typical feedback controller.
2. In conventional framework the intention is to reduce the error always the cause behind the error production is not taken into consideration. This controller offers a ability of taking into consideration the disturbances which are unmeasured also the it offers a feature of analysis of mismatch between the model and plant.
3. The preferred system offers the advantage over typical feedback framework.

2. THE PROCEDURE OF DESIGN AND STRCTURE OF INTERNAL MODEL CONTROLLER

The procedure for design of an IMC is a spacious and obvious. The development is done in various forms such as input is one and output also one (SISO), many input many output (MIMO), continuous time, discrete time procedures of design for the system with open loop which is unstable . The proposed controller includes the merged study of feedback and feed forward design of an IMC. If we consider the design view the IMC will justice the basic conditions related to the feedback control which also includes for a converter study for stability analysis, the effect due to the zero present at right half of S-plane taken into account to accomplish a system performance.

The IMC controller acuteness is rest on model order and also the requirements of control performance. In this work the open loop stable system are taken into consideration. The two-degree-of-freedom IMC (TDOF-IMC) structure is shown in fig 1. This will provide the facilitation of tuning which is separate and simultaneous for the two types of behavior of open loop stable system one is servo and another one is regulatory behavior. As shown in fig. 1(a) and 1(b), the transfer function of a plant is given by p(s), pη(s) gives the external disturbance transfer function, the output measured is given as v(s) where as the set point transfer function is given as vsp(s).

As shown in fig. 1(a), the transfer function of an internal model is represented by pm(s), the transfer function of the IMC controller is represented by C(s), the filter transfer function in which a set point filter transfer function and disturbance filter transfer function $F_r(s)$, Fη(s) are represented respectively. In Fig. 1(b), $C_f(s)$ represents the transfer function of feedback controller. If we consider a typical feedback framework and an IMC structure then an IMC is slightly different than a conventional feedback framework it uses a basic feedback and a internal model in parallel with plant.

The explicit information on plant and model mismatch and disturbances which are unmeasured consisted by a signal which is a difference between the predictions of model and the signal which is measured . Therefore the IMC has a structure which is predictive inherently.

Now the robustness of the disturbances which are unmeasured and model plant mismatch is determined by performance of servo behavior and shaping the function of sensitivity which is complementary which are further determined while design of typical feedback framework of controller. Using the standard rules of block diagram manipulation for closed-loop system shown in Fig1. The equation can be written as follows.

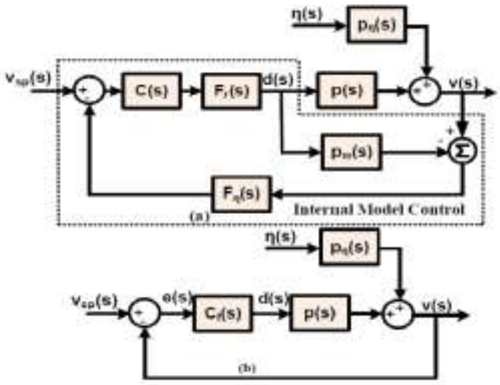

Fig. 1:- (a) The illustrative depiction of an Internal Model Control Structure (b) Traditional feedback control layout.

$$V(s) = \left[\frac{p(s)\ C(s)\ Fr(s)}{1+C(s)\ Fr(s)\ Fn(S)\ [p(s)-Pm(s)]}\right] Vsp(s)$$

$$+ \left[\frac{1-C(s)\ Fr(s)\ Fn(s)\ p(s)}{1+C(s)\ Fr(s)\ Fn(S)\ [p(s)-Pm(s)]}\right] p_n(s)\ \eta(s) \quad .....(1)$$

$$\text{Or } v(s) = T(s)\ vsp(s) + S(s)\ p\eta(s)\ \eta(s) \quad ....(2)$$

Here the function of sensitivity which is complementary is represented by T(s) while the S(s) is only sensitivity function for the structure of IMC. When MPM is not present i.e. $p(s) = p_m(s)$,

$$S(s) = 1 - C(s)\ Fr(s)\ F\eta(s)\ p_m(s) \text{ and} \quad ....(3)$$

$$T(s) = p(s)\ C(s)\ Fr(s) \quad ....(4)$$

The IMC works linearly for its sensitivity functions similar to that of traditional feedback structure works for its normal sensitivity. In the IMC scheme we have two tuning filters Fr(s) in feed forward path and Fη(s) in feedback path. The nominal sensitivity is shaped by tuning Fη(s) which is not modified by the sensitivity function which is complementary. Thus, S(s) and T(s) are shaped individually in case of IMC.

$$S_f(s) = \left(\frac{1}{1+Cf(s)p(s)}\right) . p\eta(s) \quad .... (5)$$

$$T_{f(s)} = \frac{Cf(s)p(s)}{1+Cf(s)p(s)} . p\eta(s) \quad .... (6)$$

If we consider the another side the alteration of $S_f(s)$ can be done by the $T_f(s)$, here the $S_f(s)$ can be shaped by choosing the value of $C_f(s)$ appropriately in the typical feedback network. Upon consideration of effect, the shaping of the normal sensitivity and sensitivity which is complementary is bit simple as for IMC. Thus we can say that to get performance of system in quite good manner as well as the robustness at a time, the tuning must be in simple manner and proper which is better provided by the IMC configuration.

A. Some benefits of IMC configuration:

(a) When there is no plant and model mismatch the transfer function of a loop which is closed can be minimizes as given in equation (7) and this is called as Dual Stability.

$$v(s) = [p(s)\ C(s)\ F_r(s)]\ v_{sp}(s) + [1-C(s)\ Fr(s)\ F\eta(s)\ p(s)]\ p\eta(s)\ \eta(s) \qquad \ldots\ldots.\ (7)$$

Therefore, in case of system which one is open loop and it is stable one then stability of a closed loop system which is nominal is corroborated when we choose the controller to get the poles which are stable.

Thus the conversion of any controller from the IMC configuration to the typical feedback controller Gc(s), can be done with the help of relationship as follows [16]:

$$Gc(s) = \frac{C(s)\ Fr(s)\ F\eta(s)}{1-Pm(s)C(s)\ Fr(s)\ F\eta(s)} \qquad \ldots\ldots.(8)$$

From (8) it is seen that an easy parameterization of each and every controller in this system such as Gc(s), C(s), Fη(s) controllers used for stabilizing purpose can be offered by the structure of IMC[20]:

The structure of IMC provides a benefit from the procedures required for the design and the parameters for tuning of C(s) and Fη(s) are much simpler than tuning and design of traditional feedback controller $C_f(s)$.

(b) Perfect controller : For the model to become perfect the $p(s) = p_m(s)$ and from eq.(1), C(s) is so chosen such that $C(s) = 1/p_m(s)$ is similar of getting the response which is servo in perfect manner when the exterior disturbance is not applied.

(c) Zero Steady-state Offset: To nullify the offset from the output response, we have to make the controller gain which is a steady-state , equals to the gain of the model which is called as inverse steady state gain . It can be understood easily from equation (7).

b)Procedure of Design

In the design of IMC controller, the shaping of servo response is done through a developed model which is the inverse of the linear perturbation model . Here the controller $C(s) = (P^-_{m(S)})^{-1}$ are not realizable. In the design of controller when the inverse model is used it will produce a controller which is practically not realizable for the system experiences non-minimum phase behaviour (that is with delay in time/right hand side zeros). Thus, to get the performance ideally via a 'perfect control' is impossible practically because the restriction arrived from zero at RHP. To keep this away the factorization of model is done in invertible and non-invertible components [16]. Consider the model expression as :

$$P_m(s) = P^+_m(s)\ P^-_m(s) \qquad \ldots\ldots\ldots(9)$$

Here the component of minimum phase is represented by $P^-_m(s)$ which contains the poles and zeros all are in LHS side of s-plane and the part which is noninvertible which consists of right half zeros and delay in its time is represented by $P^+_m(s)$. This separation is done such a that $P^+_m(0) = 1$. For making controller realizable and for shaping purpose of servo response we have to cascade the controller with a LPF Fr(s) which will assure that C(s) and Fr(s) will become proper. Thus,

$$C(s)\ F_r(s) = (\ P^-_m(s))^{-1}\ F_r(s) \qquad \ldots\ldots\ldots(10)$$

Here, $F_r(s)$ is chosen

$$F_r(s) = \frac{1}{(\lambda r+1)^{\wedge}n} \qquad \ldots\ldots\ldots(11)$$

In such a way that *n* will equal to relative order of that part which is minimum part of plant model whereas the parameter of tuning is λr .Now from this choices the equation no (7) can be reduced as.

$$v(s) = [\ P^+_m(s)\ F_r(s)]\ v_{sp}(s) + [1-\ P^+_m(s)\ F_r(s)\ F\eta(s)]\ p\eta(s)\ \eta(s) \qquad \ldots\ldots\ldots(12)$$

The constraint which are inherent are represented by the $p^+_{m(s)}$ which is a phase component of non-minimum behavior.

The constraints which are inherent presented on the quality of control which is achievable and any law regarding control can not neutralize this . A demonstration is done from Equation (12) that, when plant/model mismatch is not there in this case the selection of Fr(s) is so proper such that the shaping of set-point response speed can be done directly. The factorization method used for the model on which design of controller C(S) is based. The factorization is not distinctive and conveyed depending on either Integral Absolute Error (IAE) or Integral Square Error (ISE) these are the indices for performance for changes in step in set-point as well as disturbance. [19]

Design of IMC-IAE: In this method C(s) is designed by the use of criterion of Integral Absolute Error (IAE), i.e.

$$IAE = \int_0^{Ts} |vsp(t)-v(t)|dt \qquad \ldots\ldots\ldots(13)$$

Here, Ts represents settling time. The minimization in IAE is done by the factorization (14) shown which is for the input which is step and disturbances.

$$P^+_m(s) = \prod i\ (-\beta is+1)\quad R_e(\beta i) > 0 \qquad \ldots\ldots.(14)$$

The complementary sensitivity function in case of IAE factorization reduces to

$$T_{IAE}(s)=\frac{\prod i-\beta is+1}{(\lambda r\ s+1)^{\wedge}n} \quad ....(15)$$

Design of IMC-ISE : This approach corresponds to the design of C(s) using the Integral Square Error (ISE) criterion, i.e.

$$ISE=\int_0^{Ts}(v_{sp}(t)-v(t))^{\wedge}2\ dt \quad ....(16)$$

$$P^{+}_{m}(s) = \prod_{i}\frac{-\beta is+1}{\beta is+1}\ Re(\beta i)>0 \quad ......(17)$$

The poles in left half of S plane are added as a image of right hand side zeros in factorization of all pass to closed loop(17). The function of sensitivity which is complementary is minimized shown in (18) in terms of ISE factorization of plant model.

$$TISE(s) = \prod_{i}\frac{-\beta is+1}{\beta is+1}\frac{1}{(\lambda r+1)^{\wedge}n} \quad ....(18)$$

For the plant model factorization the IAE and ISE these both designs are taken into consideration. Choosing of filter is involved under design of TDOF-IMC controller a filter which is involved under choosing the controller C(s).

The filter in feed forward path is Fr(s) and in feedback path Fη(s) this is the filter which is used for designing MPM.

If the disturbance which is external and MPM are not present the servo behavior is decided by the Fr(s) of closed loop system. If selection of Fr(s) is done as given in equation (11), then the is reduced to λr selection so that the servo response will be desired. The disturbance rejection will be attained effectively by the filter Fη(s) in the feedback [20]:

$$F\eta(s) = \frac{\sum_{i=0}^{m}\propto i\ si}{(\lambda ds+1)m} \quad ....(19)$$

Here αo=1 and λd is the tuning parameter of disturbance filter, and in disturbance transfer function Pη(s) m are the number of poles.

The filter parameter λ_d its choice is dependent upon the amplification of noise which is allowable. The tuning parameter of disturbance filter, λd is tuned in such a way that the criterion of noise amplification, i.e., maximum of |C(jw)Fr(jw)Fη(jw)/C(0)Fr(0)Fη(0)|∀w, is less than a factor of 20 [20]. The tuning parameter values (λr, λd) and αi are arriving in equation (19) which can be meet by solving

$$[1 - C(s)\ Fr(s)\ F\eta(s)\ pm(s)]\ |_{S=\frac{-1}{\tau_i}} = 0 \quad ....(20)$$

The distinct time constant τi is related with the *ith* pole of Pη(s).

3. DESIGN OF CONTROL AND DESCRIPTION OF SYSTEM

This section presents , the usefulness of employment of IMC which control the output voltage of a boost type dc-dc converter . The following fig. 2. represents boost type dc-dc converter which is in terms of power stage circuit diagram.

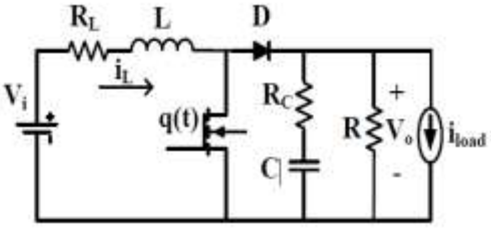

Fig. 2. Power stage circuit diagram of the boost type dc-dc converter.

Table 1. Specifications of Boost Converter

Description	***Parameter***	***Values***
Input voltage	Vin (V)	10
Capacitance	C (μF)	1930
Capacitor ESR	Rc(Ω)	0.08
Inductance	L (mH)	3.1
Inductor ESR	RL (Ω)	0.3
Switching frequency	Fs (kHz)	25
Load resistance (nominal load)	R (Ω)	90
Load resistance (change 50%)	R/2 (Ω)	45
Output voltage	Vo (V)	15
Sensing factor	B	1/10
Duty Ratio	D	0.33
Averaged equivalent parasitic resistance	R_{eq}	0.36
Load resistance (change 50%)	R/2 (Ω)	45

$$\begin{bmatrix}\frac{diL(t)}{dt}\\ \frac{dvc(t)}{d(t)}\end{bmatrix} = \begin{bmatrix}\frac{-\mathrm{Re}\,q}{L}-\frac{(1-q(t)RRc}{(R+Rc)L} & -\frac{(1-q(t))R}{(R+Rc)L}\\ \frac{(1-q(t))R}{(R+Rc)C} & \frac{-1}{(R+Rc)C}\end{bmatrix}\begin{bmatrix}iL(t)\\ Vc(t)\end{bmatrix}$$

$$+\begin{bmatrix} \frac{1}{L} & \frac{(1-q(t)RRc}{(R+Rc)L} \\ 0 & \frac{R}{(R+Rc)C} \end{bmatrix} \begin{bmatrix} Vi(t) \\ iload\,(t) \end{bmatrix} \quad \text{.......}(21)$$

Here the control input is q(t) which is taken in terms of discrete set of values {0,1} which defines the switch function in ON or OFF state.

As compared to instantaneous values of voltage and current average values are more important in many circuits [34]. Here the q(t) is a switching function whose average value corresponding to the converter duty ratio i.e. in implementation of pulse width modulation; the average control input is represented by d(t) which is a duty ratio duty ratio function it is limited in the interval which is a closed loop interval [0, 1]. By replacing q(t) with d(t) the averaged model in terms of state space [35, 36] of boost converter in Continuous conduction mode is obtained on replacement of q(t) with d(t).

As shown in equation (21) the inductor current is represented by iL(t) and Vc(t) represents the output capacitor voltage. The parameters of system which are composed of L and C where L is inductance of circuit at input side and C is capacitance of filter at output side ,the resistance of load is represented by R which is variable the capacitor and inductor parasitic resistances are represented by the Rc and R_L The inputs of disturbance are given as vi(t) which is source of voltage externally, iload (t) is current , at load side . The variable which is controlled one is the voltage at the output side vo(t).

The moto of closed-loop control system is:

(a)*Control problem associated with regulatory behavior :*
To keep output voltage constant during changes in input voltage and disturbances in load.

(b) Control problem associated with servo behavior :

Here tracking regarding the required voltage vsp(t) of set-point which is greater than the voltage Vi at source . Perturbation of signals are defined as , $\tilde{\imath}_L(t) = i_L(t) - I_L$,

$\tilde{V}_C(t) = v_C(t) - V_C$, $\tilde{v}_i(t) = v_i(t) - V_i$, $\tilde{d}(t) = d(t) - D$, here the letters in uppercase indicates the similar normal value in steady state, after taking Laplace transform of the resulting linear state-space model, the equivalent transfer function from control to output, line to output and impedance at output side which is acquired as

$$P_m(s) = \frac{\tilde{v}o(s)}{\tilde{d}(s)}$$

$$= \frac{Vo}{1-D}\;\frac{(1+CRCs)\,[\,R^2+(1-D)^2-(R+Rc)(Req+Ls)}{den\,(s)} \quad \text{.......}(22)$$

where den(s) = R(1 − D)[R(1 − D) + RC(1 + C(R + RC)s] + (R + RC)(Req + Ls)(1 + C(R + RC) s

As per table no.1 values , we have

$$P_m(s) = \frac{22.0617(1.544x10\text{^}4\ s+1)(-7.8287x10\text{^}5\ s+1)}{1.3345x10^{-5}s^2+1.8847x10^{-3}\ s+1} \quad \text{.....}(\ 23)$$

The zeros at right hand side and left hand side and a pair of poles in terms of complex conjugate is given by equation (23). The fig 2. Represents the equivalent circuit in linear form of the boost converter which is containing a LC filter which is a LPF and the Wo is the corner frequency, of the filter it is given as follows:

$$W_o = \frac{1-D}{\sqrt{LC}} = 272.5\text{rad/s} \quad \text{........}(\ 24)$$

The information about the position of right hand side zeros is given by the equation no 25. as

$$w_{RHP} = \frac{R^2(1-D)^2}{(R+RC)L} - \frac{R_{eq}}{L} = 12.273\text{krad/s} \quad \text{........}(\ 25)$$

The normal duty cycle (D) functions are represented by the Wo and W_{RHP} given in equations (24) and (25).

The transfer function from input to output of converter is given as:

$$\frac{\tilde{v}o\ (s)}{\tilde{v}i\ (s)} = \frac{(1+CRCs)(1-D)R(R+RC)}{den(s)} \quad \text{........}(\ 26)$$

and the transfer function of the impedance which is at the output side is given as:

$$\frac{\tilde{v}o\ (s)}{-\tilde{\imath}_{load}\ (s)} = \frac{num_{\ load}\ (s)}{den\ (s)} \quad \text{........}(\ 27)$$

here, num load (s) = (1 + CRCs)R x [R(1 − D)RC − R(1 − D)^2 RC + (R + RC)(Req + Ls)]

According to the consideration for the system in particular manner, we have

$$\frac{\tilde{v}o\ (s)}{\tilde{v}i\ (s)} = \frac{1.486(1.544x10^{-4}s+1)}{1.3345x10^{-5}s2+1.8847x10^{-3}s+1} \quad \text{........}(\ 28)$$

$$\frac{\tilde{v}_o\ (s)}{-\tilde{\imath}_{load}\ (s)} = -\frac{0.8567(1.544x10^{-4}s+1)(8.0639x10^{-3}s+1)}{1.3345x10^{-5}s^2+1.8847x10^{-3}s+1} \quad \text{.....}(29)$$

The effect of variations in the input voltage dynamics and and in load current on voltage of output is similar to that of control signal effect which is given in equations (28) and (29).

Design requisites of controllers:

The design of controllers for this closed loop system is done on the basis of requirements in dynamics and steady state for rejection in disturbance and changes in set .

(a) Details of Steady state in terms of regulatory and servo response: The output voltage must have the steady state error less than 1% of the normal desired output voltage.

(b) Transient prescription for change in input voltage :

Confirming stability for variations in the voltage at input side 10V±30% alteration and the overshoot undershoot should not be larger than ±10% of the normal voltage at output (13.5-16.5 V).

(c) Transient prescription for load change: Verifying stability for variations in 90 Ω to 45 Ω (-50%) variation which is twice in load current change.

(d) Transient prescription for servo response: For the variation in the set values the overshoot must not be larger than 10% deviation in set point.

B. Design of Controller:

The procedure of IMC includes two designs treated to the ways of factorizing the plant model of (23) and the designs are as follows.

a) Design of IMC-IAE: The plant model invertible part plant model is selected as

$$p_m^-(s) = \frac{22.0617(1.544x10^{-4}s+1)}{1.3345x10^{-5}s^2 + 1.8847x10^{-3}s + 1} \quad ....(30)$$

and the plants non-invertible part is selected as

$$p_m^+(s) = (-7.8287x10{-}5s+1) \quad ....(31)$$

The controller C(s) of IMC-IAE takes the form

$$C(s) = \frac{1.3345x10^{-5}s^2+1.8847x10^{-3}s+1}{22.0617(1.544x10^{-4}s+1)} \quad ...... (32)$$

Depending upon the presumed response tracking of set-point for the selected boost converter, the filter tuning parameter λr value in the forward direction of path is selected as 5.5ms. The disturbance filter Fη(s) is selected in such a way that it will cancel poles of (28), (29) to get fast rejection in disturbance, which is taken in the form as

$$F\eta(s) = \frac{3.982\times10^{-5}s^2+8.49\times10^{-3}s+1}{(\lambda d\ s+1)2} \quad ...... (33)$$

In real life applications, the robustness of system is more critical than the normal performance and measurement of the robustness of system is more critical than the normal performance and measurement of robustness of system, the sensitivity function (Ms) peak value is used and is defined as:

$$Ms = Max_{0\leq w\leq\infty} |S(jw)| \quad ...... (34)$$

From the critical point (-1,0) the measurement of closeness of the nyquist plot at all frequencies and not just at the two frequency points as associated with gain and phase margins. Ms variations normally in the range of 1.2-2.0. To supply a proper comparisons, from the designs of IMC, coefficients of filter are tuned in such a way that Ms will turn out so that we will have a value = 1.235, promising that two controllers has equal degree of robustness. Depends upon this criterion, the filter parameter in the path of feedback was chosen as λd= 0.8ms.

In feedback path a single filter is sufficient, as the polynomials at denominator for both the transfer functions of disturbance are nondistinguishable.

(b) Design of IMC-ISE : The selection of invertible part of plant model is done which is given as follows.

$$p_m^-(s) = \frac{22.0617(1.544x10^{-4}s+1)(7.8287x10^{-5}s+1)}{1.3345x10^{-5}s^2+1.8847x10^{-3}s+1} \quad ....(35)$$

and the selection of invertible part of plant model is done which is given as follows.

$$p_m^+(s) = \frac{(-7.8287x10^{-5}s+1)}{(7.8287x10^{-5}s+1\ )} \quad .... (36)$$

The controller IMC-ISE C(s) taking the form

$$C(s) = \frac{(1.3345x10^{-5}s^2+1.8847x10^{-3}s+1)}{22.0617(1.544x10^{-4}s+1)(7.8287x10^{-5}s+1\ )} \quad ....$$

(37)

This case gives the idea about the selection of tuning parameter, λr = 5.5ms and λd = 1.23ms is done in such a way that IMC design with ISE factorization and also gives out so that we will have the sensitivity function which has maximum value = 1.235 and equivalent parameters for filter Fη(s) are $\propto2 = 4.357\times10{-}5$, $\propto1=6.767\times10{-}3$.

4. SIMULATION STUDIES

In this case simulation of boost converter is carried out for three cases for regulatory behavior open loop boost (fig3.), closed loop boost with PID (fig4), closed loop boost with IMC (fig5.). The MATLAB-Simulink environment is used to carried out the simulation. The IMC scheme works on original plant model and invertible plant model which reduces the plant model mismatch which results in improving the dynamic response and boost the performance specifications.

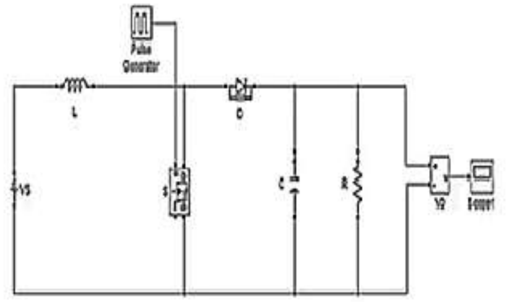

Fig.3. Simulation of Open Loop Boost Converter

The comparison between the simulation results says that an IMC having a better dynamic response compared with PID as PID is difficult to tune as well as controller performance parameter like maximum peak overshoot/ undershoots, settling time.

By using traditional approach IMC performs better than PID.

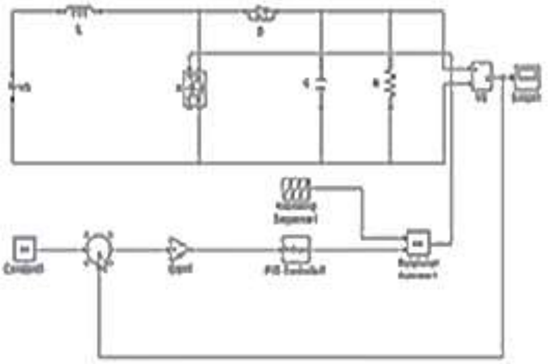

Fig.4. Simulation of Closed Loop Boost Converter with PID controller

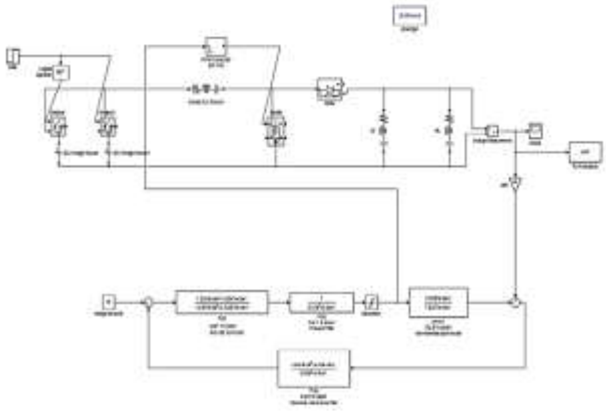

Fig.5. Simulation of Closed Loop Boost Converter with IMC controller

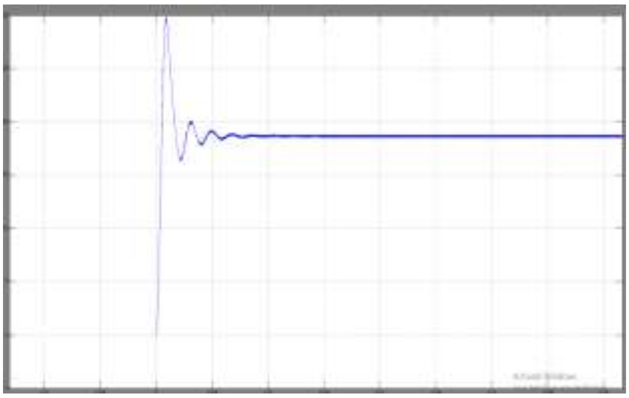

Fig.6. Simulation Result of Open Loop Boost Converter

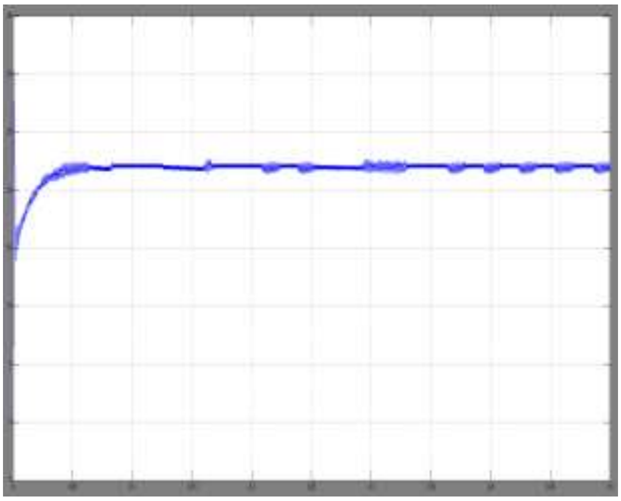

Fig.7. Simulation result of Closed Loop Boost Converter with PID Controller

Fig.8. Simulation result of Closed Loop Boost Converter with IMC Controller

5. EXPERIMENTAL EVALUATION

The hardware implementation includes a boost converter as a process model the input is supplied to the boost converter through the 12 volt battery, to take the step input between 7 to 10 volt push pull switches are provided with voltage regulators of 7809 and 7812 ,a resistive load of 95 ohm is given to the circuit. The main aim is to maintain the output voltage constant to 15 volt irrespective to changes in the voltages from 7 to 12 volt. Here the voltage mode control technique is used in this control technique a boost converter is used in closed loop form with a feedback and a controller in which the actual output voltage is compared with a set voltage and the error value is reduced by controlling the switching pulse.

To continue this process by controlling switching pulse and for reduction of error, the feedback is provided for the system for the smooth control of process variables. Basically here the PIC microcontroller is used as a feedback system. In order to communicate between the switch and microcontroller a driver circuit (TLP250H) is used which will control the switching periods of the MOSFET switch used in this system a gate driver circuit interface between the switches and microcontroller in order to understand the analog and digital signals coming towards the switch. A PIC microcontroller is employed which is programmed regarding the feedback system which compare the actual voltage with the reference voltage and then the error is used to adjust the PWM duty cycle to control the output voltage to desired value.

A driver circuit is acting as an amplifier here which takes the low power input from the given circuit and gives high signal to the switches MOSFET/IGBT. The main moto to use here MOSFET as a switch because the IGBT works with the high speed for higher power application where as MOSFET is used with the high speed for lower power application.

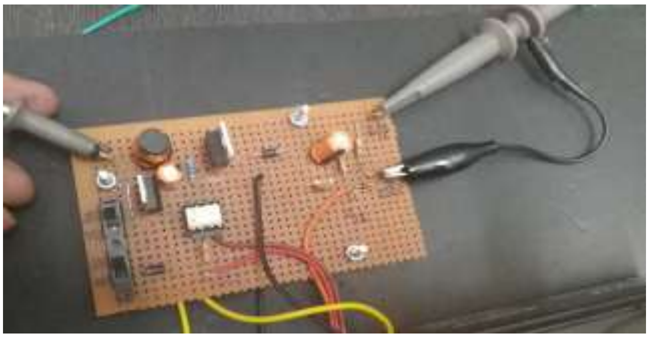

Fig.9:-Input is 9 volt

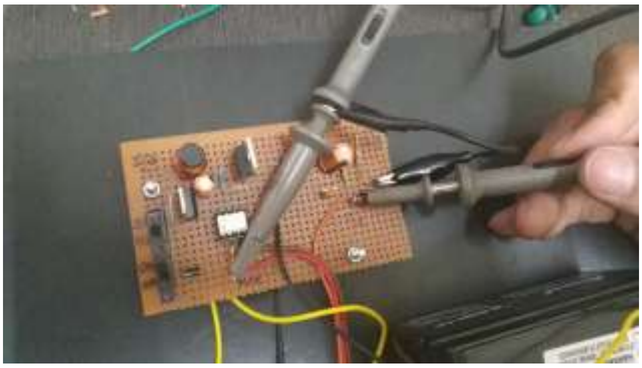

Fig.10 :-Input is 9 volt

Fig.10:- Output for given input and feedback signal

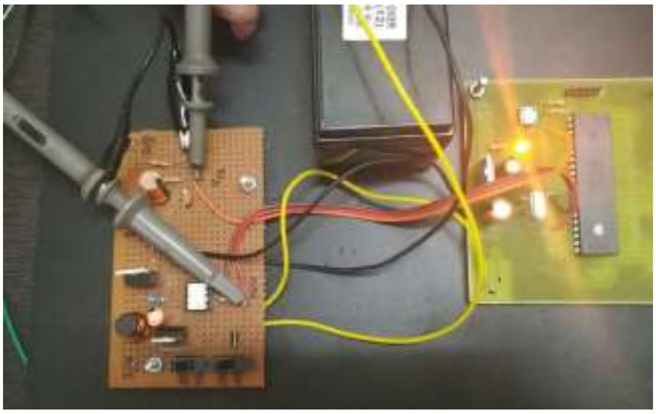

Fig.11:- Output for given input and feedback signal

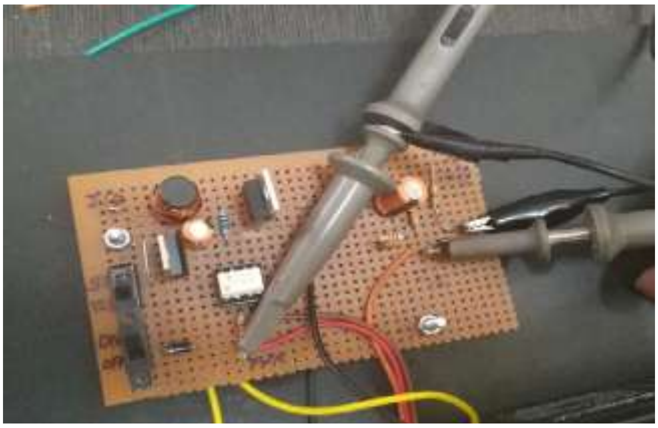

Fig.12:- Feedback Signal when input is 12 volt

6. CONCLUSIONS

A simulation studies involves a comparative study between IMC and PID in which on evaluation of results it is noted that the dynamic specifications such as the settling time overshoots/undershoots are improved, also with reduction in the problem associated with the PID controller through the use of IMC rather than PID.

An evaluation between simulation results and experimental results shows that they give same results for corresponding input changes that is with the improved regulatory behavior and servo behavior in terms of tracking. IMC provides better results in terms of its dynamic performance and in terms of tuning.Where as on evaluation of the hardware results and simulation results it is concluded that the results are one and the same

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